

INTRODUCTION TO THE NEW GUIDE FOR ROLLER COMPACTED CONCRETE PAVEMENTS

National Concrete Consortium
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GUIDE FOR _____
ROLLER COMPACTED
CONCRETE PAVEMENT
_____ 2009



National Concrete Pavement
Technology Center



PCA
Portland Cement Association

Questions??

- Why RCC Guide?
 - Expanded use
 - Expanded interest
 - Resources available, but scattered
- Who should do it?
 - CP Tech Center (Overlay Guide)
- What should be included?
 - Fundamentals, materials, mix proportioning, structural design, construction
- When is it needed?
 - Immediately, but 6 to 9 months is realistic

Technical Advisory Committee

- Wayne Adaska, Fares Abdo, Greg Halsted, Tim McConnell – PCA
- Tim Smith – Cement Association of Canada
- Wouter Gulden – ACPA – SE Chapter
- Randall Riley – ACPA – Illinois Chapter
- Matt Singel – Cement Council of Texas
- Frank Lennox – Buzzi Unicem USA
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100 +/- Page Guide for Roller Compacted Concrete—Outline

1. Key Elements of RCC
2. Common Uses
3. RCC Properties & Materials
4. RCC Mixture Proportioning
5. Structural Design
6. RCC Production
7. RCC Construction
8. Troubleshooting

APPENDIX:

- Design Examples
- Guide Specification for Construction of RCC Pavement

SECTION 1

KEY ELEMENTS of RCC PAVEMENTS



What is Roller-Compacted Concrete Pavement?



- Has different mixture proportions
- Largest difference between RCC mixtures & conventional concrete mixtures – RCC has higher percentage of fine aggregates – allows for tight packing & consolidation
- Fresh RCC is stiffer than typical zero-slump conventional concrete
- Name from the heavy vibratory steel or rubber tired rollers used to compact it into its final form
- RCC has similar strength properties and consists of the same basic ingredients as conventional concrete

What is Roller-Compacted Concrete Pavement?

- Consistency is stiff enough to remain stable under vibratory rollers, yet wet enough to permit adequate mixing and distribution of paste
- Typically placed with an asphalt-type paver equipped with a standard or high-density screed – followed by a combination of passes with rollers for compaction
- Final compaction is generally achieved within one hour of mixing
- Unlike conventional concrete pavements, RCC pavements are constructed without forms, dowels, or reinforcing steel
- Joint sawing is not always required, but when sawing is specified, transverse joints are spaced farther apart than with conventional concrete pavements

How Does it Work?

Conventional PCC Pavement

Shared materials characteristics:

- Same materials (different proportions)
- Similar curing requirements

Hot-Mix Asphalt Pavement

Shared construction characteristics:

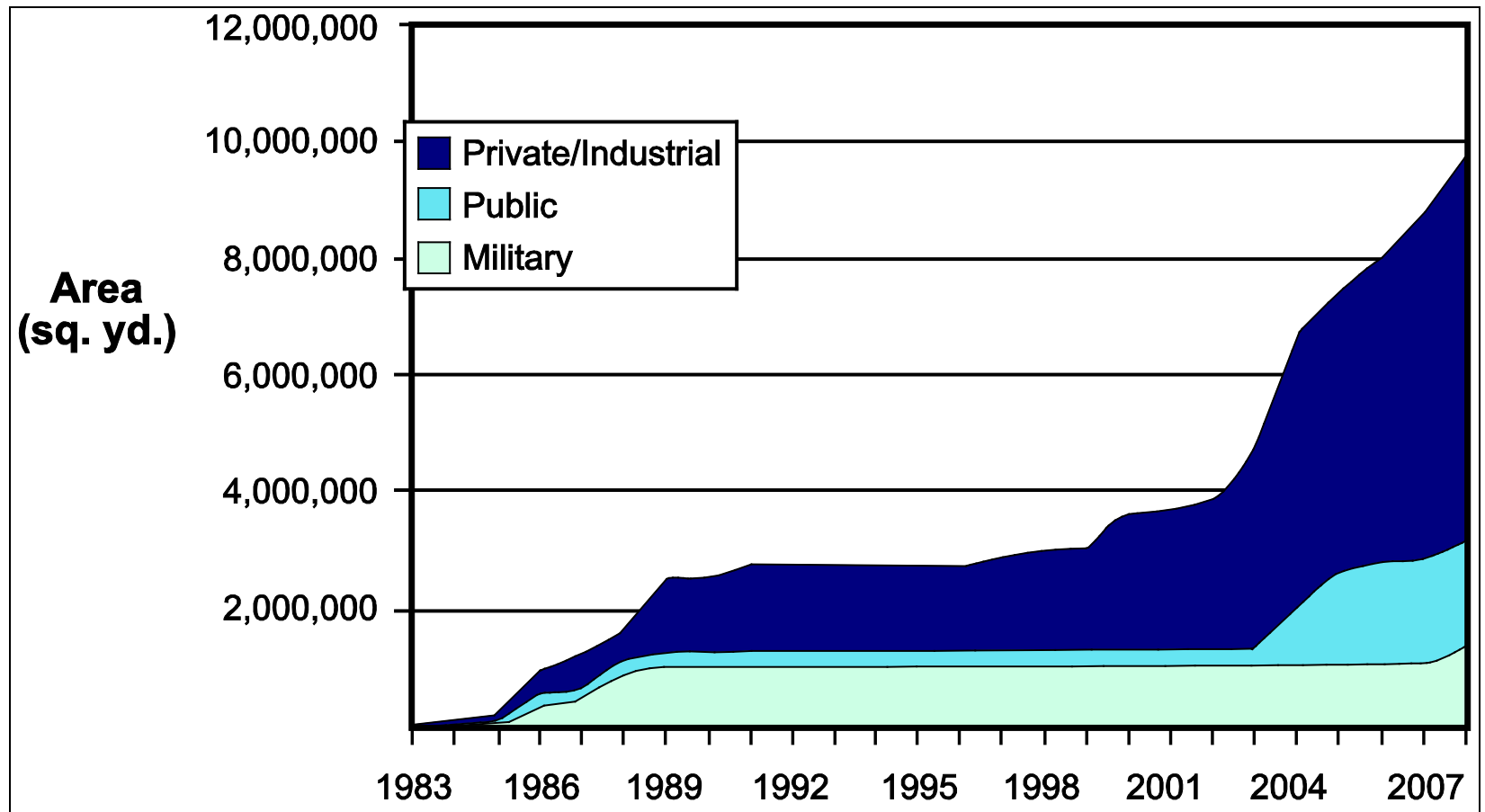
- Similar aggregate gradation
- Similar placement and compaction

Roller Compacted PCC Pavement



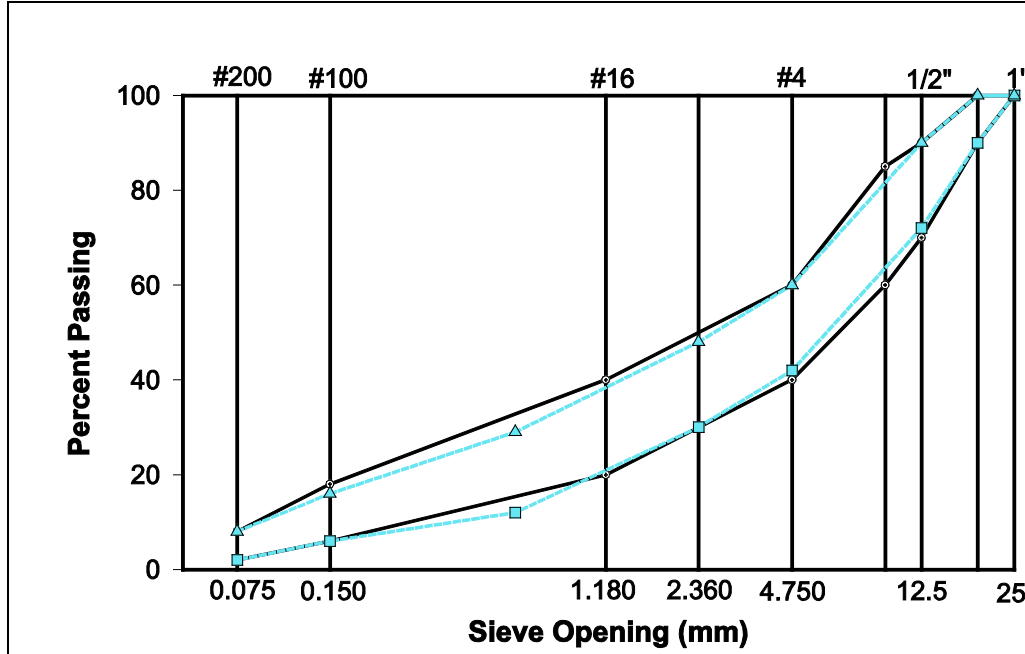
Figure 3. RCC combines aspects of conventional concrete pavement with construction practices similar to HMA pavement.

Use of RCC has been on the Increase



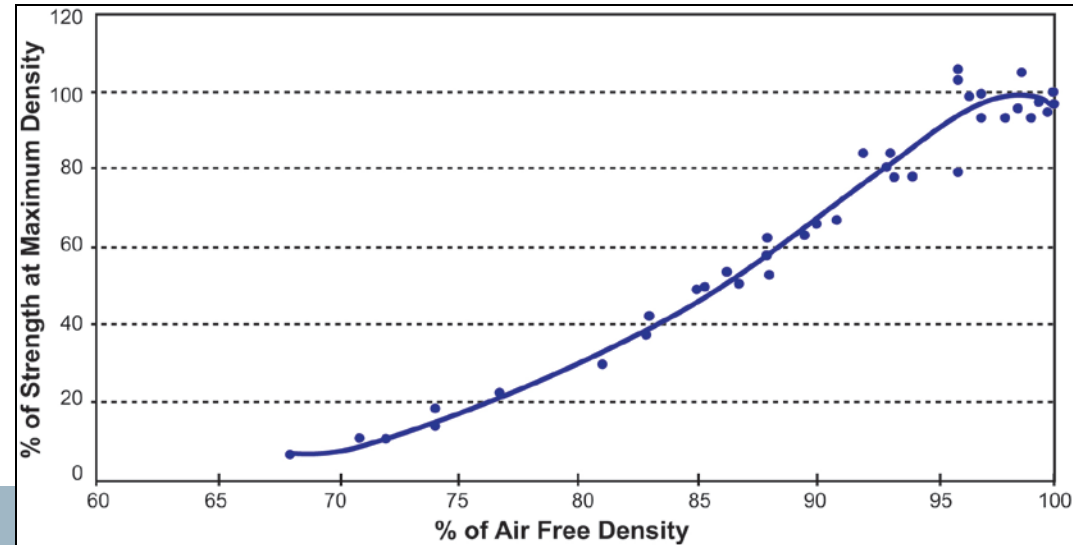
History of RCC

Gradation & Density



Typical aggregate gradation of RCC (black on chart) is similar to aggregate gradation of intermediate HMA layer (blue on chart)

Strength vs. density for various RCC mixtures



Basic Difference Between RCC & PCC

	Type of Pavement	
General Materials and Practices	Conventional Concrete Pavements	RCC Pavements
Mix materials proportions	<ul style="list-style-type: none"> • Aggregates typically account for 60 to 75 percent of the mixture by volume. • (w/cm) ratio is 0.40 to 0.45 	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • Manipulated by the paving machine, (slump is generally about 2 in.) 	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • The mixture is placed ahead of a slipform paving machine, which then spreads, levels, consolidates through vibration. 	<ul style="list-style-type: none"> • 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.

