LRGV AIA

Provider Number: A090

Roller-Compacted Concrete: A Value-Added Pavement Solution

Course Number: C21-03

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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

Course Description

Roller Compacted Concrete (RCC) pavement combines various aspects of conventional concrete pavement materials practices with some construction practices typical of flexible pavements. RCC has the same basic ingredients as conventional concrete: cement, water and aggregates, but uses about less water and a well graded aggregate that is stable under the placement action of a paver with a high density screed and finishing with a heavy duty roller.RCC offers many advantages with a few being:

- Cost savings compared to asphalt and conventional concrete pavement
- Installation in 50% or less of the time in comparison to other pavement options.
- Achieves design strength to support full traffic within 48 hours.
- Lower water content substantially reduces shrinkage; creates load transfer across joints.
- Dense highly durable material with lower maintenance cost than asphalt pavement

Learning Objectives

- Understand what roller compacted concrete (RCC) pavement is
- Learn the principal differences between asphalt, conventional concrete and RCC pavements
- Understand how RCC pavement is designed and constructed
- Understand the types of applications best suited to RCC through presentation of examples in Texas and the U.S.

Building Roads and Pavements

- Low cost
- Fast construction
- Minimize inconvenience to homes/businesses
- Built to last, low maintenance
- Aesthetics
- Ride quality (initial and long-term)
- Sustainable

Conventional Pavement Choices

Asphalt

Concrete

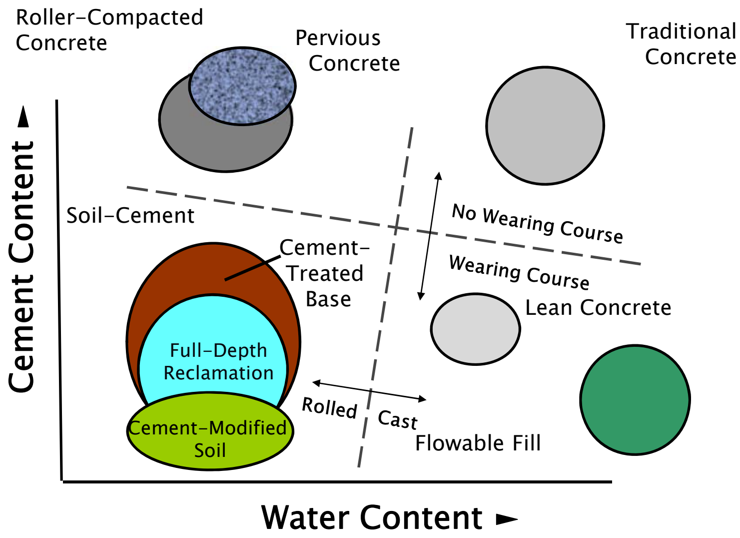
Types of Asphalt and Concrete

- Asphalt
  - Full depth asphalt
  - Asphalt + base
  - Chip seal on base
  - Pervious
- Concrete
  - Jointed/*reinforced*
  - Jointed/unreinforced
  - Continuously reinforced
  - Roller compacted concrete
  - Pervious

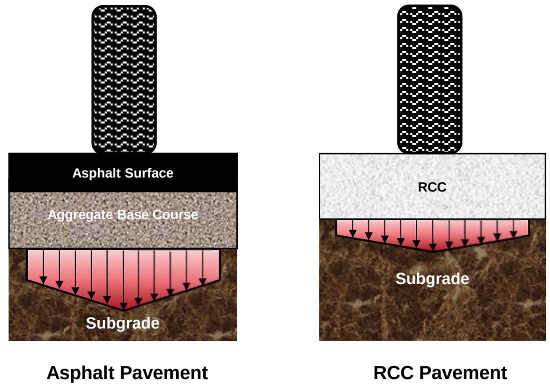
Roller Compacted Concrete

- Concrete pavement placed a different way
- No-slump concrete (very stiff)
- No forms
- No reinforcing steel
- Placed with asphalt-style pavers
- Consolidated with Vibratory Rollers
- No finishing
- Low water-cement ration (i.e. less shrinkage)

