Advances in Roller Compacted Concrete Pavements
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Roller Compacted Concrete

“Roller Compacted Concrete (RCC) is a no-slump concrete placed with asphalt type paver and compacted by vibratory rollers.”

- Zero slump (consistency of dense, damp gravel)
- No forms or finishing
- No reinforcing steel
- High production
- Placed with asphalt type pavers
- Consolidated with vibratory rollers

Concrete placed in a different way!
Multiple Characteristics

Concrete
- rigid pavement
- strength increases

Soils
- Proctor test
- density test

Asphalt
- paver
- rollers

Roller Compacted Concrete
Benefits of RCC Pavements

- Fast construction
- Economical
- Early load carrying capacity
- Supports heavy loads
- Low maintenance
- Durable
- Light surface reduces lighting requirements & Urban Heat Island effects
RCC – Experiencing a Renewal

- Originally used for heavy-duty pavements
- Growth has accelerated in last 15 years
- Increase in private & public road use
- Emergence of asphalt contractors
RCC Makes for Strange Bedfellows
Technologies to Improve Surface Appearance

Admixtures

- Surface applied liquid reacts with cement to increase paste
- Another is fully incorporated within mixture providing air and improving durability
RCC Mixture Design

 Modifications needed in typical no-slump concrete mixture procedures (ACI 211.3R) because RCC is:

- Dryer than zero slump
- Not air-entrained
- Lower cementitious content
- Higher fines content
- Nominal max. size aggregate 1/2 to 3/4 in.
Conventional Concrete vs RCC

Conventional Air-Entrained PCC

Per Cent by Volume

<table>
<thead>
<tr>
<th>Component</th>
<th>Quantity</th>
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</thead>
<tbody>
<tr>
<td>C.M.</td>
<td>12</td>
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<tr>
<td>Water</td>
<td>16</td>
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<td>Air</td>
<td>6</td>
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<td>Fine Agg.</td>
<td>22</td>
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<tr>
<td>Coarse Agg.</td>
<td>44</td>
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Roller Compacted Concrete

<table>
<thead>
<tr>
<th>Component</th>
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<tbody>
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<td>C.M.</td>
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<tr>
<td>Water</td>
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<td>Air</td>
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<tr>
<td>Fine Agg.</td>
<td>36</td>
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<tr>
<td>Coarse Agg.</td>
<td>38.5</td>
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Density:
- Conventional Air-Entrained PCC: 144 pcf
- Roller Compacted Concrete: 153 pcf
Selection of Aggregate Blend

- **Aggregate selection very important**
- 75% - 85% of mix by volume
- Responsible for mix workability, segregation & ease of consolidation
- Nominal MSA 1/2” to 3/4”
  - Most projects: 5/8” to 3/4”
  - As small as 1/2” for tighter surface and reduced segregation
  - 1” for non-wearing courses or where surface appearance is not critical
- Aggregate quality meets ASTM C33
Moisture – Density Relationship

- Maximum density
- Optimum moisture
Relationship Between Density and Strength

Dry Density (pcf)

7-day Compressive Strength (psi)

Moisture Content, % by dry wt.

9% cementious content
1 1/2 in. MSA
Modified Proctor (ASTM D 1557)
Construction Requirements

- Test section
- Subgrade preparation
- Mixing process
- Placing
- Compacting
- Curing
Test Section

- Train contractor and testing personnel
- Demonstrate workability and appearance of mix
- Demonstrate equipment capabilities
- Demonstrate construction details
  - Joints, bonding, compaction, etc.
- Develop rolling requirements/pattern
- Test RCC and develop correlation factors for density and f’c vs. MR
- Consider location of test section
Subgrade Preparation

- Stiff enough to provide resistance to compaction equipment (95% compaction)
- Ensure subgrade contractor meets compaction requirements
- Non-pumping subgrade
- Replace unsuitable materials
- Consider stabilized base
- Shape to proper lines and grades
Production

- Types of batching & mixing equipment
  - Drum & horizontal shaft mixers
  - Dry batch plants
  - Pugmills
- Must be mixed vigorously
- Uniform distribution of paste is critical for proper performance
- Maintaining proper water content critical
Moisture Sensitive

