Challenges and Solutions to Airfield Pavement Design and Construction in the North with Severe Climatic Conditions – A Case Study

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ACKNOWLEDGEMENTS

The authors would like to thank the following people:

- Andrew Turner, P.Eng., MMM Group Limited, Toronto
- Nelson Pilgrim, Airport Manager, Churchill Falls Airport
- Michael Maher, Ph.D., P.Eng., Golder Associates Ltd.
- Gary Farrington, C.E.T., Golder Associates Ltd.
- Chris Philips, P.Eng., Golder Associates Ltd.
ORDER OF PRESENTATION

- Introduction
- Churchill Falls Airport
- Available information review
- Field investigation
- Pavement designs
- Construction
- QC/QA
- Summary – lessons learned

INTRODUCTION

- Typical challenges for runway design and construction in the North
  - Severe climatic conditions
    - Severe winters
      - Deep frost penetration
      - Permafrost
  - Soil and water conditions
    - Typically glacial till
    - Undulating bedrock
    - Shallow water
  - Difficult construction conditions
    - Short construction season
    - Long distances
    - Poor roads
INTRODUCTION

➢ Typical challenges for runway design and construction in the North
  ➢ Remote locations and low human population
  ➢ High construction cost
  ➢ Design
    • New challenges
    • Custom specifications required
  ➢ Limited experience and technology?
  ➢ Few contractors available
  ➢ Lack of quality materials
  ➢ QC/QA
    • Difficult
    • Expensive
CHURCHILL FALLS AIRPORT

- In Labrador
- 280 km west of Goose Bay and 250 km east of Labrador City
- Operated by Nalcor Energy Company, Newfoundland Labrador Hydro
- Facilities
  - Runway 13/31
  - Taxiway Alpha
  - Apron
- Aircraft traffic
  - Provincial Airlines
    - Dehavill and Dash 8
  - Nalcor Energy
    - Beech King Air 250
  - Occasionally large aircrafts
Originally constructed in 1969
- Runway 13/31 – 1676 m by 46 m

Pavement history
- Construction – 90 mm of HMA, 230 mm of base, 610 mm of subbase
- First rehabilitation in 1989 – 50 mm of HMA overlay
- Second rehabilitation in 2000
  - 50 mm HMA overlay
  - 250 mm sub-drains installed 6 m north of E/P

Existing pavement condition from previous investigations
- Distresses
  - Cracking
  - Roughness
  - Frost heaving

Initial scope of work
- Review existing information
- Visual condition inspection
- Identify locations for immediate repair
- Develop rehabilitation alternatives
- Life cycle cost analysis
- Drainage recommendations

Additional Work
- Limited geotechnical investigation
- Geophysical survey using GPR
**Pavement condition evaluation**
- Document the present pavement condition
- Determine distresses that require immediate treatment in 2011
- Distresses and frost heaves areas locations to be addressed in 2012 major rehabilitation

**Gary Farrington, Senior Pavement Specialist**
- Runway divided into 100 m sections
- Distresses documented and photographed for each section
- Locations for 2011 repairs marked out in the field

**Condition inspection findings**
- Extensive high severity block cracking
- High severity longitudinal and transverse cracking
- Similar extent and severity of cracking in keel and non keel sections
- Frost heaving at numerous locations
- 2010 crack repairs in very poor condition – ravelling and cracking
- Depressions and soft spots in granular shoulders

**Distresses due to environment, drainage and materials and not due to structural deficiency**
CHURCHILL FALLS AIRPORT

- Geotechnical evaluation
  - AMEC 2011 report
  - AMEC 2010 report
  - Jaques Whitford 2005 report
  - Golder Associates Test Pits

- AMEC 2011 Investigation
  - 11 boreholes through Runway pavement
  - Approximately 200 mm of HMA
  - Limited thickness of Granular < 100 mm
  - Bedrock depths ranging from 0.5 to 1.7 m
  - Water seepage in 8 boreholes
  - Ponding water on granular shoulder
  - Frost susceptible subgrade soils
CHURCHILL FALLS AIRPORT

- AMEC 2010 Investigation
  - 14 test pits excavated in granular shoulder
  - Highly frost susceptible soils
  - Bedrock depths ranging from 0.5 to 2.9 m
  - Frost penetration depth of up to 3 m

