MAKING BETTER GRAVEL ROADS
PART 1: INTRODUCTION AND WEARING COURSE MATERIALS

David Jones
University of California Pavement Research Center

County Engineers Association of California
2016 Bedroll Conference, August 9, 2016

Oxford English Dictionary

**Dirt:** any foul or filthy substance, as mud, grime, dust, or excrement.

From old Norse word *drit*
Outline

- Introduction
- Material specifications
- Understanding performance
- Summary

Introduction

- Unpaved roads
  - Function
  - Problems
  - Sustainability
- Range of management issues primarily funding and unpaved road expertise
- “Unpaving” projects are adding to the inventory
Fines Lost

- In perspective
  - > 8 million tons per year
  - 267,000 30T trucks
- Fines loss from erosion (1mm/yr)
  - 14 million tons per year

Key National Issues

- No “owner” of unsealed road guides and specifications
- Often no owner of the problem
  - Oil, wind, solar, ethanol, etc.
- Limited unpaved road expertise and funding for
  - Road management
  - Research
- Fragmented products industry marketing solutions
- So what?
Outline

- Introduction
- Material specifications
- Understanding performance
- Summary

Key National Issues

- Sourcing unpaved road materials
  - Environmental constraints
  - Commercial sources dominate
  - Focus on base, asphalt, and concrete
- Material specifications
  - Everybody has one
  - Most based on AASHTO subbase requirements and adapted for local conditions
  - Most use grading envelope and PI range
  - Many specify non-plastic materials
- Construction specifications
  - Not often followed/enforced
  - Considered as an unnecessary expense
  - Life of gravel wearing course significantly reduced
Why Read Guidelines?
**Guidelines & Specifications - US**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Guidelines</th>
<th>FHWA Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sieve (mm. [US])</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>19</td>
<td>90 – 100</td>
<td>97 – 100</td>
</tr>
<tr>
<td>4.75</td>
<td>50 – 78</td>
<td>76 – 89</td>
</tr>
<tr>
<td>2.36</td>
<td>37 – 67</td>
<td>43 – 53</td>
</tr>
<tr>
<td>0.425</td>
<td>32 – 33</td>
<td>23 – 32</td>
</tr>
<tr>
<td>0.075</td>
<td>15 – 23</td>
<td>51 – 63</td>
</tr>
<tr>
<td></td>
<td>4 – 15</td>
<td>28 – 39</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15 – 23</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10 – 16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>or 6 – 12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>±4</td>
</tr>
<tr>
<td>Plasticity Index</td>
<td>4 – 12</td>
<td>2 – 9 if 0.075 is &lt;12% &lt;2 if 0.075 is &gt;12%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>±4</td>
</tr>
</tbody>
</table>

* Range for 0.075 mm (#200) sieve is 6.0 to 12.0% if the PI is greater than 0

Test, don’t guess!
### Guidelines & Specifications – SA

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle size distribution factor ($G_c$)</td>
<td>15 – 35</td>
</tr>
<tr>
<td>Weighted clay factor ($S_p$)</td>
<td>100 – 365</td>
</tr>
<tr>
<td>Maximum size (in.)</td>
<td>1.5 – 2.0</td>
</tr>
<tr>
<td>Strength factor (CBR)</td>
<td>&gt;15</td>
</tr>
<tr>
<td>Hardness factor (TIV)</td>
<td>20 – 65</td>
</tr>
</tbody>
</table>

1. $G_c = ((P_1 - P_{#8}) * P_{#4}) / 100$
2. $S_p = LS * P_{#40}$ or $\frac{1}{2} PI * P_{#40}$

**Calibrate for local use, conditions and test methods! Performance is always dependent on construction and maintenance quality!**

### Outline

- Introduction
- Material specifications
- Understanding performance
- Summary
Understanding Performance - USFS

Table 3-10—Aggregate wear and durability requirements.

<table>
<thead>
<tr>
<th>Test Requirement</th>
<th>Base and Subbase</th>
<th>Surfacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Los Angeles Abrasion, AASHTO T 96</td>
<td>40 % maximum</td>
<td>40 % maximum</td>
</tr>
<tr>
<td>Sodium Sulfate Soundness Loss, AASHTO T 104</td>
<td>12 % maximum</td>
<td>12 % maximum</td>
</tr>
<tr>
<td>Durability Index (coarse and fine), AASHTO T 210</td>
<td>35 minimum</td>
<td>35 minimum</td>
</tr>
<tr>
<td>Fractured Faces, ASTM D 5821</td>
<td>50 % minimum</td>
<td>75 % minimum</td>
</tr>
<tr>
<td>Liquid Limit, AASHTO T 89</td>
<td>25 maximum</td>
<td>35 maximum</td>
</tr>
<tr>
<td>Plastic Limit, AASHTO T 90</td>
<td>Nonplastic</td>
<td>2 to 9 (1)</td>
</tr>
</tbody>
</table>

Note:
(1) If the percent passing the 75 μm sieve is less than 12 percent.
(2) If the percent passing the 75 μm sieve is greater than 12 percent.

