Long-Term Performance of Failed Flexible Pavements Stabilized with Cement

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Since its founding in 1916, the Portland Cement Association has had the same mission: "Improve and expand the uses of portland cement and concrete."

**Divisions**

- Market Promotion
- Research
- Technical Services
- Codes and Standards

**Affiliates**

- Regional Cement and Concrete Promotion Partners
- American Concrete Pavement Association
- The CTL Group
- Cement Association of Canada
Cement-Based Pavement Materials

- Roller-Compacted Concrete
- Pervious Concrete
- Conventional Concrete
- Soil-Cement
- Cement-Modified Soil
- Full-Depth Reclamation
- Cement-Treated Base
- Flowable Fill

Water Content

<table>
<thead>
<tr>
<th>Cement Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rolled</td>
</tr>
<tr>
<td>Cast</td>
</tr>
</tbody>
</table>
Definition of Full-Depth Reclamation (FDR)

“...technique in which the full flexible pavement section and a predetermined portion of the underlying materials are uniformly crushed, pulverized, or blended, resulting in a stabilized base course; further stabilization may be obtained through the use of available additives.”

- Asphalt Recycling and Reclaiming Association
FDR is most appropriate under the following conditions:

- The pavement is seriously damaged and cannot be rehabilitated with simple resurfacing.
- The existing pavement distress indicates that the problem likely exists in the base or subgrade.
- The existing pavement distress requires full-depth patching over more than 15 to 20 percent of the surface area.
- The pavement structure is inadequate for the current or future traffic.
Advantages of the FDR Process

- Use of in-place materials
- Little or no material hauled off and dumped
- Maintains or improves existing grade
- Conserves virgin material
- Saves cost by using in-place “investment”
- Saves energy by reducing mining and hauls
- Very sustainable process
Engineering Benefits

- Increased Rigidity
  Spreads Loads
- Eliminates Rutting
  Below Surface
- Reduced Moisture
  Susceptibility
- Reduced Fatigue
  Cracking
- Thinner Pavement
  Section
FDR Construction Process

Pulverize, Shape, Add Cement, Mix In Place, Compact, and Surface

<table>
<thead>
<tr>
<th>Bituminous Surfacing</th>
<th>Pulverized</th>
<th>Pulverized</th>
<th>Stabilized</th>
<th>Stabilized</th>
<th>New Surfacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Granular Base</td>
<td>Subgrade</td>
<td>Subgrade</td>
<td>Subgrade</td>
<td>Subgrade</td>
<td>Subgrade</td>
</tr>
<tr>
<td>Existing road</td>
<td>Pulverization to desired depth</td>
<td>Removal of excess material (if necessary) and shaping</td>
<td>Addition of cement, mixing, reshaping, and compacting</td>
<td>Final surface course applied</td>
<td></td>
</tr>
</tbody>
</table>
Pulverization
Cement Spreading
Blending Materials and Moisture
Compaction and Grading
Curing
Surfacing
But What About Performance?
Long Term Performance of Full-Depth Reclamation Pavements

Principal Investigator and Author:

Imran M. A. Syed, PhD, P.E. Thomas L. Brown Associates, PC
Outline

1. Background
2. Purpose
3. Work Plan
4. Observations
5. Conclusions

Report Published
October 2007
1 - Background

• Waste is the enemy of progress!
• Progressive public officials seek to reduce:
  - Time
  - Materials
  - Money
• Salvation of flexible roads typically include:
  - Thick structural overlay
  - Removal and replacement
• Worn out asphalt pavements (lost resiliency) pulverized and stabilized with small amounts of portland cement to create a new roadway base
• Alternative terms often lead to confusion
2 - Purpose

• Document long-term performance
• Summarize agency experience in FDR
  - laboratory design protocol
  - field construction techniques
  - problems encountered
  - innovative approaches
  - lessons learned
• Share results with others!
3 - Work Plan

- Literature review
- Candidate project selection through close coordination with the Portland Cement Association (PCA)
  - State Departments of Transportation
  - County agencies
  - City agencies
  - Private developers
- Interaction with select officials
- Visual Pavement Condition Survey (PCI)
- Extract cores for UCS measurements
- Summarize findings in a Report
FDR Performance Evaluation
<table>
<thead>
<tr>
<th>Agency</th>
<th>Locations</th>
</tr>
</thead>
<tbody>
<tr>
<td>City</td>
<td>Cities of Westminster, Fullerton, Los Alamitos, and Buena Park, California</td>
</tr>
<tr>
<td></td>
<td>Village of Endicott, New York</td>
</tr>
<tr>
<td></td>
<td>City of Stephenville, Texas</td>
</tr>
<tr>
<td>County</td>
<td>Clark, Pierce, Spokane, and Stevens Counties, Washington</td>
</tr>
<tr>
<td></td>
<td>Geauga County, Ohio</td>
</tr>
<tr>
<td></td>
<td>Montgomery County, New York</td>
</tr>
<tr>
<td></td>
<td>Bonner County, Idaho</td>
</tr>
<tr>
<td></td>
<td>Washington County, Maryland</td>
</tr>
<tr>
<td>State</td>
<td>Idaho Transportation Department - District 6</td>
</tr>
<tr>
<td></td>
<td>South Carolina Department of Transportation</td>
</tr>
<tr>
<td></td>
<td>Texas Department of Transportation - Bryan and Fort Worth Districts</td>
</tr>
<tr>
<td>Private</td>
<td>Anne Arundel, Harford, and Prince Georges Counties, Maryland</td>
</tr>
</tbody>
</table>
The PCI is a subjective numerical rating of pavement condition, ranging from 0 (for the worst possible condition) to 100 (for the best possible condition).

