"An Innovative Approach to Locate and Repair a Runway Roughness Event at YYZ"

Kevin Chee, GTAA
Robert Pouliot, Air Canada
Tony Gerardi, APR Consultants Inc.

AIR CANADA

GTAA

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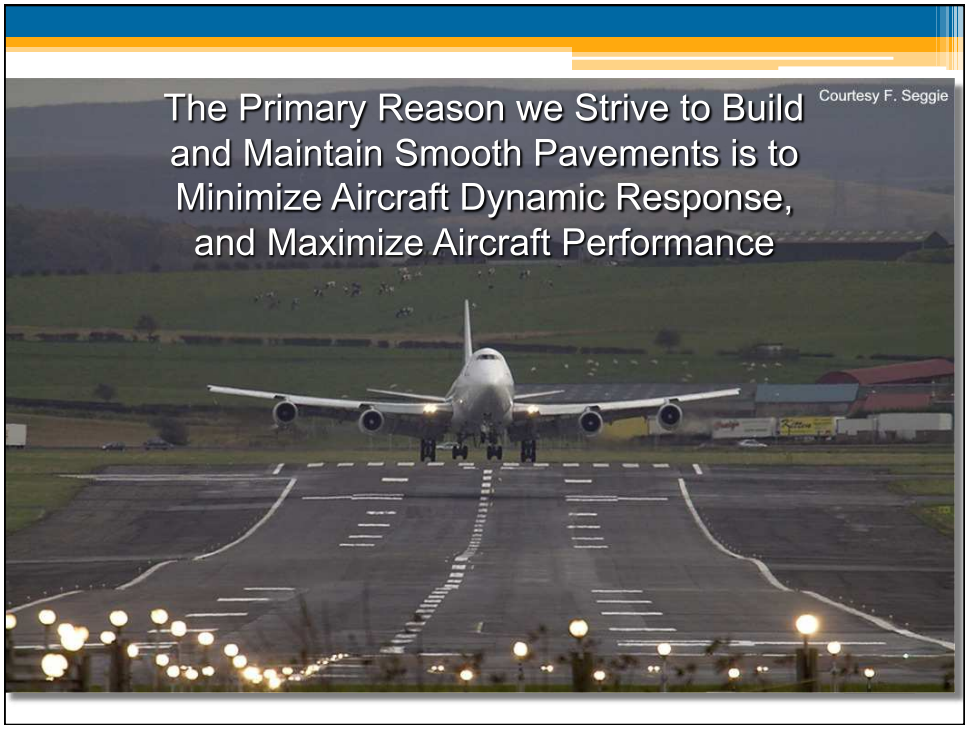
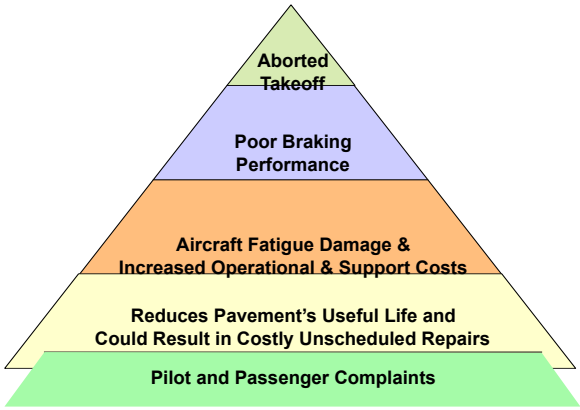
DRIVING SMOOTHNESS



Why Be Concerned About Runway Roughness?



Methods Used in Roughness Assessments

- Aircraft Simulation
  - Takeoff, Landing and Aborted Takeoff
- 30-Meter Straightedge Analysis for Long Wavelength Events
- 3-Meter Straightedge Analysis for Short Wavelength Events
- Compare to Other Runways
- Power Spectral Density (PSD), Boeing Bump, IRI

Typical Device for Assessing Runway Smoothness

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The California Profilograph Relative to a Modern Commercial Aircraft

Boeing 777-200ER
Gear Spacing 84 feet 11 inches
Equates to 3.4 California Profilograph lengths

