Importance of Aircraft-Pavement Interaction

Patrice London
EMBRAER - Engineer Team Leader – Airline Market Performance, Flight Mechanics and Weight
patrice.london@embraer.com.br

ALACPA Airports Pavement Seminar
São Paulo, Brazil, October 27th, 2009

Contents

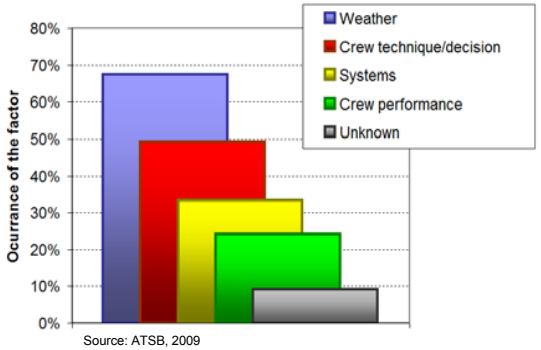
Contents

- Introduction
- Effect of Grooved Runway on Wet Landing Performance
  - Landing distance components - Certification
  - Safety margins granted by operation requirements
  - The Grooved effect on Landing Performance
- Case Study: Importance of adequate runway conservation
  - Historical: Issue reported
  - Issue Investigation
  - Results
- Conclusions

Introduction

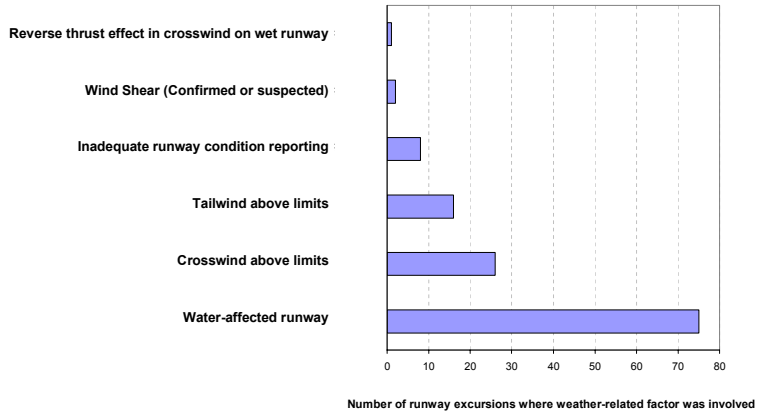
- Approach and Landings Accidents (ALAs) represent 25% of fatal accidents in aviation (Boeing, 2009).
- The weather are present in almost 70% of the runways excursions (ATSB – 2008)

Accident investigations show that, normally, a combination of the above factors was found in each of the events.



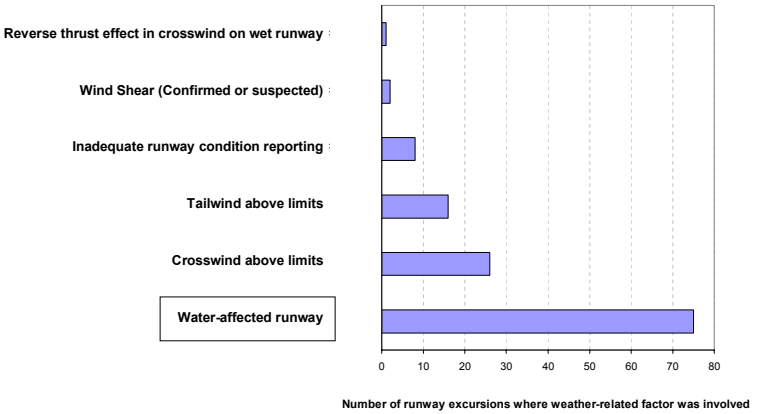
Source: ATSB, 2009

Breakdown of weather-related factors across runway excursions on landing, 1998 to 2007 (ATSB – 2008)



Introduction

Breakdown of weather-related factors across runway excursions on landing, 1998 to 2007 (ATSB – 2008)



THIS INFORMATION IS EMBRAER PROPERTY AND CANNOT BE USED OR REPRODUCED WITHOUT WRITTEN AUTHORIZATION.

