FLIGHT SERVICES

Pavement Maintenance Issues and Concerns

Boeing Perspective and Aircraft Effects

LIFECYCLE SOLUTIONS

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Outline

- **Foreign Object Debris and Damage**
  - **Sources of FOD**
  - **Engine Jet Blast Concerns**
  - **FOD Prevention- FAA and ICAO guidance**
  - **Cost to the airlines**
- **Pavement maintenance Issues and recent Boeing experience**
- **Surface roughness effects on aircraft ride quality**
- **Surface friction and the effects on aircraft performance**

What is FOD?

1. Foreign Object Debris:
A substance, debris, or article alien to a vehicle or system which would potentially cause damage

2. Foreign Object Damage:
Any damage attributed to a foreign object that can be expressed in physical or economic terms which may or may not degrade the products safety and/or performance characteristics

Definition Source: National Aerospace FOD Prevention Inc.

Sources of FOD

FOD at the Gate-Aircraft Servicing and Maintenance Operations

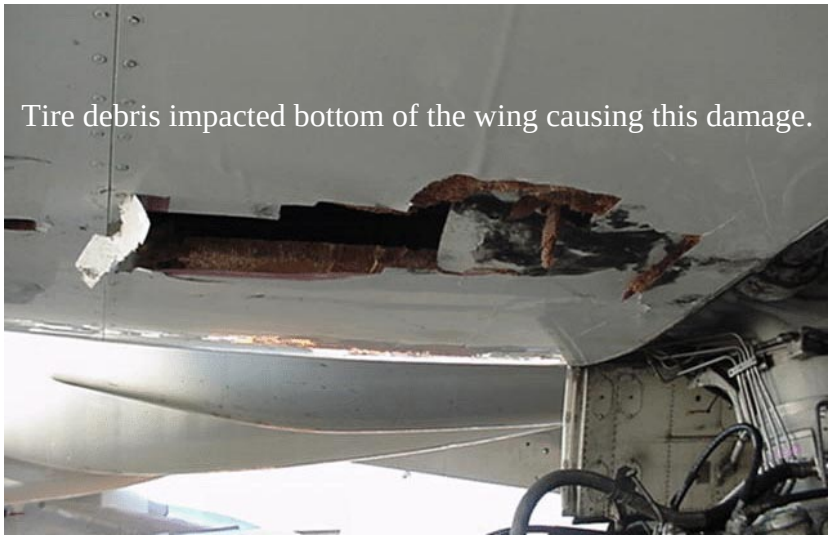
Primary source of FOD-Pavement debris

Sources of FOD

A re-treaded tire that delaminated and left debris behind- airline responsibility

Container blown into engine of L-1011 from adjacent aircraft engine thrust

Sources of FOD



FAA and ICAO Guidance

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US airports are under Part 139 requirements which specify a FOD control program in their certification manual

- **Advisory Circular 150/ 5210-24 "Airport Foreign Object Debris Management"**
- **Advisory Circular 150/ 5380-6 "Guidelines and Procedures for Maintenance of Airport Pavements"**
- **Advisory Circular 150/ 5200-18 "Airport Safety Self Inspection"**

ICAO guidance

- **ICAO Annex 14, Aerodrome Design and Operations, Chapter 10.2.1, 2.9.2**
- **ICAO Part 3 Pavements and Airport Services Manuals**

Costs to the Airlines

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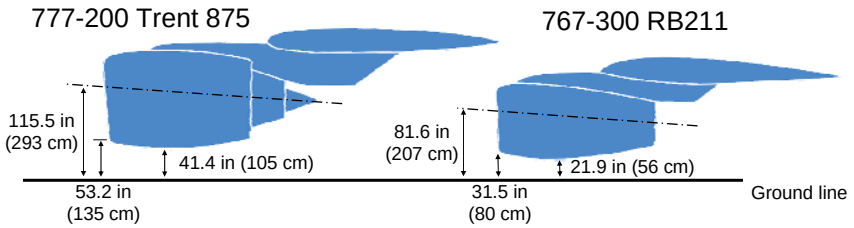
Engine Cost Data Estimates	
Purchase cost of MD-11 engine	**$8-10 million**
Purchase cost of MD-80 engine	**$3-4 million**
MD-11 engine overhaul to correct FOD damage	**$500,000-1.6 million**
MD-80 engine overhaul to correct FOD damage	**$250,000-1.0 million**
MD-11 fan blades per set	**$25,000**
MD-80 fan blades per set	**$7,000**

