CONCRETE
2019

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2019

The 19th Annual Concrete Conference

"Concrete Solutions for the Maryland Transportation Industry"

"Changing the Mindset"

Delta Hotels by Marriott – Hunt Valley, Maryland
March 12, 2019

Tech Center

QUALITY CONSTRUCTION PRACTICES FOR TODAY'S CONCRETE PAVEMENTS

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National Concrete Pavement Technology Center

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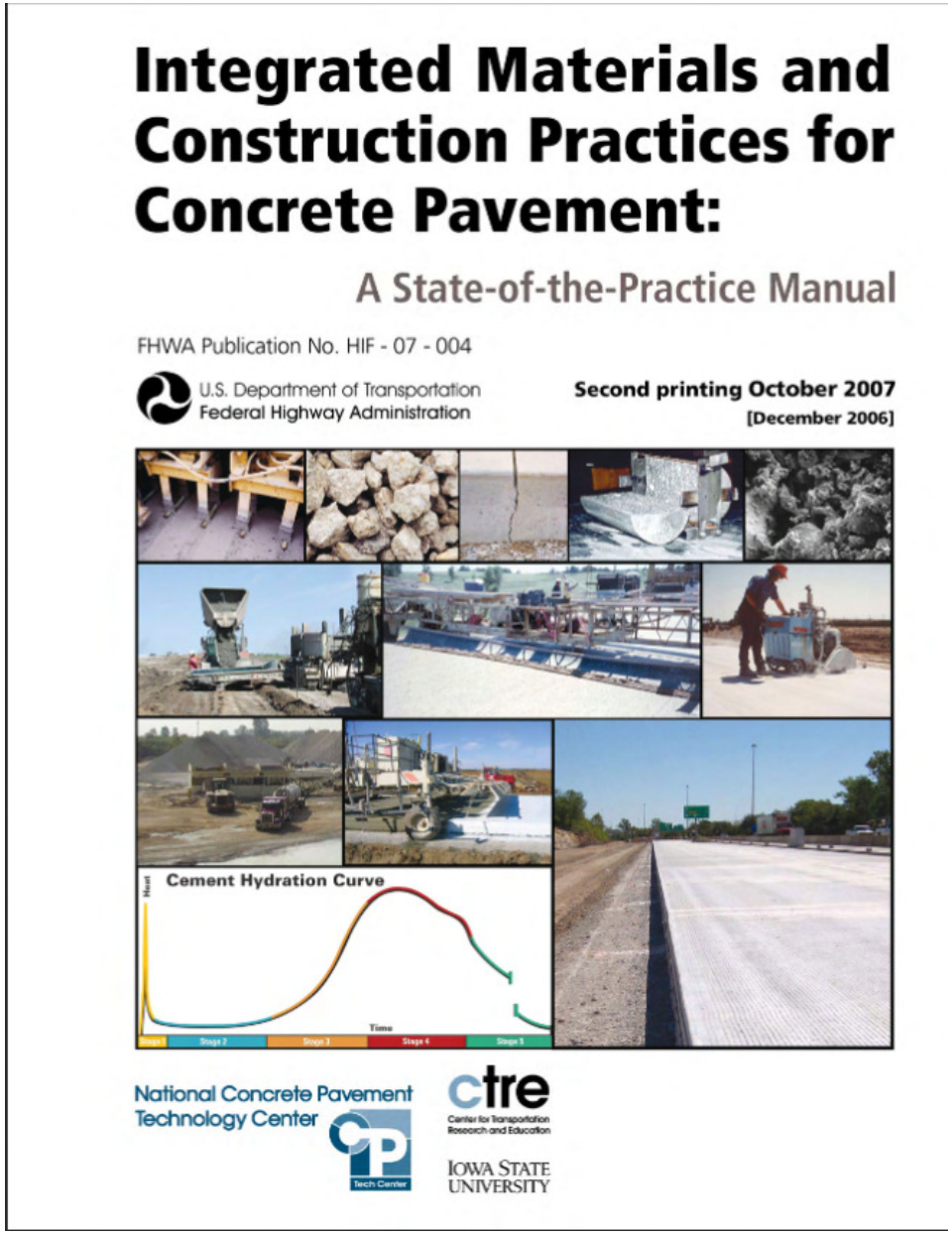
Coming soon:

IMCP Manual
Edition 2



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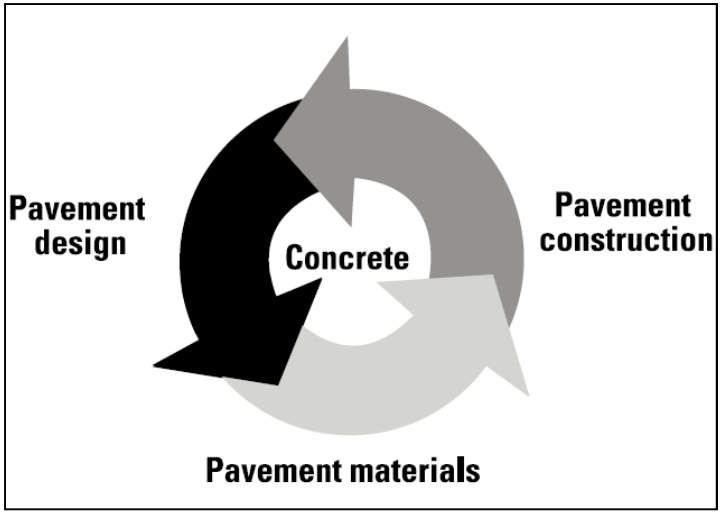
Keys to Quality Concrete Pavement

- Adequate pavement design
- Appropriate mix design
- Quality materials
- Good construction practices

What's This All About?

- Concrete pavement is an integrated system

- How to optimize the performance
  - Structural & Functional Design
  - Quality of Materials
  - Construction factors (weather, equipment, personnel)



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Concrete Pavement Basics – What do we want in a pavement?