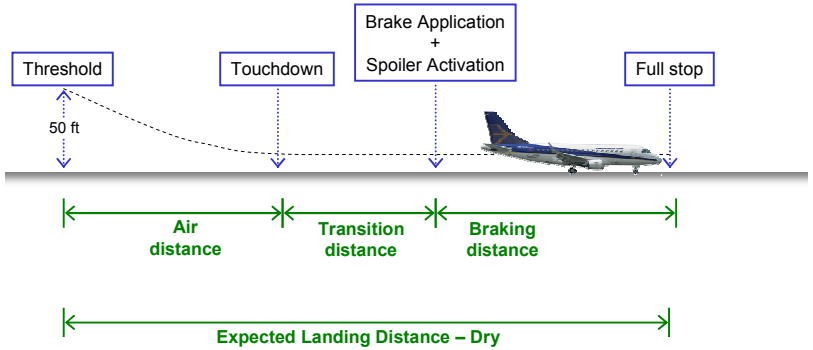
Introduction

- EASA defined a runway as "wet" when its surface is covered in water so that it appears reflective, but without significant areas of standing water present (ATSB Transport Safety Report – 2008)
- Weather-related factors did not result in any of the runway excursions without the presence of other contributing factors (ATSB Transport Safety Report – 2008)
- Runway contamination from rubber deposits can also lead to a serious reduction in runway surface friction coefficients, specially if the runway is wet. …and can cause differential braking (ATSB Transport Safety Report – 2008)
- Therefore, the runway conservation is very important for a safe landing on wet conditions
- This presentation intends to discuss two situations in wet conditions
  - The grooved effect on wet landing performance
  - The importance of runway conservation: A case study

Contents

Flight Tests - Landing Distance Components - Certification

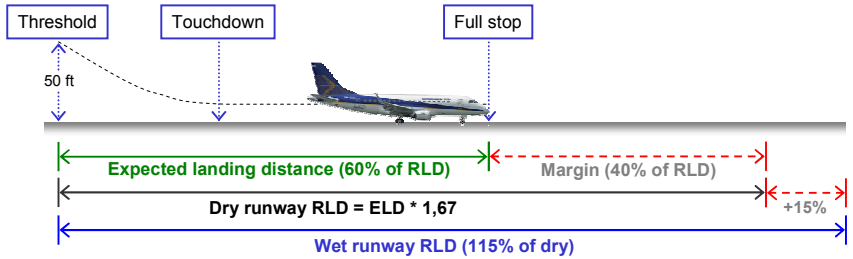
- Certification Landing Tests performed at Smooth dry runways
- According to CFR 14 Part 25 – 25.125 requirements (also AC 25-7A guide)



Effect of Grooved Runway on Wet Landing Performance

Safety Margins Provided by Operational Requirements

- **Dry runway** Regulated Landing Distance (**RLD**): The airplane shall be able to stop within 60% of the available runway length (121.195(b)).



- **Wet runway RLD:** An additional 15% over the dry RLD shall be required (121.195(d)).

Effect of Grooved Runway on Wet Landing Performance

- Grooved runways:
  - Provide, when wet, a higher friction coefficient than smooth runways
  - Restore the braking coefficient close to dry runway when runway is wet

- Some Important Airport runways are grooved / PFC:
  - Santos Dumont (SDU) – RJ, Brazil
  - Congonhas (CGH) – SP, Brazil
  - London City (LCY) – England

Grooved Surface

Effect of Grooved Runway on Wet Landing Performance

ERJ 145 flight tests performed at Moses Lake (USA)

- Based on AC 121.195(d) – 1A, must satisfy the following conditions:

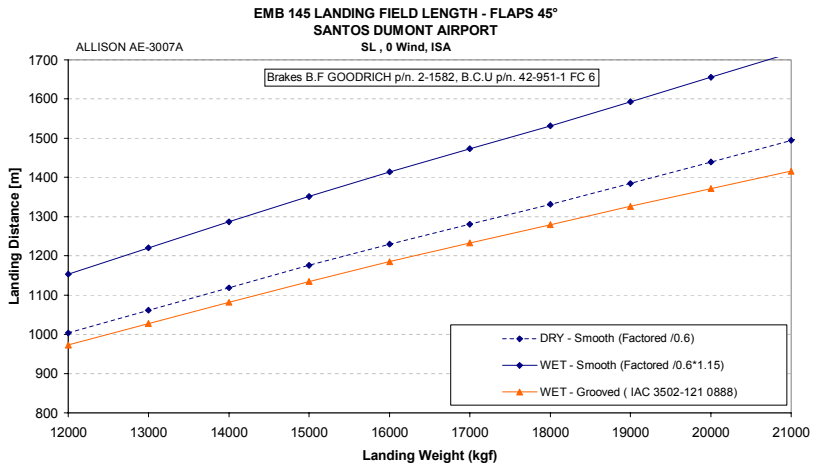
  Flight Test:
  - Air speed at threshold: $V_{50} = 1,4V_s$ (equivalent to $1,33V_{S1\text{-}g}$)

