Roller Compacted Concrete Pavement

Matthew W. Singel, PE
What Is RCC?

- RCC is
  - No Slump
  - No reinforcing steel
  - No finishing
  - Consolidated with vibratory rollers

- Concrete pavement placed in a different way!
Which Sample is RCC?
RCC Speed of Construction

- No reinforcement
- No forms
- No hand finishing

09/18/2007
Binder Selection

- Typically
  - Cement
  - Cement and flyash
- Binder content
  - 12% to 16% of aggregate weight.
- For finish
  - no less than 500 lbs per cubic yard.
Typical Mixture Design

• 450 – 550 lbs/CY Cementitious Material.
• 3400 – 3700 lbs/CY Well Graded Aggregate.
• 20 – 30 gallons/CY Water.
• W/C Ratio usually between 0.3 – 0.45.
• Water amount usually dictated by Moisture/Density Relationship.
Structural Characteristics

• Compressive Strengths
  – 4000 – 9000 psi @ 28 days.

• Flexural Strengths
  – 450 – 1100 psi.

• Strengths might be achieved with lower cement factors but surface requires fines.
Surface Texture

Highly dependent on aggregate gradation and binder content.
Surface Texture
RCC TESTING

• Laboratory Mix Design
• Test Section
• Q/C Testing during Construction
## TEST METHODS

<table>
<thead>
<tr>
<th>Method</th>
<th>Mix Design</th>
<th>Test Section</th>
<th>Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregate Gradation, SG and Abs.</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Moisture Content</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Temperature</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Consistency-Modified Vebe Test</td>
<td>not often</td>
<td>not often</td>
<td>not often</td>
</tr>
<tr>
<td>Modified Proctor Compaction Test</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Compressive Strength of Cylinders</td>
<td>yes</td>
<td><strong>yes</strong></td>
<td><strong>yes</strong></td>
</tr>
<tr>
<td>Compressive Strength of Cores</td>
<td>no</td>
<td><strong>yes</strong></td>
<td>only if needed¹</td>
</tr>
<tr>
<td>Flexural Strength of Beams</td>
<td>No</td>
<td><strong>yes</strong></td>
<td>only if needed¹</td>
</tr>
<tr>
<td>Density by Nuclear Gauge</td>
<td>no</td>
<td><strong>yes</strong></td>
<td><strong>yes</strong></td>
</tr>
</tbody>
</table>

¹ These tests may be performed if test results of molded cylinders are below specified strengths.
WHY TEST SECTIONS

• Demonstration of equipment and procedures for mixing, handling and placing
• Establishment of compaction procedures
• Evaluation/fine tuning of mixture
• Training for Q/C and construction personnel
• Development of Q/C correlation factors
SAMPLING AND TESTING AT TIME OF PLACEMENT OF TEST SECTION

• Density and moisture content using nuclear gauge
  ➢ Single probe
• Dry back moisture content
• Molded RCC specimens
  ➢ Molded cylinders with vibratory hammer (ASTM C 1435)
  ➢ Molded beams with vibratory hammer (use Army Corp Method….ASTM not currently available)
# STRENGTH TESTING PROGRAM TO DEVELOP CORRELATION FACTORS

<table>
<thead>
<tr>
<th>Test Location</th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, days</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>No. of molded cylinders</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>No. of drilled cores</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>No. of sawed beams</td>
<td>3</td>
<td>3</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>3</td>
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<tr>
<td>3</td>
</tr>
</tbody>
</table>

![Image of a person working on a construction site](image1)

![Image of a concrete block labeled A-3](image2)
COMPRESSIVE STRENGTH OF MOLDED CYLINDERS (ASTM C 1435) (Three Layers)
COMPRESSIVE STRENGTH OF MOLDED CYLINDERS (ASTM C 1435)
(Five Layers)
FLEXURAL STRENGTH OF BEAMS
(ASTM C 78)
FLEXURAL STRENGTH OF BEAMS (ASTM C 78)
## SUMMARY OF TEST RESULTS FROM THREE TEST SECTIONS

