Stabilized Roadways
26th Regional Local Road Conference
Rapid City, South Dakota
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Steve Monlux, LVR Consultants, Missoula, MT
Outline

• Richland Co Background Information
• Approach to Solution
• Alternatives Considered
• 2009 & 2010 ~ Trial Sections
• 2011 ~ 25 Mile Project
• Summary
• Richland Co Task Force
County 2008 Mission

• Ensure Public Safety on Road System
• Meet Public Expectations
• Address air quality and DEQ concerns
• Adhere to GRAVEL stewardship for the next generations
• Find surfacing alternatives with better cost/benefit
The Problem

• Heavy Truck Traffic on Weak Soil Roads
• Extensive Road Network
• Limited Budget
• Limited Rock Resources
Local Standard

• 5” Asphalt, 8” Base Gravel
• 4” Gravel (New construction)
• Spot Graveling

(Haul 90 to 110,000 cy / year)
Weak Soils (CBR= 3 or 4 typical)

5” Asphalt, + 6” Base (15 yrs old)

3” Scoria, old gravel base (after 3 months)
Richland Co Road Network & Resource Impacts

- Oil Development, Wheat, Gravel Roads
- Missouri River
- Richland County Border
- Population Center, Beet Farms, Gravel
- Montana
- North Dakota
- Yellowstone River
- 56 mi
Road Network Miles & ADT

• Function Class Miles: 1132 (341 Bus Routes)
  Arterials: 86
  Major/Minor Coll: 232
  Local: 701
  Trails: 113

• CI Plan: Collectors (with) Bus Routes = 131.2 mi
  : Improve 20-25 mi. / year

• Truck Traffic
  – Ag Traffic: Beets (Sept & Oct), Cattle, & Grain hauling
  – Oil Field:
    • Well development: 1200 trucks over 3 months (each well)
    • Crude & Water Haul: 3 to 5 trucks/day for 25 years
Structural Thickness Design

Gravel Thicknesses are based on:
* Soil Strengths
* Truck Traffic
* AASHTO 93 Guide

For Example: Rd 127 had 71 Trucks per Day ~ Thickness required is 14

<table>
<thead>
<tr>
<th>Soil Strength</th>
<th>Excellent</th>
<th>Good</th>
<th>Fair</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4</td>
<td>7</td>
<td>9</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>9</td>
<td>12</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>12</td>
<td>16</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>16</td>
<td>20</td>
<td>24</td>
</tr>
<tr>
<td>Trucks/Day</td>
<td>50</td>
<td>100</td>
<td>150</td>
<td>200</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Risk</th>
<th>Factor, %</th>
<th>Route Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>60%</td>
<td>Feeders, detour route available</td>
</tr>
<tr>
<td>Moderate</td>
<td>80%</td>
<td>Collectors, detour route available</td>
</tr>
<tr>
<td>High</td>
<td>100%</td>
<td>Arterials, no detour, school bus routes</td>
</tr>
</tbody>
</table>

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Weak Clay Subgrade Soils

Soil Strength by DCP: CBR of 1 to 6

Thin gravel layers mix with clay

Gravel with Fabric & Geogrid too costly

Gravel with Fabric & Geogrid too costly

Standard Paving Design too costly

Gravel $ Too High

Hot Mix

Crushed Gravel

Fabric

Geogrid
Approach to Solution

• Outside Assistance
  – Construction Management Contract (Century Companies)
  – Engineering Consultants (Boesh, Monlux, Holman)

• Look at all alternatives and materials available

• 2009 & 2011 ~ Build trial sections & evaluate

• 2011 ~ Project level construction with performance monitoring plan (FWD).
2010 Alternatives ~ Structural Support

• Improve Subgrade
  – Increased Subgrade Compaction → minor benefit
  – Stabilization
    • Portland Cement → Lab mix designs promising
    • Fly Ash → Billings & Sidney fly ash had low strengths
    • Lime → Cement preferred for low Plasticity soils
    • Bottom Ash, Sugar Beet Lime, Enzymes, etc → unsure, inconsistent benefits