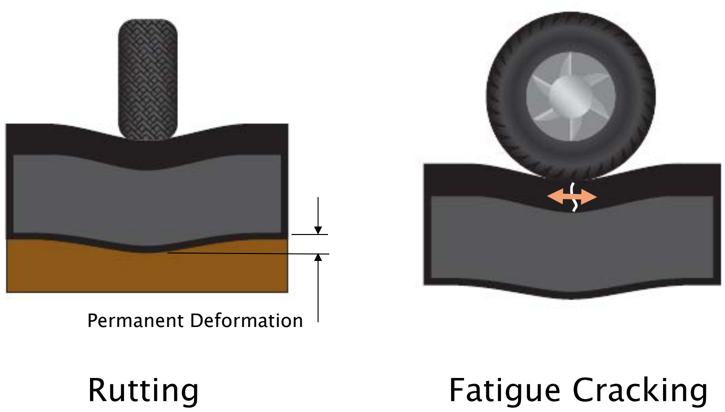
Cement-Based Pavement Materials



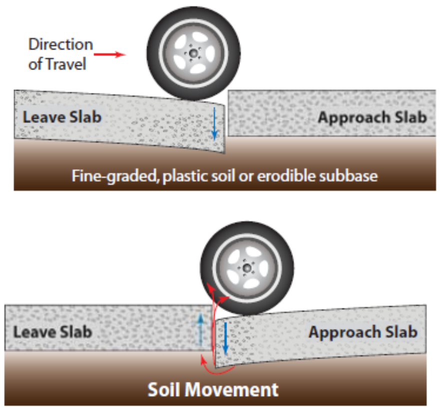
Subgrade Stresses



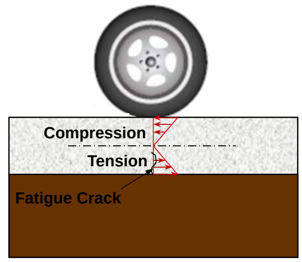
Asphalt Failure Modes



RCC Failure Modes

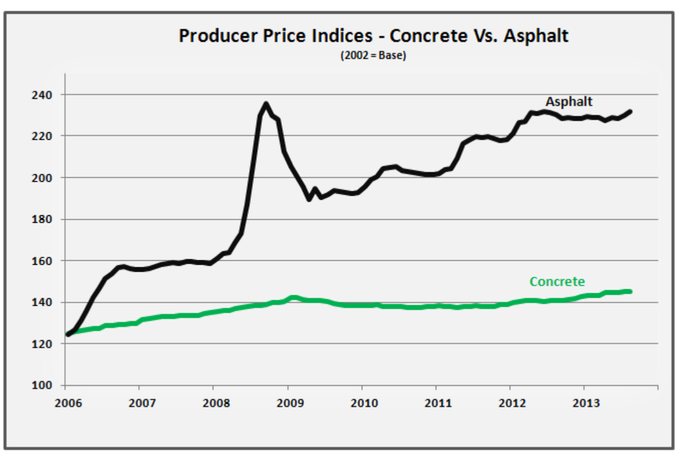


Erosion/Pumping



Tension Fatigue

Concrete vs. Asphalt Pricing Has Changed

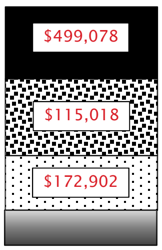


Asphalt vs. RCC Comparison

Arterial Street

- 500 Trucks per day, sandy subgrade, 20-year life, 1 mile x 24 ft

Traditional Asphalt + Aggregate



7" Asphalt

8" Graded Agg.

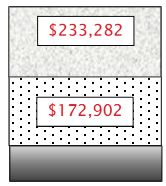
6" Cement Stab. Soil

Compacted Subg.

$786,998 Total Cost

RCC Pavement

$17,741 Curing
$18,132 Saw Cutting
$56,320 Diamond Grinding



6" RCC

6" Cement Stab. Soil

Compacted Subg.

$498,377 Total Cost

$288,621 Cost Differential

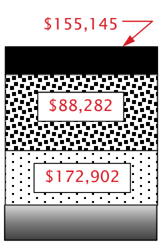
(Asphalt Break-even ~ 2.5 inches asphalt)

Asphalt vs. RCC Comparison

Residential Street or Car Parking

- 3 Trucks per day, sandy subgrade, 20-year life, 1 mile x 24 ft (126,000 sf)

Traditional Asphalt + Aggregate



2" Asphalt

6" Graded Agg.

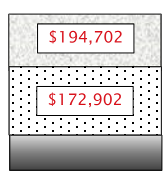
6" Cement Stab. Soil

Compacted Subg.

