Roller-Compacted Concrete Pavement

Transportation Research Board Webinar

2:00 PM – 3:30 PM

Monday, January 23, 2017

Sam Tyson, P.E.

Concrete Pavement Engineer

FHWA Office of Asset Management, Pavements, and Construction

Roller-Compacted Concrete Pavement

TRB Committee/Webinar Sponsors –

- AFD50 – Design and Rehabilitation of Concrete Pavements
- AFH50 – Concrete Pavement Construction and Rehabilitation

Roller-Compacted Concrete Pavement

Background: FHWA Publication –

Roller-Compacted Concrete Pavement

FHWA-HIF-16-003, June 2016

http://www.fhwa.dot.gov/pavement/concrete/pubs/hif16003.pdf

and numerous references cited in that document.

Roller-Compacted Concrete Pavement

Dan Zollinger, Texas A&M

- Materials and Mixtures
- Design Approaches
- Construction Considerations

Shabbir Hossain, Virginia DOT

- VDOT Experience
- Lessons Learned

Webinar Organization

Presentations – 60 minutes

Question & Answer Period – 30 minutes

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Webinar

Roller Compacted Concrete (RCC) Pavements

Dan G. Zollinger, Ph.D., P.E.

Texas A&M University, College Station, TX, USA

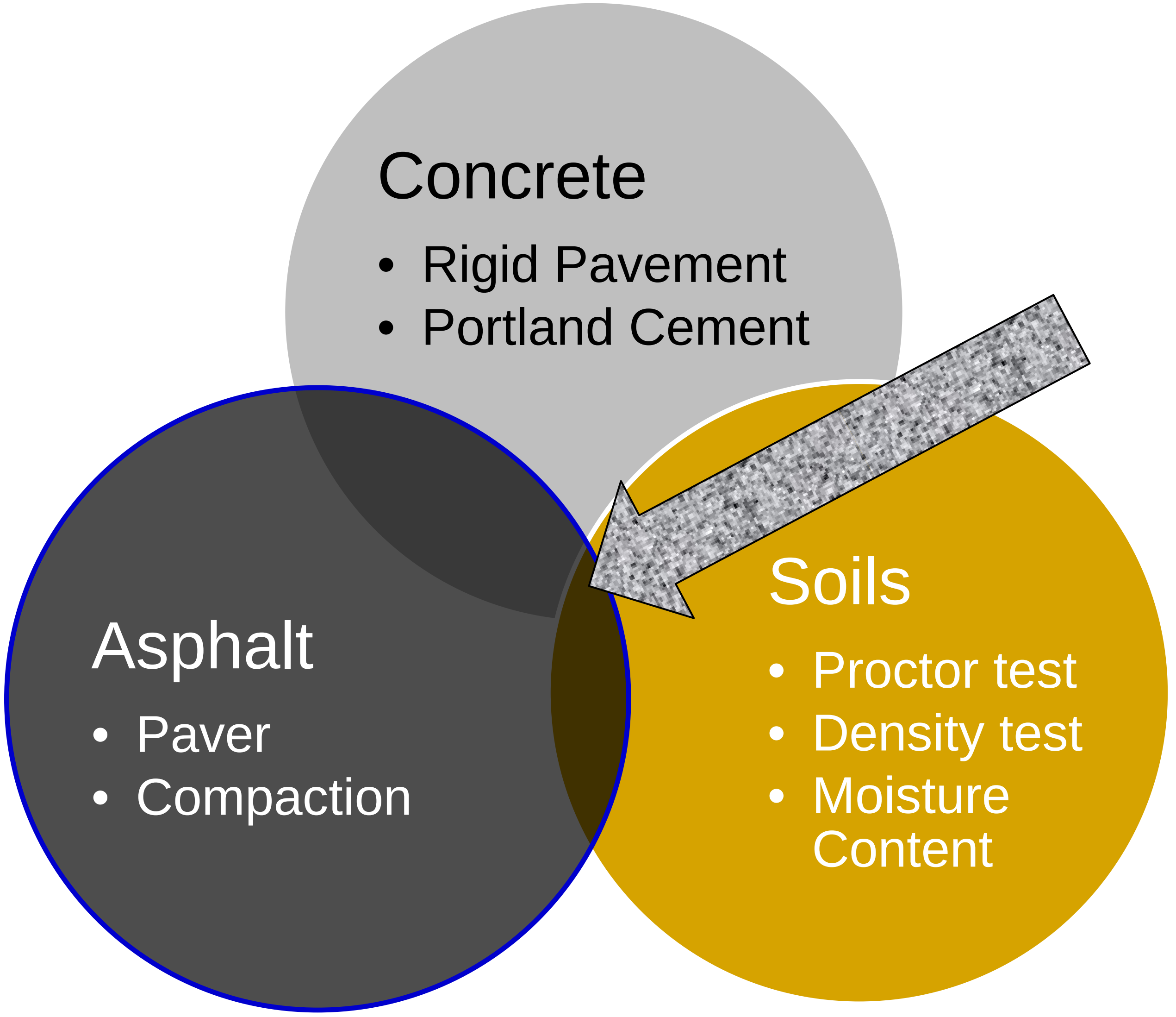
AGENDA

RCC Materials and Mixtures

Design Approaches/Features

Construction

Roller-Compacted Concrete



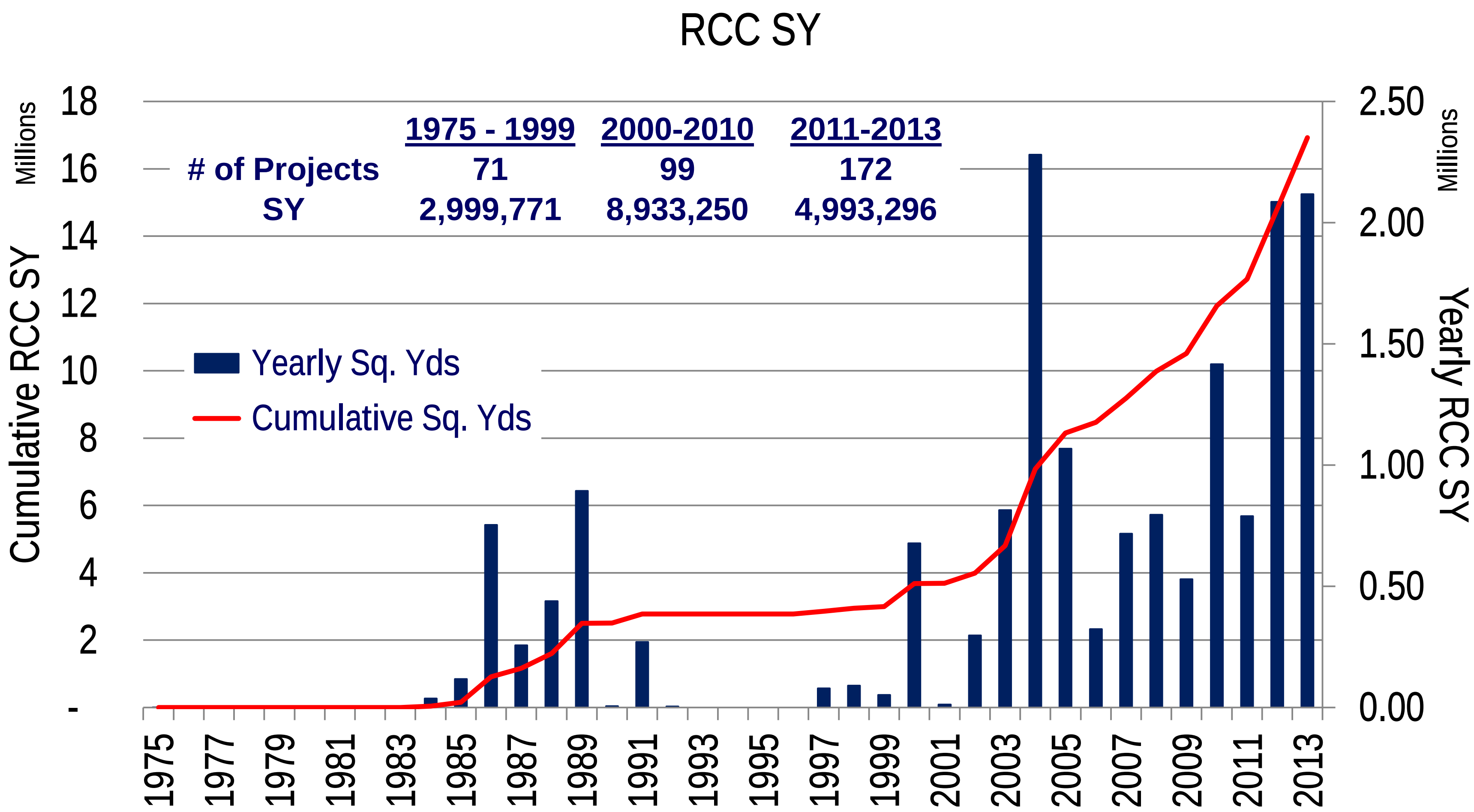
ROLLER COMPACTED CONCRETE (RCC)

A no-slump concrete that is compacted not consolidated (Rolling).

- No internal vibration. (consistency of damp gravel).
- No forms.
- No reinforcing steel or dowels.
- Compacted w/ high-density pavers
- Finishing
- Less shrinkage; tight cracks

RCC is a concrete pavement is placed differently from but has other similarities to conventional PCC!

