Managing the Life Cycle Costs of Gravel Runways

Creating and Delivering Better Solutions

A Case Study Based on 44 Gravel Surfaced Runways in Canada's North
Contents

• Issues and Challenges
• Background to the Gravel Surface Management Study
• Scope of Gravel Road Management Study
• Data Collection
• Gravel Consumption Prediction Modeling
• Analysis Inputs
• Analysis Results
• Questions
Typical Issues Relating to Gravel Surfaces

• The usable onsite gravel supplies are being depleted;
• Other onsite resources may become unavailable for environmental reasons;
• Offsite sources are many times more expensive;
• With increased usage, there will be intensified requirements for Gravel resources;
• Owner Agencies need to know how to minimize and quantify future gravel requirements.
Institutional Issues Related to Canada’s North

- Staff turnover
- Level of effort required for implementation
- Difficulty in establishing historical costs
- Creation of two governments
- Amalgamation of departments
Figure 4.9: Future Air Service Route Structure

Trunk Routes
Future Trunk Routes
Feeder Routes
Future Feeder Route
**Distribution of Airport Characteristics**

<table>
<thead>
<tr>
<th>TC Code</th>
<th>Length</th>
<th>Asphalt</th>
<th>Gravel</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&lt; 2600 ft</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>2600-4000 ft</td>
<td>0</td>
<td>19</td>
</tr>
<tr>
<td>3</td>
<td>4000-6000 ft</td>
<td>1</td>
<td>18</td>
</tr>
<tr>
<td>4</td>
<td>&gt; 6000 ft</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td><strong>8</strong></td>
<td><strong>44</strong></td>
</tr>
</tbody>
</table>
Unique to this case study

- Network of facilities vs a single facility system
- AC and Gravel performance models
- Diversity
  - Traffic
  - Size/classification code
  - Climate
- Road Accessible/Air accessible
  - Construction costs
- Territorial Division Midproject
Figure 5.1: GNWT Airport System

- Gateway Hubs
- Regional Hubs
- Community Airports
Eight Asphalt Surfaced Facilities
Airports have diverse roles in the Arctic
Air is the only access to many communities
Data Collection Challenges

• Northern Data Collection
  – Distance
  – Short Season
  – Accessibility/Travel costs

• Unique Surface Distresses
  – Thermal distresses
  – Very little fatigue distress
## Surface Distress Measurements Based on ASTM D 5340 - (PCI)

![Image](image.png)

### X5. BLANK FORMS

#### AIRFIELD ASPHALT PAVEMENT CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

<table>
<thead>
<tr>
<th>DISTRESS SEVERITY</th>
<th>QUANTITY</th>
<th>TOTAL</th>
<th>DENSITY %</th>
<th>DEDUCT VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>10L 7S</td>
<td></td>
<td>7S</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8L 6S</td>
<td></td>
<td>6S</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5L 30m²</td>
<td></td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12L 30</td>
<td></td>
<td>30</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### SKETCH:

- 1. Alligator Cracking
- 2. Bleeding
- 3. Block Cracking
- 4. Corrugation
- 5. Depression
- 6. Jet Blast
- 7. Jt. Reflection (PCC)
- 8. Long. & Trans. Cracking
- 9. Oil Spillage
- 10. Patching
- 11. Polished Aggregate
- 12. Ravelling/Weathering
- 13. Rutting
- 14. Shoving from PCC
- 15. Slippage Cracking
- 16. Swell

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**FIG. X5.1 Flexible Pavement Condition Survey Data Sheet for Sample Unit**
Surface Distresses in Arctic Climates

- Prevalent
  - Block (thermal) Cracking
  - Swell/Depressions
  - Deep seated Transverse Cracks

- Rare
  - Rutting
  - Fatigue cracking
Individual Gravel Distresses are often masked by on-going maintenance activities
Gravel surface thickness can be subjectively measured.
LCCA Requirements

- Model both AC and Gravel performance
- Pavement performance models specific to each site to accommodate the diversity of site conditions
- Need to consider both Capital and O&M budgets
- Need to forecast maintenance costs
Variables that need to be Modeled

- Traffic
  - Growth
  - Changes in use
- Asphalt
  - L&T Cracking
  - Block Cracking
  - Weathering/Raveling
  - Remaining Strength
  - Pavement Condition Index (PCI)
- Gravel Surfaces
  - Surface Thickness
  - Stockpile Volume
  - Remaining Service Life
Modeling Software (dTIMS CT)

- **User definable Performance Models**
  - Crack models
  - Roughness models
  - Gravel models

- **User Sustainable**
  - Users can redefine/update
    - Models
    - Costs
    - Budgets etc.

