DEFINITION
“Roller-Compacted Concrete (RCC) is a no-slump concrete that is compacted by vibratory rollers”
- Zero slump (consistency of damp dense gravel)
- No forms or finishing
- No reinforcing steel
- High production
- Asphalt paving equipment
- Consolidated with vibratory rollers

Concrete placed in a different way!

APPLICATIONS
- Ports, intermodal yards and military hard stands
- Warehouse facilities
- Parking areas
- Maintenance & storage yards
- Airport service areas
- Arterial roads
- Highway shoulders
- Local streets & intersections

RCC – EXPERIENCING A REVIVAL
- Originally used for heavy-duty pavements
- Growth has accelerated in last decade
- Increase in private & non-military public use
- Emergence of asphalt contractors placing RCC

MULTIPLE CHARACTERISTICS
Concrete
- rigid pavement
- strength increases

Asphalt
- paver
- rollers

Soils
- Proctor test
- density test

AGENDA
- Introduction: Definition, Applications & Benefits (Wayne Adaska)
- RCC Mixture Design & Production Process (Brian Killingsworth)
- RCC Placement Process & Case Studies (Corey Zollinger)
**Concrete PPI**

**Asphalt PPI**

Paving Material PPI Price Comparisons 1996 = 100

Source: Bureau of Labor Statistics, Producer Price Indices

**Asphalt Prices Have Soared**

**Benefits of Roller-Compacted Concrete**

- Fast construction
- Economical
- Early load carrying capacity
- Supports heavy loads
- Low maintenance
- Durable
- Light surface reduces lighting requirements and Urban Heat Island effects

**Project Considerations**

- Project size
- Site geometry
- End use
  - *Client expectations*

**The Surface Texture of RCC is Similar to Asphalt Pavement While the Color is Similar to Concrete**

**Freeze-Thaw Durability**

- Although not air-entrained, field performance very good.
  - Reference: PCA publication Long-Term Performance of RCC Pavements, RP366
  - Minor surface paste (1/16") erodes, then stabilizes
  - Most distress along joints
  - 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 de-icing agents on RCC surface for at least 60-days after completion

**Fisher Intermodal Yard, CO**
Built 1985; Photo 2009

**Fort Drum, NY**
Built 1988; Photo 2013

**Freeze-Thaw Durability**
RESOURCE MATERIAL

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

www.cement.org/pavements

NATIONAL HIGHWAY INSTITUTE TRAINING MODULES

• Based on RCC Guide
• Six One-Hour Modules
  • Introduction & Uses
  • Properties
  • Mixture Proportioning
  • Structural Design
  • Production
  • Construction
• Free
• Available at www.nhi.fhwa.dot.gov

AGENDA

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RCC MATERIALS SECTION

• RCC contains the same basic materials as conventional PCC
  • Aggregate
  • Cementitious Materials
  • Water
  • Chemical Admixtures

RCC MIX DESIGN USES SAME MATERIALS AS CONVENTIONAL CONCRETE, HOWEVER IN DIFFERENT COMBINATIONS

Achieves Similar or Better Engineering Properties Than Conventional Concrete

Typical Mix Design

Typical Engineering Properties

Compressive Strength

Flexural Strength (MOE)

Elastic Modulus

Conventional

RCC

YUMA, AZ SHARED USE PATH

JANUARY 2013

Strength Results

Roller Compacted Concrete

Conventional Concrete

Cement + FA

Coarse Agg

Fine Agg

Water

Cement

Fly Ash

3/8 Agg

1/2 Agg

Sand

Water

Cement

Fly Ash

3/8 Agg

1/2 Agg

Sand

Water

Cement

Fly Ash

3/8 Agg

1/2 Agg

Sand

Water

Cement

Fly Ash

3/8 Agg

1/2 Agg

Sand

Water

Cement

Fly Ash

3/8 Agg

1/2 Agg

Sand

Water

Cement

Fly Ash

3/8 Agg

1/2 Agg

Sand

Water

Cement

Fly Ash

3/8 Agg

1/2 Agg

Sand

Water
MIXTURE DESIGN PROCEDURE

**Step 1: Choose 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 losing ride
- Coarse mixes are very sensitive to moisture increases

**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**
- 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)

**Step 4: Cast samples to measure compressive strength**
- 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 2 inch strength test cylinders for each cement content