RCC PAVEMENT USAGE



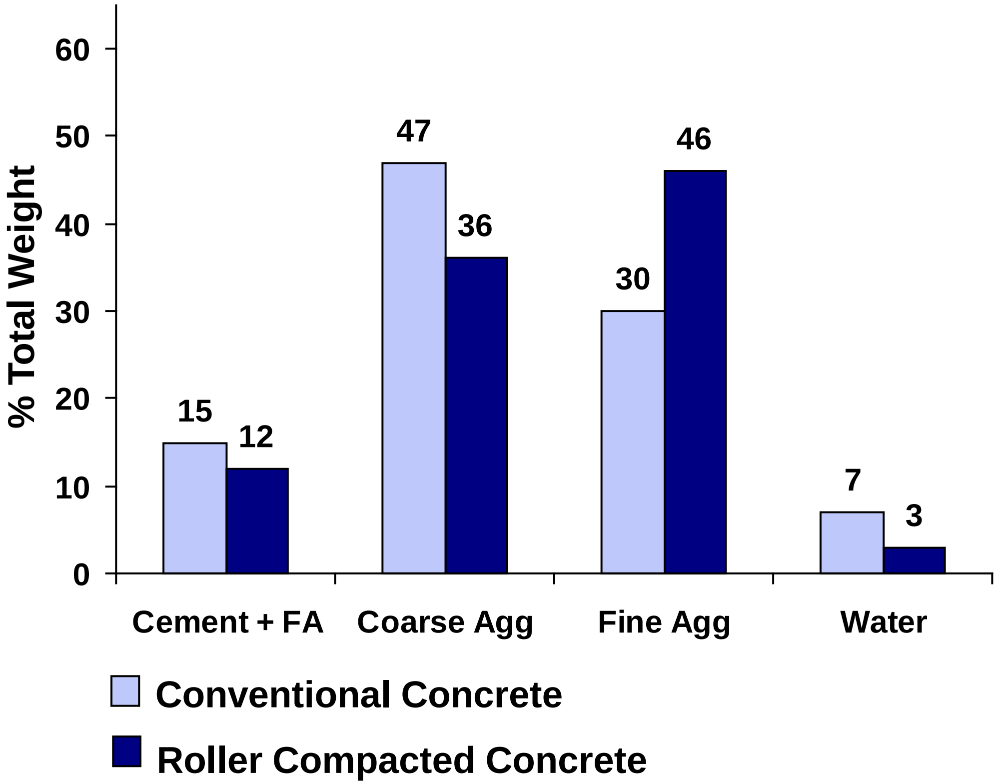
AGENDA

RCC Materials and Mixtures

Design Approaches/Features

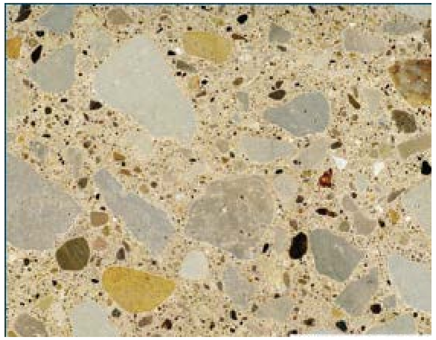
Construction

RCC MIX DESIGN USES



Typical Engineering Properties	Conventional (psi)	RCC (psi)
Compressive Strength	3,000 - 5,000	4,000 - 7,000
Flexural Strength (MOR)	500 – 700	500 - 1,000
Elastic Modulus	3.0 – 5.0 million	3.0 – 5.5 million

Conventional Concrete



RCC

MIXTURE DESIGN PROCEDURE

Step 1: Aggregate Selection

- 85% of mixture; focus on combined aggregate gradation
- Top size is ¾”
- Impacts stability, workability, compatibility, segregation potential, and strength

MIXTURE DESIGN PROCEDURE

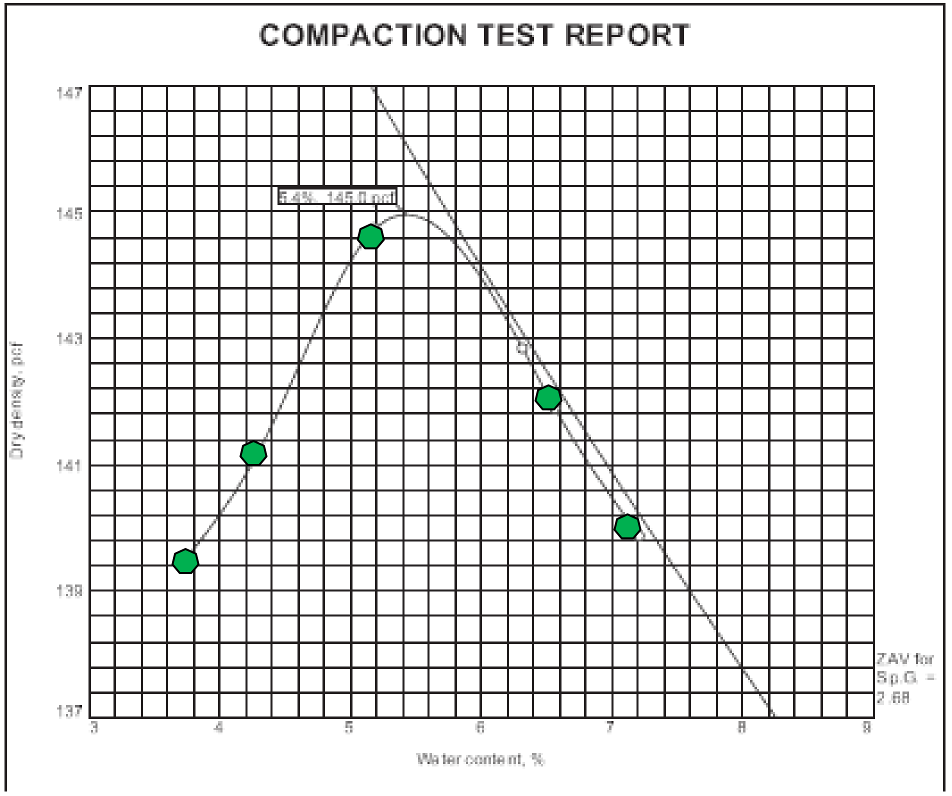
Step 2: Select cement content

- Min 450 lbs.
- 12% by wt. type I portland cement
- Mix the cement dry

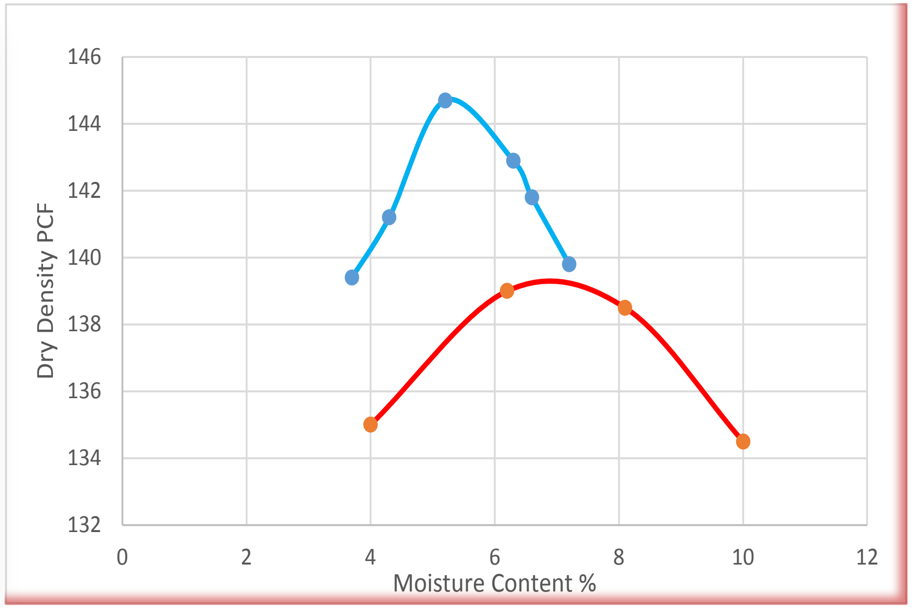
(ASTM D1557)

Step 3: Develop moisture – density relationship

- Modified proctor test
- Plot moisture-density curve
- Determine max dry density (MDD)
- Optimum moisture content (OMC)



Mixture Design Factors



- Aggregate size and gradation
- Minus 200 aggregate content
- Shape and Angularity
- Water and sand content to achieve the needed consistency
- Cement and fly ash content (minimum of 450 lb/cy)

Reference Wet Density

Reference wet density (RWD):

RWD = (MDD) x (1+ OMC)

Where

- MDD = Maximum Dry Density
- OMC = Optimum Moisture Content
- Determined in the lab in accordance with ASTM D1557

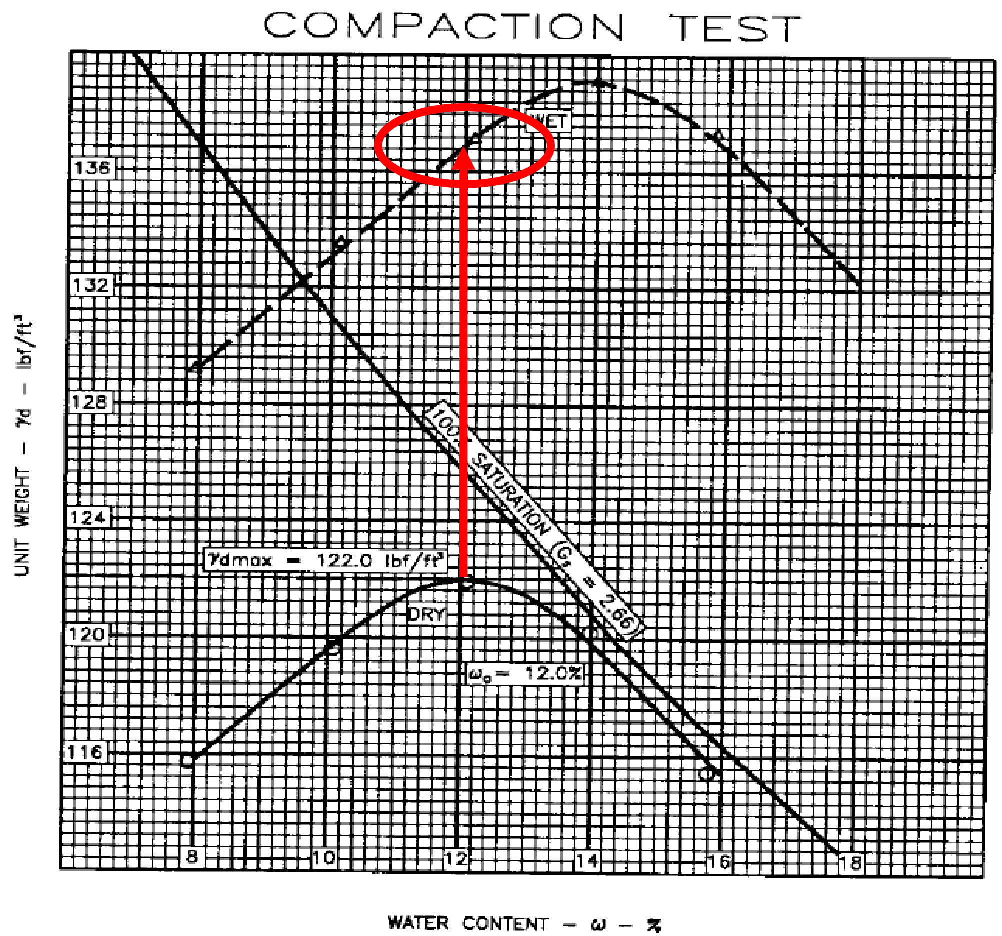


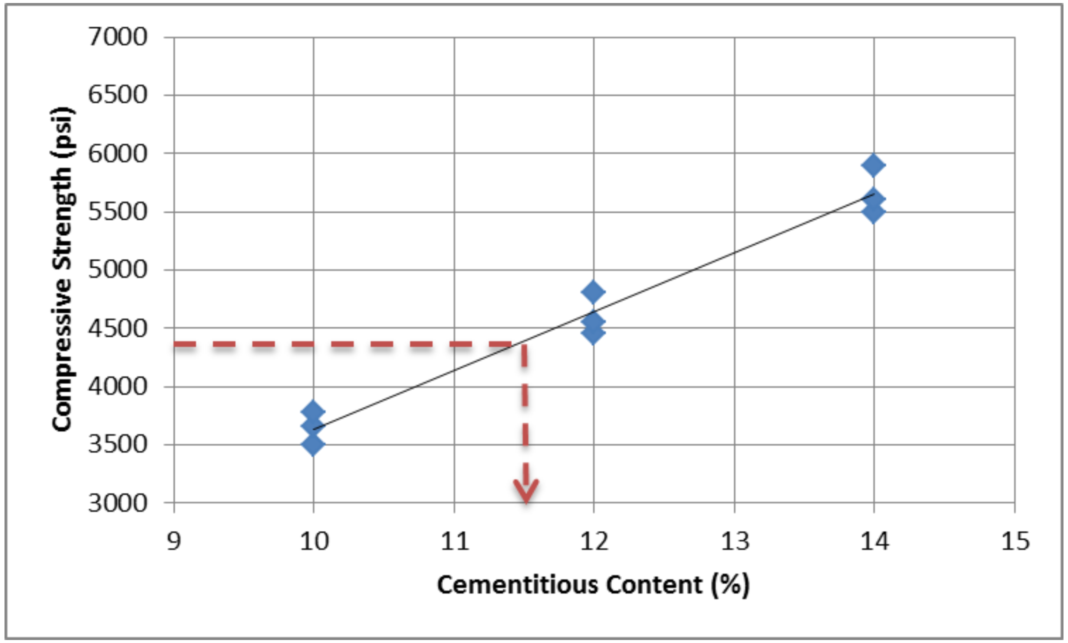
FIG. 3 Example Compaction Curve Plotting