• Base Rock
  – Fabric → prevents clay contamination
  – Geogrid → unsure benefits with high truck traffic
  – BASE 1, Enzymes, etc → unsure, inconsistent benefits
Asphalt Alternatives

Traditional Flexible Pavement: Rd 328 (2006)

Thin BST ‘Pavements’

Gravel Base – 8 & 10” Thick, 2009-10

Fabric for Separation

Subgrade Soil

Double BST

Gravel Base with BASE 1, 4” treated thickness

Structural Layer

5” Hot Mix

9” Crushed Gravel Base

Subgrade Soil

Soil Cement, 8” thick, 5% Cement 2010)
2010 & 2011 Soil Cement Designs

<table>
<thead>
<tr>
<th></th>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Soil Cement</strong></td>
<td>Soil Cement,</td>
<td>Soil Cement,</td>
</tr>
<tr>
<td><strong>8” thick, 5%</strong></td>
<td>8” thick, 5% Cement</td>
<td>10” thick, 8% Cement</td>
</tr>
<tr>
<td><strong>Compressive Strength</strong></td>
<td>225 psi</td>
<td>300 psi</td>
</tr>
<tr>
<td><strong>Freeze Thaw Durability</strong></td>
<td>Marginal</td>
<td>Good</td>
</tr>
<tr>
<td><strong>Flexural Strength</strong></td>
<td></td>
<td>56% Increase</td>
</tr>
</tbody>
</table>
BST Surface on Gravel or Soil Cement?

**BST over 10” Gravel Base**

- $400,000/mile, $2/Truck (*)
- Water infiltration to Clay Subgrade is close to structural support area
- Edge cracking & break off mtc. problems

**BST over 8” Soil Cement**

- $250,000 /mile, $1/Truck (*)
- Harder support from soil cement reduces damage from large rock punctures, turning movements, etc
- Flatter wider shoulder is less of a hazard
- Wide impermeable shoulder keeps surface water further away from critical structure support area.

(*) Maintenance Cost ??
Thin vs. Thick Asphalt Layers

- Thin BST/Otta Seals (3/4” thick)
  - Lower costs for construction, maintenance, recycling & replacement
  - Suited for low traffic & cold climates ~ more flexible & less cracking
  - Good wear surface, no structural strength
  - Quick failure from overloads during thaw

- Thick Asphalt Pavements (>3” thick)
  - Stronger ~ supports greater loads
  - Cracks in cold climates

- Warning – Both thick & thin options must have good structural support and drainage
Rock Used for Double BST

5/8” & 3/8” Clean Chips

- Cost/Mile ≈ $75,000 (Double Shot with Fabric)
  - AC (PG-58-28): 0.85 gal/SY
  - MC-3000: 0.40 gal/SY:
  - Total Chip #:/SY: 45#/SY & 27#/SY

5/8” Gravel – Otta Seal

- Cost/Mile ≈ $60,000 (Double Shot)
  - Total HF 125S: 0.82 gal/SY
  - Total Gravel: 70#/SY
Double BST Options

Clean Chip BST

Otta Seal BST with Gravel
2011 Project ~ BST on Soil Cement

Structural Layer

Double BST Otta Seal
(HFE 125S with 5/8” Gravel)

21 miles

Double BST With Chips on Fabric

4 miles

PG 58-28 Tack for Fabric
PG 58-28 with 5/8” Chips
MC 3000 with 3/8” Chips

Clay Subgrade

Soil Cement (8%, 10 inch)


