Acceptance Criteria for Unbonded Aggregate Road Surfacing Materials

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Problem

- Good sand clay gravel sources nearly depleted
- Crushed aggregates provide various levels of performance
- Need to update/improve UFGS 02731A, "Aggregate Surface Course"
Objective

- Update UFGS 02731A to allow the use of various types of unbound materials
  - Well-defined limits used to accept or reject proposed material sources
  - Differentiate between construction and maintenance situations
4 grading options
- Natural or crushed

Coarse fraction
- LA abrasion <= 50%
- Flat/elongated <= 20%

Fine fraction
- LL <= 35%
- PI = 4 to 9

<table>
<thead>
<tr>
<th>USACE Grading Requirements for Surface Aggregate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sieve Size</td>
</tr>
<tr>
<td>------------</td>
</tr>
<tr>
<td>1 in.</td>
</tr>
<tr>
<td>3/8 in.</td>
</tr>
<tr>
<td>No. 4</td>
</tr>
<tr>
<td>No. 10</td>
</tr>
<tr>
<td>No. 40</td>
</tr>
<tr>
<td>No. 200</td>
</tr>
</tbody>
</table>
MVD Specifications

- **3 material options**
  - 1 grading each
- **Coarse fraction**
  - LA abrasion <= 40%
  - MgSO4 soundness < 15%

**MVK Grading Requirements for Surface Aggregate**

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Sand Clay Gravel</th>
<th>Crushed Stone</th>
<th>Crushed Stone with Binder</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 in.</td>
<td>100</td>
<td>No data</td>
<td>No data</td>
</tr>
<tr>
<td>1-1/2 in.</td>
<td>95 – 100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>1 in.</td>
<td>75 – 100</td>
<td>No data</td>
<td>No data</td>
</tr>
<tr>
<td>3/4 in.</td>
<td>No data</td>
<td>50 – 95</td>
<td>50 – 100</td>
</tr>
<tr>
<td>1/2 in.</td>
<td>45 – 90</td>
<td>42 – 85</td>
<td>42 – 85</td>
</tr>
<tr>
<td>No. 4</td>
<td>30 – 65</td>
<td>25 – 65</td>
<td>25 – 65</td>
</tr>
<tr>
<td>No. 10</td>
<td>20 – 50</td>
<td>No data</td>
<td>20 – 50</td>
</tr>
<tr>
<td>No. 40</td>
<td>10 – 30</td>
<td>10 – 32</td>
<td>10 – 32</td>
</tr>
<tr>
<td>No. 200</td>
<td>5 – 15</td>
<td>3 – 12</td>
<td>3 – 12</td>
</tr>
</tbody>
</table>

- **Fine fraction**
  - LL <= 30%
  - PI = 5 to 15%

- **Fine fraction**
  - LL <= 30%
  - PI = 4 to 9%
Compaction Requirements

- **UFGS 02731A**
  - 100% modified Proctor

- **MVD**
  - “... compacted as evenly and densely as practicable by the controlled movement of the hauling equipment over the entire area.”
  - Dress with a motor grader
Review of Other Agencies

- 9 state DOTs
- US Forest Service
- FHWA
- South Africa, SRA and CSIR

Popular specification tests:
- gradation
- LA abrasion
- flat / elongated
- fractured face counts
- LL and/or PI
- sulfate soundness
- sand equivalent
- % passing No. 200
- No. 200 / No. 40
# Popular Specification Tests

<table>
<thead>
<tr>
<th>Test</th>
<th>Limit(s)</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gradation</td>
<td>next slide</td>
<td></td>
</tr>
<tr>
<td>LA Abrasion</td>
<td>35 to 50% max.</td>
<td>% loss</td>
</tr>
<tr>
<td>Flat / Elongated</td>
<td>10 to 20% max.</td>
<td>3 to 1 ratio</td>
</tr>
<tr>
<td>Fractured Face Counts</td>
<td>50 to 75% min.</td>
<td>at least one face</td>
</tr>
<tr>
<td>LL</td>
<td>25 to 40% max.</td>
<td></td>
</tr>
<tr>
<td>PI</td>
<td>8 to 15% max.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0 to 5% min.</td>
<td></td>
</tr>
<tr>
<td>Sulfate Soundness</td>
<td>12 to 15% max.</td>
<td>Na or Mg</td>
</tr>
<tr>
<td>Sand Equivalent</td>
<td>40 to 45% min.</td>
<td></td>
</tr>
<tr>
<td>% Passing No. 200</td>
<td>10 to 20% max.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0 to 10% min.</td>
<td></td>
</tr>
<tr>
<td>No. 200 / No. 40</td>
<td>67% max.</td>
<td></td>
</tr>
</tbody>
</table>
Target Gradations - Literature