Source:
ASTM D1557: Standard Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort

MIXTURE DESIGN PROCEDURE

Step 4: Cast & test compressive strength samples

- Calculate & Batch trial mix proportions
  - Maintain % OMC
  - Use 10, 12 & 14 %pc
- Plot results; pick %pc



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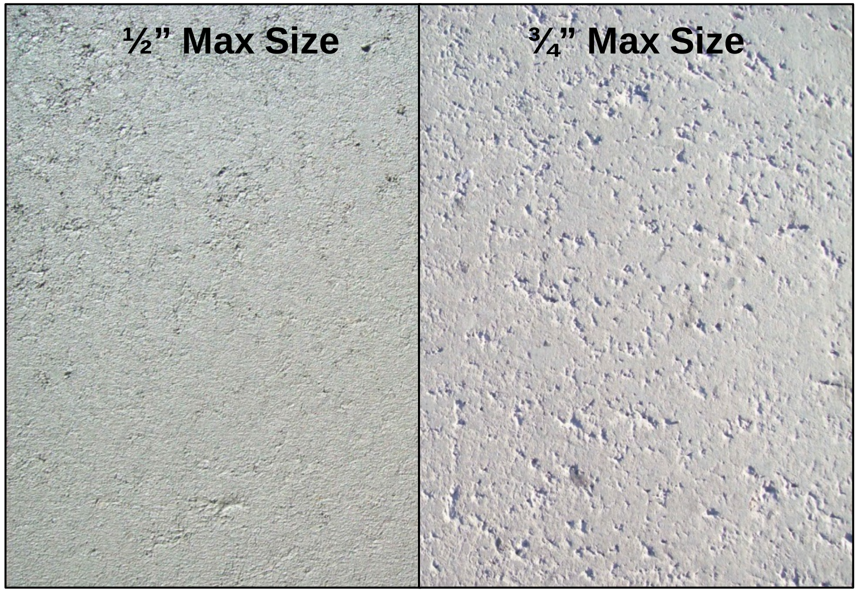
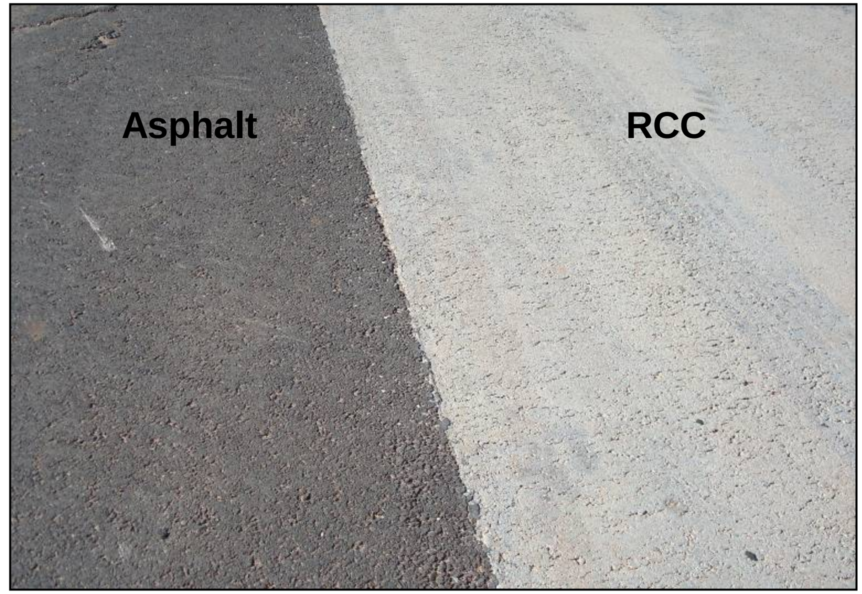
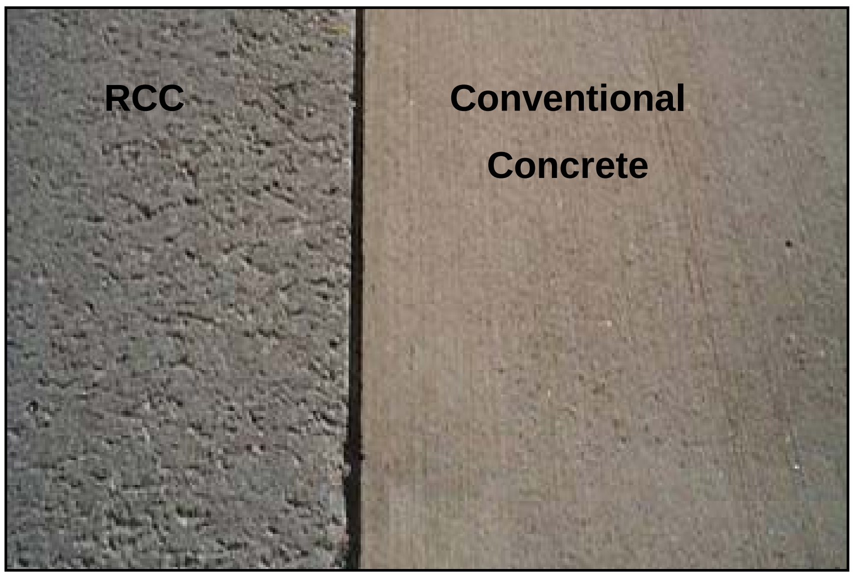
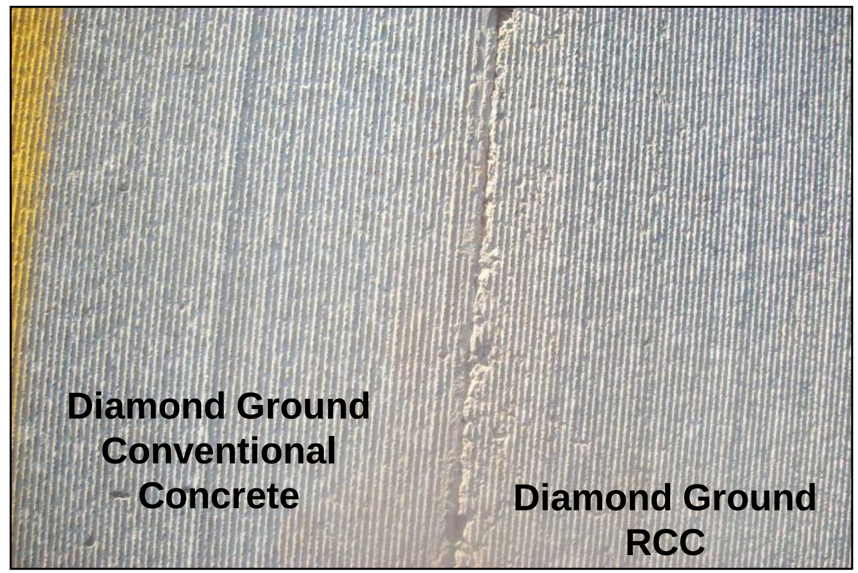
RCC Surface Texture & Color









