RCC in Missouri

Municipal Pavement Seminar

Fenton, MO

Brett Trautman

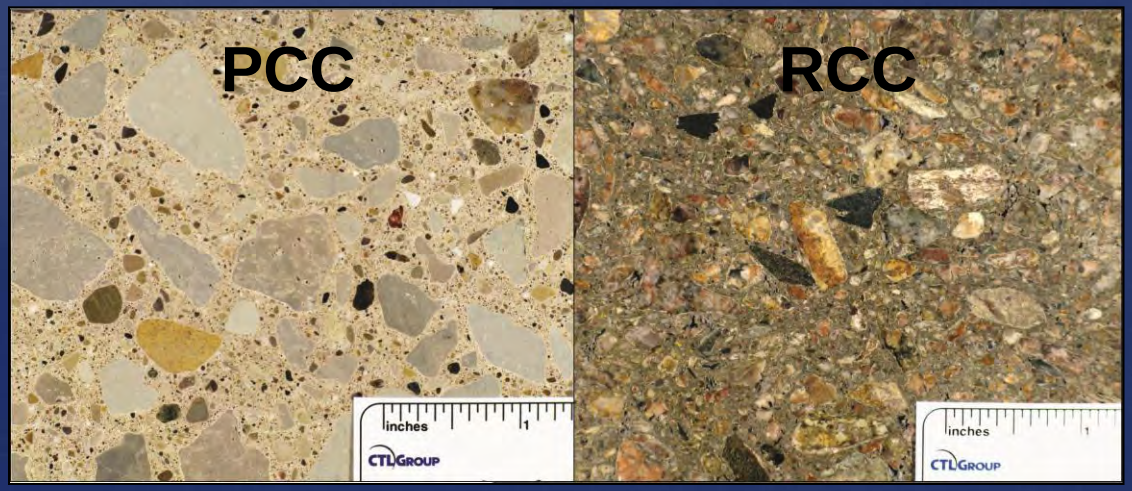
February 11, 2015

Learning Objectives

1) What is Roller Compacted Concrete and how does it compares to traditional concrete
2) MoDOT's early history using Roller Compacted Concrete
3) The lessons learned from early work
4) What MoDOT is doing with Roller Compacted Concrete today

What is Roller Compacted Concrete Pavement?

- Name from the heavy vibratory steel or rubber tired rollers



- RCC/PCC
  - Similar Strength
  - Same basic ingredients
  - Different mixture proportions
  - RCC has higher percentage of fine aggregates
  - Fresh RCC is stiffer than typical zero-slump conventional concrete

National Concrete Pavement Technology Center

What is Roller Compacted Concrete Pavement?

- Consistency stiff enough to remain stable under vibratory rollers
- Wet enough to permit adequate mixing and distribution of paste
- Placed with an asphalt-type paver equipment with a standard or high-density screed
- Follow by a combination of passes with rollers for compaction
- Final compaction achieved within one hour of mixing
- RCC pavements are constructed without forms, dowels, or reinforcing steel

National Concrete Pavement Technology Center

What is Roller Compacted Concrete Pavement

Conventional PCC Pavement

Hot-Mix Asphalt Pavement

Shared materials characteristics:

- Same materials (different proportions)
- Similar curing requirements

Shared construction characteristics:

- Similar aggregate gradation
- Similar placement and compaction

Roller Compacted PCC Pavement

National Concrete Pavement Technology Center

Material Comparison between Conventional PCC and RCC

Percent by Volume

Conventional PCC

11	16	6	26	41
C.M.	Water	Air	Fine Agg.	Coarse Agg.

Roller Compacted Concrete

10	13	1.5	35	40.5
C.M.	Water	Air	Fine Agg.	Coarse Agg.

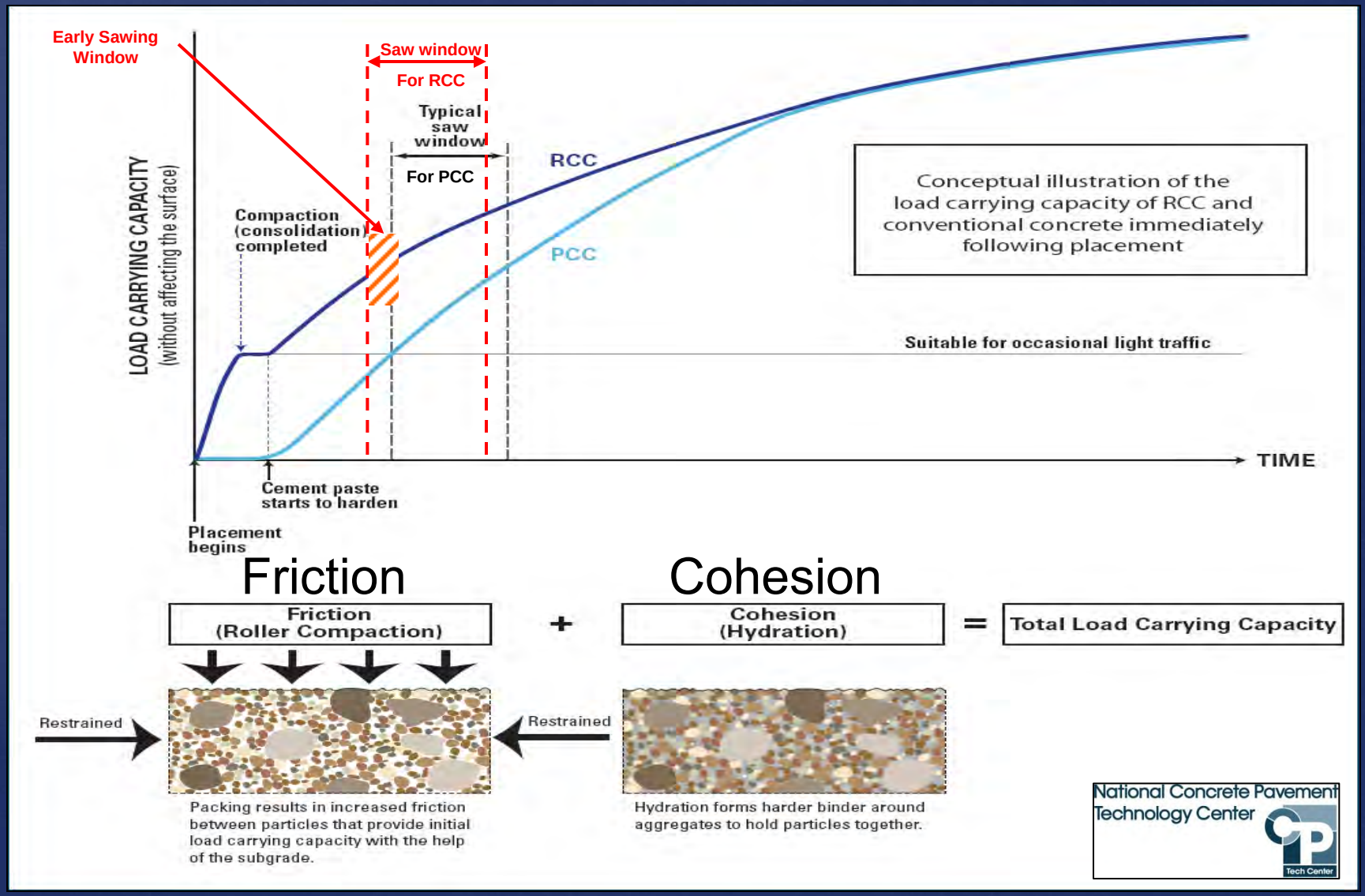
National Concrete Pavement Technology Center