<table>
<thead>
<tr>
<th>Test Section</th>
<th>Pavement Design Thickness (in.)</th>
<th>Test Location</th>
<th>Age (days)</th>
<th>Comp. Str. of Cyl. (psi)</th>
<th>Comp. Str. of Cores (psi)</th>
<th>Flexural Str. of Sawed Beams (psi)</th>
<th>Correlation Factor Cylinders, $C_{cy}$</th>
<th>Correlation Factor Cores, $C_{co}$</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>9</td>
<td>A</td>
<td>8</td>
<td>5190</td>
<td>2590</td>
<td>390</td>
<td>5.4</td>
<td>7.7</td>
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<td></td>
<td></td>
<td>B</td>
<td>8</td>
<td>4010</td>
<td>2510</td>
<td>420</td>
<td>6.6</td>
<td>8.4</td>
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<td></td>
<td>31</td>
<td>5310</td>
<td>2880</td>
<td>450</td>
<td>6.2</td>
<td>8.4</td>
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<td>2</td>
<td>9</td>
<td>A</td>
<td>9</td>
<td>4690</td>
<td>3210</td>
<td>675</td>
<td>9.9</td>
<td>11.9</td>
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<td>B</td>
<td>28</td>
<td>4520</td>
<td>3680</td>
<td>710</td>
<td>10.6</td>
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<td>9</td>
<td>4520</td>
<td>2550</td>
<td>610</td>
<td>9.1</td>
<td>12.2</td>
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<td></td>
<td>28</td>
<td>4400</td>
<td>2740</td>
<td>660</td>
<td>8.9</td>
<td>12.6</td>
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<td>A</td>
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<td>5990</td>
<td>750</td>
<td>9.1</td>
<td>9.7</td>
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<td>B</td>
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<td>6290</td>
<td>5090</td>
<td>670</td>
<td>8.4</td>
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<td>6700</td>
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<td></td>
<td>28</td>
<td>7750</td>
<td>6000</td>
<td>780</td>
<td>8.9</td>
<td>10.1</td>
</tr>
</tbody>
</table>

1 $C_{cy}$ and $C_{co}$ are based on ACI's empirical formula $R = C(f_{c})^{0.5}$

Note: Highlighted values represent minima and maxima of data ranges
Test Section

• Highly desirable, especially for larger projects

• Contractor develops rolling requirements with actual equipment and approved mix

• Assures contractor’s ability to
  – Place and compact RCC to appropriate density
  – Construct fresh, cold, and (if required) horizontal joints
  – Demonstrates surface quality and smoothness
  – Cores and/or beams can be cut for strength correlation
Subgrade/Subbase Preparation

- Must be stiff to allow full compaction of RCC
- Stable subgrade and subbase (if specified)
- Must be smooth and at specified grades
- Block off fixtures
- Set up stringlines (if necessary)
- Moisten subbase prior to RCC placement
Basic Construction Sequence

- Produce RCC material
- Transport by dump trucks
- Place with an asphalt paver
- Compact by steel drum (and sometimes) pneumatic-tired rollers
- Cure with water or curing compound
Production
Continuous Pug Mill

- High-volume applications
- 250 to 1,000 tons/hr
- Mobilize for large projects (25,000 sy+)
Central Concrete Batch Plant

- Highly accurate proportioning
- Local availability (larger metropolitan areas)
- Output for average size projects (< 5 acres)
Dry Concrete Batch Plant

- Highest local availability

- 2-step process
  - Feed into transit mixers
  - Discharge into dumps

- Reduced production (unless admixtures used)

- Most Flexible - Allows producer to service other customers between batches of RCC
Continuous Mix Pug Mill

- High-volume applications
- Excellent mixing efficiency for dry materials
- 250 to 1000+ tons/hr
- Mobile, erected on site
- Higher mobilization costs
Continuous Pug Mill

Mixing Chamber
Transporting & Placing
Placing

• Layer Thickness
  – 4 in. Minimum Thickness.
  – 9 – 10 in. Maximum Thickness in a single lift.

