PERFORMANCE REVIEW OF THE LIGHT-COLOURED PAVEMENT OF THE 2009 FRONT STREET PROJECT IN DAWSON CITY, YUKON

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• Mr. Francois Chaignon of Colas S.A.
OUTLINE

• Introduction
• Thermal modeling
• Pavement design
• Pavement construction
• Monitoring and evaluation
• Development of synthetic binder in Canada
• Conclusions
Front Street from km 713.9 – km 716.0 Klondike Highway #2 in Dawson City, Yukon.

1898 Klondike Gold Rush.

Dawson City Historical Complex National Historic Site

By 2008 the Bituminous Surface Treatment (BST) had 30 year service life.

Project must:

- Satisfy historical requirements of community.

- Protect permafrost from projected surface temperature increase.
THERMAL MODELING

• Dawson City in an area of discontinuous and warm permafrost with high ice contents and temperatures ranging from -1.0 degree C to 0.1 degrees C.
• Solar radiation absorbed at the surface is converted into heat.
• Kryotek Arctic Innovation used Alaska DOT geothermal modeling system to predict thaw depths for the 2009-2029 period.
• Predicted no increase of thaw depth for gravel and up to 2.4 to 3.5m for black surface.
• Low solar radiation absorbing surfacing system recommended.
PAVEMENT DESIGN- PAVEMENT OPTIONS

• Chip Seal / BST system.
  • Yukon has experience
  • Vast low volume road network with BST.
  • Concerns with scuffing, dust and tracking.

• Sprinkle Treatment.
  • Embedded chips in freshly laid asphalt.
  • Primarily to enhance road friction.
  • Concerns with snow plow damage.

• Coloured Paving Material.
  • Multiple petroleum based synthetic binders available.
  • Produces various colours of surface systems.
PAVEMENT DESIGN- BACKGROUND AND CONSTRAINTS

- Dawson City built hastily in 1898.
- Poor Drainage and Grade limitations caused by building elevation and dyke.
- No curb and gutter.
- Keep surface water from ingressing to permafrost critical.
- Utilize existing storm water system.
- 100mm Hot Mix Asphalt structure.
• Traditional asphalt binders with organic pigments to produce colour.

• Bituclair one of the petroleum based synthetic binders which is translucent in thin films.

• Three existing Bituclair binders (ranging from 94 to 163 penetration grade) were studied to formulate to the required Performance Grade target of PG 58-40.

• Formulation developed to meet PG 52 as high grade and PG -39 as the low grade.
PAVEMENT DESIGN- BINDER SELECTION

- Binder manufactured at the Colas Midi-Mediterranean facility in Vitrolles, France.
- Transported in 20 tonne bitutainers.
- Bitutainers reheated at the plant site.
Table 1. Aggregate Properties

<table>
<thead>
<tr>
<th>Test</th>
<th>ASTM Procedure</th>
<th>Yukon Government Specification</th>
<th>Test Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Petrographic Analysis</td>
<td></td>
<td>Coarse Agg. ≤ 25</td>
<td>111</td>
</tr>
<tr>
<td>Los Angeles Abrasion, Gradation B Max %</td>
<td>ASTM C 131</td>
<td>Fine Agg. - n/a</td>
<td>18.6</td>
</tr>
<tr>
<td>Magnesium Sulphate Soundness</td>
<td>ASTM C88</td>
<td>Coarse Agg. ≤ 12</td>
<td>8</td>
</tr>
<tr>
<td>Max % loss</td>
<td></td>
<td>Fine Agg. &lt; 16</td>
<td>10</td>
</tr>
<tr>
<td>Sand Equivalent</td>
<td>ASTM D2419</td>
<td>Coarse Agg. - n/a</td>
<td>60</td>
</tr>
<tr>
<td>Minimum</td>
<td></td>
<td>Fine Agg. &gt; 35</td>
<td></td>
</tr>
<tr>
<td>Light Weight Particles (specific gravity</td>
<td>ASTM C123</td>
<td>Coarse Agg. ≤ 1.5</td>
<td>0</td>
</tr>
<tr>
<td>less than 1.95) Max % mass</td>
<td></td>
<td>Fine Agg. - n/a</td>
<td></td>
</tr>
<tr>
<td>Flat &amp; Elongated Particles ratio</td>
<td></td>
<td>Coarse Agg. ≤ 15</td>
<td>4</td>
</tr>
<tr>
<td>Greater than 5:1</td>
<td></td>
<td>Fine Agg. - n/a</td>
<td></td>
</tr>
<tr>
<td>Max % by Mass</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plasticity Index</td>
<td>ASTM D424</td>
<td>Coarse Agg. - n/a</td>
<td>Non plastic</td>
</tr>
<tr>
<td>Maximum</td>
<td></td>
<td>Fine Agg. &lt; 4</td>
<td></td>
</tr>
</tbody>
</table>

