EAC

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Table Of Contents

FOREWORD

PURPOSE

1. Thiscircularaimstoprovideanoverarchingconceptualunderstandingofthesurfacefrictioncharacteristicsthatcontributetocontrollinganaircraftviathecriticaltire-to ground contact area.The intent is to provide broad and fund amental concepts to support proposed amendments,by ECAA, to the Standards and Recommended Practices (SARPs) in ECAR 139

2. The proposed amendments address the followingissues:

    a) Surface friction characteristics of pavements and runway surface contaminants;

    b) How surface characteristics relate to aircraft performance;

    c) Assessment of runway surface conditions;

    d) Reporting and dissemination of runway surface conditions;and

    e) The need for appropriate training of personnel involved in c) and d).

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GLOSSARY

ABBREVIATIONS/ACRONYMS

AC	Advisorycircular (FAA)
ADREP	Accident/incidentdatareporting
ADS-C	Aeronauticaldependentsurveillance —contract
AFM	Aircraftflightmanual
AIC	Aeronauticalinformationcircular
AIDC	ATS interfacilitydatacommunication
AIM	Aeronauticalinformationmanagement
AIP	Aeronauticalinformationpublication
AIS	Aeronauticalinformationservices
AIS-AIMSG	
	AeronauticalInformationServicesandAeronauticalInformationManagementSt
udyGroupAIXM	Aeronauticalinformationexchangemodel
AMSCR	Aircraftmovementsurfaceconditionreport
ARC	Aviation Rulemaking Committee (FAA)
ASTM	AmericanSocietyforTestingandMaterials
ATC	Air traffic control
ATIS	Automaticterminal informationservice
ATM	Air trafficmanagement
ATS	Air trafficservices
ATSMHS	ATS messagehandlingservicesapplications
CAA	Civilaviationauthority
CAP	CivilAviationPublication (UnitedKingdom)
CEN	ComitéEuropéendeNormalisation (EuropeanCommitteeforStandardization)
CFME	Continuousfrictionmeasuringequipment
CFR	CodeofFederalRegulations (FAA)
CPDLC	Controller-pilotdatalinkcommunications
CRFI	Canadianrunwayfrictionindex
CRM	Cockpitresourcemanagement
CS	Certificationspecifications (EASA)
EASA	EuropeanAviationSafetyAgency
ERD	Electronicrecordingdecelerometer
ESDU	EngineeringSciencesDataUnit
EUROCONTROL	the European Organisation for the Safety of Air
Navigation FAA	Federal Aviation Administration (UnitedStates)
FAR	Federal Aviation Regulations (UnitedStates)
FTF	ICAO Friction TaskForce
HMA	Hot-mixasphalt
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization

IRFI	International runway frictionindex
JAA	Joint Aviation Authorities (Europe)
JAR	Joint Aviation Requirements (Europe)
JWRFMP	Joint Winter Run way Friction Measurement Programme
METAR	Aerodrome routine meteorological report
MFL	Minimum friction level
MPD	Meanpro file depth
MTD	Mean texturedepth
Mu	Coefficient of friction
NASA	National Aeronautics and Space Administration (UnitedStates)
NOTAM	Notice to airmen
PIREP	Pilot report
PCC	Portl and cement concrete
PFC	Porous friction course
PSV	Polished stone value
SARPS	Standards and Recommended Practices (ICAO)
SMS	Safety management system
SPECI	Aerodrome special meteorological report
TALPA	Take-off and landing performance assessment
TC	Transport Canada
μ	Mu (coefficient of friction)
VEF	The calibrated air speed at which the critical engine is assumed to fail.
V1	The maximum speed in the take-off at which the pilot must take the first action (e.g.apply brakes, reduce thrust, deploy speed brakes) to stop the aeroplane within the accelerate-stop distance. V1 also means the minimum speed in the take-off, following a failure of the critical engine at VEF, at which the pilot can continue the take-off and achieve the required height above the take-off surface within the take-off distance.
WMO	World Meteorological Organisation

EXPLANATION OFTERMS

The terms contained herein are used in the context of this circular. Formally recognized ICAO definitions are notedwith an asterisk (*).

Brakingaction. Atermusedbypilotstocharacterizethedecelerationassociatedwiththewheelbrakingeffortanddirectional controllability of theaircraft.

Coefficient of friction. A dimensionless ratio of the friction force between two bodies to the normal force pressingthese two bodiestogether.

Contaminant. Adeposit(suchassnow,slush,ice,standingwater,mud,dust,sand,oilandrubber)onanaerodrome pavementtheeffectofwhichisdetrimentaltothefrictioncharacteristicsofthepavementsurface.

Critical tire/ground contact area. An area (approximately 4 square metres for the largest aircraft currently inservice) whichissubjecttoforcesthatdrivetherollingandbrakingcharacteristicsoftheaircraft,aswellasfordirectional control.

ESDUscale. Agroupingofhardrunwaysurfacesbasedonmacrotexturedepth.

Estimated surface friction. A term used by ground staff for SNOWTAM reporting purposes to characterizethe slipperinessoftherunwaysurfaceduetothepresenceofcontaminantsandprevailingweatherconditions.

Flexible pavement. A pavement consisting of a series of layers of increasing strength from the subgrade to thesurfacelayer. The structure maintains intimate contact with, and distributes loads to, the subgrade and dependson aggregateinterlock,particlefrictionandcohesionforstability.

Friction. Aresistiveforcealongthelineofrelativemotionbetweentwosurfacesincontact.

Frictioncharacteristics. Thephysical,functionalandoperationalfeaturesorattributesoffrictionarisingfromadynamicsystem.

Groovedorporousfrictioncourserunway.□□ Apavedrunwaythathasbeenpreparedwithlateralgroovingora porousfrictioncourse(PFC)surfacetoimprovebrakingcharacteristicswhenwet.

Hazard. Aconditionoranobjectwiththepotentialtocauseinjuriestopersonnel,damagetoequipmentorstructures,lossofmaterial,orreductionoftheabilitytoperformaprescribedfunction.

Retardation. The deceleration of a vehicle braking, measured inm/s^2.

Rigidpavement. ApavementstructurethatdistributesloadstothesubgradehavingasitssurfacecourseaPortland cementconcreteslabofrelativelyhighbendingresistance.

Runwaysurfacecondition.*Thestateofthesurfaceoftherunway,eitherdry,wetorcontaminated:

a) Contaminatedrunway.Arunwayiscontaminatedwhenmorethan25percentoftherunwaysurfacearea (whether in isolated areas or not) within the required length and width being used is coveredby:

— water, or slush more than 3 mm (0.125 in) deep;

— loose snow more than 20 mm (0.75 in) deep;or

— compacted snow or ice, including wetice.

b) Dry runway. A dry runway is one which is clear of contaminants and visible moisture within the requiredlength and the width beingused.

c) Wet runway. A runway that is neither dry norcontaminated.

Note1.
—Incertainsituations, itmaybeappropriatetoconsidertherunwaycontaminatedevenwhenitdoesnot meet the above definition. For example, if less than 25 per cent of the runway surface area is covered with water, slush, snoworice, butitislocatedwhererotationorlift-offwilloccur, orduringthehighspeedpartofthetake-offroll, theeffectwillbefarmoresignificantthanifitwereencounteredearlyintake-offwhileatlowspeed.Inthissituation,therunwayshould be considered to becontaminated.

Note2.—
Similarly,arunwaythatisdryintheareawherebrakingwouldoccurduringahighspeedrejectedtake- off, but damp or wet (without measurable water depth) in the area where acceleration would occur, may be considered tobedryforcomputingtake-offperformance.Forexample,ifthefirst25percentoftherunwaywasdamp,butthe remainingrunwaylengthwasdry,therunwaywouldbewetusingthedefinitionsabove.However,sinceawetrunway does not affect acceleration, and the braking portion of a rejected take-off would take place on a dry surface, it wouldbeappropriate to use dry runway take-offperformance.

Significantchange. Achangeinthemagnitudeofahazard,whichleadstoachangeinthesafeoperationoftheaircraft.

Skidresistant. Arunwaysurfacethatisdesigned,constructedandmaintainedtohavegoodwaterdrainage, which minimizestheriskofhydroplaningwhentherunwayiswetandprovidesaircraftbrakingperformanceshowntobebetterthanthatusedintheairworthinessstandardsforawet,smoothrunway.

Surface friction characteristics. The physical, functional and operational features or attributes of friction that relateto thesurfacepropertiesofthepavementandcanbedistinguishedfromeachother.

Note.— The friction coefficient is not a property of the pavement surface but a system response from themeasuring system. Friction coefficient can be used to evaluate the surface properties of the pavement provided that thepropertiesbelonging to the measuring system are controlled and keptstable.

DEFINTIONS IN ANNEX 6, PARTI

1. The definitions in Annex 6, Part I, for the operational use of flight crew were introduced via Amendment33-Ain2009.

2. Apartfromthedefinitionof"groovedorporousfrictioncourserunway",theoriginofthesedefinitionscan betracedtoanunpublishedissueofadraftFAAAdvisoryCircular,Performanceinformationforoperation withwater,slush, snow, or ice on the runway, AC 91-6B dated June 18,1986.

3. WithminorchangesthedefinitionsfromtheFAAAdvisoryCircularappearintheEASACertification SpecificationsforLargeAeroplanesCS-25,Book2,undertheheading"AMC25-13,ReducedandDeratedTakeoffThrust(Power)Procedures".Thedefinitionof"wet"wassimplifiedand minoreditorialchangesweremadetothedefinition of "contaminated runway".

4. Two accompanying notes were added to the definition of "contaminated runway" in Amendment 33-A.The concept of these notes can be traced back to discussions in the FAA Airplane Performance HarmonizationSub-Working Group which completed its task in 2002.

5. These definitions are aimed at the operation of the aircraft and not the operation of theaerodrome.However,forthepurposesofreportingprevailingrunwaysurfaceconditionsthereisaneedtoharmonizethese definitionswiththoseusedfortheoperationofanaerodrome.Atthepublicationdateofthiscircular,thiswas notthe case.

6. Theaviationindustryrecognizesthat,forsafetyreasons,harmonizationisrequired.Theconceptoftwo sets of harmonized definitions has been discussed, with one set targeting the operation of the aerodrome and theother, theoperationoftheaircraft.Thesesetsofdefinitionswouldneedtobeharmonizedinsuchawaythatsafetyis notimpaired when reporting prevailing runway surfaceconditions.

Chapter 1
INTRODUCTION

"Thereisnosubjectinscience,perhaps,onwhichthereisagreaterdiversityofopinionthaninthelawswhich govern friction; and the previous experiments, though sufficient, in many cases, for practical purposes, yet by no means tendtobring the inquiry into any more settledstate."

Nicholas Wood, Treatise upon railroads, 18361

1.1 Aviation does not have such a long history as railroads, yet the diversity of opinions related to the lawsthatgovernfrictionisgreat.Thepurposeofthiscircularistoprovidethelatestguidanceonfrictionissuesasfarasis possible, given the present state ofknowledge.

1.2 Itiscommonknowledgethatpavementstendtobecomeslipperyforbothpedestriansandvehiclesalike whentheyarewet,floodedorarecoveredwithslush,snoworice;however,nooneyethasacompleteunderstandingof the physical effects causing this slipperiness which in turn can cause accidents. The same applies to aircraftoperations onthemovementareas.Forthisreason,manypapersonfrictionissueshavebeenproducedwithintheaviationcommunity since the late1940s.

1.3 Theinformationinthiscircularshouldbeusedbynationalauthoritieswhenimplementingtheirsafety activitiesandreferencedasnecessarybyaerodromeoperators,aerodromeairnavigationserviceproviders, aircraftoperators and individuals within thoseorganizations.

CURRENTSITUATION

1.4 Worldwide,therehavebeenvariousinitiatives(seeAppendixA)carriedoutamongandwithinStatesresulting in different means of measuring and reporting in termsof:

a) policies;

b) methods;and

c) parameters.

1.5 Thesedifferencesmayleadtoconfusionandthevariouspartsoftheindustrymaynotspeakthesame"language" even though they believe they do. The key players are the persons on the ground, identifying andreportinghazardous conditions on the movement area, and the pilots using that information for safe operation of the aircraft.The roleofaeronauticalinformationservices(AIS)andairtrafficmanagement(ATM)istodisseminatetheinformationina timely manner in accordance with standardized formats and procedures established for internationaluse.

1.6 There is currently such a preponderance of information, at times incorrect and conflicting, that oftenleavesStates and operators confused. The goal should be to achieve global, non-conflicting solutions for assessing,measuring,reportingandusingrunwaysurfacefrictioncharacteristicstodeterminetheeffecton aeroplaneperformance.

TERMINOLOGY

1.7 The friction issues discussed in this circular are those related to the safe operation of an aircraft as wellasthosethatarerelevanttotheaerodromeoperator.Morespecifically,theseissuesrelatetoaircraft/runwayinteraction that depends on the critical tire/ground contactarea.

1.8 At this critical tire/ground contact area, two distinct aspects of friction issuesmeet:

a) thedesign,constructionandmaintenanceofthepavementsurfaceanditsinherentfriction characteristics;and

b) aircraft operations on the pavement surface and the contaminantspresent.

1.9 Boththeseaspectshave,throughtime,developedtheirownterminologiesthatrelatetofrictionanditisessential to distinguish the followingaspects:

a) **skid resistance** relates to the design, construction and maintenance ofpavement;

b) **brakingaction**representsthepilot's characterizationofthedecelerationassociatedwiththewheel brakingeffortanddirectionalcontrollabilityoftheaircraft.Thetermisusedinpilotreports(PIREPs); and

c) **estimated surface friction** represents the ground staff's assessment, for SNOWTAMreportingpurposes, of the slipperiness of the runway surface due to the presence of contaminants andprevailingweatherconditions.

1.10 The term "skid resistance" has been in more formal use since the establishment of a newtechnicalcommitteeonskidresistance(CommitteeE-17)inOctober1959bytheAmericanSocietyforTestingandMaterials (ASTM). It is defined by the ASTMas:

Skidresistance(frictionnumber). Theabilityofthetravelledsurfacetopreventthelossoftiretraction.

1.11 The term "braking action" has been in continuous use in the aviation industry although it has been usedin different contexts and will, as such, continue to be used in the general sense. Braking action, in the context ofreporting purposes, is used to define the stopping capability of an aircraft using wheel brakes and is related to pilot brakingactionreports. The term braking action has also been used to describe the estimated surface friction on the groundmeasured byafrictionmeasurementdeviceandreportedasaircraftstoppingcapability.TheICAOSNOWTAMformatusesthe term "estimated surface friction" and should be understood as the total assessment of the slipperiness of the surface as judged by the ground staff based upon all informationavailable.

1.12 ThefollowingwasdocumentedintheReportoftheAerodromes,AirRoutesandGroundAidsDivisional Meeting (1981) (Doc9342):

It was pointed out that the term "runway braking action" had been used in several places in<u>ECAR 139.</u>

This termhadnotbeendefined.Ontheotherhand,theterm"coefficientoffriction"waswellknown.Itwas therefore suggested that the use of the term "braking action" should be avoided. The meeting wasadvised that the term "braking action" had been selected for use in <u>ECAR 139</u>because some of themeasuring devices used did not measure directly the coefficient of friction. This was particularly sointhecaseofdevicesformeasurementsonsurfacescoveredwithiceandsnow,sointhesecasesthemoregeneralterm"brakingaction"wasadopted.Otherwise, and itwasagreedthatwhereverfeasibletheterm "brakingaction" shouldbereplacedby frictioncharacteristics.

1.13 Previously,theprincipalaimhadbeentomeasuresurfacefrictioninamannerthatwasrelevanttothe frictionexperiencedbyanaircrafttire.Currently,thereisnoconsensuswithintheaviationindustrythatthisisevenpossible.Toavoidmisunderstandingandconfusion,measuredsurfacefrictionshouldbereferredtoasmeasuredfriction coefficient, which is used in the current SNOWTAMformat.

Chapter 2

THE DYNAMICSYSTEM

2.1 The basic friction characteristics of the critical tire/ground contact area, the latter being a part of adynamic system, influences the available friction that can be utilized by an aircraft. The basic friction characteristics areproperties belonging to the individual components of the system, suchas:

a) pavement surface(runway);

b) tires (aircraft);

c) contaminants (between the tire and the pavement);and

d) atmosphere (temperature, radiation affecting the state of thecontaminant).

2.2 Figure2-1 illustratesthefrictioncharacteristicsandhowtheyinterrelateinthedynamicsystemofanaircraft inmotion.

2.3 The three main components of the systemare:

a) surface friction characteristics (static materialproperties);

b) dynamic system (aircraft and pavement in relative motion);and

c) system response (aircraftperformance).

Theaircraftresponsedependslargelyontheavailabletire-pavementfrictionandtheaircraftanti-skidsystem.