Basic Difference Between RCC & PCC

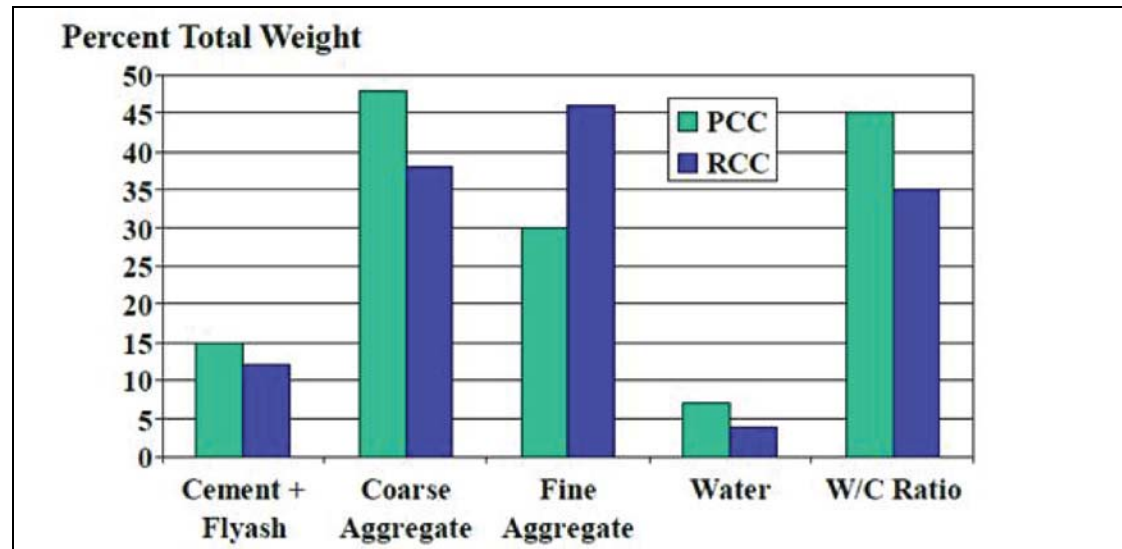
	Type of Pavement	
General Materials and Practices	Conventional Concrete Pavements	RCC Pavements
Consolidation (primarily the removal of non-entrained air)	<ul style="list-style-type: none">• Consolidation occurs internally. Initially internal vibrators and surface vibrators on the paving machine fluidize the plastic concrete, releasing air.	<ul style="list-style-type: none">• Consolidation is accomplished externally by compaction of the concrete with rollers.
Finishing	<ul style="list-style-type: none">• Finishing is conducted before initial set occurs.• Conventional concrete is usually mechanically textured to improve friction.	<ul style="list-style-type: none">• RCC pavement typically has an open texture (similar to HMA)• RCC can be textured through diamond grinding.

Basic Difference Between RCC & PCC

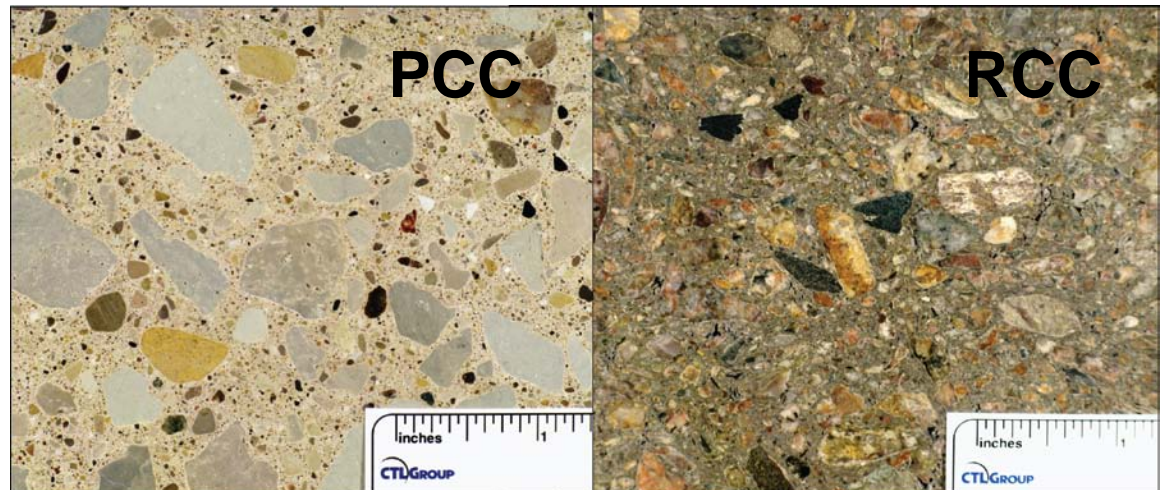
	Type of Pavement	
General Materials and Practices	Conventional Concrete Pavements	RCC Pavements
Hydration & Curing	<ul style="list-style-type: none"> • Proper hydration and curing is critical to the long-term durability of the concrete pavement. 	<ul style="list-style-type: none"> • Proper hydration and curing of the RCC mixture is critical to the long-term durability of the pavement.
Cracking, load transfer, and reinforcement	<ul style="list-style-type: none"> • In conventional jointed pavements, the location of cracks is controlled by cutting joints 	<ul style="list-style-type: none"> • Joints are not usually sawed in RCC industrial applications. When sawing is not specified, random cracks are normally tight, enabling load transfer through aggregate interlock. (20 – 60 ft. spacing) • When sawing is specified for random crack control, it is typically in applications of car & truck traffic • Fewer joints are sawed in RCC than in conventional concrete pavements, and they are spaced farther apart (20-30 feet transversely).

Basic Difference Between RCC & PCC

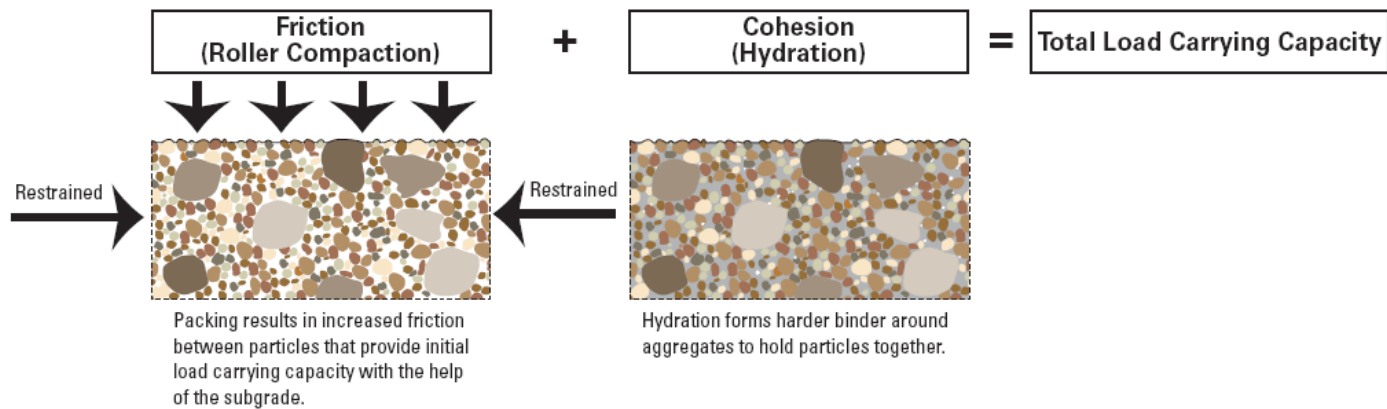
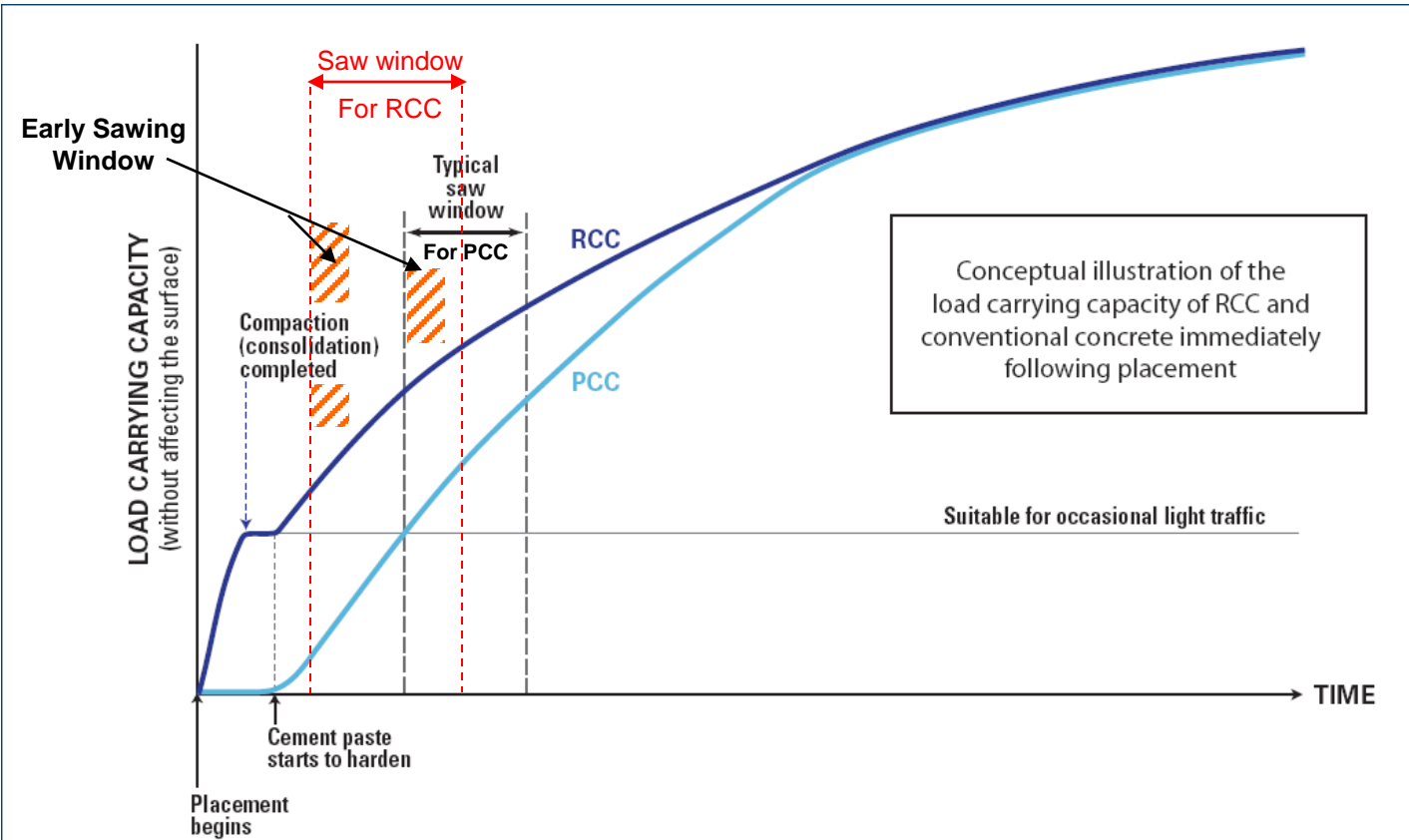
Typical material comparisons of conventional concrete and RCC