Understanding Performance - SA

- Slippery and dusty
  - Erodible
  - Good
  - Ravels
  - Washboards and ravels

Increasing plasticity
Increasing coarseness/increasing gap

Grading coefficient
Understanding Performance - SA

Guidelines & Specifications – US

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<thead>
<tr>
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<tbody>
<tr>
<td>Sieve Size (US)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 in.</td>
<td>100</td>
<td>97 – 100</td>
</tr>
<tr>
<td>#4</td>
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<td>43 – 53</td>
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<td>Grading Coefficient:</td>
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<td></td>
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<tr>
<td>(15 – 35)</td>
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<td></td>
</tr>
<tr>
<td>High range</td>
<td>26</td>
<td>36</td>
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<td>Mid range</td>
<td>31</td>
<td>34</td>
</tr>
<tr>
<td>Low range</td>
<td>32</td>
<td>32</td>
</tr>
<tr>
<td>Worst case</td>
<td>49</td>
<td>41</td>
</tr>
<tr>
<td>Shrinkage Product:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(100 – 365)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High range</td>
<td>420</td>
<td>207 / 23</td>
</tr>
<tr>
<td>Mid range</td>
<td>192</td>
<td>105</td>
</tr>
<tr>
<td>Low range</td>
<td>26</td>
<td>30</td>
</tr>
<tr>
<td>Worst case</td>
<td>420</td>
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</table>

Calibrate for local use!
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<td></td>
<td>Worst case</td>
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### Performance Prediction

- **Increasing plasticity / Increasing shrinkage product**
- **Increasing coarseness / Increasing gap**

- **Slippery and dusty**
- **Good but dusty**
- **Really good**
- **Erodible**
- **Washboards and ravels**

- **F1**
- **F2**
- **F3**
- **F4**
- **U1**
- **U2**
- **U3a**
- **U3b**
- **U4**
- **U5**
- **U6**
- **U7a**
- **U7b**
- **U8**
Discussion

- Materials that meet US federal guidance and specifications may still perform badly
  - Only two of the 14 potential in-spec materials are likely to perform well
  - Most materials are likely to washboard and ravel
  - Some materials are likely to be slippery/impassable when wet
  - Problematic for inexperienced engineers
  - Aggregate suppliers and contractors still meet the spec

- Importance of using PI (weighted) and grading together is clear
Outline

- Introduction
- Material specifications
- Understanding performance
- Summary

Summary

- Current US specs and guidance can be misleading
- Use a simple analysis tool for understanding unpaved road material performance
  - Proven to be effective in Africa, Australasia, S.E. Asia, and USA
- Use any specification, but understand performance
  - Select the best possible material
  - Blend
  - Construct properly
  - Change maintenance program
  - Improve with chemicals
- Testing is not expensive and will save money
Thank-you

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MAKING BETTER GRAVEL ROADS
PART 2: CHEMICAL TREATMENTS
AS PART OF A ROAD MANAGEMENT
STRATEGY

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County Engineers Association of California
2016 Bedroll Conference, August 9, 2016
Australian Version

Outline

- Introduction
- Status quo
- Additive categories
- Additive selection
- Summary
Introduction

- Gravel road problems
  - Fines loss (dust)
  - Wet weather passability
  - Safety
  - Environment

- Recommended approach
  - Focus on addressing above issues
  - Start with building the best possible road
  - Use chemical treatments to keep a good road good
  - Set up a simple GRMS
  - Justify approach through extended life of road and reduced maintenance

Role of Chemical Treatments
Outline

- Introduction
- Status quo
- Additive categories
- Additive selection
- Summary

Status Quo

- Timeline for road additive development
  - Chlorides since 1907
  - Lignosulfonates since 1913
  - Other organic non-petroleum and petroleum products since the 1930’s
  - Electrochemicals since 1970’s
  - Enzymes and synthetic polymers since 1980’s
  - Synthetic fluids and mineral oils since 1990’s
Status Quo

- Research and implementation
  - US Forest Service
  - US Army Corps of Engineers
  - Other US
  - International
- Where are we after 110 years?
  - Fragmented industry selling mostly proprietary products
  - No specifications
  - Poor track record/skepticism

Outline

- Introduction
- Status quo
- Additive categories
- Additive selection
- Summary
Additive Categories

- Fines retention/surface stabilization
  - Water and water with surfactants
  - Water absorbing
  - Organic non-petroleum or natural polymers
  - Organic petroleum
- Stabilization/strength improvement
  - Organic petroleum
  - Synthetic polymer emulsions
  - Concentrated liquid stabilizers

