Certification Authorities for Large Transport Aircraft (CATA)

Technical Issue Paper EASA-005 – Unusual landing operations

Date Raised:	Nov 21/2018	Updated: Sept 16/2021	Status:	**Open**
Date Revised	N/A			
Subject:	**Unusual landing operations. 25.301, 25.235, 25.491, 25.571, appendix Q**			
Related Issue(s): (Identify Discussion Paper number, if any)	Potential interaction with “Return to land” working group			

<u>Description of Issue(s)</u>:
(Give a brief background of issue(s)

Steep approach operations can lead to higher (static and dynamic) loads, for example due to higher descent velocities/load factors and/or re-definition of the landing configuration. In lieu of a more rational investigation, EASA applies flight test data measured at London City airport, which may be different from what other authorities are accepting. Return to land situations may benefit from a similar treatment.

For operation on unpaved runways, EASA CRIs have been raised in the past, but these have not been harmonized. Similar challenges may be posed by other unusual runways like slab runways.

EASA has an SEI titled “Unusual Landing operations” to reflect these differences.

<u>Background:</u>

The following points have been identified for further clarification between CATA members:

For steep approach and return to land:

- Define acceptable criteria to collect data from in-service surveys and simulator sessions (e.g. sufficient representative pilots/configurations/airports and number of landings).
- Discuss relevant related approach and flare aspects (ATC and runway/aids, weather, pilot human factors, aircraft design, operating manual) as contributing factors to higher landing sink speeds/load factors.
- And/or define simple conservative standard criteria (e.g. sink speeds or load factor limit values and spectra).
- Benefit of discussion for Autoland TBD.

For unpaved/slab runways,

- Define representative weights and runway profiles/bump wavelengths representative of unpaved runways to be used in dynamic load static load and fatigue spectrum definition.
- And/or define simple conservative standard static load factors and taxi, take-off and landing run spectra.

Related policy and guidance

-MIL 8862
-DEF-STAN 00-970
-AC 25.491-1/AMC 25.491
-ICAO Aerodrome standards

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Proposed Prioritization:
(Per CATA Technical Issues List Prioritization schema)

Question	Answer
1. Is there an active working group related to this issue?	No
2. In which documents are there deviations amongst the authorities?	Published CRIs.
3. Was this issue raised by or at the CMT?	No.
4. What is the level of impact on projects in the future (i.e. minor, major, critical)?	Medium. since the operations are unusual, but not rare. The issue directly affects design, typically affecting the fatigue spectrum and inspection programme.
5. How many authorities does the issue impact?	Issue impacts all 4 authorities
6. What is the approximate technical complexity of the issue (i.e. low, medium, high)?	Low complexity.

Recommendation:

Create an SME group with aim to harmonise interpretations of CATA members within the identified domain with a view to removing identified EASA SEI.

CATA Decision (Phase 1):
(Using CATA criteria for determination of technical issues)

Apr 3/2018 CATA accepts the CWI and agree to work on this topic, SME names have been added.

Interim CATA Position:
(Explain agreement, dissent or conclusion on this IP)

The CATA accept the SME team’s recommendation and proposed guidance paper on Rough Paved or Unpaved Runways. The guidance paper is appended directly to this CWI.

This CWI represents an agreement that the guidance paper is harmonized and accepted by all CMT authorities.

The CWI form, including the appended guidance, document a CMT member authority agreement that member authorities may reference when they are acting as the certificating authority (CA). Following CA endorsement for a particular project, the other CMT member authorities, when acting as validating authority, will accept the approach.

If any member-authority under CATA becomes aware of circumstances that make it apparent that following the guidance paper would not result in compliance with the member-authority’s applicable airworthiness standards, then the use of this guidance paper is non-binding and the member-authority may require additional substantiation or design changes as a basis for finding compliance.

This CWI remains open to address Steep Approach aspects of the task.

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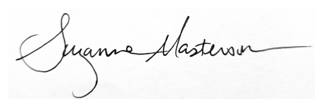
CATA Signatures:

CATA Representative	Name	Signature	Date
ANAC	Daniel Pessoa	Daniel Pessoa Martins Cunha	Assinado de forma digital por Daniel Pessoa Martins Cunha Dados: 2021.09.20 14:33:59 -03'00'
	Willian Tanji	Willian Tanji	Assinado de forma digital por Willian Tanji DN: cn=Willian Tanji, o=ANAC, ou=SAR/GGCP/GCPR, email=willian.tanji@anac.gov.br, c=BR Dados: 2021.09.20 13:53:48 -03'00'
EASA	Colin Hancock	Hancock Colin	Digitally signed by Hancock Colin Date: 2021.09.16 11:44:11 +02'00'
	Mathilde Labatut	Labatut Mathilde	Digitally signed by Labatut Mathilde Date: 2021.09.16 15:14:40 +02'00'
FAA	Suzanne Masterson		Digitally signed by SUZANNE A MASTERSON Date: 2021.09.17 07:35:53 -07'00'
	Steve Edgar	STEVEN R EDGAR	Digitally signed by STEVEN R EDGAR Date: 2021.09.20 08:46:21 -07'00'
TCCA	Canh Nham	Nham, Canh	Digitally signed by Nham, Canh DN: C=CA, O=GC, OU=TC-TC, CN="Nham, Canh" Reason: I am approving this document Location: your signing location here Date: 2021.09.16 17:05:40-04'00' Foxit PDF Editor Version: 11.0.0

Certification Authorities for Large Transport Aircraft (CATA)

Technical Issue Paper EASA-005 – Unusual landing operations

Certification Authorities for Transport Airplanes (CATA)
Guidance Paper to CATA Worklist Item EASA-005 – Rough Paved or Unpaved Runways

Subject: Operations on rough paved and unpaved runways

Summary: This document provides acceptable methods of compliance for certification of transport category airplanes / large airplanes when operation on rough paved or unpaved runways is anticipated.

Table of Contents:

1. Introduction

1.1 Purpose

This document describes acceptable methods of compliance with relevant regulations when operation on rough paved or unpaved runways is anticipated. The guidance provided in this document is not mandatory, but may be used by manufacturers[1] to show compliance with the relevant regulations, which are specified below.

1.2 References

For airplane manufacturers:

[1] Manufacturer and applicant can be used interchangeably throughout this document.

(1) Regulations

CS/RBAC/AWM/CFR (5)25.235 – Taxiing Condition
CS/RBAC/AWM/CFR (5)25.491 – Taxi, takeoff and landing roll
CS/RBAC/AWM/CFR (5)25.571 – Damage-tolerance and fatigue evaluation of structure
CS/RBAC/AWM/CFR (5)25.609 – Protection of structure
EU regulation Part-26 – Ageing aircraft

(2) Advisory material

AC/AMC 25.491, Taxi, takeoff and landing roll design loads
AC/AMC 25.571, Damage Tolerance and Fatigue Evaluation of Structure
AC 25-7, Flight Test Guide for Certification of Transport Category Airplanes; Section 42.5 Takeoff and Landing on Unpaved Runways
TCCA AC 525-006, Operation From Unpaved Runway Surfaces;

For airplane operators:

(3) TCCA AC 700-011, Issue No. 01, Operations on Runways with Unpaved Surfaces; March 16, 2012

For airport operators:

(4) Annex 14 to the Convention on International Civil Aviation, Aerodromes, Vol. I, Aerodrome Design and Operations, 8th Ed., July 2018
(5) FAA AC 150/5380-9, Guidelines and Procedures for Measuring Airfield Pavement Roughness; Sept. 30, 2009
(6) TCCA AC 302-023, Issue No. 02, Measurement and Evaluation of Runway Roughness; Dec.16, 2016\
(7) Boeing Document D6-81746, Runway Roughness Measurement, Quantification, and Application - The Boeing Method
(8) TCCA AC 300-004, Issue No. 04, Unpaved Runway Surfaces; Dec. 5, 2017

Other references:

(9) Rough Runway Analysis, Jack Hagelin, presented to ASTM E-17 Seminar; December 5, 2006
(10) DEF STAN 00-970, Issue 2 (Leaflet 49 Part 1 Section 4), Design of undercarriages - Operation from surfaces other than smooth hard runways. Specification of continuous ground unevenness; Dec. 1999
(11) MIL-A-8863C, Airplane Strength and Rigidity, Ground loads for Navy Acquired Airplanes; July 19, 1993
(12) SAE AIR 5913: Landing Gear Shock Strut Heat Damage
(13) Dept. of Defense Joint Service Specification Guide, JSSG-2006, dated October 30, 1998

1.3 Definitions

Runways, including taxiways:

1.3.1 Paved – Surfaced with asphalt or concrete

1.3.2 Rough – Runway (paved or unpaved) with bump height to length curve above the "Tolerable limit" curve of the ICAO Annex 14 Runway surface evenness criteria, or worse than the similar runway criteria specified in AC/AMC 25.491.

