SWIFT CALGARY 2012

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

Ludomir Uzarowski, Ph.D., P.Eng. and Rabiah Rizvi, B.A.Sc.,
Pavement and Materials, Golder Associates Ltd., Ontario

Golder Associates

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.**

Golder Associates

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

Golder Associates

CHURCHILL FALLS AIRPORT

Golder Associates

CHURCHILL FALLS AIRPORT

- 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

Golder Associates

CHURCHILL FALLS AIRPORT

- Initial scope of work
  - Review existing information
  - Visual condition inspection
  - Indentify locations for immediate repair
  - Develop rehabilitation alternatives
  - Life cycle cost analysis
  - Drainage recommendations
- Additional Work
  - Limited geotechnical investigation
  - Geophysical survey using GPR

Golder Associates

CHURCHILL FALLS AIRPORT

- 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

Golder Associates

CHURCHILL FALLS AIRPORT

- 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

Golder Associates

CHURCHILL FALLS AIRPORT

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 Associates

CHURCHILL FALLS AIRPORT

- **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

Test Pit ID	Layer Thickness (mm)		
	Asphalt	Granular Base	Granular Subbase
TP7	170	190	505
TP8	185	245	560
TP9	155	245	490
TP10	195	165	520
Average	176	211	519

Golder Associates

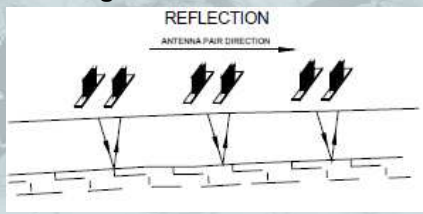
CHURCHILL FALLS AIRPORT

CHURCHILL FALLS AIRPORT

- 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

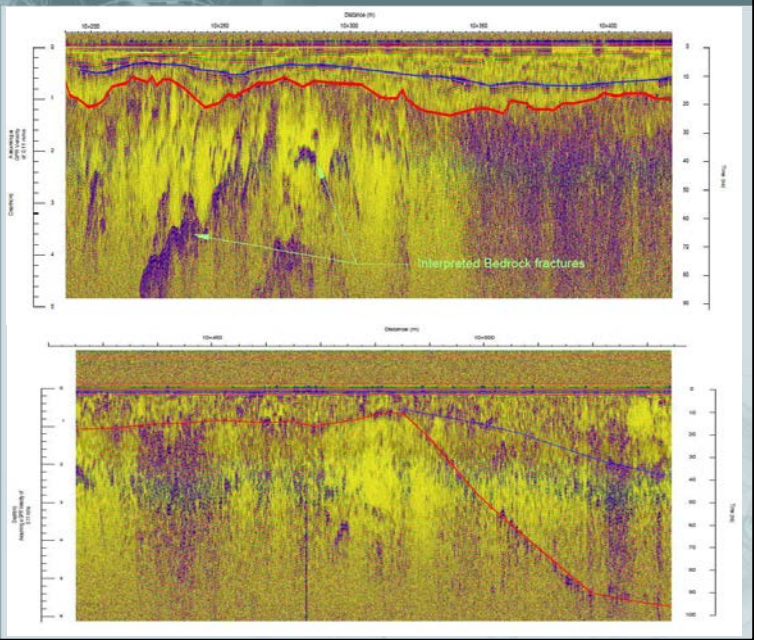
CHURCHILL FALLS AIRPORT

- **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**



Golder Associates

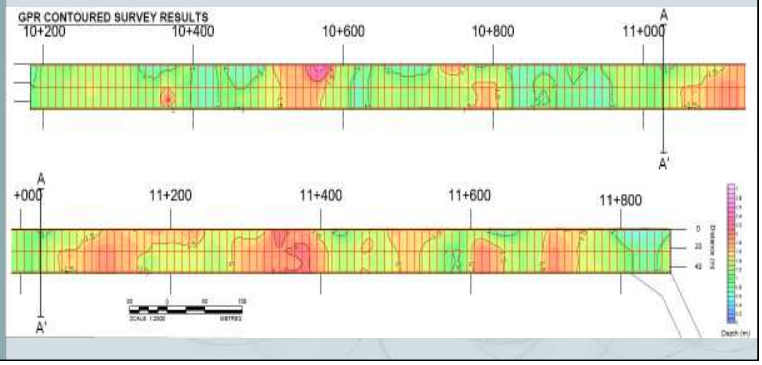
CHURCHILL FALLS AIRPORT



Golder Associates

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



Golder Associates

CHURCHILL FALLS AIRPORT

- **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

Golder Associates

CHURCHILL FALLS AIRPORT

- **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**

Golder Associates

CHURCHILL FALLS AIRPORT - DESIGN

- **Pavement designs – initially 4 alternatives**
- **TC/PWGSC "Manual of Pavement Structural Design ASG-19"**
  - **Verified using FAA and ICAO methodologies**
- **Parameters**

