Concrete Pavement Innovation & Technology Transfer Workshop
Composite Pavements: Roller Compacted Concrete
AGENDA

• Roller Compacted Concrete
  • What is it? Where has it Been Used? and Why?

• Pavement Design

• Mix Design

• Construction Process

• Recent Research Results
ROLLER COMPACTED CONCRETE IS A ZERO SLUMP CONCRETE With A Long History Of Good Performance On Heavy Duty Pavements

Roller Compacted Concrete Pavements

• Concrete Pavement, Placed more efficiently  
• No Slump, low water content  
• Consistency of cement treated base  
• Placed by asphalt pavers  
• Compacted with vibratory rollers  
• No forms  
• No reinforcing steel  
• No finishing  
• Normal concrete strength  
• Low W/C ratio = limited shrinkage cracks  

Historical RCC Uses

• Intermodal Port/ Freight/ Manufacturing  
  • Ports of Houston, Long Beach, LA, Jacksonville  
  • Central Freight – Austin, TX  
  • Honda, Kia, BMW, Saturn – GA, TN, SC  
  • Jack Daniel's– Lynchburg, TN  
  • Proctor & Gamble - PA  
  • Lowe’s– Rome, GA  
  • Kansas City Southern, CSX, Norfolk Southern 

Port of Houston – 2008
MANY FREIGHT FACILITIES HAVE CHOSEN RCC TO WITHSTAND THE HEAVY LOADS WITH GOOD SUCCESS

Central Freight
Austin, TX (1987)

7 “- 8” RCC over 12” Soil stabilization – 19 Acres

Covenant Transport
Chattanooga, TN (Early 1990’s)

6.5” RCC -15 Acres

CSX Terminal
Jacksonville, FL (2010)

14” RCC
PORTS & DISTRIBUTION CENTERS ARE USING RCC FOR LONG TERM DURABILITY, SPEED OF CONSTRUCTION, & COST SAVINGS

Port of Houston, TX – 3RD Phase > 120 acres total

Lowe's Distribution Center, Rome, GA
USE OF RCC PAVEMENTS IN US

RCC utilization began growing in early 2000’s & is now growing at a faster rate

RCC SY

<table>
<thead>
<tr>
<th>Yearly Sq. Yds</th>
<th>Cumulative Sq. Yds</th>
</tr>
</thead>
<tbody>
<tr>
<td>1975 - 1999</td>
<td>2,999,771</td>
</tr>
<tr>
<td>2000-2010</td>
<td>8,933,250</td>
</tr>
<tr>
<td>2011-2013</td>
<td>4,993,296</td>
</tr>
</tbody>
</table>

- # of Projects

- Yearly Sq. Yds

- Cumulative Sq. Yds

- Yearly RCC SY

- Cumulative RCC SY
PAVEMENT TYPES & OWNERS ARE CHANGING
Industrial Still Remains Largest Application Type, But Roadway are Increasing
I-285 SHOULDER REPLACEMENT
Atlanta, GA

- 35 Lane Miles of 10’ Shoulder
- 38,500 CY of material placed
- Material placed on weekends only
RICHLAND AV. (US 78) AIKEN, SC
Completed Project
LAKE VIEW HEROES DRIVE
IRI Measurements (Average)

Overall AVG 63.7
Overall Max 116.7
Overall Min 31.7
Village of Streamwood Streets
Streamwood, IL

Project Information

- Owner: City of Streamwood
- Use Type: Residential
- Year Built: 2011, 2013
- Quantity: 1000 CY each

Additional Details

- Thickness: 2” HMAC / 6” RCC
- City forces completed all work
# Yuma East Wetlands Hike Trail
Yuma, AZ

## Pavement Design Information
- Owner: City of Yuma
- Use Type: Trail
- Year Built: 2013
- Thickness: 5” RCC / Compacted Subgrade
- Quantity: 1,700 CY

