QUALITY CONTROL OF TRENCH BACKFILL AT HIGHWAY CROSS-DRAIN PIPES

Zhongjie “Doc” Zhang, PhD, P.E.

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Purposes of Quality Control

- Guarantee sufficient surrounding support to pipes for their stability and integrity
- Provide adequate support to pavement structures at the locations of highway cross-drain pipes
The unexpected deterioration of pavement ride comfort due to “dips” in pavement surfaces at highway cross-drain locations.
Field Investigation Indicates

- Under the same traffic and environmental conditions, pavement “dips” occurred at some cross-drain pipe locations but not at others.
- Pavement “dips” occurred mainly due to weaker trench backfill than adjacent subgrade soils.
Pavement “dips” and PRR

PRR is the ratio of average penetration resistances within and outside of a trench area.

[Diagram showing Penetration Resistance Ratio vs Case Number. The graph compares 'with dip' and 'without dip' cases, with 'with dip' represented by blue circles and 'without dip' by pink squares. The ratio decreases as the case number increases.]
Typical DCP Profiles

- Asphalt: 9 cm (3.5"
- Soil Cement: 21.5 cm (8.5"

Concrete pipe: 91 cm (36"

- Backfill
- Subgrade
- Soil cement (15 cm or 6"

Asphalt: 20 cm (8"
Soil Cement: 15 cm (6"

Concrete pipe dia. = 66 cm

Metal pipe: 112 cm (44"

Asphalt: 4 cm (1.5"
Soil cement: 20 cm (8"

Depth, cm

Out of trench
In trench 1
In trench 2

NDCP, Blows/10 cm Penetration

NDCP, Blows/10 cm Penetration

Site 1: in trench
Site 2: in trench
Site 3: out of trench

Concrete pipe: 112 cm (44"

Concrete pipe dia. = 66 cm
Field Testing
DCP Data Probability Histogram

Subgrade Soils

Sand Backfill

Average N_{DCP} = 7.0
Median N_{DCP} = 5.3

Average N_{DCP} = 4.0
Median N_{DCP} = 3.2
Prevention of Pavement Dips

To prevent pavement surface “dips”, trench backfill should

- be compatible with the adjacent subgrade soils in stiffness, or
- have a penetration blow count, $N_{DCP}$, equal to or larger than 10 hammer blows per 4 inch (10cm) penetration in Louisiana
Objective of Field Testing

Investigate

- How the criterion of backfill quality could be missed in the field construction
- What kind of measures should be taken to prevent it from occurring
<table>
<thead>
<tr>
<th>Construction Project</th>
<th>No. of Trenches</th>
<th>Backfill Material</th>
<th>Status of Testing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>In Trench</td>
</tr>
<tr>
<td><strong>019-30-0015 (LA 964)</strong></td>
<td>4</td>
<td>Sand (Compaction)</td>
<td>Finished</td>
</tr>
<tr>
<td><strong>019-05-0026 (US 61)</strong></td>
<td>4</td>
<td>Kentucky crushed limestone (Compaction)</td>
<td>Finished</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Sand (flooding)</td>
<td>Finished</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Bedding material (30% sand, 70% gravel, compaction)</td>
<td>Finished</td>
</tr>
<tr>
<td><strong>077-02-0013 (LA 73/LA 74)</strong></td>
<td>3</td>
<td>Selected soil PI &lt; 10</td>
<td>Finished</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Mexican crushed limestone</td>
<td>Finished</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Sand (compaction)</td>
<td>Finished</td>
</tr>
<tr>
<td><strong>061-05-0044 (LA 10)</strong></td>
<td>4</td>
<td>RAP</td>
<td>Finished</td>
</tr>
</tbody>
</table>
Major Influence Factors on Trench Backfill Quality

- Contractors’ Behavior
- Backfill Material
- Pipe Cover Layer
- Configuration of Cross-Drain Trench
Contractors’ Behavior

- The most important factor in quality control
- Most are experienced
- Tension can build in the field when under pressure due to construction delays, under traffic, bad weather, wrong moisture content of backfill, poor drainage conditions
- They should be a team player and share the consequences of the quality of their construction products, good or bad
Major Influence Factors on Trench Backfill Quality

- Contractors’ Behavior
- Backfill Material
- Pipe Cover Layer
- Configuration of Cross-Drain Trench
Backfill Material

- Compaction
- Moisture Adjustment
- Seepage Stability
Gradation of Different Backfills

Gradation Curve

- DOTD Granular upbound
- DOTD Granular lowbound
- Sand, LA 964
- Sand gravel, LA 964
- Kentucky limestone
- Mexican limestone
- Selected soil
- RAP
### Gradation Characteristics of Backfill Material

