Roller Compacted Concrete Pavement

- Mix Design & Construction

AGENDA

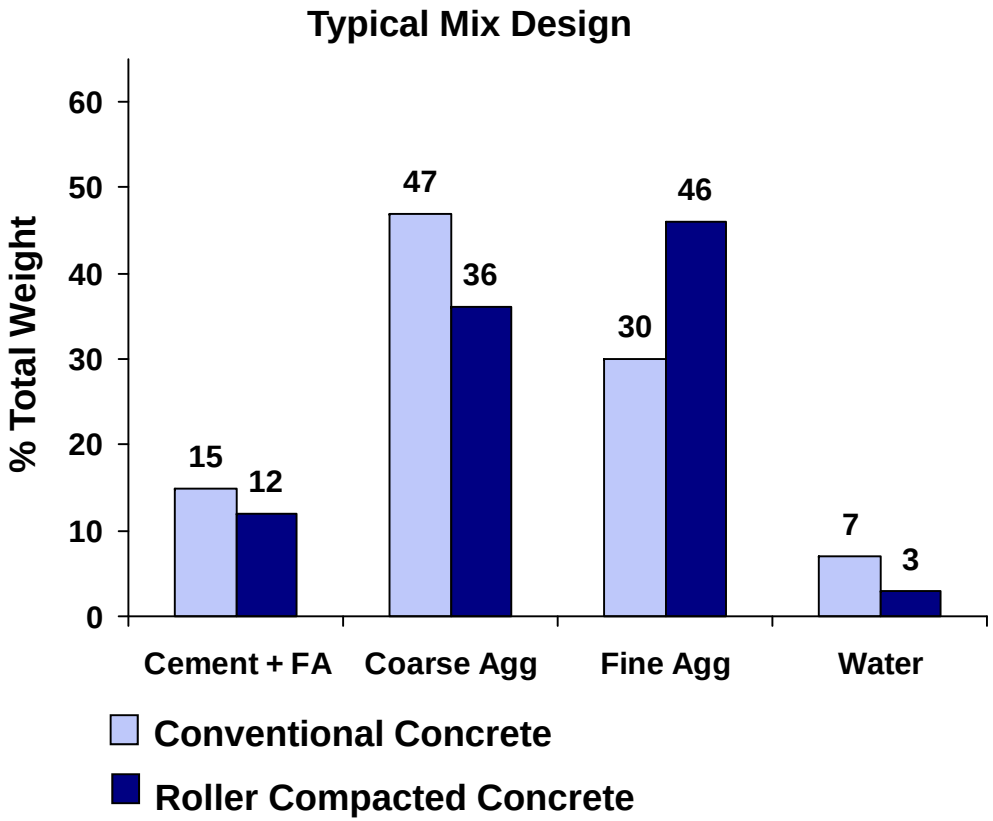
- **RCC Mix Design**
- **RCC Mix Production**
- **RCC Construction Process**

THE FINAL SURFACE TYPE WILL DICTATE THE NECESSARY TECHNIQUES & EQUIPMENT NEEDED TO BE SUCCESSFUL

	Natural RCC	Diamond Ground RCC	Asphalt
			
Applications	• Ports • Distribution centers • Industrial yards • Residential roads • Parking lots	• Collector / Arterial local roads • Highway Shoulders • State routes	• Any pavement type
Factors	• Lowest Cost • Most sensitive to contractor skill level • Least smooth • “Asphalt” appearance	• Medium cost increase • Increased construction time • Improved smoothness, skid resistance • Reduced noise	• Highest cost • Increased construction time • Least sensitive to contractor skill level • Improved smoothness, skid resistance

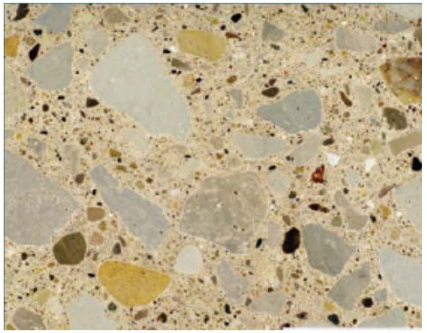
RCC MIX DESIGN USES SAME MATERIALS AS CONVENTIONAL CONCRETE, HOWEVER IN DIFFERENT COMBINATIONS