Natural Aggregate

Percent Finer = \(100 \cdot \left( \frac{\text{sieve size}}{\text{max. size}} \right)^{0.45}\)
**Target Gradations - Literature**

**Crushed Aggregate**

![Graph showing percent passing vs. nominal particle size for crushed aggregate gradations.](image)

**Equation:**

\[
Percent \ Finer = 100 \cdot \left( \frac{sieve \ size}{max. \ size} \right)^{0.45}
\]
This Study - 5 Aggregate Sources

1) Sand clay gravel, SCG

Greenwood Hill Gravel in Greenwood, MS
5 Aggregate Sources

2) Crushed limestone, LS

GW-GM

Vulcan Materials Co., Reed Quarry, Gilbertsville, KY
5 Aggregate Sources

3) Sandstone, SS

GP-GM

Pine Bluff Sand and Gravel, River Mountain Quarry, Delaware, AR
5 Aggregate Sources

4) Igneous, IGN

McGeorge Corp., Granite Mountain Quarries, Little Rock, AR
5) Sandstone with binder, SSB

GC

Martin Marietta Aggregates, Sawyer Quarry, Sawyer, OK
Experimental Approach

New Construction Test Section

Maintenance Test Section

East Curve
Experimental Approach

New Construction

10 (SSB)  9 (IGN)  8 (SS)  7 (LS)  6 (SCG)

sta 2+50  sta 2+50

Maintenance

1 (SCG)  2 (LS)  3 (SS)  4 (IGN)  5 (SSB)

sta 0  sta 0

N

wet traffic lane

dry traffic lane

Particle Size Distribution

igneous and sandstone

Nominal Sieve Opening (mm)

Percent Finer

No. 4 No. 40 No. 200

3/4 in. UFGS, No. 1
MVD, Stone
SS IGN
Particle Size Distribution

sandstone with binder

<table>
<thead>
<tr>
<th>No.</th>
<th>Material Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>MVD, Stone w/ Binder</td>
</tr>
<tr>
<td>40</td>
<td>UFGS, No. 2</td>
</tr>
<tr>
<td>200</td>
<td>SSB</td>
</tr>
</tbody>
</table>

Nominal Sieve Opening (mm)

Percent Finer

3/4 in. No. 4 No. 40 No. 200
<table>
<thead>
<tr>
<th>Test</th>
<th>SCG</th>
<th>LS</th>
<th>SS</th>
<th>IGN</th>
<th>SSB</th>
</tr>
</thead>
<tbody>
<tr>
<td>LA Abrasion</td>
<td>18.2</td>
<td>18.8</td>
<td>33.5</td>
<td>27.3</td>
<td>27.8</td>
</tr>
<tr>
<td>Flat / Elongated</td>
<td>4.2</td>
<td>5.8</td>
<td>5.5</td>
<td>5.8</td>
<td>10.8</td>
</tr>
<tr>
<td>LL</td>
<td>31</td>
<td>NP</td>
<td>NP</td>
<td>NP</td>
<td>28</td>
</tr>
<tr>
<td>PI</td>
<td>18</td>
<td>NP</td>
<td>NP</td>
<td>NP</td>
<td>14</td>
</tr>
<tr>
<td>Sulfate Soundness</td>
<td>1.0</td>
<td>0.3</td>
<td>4.2</td>
<td>0.4</td>
<td>6.4</td>
</tr>
<tr>
<td>Sand Equivalent</td>
<td>20</td>
<td>73</td>
<td>23</td>
<td>61</td>
<td>10</td>
</tr>
<tr>
<td>Linear Shrinkage</td>
<td>6.1</td>
<td>1.1</td>
<td>0.2</td>
<td>0.5</td>
<td>6.4</td>
</tr>
<tr>
<td>% Passing No. 200</td>
<td>14.4</td>
<td>6.3</td>
<td>6.8</td>
<td>3.6</td>
<td>22.8</td>
</tr>
<tr>
<td>No. 200 / No. 40</td>
<td>67%</td>
<td>53</td>
<td>36</td>
<td>28</td>
<td>66</td>
</tr>
</tbody>
</table>
• **Targets**
  
  o Subgrade CBR = 5 to 10%
  o Surface to receive maintenance layer to have dry unit weight = 130 pcf
  o Compaction of surface layers to be similar to field
New Construction Test Section

