Use of HWD (deflection), Backcalculation, and Multilayer Elastic Analysis for Airport Pavement Evaluation

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• Hatch Mott MacDonald
Presentation Outline

• Project Background
• Supplemental Research Work
• FWD, Backcalculation, & ELT
• Case Study
• Decision Tree (Rehab Options)
• Evaluation
• Conclusions & Recommendations
Project Background

Scope & Objectives

• 3-year airside pavement improvement program
• Year 1 program
  – Taxiway ‘A’
  – Apron V
  – Apron I (northern two-thirds)
  – Runway 11-29 (300 m beginning at the western end)

• Objective
  – Determine the existing pavement structure
  – Analyze the structure in terms of pavement strength
  – Develop recommendations for rehabilitation
Project Background
Pavement Evaluation

• Series of 14 boreholes (BH)
  – To determine pavement structure and layer types
• Dynamic Cone Penetrometer (DCP) at 5 BH
  – To determine the strength of the granular layer underlying the pavement surface
• Visual distress survey
  – To assess surface distress condition
• Heavy Weight Deflectometer (HWD) survey
  – To determine pavement structural strength
Supplemental Research Work

• New methodology developed within Stantec, to develop and evaluate rehabilitation options
  – FWD Analysis
  – Backcalculation
  – Multi-layer elastic analysis

• Case Study
  – Runway 11-29
FWD, Backcalculation, & ELT Pavement Evaluation

• **FWD Analysis**
  – Determine in-situ structural capacity of the pavement structure (and subgrade soil conditions)

• **Backcalculation**
  – Procedure to determine Young’s modulus of Elasticity for pavement materials, using measured surface deflections by working elastic layer theory “backwards”

• **Elastic Layer Analysis**
  – Measurement of deflections, stresses, and strains
Case Study
Runway Structure

<table>
<thead>
<tr>
<th>Avg. Core Thicknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC</td>
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<tr>
<td>5.9</td>
</tr>
</tbody>
</table>

150 mm (Asphalt layer)

300 mm (Crushed stone base and subbase layers)

Backcalculation is based on semi-infinite half-space of subgrade

Rigid Layer is present within less than 3 metres from the surface
Case Study
FWD & Backcalculation

HWD Inputs
• 2 drops at each load level
• 3 load levels
  – 60 kN (13,500 lbf)
  – 90 kN (20,200 lbf)
  – 120 kN (27,000 lbf)

HWD Analysis Outputs
• E1 - modulus of asphalt layer
• E2 - modulus of the base/subbase layer
• E3 - modulus of the subgrade layer
• Statistics - Average, Standard deviation, Maximum, Minimum, Coefficient of Variance
## Case Study

### Backcalculation: Layer 1 - Asphalt

<table>
<thead>
<tr>
<th>Drop No.</th>
<th>Stress (kPa)</th>
<th>Load (kN)</th>
<th>E1 (MPa) Avg</th>
<th>E1 (MPa) StDev</th>
<th>E1 (MPa) Max</th>
<th>E1 (MPa) Min</th>
<th>COV</th>
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<tbody>
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<td>61</td>
<td>3,393</td>
<td>1,364</td>
<td>6,171</td>
<td>1,630</td>
<td>40.2%</td>
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<tr>
<td>2</td>
<td>1362</td>
<td>96</td>
<td>3,415</td>
<td>1,214</td>
<td>6,043</td>
<td>1,835</td>
<td>35.5%</td>
</tr>
<tr>
<td>3</td>
<td>1793</td>
<td>127</td>
<td>3,582</td>
<td>1,411</td>
<td>6,372</td>
<td>1,900</td>
<td>39.4%</td>
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<tr>
<td>4</td>
<td>865</td>
<td>61</td>
<td>3,621</td>
<td>981</td>
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<td>27.1%</td>
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<tr>
<td>5</td>
<td>1274</td>
<td>90</td>
<td>3,704</td>
<td>1,073</td>
<td>5,570</td>
<td>2,106</td>
<td>29.0%</td>
</tr>
<tr>
<td>6</td>
<td>1694</td>
<td>120</td>
<td>3,645</td>
<td>1,151</td>
<td>5,695</td>
<td>2,085</td>
<td>31.6%</td>
</tr>
<tr>
<td>Overall Avg</td>
<td></td>
<td></td>
<td>92.5</td>
<td>3,560</td>
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<table>
<thead>
<tr>
<th>Drop No.</th>
<th>Stress (psi)</th>
<th>Load (lbf)</th>
<th>E1 (psi) Avg</th>
<th>E1 (psi) StDev</th>
<th>E1 (psi) Max</th>
<th>E1 (psi) Min</th>
<th>COV</th>
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<tbody>
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<td>13,646</td>
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<td>20,241</td>
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<td>26,917</td>
<td>528,682</td>
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<tr>
<td>Overall Avg</td>
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<td>20,782</td>
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Asphalt layer is in fair to good condition.
## Case Study
### Backcalculation: Layer 2 – Base/subbase