Tech Center

Basic Difference between PCC and RCC

	Type of Pavement	
General Materials and Practices	**Conventional Concrete Pavements**	**RCC Pavements**
Mix materials proportions	• Aggregates typically account for 60 to 75 percent of the mixture by volume. • (w/cm) ratio is 0.40 to 0.45	• Aggregates compose 75 to 85 percent of RCC mixtures by volume. • (w/cm) ratio of 0.34 to 0.40 is typically lower than that used in conventional concrete mixtures
Workability	• Manipulated by the paving machine, (slump is generally about 2 in.)	• The mixture has the consistency of damp aggregates. RCC's relatively dry and stiff (zero slump) • Mixture is not fluid enough to be manipulated by traditional concrete paving machines.
Paving 	• The mixture is placed ahead of a slipform paving machine, which then spreads, levels, consolidates through vibration.	• Typically the RCC mixture is placed with a conventional or heavy-duty, self-propelled asphalt paving machine • To initially consolidate the mixture to a slab of uniform thickness.

Early Load Carrying Capacity of PCC and RCC



Comparison of Surfaces

National Concrete Pavement Technology Center

The Beginning

- Quarterly Meeting with MO/KS Chapter, ACPA
  - Georgia DOT used on shoulders
- Annual MO/KS Chapter, ACPA van trip
  - Visited Continental Cement facility in 2007
  - Used around there new plant

The Beginning

- RCC Demonstration
- Hosted by Continental Cement on November 16, 2007
- Observed lay down operation
- Decision made to develop specification

First Steps

- St. Louis contractor built an aggregate stockpile pad
  - Constructed in July 10, 2008
  - Learning curve
  - Tried three different cement contents:
    1) 400 lbs/cu. yds
    2) 450 lbs/cu. yds
    3) 500 lbs/cu. yds

First Steps

- Contractor constructed a temporary shoulder & by-pass
  - Rte 364, St. Charles Co.
  - Constructed on November 20, 2008
  - Used base spreader on shoulder
  - Performed well

MoDOT's Demonstration Project

- Project Details
- 6 inch RCC Overlay
- Two 10.5 foot lanes
- Approximately 2000 ft. long
- Ponderosa Road just south of Gans Road interchange south of Columbia, MO
- October 29 & 30 2008

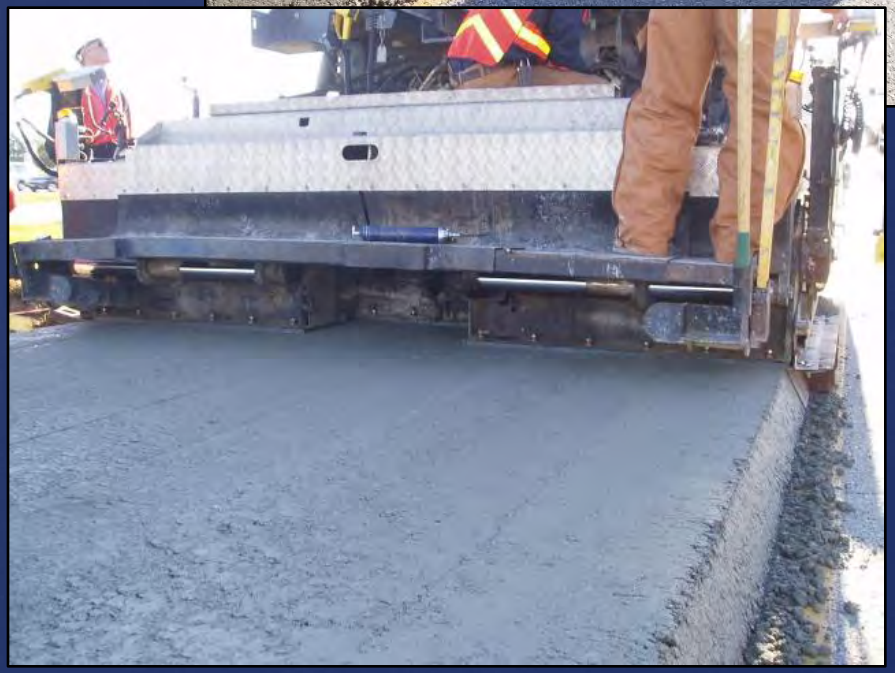
Original Condition

Mix Design

- 1” Stone 1461 lbs/cu yds
- Manufactured Sand 1813 lbs/cu yds
- Cement 503 lbs/cu yds
- Water 267 lbs/cu yds (32 gallons)
- w/c Ratio 0.53