- No previous Hot Mix Asphalt had been constructed in Dawson City, Yukon.
- Aggregate source was the tailings stockpile left from the 1900’s gold dredges.
- Petrographic Analysis indicated Basalt and aggregate properties confirmed suitability.
- Bottom 75mm Lift material produced to Yukon 12.5mm dense graded specification.
- Top 25mm lift Nominal Maximum Aggregate Size of 4.75mm.
- Superpave 4.75 and MTQ ESG-5 grading specifications utilized.
- Produced 2.5/5mm and 0/2.5mm materials.
PAVEMENT DESIGN- MIX DESIGN

• Mix design to Asphalt Institute MS-2 Manual for Marshall Mixes.

• Yukon Government HMA Specifications.

Consideration:

1. Mix Performance for low volume roads.
2. Dense graded mixture.
3. Air Voids of 3.2%.
4. 6.4% asphalt cement.
5. Volume of effective asphalt binder of 11.7.

The mix design for the light-coloured paving material was developed using the guidelines provided in the Asphalt Institute MS-2 Manual [6]. Mix properties are provided in Table 4.

<table>
<thead>
<tr>
<th>50 Blow Marshall</th>
<th>Mix Design</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Binder Specific Gravity</td>
<td>1.000</td>
<td>--</td>
</tr>
<tr>
<td>Binder absorption combined aggregate</td>
<td>1.16</td>
<td>--</td>
</tr>
<tr>
<td>Bulk Specific Gravity of combined aggregate</td>
<td>2.629</td>
<td>--</td>
</tr>
<tr>
<td>Binder content</td>
<td>6.4% by dry agg.</td>
<td>--</td>
</tr>
<tr>
<td>Percent air voids</td>
<td>3.2</td>
<td>3.0 – 5.0</td>
</tr>
<tr>
<td>Percent Voids in Mineral Aggregate (VMA)</td>
<td>14.9</td>
<td>Min 14.0</td>
</tr>
<tr>
<td>Percent Voids Filled with Asphalt (VFA)</td>
<td>78.3</td>
<td>65-78</td>
</tr>
<tr>
<td>Percent effective asphalt content</td>
<td>4.9</td>
<td>--</td>
</tr>
<tr>
<td>Binder film thickness</td>
<td>6.6</td>
<td>--</td>
</tr>
<tr>
<td>Dust to binder ratio</td>
<td>1.5</td>
<td>0.9-2.0</td>
</tr>
</tbody>
</table>
Consideration:

2. Albedo/reflectivity.

- Colour of the aggregate skeleton.
- Mineral filler Titanium Dioxide chosen for heat resistance.
- Titanium Dioxide dosed to lighten the final colour.