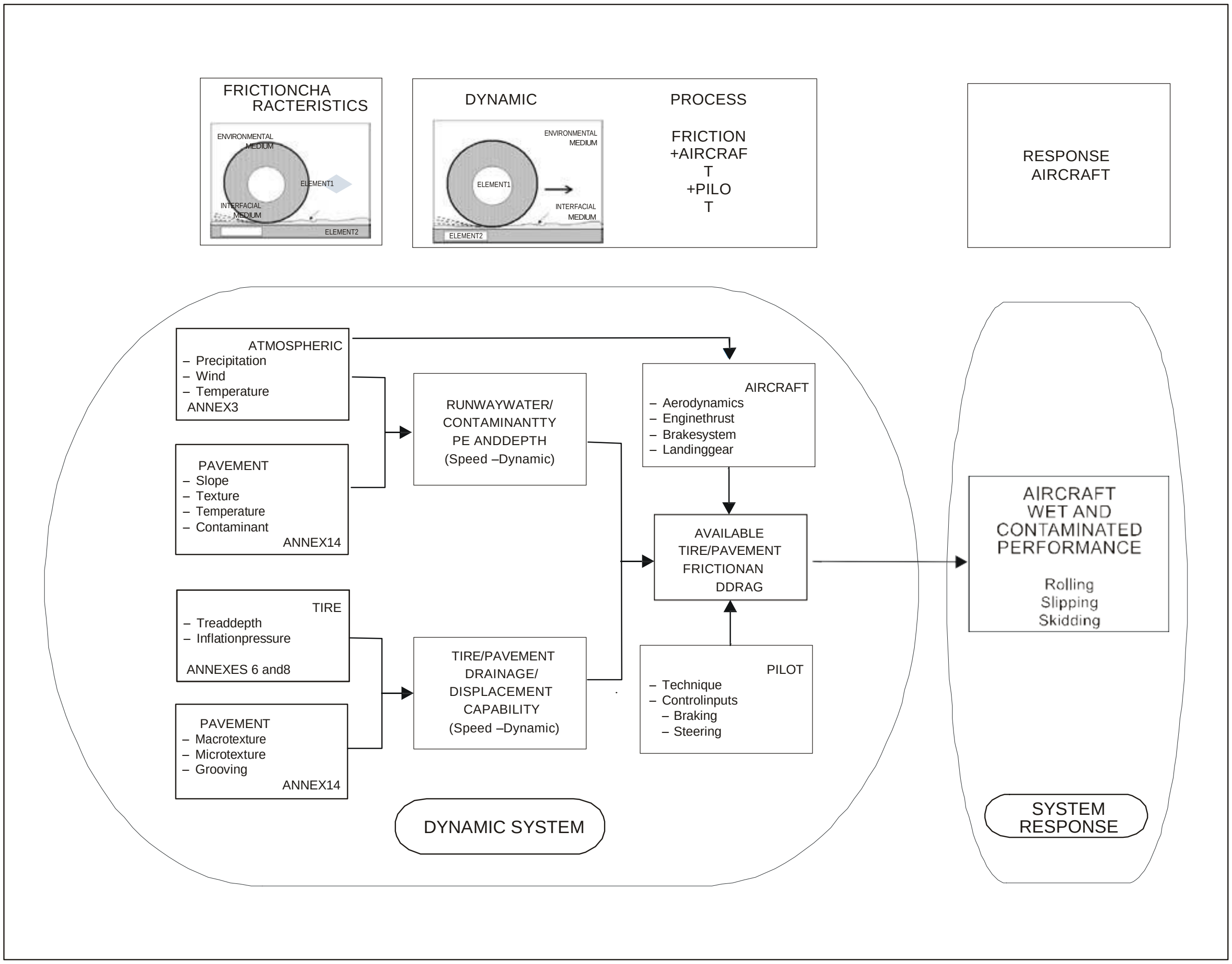


Figure 2-1. Basic friction characteristics, the dynamic system and the systemresponse

PAVEMENT

FUNCTIONALREQUIREMENTS

3.1 A runway pavement, considered as a whole, is required to fulfil three basic functions asfollows:

a) provide adequate bearingstrength;

b) provide good riding qualities;and

c) provide good surface frictioncharacteristics.

3.2 Other requirementsinclude:

a) longevity;and

b) ease ofmaintenance.

3.3 Thefirstcriterionaddressesthestructureofthepavement,thesecondthegeometricshapeofthetopofthe pavementandthethirdthetextureoftheactualsurfaceanddrainagewhenitiswet,textureandslopebeingthe mostimportantfrictioncharacteristicsofrunwaypavement.Thefourthandfifthcriteriaaddress,inadditio ntothe economic dimension, the availability of the pavement for aircraftoperations.

DRYRUNWAY

3.4 When in a dry and clean state, individual runways generally provide operationally insignificant differencesinfrictionlevels,regardlessofthetypeofpavementandtheconfigurationofthesurface.Moreov er,thefrictionlevel available is relatively unaffected by the speed of the aircraft. Hence, the operation on dry runway surfaces is satisfactorily consistent, and no particular engineering criteria for surface friction are needed for thiscase.

WETRUNWAY

3.5 The problem of friction on runway surfaces affected by water can be expressed primarily as ageneralizeddrainage problem consisting of three distinctcriteria:

a) surface drainage (surface shape,slopes);

b) tire/ground interface drainage (macrotexture); and

c) penetration drainage(microtexture).

3.6 Thesethreecriteriacanbesignificantlyinfluencedbyengineeringmeasures,anditisimportanttonote that all of them must be satisfied to achieve adequate friction in all possible conditions ofwetness.

CONTAMINATEDRUNWAY

3.7 Theproblemoffrictiononrunwaysurfacesaffectedbycontaminantscanbeexpressedprimarilyasa generalized maintenance problem consisting of improved interfacial drainage or removal of the contaminants. Themostdominant of theseare:

a) maintenance of improved interfacial drainage capability for pavements contaminated by water(morethan 3 mm indepth);

b) removal of rubber deposits;

c) removal of snow, slush, ice or frost;and

d) removal of other deposits such as sand, dust, mud andoil.

3.8 Theseissuescanbesignificantlyinfluencedbythelevelofmaintenanceprovidedbytheairport operator.

DESIGN Texture

Surfacetexture

3.9 Themostimportantaspectofthepavementsurfacerelativetoitsfrictioncharacteristicsisthesurfacetexture.Theeffectofsurfacematerialonthetire-to-groundcoefficientoffrictionarisesprincipallyfromdifferencesin surface texture. Surfaces are normally designed with sufficient macrotexture to obtain a suitable water drainage ratein thetire/roadinterface.Thetextureisobtainedbysuitableproportioningoftheaggregate/mortarmixorbysurface finishing techniques. Pavement surface texture is expressed in terms of macrotexture and microtexture (see Figure3-1). However,thesearedefineddifferentlydependingonthecontextandmeasuringtechniquethetermsareusedin. Furthermore, they are understood differently in various parts of the aviation industry.EAC 139.19 containsfurther guidance on thissubject.

3.10 TextureisdefinedinternationallythroughISOstandards.[1] Thesestandardsrefertotexturemeasuredby volume or by profile and expressed as mean texture depth (MTD) or mean profile depth (MPD). These standardsdefinemicrotexturetobebelow0.5MPDandmacrotexturetobeabove0.5MPD.Thereisnouniversallyagreedrelationshipbetween MTD andMPD.

Chapter 3

Microtexture

3.11 Microtexture is the texture of the individual stones and is hardly detectable by the eye. Microtextureisconsidered a primary component in skid resistance at slow speeds. On a wet surface at higher speeds a water film may prevent direct contact between the surface asperities and the tire due to lack of drainage from the tire-to-groundcontactarea.

1. TheInternationalOrganizationforStandardization,Characterizationofpavementtexturebyuseofsurfaceprofiles:—Part2:Terminology and basic requirements related to pavement texture profile analysis, ISO 13473-2,2002.

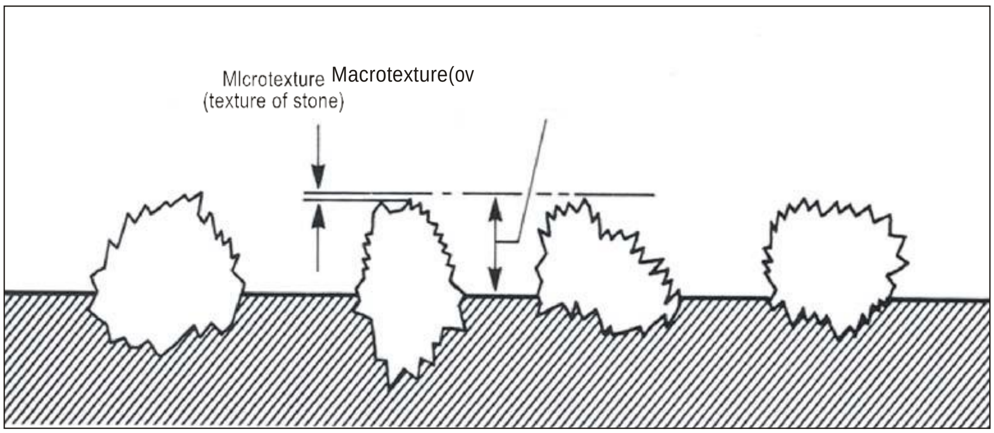


Figure 3-1. Microtexture andmacrotexture

3.12 Microtexture is a built-in quality of the pavement surface. By specifying crushed material that willwithstand polishing,microtextureanddrainageofthinwaterfilmsareensuredforalongerperiodoftime.Resistanceagainst polishingisexpressedthroughthepolishedstonevalue,whichisinprincipleavalueobtainedfromfriction measurementin accordance with international standards (ASTM D 3319, CEN EN1097-8).

3.13 A major problem with microtexture is that it can change within short time periods without beingeasily detected. A typical example of this is the accumulation of rubber deposits in the touchdown area which will largelymaskmicrotexture without necessarily reducingmacrotexture.

Macrotexture

3.14 Macrotextureisthetexture betweentheindividualstones.Thisscaleoftexturemaybejudgedapproximatelybytheeye.Macrotextureis primarilycreatedbythesizeofaggregateusedorbytreatmentofthesurface.Groovingaddsto themacrotexture,althoughhowmuchitaddsdependsonwidth,depthandspacing.Macrotextureisthemajor factor influencing the tire/ground interface drainage capacity at highspeeds.

Engineering Sciences Data Unit(ESDU)

3.15 ESDU describes the microtexture as the texture of the individual stones of which the runway isconstructedand depends on the shape of the stones and how they wear. This type of texture is the texture which makes thesurface feel more or less harsh but which is usually too small to be observed by the eye. It is produced by the surfaceproperties(sharpnessandhardness)oftheindividualchippingsorparticlesofthesurfacewhichcom eindirectcontactwiththe tires.

3.16 Formeasurementofmacrotexture,simplemethodssuchastheso-calledvolumetric"sandpatch"and"NASA grease patch" methods were developed. These were used for the early research which today's airworthinessrequirementsare based upon and as such are referred to through underlying documentation. For airworthiness, ESDU documentation is referenced and used. ESDU 71026 and ESDU 95015 refer to texture measurements from runways made in theseventies using the sand or grease patch measuring technique. From these measurements ESDU developed a scale classifyingthe macrotexture A through E (see Chapter 5 of thiscircular).

Drainage

3.17 Surfacedrainageisabasicrequirementofutmostimportance.Itservestominimizewaterdepthonthes urface. The objective is to drain water off the runway in the shortest path possible and particularly out of the area ofthe wheelpath.Quiteobviously,thelongerthepaththatsurfacewaterhastotaketoexittherunway,thegreaterth e drainage problem will be.

3.18 Topromotethemostrapiddrainageofwater,therunwaysurfaceshould,ifpracticable,becambered exceptwhereasinglecrossfallfromhightolowinthedirectionofthewindmostfrequentlyassociatedwithra inwould ensure rapiddrainage.

3.19 Theaveragesurfacetexturedepthofanewsurfaceshouldbedesignedtoprovideadequatedrainagein expected rainfall conditions. Macrotexture and microtexture should be taken into consideration in order to providegoodsurface friction characteristics. This requires some form of special surfacetreatment.

3.20 Drainagecapabilitycan,inaddition,beenhancedbyspecialsurfacetreatments,suchasgroovingandp orous friction course which drains water initially through voids of a specially treated wearingcourse.

3.21 It should be clearly understood that special surface treatment is not a substitute for goodrunway construction and maintenance. Special treatment is certainly one of the items that should be considered whendeciding onthemosteffectivemethodforimprovingthewetfrictioncharacteristicsofanexistingsurface,butotheritems(drainage, surface material, slope) should also beconsidered.

3.22 When there is reason to believe that the drainage characteristics of a runway, or portions thereof, arepoor duetoslopesordepressions,thentherunwaysurfacefrictioncharacteristicsshouldbeassessedundernaturalorsimulatedconditionsthatarerepresentativeoflocalrainfallrates.Correctivemaintenanceactiontoimprovedrainageshould be taken if foundnecessary.

Drainage characteristics of the movement and adjacentareas

3.23 Rapid drainage of surface water is a primary safety consideration in the design, constructionandmaintenance of pavements and adjacent areas. It serves to minimize the water depth on the surface, in particular inthe area of the wheel path. The objective is to drain water off the runway in the shortest path possible and particularly outofthe area of the wheel path. There are two distinct drainageprocesses:

a) natural drainage of the surface water from the top of the pavement surface;and

b) dynamic drainage of the surface water trapped under a moving tire until it reaches outside thetire-to-ground contactarea.

3.24 Both processes can be controlledthrough:

a) design;

b) construction;and

c) maintenanceofthepavementsinordertopreventaccumulationofwateronthepavementsurface.

Design and maintenance of pavement fordrainage

3.1 Naturaldrainageisachievedthroughthedesignofslopesonthevariouspartsofthemovementarea allowingthesurfacewatertoflowawayfromthepavementtotherecipientassurfacewaterorthroughasubsurfacedrainagesystem.Theresultingcombinedlongitudinalandtransverseslopeisthepathforthenaturaldrainagerun-off.This path can be shortened by adding transversegrooves.

3.2 Dynamic drainage is achieved by providing texture in the pavement surface. The rolling tire builds upwaterpressure and squeezes the water out the escape channels provided by the texture. The dynamic drainage of thetire-to-ground contact area is improved by adding transversegrooves.

3.3 Thedrainagecharacteristicsofasurfacearebuiltintothepavement.Thesesurfacecharacteristicsare:

a) slope;and

b) texture, including microtexture andmacrotexture.

Slope

3.4 Adequate surface drainage is provided primarily by an appropriately sloped surface in both thelongitudinal andtransversedirections,andsurfaceevenness.Themaximumslopeallowedforthevariousrunwayclasses and variouspartsofthemovementareaisgivenin<u>ECAR 139</u>Furtherguidanceisgivenin<u>EAC 139.9</u>

Macrotexture (drainage)

3.5 Theobjectiveistoachievehighwater-dischargeratesfromunderthetirewithaminimumofdynamicpressure build-up, and this can be achieved only by providing a surface with an openmacrotexture.

3.6 Interfacedrainageisactuallyadynamicprocesshighlycorrelatedtothesquareofspeed.Therefore,macrotexture is particularly important for the provision of adequate friction in the high-speed range. From theoperational aspect,thisismostsignificantbecauseitisinthisspeedrangewherelackofadequatefrictionismostcriticalwithrespect to stopping distance and directional controlcapability.

3.7 In this context it is worthwhile to make a comparison between the textures applied in road constructionand runways. The smoother textures provided by road surfaces can achieve adequate drainage of the footprint ofan automobiletirebecauseofthepatternedtiretreads,whichsignificantlycontributetointerfacedrainage.Aircrafttires,however,cannotbeproducedwithsimilarpatternedtreadsandhaveonlyanumberofcircumferentialgrooveswhichcontributesubstantiallylesstointerfacedrainage.Theireffectivenessdiminishesrelativelyquicklywithtirewear.

3.8 <u>ECAR 139</u>recommends a macrotexture of no less than 1 mm MTD. Coincidentally, thishappenstobeconsistentwiththetexturedepthofthesurfaceontheESDUscalethatisusedindetermininгthecertified performance data for a wet, grooved or porous friction coursesurface.

Microtexture (drainage)

3.9 The interface drainage between the individual aggregate and the tire is dependent upon the fine textureon the surface of the aggregate. At lower speeds water can escape as the pavement and tire come in contact.Aggregates susceptible to polishing can lessen thismicrotexture.

3.10 It is of utmost importance to choose crushed aggregates, which can provide a harsh microtexture thatwillwithstandpolishing.

Rainfall

3.11 Rainfallbringsmoisturetotherunway,whichwillhaveaneffectonaircraftperformance.Flighttestdatashowthatevensmallamountsofwatermayhaveasignificanteffectonaircraftperformance,e.g.dampruns ways effectively reduce aircraft braking action below that of a clean and dryrunway.

3.12 Rainfallonasmoothrunwaysurfaceaffectsaircraftperformancemorethanrainfallonarunwaysurfacewithgoodmacrotexture.Rainfallonrunwaysurfaceswithgooddrainagehasalessereffectonaircraftperformance.Grooved runways and runways with porous friction course surfaces fall into this category. However, there comes atime when the drainage capabilities of any runway exposed to heavy or torrential rain can be overwhelmed bywater,especially if maintenance has beenneglected.

3.13 At sufficiently high rainfall rates water will rise above the texture depth. Standing water will occur, leading to equally hazardous situations as might occur on smooth runways. Improved performance at such rainfall ratesshouldnotbeusedanymore.Forexample,agroovedorPFCrunwaysubjecttotorrentialrainfallmightperformworsethana regular smooth, wet runway.

Currentresearch

3.14 Thereisongoingresearchtryingtolinkrainfallrate,textureanddrainagecapacity.Thisisanimportantrelationshipwheretheaimistoestablishcriticalrainfallratesasafunctionoftextureanddrainagecharacteristics.Threshold values could then be established where, for instance, a wet, skid-resistant surface would no longer qualifyfor performance credit or where there would be a risk of aquaplaning. Runways could then be classified based ondifferentdrainagecharacteristics.