- Jacques Whitford 2005 Investigation
  - Six test pits in the granular shoulders
  - Frequent cobbles and boulders ranging in size from 0.5 to 2.0 m
  - Bedrock depth ranging from 0.5 to 2.8 m
  - Groundwater level ranging from 1 to 2 m

- Golder Test Pits
  - 4 test pits excavated through runway pavement
  - 6 test pits excavated through granular shoulder
  - Subgrade soils – silty sand with cobbles and boulders
  - Water infiltration in 2 runway and 2 shoulder test pits
  - Samples obtained for lab testing
  - Pavement Structure

<table>
<thead>
<tr>
<th>Test Pit ID</th>
<th>Asphalt</th>
<th>Granular Base</th>
<th>Granular Subbase</th>
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<tbody>
<tr>
<td>TP7</td>
<td>170</td>
<td>190</td>
<td>505</td>
</tr>
<tr>
<td>TP8</td>
<td>185</td>
<td>245</td>
<td>560</td>
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<td>TP9</td>
<td>155</td>
<td>245</td>
<td>400</td>
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<tr>
<td>TP10</td>
<td>185</td>
<td>165</td>
<td>520</td>
</tr>
<tr>
<td>Average</td>
<td>176</td>
<td>211</td>
<td>519</td>
</tr>
</tbody>
</table>
GPR survey by Golder Geophysical Department June 23 to 24, 2011

Objective
- Delineate the bedrock beneath the Runway

Smart Tow Noggin System

500 MHz antenna used

Analysis – Reflexw software

Survey grid
- Three line parallel to runway centreline – 1680 m long and 22 m apart
- 175 lines perpendicular to runway centreline – 45 m long and 10 m apart
- Four supplementary lines on grass east and west of runway
Ground Penetrating Radar (GPR) – basics
- Two antenna – transmitter and receiver
- Control console and computer for real time graphic display
- Transmitter emits electromagnetic energy
- Emitted waves are reflected back and recorded by the receiver
- Waves are reflected at abrupt changes in subsurface material
- Time between the transmitted and received wave indicates depth of change in material
CHURCHILL FALLS AIRPORT

GPR results
- Verified against AMEC and JW reports findings and Golder’s test pits
- Produce a bedrock contour map
- Difficult to delineate due to fractured bedrock and presence of cobbles and boulders
- Bedrock depth ranged from 0.5 to 2.85 m

Laboratory results
- Base and subbase material generally within Transport Canada ASG-06 envelope
- Base and subbase material was relatively clean with low percent passing 75µm sieve
- High and variable silt and clay content for subgrade material from 20 to 60 percent

Groundwater
- Water infiltration in 2 pavement test pits and 2 shoulder test pits
- Water level ranging from 0.6 to 2.0 m
- Water generally at bedrock level
Summary of existing pavement condition

- Heavily distressed pavement including high severity cracking and frost heaving
- Crack repairs carried out in 2010 were severely deteriorated
- Highly frost susceptible subgrade soils with large cobbles and boulder
- Deep frost penetration depth of up to 3 m
- Undulating and shallow bedrock and groundwater
- Good quality existing granular material

Pavement designs – initially 4 alternatives

  - Verified using FAA and ICAO methodologies

Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tr>
<td>Air Freezing Index</td>
<td>2677 °C-days</td>
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<tr>
<td>Subgrade Bearing Strength, S</td>
<td>65 kN</td>
</tr>
<tr>
<td>Aircraft Load Rating (ALR)</td>
<td>9</td>
</tr>
<tr>
<td>Tire Pressure</td>
<td>&gt; 1 MPa</td>
</tr>
</tbody>
</table>

- Required equivalent granular thickness 105 cm
- Frost penetration 3.0 m
- Marginal landing of ALR 11 aircraft required
**CHURCHILL FALLS AIRPORT - DESIGN**

- **Alternative 1**
  - Reconstruction without grade raise
    - 10 cm new HMA
    - 30 cm granular base
    - 60 cm subbase
  - Design life 15 years
  - Sequence
    - Remove existing pavement to a depth of 1.0 m
    - Install sub-drains
    - Place subbase, base and HMA
  - Drainage – critical aspect
    - Deep sub-drains required

- **Alternative 2**
  - Reconstruction with 0.5 m grade raise
    - 10 cm new HMA
    - 30 cm granular base
    - 60 cm subbase
  - Design life 15 years
  - Sequence
    - Remove existing pavement to a depth of 0.5 m
    - Install sub-drains
    - Place subbase, base and HMA
  - Benefits
    - Reduced frost penetration into subgrade
    - Better protection against frost heaving
    - Shallower sub-drains required
Alternative 3