1.3.3 Unpaved – A surface composed of unbound or natural materials. Unpaved surfaces may include gravel, coral, sand, clay, hard packed soil mixtures, grass, turf or sod.

1.3.3.1 Semi-prepared – An existing runway or taxiway that may have required a considerable construction effort. Variable factors influencing roughness intensity can be foundation soil structure, climate (e.g. frost heave), size of aircraft, pavement composition, maintenance standards and the number of aircraft using the runway. This type of field may be surfaced with landing mat or a protective membrane, or have improved evenness and bearing strength through continued levelling, compaction and removal of foreign objects. For commercial applications, most gravel runways and some grass runways would fit into this definition.

1.3.3.2 Unprepared – An unsurfaced natural ground area typically suitable only for operation of military cargo-type aircraft with little or no preparation. There are probably very few (if any) commercial aircraft operations today on runways with this type of preparation. This kind of operation is out of the scope of this policy.

2. Background

2.1 Aircraft Certification

2.1.1 Airplanes are designed to withstand the static, dynamic, and fatigue loads that occur during the life of the airplane. Static and dynamic ground load conditions are specified in part 25 subpart C, and fatigue and damage tolerance requirements are contained in CS/RBAC/AWM/CFR(5)25.571. These requirements include taxi, take-off and landing roll operation on runways and taxiways.

2.1.2 Relevant structural requirements include the following:

CS/RBAC/AWM/CFR (5)25.235: "The shock absorbing mechanism may not damage the structure of the airplane when the airplane is taxied on the roughest ground that may reasonably be expected in normal operation."

CS/RBAC/AWM/CFR (5)25.491: "Within the range of appropriate ground speeds and approved weights, the airplane structure and landing gear are assumed to be subjected to loads not less than those obtained when the aircraft is operating over the roughest ground that may reasonably be expected in normal operation."

CS/RBAC/AWM/CFR (5)25.571: “An evaluation of the strength, detail design, and fabrication must show that catastrophic failure due to fatigue, corrosion, manufacturing defects, or accidental damage, will be avoided throughout the operational life of the airplane.… Each evaluation required by this section must include-- The typical loading spectra, temperatures, and humidities expected in service; …”

CS/RBAC/AWM/CFR (5)25.609: ” Each part of the structure must be suitably protected against deterioration or loss of strength in service due to any cause, including – (1) Weathering; (2) Corrosion; and (3) Abrasion;”

Point 26.305 of EU regulation Part-26 requires Type Certificate (TC) holders to “establish and implement a process that ensures that the continuing structural integrity programme remains valid throughout the operational life of the aeroplane, taking into account service experience and current operations.”

2.1.3 Service experience shows that there are three types of runway roughness that may affect the structural integrity of the aircraft including landing gears and their attachments (see Ref. 9):

- Single Discrete Bump Events – Limit Loads
- Continuous Long Wavelength Bumps – Fatigue Loads
- Continuous Short Wavelength Bumps – Truck Pivot Joint Fatigue

Each type imposes different runway roughness criteria

Continuous short wavelength bumps can cause heat damage due to friction in the landing gear truck beam (bogie beam) pivot joint. This type of roughness requires additional investigation that is not addressed in this document. Short wavelength bumps are generally between 2m and 7m, and long wavelength bumps are more than 10m.

2.1.4 Design Loads: The AC/AMC to 25.491, Taxi, Takeoff and Landing Roll Design Loads provides guidance for showing compliance with CS/RBAC/AWM/CFR (5)25.491 for operation on paved runways and taxiways. The AMC references San Francisco Runway 28R, which was known to cause high loads on airplanes until it was resurfaced. The AMC provides the runway profile of San Francisco Runway 28R, before it was resurfaced, and indicates that a dynamic analysis based on that runway profile may be used to comply with CS/RBAC/AWM/CFR (5)25.491. AC/AMC 25.491 also includes two discrete load conditions (the manufacturer may choose one to evaluate) and a combined load condition.

However, AC/AMC 25.491 does not provide criteria for unpaved runways or rough paved runways, whose profile may be more severe than the old San Francisco runway profile, and which may cause higher loads. Therefore, if operation on rough paved or unpaved runways is anticipated, the applicant must account for that operation during the design and certification of the airplane. This document provides a means of compliance, but not the only means, for such design.

2.1.5 Fatigue Loads: AC/AMC 25.571, Damage Tolerance and Fatigue Evaluation of Structure provides guidance on compliance with CS/RBAC/AWM/CFR (5)25.571, but does not provide specific criteria for paved, unpaved or rough runways. As with all flight and ground loads used for the fatigue and damage tolerance evaluation of the airplane, the applicant is responsible for developing their own fatigue loads spectrum. AC/AMC 25.571 states: "The loading spectrum … should be based on measured statistical data of the type derived from government and industry load-history studies and, where data is insufficient or unavailable, on a conservative estimate of the anticipated use of the airplane." Therefore, as with design loads, if operation on rough paved or unpaved runways is anticipated, the applicant must account for that operation when developing the airplane's fatigue load spectrum.

2.1.6 In service operations – roles and responsibilities. During design and certification, the manufacturers account for the roughest ground expected to occur in operation, but they may not anticipate all runways or runway conditions. The operator is responsible for consulting with the manufacturer when operating on rough paved or unpaved runways that may not have been evaluated during certification. Airplane operators should also consult with airport operators if runway roughness is negatively affecting operations or may be causing unanticipated damage to their airplanes. More information on the roles and responsibilities of airplane and airport operators is included in Appendix A.

2.2 Past Practice

2.2.1 Numerous large airplanes have been certified in the past to operate on unpaved or rough paved runways. Various criteria were applied to those projects, as described below. The purpose of this policy is to define a harmonized standard.

2.2.2 EASA Certification Review Items (CRIs)

In the past, EASA has issued CRIs with means of compliance for structural requirements for operation on unpaved runways:

- Static requirements: In lieu of the factor of 1.7 specified in AMC to 25.491 section 5(a), and in line with MIL-A-008862A (later superseded by Ref. 11), a factor of 2 is indicated for the main landing gear and airframe, and a factor of 3 for the nose landing gear. The discrete steps of MIL-A-008862A were considered as too severe for civil operation and were not required in the CRI. Another CRI indicates assessment of static loads through flight test load survey. Yet another requests to evaluate the dynamic effects of the increase of the longer wavelength roughness.
- Updated fatigue spectrum, and vibration levels for crew and equipment: In one CRI, the profiles of DEF-STAN 00-970 (Ref. 10) up to Class B are indicated as an acceptable representation of up to semi-prepared runways. In another CRI, a mission mix of a survey of aerodromes (elevation profile or flight test load survey) representative of the operational network on one hand, and the most critical aerodrome for the model on the other is indicated.
- Protection of structure and systems: evaluation of damage due to impact of foreign objects (like stones), the effect of dust and the necessary protection measures (e.g. stone deflectors) and maintenance practices.

- Airplane Flight Manual (AFM) limitations: Aerodrome surface definition, contamination, wind conditions, weight and CG, tyre pressure, and aircraft configuration.