3.15 Various studies have been performed over the past decades to relate rain intensity andrunway characteristicstowaterdepthontherunway.Waterdepthontherunwaydetermineswhataircraftperformancedatashouldbeusedbytheflightcrew,e.g.regularwetperformanceorstandingwaterperformance.Itseemsthatwaterdepthmodellingiscurrentlytheonlyavailablemethodthatcanbeusedinatimelymannertoinformflightcrewsoftheamount of water present on a runway. Runway design parameters, notably texture depth, are a main indicator ofwaterdepthasafunctionofrainintensity.Rainintensityitselfcanbederivedfromweatherradardataorforward-scattermeters. Weather radar information can provide a timely warning, whereas forwardscatter meters can potentiallyprovide actual rain intensity information for each runway third. These are all subjects that needs furtherstudy.

Current reportingpractices

3.16 Disregardingwinteroperations,arunwayiscurrentlyreportedasdry,damp,wetorcontaminatedasaresultofstandingwater.AdditionallyaNOTAM“slipperywhenwet”maybeissuedwheneverasignificantportionofa runway drops below the minimum friction level (MFL) as indicated in Table 3-1 ofEAC 139.19

3.17 Classifying a runway as damp or wet is not at all a straightforward matter because various subjectivecriteria,dependingupontheaerodromeortheState’sstandardsorpolicies,maybeused.Different practicesareusedrangingfromwhether or not the runway wetness causes it to appear shiny, the use of the “effectively dry” provision in current EU-OPS,reportingarunwayaswetonlyduringheavyrainfallorreportingarunwayaswetwheneverrainisfalling.

3.18 Reporting flooded runway conditions is difficult because methods for accurate, reliable andtimely determination of the water depth on a runway are not available. Flooded runway conditions have contributed toseveral accidents worldwide. Obviously the frequency of occurrence of flooded runway conditions will be higher for theregions more prone to torrential rainfall and equally for the lower macrotexturerunways.

3.19 There are currently no internationally agreed terms for reporting the intensity level ofrainfall.

CONSTRUCTION

Selection of aggregates and surfacetreatment

3.20 **Crushedaggregates.**Crushedaggregatesexhibitagoodmicrotexture,whichisessentialinobtaining good frictioncharacteristics.

3.21 **Portland cement concrete (PCC).** The friction characteristics of PCC are obtained by transversal texturingofthesurfaceoftheconcreteunderconstructionintheplasticphysicalstatetogivethefollowingfinishes:

a) brush orbroom;

b) burlap drag finish;and

c) saw-cutgrooving.

3.22 For existing pavements (or new brand-hardened pavements) the saw-cut technique is typicallyused.

3.23 The two first techniques provide rough surface texture, whereas the saw-cut groove technique providesa good surface drainagecapacity.

3.24 **Hot-mixasphalt.** Bituminousconcretemusthavegoodwaterproofingwithhighstructuralperformance.Thespecificationofmixturedependsondifferentfactors,suchaslocalguidelines,typeandfunctionofsurfaces,typeand intensity of traffic, raw materials andclimate.

3.25 Withaselectionofcrushedaggregatesofgoodshapeandawell-gradedasphaltmixdesignratingcombinedwithstandardmechanicalcharacteristics(e.g.adhesionofbindertoaggregates,stiffness,resistanceto permanentdeformation,resistancetofatigue/crackinitiation,resistancetoabrasion),theexpectedmacrotexturewill normally reach 0.7 to 0.8 mm with an 11 to 14 mm sizeaggregate.

3.26 **Groovingandporousfrictioncourse.** Twomethodswhichhavehadsignificantinfluenceonimproved frictioncharacteristicsforrunwaypavementsaregroovingandtheopen-graded,thin,hot-mixasphalt(HMA)surfacecalled porous friction course(PFC).

3.27 Additional guidance on grooving of pavements and the use of a PFC is contained inEAC 139.11 Doc 9157, Part3.

Grooving

3.28 The primary purpose of grooving a runway surface is to enhance surface drainage andtire/groundinterfacialdrainage.Naturaldrainagecanbesloweddownbysurfacetexture,butcanbeimprovedbygrooving,whichprovidesashorterdrainagepathwithmorerapiddrainage.Groovingaddstotextureinthetire/groundinterfaceand provides escape channels for dynamicdrainage.

3.29 Thefirstgroovedrunwaysappearedonmilitaryaerodromesin theUnitedKingdom(mid-1950s).TheUnitedStatesfollowedupbyestablishingagroovedNASAresearchtrack(1964and1966)Thefirstcivilaerodromes with grooved runways were Manchester in the United Kingdom (1961) and John F. Kennedy in the United States(1967). Ten years later (1977) approximately 160 runways had been grooved worldwide. The research conducted in theseearly yearsisthefoundationforthedocumentationinEAC 139.ReportsfromthisresearchareavailablefromtheNASA Technical Report Server(NTRS).

3.30 Runwaygroovinghasbeenrecognizedasaneffectivesurfacetreatmentthatreducesthedangerofhydroplaningforanaircraftlandingonawetrunway.Thegroovesprovideescapepathsforwaterinthetire/ground contact area during the passage of the tire over the runway. Grooving can be used on PCC and HMA surfacesdesigned forrunways.

3.31 Inaddition,theisolatedpuddlesthatarelikelytobeformedonnon-groovedsurfacesbecauseofunevensurfaceprofilearegenerallyreducedinsizeoreliminatedwhenthesurfaceisgrooved.Thisadvantageisparticularly significantinregionswherelargeambienttemperaturevariationsmaycauselow-magnitudeundulationsintherunway surface.

3.32 **Construction methods.** Grooves are saw-cut by diamond-tipped rotary blades. The end-product qualityofthegroovesproducedcanvaryfromoperatortooperator.Theequipmentisspecialized,althoughit canbebuilt"in-house" by the operator. This equipment should be operated only by skilledoperators.

3.33 **Tolerances.**Inorderforawet,groovedrunwaysurfacetobeconsideredforaircraftperformance,thesaw- cut grooves must meet tolerances set by the State for alignment, depth, width and centre-to-centrespacing.

3.34 **Clean-up.**Clean-upofwastematerialmustbecontinuousduringagroovingoperation.Alldebris,wasteand by-products generated by the operation must be removed from the movement area and disposed of in anapproved manner in compliance with local and Stateregulations.

3.35 **Maintenance.**Asystemmustbeestablishedforsecuringthefunctionalpurposeofmaintainingcleangrooves (rubber removal) and preventing or repairing collapsedgrooves.

3.36 The macrotexture of the runway surface can be effectively increased by grooving, and this is applicabletoasphalt and concrete surfacing. The macrotexture of ungrooved, continuously graded asphalt is typically in the rangeof0.5to0.8mmandslightlyhigherforstonemasticasphalt.Inservice, grooveswеardownwithtraffic,andthishasthe effect of reducing macrotexture over time. Various States use differing groove geometry, and Table 3-1 showsexamples of these and the effect of grooving on macrotexture for new and worn grooves. Porous asphalt and specialfriction-treatmentsurfacingsnormallyhavehighermacrotextureandarenotgrooved.

Table3-1. Groovegeometry

		Groovegeometry			Macrotexture(mm)	
					Asphalt	
		Wi dth(	Dep th(	Centre-to- centrespaci	Ungroove d	Grooved
Australia	New	6	6	38	0.65	1.49
Norway	New	6	6	125	0.7–1.6	0.95–1.81
UnitedKingdo	New	4	4	25	0.65	1.19
UnitedStates	Halfworn	6	3	38		1.02

3.61 The effect of grooving on macrotexture can be calculated for any groove geometry andsurfacing macrotexture using the following equation, which is applicable to rectangular/squaregrooves:

$$Mg = \frac{WD + M_u(S-W)}{S}$$

where: Mg = groovedmacrotextur e;

W =

D = groovedepth;

Mu = ungroovedmacrotext ure;

S =

Example from a United Kingdomairport

Grooves 3 mm deep and wide with a spacing of 25 mm and an ungrooved macrotexture of 0.64 mm will give agrooved macrotextureof:

(3 x 3 + 0.64 x (25–3))/25 = 0.92mm.

3.62 Inservice,thegrooves weardownwithtrafficandpartlyfillwithrubberinthetouchdownareas.Althoughthiswearandcloggingaffectonlypartoftherunway,andtheaveragetextureisstillmainlydeterminedbytheunwornandunclogged groovesontherestofrunway,itisusualtoaimforamacrotextureofrathermorethan1.0mmduring construction.

3.63 The pitch and size of groove vary by airport/authority (as shown for the State level in Table 3-1andfortheairportlevelintheexampleabove),andtheresultantneteffectonthetextureofthegroovedasphaltisdemonstrated. Thisindicatesthatgroovingaddsmorethanasmallamounttotherunwaytextureonairportsthatusethelargergrooves.

3.64 Grooving, however, has its limits. It will not cope totally with standing water due to ruts and pondingintherunway(commoninwornoutrunways),deepstandingwaterduetoheavyprecipitationandstandingwaterduetothe grooves and texture being filled with accumulation of rubber. However, grooving does make a difference to the grip ona wet runway as the water gets deeper on therunway.

3.65 Followingonfromtheabove,ithasbeenshown(Benedetto[2]etal.)thatbettermacrotexturedepthonarunwaysurfacemeansthelossofskidresistanceduringincidentsofheavyprecipitationisreduced(seeFigure3-2). ThisisimportantbecauseitunderlinestheECAArequirementforbothfrictionlevelsandtexturedepth.AsshowninFigure32,asspeedincreases,gripreduces.Groovingoffsetsthiseffectbyaddingmacrotexture,asindicatedbythe gap between the rough and smoothtraces.

Porous frictioncourse

3.66 Asanalternativetogrooving,aporousfrictioncourse(PFC)wasdevelopedintheUnitedKingdomin1959.Thefirst“frictioncourse”onarunwaywaslaidin1962.Itwasdeliberatelydesignednotonlytoimprove theskidresistance but to reduce the incidence of hydroplaning by providing a highly porous material toensureaquickgetawayofwaterfromthepavementsurfacedirectlytotheunderlyingimperviousasphalt. Thisasphaltmixtureisdesignedtopresentstructuralopenvoids(20to25percent)permittingnaturalordynamicdrainageatthetire/surfaceinterface.

3.67 Two main difficulties that relate to skid resistance that can appear when using PFCare:

2. A.Benedetto.“Adecisionsupportsystemforthesafetyofairportrunways:thecaseofheavyrainstorms”in:*TransportationResearch Part A: Policy and Practice*, 2002, Vol. 36, Issue 8, pp.665–682.

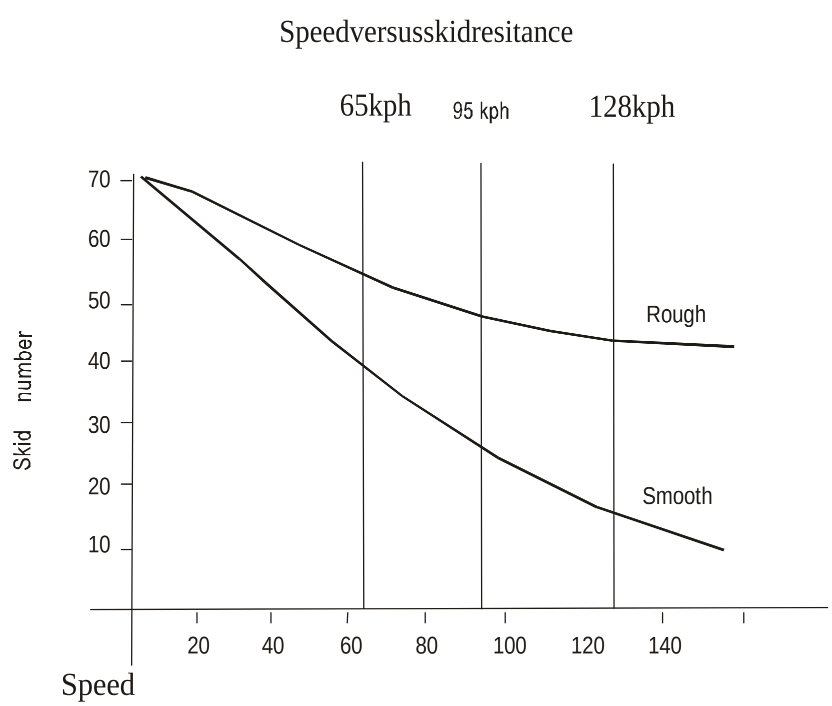


Figure3-2. The effect of grooves on macrotexture (courtesy of UK CAP683)

a) Rubber deposits must be monitored and must be removed before filling up the structural voidspaces. The functional effectiveness of PFC becomes nil if the removal is performed toolate.

b) Contamination may also fill void spaces and reduce this drainageefficiency.

MAINTENANCE

3.68 An appropriate maintenance programme should ensure adequate side drainage, rubber removal and cleaningof runway (non-winter)contaminants.

Removal ofrubber

3.69 The overarching purpose of rubber removal is to restore the inherent friction characteristics andunmask covered, painted runway markings. Every aircraft landing creates rubber deposits. Over time rubber depositsaccumulate,primarily in the touchdown and braking area of a runway. As a result the texture is progressively reduced, and thepainted area iscovered.

3.70 There are four methods of removing runwayrubber:

a) waterblasting;

b) chemicalremoval;

c) shot blasting;and

d) mechanicalmeans.

3.71 Nosinglemethodofremovalissuperiortoanyotherorforagivenpavementtype.Methodscanbecombined. The chemical method can be used to pre-treat or soften the rubber deposit before water blasting.Additional guidance on removal of rubber and other surface contaminants can be found inEAC 139.19.

3.72 **Damage to surface and installations.** One concern with rubber removal is not to damage theunderlying surface. Experienced operators who are familiar with their equipment are able to remove the required amount ofrubberwithoutcausingunintendeddamagetothesurface.Alessexperiencedorlessdiligentoperatorusingthesame equipment can inflict a great deal of damage to the surface, grooves, joint sealant materials, and ancillary items suchas paintedareasandrunwaylightingmerelybylingeringtoolonginoneareaorfailingtomaintainaproperforwardspeed.

3.73 Most damage appears to be associated with water blasting so only experienced operators should be used. Least damage appears to be associated with chemicalremoval.

3.74 **Retexturing.**Removalofrubberwithshotblastingcanhavetheadvantageofretexturingapolished pavementsurface.

3.75 The United States Transportation Research Board report[3] synthesizes the current information availablein runwayrubberremoval,includingtheeffectseachremovalmethodhasonrunwaygrooving,pavementsurfacesand appurtenances normally found on an aerodrome runway. Some regard this field as more of an art than a science.Thus, the report seeks to find those factors that can be controlled by the engineer when developing a runway rubberremovalprogramme.Thesynthesisidentifiesdifferentapproaches,modelsandcommonlyusedpractices,recognizingthe differences in each of the different rubber removalmethods.

SKIDRESISTANCE

Loss of skidresistance

3.76 The factors that cause loss of skid resistance can be grouped into twocategories:

a) mechanicalwearandpolishingactionfromrolling,brakingofaircrafttiresorfromtoolsusedformaintenance;and
b) accumulation ofcontaminants.

3.77 Thesetwocategoriesdirectlyrelatetothetwophysicalfrictioncharacteristicsofrunwaypavementsthatgenerate friction when in contact and relative motion with the aircrafttire:

a) microtexture;and

b) macrotexture.

3.78 ThePSVtestinvolvessubjectingasampleofsimilarlysizedaggregateparticlestoastandardamountofpolishingandthenmeasuringtheskidresistanceofthepolishedspecimen.Oncepolished,thespecimensare soaked and then skid-tested with a British pendulum. Thus, the PSV value is in fact a friction measurement in accordancewithinternational standards (ASTM D 3319, ASTM E 303, CEN EN1097-8).

3.79 Microtexture is reduced by wear and polishing.

Macrotexture (skidresistance)

3.80 Becausemacrotextureaffectsthehigh speedtirebrakingcharacteristics,itisofmostinterestwhenlooking atrunwaycharacteristicsforfrictionwhenwet.Simplyput,aroughmacrotexturesurfacewillbecapableofa greatertire- to-ground friction when wet than a smoother macrotexture surface. Surfaces are normally designed with asufficientmacrotexture to obtain suitable water drainage in the tire/pavementinterface.

3.81 ThroughtheharmonizedFAR25(1998)andCS-25(2000)certificationspecifications,therearetwo aeroplanebrakingperformancelevelsdefined—

oneforwet,smoothpavementsurfacesandoneforwet,groovedor PFCpavementsurfaces.Abasicassumptionabouttheseperformancelevelsisthattheaircrafttirehasaremaining tread depth of 2mm.

3.82 It is preferable to develop programmes aimed at improving surface texture and drainage of runwayssuch that the safety isimproved.

3.83 Macrotextureisreducedandlostasthevoidsbetweentheaggregatebecomefilledwithcontaminants.This can be a transient condition, such as with snow and ice, or a persistent condition, such as with the accumulationofrubberdeposits.

Surfacedressing

3.84 Skidresistanceforpavementsurfacescanbeimprovedbysurfacedressingusinghigh-qualitycrushed aggregatesandmodifiedpolymerbinderforbetteradhesionofgranularitiesonthesurfaceandforminimizingloose aggregates. The size of aggregates is limited to 5 mm. Nevertheless, this kind of product exhibits high texture depthand may potentially damage aircraft tires through wear. The application of these techniques must be consideredon pavements which present good structural and surfacecondition.