  Data Expansion:
  - Air time = maximum ($T_{air\ test}$ + 2 sec , 7 sec)
  - $V_{50} = 1,4V_s$
  - $V_{TD} / V_{50} = 0,96$
  - 15% of margin over the expanded landing distance
  - $LD_{Wet\ Grooved} \leq LD_{Dry}$ (LD = Landing distance)

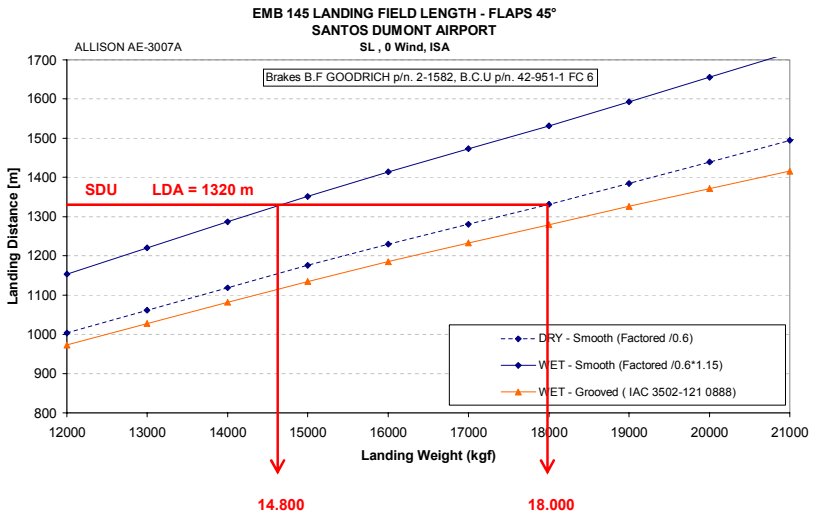
The operation speed is V_{REF}, defined by 25.125

Note: The 60% margin described on 121.195 (b) does not apply for this case

Effect of Grooved Runway on Wet Landing Performance



Effect of Grooved Runway on Wet Landing Performance



Effect of Grooved Runway on Wet Landing Performance

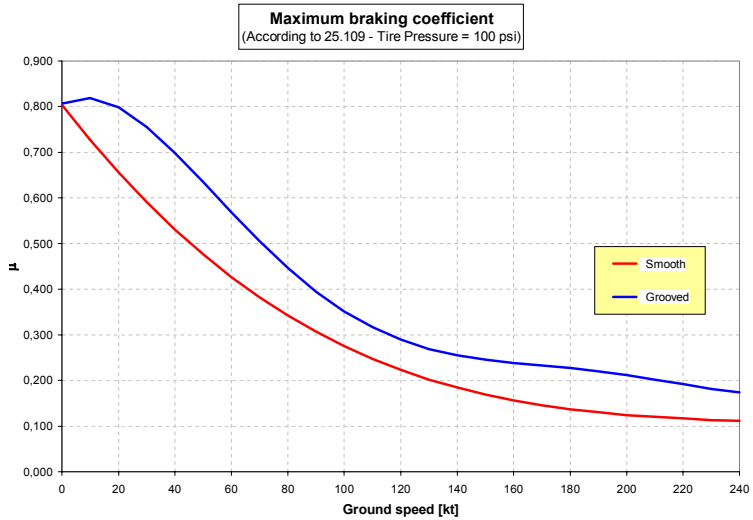
Wet landing distance analytical method based on RTO Airplane Braking Coefficient

- Application of CFR 14 Part 25 – 25.109 (RTO) requirements to Wet grooved landing performance
  - Alternate means of compliance (Issue Paper)
  - Maximum braking coefficient = Function [Tire Pressure, Ground speed , Runway type (Smooth or Grooved)]
- Physically, there are no differences between braking at RTO or Landing
- $RLD_{Wet\ Grooved} = RLD_{Wet\ Smooth} - (BD_{Smooth} - BD_{Grooved})$

