Ground Tire Rubber (GTR) as a Stabilizer for Subgrade Soils

FDOT Contract Number: BDK81 977-03

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Problem Statement

- GTR supplies may increase when not used in Hot Mix
- Are other highway applications possible?
Outline

- Objectives
- Task overview
- Results
Objective

- Determine the key pavement engineering properties of GTR and stabilized Florida subgrade soil blends
Tasks

- Task 1 Literature Search
- Task 2 Determine GTR Sources
- Task 3 Determine Subgrade Sources
- Task 4 Test Program Development
- Task 5 Database Development
- Task 6 Sampling
- Task 7 Testing
- Task 8 Data Reduction
- Task 9 Data Analysis
- Task 10 Technology Transfer
Literature Search

**Density**
- Decreased with increase of GTR

**LBR**
- Decreased with increase of GTR
- Smaller sizes of GTR result in larger decreases of CBR/LBR

**Resilient Modulus**
- Decreased with increase of GTR

**Permeability**
- Increased slightly with maximum percentages of rubber

**Consolidation**
- No literature on Consolidation of granular soils was found

**Creep**
- Minimum failure strain at ~3%
GTR Subgrade Choices

- Three soil types (FDOT SMO Aided)
  - Low LBR (20) – A-3
  - Medium LBR (40) – A-2-4
  - High LBR (80) – A-2-4

- FDOT approved GTR supplier with three sizes
  - 1 inch (Range: 1-inch to 3/8-inch)
  - 3/8 inch (Range: 1/2-inch to #4 sieve)
  - #40
Global Tire Recycling Plant Site Visit

A very happy Amir

A very serious Alex
Testing Program

1. Atterberg Limits
2. Optimum Moisture Content
3. Sieve Analysis
4. Volumetric Mixing
5. LBR
6. Resilient Modulus
7. Creep
8. Permeability
9. Consolidation

Subgrade Only

Subgrade GTR Blends
Atterberg limits

- Low LBR Subgrade
  - No fines

- Medium & High LBR Subgrade
  - No plastic fines
Moisture Density (Modified Proctor)

High LBR

Medium LBR

Low LBR
## Test Results: Optimum Moisture Content

<table>
<thead>
<tr>
<th>Source</th>
<th>Maximum Dry Density (pcf)</th>
<th>Optimum Moisture Content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low LBR</td>
<td>107</td>
<td>12.5%</td>
</tr>
<tr>
<td>Medium LBR</td>
<td>115</td>
<td>10.0%</td>
</tr>
<tr>
<td>High LBR</td>
<td>122</td>
<td>7.5%</td>
</tr>
</tbody>
</table>
Sieve Analyses

- FDOT (LBR 80)
- A-2-4 (LBR 80)
- FDOT (LBR 40)
- A-2-4 Sand (LBR 40)
- FDOT A3 Sand (LBR 20)
- A3 Sand (LBR 20)
# Sieve Analysis Results

<table>
<thead>
<tr>
<th>Grain Size Characteristic</th>
<th>Low LBR Material</th>
<th>Medium LBR Material</th>
<th>High LBR Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uniformity Coefficient</td>
<td>2.2</td>
<td>2.0</td>
<td>4.1</td>
</tr>
<tr>
<td>Curvature Coefficient</td>
<td>1.1</td>
<td>63.9</td>
<td>1.4</td>
</tr>
<tr>
<td>Passing # 200</td>
<td>5%</td>
<td>20%</td>
<td>12%</td>
</tr>
<tr>
<td>AASHTO Classification</td>
<td>A-3</td>
<td>A-2-4</td>
<td>A-2-4</td>
</tr>
<tr>
<td>USCS Classification</td>
<td>SP</td>
<td>SM</td>
<td>SM</td>
</tr>
</tbody>
</table>
Volumetric Blending