3.85 Comprehensiveguidanceonmethodsforimprovingtherunwaysurfacetextureisavailablein EAC 139.11, Chapter 5.

Chapter 4

Coefficient Of Frictionandfriction Measuringdevices

COEFFICIENT OFFRICTION

4.1 It is erroneous to believe that the coefficient of friction is a property belonging to the pavement surface and istherefore partofitsinherentfrictioncharacteristics.AsdescribedinChapter2,itisasystemresponsegeneratedby the dynamic system consisting ofthe:

a) pavementsurface;

b) tire;

c) contaminant;and

d) atmosphere.

4.2 Ithasbeenalongsoughtgoaltocorrelatethesystemresponsefromameasuringdevicewiththesystemresponsefromtheaircraftwhenmeasuredonthesamesurface.Asubstantialnumberofresearchactivitieshavebeencarried out that have brought new insight into the complex processes taking place. Nevertheless, to date, there isno universallyacceptedrelationshipbetweenthemeasuredcoefficientoffrictionandthesystemresponsefromtheaircraftalthough one State uses the coefficient of friction measured by a decelerometer and relates it to aircraft landingdistances(see AppendixA).

FRICTION MEASURINGDEVICES

Performance and use of friction measuringdevices

4.3 Friction measuring devices have two distinct and different uses at anaerodrome:

a) For maintenance of runway pavement, as a tool for measuring friction related tothe:
   1) maintenance planning level;and

   2) minimum frictionlevel;

b) For operational use as a tool to aid in assessing estimated surface friction when compacted snowand ice are present on therunway.

State-establishedcriteriaforfrictioncharacteristics

4.4 States should establish criteria for the friction characteristics related to the different levels mentioned in4.3and, as part of this, determine the performance criteria for the approval of friction measuring devices to be used intheir State. EAC 139.19Table3-1,indicatesthelevelsoffrictionassociatedwithsomefrictionmeasuringdevices.However, it must be noted that Table 3-1 refers to specific tests and specific friction measuring devices and cannot,andmustnot,betakenasglobalfrictionvaluesvalidforotherfrictionmeasuringdevicesofthesame makeandtype.

State-established performancecriteriafor friction measuringdevices

4.5 States are required to ensure that the acceptable friction measuring devices fulfil the performancecriteriaset by the State, taking into consideration factors such as repeatability and reproducibility for individual frictionmeasuringdevices.InorderforTable3-1ofEAC 139.tobeutilizedproperly,Statesshouldhaveinplaceproper calibration and correlation methods. Repeatability and reproducibility of continuous friction measuring equipmentshould meetperformancecriteriabaseduponmeasurementona100-mtestsurfacelength.Thislengthcorrespondstothe length considered significant for maintenance and reporting action byICAO.

4.6 Currently,repeatabilityintheorderof±0.03andreproducibilityintheorderof±0.07coefficientoffrictionunitsareclaimedtobeachievable.However,therehasnotyetbeenaninternationalconsensusonhowtoexpressrepeatabilityandreproducibilityinthecontextoffrictionmeasurementstobeusedformaintenanceandreporting purposes at aerodromes, although various design and measuring principles areavailable.

4.7 A major challenge for manufacturers producing friction measuring devices is an urgent replacement forthe NASAWallopsFlightFacility,situatedontheeasternshoreofVirginia,UnitedStates,whichisnolongeravailablefor thecertificationtestingoffrictionmeasuringdevices.State-endorsedfacilitieswillberequiredinthefutureinordertotake on the role played by the NASA Wallops FlightFacility.

4.8 Thereis,atpresent,nogloballyacceptedproceduresfordevelopingmethodsandlogisticsforusingthefriction measuring devices. States have chosen to develop methods and logistics based on localconditionsandhistoricalfleetsoffrictionmeasuringdeviceswithintheState.SomeStateshavedevelopedproceduresforcontrollingtheuncertaintiesinvolvedandhaveapprovedspecificfrictionmeasuringdevicesandhowtousethemrelativetothedesign and maintenance criteria set by the State. Some of these States have made detailed information related totheir use of friction measuring devices available through the Internet suchas:

a) Canadahttp://www.tc.gc.ca/eng/civilaviation/publications/tp14371-air-1-0-462.htm
http://www.tc.gc.ca/eng/innovation/tdc-projects-air-f-5620-332.htm

b) UnitedKingdom
http://www.caa.co.uk/application.aspx?catid=33&pagetype=65&appid=11&mode=detail&id=165

c) UnitedStates
http://www.airweb.faa.gov/Regulatory_and_Guidance_Library/rgAdvisoryCircular.nsf/0/2B97B2812BE290E986256C690074F20C?OpenDocument

http://www.airweb.faa.gov/Regulatory_and_Guidance_Library/rgAdvisoryCircular.nsf/0/B2A4EA852BABD7B7862569F1006DC943?OpenDocument

http://www.airweb.faa.gov/Regulatory_and_Guidance_Library/rgAdvisoryCircular.nsf/0/F9FEF87275AF78E986256A7900707EE1?OpenDocument

Chapter 5
AIRCRAFTOPERATIONS

FUNCTIONAL FRICTIONCHARACTERISTICS

How rolling, slipping and skidding affect theaircraft

5.1 **Aircraft/runwayinteraction.**Mechanicalinteractionsbetweenaircraftandrunwaysarecomplex and dependonthecriticaltire/groundcontactarea.Thissmallarea(approximately4squaremetresforthelargest aircraftcurrentlyinservice)issubjecttoforcesthatdrivetherollingandbrakingcharacteristicsoftheaircraft ,aswellas directionalcontrol.

5.2 **Lateral(cornering)forces.**Theseforcesallowdirectionalcontrolonthegroundatspeedswhereflightcontrolshavereducedeffectiveness.Ifcontaminantsontherunwayortaxiwaysurfacesignificantlyreduce thefrictioncharacteristics,specialprecautionsshouldbetaken(e.g.reducedmaximumallowablecrosswindfortake-offand landing, reduced taxi speeds) as provided in operationsmanuals.

5.3 **Longitudinalforces.**Theseforces,consideredalongtheaircraftspeedaxis(affectingaccelerationanddeceleration),canbesplitbetweenrollingandbrakingfrictionforces.Whentherunwaysurfaceiscoveredbyaloosecontaminant(e.g.slush,snoworstandingwater),theaircraftissubjectedtoadditionaldragforces fromthecontaminant.

Rolling friction forces

5.4 Rollingfrictionforces(unbrakedwheel)onadryrunwayareduetothetiredeformation(dominant)andwheel/axlefriction(minor).Theirorderofmagnituderepresentsonlyaround1to2percentoftheaircraftapparentweight.

Braking forces —generaleffects

5.5 Braking forces are generated by the friction between the tire and the runway surface whenbraketorqueisappliedtothewheel.Frictionexistswhenthereisarelativespeedbetweenthewheelspeedandthetirespeedatthecontact with the runway surface. The slip ratio is defined as the ratio between the braked and unbraked (zero slip)wheel rotation speeds in revolutions per minute(rpm).

The maximum possible friction force depends mainly on the runway surface condition, the wheel

5.1 load,thespeedandthetirepressure.Themaximumfrictionforceoccursattheoptimumslipratiobeyondwhichthefriction decreases. The maximum braking force depends on the friction available as well as the braking systemcharacteristics,
i.e. anti-skid capability and/or torquecapability.

5.2 Thecoefficientoffriction,μ,istheratiobetweenthefrictionforceandtheverticalload.Onagood,dry surface, the maximum friction coefficient, μmax, can exceed 0.6, which means that thebraking force can representmore than 60 per cent of the load on the braked wheel. On a dry runway, speed has little influence on μmax.
Whentherunwayconditionisdegradedbycontaminantssuchaswater,rubber,slush,snoworice,μmaxcanbereduceddrastically,affecting the capability of the aircraft to decelerate after landing or during a rejectedtake-off.

5.3 The general effects of runway surface conditions on the braking friction coefficient are brieflysummarizedin paragraphs 5.9 to 5.17 below.

5.4 **Wetcondition(lessthan3mmofwater).**μmaxinwetconditionsismuchmoreaffectedbyspeed(decreasing when speed increases) than it is in dry conditions. At a ground speed of 100 kt, μmax on a wet runwaywith standardtexturewillbetypicallybetween0.2and0.3;thisisroughlyhalfofwhatonewouldexpecttoobtainatalow speed such as 20 kt.

5.5 On a wet runway, μmax is also dependent on runway texture. A higher microtexture (roughness) willimprovethe friction. A high macrotexture, PFC or surface grooving will add drainage benefits; however it should be noted thatthe aircraftstoppingperformancewillnotbethesameasonadryrunway.Conversely,runwayspolishedbyaircraftoperations or contaminated by rubber deposits or where texture is affected by rubber deposits after repeated operations canbecome very slippery. Therefore, maintenance must be performedperiodically.

5.6 **Loosecontaminants(standingwater,slush,wetordrysnowabove3mm).**Thesecontaminantsdegrade μmax to levels which could be expected to be less than half of those experienced on a wet runway.Microtexture haslittleeffectintheseconditions.Snowresultsinafairlyconstantμmaxwithvelocity,whileslushandstandingwater exhibit a significant effect of velocity onμmax.

5.7 Becausetheyhaveafluidbehaviour,waterandslushcreatedynamicaquaplaningathighspeeds,aphenomenonwherethefluid’sdynamicpressureexceedsthetirepressureandforcesthefluidbetweenthetireand ground, effectively preventing physical contact between them. In these conditions, the braking capabilitydrops drastically, approaching or reachingnil.

5.8 Thephenomenoniscomplex,butthedrivingparameteroftheaquaplaningspeedistirepressure.High macrotexture(e.g.aPFCorgroovedsurface)hasapositiveeffectbyfacilitatingdynamicdrainageofthetire-runway contact area. On typical airliners, dynamic aquaplaning can be expected to occur in these conditions aboveground speeds of 110 to 130 kt. Once started, the dynamic aquaplaning effect may remain a factor down to speedssignificantly lower than those necessary to triggerit.

5.9 **Solidcontaminants(compactedsnow,iceandrubber).**Thesecontaminantsaffectthedeceleration capability of aircraft by reducing μmax. These contaminants do not affectacceleration.

5.10 Compactedsnowmayshowfrictioncharacteristicsthatarequitegood,perhapscomparabletoawet runway. However, when the surface temperature approaches or exceeds 0ºC, compact snow will become moreslippery, potentially reaching a very lowμmax.

5.11 Thestoppingcapabilityonicecanvarydependingonthetemperatureandroughnessofthesurface.In general, wet ice has a very low friction (μmax as low as 0.05) and will typically prevent aircraft operations until thefrictionlevelhasimproved.However,icethatisnotmeltingmaystillallowoperations,albeitwithaperformancepenalty.

Runway-surface contaminants resulting from the operation of aircraft, but which are not usuallyconsideredascontaminantsforaeroplaneperformancepurposes, arerubberdepositsorde-icingfluidresidues.Theseitemsareusuallylocalizedandlimitedtoportionsoftherunway.Runwaymaintenanceshouldmonitorthesecontaminantsandremovethemasneeded.AffectedportionswillbenotifiedviaNOTAMwhenthefrictiondropsbelowtheminimum required frictionlevel.

Contaminant dragforces

5.1 Whentherunwayiscoveredbyaloosecontaminant(e.g.standingwater,slush,non-compactedsnow),thereareadditionaldragforcesresultingfromthedisplacementorcompressionofthecontaminantbythewheel.Thedriving factors of these displacement drag forces are aircraft speed and weight, tire size and deflectioncharacteristics, andcontaminantdepthanddensity.Theirmagnitudecansignificantlyimpairtheaccelerationcapabilityoftheaircraftduringtakeoff.Forexample,13mmofslushwouldgeneratearetardationforcerepresentingabout3percentoftheaircraftweightat100ktforatypicalmid-sizepassengeraircraft.

5.2 A second effect of these displaceable contaminants (slush, wet snow and standing water)istheimpingementdrag,wherebytheplumeofsprayedcontaminantcreatesaretardationforcewhen impactingtheaircraftstructure. The combination of the displacement retardation force and impingement retardation force can be as high as8 to 12 per cent of the aircraft weight for a typical small/mid-size passenger aircraft. This force can be large enough thatin the event of an engine failure the aircraft may not be able to continueaccelerating.

Aircraft runway performanceimplications

5.1Itisobviousfromtheinformationprovidedabovethatassoonastherunwayconditiondeviatesfromthe ideal dry and clean state, the acceleration and deceleration capabilities of the aircraft may be affected negatively witha directimpactontherequiredtake-off,accelerate-stopandlandingdistances.Reducedfrictionalsoimpairsdirectional control of the aircraft, and therefore the acceptable crosswind during take-off and landing will bereduced.

Qualitativeassessment

5.2 Qualitatively, the impacts on the aircraft's maximum braking capability can be summarized asfollows:

a) Wet and solidcontaminants:

1) acceleration and hence take-off distance not affected;and

2) reduced braking capability, longer accelerate-stop and landingdistances.

b) Loosecontaminants:

1) accelerationcapabilityreducedbydisplacementandimpingementdrag(slush,wetsnowand standing water) or the force required to compress the contaminant (dry snow);and

2) decelerationcapabilityreducedbylowerfriction,aquaplaningathighspeeds,partially compensatedby displacement and impingementdrag.

5.3 As aresult:

a) take-off distance is longer (worse when the contaminant isdeeper);

b) accelerate-stop distance is longer (less so when the contaminant is deeper because ofhigherdisplacement and impingement drag);and

c) landingdistanceislonger(lesssowhenthecontaminantisdeeperbecauseofhigherdisplacement and impingementdrag).

Quantitativeassessment

5.4 Quantitatively, the following data provide the order of magnitude of the effects of runway conditions ontheactualperformanceofatypicalmedium-sizeaircraft,thereferencebeingdryconditions.(Accelerate-stopdistanceeffects assume take-off rejection at the same V1 speed, and the braked ground phase is calculated with maximumpedal braking.)Itshouldbementionedthattheimpactonregulatoryperformancemaybedifferentbecausetheregulatory calculation rules are dependent upon runwayconditions.

a) Wet conditions (no reversers):

1) acceleration and continued take-off are notaffected;

2) the accelerate-stop distance is increased by approximately 20 to 30 per cent. A grooved orPFC runway will reduce this penalty to approximately 10 to 15 percent;

Note. — Use of reverse thrust (one-engine inoperative) will reduce this effect by 20 to 50percentdependingontheeffectivenessofthereversersandrunwayconditions.

3) thebrakedlandinggroundphaseisincreasedby40to60percentonasmoothrunwayand 20 per cent on a grooved or PFCrunway.

Note.— Use of all-engine reverse thrust will reduce this effect by approximately 50 percentdependingontheeffectivenessofthereversersandrunwayconditions.

b) 13 mm of water or slush-coveredconditions:

1) the take-off distance is increased by 10 to 20 per cent with all-engines operating due todisplacementand impingementdrag;

Note.—Theeffectontheone-engineinoperativetake-offdistancewillbesignificantlylarger.

2) theaccelerate-stopdistancewillincreaseby50to100percent,reducedtoa30to70percentincrease with the use of thrust reversers (one-engine inoperative);and

3) the braked landing ground phase is increased by 60 to 100 per cent depending on theactual depth of the water or slush on the runway. This can be reduced significantly by the use ofreverse thrust.

c) Compact snow:

1) acceleration and continued take-off are notaffected;

2) the accelerate-stop distance is increased by 30 to 60 per cent, reduced to 20 to 30 per centwiththe use of thrust reversers (one-engine inoperative);and

3) thebrakedlandinggroundphasemayincreaseby60to100percent.Evenwiththeuseofreverse thrust, this may be as much as 1.4 to 1.8 times the dry runwaydistance.

4) thebrakedlandinggroundphasemayincreasebydistancesfromthevaluesnotedforcompactsnow to distances approaching the wet ice conditions notedbelow.

d) Wet iceconditions:

1) acceleration and continued take-off are notaffected;

2) the accelerate-stop distance is more than doubled, even with the use of thrust reversers;and

3) the braked landing ground phase may increase by a factor of 4 to 5. Even with the use ofreverse thrust this may be as much as 3 to 4 times the dry runwaydistance.

5.5 Wet ice conditions correspond to a braking action reported as “nil”, and operations should not beconductedduetotheperformanceimpactsdiscussedaboveandthepotentialforlossofdirectionalcontrolo ftheaircraft.

5.6 Asasummary,Figures5-1to5-3provideavisualindicationoftheimpactoftheseverityofrunway conditions on take-off distance, accelerate-stop distance and the landing ground phase for a typical medium-sizeaircraft withthrustreversersofaverageefficiency.Thetypicaleffectofawet,skid-resistantsurface(e.g.PFCorgrooved)isalsoprovided.

General

5.7 Aircraftbrakingsystemtechnologyhasevolvedsteadilyoverthepastdecadesinordertomaximizeit soverallefficiencysuchasdecelerationcapability,weight,durability,maintainability,reliabilityandcost perlanding.A short review of its main components is providedbelow.

Tires

5.8 Themainevolutionhasbeeninthestructureofthetireevolvingfrombiastoradialplieswithreducedw eightandimproveddurability.Bothbias-andradial-typetiresexisttoday.Intermsoffriction,thedurability/frictioncompromiseofrubbercompoundshasreach edmaturity,withalltiretypesshowingsimilarlevelsofμmaxonvarious types ofsurfaces.

5.9 Circumferential grooves contribute to drainage in the contact area, which reduces aquaplaningoccurrences.This positive effect diminishes with tire wear. Maximum friction values provided for certification of accelerate-stopdistances on wet runways are consistent with a 2-mm minimum tread depth on allwheels.