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<th>E1 (MPa)</th>
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<tbody>
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<td></td>
<td></td>
<td></td>
<td>Avg</td>
</tr>
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<td>61</td>
<td>3,799</td>
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<td>1793</td>
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<td>4,260</td>
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<tr>
<td>4</td>
<td>865</td>
<td>61</td>
<td>4,223</td>
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<td>4,254</td>
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<tr>
<td>Overall Avg</td>
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<td>92.5</td>
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<table>
<thead>
<tr>
<th>Drop No.</th>
<th>Stress (psi)</th>
<th>Load (lbf)</th>
<th>E1 (psi)</th>
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<tbody>
<tr>
<td></td>
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<tr>
<td>Overall Avg</td>
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<td></td>
<td>20,782</td>
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</table>

Increased base/subbase modulus due to compensation effect of rigid layer.
## Case Study
### Backcalculation: Layer 3 – Subgrade

<table>
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<tr>
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<th>E1 (MPa)</th>
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</thead>
<tbody>
<tr>
<td></td>
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<td>398</td>
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<td>4</td>
<td>865</td>
<td>61</td>
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<td>5</td>
<td>1274</td>
<td>90</td>
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<tr>
<td>6</td>
<td>1694</td>
<td>120</td>
<td>393</td>
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<tr>
<td>Overall Avg</td>
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<td>388</td>
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<table>
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<td>55,711</td>
<td>25,360</td>
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<tr>
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<td>197</td>
<td>57,090</td>
<td>24,109</td>
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<td>57,699</td>
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<td>58,179</td>
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<td>246</td>
<td>57,065</td>
<td>22,324</td>
</tr>
<tr>
<td>Overall Avg</td>
<td>20,782</td>
<td>56,321</td>
<td></td>
</tr>
</tbody>
</table>

Higher variability is an indication of inconsistent layer
Decision Tree (Rehab Options)
If surface condition is very poor to poor

Rehab Options:

1. Hot in place recycling of the existing asphalt and overlay with a new HMA high stiffness surface layer (SMA* or Superpave* with PG 70-34* or PG 76-34* or equivalent)

2. Total reconstruction

* Use 1.5% lime by weight for high stiffness HMA Use 0.3 - 0.5 AC% above optimum for durability Consider use of warm asphalt mix technology
Decision Tree (Rehab Options)
If surface condition is poor to fair

Rehab Options:

1. Mill 80 mm (3 in) of existing asphalt and overlay with a 125 mm (5 in) of HMA high stiffness surface layer (SMA* or Superpave* with PG 70-34* or PG 76-34* or equivalent)

2. If milling is not an option, then overlay 125-180 mm (5 -7 in) after surface sealing & repair
Decision Tree (Rehab Options)
If surface condition is **fair to good**

Rehab Options:

1. Mill 50 mm (2 in) and overlay 80 mm (3 in) of HMA high stiffness surface layer (SMA* or Superpave* with PG 70-34* or PG 76-34* or equivalent)

2. If milling is not an option, then overlay with 50 mm (2 in) after surface sealing & repair
Decision Tree (Rehab Options)
If surface condition is good to very good

Rehab Options:

1. Mill 25 mm (1 in) and overlay with 50 mm (2 in) of HMA high stiffness surface layer (SMA* or Superpave* with PG 70-34* or PG 76-34* or equivalent)

2. If milling is not an option, then overlay 40-50 mm (1.5-2 in)
Evaluation
Rating Criteria - Scale

- 1 – 5 Rating Index Scale
  - Rating Index 5 = very good
  - Rating Index 4 = good
  - Rating Index 3 = fair
  - Rating Index 2 = poor
  - Rating Index 1 = very poor
Evaluation
Rating Criteria – Functional vs. Structural

• Functional conditions
  – Based on surface distress

• Structural conditions
  – Based on Backcalculation
  – Based on Multilayer Elastic Analysis Results
    • To reduce pavement deflection and tensile strain at bottom of asphalt layer under main gear of the design aircraft
    • Reduce surface deflection as follows:
Evaluation
Rating Criteria – Deflection Performance

- Deflection vs. Strain Relationship
  - 25 microns (4 mils) or less = Very good
  - 100 – 150 microns (4 – 6 mils) = Good
  - 150 – 200 microns (6 – 8 mils) = Fair
  - 200 – 250 microns (8 – 10 mils) = Poor
  - 250 microns (10 mils) or higher = Very Poor
Evaluation
Results

• FWD Analysis
  – Avg. deflection = 192 microns (7.9 mils)
  – Standard deviation = 53 microns (2.1 mils)

• Multilayer Elastic Analysis
  – Low subgrade deflection
  – Less than 120 micro strains for the tensile strain at the bottom of the asphalt layers

Indicating fair to good runway condition
Conclusions & Recommendations

- Rating Index = 3 - 4 (fair to good)
  - Based on calculations and visual inspection
- Rehab Options
  - Mill 50 mm (2 in) and overlay 80 mm (3 in) of HMA high stiffness surface layer (SMA* or Superpave* with PG 70-34* or PG 76-34* or equivalent)
  - If milling is not an option, then overlay with 50 mm (2 in) after surface sealing & repair
Conclusions & Recommendations

• To replace SMA/Superpave, recommend performance grades (PG):
  – Use 1.5% lime by weight for high stiffness HMA
    • Improve stiffness
    • Prevents stripping potential
    • Reduces rutting potential
  – Use 0.3 - 0.5 AC% above optimum
    • Improve durability, i.e. reduce cracking potential
  – Consider use of warm asphalt mix technology
    • Similar to Boston Logon International taxiway
Questions

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