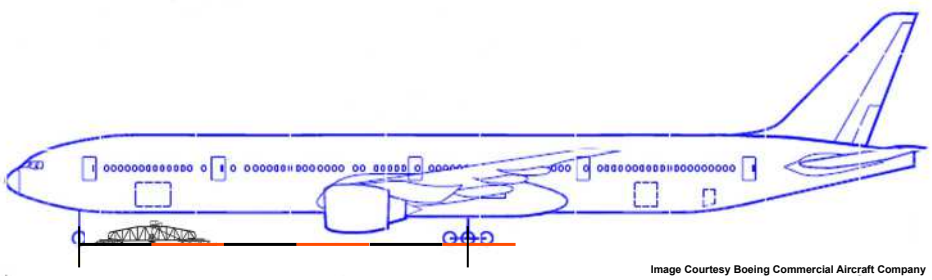

Image Courtesy Boeing Commercial Aircraft Company

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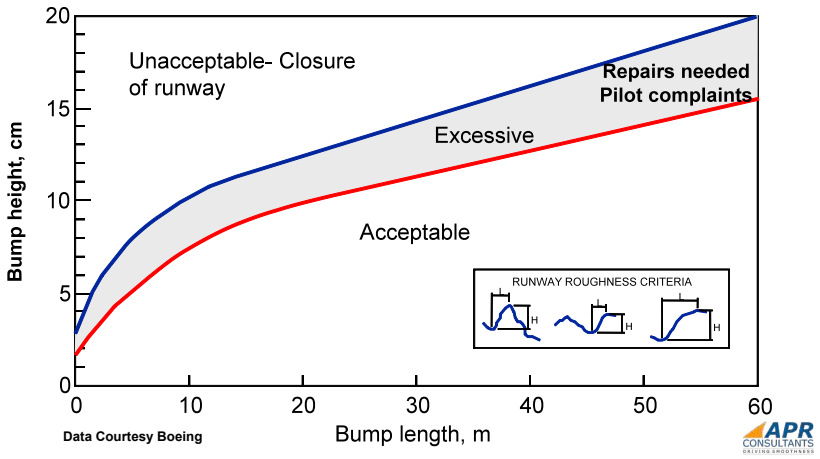
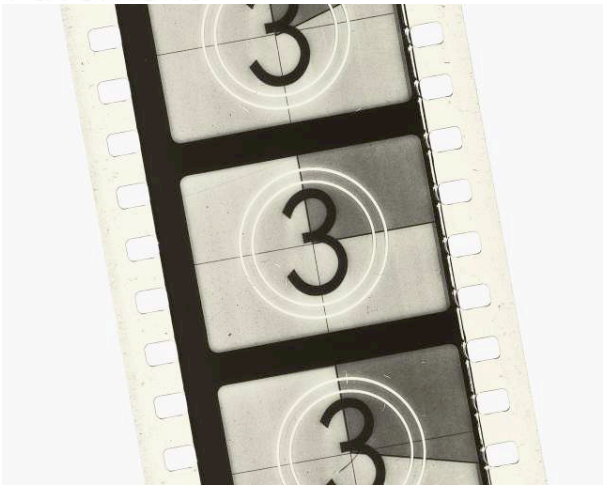
Boeing Runway Roughness Criteria – Single Event Limit Load



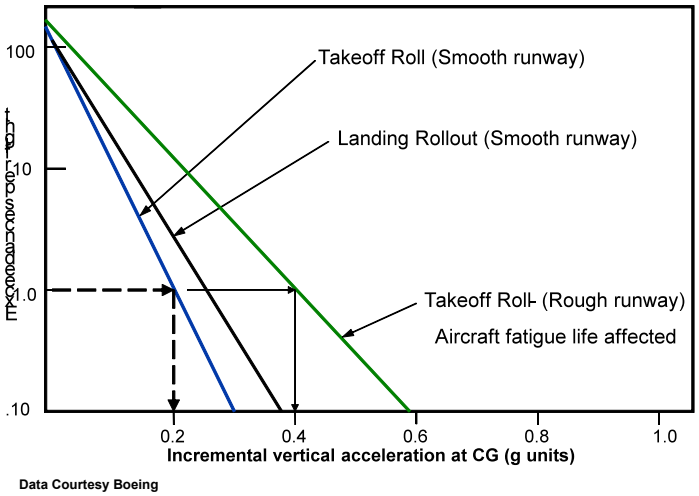
Boeing Runway Roughness Criteria

- **Intended to Identify Unacceptable Single Bumps and Dips**
- **Does not Account for Multiple Bumps**
- **Does not Consider Aircraft Type**
- **Does not Consider the speed of encounter**