Wheels

5.10 Wheel technology has long since come to maturity, with forged aluminium alloys ensuring thebestcompromise between weight and durability. The wheels include fuse plugs that will ensure safe tire deflation followinga high-energy stop before there is any possibility of a potentially hazardous tireburst.

Figure5-1. Impactoftherunwayconditiononactualtake-offdistance(all-enginesoperative)

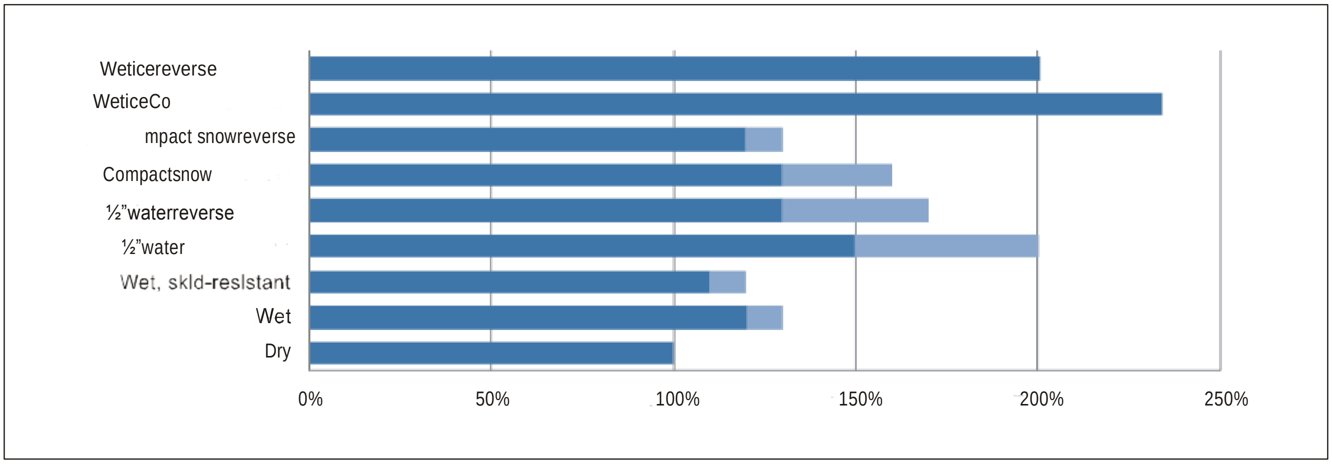


Figure5-2. Impact of the runway condition on accelerate-stopdistance

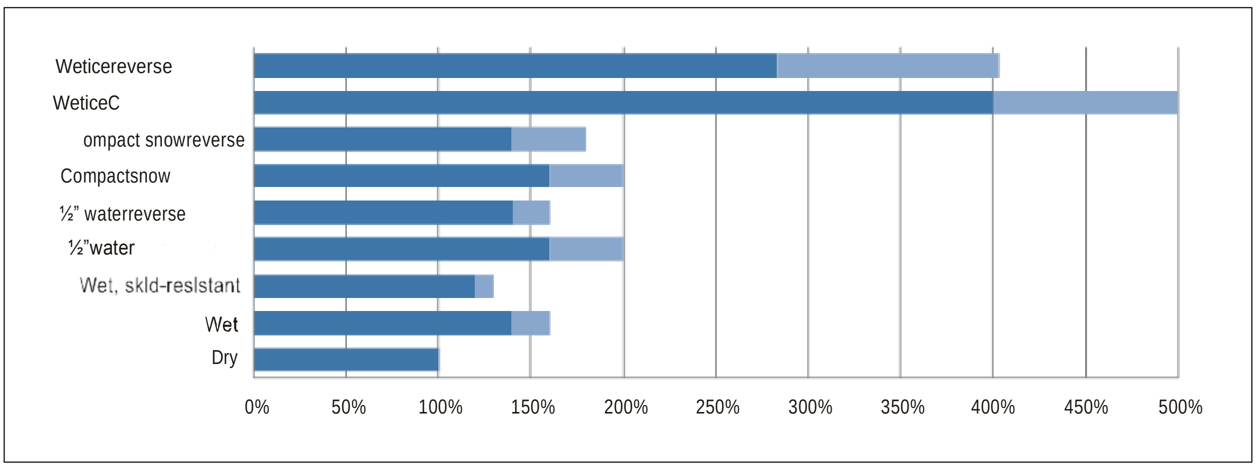


Figure5-3. Impact of the runway condition on the landing groundphase

Brakes

5.1 Discbrakesarethenorm.Discmaterialshaveevolvedfrommetal(steelorevencopperinsomespecificcases) to carbon. Both types coexist, but the light weight, durability and decreasing relative cost of carbon versussteeltend to make it the dominant technology for larger civilairliners.

5.2 Whilethemaximumbrakeenergyabsorptioncapabilityisdirectlydrivenbythematerialandmassofthe discs,themaximumtorquedependsonthedisknumberanddiameter,aswellastheappliedpressureonthediscs. Brake temperature and speed also affect this maximumtorque.

5.3 Pressureisappliedbyhydraulicpistonsthroughapressureplate.Electricallyactuatedpistonsarean emerging technology which will soon be in airlineservice.

Anti-skidsystem

5.4 Brakesaredesignedforamaximumtorquethatisachievedwhenthemaximumavailablepressureisapplied by pistons. When the vertical load on the wheel is high on a good friction surface (e.g. high aircraft weight ona dryrunway),themaximumavailabletire/groundfrictionforcewillnormallyexceedthatwhichcanbeobtainedatmaximumtorque.Inthiscase,thebrakingforcewillbetorque-limited(belowthetire/runwayfrictionlimit),withthe maximum value achieved when maximum pedal braking is applied.

5.5 Whentheloadonthewheeland/orμmaxdecreases,themaximumfrictionforcebetweenthetireandthegroundmaydecreasetolevelswheretheresultingtorquewillbebelowthemaximumtorquecapabilityofthebrake.Inthiscase,iffullpressureisallowedthroughthepistonstothewheelbrake,thewheelwilllockandthetirescouldfail.

5.6 To avoid this phenomenon, anti-skid systems have been developed which monitor the wheel-slip ratioandgovern piston pressure to achieve the best braking efficiency. These systems have evolved from primitive on/offdesignstofullymodulatingsystemstakingadvantageofthelatestdigitalcontroltechnologies.Theefficiencyoftheanti-skid system is the ratio between the average braking force achieved and the theoretical maximum braking force obtainedatthe optimum slip ratio (providingμmax).

5.7 This efficiency ranges between 0.3 for on/off systems to around 0.9 for modern, digital anti-skidsystems.Forcertification,anti-skidsystemoperationmustbedemonstratedbyflight-testingonasmooth,wetrunway,andits efficiency must be determined. In addition, modern anti-skid systems provide elaborate functions such as autobraking,maintainingapresetdecelerationlevel(frictionpermitting),allowingareductioninbrakewearandimprovementin passengercomfort.

5.8 Atverylowspeeds(below10kt),duetosensoraccuracylimits,antiskidbehaviourmaybecomeerraticand affect directional control. The latest systems however include a means to avoid thisanomaly.Bydesign,antiskidsystemsareeffectiveonlyifwheelspinexists,whichmaynotbethecasewhen dynamic aquaplaningoccurs.

Braking system test andcertification

5.1 Due to their critical influence on aircraft safety and regulatory performance, braking systems are subjecttoa thorough test and certification process before entry into service. They must comply with stringent regulations whichwill drive the architecture (e.g. redundancies, back-up modes in case of failure) as well as the design ofcomponents.

5.2 Brakeenduranceisprovenbybenchtests(dynamometer).Themaximumenergycapacityistestedboth onthebenchandthroughanactualaircraftrejectedtake-offtestin,orcloseto,themaximumwearcondition.Themaximumtorqueisidentifiedbyaircraftflighttestsaswellastheanti-skidefficiencyafterfine-tuningonbothdryandwet runways. These tests are also used to identify the aircraft performancemodel.

5.3 Itshouldbenotedthatnospecifictestsarerequiredoncontaminatedrunwayswithregardtobrakingsystembehaviouroraircraftperformance.Thecorrespondingdatamaybecalculatedbasedonthecertifiedmodelindry and wet conditions, supplemented by accepted methods for the effects of contamination on performance that arebased on previous test results obtained from a variety of aircrafttypes.

TEXTURE AND AIRCRAFT PERFORMANCE ON WETRUNWAYS

Wet runway certificationstandards

5.4 Sincetheearly1990s,JAA-certifiedaircrafttake-offperformanceforrejectedtake-offhasrequiredwetrunwayaccountabilityaspartoftheaircraft’sperformancecertification.TheFAAaddedasimilarrequirementin1998. This wet runway standard uses a wet runway μmax relationship from ESDU 71026 methods which have been codifiedin FAA/JAA airworthiness standards, endorsed subsequently by EASA inCS-25.

5.5 TheFAA/JAAairworthinessstandardsallowtwolevelsofaircraftperformancetobeprovidedinthe aeroplane flight manual for wet runway take-offs: wet, smooth runway performance and wet, grooved orPFC (sometimes referred to as wet, skid-resistant) runway performance. The wet, smooth runway performance data mustbe provided, while the wet, grooved/PFC data may be provided at the aircraft manufacturer’soption.

5.6 The certification requirements for aircraft rejected take-off stopping performance on a wet runway usesthe wet runway μmax relationship from ESDU report 71026, which contains curves of wet runway braking coefficientsversus speedforsmoothandtreadedtiresatdifferentinflationpressures.Thedataarepresentedforrunwaysofvarioussurfaceroughnessincludinggroovedand PFCsurfaces.TheESDUdataaccountforvariationsinwaterdepth,fromdamp to flooded; runway surface texture within the defined texture levels; tire characteristics and experimentalmethods.Indefiningthestandardcurvesofwetrunwaybrakingcoefficientversusspeedthatareprescribedbytheequationscodified in 14 CFR and EASA CS-25.109, the effects of tire pressure, tire tread depth, runway surface texture anddepthof the water on the runway were considered asfollows:

a) **Tire pressure.** The regulations provide separate curves for different tirepressures.

5.1 **Tiretreaddepth.**Thestandardcurvesarebasedonatiretreaddepthof2mm. Thistreaddepthisconsistent

a) with tire removal and retread practices reported by aircraft and tire manufacturers andtireretreaders.

b) **Depthofwaterontherunway.**Thecurvesusedintheregulationsrepresentawell-soakedrunway with no significant areas of standingwater.

5.2 Runway surface texture is taken into account in the definition of two different performance levels.One performancelevelisdefinedforawet,smoothrunwayperformance.Theotherisforawet,groovedorPFCrunway performancelevel.

5.3 ESDU71026groupsrunwaysintofiveclassifications.Theseclassificationsarelabelled“A”through“E” with “A” being the smoothest and “C” the most heavily textured, non-grooved, non-PFC surface asfollows:

Classification	Texturedepth(mm)
A	0.10–0.14
B	0.15–0.24
C	0.25–0.50
D	0.51–1.00
E	1.01–2.54

Wet, smooth runwayperformance

5.4 Thewet,smoothrunwayperformanceisalevelthathasbeendeemedappropriateforuseona“normal”wetrunway,thatisarunwaywhichhasnotbeenspecificallymodifiedorimprovedtoprovideimproveddrainageand therefore betterfriction.

5.5 ClassificationArepresentsaverysmoothtexture(anaveragetexturedepthof0.10mm)andisnotoftenfoundataerodromesservedbytransportcategoryaeroplanes.Mostungroovedrunwaysataerodromesservedby transport category aeroplanes fall into classification C. The curves in FAR and CS-25.109 used for wet, smoothrejected take-off runway performance represent a level midway between classification B andC.

Wet, grooved or PFC runwayperformance

5.6 FAA/JAA/EASA standards allow for a second wet runway rejected take-off performance level thatreflects the improvement in braking friction available from grooved and PFCrunways.

5.7 These surface treatments will result in a significant improvement in the wet runway stoppingperformance,butwillnotbeequivalenttodryrunwayperformance.Theμmaxlevelinthe FAA/JAA/EASAstandardsforgroovedandPFCrunwaysisalevelmidwaybetweenclassificationDandEasdefinedinESDU71026.Asanalternative,theregulations also permit using a wet, grooved or PFC braking coefficient that is 70 per cent of the braking coefficientusedto determine the dry runway accelerate-stopdistances.

5.8 Oneadditionalconstraintfortakingperformancecreditforthegrooved/PFCsurfaceisthatther unway must be built and maintained to a specific standard as described in FAA AC 150/5320-12C or itsequivalent.

Wet, skid-resistant pavement — improved stoppingcapability

The"ImprovedStandardsforDeterminingRejectedTakeoffandLandingPerformance"[1]adop

5.9 tedbythe FAAallowoperatorstotakecreditfortheimprovedstoppingcapabilityduringarejectedtake-offonwet runwaysthatare grooved or treated with a PFC overlay, but onlyif:

a) such data are provided in the aircraft flight manual [aircraftmanufacturer];

b) the operator [aircraft operator] has determined that the runwayis:

1) designed [aerodromeoperator];

2) Federal Aviation Administration, Department of Transportation, Office of Aviation Policy and Plans, Improved StandardsforDetermining Rejected Takeoff and Landing Performance, Federal Register, RIN: 2120-AB17, 63, FR 8298, February 18,1998.

3) constructed [aerodrome operator];and

4) maintained [aerodromeoperator];

c) in a manner acceptable to the administrator[State].

5.1 Thestandardenhancessafetybytakingintoaccountthehazardousconditionofarejectedtake-offona wet runway, and it creates an economic incentive to develop more stringent design, construction and maintenance programmes for runways to be considered acceptable for wet, grooved or PFC runway aircraft performance. Whilethe improved wet friction characteristics of these surfaces also benefit landing safety, the basic FAA/JAA/EASAcertification and operational rules do not provide landing performance credit for them. Nevertheless, some State authorities, suchas the FAA/JAA/EASA, have developed alternative means of compliance which may provide such credit on acase-by-case basis.Atpresentitisrecognizedbytheaviationindustrythatfurtherdevelopmentandregulationoftheconceptare needed.

5.2 The FAA has produced an advisory circular[2] which provides relevant guidelines and procedures relatedtoconstruction and maintenance of skid-resistant aerodrome pavementsurfaces.

RELATIONSHIP BETWEEN AIRCRAFT PERFORMANCESTANDARDS AND AERODROME MINIMUM FRICTION STANDARDS FOR WETRUNWAYS

5.3 Intheaviationworlditisoftenassumedthattheminimumfrictioncriteriain EAC 139.19Table3-1,andFAAAC150/5320-12Cprovideaminimumfrictionlevelwhichwouldallowtheaircrafttoachievetheperformance publishedintheAFMforasmooth,wetrunway.Ithasalsofurtherbeenassumedinmanyquartersthatiftherunway cannotmeettheminimumfrictionlevelthatiscalledforinTable3-1andtheaerodromedeclarestherunwayslippery when wet, then the aircraft’s performance would bedegraded.

5.4 However, the truth of the matter is that a relationship has not been established between the wheelbraking and friction assumptions used in the aircraft performance standards and the minimum friction standards stated inECAAECAR 139andFAAAC150/5320-12C.Thecertificationrequirementsforaircraftperformancedonotprovidea performance level to specifically address the case when an aerodrome reports a runway as slippery when wet because it failed a friction survey as defined by the ECAAand FAA advisorylevels.

5.5 The FAA Aviation Rulemaking Committee (ARC) working on take-off and landing performanceassessment(TALPA) recommends reducing the effective braking action for a wet runway from “good” to “medium” when therunway is designated as slippery when wet.

1. FederalAviationAdministration,Measurement,Construction,andMaintenanceofSkidResistantAirportPavementSurfaces,FAAAC 150/5320-12C,1997.

Chapter 6

REPORTING OF RUNWAY SURFACECONDITIONS

ICAO REPORTINGFORMATS

6.1 Theneedtoreportandpromulgaterunwaysurfaceconditionsisspecifiedin ECAR 139whichstipulatesthatinformationontheconditionofthemovementareaandtheoperationalstatusofrelatedfacilities shallbeprovidedtotheappropriateaeronauticalinformationservicesunits,andsimilarinformationofoperationalsignificancetotheairtrafficservicesunits,toenablethoseunitstoprovidethenecessaryinformationtoarrivingand departing aircraft. The information shall be kept up to date and changes in conditions reported withoutdelay.

6.2 Additionally, Annex 3, Appendix 3, 4.8.1.5, requires that information on, *inter alia*, the state of therunway beprovidedassupplementaryinformationintheaerodromeroutinemeteorologicalreport(METAR)andaerodrome special meteorological report (SPECI). This provision is subject to regional air navigation agreement and isnot implemented in all ICAO regions but does require that information on runway surface conditions should be passed tothe aerodrome meteorological office as needed.

6.3 Information on the runway surface condition includes the runway surface friction characteristics whichare assessedaccordingtotheaerodromemaintenanceprogramme,thepresenceofwater,snow,slush,iceorother contaminants on the runway, as well as the estimated surface friction in operationalconditions.

6.4 ICAOspecifiesthatthereportingandpromulgationofinformationonrunwaysurfaceconditionsismadethrough the followingmedia:

a) aeronautical information publications(AIPs);

b) aeronautical information circulars(AICs);

c) notice to airmen(NOTAM);

d) SNOWTAM;

e) aerodrome routine and special meteorological reports(METAR/SPECI);

f) automatic terminal information services (ATIS);and

g) air traffic control (ATC)communications.