## Additional Details
- City Park, environmentally sensitive area
- Did not want Asphalt due to hydrocarbons
- Lacked funds for conventional concrete
- RCC made it feasible
AGENDA

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**RCC IS A JOINTED PLAIN CONCRETE PAVEMENT WITHOUT DOWELS**

<table>
<thead>
<tr>
<th>Contraction (Control) Joint</th>
<th>Construction Joint</th>
<th>Isolation (Expansion) Joint</th>
</tr>
</thead>
</table>
| • Use at short joint spacing  
• Made by saw cut, or tooled  
• Early entry cuts = 1/4 depth  
• Saw cut within 2 to 6 hours of paving | • Use at end of construction day  
• Use thickened edge for heavy duty applications  
• Keyways not recommended | • Isolate pavement features with differential movements  
• Do not use at regular spaced joints in paving lane  
• Full thickness, vertical joint, sealed with compressible material |

1) Jointing recommendations should be based on ACI 330
RCC MIX DESIGN USES SAME MATERIALS AS CONVENTIONAL CONCRETE, HOWEVER IN DIFFERENT COMBINATIONS
Achieves Similar or Better Engineering Properties Than Conventional Concrete

<table>
<thead>
<tr>
<th>Typical Engineering Properties</th>
<th>Conventional (psi)</th>
<th>RCC (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressive Strength</td>
<td>3,000 - 5,000</td>
<td>4,000 - 10,000</td>
</tr>
<tr>
<td>Flexural Strength (MOR)</td>
<td>500 – 700</td>
<td>500 - 1,000</td>
</tr>
<tr>
<td>Elastic Modulus</td>
<td>3.0 – 5.0 million</td>
<td>3.0 – 5.5 million</td>
</tr>
</tbody>
</table>

Typical Mix Design

**Conventional Concrete**

- Cement + FA: 15%
- Coarse Agg: 47%
- Fine Agg: 30%
- Water: 7%

**Roller Compacted Concrete**

- Cement + FA: 12%
- Coarse Agg: 46%
- Fine Agg: 7%
- Water: 3%
MIX DESIGN: SOIL COMPACTION METHOD

- Easiest….But concrete people are not familiar with it…
- Most common method used in the U.S. for RCC paving mixtures
- Testing equipment readily available at construction materials laboratories
- Three major steps
  1) Select aggregate blend with minimal voids
  2) Determine optimum moisture content and maximum density (ASTM D1557)
  3) Determine cementitious content
STEP 1: AGGREGATE SELECTION

- **Aggregate selection very important**
- 85% of mix by volume
- Responsible for mix workability, segregation & ease of consolidation
- Quality of aggregates should meet ASTM C33
- **Nominal Maximum Size Aggregate**
  - Most projects: 5/8” to 3/4”
  - As small as 1/2” for tighter surface and reduced segregation
  - 1-1/2” may be used for non-wearing courses or where surface appearance is not critical
- **Plasticity Index (PI) < 5**
- Multiple aggregate piles
- Consider availability when preparing specs (during design phase)
STEP 1: AGGREGATE SELECTION

Step 1: Chose well – graded aggregates
• Selection based on gradation test results of available aggregates
• Multiple aggregates may be evaluated
• Quantity of aggregate sources depends on mixing equipment being utilized (Central mix, pugmill, etc)
• Avoid gaps in gradation
• Finer mixes (above the 45° line) are easier to achieve density at or slightly above optimum moisture
  • When paved at or near optimum moisture, the ride is improved
  • Can tolerate isolated increases in moisture content without loosing ride
• Coarse mixes are very sensitive to moisture increases

Combined Aggregate Gradation Band

0.45 Power, 3/4" MS
Suggested Lower Limit
Suggested Upper Limit

Percent Passing

0 10 20 30 40 50 60 70 80 90 100

Sieve Number

#200 #100 #50 #30 #16 #8 #4 3/8" 1/2" 3/4" 1"