Comparison of aggregate distribution of conventional concrete (left) and roller compacted concrete (right) (photos courtesy of CTL Group)

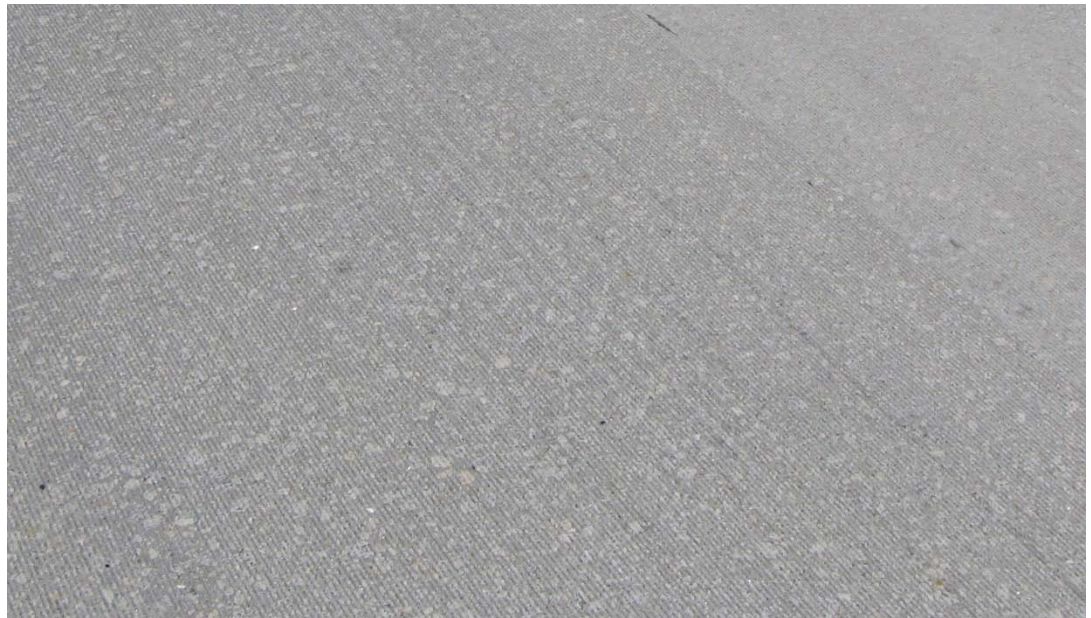


Early Load Carrying Capacity of RCC & PCC



Comparison of Surfaces

Diamond Grinding



Benefits of RCC

- The primary benefit of RCC is that it can be constructed quickly and cost-effectively
- Savings associated with RCC primarily due to
 - Reduced cement content
 - Reduced forming, placement, and compaction
 - RCC needs no forms or finishing
 - No dowels, tie rods, or steel reinforcement
 - Can be placed up to 10 inch lifts
 - Reduced construction times
- The lower paste content in RCC results in less concrete shrinkage and reduced cracking from shrinkage-related stresses
- RCC can be designed to have high flexural, compressive, and shear strengths, which allow it to support heavy, repetitive loads

Benefits of RCC

- With its low permeability, RCC provides excellent durability and resistance to chemical attack, even under freeze-thaw conditions
- RCC eliminates rutting and subsequent repairs
- RCC resists abrasion, similar to conventional concrete pavement, even under heavy loads and high traffic volumes
- With RCC pavements' light-colored surface, lighting requirements for parking and storage areas are reduced

Benefits of RCC

- An occasional light vehicle, such as a car exiting a driveway, can travel a short distance on RCC pavement before opening strength is reached without causing damage
- Depending on the mix, and utilizing high-density pavers, RCC can be placed in lifts as thick as 10 in.
- RCC pavements have a solar reflectance index (SRI) greater than 29.
- Freeze-thaw durability of RCC is high even without the use of air entrainment. For decades, RCC pavements in cold regions in Canada and the northern U.S. have shown excellent freeze-thaw resistance.

Potential Limitations of RCC

- Because of the type equipment used & placement practices, diamond grinding or asphalt surfacing typically needed for speeds greater than 30 mph
- The amount of RCC that can be mixed in a transit mixer or ready mix truck is typically lower than for conventional concrete, due to the dryness of the RCC mix
- Multiple horizontal lifts and adjacent slabs must be placed within an hour to ensure good bonding (unless adjacent cold joint is planned)

Potential Limitations of RCC

- Pavement edges are more difficult to compact, so most specifications require 96% modified Proctor density on cold joints instead of the 98% required on interior pavement sections
- Due to relatively low water content, hot-weather RCC paving requires extra vigilance to minimize water loss to evaporation
- Due to the dryness of the RCC mixture, admixture dosage requirements can be higher for RCC than for conventional concrete

Section **2**

COMMON USES of RCC PAVEMENTS



Section 2

RCC Selection Considerations

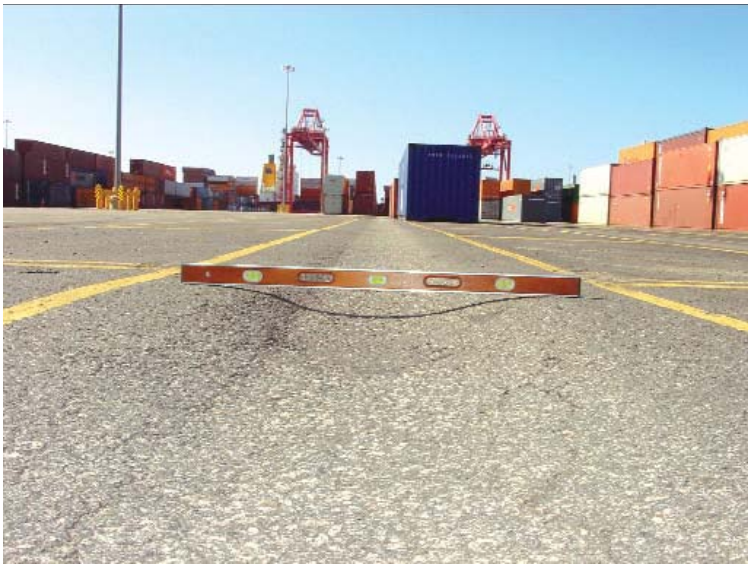


- Applications
 - Ports/Heavy Industry
 - Light Industry
 - Airports
 - Local Streets
 - Arterial Streets
 - Shoulders/Widening
 - Base for Overlays
- Factors to Consider

Ports & Heavy Industry



- **Type of Traffic**
 - Heavy Port Equipment (30 to 60 kips per tire)
- **Design**
 - USACE Method
 - RCCPave Program
- **Plant & Transport**
 - Continuous Flow
 - Pugmill
 - Horizontal Shaft
- **Placement**
 - High Density Paver
- **Surface Treatment**
 - None for Speed < 30 mph
- **Jointing**
 - Typically None
 - Lane Traffic – Sawing done to improve load transfer



Light Industry & Access Roads



- **Type of Traffic**

- High Volume of Trucks (80 kips)

- **Design**

- StreetPave Program
- WinPASS Program

- **Plant & Transport**

- Pugmill
- Horizontal Shaft
- Batch Plant for Smaller Projects (Fix or transit depends on thickness)

- **Placement**

- High Density Paver
- Conventional Paver

- **Surface Treatment**

- None for Speed < 30 mph

- **Jointing**

- Typically None
- Lane Traffic – Sawing done to improve load transfer

Airport Service

(Storage/Parking Areas, or Base)



- **Type of Traffic**

- Airplanes and Maintenance Equip.

- **Design**

- RCCPave Program
- USACE Method

- **Plant & Transport**

- Batch Plant
- Pugmill or Horizontal Shaft Mixers for Large Projects (Depends on Volume)

- **Placement**

- Conventional Paver
- High Density Paver for Thicker Pavements

- **Surface Treatment**

- Milling or Overlays May be Required in Areas with Airplane Traffic

- **Jointing**

- Typically Required Except in Maintenance Areas

Arterial Streets

- **Traffic is always a major concern when paving arterial streets**
 - Traffic constraints and time required to place multiple asphalt lifts
 - Some choose to use a single lift of RCC pavement



- **Type of Traffic**
 - Buses, Passenger cars
 - Trucks
- **Design**
 - StreetPave
 - WinPASS
- **Plant & Transport**
 - Pugmill or Horizontal Shaft Mixer
 - Batch Plant
(Depends on Volume)
- **Placement**
 - High Density Paver
- **Surface Treatment**
 - Milling
 - RCC Base with Overlay (High Speed Facilities)
- **Jointing**
 - Typically Required

Arterial Streets



1st Example

1st Example

- Reconstructed Lane Avenue pavement in Columbus, Ohio
- Consists of 8 in. of RCC surfaced
- 3 in. of asphalt to provide smoothness for higher speed traffic
- RCC pavement constructed under traffic for this four-to-six lane arterial street

2nd Example

- 2009 reconstruction of US 78 in Aiken, South Carolina
- 10 in RCC pavement replaced existing full-depth asphalt pavement
- RCC surface diamond ground for this four-lane section, improved smoothness & provide surface texture at affordable cost



2nd Example

Local Street & Roadway



- **RCC for new Residential Developments**

- Provides strong working platform during site-work & construction
- Surface treatments can be applied once the development nears completion

- **Type of Traffic**
 - Passenger cars
 - Delivery Trucks
- **Design**
 - StreetPave
 - WinPASS
- **Plant & Transport**
 - Batch Plant or Continuous Flow Mixer for Large Volumes
- **Placement**
 - Conventional Paver
- **Surface Treatment**
 - Speeds > 30 mph surface smoothness important
 - Diamond grinding
- **Jointing**
 - To control random cracking