- **Moisture control imperative**
- 0.5 gallon = 0.1% moisture
- Measure moisture in stockpile & mixture continuously
- Maintain stockpile moisture content consistent (sprinkling, covers, etc)
- Loader operator plays important role
- Coarser mixtures very sensitive to moisture increases
Drum & Horizontal Shaft Mixers

- Highly accurate proportioning
- Local availability
- Smaller output capacity
- Longer mix times than conventional concrete
- More cleaning with drum mixer
- Dedicated production
- Horizontal shaft spiral blade mixer very efficient
Dry Concrete Batch Plant

- Highest local availability
- Very good for small jobs
- 2-step process
  - Feeds transit mixers
  - Discharge into dumps
- Mix 50 -60% capacity
- Low production
- Segregation concern
- Intermittent cleaning required
- Portable pugmill mixers
Pugmills

- Batch or continuous
- High-volume applications
- 125 to 250 + cy/hr
- Excellent mixing efficiency
- Mobile, erected on site
Placing

- Production should match paver capacity
- Uninterrupted forward
- Material transfer device
- Layer Thickness
  - 4” min. thickness
  - 9” to 10” max. thickness (single layer)
- Timing Sequence
  - Limited time (generally 60 minutes max.) for placement of adjacent lanes to maintain “fresh joint”
  - Multiple lifts placed within 60 minutes for “fresh joint”
Placing Equipment

Conventional asphalt pavers

- Available everywhere
- Provide some initial density (80-85%)
- Relatively smooth surface
- Lift thickness range: 4” - 6”
- Increased roll down to achieve density
Placing Equipment

High density pavers

• Vibrating tamping screed
• High initial density (> 90%)
• Lift thickness range: 4”- 10”
• Less roll-down
• High-volume placement (1,000 to 2,000 yd$^3$ per shift)
Proper compaction is critical for strength and durability

Compact to 98% Modified Proctor (ASTM D1557)

Vibratory steel dual-drum roller

Pneumatic tire or rubber coated steel drum to smooth surface

Finish w/smaller steel roller
Compaction Very Important

Various RCC Mixes
Various Cement
Various Ash
Various Aggregates

\[
y = -3E-05x^4 + 0.0105x^3 - 1.7042x^2 + 138.45x^2 - 5607x + 90530
\]

\[
R^2 = 0.9786
\]
Edges Critical to Performance

- Compaction more difficult
- Segregation more likely
- Minimize number of cold joints
- Care needed to match grade from cold to fresh joint
Edge Compaction

Compaction shoe
• Adjacent lane should be placed within 60-minutes
• Must keep edges moist until adjacent lane placed
Cold Joint Construction

- Cut joints back to fully compacted RCC
- Cut edge should be vertical and clean
- Place fresh RCC slightly higher to allow for reasonable “roll down”
Running Longitudinal Cold Joint
Curing

• **EXTREMELY IMPORTANT**

• Water, sheeting or concrete curing compound

• Application rate depends on surface texture
Quality Control Testing

### Moisture & Density
- Tested with nuclear gage in direct mode
- Test density behind paver & after roller to establish rolling patterns to achieve specified density
- Achieve 98% of modified proctor wet density
- Nuclear gage gives general moisture fluctuation indication - Calibrate with oven dried moisture
- Oven dried is most accurate

### Compressive Strength
- Cylinders prepared with vibratory hammer according to ASTM C1435
  - 4 lifts for 6” X 12” cylinders
  - 3 to 4 cylinders per set
  - Strength timing often depends on traffic opening (1, 3, 7, 28 days)
- Cores can be obtained where density is not being achieved
Resource Materials

- Introduction
- Applications
- Properties
- Mixture Proportioning
- Structural Design
- Production
- Construction
- Troubleshooting

cement.org/bookstore
rccpavementcouncil.org
Summary Comments

- Use of RCC in the United States is growing
- Emergence of asphalt contractors
- Major benefits include cost, speed of construction and early trafficking
- Surface textures can vary (manage expectations)
- Mix designs for RCC pavements typically use the soil compaction method
- Compaction/Density...important for strength & durability
- Special attention paid to fresh and cold joints
- Moisture ranges are tight +/- 0.5 percent of optimum
- Curing essential for durable surface