0.45 Power curve
STEP 2: MOISTURE DENSITY RELATIONSHIP

Step 2: Select a mid-range cementitious content
- Minimum 450 lbs cement / CY
- 12% Type I Portland cement is selected for the first trial batch
- Based % on weight, so make enough and do not worry about volumes yet
- Mix the cement dry, and then add water

Step 3: Develop moisture – density relationship plots
- Perform a modified Proctor test at the selected cement content
- Construct moisture-density relationship curve (Use spreadsheet)
- Determine Maximum Dry Density (MDD) and Optimum Moisture Content (OMC)

(ASTM D1557)
STEP 3: COMPRESSION STRENGTH CURVE

Step 4: Cast samples to measure compressive strength (ASTM C 1435)
- Calculate trial mix proportions
- Batch RCC materials
  - Maintain percent Optimum Moisture Content as determined in step 3
  - Use varying cementitious contents such as 10, 12, and 14 percent
- Make compressive strength test cylinders for each cement content
MATERIAL WEIGHT & VOLUME CALCULATIONS

1) Select Combination of Aggregate & Sand for best gradation & workability: Use 45% coarse aggregate & 55% sand

2) Determine Maximum Dry Density: 140 pcf
   Optimum Moisture: 6.5%
   Maximum Wet Density = 140 x 1.065 = 149.1 pcf

3) Total Dry Weight of Materials (pcy) – 140 x 27 = 3,780 lbs
   Determine a cement content (pcy) – 450 pounds

4) Total Dry Weight of Sand + Coarse Aggregate = 3780 - 450 = 3,330 lbs

5) Split Dry Weight of Sand & Coarse by aggregate combination as determined in step 1:
   Coarse Aggregate: .45 x 3,330 = 1,498.5 lbs
   Sand : .55 x 3,330 = 1,831.5 lbs

6) Calculate Water Weight:
   = (149.1-140) x 27 = 246 lbs

7) If Desired, convert weight to volume via SG_{ssd} and then calculate Air content, W/C ratio, etc

8) Prepare compressive strength cylinders and flexural strength beams
FREEZE-THAW DURABILITY

- Although not air-entrained, field performance very good
  - Reference: Long-Term Performance of RCC Pavements, RP366
- Most distress along joints
- Minor surface paste (1/8”) erodes, then stabilizes
- RCC results variable under ASTM C666 (F-T) and C672 (deicing/scaling)
- Conventional concrete tests appear to be too severe based on actual experience
- Durability tests used for concrete masonry units (ASTM C1262) and precast paving units (ASTM C67) possibly more appropriate
- DO NOT use deicing agents on RCC surface for at least 30-days after completion

BN Intermodal Yard, CO
Built 1985; Photo 2009

Fort Drum, NY
Built 1988; Photo 2013
ADMIXTURES ARE BEING USED TO IMPROVE WORKABILITY AND INCREASE HAUL TIME

Intended Purpose for Admixtures in RCC
- Increase haul time while maintaining workability
- Retain moisture
- Improve surface finish
- Increase compressive strength
- Increase density behind paver
- Currently using Grace VSC500 @ 3 cwt
AGENDA

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THE FINAL SURFACE TYPE WILL DICTATE THE NECESSARY TECHNIQUES & EQUIPMENT NEEDED TO BE SUCCESSFUL

<table>
<thead>
<tr>
<th>Natural RCC</th>
<th>Diamond Ground RCC</th>
<th>Asphalt</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Natural RCC" /></td>
<td><img src="image" alt="Diamond Ground RCC" /></td>
<td><img src="image" alt="Asphalt" /></td>
</tr>
</tbody>
</table>