- The Owner wants:
  - Cost Effective/Reliable
  - Low Maintenance
  - Durability
- The Contractor wants:
  - Workability
  - Constructibility
- The Public wants:
  - Safety
  - Rideability

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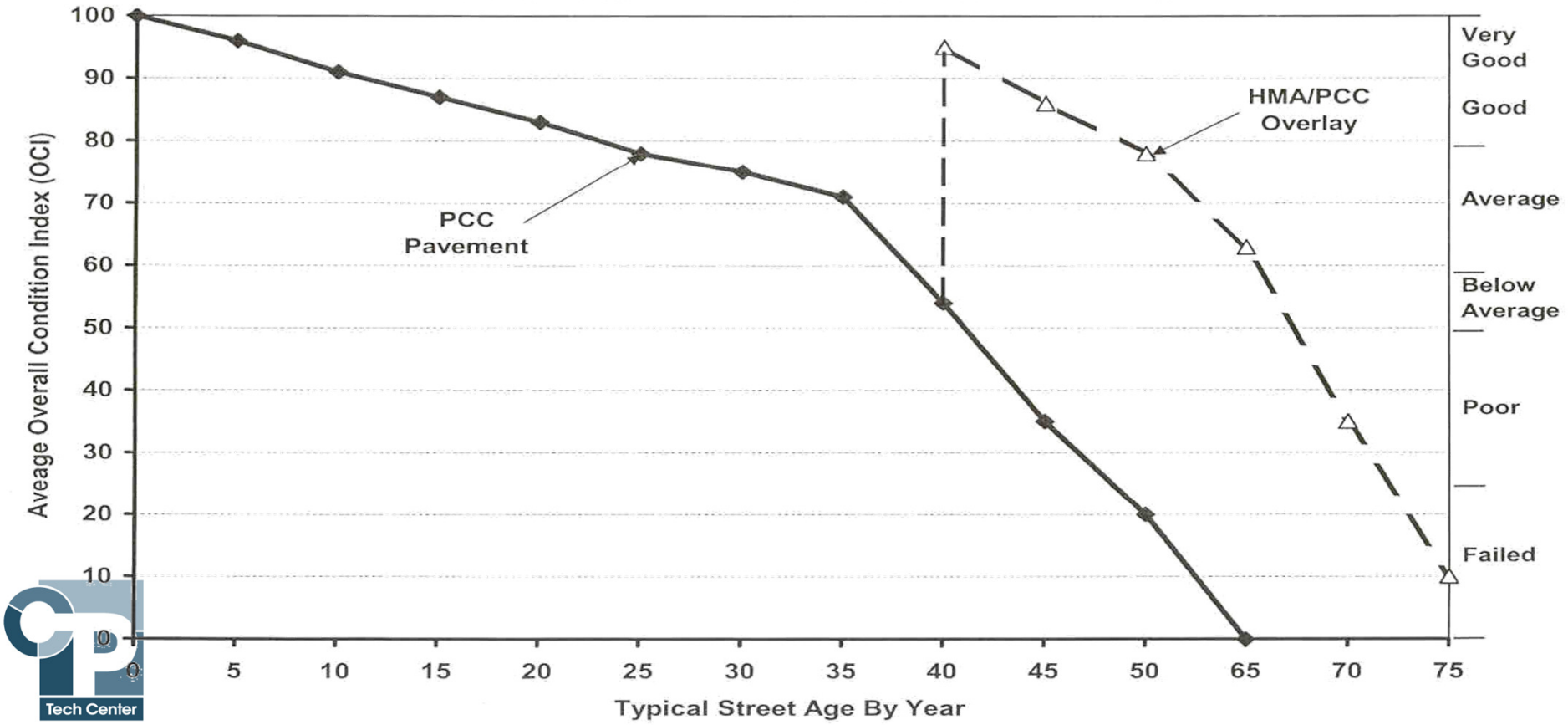
Performance

Figure 8

West Des Moines PCC Pavement and HMA/PCC Perfomance Curves

(Based on Typical Street Conditions Up to the First Overlay)



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What Causes Concrete Distress?

- Inadequate Design and Construction
- Overload / Fatigue
  - Thickness
- Poor Support & Drainage
- High Permeability- Chemical Attack
  - Soft Water / Acid
  - Sulfates
  - De-icing Salts
- Freeze Thaw Cycling

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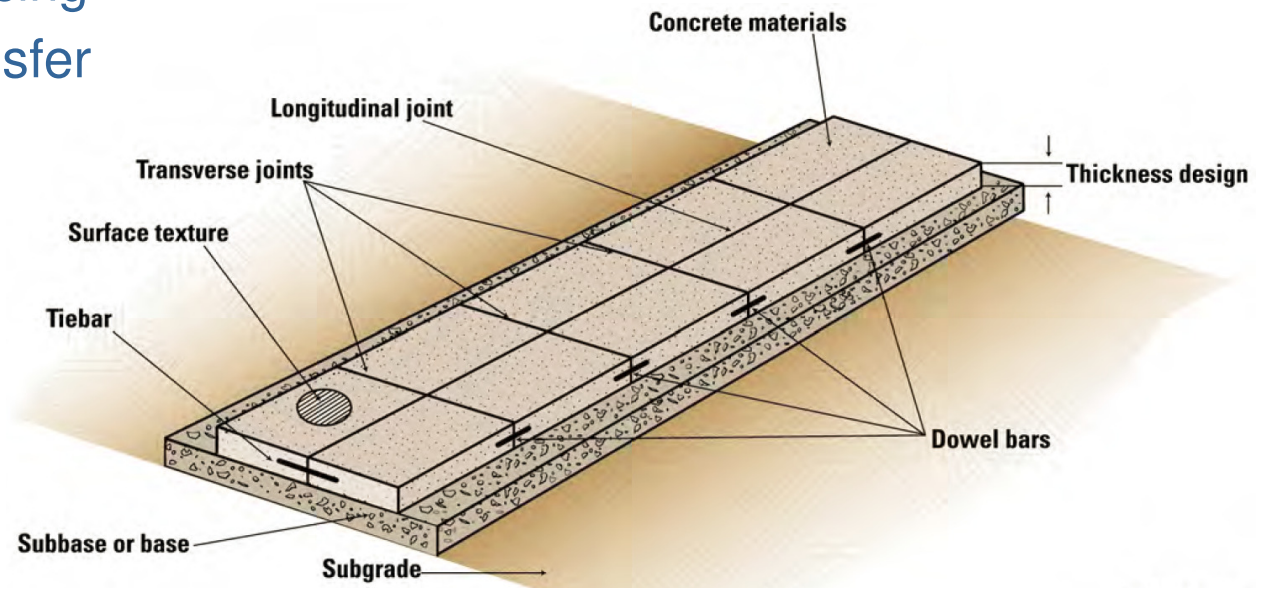
Keys to Quality Concrete Pavement