Achieves Similar or Better Engineering Properties Than Conventional Concrete



Typical Engineering Properties	Conventional (psi)	RCC (psi)
Compressive Strength	3,000 - 5,000	4,000 - 10,000
Flexural Strength (MOR)	500 – 700	500 - 1,000
Elastic Modulus	3.0 – 5.0 million	3.0 – 5.5 million

Conventional Concrete

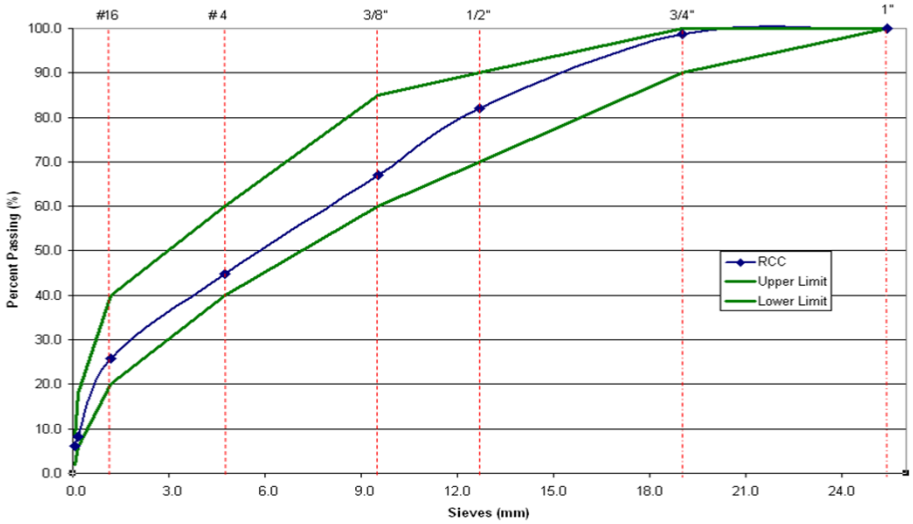


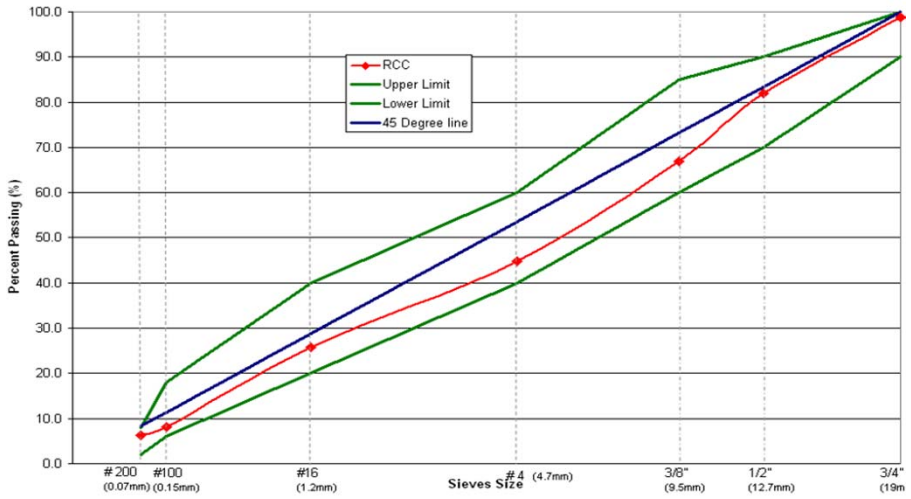
RCC

MIXTURE DESIGN PROCEDURE

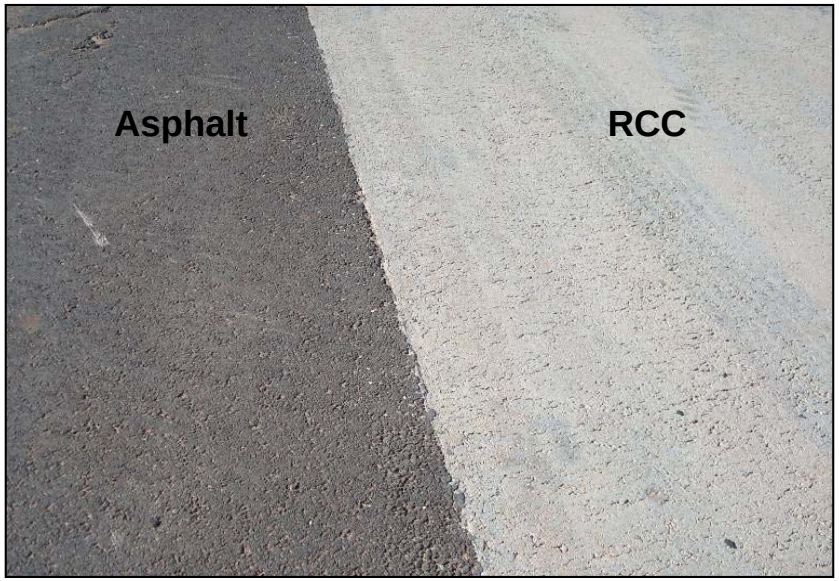
Step 1: Chose well – graded aggregates

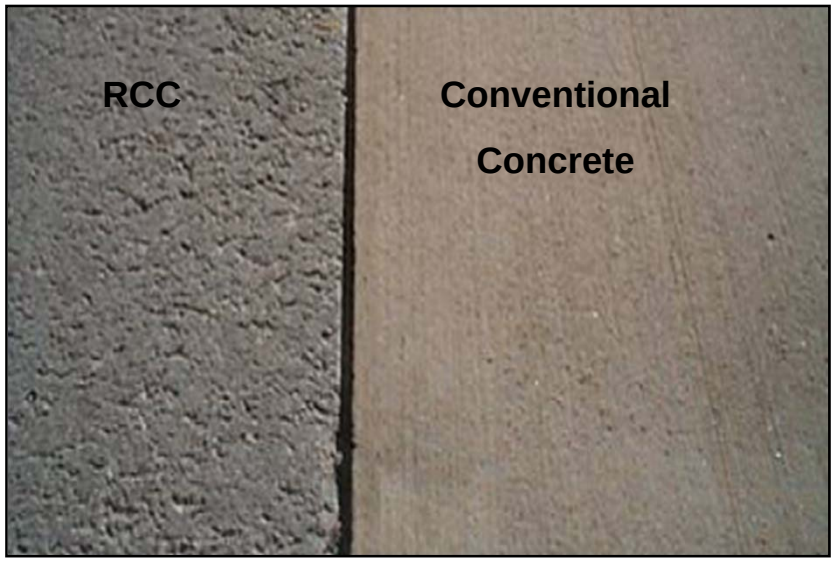
- **Selection based on gradation test results of available aggregates**
- **Multiple aggregates may be evaluated**
- **Quantity of aggregate sources depends on mixing equipment being utilized (Central mix, pugmill, etc)**
- **Avoid gaps in gradation**
- **Finer mixes (above the 45º line) are easier to achieve density at or slightly above optimum moisture**
  - **When paved at or near optimum moisture, the ride is improved**
  - **Can tolerate isolated increases in moisture content without loosing ride**
- **Coarse mixes are very sensitive to moisture increases**