### Applications

<table>
<thead>
<tr>
<th>Natural RCC</th>
<th>Diamond Ground RCC</th>
<th>Asphalt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed Limit &lt; 35 mph</td>
<td>Speed Limit &gt; 35 mph</td>
<td>Any pavement type</td>
</tr>
<tr>
<td>Ports</td>
<td>Collector / Arterial local roads</td>
<td></td>
</tr>
<tr>
<td>Distribution centers</td>
<td>Highway Shoulders</td>
<td></td>
</tr>
<tr>
<td>Industrial yards</td>
<td>State routes</td>
<td></td>
</tr>
<tr>
<td>Residential roads</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parking lots</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Factors

<table>
<thead>
<tr>
<th>Natural RCC</th>
<th>Diamond Ground RCC</th>
<th>Asphalt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lowest Cost</td>
<td>Medium cost increase</td>
<td>Highest cost</td>
</tr>
<tr>
<td>Most sensitive to contractor skill level</td>
<td>Increased construction time</td>
<td>Increased construction time</td>
</tr>
<tr>
<td>Least smooth</td>
<td>Improved smoothness, skid resistance</td>
<td>Least sensitive to contractor skill level</td>
</tr>
<tr>
<td>“Asphalt” appearance</td>
<td>Reduced noise</td>
<td>Improved smoothness, skid resistance</td>
</tr>
</tbody>
</table>
THE FINAL SURFACE TYPE DICTATES THE NECESSARY TECHNIQUES & EQUIPMENT NEEDED TO BE SUCCESSFUL

<table>
<thead>
<tr>
<th>Surface Type</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural RCC</td>
<td>20</td>
<td>39</td>
<td>46</td>
</tr>
<tr>
<td>Diamond Ground RCC</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Asphalt</td>
<td>26</td>
<td>18</td>
<td>7</td>
</tr>
</tbody>
</table>

The chart illustrates the number of projects for each surface type from 2011 to 2013.
THE SURFACE TEXTURE OF RCC IS SIMILAR TO ASPHALT PAVEMENT WHILE THE COLOR IS SIMILAR TO CONCRETE.
TECHNOLOGIES ARE BEING USED TO IMPROVE SURFACE DURABILITY & APPEARANCE

- Colloidal Silica
- Reacts with cement to increase paste
- Improves surface appearance
- Reduces surface dusting
- Improves surface durability

<table>
<thead>
<tr>
<th>Schmitz Hammer (Rebound Test Results)</th>
<th>No Day1</th>
<th>Day1 @ 4:1</th>
<th>Day1 @ 8:1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Edge</td>
<td>Edge</td>
<td>Edge</td>
</tr>
<tr>
<td></td>
<td>Center</td>
<td>Center</td>
<td>Center</td>
</tr>
<tr>
<td>30</td>
<td>24</td>
<td>28</td>
<td>26</td>
</tr>
<tr>
<td>24</td>
<td>14</td>
<td>28</td>
<td>31</td>
</tr>
<tr>
<td>22</td>
<td>25</td>
<td>31</td>
<td>30</td>
</tr>
<tr>
<td>26</td>
<td>26</td>
<td>34</td>
<td>30</td>
</tr>
<tr>
<td>16</td>
<td>34</td>
<td>29</td>
<td>26</td>
</tr>
<tr>
<td>21</td>
<td>30</td>
<td>25</td>
<td>35</td>
</tr>
<tr>
<td>20</td>
<td>25</td>
<td>32</td>
<td>40</td>
</tr>
<tr>
<td>34</td>
<td>26</td>
<td>24</td>
<td>30</td>
</tr>
<tr>
<td>18</td>
<td>30</td>
<td>34</td>
<td>28</td>
</tr>
<tr>
<td>24</td>
<td>31</td>
<td>31</td>
<td>38</td>
</tr>
</tbody>
</table>

| AVERAGE | 23.5 | 26.5 | 29.6 | 31.4 | 26.6 | 27.3 |
| AVERAGE | 2800 | 3250 | 3800 | 4250 | 3250 | 3400 |
WE RECOMMEND USING A TWIN SHAFT OR PUGMILL MIXER FOR PRODUCING RCC