- **Adequate pavement design**
- Appropriate mix design
- Quality materials
- Good construction practices

Pavement Elements

Select parameters that economically meet needs of project

- Support system
- Environment
- Materials
- Thickness
- Joint spacing
- Load transfer



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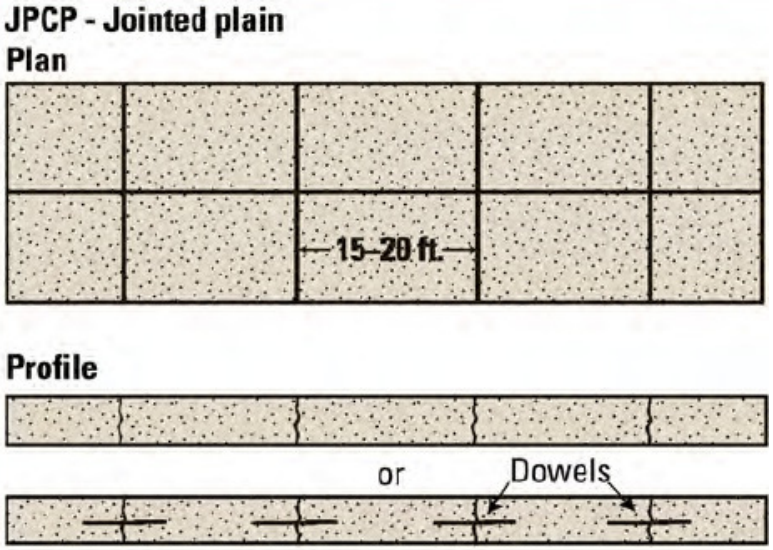
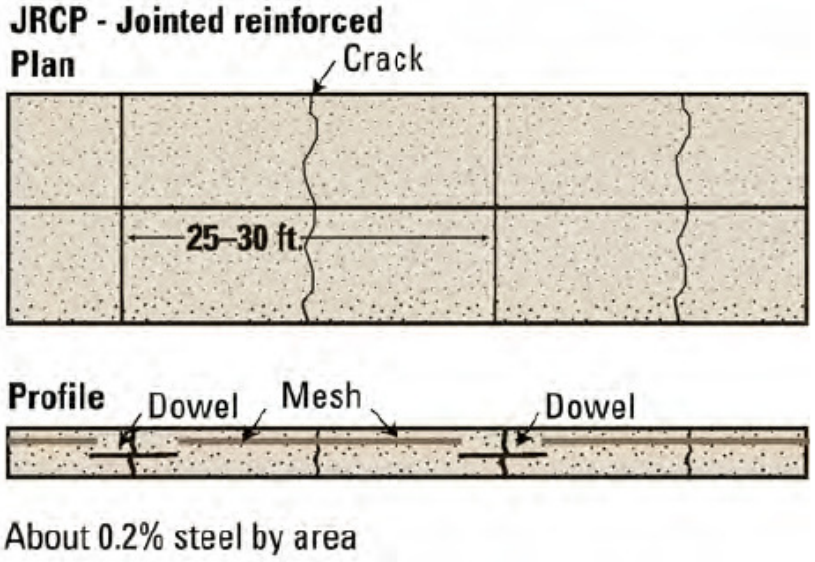
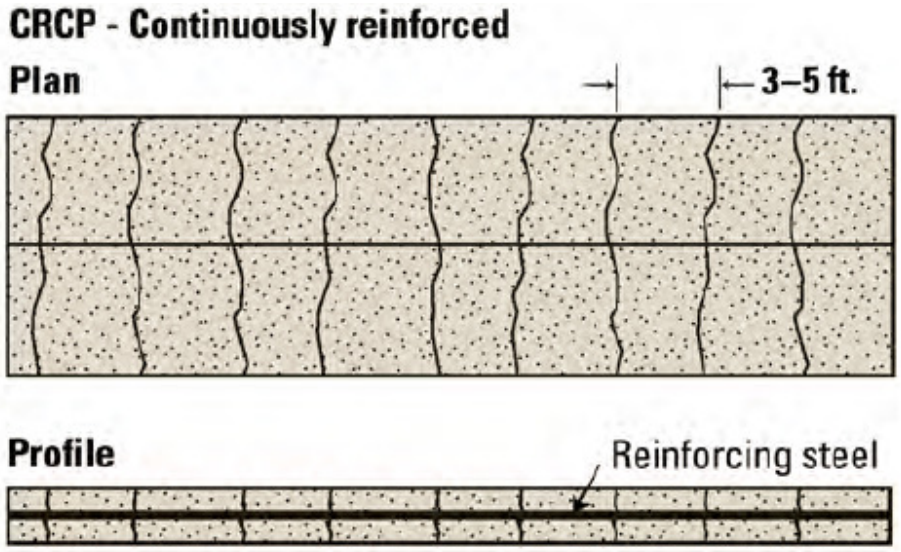
Concrete Pavement Types

- Jointed Plain (JPCP)
- Jointed Reinforced (JRCP)
- Continuously Reinforced (CRCP)





