

Runway Roughness Evaluation- Boeing Bump Methodology



LIFECYCLE
SOLUTIONS

Michael Roginski, PE, Principal Engineer
Boeing Airport Compatibility Engineering
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Outline

- Types of Roughness and Boeing Bump Criteria details
- Profiling Equipment Comparison
- Case Studies done by Boeing
- Standardization of Roughness Criteria
- Conclusions

What Type of Roughness is Addressed by the Boeing Bump Criteria

Limit Loads – Single discrete, large wavelength bumps on a runway, which if severe enough, could lead to structural failure by exceeding the limit design loads of an aircraft. Currently, the Boeing Bump Criteria addresses this issue, such that bumps reaching the unacceptable level are repaired.

Two other loading conditions can be addressed by more sophisticated techniques:

- 1) Fatigue Loads – Continuous large wavelength bumps, which exceed the aircraft design fatigue criteria. This criteria is based on a change in vertical acceleration at the aircraft cg which cannot exceed a once per flight occurrence level.
- 2) Landing gear truck pivot joint – Continuous short wavelength bumps, which are primarily only an issue in Russia and CIS countries due to poor construction methods for concrete.

Pavement Maintenance Priorities

Runway pavements should fill the following functions:

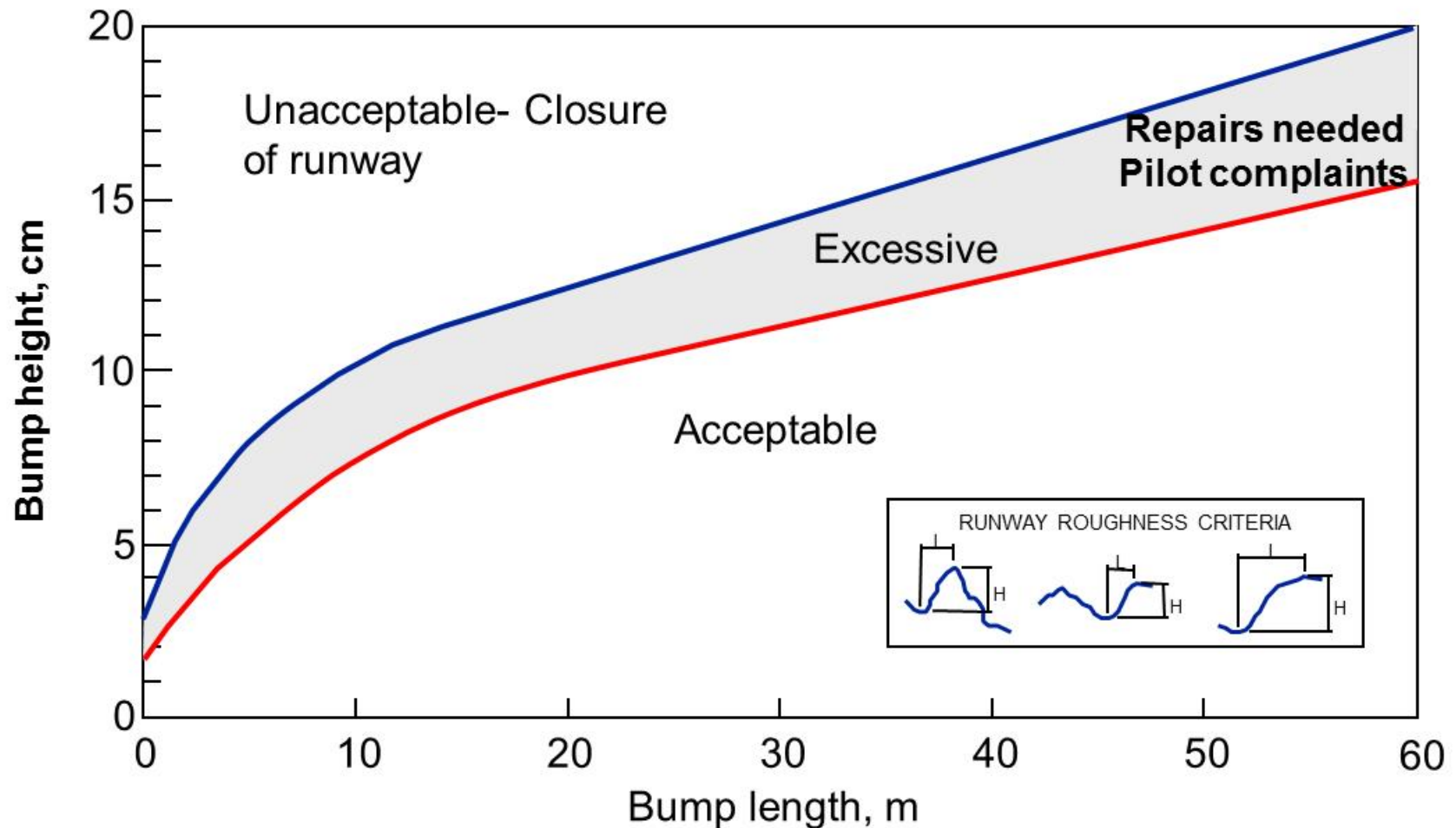
1.) Provide adequate bearing strength- addresses the structure of the pavement- ability to support aircraft loads

2.) Provide good ride quality- addresses surface geometrics and runway roughness- ability of aircraft to maneuver without incident

3.) Provide good surface friction characteristics- addresses texture and slope of pavement – ability to provide for adequate drainage and aircraft braking performance

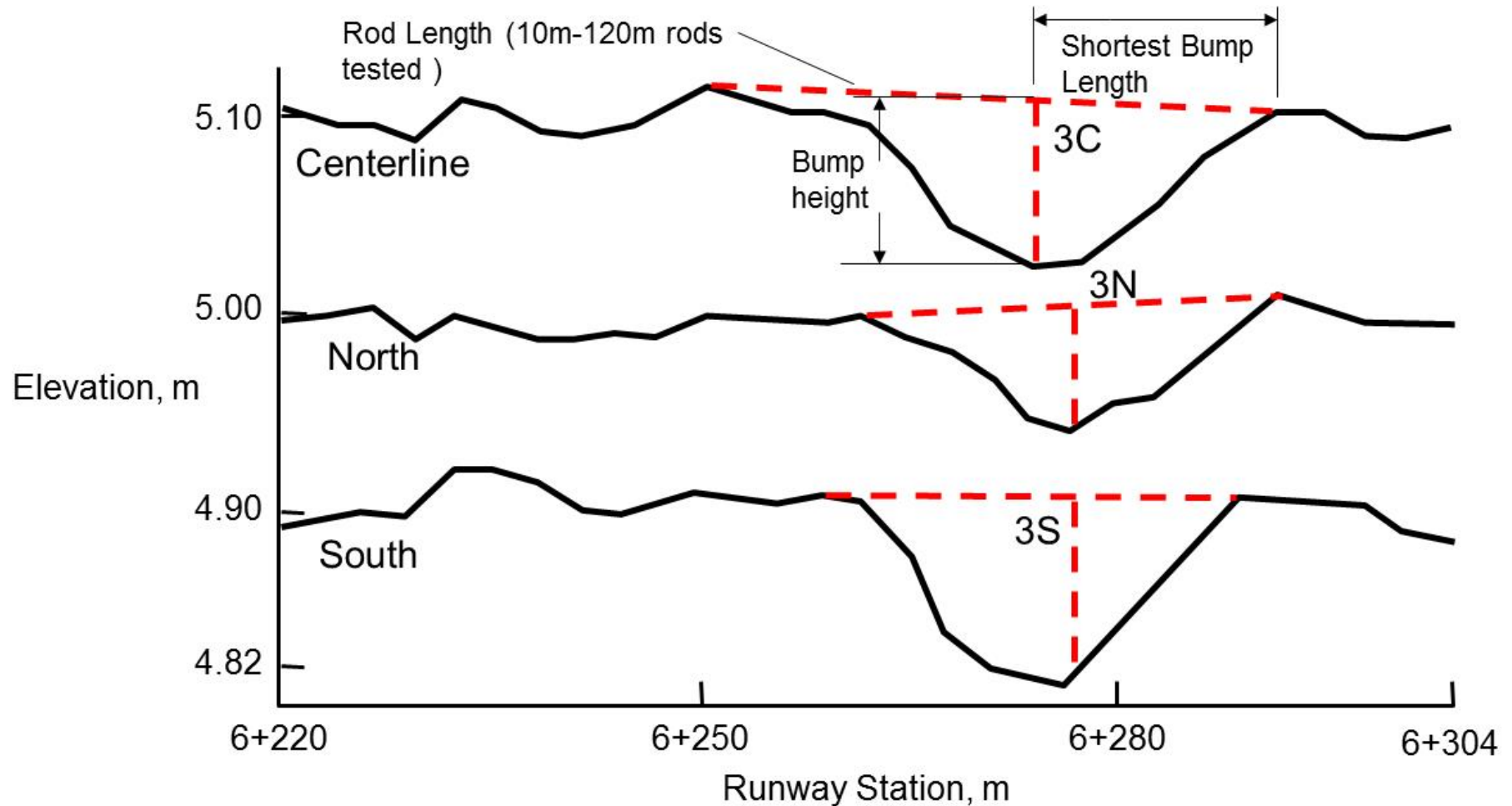
All of these functions are tied to proper pavement maintenance ensuring the pavement is adequate for safe aircraft operations.