2.2.3 FAA Issue Papers and FAA and TCCA Advisory Material

The FAA applied issue papers to establish criteria for certification on unpaved runways. Those criteria are now included in AC 25-7D. Similar criteria are outlined in TCCA AC 525-006. These ACs provide guidance on the following considerations:

- Surface Definition
- Airplane Performance
- Airplane Handling
- Systems, Engines and Structure
- Maintenance
- Airplane Flight Manual

2.2.4 Airplane Flight Manual Limitations

Example of possible practical AFM runway and taxiway limitations regarding surface definition are:

- Surface material and type.
- Surface strength, expressed as a *California Bearing Ratio* (CBR), or other accepted runway strength classification systems. CBR is defined as the ratio of the bearing strength of a given soil sample to that of crushed limestone gravel. The method and conditions used to measure the surface strength should be identified. Qualitative descriptions of surface strength such as "hard", "firm" or "soft" may be used, provided an acceptable method is established to correlate these to a quantitative surface strength measurement.
- Pavement Bearing Strength where critical as expressed in the *ICAO-PCN* strength reporting system, *Transport Canada Pavement Load Rating* (PLR) charts or other accepted pavement strength classification system;
- Maximum aggregate size;
- Degree of grading and/or compaction of materials in surface;
- Allowable extent of rutting, undulations, or roughness;
- Allowable extent of surface vegetation;
- Allowable extent of damp areas, or standing water;
- Allowable extent of soft areas, or accumulations of loose material;
- Allowable extent of bare areas or lost material.
- The requirement to inspect the runway at a frequency dictated by local conditions to assure that it is in a satisfactory condition;

- Appropriate weight and c.g. limitations;
- Tire pressure limitations;
- Approved aircraft configurations including any special equipment required, flap settings and applicable speed limitations;
- Thrust limits, powerplant control settings and use of reverse thrust during ground manoeuvering and prior to brake release

2.2.5 For visibility and traceability, design approval for operation on rough paved or unpaved runways should be reflected in the type certificate data sheet (TCDS).

2.3 Runway roughness criteria and measurements

2.3.1 The references listed below provide both artificial and actual runway roughness criteria, which are compared below and in Appendix B. While the purpose of the different references varies, a comparison of the criteria from each of these references is useful.

2.3.2 Runway roughness is presented in terms of maximum bump height for each bump length, as indicated in Figure 1. A representation as such is an envelope of runway roughness. One roughness curve may correspond to multiple actual runway profiles. As indicated in Figure 1, these criteria address single or discrete event roughness. These criteria may be used to support determination of design loads.

2.3.3 AC/AMC 25.491, Taxi, takeoff and landing roll design loads, provides the runway profile of San Francisco Runway 28R, before it was resurfaced, and indicates that a dynamic analysis based on that runway profile may be used to comply with § 25.491 for normal, paved runways. The AC/AMC also provides a modified profile that reduces a severe bump included in the original profile. These profiles are presented in Figure 2 below in terms of bump height versus bump length.

2.3.4 Boeing Document D6-81746, Runway Roughness Measurement, Quantification, and Application (Ref. 7) describes a method by which airplane and airport operators can assess a given runway’s roughness, whether repair is needed, and how to make that repair.

2.3.5 ICAO Annex 14 (Ref. 4) includes criteria originally derived from the Boeing document and outlines when maintenance actions are necessary to repair runway roughness. Annex 14 defines the acceptable, tolerable and excessive limit levels of runway surface irregularity for paved runways of certain classes of airports, in terms of height to length bump ratio. This document stipulates when runway maintenance is necessary and when it can be delayed. Criteria from Annex 14 is shown in Figure 1 below.

2.3.6 For runway roughness requirements applicable in Russia and the Commonwealth of Independent States, please refer to the Federal Air Transport Agency and the Interstate Aviation Committee.

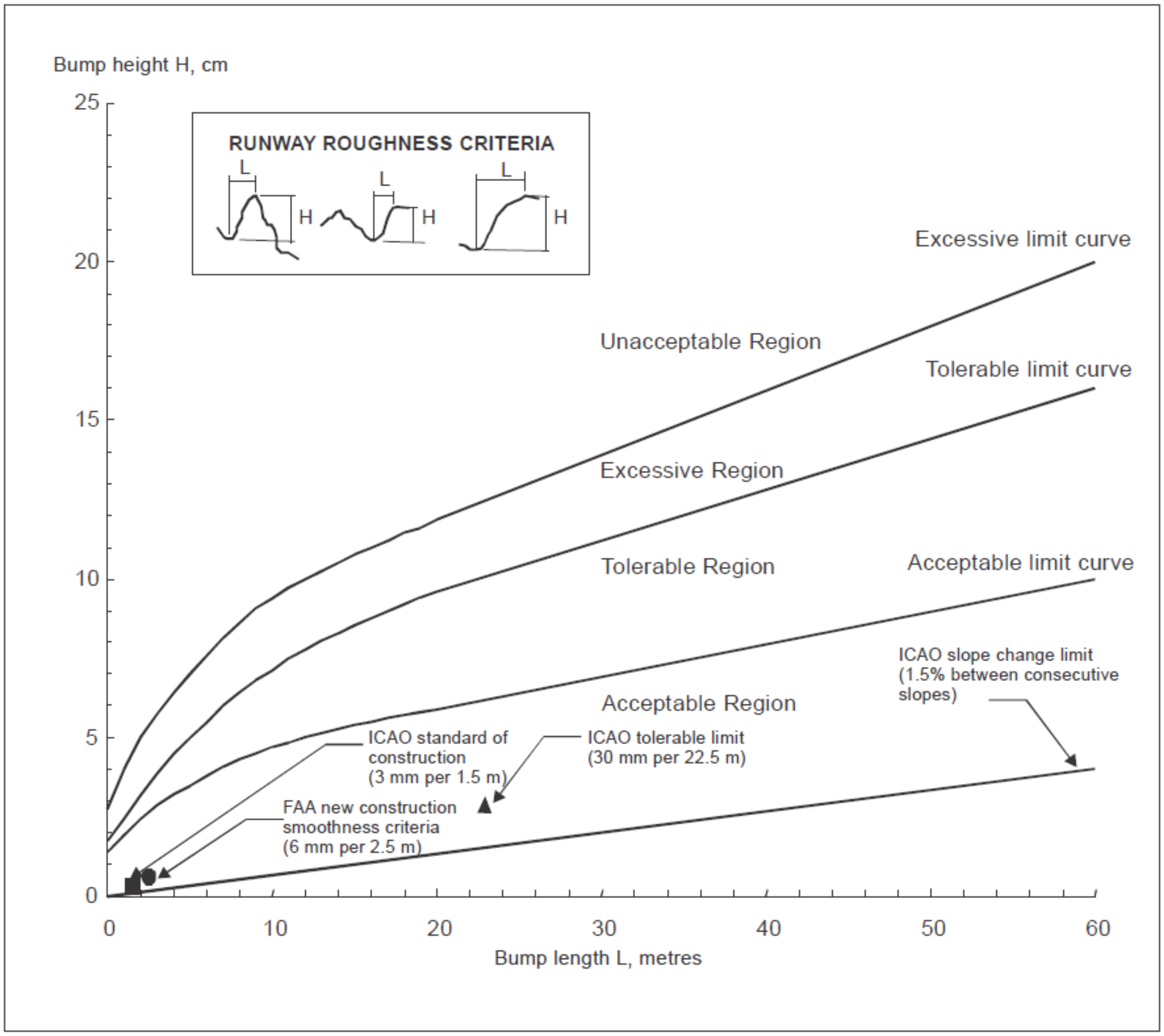


Figure A-3. Comparison of roughness criteria

Note.— These criteria address single event roughness, not long wavelength harmonic effects nor the effect of repetitive surface undulations.

FIGURE 1 – ICAO Annex 14 – Aerodrome Design and Operations

2.3.7 Figure 2 shows the runway bump curve of an unpaved semi-prepared runway in Mouila, Gabon as a representative example of a very rough unpaved runway. It is compared with the bump ratios of the ICAO criteria, and San Francisco 28R, factored and unfactored, up to a bump length of 60m. Other bump ratio curves are available in the Appendix for comparison. Please note that these curves have been calculated with H and L according to the inset sketch below in Figure 2, for wavelengths W up to 120m (W is internal to the curve calculation, see Refs. 5 and 7).