About 0.2% steel by area



PAVEMENT DESIGN

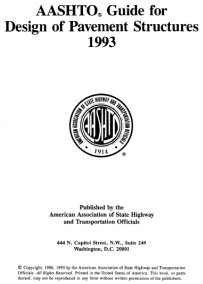
DARWin ME™
Mechanistic Empirical Pavement Design

AASHTOWare Pavement ME
(previously known as DARWin-ME and MEPDG)

ACPA
StreetPave 12
Structural Design Software for Street and Road Concrete Pavements

ACPA StreetPave

aci™
325 & 330



AASHTO 93
(software as ACPA WinPAS)

PavementDesigner.org

WinPAS 12

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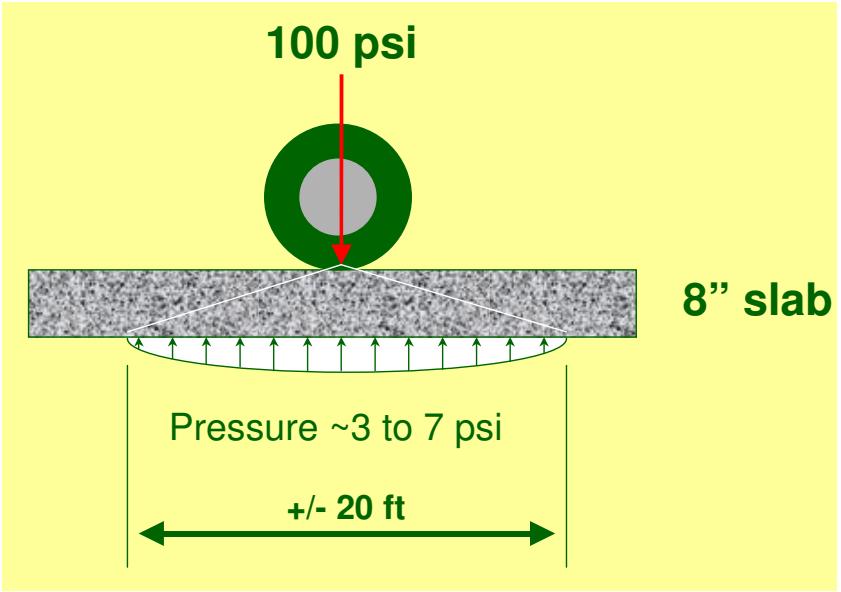
What is Important – Strength or Uniformity of Subgrade?

- PCC pavements are rigid
- Vehicle loads are distributed over large areas (beam strength) (15-20 ft)
  - Minor deflections
  - Low subgrade pressures
- Subgrade uniformity is more important than strength



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Achieving Quality Subgrade

- Achieving uniform subgrade support is one of the most important and most difficult problems facing the paving industry today:
  - Inherent variability of soils
  - Influences from water
  - Influences from temperature
  - Influences of construction activities
  - Abrupt changes in soil type, moisture content, and density

Subbases for PCC Pavements

- Under most conditions, at least one subbase/base layer is needed for optimum pavement performance
- Typical subbase materials:
  - Crushed concrete
  - Crushed limestone
  - Mixture of gravel, sand, soil
  - Stabilized material

Purpose of Subbases Under Concrete Pavements

- Maintain uniform support
- Protect subgrade from deformation from traffic loading
- Assure stable construction platform
- Provide adequate drainage from water infiltration
- Prevent excessive shrink and swell of high volume-change soils
- Help control excessive or differential frost heave
- Minimize mud-pumping of fine-grained soils
- Prevent consolidation of subgrade

Subbases - Long Term Performance

No Granular Subbase

With Granular Subbase

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Pavements within 2 blocks of each other

Keys to Quality Concrete Pavement

- Adequate pavement design
- **Appropriate mix design**
- Quality materials
- Good construction practices

MIXES AND MATERIALS

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How we proportion to achieve design goals?

		Workability	Transport	Strength	Cold weather	Shrinkage	Aggregate stability
Aggregate System	Type, gradation	✓✓	-	-	-	-	✓✓
Paste quality	Air, w/cm, SCM type and dose	✓	✓✓	✓✓	✓✓	✓	✓
Paste quantity	Vp/Vv	✓	-	-	-	✓✓	-

Critical Properties of Concrete

Properties for a uniform concrete are constantly the same from batch to batch even though materials may vary

- Many factors:
  - Water content
  - Aggregates
  - Entrained Air
  - Time & Temperature
  - Cement
  - Supplemental Cementitious Material (SCM)
  - Admixtures

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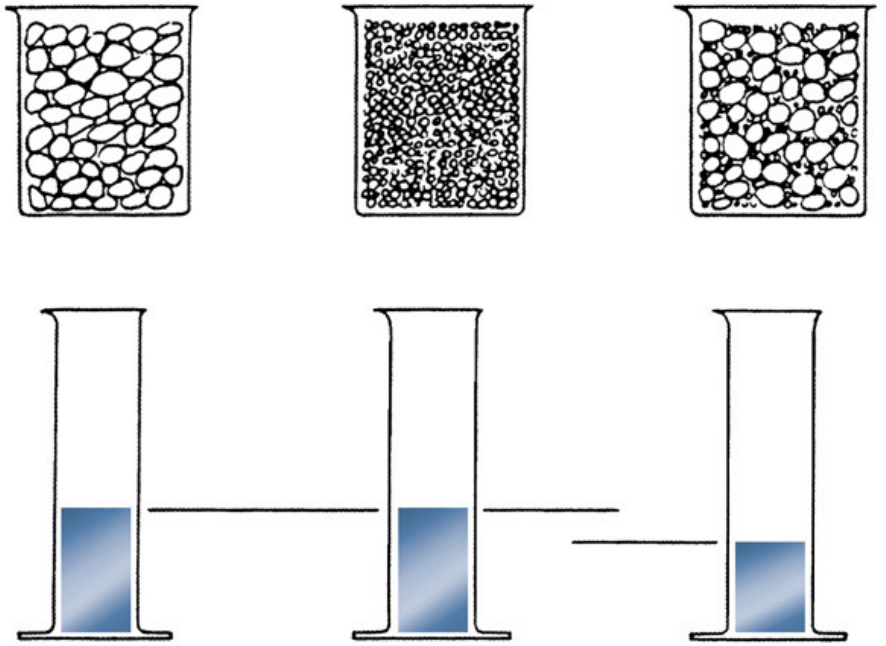
Keys to Quality Concrete Pavement