Boeing Runway Roughness Criteria-Single Event Limit Load

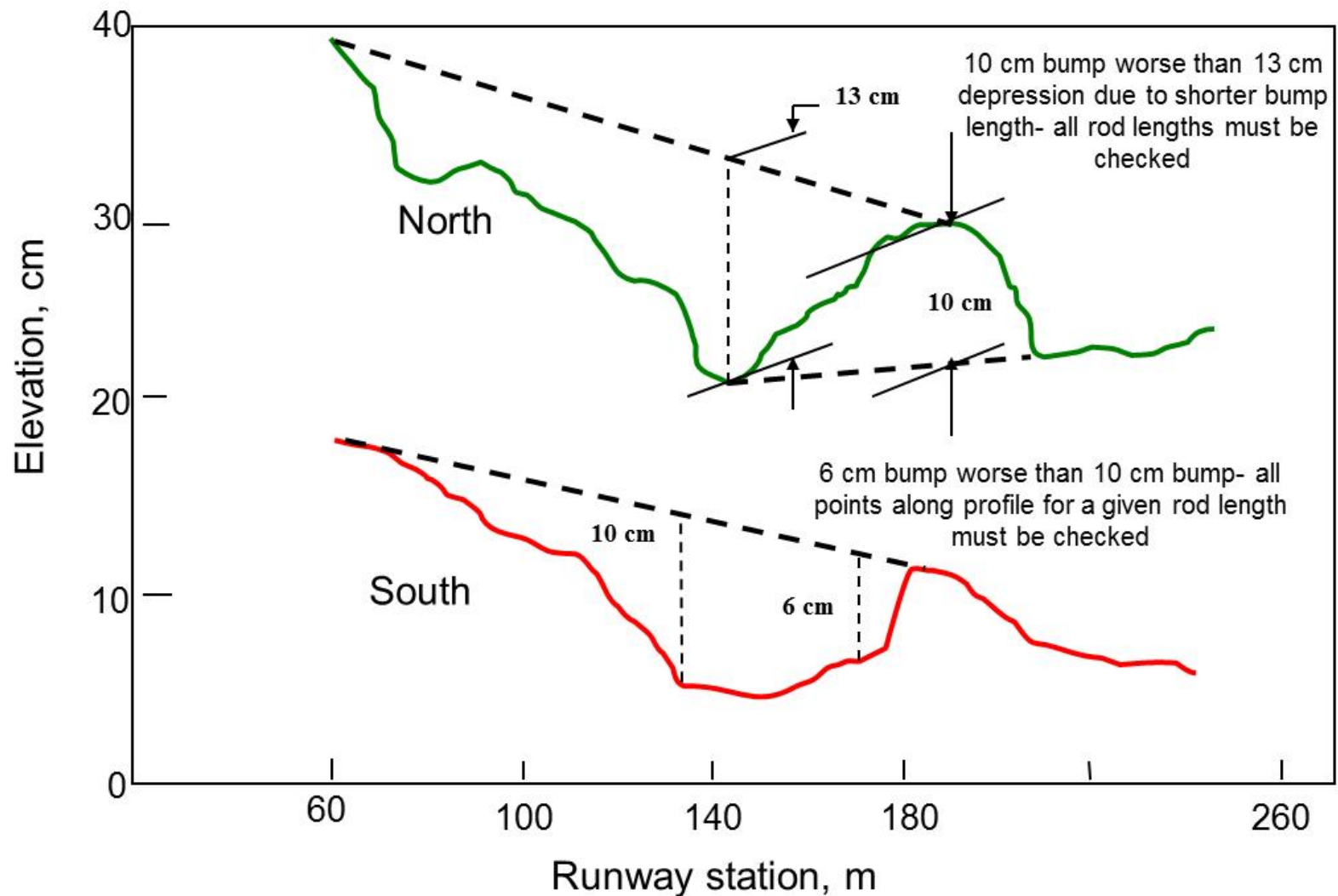


Long Wave Depression

Bump Definition



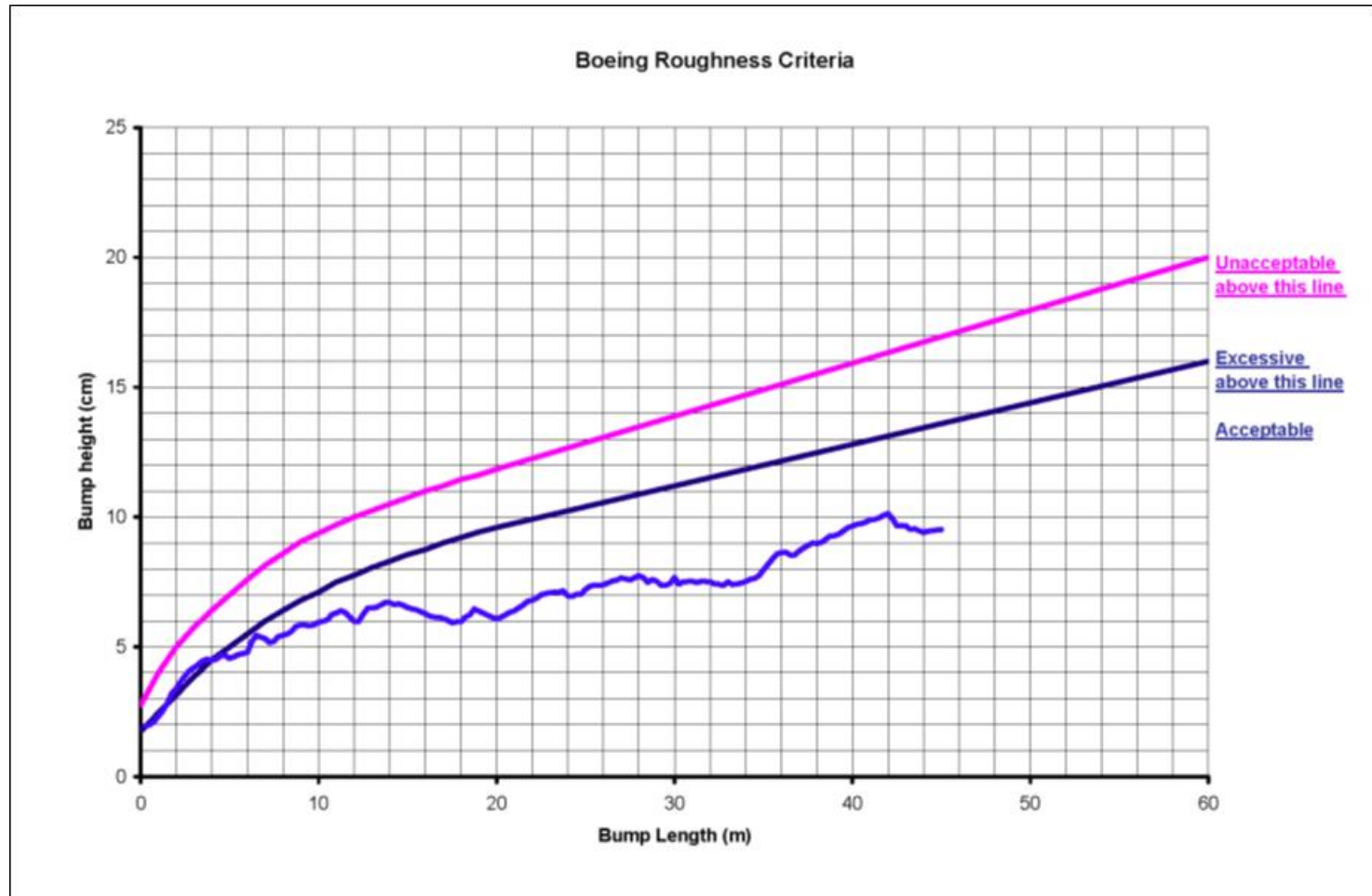
Details of the Boeing Method- Long Wave Depression



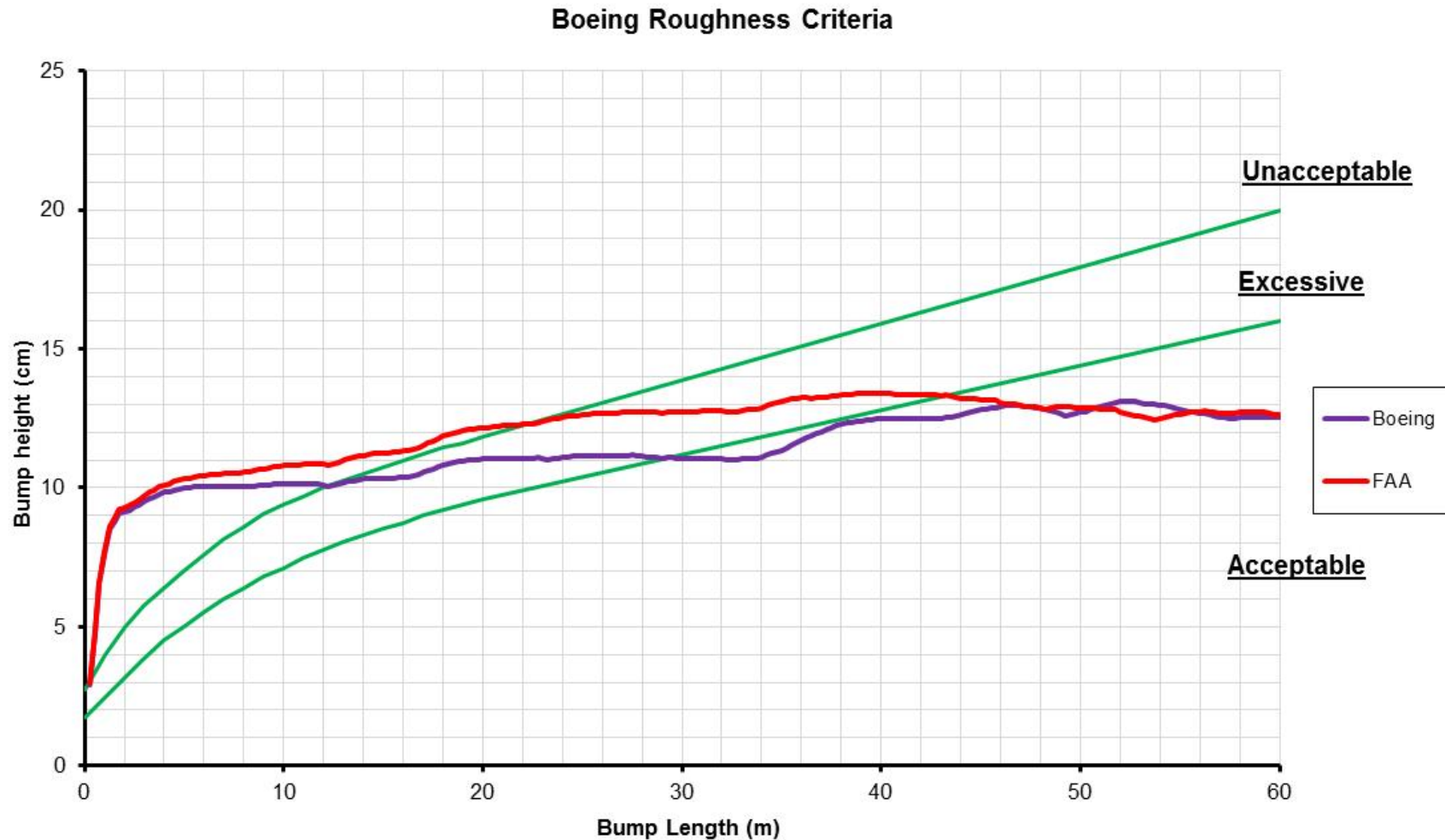
Details of the Boeing Bump Analysis

- Profile smoothing done prior to bump analysis to eliminate raw data roughness which is not necessarily affecting aircraft response. Data is curve fitted with a smooth spline every 200 meters. This flattens the profile to better observe roughness.
- Rod lengths to be checked start at 5m up to 120 m, increments of 5-10 m typically adequate.
- Plot of worst bumps versus the Boeing criteria indicates areas needing repair. More detailed analysis can be done by plotting 100-200m profile segments.

