Effect of Runway Condition on Aircraft Performance

- Macrotexture
- Contamination
- Microtexture
- Rutting
- Water accumulation
- Rubber
## Effects in Performance Models

Braking Performance accounts for:

<table>
<thead>
<tr>
<th>Effect</th>
<th>Dry/Wet</th>
<th>Hard Contaminants</th>
<th>Fluid Contaminants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective wheel to ground friction</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Displacement Drag</td>
<td>-</td>
<td>-</td>
<td>Yes</td>
</tr>
<tr>
<td>Compression Drag</td>
<td>-</td>
<td>-</td>
<td>Yes</td>
</tr>
<tr>
<td>Impingement Drag</td>
<td>-</td>
<td>-</td>
<td>Yes</td>
</tr>
<tr>
<td>Aquaplaning</td>
<td>-</td>
<td>-</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Current Regulatory Dispatch Requirements

\[
\text{RLD}_{\text{dry}} = \frac{\text{ALD}}{0.6}
\]

\[
\text{RLD}_{\text{wet}} = 1.15 \times \text{RLD}_{\text{dry}}
\]

Max of \( \text{RLD}_{\text{conta}} \left\{ 1.15 \times \text{ALD}_{\text{conta}}, \text{RLD}_{\text{wet}} \right\} \)

RLD shorter than Landing Distance Available (LDA)
EASA Dispatch Requirements for contaminated runways

- Under EASA regulation CS25.1591 manufacturers may publish takeoff and landing performance for contaminated runways
- Associated AMC provides friction models for various contaminants
Current Regulatory In-Flight Requirements

The flight crew must check that a safe landing can be performed in the expected conditions

(1) Former EU-OPS 1.400
Accident Statistics

10 year moving average hull loss rate by accident category per million flights
Situation of the Industry Today

- Different terminology
- Different contaminant types
- Insufficient depth accuracy
- No correlation with A/C performance
- Not up to date

Reporting NOT Performance-Relevant

ICAO Regional GRF Seminar, Paris
...need reports that are directly related to the performance of the aircraft.
End to End System

Common Language
- Contaminant Types
- Runway Condition Codes
- Direct Input to Performance Assessment

Performance Relevance
- Depth Thresholds & Temperatures
- Significant Changes
Airworthiness – Annex 8

• Option for takeoff performance on contaminated runway
• Mandate split of landing performance information into
  – At Time of Takeoff data (dispatch)
  – At Time of Landing data (in-flight)
• New At Time of Landing Distances shall reflect real operating practices
• Both types of landing distances may be provided for contaminated runways
Operations - Annex 6

• For large and small airplanes
• Mandate AIREP when conditions worse than reported
• Mandate in-flight check with appropriate margin before starting approach
Aeroplane Performance Manual

- Introduction to Operations on Contaminated Runways
- 4 Flight-Phase oriented Chapters
  - Take-off
  - En-Route
  - Landing
  - Missed Approach

- Clear Focus on GRF

- Other information considered as non-controversial
- Based on existing national guidance and practices

- Still under Review by Ops Section
Chapter on Operations On Contaminated Runways

- Description of the RCR for Operators and Pilots
- Introduction to the Assessment Process applied by the Aerodrome
- Description and use of the RCAM and RWYCC
- Considerations for making AIREPs of Braking Action
- Training Syllabus
Chapter on Landing

• Derivation of Landing Performance Data for Time of Arrival
• Publication of Data and Limitations
• Fallback Generic Factors in case no Data is provided by the Manufacturer
• Regulatory background
• Considerations for Performance Assessment in Approach Preparation
• Considerations for Flight Crew
• Pilot Procedures for Landing on Length-Limited Runways
Guidance for Manufacturers

• Publish Operational Landing Distances
  – “Minimum” Compliance with principles
  – Cover all 6 friction levels
  – Introduce Accountability for
    • Temperature effect
    • Runway slope effect
    • Approach speed increment effect
ICAO Doc 10064 Aeroplane Performance Manual

- Provides the **effective wheel to ground coefficient** for each RwyCC
- Not specific to an individual aeroplane
- Adaptable to the anti-skid system type
- Ensures harmonized **Landing Distances at Time for Arrival** between all types

<table>
<thead>
<tr>
<th>RwyCC</th>
<th>Runway Surface Condition Description</th>
<th>Pilot-Reported Braking Action</th>
<th>Wheel Braking Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>DRY</td>
<td>Good</td>
<td>90 per cent of certified value used to comply with Annex 8 Part IIB 2.2.7 e)</td>
</tr>
<tr>
<td>5</td>
<td>FROST (The runway surface is covered by any visible dampness or water up to and including 3mm deep.) SLUSH (up to and including 3mm depth) DRY SNOW (up to and including 3mm depth) WET SNOW (up to and including 3mm depth)</td>
<td>Good</td>
<td>Per method defined in Note 2 below.</td>
</tr>
<tr>
<td>4</td>
<td>COMPACTED SNOW (Outside air temperature minus 15 degrees Celsius or below)</td>
<td>Good to Medium</td>
<td>0.20³</td>
</tr>
<tr>
<td>3</td>
<td>WET (Shiny/ Wet snow) DRY SNOW (more than 3mm depth) WET SNOW (more than 3mm depth) DRY SNOW ON TOP OF COMPACTED SNOW (Any depth) WET SNOW ON TOP OF COMPACTED SNOW (Any depth) COMPACTED SNOW (Outside air temperature above minus 15 degrees Celsius)</td>
<td>Medium</td>
<td>0.16³</td>
</tr>
<tr>
<td>2</td>
<td>STANDING WATER (more than 3mm depth) SLUSH (more than 3mm depth)</td>
<td>Medium to Poor</td>
<td>(1) For speeds below 85 per cent of the aquaplaning speed³: 50 per cent of the wheel braking coefficient determined for RwyCC=5, but no greater than 0.16; and (2) For speeds at 85 per cent of the aquaplaning speed⁴ and above: 0.05³.</td>
</tr>
<tr>
<td>1</td>
<td>ICE</td>
<td>Poor</td>
<td>0.07³</td>
</tr>
</tbody>
</table>
ICAO Doc 10064 Aeroplane Performance Manual