Short Video of Commuter Aircraft on Rough Pavement



The True Measure of Runway Roughness is the Aircraft "G" level



Data Courtesy Boeing

Toronto Pearson: Current Airfield Map

Toronto Pearson Airport – Canada's Largest Airport

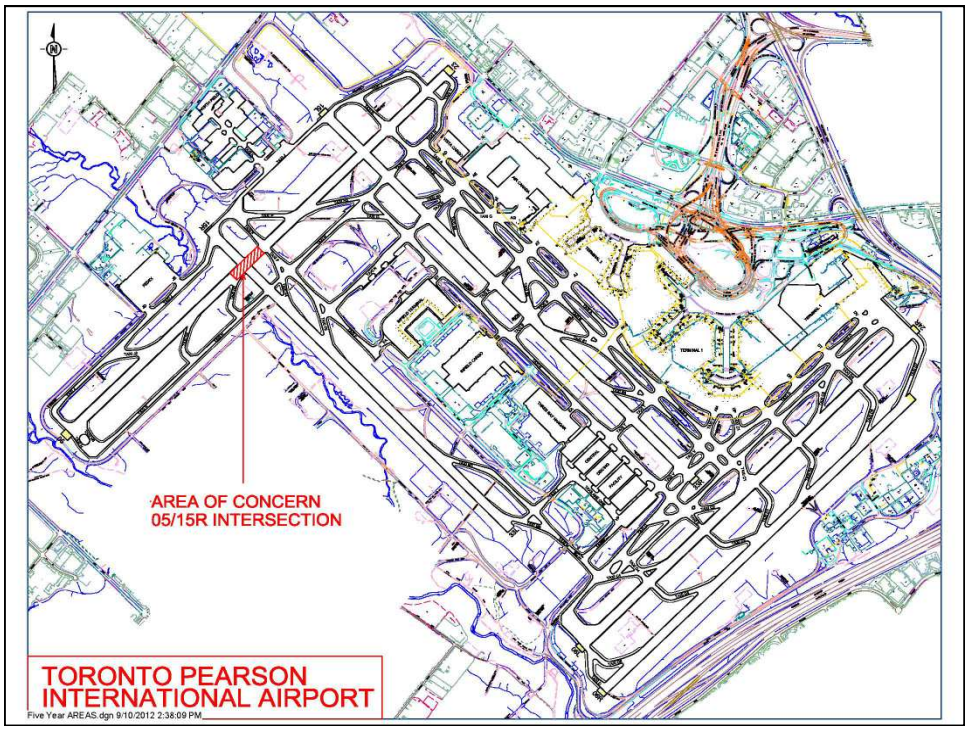
- 2011 Passenger Volume:33.4 Million PAX.
- Ranking in North America: 12th busiest airport (in terms of passenger volume)
- Total airside paved areas: approx. 1,468,000 m2
- Layout: 5 runways
- # aircraft movements: approx. 428,000 annually
- Cargo processed in 2011: over 500,000 kg

Toronto Pearson Airport – Traffic Volume for Runway 05-23 in 2011

- Runway 05-23: 81,360 total departures
  86,124 total arrivals
- 39.5 % of all Toronto Pearson arrivals and departures use the Runway 05-23.
  - % airport departures using 05: 9.5 %
  - % airport arrival using 05: 21.2 %
  - % airport departures using 23: 28.8 %
  - % airport arrival using 23: 19.4 %
- 05-23 is the most frequently used runway at the airport.