THE SURFACE TEXTURE OF RCC IS SIMILAR TO ASPHALT PAVEMENT WHILE THE COLOR IS SIMILAR TO CONCRETE





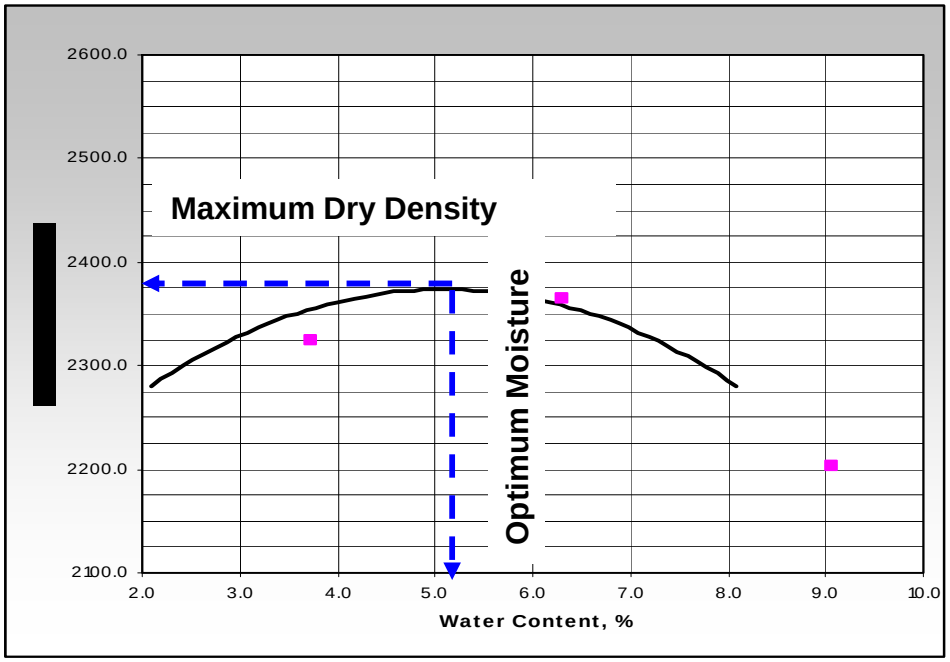
MIXTURE DESIGN PROCEDURE

Step 2: Select a mid – range cementitious content

- **Minimum 450 lbs cement / CY**
- **12% Type I Portland cement is selected for the first trial batch**
- **Based % on weight, so make enough and do not worry about volumes yet**
- **Mix the cement dry, and then add water**

- ***Step 3: Develop moisture – density relationship plots***
- **Perform a modified Proctor test at the selected cement content**
- **Construct moisture-density relationship curve (Use spreadsheet)**
- **Determine Maximum Dry Density (MDD) and Optimum Moisture Content (OMC)**

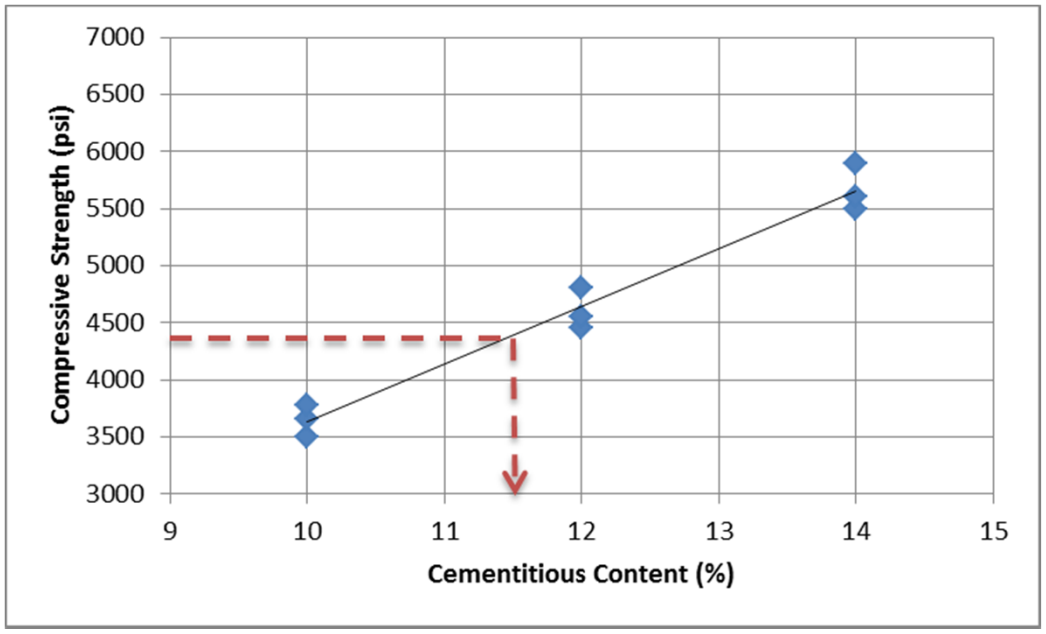
(ASTM D1557)