• Timing Sequence
  – Adjacent lanes placed within 60 minutes for “fresh joint”
  – Multiple lifts placed within 60 minutes for “fresh joint”
  – Note: times can be increased with admixtures, positive weather conditions, etc.

• Production should match paver capacity
  – Continuous forward motion for best smoothness
Placing Equipment

• High density pavers
  – Vibrating screed
  – Dual tamping bars
  – High initial density, 90-95%
  – Reduces subsequent compaction
  – High-volume placement (1,000 to 4,000 cubic yards per shift)
High Density Screed

Screed uses Dual Tamping Bars and Vibrators to Achieve initial density.
Wide Paving Widths

Paving widths up to 35 feet at 9 inches thick
Paving Train
Paving Train
Compaction-Final Density

- Final density is critical for strength and durability
- Compacted to 98% Modified Proctor
- Rubber-tire roller
- DD 130 steel wheel
- Rubber coated steel drum roller
Concrete Curing Compound

- White-pigmented concrete curing compounds
- Apply at 1 to 1 ½ times the normal application rate for conventional concrete pavement.
Moisture/Density Relationship

- Develop Proctor Density using proposed mixture design.
- Evaluate moisture-density and density-strength relationships in the test section.
- Most slabs require 98% compaction throughout the slab to achieve proper flexural strength.

Nuclear Gauge - ASTM C1040
[Direct Transmission]
Strength Testing

• Fabricating Cylinders
• With Vibrating Hammer
• ASTM C1435
Port of Houston Authority Pavement Requirements

- Heavy Duty Pavements
- Durability
- Low Maintenance
- Level Surface
- Speed of construction
- Low Cost
Bayport Phase 1 Container Yard
Heavy Duty Pavement

Heavy Loading from Rubber Tire Gantry (RTG)
Heavy Duty Pavement

Point Loads from Container Corner Castings
Heavy Duty Pavement

Loaded Containers (Max. 5 High)
Containers & Equipment

Rubber Tired Gantry (RTG) Cranes
Containers & Equipment

“Top Pick” Lifts

THDC 955
–courtesy the Taylor Group
Subgrade Design

Both Lime (5%) & Cement (5%) Stabilization
RCC Pavement Section Components

18” RCC Surface
12” CTB w/ Recycled concrete
4” Drainage Layer
8” Stabilized Subgrade

GROUNDED CONTAINER STORAGE
Low Maintenance

Cracking
Level Surface

Surface After Grinding
Time Comparisons

50 Acre Container Yard using conventional methods of concrete placement

17 Month Project

VS.

50 Acre Container Yard using Roller Compacted Concrete

11 Month Project
Cost Comparisons

Example:

50 Acre Paved Container Yard Project Comparisons

18” Reinforced Concrete Paving - $80.00 SY

14” Reinforced Concrete Paving – $68.00 SY

VS.

18” RCC Concrete Paving - $50.00 SY

14” RCC Concrete Paving - $40.00 SY
POH Bayport Terminal
Houston, Texas

45 Acres in 2007
POHA Bayport Terminal
Phase I Section I

- Project Let 2006
- Project built 2007
- 50 Acres of RCC Pavement
- Anticipated construction time savings: 4 months
- Exceeded time estimated time savings by over a month
Central Freight
Austin, Texas

10 Acres in 1987
Border Station
Brownsville, Texas

15 Acres in 1998-99
Port Staging Site
Corpus Christi, Texas

2 Acres in 1993
POH Bayport Terminal
Houston, Texas

45 Acres in 2007
Thank You!

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Which Sample is RCC?