Shoulders & Widening



- **Meets New Lane and Drop Off Criteria**

- Strength and speed of construction make it suited to road-widening applications
- Material provides a stable foundation that can be surfaced

- **Type of Traffic**
 - Buses, Passenger cars
 - Trucks
- **Design**
 - Thickness No Greater Than Mainline
- **Plant & Transport**
 - Pugmill or Horizontal Shaft Mixer
 - Batch Plant
- **Placement**
 - High Density Paver (Thickness > 7")
 - Conventional Paver (Thickness < 7")
- **Surface Treatment**
 - Rumble Strips
- **Jointing**
 - Match Existing Jointing

Shoulders & Widening

Example

Georgia DOT to reconstruct shoulders on I-285

- Existing asphalt shoulders were badly distressed
- Existing shoulder milled out and replaced with 10 ft. wide and 6 to 8 in. deep section of RCC
- Rumble strips grounded into the surface to conform to interstate highway safety requirements
- Project included 34 shoulder miles of RCC
- Northbound & southbound outside shoulders replaced for 17 centerline miles
- No surfacing was placed on the RCC



Two-Lift Systems for High-Speed Roadways

- For highway speeds today, RCC used as a base under a thin asphalt wearing course for rideability
- Could use as a base under an unbonded conventional concrete overlay
 - Would provide long-term advantages for two-lift pavement systems
- Provides an excellent construction platform
- Example – design a long-term pavement < 10 in. thick with a surface renewal limited to a 30 – 40 yr. cycle
 - Use a conventional concrete overlay over an RCC pavement
 - This affordable system could be a wet-on-dry two-lift system that would consist of an RCC base with a thin (4 in. to 5 in.) unbonded concrete overlay
 - Separation layer would be required



Two-Lift Systems for High-Speed Roadways



- **Type of Traffic**
 - Highways: High-volume truck, bus
- **Thickness Design**
 - AASHTO Design Guide (1993, 1998)
 - AASHTO Mechanistic-Empirical Pavement Design Guide (M-E PDG)
 - StreetPave or WinPas computer programs for mixed-vehicle traffic
- **Surface Treatment**
 - Conventional concrete for second lift
- **Sawed Joints**
 - Typically not sawed when an unbonded concrete overlay is used

Logging Facilities, Composting Areas, and Storage Yards



- **Type of Traffic**
 - Slow-speed heavy equipment
 - **Thickness Design**
 - The USACE method
 - RCC-PAVE computer program
 - **Surface Treatment**
 - Typically no surface treatment
 - Surface smoothness has an approximately ½ in. maximum variance for a 10 ft. straight edge
 - **Sawed Joints**
 - None
- First used for log handling facilities in Canada in the mid-1970s
 - Requires pavement strength and durability to support the heavy loads
 - Surface appearance, texture, and smoothness are of lesser importance for these applications
 - Coarser aggregates can be used

Section **3**

RCC PROPERTIES and MATERIALS



RCC Engineering Properties

- Strength
- Modulus of Elasticity
- Fatigue
- Bond Strength
- Freeze-Thaw Durability
- Shrinkage
- Permeability



RCC Strength

- Compressive strength
 - 4,000 to 6,000 psi
- Flexural strength
 - 500 to 1,000 psi

$$f_r = C \sqrt{f_c}$$

Where C between 9 and 11



Freeze-Thaw Durability

- Field performance without air entrainment has been excellent (PCA pub. RP366)
- Minor surface paste (1/16 in.) erodes, then stabilizes
- RCC results variable under ASTM C666 (F/T) and C672 (Deicer scaling)
- These tests appear to be extremely harsh based on actual experience
- Durability tests for masonry concrete and precast units (ASTM C1272) possibly more appropriate

Freeze-Thaw Durability



RCC Materials Selection

- Aggregates
 - Coarse aggregates
 - Fine aggregates
- Cementitious Materials
 - SCMs (fly ash, slag, silica fume)
- Water
- Chemical Admixtures
 - Water reducers & retarders
 - Polycarboxylate superplasticizers

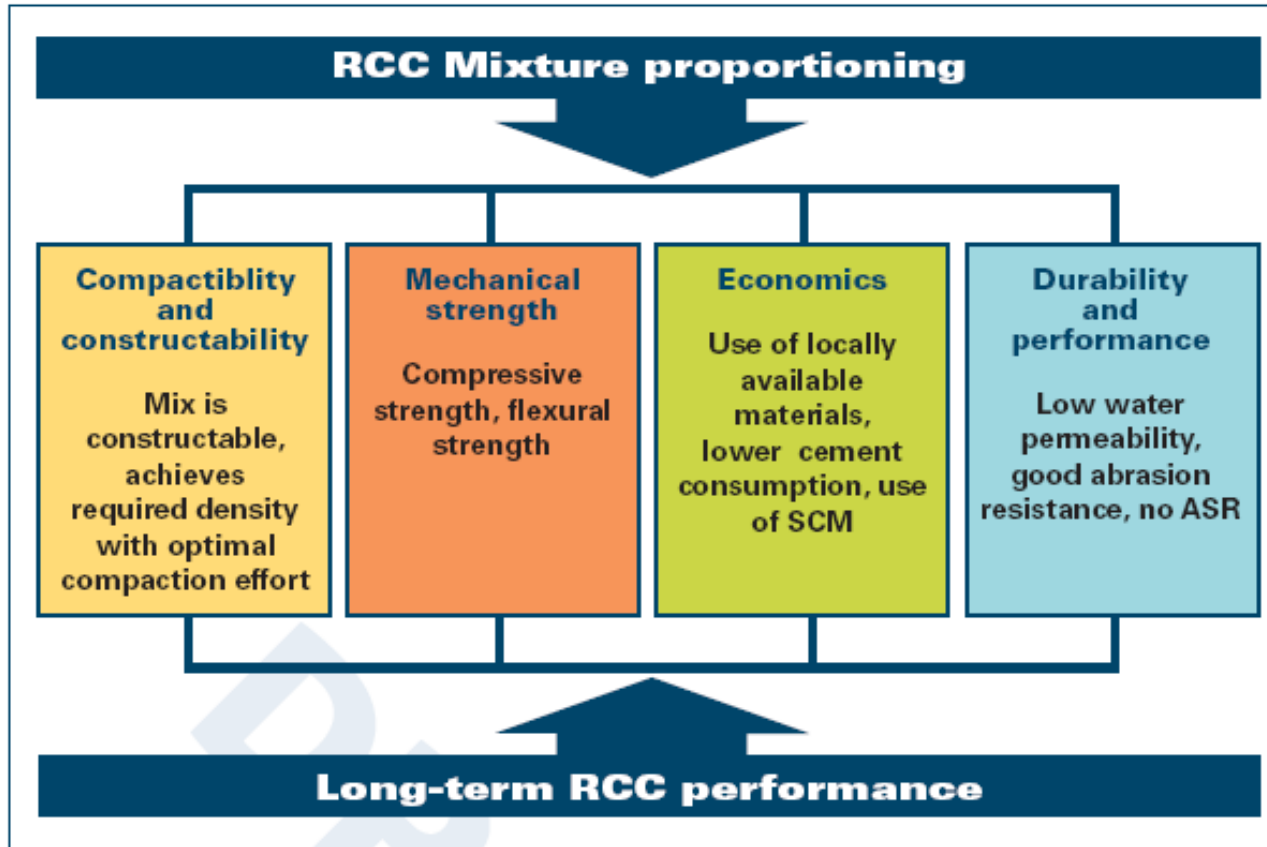


Section **4**

RCC MIXTURE PROPORTIONING



RCC Mixture Proportioning



Factors to Consider in Mixture Proportioning

Common Methods

- Soil Compaction
- Consistency/Workability
 - Concrete consistency
 - Optimal paste volume
- Solid Suspension Model
 - Optimizes packing density
 - Uses computer simulations



Materials Consideration

- Aggregates
- Water
- Cementitious Materials
- Chemical Admixtures
- Required Compressive Str.
 - Provide a factor of safety
 - ACI 214R-02 Evaluation of Strength Results of Concrete



Soil Compaction Method

Steps in Soil Compaction Method

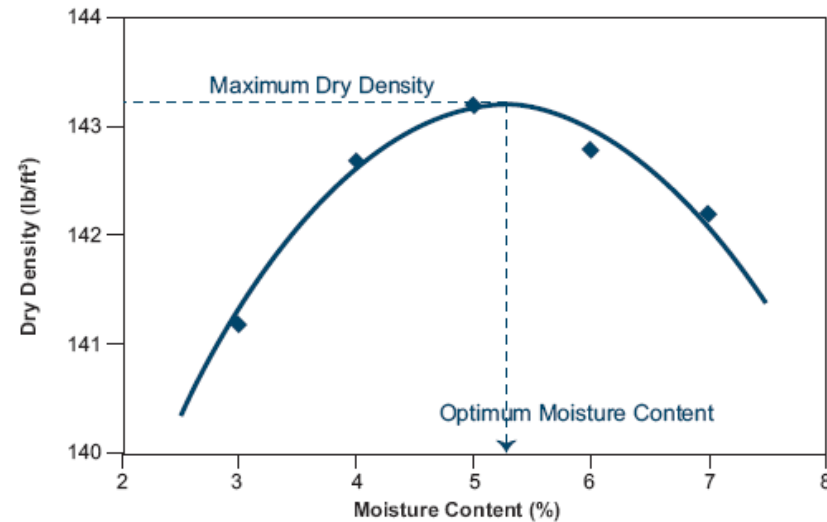
1. Choose well graded aggregate
2. Select mid-range cement content
3. Develop M-D relationship plots
4. Cast samples for compressive strength
5. Test specimens
6. Calculate mixture proportions



Soil Compaction Method

Develop Moisture-Density Plots

- ASTM D1557 modified Proctor
- Moisture range 4% to 8%
- Plot different cement contents