$416,329 Total Cost

RCC Pavement

$ 17,741 Curing
$ 18,132 Saw Cutting



5" RCC

6" Cement Stab. Soil

Compacted Subg.

$403,177 Total Cost

$13,152 Cost Differential

RCC Pavement

Comparison: RCC and Asphalt Pavement

Attribute	RCC	Asphalt
Pavement Type	Rigid	Flexible
Cost	Low	High
Time	Fast	Slow
Inconvenience	Low	High
Use of Existing Materials	Yes	No
Permanence/ Durability	High	Moderate
Moisture Susceptibility	Low	Moderate
All-Weather Platform	High	Low
Optimization Benefits	High	Low

*Using flex base

Pavement Surfaces

RCC, Conventional Concrete & Asphalt

- RCC cannot be textured
- RCC surface more "open-graded", like asphalt
- Smaller aggregates provide more "closed" surface

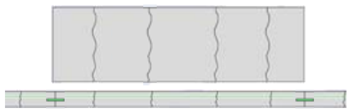
How Does RCC Differ from Conventional Concrete?

- Surface texture resembles asphalt, not concrete (no surface drags or tining)
- Pavement smoothness at higher speeds
- “Handwork” cannot be done w/ RCC
- No steel (dowels or reinforcing)
- Much faster construction
- Faster early trafficking

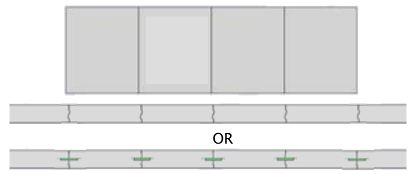
Properties
Conventional vs. RCC

Property	Conventional	RCC
Compressive Strength	3,000-6,000 psi	4,000-8,000 psi
Flexural Strength	500-700 psi	600-1000 psi
Elastic Modulus	3-5 million psi	3-6 million psi
Shrinkage	Higher	Lower
1-Day Strength	1,500-3,000 psi	2,500-4,000 psi

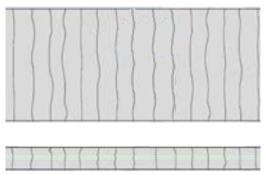
Concrete Pavement – Types



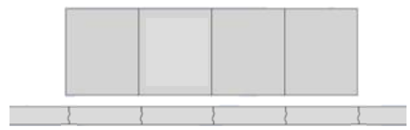
Jointed-Reinforced



Jointed-Plain (unreinforced)



