Enhancing Pavement Management
APR’s Products and Services

Mr. Michael Gerardi
APR Consultants, Inc.
mag@aprconsultants.com

May 13, 2015
APR Consultants

• APR was Incorporated in 1993
• Develop Products and Services to Evaluate Airfield Pavement Profiles
  ▫ Quantify Ride Quality
  ▫ Pavement Management
  ▫ Develop Repair Solutions
  ▫ Evaluate Pavement Design
  ▫ Measure Pavement Profiles
  ▫ Track Profile Shape Changes
Quantifying Ride Quality

• APR Pioneered the use of Aircraft Simulation to Assess Pavement Rideability
  ▫ Takeoff, Landing, Constant Speed Taxi, Aborted Takeoff
  ▫ Emulates 14 Different Commercial Aircraft
  ▫ Predict Responses at Pilot’s Station and Center of Gravity
  ▫ Predict Pavement Loads
• Integrates into Airport’s Pavement Management Program
Aircraft Simulation

Takeoff: Boeing 737-800 Aircraft 630000 lbs GW
Training Profile Number 1 (R/W 17R CL 13 June 1998) (Grade Removed)
Air Temperature = 85 °F
Field Elevation = 500 ft
Profile Filename = Centerline.dat
Sim. Start = 20 ft
Output Filename = Deleteme.out
Headwind = 0 (kts)
RQF = 3.2452
Complete Simulation = Yes

Accelarations at the Pilot’s Station (PSA)
Accelarations at Center of Gravity (CGA)
Runway Profile

Elevation (ft)
Distance (feet)
Profile Measurement

- The Auto Rod and Level
  - Measures a True Elevation Data Point Every .25-Meter
  - Can Measure a 3,300-Meter Line of Survey in Approximately 1 Hour
  - Equipment is Rugged and Weatherized
  - Requires a Team of Two plus Vehicle to Transport
Why Measure True Profile?

- Perfect for Pavement Management
  - Track Settlement over Time.
Why Measure True Profile (Con’t)?

- Quantify Amount of Settlement
- Predict When Repairs Will be Necessary
Why Measure True Profile (Con’t)

- Important to Capture All Wavelengths and Grade Changes
  - Due to Gear Spacing and Speed of Encounter, Aircraft will Respond to Events up to 100-Meter Long
- AR&L Measures All Wavelengths Relatively Quickly
Why Aircraft Simulation

• The Best Method of Reporting Runway Ride Quality is to use Instrumented Aircraft
• Next Best is Aircraft Simulation
  ▫ Validated Accuracy and Repeatable
  ▫ Multiple Commercial Aircraft Types Available
  ▫ Simulates Any Operation in Any Condition
  ▫ If Roughness Exists, Aircraft Simulation will Identify the Event’s Precise Location
Why Aircraft Simulation (Con’t)

- A Common Alternative to Aircraft Simulation is using the Boeing Bump Index (BBI) Contained in ProFAA
  - BBI can be a Good “First Look” Depending Upon the Roughness Type
  - By its Nature, BBI is Limited in What it Can Detect
  - Can Falsely Declare a Rough Runway as Acceptable
Real-World Runway Roughness

- Multiple Events Located in the Runway’s Overrun Area
- Approximately 300 meters of undulating pavement
- Wavelengths are approximately 30 meters
- Undulations Result in a Harmonic Resonance about the Aircraft’s Nose Gear Resulting in Accumulating Nose Pitch
Pavement Roughness
Why Does BBI Fall Short?

• BBI Only Evaluates at One Event at a Time
  ▫ Multiple Event Roughness Typically Produces Greater Aircraft Responses than Single Event
  ▫ Multiple Event Roughness is More Common than Single Event Roughness

• Does Not Take into Account Aircraft Specifics
  ▫ Does Not Account for:
    • Speed of Encounter
    • Weight of Aircraft
    • Gear Spacing (Distance from Nose to Main Gear)
Takeoff with Roughness in the Overrun

**Takeoff: Boeing 737-800 Aircraft 172500 lbs GW**

Runway 4L-22R at Centerline
Field Elevation = 0 (ft)
Sim. Start = 0 (ft)
Profile Filename = EWR 4L-22R CL_x.dat
Output Filename = Deleteme.out
Headwind = 0 (kts)
RQF = 3.0229
Complete Simulation = Yes

**Graph:**
- Plot: Pilot Sta. Vert Acc (g's)
- Plot: CG Vert Acc (g's)
- Plot: Elevation (in)

**Axes:**
- Distance (feet)
- Elevation (in)
- Pilot Sta. Vert Acc (g's)
- CG Vert Acc (g's)
Takeoff with Roughness at 600 Meters
Using Technology to Meet Client’s Needs

Profile Measurement

11-Point Analysis

Comprehensive Report

Role Quality Analysis Report for Runway 07R-25L at the Springfield International Airport

April 21, 2013
Profile Measurement

• APR Sells the AR&L
  ▫ Provides Most Flexibility for Owner to Measure on Demand

• APR Can Provide the Profile Measurement as a Service

• Alternative Profile Measurement Techniques
  ▫ High-Speed Profile Data
    • APR Cannot Attest to Simulation Accuracy
  ▫ Traditional Survey Profile Data
    • Slow But Effective
Analysis – Profile Evaluation