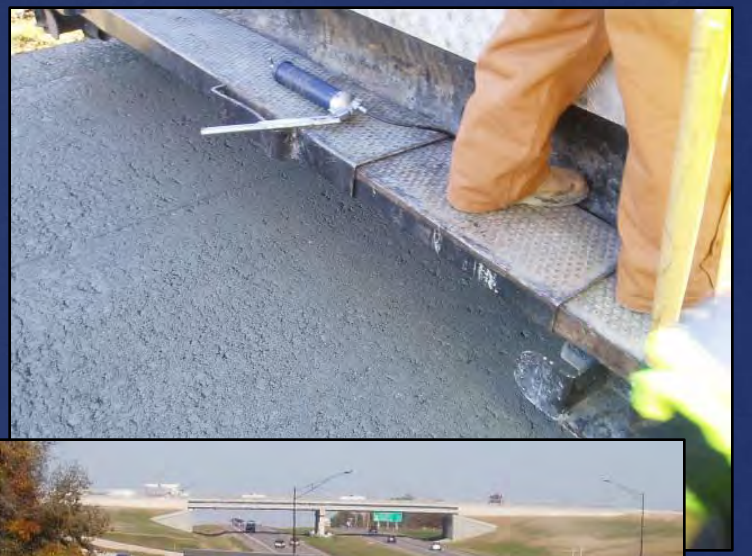
Construction

Day 1



Construction

Day 1



Construction

Day 2

Construction

Day 2

Profilograph

- Test Results
  - Day 1 – 69 inches/mile
  - Day 2 – 85 inches/mile
- Current acceptance level is 65 inches/mile for speed limit less than 45 mph
- Zero blanking band

Compressive Strength (psi)

	Day 1		Day 2	
	Core	Cylinder	Core	Cylinder
1 day*	3450	2030	2110	2765
3 day*	3910	3500	3080	3940
7 day*	4360	5040	3490	4570
14 day	n/a	5240	n/a	5465
28 day**	3480	5560	2678	5700

**1 core at 950 feet*

***Average of 3 cores at 250, 600 and 950 feet*

Calculated Density (lbs/cu ft)

	Day 1	Day 2
Calculated Density	144.1	139.5

- *Performed on extracted cores*

Linear Traverse

	Day 1	Day 2	ASTM Range
% Air	9.9	17.4	n/a
Spacing Factor	0.016	0.009	0.004 – 0.008
Specific Surface	167	152	600 - 1100

- *Average of 2 specimens*
- *Specimens taken beams cut out of the pavement*

Rapid Chloride Permeability (coulombs)

	Day 1	Day 2
Permeability	Est. 10,000+	Est. 10,000+

- *Average of 3 core from 1300, 1650 and 1900 feet*

Boil Test (%)

	Day 1	Day 2
Permeable Voids	19.54	20.54

- *Average of 3 cores at 250, 600 and 950 feet*

What Happen?

- Extracted cores from Continental's plant
- Cores from 2002 and 2007 placement
- Determine in-place properties
- Concern that RCC would get a bad rap

Comparison with other jobs

	Day 1 MoDOT project	Day 2 MoDOT project	2002 RCC project	2007 RCC project	2008 RCC project
Calculated Density	144.1	139.5	155.9	156.5	151.5
Percent Air	9.9	17.4	1.9	1.1	2.6
Permeability	Est. 10,000+	Est. 10,000+	645	698	---
Permeable Voids	19.54	20.54	8.63	9.32	---

2002 and 2007 RCC projects at Continental Cement Facility
2008 RCC project temporary shoulders in St. Charles Co.

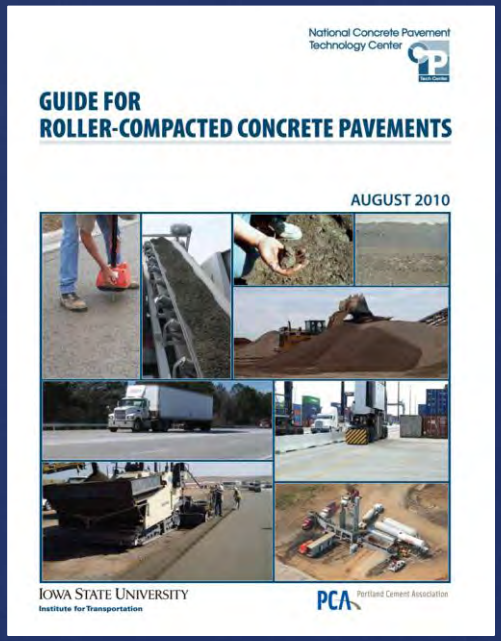
After 3 months

Current Condition

- Placed an asphalt overlay to improve the ride
- Structurally RCC performing very well
  - Moderate Success

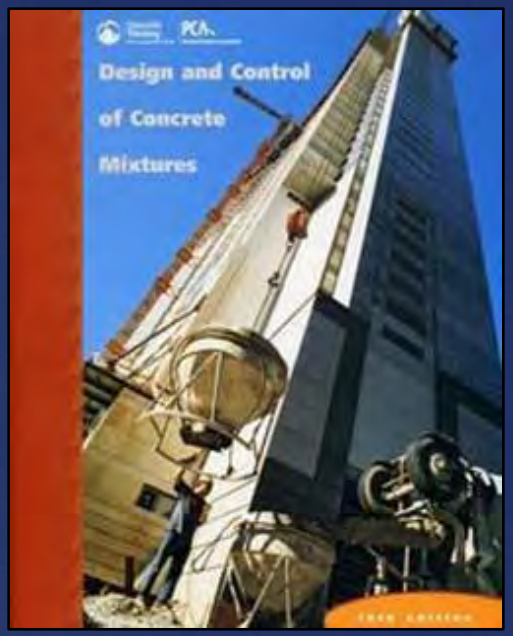
Future of RCC in Question

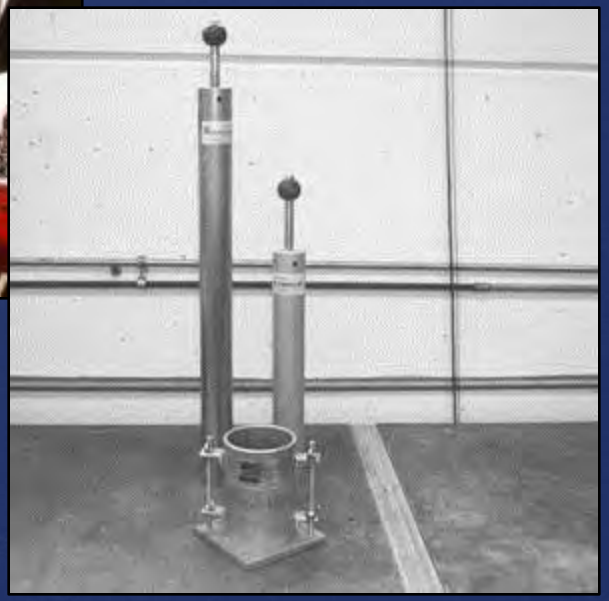
- After MoDOT's demonstration project contractors reluctant to utilize RCC
- Hosted RCC training session
  - Training conducted by CP Tech Center
  - Held February 6 -7, 2012 at the Central Laboratory