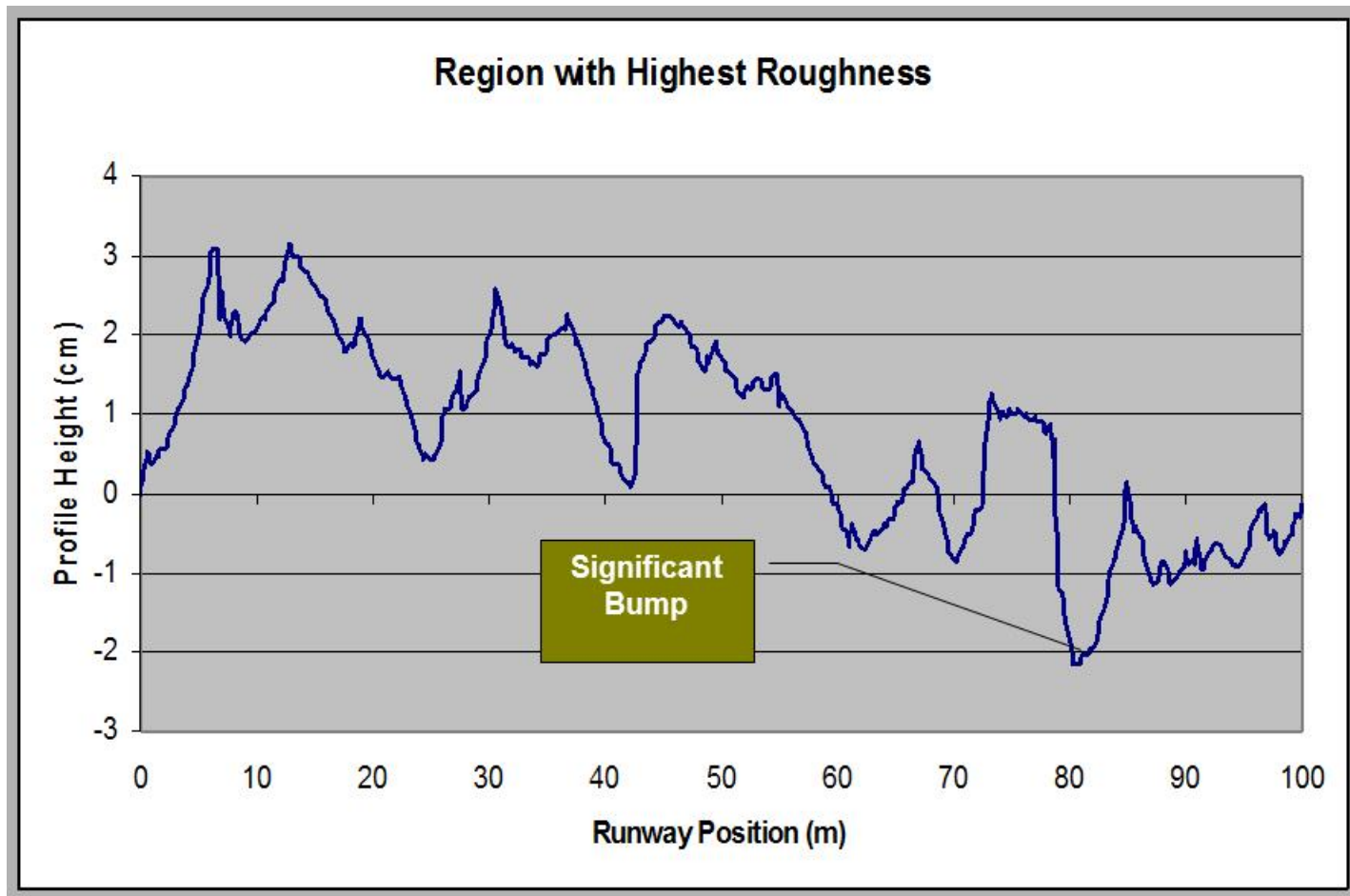
Boeing Bump Analysis- Plot of Worst Bumps



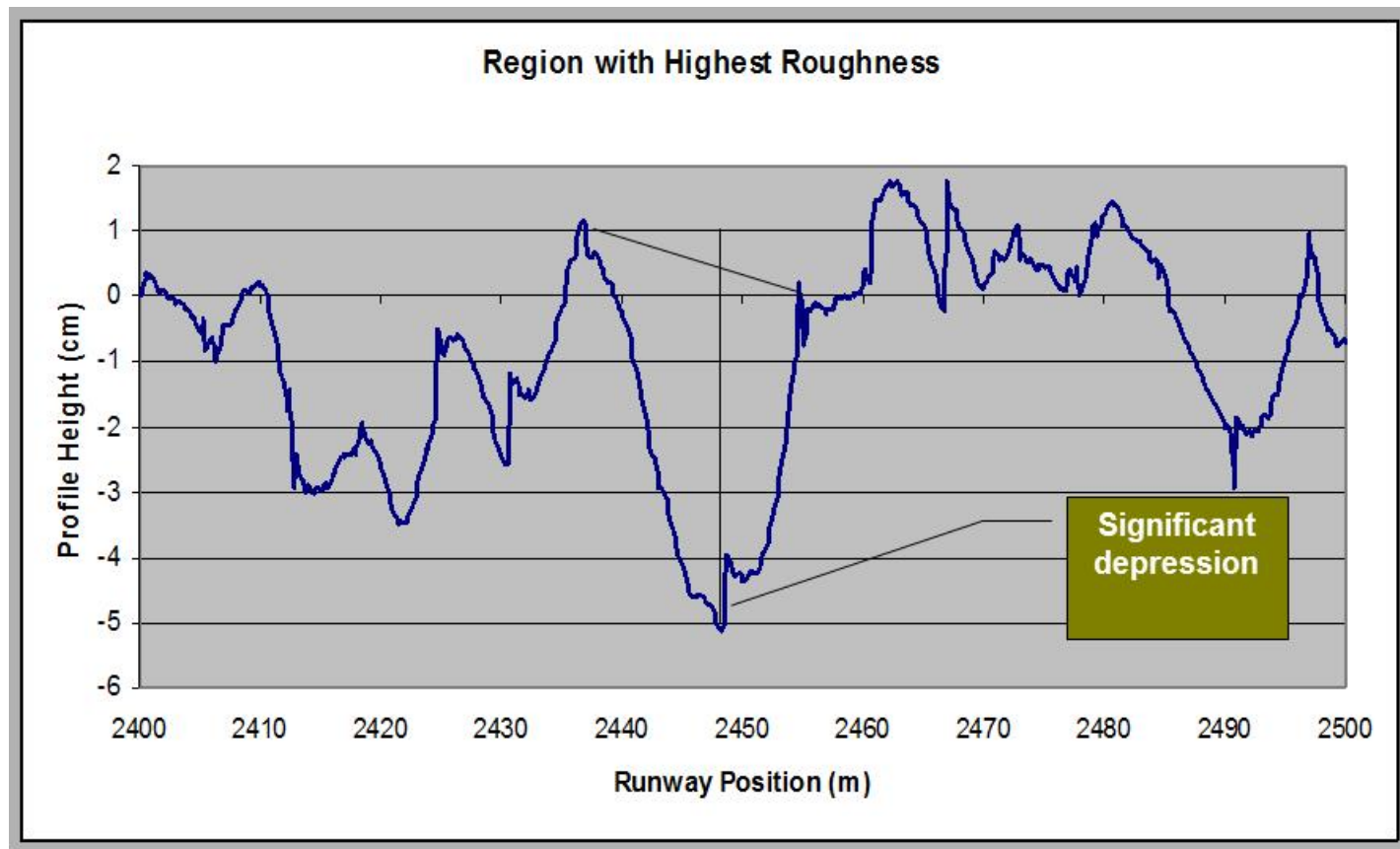
Profile Smoothing Comparison- Boeing vs PROFAA