MIXTURE DESIGN PROCEDURE

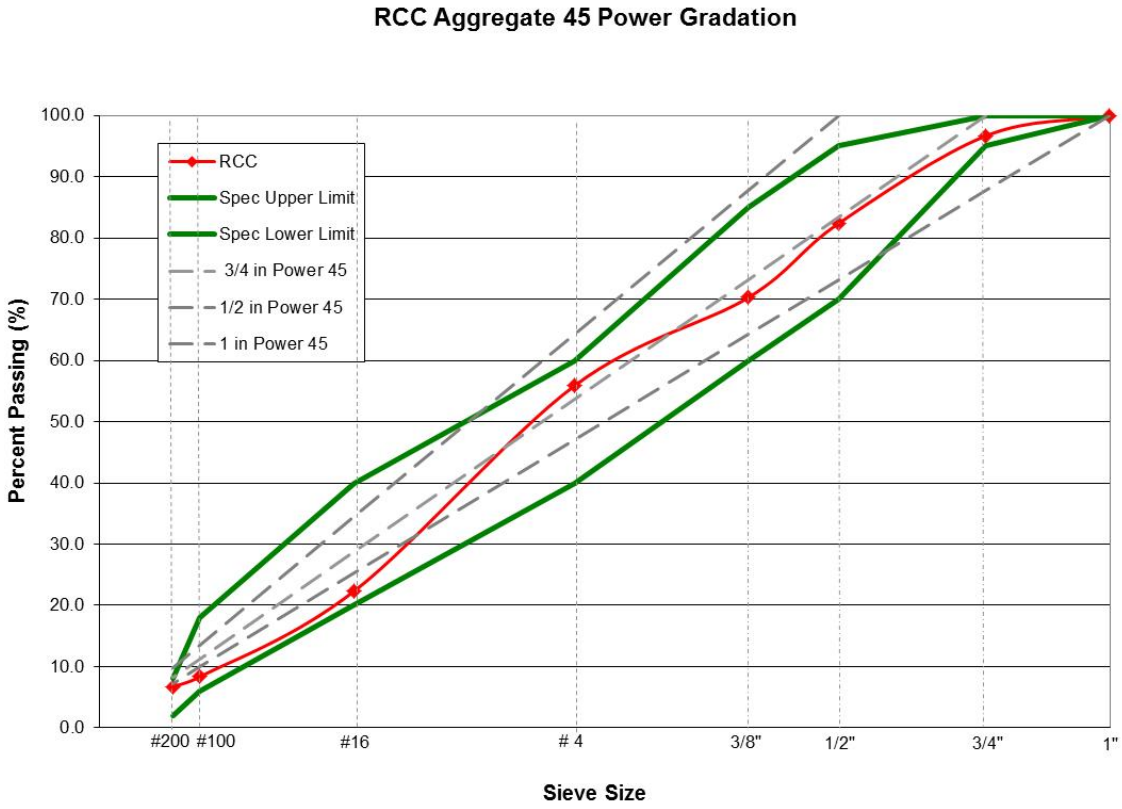
Step 4: Cast samples to measure compressive strength (ASTM C 1435)

- **Calculate trial mix proportions**
- **Batch RCC materials**
  - **Maintain percent Optimum Moisture Content as determined in step 3**
  - **Use varying cementitious contents such as 10, 12 and 14 percent**
- **Make compressive strength test cylinders for each cement content**



MIXTURE DESIGN LTRC ACCELERATED LOAD FACILITY

Mix Quantities	
Max Dry Density (lbs/CF)	146.0
Max Wet Density (lbs/CF)	155.5
Optimum % Moisture	6.5%
Coarse Aggregate absorption %	0.2%
Fine Aggregate absorption %	2.1%
Aggregate #3 absorption %	0.0%
Coarse Aggregate Moisture %	1.3%
Fine Aggregate Moisture %	4.5%
Aggregate #3 Moisture %	0.0%
% Cementitious	11.4%
% Cement	11.4%
% Fly Ash (of cement replace)	0.0%
Target Coarse Aggregate %	45
Target Fine Aggregate%	55
Target Aggregate #3 %	0