## Otta Seal Materials Specs

### High Float Emulsion Spec (5-4-2011)

<table>
<thead>
<tr>
<th>Requirement</th>
<th>HF125S (Note A)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tests on Emulsion</strong></td>
<td>Min</td>
</tr>
<tr>
<td>Viscosity, Saybolt Furol, Seconds at 50°C</td>
<td>35</td>
</tr>
<tr>
<td>Residue by Distillation, % by Mass</td>
<td>65</td>
</tr>
<tr>
<td>Demulsibility, %, 50 ml 0.1 N CaCl₂</td>
<td>75</td>
</tr>
<tr>
<td>Oil Portion of Distillate, volume/Mass, %</td>
<td>1.0</td>
</tr>
<tr>
<td>Sieve Test, % by Mass</td>
<td>0.1</td>
</tr>
<tr>
<td>Storage Stability Test, 24 hr, % by Mass</td>
<td>1</td>
</tr>
<tr>
<td>Coating Test</td>
<td>Note B</td>
</tr>
<tr>
<td>Coating ability &amp; water resistance ASTM D244:</td>
<td></td>
</tr>
<tr>
<td>Coating, dry aggregate</td>
<td>good</td>
</tr>
<tr>
<td>Coating, after spraying</td>
<td>fair</td>
</tr>
<tr>
<td>Coating, wet aggregate</td>
<td>fair</td>
</tr>
<tr>
<td>Coating, after spraying</td>
<td>fair</td>
</tr>
</tbody>
</table>

| Adhesion Agent, % by Weight of Residue | Note C |

### Proposed Gradation Limits (5-4-2011)

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Richland Co Spec</th>
<th>MN Otto Seal Spec</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/4&quot;</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>5/8&quot;</td>
<td>82</td>
<td>100</td>
</tr>
<tr>
<td>3/8&quot;</td>
<td>64</td>
<td>76</td>
</tr>
<tr>
<td>#4</td>
<td>48</td>
<td>67</td>
</tr>
<tr>
<td>#16</td>
<td>23</td>
<td>38</td>
</tr>
<tr>
<td>#40</td>
<td>11</td>
<td>26</td>
</tr>
<tr>
<td>#200</td>
<td>4</td>
<td>10</td>
</tr>
</tbody>
</table>

Note A: Certificate of Compliance and test reports are required.

Note B: Follow ASTM D244, except that the mixture of limestone and emulsified asphalt shall be capable of being mixed vigorously for 5 minutes, at the end of which period the stone shall be thoroughly and uniformly coated. The mixture shall then be completely immersed in tap water and the water poured off. The stone shall not be less than 90% coated.

Note C: The emulsion must include an adhesion agent and suppliers should cover costs for such in their bids. The actual amount of adhesion agent must be determined by ASTM D244 with aggregate from the planned source after contract award."
2011 & 2012 Projects (Tentative)

2011 Work

Future Construction

BST over Soil Cement 25 miles (2011)
## Preliminary Cost Comparison

<table>
<thead>
<tr>
<th>Option</th>
<th>Life by FWD (80,000 GVW trucks) (a)</th>
<th>Construction</th>
<th>Ann Mtc</th>
<th>Per Truck</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface Support Structure</td>
<td>600,000</td>
<td>$900,000</td>
<td>?</td>
<td>$1.50</td>
</tr>
</tbody>
</table>

(a) Based on Spring 2011 FWD back-calculation, better info available in 2012
(Note that 75 Trucks/day ≈ 20,000/yr)

(b) Costs are very project specific
# Preliminary Cost Comparison

<table>
<thead>
<tr>
<th>Option</th>
<th>Life by FWD (80,000 GVW trucks) (a)</th>
<th>Costs/Mile (b)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Construction</td>
</tr>
<tr>
<td>Surface</td>
<td>Support Structure</td>
<td>600,000</td>
</tr>
<tr>
<td>5” Hot Mix</td>
<td>9” Base on Fabric</td>
<td>100,000</td>
</tr>
<tr>
<td>Double Chip BST</td>
<td>10” Base on Fabric</td>
<td></td>
</tr>
</tbody>
</table>

(a) Based on Spring 2011 FWD back-calculation, better info available in 2012  
(Note that 75 Trucks/day ≈ 20,000/yr)

(b) Costs are very project specific

(c) Base thickness inadequate – see next slide
## Preliminary Cost Comparison

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<tr>
<td>5” Hot Mix</td>
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<td>600,000</td>
</tr>
<tr>
<td>Double Chip BST</td>
<td>10” Base on Fabric</td>
<td>100,000</td>
</tr>
<tr>
<td>Double Chip BST on Fabric</td>
<td>10” Soil Cement (8% Cement)</td>
<td>1,000,000</td>
</tr>
<tr>
<td>Double Otta Seal BST</td>
<td></td>
<td>2,000,000</td>
</tr>
<tr>
<td>Treated Gravel</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(a) Based on Spring 2011 FWD back-calculation, better info available in 2012
(Note that 75 Trucks/day \(\approx\) 20,000/yr)