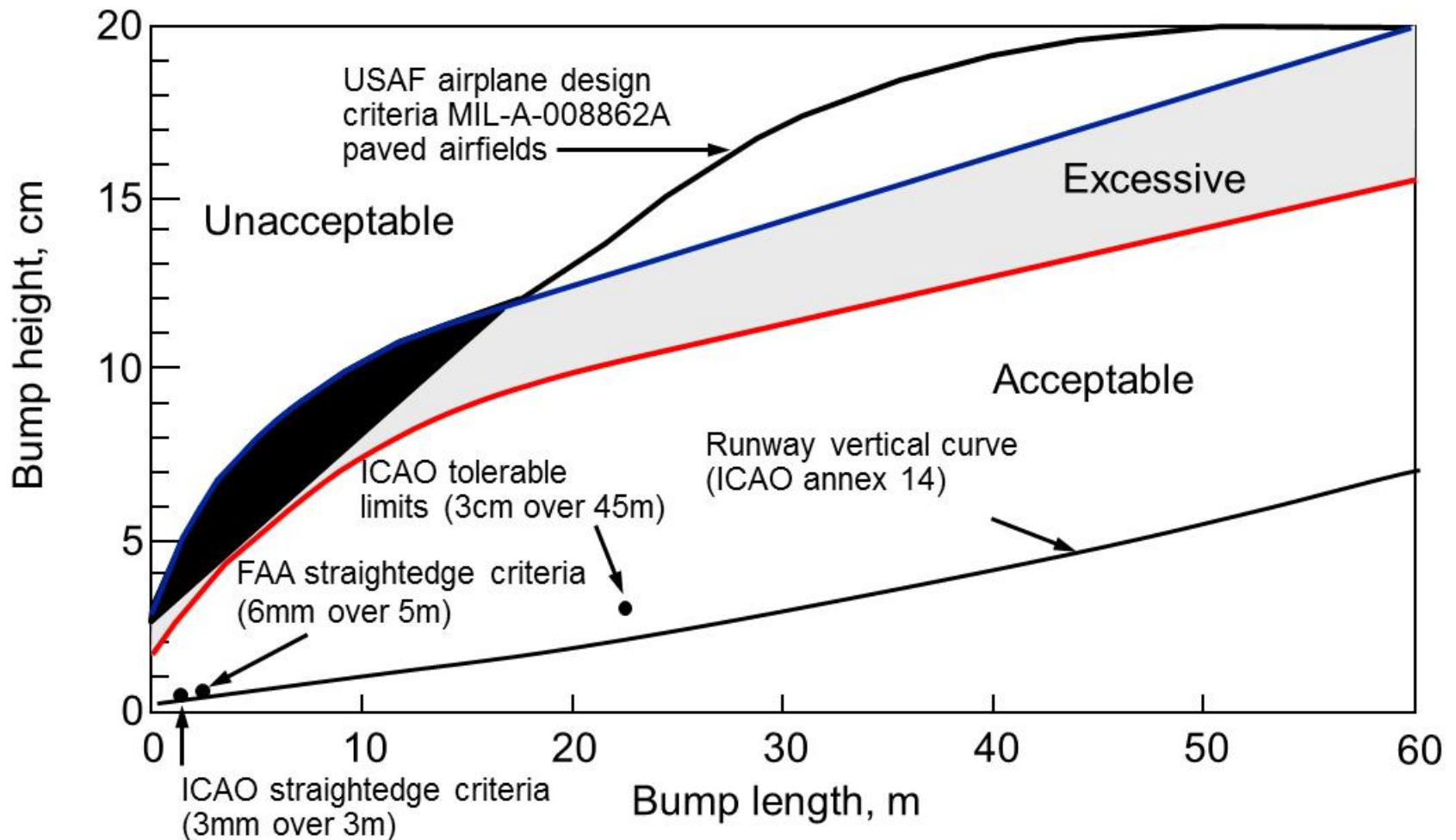
Boeing Bump Analysis- Detail of Excessive Bumps



Boeing Bump Analysis- Detail of Excessive Bumps



Comparison Between Boeing Criteria and other Criteria



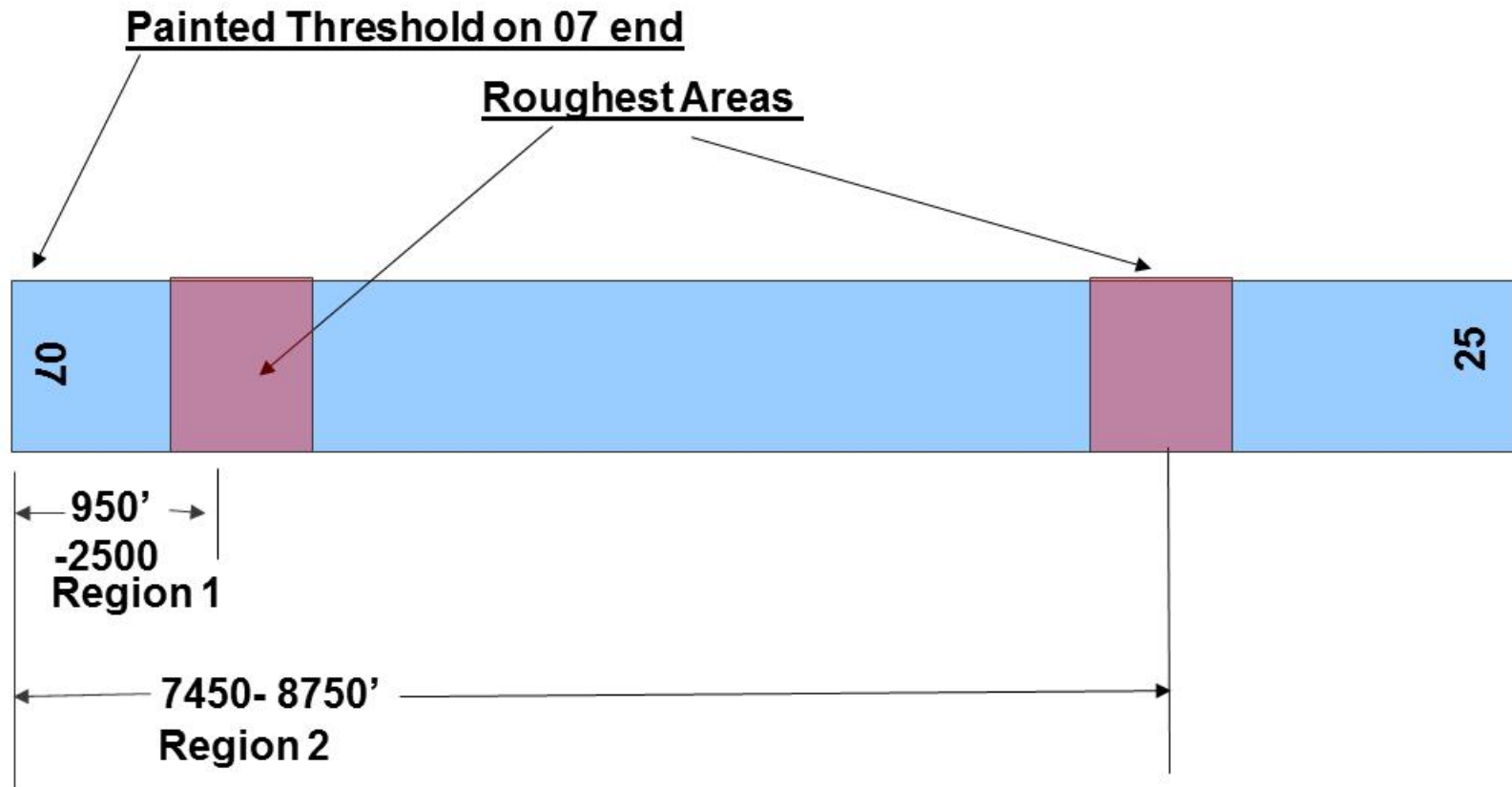
Runway Profiling Equipment Comparison



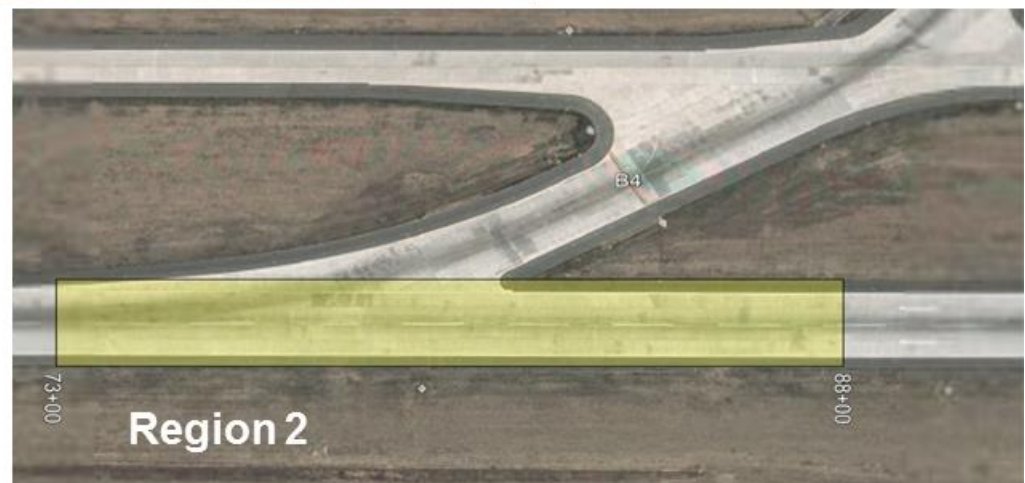
Pavement Assessment Process

- Compare profiles from 3 profiling devices
- Verify that regions of roughness are similar in magnitude for all profilers
- Compare 2 Lines of Survey (CL and 15 Feet Left of CL)
- Roughness determined using Boeing Bump Criteria
- Initial consultant request to review runway 07/25 came to Boeing in 2007. Main concern was fatigue, primarily region 1 dual bump exceeding the once per flight fatigue limit.

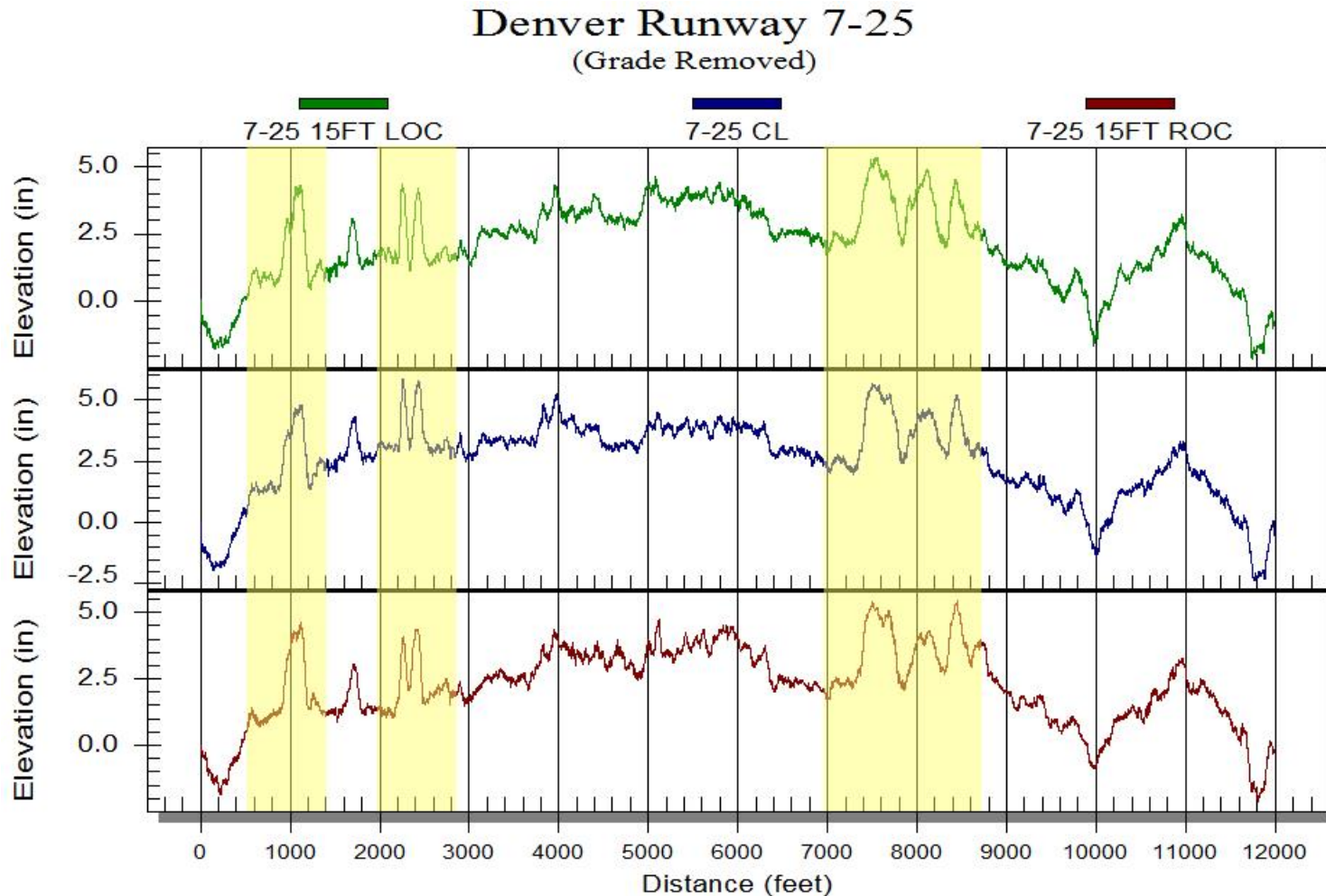
Areas of Roughness from APR survey- 2006