AGENDA

RCC Materials and Mixtures

Design Approaches/Features

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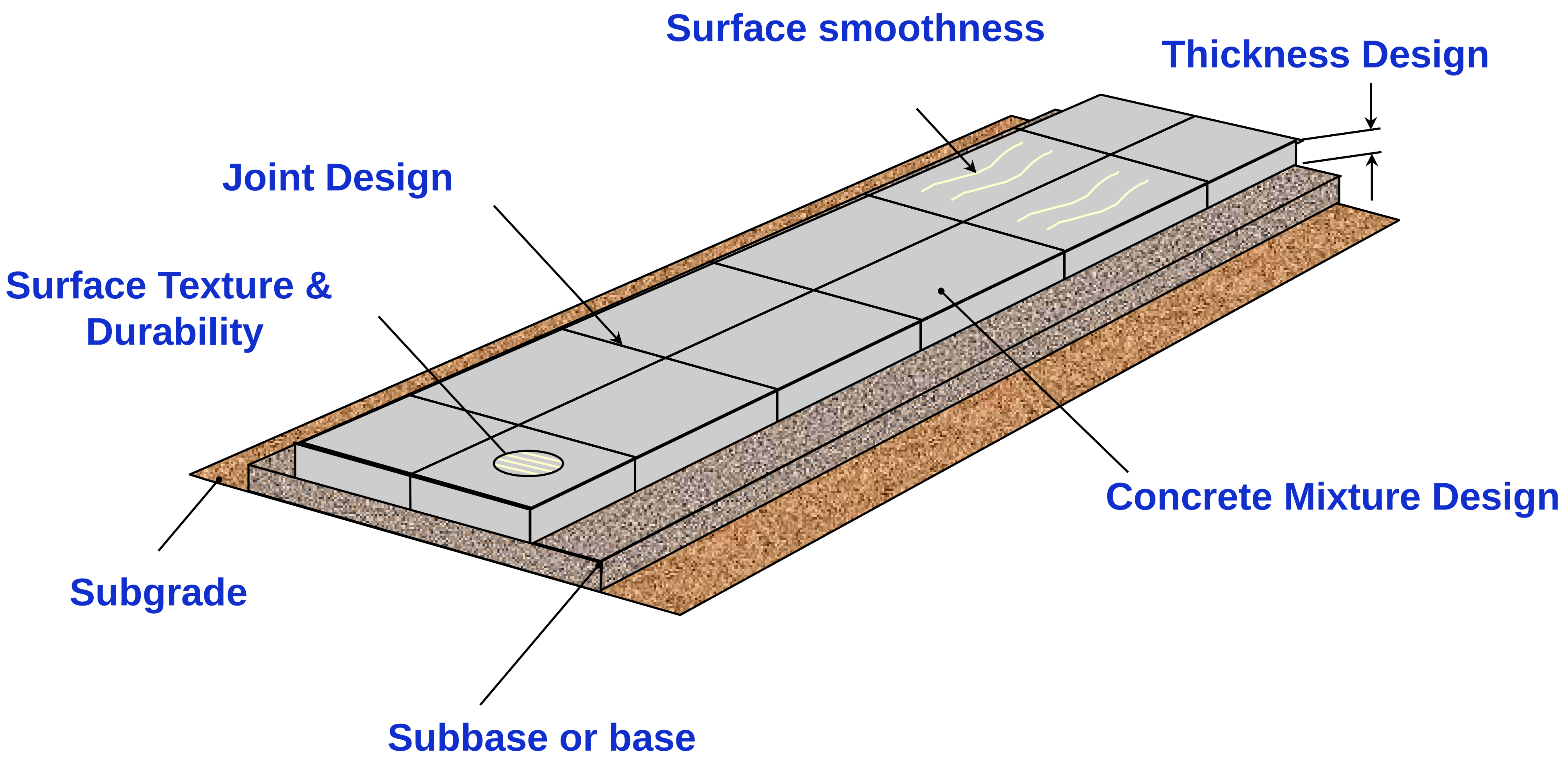
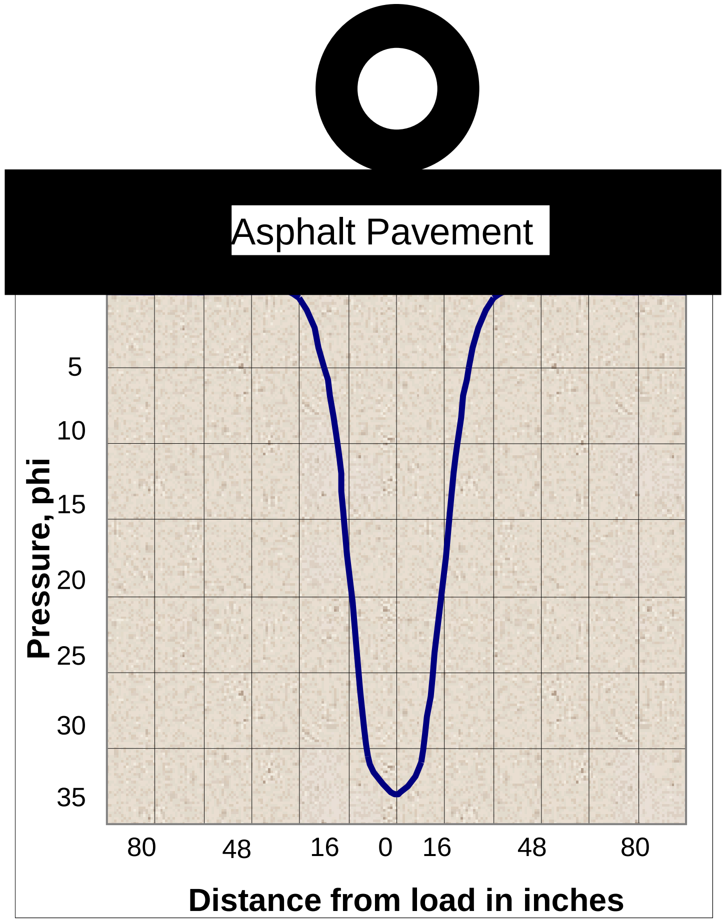
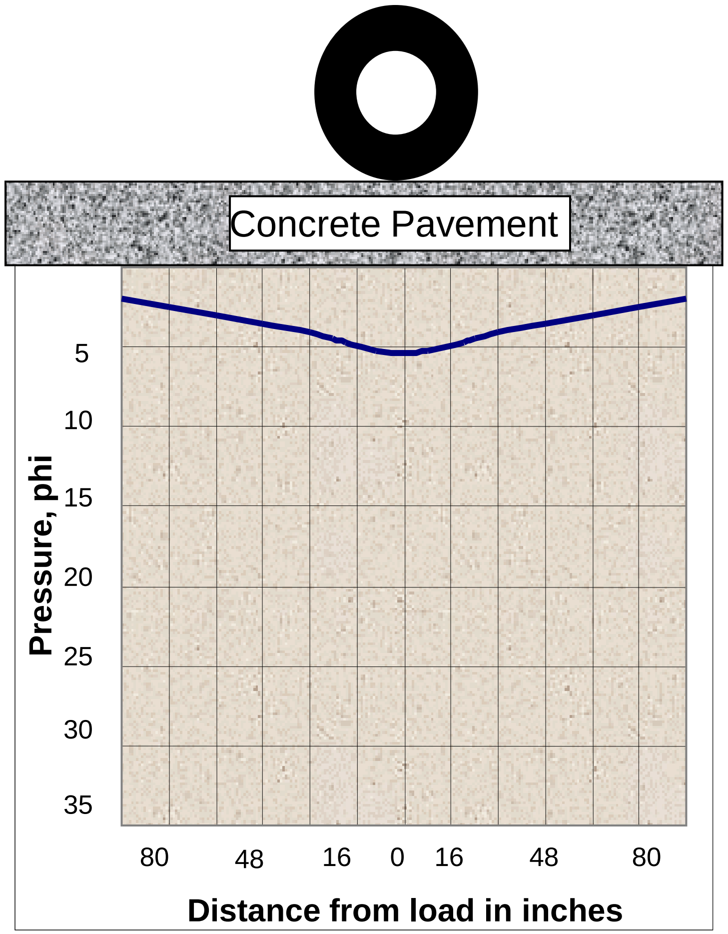
DESIGN COMPONENTS OF RCC PAVEMENT



RCC vs ASPHALT SURFACE LAYERS

- Load concentration
- Deflections
- Base layer strength





- Subgrade uniformity
- Subgrade erodibility

NEED/USE OF A SUBBASE

Subbase (Granular/stabilized)**:**

- Provide construction platform
- To minimize or eliminate the potential for erosion
- At transitions

Factors:

- If joints/cracks are partially sealed
- Water
- Expansive clay soils
- Erodible base materials
- Traffic and load level

Conditions for Pumping

1. Lower/non drainable shear strength materials
2. Partially or no sealed joints - water penetration
3. Slab lift off – corners and edges
4. Truck traffic

SOIL STABILIZATION

1. What is it?

Mixing calcium based additives into the soil

- PI ranges from mid to high: Cement, fly ash, asphalt
- Materials: Cement fly ash, lime, and foamed asphalt

2. What does it do?

- **Increases workability and strength**
- **Reduces moisture susceptibility**
- **Provide construction platform**
- **Provide uniform, stable support**
- **Reduces erodibility**

3. Cost Comparison

- **4” Gran. Base: $2.80 - $4.20/SY**
- **6” Soil stabilization**
  - **Working platform: $1.90 - $2.50/SY**
  - **Expansive soil mitigation: $2.50 - $3.30/SY**

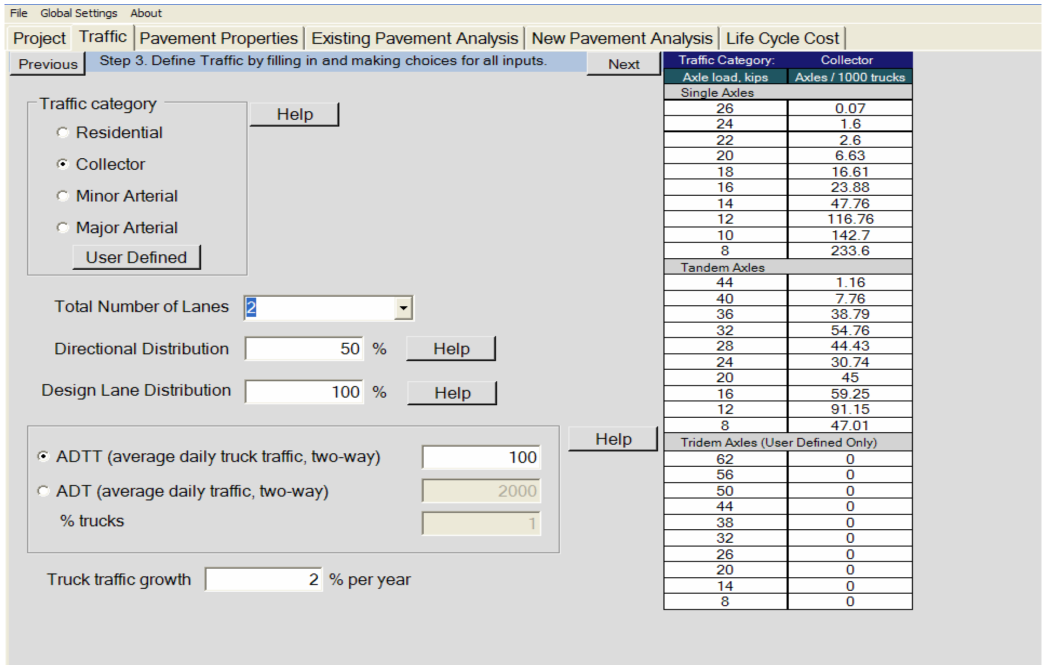
RCC THICKNESS DESIGN

- **Updated mechanistic design method for concrete pavement**
  - Fatigue & erosion analysis
  - Jointing spacing & load transfer recommendations
  - Thickness rounding & reliability considerations
  - Analysis of existing concrete pavements
- **Life cycle cost analysis module**

