RCC Pavements for Commercial and Industrial Applications

TN Concrete Pavement & Cement-Based Pavement Solution Conference
Nashville, TN
January 31, 2014

Fares Abdo, PE
Director of Technical Services
fabdo@morgan-corp.com
Outline

- Brief Overview
- Commercial & Industrial Applications
- Value Engineered Case Studies
Brief Overview of RCC
What is RCC?

- Definition: “Roller-Compacted Concrete (RCC) is a no-slump concrete that is compacted by vibratory rollers.”
- Zero slump (consistency of dense-graded aggregate)
- No forms needed
- No reinforcing steel
- No finishing
- Consolidated with vibratory rollers

After curing, RCC properties are similar to PCC
Shared Characteristics

**Conventional Concrete Pavement**

Shared materials characteristics:
- Same materials (different proportions)
- Similar curing requirements

**Asphalt Pavement**

Shared construction characteristics:
- Similar aggregate gradation
- Similar placement and compaction

**RCC Pavement**
Benefits of RCC Paving

■ Capacity and durability: Similar benefits unreinforced conventional concrete offers

■ Fast construction with minimum labor
  ■ Production: ½ to 1 acres per day per paving train, one lift up to 10-inches thick

■ Economical
  ■ Can beat HMA on initial cost and cost much less to own over the service life of the pavement
Construction
Mixing: Continuous Mix Pugmill

- 250 to 600 tons/hr
- Excellent mixing efficiency
- Mobile, erected on site
- Mobilization cost
Central Concrete Batch Plants

- Local availability
- Smaller output capacity
- Longer mix times than conventional concrete
- Frequent cleaning
- Dedicated production
Transporting
Paving Equipment
Paving Equipment
Dual-Lift Construction
Placing Equipment

- High density pavers
  - Vibrating screed
  - High initial density, 90-95%
- High-volume placement (capable of placing 1,000 to 2,000 cubic yards per shift)
Compaction

- High density is critical for strength and durability
- Vibratory rollers to achieve density
- Smaller Rubber-tire or steel-drum roller to improve surface texture
Commercial & Industrial Applications
Military Facilities

Ft. Lewis, WA, 1986

Ft. Drum, NY, 1990

Ft. Carson, CO, 2008
Parking Areas

134 acre parking facility at Saturn plant, TN, 1988

BMW, SC, 2009
45 acres

Plant Vogtle, GA, 2011
75 acres

Ohio Turnpike Service Plaza, 2010
Port Facilities
Intermodal Facilities

South Carolina Inland Port, 2013
38 acres
Value Engineered Case Studies
Value Engineered Options

Goals

- Equal or better structural capacity/service life
- Faster construction
- Cost savings
  - Initial cost
  - Cost to own
- Less operational interruptions for maintenance/rehab
VE Options for Two Recent Projects

- **GA Port Authority-Ocean Terminal**
  - Ocean Terminal Typical Pavement Section
  - Value Engineered Option
  - Pavement Section Optimization

- **South Carolina Inland Port**
  - Design Sections: Intermodal Dual and Single Lifts
  - Value Engineered Sections
  - Why Soil-Cement Base?
  - Project Notables
Georgia Port Authority
Ocean Terminal, Savannah
Aggregate Sources
≈ 165 miles from project

Ocean Terminal, GA
Ocean Terminal, GA

Phase 1: 48,400 SY
Phase 2: 30,000 SY
Ocean Terminal, GA

- Typical Ocean Terminal pavement
  - Flexible pavement
    - 10” aggregate base
    - 5” asphalt

- Purposes of proposed alternate
  - Provide equal or higher structural capacity using RCC and CTB layers
  - No additional cost
Structural Capacity/Predicted Service Life for Assumed Loadings

- Hot-mixed asphalt and RCC equivalent structural numbers
- RCC PAVE software predictions
- PCA PAVE Software predictions
### Pavement Analysis - Equivalent SN Approach

#### Materials and SN Coefficients

<table>
<thead>
<tr>
<th>Material</th>
<th>SN Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>HMA</td>
<td>0.44</td>
</tr>
<tr>
<td>RCC</td>
<td>0.5</td>
</tr>
<tr>
<td>GABC</td>
<td>0.18</td>
</tr>
<tr>
<td>CTB</td>
<td>0.22</td>
</tr>
</tbody>
</table>

#### Notations

<table>
<thead>
<tr>
<th>Material</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HMA</td>
<td>Hot-Mixed asphalt, Binder or Surface Course</td>
</tr>
<tr>
<td>RCC</td>
<td>Roller-Compacted Concrete¹</td>
</tr>
<tr>
<td>GABC</td>
<td>Graded Aggregate Base Course</td>
</tr>
<tr>
<td>CTB</td>
<td>Cement-Treated Base²</td>
</tr>
</tbody>
</table>

#### Design Section, HMA & GABC

<table>
<thead>
<tr>
<th>Material</th>
<th>Thickness, In.</th>
<th>SN/in.</th>
<th>SN/layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>HMA</td>
<td>5</td>
<td>0.44</td>
<td>2.20</td>
</tr>
<tr>
<td>GABC</td>
<td>10</td>
<td>0.18</td>
<td>1.80</td>
</tr>
<tr>
<td><strong>Total SN</strong></td>
<td></td>
<td><strong>4.00</strong></td>
<td></td>
</tr>
</tbody>
</table>

