Optimize Unbound Aggregate Bases Through Laboratory Tests

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Outline

• Background
• Objective
• Laboratory Tests
• Test Results
• Preliminary Conclusions
Detrimental Effects of Water

- Stripping in HMA
- Reduction of Granular Layer Stiffness & Strength
- Loss of Subgrade Support
- Debond between Pavement Layers
- Reduction in Pavement Service Life
Detrimental Effects of Water

Diagram showing the effects of water on aggregate and subgrade layers.
Source of Free Water

From water table

Upward movement of water table

Vapor movement

From edge

Compacted subgrade pavement

From edge
Subsurface Drainage Pavement

- Asphalitic or PCC Pavement
- Permeable Base
- Granular or Geotextile Separator Layer
- Geotextile
- Edgedrain
- Subgrade
- 0.9m
Typical Permeable Bases

• Cement-treated open graded base;

• Asphalt-treated open graded base;

• Unbound aggregate base
Objective

An optimal gradation

• Adequate drainability

• Structural stability
Factors Affecting Drainability

- Infiltration Rate
- Width of Pavement (No. of Lanes)
- Cross & longitudinal slopes
- Ks of base layer
- Thickness of base
- Degree of drainage required
## Criteria of Drainage Quality

### AASHTO Guide (50% Drainage)

<table>
<thead>
<tr>
<th>Quality of Drainage</th>
<th>Time to Drain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>2 hours</td>
</tr>
<tr>
<td>Good</td>
<td>1 day</td>
</tr>
<tr>
<td>Fair</td>
<td>7 days</td>
</tr>
<tr>
<td>Poor</td>
<td>1 month</td>
</tr>
<tr>
<td>Very Poor</td>
<td>Does Not Drain</td>
</tr>
</tbody>
</table>
## Criteria of Drainage Quality

### Pavement Rehabilitation Manual (85% Saturation)

<table>
<thead>
<tr>
<th>Quality of Drainage</th>
<th>Time to Drain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>&lt; 2 hours</td>
</tr>
<tr>
<td>Good</td>
<td>2~5 hours</td>
</tr>
<tr>
<td>Fair</td>
<td>5~10 hours</td>
</tr>
<tr>
<td>Poor</td>
<td>&gt; 10 hours</td>
</tr>
<tr>
<td>Very Poor</td>
<td>&gt;&gt; 10 hours</td>
</tr>
</tbody>
</table>
Permeable Base

Permeability Requirement

Ks= 1000 ft/day (FHWA);

Ks=2690 ft/day (Excellent drain condition)

\[ q = q_i \times W_c = kH \left( S + \frac{H}{2L} \right) \]
Permeable Base

Structural stability: (?)
- CBR (50~100%)
- DCP (3~5 mm/blow)
- Geogauge stiffness

Repeated load triaxial tests
- Mr
- Permanent deformation
Unbound Aggregate Base

Particle Diameter (mm) vs. Percent Finer (%)

- New Jersey NSOG
- New Jersey NSOG
- LA Class II
- LA Class II
- Wisconsin Upper
- Wisconsin lower
- AASHTO No. 57-Upper
- AASHTO No. 57-Lower

Decreasing Ks → Increasing stability
Increasing Ks → Decreasing stability
Mexican Limestone (ML)
Generating New Gradations

Original Material

Sieve through the following sieves: 1'', ¾'', ½'', 3/8'', No.4, No. 40, and No. 200

Divide into different size groups

New Gradation

Remixing these groups together according to certain ratios
ML-Compaction Curves

Moisture content (%) vs. Dry density (pcf)

- ML-LA Class II-Coarse
- ML-LA Class II-Fine
- ML-LA Class II-New Jersey-Mean
- ML-Modified gradation-Coarse
- ML-Modified gradation-Fine
Lab Permeability Tests

Diagram:
- Constant head water tank
- Sample
- h₁-h₂
- L
Permeability Test Set-Up

- Large water tank
- Manometer tubes
- Constant head tank
- Permeameter
RLT (Repeated Load Triaxial) Tests
RLT Tests
RLT Typical Results

![Graph showing RLT Typical Results](image-url)
\[ \varepsilon_r = \frac{\delta_{r \cdot N}}{L_0 \left( -\varepsilon_p \varepsilon_{n-1} \right)} \]

\[ \varepsilon_p = \frac{\delta_{p \cdot \text{total}}}{L_0 \left( -\varepsilon_p \varepsilon_{n-1} \right)} \]

\[ M_r = \frac{\sigma_d}{\varepsilon_r} \]
Test Results

![Graph showing the relationship between dry density (pcf) and permeability (ft/day). The graph includes data points for ML-LA-Coarse gradation.]
## Test Results