Parameter	Value
Air Freezing Index	2677 °C-days
Subgrade Bearing Strength, S	65 kN
Aircraft Load Rating (ALR)	9
Tire Pressure	> 1 MPa

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

Golder Associates

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

Golder Associates

CHURCHILL FALLS AIRPORT - DESIGN

- **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

Golder Associates

CHURCHILL FALLS AIRPORT - DESIGN

- **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

Golder Associates

CHURCHILL FALLS AIRPORT - DESIGN

- **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**

Golder Associates

CHURCHILL FALLS AIRPORT - DESIGN

- **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

Golder Associates

CHURCHILL FALLS AIRPORT - DESIGN

- Drainage
  - Generally 0.5 m below the top of subgrade

Table 12: Recommended Sub-Drain Depth below the Ground Surface

Option Number	Depth Below Existing Ground Surface
1	2.5
2	2.0
3	2.0
4	1.5
5	2.5

- 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

Golder Associates

CHURCHILL FALLS AIRPORT - DESIGN

- Life Cycle Cost Analysis

OPTIONS	STRATEGY DESCRIPTION	INITIAL COST	MAIN'T COST	LCC	RANKING
1	Reconstruction without Grade Raise	$15,875,237	$3,629,954	$19,505,191	4
2	Reconstruction with Grade Raise	$14,800,988	$3,369,205	$18,170,193	3
3	Major Pavement Rehabilitation with Drainage Improvement	$12,408,534	$3,418,436	$15,826,970	1
4	Pavement Insulation and Rehabilitation	$18,113,928	$3,011,525	$21,125,453	5
5	Pavement Rehabilitation without Grade Raise	$10,063,654	$6,641,407	$16,705,061	2

- 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

Golder Associates

CHURCHILL FALLS AIRPORT - DESIGN

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

Golder Associates

CHURCHILL FALLS AIRPORT - DESIGN

- **Asphalt cement PG 52-40 PM**
- **Aggregate requirements**

Physical Test	Test Method	Requirement	
		Surface Course	Base Course
Los Angeles Abrasion - % Maximum (1)	ASTM C131	37	37
Absorption - % Maximum	ASTM C127	1.75	2
Magnesium Sulphate Soundness - 5 Cycles - % Maximum (2)	ASTM C88	12	12
Petrographic Number - Maximum	CSA A23.2-15A	135	135
Freeze-Thaw Test - 5 Cycles - Percent Maximum	CSA A23.2-24A	8	10
Crushed Particles - % Minimum (3)	ASTM D5821	90	90
Flat & Elongated Particles - % Maximum (4)	ASTM D4791	20	20
Loss by Washing - % Maximum Passing (5)	ASTM C117	1.75	1.75
Micro Deval - % Maximum	ASTM D6928	18	18
Clay Lumps - % Maximum	CSA A23.2-3A	1	1
Low Density Particles - % Maximum	CSA A23.2-4A	1	1
Friable or Slatey Siltstone - % Maximum	CSA A23.2-15A	1	1

Golder Associates

CHURCHILL FALLS AIRPORT - DESIGN

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

Table 4 – Physical Properties of Asphalt Mixtures

Physical Property	Surface Course		Binder Course	
	Minimum	Maximum	Minimum	Maximum
Asphalt Cement Content Percent	5.3	-	5.0	-
Marshall Stability N. at 60C	10,000	-	9,000	-
Marshall Flow Index (mm)	2.5	4.25	2.5	4.25
Percent Air Voids (1)	2.5	4.5	3.0	5.0
Target Percent Air Voids (1)	3.5		4.0	
Percent Voids in Compacted Mineral Aggregate	15	-	14	-
Modified Lottman AASHTO T283 - Tensile Strength Ratio	0.8	-	0.8	-
Moisture Content of Hot-Mix Asphalt by Oven Method, AASHTO T329 as Percent of HMA	-	0.3	-	0.3