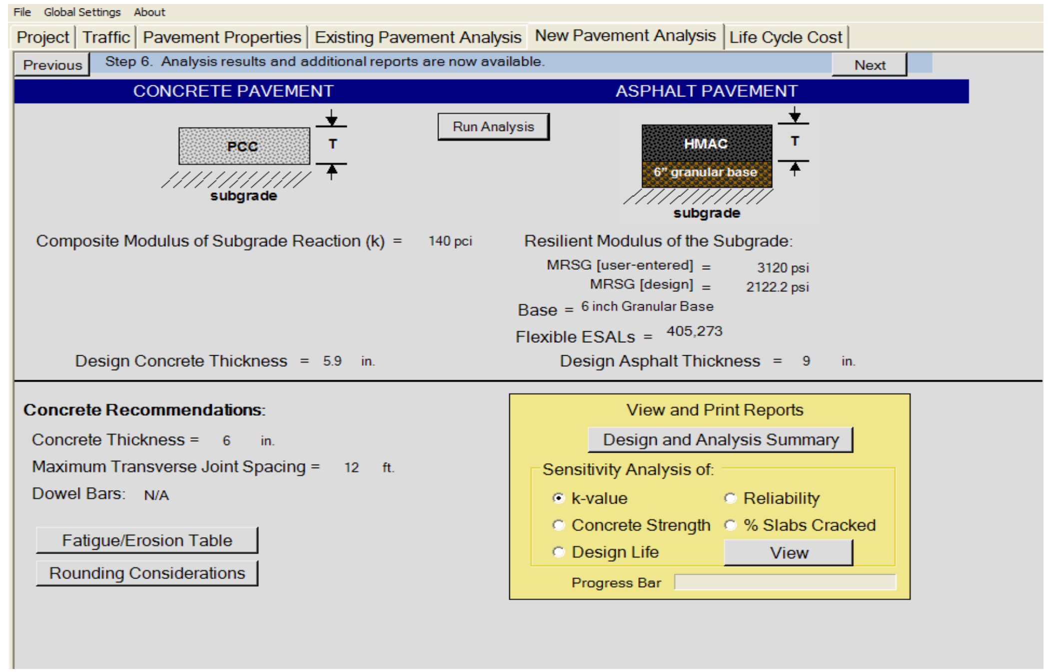
- Applicable design procedures for RCC pavement include:
- American Association of State Highway and Transportation Officials (AASHTO) Pavement ME and 1998 Design
- American Concrete Institute (ACI) 330 [6] and 325
- RCC-Pave
- American Concrete Pavement Association (ACPA) StreetPave™,
- U.S. Army Corps of Engineers thickness design procedure

FOR MOST APPLICATIONS STREETPAVE IS A GOOD DESIGN PROCEDURE

Traffic Input



Output



- **Numbers & weights of heavy axle loads expected during the design life**
- **ADT (average daily traffic in both directions)**
- **ADTT (average daily truck traffic in both directions)**
  - **Allows for multiple truck types**

- **Thickness requirements for both asphalt & concrete**
- **Joint Spacing Recommendations**
- **Allows for Design for sub-base layers**
- **Design for fatigue damage in bound layers, rutting in unbound layers**
- **Mechanistic Empirical – layered elastic model**

THERE ARE ALSO SIMPLIFIED PROCEDURES THAT USE DESIGN TABLES

A manual alternative:

Two Sets of Tables

- **30-year design with concrete curb & gutter or concrete shoulder**
  - **May use supported edge condition when RCC when fresh joint is used between the lane and shoulder**
- **30-year design without concrete curb & gutter or concrete shoulder**
  - **3 concrete flexural strengths**
  - **4 subgrade k-values**
  - **Several traffic classifications**

Given subgrade k value, RCC MOR, traffic classification, and ADTT, thickness is read directly from tables

CONCRETE Information

ACPA

AMERICAN CONCRETE PAVEMENT ASSOCIATION

Design of Concrete Pavement for Streets and Roads

Design and construction standards for streets and roadways should provide for pavements with both long service life and low maintenance. As a guide in achieving this goal, this publication provides designs that meet traffic requirements and will result in the lowest annual cost when considering both initial construction cost and pavement maintenance.

Following are the factors involved in the design process for concrete streets and roads:

1. Street classification and traffic
2. Geometric design
3. Subgrades and subbases
4. Concrete quality
5. Thickness design
6. Jointing
7. Construction specifications

Several other ACPA publications, *Subgrades and Subbases for Concrete Pavements*[1], *Design and Construction of Joints for Concrete Streets*[2], and *Construction Specification Guideline for Concrete Streets and Local Roads*[3], discuss the details of subgrades and subbases, jointing practices, and specifications in much greater detail.

Street Classification and Traffic

Comprehensive traffic studies have shown that streets of similar character have essentially the same traffic densities and axle load intensities. A practical approach to thickness design is to establish a street classification system that provides an axle load distribution for the various categories of streets. This information sheet has divided street pavements into six different classifications. Descriptions for each classification include traffic volumes, types of vehicles, and maximum axle loadings. These classifications are listed in the Thickness Design section of this document.

Geometric Design

Utilities

During the construction of new subdivisions and commercial developments, utilities are commonly placed in the right-of-way outside the pavement area to facilitate maintenance, possible additions, and upgrades to utility systems. Present and future needs must be evaluated and provisions made for utilities. Forethought can eliminate the tearing up of existing pavements for work on utilities. In some instances, particularly for older infrastructure, underground utilities must be located within the paved area. In these cases, it is usually recommended to incorporate the pavement construction project with utility replacement, such as sewers, water mains, gas lines, and electrical and communications conduits.

Integral Curbs

A practical and economical way to build concrete pavements for streets is with an integral curb section. An integral curb is constructed with the pavement in a single operation — all concrete work being done simultaneously. When using forms, the curb is easily shaped with a template and straightedge as the pavement is placed. Integral curbs can also be constructed to almost any desired cross section using a slipform paver.

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Simplified Design Tables

Table 13(a). Concrete Thickness (inches), 30-Year Design WITH Concrete Curb and Gutter or Concrete Shoulders

Traffic classification		k = 100 pci			k = 150 pci			k = 200 pci			k = 300 pci		
		Modulus of rupture (psi)			Modulus of rupture (psi)			Modulus of rupture (psi)			Modulus of rupture (psi)		
		550	600	650	550	600	650	550	600	650	550	600	650
Light residential 2-lane	ADTT = 3	5.0	5.0	4.5	5.0	4.5	4.5	4.5	4.5	4.0	4.5	4.0	4.0
Residential 2-lane	ADTT = 10	5.5	5.5	5.0	5.5	5.0	5.0	5.0	5.0	4.5	5.0	4.5	4.5
	ADTT = 20	6.0	5.5	5.5	5.5	5.5	5.0	5.5	5.0	5.0	5.0	5.0	4.5
	ADTT = 50	6.0	6.0	5.5	5.5	5.5	5.0	5.5	5.0	5.0	5.0	5.0	4.5
Collector 2-lane	ADTT = 50	6.5	6.0	6.0	6.0	6.0	5.5	6.0	5.5	5.5	5.5	5.5	5.0
	ADTT = 100*	6.5	6.5	6.0	6.5	6.0	6.0	6.0	6.0	(5.5)	6.0	(5.5)	(5.5)
	ADTT = 500*	7.0	6.5	6.5	6.5	6.5	6.0	6.5	6.0	6.0	6.0	6.0	(5.5)
Business 2- or 4-lane	ADTT = 400*	7.0	6.5	6.5	6.5	6.5	6.0	6.5	6.0	6.0	6.0	6.0	(5.5)
	ADTT = 700*	7.0	7.0	6.5	7.0	6.5	6.0	6.5	6.0	6.0	6.0	6.0	(5.5)
Minor arterial 4-lane	ADTT = 300*	7.5	7.5	7.0	7.5	7.0	6.5	7.0	6.5	6.5	6.5	6.5	6.0
	ADTT = 600*	8.0	7.5	7.0	7.5	7.0	7.0	7.5	7.0	6.5	7.0	6.5	6.5
Industrial 4-lane	ADTT = 300*	8.0	8.0	7.5	8.0	7.5	7.0	7.5	7.0	7.0	7.0	7.0	6.5
	ADTT = 800*	8.5	8.0	8.0	8.0	7.5	7.5	8.0	7.5	7.0	7.5	7.0	7.0
Major arterial 4-lane	ADTT = 700*	8.5	8.0	7.5	8.0	7.5	7.5	8.0	7.5	7.0	7.5	7.0	6.5
	ADTT = 1100*	8.5	8.0	8.0	8.0	8.0	7.5	8.0	7.5	7.0	7.5	7.0	7.0
	ADTT = 1500*	8.5	8.5	8.0	8.5	8.0	7.5	8.0	7.5	7.5	7.5	7.5	7.0

* Dowels recommended when ADTT is greater than or equal to 80:

1. If pavement thickness is 6" or less dowels not recommended
2. If pavement thickness is 6.5" to 7.5" use 1" dowels
3. If pavement thickness is 8" or greater use 1¼" dowels

Use No Dowel Option

CONVERSIONS
1 in. = 25.4 mm
100 psi = 0.689 MPa
100 pci = 27.15 MPa/m

Simplified Design Tables

Table 13(b). Concrete Thickness (inches), 30-Year Design WITHOUT Concrete Curb and Gutter or Concrete Shoulders

Traffic classification	k = 100 pci			k = 150 pci			k = 200 pci			k = 300 pci		
	Modulus of rupture (psi)			Modulus of rupture (psi)			Modulus of rupture (psi)			Modulus of rupture (psi)		
	550	600	650	550	600	650	550	600	650	550	600	650
Light Residential ADTT = 3	6.0	5.5	5.5	5.5	5.5	5.0	5.5	5.0	5.0	5.0	5.0	4.5
Residential 2-lane ADTT = 10	6.5	6.5	6.0	6.5	6.0	6.0	6.0	6.0	5.5	6.0	5.5	5.5
ADTT = 20	7.0	6.5	6.0	6.5	6.0	6.0	6.5	6.0	5.5	6.0	5.5	5.5
ADTT = 50	7.0	7.0	6.5	7.0	6.5	6.0	6.5	6.0	6.0	6.0	6.0	5.5
Collector 2-lane ADTT = 50	7.5	7.0	7.0	7.0	7.0	6.5	7.0	6.5	6.5	6.5	6.5	6.0
ADTT = 100*	8.0	7.5	7.0	7.5	7.0	6.5	7.0	7.0	6.5	7.0	6.5	6.0
ADTT = 500*	8.0	8.0	7.5	8.0	7.5	7.0	7.5	7.0	7.0	7.0	7.0	6.5
Business 2- or 4-lane ADTT = 400*	8.0	8.0	7.5	7.5	7.5	7.0	7.5	7.0	7.0	7.0	7.0	6.5
ADTT = 700*	8.5	8.0	7.5	8.0	7.5	7.0	7.5	7.5	7.0	7.5	7.0	6.5
Minor Arterial 4-lane ADTT = 300*	9.0	8.5	8.0	8.5	8.0	7.5	8.0	8.0	7.5	8.0	7.5	7.0
ADTT = 800*	9.5	9.0	8.5	9.0	8.5	8.0	8.5	8.0	7.5	8.0	7.5	7.5
Industrial 4-lane ADTT = 300*	9.5	9.0	8.5	9.0	8.5	8.0	8.5	8.5	8.0	8.5	8.0	7.5
ADTT = 800*	10.0	9.5	9.0	9.5	9.0	8.5	9.0	9.0	8.0	8.5	8.0	8.0
Major Arterial 4-lane ADTT = 700*	10.0	9.5	9.0	9.5	9.0	8.5	9.0	8.5	8.0	8.5	8.0	8.0
ADTT = 1100*	10.0	9.5	9.0	9.5	9.0	8.5	9.0	8.5	8.5	8.5	8.5	8.0
ADTT = 1500*	10.0	9.5	9.0	9.5	9.0	8.5	9.0	9.0	8.5	9.0	8.5	8.0