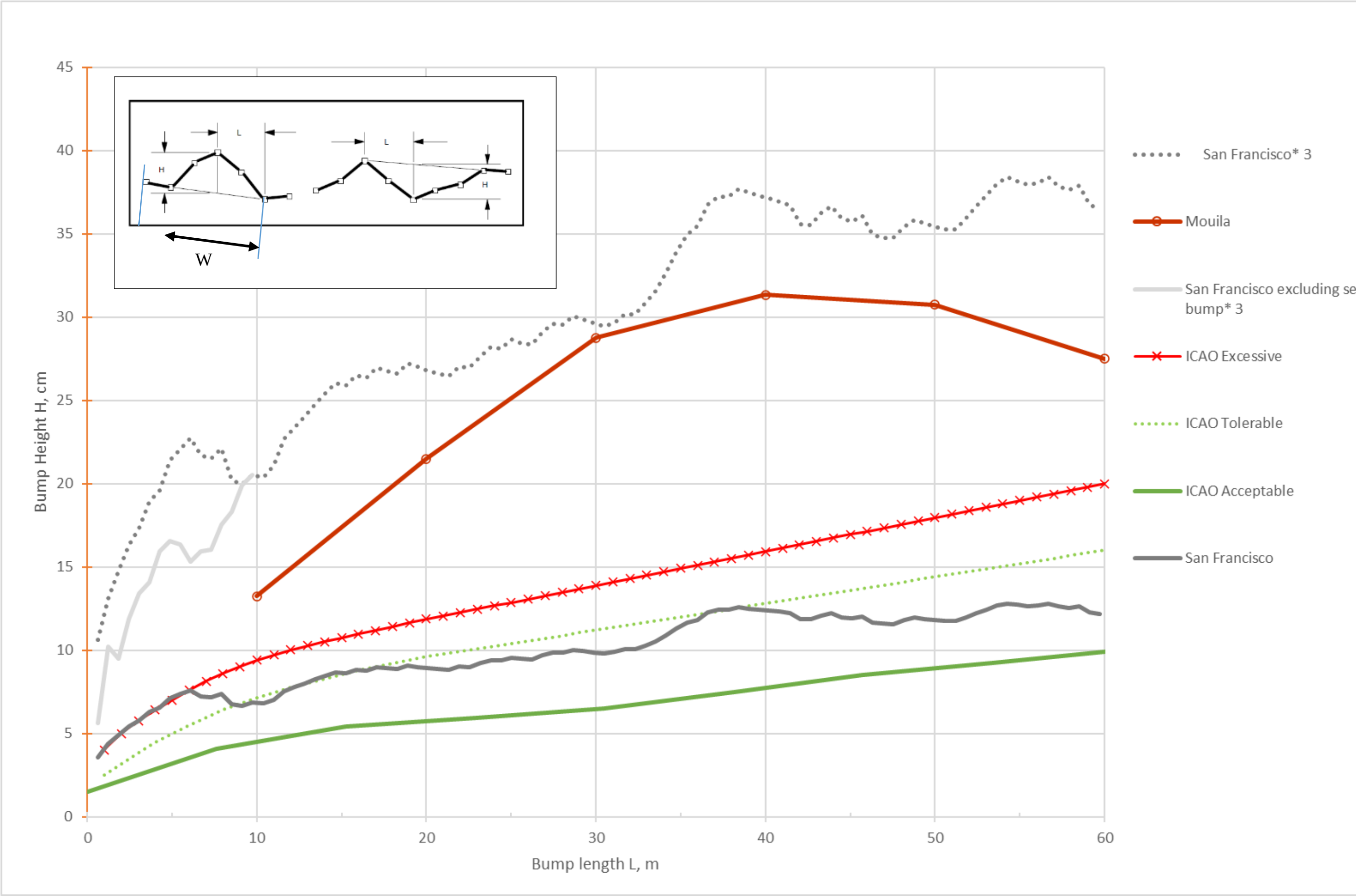


FIGURE 2 – Comparison of runway roughness data

2.3.8 It is observed that the bump height for semi-prepared and rough paved runways, such as the Mouila runway, can be significantly higher than that of ICAO (Ref. 4) tolerable limit curve (green dotted line), and the San Francisco profile, which is widely used for compliance with CS/RBAC/AWM/CFR (5)25.491.

2.3.9 When developing this policy, the CATA group considered whether a single factor could be applied to the San Francisco profile that would envelope most semi-prepared and rough paved runways. As shown in Figure 2, multiplying the San Francisco bump height by a factor of 3 results in a profile that envelopes all the field observations with a reasonable curve shape and with an acceptable degree of conservatism. This factored San Francisco profile is therefore proposed as an acceptable method of compliance, as indicated in 3.3.1 below. It is to be noted that, in multiplying this profile by a factor of 3, the spatial distribution of the bumps along the runway remains unchanged.

2.3.10 The applicant is responsible for defining their fatigue loads spectrum as outlined in section 3.

Note: This is the information available at the time of the publication of this document. This policy may be updated if new evidence becomes available.

3. Policy

3.1 General considerations

3.1.1 In case it is intended to conduct ground operations on semi-prepared unpaved or rough paved runways beyond the ICAO Annex 14 tolerable limit curve defined for paved runways, or worse than the similar runway criteria specified in AC/AMC 25.491, any effect of this increased roughness on the structure and systems of the aircraft, including landing gears and their attachments, should be taken into account. Aircraft ground loads appropriate to the surfaces to be approved for operation shall be considered in meeting the appropriate certification requirements. Fatigue and damage tolerance, including accidental damage inspections and life limits for landing gear and other structural elements, should be reviewed and revised as appropriate.

3.1.2 In addition, appropriate design measures to protect aircraft structures and systems need to be taken, as well as the definition of required maintenance and continued airworthiness actions in the Airplane Maintenance Manual (AMM). Any limitations defined should also be properly documented in the AFM (see 2.2.4).

3.2 Rough paved and unpaved runways: Taxi, take-off and landing roll

3.2.1 For design and fatigue loads, applicants should account for the unique operations on unpaved and rough paved runways by –

1. Directly measuring the longitudinal runway profiles on which the airplane will be operating, and then analyzing the airplane response using those profiles, or
2. Measuring the airplane response during a ground test on those runways.

For analysis, a limited number of runway profiles may be used if it can be shown (e.g. bump length/height curve or Power Spectral Density (PSD)) that these profiles conservatively address all anticipated operations. Likewise for test, a limited number of runways may be evaluated if these can be shown to conservatively cover for all anticipated operations.

3.2.2 In case the runway profile is measured, the sampling interval should be fine enough to cover all frequencies relevant to the structure strength, and fatigue and damage tolerance, considering the aircraft flexible response. Wavelengths above certain values that don’t significantly contribute to airplane response may be ignored. Please see references (5) to (7) for measurement of runway profiles.

3.2.3 Alternatively, a flight/ground loads survey may be performed to measure airframe and landing gear accelerations, shock strut displacement, and strain responses to the surface excitation. In this case, the survey should include sufficient instrumentation to fully assess the landing gear and airframe loads. Sufficient flight/ground tests should be performed to cover variations in aircraft weight and center of gravity, aerodynamic configuration, ground speeds, etc.

3.2.4 For design loads, in lieu of measuring runway profiles, the applicant may use the factored profile specified in 3.3.1.

3.2.5 When analyses are used, the airplane model(s) should be validated by ground test, measuring airplane responses such as stresses, strains, shock strut displacement, accelerations and damping. The principles of AMC 25.301 and AC/AMC 25.307 apply when taking credit of previous similar test evidence. A range of operating conditions (aircraft weight and center of gravity, ground speed, etc.) should be explored, as detailed in section 4 of AC/AMC 25.491.

3.2.6 The Type Certificate holder may communicate to the aircraft operator through the relevant manuals the aircraft usage that was assumed (runways operated) to define the inspection programme. Operators should also consult with Type Certificate (TC) holders when operating on unpaved or rough paved runways that may not have been evaluated during the original certification of the airplane.

3.2.7 Unless the design assumptions are conservative, as explained below, there should be monitoring of the actual usage in an in-service survey (see EASA Part 26.305). If operations on a certain runway or runways are found to cause higher design or fatigue loads than were considered during certification, the TC holder must make changes to the design or to the airplane’s maintenance program, or impose additional airworthiness limitations, as necessary. These changes and limitations may need to be mandated by airworthiness directive.

