Performance of Thin RCC Pavements over Soil Cement under Accelerated Pavement Testing

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Outline

- Background
- Research Objectives
- Construction of RCC Test Sections
- Discussion of Results
- Fatigue Analysis
- Conclusions
Background

- LADOTD seeks alternative use of roller compacted concrete (RCC) for low volume roadways in locations such as:
  - Shale gas exploration/Logging & Agricultural activities
- RCC is a stiff, zero-slump concrete mixture placed with modified asphalt paver and compacted using heavy vibratory steel drum rollers
PCA provides a software called *RCC-PAVE* for Structural Design of RCC for Industrial Pavements

- Follows rigid pavement design method
- compute tensile stress at bottom of slab and keep fatigue damage within an allowable limit
- The minimum thickness on the chart is 8 in.
The fatigue equation of RCC-PAVE by PCA:

\[ \log N_f = 10.25476 - 11.1872 \times (SR) \quad \text{for } SR > 0.38 \]

Where: SR – stress ratio, \( N_f \) – allowable number of load repetitions

- RCC has traditionally been used for pavements carrying heavy loads with thickness > 8”
- LADOTD is looking for pavement design solutions for thin-RCC surfaced pavement used for low volume roadways with heavy truck trafficking
Research Objectives

☐ To determine the structural performance and load carrying capacity of thin RCC surfaced pavements under APT loading;

☐ To determine the applicability of using a thin RCC surfaced pavement structure (with cement treated or stabilized base) as a design option for low-volume pavement design in Louisiana
**Constructed RCC Test Sections**

- Six full-scale RCC pavement test sections were constructed at Pavement Facility of Louisiana Transportation Research Center (LTRC)
  - Each section: 71.7-ft long and 13-ft wide

<table>
<thead>
<tr>
<th>Section 1</th>
<th>Section 2</th>
<th>Section 3</th>
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<tbody>
<tr>
<td>(8+12RCC)</td>
<td>(6+12RCC)</td>
<td>(4+12RCC)</td>
</tr>
<tr>
<td>8&quot; RCC</td>
<td>6&quot; RCC</td>
<td>4&quot; RCC</td>
</tr>
<tr>
<td>12&quot; Cement Treated Base</td>
<td>12&quot; Cement Treated Base</td>
<td>12&quot; Cement Treated Base</td>
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<tr>
<td>Existing Subgrade</td>
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<tr>
<td>8&quot; RCC</td>
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<td>8.5&quot; Soil Cement Base</td>
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<td>10&quot; Cement Treated Subgrade</td>
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</tbody>
</table>

Lane 1: Section 1, 2 & 3

Lane 2: Section 4, 5 & 6

Image of constructed RCC pavement test sections.
RCC Mixture

- No. 67 crushed limestone (CL)
- No. 89 CL Manufactured sand
- Type I portland cement
  - 43% coarse + 57% fine
  - 450 pcy
  - Optimum moisture 6.5%
  - UCS >4000 psi @28days
The selected soil is classified as A-6

- Contains: 47.7% silt & 30% clay
- LL = 32; PL = 18; and PI = 14
- Optimum Moisture = 18.5% and Max. Dry Density = 104 pcf
Cement Content

- Cement contents were determined by DOTD TR 432 to achieve 7-day UCS of 150 or 300 psi.
  - 6% was used for cement treated base (Sections 1-3)
  - 8% was used for soil cement (Sections 4-6)
Construction
Production and Transportation

- Rapidmix 400C horizontal twin shaft pugmill was used for RCC production
- High Production rate, Self Contained and Mobile

- The transportation time was also kept as minimum as possible
- Protective cover was used to reduce excessive moisture evaporation.
Placement of RCC

- Rollcon high density paver was used to place the RCC
- Provides smoother surface due to higher initial density
- Paving Speed was selected based on trail test pit
Compaction of RCC

- Vibratory steel drum roller was used to compact the RCC layer.
Joints and Curing

- Single lift and No Construction Joints
- Saw-cut joints were introduced
  - For 8 in. RCC: 1.5 in. deep at 20-ft interval
  - For 6 in. RCC: 1 in. deep at 15-ft interval
  - For 4 in. RCC: 0.5 in. deep at 10-ft interval