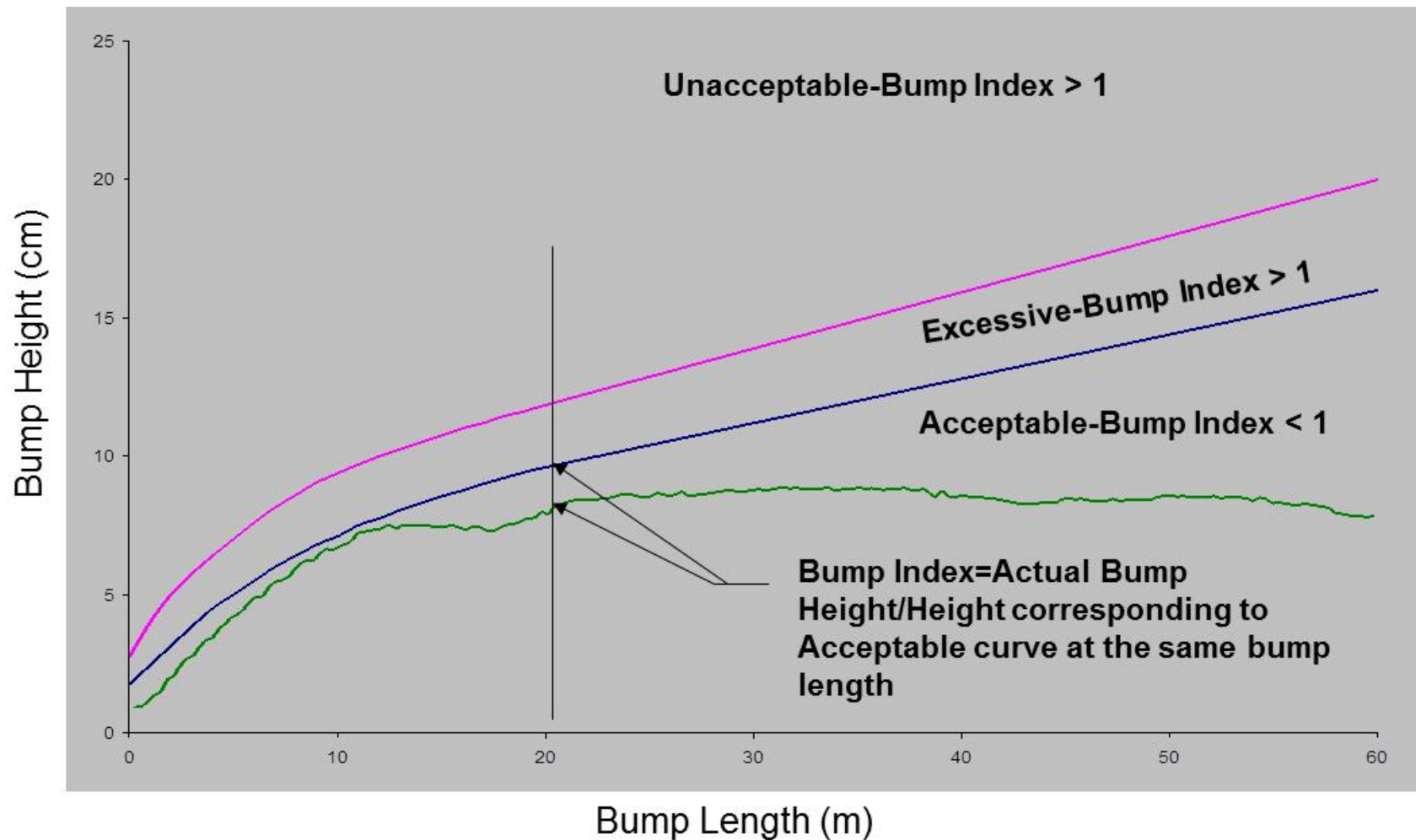
Areas of Roughness from APR survey- 2006