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

Physical Test	Result	Specifications
Los Angeles Abrasion	19.5 %	< 35 %
Percent Crushed	98.8 %	> 90 %
Plasticity Index	0	0
Petrographic Number	136[1]	< 150
Micro-Deval – Coarse	6.1 %	< 25
Micro-Deval - Fine	13.8 %	< 30

  - HMA aggregates

Coarse Aggregate	1/2" Stone	3/4"	Surface Specifications	Base Specifications
Los Angeles Abrasion, %	19.0	21.8	< 37	< 37
Specific Gravity	2.696	2.698		
Absorption, %	0.604	0.560	< 1.75	< 2
Soundness, %	< 1	< 1	< 12	< 12
Petrographic Number	134	*In Progress*	< 135	< 135
Freeze-Thaw 5 cycles	7.2	*In Progress*	< 8	< 10
Crushed Particles, %	100.0	100.0	> 90	> 90
Flat & Elongated Particles, %	4.2	6.2	< 20	< 20
Loss by Washing, %	1.1	1.0	< 1.75	< 1.75
Micro-Deval, % Loss	7.4	6.2	< 18	< 18
Clay Lumps, %	0	0	< 1	< 1
Low Density Particles, %	0	0	< 1	< 1
Friable or Slatey Siltstone, %	0	0	< 1	< 1

CHURCHILL FALLS AIRPORT - CONSTRUCTION

- **QC - HMA**
  - **Surface course**

Aggregate Source	Aggregate Type	Aggregate Percent	Specific Gravity	Agg Absorp.	Cumulative Percent Passing								
					25000	19000	12500	9500	4750	2000	425	150	75
Combined Aggregate Characteristics			2.684	0.89		100	96.7	87.7	67.6	42.7	16.4	8.7	5.7
Churchill Falls Airport Gradation Specification					100		93-100		55-75	35-55	15-30	5-20	3-8

Marshall Properties

Trial Number	AC, %	Air Voids, %	VMA, %	Stability, kN	Flow, mm	Bulk Density (kg/m^3)	Max. Density (kg/m^3)	Absorption, %	Film Thickness, µm	Dust Ratio
Selected	5.9	4.0	16.3	10.6	3.3	2379	2477	0.65	8.4	1.09
Specification		2.5 - 4.5	> 15.0	> 10.0	2.5-4.25					0.6-1.2

  - **Base course**

Aggregate Source	Aggregate Type	Aggregate Percent	Specific Gravity	Agg Absorp.	Cumulative Percent Passing								
					25000	19000	12500	9500	4750	2000	425	150	75
Combined Aggregate Characteristics			2.688	0.84		100	84.8	75.3	55.8	36.7	15.1	8.3	5.4
Churchill Falls Airport Gradation Specification					100		70-85		40-65	20-42	15-30	5-20	3-8

Marshall Properties

Trial Number	AC, %	Air Voids, %	VMA, %	Stability, kN	Flow, mm	Bulk Density (kg/m^3)	Max. Density (kg/m^3)	Absorption, %	Film Thickness, µm	Dust Ratio
Selected	5.4	3.6	14.7	9.5	2.7	2416	2506	0.76	8.1	1.17
Specification		3.0 - 5.0	> 14.0	> 9.0	2.5-4.25					0.6-1.2

Golder Associates

CHURCHILL FALLS AIRPORT - CONSTRUCTION

- **Sub-drains construction**
  - **Extensive rock cutting**
  - **Large volume of excavation**

CHURCHILL FALLS AIRPORT - CONSTRUCTION

- Granular materials and aggregate production

Golder Associates

CHURCHILL FALLS AIRPORT - CONSTRUCTION

- Granular materials and aggregate production

Golder Associates

CHURCHILL FALLS AIRPORT - CONSTRUCTION

- HMA production

Golder Associates

CHURCHILL FALLS AIRPORT - CONSTRUCTION

- Granular base
  - Generally good
  - Localized segregation

Golder Associates

CHURCHILL FALLS AIRPORT - CONSTRUCTION

- Material hauling issue
  - Long distance
  - Gravel roads – dust

CHURCHILL FALLS AIRPORT - CONSTRUCTION

- 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

Golder Associates

CHURCHILL FALLS AIRPORT - CONSTRUCTION

- Construction completed successfully in September 2012

Golder Associates

CHURCHILL FALLS AIRPORT - CONSTRUCTION

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 ?
luzarowski@golder.com
rrizvi@golder.com