Moisture Damage in HMA with Marginal Aggregates

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1. Why This Research?
2. Approach & Testing Program
3. Analysis/Discussion
4. Future Work
5. Summary
Depleting Aggregate Sources

The Issue: Aggregate Availability
District 1-0 Available Aggregates

- Approximately 30 to 35 Sand and Gravel Operations.

- Of that total only 1 source is able to meet the current Bituminous criteria for # 8’s, needed 9.5mm mixes.

- That source will be depleted in approximately 5 years.
Aggregate Selection Criteria

- PennDOT Bituminous Type A Course Aggregate Requirements
  - Crush Count
  - LA Abrasion
  - Sodium Sulfate
  - Absorption
  - Gradation
  - Skid Resistance Level
# Coarse Agg. Quality Requirements

<table>
<thead>
<tr>
<th></th>
<th>Type A</th>
<th>Type B</th>
<th>Type C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Soundness, Max. %</strong></td>
<td>10</td>
<td>12</td>
<td>20</td>
</tr>
<tr>
<td><strong>Abrasion, Max. %</strong></td>
<td>45</td>
<td>45</td>
<td>55</td>
</tr>
<tr>
<td><strong>Thin and Elongated Pieces, Max. %</strong></td>
<td>15</td>
<td>20</td>
<td>—</td>
</tr>
<tr>
<td><strong>Material Finer Than 75 μm (No. 200) Sieve, Max. %</strong></td>
<td>*</td>
<td>*</td>
<td>10</td>
</tr>
<tr>
<td><strong>Crushed Fragments, Min. %</strong></td>
<td>55</td>
<td>55</td>
<td>50</td>
</tr>
<tr>
<td><strong>Compact Density (Unit Weight), Min. kg/m³ (lbs./cu. ft.)</strong></td>
<td>1100 (70)</td>
<td>1100 (70)</td>
<td>1100 (70)</td>
</tr>
<tr>
<td><strong>Deleterious Shale, Max. %</strong></td>
<td>2</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td><strong>Clay Lumps, Max. %</strong></td>
<td>0.25</td>
<td>0.25</td>
<td>3</td>
</tr>
<tr>
<td><strong>Friable Particles, Max. % (excluding shale)</strong></td>
<td>1.0</td>
<td>1.0</td>
<td>—</td>
</tr>
<tr>
<td><strong>Coal or Coke, Max. %</strong></td>
<td>1</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td><strong>Glassy Particles, Max. %</strong></td>
<td>4 or 10</td>
<td>4 or 10</td>
<td>—</td>
</tr>
<tr>
<td><strong>Iron, Max. %</strong></td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td><strong>Absorption, Max. %</strong></td>
<td>3.0</td>
<td>3.5</td>
<td>—</td>
</tr>
<tr>
<td><strong>Total of Deleterious Shale, Clay Lumps, Friable Particles, Coal, or Coke Allowed, Max. %</strong></td>
<td>2</td>
<td>2</td>
<td>15</td>
</tr>
</tbody>
</table>
The Stopper

- Type A Sodium Sulfate requirement of 10% or less.

- Type A Absorption requirement of 3% or less.

- Many of District 1-0’s sources are between 12% and 20% on the Sodium Sulfate test.

- All other requirements can be met and the materials have an excellent skid value.
Outsource Aggregates

- District producers forced to acquire aggregates from outside the District.

- Materials are brought in by boat, rail, and truck.

- SRL E material hauled a 100 mile distance for District 1-0 SMA projects.

- Result: Increase in the cost of the raw material.
The Idea

- To use District 1-0 local aggregates on lower volume roads.

- To evaluate HMA performance with these aggregates to determine what would be the best course of action if the materials were to be incorporated.

- To implement the best course of action on an actual project and then monitor its performance.
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Materials

■ Five Gravel Aggregate Sources

■ One Limestone Aggregate

■ For each aggregate
  ■ Control
  ■ Liquid Antistripping Agent (LAS)
  ■ 50/50 Blend on #8 Material (Gravel+Limestone)
  ■ 1% Lime (No Data Yet)
Aggregates to Be Evaluated