MIXING EFFICIENCY

- RCC must be mixed vigorously
- Uniform distribution of paste is critical for proper performance

FACTORS TO CONSIDER DURING MIX PRODUCTION

1. Moisture control
   - 0.5 gallon = 0.1% moisture
   - Measure moisture in stockpile & mixture continuously with ovens
   - Maintain stockpile moisture content consistent (sprinkling, covers, etc)
2. Avoid aggregate segregation
   - Stockpile management, loader operator, loading dump trucks, delivering mix to paver, placement techniques
3. Consistent production rate to meet paver demand - paver needs to keep moving (smoothness, compaction are negatively impacted when paver stops)
4. Adequate number of trucks for consistent mix delivery to paver
5. Plant location should be within 30 minutes of paving location

<table>
<thead>
<tr>
<th>Width (ft)</th>
<th>Depth (in)</th>
<th>Speed (ft / min)</th>
<th>Production Rate (CY / HR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>7</td>
<td>6</td>
<td>24</td>
</tr>
<tr>
<td>12</td>
<td>8</td>
<td>7</td>
<td>124</td>
</tr>
<tr>
<td>12</td>
<td>8</td>
<td>8</td>
<td>142</td>
</tr>
</tbody>
</table>

SELECTION OF MIXING EQUIPMENT IS BASED ON PROJECT TYPE AND VOLUME REQUIREMENTS

<table>
<thead>
<tr>
<th>Mixer Type</th>
<th>Description</th>
<th>Factors to Consider</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Batch</td>
<td></td>
<td>Feedlot available in most locations</td>
</tr>
<tr>
<td>Central Mix</td>
<td></td>
<td>Good for demonstrations &amp; smaller applications</td>
</tr>
<tr>
<td></td>
<td></td>
<td>30 to 60 CY/hr - reduced batch size, increased mixing time</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Typically at fixed locations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mixing consistency is average – depends on batch size &amp; mixing time</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Batch to batch moisture fluctuations can be high (+/- 0.4%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Easy to incorporate admixtures, fibers, etc.</td>
</tr>
</tbody>
</table>
TILT MIXERS

<table>
<thead>
<tr>
<th>Mixer Type</th>
<th>Description</th>
<th>Factors to Consider</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal</td>
<td>Spiral Blade Mixer</td>
<td>• An inexpensive alternative to twin shaft mixers</td>
</tr>
<tr>
<td></td>
<td>• 8 cubic yard yield for RCC</td>
<td>• 30 second mix time</td>
</tr>
<tr>
<td></td>
<td>• RCC theoretical rating at 320 yards per hour (30 second mix time)</td>
<td>• Mixer can charge all types of trucks (portable concrete wetbelt may be added for</td>
</tr>
<tr>
<td></td>
<td>• No permitting required</td>
<td>additional height and high speed discharge into any truck)</td>
</tr>
<tr>
<td></td>
<td>• Easy to incorporate admixtures, fibers, etc.</td>
<td>• RCC theoretical rating at 320 yards per hour (30 second mix time)</td>
</tr>
</tbody>
</table>

TWIN SHAFT OR PUGMILL MIXERS

<table>
<thead>
<tr>
<th>Mixer Type</th>
<th>Description</th>
<th>Factors to Consider</th>
</tr>
</thead>
<tbody>
<tr>
<td>Twin Shaft –</td>
<td>Horizontal Mixer – Batch Type</td>
<td>• High production rates: 150 to 200 CY / hr</td>
</tr>
<tr>
<td></td>
<td>• Excellent mixing efficiency for dry materials</td>
<td>• Mobile – 1 or 2 loads, easily set up in 1 day</td>
</tr>
<tr>
<td></td>
<td>• Batch system may induce load to load moisture fluctuation</td>
<td>• Same capabilities &amp; requirements as operating ready mix plant</td>
</tr>
<tr>
<td></td>
<td>• No permitting required</td>
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<tr>
<td></td>
<td>• Easy to incorporate admixtures, fibers, etc.</td>
<td>• Same capabilities &amp; requirements as operating ready mix plant</td>
</tr>
</tbody>
</table>

