Use of Tire Shreds in Lightweight Fill Construction
SPR-3370 - Use of Tire Shreds in Lightweight Fill Construction

Contract No. B 27562 and R-29217
SR 110 in Marshall County and
SR 19 in Elkhart County

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I. Background

- Existing pavements at SR-110 and SR-19 needed widening and raising of pavement level
- Use of lightweight fill (expanded shale) was recommended because the existing road was built over a peat deposit. However, expanded shale is expensive and difficult to compact
- For **SR-110**, a tire shred-sand mixture was used between stations 276+00 and 294+69. The project consisted of raising the grade by about three feet at a few locations and widening the existing embankment by approximately five feet
- For **SR-19**, a tire shred-sand mixture was used as the fill material for the shoulders of the pavement
Cross-Section of Embankment (SR -110)

Compaction Details
1) D6 10 T roller
2) Lift thickness: 6 inches
3) Number of passes: 6-8

Asphalt Pavement over compacted aggregate

Geogrid

Tire shred-sand mixture

Existing fill

Drain Cross Section

6-12 inch top soil

Geotextile wrapping

Aggregate for under drains

Between 4:1 (H:V) to 3:1
II. Tire Shredding Sequence

Scrap tires are collected in trailers and transported to the tire-shredding plant

(Courtesy of Dillion Tires Recycling)
Scrap tires are fed into the shredding unit
(Courtesy of Dillion Tires Recycling)
Rotary shear shredders tear apart the whole tires into shreds
(Courtesy of Dillion Tires Recycling)
Shredded tires are sieved, and shreds not passing the sieve are conveyed back into the shredder for further size reduction.

(Courtesy of Dillion Tires Recycling)
Magnet is used to remove the steel wires present in shredded material
(*Courtesy of Dillion Tires Recycling*)
Conveyor is used to collect shredded tires in piles and transported to job sites/landfills by trucks

(Courtesy of Dillion Tires Recycling)
III. Testing

Materials Used

**Tires**
- 2-inch nominal size
- Average length: 83mm
- Average width: 54mm
- Average thickness: 14mm
- Average aspect ratio (length/width): 1.6

**Sand**
- USCS classification: SP
- $D_{10}=0.24$ mm
- $D_{30}=0.35$ mm
- $D_{60}=0.71$ mm
- $D_{50}=0.52$ mm
- Fines < 5%, WC: 4%
Material Characterization

Frequency Distribution of Length of Tire Shreds

Length (mm) vs. Frequency (%)

- Lengths: 50, 70, 90, 110, 130
- Frequency: 0, 10, 20, 30, 40, 50

- The graph shows the distribution of tire shred lengths with the highest frequency between 90 and 110 mm.
Material Characterization

Frequency Distribution of Width of Tire Shreds

- Frequency Distribution of Width of Tire Shreds
- Material Characterization
- Laboratory Testing

[Graph showing frequency distribution of tire shred widths]
Material Characterization

Grain-Size Distribution for Sand

- Field Sand
- Ottawa sand

% Finer (by weight)

Particle Size (mm)

D_{50} (field) = 0.52 mm
D_{50} (Ottawa) = 0.38 mm
Compaction Studies

Compaction mold

*Diameter*: 27.9 cm  
*Height*: 23.2 cm

**Standard Proctor energy** of 600 kN-m/m³

No. of layers = 4  
No. of blows = 291 for each layer  
(using Standard Proctor hammer)
Compaction Tests Performed in the Laboratory

(Percent shown in the figures are by weight of tire shreds in the mixture)
Unit Weight of Mixture x TS Content in the Mixture (by weight)
Unit Weight of Mixture x TS Content in the Mixture (by weight)
Relation between Unit Weight of Mixture and TS Content

\[ \gamma = 17.875 -0.0549(TS) -0.000629(TS)^2 \]

\[ \rho = 113.748 -0.3492(TS) -0.00400(TS)^2 \]

\( \gamma \) is the unit weight of the mixture in \textbf{kN/m}^3
\( \rho \) is the density of the mixture in \textbf{pcf}