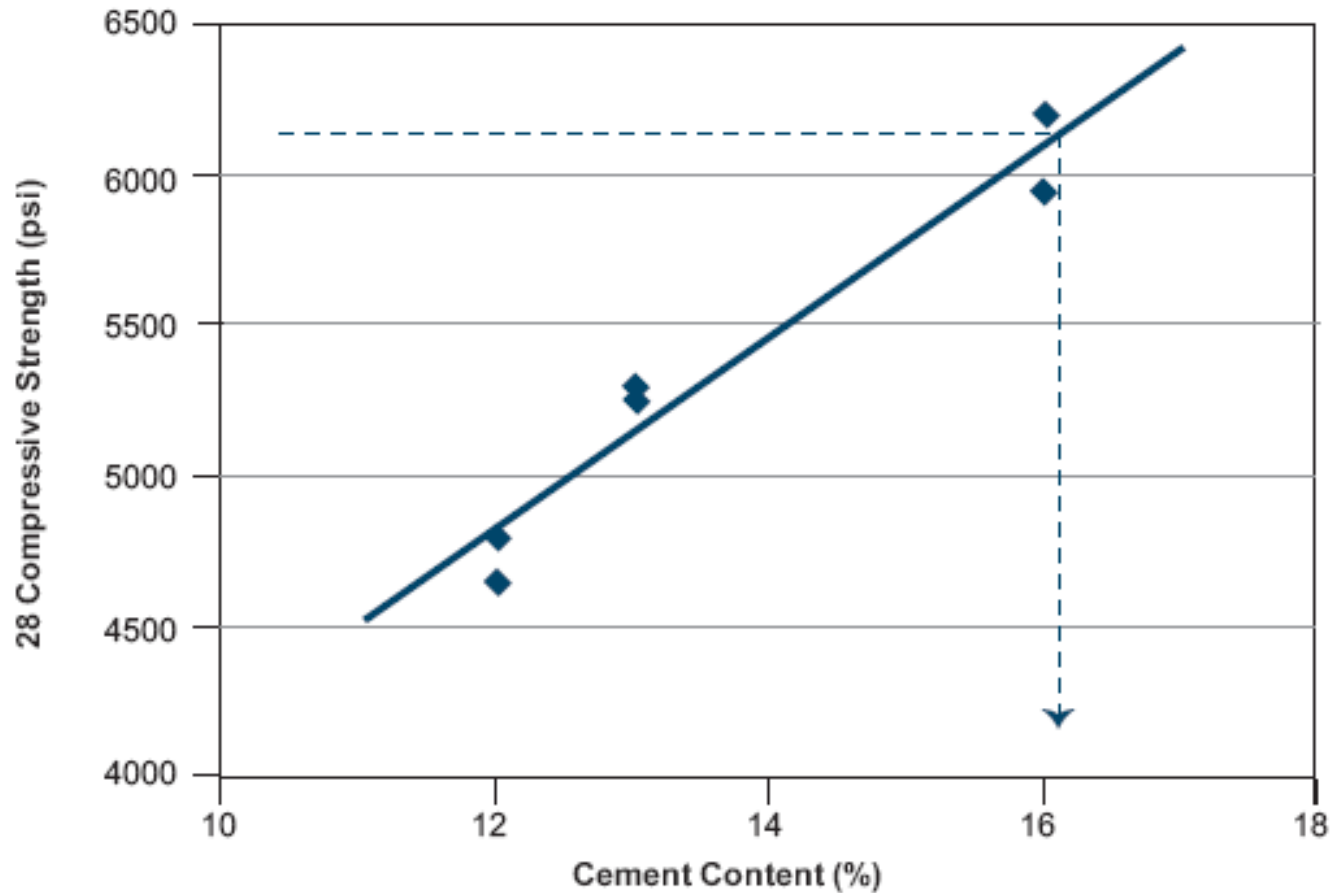


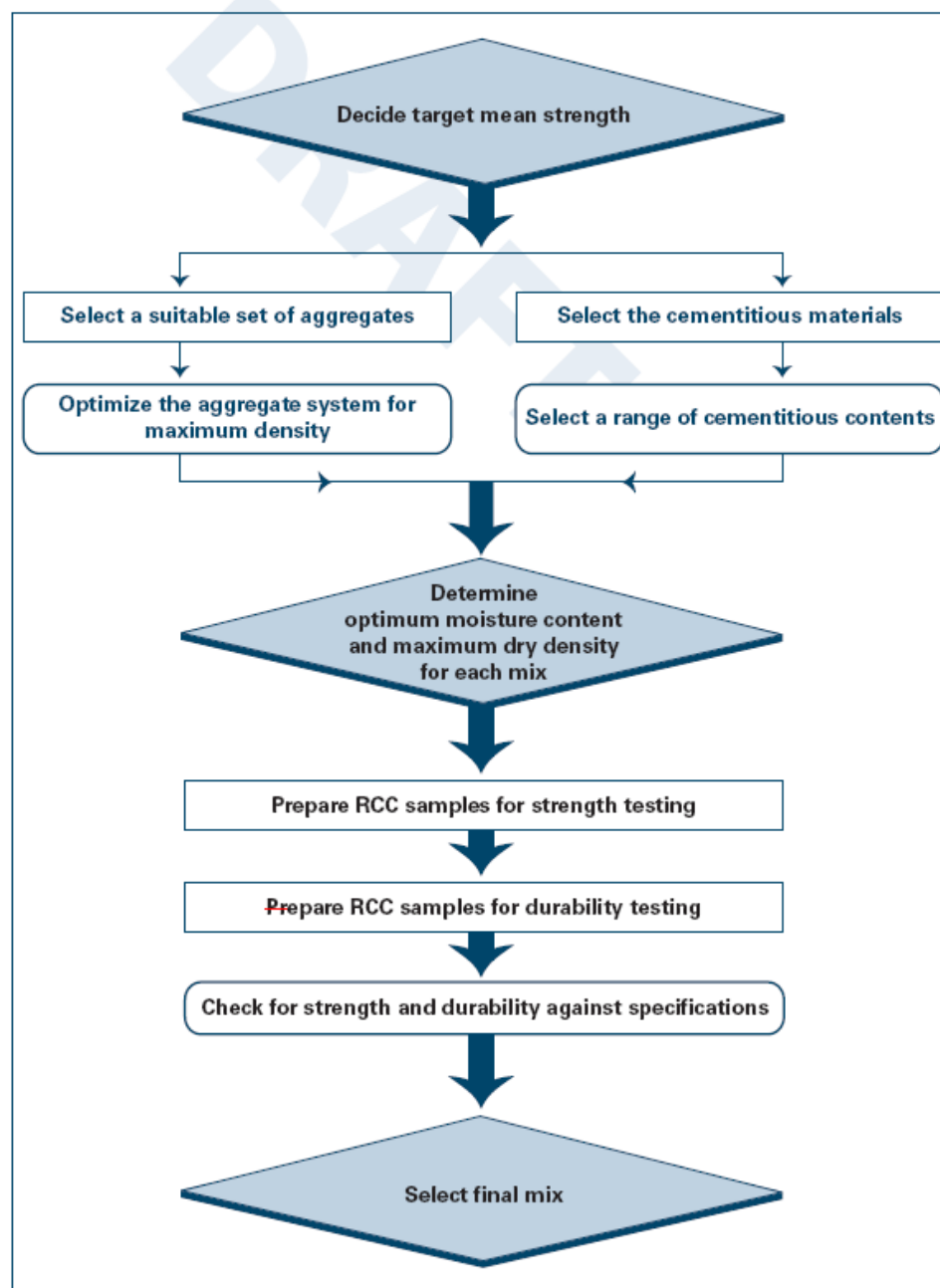
Cast Samples for Compressive Strength

- ASTM C1435 vibrating hammer
- Mold cylinders at optimum moisture



Test Specimens and Select Required Cement Content

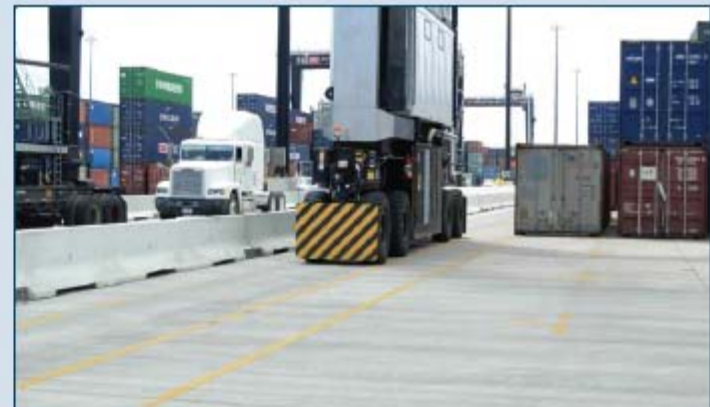




Flowchart Using Soil Compaction Method

Section **5**

STRUCTURAL DESIGN of RCC PAVEMENTS



Basis for Design

- Follows rigid pavement design methods
- Plain, undoweled, unreinforced concrete pavement
- Function of expected loads, concrete strength and subgrade
- Single lift RCC thicknesses vary from 4 in. to 10 in.



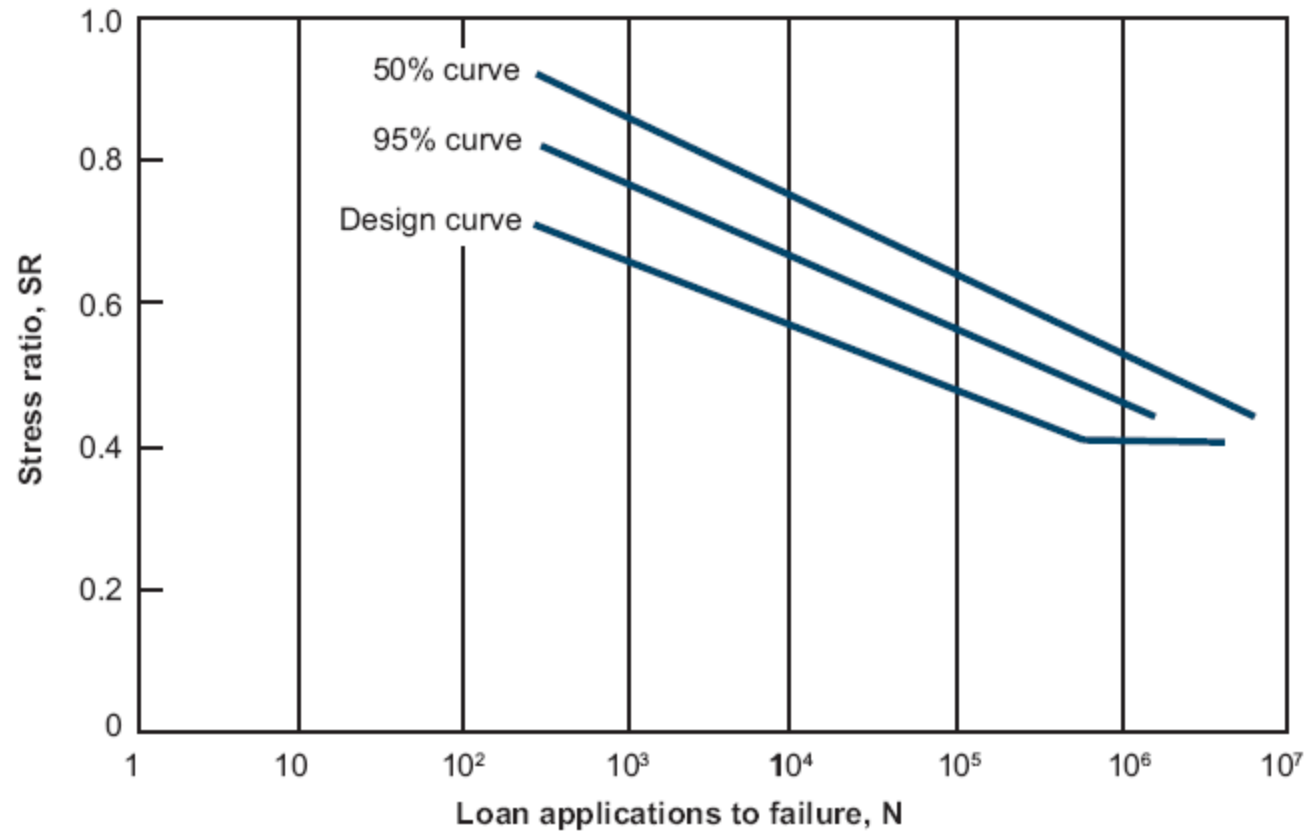
Design Procedures

- Heavy duty pavements (loaders, haulers, tanks)
 - PCA design procedure (RCC-PAVE)
 - U.S. Corps of Engineers procedure
- Mixed roadway vehicle traffic (cars, trucks)
 - ACPA StreetPave
 - ASSHTO 1993 (WinPas)
 - ACI 330 on Concrete Parking Lots