- Provides the effective wheel to ground coefficient for each RWYCC
- Not specific to an individual aeroplane
- Adaptable to the anti-skid system type
- Ensures harmonized Landing Distances at Time for Arrival between all types
- Based on existing EASA guidance on contaminated runway friction from historic flight tests
Chapter on the Situation for Takeoff

• RWYCC provides information on friction only
• At takeoff fluid contaminants generate drag
  – Displacement
  – Compression
  – Impingement
• Takeoff can be limited by
  – Distance needed to accelerate to lift-off speed
  – Distance needed to accelerate to decision speed V1 and come to full stop on available runway
• Contaminant drag must be accounted for in takeoff computations

Takeoff computation must be done for prevailing contaminant!
Takeoff

Computation with Contaminant Type and Depth

• Takeoff performance presented for contaminant type and depth
Takeoff
Computation with Contaminant Type and Depth

- Typical manufacturer data certified to CS25 pre-Amdt 2 does not cover many contaminants in the RCAM
- Missing:
  - Frost
  - Dry Snow
  - Wet Snow
  - Compacted Snow at OAT above -15°C
  - Slippery When Wet
  - Ice Cold & Dry

- APM offers advice on how to compute for missing contaminants conservatively

### Runway condition assessment matrix (RCAM)

<table>
<thead>
<tr>
<th>Runway condition code</th>
<th>Runway surface description</th>
<th>Aeroplane deceleration or directional control observation</th>
<th>Pilot report of runway braking action</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>WET ICE ²</td>
<td>Braking deceleration is minimal to nonexistent for the wheel braking effort applied OR directional control is uncertain.</td>
<td>LESS THAN POOR</td>
</tr>
<tr>
<td>1</td>
<td>WET ICE ²</td>
<td>Braking deceleration is significantly reduced for the wheel braking effort applied OR directional control is significantly reduced.</td>
<td>POOR</td>
</tr>
<tr>
<td>2</td>
<td>3 mm and more depth of water or slush:</td>
<td>Braking deceleration OR directional control is between Medium and Poor.</td>
<td>MEDIUM TO POOR</td>
</tr>
<tr>
<td>3</td>
<td>3 mm and more depth:</td>
<td>Braking deceleration is noticeably reduced for the wheel braking effort applied OR directional control is noticeably reduced.</td>
<td>MEDIUM</td>
</tr>
<tr>
<td>4</td>
<td>-15ºC and Lower outside air temperature:</td>
<td>Braking deceleration OR directional control is between Good and Medium.</td>
<td>GOOD</td>
</tr>
<tr>
<td>5</td>
<td>Less than 3 mm depth:</td>
<td>Braking deceleration is normal for the wheel braking effort applied AND directional control is normal.</td>
<td>GOOD</td>
</tr>
<tr>
<td>6</td>
<td><strong>DRY</strong></td>
<td>---</td>
<td>---</td>
</tr>
</tbody>
</table>
Takeoff
Computation with Downgraded RWYCC

**METAR**
PAMC 13\textsuperscript{09:53} Z AUTO 000\textsuperscript{KT} 10SM CLR M09/M12 A2972 RMK AO2 SLP073 T10891117 TSN0=

**FICON**
IMCG 03/104 MCG RWY 05 FICON 2/2/2 100 PCT COMPACTED SN OBS AT 1803121907, 1803121907-1803131907

APM recommends “to delay take-off. However, […], it may be sufficient to determine performance in nominal conditions and to adopt appropriate operational procedures such as considering reduced crosswind limits, using the full length of available runway and avoiding rolling take-off.”
### Landing Performance Level

**Direct input into At Time of Arrival**

<table>
<thead>
<tr>
<th>Date</th>
<th>Performance Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-11 July 2019</td>
<td>Poor</td>
</tr>
</tbody>
</table>

**Poor**

- Drifting Snow
- Rwy 09L Chemically Treated
- Twy B

---

**METAR**

- UUEE 050230Z 17004MPS 0900 R25R/P1500U +SHSN VV004
- M01/M01 Q1017 75590230
- 25590230

**SNOWTAM**

- ENCN 0911400 09L 3/3 22/50/50/05/02 Dry Snow/Wet Snow

---

**Assessment**

- Contamination 100/100/100/0% Sand Applied
- Apron B/CLSD All Remaining Aprons
- Rwy 09L Chemically Treated
- Twy B Poor
Thank you