- Major rehabilitation with 0.5 m grade raise
  - Pulverize existing asphalt and mix 50/50 with existing granular base
  - Place 40 cm of new granular base
  - Place 10 cm of new HMA
- Design life 15 years
- Benefits
  - Similar to those of Alternative 2
  - Using reclaimed materials
  - Lower cost
  - Shallower sub-drains required

Alternative 4

- Pavement insulation and rehabilitation
- Design by Golder’s Alaska Office
- Design
  - 10 cm new HMA
  - 30 cm granular base
  - 15 cm subbase
  - 15 cm extruded polystyrene insulation
  - 45 cm subbase (pulverized asphalt and granular base)
- Allowed frost penetration into subgrade 200 to 230 mm
- Design life 18 years
Alternative 5

Requested by Transport Canada
Based on previous experience at CF
Design
- Localized repairs
- Mill entire thickness of asphalt
- Place 10 cm of new granular base
- Place 10 cm of new HMA
Design life about 10 years
Drainage – critical aspect
- Besides deep sub-drains granular base of good permeability required

Drainage
- Generally 0.5 m below the top of subgrade

<table>
<thead>
<tr>
<th>Option Number</th>
<th>Depth Below Existing Ground Surface</th>
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<tbody>
<tr>
<td>1</td>
<td>2.5</td>
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<tr>
<td>2</td>
<td>2.0</td>
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<tr>
<td>3</td>
<td>2.0</td>
</tr>
<tr>
<td>4</td>
<td>1.5</td>
</tr>
<tr>
<td>5</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Two longitudinal sub-drains along the N and S edges of pavement and the intercept ditch
Initially lateral subdrains considered but then eliminated due to potential for differential frost heave
Protection of new sub-drains against frost heave
Life Cycle Cost Analysis

- Alternative 4 the most reliable
- Alternative 3 more reliable than Alternative 5
- Alternative 5 has the lowest initial cost
- Alternative 5 selected for construction – there are concerns associated with it

<table>
<thead>
<tr>
<th>OPTIONS</th>
<th>STRATEGY DESCRIPTION</th>
<th>INITIAL COST</th>
<th>MAINT COST</th>
<th>LCC</th>
<th>RANKING</th>
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<tbody>
<tr>
<td>1</td>
<td>Reconstruction without Grade Raise</td>
<td>$15,875,237</td>
<td>$3,629,954</td>
<td>$19,505,191</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>Reconstruction with Grade Raise</td>
<td>$14,800,986</td>
<td>$3,368,205</td>
<td>$18,170,193</td>
<td>3</td>
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<tr>
<td>3</td>
<td>Major Pavement Rehabilitation with Drainage Improvement</td>
<td>$12,408,534</td>
<td>$3,418,436</td>
<td>$15,826,970</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Pavement Insulation and Rehabilitation</td>
<td>$10,113,920</td>
<td>$3,011,525</td>
<td>$13,125,453</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>Pavement Rehabilitation without Grade Raise</td>
<td>$10,063,654</td>
<td>$6,641,407</td>
<td>$16,705,061</td>
<td>2</td>
</tr>
</tbody>
</table>

Paving specifications

- Customized to meet local conditions
  - Aircraft loading – required strength
  - Surface texture
  - Available materials
  - Local experience
- Granular base material
  - 90% crushed, MicroDeval <25, LA <35
  - maximum 5% passing 75 µm sieve
- Asphalt paving
  - Durable asphalt mixes
  - Tight mat and joint compaction requirements
  - Paving in echelon using ShuttleBuggy
  - Infrared heaters
CHURCHILL FALLS AIRPORT - DESIGN