- Adequate pavement design
- Appropriate mix design
- **Quality materials**
- Good construction practices

Aggregate Gradation

- Concrete aggregate should be well-graded
- Control combined grading to increase amount of aggregate in the mix
  - Reduced paste (shrinkage, heat, cost)

Aggregate is inexpensive and a good filler



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Effects of SCMs on Fresh Concrete

- Reduce water requirement
- Reduce heat
- Retard setting
- Slow initial strength gain

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How Much SCM?

	% of total cementitious
• Class F fly ash:	15% - 25%
• Class C fly ash:	15% - 40%
• Slag:	25% - 50%

Too little – no benefit
Too much – slow setting, slow strength gain, cracking risk

Blended at the concrete batch plant,
blended at the cement plant or interground
at the cement plant

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Keys to Quality Concrete Pavement

- Adequate pavement design
- Appropriate mix design
- Quality materials
- **Good construction practices**

Concrete Pavement Construction

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Field Verification

- Test mixture properties (before and during construction)
- Use production equipment
- Preconstruction meeting
- Quality control plan

Concrete Production

- Setting up the plant
- Handling materials
- Stockpile management
- Batching
- Mixing concrete
- Delivering concrete
- Field adjustments

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Plant Checklist

Table 8-2. Concrete Plant Checklist

No.	Inspection item
1	Check foundations of stockpiles for proper separation and adequate drainage.
2	Check bins for adequate partitions to prevent intermingling of aggregates.
3	Check scales with test weights throughout range to be used.
4	Check scales for seals by approved agency.
5	Check water meter for accuracy.
6	Check for leakage of lines.
7	Check capacity of boilers and chillers if their use is anticipated.
8	Check admixture dispensers for accuracy.
9	Check mixers for hardened concrete around blades.
10	Inspect concrete hauling units for cleanliness.
11	Check to ensure that all concrete-making materials have been certified and approved for use.
12	Observe stockpiling operations. Verify that segregation and contamination will not occur.
13	Observe charging of the bins. Verify that segregation and contamination will not occur.
14	Review aggregate moisture tests.
15	Observe batching operations at start and periodically during production.
16	Check scales for zeroing.
17	Check to ensure proper batch weights are set on the scales.

Handling Materials

- Efficient and controlled materials handling is mandatory for consistent quality.
- A plant can have many material feeds depending on the mix design and specifications.
- Stockpile management is a key element.

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Stockpile Management

- Delivery, storage, loading
- Place a pad or aggregate separation layer
  - Prevent contamination
- Maintain uniform
  - Gradation
  - Moisture
- Basic stockpile principles

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Batching

- Key items to control uniformity include batching sequence and accurate weights and measures.
- Considerations for controlling batch-to-batch consistency are critical.

Concrete Mixing and Delivery

- The concrete must be thoroughly mixed either at the plant or in the transit mixer.
- If allowed by specifications, adjustments to the mix are possible if a transit mixer is used.
- Ideally, the paver controls the production and delivery rate.

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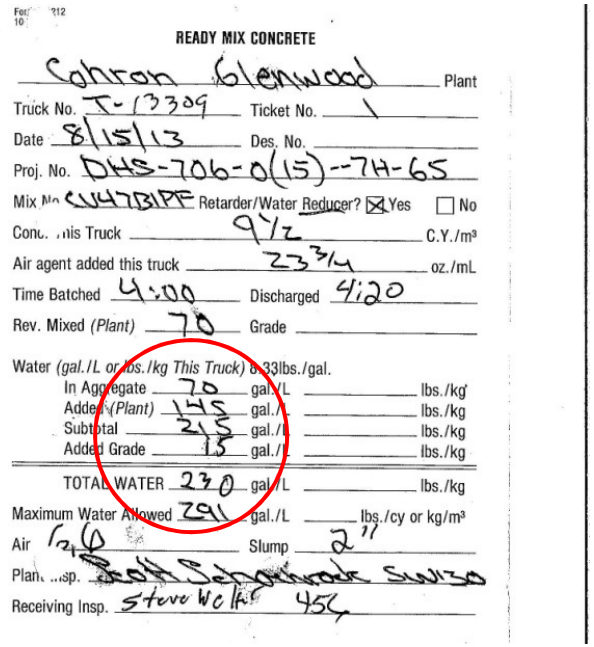
Field Adjustments

- Ambient temperatures
- Material variability
- Material supply changes

Adding Water

- Watch the amount of added water!
- Added water not to exceed max w/c (check batch tickets)
- If water added, mix for additional 30 revolutions



READY MIX CONCRETE

Cohron Glenwood Plant

Truck No. T-13309 Ticket No. 1

Date 8/15/13 Des. No.

Proj. No. DHS-706-0(15)--7H-65

Mix No. CV47B1PF Retarder/Water Reducer? ☒ Yes ☐ No

Conc. This Truck 9½ C.Y./m³

Air agent added this truck 23 3/4 oz./mL

Time Batched 4:00 Discharged 4:20

Rev. Mixed (Plant) 70 Grade

Water (gal./L or lbs./kg This Truck) @ 8.33lbs./gal.