Lesson Learned

- Mix proportioning is critical
  - Evaluate different options
  - Determine optimal moisture content





Lesson Learned

- Use concrete quality aggregates
  - Used aggregate not approved for concrete

Lesson Learned

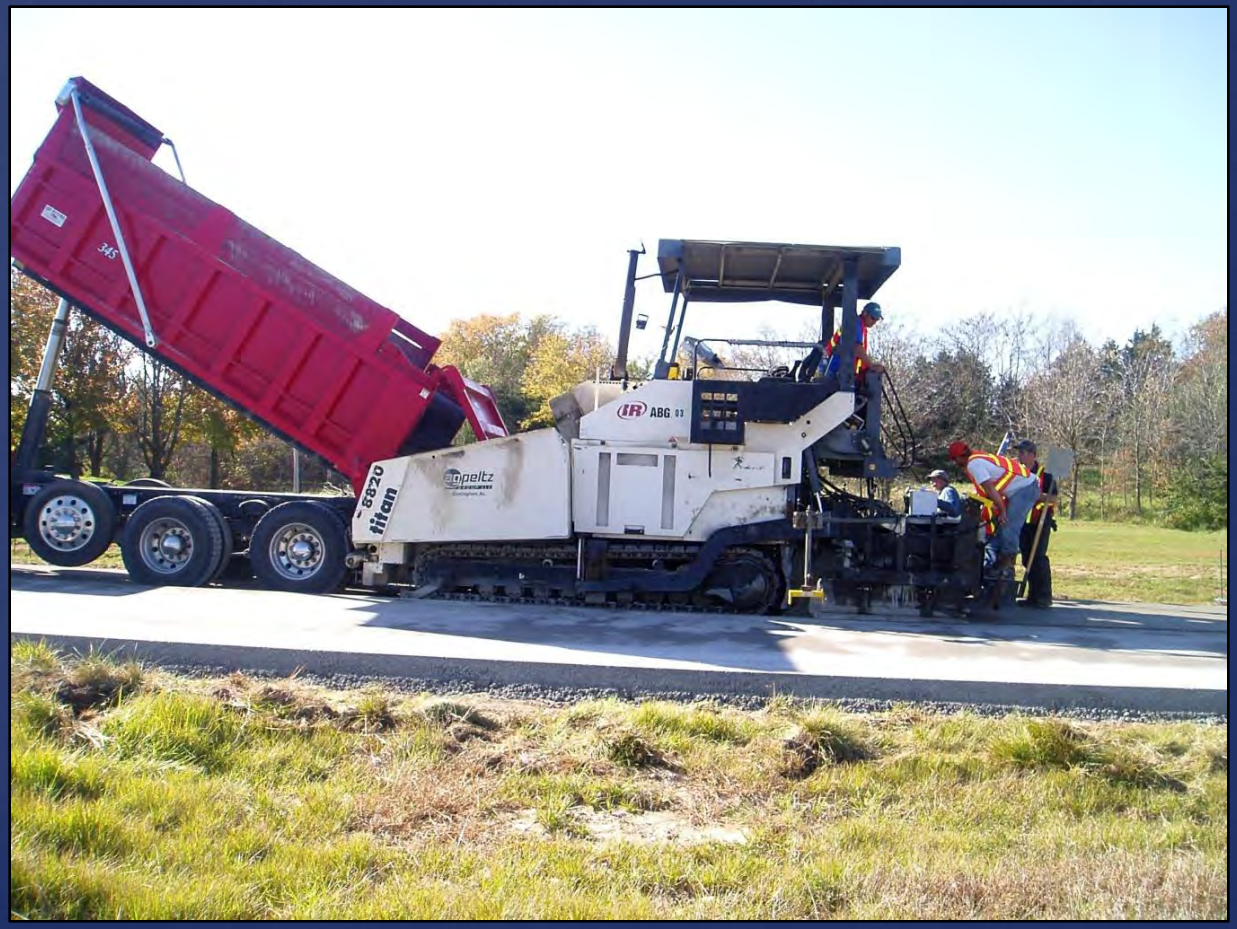
- Avoid using 100% crushed aggregates
  - Manufactured sand used instead of natural sand
  - RCC difficult to compact; increase angularity
  - Increase in w/cm ratio; increase in minus No. 200

Lesson Learned

- Prevent moisture loss during delivery
  - Waiting 30 to 40 minutes

Lesson Learned

- Equipment needs to be functioning properly
  - Tamper screed not operating correctly



Lesson Learned

- Use good lay down procedures
  - Dumping the paver wings

Lesson Learned

- Monitor density and moisture content throughout placement
  - Moisture content key

Lesson Learned

- Curing is critical
  - White curing compound not applied

2008 Weber

2007 Continental

2008 MoDOT

Recent RCC History

- Constructed 1 project in 2012
  - **Rte 54, Cole Co. (one gore area)**
- Constructed 3 projects in 2013
  - **Rte 32 & 19, Crawford & Dent Cos. (2 ft. shoulders)**
  - Rte 87, Moniteau & Cooper Cos. (2 ft. shoulders)
  - Rte 160, Ripley Co. (widening)
- Constructed 2 projects in 2014
  - Rte 19, Dent & Shannon Cos. (2 ft. shoulders)
  - Rte 21 & 106, Reynolds Co. (2 ft. shoulders)