Continuously Reinforced

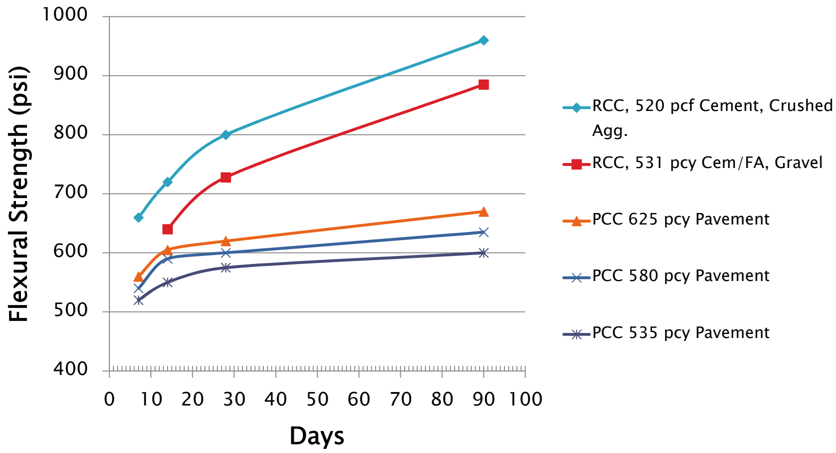


Roller Compacted Concrete

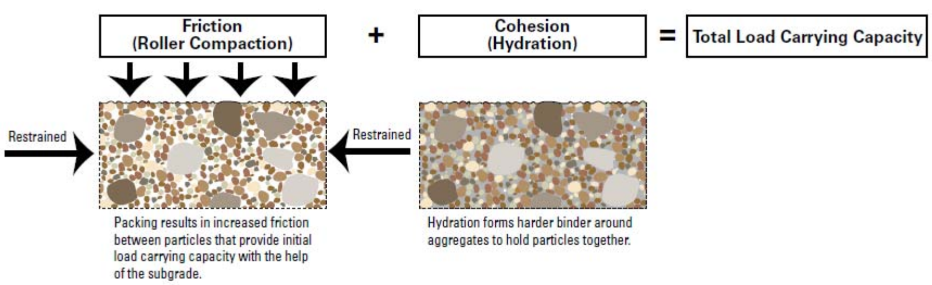
Pavement Type Comparison

Characteristic	Jointed-Reinf	Jointed-Plain	RCC	Cont. Reinf.
Transverse joint spacing	25-100+ ft	12-20 ft	12-20+ ft	n/a
Transverse crack spacing	12-20 ft	n/a	n/a	2-6 ft
Joint width	~0.02-.04	~0.1	~0.1	~0.7
Rut-resistant surface	Yes	Yes	Yes	Yes
Shrinkage accounted for	Cracks/Joints	Joints	Joints	Cracks
Reinforcing	.06-0.25%	None	None	0.4-0.85%
“Expansion” joints used	Yes	No	No	Maybe
Load transfer across panels	Dowel/Agg Int	Dowel/Agg Int	Dowel/Agg Int	Agg Int/Shear
Tiebars in longitud. joints	Yes	Yes	No	Yes
Longitudinal joint spacing	12-14 ft	12-14 ft	12-14 ft	12-14 ft
Minimize joints	Yes	No	No	Yes
AASHTO-62 to 93	Yes	Yes	Yes	Yes
AASHTO DARWin-ME	NO	Yes	Yes	Yes
TxDOT	No, but	Yes	Yes	Yes (mostly)

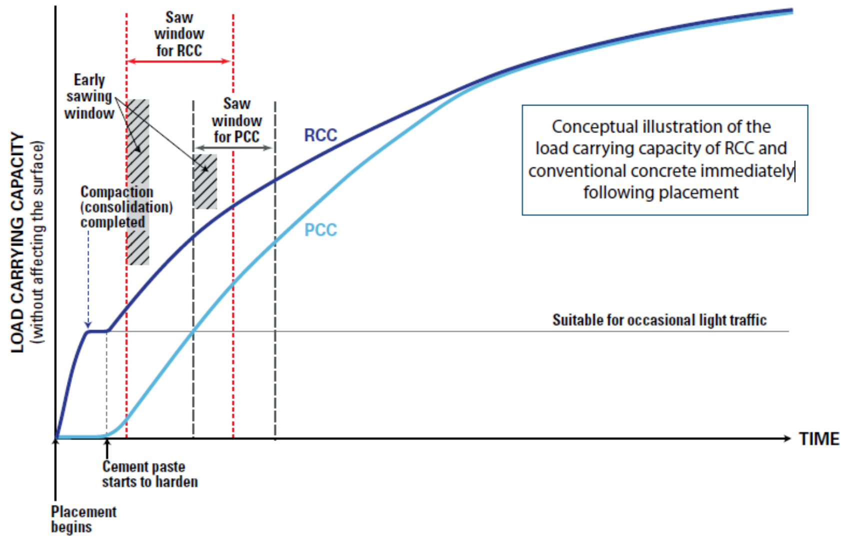
RCC Develops Greater Flexural Strength



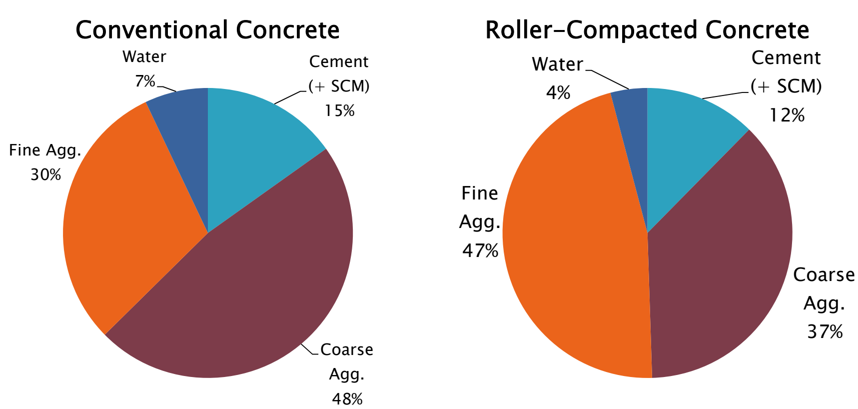
RCC Strength Development



Sawing & Trafficing
RCC and Conventional Concrete



Mixture Design
Conventional vs. RCC



Mixture Design

- Not proportioned in same way as conventional concrete
- Proportioning is similar to soil-cement or cement-treated aggregates
- Largest aggregate (nominal maximum size) are 1/2” or 5/8”