Airframe-Engine Integration

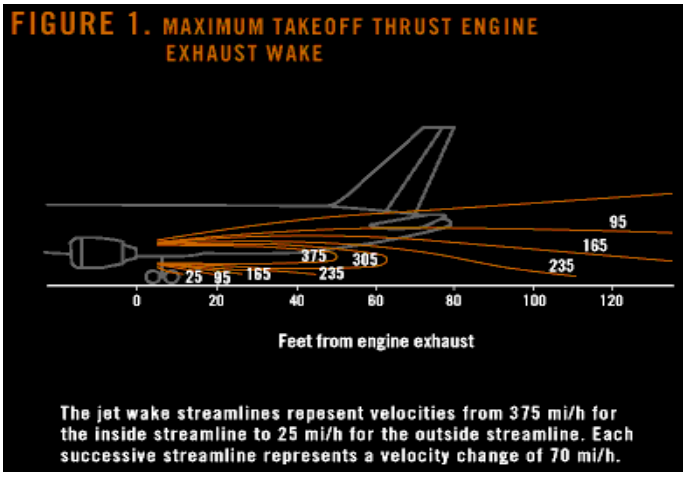
- **Engine installations similar to previous Boeing twin-engine airplanes**
- **Foreign object damage susceptibility equivalent to existing below-wing configurations**



Engine	Forward clearance	Minimum ground clearance
PW4074	48.0 in (122 cm)	36.2 in (92 cm)
Trent 875	53.2 in (135 cm)	41.4 in (105 cm)
GE90-75B	43.5 in (110 cm)	32.1 in (82 cm)

Airplane	Forward clearance	Minimum ground clearance
737NG	21.5 in (55 cm)	18.0 in (46 cm)
757	43.7 in (111 cm)	32.7 in (83 cm)
767-300	31.5 in (80 cm)	21.9 in (56 cm)

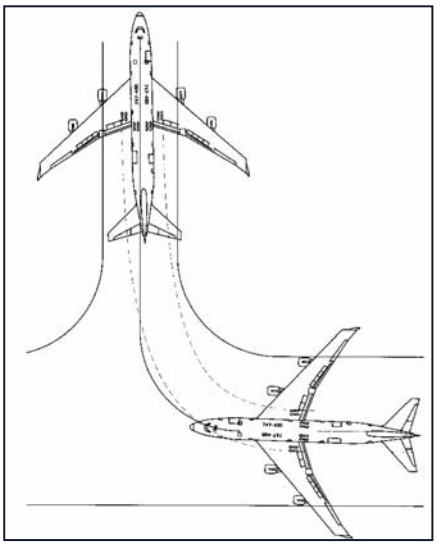
Jet Blast Concerns- Takeoff Thrust



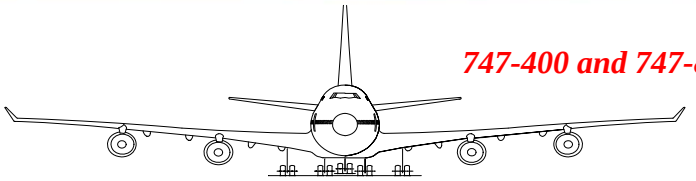
At full power the typical exhaust wake 60 meters beyond the aircraft can reach 240 km/hr (150 mph), similar to a category 5 hurricane.

Operational FOD Sources

- **Jet blast from aircraft turning at RW/TW intersections can blow FOD onto runway**
- **Ingestion potential exists over unpaved shoulders**



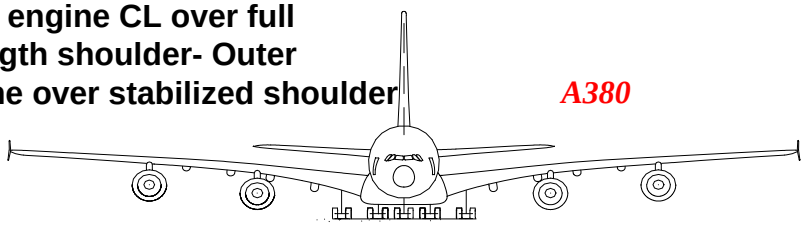
Jet Blast Concerns- Ground Maneuvering



747-400 and 747-8F

10.5 m	23-meter Taxiway	10.5 m

Inner engine CL over full strength shoulder- Outer engine over stabilized shoulder