(b) Costs are very project specific

(c) Base thickness inadequate – see next slide

(d) Gravel replacement & treatment costs are likely high, replacement frequency variable
# Base Thickness Requirements for BST Pavements (WSDOT - LE)

<table>
<thead>
<tr>
<th>Max Traffic (80,000 GVW Trucks)</th>
<th>Subgrade Condition</th>
<th>Base Thickness, inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>50,000</td>
<td>Poor</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Good</td>
<td>12</td>
</tr>
<tr>
<td>125,000</td>
<td>Poor</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Good</td>
<td>12</td>
</tr>
<tr>
<td>250,000</td>
<td>Poor</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Good</td>
<td>13</td>
</tr>
</tbody>
</table>

### Table: WSDOT Flexible Pavement Layer Thicknesses Design Table

<table>
<thead>
<tr>
<th>Design Period (ESALs)</th>
<th>Subgrade Condition</th>
<th>Layer Thickness¹ (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>HMA Surfaced</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reliability = 75%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HMA Surface Course</td>
</tr>
<tr>
<td>&lt; 100,000</td>
<td>Poor</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>Good</td>
<td>0.25</td>
</tr>
<tr>
<td>100,000 to 250,000</td>
<td>Poor</td>
<td>0.30</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>0.30</td>
</tr>
<tr>
<td></td>
<td>Good</td>
<td>0.30</td>
</tr>
<tr>
<td>250,000 to 500,000</td>
<td>Poor</td>
<td>0.95</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>0.95</td>
</tr>
<tr>
<td></td>
<td>Good</td>
<td>0.95</td>
</tr>
</tbody>
</table>

1. Based on the 1993 AASHTO Guide for Design of Pavement Structures for flexible pavements with the following inputs:
   \[ E_{a} = 1.7 \quad \beta_{a} = 0.40 \]
   Subgrade condition (effective modulus):
   \[ \beta_{g} = 0.59 \quad \text{Average} = 0.13 \]
   Poor: \( M_{g} = 95 \text{ MPa (14,000 psi)} \)
   Good: \( M_{g} = 140 \text{ MPa (20,000 psi)} \)

2. Gravel borrow may be substituted for a portion of crushed stone when the required thickness of the crushed stone is at least 245 mm. The minimum thickness of crushed stone is 125 mm when such a substitution is made.

3. The assumed elastic modulus for BST (BST) is 500 MPa (72,000 psi).

4. The assumed thickness for all BST layers is 25 mm (1 inch).

5. Crushed stone thickness increases to a total pavement structure of approximately 305 mm (12 inches) based on modulus and flexural conditions.

### Table: Subgrade Condition, Modulus \( M_{R} \), psi, CBR

<table>
<thead>
<tr>
<th>Subgrade Condition</th>
<th>Modulus ( M_{R} ), psi</th>
<th>CBR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor</td>
<td>5,000</td>
<td>3.5</td>
</tr>
<tr>
<td>Average</td>
<td>10,000</td>
<td>7</td>
</tr>
<tr>
<td>Good</td>
<td>20,000</td>
<td>13</td>
</tr>
</tbody>
</table>

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10/30/2011

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BST over Base ~ Rehab Strategy (Government of Yukon)

- Rip and disc failed BST pavements
- If BST was rutting, add more base
- Rebuild BST
Summary/Conclusions

BST and Otta seal cost less to build and maintain than hot mix if structural support and drainage are adequate.

Stabilize soil if rock costs are high.

Fabric under chip seal reduces cracking & increases life.

Gravel stabilized with clay & chloride can be cost effective.

Estimate life cycle costs.

Document performance and share information.
Richland County Task Force

- Russ Huotari - Richland Co
- Josh Johnson - Interstate Engineering
- John Twedt, Troy Kelsey - Century Companies
- Steve Monlux – LVR Consultants