APR Profiles-Regions 1 and 2 as noted

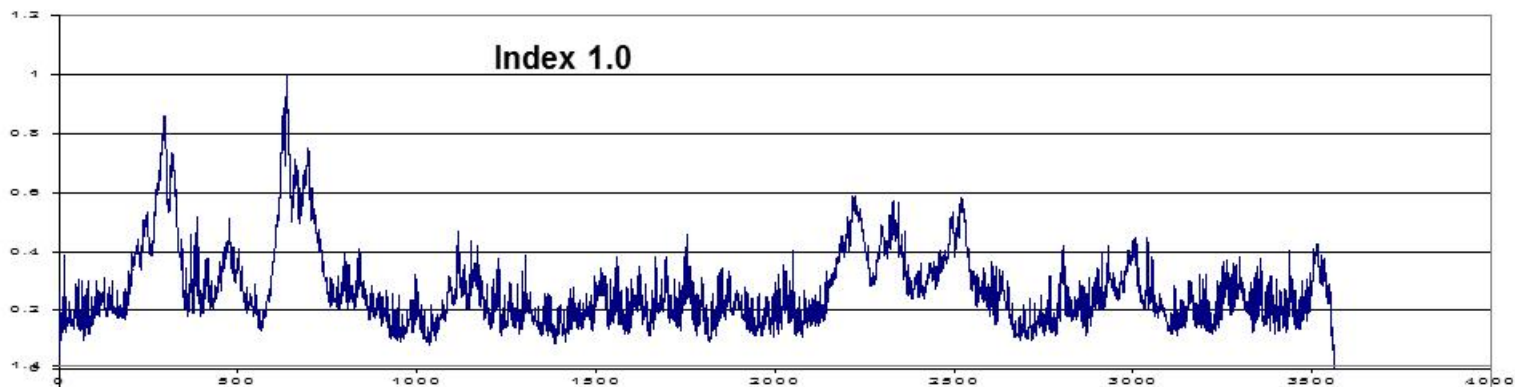


Bump Index Definition- PROFAA method

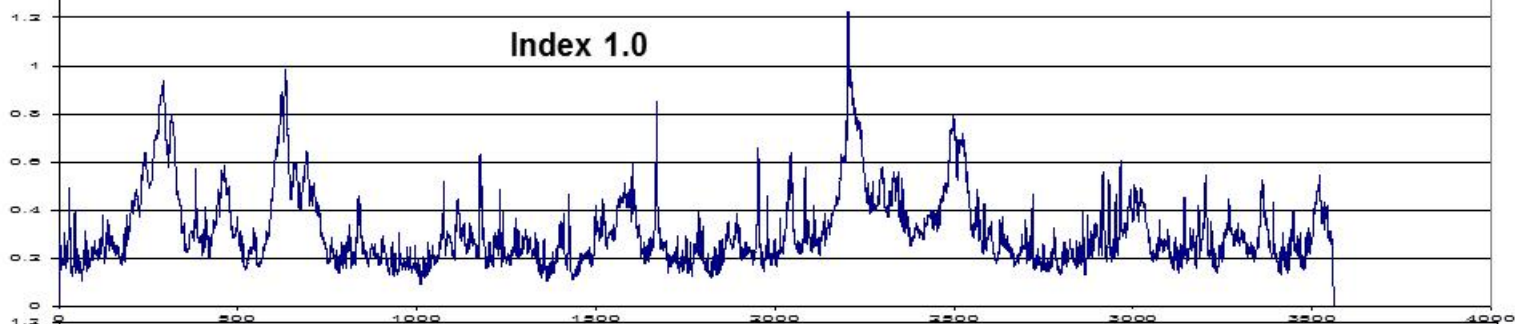


Runway 07/25 Centerline Profile- Bump Index Comparison

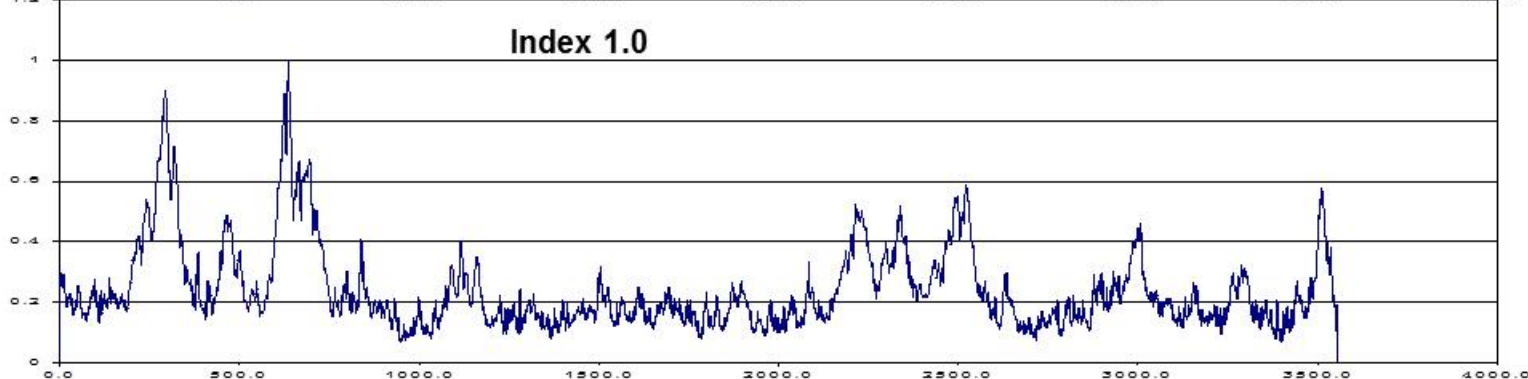
APR



Boeing



FAA



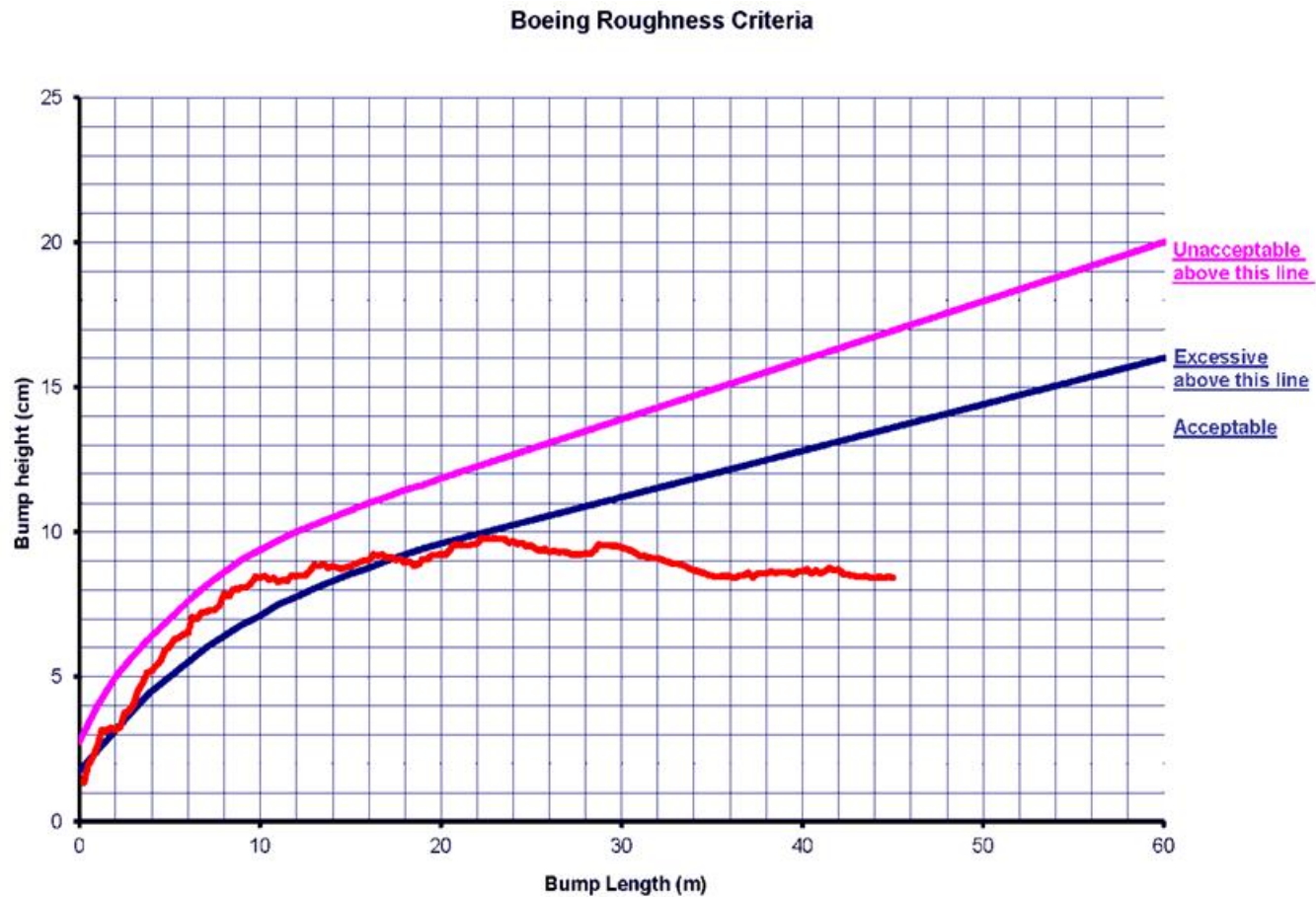
Conclusions

- Profiles from all three devices seem to match well- areas of roughness on runway correlate between all three.
- Boeing bump analysis consistent – bump index values, although differing in magnitude, are maximum at the same locations along the runway
- Locations of overall worst bumps in the same areas for all three profiling devices
- All three profilers are useful in determining general areas of roughness needing repair