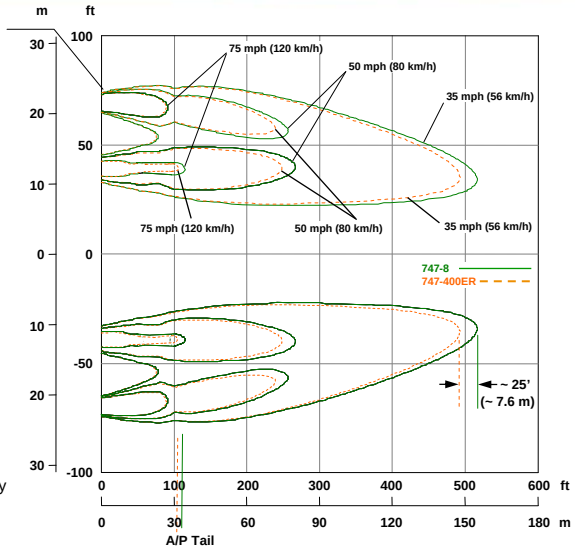


A380

10.5 m	23- meter Taxiway	10.5 m

Jet Blast Concerns-Breakaway Thrust

Exhaust contour within the 44 m Code E shoulder width requirement



- Sea level, standard day
- Static A/P
- No wind
- All engines running
- 1.5% ground up-slope
- Steady state contours

Pavement Maintenance Issues-Recent Boeing Experience

Pavement Maintenance Priorities

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Runway pavements should fill the following functions

1.) Provide adequate bearing strength- addresses structure of pavement

2.) Provide good ride quality- addresses surface geometrics

3.) Provide good surface friction characteristics- addresses texture and slope of pavement

All of these functions are tied to proper pavement maintenance and the availablity of the pavement for safe aircraft operations

Unsealed Reflection Cracks

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Asphalt overlay on concrete slabs had deteriorated and reflection cracks extended entire length of runway

Lack of pavement maintenance-sealing led to jet blast incident

Unsealed Reflection Cracks- Jet Blast Damage

Groove Degradation and FOD Issue

- **Newly overlayed runway experienced severe FOD problems**
- **Groove breakdown exacerbated the problem**
- **Aircraft deliveries suspended until solution was found**

Groove Degradation and FOD Issue

- **August 21 – Airport Technology notified by Everett Delivery Center and Flight Test that aircraft were sustaining serious FOD damage**
- **The recently reconstructed section of the runway was the suspected source of the FOD**
- **Airport Technology confirmed the poor construction and identified Interim solutions which minimized disruption to numerous Boeing deliveries.**
- **Worked with the FAA, airport authorities and consulting engineers to identify a permanent fix.**
- **September 11 - Runway repair of the damaged area (over one mile long) completed. No FOD damage reported since.**

Lack of Proper Transverse Slope-Runway Contamination

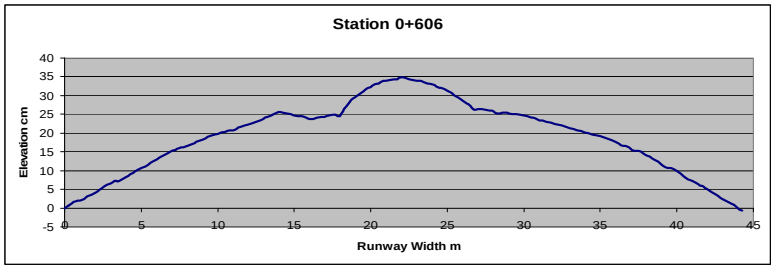
• Standing water due to improper transverse gradient suspected of causing loss of 777 junction box clamps