TS is the tire shred content in \% (by weight) in the mixture

NOTE: These equations were developed for the specific tire shred size and sand used in the compaction tests performed in the laboratory
Density of Tires and Mixture (Uncompacted State)

- Density (uncompacted state)
  - Tire shreds
  - 60:40 TS-sand mixture (by volume)

was determined in the field by filling a 0.5-cubic-yard box

<table>
<thead>
<tr>
<th>Material</th>
<th>Density (Uncompacted State)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixture (60:40; TS:Sand by Volume)</td>
<td>74 pcf</td>
</tr>
<tr>
<td>Tire Shreds</td>
<td>31 pcf</td>
</tr>
</tbody>
</table>
Density of sand (uncompacted state) = 90 pcf (assumed)
Density of tire shreds (uncompacted state) = 31 pcf

\[
\left( \frac{TS}{Sand} \right)_{\text{volume}} = \frac{60}{40} \quad \Rightarrow \\
\left( \frac{TS}{Mix} \right)_{\text{weight}} = \left( \frac{0.6 \times 31}{0.6 \times 31 + 0.4 \times 90} \right) = 0.34
\]

TS:Sand = 60:40 (by volume in uncompacted state) corresponds to TS content of 34% (by weight) in the mixture (in uncompacted state)

We can obtain the compacted density for this ratio from:

\[
\rho = 113.748 - 0.3492(TS) - 0.00400(TS)^2
\]

\[
\rho_{mix(60:40 \rightarrow TS:Sand)} = 96 \text{ pcf}
\]
Density of sand (uncompacted state) = 90 pcf (assumed)
Density of tire shreds (uncompacted state) = 31 pcf

\[
\left( \frac{TS}{Sand} \right)_{\text{volume}} = \frac{70}{30} = \left( \frac{0.7 \times 31}{0.7 \times 31 + 0.3 \times 90} \right) = 0.44
\]

TS:Sand = 70:30 (by volume in uncompacted state) corresponds to TS content of 44 % (by weight) in the mixture (in uncompacted state)

We can obtain the **compacted** density for this ratio from:

\[
\rho = 113.748 - 0.3492(TS) - 0.00400(TS)^2
\]

\[
\rho_{\text{mix}}(70:30 \rightarrow TS:Sand) = 90 \text{ pcf}
\]
Variation of Density with Tire Shred Content

Laboratory Testing

Density of Mix (pcf)

Tire Shred Content (% by Weight) in Mixture

60:40 (by volume)

70:30 (by volume)
Based on the test results, segregation is observed for mixtures with TS content > 30 % (by weight) in the mixture
# Compacted Unit Weight from Test Pads

<table>
<thead>
<tr>
<th>Compaction Lift Thickness</th>
<th>Mixing Ratio (TS/Sand by volume)</th>
<th>Compaction Type</th>
<th>Compacted Unit Weight (kN/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Test-Pit Method</td>
<td>Nuclear-Gauge Method</td>
</tr>
<tr>
<td>150 mm (6 inch)</td>
<td>50/50</td>
<td><strong>Bulldozer</strong></td>
<td>17.32</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sheepsfoot roller</td>
<td>13.32</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Steel-drum roller</td>
<td>16.16</td>
</tr>
<tr>
<td></td>
<td>60/40</td>
<td><strong>Bulldozer</strong></td>
<td>14.42</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sheepsfoot roller</td>
<td>12.39</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Steel-drum roller</td>
<td>14.14</td>
</tr>
<tr>
<td>300 mm (12 inch)</td>
<td>50/50</td>
<td><strong>Bulldozer</strong></td>
<td>16.75</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sheepsfoot roller</td>
<td>15.61</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Steel-drum roller</td>
<td>16.68</td>
</tr>
<tr>
<td></td>
<td>60/40</td>
<td><strong>Bulldozer</strong></td>
<td>16.61</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sheepsfoot roller</td>
<td>16.77</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Steel-drum roller</td>
<td>15.86</td>
</tr>
</tbody>
</table>
Weight-to-Volume Ratio Conversion