Reported Runway Roughness

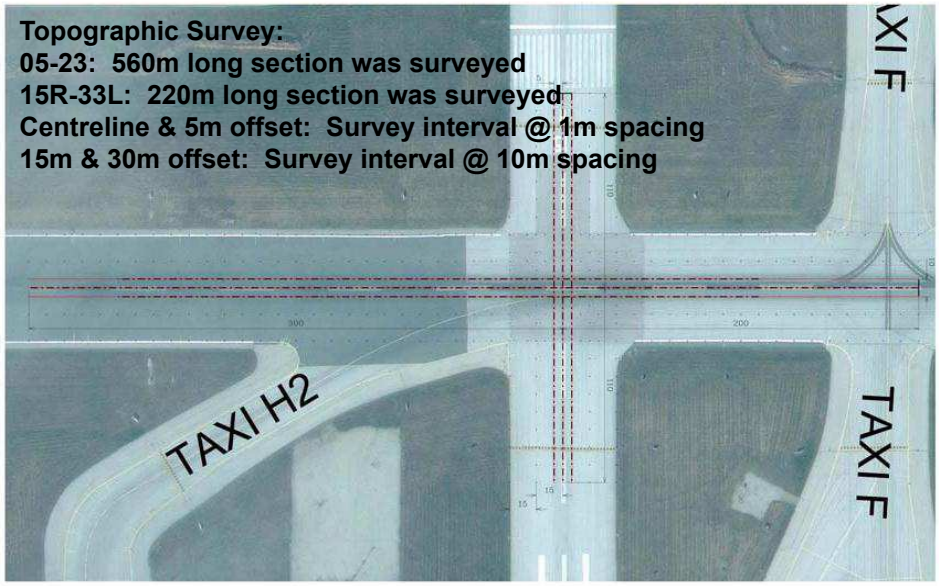
- It was first reported to GTAA by Air Canada in July 2011.
- Pilots operating Boeing 777 and Airbus A320 aircraft on runway 05-23 were reporting runway roughness in & around the intersection with 15R-33L.
- This was confirmed/quantified with on-board instrumentation measurements from the on-board Flight Data Monitoring (FDM) System.



Repair Strategy

THE SOLUTION – What we did to fix it!

1. Topographic survey – before, during and after construction
2. Used aircraft simulation to locate bumps causing pilot complaints
3. Aircraft simulations used to finalize repair design
4. Minimize operational impact during construction



Use Aircraft Simulation to Isolate Roughness

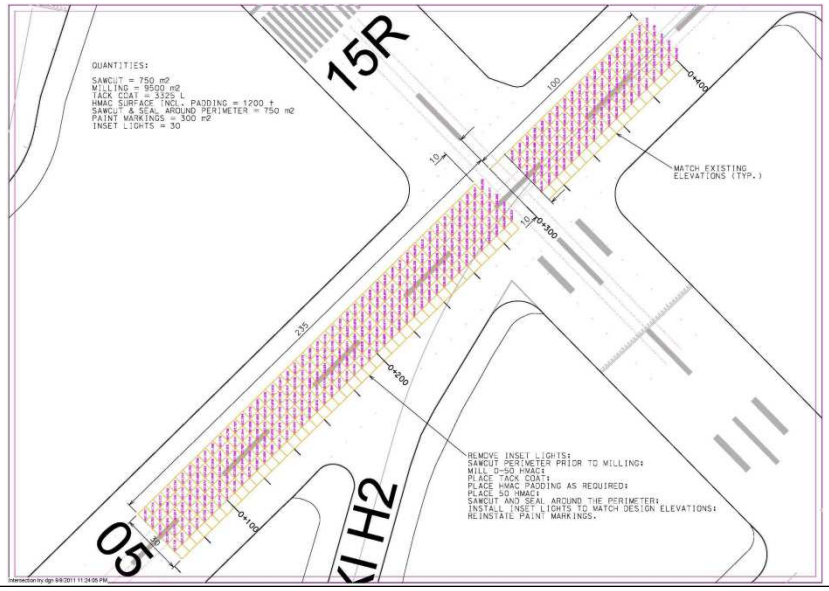
- Aircraft B737, B747 and B777 were selected because they represent a good cross section of commercial aircraft gross weights and gear spacing.
- Aircraft simulations on these selected aircraft types were conducted to perform takeoff, landing and high speed abort operations from both ends of the runway.
- Roughness events were identified before and after the intersection of Runway 15R-33L.

Repair Options

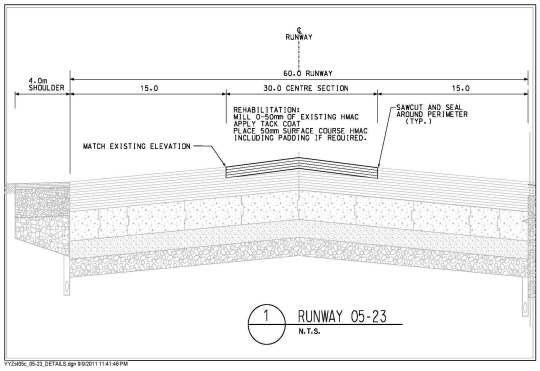
Three repair options were reviewed and analyzed.