Case Study 1- Transition Ramp Bump



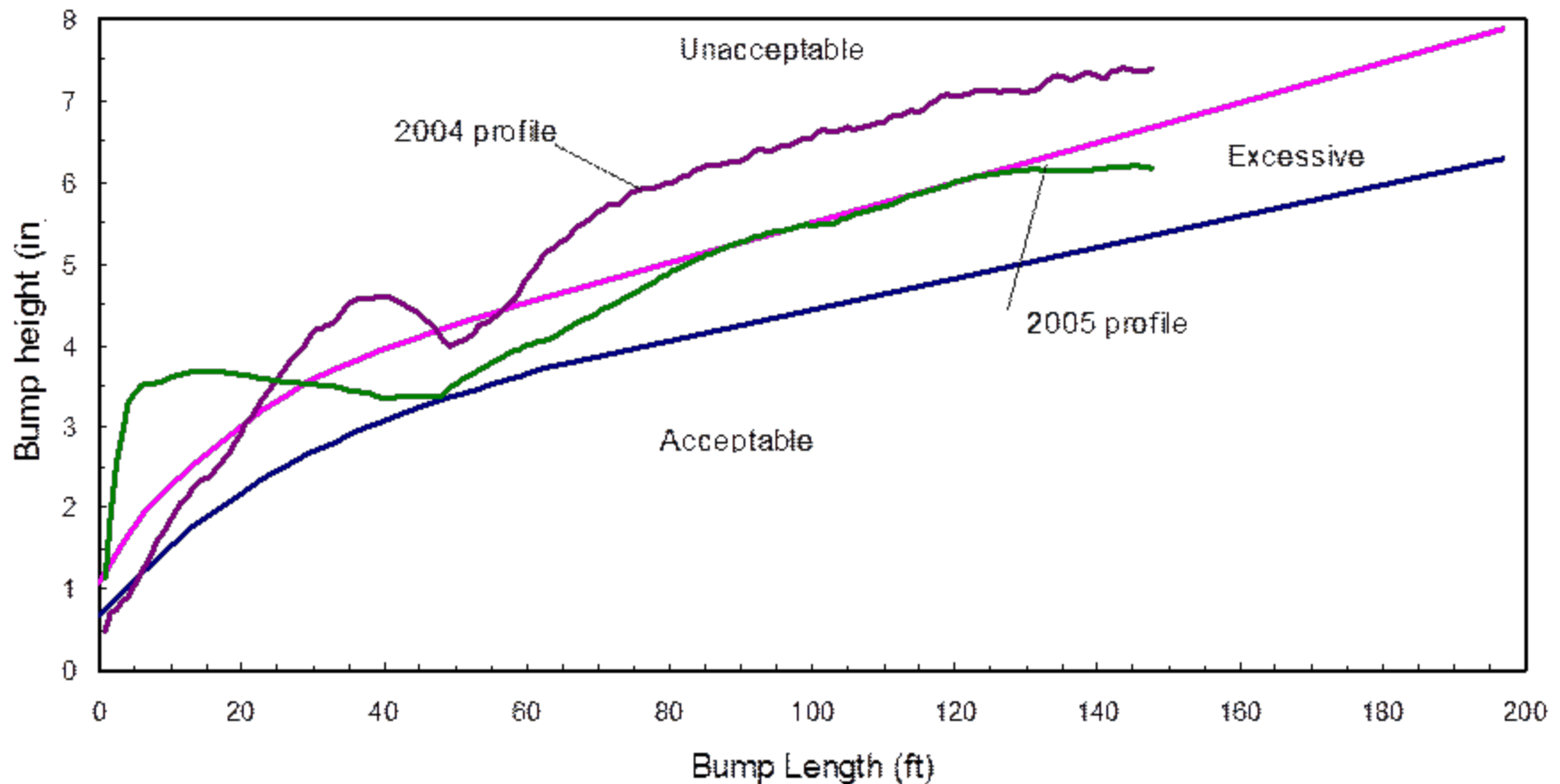
Case Study 1- Transition Ramp Bump



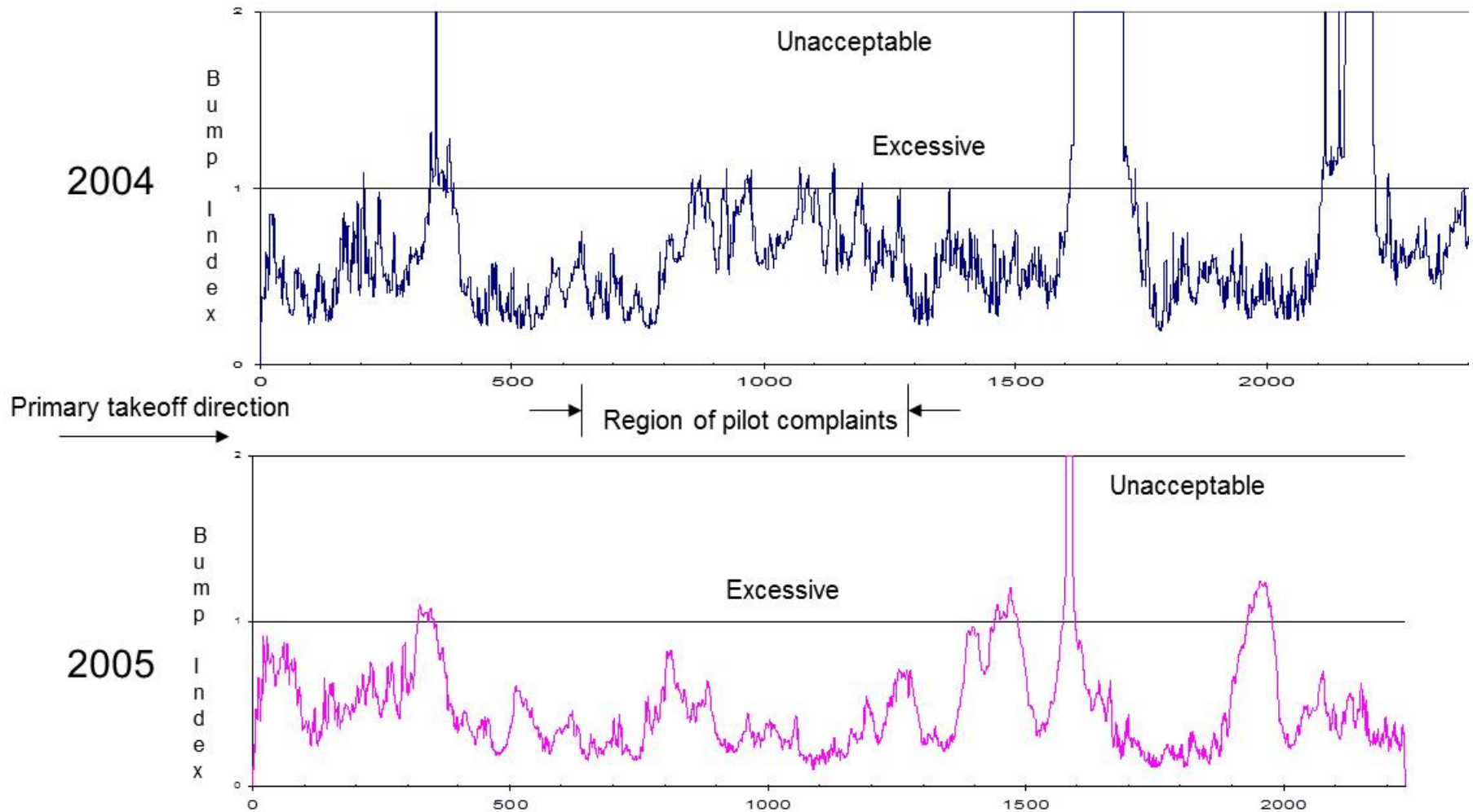
Case Study 3- Unacceptable Roughness Condition



Boeing Runway Roughness Assessment- Unacceptable Condition-Plot of worst bumps



Boeing Runway Roughness Assessment- Unacceptable Condition 2004 vs. 2005 Survey





Working Toward an Industry Standard

Pavement Roughness- Current Situation

- There is no industry standard which clearly defines when a airfield pavement has become “too rough”
- Problems can be aircraft specific-i.e. heavier aircraft at high speed more susceptible to long wavelength bumps
- New construction smoothness criteria is no longer applicable as pavement deteriorates
- Action by the airport is typically initiated by pilot complaints-
FAA currently doing aircraft simulator research to assess pilot feedback on runways of varying roughness.

FAA Guidance on Roughness

NEW CONSTRUCTION and Overlays

AC 150/5300-13, Airport Design

- Surface Gradient
- Maximum grade allowance and changes in grade provisions

AC 150/5370-10F, Standards for Specifying Construction of Airports

- Construction tolerances must be met
- Acceptance criteria for smoothness- straightedge or profilograph

AC 150/5370-13A, Off-Peak Construction of Airport Pavements Using Hot Mix Asphalt

- Temporary ramp guidance. Recommends longitudinal ramps of 4.5 m (15 ft) for each 25 mm (1 inch) of compacted overlay.
- When practicable, it is recommended that the ramp proceed in the predominant aircraft direction resulting in “down” ramps. Avoids possible engine ingestion of loose material.

FAA Guidance on Roughness- Assessing Older Pavements

FAA Advisory Circular 150/5380-9(released 9/30/09)



Advisory Circular

Subject: Guidelines and Procedures for
Measuring Airfield Pavement Roughness

Date: 9/30/2009

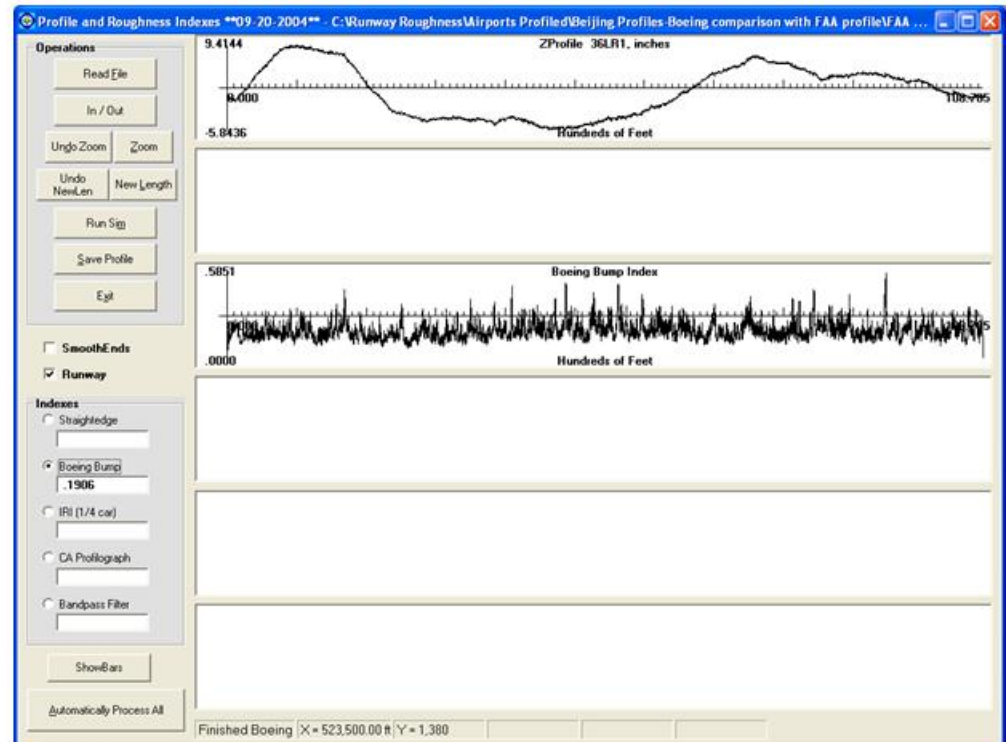
AC No: 150/5380-9

Initiated by: AAS-100

Change:

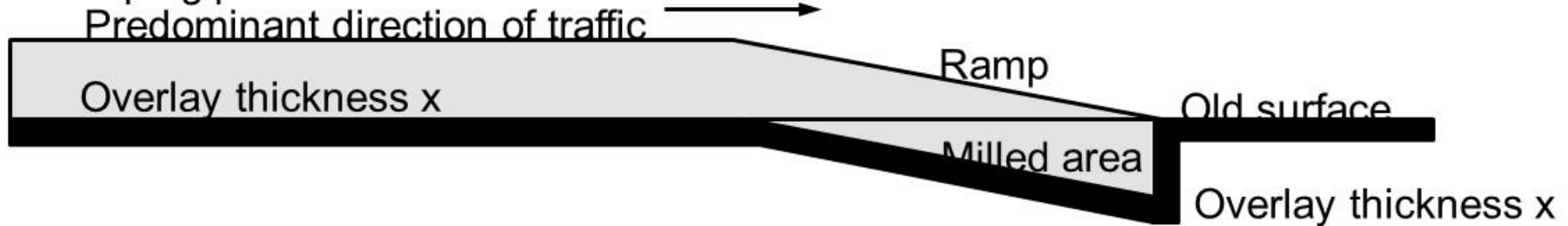
1. **PURPOSE.** This Advisory Circular (AC) provides guidelines and procedures for measuring and evaluating runway roughness as identified by surface profile data of rigid and flexible airport pavements. The guidance in this AC provides technical procedures to quantify surface irregularities and to determine how surface irregularities may affect specific categories of airplanes.
2. **APPLICATION.** The FAA recommends the guidelines and standards in this AC for evaluating the roughness of new and existing paved surfaces. In general, use of this AC is not mandatory. However, use of this AC is mandatory for all projects funded with federal grant monies through the Airport Improvement Program (AIP) and with revenue from the Passenger Facility Charges (PFC) Program. See Grant Assurance No. 34, "Policies, Standards, and Specifications," and PFC Assurance No. 9, "Standards and Specifications."
3. **RELATED READING MATERIAL.** Appendix I, Bibliography, lists further guidance and technical information.
4. **METRIC UNITS.** To promote consistency with International Civil Aviation Organization (ICAO) guidance, the text and figures include both metric and English dimensions. Dimensions are provided first in metric units. Readers should keep in mind that English units are based on operational significance and