The reporting formats for a) to d) are described in Annex 15. The reporting formats for e) are described in Annex 3and,for f) and g), in Doc4444.

The increasing use of ground/air-ground data link and computerized systems, both on board the aircraftand ontheground,isbeingprogressivelysupplementedwithdigitizedinformationsuchasCPDLCanddigitalSNOWTAM.

6.1 Currently, Annex 15 requires, *inter alia*, a description to be provided in the AIP of the typeoffrictionmeasuringdeviceused.Inaddition,therunwaysurfacefrictioncharacteristicsarerequiredtobedescribedintheAIP,AICsandNOTAMs.Forwinteroperations,abriefdescriptionofthesnowplanisalsorequiredtobepromulgatedintheAIP.

Aeronautical information publication(AIP)

6.2 Friction issues in the AIP are relatedto:

a) runway physical characteristics;and

b) the snowplan.

6.3 Annex15,Appendix1,Part3—Aerodromes(AD),AD2.12,requiresadetaileddescriptionofrunway physicalcharacteristics.Thephysicalcharacteristicsofawet,skid-resistantsurfacecanbeincludedintheremarks.

6.4 InAD1.2.2,abriefdescriptionshouldbegivenofgeneralsnowplanconsiderationsforaerodromesand heliportsavailableforpublicuseatwhichsnowconditionsarenormallyliabletooccur.Relatedfrictionissuesinclude:

a) measuring methods and measurementstaken;

b) system and means ofreporting;

c) cases of runway closure;and

d) distribution of information about snow, slush or iceconditions.

Aeronautical information circular(AIC)

6.5 An AIC should be originated whenever it is necessary to promulgate aeronautical information that doesnot qualifyforinclusioninanAIPoraNOTAM.Relatedfrictionissuesincludetheadvanceseasonalinformationonthesnowplan.

Notice to airmen(NOTAM)

6.6 A NOTAM should be originated and issued promptly whenever information to be distributed is ofa temporarynatureandofshortdurationorwhenoperationallysignificantpermanentchangesortemporarychangesoflong duration are made at shortnotice.

6.7 This applies to the friction issues related tothe:

a) physical characteristics published in the AIP;and
b) presenceorremovalof,orsignificantchangesin,hazardousconditionsduetosnow,slush,iceor water on the movementarea.

SNOWTAM

6.8 The need to establish the SNOWTAM format originated from IATA as a consequence of bad experiences insouthernEuropeduringthewinterof1962to1963.IATAconsideredthat"thetimehascometorecognisethefactthatwiththeoperationofhighspeedturbine-poweredaircraftsuchinformationisoftenofequalimportancetoinformationconcerning other weather phenomena which at present determines the operational usability of anaerodrome".

6.9 AtaninformalICAOmeetinginParisin1963,theSNOWTAMformatwasrecommended.Themeeting agreed that the most important objective, as espoused by IATA and IFALPA and recognized by States, was to reachtheidealconditionswhereprecipitantswereremovedfromallaerodromemanoeuvringareasassoonastheyappeared, thus ensuring that flight operations remainedunhampered.

6.10 SNOWTAM is a special series NOTAM notifying the presence or removal of hazardous conditionsduetosnow,ice,slushorstandingwaterassociatedwithsnow,slushandiceonthemovementareabymeansofaspecificformat. Annex 15, Appendix 2, provides instructions for the completion of the SNOWTAM format, includingdescriptions of the termsused.

METAR/SPECI

6.11 Subjecttoregionalairnavigationagreement,itispermissibletoincludeinformationonthestateoftherunwayasapartofthesupplementaryinformationoftheMETAR/SPECImeteorologicalreport,whichisissuedhourlyor half-hourlyinthecaseofMETAR,orasneededinthecaseofSPECI.Thedetailedspecificationsoftherequired information can be found in Annex 3, Appendix 3, with detailed coding information provided in the WorldMeteorological Organisation's *Manual on Codes* (WMO-No.306).

DATA GATHERING AND INFORMATIONPROCESSING

6.12 Several automated systems are becoming available which provide a remote indication of runwaysurfaceconditions, while others are still under development. At present, these systems are not in widespread use, andsystemsthat provide an accurate indication of braking action seem a long way off. This unavailability strongly affects therelatedcommunication process.

6.13 Consequently,aerodromeoperatorsneedtogatherrelevantdata,processtherelatedinformationusing manual systems and make information available to users using conventional ways that require a considerable amountof timeinadditiontotheneedtoobtainaccesstorunways,whichisoftendifficult,particularlyatbusyaerodromes.

6.14 Presently, the primary means of communication are ATIS and ATC, in addition toSNOWTAM.

Automatic terminal information service(ATIS)

6.15 ATIS presents a very important means of transmitting information, relieving operational personnel fromthe routine duty of transmitting runway conditions and other relevant information to the flightcrew.

6.16 OneinherentweaknessintheATSsystemisthecurrencyoftheinformation.Thisisduetothefactthat flight crews generally listen to ATIS on arrival, some twenty minutes before landing, and in rapidly changing weather,the runway conditions may vary dramatically in such a timespan.

Air traffic control(ATC)

6.17 TheorganizationresponsibleforgatheringdataandprocessinginformationofoperationalsignificancerelatingtorunwayconditionsusuallytransmitssuchinformationtoATC,andATC,inturn,providesthisinformationtotheflightcrewifdifferentfromtheATIS.Atpresent,thisprocedureappearstobetheonlyonethatisable toprovidetimely information to the flight crew, especially in rapidly changingconditions.

6.18 Inadditiontobeingtimely,informationdisseminatedthroughATCmaycontainadditionalinformationassociatedwithweatherobservedandforecastedbyMETpersonnel,evenbeforeitisavailableonATIS,aswellasinformation gathered by other flight crew, such as braking action reports. This arrangement provides pilots with thebestpossible information available within the current system for sound decisionmaking.

6.19 Finally, where visibility conditions and aerodrome configuration permit, ATC can provide the flight crew,atvery short notice, with their own immediate observations, such as a rapid change in rainfall intensity or the presenceof snow, notwithstanding that this may be considered as unofficialinformation.

Communicationnetwork

6.20 Air-ground communication between the flight deck and ATS has generally been conductedthrough radiotelephony speech but large areas remain beyond the high frequency (HF) or very high frequency (VHF)coverage. Theburdenofvoicecommunicationandthesaturationofpresent ATCcapabilitieshavecreatedastrongdemand forautomated ATS transmission of which digital data link has become a key element. Therefore, in the near future,service providersanduserswillneedtoadapttheirgroundcommunicationssystemstointernationaldatalinkrequirments.

6.21 Amendments82and83toAnnex10,VolumeIII,PartI,whichbecameapplicableon22November2007and 22 November 2008, respectively, contain provisions in Chapter 3, 3.5.2 and 3.5.3,concerning:

a) ADS-C andCPDLC;

b) FIS (including ATIS and METAR);

c) ATS interfacility data communication (AIDC);and

d) ATS message handling services applications (ATSMHS).

6.22 BoththeattachmenttoAnnex10,VolumeIII,PartI,andDoc9694giveguidanceonairtrafficservicesdatalinkapplications.Further,Doc9776,Doc9805,Doc9816andtheupcomingManualonAeronauticalSatellite Services provide guidance material for the implementation of telecommunicationsystems.

DIGITALNOTAM

6.23 A transition strategy is being developed to ensure the availability of real-time accredited andqualityassuredaeronauticalinformationtoanyATMuserinagloballyinteroperableandfullydigitalenvironment.Itisrecognizedthattosatisfy new requirements arising from the Global ATM Operational Concept, aeronautical information services (AIS)must transition to the broader concept of aeronautical information management(AIM).

6.24 Oneofthemostinnovativedataproductsthatwillbebasedonthestandardaeronauticaldataexchange model is a digital NOTAM that will provide dynamic aeronautical information to all stakeholders with an accurate andup- to-datecommonrepresentationoftheaeronauticalenvironmentinwhichflightsareoperated.ThedigitalNOTAM isdefinedasadatasetthatcontainstheinformationincludedinaNOTAMinastructuredformatwhichcanbefully interpreted by an automated computer system for accurate and reliable update of the aeronautical environment bothfor automated information equipment andhumans.

6.25 Some radical improvements that will be delivered by the digital NOTAM projectinclude:

a) graphical visualization instead of simpletext;

b) improved NOTAM data quality because digital data enable automatic validation;and

c) improved information-filteringcapabilities.

6.26 TogetherwithotherStatesandinternationalorganizations,EUROCONTROLandtheFAAareworkingwiththeICAOAISAIMStudyGrouptodefinethefutureexchangeofNOTAMinformationinanXMLformat.Thisformat,theaeronauticalinformationexchangemodel(AIXM),isaspecificationdesignedtoenabletheencodinganddistribution,indigitalformat,oftheaeronauticalinformationthatmustbeprovidedbythenationalAISinaccordancewithICAOprovisions.TheFAAiscurrentlydeployingasystemtobeusedfordigitalNOTAMsubmissioninthefederalUnitedStatesNOTAMsystemthatusesAIXM5asthedataencodingformat.Similarly, EUROCONTROLplanstohaveaninitial digital NOTAM operational capability early in 2012 through the European AIS Database (EAD). AIXM5 isbeing considered for inclusion in ICAO guidancematerial.

6.27 ThedigitalNOTAMconceptofoperationsassumesthatthecurrentNOTAMformatwillcontinueto beused for at least 15 years, in parallel with the new XML format which is easier for computers to decode. Thesame applies to SNOWTAMmessages.

FUTURE DEVELOPMENTS

6.28 There are inherent weaknesses in both the ATIS and ATC systems as means of transmittingsafety-critical information.

6.29 With the introduction of new technologies which will make widespread automated equipment availablefordata gathering and information processing, relevant information will be transmitted instantaneously to allpartiesconcernedsuchastheflightcrew,ATCandtheaerodromeoperator.Suchasystemshouldalsobecapab leofATISintegration, eliminating weak points of communication throughATC.

6.30 The ATC community is aware of its critical role in disseminating information on runway conditions, suchasinformation on contaminants, runway friction and braking action. Notwithstanding, ATC is also aware that relyingon operational personnel for such a task invites opportunities for human-related active failures tooccur.

Automatedsystems

6.31 Norway has developed an automated system where SNOWTAM information gathered and assessedis processed from the inspection vehicle. The ground staff is specially trained and authorized to use personalidentificationtologontothesystem.Theassesseddataareenteredonatouchscreenwherethereisabuilt-inlogicthatprohibits entering wrong or conflicting data according to applicable rules andregulations.

6.32 Upon activating the SEND button, the SNOWTAM data are then sent to an AIS network for screeningand processing.Theoperatorisgivenfeedbackasthedataareprocessedandcanverifyifthetransmissionhasbeeunsu ccessful.UsingtheAISnetwork,theATCandotherenduserswillbeabletoreceivetheSNOWTAM,whichisals o available on the Internet. The whole process occurs within a time frame of typically less than 15seconds.

Chapter 7

SAFETY, HUMAN FACTORS ANDHAZARDS

SAFETY

Evolution ofsafety

7.1 In retrospect, the historical progress of aviation safety can be divided into three distinctareas:

a) the fragile system (1920s to1970s);

b) the safe system (1970s to mid-1990s);and

c) the ultra-safe system (mid-1990sonwards).

7.2 Moderntechnologiesmakethedailycollectionandanalysis ofroutineoperationaldata,includingfrictiondata,possible.Thisinformation,exchangedthroughtheNOTAMsystem,highlightstheemergingissuesrelatedtofriction.

Digital, up-to-datedata

7.3 Future air traffic management (ATM) will rely on advanced data exchange and data-sharing servicesthatwill communicate aeronautical information. As a prerequisite, all information has to be supplied in digitalformatrenderingitsuitableforautomaticprocessingwithouthumanintervention.A“digitalNOTAMorSNOWTAM”canbe defined as a structured data set that contains the information currently distributed by text NOTAMmessages.

7.4 Thefocusisoncorrect,completeandup-to-datedata.ThecurrentNOTAMandSNOWTAMmessageswill continue to be issued, but the messages will be based on conversion of the digital aeronautical data, which willbecomethereference.

7.5 In short, it can be said that provisions developed during the fragile system and revised in the safesystemnow need to be updated in the ultra-safe system using digital, up-to-date data as shown in Figure7-1.

Humaninterface

7.6 Even with automatic processing three distinct human interfaces can beidentified:

a) **the ground staff** who produce the information or control/calibrate the instrument providingtheinformation for automaticprocessing;

b) **the ATM staff** who, by radio phraseology, transfer the information to the end user;and

c) **the flight crew** who make use of theinformation.

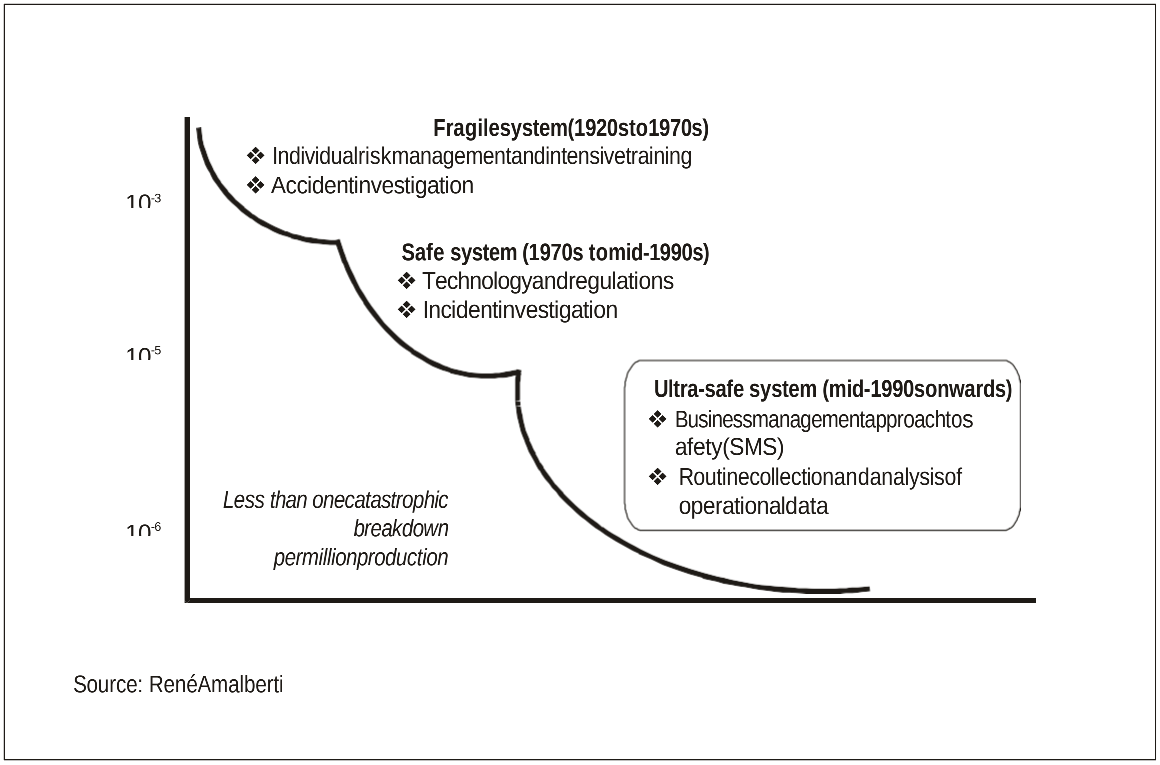


Figure 7-1. Historical evolution of aviationsafety

7.7 ToassistwithintroducingcommonalityonfrictionissuesacrossStates,itisrecommendedthatStatesintroduceregulationsrequiringoperatorstoprovidetrainingtothegroundandATMstaffandflightcrewinaccordance with AppendixB.

Gate-to-gateconcept

7.8 Thegate-to-gateconceptinvolvesconsideringandmanagingaflightasacontinuousevent.Itinvolves coordinating ATM processes with those of the airport and aircraft operators to provide a safe and seamlessmanagementapproach.Withthenewgate-to-gateconceptespousedintheICAOGlobalAirNavigationPlan,allthe activitiesrelatedtotheaerodromemovementareawillbeinthemiddleoftheloop.Up-to-datefriction-relateddatawillbedealtwithfromaHumanFactorsperspectivehighlightingwhenandhowtousethem.AppendixCliststhefriction issues relevant to each segment offlight.

Safetymargins

7.9 On the whole, to be on the safe side, the methodology used for aircraft performance assessmentsshould be conservative. Some parameters that have an influence on aircraft performance are known beforehand withsufficient accuracy; other parameters have greater uncertainty or may change rapidly. For parameters that cannot bedetermined accurately, additional conservatism may need to beapplied.

7.10 Adouble(andunnecessary)applicationofsafetyfactorsmayleadtogreateconomicpenaltiesand unintendedconsequencessuchasanill-adviseddiversion,andtheabsenceofanecessarysafetyfactormayleadto unsafesituations.Therefore,itisessentialtoknowtheuncertaintyofrelevantparametersandwhetherornota parameter used by the flight crew already includes a safetymargin.

HUMANFACTORS

Introduction

7.11 HumanFactorsaffectthegatheringofrunwayfrictiondataandalsothewaysuchinformationisgiventothosewhoneedit.Thekeyparticipantsinthisprocessarethedatagatherers,datatransmittersandtheusersoftheinformation(seeFigure72).Itisessentialthatbothparties(transmitterandreceiver)withinthecommunicationloophaveaclear,unambiguousandcommonunderstandingoftheterminology.Situationssuchasroutinemaintenanceor runway contamination scenarios alter the demands for cooperation between the variousparticipants.