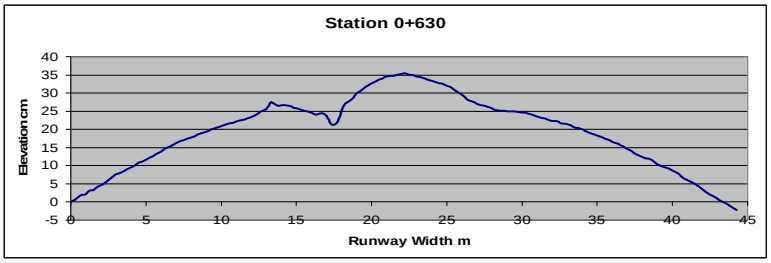
• Water depth in some areas as high as 2.5 cm and in high speed braking areas. Flight performance manual suggests not taking off when contamination exceeds 1.25 cm, water impingement concern.

Lack of Proper Transverse Slope

Junction box clamps on 777 truck beam susceptible to water impingement due to ponding.

Lack of Proper Transverse Slope





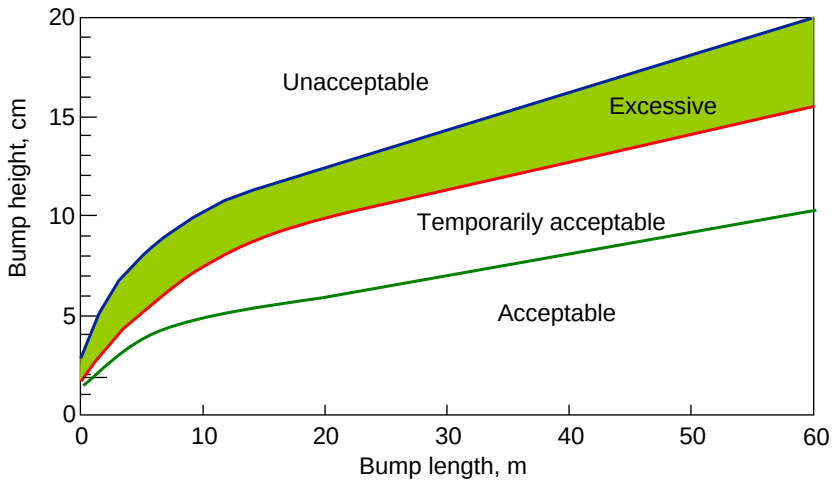
Improper Reflective Bead Application-FOD Issue

Improper glass bead placement led to a foreign object debris (FOD) issue.

Damage to 10 new 737 aircraft engines cost $50 mil US dollars.

Surface Roughness Effects on Aircraft

ICAO Roughness Curve Approved for Annex 14, Amendment 10, 4th Edition



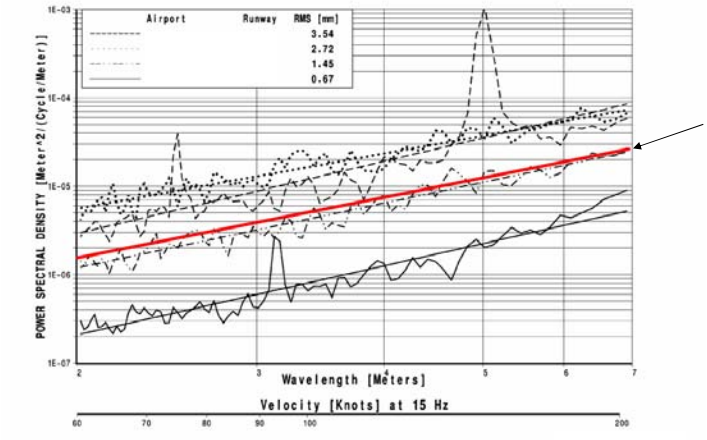
What Types of Roughness are We Concerned About at Boeing?

- Three Types of Structural Concerns Affecting Aircraft:
  1) **Limit Loads – Single Discrete Bumps which could lead to structural failure. Currently addressed by Boeing Bump Criteria**
  2) **Fatigue Loads – Continuous Large Wavelength Bumps**
  3) **Landing Gear Truck Pivot Joint – Continuous Short Wavelength Bumps. Only a real concern in Russia and CIS countries**
- Each type imposes a different runway roughness criteria. Types 2 and 3 require dynamic analysis.
- Current standards address mainly first two types.
- Third type is relatively unknown, and not directly addressed in current standards.