Colour Tones of the Various Percentages of Titanium Dioxide Addition
PAVEMENT CONSTRUCTION – EQUIPMENT PREPARATION

• Parallel Flow Continuous Drum Mixer available for project.
• Residual black components cleaned.
• System added at the plant to introduce titanium dioxide.
• Asphalt pump and associated piping changed.
• Hot Aggregate and trial batch used for final removal of black residue.
• Quality management plan identified cleaning of the trucks, plant, pavers, rollers, hand tools and even new boots for the crew.
PAVEMENT CONSTRUCTION – BASE PREPARATION

- Final site grading
- 75mm Base lift of conventional Hot Mix Asphalt
• CRS-1P Bond Coat
• Bond Coat applied at rate of 300g/m² of residual binder.
PAVEMENT CONSTRUCTION – PAVING

• Test strip:
  • Potential maintenance material.
  • Allow calibration of the plant and crew for required placement procedures.
  • Compaction achieved with a double steel vibratory roller.
  • No workability issues.
GROUND VIEW OF FRONT STREET, DAWSON CITY, YUKON, SEPTEMBER 2009

AERIAL VIEW OF FRONT STREET, DAWSON CITY, YUKON, SEPTEMBER 2009
MONITORING AND EVALUATION – PAVEMENT CONDITION

- Annual inspections.
- Visual pavement condition record established to monitor surface condition, subsurface condition, drainage, deterioration, distortion and riding comfort,
- Pavement Rating System for Low Volume Asphalt Roads from the Asphalt Institute adequate for this project.

Figure 5. Front Street Pavement Condition as of May, 2015.
Geothermal Modeling predicted the impact of surfacing materials on the quantity of heat transferred to deeper soil strata.

The Predicted Mean Annual Surface Temperature (MAST) would stay constant with gravel and increase by 3 degrees over 10 years with a black surface.

The albedo or solar reflectance of a surface is defined as the ratio of the reflected to incident solar light.

- A perfect reflector has an albedo of 1,
- a surface that has no reflectance has an albedo of 0.

The albedo for the existing gravel road network was not available in the planning phase of the project.

Assessment of light coloured pavement indicated a solar reflectance or albedo of 0.22 for a fully coated specimen and an albedo of 0.27 for saw cut surfaces.
MONITORING AND EVALUATION – GEOTHERMAL MODELING AND SURFACE ALBEDO

2013 field measurements of the solar reflectance or albedo was found to be between 0.21 and 0.25 while the albedo of the surrounding gravel surfaces was found to be between 0.17 and 0.21.
DEVELOPMENT OF SYNTHETIC BINDER IN CANADA – USES IN CANADA

• Synthetic Binders have been used throughout Europe for several decades.

• Light –coloured pavement provides a high albedo surface useful for maintaining low heat absorption which can protect permafrost.

• Lower heat absorption will reduce surface temperature of pavement.
DEVELOPMENT OF SYNTHETIC BINDER IN CANADA

• Difficult logistics and high cost to deliver the light coloured binder to North America.

• Gecan and the Colas S.A. Research Centre (CST) were tasked with finding the resource materials in North America to formulate various performance grades of synthetic binders and emulsion.
DEVELOPMENT OF SYNTHETIC BINDER IN CANADA

• Local components met technical properties.
• Produced dark amber brown binders instead of the traditional Bituclair golden colour.
• The performance graded synthetic binders developed were based on the common binder used in Canada for PG 64-28, PG 58-28 and PG 58-34.
• Developed Emulsion grade.
• Paving material mix design work was performed to confirm the production of coloured pavement.
DEVELOPMENT OF SYNTHETIC BINDER IN CANADA – DEVELOPING PERFORMANCE GRADE SYNTHETIC BINDERS

Coloured Paving Materials (Red and Beige) Produced with North American Sourced Components
DEVELOPMENT OF SYNTHETIC BINDER IN CANADA

Coloured Slurry Produced with North American Sourced Components – 2015 trial
BITUCLAIR SEALCOAT
BEAVER CREEK TEST SECTION 2016
CONCLUSIONS

1. The paving of Front Street in Dawson City was a unique project with technical and construction challenges.

2. The performance review of the light-coloured pavement indicates that the objectives set forward by the Yukon Government have been met in terms of albedo to protect underlying permafrost and also maintain frontier aspect of Dawson City.

3. The project in Dawson City provided evidence that light-coloured pavement provides a high albedo surface useful for maintaining lower heat absorption, lower pavement temperature and increasing pavement performance.

4. The laboratory work carried out by Gecan indicate it is possible to manufacture synthetic binders with North American components that meet conventional PG formulations.