Problemstatement

7.12 ThemainHumanFactorsissueisthateachactionispartofachainofeventsthatrequirescooperationbetweenpartiesandforthoseactionstobeexecutedinaparticularorder,eachonedependentuponasuccessfuloutcomefromthepreviousone.Althoughthe“howtodoit”partcanbeplanned,writtendownasinstructionsandagreed in advance by all participants, team work, negotiation, communication and cooperation are required to achieve theend result. Work accomplished so far by the FTF has shown that, worldwide, this has not always beenachieved.

Participants

7.13 Who are the main participants in these operations? From the aerodrome authority, a small team oftrainedoperatives is responsible for using specialist equipment (such as CFME) to gather runway friction data. From theairline operator,theflightcrewisresponsibleforthesafemanagementoftheflight.Betweenthesetwositstheairtrafficcontroller(ATC)who,inthiscase,primarilypassesinformationabouttherunwaytotheaircraftandthenactsuponresponsesthataregeneratedfromthecockpitasaresult.Connectedtothisinformationflowistheairline’sdispatch,operationscentreorhandlingagentthatusestheinformationgatheredfromtheflightcrew,ATCandtheaerodromeauthority to plan or amend flight schedulesaccordingly.

Communication andteamwork

7.14 ForovertwentyyearsmuchoftheemphasisconcerningflightdeckHumanFactorshasbeenplac edon team training and crew resource management (CRM) with the aim of training pilots to utilize all the resources available to them (including human resources) to operate safely. Many tasks involve an element of teamwork, and in suchcases communicationamongteammembersiscrucial.Oneofthequestionsoftenposedduringtheintroductoryphase ofteamtrainingis“whoistheteam?”Inansweringthisquestion,mostpeople,initiallyatleast,mentiontheircolle aguesintheimmediatevicinityactuallyinvolvedintheday-to-daytasks.Fewwilllookoutsideoftheirimmediateareaofexpertise and consider other players in the system with whom they come into contact. Failure to consider the extent of the“team”at best leads to poor communication and, at worst, can lead to mistrust, misunderstandings or even personalityconflicts. In any event, the safety of the system is likely tosuffer.

Maintenance(Functional)			
Aerodrome(1)		ATC(2)	Flight crew(3)
Operatives	Management		
Gathers information€	information and takesaction		
Operational(Contaminated)			
Aerodrome(1)		ATC(2)	Flight crew(3)
Gathersinformation€		Transmitsinformation€	Interpretsinformationand €makes adecision

Figure 7-2. Key participants in the gathering and provisionof runway frictiondata

7.15 Beginningaseriesoffrictionrunsonanactiverunwayclearlyrequirescloseliaisonbetweentheduty runwaycontrollerinthevehiclecontrolroomandtheoperativedrivingthefrictionvehicle.Theseindividualshavedifferentgoals,however.Thedriverwantsadequatetimetocarryoutalltherunswithoutinterruption,andtheATC officerwantsminimumdisruptiontotrafficflow.Inthecaseofregulardata-gatheringrunsformaintenancepurposes,this work can generally be accommodated at night after the aerodrome closes or during times of the day when trafficlevelsarelow.

7.16 Inadverseweatherconditions,whencontaminationmaybepresent,ashiftingoalsoccurs.TheATC officerwantstheoperativesouttotherunwayassoonaspossibleandwantsthemtoremainavailablesothatregular updates can be obtained on demand. However, the driver may now have other higher priorities and may not be abletowaitattheendoftherunwayincaseanotherfrictionruniscalledfor.Thepossibilitythatthefrictionequipmentdriverhasotherpressuresshouldbeborneinmindalthoughgoodmanagementandsupervisionshouldalleviatethese.The driver may also believe that the data are unreliable and thus the task of gathering the data is a waste of time.However,because of traditional hierarchies, the driver may not feel empowered to refuse the request fromATC.

7.17 Withplanningandcooperation,routinefrictiontestingshouldnotinconveniencepilots;indeedtheymay well be unaware of the operation. But when the runway is contaminated, the flight crew is keenly aware thatinformation from the runway passed via ATC is of vital importance. A diversion is never a “desirable” event, and this maycontributetothefactthatflightcrewsfocusonthatportionofinformationthatsupportstheirdesiretolandatthedestination,soany transmissionthatindicatesgoodconditionswillbeseizedupon.Itispossiblethatsomeaircraftmayhavelimitedairholding time, within fuel reserve limits, before being committed todivert.

Challenges

7.18 Forallparticipants,thereareanumberoffactorsthatcanobstructgoodinformationgatheringand exchange. Instead of focusing on the individuals and tasks, paying attention to the situation or conditions inwhich individualsoperatecanrevealproblemsandhencesolutions.Itisdifficulttochangepeople;changingthesituationin which they work is theanswer.

Communication

7.19 OneoftheprimeHumanFactorsissuesiscommunication.ATCdependsonit,CRMisallaboutitandengineers spend a good deal of their time working with equipment to facilitateit.

7.20 There are many factors that contribute to communication breakdowns such as expectation, hearingwhatonewantsorexpectstohearratherthanwhatwasactuallysaid,andassumption.Humancorruptionofdatathrough emphasis or opinion can have an impact on meaning and can cause misunderstanding ormisinterpretation.

7.21 Communication,however,isaboutmorethanjustthehumanvoice.Whileverbalcommunicationmaybefraughtwithproblems,writtencommunicationcanalsobeaminefield.Handoverofworkatbreaksorshiftchanges often involveswrittenaswellasverbalcommunicationandhasbeenshowntobeasourceofproblemsinmanyindustries, notjustaviation.Incompletelogentries,rushedandinadequateverbalexchangesorlackofasystematicmeansof conveying the status of a task all contribute to handoverproblems.

Standards andprocedures

7.22 Some of the major sources of written communication are the procedures and instructions, which arebased on regulatory standards designed to assist in the correct performance of the task. Not infrequently, however,procedures canbepoorlywritten,incomplete,incompatiblewithotherproceduresrelatedtocomplementarytasks,non-existentor just plain wrong. Correct procedure writing is an art, and it is all too easy to find examples which contravene many ofthe basictenetsofgoodHumanFactorsmanagementwith,forexample,toomuchcross-referencingorapoorlayout.The manner in which procedures are presented and accessed is also important. If procedures are difficult to access theywill notbeused.Inanidealworlditshouldbeaseasytodotherightthingasthewrongone.Inadequateattentiontotheproduction of good procedures is a guaranteed means of ensuring that they will not be followed. It may be thatfrontline staffknowbetterthantheprocedurewriterwhatconditionstheproceduresaretobeusedin.Ifso,theyshouldbeconsulted inadvance.

Training, education and skillsmaintenance

7.23 Afterinitialtrainingcomesthechallengeofmaintainingcompetencyinthetask.Thisisnotnormallya problem with everyday, well-practised tasks but the increasing reliability of systems and the increase inreplaceablecomponentscanmakeitdifficultfortheindividualtomaintainskillsoncelearned.Infrequentfaults maybeexperiencedonly bychance.Thisis whytrainingandpracticeinhandlingCFMEisvitallyimportantbecauseitisararelyused,non-standardoperation. Allied to this should be clear reference material that explains data or assessment methods and the use towhich theycanbeput.Toolsthatmakethisprocessspeedy,efficientandaccuratemayhavetobedeveloped.Theeventmaybeunanticipated, not previously experienced and possibly dangerous, perhaps involving the use ofunfamiliarequipment.Ratherthanjusttraining,focusshouldalsobeplacedoneducation,suchashowtoensure everyoneinvolvedhasthe requisite knowledge, how to decide which aspects are most important and when specialist judgement must be used.Thiseducation should provide individuals with an understanding of their own role and also an appreciation of how theirpersonalroles interact with the roles ofothers.

On-the-job training

7.24 Anotherareathatinvolvesagooddealofcommunicationison-the-jobtraining.Learningfromtheexpertmaybeeffectivebutreliesonclearandaccuratecommunicationandgoodteachingskills.Oftentheassumptionismadethatthebestworkersarethemostcapableofpassingontheirskills,butthisisnotalwaysthecase.Thereal“natural” may find it extremely difficult to understand why the novice is havingproblems.

Conclusion

7.25 ThestudyofHumanFactorsisataskwhichdemandsamethodicalapproach.Whenevererrorintrudes intohumanactivity,disruptingobjectivesorevencausingincidentsoraccidents,itscausemustbeidentified.Such cause will often be a sequence of misunderstandings or inappropriate actions. Each of these might well be harmlessin isolation,buttogetherleadtofailure.Thehumantraitswhichleadtothesemistakesrequirepatientstudyiftheyaretobeovercome.

HAZARDS

Risk management versus frictionissues

7.26 Theapplicationofsafetymanagementintheconductofaircraftoperationsrelativetothecriticaltire/ground contact area is a complex one.

7.27 No activity can be absolutely free of risk, but activities can be controlled to ensure that risk is reducedtoanacceptablelevel.Iftheriskremainsunacceptablyhigh,activitieswillhavetobedelayedormodified andanewrisk assessment carried out. Often, a balance must be stuck between the requirements of the task and the need to makethe performance of the task safe. The balance may sometimes be difficult to achieve but should always be biasedtowards safety. The modern approach to risk management recommends the process show in Figure7-3.

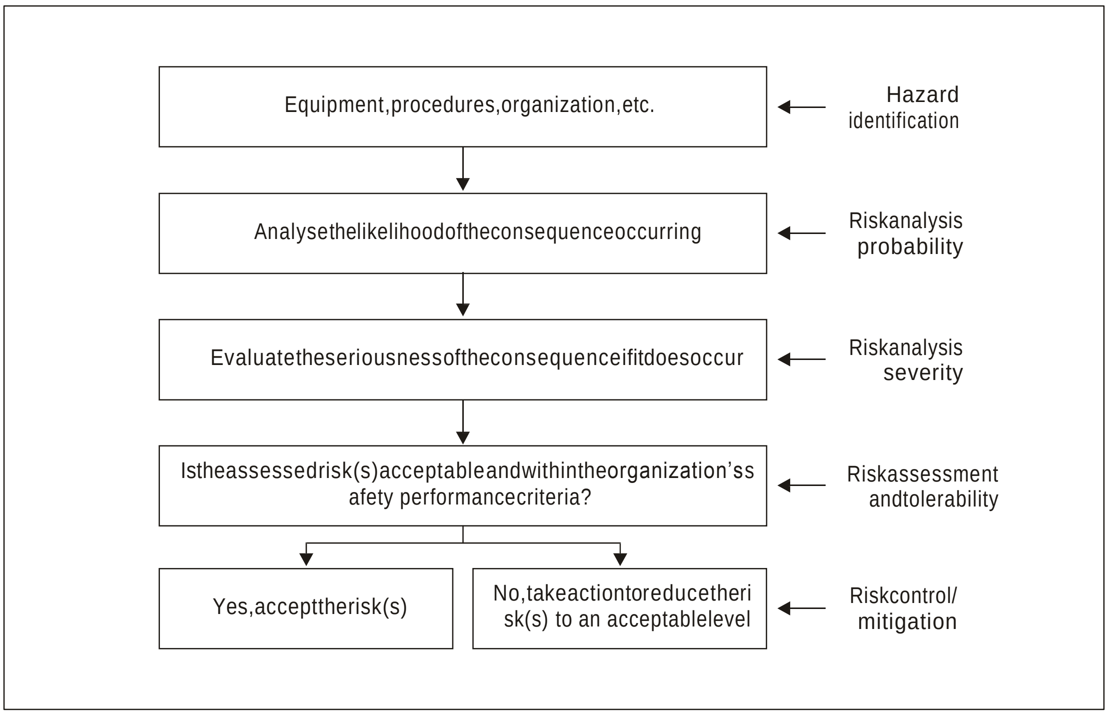


Figure 7-3. The process of safety risk management (source: Doc9859)

7.28 This process appearsrathersimpleinconcept, andindeedtheprocessmayactuallybeeasilyintroduced for thoseprocess-basedindustriesthatbenefitfromsufficientknowledge,timeandplanningcapacityandthathavefirmcontrolove rtheiroperations.However,persons withresponsiveroles withrespecttofrictionissues,suchasgroundstaffandflightcrew, face a more complex process due to the variable nature of meteorological conditions than the schematicmodelsuggests.Exposuretothehazardsmightbetooshorttogainexperience.Thisstressestheimporta nceoftraining.

7.29 Effectiveriskassessmentfirstrequiressounddatatoenabletheidentificationofhazards.AppendicesD throughGlistsomeknownhazardscommonlyassociatedwithphysical,functionalandoperationalfrictionchara cteristics:

a) Appendix D — hazards related to friction issues andpavement;

b) Appendix E — hazards related to friction issues andaircraft;

c) Appendix F — hazards related to friction issues and reporting format;and

d) Appendix G — hazards related to friction issues and theatmosphere.

Persons involved should be trained to identify hazardous conditions and to follow establishedproceduresand standards associated with the identified hazard. The processes involved in the critical tire/ground contactarea necessitatesoundassessmentandjudgementtobemadebythosewhoidentifytheconditionsatthemovementareaand

7.30 those who operate on the movement area in the prevailing conditions. The question they should ask whileexecuting their assessment and judgement should be: "Should you be doing this?" This way they will challenge theirown assessment andjudgement.

Appendix A

PROGRAMMES ON FRICTIONMEASUREMENTAND ASSESSMENT AND REPORTINGOFRUNWAY SURFACECONDITIONS

CANADIAN RUNWAY FRICTION INDEX(CRFI)

1. TheCanadianrunwayfrictionindex(CRFI)andassociatedrecommendedlandingdistancetablesarecommonlyusedinCanadaasapilotaidindeterminingwhetheralandingcanbesafelyaccomplishedonawinter-contaminated runway. The following describes the measurement of CRFI, the research that went into establishing adirect correlation with aircraft braking performance, and the basis for establishing the recommended landing distancetables.

Measurement

2. Findings from the Joint Winter Runway Friction Measurement Programme (JWRFMP) have resultedin improvedaeronauticalguidancematerialinCanada,wherewinterisamajorpreoccupation.Adecelerometerisusedtodetermine, with some accuracy, the effect that a contaminant has on reducing the surface friction of a runway and to provide meaningful information to pilots. The readings taken by this instrument are averaged and reported as aCanadianrunway friction index(CRFI).

3. An electronic recording decelerometer (ERD) is used for runway friction measurement duringwinter operations at virtually all Canadian airports. It is a spot measurement device that uses a piezo-electric accelerometerto measuredeceleration.Thedeviceisrigidlymountedinthecabofanairportvehicle,andreadingsaretakenby accelerating the vehicle to 50 km/h and then applying the brakes to the point of wheel lock-up. A numberofmeasurementsaretakenatvariousintervalsoneachsideoftherunwaycentrelineandaveragedtoprovideasingle friction value for the entire runway surface. The output is termed theCRFI.

4. TheadvantagesoftheERDoverotherfrictionmeasuringdevicesareitssimplicityandthefactthattheCRFIcorrelateswellwithaircraftbrakingcoefficientsmeasuredduringtheJWRFMP.ThemaindisadvantagesoftheERD compared to continuous friction measuring devices are a longer runway occupancy time and the effect ofoperatortechnique on measurement, particularly on surfaces where contamination is notuniform.

5. Decelerometers are used only during winter operations and only on surfaces contaminated by ice orfrost,wet ice (ice covered with a thin film of water), sand, aggregate material, compacted snow, loose snow up to 2.5 cm (1in)deep,andicecoveredbyslush.Theyarealsousedwhenanti-icingorde-icingchemicalshavebeenappliedtothe runway.

DecelerometerreadingsmaybeinaccurateundercertainconditionssoCRFIisnotprovidedtopilotsforwet surfaces with no other contaminant, for slush with no other contaminant, or when loose

1. snow on the runwayisdeeper than 2.5 cm (1in).

2. The CRFI value describes braking action quantitatively. This number, along with a runwaysurfaceconditionreport,providesanoveralldescriptionoftherunwayintheaircraftmovementsurfaceconditionreports(AMSCR) provided to air traffic services, which in turn provide it to pilots through ATIS orNOTAM.

Reporting

3. A typical AMSCR includes a CRFI number along with a surface description and other relevantinformation.Typicallyduringpre-flightplanningaNOTAMisavailable.Onceairborne,thecrewgetsinformationthroughtheATIS,and with rapidly changing conditions, verbal updates are usually available through thetower.