AM-A #8
Retained On #4 Sieve

AM-A #8
Passing #4 Sieve

TR-C #8
Retained On #4 Sieve

TR-C #8
Passing #4 Sieve
Aggregate Quality

Aggregate Water Absorption, %

Local Aggregates

Limestone
Aggregate Quality

Sodium Sulfate Soundness, % Loss

AGG1
AGG2
AGG3
AGG4
AGG5
Limestone
Testing Program

- AASHTO T-283 (PennDOT Version)
- Model Mobile Load Simulator (MMLS3)
- Dynamic Modulus (Repeated Freeze-Thaw Cycles)
- Environmental Conditioning + Dynamic Modulus?
Moisture Sensitivity (AASHTO T-283)

51 mm / min @ 25 °C

Avg Dry Tensile Strength

Avg Wet Tensile Strength

TSR = Wet ≥ 85 %

Dry
MMLS3
MMLS3 – Specimen Set-Up
MMLS3- Dry/Wet Testing
MMLS3 – Profile Measurements
MMLS3 – Wet Testing

\[ T = 52 \, ^{\circ}\text{C} \]
Dynamic Modulus Testing
Dynamic Modulus Test

TIME LAG, $T_l$

PERIOD, $T_p$

LOAD

LOAD

AXIAL STRAIN

TIME, SEC

$\sigma_0$  $\varepsilon_0$

0.00  0.05  0.10  0.15
Why This Research?

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Future Work

Summary
Conditioning under Vacuum

High Vacuum

Low Vacuum

% Saturation
Saturation Levels

![Bar chart showing saturation levels for different aggregates and formulations.](image-url)
Tensile Strength Results

TRS-Dry Subset

TRS-Wet Subset
TSR Results

Test Groups

1

2

3

4

5

Control

50/50

LAS

Tensile Strength Ratio

0.00 0.20 0.40 0.60 0.80 1.00 1.20
Model Mobile Load Simulator
(MML$S^3$)
MMLS3 – Dry Testing
MMLS3- Wet Testing
MMLS3 – Rut Measurement
Distress Evaluation

1. TRM1: 7.89% AV
2. TRM2: 7.61% AV
MMLS3 – Wet Testing

AGG1 - Rutting vs Load Cycles

Air Void Range: 7.4-7.8%

Rutting (mm)

Cycles

0 100,000 200,000 300,000 400,000
MMLS3 – Dry Testing

AGG1 - Rutting vs Load Cycles

Air Void Range: 7.3-7.9%
MMLS3 – Dry/Wet Comparison

AGG1 - Rutting vs Load Cycles

Rutting (mm) vs Cycles

0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5
0 50,000 100,000 150,000 200,000 250,000 300,000 350,000 400,000
Cycles
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Further Analysis with Dyn. Mod.

- Modulus is the primary input to the AASHTO MEPDG rutting and fatigue models
- Impact of Repeated Freeze-Thaw Cycles on Modulus
- Effect of Levels of Moisture Damage on Pavement Life
- How much more rutting and cracking for a 10, 20, 30, etc percent reduction in modulus?
AASHTO MEPDG Rutting Model

\[ RD = \sum_{i=1}^{k} (\varepsilon_p)_i h_i \]

\[ \varepsilon_p = \varepsilon_r \left( a_1 T^{a_2} N^{a_3} \right) \]

Field Calibrated Coefficients

From Layered Elastic Analysis
Depends on \( E^* \)
AASHTO MEPDG Fatigue Model

Field Calibrated Coefficients

\[ N_f = k_1 \left( \frac{1}{\varepsilon_t} \right)^{k_2} \left( \frac{1}{E} \right)^{k_3} \]

Stress Level Effect Increases With Decreasing \( E^* \)
Further Analysis

Schwartz, 2004

The diagram illustrates the relationship between percent of design distress and percent of design modulus for AC Rutting and Alligator Cracking. The graph shows a linear decrease in percent of design distress as the percent of design modulus increases, indicating a direct correlation between the two variables. The data is sourced from Schwartz's 2004 study.
Using ECS/DM Test Set-Up?

- Weather stripping
- Membrane
- Direction of water flow
- O Ring
Summary

- Type A Aggregate is Depleting in District 1-0
- Could We Utilize Type B and C Aggregates?
- Laboratory Evaluation of 5 Local Aggregates
  - Tensile Strength Ratio
  - Model Mobile Load Simulator
  - Dynamic Modulus after Repeated Freeze/Thaw
Summary

- Significant Improvement with LAS
- Some Improvement with 50/50 Blend
- Evaluate Modulus Reduction with Repeated Freeze/Thaw
- Analysis of MMLS3 Data
- Utilize ECS/Dyn Mod System?
Thank You!