PCA Procedure

- Monolithic slab action for multi-layer construction
- Load transfer across joints/cracks
- Conservatism
 - Design curve below fatigue tests
 - Strength gain with age

Fatigue Relationship for RCC (PCA)



Thickness Design Procedure (PCA)

- Supporting strength of subgrade (k value)
- Vehicle characteristics
 - Wheel loads
 - Wheel spacing
 - Tire characteristics (contact area, contact pressure)
 - Number of load repetitions during design life
- Flexural strength
- Modulus of elasticity

Design Example

Straddle Carrier



Design Example

- Straddle Carrier, Single Wheel
- Axle load: 60,000 psi, Wheel load: 30,000 psi
- Tire pressure: 100 psi
- Tire contact area: $30,000/100 = 300$ sq in
- Subgrade modulus: 100 psi/in
- RCC flexural strength: 650 psi
- RCC modulus of elasticity: 4,000,000 psi
- Load frequency: 30 reps/day
- Design life: 20 years
 - $20 \text{ yr} \times 365 \text{ days/yr} \times 30 \text{ reps/day} = 219,000$ total reps

Design Example

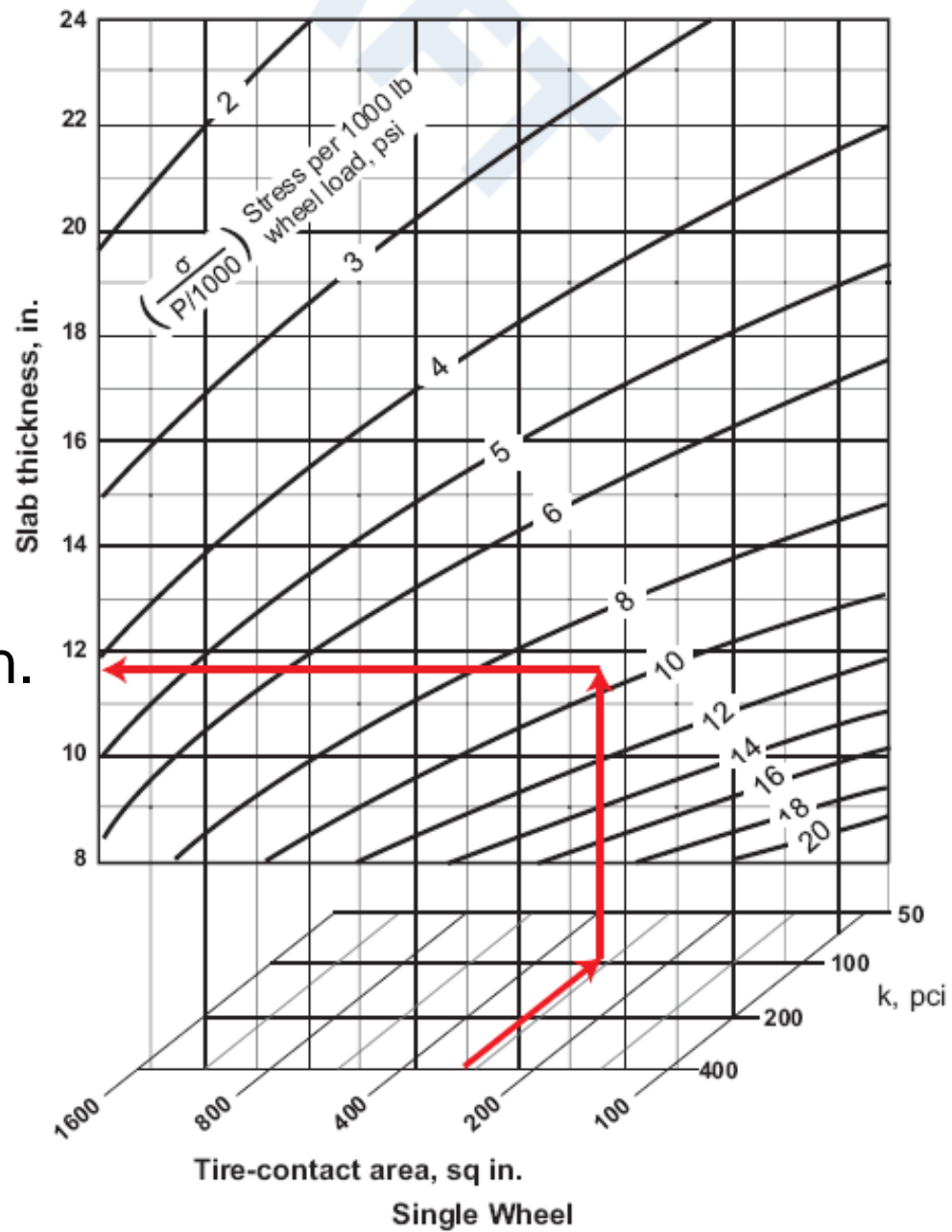
Table 5-1. Stress ratios and allowable load repetitions (from PCA IS233)

Stress ratio	Allowable repetitions	Stress ratio	Allowable repetitions
0.41	465,000	0.56	9700
0.42	360,000	0.57	7500
0.43	280,000	0.58	5800
0.438	219,000	0.59	4500
0.44	210,000	0.60	3500
0.45	165,000	0.61	2700
0.46	130,000	0.62	2100
0.47	100,000	0.63	1600
0.48	76,000	0.64	1200
0.49	59,000	0.65	950
0.50	46,000	0.66	740
0.51	35,000	0.67	570
0.52	27,000	0.68	440
0.53	21,000	0.69	340
0.54	16,000	0.70	260
0.55	12,000		

Design Example

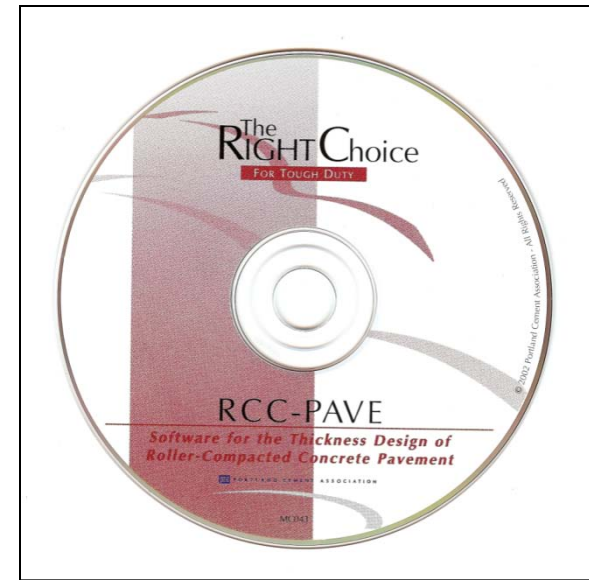
- Design stress ratio (Table 5-1), $SR = 0.438$
- Allowable stress, $\sigma = f_s \times SR$
 $= 650 \times 0.438 = 285 \text{ psi}$
- Maximum single wheel load,
 $P = 120,000/4 = 30,000 \text{ lbs}$
- Allowable stress per 1000-lb load
 $= \sigma / (P/1000) = 285/30$
 $= 9.5 \text{ psi/kip}$

11.5 in.



RCC-PAVE Computer Program

- Pavement evaluation or thickness design
- Interior or edge loading
- Standard vehicle and user defined loading options
- Developed for heavy-duty pavements with less than 700,000 total load repetitions



Type of Joints

- Construction joints
- Sawed (contraction) joints
- Isolation joints
- Expansion joints

Reasons for Jointing

- Control random cracking
- Improve appearance
- Provide mechanism for regularly spaced thin cracks to improve aggregate interlock
- Sawed joints are easier to seal
- Early-entry sawing widths are thin enough that joint sealing is not required

Joint Efficiency

- USACE testing indicated wide variation in joint efficiency (2.2% to 89%)
- Joint efficiency reduced by:
 - Repetition of heavy loads
 - Smaller coarse aggregate
 - Cold pavement temperatures
 - Increase in joint or crack openings

Joint Spacing

- **Transverse Sawed Joints**
 - Joint efficiency important
 - For pavements 8 in or greater spacing should be 3 to 4 times (in ft) the pavement thickness (in inches)
 - < 8 in. spacing 15 to 20 ft.
- **Longitudinal Sawed Joints**
 - For pavements 8 in or greater spacing should be 2.5 times (in ft) the pavement thickness (in inches)
 - < 8 in. spacing 15 to 20 ft.
 - Maintain reasonably square joint pattern

Isolation and Expansion Joints

- Allow for differential horizontal and vertical movement
- Minimizes compressive stresses that develop between the pavement and structure
- Expansion joints should be considered for large areas of RCC placement. Spacing of these joints depends on thickness of the RCC, water and cement content and foundation restraint.