- APR Repair Suggestion
  - Best aircraft response; however constructability and surface slope were unable to achieve a satisfactory level.
- GTAA Repair Option 1
  - Aircraft response was reduced to an acceptable level; constructability and surface slope & runoff were able to achieve a satisfactory level. (The Best Overall Option – Selected)
- GTAA Repair Option 2
  - Aircraft response was minimized to an acceptable level; however constructability and surface slope & runoff were not as good as Option 1.

Repair Option 1 – Spot Elevations Plan



Repair Option 1 – Typical Detail

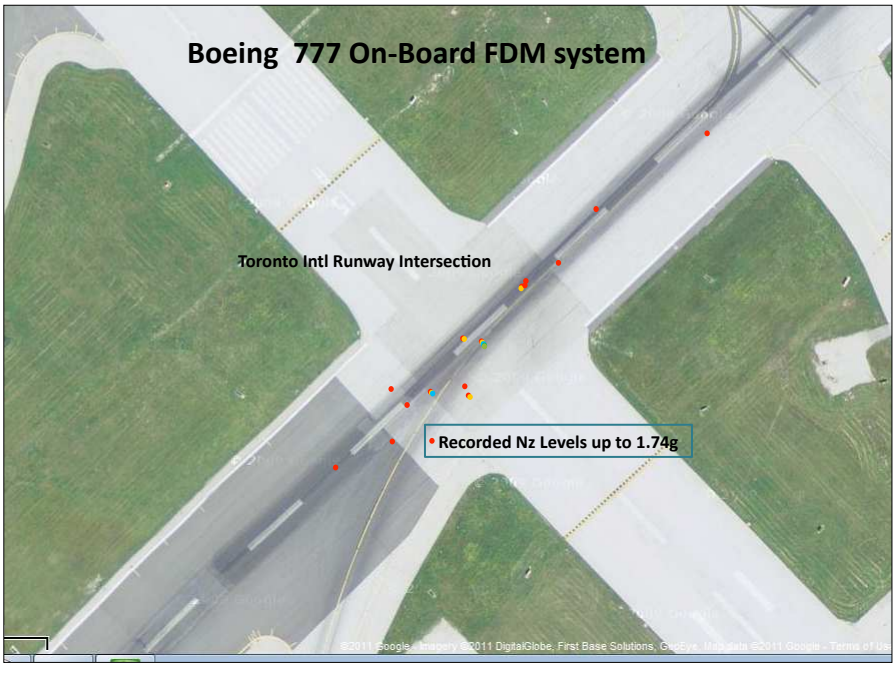


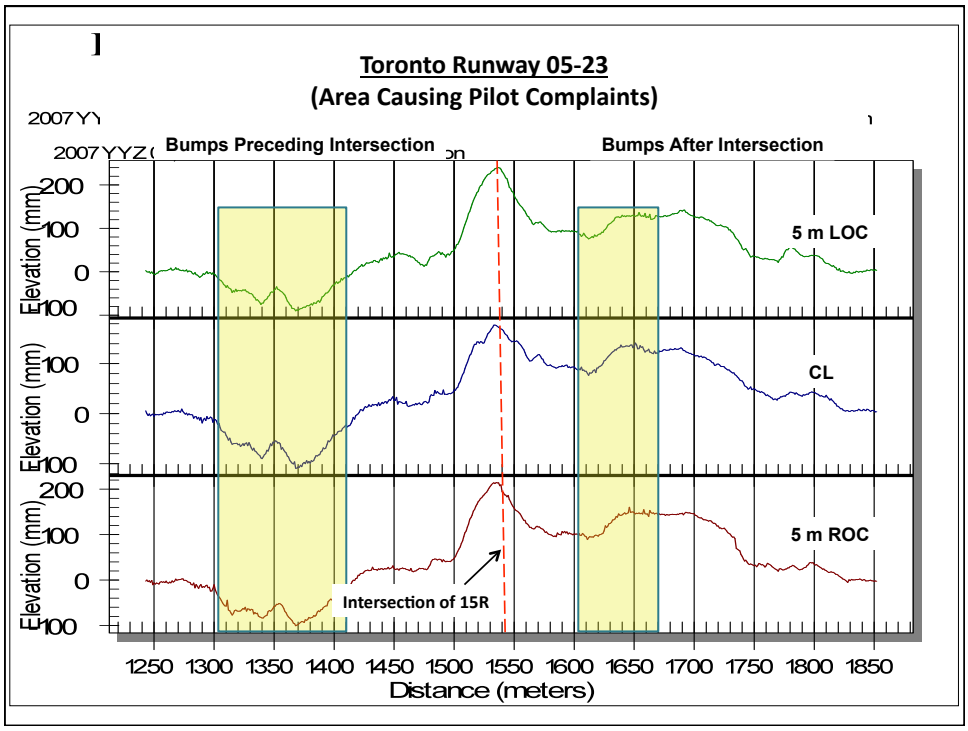
Operational Impacts Consideration

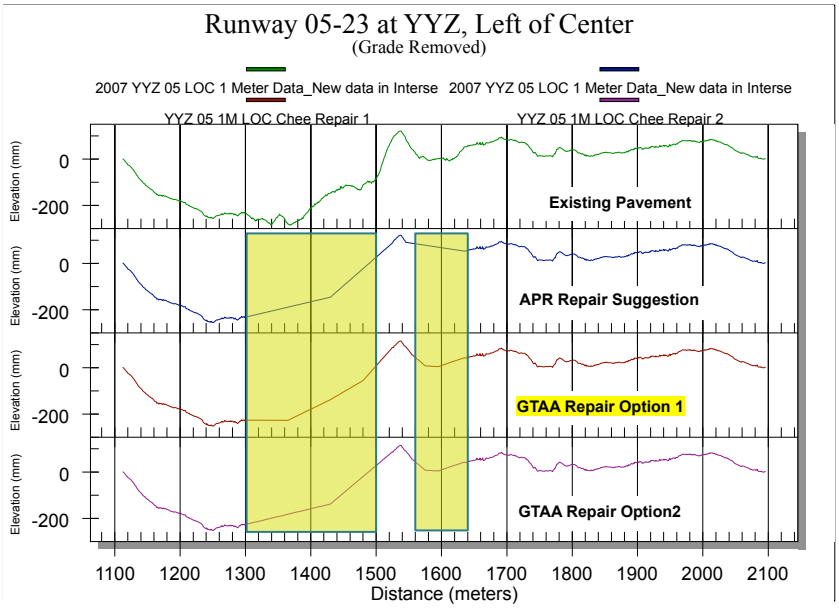