Dozens of core samples were obtained from the project study areas for unconfined compressive strength (UCS) determination.

<table>
<thead>
<tr>
<th>PCI Value</th>
<th>Pavement Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-10</td>
<td>Failed</td>
</tr>
<tr>
<td>10-25</td>
<td>Very Poor</td>
</tr>
<tr>
<td>25-40</td>
<td>Poor</td>
</tr>
<tr>
<td>40-55</td>
<td>Fair</td>
</tr>
<tr>
<td>55-70</td>
<td>Good</td>
</tr>
<tr>
<td>70-85</td>
<td>Very Good</td>
</tr>
<tr>
<td>85-100</td>
<td>Excellent</td>
</tr>
</tbody>
</table>
4 - Observations

- Over 150 roadways evaluated (79 in-depth)
- Overall - excellent long-term performance
- Average PCI of all study pavements was 89
- UCS of cores were from 260 to over 1000 psi
- Cement contents ranged from 2 to 12 percent
- Average cement content was 5 percent
- Owners are happy with the performance of FDR and plan to do more work in the future
- No major failures were observed that could be attributed to the cement-stabilized base
79 Projects Evaluated In-Depth

average project age of roadways was 9 years
Montgomery County, New York

- Began reclaiming roadways in the late 1980’s
- Started using FDR with cement exclusively in 2000
- PCI values average above 84
- Conducts freeze-thaw tests during FDR design process
- 10-inch base thickness
- Uses 4 to 6 percent portland cement
- Often incorporates widening along with FDR projects
Texas DOT - Bryan District

- On rural farm to market (FM) system
- FDR since 1996
- PCI values generally above 85
- Cement content 3 to 4 percent
- Typical 10-inch recycled layer with two-course chip seal
- TTI evaluated 25 projects
  - Stiff but not brittle base
  - Minimal shrinkage cracking
  - Improved waterproofing
- TxDOT Pavement Design program indicated that an overlay is needed after nine years. So far the roads are doing well and no overlay!
Westminster, California

- Began FDR in 1989
- Thickness between 9 and 12 inches
- PCI’s mostly above 85
- Utility cuts causing distress
- Slurry seal every 7 years
- Open to traffic during construction operations
- Typically 6 percent cement
- 2.75-inch asphalt surface
- Geotextile used in surface layer to reduce reflective cracking
- State provides credit for recycling
- 50 percent cost savings
Idaho Transportation Department – District 6

- Began CRABS in early 1990’s
- Thickness between 6 and 9 inches
- PCI’s above 85
- Environmental extremes!
  - -40° to over 100° F
  - 8 to 30 inches rain
- Open to traffic during construction operations
- Typically 2 percent cement
- ITD does not allow the incorporation of subgrade soils in FDR work
Spokane County, Washington

- Started FDR program in late 1990’s
- PCI values either 99 or 100
- 8 to 10 inches thick
- 3 to 5 percent cement
- Spring load restrictions reduced through FDR
- Strength reduced from over 600 psi to less than 400 psi (per PCA)
- Joint venture with local contractors
  - County does initial prep, compaction, and finishing
  - Contractor performs pulverizing and mixing work
- 30 to 50 percent cost savings
5 - Conclusions

• FDR is a successful technique providing highway officials a cost-effective tool to maintain the highway network

• High cement contents can lead to very stiff bases causing shrinkage cracks in the pavement surface

• The current trend is to lower cement contents and target seven-day UCS to between 200 and 400 psi

• Many agencies avoid cutting in to the subgrade
Conclusions

“Portland Cement is probably the closest thing we have to a universal stabilizer.”

Chemical Stabilization Technology for Cold Weather
United States Army Corps of Engineers, September 2002

- Since portland cement stabilizes many materials, it is considered as a “universal stabilizer” by most - expectations are high
- Agencies like to use portland cement to “dry” soils
- More water is used during construction and not enough during curing - leads to shrinkage problems
- Use of standard Proctor vs. modified Proctor
Full Report
60 pages
PCA SR016

Summary
4 pages
PCA IS689
for additional information, please visit the PCA website at

www.cement.org/pavements