Initial buildup
CBR = 4 to 25%

After reworking top 6 in.
Moisture = 13 to 19%
CBR = 5 to 15%
Maintenance Test Section

3 to 5 in. clay-limestone mix remains
CBR = 50 to 100% over
CBR ~ 10% at 10 in.

Placed 6 in. of SCG at
6 to 8% moisture
Dry unit wt. = 128 to 130 pcf
Placing Surface Materials

- Spread with John Deere 550G track dozer
- Add 16 coverages with dozer
- Smooth with static steel drum
Placing Surface Materials

Maintenance Test Section

New Construction Test Section
15 to 20 mph

- Pickup w/ 500 lb
- Small empty dump truck
- Flatbed w/ 2000 lb
- Emulsion truck w/ 750 gal
<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Front Axle, lb</th>
<th>Rear Axle, lb</th>
<th>Inflation Pressure, psi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pickup Truck</td>
<td>2600</td>
<td>2400</td>
<td>40</td>
</tr>
<tr>
<td>Dump Truck</td>
<td>6800</td>
<td>7500</td>
<td>110</td>
</tr>
<tr>
<td>Flatbed</td>
<td>5500</td>
<td>11000</td>
<td>80</td>
</tr>
<tr>
<td>Emulsion</td>
<td>5700</td>
<td>21800</td>
<td>80</td>
</tr>
</tbody>
</table>
Climate

Cumulative Precipitation (in.)

1-Aug-04  20-Sep-04  9-Nov-04  29-Dec-04  17-Feb-05  8-Apr-05  28-May-05

Median Temperature (F)

C = (5/9) (F - 32)
August 2004
Pickup Truck
150 passes
dry conditions
October 2004
Pickup Truck
2500 passes
dry conditions
After Rainy Oct./Nov. (> 10 in.)

17 November 2004
Dump Truck, 10 passes
dry surface – wet subgrade

Only LS on New Construction Rutted:
- 4 to 6 in.
- both wheelpaths

All other items had no distress.
05 April 2005
Emulsion Truck
200 passes

relatively dry conditions
maintenance section
16 Feb 2005
Dump Truck
200 passes

very wet conditions
maintenance section
08 Mar 2005
Pickup Truck
150 passes
very wet surface
1.25 in. rain event
maintenance section
01 April 2005
Flatbed Truck
50 passes
wet conditions
maintenance section
15 April 2005
Flatbed Truck
25 passes

wet subgrade
new construction section

least subgrade rutting
Summary

• **New Construction (no subbase)**
  - All materials could support light traffic adequately in dry conditions
  - SCG had surface rutting when wet, even under light traffic
  - Aggregates with high fines and plasticity partially protected subgrade from rain, thus prolonging life of road
  - SSB performed best under heavy traffic
  - If heavy traffic is possible, road should include a subbase
• **Maintenance (SCG subbase)**

  - All materials, except SCG, could support light traffic adequately in dry or wet conditions.
  - SCG had surface rutting when wet, even under light traffic.
  - SS and IGN performed best under medium and heavy traffic in wet conditions.
South African Approach

Sp = linear shrinkage (%) x No. 40

Grading Coefficient (Gc) = \( \frac{(1 \text{ in.} - \text{No. 10}) \cdot \text{No. 4}}{100} \)
Conclusions

- **Subbase layer is recommended if heavy traffic is possible**
  - If no subbase, criteria for surface aggregate will be different than for the case of aggregate on top of subbase

- **Key components of new specification:**
  - overall gradation
  - minus No. 200
  - No. 200 / No. 40
  - Apply concept similar to South Africans’ but adjust for higher precipitation
  - plasticity of fines
  - linear shrinkage?