FACTORS TO CONSIDER FOR PAVING

- Consistent Mix Delivery to Paver
  - 10 Wheel dump trucks - Cover loads
  - Keep trucks clean
  - Plan trucking route (traffic, truck staging)
  - Avoid segregation in truck loading / unloading
  - Avoid end of load segregation
  - Consider using material transfer machine & insert hopper
  - Balance speed of paver with mix delivery
  - Use paving calculator
  - Keep paver moving (material transfer machine)
  - Keep head of material constant in hopper and screed
  - Keep augers feeding material consistent
  - 2 to 3 man operation
  - Limited to 2 aggregate sizes

RCC IS PAVED WITH ASPHALT EQUIPMENT

Achieving Density & Smoothness is Critical

- Standard Paver
  - High density pavements (Vogele or ABG Titan)
  - High initial density (> 80%)
  - Availability is increasing, but still limited
  - Smoother surface with higher initial density
  - Less roll down to achieve density
  - High-production (6 to 8 ft/min)
  - Lift thick range: 4" to 6"
  - Adjacent lanes easily paved
  - Strongly RECOMMENDED

FACTOR TO CONSIDER FOR PAVING

- Mix Delivery
  - 10 Wheel dump trucks - Cover loads
  - Keep trucks clean
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  - 2 to 3 man operation
  - Limited to 2 aggregate sizes

- Finish Rolling
  - Combination, dual steel or rubber tired
  - Maximum weight - 6 short ton
  - Remove roller marks
  - Once completed, keep roller off of the area

AGENDA

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LONGITUDINAL JOINTS CAN BE BUILT 3 DIFFERENT WAYS

**Vertical Cold Joint**
- Place width of lane
- Saw cut full depth early next day
- Remove with blade & loader
- Keep water
- Reduce waste with paving shoes
- Place adjacent lane and match thickness of existing lane
- Good performance, limited load transfer

**Angular Cold Joint**
- Need high-density paving
- Attach shoe to screed
- Maximum angle 15°
- Use plate tamper to improve edge durability
- No saw cutting required
- Place adjacent lane next day
- Limited performance, possible shear crack

**Fresh (Hot) Joints**
- Keep for 30 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 longitudinal saw cut
- Use small loader to create fresh vertical transverse joint
- Move quickly – keep moist!
- Coordination is key, avoid breakdowns

MANHOLES & CURBS ARE EASILY INCORPORATED

**Curb & Carrier**
- 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

**Paving**
- 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
  - See cut hardened RCC, place manhole, tie in with conventional concrete

QC / QA INCLUDES TESTING FOR DENSITY, MOISTURE CONTENT & COMPRRESSIVE STRENGTH

**Moisture & Density**
- Density tested with nuclear gage
- Achieve 90% of modified proctor wet density
- Direct Transmission
- Moisture content checked with oven

**Compressive Strength**
- Cylinders prepared with vibratory hammer according to ASTM C1435
- Tensioned at 1, 3, 7, 28 days
- Cores may be obtained where density is not being achieved

RCC PAVEMENTS NEED TO BE CURED & SAW CUT FOR PERFORMANCE & AESTHETIC BENEFITS

**Curing**
- Applied at same rate or slightly higher than conventional concrete
- Ensure uniformity with application process
- Apply as soon as possible behind roller operation
- Recommend WR Meadows 1200 to 1600
- Ensures durable surface

**Saw Cut & Fill Joints**
- More aesthetically pleasing
- Early entry saw very effective, shortly following placement
- Recommend sawing within 2-6 hours to avoid uncontrolled cracking
- Depth: 1" to 1.5"
- Spacing: Maximum 36 times thickness

RECENTLY, CITY STREETS & HIGHWAY SHOULDERS HAVE BEEN SUCCESSFULLY COMPLETED WITH RCC

**Richland Ave (US 78)**
- Aiken, SC - 2009
- Owner: South Carolina DOT
- Use Type: US Highway
- Year Built: 2009
- Thickness: Milled 10" asphalt
  - Placed 10" RCC
- Traffic: 6000 ADT, 4 lanes
- Speed: 45 mph

**Additional Details**
- Replaced 27,500 SF in 15 days
- Placed 10" RCC in 1 day
- All milled areas were paved within same day
- Maintained 1 lane open in each direction
- Traffic re-opened within 24 hours
**RICHLAND AV. (US 78) AIKEN, SC**