Surface Roughness Effects on Aircraft

Surface Roughness Effects- Short Wave Bumps

- Shows bump height intensity versus bump wavelength



Acceptable Threshold

Airports Surveyed by Boeing for Roughness

FAA and Boeing SurPro Profilers

FAA Guidance on Roughness

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

U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: Guidelines and Procedures for Measuring Airfield Pavement Roughness | **Date:** 9/30/2009 | **Initiated by:** AAS-100 | **AC No:** 150/5380-9 | **Change:**

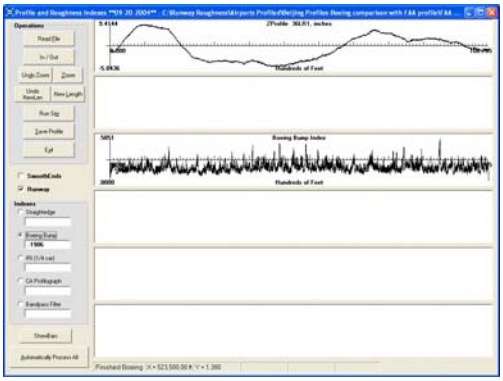
1. **PURPOSE.** This Advisory Circular (AC) provides guidelines and procedures for measuring and evaluating runway roughness as identified by surface profile data of rigid and flexible airport pavements. The guidance in this AC provides technical procedures to quantify surface irregularities and to determine 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 1, 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



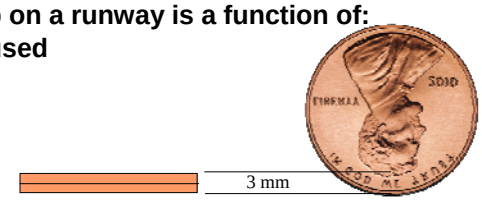
Surface Friction Effects on Aircraft

Aircraft Excursions are typically the result of multiple factors

- **Excursions are not the result of a single issue**
  - **Typically 2, 3 or more issues are involved**
    - **Weather conditions**
    - **Pilot technique**
    - **Runway conditions**
    - **Performance capability of the airplane**
  - **Often if 1 of the multiple issues were changed a successful stop would occur**
- **Focus on landing**

Runway condition affects aircraft stopping performance

- **Ability of the airplane to stop on a runway is a function of:**
  - **Amount of wheel braking used**
    - **Manual or Auto brake**
  - **Remaining tire tread**
  - **How wet is wet?**
    - **Saturated**
      - **3mm generally accepted threshold for dynamic hydroplaning**
    - **Heavy rain**
  - **Runway condition - texture**
    - **Grooved / PFC or Wet smooth (non-grooved runways)**
      - **Rubber build up**
      - **Polishing**



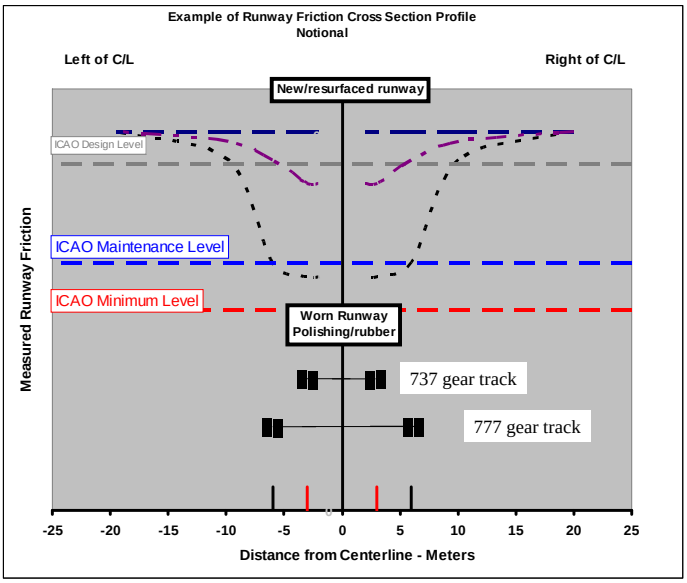
Stopping capability on a wet runway can vary significantly due to surface condition