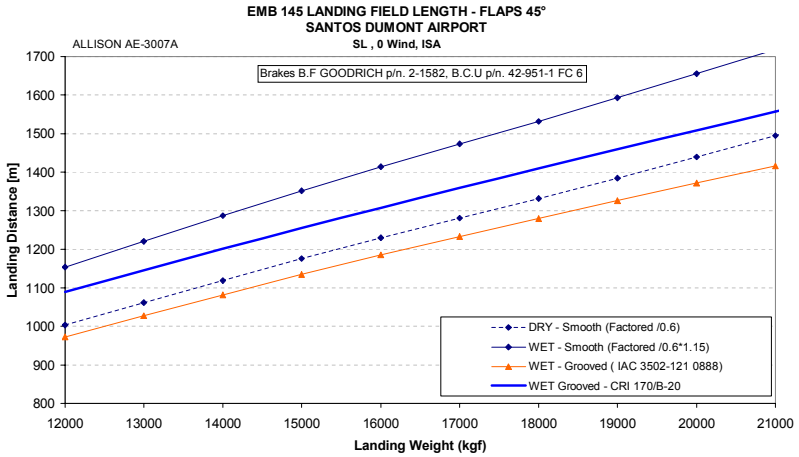
Where: RLD = Regulated Landing Distance

BD = Braking Distance

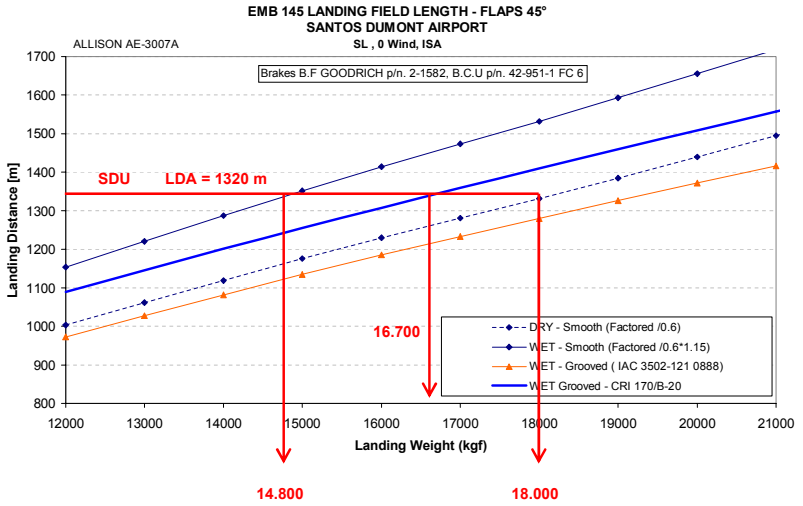
Effect of Grooved Runway on Wet Landing Performance



Effect of Grooved Runway on Wet Landing Performance



Effect of Grooved Runway on Wet Landing Performance



Effect of Grooved Runway on Wet Landing Performance

Results:

1) The 15% margin application [121.195(d)] is the most conservative result

2) The flight test [AC 121.195(d)]
   - Is an alternative means of compliance to 121.195(d) requirement
   - Is the best result, and can restore the dry landing performance

3) The Analytical Method, based on RTO requirements [25.109]
   - Is very conservative relative to flight tests, but better than the 15% margin
   - Is a cheaper alternative to flight tests, specially for EMBRAER since there isn't a allowable grooved runway to perform it on Brazil. We must send the aircraft to USA (larger costs)

Contents

Historical: Issue reported

"The flight crew reported that during landing on a wet runway, they applied full brake pedal and the aircraft appeared to have a reduced brake performance "

Other aspects:

- It was just an incident reported without major consequences
- The brake issue appeared at low speed

Issue Investigation

1) Brake system

- "Maintenance personnel checked Brakes units 1 and 2. Tests were satisfactory."
- "A high speed taxi was carried and no faults were found"

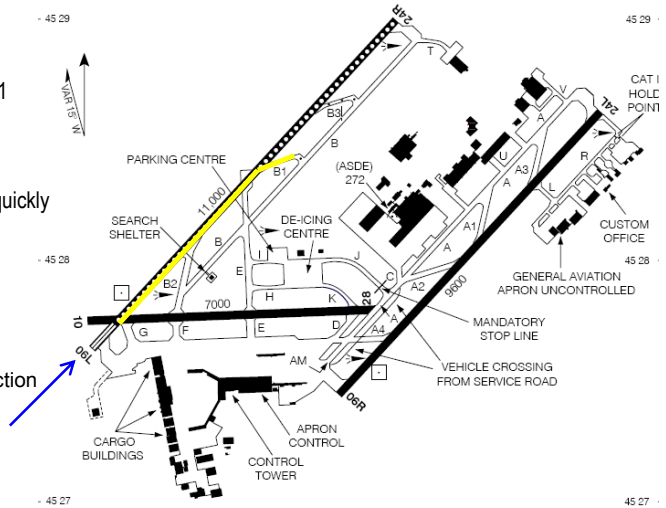
2) Performance data

- Performance data also checked.
- Landing distance coherent to CAFM (computerized Airplane Flight Manual)