<table>
<thead>
<tr>
<th>Mixer Type</th>
<th>Description</th>
<th>Factors to Consider</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Twin Shaft – Horizontal Mixer</strong></td>
<td><strong>Batch Type</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Description</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>High production rates: 50 to 220 CY / hr</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Excellent mixing efficiency for dry materials</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mobile – 1 or 2 loads, easily set up in 1 day</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Batch setup may induce load to load moisture variability</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mixing system only – requires a batching system</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Same capabilities &amp; requirements as operating ready mix plant</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No permitting required</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Easy to incorporate admixtures, fibers, etc</td>
<td></td>
</tr>
<tr>
<td><strong>Pugmill – Continuous Twin Shaft</strong></td>
<td><strong>Description</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>High production rates: 50 to 300+CY / hr</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Excellent mixing efficiency for dry materials</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Highly consistent mix properties, minimal moisture fluctuation – easy adjustment</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Mobile – 1 load, easily erected on site &amp; calibrated in 1 day</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Need to find good location, obtain permits</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Self contained – Gen set, batch house</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>2 to 3 man operation</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Limited to 2 aggregate sizes</strong></td>
<td></td>
</tr>
</tbody>
</table>
**FACTORS TO CONSIDER FOR PAVING**

**Consistent Mix Delivery to Paver**

<table>
<thead>
<tr>
<th>Mix Delivery</th>
<th>Paver Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 10 Wheel dump trucks - Cover loads</td>
<td>• Balance speed of paver with mix delivery</td>
</tr>
<tr>
<td>• Keep trucks clean</td>
<td>• Use paving calculator</td>
</tr>
<tr>
<td>• Plan trucking route (traffic, truck staging)</td>
<td>• Keep paver moving (material transfer machine)</td>
</tr>
<tr>
<td>• Avoid segregation in truck loading / unloading</td>
<td>• Keep head of material constant in hopper and screed</td>
</tr>
<tr>
<td>• Avoid end of load segregation</td>
<td>• Keep augers feeding material consistent</td>
</tr>
<tr>
<td>• Consider using material transfer machine &amp; insert hopper</td>
<td>• Use grade control devices (string, big ski, etc)</td>
</tr>
<tr>
<td></td>
<td>• Don’t pave over standing water</td>
</tr>
</tbody>
</table>
RCC IS PAVED WITH ASPHALT EQUIPMENT
Achieving Density & Smoothness is Critical

<table>
<thead>
<tr>
<th>Standard Paver</th>
<th>HIGH DENSITY PAVER</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Standard paver (80% to 85% initial density)</td>
<td>• High density screed (Vogege or ABG Titan)</td>
</tr>
<tr>
<td>• Available in all markets</td>
<td>• High initial density (&gt; 90%)</td>
</tr>
<tr>
<td>• High-production (6 to 8 ft/min)</td>
<td>• Availability is increasing, but still limited</td>
</tr>
<tr>
<td>• Lift thick range: 4” to 6”</td>
<td>• Smoother surface with higher initial density</td>
</tr>
<tr>
<td>• May require multiple lift paving</td>
<td>• Less roll down to achieve density</td>
</tr>
<tr>
<td>• Impossible to pave adjacent lanes</td>
<td>• High-production (6 to 8 ft/min)</td>
</tr>
<tr>
<td>• Increased roll down to achieve density (grade control problems)</td>
<td>• Lift thick range: 4” to 9”</td>
</tr>
<tr>
<td>• Easier to fix segregated areas before compaction</td>
<td>• Adjacent lanes easily paved</td>
</tr>
<tr>
<td></td>
<td>• Recommended</td>
</tr>
</tbody>
</table>
HIGH DENSITY ASPHALT PAVERS PROVIDE A SMOOTHER FINISHED PROFILE & HIGHER QUALITY PRODUCT