Performance Prediction

- Increasing plasticity
- Increasing coarseness / increasing gap

Calibrate for local use!
Water Absorbing

- Increasing plasticity/Shrinkage product
- Increasing coarseness/increasing gap

Grading coefficient:
- Good
- Fair with maintenance

Slippery and dusty
- Erodible
- Good but dusty
- Ravels
- Washboards and ravels

Water Absorbing

Good
- Good but dusty
- Good
- Fair with maintenance
- Good

- Slippery and dusty
- Washboards and ravels
Organic and Synthetics

Grading coefficient

- Increasing coarseness / increasing gap

Conc. Liquid Stabilizers

Grading coefficient

- Increasing coarseness / increasing gap
Outline

- Introduction
- Status quo
- Additive categories
- Additive selection
- Summary

Current Practice

- Currently based on:
  - Experience
  - Guides
    - US Army Corps of Engineers
    - FPInovations (Canada)
    - FHWA
  - Preferred lists
  - Marketing by suppliers
Background

- 1999 US Forest Service Guide
- New developments since 1999
  - More products (±200 in USA)
  - More/refined categories
    - Dust control vs. stabilization
  - Additional experience
    - Documented field trials
  - Requests for more detailed guidance, preferably with ranking

New FHWA (UCPRC) Guide

- Ten-step process
- Have a clear objective
  - Temporary dust control
  - Long-term fines preservation
  - All weather passability
  - Unpaved road management
    - Reduced maintenance
    - Extended gravel replacement intervals
- Manual, spreadsheet, and web-based
- Focused on keeping a good road good
Treatment Selection Tools

- Specifications
  - Example specification language to cover all product sub-categories in terms of procurement, environmental and application
- Based on certificate of compliance for procurement
  - Sub-category
  - Verifications
    - Meets category specifications
    - Safety data sheet
    - Environmental requirements
- Use as basis for QC/QA
Example Spec Language

Example Provisional Specification: Calcium Chloride Solution
Clear odorless liquid intended for fines preservation, dust control and/or stabilization of unpaved roads. It has the following properties in its undiluted state.

<table>
<thead>
<tr>
<th>Test Parameter</th>
<th>Suggested Acceptance Limits</th>
<th>Suggested Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium chloride content</td>
<td>28 – 42%</td>
<td>ASTM E449</td>
</tr>
<tr>
<td>Total magnesium as MgCl₂</td>
<td>&lt; 6.0%</td>
<td>ASTM E449</td>
</tr>
<tr>
<td>Total alkali chlorides as NaCl</td>
<td>&lt; 6.0%</td>
<td>ASTM E449</td>
</tr>
<tr>
<td>Calcium hydroxide content</td>
<td>&lt; 0.2%</td>
<td>ASTM E449</td>
</tr>
<tr>
<td>pH (5% solution)</td>
<td>7.0 – 9.0</td>
<td>ASTM D1293</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>1.28 – 1.44</td>
<td>ASTM D1439</td>
</tr>
</tbody>
</table>

Notes
1. ASTM D98/AASHTO M144

Example Provisional Specification: Lignosulfonate: Calcium
Dark brown lignin-based liquid or powder with woody odor derived from the wood pulping using the sulfite process used in the manufacture of cellulose products and designed for fines preservation, dust control and/or stabilization of unpaved roads. It has the following properties in its undiluted/undissolved state.

<table>
<thead>
<tr>
<th>Test Parameter</th>
<th>Suggested Acceptance Limits</th>
<th>Suggested Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lignin sulfonate content (ready to use)</td>
<td>&gt; 25%</td>
<td>ASTM D4900</td>
</tr>
<tr>
<td>Residue (total solids content)</td>
<td>≥ 52%</td>
<td>ASTM D4903/D2834</td>
</tr>
<tr>
<td>Lignin sulfonated content of residue</td>
<td>≥ 50%</td>
<td>ASTM D4903/D2834</td>
</tr>
<tr>
<td>Reducing sugars content of residue</td>
<td>&gt; 25% of dry weight</td>
<td>ASTM D5896/D6406</td>
</tr>
<tr>
<td>pH</td>
<td>6.0 – 9.0</td>
<td>ASTM D1293</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>≥ 1.20</td>
<td>ASTM D1429</td>
</tr>
<tr>
<td>Absolute viscosity (Brookfield)</td>
<td>&lt; 1,000 cP @ 77°F (25°C)</td>
<td>ASTM D2196</td>
</tr>
</tbody>
</table>

Outline

- Introduction
- Status quo
- Additive categories
- Additive selection
- Summary
Summary

- Huge selection of additives
- There are no wonder products
- Select treatment based on
  - Problem/objective/capability
  - Traffic, climate and materials
  - Cost-benefit
  - Vendor credibility
- Understand performance
- Apply and maintain appropriately
- Testing is not expensive and will save money!
Thank-you

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