Predicting landingdistance

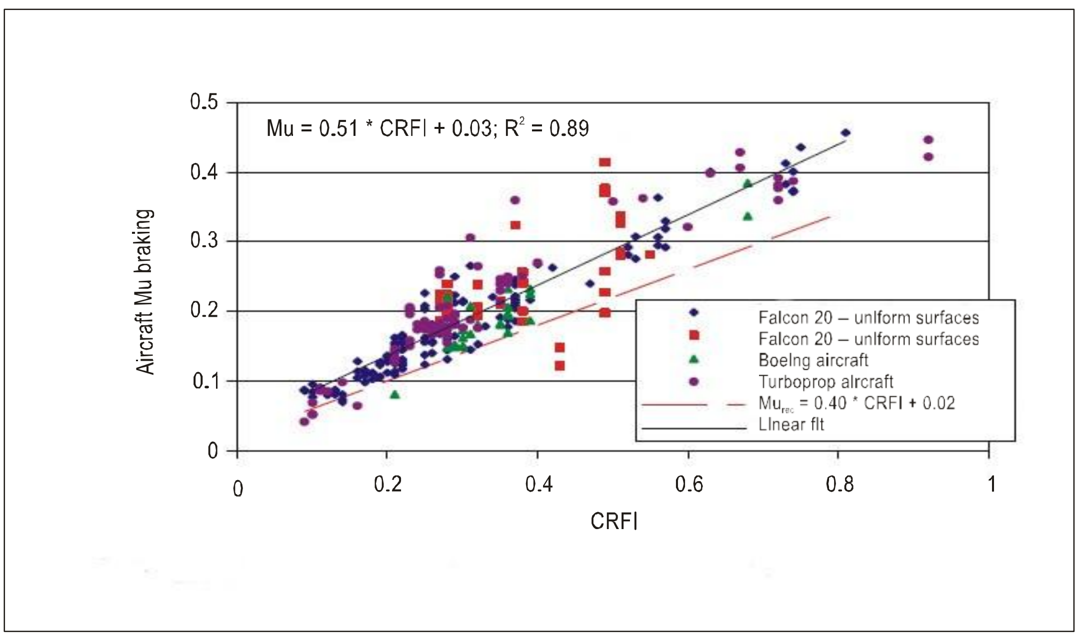
4. ThepredictionoflandingdistanceasafunctionoftheCRFIisbasedonanacceptablecorrelationoftheaircraft braking coefficient (Mu braking) and CRFI. Aircraft deceleration is modelled as a function of aircraftparameters andmeasuredrunwayfriction(CRFI),andmodelsofaircraftbrakingdistanceandrecommendedlandingdistancearecreatedforcontaminatedrunways.Theexpressionforrecommendedlandingdistanceisgivenintermsoftheaircraftflight manual (AFM) landing distance andCRFI.

5. Figure A-1 plots the mean aircraft Mu braking against the CRFI for 275 aircraft test runs oncontaminatedsurfaces, including surfaces which were non-uniformlycontaminated.

6. To account for data scatter resulting from uncertainties in the measurement of both Mu braking andCRFI,as well as operation on non-uniform surfaces, a line is shown representing the minimum recommended Mu, given bythe equation Murec = 0.40 × CRFI +0.02.

7. The term "recommended" indicates that the values include a safety factor. The Murec line is drawn belowat least95percentofthedatapointsinFigureA-1,givinga95percentprobabilitythatthebrakingdistancescomputedfrom the deceleration models will beachievable.

8. TheCRFItablesofrecommendedlandingdistancesweredevelopedforaturbojetaircrafttypeusingno reverse thrust, or using either turbojet reverse thrust or turbopropeller discingthrust.



FigureA-1.Mean aircraft Mu braking plotted against theCRFI for 275 aircraft test runs on contaminatedsurfaces

Application of the CRFItables

9. AlthoughtheCRFItablesofrecommendedlandingdistanceswerederivedfromperformancedatafromFalcon20andDash8aircraft,theyareconsideredtobeapplicabletojettransportaircraftandturbopropaircraftingeneral for a number of reasons. First, the correlation between the aircraft braking coefficient and CRFI was found tobe similar for the different aircraft types tested. The relationships used for the deceleration models areessentially dependent on the aircraft wheel braking system (and reverse/discing thrust if used) and are not significantly affectedby otheraircraftcharacteristics.Anaircraftwithamoreadvancedanti-skidbrakingsystemcouldperformbetterthanthe CRFI table predictions, while an aircraft without an anti-skid system would exceed the CRFI table predictions.Second,theequationsusedtomodelthecomponentsoftherecommendedlandingdistanceswerebasedonaseriesofFalcon20performancelandings,butaretypicalofmostaircrafttypes,beingessentiallytime/distancerelationships dependentonapproachgroundspeed,flaretechniqueandtimetodeployliftdumpdevices.Theinclusionofsafety factors allows for minor deviations in landing techniques, such as a slightly extended flare or late application ofreverse thrust,whichwillresultinlandingdistanceslongerthanoptimal,butstillwithintheCRFItableofrecommendeddistances. Third, major differences between aircraft types are accounted for by entering the specific aircraft AFMlanding distanceintotheCRFItableandfactoringthatdistancebasedonthevalueoftheCRFI.TheCRFItabledataare consistentwithcurrentregulationsrequiringthefactoringofAFMlandingdistanceforoperationsonwetordryrunways.

ExampleusingtheCRFItable*:*Ifasurfaceconditionreportisprovidedbytheairportwhichincludesa CRFIreadingof0.4,anaircrafthavinganunfactoredlandingdistanceof3000ftonabareanddrysurfacebasedonthe aircraft flight manual would need 5 910 ft of runway length, without the use of thrust reversers, using the CRFI tablewith thrust reversers. If the pilot chooses to use thrust reversers, the recommended landing distance would be 5 340 ftusing theCRFItablewiththrustreversers.Ifthefrictionreadingis0.27,thesedistanceswouldbe6860ftand5950ft,respectively (see the CRFI tables atwww.tc.gc.ca/eng/civilaviation/publications/tp14371-air-1-0-462.htm.

Conclusion

10. Brakingcoefficientswereobtainedforseveralinstrumentedaircraftduringfullbrakingtestsonwinter-contaminated runways during the JWRFMP. These data were compared to the runway friction measured bythe TransportCanadaERDtoprovideamodelforthepredictionofaircraftlandingdistanceonwinter-contaminatedrunways based on the CRFI. Tables of recommended landing distances, independent of specific aircraft type, were developedasa function of the CRFI and published by Transport Canada as advisorymaterial.

TAKE-OFF AND LANDING PERFORMANCE ASSESSMENT— AVIATION RULEMAKING COMMITTEE(TALPA/ARC)

11. FollowingtheoverrunofaBoeing737atMidwayinDecemberof2005,theFAAfoundanumberof deficiencies in the regulations and guidance affecting the certification and operation of aircraft and aerodromes foraircrafttake-off and landing operations on runways contaminated by snow, slush, ice or standing water. As such they charteredan Aviation Rulemaking Committee (ARC) to address take-off and landing performance assessment (TALPA)requirements andguidancefortheturbine-enginedaircraftcertifiedunder14CFRParts23or25andoperatedunderPart91subpartK,121, 125 or 135. In formulating their recommendations it became clear to the ARC that the ability to communicateactual runway conditions to pilots in real time and in terms that directly relate to expected aircraft performance was critical tothe success of theproject.

12. WhileresearchingcurrentNOTAMprocesses,numeroussignificantshortcomingswerediscoveredthat hampered this communication effort. Without accurate real-time information, pilots cannot adequately assess take-offor landingperformance.

13. ThecornerstoneoftheTALPAARCrecommendationsisaconceptusingapavedrunwayconditionassessment table (referred to as “the matrix”) as the basis for performing runway condition assessments byaerodrome operators and for interpreting the reported runway conditions by pilots in a standardized format. Thematrix:

a) aligns runway surface conditions reported by aerodrome operators with contaminatedlanding performance data supplied by the aeroplanemanufacturer;

b) ties together runway contaminant descriptions and braking action and can be used totranslatebetween these two methods of reporting runway surfaceconditions;

c) provides a shorthand method of relaying runway surface condition information to flight crewsthrough the use of runway condition codes to replace the reporting of µreadings;

d) provides for a standardized method of reporting runway surface conditions for allaerodromes;

e) provides more detailed information for the flight crew to make operational decisions;and

f) standardizes the terminology used in pilot braking actionreports.

14. Inordertosucceed,thisconceptwillrequireextensiveretrainingofaerodromeoperationspersonnel,dispatchersandpilotstoensurethattheapplicationofthematrixisconsistentacrossaerodromesandthatinterpretationof the results and reporting of braking performance via PIREPs is consistent with the terms of thematrix.

INTERNATIONAL RUNWAY FRICTION INDEX(IRFI)

15. The ASTM standard IRFI defines and prescribes how to calculate the IRFI for winter surfaces. The IRFI isa harmonizedreportingindexintendedtoprovideaircraft operators withinformationonthetire-surfacefrictioncharacteristics ofarunway. In addition, aerodromemaintenancestaffcanuseittomonitor runwayfrictioncharacteristics,asaguidetothe surface maintenancerequired.

16. The prescribed method evaluates each 100 m and averages them for each third of the runway. Itreducesthe present variations of the 100 m surface lengths from as much as 0.2 down to typically 0.04. The sampling schemeof a full runway length (spot or continuous measurements) may yield additionalvariation.

17. Areferencedevice,whichisrequiredforcalibration,mustbededicatedtothispurpose,andtheaviationcommunityoreachStatemustagreeonitsprovision,ownershipandservices.AstandardtocalculatetheIRFI, which accommodates all major measurement techniques and equipment currently used around the world, has beendevelopedby theASTM.

18. In order to implement a concept such as the IRFI, an infrastructure, logistics and associatedharmonizationmethodstocontrolthefrictionmeasuringdevicesthemselvesneedtobeestablishedbyStatestosuchadegreethatthey can be utilized within the constraint of a safety managementsystem.

EASA RUNWAY FRICTION CHARACTERISTICSMEASUREMENTAND AIRCRAFT BRAKING(RuFAB)

19. In2008EASAlaunchedtheresearchprojectRuFABtohelpidentifypossibilitiesforharmonizingrunway friction characteristic measurement technologies and provide a basis for improving and harmonizing theimplementationof currentECAA ICAO Standards and Recommended Practices (SARPs) within EASA member States. This could providethe opportunity for a global standardized application and contribute to the progress of theICAO action plan. Finally itwould prepareprerequisitestofutureEASArulesforaerodromesafety.

1. Thefirstphaseoftheprojectwastoreviewpertinentliteratureaswellasexistingandpreviousresearch results in the evaluation of runway surface friction characteristics and aircraft brakingperformance.

2. The scope of the following two phases of the study was to obtain an overview of the stateofimplementation of the provisions for contaminated runways (contained inECAR 139 advisory documentsand international specifications) and of the state of harmonization between these and national requirements and practices.InitscomprehensiveoverviewoftheimplementationofECAASARPs,thestudydistinguishedbetweenmeasurementoffunctional friction characteristics and measurement of operational runway frictioncharacteristics.

3. The research project has been completed, and the results and recommendations are ready fordiscussionwithICAOworkinggroups,expertsandthestakeholdercommunitiesbutmayalsobereviewedinthelightoftheworkcarried out by the FAA TALPA/ARC. The report of the project is availableat:
   http://www.easa.eu.int/ws_prod/g/g_sir_research_projects_airports.php#2008op28.

Appendix B

TRAINING FOR GROUND STAFF, ATM STAFF AND FLIGHTCREW

Frictionissue	Training			Remarks
	Groundstaff	ATMstaff	Flightcrew	
AIP	Publishingfricti onal characteristics		Use ofpublishedc haracteristics	
AICs	Newfrictio nalinforma tion		Newfriction alinformatio n	
Reportingformat	Assessment	Dissemination	Use ofinformation	
Terminology	Hazards Contaminants	Hazards Contaminants	Hazards Contaminants	
Phraseology	Frictionalterms	Frictionalterms	Frictionalterms	
Processes	Data collectionandre	Dissemination	Use ofinformation	

FRICTION ISSUES VERSUS SEGMENT OFFLIGHTS

Objectives, requirementsandi nformation	Essential	Com ments	Cruis e	Collec tion	Appro ach/l andi ng	Surf acea rriv al	Ramp	Plann ing/d ispat ch	Ram p	Surfaced eparture	Departu re/ take- off	Dispersion
ATMobjective GlobalAir Traffic Management Concept (Doc9854)			Aircraft are ataltitud andmovi towards their destinat but yetsubje toaction relatedt thearriva phase	Aircraft are sequen andspac tobring themint thetermi areafor arrival	Aircraft are assigne runway andont the surface	Aircr aft are move off runwa andto thera	Aircrafta re manoeu intothe parking location	Integra tion intothe ATM environ mentto achieve close match betwee theuser- preferr trajecto andthe system deliver trajecto	Flight s are moved and the parkin locati	Aircraft aremoved fromthe rampto the departure queue	The departur queuean therunw are manage tolaunch aircraft fromthe queueint the airspace	Getaircraft up andout ofthe terminal intothe en-route structure
Clearedlength Reportedwhen lessthan publishedlength	**Y**	Relevan aircraft perfor		●	●			●			●	
Clearedwidth Reportedwhen lessthan publishedwidth	**Y**	Crossw andengi failure scenari		●	● Cross			●			● Crosswi Engine failure	
Deposits	**Y**	In thirds forrun ways		●	●			●			●	
Meandepth	**Y**	In third sfor(RS M). Prese		●	●			●			●	
Extentofcontam ination	**Y**	In third		●	●			●			●	
Brakingaction(f rictioncoefficie	**Y**	In third		●	●			●			●	

Appendix C

Objectives, Requirements And information	Essential	Comments	Cruise	Collection	Approach landing	Surface arrival	Ramp	Planning/dispatch	Ramp	Surface departure	Departure take-off	Dispersion
Runway temperature Currently not available	N/Y	Could be relevant in anticipation of possible reduced braking action asaresultof precipitation and cold runway surface temperatures		• Possible reduced braking action				• Possible reduced braking action				
Rainfallrate Currentlynot harmonized. Broad indicationssuch as–RA/RA/+RA could belinked to range of rainfall rates Which in turn could belinked Overfilling. Part of METAR/ATIS.	N/Y	Couldbean indicationof potential hazardous runway conditions depending uponrainfall rateand runwaydesign		•	• Significant increase			•			• Significant increase	
Furtherclear anceexpected	N		•		I			•				
Taxiway	N	Anticipatedt axirouting				•		•		•		
Apron	N/Y						•	•	•			

Appendix D

HAZARDS RELATED TO FRICTION ISSUES ANDPAVEMENT

Hazard	Frictioncharacteristics			Significantchange
	Physical	Functional	Operational	
Texture	Microtexture	Slippery	Slippery	Retexture
	Macrotexture	Wet,smooth		Different from BC
	Macrotexture	Wet, skidresistant		Different from DE
Noslope	Standingwater	Poor drainageattire/groundi	Longer stoppingdistance	Newdesign
		Hydroplaning	Loss ofdirectional control	
Naturalrou ndedaggreg ate	Susceptib letopolish ing	Slippery	Slippery whenwet	Retexture Repave
Rubber depositoncrus hedaggregate	Covertexture	Reducedtexture	No performancecre diton wet,skid-resistantpaveme nt	Remove rubberdeposit
		Slippery	Slippery	
Rubber depositonnat ural,smootha ggregate	Covertexture	Reducedtexture	Longer stoppingdistance	
		Slippery	Slippery	
Grooves	Closing duetodefo rmation	Poor drainageattire/groundi nterface	Longer	Opengrooves
			No performancecre diton wet,skid-resistantpaveme nt	
	Filledwi thconta minant	Poor drainageattire/ groundinterface	Longer	Removecontaminant
			No performancecre diton wet,skid-resistantpaveme	

Appendix E

HAZARDS RELATED TO FRICTION ISSUES ANDAIRCRAFT

Hazard	Frictioncharacteristics			Significantchange
	Physical	Functional	Operational	
Tirewear	Tire treaddepth	Drainage attire/ groundinterface	Basic assumption forwetskidresi stance	Basic assumption basedontire tread depth of 2mm
Change ininflationp ressure	Inflationpre ssure	Drainage capabilityattire/grou ndinterface	Basic assumption forwetskidresi stance	Curves (e.g. equations)inharmonizedcertificatio nspecifications for 50, 100,200and 300 pounds persquareinch(psi)

Appendix F

HAZARDS RELATED TO FRICTION ISSUES AND REPORTINGFORMAT

	Frictioncharacteristics			
	Physical	Functional	Operational	
Clear anddry	Dry		Certificationlimite	
Damp			Wet	
Wet,smooth	Wet	Reduced	Wet	Less than 3mm
Wet, skidresistant	Wet	Reduced brakingaction	Wet,skid-resistantperfo rmancedata	Less than 3mm
Standingwater	Wet	Hydroplaningsusce		Above 3mm
Rime or frostcovered	Thin layer; depthnormally less than 1mm			
Loosesnow				20mm*
Drysnow	Covera geDept	Reduced brakingactionDra	Longer stoppingdistanceL	10, 25, 50, 100 percent
Wetsnow	Covera geDept	Reduced brakingactionDra	Longer stoppingdistanceL	10, 25, 50, 100 percent
Slush	Covera geDept	Reduced brakingactionDra	Longer stoppingdistanceL	10, 25, 50, 100 percent
Wetice Compacted snow oriceIce	Coverage	Reduced brakingaction	Longer stoppingdistance	10, 25, 50, 100 percent
Compacted orrolledsnow	Coverage	Reduced brakingaction	Longer stoppingdistance	10, 25, 50, 100 percent
Frozenruts orridges	Coverage	Reduced brakingaction	Longer stoppingdistance	10, 25, 50, 100 percent
Sand	Present	Reduced	Longer	
Mud	Present	Reduced	Longer	
Oil/fuelspillage	Present	Reduced	Longer	
*Recommendedchange.				

AppendixG

HAZARDS RELATED TO FRICTION ISSUES AND THEATMOSPHERE

Hazard	Frictioncharacteristics			Significantchange
	Physical	Functional	Operational	
Precipitation	Contaminant	Influence onanti-skidsystem	Reduced brakingaction	
Wind	Crosswind	Moveaircraft	Loss of directionalcontol	
Temperature	Freezingprecipitation	Influence onanti-skidsystem	Reduced brakingaction	
Radiation	Freezing moistureonground	Influence onanti-skidsystem	Reduced brakingaction	