- Assuming the following uncompacted unit weights:

  \[
  \gamma_{\text{sand}} = 90 \text{ pcf} \\
  \gamma_{\text{tire-shred}} = 31 \text{ pcf}
  \]

\[
\left( \frac{TS}{Sand} \right)_{\text{volume}} = \left( \frac{TS}{Sand} \right)_{\text{weight}} \left( \frac{\gamma_{\text{Sand}}}{\gamma_{\text{TS}}} \right)
\]
The tire shred-sand volume ratio is the volume ratio of the components to be loaded into the loader bucket during the mixing process to obtain the weight ratios shown in the Table.

<table>
<thead>
<tr>
<th>TS:Sand* (by volume)</th>
<th>TS:Sand (by weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>70/30</td>
<td>44/56</td>
</tr>
<tr>
<td>60/40</td>
<td>34/66</td>
</tr>
<tr>
<td>50/50</td>
<td>25/75</td>
</tr>
</tbody>
</table>
Specific gravity of tire shreds was determined using ASTM C127 ("Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate")

Tires placed in a container, and mass determined in air

Wire suspending the container

Tires submerged in water and weighed to determine displaced volume
Specific Gravity

Sand

Specific gravity of sand was determined using ASTM D854 ("Standard Test Methods for Specific Gravity of Soil Solids by Water Pycnometer")

Soil taken in pycnometer and weighed

De-airing was done to determine the displaced volume
<table>
<thead>
<tr>
<th>Material</th>
<th>Specific gravity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tire Shreds</td>
<td>1.22</td>
</tr>
<tr>
<td>Sand</td>
<td>2.69</td>
</tr>
</tbody>
</table>
IV. Construction of Tire Shred-Sand Fill

Companies Involved

- **Tire shredding Company**

DILLON TIRES RECYCLING
North Liberty
IN 46554

- **Mixing and trucking**

Klink Trucking, Inc.
Ashley,
IN 46705

- **Job Sites:**
  I. SR-110
  (4.0 miles West of US31)
  Marshall County,
  IN
  II. SR-19
  (At junction of CR 46)
Project Details of Job Site at SR-110

- Tire shred-sand mixture: TS:sand volume mixing ratio of 60:40
- Total fill: 2,200 cubic yards
- Shredded tires: ~ 880 Tonnes
- B-borrow material: ~ 1,700 Tonnes
Mixing Procedure

Three buckets of shredded tires was piled

Two buckets of sand was dumped on shredded-tire pile
Mixing Procedure

Loader bucket thoroughly mixing shredded tires and sand

Pile of shredded tire-sand mixture
Fill Construction using Mixture

Mixed material taken to construction site and dumped in place

Mixture spread over the geotextile and geogrid in lifts of 12 inches using tracked bull-dozer
Fill Construction using Mixture

Mixture compacted with three passes of 5 T smooth-drum roller

Side slopes encased with geotextile
Fill Construction using Mixture

Geogrid placed above the top lift of the mixture to distribute loads from the pavement

Aggregate placed above geogrid
Paving

Pavement laid on 9-inch compacted aggregate (No. 53)

Paved material compacted
Road open to traffic in the 3rd week of October 2008
Field Monitoring of SR-110

Settlement of fill material at SR-110 was monitored using surveying equipment along station 291 + 41, where maximum tire shred-sand fill was placed.