3.3 Design loads and strength

3.3.1 In the absence of measured data of runway profiles on which the aircraft will be operated, a factor of 3.0 on the height of the elevation profiles specified in AC/AMC 25.491 section 4 is considered as acceptable.

3.3.2 Alternatively, when measured data of runway profiles on which the aircraft will be operated are available, loads can be established by analysis, supported by validation of the airplane model(s) as specified in 3.2.5.

3.3.3 In the absence of a more rational analysis, sections 5 and 6 of the AC/AMC 25.491 remain applicable.

3.4 Fatigue and Vibration Spectra

3.4.1 The fatigue evaluation should take into consideration the anticipated operations on rough paved and unpaved runways . The assumed aircraft mission profile should be representative of typical taxi, take-off and landing operations (e.g. percentage of operation on unpaved or rough runways).

3.4.2 The fatigue load spectrum assumed for certification should be conservative or validated through ground tests, and could be further supported by an in-service survey. The number of ground tests should be commensurate to the uncertainty (scatter) relative to the number of operational conditions and variations, and the conservatism of the assumptions.

3.4.3 It is up to the manufacturer to anticipate the percentage of operations on unpaved or rough runways. Given the uncertainties in actual operation, the actual usage should be monitored or limited via the Airworthiness Limitations Section.

3.4.4 For fatigue evaluation under rough runway conditions, the applicant may choose to justify and continue using the fatigue methodologies they have been using for operations on normal runways. JSSG-2006 (Ref. 13) includes Power Spectral Density (PSD) for runway profiles of paved, semi-prepared, and unprepared airfields (figures 12, 13, and 14), and indicates that runway unevenness profiles can be generated from the specified runway roughness PSD. For each of the three types of airfield, the PSD is differentiated into three levels of intensity: maximum, mean, and minimum. The applicant can take reference of these in their fatigue evaluation.

3.5 Other considerations

3.5.1 Runways made from concrete slabs: When settling, small steps between slabs can develop. Although their height may be within the required aerodrome certification values, being at constant intervals, they introduce an excitation around a narrow frequency band, the center of which depends on airplane speed. This has been found to detrimentally affect fatigue life including truck pivot joints in bogie beam type landing gears. Possible discrete discontinuities such as slabs should be taken into account separately, in a way representative of their effect on fatigue and damage tolerance.

3.5.2 Some main landing gear equipped with a cantilevered type shock strut (also known as telescopic shock strut) are known to be prone to developing “burning marks” in the stroking mechanism under certain operating conditions. The cantilevered shock strut stays perpendicular to the runway when taxing or landing, so that side loads and braking loads may cause significant radial loads on the sliding tube bearing, which supports the inner cylinder (piston) that slides inside the outer cylinder. The burning marks are results of thermal spikes that are generated by rapid stroking under elevated pressure on the stroking surface of the cylinder. Operations on rough runways are conducive to such conditions. The piston can get stuck and suddenly release if the landing gear crosses a powerful bump. Cracks are found to develop under such a condition and a continuing airworthiness issue ensues. It is thus advisable to take this into consideration in the gear design should operations on rough runways be anticipated. SAE ARP5913 (Ref. 12) provides some information in this regard.

3.5.3 Unpaved runways: Structure and systems protection

Operation on unpaved runways increases the risk of contamination (dust, dirt) and/or foreign object damage (FOD), such as stones and debris being thrown at the aircraft by the tires or by jet/propeller wash. This needs to be addressed by the applicant in the corrosion and accidental damage evaluation required by CS/RBAC/AWM/CFR (5)25.571. Unless conservative assumptions are made, appropriate size and weight of debris, their impact energy, and likely impacted areas need to be defined, preferably supported by previous experience on the applicant's other models that also operate on unpaved runways.

For protection of structure and systems from debris impact, airplanes may require modifications to install protective systems (See Ref. 3)

3.5.4 Maintenance, limitations and continued airworthiness

Unless there is conservatism in the assumptions of runway condition, or credit can be taken from aerodrome maintenance (through operational regulation), limitations should be introduced in the AFM and AMM as necessary, to ensure that conditions assumed or measured during certification, are maintained in service. (See section 2.2.4.)

Additional or more stringent inspections (pre-flight, and/or at regular intervals) may be needed in the AMM due to increased severity of the fatigue spectrum, FOD, corrosion, etc.

APPENDIX A – In service operations - roles and responsibilities

<u>Role of Airplane Operators</u>

During design and certification, the manufacturer accounts for the roughest ground expected to occur in operation. However, the manufacturer may not anticipate all runways or runway conditions, which may lead to structural design or fatigue issues in service. The following operator responsibilities ensure that such design and fatigue issues are addressed:

Operators must follow their approved maintenance manual and airplane flight manual, which includes contacting the TC holder to report service difficulties, including those related to ground operations, when necessary. Operators should also consult with TC holders when operating on unpaved or rough paved runways that may not have been evaluated during the original certification of the airplane.

Airplane operators should consult with <u>airport</u> operators if runway roughness is negatively affecting operations or may be causing unanticipated damage to their airplanes.

Transport Canada Civil Aviation (TCCA) AC 700-011, Operations on Runways with Unpaved Surfaces (Ref.3) provides guidance to airplane operators for the safe operations of airplanes on runways constructed with unpaved runways. This AC addresses the effects of unpaved runways on airplane performance and handling, protection of airplanes for unpaved surface operation, and certification of airplanes for unpaved surface operations.

<u>Role of Airport Operators</u>

References 6, 7 and 8 provide guidance on measuring runway roughness, and on repairing runways. FAA AC 150/5380-9, Guidelines and Procedures for Measuring Airfield Pavement Roughness (Ref. 5) “provides airport operators with procedures to evaluate a pavement surface profile in terms of roughness and the impact pavement roughness may have on civilian airplanes.”

TCCA AC 300-004, Unpaved Runway Surfaces (Ref 8) outlines methods for measuring and reporting surface shear strength for unpaved runways, and provides recommended practices for condition inspection, maintenance and repair of airport gravel surfaces and turf landing strips.

For EASA Member States’ aerodromes, according to EU Basic Regulation 2018/1139, Article 2, 1.(e), aerodromes without paved instrument runways are exempt from the certification and maintenance requirements of section IV, and therefore the implementing rules CS-ADR-DSN and Part-ADR.OPS AC 302-023, derived from the ICAO standards of the previous section. Exempted aerodromes are under the responsibility of Member States. For paved runways, aerodromes handling no more than 10000 commercial air transport passengers per year are also exempted. In other countries, aerodromes have varied degrees of oversight and conditions.

EASA Member States Aircraft operators, in accordance with the EU Basic Regulation 2018/1139 Annex V, must ascertain adequacy of facilities required for the flight. The implementing Air Operation Rules Part ORO or CAT (Commercial Air Transport) don't establish any specific procedure or operating limitation regarding surface evenness or bearing strength.

As a conclusion, for European non-certified aerodromes, such as all unpaved aerodromes, no credit of runway quality can be taken from generic operational certification.

APPENDIX B - Examples of elevation profiles, and their corresponding PSD and maximum bump height to length curves

The following figures present, for several runways (real and artificial), a representation of their roughness in different formats:

- The elevation profile: a direct representation of height vs. distance to the head of the runway.
- The PSD: the Power Spectral Density, or conversion of the elevation profile to the frequency domain (squared). The PSD lines of the ISO 8608 classes A to E (from very good to very poor) of road quality are presented for reference. In some figures, the ISO lines are represented dotted, with the 3 superimposed PSD lines of JSSG-2006 (Ref. 13) Fig. 13.
- The Boeing or ICAO bump curve (maximum bump height for each bump length). The ICAO tolerable and excessive curves are presented for reference.

References:

- ISO 8608 Mechanical vibration — Road surface profiles — Reporting of measured data, Edition 2; Nov. 1, 2016.
- DEF STAN 00-970, a Defence standard for Design of undercarriages - Operation from surfaces other than smooth hard runways (Ref. 9) provides a runway elevation profile definition with different factors (1 for paved runways, 2.5 for partially graded unpaved runways) depending on surface preparation.
- Military standard MIL-A-8863C (Ref. 10) presents observed bump ratios, and discrete steps, for paved, semi-prepared and un-prepared fields. Criteria from MIL-A-8863 are shown in Figure 2.