MoDOT Project Locations

Project Locations

★ **Built 2012 (1)**

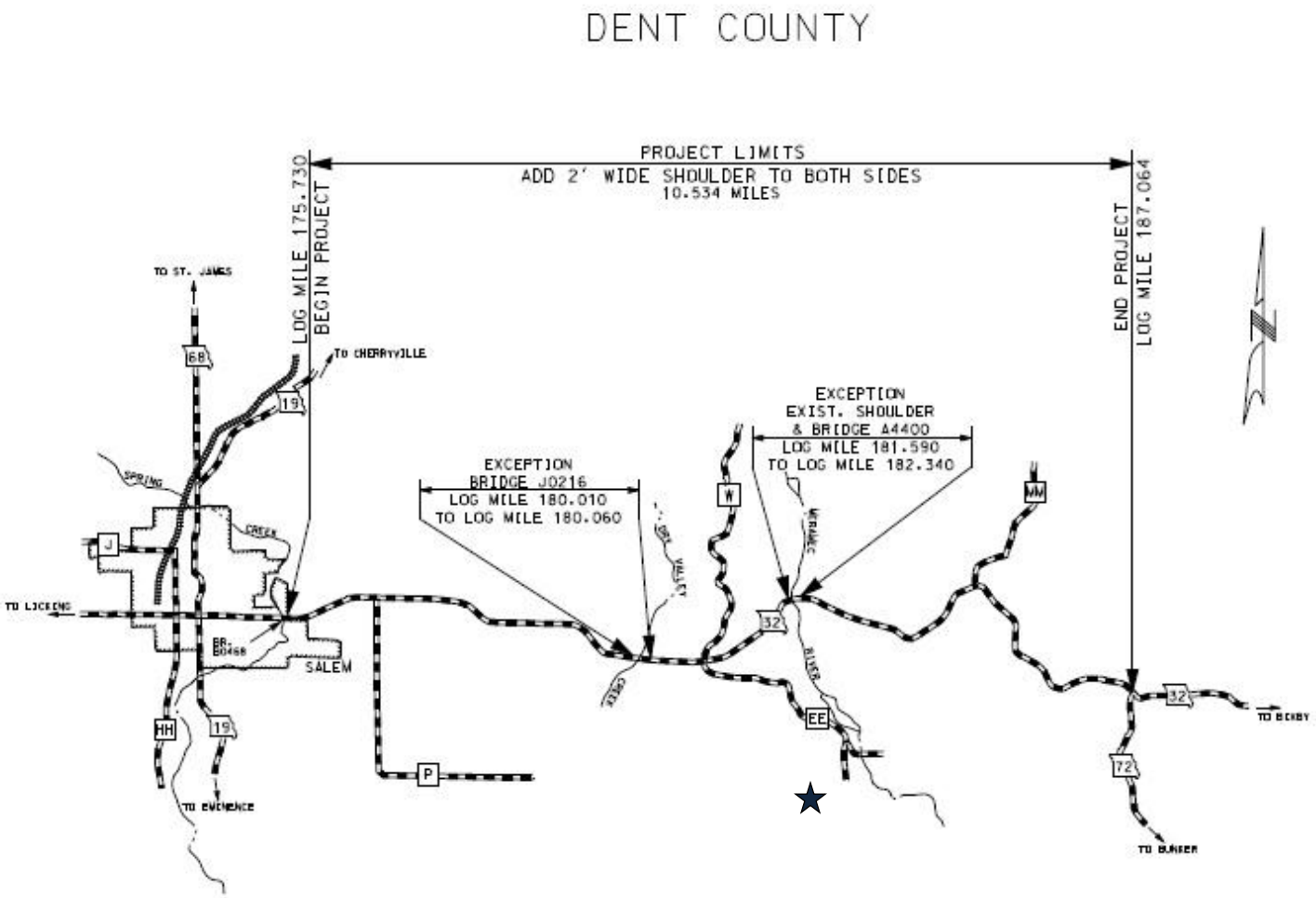
★ **Built 2013 (3)**

★ **Built 2014 (2)**

Route 54, Cole Co.

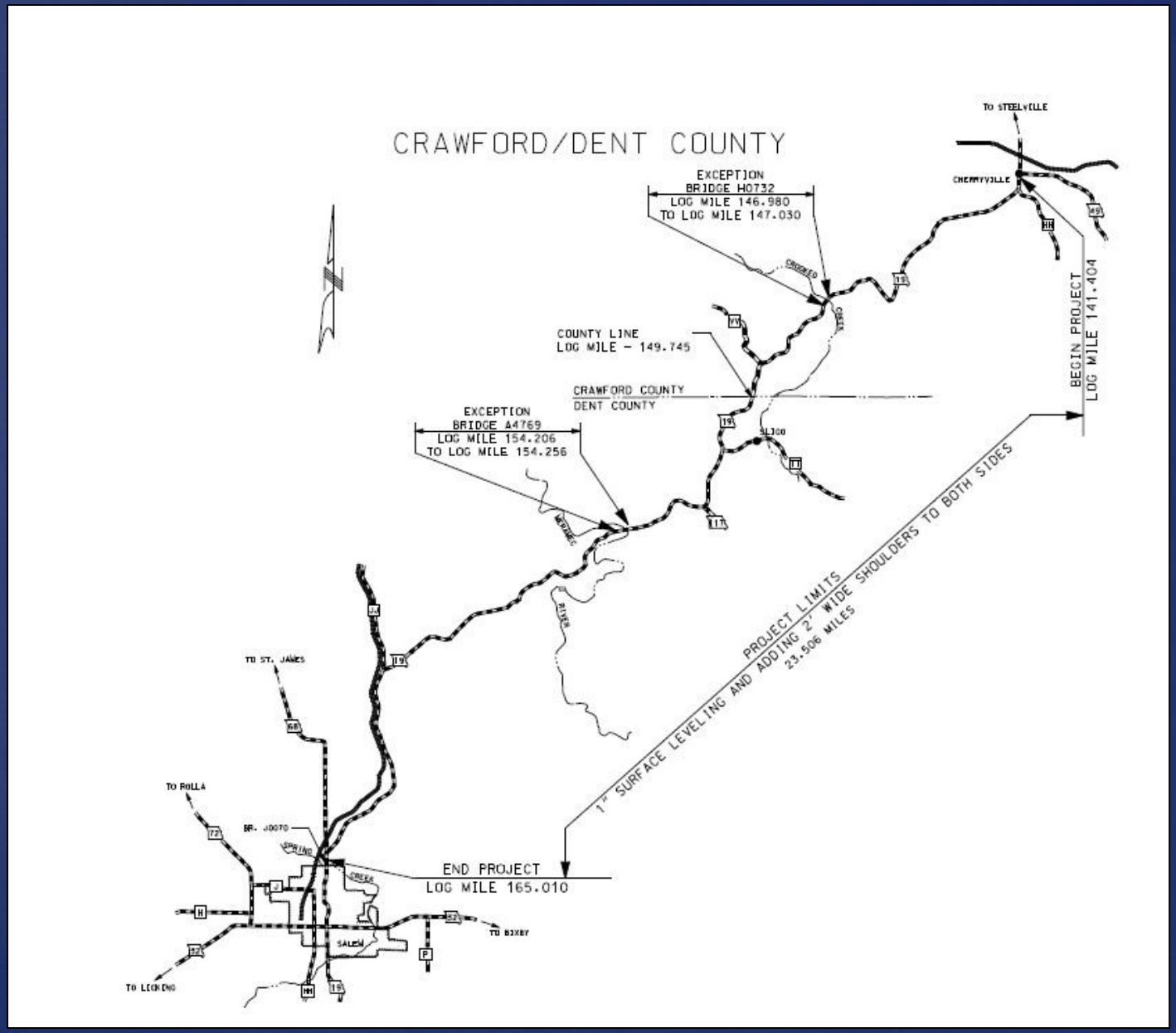
- Asphalt plant broke down
- Requested permission to use RCC in lieu of Bituminous Base
  - Contractor had been developing RCC mix designs
  - Covered with 1 ¾" asphalt mix (BP-1)
- Worked well