- **Multiple Budget Categories**
# Surfacing Gravel Thickness as a Measure of Network Health

<table>
<thead>
<tr>
<th>Condition</th>
<th>Thickness</th>
<th>To ACA</th>
<th>Colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>V Good</td>
<td>250 mm</td>
<td>400 mm</td>
<td>Green</td>
</tr>
<tr>
<td>Good</td>
<td>200 mm</td>
<td>250 mm</td>
<td>Blue</td>
</tr>
<tr>
<td>Fair</td>
<td>150 mm</td>
<td>200 mm</td>
<td>Pink</td>
</tr>
<tr>
<td>Poor</td>
<td>100 mm</td>
<td>150 mm</td>
<td>Yellow</td>
</tr>
<tr>
<td>V Poor</td>
<td>0 mm</td>
<td>100 mm</td>
<td>Red</td>
</tr>
</tbody>
</table>
Historic rate of gravel loss can be calculated and future rates of loss projected.
ACP Distress Prediction Modeling

Pavement Performance - Distress Prediction Modeling

- Structure
- Age
- Traffic
- Environment
- Condition

- Crack Initiation
- Crack Progression
- Rutting
- Roughness
- Deep Transverse Cracks
- Raveling

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Gravel Loss Rate Prediction Modeling

- Subgrade Modulus
- Sub-base Thickness
- Traffic
- Surface trt
- Drainage

Gravel Loss into Subgrade due to low subgrade strength

Gravel Loss into Subgrade due to reduced gravel thickness

Gravel loss due to Traffic

Spot failure gravel requirements

Total Gravel loss rate
Calibration of Gravel Loss Rate

- If historically 1,000 tonnes of Gravel for thickness replenishment and spot repairs at a given site/year - the models are calibrated such that 1,000 tonnes are used in year 1 for thickness replenishment and spot repairs.
- Each site has a different set of gravel loss attribute components.
- Loss rate then used to back calculate loss component for traffic, subgrade modulus, sub-base thickness and surfacing structure.
- Once a component based loss rate is established, it can be used to forecast future loss rates under varying conditions.
Gravel Stockpile Volume vs Age

- Gravel Stockpile Volume
- Airport Stockpile Volume

- Unprogrammed Gravel Usage
- Programmed Gravel Usage
- Critical Stockpile Volume

Years
Gravel Remaining Service Life

Years

Airport Gravel RSL

1

1

Gravel Production Zone

Years

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## Analysis Inputs

### Maintenance/Rehabilitation Treatments and Costs

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Unit Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patrolling/Blading</td>
<td>$0.05/m²</td>
</tr>
<tr>
<td>Spot Repairs</td>
<td>$35/m²</td>
</tr>
<tr>
<td>Re-Gravelling</td>
<td>$35/tonne</td>
</tr>
<tr>
<td>Gravel Production</td>
<td>$10-$100/m³</td>
</tr>
</tbody>
</table>
LCC_{pv} = CC + OC_{pv} + (R+M)C_{pv} - SC_{pv}

Where:

LCC_{pv} = Present Value of all Life Cycle Costs
CC = Initial construction costs of the pavement structure
OC_{pv} = Present value of the operating costs to the users/owners of the pavement
(R+M)C_{pv} = Present value of the sum of all rehabilitation and maintenance costs over the analysis period.
SC_{pv} = The present value of the residual pavement structure components at the end of the analysis period (also called salvage value)
LCCpv = (R+M)Cpv

LCCpv is often referred to as Present Value Cost or PVCost
The LCCA Evaluates Several Strategies for Each Gravel Segment (including aprons, taxiways and itinerant parking)

- Strategy is comprised of combinations of individual treatments and treatment application timings
- For a given segment there are hundreds potential preservation strategies.
- Each strategy has a life-cycle cost measured in present worth at a discount rate of 4%
- Each strategy has a benefit measured as the present worth of the value of the gravel in-place in each year of the life cycle
Analysis Scenarios

Typically Conduct Optimization Analysis for Several Funding Scenarios

• Minimum Cost to keep the facility open – trades off re-gravelling with the cost of spot repairs (high maintenance costs)

• Current funding levels

• Unconstrained funding in order to maximize the asset value/cost ratio

• Evaluate the LCCA effect of conversion any segment to ACP surface

• Optimal funding to provide a uniform funding scheme while maximizing the asset value/cost ratio

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Max Benefit/Cost

Min PV Cost

Worst First

Max Net Benefit

Optimized to Maximize Network Asset Value (with limited budget)
Analysis Results at Various Budget Levels

Loss of Asset Value at Various Budget Levels

- Average Network Asset Value
- Loss Rate (%)

Year:
- 2006
- 2008
- 2010
- 2012
- 2014
- 2016
- 2018
- 2020
- 2022
- 2024

Recommended
### Cost Comparison of Various Budget Levels for 20 year Period

<table>
<thead>
<tr>
<th>Budget Category</th>
<th>Total Cost 20 yrs ($Million)</th>
<th>PV Cost 20yrs ($Million)</th>
<th>Average Gravel thickness 2020 mm</th>
<th>Asset Value in 2020 ($Million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Cost (all treatments)</td>
<td>$82.2</td>
<td>$59.7</td>
<td>207</td>
<td>$23.7</td>
</tr>
<tr>
<td><strong>$4.5 Million (all treatments)</strong></td>
<td>$96.9</td>
<td>$67.5</td>
<td>372</td>
<td><strong>$43.2</strong></td>
</tr>
<tr>
<td>Minimum Cost (gravel only)</td>
<td>$94.4</td>
<td>$67.5</td>
<td>217</td>
<td>$24.9</td>
</tr>
<tr>
<td>$4.5 Million (gravel only)</td>
<td>$102.3</td>
<td>$71.1</td>
<td>321</td>
<td>$36.6</td>
</tr>
</tbody>
</table>

* Recommended Scenario

**Current Practices
Benefits

• Fundamental part of rationalizing OM&R program
• Up to date status of network health
• Standardizing/Automating inspection and condition monitoring
• Provides managers with a better understanding of the network
• Tool for justifying funding requests
• Integral part of an agencies due diligence process
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