Batch Size (CF)	27	Soil Mechanics		
Ingredient	**Batch Weight (lbs/CY)**	**Specific Gravity (Apparent)**	**Absolute Volume (CF)**	
Cement	450	3.150	2.289	
Fly Ash	0	2.910	0.000	
Coarse Aggregate	1571	2.750	9.157	
Fine Aggregate	1921	2.760	11.152	
Aggregate #3	0	2.650	0.000	
Total Water content (lbs)	256	1.000	4.106	

AGENDA

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FACTORS TO CONSIDER DURING MIX PRODUCTION

1. **Moisture control ……Moisture control……Moisture control!**
   - **0.5 gallon = 0.1% moisture**
   - **Before production begins, measure moisture in stockpile**
   - **Measure moisture in mixture continuously with stove, reduce as project proceeds**
   - **Maintain stockpile moisture content consistent – build stockpiles early**
   - **Consume the stockpile in a consistent manner**

FACTORS TO CONSIDER DURING MIX PRODUCTION

2. Avoid aggregate segregation

- **Aggregate selection (smaller top size, multiple sizes)**
- **Stockpile management**
- **Loader operator**
- **Gob hopper**
- **Delivering mix to paver**
- **Placement techniques**

FACTORS TO CONSIDER DURING MIX PRODUCTION

3. Consistent production rate to meet paver demand –

- **Primary factor in plant type selection**
- **paver needs to keep moving as smoothness, compaction are negatively impacted when paver stops**
- **Ensure cement delivery is planned, cement pigs when needed**
- **Use extra aggregate bins if needed**

Width (ft)	Depth (in)	Speed (ft / min)	Production Rate (CY / HR)
12	7	6	94
12	8	7	124
20	7	6	130
30	7.5	5	175

FACTORS TO CONSIDER DURING MIX PRODUCTION

1. **Adequate number of trucks for consistent mix delivery to paver**
2. **Plant location should be within 30 minutes of paving location (without admixtures), with admixtures no more than 1 hour.**

CENTRAL MIX TILT DRUM

Advantage	Disadvantage
• Moderately available in most locations • Minimal investment to start business • Good for demonstrations & smaller applications • Have moisture sensors in sand, but may not be accurate enough • Weigh based, ticket produced • Easy to incorporate admixtures, fly ash	• Slow production - 30 to 90 CY/hr • Poor to average mix & moisture consistency • Small batch size, increased mix time • Limited mobility • Batch to batch moisture fluctuations can be high (+/- 0.4%)

TWIN SHAFT HORIZONTAL MIXER – BATCH TYPE

Advantage	Disadvantage
• Can be incorporated into ready mix business • Mobile – 1 or 2 loads, easily set up in 1 day • Reduced financial investment • Medium to high production rates: 50 to 220 CY / hr • Good mixing consistency • No permitting required • Easy to incorporate admixtures, fibers, etc • Can produce other products	• Mixing system only – requires a batching system • Plant must be dedicated to RCC • Requires generator • If RCC equipment breaks, then plant is shut down

HORIZONTAL TWIN SHAFT PUGMILL

Advantage	Disadvantage
• High production rates: 50 to 300+CY / hr • Excellent mixing efficiency for dry materials • Highly consistent mix properties, minimal moisture fluctuation – easy adjustment • Mobile – 1 load, easily erected on site & calibrated in 1 day • Self contained – Gen set, batch house • 2 to 3 man operation	• Largest investment • Need to find good location, obtain permits • Limited to 2 aggregate sizes without additional cold feed bins • Difficult to incorporate admixtures, fly ash

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FACTORS TO CONSIDER FOR PAVING

Consistent Mix Delivery to Paver

Mix Delivery

- 10 Wheel dump trucks - Cover loads
- Keep trucks clean
- Plan trucking route (traffic, truck staging)
- Avoid segregation in truck loading / unloading
- Avoid end of load segregation
- Consider using material transfer machine & insert hopper