* Dowels recommended when ADTT is greater than or equal to 80:

1. If pavement thickness is 6" or less dowels not recommended
2. If pavement thickness is 6.5" to 7.5" use 1" dowels
3. If pavement thickness is 8" or greater use 1¼" dowels

Use No Dowel Option

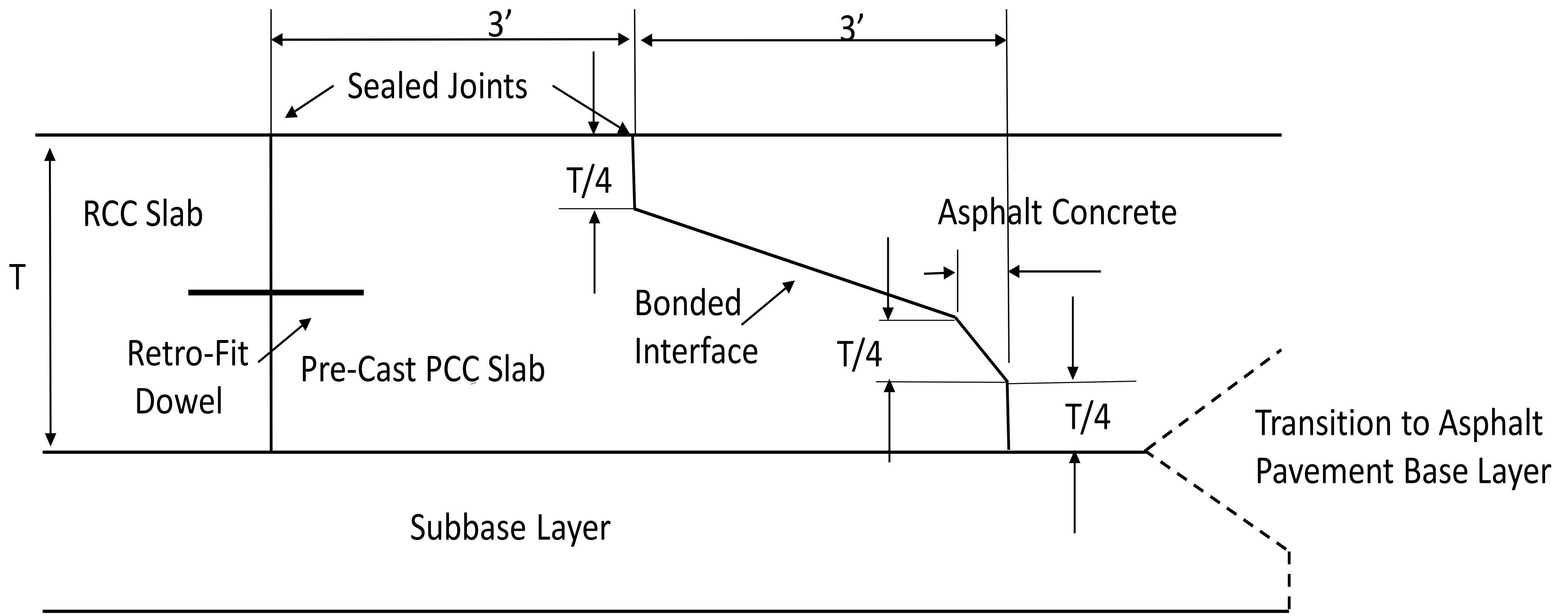
CONVERSIONS
1 in. = 25.4 mm
100 pci = 0.689 MPa
100 pci = 27.15 MPa/m

ACI DESIGN TABLE FOR PARKING LOTS

Table 5-5. Design of concrete parking lots (ACI 330R-08)

Twenty-year design thickness recommendations, in. (no dowels)		k = 500 psi/in. (CBR = 50; R = 86)				k = 400 psi/in. (CBR = 38; R = 80)				k = 300 psi/in. (CBR =26; R = 67)			
	MOR, psi:	650	600	550	500	650	600	550	500	650	600	550	500
Traffic category*	A (ADTT =1)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.5
	A (ADTT = 10)	4.0	4.0	4.0	4.5	4.0	4.0	4.5	4.5	4.0	4.5	4.5	4.5
	B (ADTT = 25)	4.0	4.5	4.5	5.0	4.5	4.5	5.0	5.5	4.5	4.5	5.0	5.5
	B (ADTT = 300)	5.0	5.0	5.5	5.5	5.0	5.0	5.5	5.5	5.0	5.5	5.5	6.0
	C (ADTT = 100)	5.0	5.0	5.5	5.5	5.0	5.5	5.5	6.0	5.5	5.5	6.0	6.0
	C (ADTT = 300)	5.0	5.5	5.5	6.0	5.5	5.5	6.0	6.0	5.5	6.0	6.0	6.5
	C (ADTT = 700)	5.5	5.5	6.0	6.0	5.5	5.5	6.0	6.5	5.5	6.0	6.5	6.5
	D (ADTT = 700)†	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5
		k = 200 psi/in. (CBR = 10; R = 48)				k = 100 psi/in. (CBR = 3; R = 18)				k = 50 psi/in. (CBR = 2; R = 5)			
	MOR, psi:	650	600	550	500	650	600	550	500	650	600	550	500
Traffic category*	A (ADTT =1)	4.0	4.0	4.0	4.5	4.0	4.5	4.5	5.0	4.5	5.0	5.0	5.5
	A (ADTT = 10)	4.5	4.5	5.0	5.0	4.5	5.0	5.0	5.5	5.0	5.5	5.5	6.0
	B (ADTT = 25)	5.0	5.0	5.5	6.0	5.5	5.5	6.0	6.0	6.0	6.0	6.5	7.0
	B (ADTT = 300)	5.5	5.5	6.0	6.5	6.0	6.0	6.5	7.0	6.5	7.0	7.0	7.5
	C (ADTT = 100)	5.5	6.0	6.0	6.5	6.0	6.5	6.5	7.0	6.5	7.0	7.5	7.5
	C (ADTT = 300)	6.0	6.0	6.5	6.5	6.5	6.5	7.0	7.5	7.0	7.5	7.5	8.0
	C (ADTT = 700)	6.0	6.5	6.5	7.0	6.5	7.0	7.0	7.5	7.0	7.5	8.0	8.5
	D (ADTT = 700)†	7.0	7.0	7.0	7.0	8.0	8.0	8.0	8.0	9.0	9.0	9.0	9.0

RCC/AC Pavement Transition



AGENDA

RCC Materials and Mixtures

Design Approaches/Features

Construction

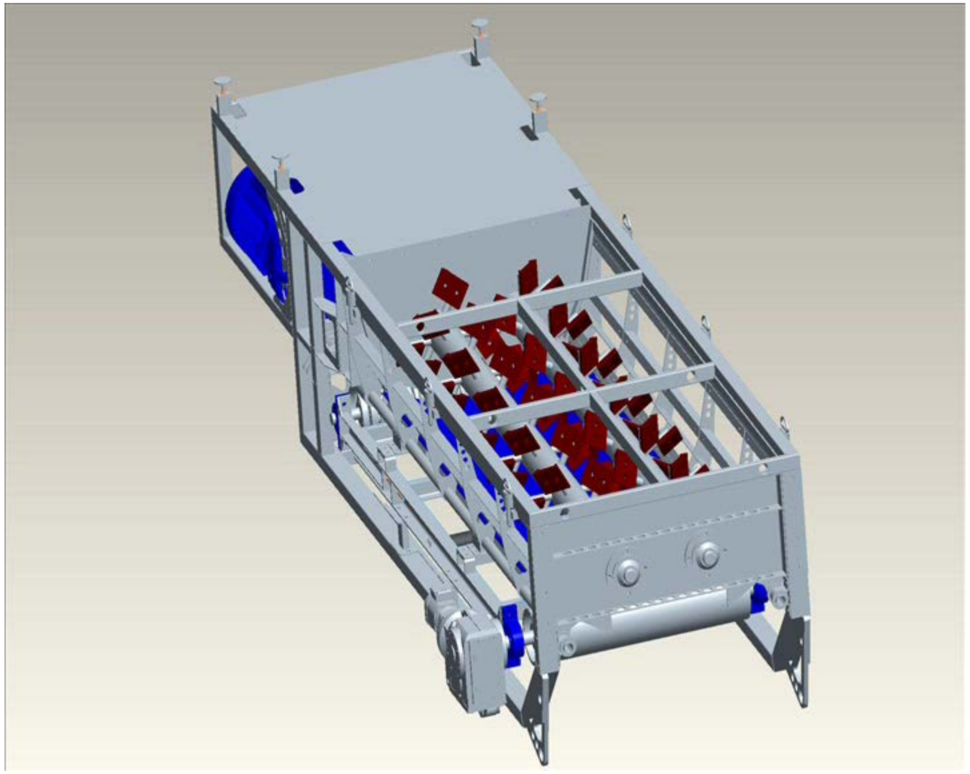
CHOICE OF MIXER

Mixer Type	Photo	Factors to Consider
Pugmill – Continuous Twin Shaft		• Product rates: 50 to 300+CY/hr • Good efficiency and consistency • Easy adjustment • Mobile – 1 load, 1 day set up and & calibration • Self contained – Gen set, batch house • 2 to 3 man operation • # of Aggregates depends on Feeder system • Permit required
Twin Shaft – Horizontal Mixer - Batch Type		• Production rates: 50 to 220 CY/hr • Good efficiency • Mobile – 1 or 2 loads, easily set up in 1 day • Batch operations may induce load to load moisture variability • No permitting required • Easy to incorporate admixtures, fibers, etc

TRADITIONAL MIXING

Mixer Type	Photo	Factors to Consider
Central Mix		• Better for smaller applications: 30 to 90 CY/hr – reduced batch size, increased mixing time • Fixed location • Average mixing consistency • Batch to batch moisture fluctuations • Easy to incorporate admixtures, fibers, etc
Dry Batch		• Readily available • Slow production – and poor consistency • Material must be transferred • Moisture control is inconsistent • Test to ensure mix can be discharged • NOT Recommended