Route 32, Dent Co.



★ Concrete & asphalt plant location

Route 19, Dent & Crawford Co.



Project Information

Scope: Overlay the existing pavement and add 2 ft. shoulders to both side of roadway

Contractor: Rolla Asphalt

Project Length:

Route 32 – 10.534 miles

Route 19 – 23.506 miles

Area of RCC:

Route 32 – 11,421 sq. yd.

Route 19 – 27,463 sq. yd.

Volume of RCC:

Route 32 – 1,824 cu. yd.

Route 19 – 4,386 cu. yd.

Concrete Batch Plant

Concrete Mixer

- Mixer Capacity – 6 cu. yd.
- Batch Size – 5 ½ cu. yd.
- Mixing Time – 45 seconds

Materials

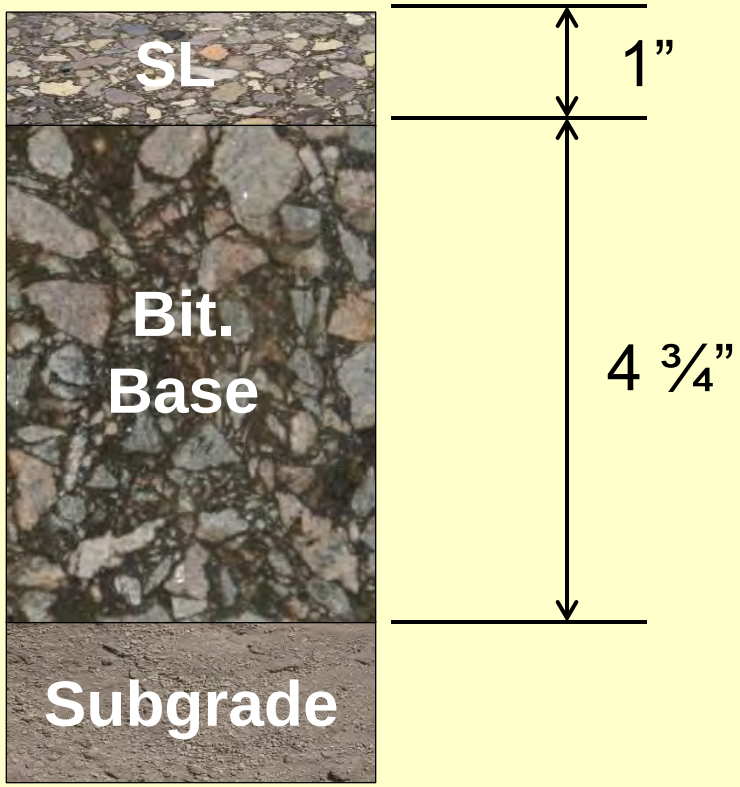
- Coarse Aggregate
  - 1” max. top size
  - Dirty Fraction (No. 200 approx. 9%)
  - Gasconade Dolomite (PCCP Quality)
- Fine Aggregate
  - Class B sand
  - Osage River
- Cement
  - Type I/II
- Fly Ash
  - Class C
- No liquid admixtures used

Mix Design Criteria

Criteria	Value
Cementitious Content	500 lbs./cu. yd.
Percent Fly Ash	20%
w/c Ratio	0.4
Percent Fine Aggregate	25%
Design Air	0%