- Repair done on the most frequently used runway.
- Work must be done as fast as possible to minimize closure duration.
- Closure schedule was coordinated and agreed between all stakeholders including airline carriers. Work was carried out on an extended weekend closure from Friday night to Monday morning after the Labour Day weekend in September 2011.
- Work was completed as per schedule.

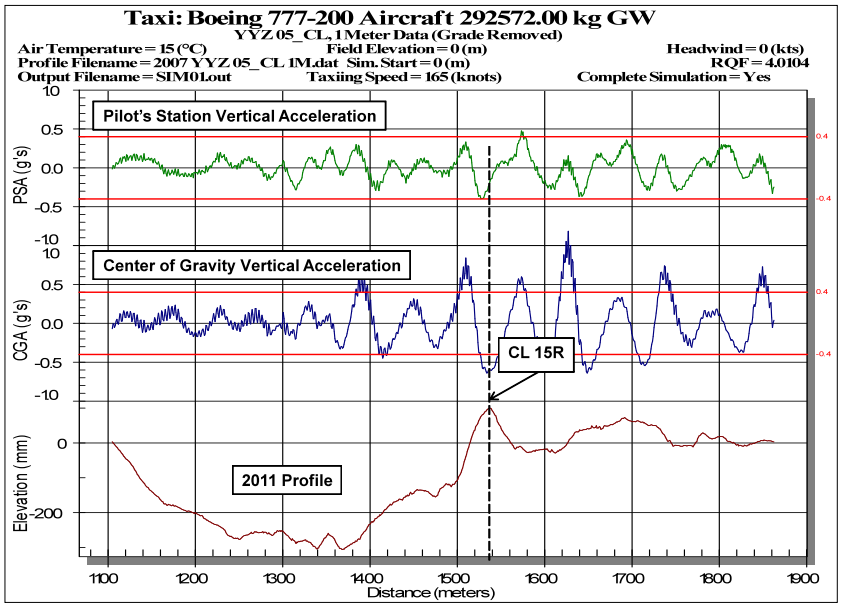
On-Board Health Monitoring Systems on Air Canada Jets

- Sophisticated sensor network designed to track the structural integrity of each aircraft by tail number
- "Nz" Center of gravity vertical acceleration measures the aircraft response to bumps/dips
- GPS accurately locates the event