Section **6**

RCC PRODUCTION



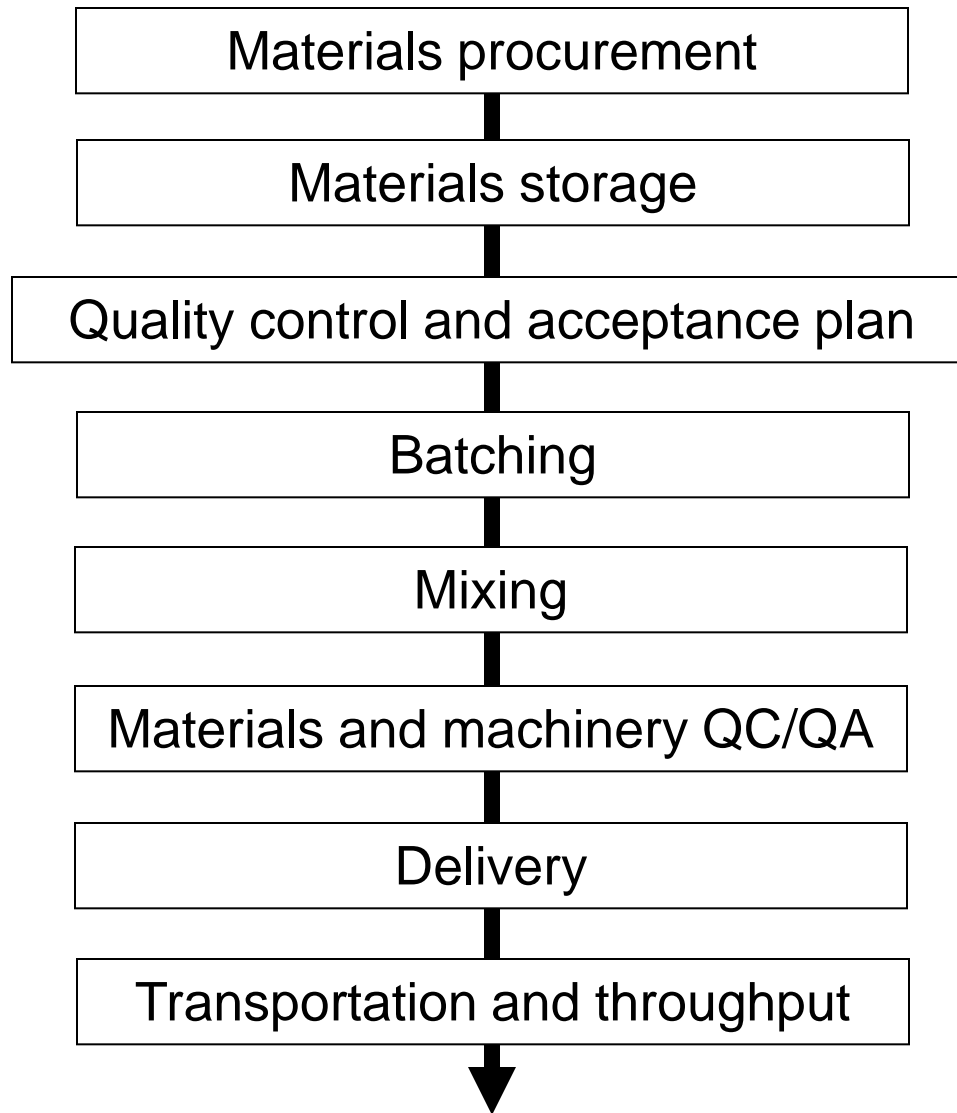
Section 6

RCC Production



- The Production of RCC involves the following processes:
 - Materials selection and source verification
 - Handling and storage of materials
 - Mixing
 - Batching and monitoring
 - Production planning
 - Transportation
 - Quality control

Flowchart of the RCC Process of Production



Preconstruction Testing

Table 6-1. SAMPLE QUALITY-CONTROL TESTS

(Comes from PCA's Roller Compacted Concrete Quality Control Guide –EB215, Table 4.1)

Material Tested	Test Procedure	Test Standards	Frequency
Water	Quality	ASTM C94 *CSA A23.1	Prior to construction or as required
Cement	Physical/Chemical Properties	ASTM C150 or equivalent CSA A3000	Manufacturer's certification or prequalified
Pozzolan	Physical/Chemical Properties	ASTM C618 or equivalent CSA A3000	Manufacturer's certification or prequalified
Admixtures	Chemical Properties	ASTM C494 ASTM C260 CSA A23.1	Manufacturer's certification
Aggregates *CSA – Canadian Standards Association	Quality	ASTM C33 CSA A23.1	At initial project start. 1/ week to 1/month thereafter depending on history with source.

RCC Mixing Plants

- The Two methods of mixing - Batch-type and Continuous Mixers
- Batch-type mixers
 - Consist of tilt or fixed drum and transit mixers (dry batch ready mix trucks)
 - Typically used for smaller projects
 - Mixer needs to be emptied completely after each mixing cycle
- Continuous mixers
 - Include pug mills and horizontal shaft mixing plants
 - Typically used for larger projects and produce RCC at a constant rate
 - Materials are continuously entered at one end as the freshly mixed RCC exits the other end



RCC Mixing Plants

- The choice of mixer should be made by the contractor/supplier based on:
 - Required performance specifications for a homogenous product
 - Size of the project
 - Equipment availability
 - Economics
 - Distance considerations
- The relatively dry RCC mixture requires rigorous mixing energies to provide a uniform mixture which can reduce the plant's mixing capacity



Batch Plant



- Tilt Drum Mixer
 - Capacity of the batch plant mixer is reduced to about 50% to 90% for RCC production
 - Due to the high mechanical stress on the equipment
 - Normal mixing volume is 5 to 9 cu. yd. per 10 cu. yd. capacity



Dry Batch Plant Transit Mixer



- (Ready Mix Trucks)
 - The mixing capacity is reduced by about 50% to 60% compared to conventional concrete
 - Normal mixing volume is 5-6 cu. yd. per 10 cu. yd. capacity load
 - Mixing time is approximately 1 min. per cubic yard
 - Discharge into a dump truck is about 1 min. per cubic yard

Dry Batch Plant Transit Mixer

- Highest local availability
- 2-step process
 - Feed into transit mixers
 - Discharge into dump trucks
- Reduced production
- Most Flexible - Allows producer to service other customers between batches of RCC



Continuous Flow Plant

- Materials are continuously fed into mixer at the same rate the RCC is discharged
- Typically used for larger RCC projects
- Usually non-tilting and have mixing chambers with screw-type blades rotating in the middle of the drum
- Mixing time is usually controlled by the slope of the drum, which is typically 15°
- Some volume of material (between 1 to 5 cu. yd. or more) might need to be wasted during the initial start-up
- Many continuous flow mixing plants can be stopped “midstream” and restarted at the same proportions



Pugmill Mixer

Type of Continuous Flow



- The aggregate is metered onto the main belt and conveyed to the pugmill where the water and cementitious materials are added
- Materials are added based on calculated feed rate in tons/hr. (250-500)
- Materials enter the pugmill at one end and are transported to the other end by a belt that moves through the mixing chamber with spinning paddles
- Total mix time generally ranges from about 10 to 30 seconds
- Mixing times cannot be adjusted for most continuous pugmills

Horizontal Shaft Mixer Type of Continuous Flow



Batching and Monitoring

- Accurate batching of materials is the basis of producing quality RCC mixtures
- Tolerances for batching should be in accordance with ASTM C94
- During start-up operations the mixing plant (batch or continuous) must be properly calibrated
- Calibration of each constituent should occur at the minimum, average, and maximum production rates expected for the project
- If the plant experiences a mechanical shutdown or there is an unexpected change in the properties of the RCC, re-calibration may be necessary

Specifications for Batching

- Similar to those of conventional concrete pavement
- For RCC the following points should be carefully considered:
 1. Ideally, the plant should be equipped with moisture sensors
 2. The aggregate bins should be designed to avoid segregation. Screens can also be placed for removing oversize aggregates
 3. Metering and feeding equipment should be synchronized to maintain accuracy in batching and mixing
 4. Aggregate scale calibration and accuracy should be verified frequently
 5. Aggregate should be moist or SSD

Section **7**

RCC CONSTRUCTION



Section 7

RCC Construction



- Construction of RCC pavement typically involves the following:
 - Batching and mixing
 - Subgrade and base course preparation
 - Transportation
 - Placement
 - Compaction
 - Joint construction
 - Curing and protection

Subgrade and Base Course Preparation



- Should be uniformly compacted to a minimum of 95% of the maximum dry density, in accordance with ASTM D 1557
- Must be able to support and be stiff enough to allow for compaction of the RCC pavement
- Any unsuitable soil or material should be removed and replaced
- Adequate smoothness is a requirement for pavements that have relatively tight smoothness tolerances
- Must be uniformly moist at the time of RCC placement

Transporting RCC



- RCC mix is typically transported to the job site in dump trucks
- Because of the very dry consistency of RCC, fluidizing admixtures are sometimes used when hauling in transit mixers
- The Fleet capacity and configuration should be determined by:
 - Mixer throughput
 - Hauling distance
 - Paving plant capacity
 - Climate
 - Time (day/night) of paving

Transporting RCC



- Dump trucks should be kept clean by frequent washing
- RCC should be covered with tarps or other suitable coverings in order to avoid excessive moisture loss
- Mixture should be kept slightly above the optimum moisture content (OMC) in order to accommodate water loss during transportation

Trial Construction (Test Strips)



- Depending on the experience of the contractor and size of the project, test strips can be used to:
 - Validate the design
 - Method of construction
 - Curing process
 - Joint construction
 - Field and laboratory testing of RCC

Placement



- When RCC is placed with an asphalt paver sometimes modifications to the paver are necessary to accommodate relatively large amount of material moving through the paver
- Modifications may include:
 - Enlarging the gates between the feed hopper and screed
 - Adjusting the spreading screws in front of the screed to ensure concrete is spread uniformly across the width of the paving lane



Placement



- Paver should be able to place RCC to at least 80% of the wet density across the entire paving width before rolling begins
- Paver should have enough RCC paving capacity to place at least 1.5 times the mixer's nominal production capacity
- To prevent segregation during placement:
 - Paver hopper should never be completely emptied
 - Sides of the hopper never be raised
 - RCC should always cover the feed auger shaft

Placement



- RCC placement operations should meet surface uniformity and lift thickness requirements
- Paver is usually equipped with automatic grade-control devices, such as a traveling ski or electronic stringline grade control device
- Stringline maybe used to improve or enhance pavement smoothness when used on both sides of the screed for the first lane
- On the outside edge on subsequent lanes using the finished edge as the guide on the other side

Placement



- Pavers are typically equipped with vibratory screeds to provide some initial external compaction
- Field experience shows a typical is a 10% to 25% difference between the thickness placed by the paver and its thickness after compaction
- Typically conventional asphalt machines are used for lifts that are 6 in. thick
- High density asphalt paving machines have been used successfully for pavements up to 10 in. thick

Placement



- If more than one lift is required to provide the design thickness:
 - Current practice is to place two lifts of equal thickness
 - Top lift should be placed within 60 minutes of the lower lift to allow for adequate bonding between layers
- If the top lift is placed more than 60 minutes after the bottom lift
 - Layers are generally considered to be only partially bonded
 - Results in a loss of structural capacity
- Full bond between the layers may be more easily achieved by applying a thin layer of high-slump mortar or grout just prior to placement of the upper lift