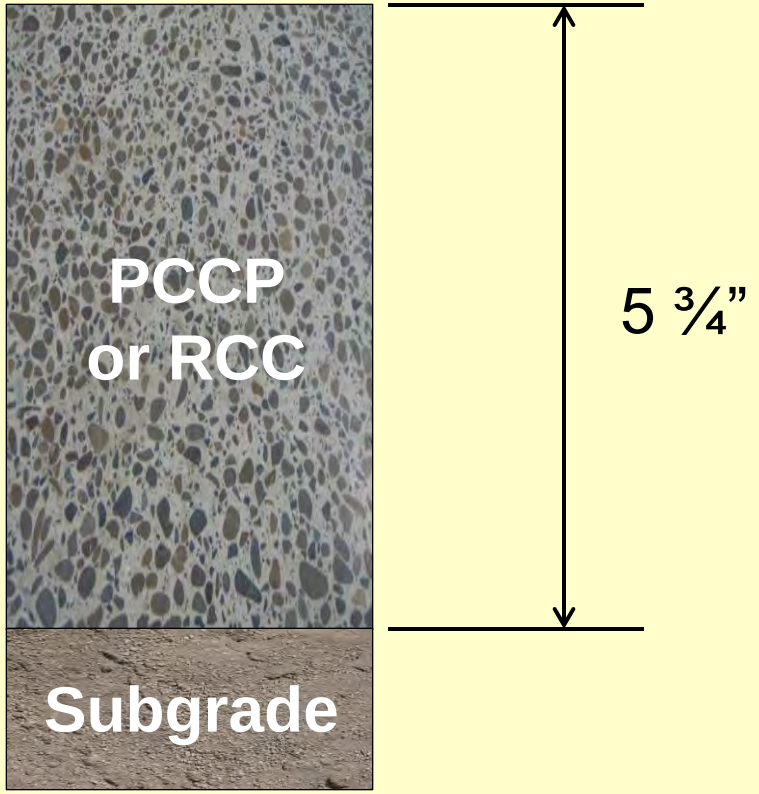
Shoulder Structure – Type A2

Asphalt Option



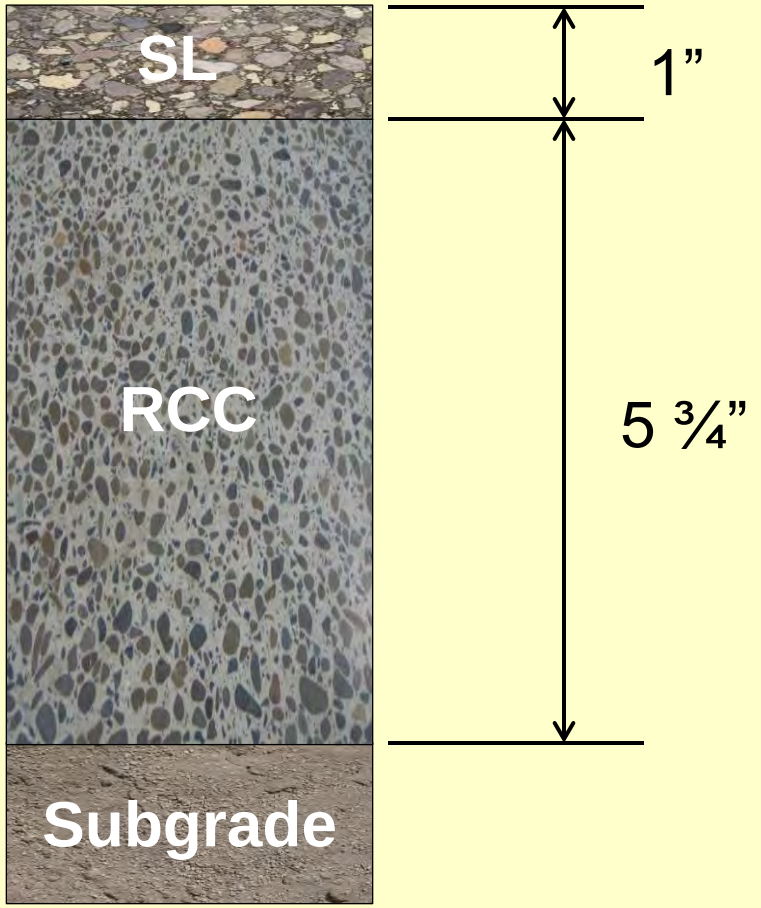
Total Thickness= 5 ¾”

Concrete/RCC Option



Proposed Shoulder Structure

RCC Option



Total Thickness= 6 ¾”