Mixture Design

Attribute	Conventional	RCC
Air entrainment	Req’d in F/T areas	None
Paste content	Higher	Lower
Water content	Higher	Lower
Cement content	Same/Higher	Same/Lower
Aggregate Gradation	Often gap-graded	Well-graded (similar to asphalt)
Admixtures	Water reducer, air entrainer, retarder or accelerator	Usually none, sometimes
Maximum nominal size aggregate	1 ½ to 2”	½ to 5/8”
Passing 200 sieve	0-3%	2-8%
Slump	1-3”	0
Proportioning Method	ACI 211	Soil Compaction Methods
Proportioning Goals	Strength, durability (w/cm), consistency (slump)	Strength, compatibility, durability (cement content)
Field QA/QC	Comp. cylinders or flex. beams, slump, air cont.	Comp. cylinders, density, moisture content

Benefits of RCC

- RCC vs. Asphalt
  - Less expensive with equivalent sections (+ project size
  - Supports loads rigidly, and reduces subgrade stresses
  - Less maintenance
  - Placement time same or less
  - Asphalt smoother because of thinner lifts
- RCC vs. Conventional Concrete
  - Less expensive (no reinforcing/dowels)
  - Faster
  - Carries light traffic in hours, can be open in 24 hours
  - But surface texture and smoothness may require grinding for higher-speed pavements

Thickness Design of RCC Pavements

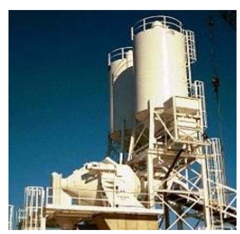
- Follows rigid pavement methods
- Plain, un-doweled, un-reinforced concrete pavement
- Three methods currently used:
  - RCC Pave – PCA, based on COE and CTL data/mechanistic methods
    - Best for industrial pavements, single large loads
  - StreetPave – ACPA (PCA), based on PCA mechanistic methods
    - Best for street and parking lot design, mixed traffic
  - PCA-Pave (beta) – PCA beta, based on PCA/TTI research using layer-elastic methods
    - Best for analysis/design single and mixed traffic (experimental/research use, verification)

RCC Construction Sequence

- Produce RCC material
- Transport with covered dump trucks
- Place with asphalt-style paver
- Compact with rollers
- Cure (curing compound or water)

RCC Production Methods

Twin-Shaft Continuous Pug Mill



Central Mix Batch Plant

Twin-Shaft Horizontal Mixer

Dry-Batch Concrete Plant

RCC Production Methods
Comparisons

Attribute	Pug Mill	Horiz. Twin Shft	Central Mix/Batch	Dry Batch
Prod'n rate	50-300+ cy/hr	50-200 cy/hr	30-90 cy/hr	<50 cy/hr
Batching	Continuous	Batch	Batch	Batch
Mix efficiency	High/fast	High/fast	Moderate	Slow
Mix consistency	Excellent	Excellent	Good	Moderate
Moisture consistency	Excellent	Good	Moderate	Poor
Mobility	1-day set-up	1-day set-up	Semi-mobile	Stationary
Considerations	Best method for high, consistent production, but mobilization $	Flexibile, easy add-on to dry batch; needs batch system	Avail in some metro areas and highway contr.	Plant/trucks "dedicated" to RCC; much slower than conv. Conc.
Best for	Large jobs (25k sy+), multiple jobs in close proximity	Small to large jobs	Small to medium jobs	Small jobs or demo

Transporting RCC

- Rear dump trucks normally used
- Minimize transport time
- Covers required – moisture retention
- Longer hauls, hot/windy conditions, use water reducer to extend transport time

RCC Placement Methods

Conventional Concrete

Roller-Compacted Concrete Pavement

RCC Placement Methods
Standard and High-Density Asphalt Pavers

Attribute	Standard Asphalt Paver	High-Density Paver
Compaction Method	Vibrating Screed/Tamping Bars	Heavy-duty dual tamping bars/vibrating screed
Initial compaction	85-90%	90-98%
Max. lift thickness	6-8”	10”
Prod’n Rate	Low to moderate (varies)	High (1,200 Tons/Hr)
Availability	All Areas	Limited, RCC Contractors
Roll-down	≥1” (less grade control)	<1”
Surface Smoothness	Moderate	High
Max. Paving Width	Varies (to 30’+)	To 50’