<table>
<thead>
<tr>
<th>Material</th>
<th>Effective size $D_{10}$ (mm)</th>
<th>$D_{30}$ (mm)</th>
<th>$D_{60}$ (mm)</th>
<th>Uniformity Coefficient $C_u$</th>
<th>Coefficient of Gradation $C_c$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>0.17-0.3</td>
<td>0.32-0.43</td>
<td>0.46-0.78</td>
<td>1.8-3</td>
<td>0.79-1.36</td>
</tr>
<tr>
<td>Kentucky limestone</td>
<td>0.07-0.3</td>
<td>0.6-1.7</td>
<td>1.7-6</td>
<td>5.67-85.7</td>
<td>0.71-6.88</td>
</tr>
<tr>
<td>Mexican limestone</td>
<td>0.48</td>
<td>1.7</td>
<td>7.0</td>
<td>14.6</td>
<td>0.86</td>
</tr>
<tr>
<td>Bedding (Sand gravel)</td>
<td>0.3-0.33</td>
<td>0.65-2.3</td>
<td>4-12</td>
<td>13.3-40</td>
<td>0.35-2.29</td>
</tr>
<tr>
<td>RAP</td>
<td>0.3-1.2</td>
<td>1.6-4.8</td>
<td>6.4-12.5</td>
<td>10.4-21.3</td>
<td>0.76-1.53</td>
</tr>
<tr>
<td>Selected soil</td>
<td>0.014</td>
<td>0.048</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Field Compaction Equipment

Wacker Packer  Vibratory Roller  Vibratory Plate
Effects of Compaction

The graph shows the effects of backfill thickness on the number of blows (N_{DCP}) required for compaction. Different materials such as RAP (recycled asphalt pavements), sand, and crushed stone are compared at varying thicknesses. The graph indicates that heavier materials (e.g., heavy crushed stone) require more blows at the same thickness compared to lighter materials (e.g., light sand).
Field Compaction - Sand

(a) Sand Backfill with Good Compaction

(b) Sand Backfill with Poor Compaction
Field Compaction –
Kentucky Limestone

(a) 1 ft Lift

(b) 2 ft Lift
Field Compaction – RAP

(a) 12-inch Lift

(b) 18-inch Lift
Field Compaction – Selected Soil
## Compaction Characteristic Summary

<table>
<thead>
<tr>
<th>Material</th>
<th>Maximum Dry Density pcf</th>
<th>Working Moisture Range, %</th>
<th>Compaction in field</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Standard Proctor</td>
<td>Modified Proctor</td>
<td>Standard Proctor</td>
</tr>
<tr>
<td>Sand</td>
<td>105 - 107</td>
<td>107 - 109</td>
<td>4 - 7</td>
</tr>
<tr>
<td>Kentucky limestone</td>
<td>135 - 139</td>
<td>144 - 146</td>
<td>5 - 7</td>
</tr>
<tr>
<td>Mexican limestone</td>
<td>116 -121</td>
<td>127-129</td>
<td>8 - 12</td>
</tr>
<tr>
<td>Bedding (Sand gravel)</td>
<td>125 - 128</td>
<td>132 - 134</td>
<td>5 - 8</td>
</tr>
<tr>
<td>RAP</td>
<td>102 - 104</td>
<td>110 -112</td>
<td>5 - 9</td>
</tr>
</tbody>
</table>
| Selected soil                  | 106 - 109               | 112 - 115                | 15 - 18             | 13 – 16             | Not easy
Backfill Material

Compaction

- Moisture Adjustment
- Seepage Stability
Moisture Adjustment

- How fast a backfill material can be dried out in the field
- Laboratory dry-out test
Laboratory Dry-Out Test Results

- Silt
- Sand
- Kentucky limestone
- Mexican Limestone
- RAP
- Bedding Material

Graph showing Hours to Optimum Moisture, hour on the y-axis and Moisture Content, % on the x-axis.
## Typical Moisture Content Values

<table>
<thead>
<tr>
<th>Material</th>
<th>Optimum Moisture Content, %</th>
<th>Maximum Moisture without water flow-out, %</th>
<th>Possible Field Moisture, %</th>
<th>Field Working Moisture Range, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>5</td>
<td>17</td>
<td>&lt; 17</td>
<td>12</td>
</tr>
<tr>
<td>Kentucky limestone</td>
<td>5.5</td>
<td>11</td>
<td>&lt; 11</td>
<td>5.5</td>
</tr>
<tr>
<td>Mexican limestone</td>
<td>8.5</td>
<td>14</td>
<td>&lt; 14</td>
<td>6.5</td>
</tr>
<tr>
<td>Bedding (Sand gravel)</td>
<td>5.5</td>
<td>15</td>
<td>&lt; 15</td>
<td>10.5</td>
</tr>
<tr>
<td>RAP</td>
<td>6</td>
<td>15</td>
<td>&lt; 15</td>
<td>9</td>
</tr>
<tr>
<td>Selected soil</td>
<td>16</td>
<td>31</td>
<td>&lt; 31</td>
<td>15</td>
</tr>
</tbody>
</table>
Backfill Material

Compaction

Moisture Adjustment

- Seepage Stability
Seepage Stability

- Resistance to erosion caused by underground water that goes through backfill, or water leaks to the backfill from the joints of cross-drain pipes.
  - Backfill dry density
  - Backfill cohesion or particle interlock