High Density Paver

- High density screed (Vogele or ABG Titan)
- High initial density from paver (90% - 96%)
- Smoother surface due to higher initial density
- Less “roll down” to achieve final density
- High-production (6 to 8 ft/min)
- 10 to 30 ft width
- Lift thick range: 4” to 9”
<table>
<thead>
<tr>
<th>Initial Compaction</th>
<th>Finish Rolling</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Initial: 10 - 12 ton static &amp; vibratory roller</td>
<td>• Combination, dual steel or rubber tired</td>
</tr>
<tr>
<td>• Establish roll pattern (check density a lot!)</td>
<td>• Maximum weight - 6 short ton</td>
</tr>
<tr>
<td>• Adjust roll pattern based on moisture content</td>
<td>• Remove roller marks</td>
</tr>
<tr>
<td>• Compact to 98% density - wet</td>
<td>• Once completed, keep roller off of the area</td>
</tr>
<tr>
<td>• Adjust moisture content if needed – impacts smoothness &amp; compaction</td>
<td></td>
</tr>
<tr>
<td>• Finer mixes achieve density easier</td>
<td></td>
</tr>
</tbody>
</table>

- Grape Creek Road – San Angelo, TX
- Fairforest Way
- Greenville, SC
- Fairforest Way
- Greenville, SC
**LONGITUDINAL JOINTS CAN BE BUILT 3 DIFFERENT WAYS**

<table>
<thead>
<tr>
<th>Vertical Cold Joint</th>
<th>Angular Cold Joint (Preferred Method)</th>
<th>Fresh (Hot) Joints</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Pave width of lane</td>
<td>• Need high density paver</td>
<td>• Pave for 50 minutes then move back to beginning and match original lane</td>
</tr>
<tr>
<td>• Saw cut full depth early next morning</td>
<td>• Attach shoe to screed</td>
<td>• Do not compact original lane within 2 ft of edge until adjacent lane is paved</td>
</tr>
<tr>
<td>• Remove with blade &amp; loader</td>
<td>• Maximum angle 15°</td>
<td>• Recommend a longitudinal saw cut</td>
</tr>
<tr>
<td>• Expect waste</td>
<td>• Use plate tamper to improve edge durability</td>
<td>• Use small loader to create fresh vertical transverse joint</td>
</tr>
<tr>
<td>• Reduce waste with paver shoe &amp; plate tamper</td>
<td>• No saw cutting required</td>
<td>• Move quickly – keep moist!</td>
</tr>
<tr>
<td>• Pave adjacent lane and match thickness of existing lane</td>
<td>• Pave adjacent lane next day</td>
<td>• Coordination is key, avoid breakdowns</td>
</tr>
<tr>
<td>• Good performance, limited load transfer</td>
<td>• Lowest cost</td>
<td></td>
</tr>
</tbody>
</table>

**LONGITUDINAL JOINTS CAN BE BUILT 3 DIFFERENT WAYS**

- Angular Cold Joint
- Vertical Cold Joint
- Fresh (Hot) Joints

**Angular Cold Joint**

- Need high density paver
- Attach shoe to screed
- Maximum angle 15°
- Use plate tamper to improve edge durability
- No saw cutting required
- Pave adjacent lane next day
- Lowest cost

**Vertical Cold Joint**

- Pave width of lane
- Saw cut full depth early next morning
- Remove with blade & loader
- Expect waste
  - Reduce waste with paver shoe & plate tamper
- Pave adjacent lane and match thickness of existing lane
- Good performance, limited load transfer

**Fresh (Hot) Joints**

- Pave for 50 minutes then move back to beginning and match original lane
- Do not compact original lane within 2 ft of edge until adjacent lane is paved
- Recommend a longitudinal saw cut
- Use small loader to create fresh vertical transverse joint
- Move quickly – keep moist!
- Coordination is key, avoid breakdowns
Curb & Gutter