Runway Condition Measurements

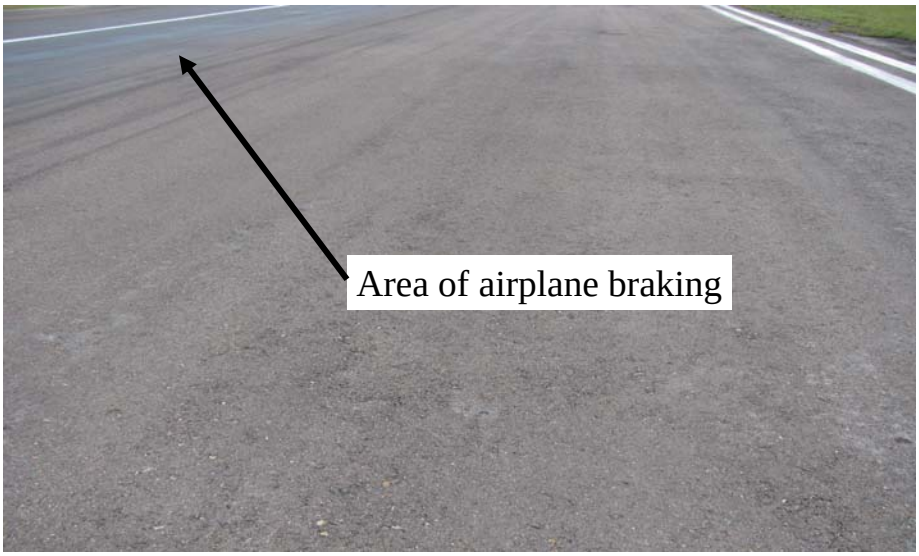
- Runway texture (roughness)-microtexture

- Periodically measure friction using CFME - macrotexture

Runway Deterioration Polishing/Rubber Deposits



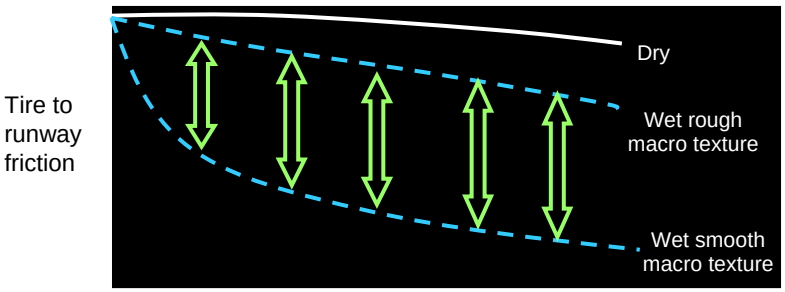
Recent 737-900 Overrun



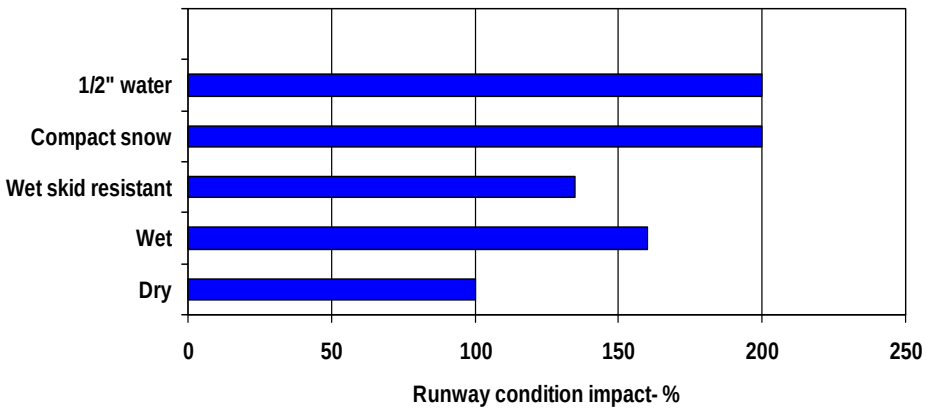
Recent 737-900 Overrun

Runway Macrotexture Effect on Friction

- ***As macrotexture affects the high speed tire braking characteristics, it is of most interest when looking at runway characteristics for friction when wet***
- ***Simply put, a rough macrotexture surface will be capable of a greater tire to ground friction when wet than a smoother macrotexture surface***



Typical Effect of Runway Condition on Landing



Questions?