Paver Operation

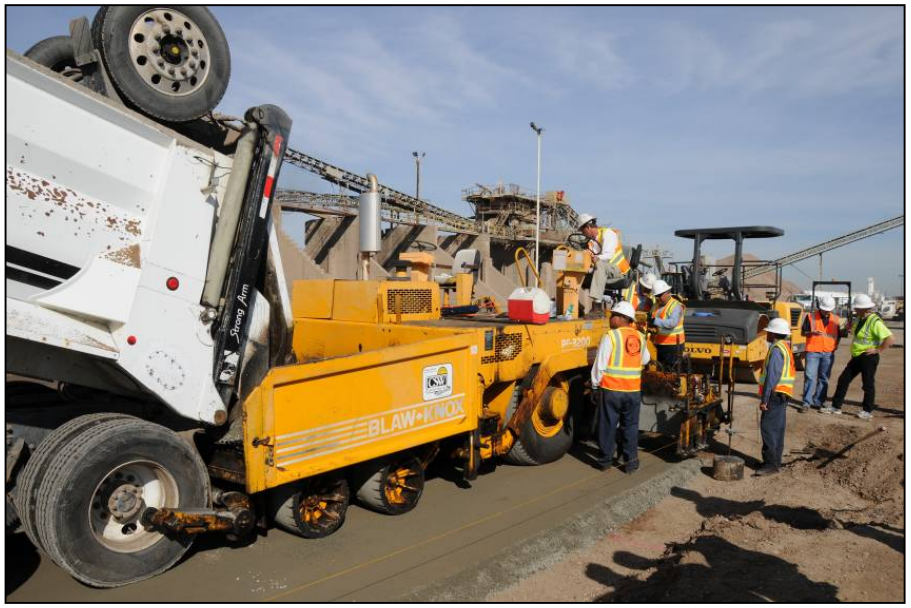
- Balance speed of paver with mix delivery
- Keep paver moving (material transfer machine)
- Keep head of material constant in hopper and screed
- Keep augers feeding material consistent
- Use grade control devices (string, big ski, etc)
- Don't pave over standing water

RCC IS PLACED WITH ASPHALT PAVERS

Achieving Density & Smoothness is Critical

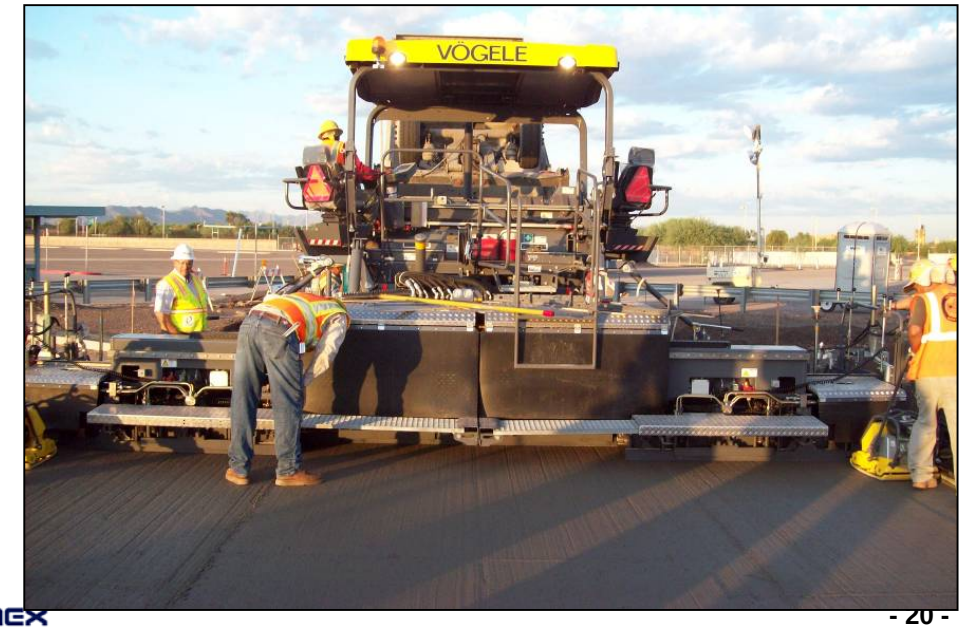
Standard Paver

- Low initial density from paver (80% - 85%)
- Available in all locations
- High-production (6 to 8 ft/min)
- Lift thick range: 4” to 6”
- Good when RCC topped with asphalt
- Requires more compaction to achieve density (grade control problems)
- Easier to fix segregated areas before compaction