- White pigmented water base concrete curing compound was sprayed
In Situ Testing during the Construction

- Field Testing Methods
  - FWD
  - Surface roughness/walking profiler
  - RCC Surface Texture & Friction
Section 1  IRI = 359.5 in/mi

Section 2  IRI = 469.7 in/mi

Section 3  IRI = 622.7 in/mi

Section 4  IRI = 190.1 in/mi

Section 5  IRI = 122.2 in/mi

Section 6  IRI = 167.5 in/mi
Instrumentation Layout (Sensors)

- Pressure Cell
- Asphalt Strain Gage
- Concrete Strain Gage
- TDR
- Thermocouple
Accelerated Pavement Testing - ATLaS30

- Dual-tire load, 130psi
- Load: up to 30 kips
- Speed: 4~6 mph
- Bi-directional loading
- Effective length: 42-ft
- About 10,000 passes/day
Accelerated Loading Testing

- Roughly 78,000 reps. for each load level,

9,000 lb, 16,000 lb, 20,000 lb, 22,000 lb, 25,000 lb
## Loading Sequence and Passes

<table>
<thead>
<tr>
<th>Loads</th>
<th>Section 4</th>
<th>Section 5</th>
<th>Section 6</th>
<th>Section 3</th>
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<tbody>
<tr>
<td></td>
<td>8+8.5RCC</td>
<td>6+8.5RCC</td>
<td>4+8.5RCC</td>
<td>4+12RCC</td>
<td>6+12RCC</td>
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<tr>
<td>9kip</td>
<td>78500</td>
<td>78000</td>
<td>78500</td>
<td>73000</td>
<td>78000</td>
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<tr>
<td>16kip</td>
<td>78500</td>
<td>78000</td>
<td>78500</td>
<td>73000</td>
<td>78000</td>
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<tr>
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<tr>
<td>22kip</td>
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<td>78000</td>
<td>78500</td>
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<td>78000</td>
</tr>
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<td>25kip</td>
<td>78500</td>
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<tr>
<td>16kip</td>
<td>-</td>
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<td>314000</td>
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<td>155000</td>
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<tr>
<td>9kip</td>
<td>-</td>
<td>34000</td>
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<td>30000</td>
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</tr>
<tr>
<td>22kip</td>
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<td>30000</td>
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<td>-</td>
<td>22000(Running)</td>
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<tr>
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<td>137000</td>
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<td>20kip</td>
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<td>290000</td>
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<td>25kip</td>
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<td>325000</td>
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<td>1756000</td>
<td>706500</td>
<td>196000</td>
<td>637000</td>
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<tr>
<td>Est. ESALs</td>
<td>11.3 M</td>
<td>87.4 M</td>
<td>19.2 M</td>
<td>2.7 M</td>
<td>16.8 M</td>
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</tbody>
</table>
Distress Observed (8+8.5RCC) – Section 4

- Approximately after 392,500 load repetition (11.28 million equivalent ESALs), no significant damage was observed.
- Due to very high load carrying capacity, the test was discontinued thereafter.

Current Pavement Condition

Loading

(8+8.5RCC)
Visual Distresses (87.4 million ESALs)

- Longitudinal cracks were observed along the wheel path and at the edge of the tire print
- Pumping action was observed through cracks and joints

Pavement Condition at the end of testing

IRT from 122 – 160 in/mi

1.75 million Passes

Loading Sequence

<table>
<thead>
<tr>
<th>No. of Repetition (Thousands)</th>
<th>0</th>
<th>500</th>
<th>1000</th>
<th>1500</th>
<th>2000</th>
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<tr>
<td>ATLs Load (kip)</td>
<td>0</td>
<td>5</td>
<td>10</td>
<td>15</td>
<td>20</td>
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</table>

<table>
<thead>
<tr>
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Pavement Condition at the end of testing
Distress Observed (4+8.5RCC) – Section 6

- **Visual Distresses (19.2 million ESALs)**
  - Longitudinal cracks, localized fatigue cracking failure
  - Pumping action was observed through the cracks and joints

IRI from 168 – 273 in/mi

706,500 Passes
Due to relatively weaker support, an early longitudinal crack was observed after 55,000 passes under 9 kip dual tire loading.