RCC Compaction

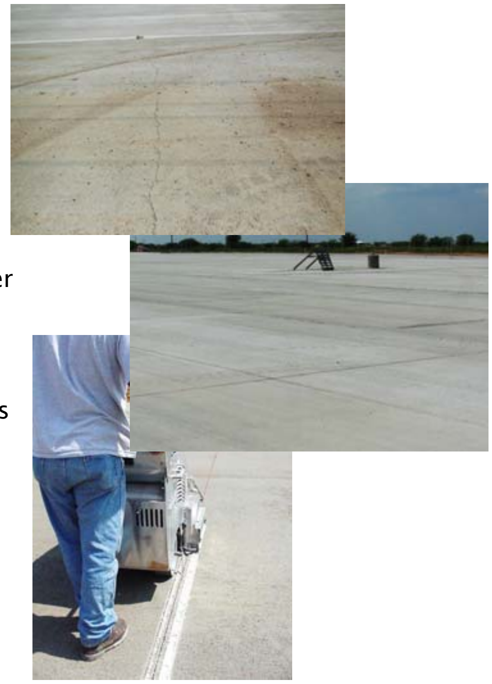
- Compaction is critical
- Compact to 98% of modified proctor (ASTM D1557)
- Vibratory/non-vibratory roller
- Rubber-tire roller

RCC Curing

- Curing is critical
  - As with all concrete
  - But RCC has lower water content, no “bleeding”
- Curing starts as soon as compaction is completed
- Three methods:
  - Moist cure
  - Curing compound
  - Asphalt emulsion

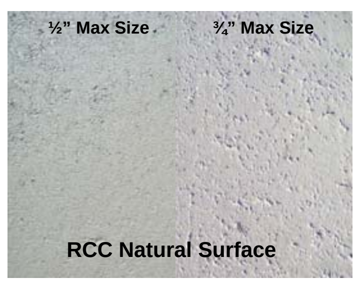
RCC Jointing

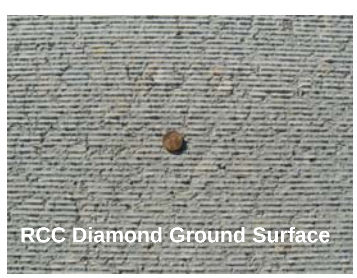
- Natural cracking
  - 20-80' spacing
  - Relatively narrow cracks
  - Seal if > 1/8"
  - Provides partial load transfer (agg. Interlock)
- Saw-Cut joints
  - Aesthetics
  - Use early entry saws 2-6 hrs @ 1-1 ½ "depth
  - Spacing: 20' for ≤ 8", more for > 8" thickness
  - Easier to maintain
  - Keeps crack width small, promotes better load transfer



RCC Surface and Smoothness

- RCC surface has aggregates visible (similar to asphalt)
- Textures not possible (e.g. broom, tining)
- Smaller aggregates promote more "closed" texture
- Smoothness good to ~45 mph (less for standard paver)
- Diamond grinding for higher-speed traffic, and texture.





QC/QA for RCC

- Aggregate gradation (sieve analysis)
- Density (nuclear gauge)
- Compression cylinders (ASTM C1435, for RCC)
- Moisture (microwave/oven dried)
- Beams not normally used (no casting standard, difficult to cut)

Manholes & Curbs

- Curb & Gutter
  - Placed before RCC
  - Serves as compaction aid
  - Seal joint
  - Or drill and route rebar into cold RCC, and place ribbon curb afterwards
- Manholes, Inlets
  - Plywood on RCC before construction
  - Saw RCC, fill w/ conventional concrete

Tank Hardstand and Helipad
Fort Hood, Texas – 1984 & 1987

- First large RCC in U.S.
- 18,000 sy, 10" thick, $58/sy at time
- 300 lb cement, 160 lb FA
- 1 ½" aggregate had some segregation
- ¾" agg test area better
- Placed in very hot, windy weather
- Natural cracks
- Flex strength of 800-900 psi

Central Freight Distribution Ctr.
Austin, Texas – 1987

- Truck terminal
  - 7" & 8" pavements
  - 90,000 sy
  - RCC bid 25% less than asphalt
- Natural cracks
  - 23-50' spacing
  - Routed/sealed @ 5 yr
- Continuous use, little maintenace @ 26 yrs:
  - Still performing: 500-1,000 trucks/day
  - 1 "failure" (subgrade)
  - Some joints opening, small faulting
  - Could grind/reseal