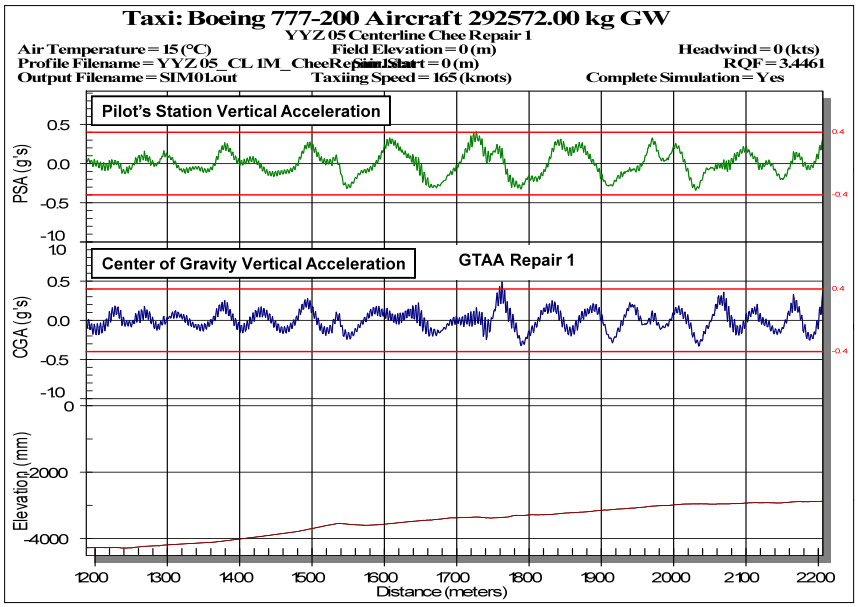



Toronto Runway 05-23
(Area Causing Pilot Complaints)
Bumps Preceding Intersection
Bumps After Intersection
5 m LOC
CL
5 m ROC
Intersection of 15R
Elevation (mm)
200
100
0
-100
1250 1300 1350 1400 1450 1500 1550 1600 1650 1700 1750 1800 1850
Distance (meters)

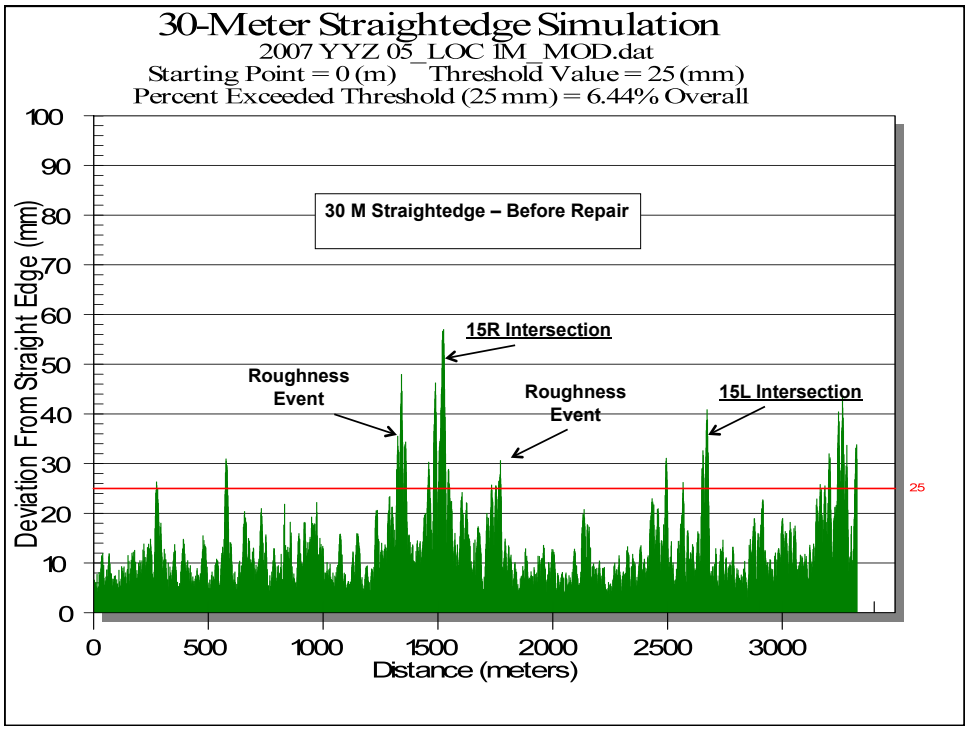

Runway 05-23 at YYZ, Left of Center
(Grade Removed)
2007 YYZ 05 LOC 1 Meter Data_New data in Interse
2007 YYZ 05 LOC 1 Meter Data_New data in Interse
YYZ 05 1M LOC Chee Repair 1
YYZ 05 1M LOC Chee Repair 2
Existing Pavement
APR Repair Suggestion
GTAA Repair Option 1
GTAA Repair Option2
Elevation (mm)
0
-200
1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100
Distance (meters)