This section failed at about 2.7 million ESALs of loading with extensive cracking.

IRI from 622 – 695 in/mi

wheel path
Distress Observed (6+12RCC) – Section 2

- On-going (16.8 million EASLs)
- Longitudinal cracks
- Pumping and Local failure

<table>
<thead>
<tr>
<th>6” RCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 &quot;Cement Treated Base</td>
</tr>
<tr>
<td>Existing Subgrade</td>
</tr>
</tbody>
</table>

(6+12RCC)

IRI from 469 – 537 in/mi

637,000 Passes
Crack Mapping on (6+8.5RCC) – Section 5

After 1,050,000 Load Repetition
After 1,230,000 Load Repetition
After 1,500,000 Load Repetition
After 1,750,850 Load Repetition

6" RCC
8.5" Soil Cement Base
10" Cement Treated Subgrade
Existing Subgrade
Crack Mapping on (4+8.5RCC) – Section 6

4"RCC
8.5 "Soil Cement Base
10" Cement Treated Subgrade
Existing Subgrade

After 390,000 Load Repetition
After 480,000 Load Repetition
After 560,000 Load Repetition
After 706,500 Load Repetition
Crack Mapping on (4+12RCC) – Section 3

4"RCC
12 "Cement Treated
Base
Existing Subgrade

(4+12RCC)
Crack Mapping on (6+12RCC) – Section 2

On-going

6” RCC
12 "Cement Treated Base
Existing Subgrade

After 455,000 Load Repetition
After 525,000 Load Repetition
After 550,000 Load Repetition
After 610,000 Load Repetition
Comparison of Cracking Pattern

- Crack initiated at the weakest subgrade location
- Cracking pattern for thicker section was much wider than the thinner section
- Uniform subgrade resulted in a final cracking failure covering the entire loading area for 6+8.5RCC & 4+12RCC
Fatigue Damage Analysis of Thin RCC

- RCC-PAVE fatigue damage model is not suitable for the fatigue performance analysis of thin RCC test sections.

\[ \log N_f = 10.25476 - 11.1872 \times (SR) \quad \text{for } SR > 0.38 \]

\[ N_f = \infty \quad \text{When } SR \leq 0.38 \]

- The measured SRs relatively low
  - SRs ranged 0.1 ~ 0.45 under APT loads
Fatigue Damage Analysis [cont.]

Based on the APT results, obtained two fatigue equations:

For 6 in. RCC: \[ \log N_f = 9.507 - 12.597 \times SR \]

For 4 in. RCC: \[ \log N_f = 9.071 - 12.729 \times SR \]

Combined Model: \[ \log N_f = 7.835 + 0.3h_{RCC} + 0.39h_{RCC}SR - 14.484SR \]
Summary and Conclusions

- Except two 8” RCC test sections, the best performer is (6”RCC + 8.5” soil cement) section, with
  - Ridable surface and relatively low IRI;
  - Outstanding load carrying capacity, est. ESALs = 87.4 M;
  - Potential to be used for heavy-loaded, medium speed pavements;
- Sections (4”RCC+8.5” soil cement) and (6”RCC+12” cement treated) also performed very well
  - Both can carry large amounts of heavy traffic (half axle >20kips); Est. ESALs > 15 M
  - Surface IRI need to be controlled during the construction
  - Potential to be used for low-volume roads with heavy truck traffic.
Summary and Conclusions (cont.)

- Three RCC sections failed under fatigue cracking. The observed fatigue cracks were initiated first either in the middle or at the edge of the tire print along a longitudinal direction;

- The width of fatigue cracking pattern was found much wider for 6-in RCC sections (e.g. 6+8.5RCC) than that for 4-in. RCC sections, indicating thicker RCC provides better load-spreading;

- RCC-Pave fatigue models were found not suitable for the fatigue life prediction of thin RCC sections evaluated;

- Two preliminary fatigue models for thin RCC pavement fatigue analysis were developed.
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Thank you!