High Density Paver

- High density screed (Vogele or ABG Titan)
- High initial density from paver (90% - 96%)
- Availability is increasing, but still limited
- Smoother surface due to higher initial density
- Less “roll down” to achieve final density
- High-production (6 to 8 ft/min)
- Lift thick range: 4” to 9”
- Strongly RECOMMENDED



ROLLERS ARE USED TO ACHIEVE DENSITY AND PROVIDE FINISH

Initial Compaction

- Initial: 10 - 12 ton static & vibratory roller
- Establish roll pattern (check density a lot!)
- Adjust roll pattern based on moisture content
- Compact to 98% density - wet
- Adjust moisture content if needed – impacts smoothness & compaction
- 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

LONGITUDINAL JOINTS CAN BE BUILT 3 DIFFERENT WAYS

Vertical Cold Joint

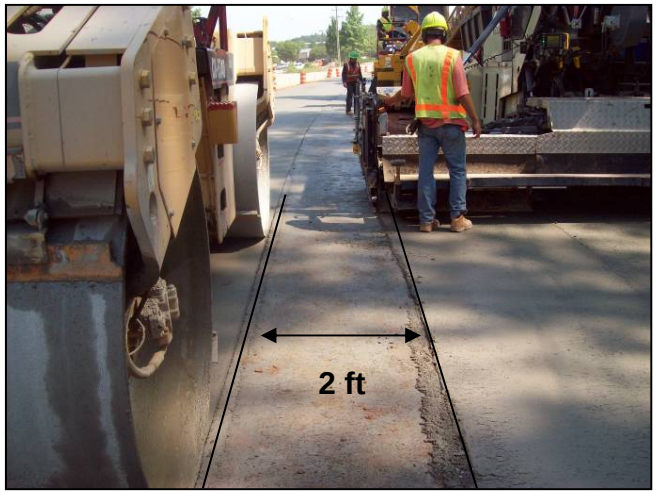
- Pave width of lane
- Saw cut full depth early next morning
- Remove with blade & loader
- Expect waste
  - Reduce waste with paver shoe & plate tamper
- Pave adjacent lane and match thickness of existing lane
- Good performance, limited load transfer

Angular Cold Joint

- Need high density paver
- Attach shoe to screed
- Maximum angle 15º
- Use plate tamper to improve edge durability
- No saw cutting required
- Pave adjacent lane next day
- Lowest cost

Fresh (Hot) Joints

- Pave for 50 minutes then move back to beginning and match original lane
- Do not compact original lane within 2 ft of edge until adjacent lane is paved
- Recommend a longitudinal saw cut
- Use small loader to create fresh vertical transverse joint
- Move quickly – keep moist!
- Coordination is key, avoid breakdowns



MANHOLES & CURBS ARE EASILY INCORPORATED INTO STREETS

Curb & Gutter

- Traditional curb & gutter placed before RCC
  - Serves as compaction aid
  - Joint may need to be sealed
- Alternatively, ribbon curb can be placed
  - Drill & grout rebar into cold RCC
  - Place ribbon curb afterwards

Manholes, Inlets

- Plywood plate is placed on top of hole before RCC is placed
- After paving, two methods are available:
  - Dig RCC immediately while fresh, place manhole and re - compact material with hand tampers
  - Saw cut hardened RCC, place manhole, tie in with conventional concrete

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

Moisture & Density

- Tested with nuclear gage in direct mode
- Test density behind paver & after roller to establish rolling patterns to achieve density
- Achieve 98% of modified proctor wet density
- Nuclear gage gives general moisture fluctuation indication - Calibrate with oven dried moisture
- Oven dried is most accurate

Compressive Strength

- Cylinders prepared with vibratory hammer according to ASTM C1435
  - 3 to 4 cylinders per set
  - Strength timing often depends on traffic opening (1, 3, 7, 28 days)
- Cores can be obtained where density is not being achieved

WHEN CURED & SAW CUT RCC PERFORMANCE IMPROVES

Curing

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

Saw Cut & Fill Joints

- More aesthetically pleasing
- Early entry saw very effective, shortly following placement
- Recommend sawing within 2 - 6 hours to avoid uncontrolled cracking
- Depth: 1” to 2”
- Spacing: Maximum 36 times thickness

Questions?

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