Compaction



- Compact to 98% modified Proctor
- RCC is usually compacted with a 10-ton dual-drum vibratory roller immediately after placement
- Rubber-tired rollers used
 - Final pass to remove surface cracks and tears
 - Provide a smooth tight surface
- In tight areas such as adjacent to forms, plate or hand compactors are most suitable

Compaction



- If the RCC is too dry for compaction:
 - surface will appear dusty or grainy and may even shear (tear) horizontally
 - Aggregate segregation is likely to occur
 - Density will be difficult to obtain, especially in the lower lift
- If the RCC is too wet for compaction:
 - surface will appear shiny and pasty
 - RCC will exhibit “pumping” behavior under the roller and even under foot traffic

Compaction



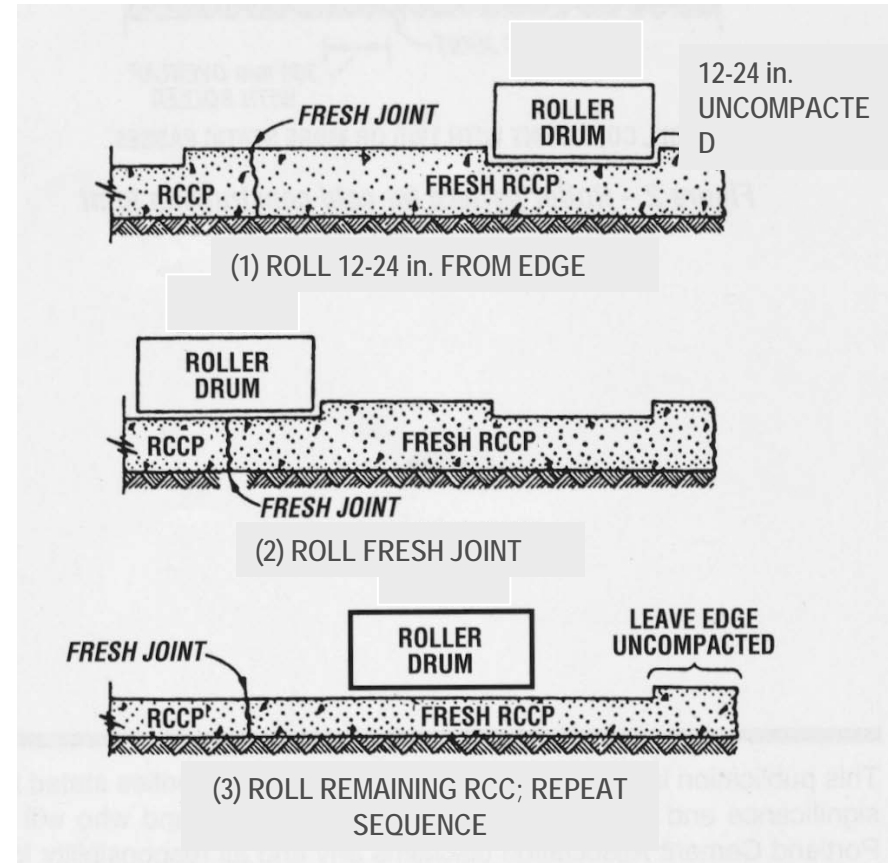
- Typically, compaction should be completed:
 - Within 15 min of spreading
 - 45 min of initial mixing
- Each RCC mixture will have its own characteristic behavior for compaction depending on:
 - Admixtures
 - Temperature
 - Humidity
 - Wind
 - Plasticity of fine aggregates
 - Overall grading, and NMSA

Compaction

- Typically, four to six passes of a dual-drum 10-ton vibratory roller will achieve the desired density of at least 98% for RCC lifts in the range of 6-10 inches
- Over compaction or excessive rolling should be avoided
 - May reduce the density of the upper portion of the lift
- Vibratory passes should be done with care, especially at the edges and end strips, since excessive vibration can lead to edge collapse

Fresh Joints

- Joint formed between adjacent paver lanes placed and then compacted within 1 hour (+/-)
 - Do not roll to edge
 - Leave 12 to 18 inches uncompact on first lane
 - Compact after second lane placed

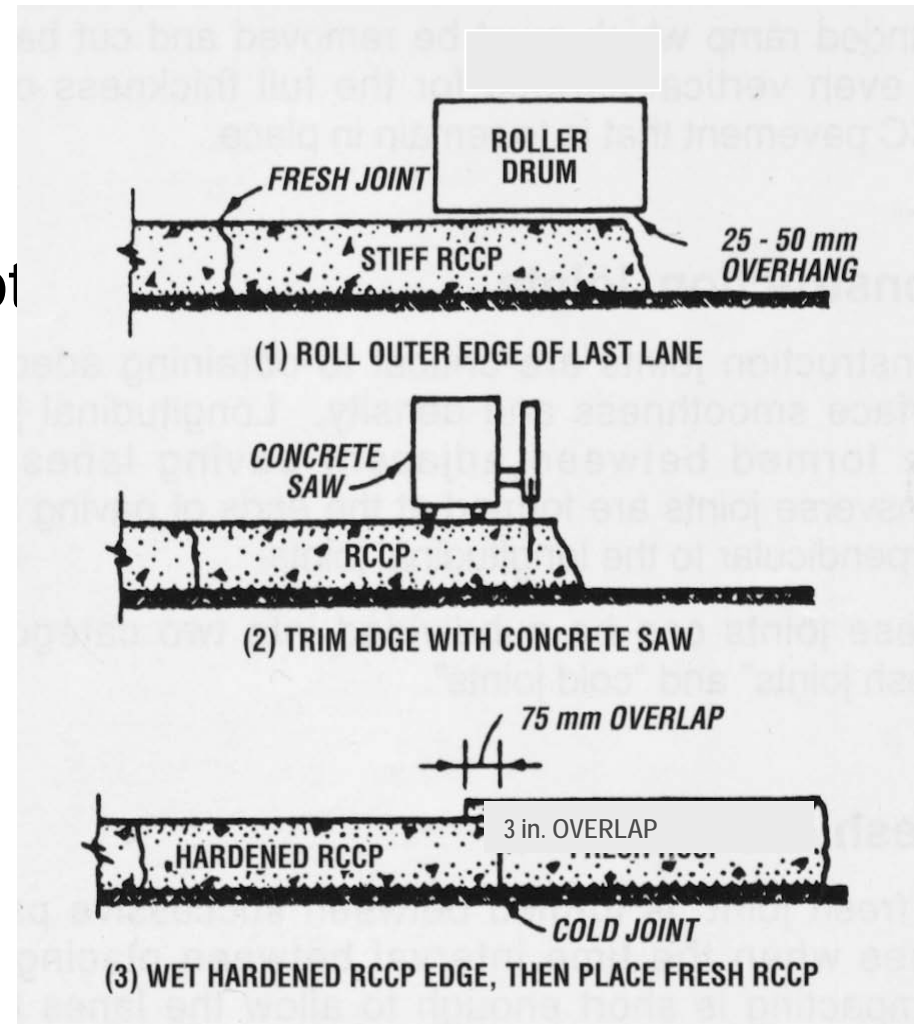


Fresh Joint



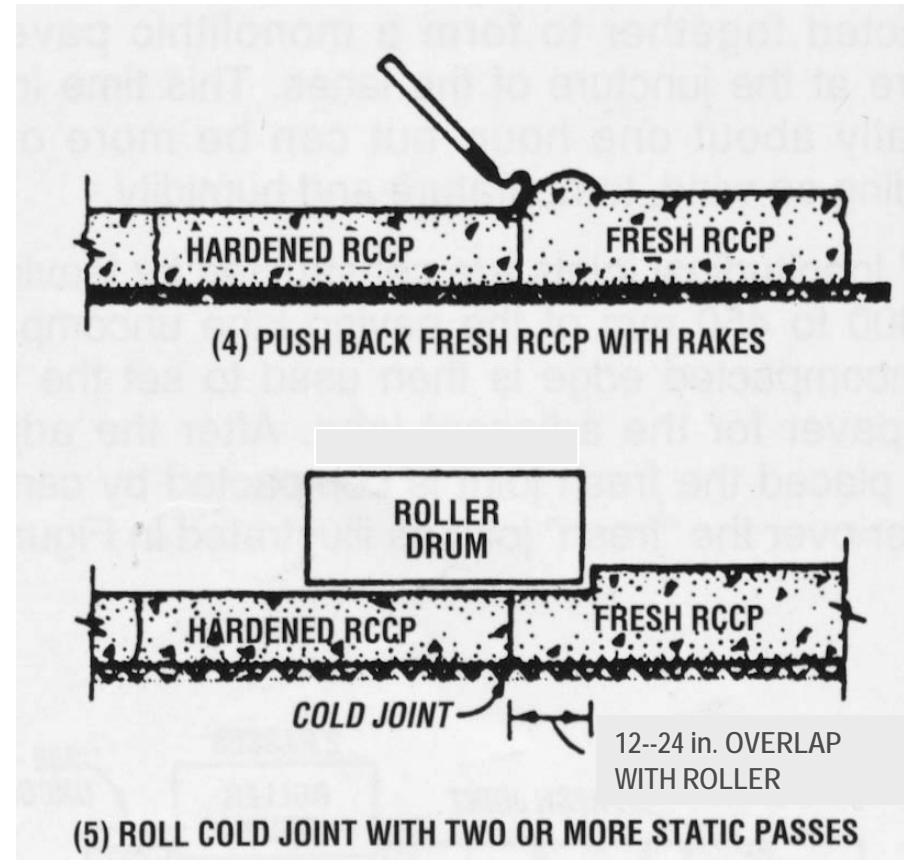
Cold Joints

- Joint formed between adjacent paver lanes after one hour (+/-)
- First lane hardened, cannot be compacted
 - Roll to edge
 - Trim edge with saw
 - Wet edge, place fresh RCC



Cold Joints (continued)

- Push back overlap with rakes
- Roll cold joint



Jointing

- Primary reason is to reduce or prevent random cracking
 - Typical crack at 20 to 60 ft spacing depending on thickness
 - Can improve load transfer across the joint by minimizing crack openings
- Square jointing patterns in large storage areas



Jointing

- Transverse sawed joints:
 - 20 ft spacing less 8" thick RCC
 - 3 to 4 times RCC thickness in inches for 8" or greater RCC (ft)
- Longitudinal sawed joints:
 - 20 ft spacing less than 8" thick RCC
 - 2.5 times the RCC thickness in inches for 8" or greater RCC (ft)



Curing

- Curing begins immediately after final compaction
- Extremely important - ensures surface durability
- Remember – RCC is low in moisture to begin with
- Three commonly used curing methods:
 - Moist cure
 - Concrete curing compound
 - Asphalt emulsion



THANK YOU!

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