• Thorough Analysis of the Measured Profile Data
  ▫ Visual Profile Analysis
    • Perform a Visual Inventory of Suspicious Areas Prior to Simulations
  ▫ Baseline Comparison (If Applicable)
    • Direct Comparison to Baseline Profile
    • 150-Meter Straightedge Analysis
Analysis – Profile Evaluation
Analysis – Aircraft Simulation

• Simulations are Conducted on Both Ends of the Runway
• Two Classes of Aircraft – Narrow and Wide Bodied Aircraft
  ▫ VSweep Analysis
    • Simulates All Possible Speeds on Every Meter of Measured Profile
  ▫ Constant Speed Taxi
  ▫ Conventional Takeoff
  ▫ Aborted Takeoff
  ▫ Landing
# Analysis – VSweep

<table>
<thead>
<tr>
<th>Line of Survey</th>
<th>Section</th>
<th>Chainage</th>
<th>RQI</th>
<th>PSA Peak (g<em>m</em>gal)</th>
<th>CG Peak (g<em>m</em>gal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>717-880</td>
<td>1</td>
<td>1172-1322</td>
<td>3.49</td>
<td>0.65</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1322-1472</td>
<td>3.45</td>
<td>0.63</td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>1472-1622</td>
<td>2.62</td>
<td>0.58</td>
<td>0.14</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>1622-1772</td>
<td>3.26</td>
<td>0.59</td>
<td>0.14</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>1772-1922</td>
<td>3.50</td>
<td>0.72</td>
<td>0.14</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>1922-2072</td>
<td>2.92</td>
<td>0.58</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>2072-2222</td>
<td>2.67</td>
<td>0.54</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>2222-2372</td>
<td>2.72</td>
<td>0.44</td>
<td>0.14</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>2372-2522</td>
<td>2.23</td>
<td>0.41</td>
<td>0.11</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>2522-2672</td>
<td>2.64</td>
<td>0.54</td>
<td>0.14</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>2672-2822</td>
<td>2.70</td>
<td>0.58</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>2822-2972</td>
<td>2.46</td>
<td>0.42</td>
<td>0.17</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>2972-3122</td>
<td>2.76</td>
<td>0.61</td>
<td>0.19</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>3122-3272</td>
<td>1.19</td>
<td>0.64</td>
<td>0.14</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>3272-3422</td>
<td>2.58</td>
<td>0.60</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>3422-3572</td>
<td>2.06</td>
<td>0.39</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>3572-3722</td>
<td>2.18</td>
<td>0.44</td>
<td>0.14</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>3722-3872</td>
<td>2.29</td>
<td>0.47</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>3872-4022</td>
<td>2.03</td>
<td>0.41</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>4022-4172</td>
<td>2.09</td>
<td>0.34</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td>21</td>
<td>4172-4322</td>
<td>2.77</td>
<td>0.57</td>
<td>0.17</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>4322-4472</td>
<td>4.80</td>
<td>1.02</td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td>23</td>
<td>4472-4625</td>
<td>3.00</td>
<td>0.60</td>
<td>0.20</td>
</tr>
</tbody>
</table>

**Diagram:**

- **Event Area 1:**
- **Event Area 2:**

*Image of APR Consultants logo at the bottom right corner.*
Analysis – Aircraft Simulation

• Two Classes of Aircraft – Narrow and Wide Bodied Aircraft
  ▫ VSweep Analysis
    • Simulates All Possible Speeds on Every Meter of Measured Profile
  ▫ Constant Speed Taxi
  ▫ Conventional Takeoff
  ▫ Aborted Takeoff
  ▫ Landing
Analysis – Aircraft Simulation
Analysis – Straig特edge Analysis

• APR’s Standard Analysis Conducts a Variety of Straig特edge Analyses
  ▫ 3-meter / 3mm Straig特edge
    • Compare to ICAO Annex 14
  ▫ 30-meter / 25mm Straig特edge
    • Identify Events that will Cause Poor Aircraft Response
  ▫ Straig特edge Analysis Sweep
    • Compares Subject Runway to That of Known Rough and Known Smooth Runways
Analysis – Straightedge Analysis

Runway 07L-25R, 7M Left of Center
3-Meter Straightedge Simulation
Starting Point = 0 (m)  Threshold Value = 3 (mm)
Percent Exceeded Threshold (3 mm) = 45.15% Overall

Event Area 1

Event Area 2

Runway 07L-25R, 7M Left of Center
30-Meter Straightedge Simulation
Starting Point = 0 (m)  Threshold Value = 25 (mm)
Percent Exceeded Threshold (25 mm) = 1.69% Overall

Event Area 1

Event Area 2
Graphical Summary
Pavement Smoothness Index

- Included in the Report’s Executive Summary
  - Divides Runway into 150-meter Sections
  - Each Analysis is Numerically Incorporated into One Index for each Section
  - Easy to Understand and Compare to Previous Reports
Analysis – Report Deliverable

• Includes Detailed Analysis and all Plots:
  ▫ All Profiles
  ▫ All Baseline Comparisons
  ▫ All Aircraft Simulations
  ▫ All Straightedge Analyses
• Includes 22 Years of Experience and Engineering Judgement
Conclusions

• APR has Been Enhancing Pavement Management for 22 Years
• In that Time, APR has Developed Effective Methods of Profile Measurement, and Analysis Software
• This Technology is Very Effective at:
  ▫ Identifying Ride Quality of Airfield Pavements
  ▫ Monitoring Profile Shape Changes (Settlement)
  ▫ Pavement Repairs
  ▫ Design Evaluation
The End