RECOMMEND USING A PUGMILL MIXER DUE TO HIGH PRODUCTION RATES & EFFICIENT MIXING PROCESS

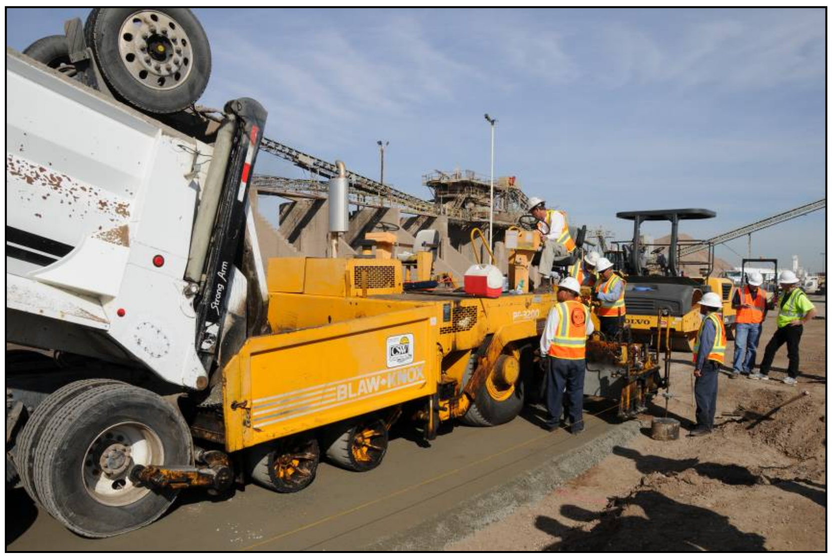


PUGMILL MIXING

RCC PLACED USING ASPHALT PAVERS

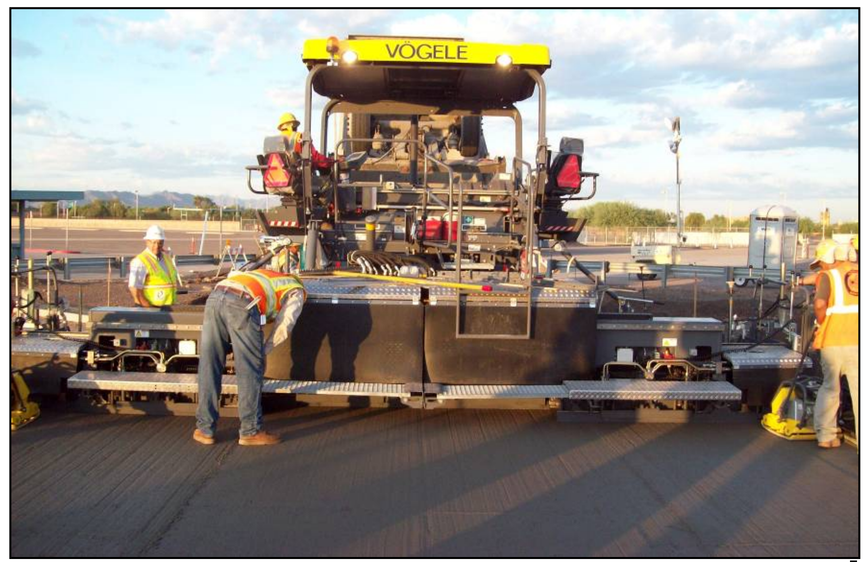
Standard Paver

- 80% to 85% initial density)
- Availability is good
- Paves 6 to 8 ft/min
- Lift thick range: 4” to 6”
- Impossible to pave adjacent lanes
- Increased compaction needed
- Easier to fix segregated areas



High Density Paver

- High initial density (> 90%)
- Availability still limited
- Paves (6 to 8 ft/min)
- Smoother surface and less compaction
- Lift thick range: 4” to 9”
- Adjacent lanes easily paved
- Strongly RECOMMENDED

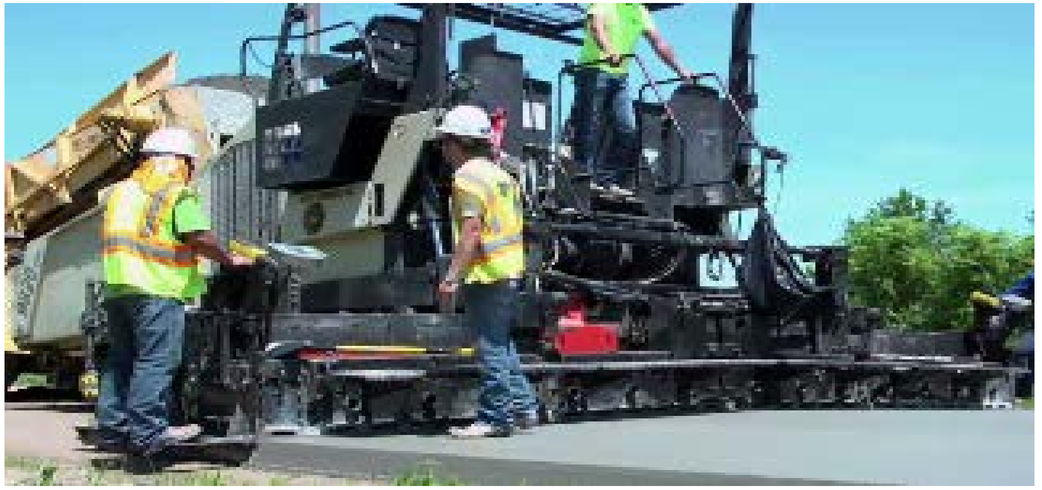


RCC PLACED USING ASPHALT PAVERS

RCC PLACED USING ASPHALT PAVERS

High Density Paver

- High density screed (Vogele or ABG Titan)
    - Dual tamping bars
    - Single tamping bar
- High initial density from paver (90% - 96%)
- Smoother surface due to higher initial density
- Less “roll down” to achieve final density
- Paves 6 to 8 ft/min
- 10 to 30 ft width
- Lift thick range: 4” to 9”



ROLLING & FINISHING

Initial Compaction

- Initial: 10 - 12 ton static & vibratory roller
- Establish/Adjust roll pattern
- Compact to 98% density - wet
- Adjust roll pattern based on moisture content if needed
- Finer mixes achieve density easier

Finish Rolling

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

Grape Creek Road – San Angelo, TX


Fairforest Way
Greenville, SC

Fairforest Way
Greenville, SC

RCC CURING and SAWING

Curing

- Applied at a higher rate, typically
- Uniform application process
- Minimal bleeding – apply asap
- Recommend wax based
- Good surface strength ensures durable surface
- 120 -- 150 sq ft/gal recommended rate

Saw Cut & Fill Joints

- Straight cuts
- Early entry sawing
- Cut within 2 - 6 hours Depth: 1” to 2”
- Spacing: follow ACI 325 recommendations

3 TYPES OF MAKING LONGITUDINAL JOINTS

Vertical Cold Joint

- Pave width of lane
- Saw cut full depth early next morning
- Remove with blade & loader
- Pave adjacent lane and match thickness of existing lane

Angular Cold Joint

- Need high density paver
- Attach shoe to screed
- Maximum angle 15º
- Use plate tamper to improve edge durability
- Pave adjacent lane next day

Fresh Joints

- Pave for 50 minutes then pave next lane
- No compaction within 2' of edge
- Recommend a long saw cut
- Create fresh trans joint
- Move quickly – keep moist!

FINAL SURFACE TYPE

	Bare RCC	Diamond Ground RCC
		
Applications	• Ports • Distribution centers • Industrial yards • Residential roads • Parking lots	• Collector / Arterial local roads • Highway Shoulders • State routes
Factors	• Lowest Cost • Least smooth • “Asphalt” appearance	• Higher cost • Incr construction time • Improved smoothness, skid resistance • Reduced noise

USE OF CONSTRUCTION JOINTS

Curb & Gutter

- Place 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

Manholes, Inlets

- Plywood plate is placed before RCC
- After paving, two methods are available:
  - Dig RCC out while fresh
    - place manhole and re - compact
    - Saw cut hardened RCC, place manhole

QC / QA

Moisture & Density

- Tested with nuclear gage in direct mode
- Test density behind paver & after roller
- Achieve 98% density
- Calibrate the Nuclear gage
- Oven dried is most accurate

Compressive Strength

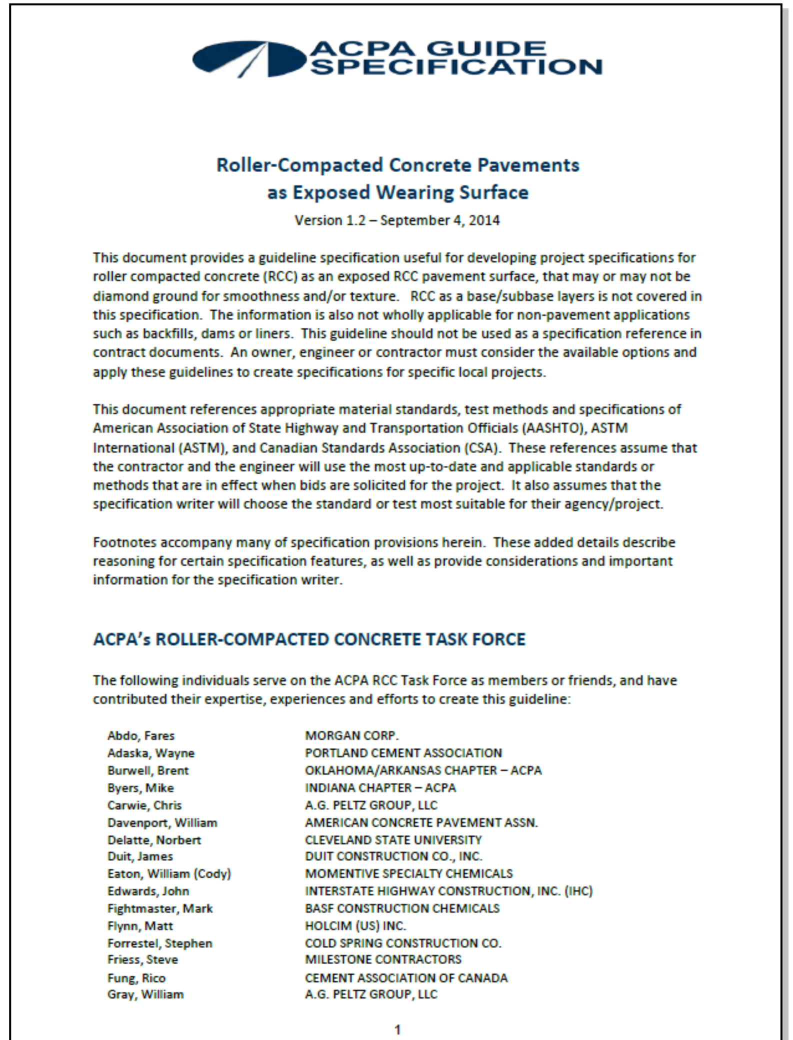
- Cylinders prepared IAW ASTM C1435
  - 3 to 4 cylinders per set
  - Strength (1, 3, 7, 28 days)
- Cores can be taken

THERE ARE EXCELLENT TECHNICAL REFERENCES AVAILABLE

Developed by the CPTech Center at Iowa State

Covers all aspects

Available through PCA



ACPA GUIDE SPECIFICATION

Roller-Compacted Concrete Pavements
as Exposed Wearing Surface

Version 1.2 – September 4, 2014

This document provides a guideline specification useful for developing project specifications for roller compacted concrete (RCC) as an exposed RCC pavement surface, that may or may not be diamond ground for smoothness and/or texture. RCC as a base/subbase layers is not covered in this specification. The information is also not wholly applicable for non-pavement applications such as backfills, dams or liners. This guideline should not be used as a specification reference in contract documents. An owner, engineer or contractor must consider the available options and apply these guidelines to create specifications for specific local projects.