#### Alternate Section, RCC & CTB (based on equivalent SN)

<table>
<thead>
<tr>
<th>Material</th>
<th>Thickness, In.</th>
<th>SN/in.</th>
<th>SN/layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCC</td>
<td>6</td>
<td>0.50</td>
<td>3.00</td>
</tr>
<tr>
<td>CTB</td>
<td>6</td>
<td>0.20</td>
<td>1.20</td>
</tr>
<tr>
<td><strong>Total SN</strong></td>
<td></td>
<td><strong>4.20</strong></td>
<td></td>
</tr>
</tbody>
</table>

#### Footnotes

1. RCC specified compressive strength = 4,000 psi at 28 days.

2. Assume 50% GABC mixed with 50% in-situ soil to make the blended aggregates/soil for CTB. CTB compressive strength target = 300 - 500 psi at 7 days.
Pavement Analysis - Equivalent SN Approach

Asphalt Pavement Design

- 5” HMAC
- 10” Aggregate Base
- Subgrade

Structural Number = 4.00

Roller Compacted Concrete Design

- 6” RCC Concrete
- 6” Cement Treated base
- Subgrade

Structural Number = 4.20
# Prediction using RCC Pave

## Truck Traffic, RCC with CTB Option, 20 Yr

<table>
<thead>
<tr>
<th>Axle Type</th>
<th>Load, lbs</th>
<th>Allowable Repetitions/Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Axle Dual Wheel</td>
<td>18,000</td>
<td>Unlimited</td>
</tr>
<tr>
<td>Tandem Axle, Dual Wheel</td>
<td>40,000</td>
<td>Unlimited</td>
</tr>
</tbody>
</table>
PCA PAVE Predictions Using Semi Trailer Trucks, HMA over GABC, and RCC over CTB Options

- How to model undefined traffic?
- Selected truck traffic for comparison purposes
  - Same traffic to analyze
    - 5” HMA over 10”DGA
    - RCC over CTB value-engineered option

Total Truck Weight: 12k+40k+40k = 92k lbs
10 Trucks/day, 5” HMA over 10” GABC, on Sandy Soil

Predicted Damage in percent within its design life

Asphalt Fatigue (Life > 30 years)
Subgrade rutting (Life > 30 years)
50 Trucks/day, 5” HMA over 10” GABC, on Sandy Soil

Predicted Damage in percent within its design life

- Asphalt Fatigue (Life: 13.11 years)
- Subgrade setting (Life: 18 years)
100 Trucks/day, 5” HMA over 10” GABC, on Sandy Soil

Predicted Damage in percent within its design life

- Asphalt Fatigue (Life = 8.919 years)
- Subgrade rutting (Life = 8.227 years)

Failure Level 75.0%  Service Level 99.0%  Design Life 8.9 years  Service Life 9.9 years

12k + 40k + 40k = 92k lbs
100 Trucks/day, 6” RCC over 6” CTB, on Sandy Soil

Predicted Damage in percent within its design life

- RCC Fatigue (Life > 20 years)
- NCHRP CTB (Life > 20 years)
- Subgrade rutting (Life > 20 years)

12k + 40k + 40k = 92k lbs
1000 Trucks/day, 6” RCC over 6” CTB, on Sandy Soil

Predicted Damage in percent within its design life

12k+40k+40k = 92k lbs
Pavement Section Optimization

- Reinvesting pulverized asphalt in CTB layer
- Cost savings allowed for thicker pavement
- RCC Pave analyses
  - Various RCC and CTB thicknesses to maximize strength within available budget
Phase I As-Built Section

- RCC/Cement-Treated Soil
  - 9” cement-treated soil
  - 7” RCC

Made possible by value engineered design/mix optimization/recycling of in-situ materials
RCC Pave Prediction of Improved Section

Straddle Carrier, 20 Yrs

- 6" RCC over 6" CTB
- 7" RCC over 9" CTB

Single wheel loading
RCC Pave Prediction of Improved Section

Container Handler, 20 Yrs

Dual-wheel loading

Graph showing allowable daily repetitions vs. dual wheel load (X 1000 lbs) for 6" RCC over 6" CTB and 7" RCC over 9" CTB.
Case Study – Ocean Terminal, GA

>33% strength

19% savings on initial cost vs. HMA
South Carolina Inland Port
Greer, SC
SC Inland Port – Site Conditions

- Variable soils
  - Sandy SILT in fill area
  - Silty SAND in cut areas
- 0.5% grade
SC Inland Port – VE Options

Dual Lifts: 94,000 yd²

Design
- RCC: 14"
- GAB: 3"
- Prepared Subgrade

Value Engineered
- RCC: 13"
- CTSB: 6"
- Prepared Subgrade

Single Lift: 88,000 yd²

Design
- RCC: 10" and 10.5"
- GAB: 3"
- Prepared Subgrade

Value Engineered
- CTSB: 9.5"
- Prepared Subgrade

GABC: Graded aggregate base
CTSB: Cement treated soil base
SC Inland Port – CTS Base Construction
Why CTS base?
SC Inland Port – Benefits of CTS Base

- Structural capacity
- Load transfer at joints and cracks
- Limited downtime after rain events
- Economical
- Sustainability attributes
SCIP RCC Placement
SCIP RCC Placement
SCIP RCC Placement
Transverse Construction Joint

One day old RCC
Notables

- RCC and CTS base option provided higher structural capacity at no additional cost

- CTS was key to overcome site conditions during an unusual wet season

- Variable soils required extensive strength testing and proof rolling

- One lift production rate as high as one acre/day per each paving train
Questions?

Fares Abdo, PE
Director of Technical Services
fabdo@morgan-corp.com