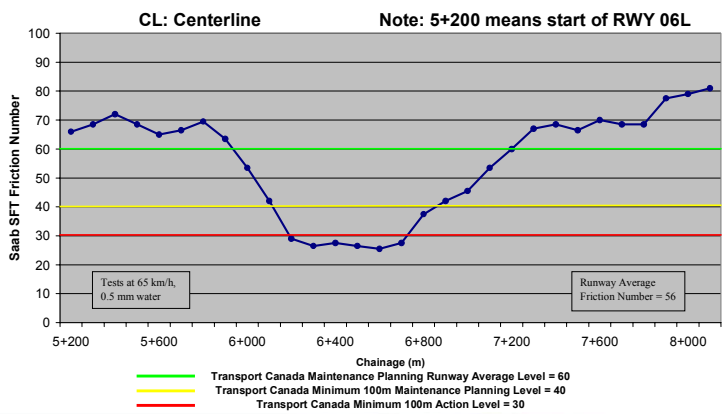
3) Crew action:

- Intention to exit at B1 taxiway (common practice in order to quickly exit the runway)

Landing direction



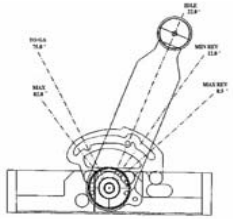
4) Airport Data: Poor braking friction number near B1 According to airport (Contamination by Rubber deposit)



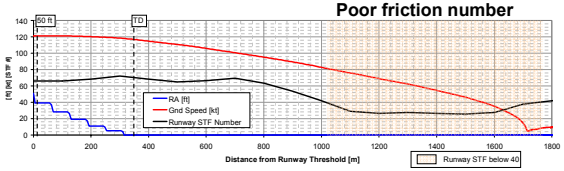
5) FDR analysis

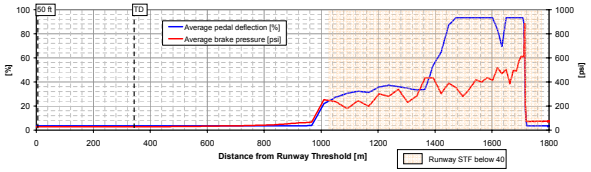
Expected Nx wet > 0,20
(without thrust reverse)

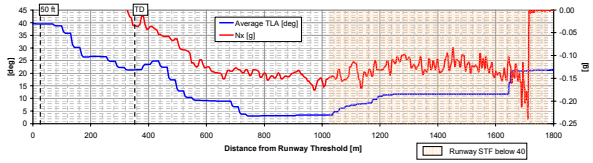
TLA (deg)	Meaning
0,5	Full Reverse Thrust
12	Idle Reverse Thrust
22	Idle Thrust
75	TO/GA
82	Max



Poor friction number







Investigation Results

- There was no brake system fault with the aircraft
- The brake application occurred:
  - Less than 40% of brakes pedal ➔ 1000 m after MLG touchdown
  - Full brakes ➔ 1140 m after touchdown
  - All brakes application occurred in the "poor airport runway friction number" portion
- The issue appeared due to wet conditions but also to:
  - Pilot action: Absence of full brakes application all the time
  - Airport maintenance: Poor runway condition due to rubber deposit contamination

Contents

Conclusions

Runway Conditions on Wet Landing Performance

1) Grooved runway treatment allow a great improvement on Wet Landing distance

- Grooved must be kept properly
- Three allowable methods :
  - Following the CFR 14 Part 121 – 121.195 (d) – The most conservative results
  - Flight Test: leads to better landing Performance (similar to dry one)
  - Analytical Method: Conservative relative to Flight test. Objective: Cost reduction.

2) Runway conservation: very important for landing performance, specially at wet conditions

References

- *Annual Safety Review*. EASA, 2007.
- *Runway excursions, Part 1: A worldwide review of commercial jet aircraft runway excursions*. ATSB, 2009.
- *Statistical Summary of Commercial Jet Airplane Accidents*. Boeing Co., 2009.
- *The Flight Safety Foundation Website*. <www.flightsafety.org>.
- *Flight Safety Digest*, Vols. 17 and 18. Nov 98 to Feb 99.
- *ALAR Briefing Note 8.5 – Wet or Contaminated Runways*. FSF, 2000.