This document references appropriate material standards, test methods and specifications of American Association of State Highway and Transportation Officials (AASHTO), ASTM International (ASTM), and Canadian Standards Association (CSA). These references assume that the contractor and the engineer will use the most up-to-date and applicable standards or methods that are in effect when bids are solicited for the project. It also assumes that the specification writer will choose the standard or test most suitable for their agency/project.

Footnotes accompany many of specification provisions herein. These added details describe reasoning for certain specification features, as well as provide considerations and important information for the specification writer.

ACPA's ROLLER-COMPACTED CONCRETE TASK FORCE

The following individuals serve on the ACPA RCC Task Force as members or friends, and have contributed their expertise, experiences and efforts to create this guideline:

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Guideline specification for Exposed Surface RCC pavements

Thank You

Questions?

BIDDING PROJECTS

- Volume of RCC paving on the project
- Site geometry
- Project phasing
- Pavement thickness
- Pavement width
- Final surface characteristics
- Traffic control
- Opening to traffic
- Daily working schedule

Virginia’s Experience with Roller Compacted Concrete Pavement

Shabbir Hossain, Ph.D., PE
Senior Research Scientist
Virginia Transportation Research Council
Virginia Department of Transportation

TRB Webinar, January 23, 2017

Two VDOT pavement projects

FHWA's Highways for LIFE

Access roads to Staffordboro Commuter Parking Lot and part of Staffordboro Blvd in Stafford (2 lane-miles)

Three ramps from I-295S to US 60E, US 60W and I-64W in Richmond

- Stafford
  - September - October 2013
  - June - August 2014
- Richmond – October 2015

Base stabilization needed in Stafford

Soft existing base/subgrade

Stabilized with Geogrid + 6” #57 +
6” base aggregate (VDOT 21B)

RCC Mixture Proportions

Material (lb/yd^3) & Characteristics	Stafford	Richmond
Type II cement	479	375
Fly ash (Class F)	85 (15%)	125 (25%)
Coarse aggregate (Size)	1,600 (No.68)	850 (No.57)
Coarse aggregate (Size)	630 (No.10)	850 (No.78)
Fine aggregate (natural sand)	1,119	1,600
Water	233	217
Water–cementitious materials ratio	0.41	0.43
Optimum moisture content (OMC), %	5.75	5.70
Maximum dry density, pcf	142.9	143.5
Maximum wet density, pcf	151.1	151.7

Stafford - Batch Plant w/ Pugmill

Portable Pugmill

- Production 200 tons/hr
- Haul Truck – 9 CY
  - Pugmill with 5 CY capacity
  - 2 batches in 10 min
- Moisture test
  - Hot plate
- Plant to Site
  - Max 30 min
- Mix to Compact
  - Max 60 min

Richmond – Stationary Mixer

Batch Plant w/ stationary mixer

Microwave Moisture Meter

High Density Asphalt Paver

- 6” to 8” RCC
- 90% density behind the paver
- Continuous operation

Continuous Operation Needed

- Stop and go operation can create cold joints
- Detailed production and hauling plans needed to complete compaction in 60 minutes of mixing

Roller to Compact

- 10 Tons
- 2 to 3 passes
- Static mode
- > 98% density
- Too dry difficult to compact
- Over rolling may cause separation of top 2" or so

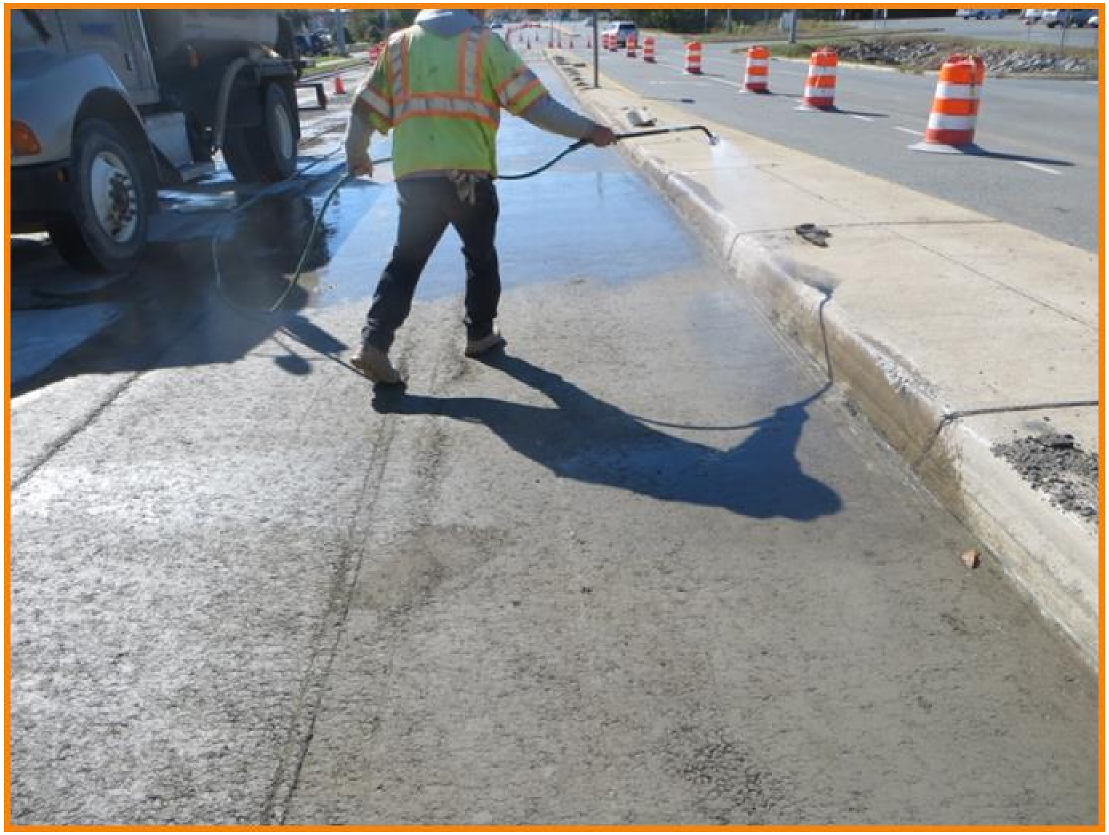
Mix moisture

- Too wet
  - Unstable mix
  - Difficult to achieve thickness
  - Surface cracking / scaling

- Desirable moisture within 1% above OMC

Field Density – Nuclear Gauge

Curing – Water Spray in Stafford



- Water cured for 7 days
- Open to traffic in 24 to 48 hours
- A small section in 6 hours
- Curing continued with water truck under live traffic.

Curing Compound in Richmond

- Wax-based curing compound
- Asphalt overlay in 1 to 2 weeks

Joints – Early-entry Saw

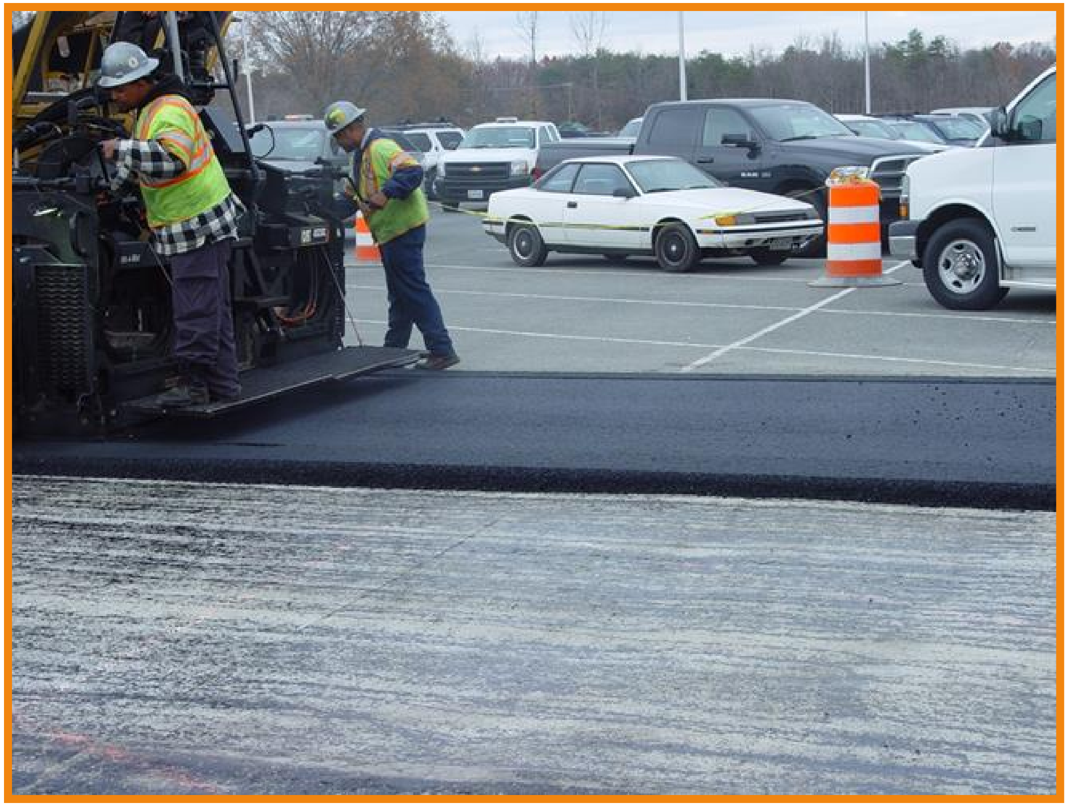
- Every 15 ft
- ¼ depth
- 3-4 hours
- Avoid raveling

QC/QA Strength Test

Average Strengths

- Cylinder Compressive Strength
  - 24 hours > 2,500 psi
  - 28 days > 4,780 psi with a COV 18%
  - 28 days modulus of elasticity ≈ $4x10^6$ psi
- Beam Flexural Strength >700 psi (28 days)
- 4-inch cores
  - Cored at 5 days, wrapped in plastic, and tested after 5 more days
  - Compressive strength > 4,000 psi

Overlaid with Asphalt



- Stafford
  - 2 inches
  - 1-3 months
- Richmond
  - 3 inches
  - 1-2 weeks
  - before traffic

Stafford Project Performance

- 2-3 years of Traffic.
- No performance problem reported

- Most control joints reflected through AC
- Minimum deterioration around asphalt cracks

Richmond Project Performance

- 1 year of traffic
- No visible distress
- No cracks or control joints reflected through asphalt layer.

CONCLUSIONS

- RCC successfully placed, requires:
  - Firm base
  - Good compactable mixture
  - Proper and consistent moisture
  - Pugmill / plant with enough capacity
  - Compact within 60 minutes of mixing
  - Continuous paving operation
  - High density paver with proper adjustments > 90% density
  - Roller achieve > 98% density