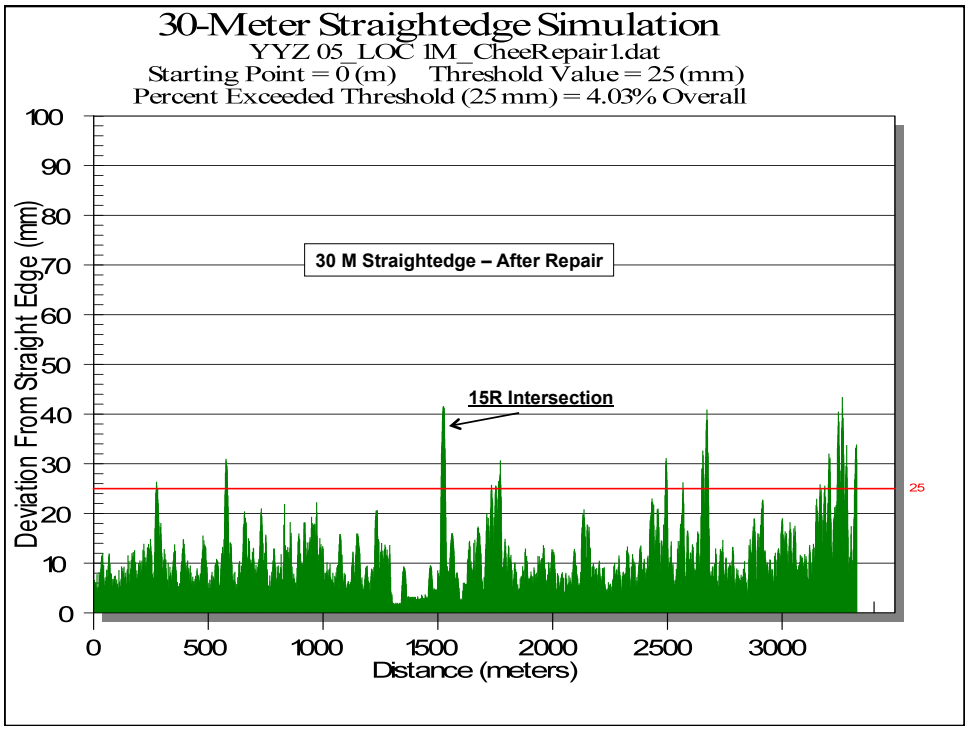


Runway 05: Simulation of Boeing 777-200 Response Before Repair



Runway 05: Boeing 777-200 Response After Repair


30-Meter Straightedge Simulation
2007 YYZ 05_LOC 1M_MOD.dat
Starting Point = 0 (m) Threshold Value = 25 (mm)
Percent Exceeded Threshold (25 mm) = 6.44% Overall
30 M Straightedge – Before Repair
15R Intersection
Roughness Event
Roughness Event
15L Intersection
25
Deviation From Straight Edge (mm)
Distance (meters)
0
10
20
30
40
50
60
70
80
90
100
0
500
1000
1500
2000
2500
3000


30-Meter Straightedge Simulation
YYZ 05_LOC 1M_CheeRepair1.dat
Starting Point = 0 (m) Threshold Value = 25 (mm)
Percent Exceeded Threshold (25 mm) = 4.03% Overall
30 M Straightedge – After Repair
15R Intersection
25
Deviation From Straight Edge (mm)
Distance (meters)
0
10
20
30
40
50
60
70
80
90
100
0
500
1000
1500
2000
2500
3000

Conclusions

- GTAA, working with Air Canada and APR Consultants, identified and corrected roughness problem in 3 months.
- Air Canada on-board aircraft FDM systems provided aircraft response data.
- APR Consultants identified the specific bumps causing the response and developed a repair plan.
- GTAA designed and implemented the repair.