- Asphalt cement PG 52-40 PM
- Aggregate requirements

<table>
<thead>
<tr>
<th>Physical Test</th>
<th>Test Method</th>
<th>Requirement</th>
</tr>
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<tbody>
<tr>
<td>Los Angeles Abrasion - % Maximum (1)</td>
<td>ASTM C131</td>
<td>37</td>
</tr>
<tr>
<td>Absorption - % Maximum</td>
<td>ASTM C127</td>
<td>1.75</td>
</tr>
<tr>
<td>Magnesium Sulphate Soundness - 5 Cycles - % Maximum (2)</td>
<td>ASTM C88</td>
<td>12</td>
</tr>
<tr>
<td>Petrographic Number - Maximum</td>
<td>CSA A23.2-15A</td>
<td>135</td>
</tr>
<tr>
<td>Freeze-Thaw Test - 5 Cycles - Percent Maximum</td>
<td>CSA A23.2-24A</td>
<td>8</td>
</tr>
<tr>
<td>Crushed Particles - % Minimum (3)</td>
<td>ASTM D5821</td>
<td>90</td>
</tr>
<tr>
<td>Flat &amp; Elongated Particles - % Maximum (4)</td>
<td>ASTM D4791</td>
<td>20</td>
</tr>
<tr>
<td>Loss by Washing - % Maximum Pasing (5)</td>
<td>ASTM C117</td>
<td>1.75</td>
</tr>
<tr>
<td>Micro Deval - % Maximum</td>
<td>ASTM D6928</td>
<td>18</td>
</tr>
<tr>
<td>Clay Lumps - % Maximum</td>
<td>CSA A23.2-3A</td>
<td>1</td>
</tr>
<tr>
<td>Low Density Particles - % Maximum</td>
<td>CSA A23.2-4A</td>
<td>1</td>
</tr>
<tr>
<td>Friable or Silty Siltstone - % Maximum</td>
<td>CSA A23.2-15A</td>
<td>1</td>
</tr>
</tbody>
</table>

CHURCHILL FALLS AIRPORT - DESIGN

- Mix requirements
  - Gradation – modified TC based on NF/L experience

### Table 4 – Physical Properties of Asphalt Mixtures

<table>
<thead>
<tr>
<th>Physical Property</th>
<th>Surface Course</th>
<th>Binder Course</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum</td>
<td>Maximum</td>
</tr>
<tr>
<td>Asphalt Cement Content Percent</td>
<td>5.3</td>
<td>-</td>
</tr>
<tr>
<td>Marshall Stability N. at 60°C</td>
<td>10,000</td>
<td>-</td>
</tr>
<tr>
<td>Marshall Flow Index (mm)</td>
<td>2.5</td>
<td>4.25</td>
</tr>
<tr>
<td>Percent Air Voids (1)</td>
<td>2.5</td>
<td>4.5</td>
</tr>
<tr>
<td>Target Percent Air Voids (1)</td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td>Percent Voids in Compacted Mineral Aggregate</td>
<td>15</td>
<td>-</td>
</tr>
<tr>
<td>Modified Lottman AASHTO T283 - Tensile Strength Ratio</td>
<td>0.8</td>
<td>-</td>
</tr>
<tr>
<td>Moisture Content of Hot-Mix Asphalt by Oven Method, AASHTO T329 as Percent of HMA</td>
<td>-</td>
<td>0.3</td>
</tr>
</tbody>
</table>
CHURCHILL FALLS AIRPORT - DESIGN

- QA to verify QC
- Acceptable, borderline and rejectable zones
- HMA acceptance
  - Asphalt cement content
  - Gradation
  - Air voids
  - Filed compaction
  - Joint compaction
  - Smoothness
  - (Marshall stability and flow – no payment items)

CHURCHILL FALLS AIRPORT - CONSTRUCTION

- QC results
  - Granular base

<table>
<thead>
<tr>
<th>Physical Test</th>
<th>Result</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Los Angeles Abrasion, %</td>
<td>19.9</td>
<td>&lt; 35 %</td>
</tr>
<tr>
<td>Percent Crushed, %</td>
<td>98.8</td>
<td>&gt; 90 %</td>
</tr>
<tr>
<td>Plasticity Index</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Petrographic Number</td>
<td>136°</td>
<td>&lt; 150</td>
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<tr>
<td>Micro-Deval – Coarse, %</td>
<td>6.1</td>
<td>&lt; 25</td>
</tr>
<tr>
<td>Micro-Deval – Fine, %</td>
<td>13.8</td>
<td>&lt; 30</td>
</tr>
</tbody>
</table>