FAA Software PROFAA Includes Boeing Bump Analysis

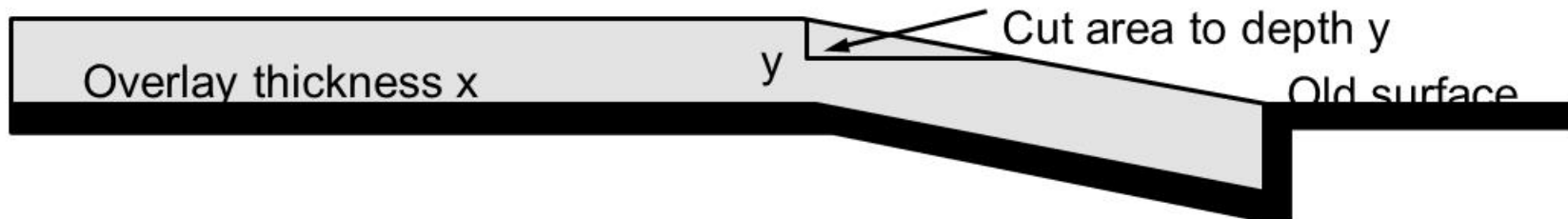


Runway Temporary Ramping Guidance

A. Ramping prior to aircraft traffic

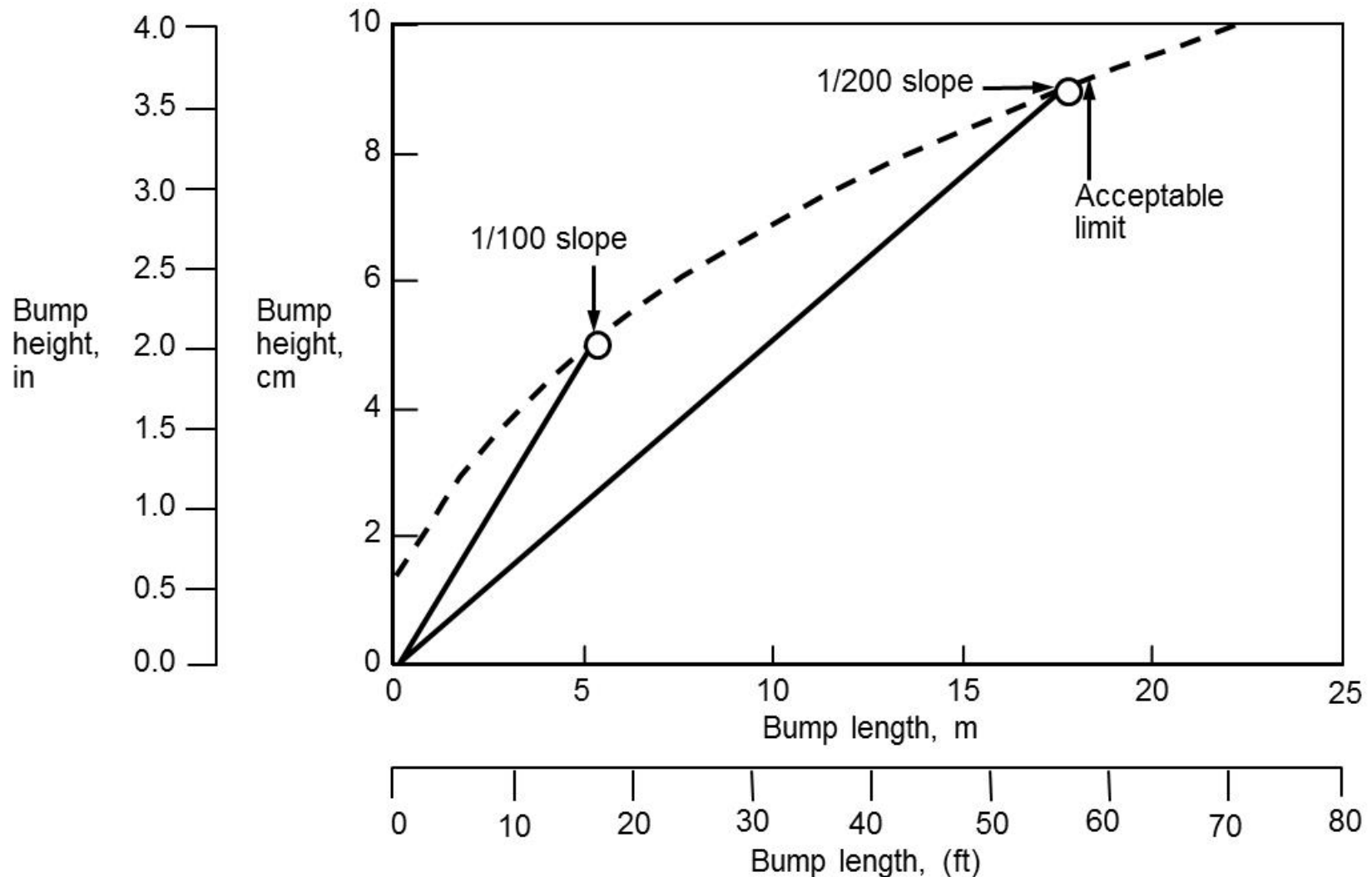


B. Surface preparation prior to resumption of paving



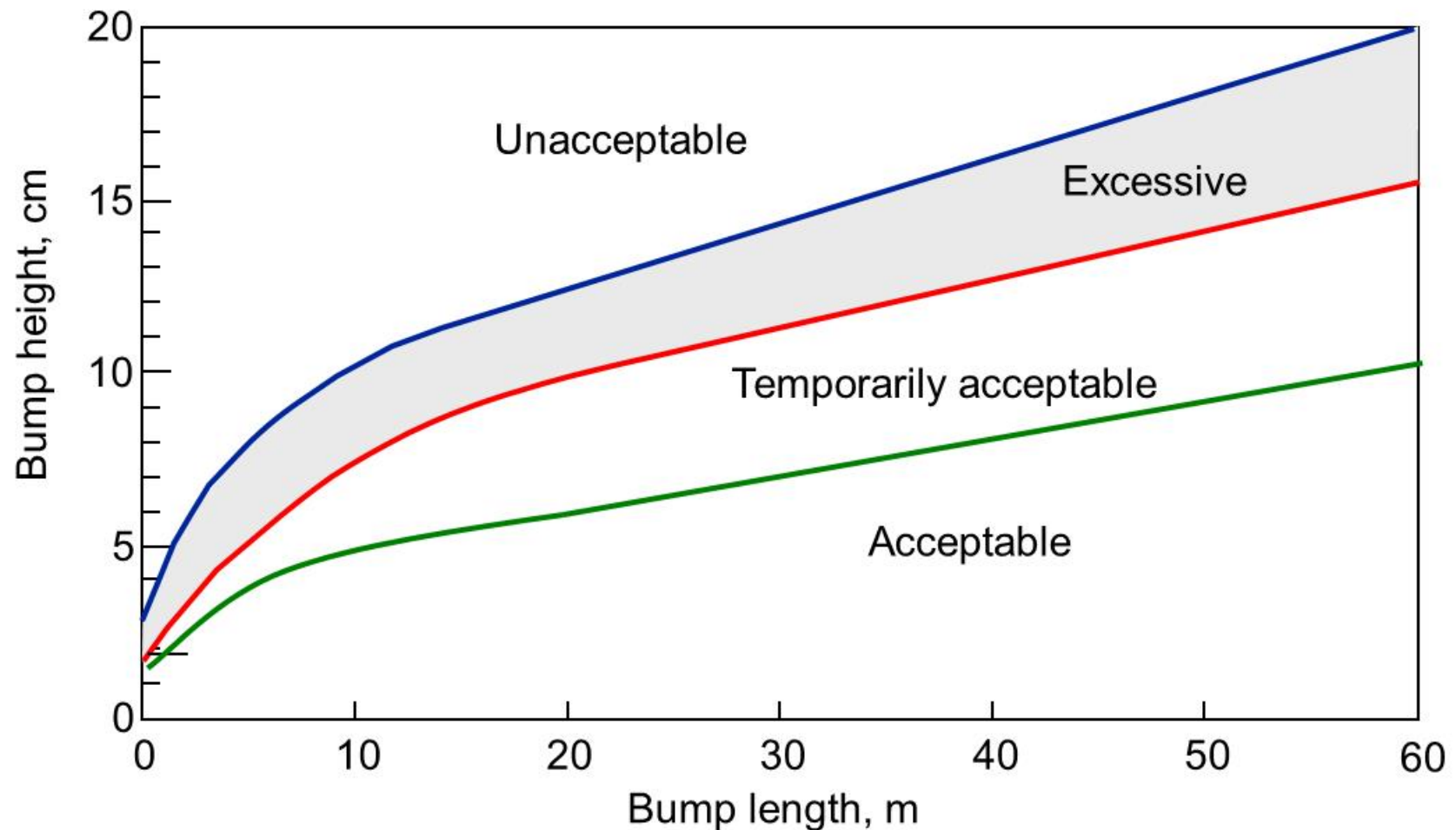
- Notes
1. When overlay thickness $x \leq 5$ cm, then ramp slope = 1.0%
 2. When overlay thickness $x > 5$ cm, then ramp slope = 0.5%
 3. Depth y should be at least 2 times the maximum aggregate size

Boeing Roughness Criteria Applied to Temporary Construction Ramps



ICAO Roughness Curve

Approved for Annex 14, Amendment 10, 4th Edition



ICAO Guidance- Annex 14, Attachment A

Surface Unevenness

Surface Irregularity	Minimum acceptable length of irregularity (m)								
	3	6	9	12	15	20	30	45	60
Maximum surface irregularity height (cm)	2.9	3.8	4.5	5	5.4	5.9	6.5	8.5	10
Temporary acceptable surface irregularity height (cm)	3.9	5.5	6.8	7.8	8.6	9.6	11	13.6	16
Unacceptable surface irregularity height (cm)	5.8	7.6	9.1	10	10.8	11.9	13.9	17	20

If the maximum limits are exceeded, corrective action should be undertaken as soon as reasonably practicable to improve the ride quality. If the temporarily acceptable limits are exceeded, the portions of the runway that exhibit such roughness should have corrective measures taken immediately if aircraft operations are to be continued. If the unacceptable limits are exceeded and the roughness resides in the area of aircraft operations, then the runway should be closed until repairs are made to restore the condition to the acceptable region.

The maximum permissible step type bump, such as that which could exist between adjacent slabs, is simply the bump height corresponding to zero bump length at the upper end of the acceptable region of the roughness curve. The bump height at this location is 1.75 cm.

Recommendations for ASTM standard

- Current ASTM E1274 - 03(2012), Standard Test Method for Measuring Pavement Roughness Using a Profilograph, states that “*Calculations can be done manually with the blanking band and excessive height templates or electronically with routines in a computer.*” However, procedures for doing the calculations on a computer are not defined in the standard and suitable procedures had to be developed in order to perform the calculations using a computer program.
- The excessive height templates in the current standard were defined for highways and are based on a standard 25 ft (7.6 m) straightedge. The Boeing bump has to be implemented as an index rather than an excessive height template because the bump limit criteria varies with bump length.
- The new standard will provide bump template simulation procedures with a bump height and base length, in conjunction with the procedures for Boeing bump index computations in a computer program- preferably PROFAA.

Conclusions

- Aircraft are susceptible to three types of roughness, and the Boeing Bump Criteria addresses single event long wavelength type roughness, and to some extent fatigue loading effects on aircraft. Short wave roughness typically only a concern in Russia and the CIS due to poor construction techniques.
- Typical roughness problems based on Boeing experience in this area are the result of the following: Poor maintenance, failures in base and/or subbase materials, clay soils and issues dealing with moisture, and improper use of transition ramps.
- Guidance is needed for airports on how to address and measure roughness. Recent ICAO acceptance of the Boeing Bump, working towards developing an ASTM standard, and the FAA advisory circulars and PROFAA software all provide technical guidance in this area.

Preguntas?

Muchas Gracias!