<table>
<thead>
<tr>
<th>Days elapsed after opening the pavement to traffic</th>
<th>Average Settlement at edges of pavement (mm)</th>
<th>Settlement at center of pavement (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>37</td>
<td>-6</td>
<td>0</td>
</tr>
<tr>
<td>55</td>
<td>6</td>
<td>*</td>
</tr>
<tr>
<td>103</td>
<td>15</td>
<td>24</td>
</tr>
</tbody>
</table>

*data measurement error

Three nails driven along a section in the pavement to monitor settlements.
## Cost Analysis for SR-110

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lightweight Aggregate</td>
<td>$232,264.00</td>
</tr>
<tr>
<td>Subgrade Treatment II A</td>
<td>$ 7,357.00</td>
</tr>
<tr>
<td>Geogrid II</td>
<td>$12,783.58</td>
</tr>
<tr>
<td>Compacted Aggregate #53</td>
<td>$51,194.40</td>
</tr>
<tr>
<td>Geotextiles</td>
<td>$17,901.26</td>
</tr>
<tr>
<td>Underdrain</td>
<td>$38,922.64</td>
</tr>
<tr>
<td>Underdrain, Outlet</td>
<td>$ 6,659.19</td>
</tr>
<tr>
<td>Outlet Protector</td>
<td>$ 71,470.00</td>
</tr>
<tr>
<td>Tire Shreds/Sand Mixture</td>
<td>$141,069.95</td>
</tr>
<tr>
<td>Total Savings through use of tire shred-sand mixture (compared with cost of using expanded shale)</td>
<td>-$ 94,968.50</td>
</tr>
</tbody>
</table>
Summary (SR-110 Project)

- Nearly 880 T of scrap tires were used in this project (equivalent to ~ 90,000 passenger car scrap tires)

- Approximately 2,580 T of mixture (2200 cubic yards) was utilized. This correspond to ~ 112 truck loads

- No rutting was observed during compaction or on finished pavement subjected to traffic loads

- Settlement of about 18 mm was observed due to traffic loads in ~100 days

- Total savings of $94,000 was realized on this project by using tire shreds-sand mixture fill
Project Details of Job Site at SR 19

- Tire shred-sand mixture: TS:sand volume mixing ratio of 60:40
- Total fill: ~ 800 cubic yards
- Shredded tires: ~ 248 Tonnes (equivalent to 24,800 passenger car tires)
- Eight stakes were installed along the shoulder at stations 191 and 196+80 at 100 ft intervals (alternated, left to right to monitor the settlements)

stations: 191+00 LT, 193+00 LT, 195+00 LT, 196+50 LT, 191+00 RT, 193+00 RT, 195+00 RT, and 196+50 RT
Road Widening at SR-19

Existing embankment section was widened using conventional fill material.

Mixing of tire shreds and sand was done at the job site for construction of pavement shoulders.
Each lift of mixture placed over geotextile and compacted

Geotextile wrapped around compacted lift of mixture
Compaction in lifts continued until final lift reached
## Field Monitoring of SR-19 (INDOT)

<table>
<thead>
<tr>
<th>Station</th>
<th>Days Elapsed</th>
<th>Settlement (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>191+00 LT</td>
<td>107</td>
<td>18</td>
</tr>
<tr>
<td>193+00 LT</td>
<td>107</td>
<td>0</td>
</tr>
<tr>
<td>195+00 LT</td>
<td>107</td>
<td>*</td>
</tr>
<tr>
<td>196+50 LT</td>
<td>107</td>
<td>12</td>
</tr>
<tr>
<td>191+00 RT</td>
<td>90</td>
<td>6</td>
</tr>
<tr>
<td>193+00 RT</td>
<td>90</td>
<td>12</td>
</tr>
<tr>
<td>195+00 RT</td>
<td>90</td>
<td>3</td>
</tr>
<tr>
<td>196+50 RT</td>
<td>90</td>
<td>27</td>
</tr>
</tbody>
</table>

* stake got damaged
## Cost Analysis for SR-19

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geogrid</td>
<td>$1,972.44</td>
</tr>
<tr>
<td>Geotextiles</td>
<td>$6,436.31</td>
</tr>
<tr>
<td>Borrow, Cohesive</td>
<td>$45,821.88</td>
</tr>
</tbody>
</table>
Summary (SR-19 Project)

- A Total of ~ 248 Tonnes of tire shreds were used in this project (equivalent to 24,800 passenger car tires)

- Maximum settlement along the shoulder of the section of tire shred-sand mixture fill was less than 30 mm after about 90 days of opening the pavement to traffic