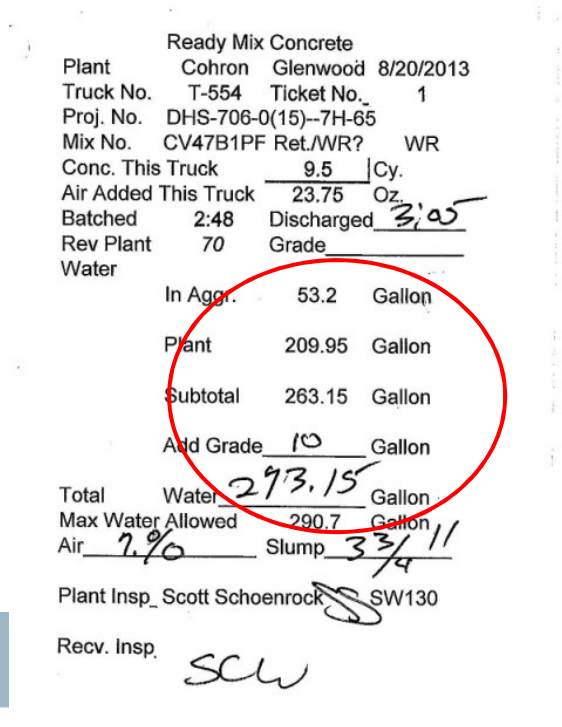
In Aggregate	70	gal./L	lbs./kg
Added (Plant)	145	gal./L	lbs./kg
Subtotal	215	gal./L	lbs./kg
Added Grade	15	gal./L	lbs./kg
TOTAL WATER	230	gal./L	lbs./kg

Maximum Water Allowed 291 gal./L lbs./cy or kg/m³

Air 1½ Slump 2"

Plant Insp. Scott Schoenrock SW130

Receiving Insp. Steve Wolf 456



Ready Mix Concrete

Plant Cohron Glenwood 8/20/2013

Truck No. T-554 Ticket No. 1

Proj. No. DHS-706-0(15)--7H-65

Mix No. CV47B1PF Ret./WR? WR

Conc. This Truck 9.5 Cy.

Air Added This Truck 23.75 Oz.

Batched 2:48 Discharged 3:05

Rev Plant 70 Grade

Water

In Aggr.	53.2	Gallon
Plant	209.95	Gallon
Subtotal	263.15	Gallon
Add Grade	10	Gallon
Total Water	273.15	Gallon
Max Water Allowed	290.7	Gallon

Air 7.0% Slump 3 3/4 11

Plant Insp. Scott Schoenrock SW130

Recv. Insp. SCW

Adding 1 gallon / cu. yd:

- Increases workability ~1”
- Lowers strength ~200 psi
- Increases drying shrinkage ~10%
- Increases permeability ~ 50%

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Paving Operations

- Equipment Set-up
- Steel
- Guidance
- Placement
- Finishing
- Edge Slump
- Texturing
- Curing
- Weather
- Joints/Jointing
- Maturity

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Equipment Setup

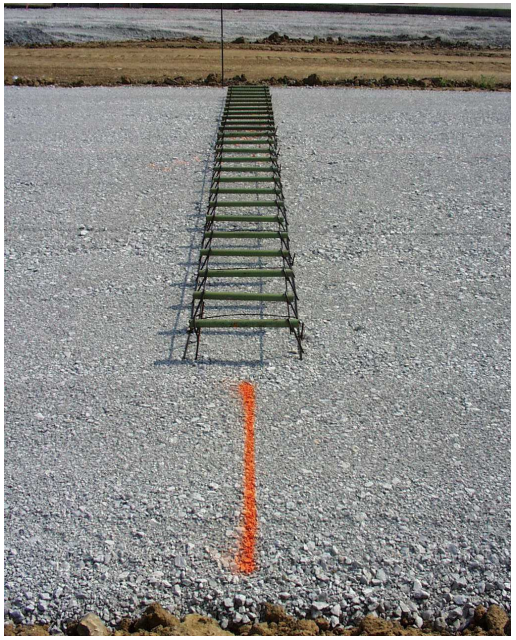
Equipment Setup

The following critical elements should be in place before production paving starts (IPRF 2003):

- Check all the equipment in the paving train to make sure it is in operational condition.
- Verify that an acceptable length of grade is available for concrete paving.
- Check that approved test reports are available for all materials in storage at the job site and the plant site.
- Verify that backup testing equipment is available; develop extra equipment backup plans.
- Verify that all necessary concrete placement tools are available, such as hand tools, straight edges, hand floats, edgers, and hand vibrators.
- Verify that radio/telephone communication with the plant is operational.
- Verify that equipment is available to water the grade, if necessary.
- Monitor the string line regularly and re-tension as necessary (slipform only).
- Check the forms for proper bracing (fixed-form only).
- Verify that the day's work header is in place (or just saw off the excess).
- Develop an extreme-weather management plan.
- Check the weather forecast for each day of paving.
- Make sure a sufficient length of plastic covering is available in case of sudden and unexpected rain.

Dowel Bars and Tiebars

- Pre-placed bars
- Inserted bars



Forms/Stringlines

- Forms control elevation/guidance for general screed paving.
- Stringlines control the “steering” of the paver and the elevation and slab thickness.
- Stringlines have a dramatic effect on pavement smoothness and uniformity.

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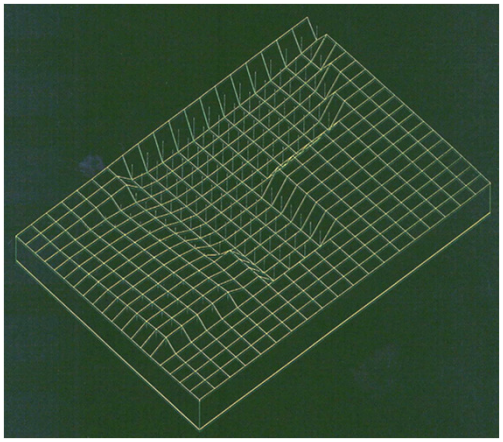
Stringless Paving

- Total station technology
- Increases clearances/working platform
- Improved smoothness