- Mixing by volume used in the field
- 4%, 8%, 16%, 24%, 32% GTR by volume
- Corresponds to
  - 1/2”, 1”, 2”, 3” and 4” GTR layers in a 12” lift
<table>
<thead>
<tr>
<th>Soil Type</th>
<th>GTR % by Weight</th>
<th>GTR % by Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>High LBR</td>
<td>1.1</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>2.3</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>4.7</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>7.1</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>9.7</td>
<td>32</td>
</tr>
<tr>
<td>Medium LBR</td>
<td>1.2</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>2.4</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>4.8</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>7.4</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>10.0</td>
<td>32</td>
</tr>
<tr>
<td>Low LBR</td>
<td>1.3</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>2.6</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>5.3</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>8.0</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>10.9</td>
<td>32</td>
</tr>
</tbody>
</table>
LBR
LBR (cont.)

- Limerock Bearing Ratio
- 15 lb surcharge for subgrade
Limerock Bearing Ratio Results

<table>
<thead>
<tr>
<th>Soil</th>
<th>Soaked LBR</th>
</tr>
</thead>
<tbody>
<tr>
<td>High LBR</td>
<td>88</td>
</tr>
<tr>
<td>Med LBR</td>
<td>38</td>
</tr>
<tr>
<td>Low LBR</td>
<td>20</td>
</tr>
</tbody>
</table>
Limerock Bearing Ratio Results

High LBR Blends

Medium LBR Blends

Low LBR Blends

- All Decrease
- # 40 Blends Worst
Limerock Bearing Ratio Results

High LBR Blends

Medium LBR Blends

Low LBR Blends

Largest Decrease # 40
Resilient Modulus

Tests performed by the State Materials Office (SMO)
% GTR vs. Resilient Modulus

High LBR

Medium LBR

Low LBR

All Decrease
Low Mr Decrease < Medium LBR < High LBR
Creep
High LBR Material

Strain vs. Duration High LBR Material

30-Year Deflection Projection High LBR Material
Medium LBR Material

Strain vs. Duration Medium LBR Material

30-Year Deflection Projection for Medium LBR Material

\[ y = 0.0003 \ln(x) + 0.0136 \]

\[ y = 0.001 \ln(x) + 0.1623 \]

virgin Material
16% GTR 1"
32% GTR 1"
16% GTR 3/8"
32% GTR 3/8"
16 % GTR #40
32% GTR #40

\[ y = 0.0003 \ln(x) + 0.0136 \]

\[ y = 0.001 \ln(x) + 0.1623 \]
Low LBR Material

Strain vs. Duration Low LBR Material

30-Year Deflection Projection for Low LBR Material

Strain (in/in) vs. Duration (day)

- Virgin Material
- 16% GTR 1"
- 32% GTR 1"
- 16% GTR 3/8"
- 32% GTR 3/8"
- 16% GTR #40
- 32% GTR #40

Deflection (in) vs. Duration (day)

- \( y = 0.0007 \ln(x) + 0.0501 \)
- \( y = 0.0019 \ln(x) + 0.202 \)

Florida Institute of Technology
Strain Rate vs. GTR % for each Soil Type

- **High LBR**:
  - Creep Strain Rate × 10^-4 vs. GTR %
    - 0%:
      - 1": 0.5
      - 3/8": 0.3
      - #40:
    - 16%:
      - 1": 0.2
      - 3/8": 0.1
      - #40:
    - 32%:
      - 1": 0.1
      - 3/8": 0.05
      - #40:

- **Medium LBR**:
  - Creep Strain Rate × 10^-4 vs. GTR %
    - 0%:
      - 1": 0.3
      - 3/8": 0.2
      - #40:
    - 16%:
      - 1": 0.1
      - 3/8": 0.05
      - #40:
    - 32%:
      - 1": 0.05
      - 3/8": 0.02
      - #40:

- **Low LBR**:
  - Creep Strain Rate × 10^-4 vs. GTR %
    - 0%:
      - 1": 0.2
      - 3/8": 0.1
      - #40:
    - 16%:
      - 1": 0.1
      - 3/8": 0.05
      - #40:
    - 32%:
      - 1": 0.05
      - 3/8": 0.02
      - #40:

- Creep not a concern
- All relatively acceptable if 10^-4
- #40 with Low Material will produce 0.3% strain over 30 years
Permeability

Constant Head Permeability Test Set-up
Test Results: Constant Head Permeability

- Virgin Material
  - One Order of Magnitude Differences

<table>
<thead>
<tr>
<th>Soil</th>
<th>Hydraulic Conductivity, k (cm/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High LBR</td>
<td>$1.2 \times 10^{-5}$</td>
</tr>
<tr>
<td>Medium LBR</td>
<td>$2.8 \times 10^{-6}$</td>
</tr>
<tr>
<td>Low LBR</td>
<td>$3.7 \times 10^{-4}$</td>
</tr>
</tbody>
</table>
Constant Head Permeability

High LBR Blends

Medium LBR Blends

Low LBR Blends

Very little change for all cases
Low LBR Material

- Typical results
- No significant change

<table>
<thead>
<tr>
<th>Soil</th>
<th>GTR</th>
<th>k (cm/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low LBR</td>
<td>0</td>
<td>3.7E-04</td>
</tr>
<tr>
<td>Med LBR</td>
<td>0</td>
<td>4.2E-06</td>
</tr>
<tr>
<td>High LBR</td>
<td>0</td>
<td>6.3E-06</td>
</tr>
</tbody>
</table>
Consolidation

Custom 4-inch Consolidation Molds
Consolidation

- **Virgin Material Slope**

<table>
<thead>
<tr>
<th>Soil</th>
<th>Compression Index, $C_c$</th>
</tr>
</thead>
<tbody>
<tr>
<td>High LBR</td>
<td>0.010</td>
</tr>
<tr>
<td>Med LBR</td>
<td>0.007</td>
</tr>
<tr>
<td>Low LBR</td>
<td>0.008</td>
</tr>
</tbody>
</table>
Consolidation Results

High LBR Blends

Medium LBR Blends

Low LBR Blends

1” and 3/8 “ produce no change
# 40 blend causes change
Consolidation Results

High LBR Blends

Medium LBR Blends

Low LBR Blends

- No clear trends
- Typical clays
- $10^{-3}$ to $10^{-4}$
- Much higher

**Coefficient of Consolidation ($C_v$, in/sec)**

**Pressure (tsf)**

**Virion Soil**

1” GTR 16%

1” GTR 32%

3/8” GTR 16%

3/8” GTR 32%

#40” GTR 16%

#40” GTR 32%
Summary

- With increasing GTR %:
  - Density decreases
  - LBR decreases
  - Resilient Modulus decreases
  - No significant Creep
  - Not Consolidating
  - No significant change in Permeability
Conclusions

GTR Subgrade blends are not desirable for highway use

LBR
- Decreases linearly with an increase of GTR
- #40 mesh GTR blends produced largest LBR decrease
- Low and Medium LBR subgrade blends were classified as unsuitable for use as a subgrade material
- High LBR subgrade blends with 1-inch GTR and 3/8-inch GTR produce acceptable LBR’s up to 8% GTR by volume
- #40 GTR High LBR blends produce acceptable LBR’s only at 4% GTR by volume
Conclusions

Constant Head Permeability
- High LBR soil blends produce a small increase in k
- Low and Medium LBR soil blends showed no significant k changes

Consolidation
- Compressibility of 1” and 3/8” blends showed no change compared to virgin material
- Compressibility of #40 mesh GTR blends increased by three to five magnitudes over the virgin material
- $C_v$ values in the soil/GTR blends were three to four orders of magnitude larger than typical remolded clays
Recommendations

- Blends of High LBR Subgrade with minimal GTR concentrations could be suitable for the subgrade layer.
- Could be suitable as a possible lightweight, non-structural backfill due to decrease in density and increase in internal friction angle.
Questions?