**Completed Project**

- **Project Information**
  - **Owner:** City of Aiken
  - **Use Type:** Collector / Arterial
  - **Year Built:** 2011
  - **Quantity:** 2550 CY

- **Additional Details**
  - Thickness: 6" RCC / 8" Stabilized Subgrade (Lime & Cement)
  - Diamond-Ground Surface
  - First RCC pavement in West Texas

**Grape Creek Road**

**San Angelo, TX**

- **Project Information**
  - **Owner:** City of San Angelo
  - **Use Type:** Collector / Arterial
  - **Year Built:** 2011
  - **Quantity:** 2000 CY

- **Additional Details**
  - Thickness: 6" RCC / 8" Stabilized Subgrade (Lime & Cement)
  - Diamond-Ground Surface
  - First RCC pavement in West Texas

**Village of Streamwood Streets**

**Streamwood, IL**

- **Project Information**
  - **Owner:** Village of Streamwood
  - **Use Type:** Residential
  - **Year Built:** 2011, 2013
  - **Quantity:** 1000 CY each

- **Additional Details**
  - Thickness: 2" HMA / 6" RCC
  - City forces completed all work

**LOWE’S DISTRIBUTION CENTER**

**Rome, GA - 2012**

- **Project Information**
  - **Owner:** Lowe’s
  - **Use Type:** Distribution Center
  - **Year Built:** 2012
  - **Size:** 65 Acres
  - **Volume:** 65,000 CY

- **Additional Details**
  - **Thickness:** 7" RCC / 6" Aggregate Base
  - **Traffic:** 600 Trucks / day
  - **Roadway:** Pavement 60 ft wide, 150 to 180 CY/hour
  - **RCC paving completed in 2 months, 11 days (Calendar)
  - **Saved $3.5 M versus asphalt with concrete daily striping

**ROLLER COMPACTED CONCRETE HAS BEEN USED ON MANY SUBDIVISION STREETS IN OHIO SINCE 2001**

<table>
<thead>
<tr>
<th>Short List of Developments with RCC in Columbus, OH Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Longwood fractured frame / 6&quot; RCC</td>
</tr>
<tr>
<td>• Marble Cliff Crossing</td>
</tr>
<tr>
<td>• Albatross Place</td>
</tr>
<tr>
<td>• Creighton Farms Way</td>
</tr>
<tr>
<td>• Creekside</td>
</tr>
<tr>
<td>• Freshwater Greens</td>
</tr>
<tr>
<td>• The Preserve</td>
</tr>
<tr>
<td>• Kensington</td>
</tr>
<tr>
<td>• Grant Run</td>
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<tr>
<td>• Park of Waggner</td>
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</tr>
<tr>
<td>• Blendon Reserve</td>
</tr>
<tr>
<td>• Cedar Run</td>
</tr>
<tr>
<td>• Creekstone 1</td>
</tr>
<tr>
<td>• Creekstone 2</td>
</tr>
<tr>
<td>• Haley Hollow</td>
</tr>
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</tr>
<tr>
<td>• Haley Hollow</td>
</tr>
</tbody>
</table>
### Project Information:
- **Owner:** Southern Company
- **Use Type:** Distribution Center
- **Year Built:** 2012
- **Size:** 363,000 SY
- **Volume:** 51,500 CY

### Additional Details:
- Thickness: 4, 6, 7, 10 & 18" RCC
- Pavement Types: Parking lot, Laydown areas, Haul Roads, Industrial area
- Converted 2" AC / 6" Ag Base to 4" RCC / 6" Soil cement
- Reduced lighting by 50%
- Saved owner 25%

### PLANT VOGTLE NUCLEAR PLANT

**GA – 2011 to 2013**

- **Owner:** Yuma Truck Driving School
- **Use Type:** Truck Parking
- **Year Built:** 2013
- **Size:** 6280 SY
- **Volume:** 1,215 CY

### Project Information:
- **Owner:** Yuma Truck Driving School
- **Use Type:** Truck Parking
- **Year Built:** 2013
- **Size:** 6280 SY
- **Volume:** 1,215 CY

### Additional Details:
- Thickness: 7" RCC / Compacted Subgrade
- Traffic: 20 Trucks / day
- Paved 18 ft wide
- RCC paving completed in 2 days
- Used 95% passing ½" Sieve
- Owner knew that asphalt wouldn’t hold up to the turning movements of the trucks
Questions?

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