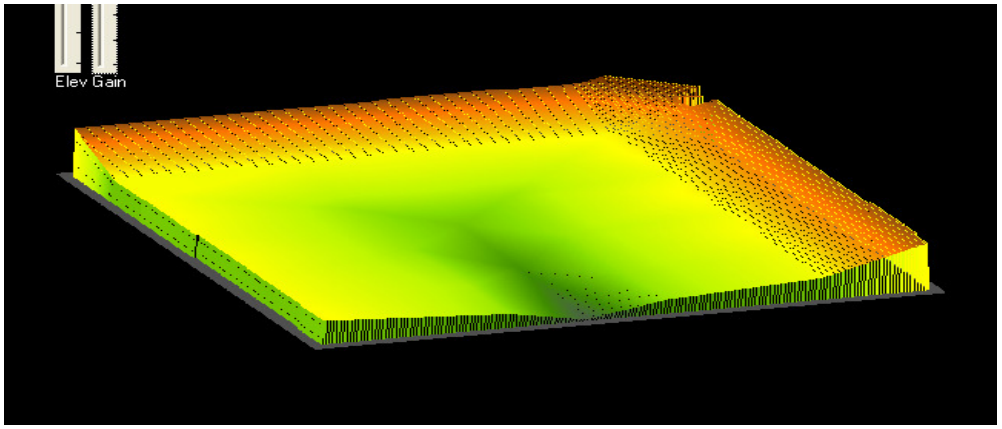
Laser Screeds

- Creating a Profile
  - a profile of the project is created using the points from the site survey.

3-D View



Surface Views



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Laser Screeds

- Total station sends multiple signals every second
- Laser receivers on the placement head pick up the signals
  - Send data to the on-board computer
  - Tell the computer “where” the head is
- Computer adjusts the head to the designed elevation

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Slipform Placement

- The single most important aspect of paving is uniform and consistent equipment operation.
- Workability and consistency of the mix are required to construct a smooth and high performance pavement.

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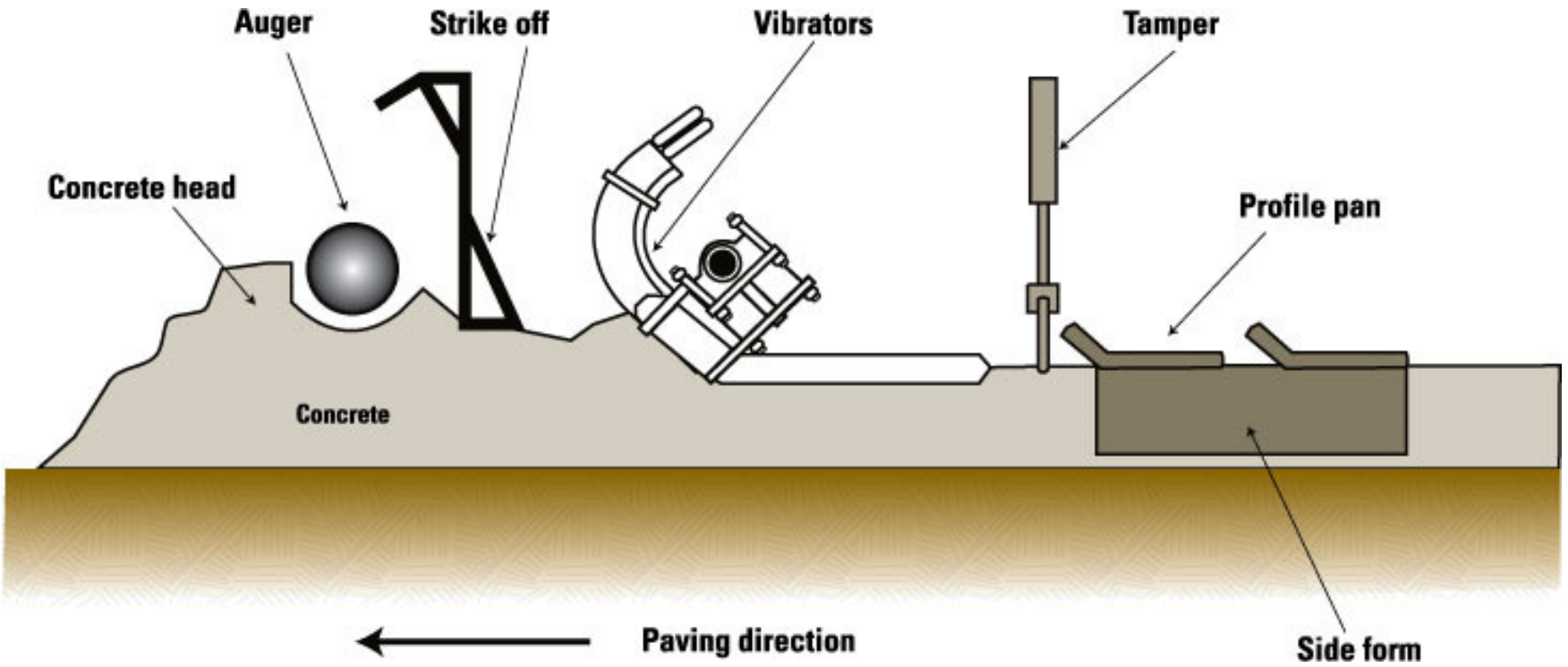
Slipform Paver Components



Proper Consolidation

- The internal vibrators on the paver fluidize the concrete for extrusion.
- Adequate consolidation is required around dowels and tie bars as well as throughout the slab.
- Note the effect of vibration in relation to paver speed.