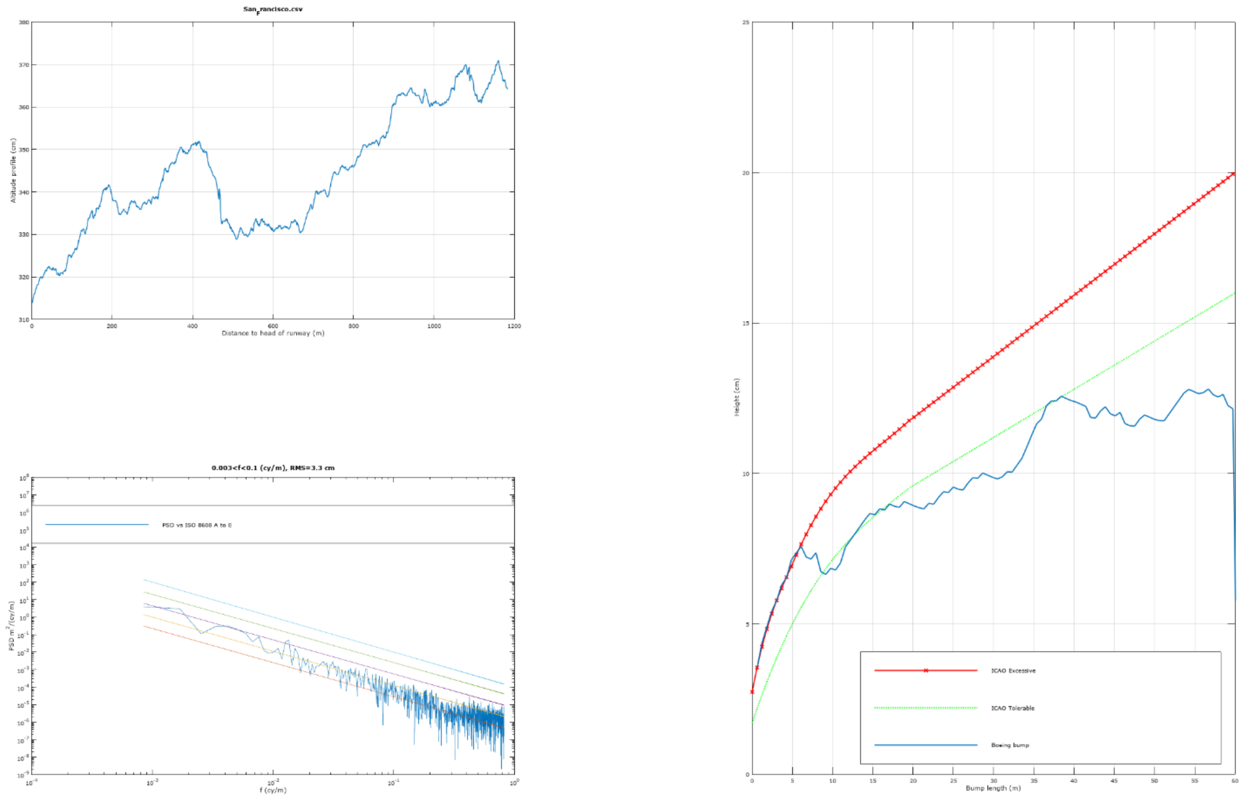


Figure A 1 San Francisco runway 28R

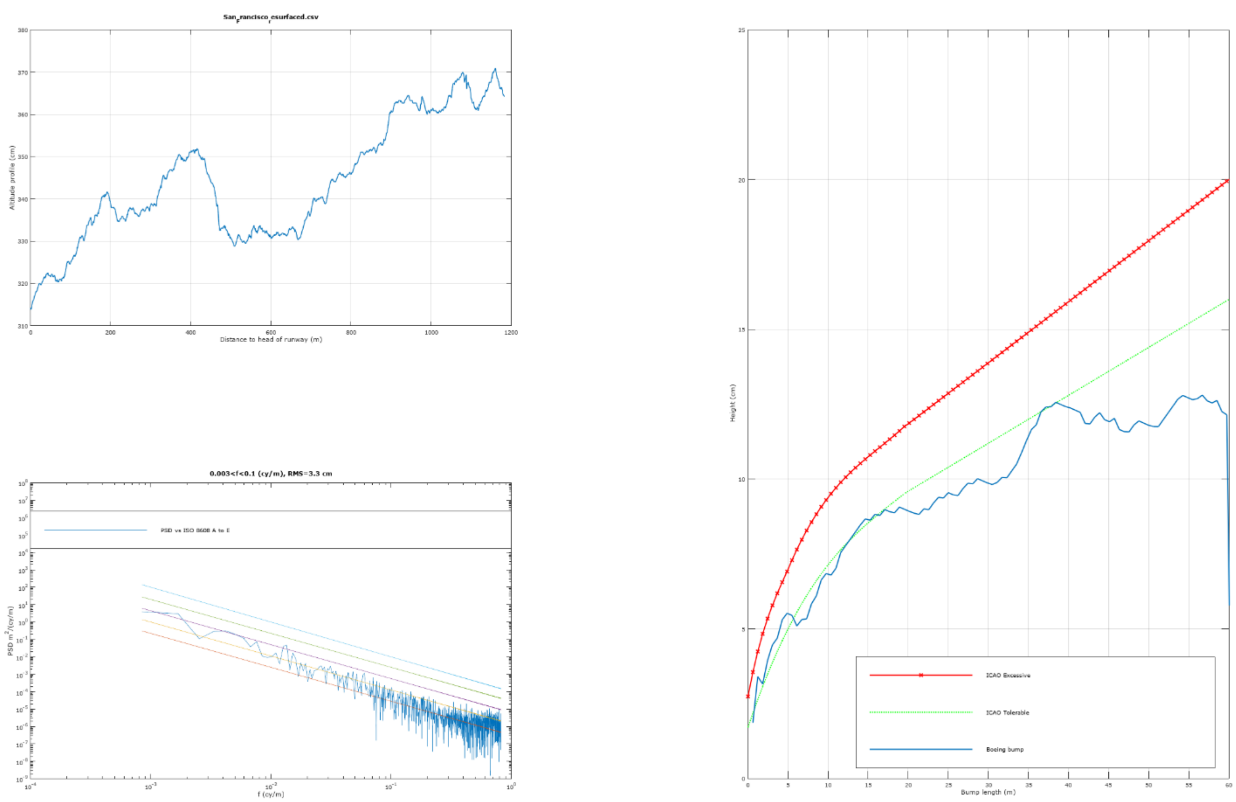


Figure A 2 San Francisco runway 28R repaired (Table 2 of AMC 25.491)