Central Freight Distribution Ctr. Austin, Texas – 1987

Natural Crack

Longitudinal Joint

Hornsby Bend Compost Yard

Austin, TX – 1987 & 90

- 90,000 sq yd, Five basins – “Dillo Dirt”
  - 12 in thick, 2 lifts
  - Haul roads, 9 in RCC
  - 3:1, 5:1 and 10:1 slopes
- Mix Design
  - 12% cement
  - No fly ash
  - ¾ in max aggregate
  - 3300 psi @ 38 D
- $43.47/cu yd or ~$31/sq yd
- Still functions daily

Port Staging Site

Corpus Christi

- 2 Acres
- 1993

Los Tomates Border Station

Brownsville

- 1999
- 15 Acres
- 10 in, 2 lifts
- 5000 psi
- 520 lbs cement
- Sawed joints

City Arterials
San Angelo, TX – 2011 & 2012

- Grape Creek Road: 15,000 sy
- 50th Street: 30,000 sy
- 50-year design life
- Years of deferred maintenance on asphalt roads
- 75 yr maintenance:
  - Asphalt (8 yr sealcoat + 24-year mill/o'lay) = $7.5M
  - RCC (overlay @ 50-60 yrs = 1.4 M)

Port of Houston
Bayport Container Terminal – 2007 to 2012

- Largest RCC site in U.S.
  - 45, 48, 35 acres – 2007,09, 12
- 14 and 18" RCC
  - 2-lift construction
  - 30 yr design
  - 8" CTB
  - 4" pervious drainage
  - 12" lime/cement subgrade
- Production:
  - 8-11 acres/month RCC
  - 2 acres/month PCC (2004 60 acre project)
- Costs:
  - RCC $45-$72/sy (18")
  - PCC $65-$100/sy (15")
  - 2009 alt: $32.2 Conv. vs. $27.5M RCC (15% savings)

Pioneer Natural Resources
Victoria, TX – 2013

- Pipe fabrication for Eagle Ford oil/gas
- 60 acres
- Originally 15" unsurfaced aggregate
- Replaced with 7" RCC on stabilized base
- 20% cost savings
- Significant maintenance savings
- Owner cited less risk/clean-up in fuel/oil spills
- 60 acres placed in less than two months

Bighorn Ave.
Alliance, Nebraska -1994

City Streets
Columbus, Ohio – Since 2000

- Over 30 developments
- RCC serves as pavement structure
- Thin asphalt surface (not really needed)
- Roads not destroyed during subdivision development phase

Honda America Plant
Lincoln, Alabama – Since 2002

Farm-to-Market Road

South Carolina DOT - 2001

Beltway Shoulders (I-285)

Atlanta, GA - 2004

- Georgia DOT
- Outside shoulder reconstruction (10' wide)
- 17.3 miles (n & s)
- 38,500 cy
- Mainline traffic volume to 155,000 vpd.

Lowe's Distribution Center Rome, Georgia – 2012

- 69 Acres
- 65,000 cy
- 7" RCC on 6" aggregate base
- 400 trucks/day
- Paved 30' wide, 150 to 180 cy/hr
- RCC paving completed in 2 months
- Saved $3.5M vs. asphalt with concrete dolly strips

Richland Ave (US 78)
Aiken, South Carolina – 2009

- South Carolina DOT
- Milled 10" asphalt, replaced with 10" RCC
- Traffic: 6,000 ADT, 4 lanes
- 45 mph
- Replaced 27,500 sy in 15 days
- All milled arease were paved within same day
- Maintained 1 lane open in each direction
- 20' saw-cut joints (3 hrs)
- Open to traffic @ 24 hrs

Sustainability Considerations

- Long-life, low-maintenance
- Light surface:
  - Cooler pavement reduces urban heat island effect
  - Lower lighting requirements
  - Improved safety because of night reflectivity
- Contains spills to surface
- Completely recyclable into aggregate for future base course or concrete
  - Easier to recycle than conventional – no steel

Parting Thoughts

- TxDOT
  - Spec approved
  - First project, Brownwood Safety Rest Area, 2014
- Project specifications
- Contractor availability in Texas
- Cement Council of Texas can help

Thank You!

- Questions?
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