Material comparison

<table>
<thead>
<tr>
<th>Material</th>
<th>Density</th>
<th>Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kentucky limestone:</td>
<td>high</td>
<td>high</td>
</tr>
<tr>
<td>Mexican limestone:</td>
<td>medium</td>
<td>medium</td>
</tr>
<tr>
<td>RAP:</td>
<td>low</td>
<td>high</td>
</tr>
<tr>
<td>Bedding:</td>
<td>medium</td>
<td>medium</td>
</tr>
<tr>
<td>Selected soil:</td>
<td>low</td>
<td>low</td>
</tr>
<tr>
<td>Sand:</td>
<td>low</td>
<td>low</td>
</tr>
</tbody>
</table>
Summary for Backfill Material

- Kentucky limestone: The best choice
  - Easy to compact to a high dry density and stiffness
  - Narrow moisture range in the field
  - Strong particle interlock with good seepage stability
- Followed by Mexican limestone, RAP, bedding material (sand gravel mixture), selected soil, and sand
Major Influence Factors on Trench Backfill Quality

- Contractors’ Behavior
- Backfill Material
  - Pipe Cover Layer
  - Configuration of Cross-Drain Trench
Pipe Cover Layer

- **Refers to the subgrade soil over pipes**
- **It is a buffer zone between a pavement structure and pipes for construction and traffic loading**
- **A thick and well compacted cover layer will spread traffic loading well out of trench area**
Pipe Cover Layer – 4.4 feet

Limestone backfill
Construction Loading Influence
– Embedded pressure cells

<table>
<thead>
<tr>
<th>Layer</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>12&quot;</td>
<td>layer 1</td>
</tr>
<tr>
<td>8&quot;</td>
<td>Asphalt Pavement</td>
</tr>
<tr>
<td>8.5&quot;</td>
<td>Mexican Limestone</td>
</tr>
<tr>
<td>42&quot;</td>
<td>Subgrade</td>
</tr>
<tr>
<td>4&quot;</td>
<td>Selected Soil</td>
</tr>
</tbody>
</table>

Pressure cells

Layer 1

Selected Soil
Construction Loading – on Binder

- **24” depth**
  - Top Horizontal: 17.5 psi
  - Top Inclined: 8.5 psi
  - Bottom Horizontal: 4.2 psi

- **50” depth**
  - Bottom Horizontal: 1.0 psi
Traffic loading influence

- Stresses at various construction stages

- Bottom Gauge

- S1: 5.59 psi, 45°, 25.5"
- S2: 36.8 psi, 5", 8.5"
- S3: 36.8 psi, 2" Wearing Course
- S4: 36.8 psi, 5" Binder Course
- Soil Cement: 36.8 psi, 12"
- Lime Treated: 3.47 psi, 1.19 psi, .88 psi, .86 psi, 12"
- Subgrade: 1.17 psi
Major Influence Factors on Trench Backfill Quality

- Contractors’ Behavior
- Backfill Material
- Pipe Cover Layer
- Configuration of Cross-Drain Trench
Compaction in subgrade backfill areas is important:

- If properly compacted, it can provide a smooth transition in stiffness.
- Otherwise, it can be a weak area if poorly compacted.
Field Example of Subgrade Backfill Area
## Unit Cost Comparison

<table>
<thead>
<tr>
<th>Material</th>
<th>Material Unit Cost $/cubic yd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>5 – 6</td>
</tr>
<tr>
<td>Kentucky limestone</td>
<td>29</td>
</tr>
<tr>
<td>Mexican limestone</td>
<td>25</td>
</tr>
<tr>
<td>Bedding (sand gravel)</td>
<td>8 – 15</td>
</tr>
<tr>
<td>RAP</td>
<td>0</td>
</tr>
<tr>
<td>Selected soil</td>
<td>3 – 8</td>
</tr>
<tr>
<td>Flowable Fill</td>
<td>70 – 100</td>
</tr>
</tbody>
</table>
Conclusions

Material:

- Crushed Limestone is recommended as cross-drain trench backfill if their gradations meet LA Specification 1003.03(d)
- Flowable fill can be used when cost is justified
- Sand and Selected soil that meet current LA DOTD specification can be used if proper compaction can be reached.
- More field testing work using RAP and bedding material as backfill should be conducted
Compaction control:

- Contractors share the consequences of their products by deducting payment for poor construction quality.
- DCP test can be used for final acceptance:
  - Average DCP values over the depth of 4 ft within backfill shall at least be 10 blows per 4” penetration (smaller than 10 mm/blow), or
  - Average DCP values over the 4 ft depth within and out of trench areas are compatible with each other.
Implementation

- LTRC research project: Alternative Methods to Trench Backfill
- Project Review Committee recommends a change in the current specifications for Trench backfill
- Stone aggregate or recycled Portland cement concrete be required for backfill materials for all cross drain pipes and side drain pipes under paved areas of travel lanes, shoulders, and turnouts
Implementation (cont.)

- Each district evaluates the option of using RAP as trench backfill before RAP is officially specified as backfill material
- The modification of Section 701 is coming

THANKS!