Traffic Control

Coldmilling Edge

- Establish straight, vertical edge in decent material

Remove Pulverized Material

Clean Roadway

Compact Subgrade

Open Trench

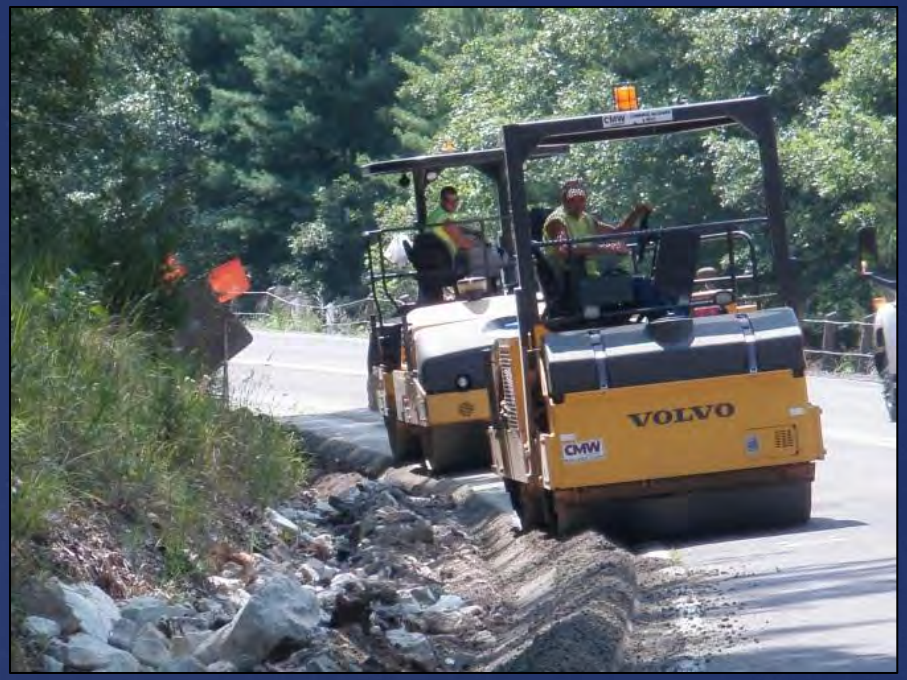
RCC Placement

RCC Placement

Clean Roadway

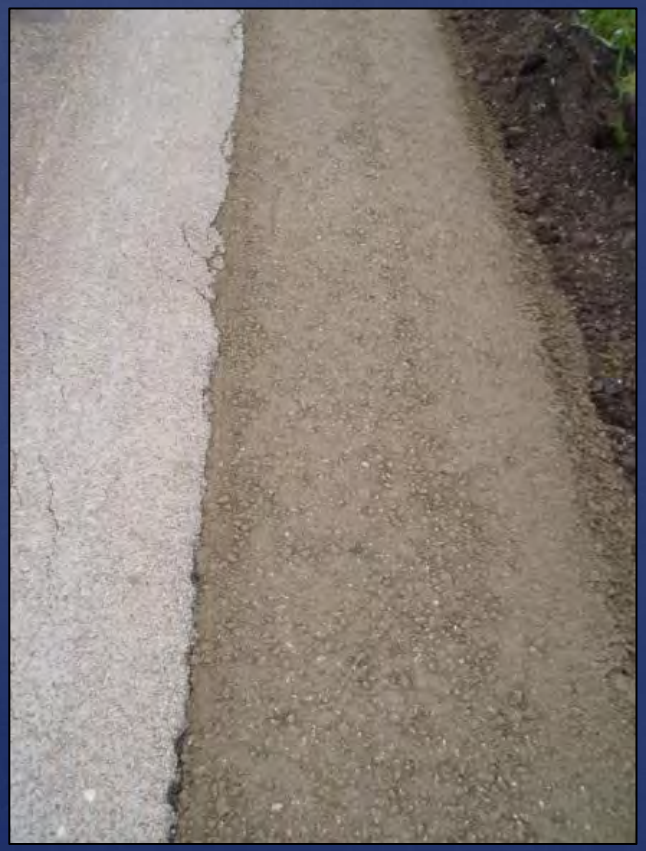
Compacting RCC

- Roller Weight – 12 tons each
  - First roller vibrator
  - Second roller Static



Compacted RCC

- Production rate ranged from 3 to 9 miles per day



Density Requirements

- MoDOT specifications require density no less than 95.0% of the maximum laboratory density
  - Performed 30 min. after roller completion
  - Use AASHTO T 310, direct transmission
  - Wet density
  - One QC test per 7,500 sq. yd.
  - One QA test per 30,000 sq. yd.
  - Random locations
- Contractor determine density using backscatter mode for process control

Density Testing

Density Results

- Average Density – 96.7%
- Minimum Density – 95.0%
- Maximum Density – 98.3%

- If density below 95.0%, a core is taken from the area. If compressive strength is over 3,500 psi @ 28 days, concrete is acceptable
  - Core taken within 7 days of density test

Curing RCC

Grade Slope

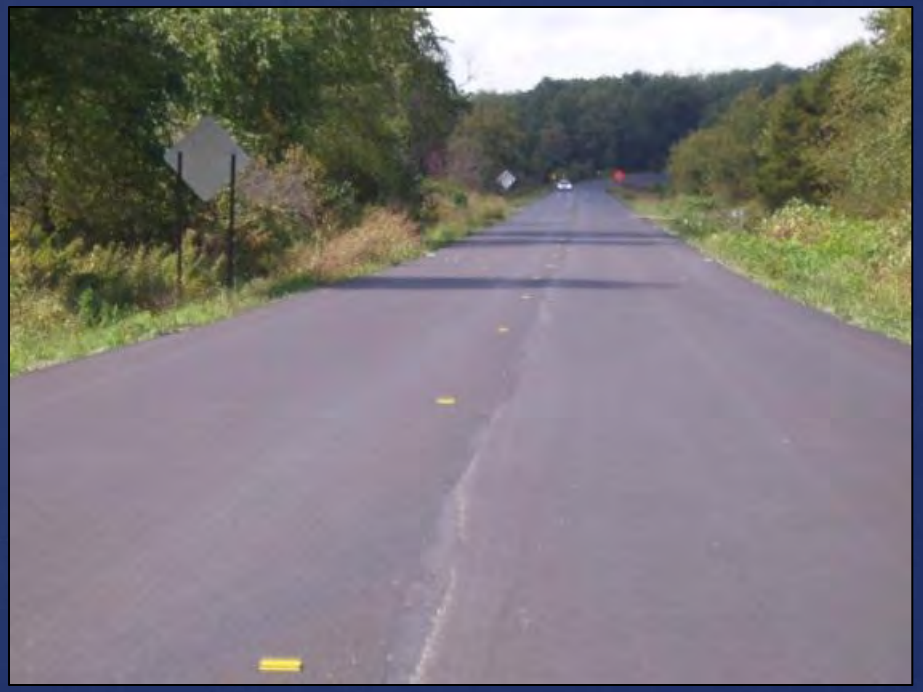
In-place RCC Shoulder

In-place RCC Shoulder

What About Asphalt

Placing Asphalt Mix

Placed Asphalt Mix



Bonding Surface Leveling to RCC

Experimental Features

1) Forming Safety Edge
2) Forming Transverse Joints

Safety Edge

Safety Edge

Transverse Joints

- Specifications require transverse joints every 15 ft.
- Contractor proposed 45 ft. transverse joint spacing
- Literature indicates transverse crack spacing between 30 ft. & 60 ft. for RCC
- MoDOT agreed to 30 ft. joint spacing
- Contractor proposed too try a transverse joint former

- Trial section placed at asphalt plant
- Looked promising & MoDOT approved use

Transverse Joint Former

Transverse Joint Former

Formed Transverse Joints

Formed Transverse Joints

Test Sections

- District constructed two test sections to evaluate different traverse joints:

1) Transverse joint saw cut every 30 ft.
2) No transverse joint installed; allowed to crack

- All of Rte 32 utilized transverse joint forming device
- Most of Rte 19 utilized transverse joint forming device except for:

- One mile section on south side of roadway, beginning 2 miles from Cherryville and going north used 30 ft. joint spacing
- One mile section on south side of roadway, beginning 1 miles from Cherryville and going north had no joints installed

Future

- Continue to use RCC for shoulders
- Limit the use of composite pavement
  - Concern with the long term bond between RCC and asphalt mix
- Allow a finer coarse aggregate fraction
  - ¾ inch max. top size; tighter surface
- Increase density from 95.0% to 98%
- Increase cement from 400 lbs. to 450 lbs.
- Evaluate long term performance of formed transverse joints
- Evaluate long term performance of the safety edge

Questions

brett.trautman@modot.mo.gov

(573) 751-1036