- HMA aggregates

<table>
<thead>
<tr>
<th>Coarse Aggregate</th>
<th>1/2&quot; Stone</th>
<th>3/4&quot;</th>
<th>Surface Specifications</th>
<th>Base Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Los Angeles Abrasion, %</td>
<td>19.9</td>
<td>21.8</td>
<td>&lt; 27</td>
<td>&lt; 27</td>
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<tr>
<td>Specific Gravity</td>
<td>2.596</td>
<td>2.595</td>
<td></td>
<td></td>
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<tr>
<td>Absorption, %</td>
<td>0.804</td>
<td>0.560</td>
<td>&lt; 1.75</td>
<td>&lt; 2</td>
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<tr>
<td>Soundness, %</td>
<td>&lt; 1</td>
<td>&lt; 1</td>
<td>&lt; 12</td>
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<td>Petrographic Number</td>
<td>In Progress</td>
<td></td>
<td>&lt; 135</td>
<td>&lt; 135</td>
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<tr>
<td>Freeze-Thaw 5 cycles</td>
<td>7.2</td>
<td>In Progress</td>
<td>&lt; 8</td>
<td>&lt; 10</td>
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<tr>
<td>Crushed Particles, %</td>
<td>100.0</td>
<td>100.0</td>
<td>&gt; 90</td>
<td>&gt; 90</td>
</tr>
<tr>
<td>Fine &amp; Elongated Particles, %</td>
<td>4.2</td>
<td>6.2</td>
<td>&lt; 20</td>
<td>&lt; 20</td>
</tr>
<tr>
<td>Loss by Washing, %</td>
<td>1.1</td>
<td>1.0</td>
<td>&lt; 1.75</td>
<td>&lt; 1.75</td>
</tr>
<tr>
<td>Micro-Deval, % Losses</td>
<td>7.4</td>
<td>9.2</td>
<td>&lt; 18</td>
<td>&lt; 18</td>
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<tr>
<td>Clay Lumps, %</td>
<td>0</td>
<td>0</td>
<td>&lt; 1</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>Low Density Particles, %</td>
<td>0</td>
<td>0</td>
<td>&lt; 1</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>Flakes or Flaky Shatter, %</td>
<td>0</td>
<td>0</td>
<td>&lt; 1</td>
<td>&lt; 1</td>
</tr>
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</table>
# Churchill Falls Airport - Construction

## QC - HMA

### Surface Course

<table>
<thead>
<tr>
<th>Aggregate Source</th>
<th>Aggregate Type</th>
<th>Aggregate Percent</th>
<th>Specific Gravity</th>
<th>Avg. Acres/ft²</th>
<th>Cumulative Percent Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>26000</td>
<td>100, 190, 280, 4700, 6200, 8200, 12,000, 150, 75</td>
</tr>
</tbody>
</table>

### Marshall Properties

<table>
<thead>
<tr>
<th>Trial</th>
<th>AC, %</th>
<th>Air Voids, %</th>
<th>VMA, %</th>
<th>Stability, %</th>
<th>Flow, mm</th>
<th>Bulk Density (kg/m³)</th>
<th>Max. Density (kg/m³)</th>
<th>Absorption, %</th>
<th>Film Thickness, mm</th>
<th>Druce Rate, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.9</td>
<td>4.8</td>
<td>18.3</td>
<td>18.6</td>
<td>5.3</td>
<td>2279</td>
<td>2477</td>
<td>0.65</td>
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<th>Max. Density (kg/m³)</th>
<th>Absorption, %</th>
<th>Film Thickness, mm</th>
<th>Druce Rate, %</th>
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<tbody>
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<td>5.9</td>
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<td>2500</td>
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<td></td>
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</tbody>
</table>

## Churchill Falls Airport - Construction

- Sub-drains construction
- Extensive rock cutting
- Large volume of excavation
Granular materials and aggregate production

Granular materials and aggregate production
CHURCHILL FALLS AIRPORT - CONSTRUCTION

- HMA production

Granular base
- Generally good
- Localized segregation
Material hauling issue
- Long distance
- Gravel roads – dust

Paving in echelon using a ShuttleBuggy
CHURCHILL FALLS AIRPORT - CONSTRUCTION

- HMA mat paved in echelon

CHURCHILL FALLS AIRPORT - CONSTRUCTION

- Using millings for shoulders
CHURCHILL FALLS AIRPORT - CONSTRUCTION

- QC issues
  - Initial mix production
  - QC/QA initial correlation
  - Extraction/gradation versus ignition oven
  - Marshall stability and laboratory air voids

CHURCHILL FALLS AIRPORT - CONSTRUCTION

- Construction completed successfully in September 2012
LESSONS LEARNED

- Projects in the North
  - Be aware of challenges
  - Experience is critical
  - Team work
  - Insist on quality
  - Identify and solve issues early
  - Be open to innovations
  - The cheapest solutions may not always be the best for long term performance
THANK YOU!

QUESTIONS?

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