<table>
<thead>
<tr>
<th>Gradation</th>
<th>Dry density</th>
<th>Ks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(pcf)</td>
<td>(ft/day)</td>
</tr>
<tr>
<td>LA-Class II-Coarse</td>
<td>116</td>
<td>2278</td>
</tr>
<tr>
<td>LA-Class II-Fine</td>
<td>129</td>
<td>151</td>
</tr>
<tr>
<td>New Jersey-Mean</td>
<td>104</td>
<td>2837</td>
</tr>
<tr>
<td>Modified-Coarse</td>
<td>107.6</td>
<td>3369</td>
</tr>
<tr>
<td>Modified-Fine</td>
<td>124</td>
<td>2277</td>
</tr>
</tbody>
</table>
1-h/1-yr Precipitation

(After Cedergren et al. 1973)
Comparison of Drain Quality

Infiltration method: i=2.4 in/hr; C=0.33-0.50

q=1.992 ft³/day/ft

AC
Permeable base (6”)
Subgrade

Infiltration rate: 0.015 ft/ft

24 ft 10 ft
### Drainage Requirements in Pavements - LA CII-C.drp

#### Roadway Geometry

- **W**: 44 ft
- **SR**: 0.0180 ft/ft
- **LR**: 52.88 ft

#### Sieve Analysis

- **S**: 0.0100 ft/ft
- **SX**: 0.0150 ft/ft

#### Inflow

- **q1**: 1.992 ft³/d/ft²
- **qm**: rt³/d/ft²

#### Permeable Base

- **H**: 0.5 ft
- **U**: 50. %
- **t**: 27.09 hr
- **qd**: rt³/d/ft²

#### Edge Drain - Pipe

- **D**: in
- **Le**: ft
- **Q**: ft³/d

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**W = b + 2c**

**SR = \sqrt{S^2 + SX^2}**

**LR = W \sqrt{1 + (\frac{SR}{SX})^2}**

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**Geometry A**

- **Sx**
- **b**
- **c**

**Geometry B**

- **Sx**
- **b**
- **c**

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**Pavement**

- **Separator layer**
- **Subgrade**
- **Geotextile pre-pave installation**

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**LR** 52.88 ft

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**W** 44 ft
# DRIP Results

<table>
<thead>
<tr>
<th>Base material</th>
<th>Ks (ft/day)</th>
<th>T&lt;sub&gt;50&lt;/sub&gt; (hour)</th>
<th>Quality of drain *</th>
</tr>
</thead>
<tbody>
<tr>
<td>LA Class II-Coarse</td>
<td>2278</td>
<td>2.59</td>
<td>Good</td>
</tr>
<tr>
<td>LA Class II-Fine</td>
<td>151</td>
<td>27.1</td>
<td>Fair</td>
</tr>
<tr>
<td>New Jersey-Mean</td>
<td>2837</td>
<td>2.67</td>
<td>Good</td>
</tr>
<tr>
<td>Modified-Coarse</td>
<td>3369</td>
<td>1.75</td>
<td>Excellent</td>
</tr>
<tr>
<td>Modified-Fine</td>
<td>2277</td>
<td>2.11</td>
<td>Good</td>
</tr>
</tbody>
</table>

* Based on 50% drainage
RLT Results (Mr)

Number of loading cycles

Resilient modulus (psi)

- ML-LA Class II-Coarse
- ML-New Jersey
- ML-LA Class II-Fine
- ML-Modified-Coarse
- ML-Modified-Fine
RLT Results ($\varepsilon_p$)
RLT Results

Permanent vertical strain ($10^{-3}$)

Permanent vertical strain rate ($10^{-3}$/cycle)

- ML-LA Class II-Coarse
- ML-New Jersey
- ML-LA Class II-Fine
- ML-Modified-Coarse
- ML-Modified-Fine
Conclusions & Recommendations

• A large variation of base behavior will be expected with LA Class II gradation.

• LA Class II coarse gradation will perform better.

• Permanent deformation shall provide a better indicator to structural stability.
Conclusions & Recommendations

• A modified gradation was determined;
• Constructability of the modified gradation should be examined;
• Worthwhile of considering drainability under unsaturated conditions;
• Costs of modified gradations should be considered.