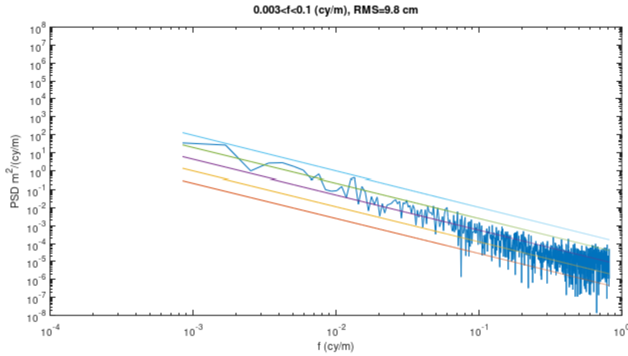


Figure A 3 PSD of 3 San Francisco runway 28R repaired (Table 2 of AMC 25.491)*

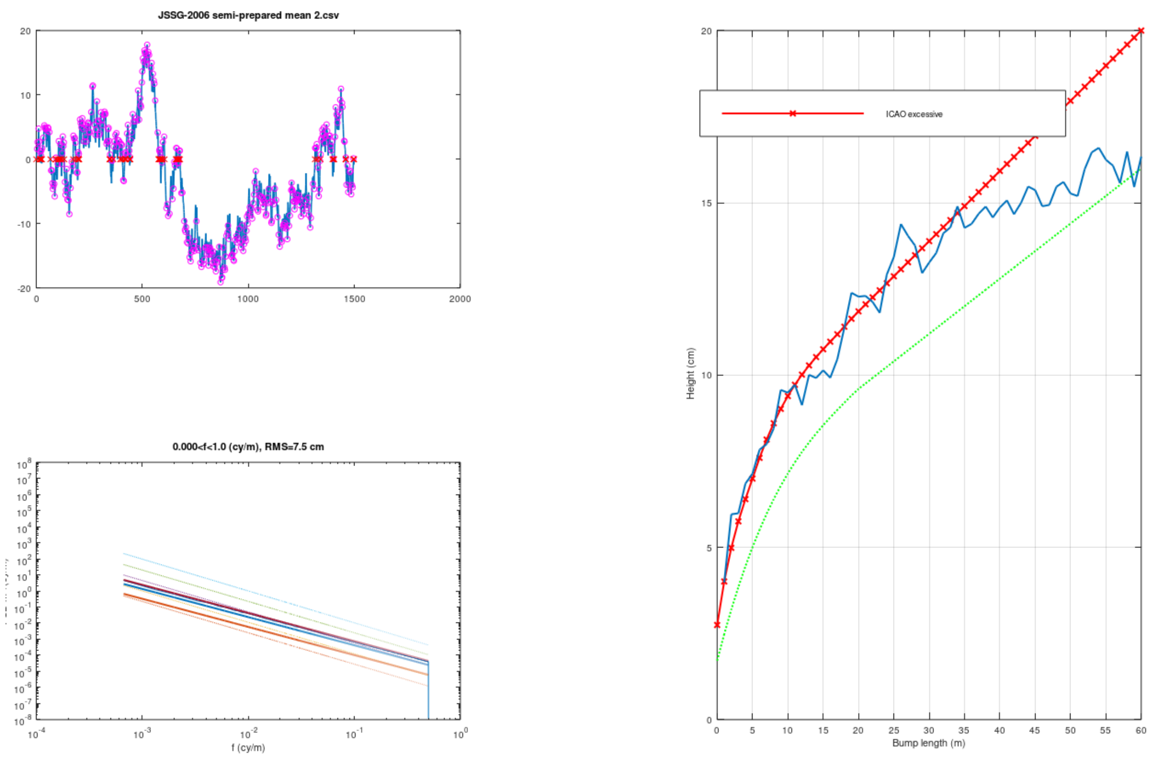


Figure A 4 Reconstruction of JSSG-2006 (Ref. 13) fig 13 (semi-prepared, 2.mean) PSD. Phase=rnd() Here the 3 JSSG lines are continuous and the ISO lines are dotted.

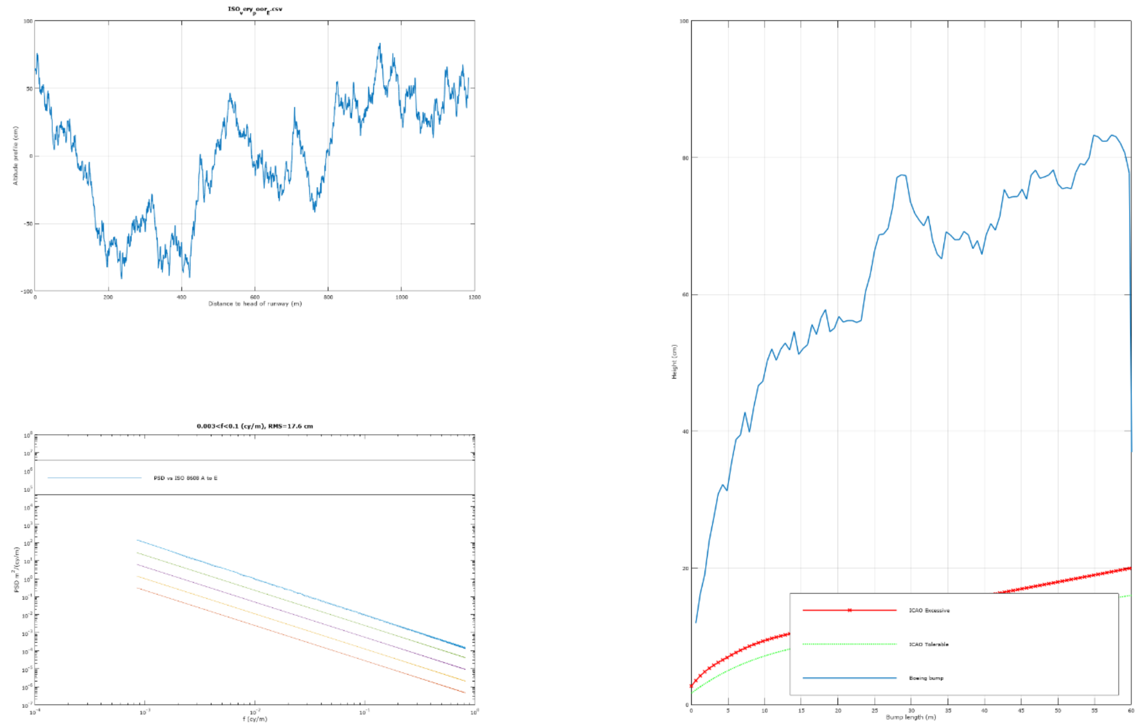


Figure A 5 Reconstruction of ISO 8608 class E (very poor, top PSD blue line) road profile

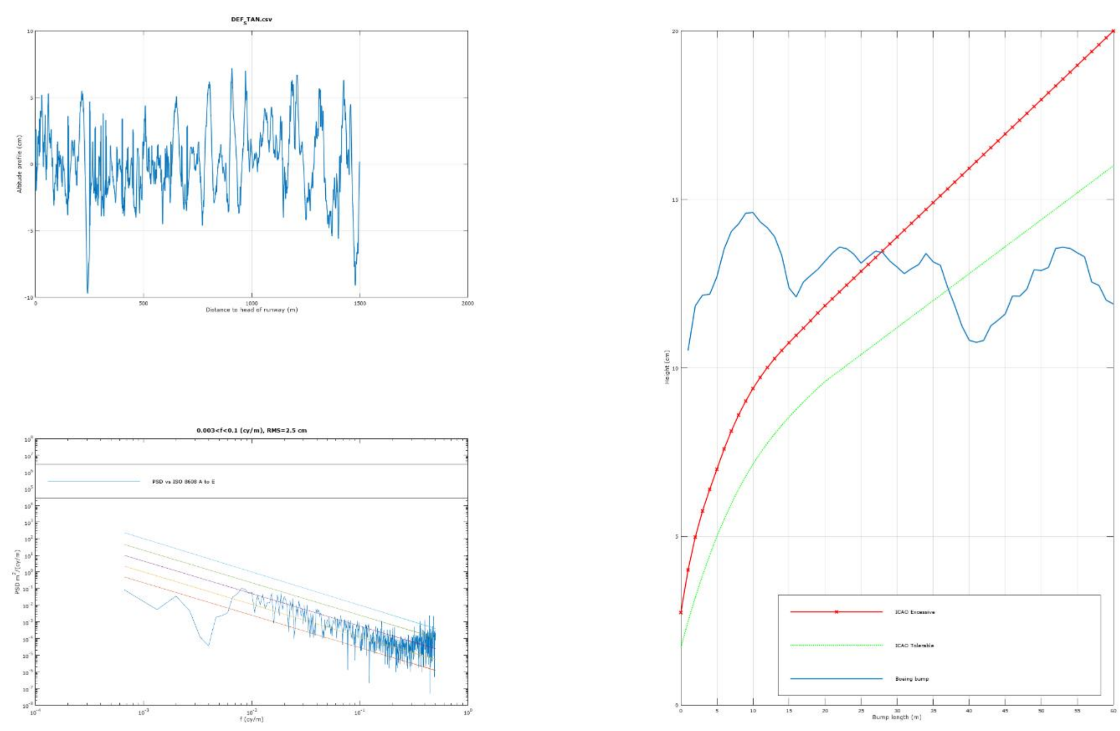


Figure A 6 DEF-STAN-00-970 class A (factor 1)