- Traditional curb & gutter placed before RCC
  - Serves as compaction aid
  - Joint may need to be sealed
- Alternatively, ribbon curb can be placed
  - Drill & grout rebar into cold RCC
  - Place ribbon curb afterwards

Manholes, Inlets

- Plywood plate is placed on top of hole before RCC is placed
- After paving, two methods are available:
  - Dig RCC immediately while fresh, place manhole and re-compact material with hand tampers
  - Saw cut hardened RCC, place manhole, tie in with conventional concrete
QC / QA PROCESS INCLUDES TESTING FOR DENSITY, MOISTURE CONTENT & COMPRESSIVE STRENGTH

<table>
<thead>
<tr>
<th>Moisture &amp; Density</th>
<th>Compressive Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Tested with nuclear gage in direct mode</td>
<td>• Cylinders prepared with vibratory hammer according to ASTM C1435</td>
</tr>
<tr>
<td>• Test density behind paver &amp; after roller to</td>
<td>• 3 to 4 cylinders per set</td>
</tr>
<tr>
<td>establish rolling patterns to achieve density</td>
<td>• Strength timing often depends on traffic opening (1, 3, 7, 28 days)</td>
</tr>
<tr>
<td>• Achieve 98% of modified proctor wet density</td>
<td>• Cores can be obtained where density is not being achieved</td>
</tr>
<tr>
<td>• Nuclear gage gives general moisture fluctuation</td>
<td></td>
</tr>
<tr>
<td>indication - Calibrate with oven dried moisture</td>
<td></td>
</tr>
<tr>
<td>• Oven dried is most accurate</td>
<td></td>
</tr>
</tbody>
</table>
WHEN CURED & SAW CUT RCC PERFORMANCE IMPROVES

<table>
<thead>
<tr>
<th><strong>Curing</strong></th>
<th><strong>Saw Cut &amp; Fill Joints</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Applied at slightly higher rate than conventional concrete</td>
<td>• More aesthetically pleasing</td>
</tr>
<tr>
<td>• Ensure uniformity with application process</td>
<td>• Early entry saw very effective, shortly following placement</td>
</tr>
<tr>
<td>• Apply as soon as possible behind roller operation</td>
<td>• Recommend sawing within 2 - 6 hours to avoid uncontrolled cracking</td>
</tr>
<tr>
<td>• Recommend Resin Based compound</td>
<td>• Depth: 1” to 2”</td>
</tr>
<tr>
<td>• Ensures durable surface</td>
<td>• Spacing: Maximum 36 times thickness, &lt; 20 ft</td>
</tr>
</tbody>
</table>
ACCELERATED LOADING RCC OVER SOIL CEMENT

Tyson Rupnow, Ph.D., P.E.
Zhong Wu, Ph.D., P.E.

LTRC Project 12-7P
Accelerated Loading Test Setup

- Started on Section 4
- then Section 5
- then Section 6

- Roughly 78,000 reps. for each load level

• 9,000 lb
• 16,000 lb
• 20,000 lb
• 22,000 lb
• 25,000 lb
Summary of Current Loading Results

- To date, each of three sections tested has received more than 390,000 heavy load repetitions, which equivalent to 10.9 million ESALs.
  - No severe cracking, or significant changes in measured roughness, or faulting, therefore, no section has reached to a failure mode.
- According to 1993 design guide, a 4”-, 6”- or 8”-PCC pavement would have a design pavement life of 0.7, 1.9 or 6.6 million ESALs, respectively.
  - Obviously, all RCC sections have passed above design lives;
  - Continue loading in order to determine the failure modes/mechanism for those thin RCC test sections.
  - Test results will be used to come up a pavement design procedure for thin RCC pavement design in Louisiana.
SOME FACTORS TO CONSIDER WHEN BIDDING PROJECTS

- Volume of RCC paving on the project
- Site geometry
- Project phasing
- Pavement thickness
- Pavement width
- Final surface characteristics
- Traffic control
- Opening to traffic
- Daily working schedule
Questions?

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