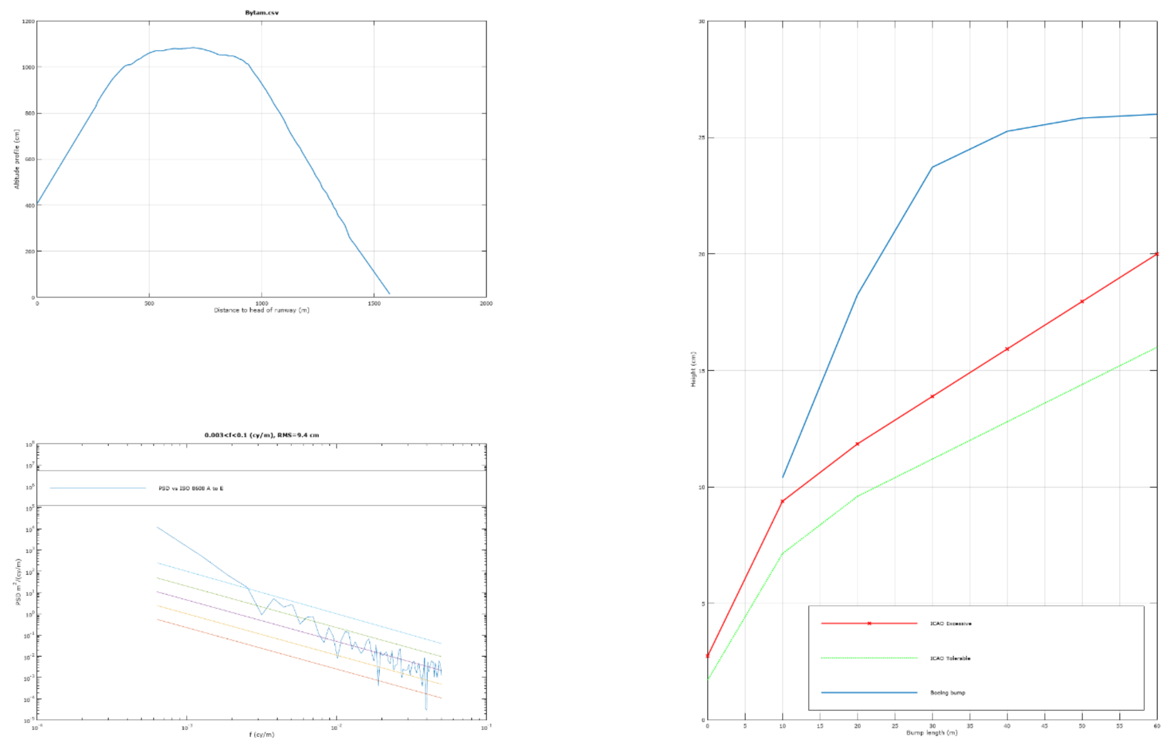


Figure A 7 Bytam runway (laterite)

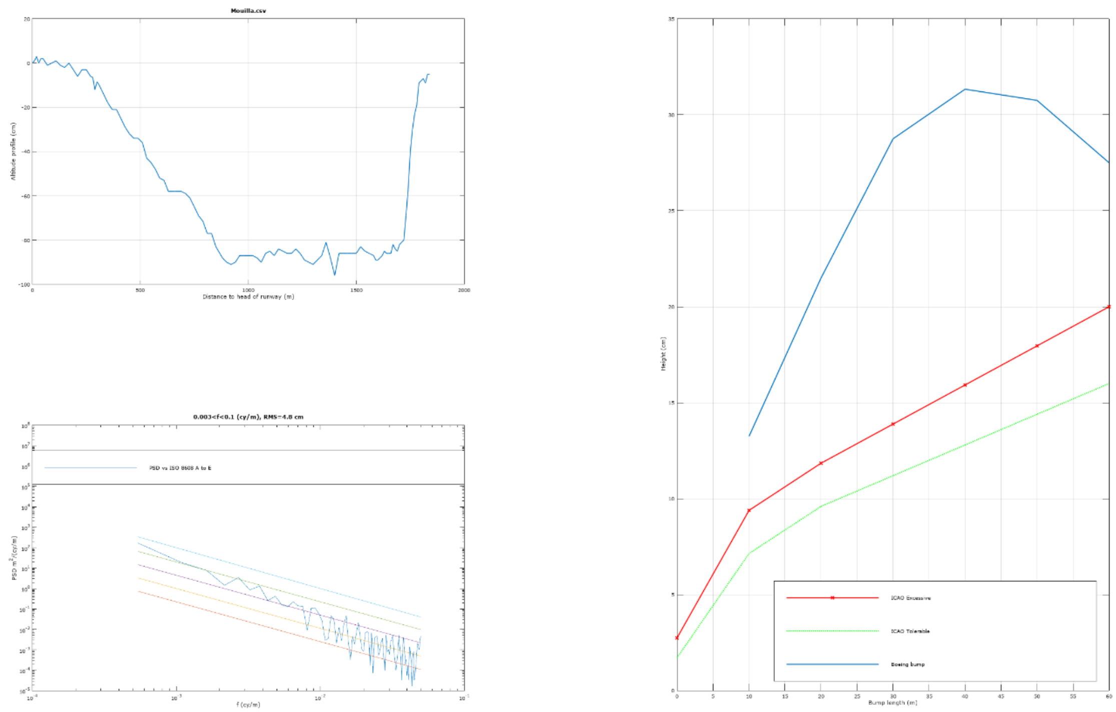


Figure A 8 Mouila runway (asphalt)

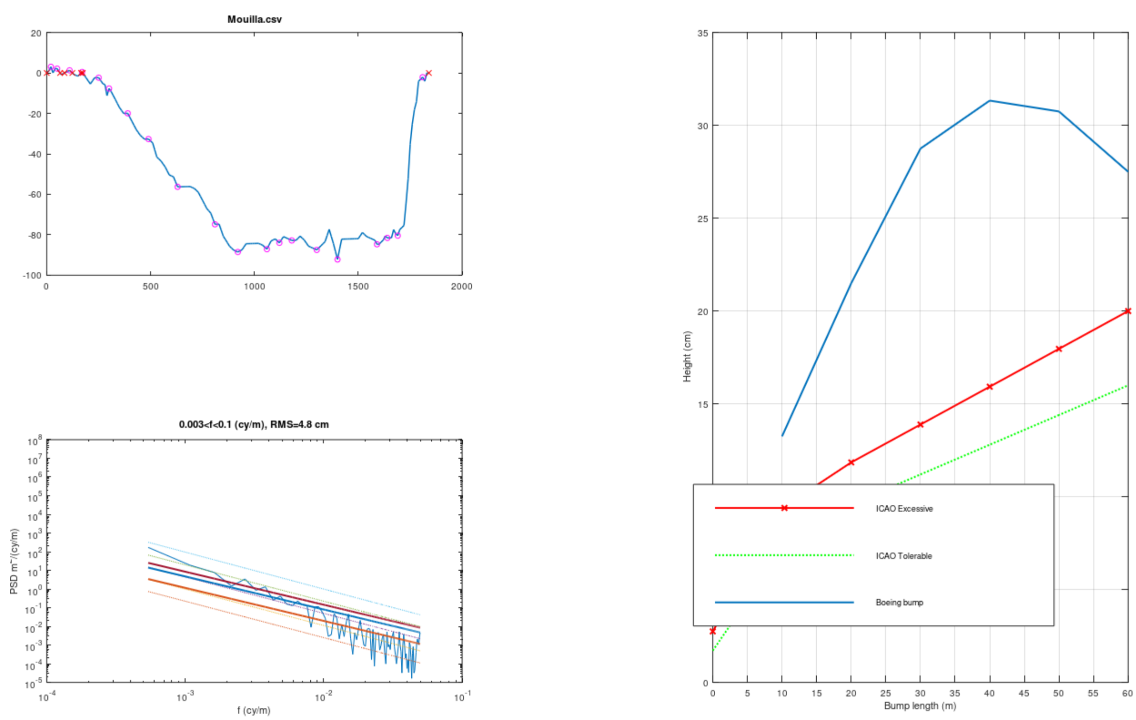


Figure A 9 Mouila runway vs. JSSG-2006 (Ref. 13) fig 13 (semi-prepared) PSDs (continuous line) vs. ISO (dotted lines)

B1. Appendix B. Additional runways. Maximum bump height to length curves