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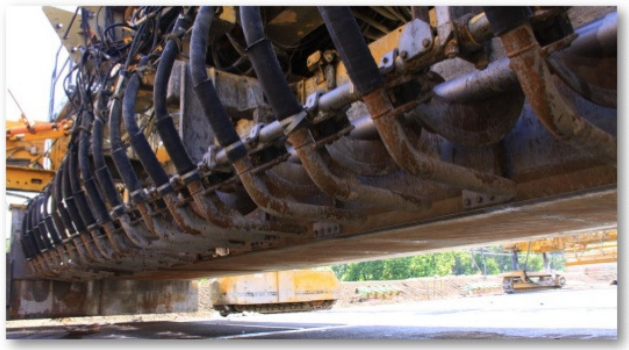
Consolidation

Vibrator Setup



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Slump Test

- Used to check consistency between loads & wetness
- Used to approximate workability/ consistency
- ½” – 2 ½” (machine finish) ½” – 4” (hand finish)

Air Testing

- Calibrate the air meter
- Target is 8% before paver
- Target is 6% after paver

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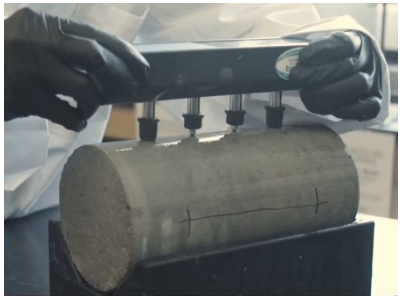
Air Testing – Behind the Paver

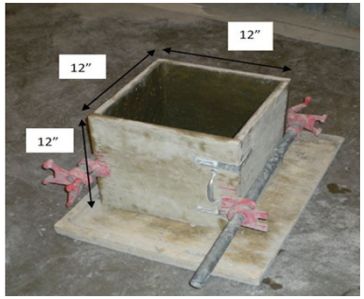
- Slipform pavers can have air loss of 2 % or greater
- Specs allow for checking behind the paver
- Allow check once in morning & if mix changes, once again
- Amount of air entrainment agent is contractor responsibility

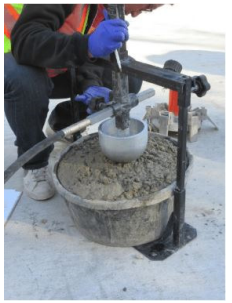
Sampling concrete behind the paver

PEM – what, how & when do we measure?

	Shrinkage	Transport	Freeze/Thaw Durability	Aggregate Stability	Workability	Strength
How do we measure?	Paste content Drying shrinkage Dual Ring	Resistivity Formation Factor	w/cm ratio Air content SAM Calcium Oxychloride (LT-DSC)	ASR D-Cracking	Box Test V-Kelly	Flexural & Compressive (Maturity Method)
Mix Design	✓	✓	✓	✓	✓	✓
QC/Acceptance		✓	✓		✓	✓







Construction - Adding Surface Water to Concrete

Wet burlap drag

- Specs prohibit adding water to slab by spray, wand, brush or other methods
- Wet burlap drag is allowed
- Decrease moisture if slurry or small bubbles develop on trailing edge of burlap

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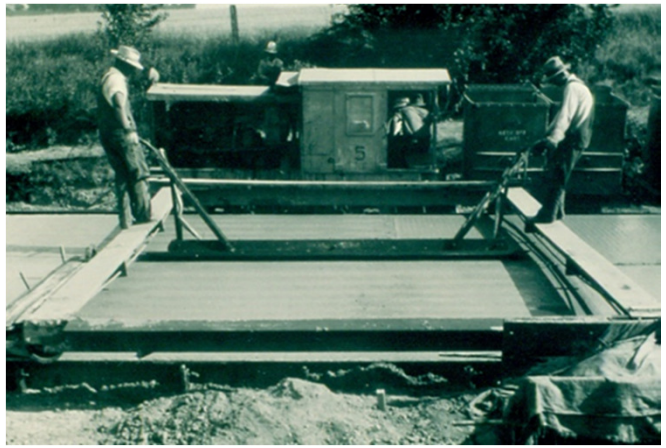
Finishing

- Hand finishing is generally not required.
- Check surface with straight edge. (1/4“ tolerance checked w/10’ – 20” straight edge)
- Headers are generally a source of localized roughness (several options are available).



Edge Slump

- Edge slump can arise from a number of factors.
  - Materials
  - Equipment
- Early detection and corrective action is required.

Edge Quality

Using a level to check edge slump

- Increase in mix water may cause edge slump
- Use temporary form to repair edge slump
- ½" edge slump permissible if no abutting pavement.
- ¼" edge slump permissible if abutting pavement

Texturing and Smoothness

- Provide friction and skid resistance
- Texturing options
  - Drag textures
  - Longitudinal tining
  - Transverse tining
  - Diamond grinding

Curing

- Start Early
- Keep it wet & warm. When it dries, it dies.
- Does it affect strength? Yes.
- Surface should be uniform white on surface & edges
- Application rate = 0.067 gal per SY
- Apply within 30 min.
- Should not track after 12 hours

Non-uniform cure

Uniform cure placed quickly

Weather Considerations

- Monitor forecast to determine if protection is necessary
- Cold weather placement
  - Heat mix water
  - Use blankets
  - Avoid thermal shock

Hot weather precautions

Rate of Evaporation

Hyperpave

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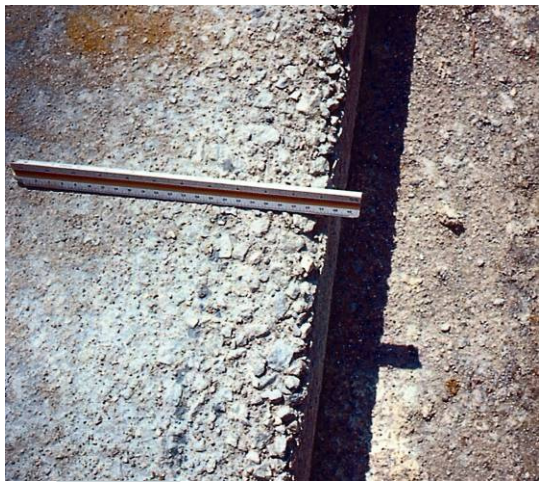
Weather Considerations

- Protection from rain
  - Do not finish rain water into the surface
    - Raises the W/C ratio
  - Cover with plastic



Jointing of Concrete Pavements

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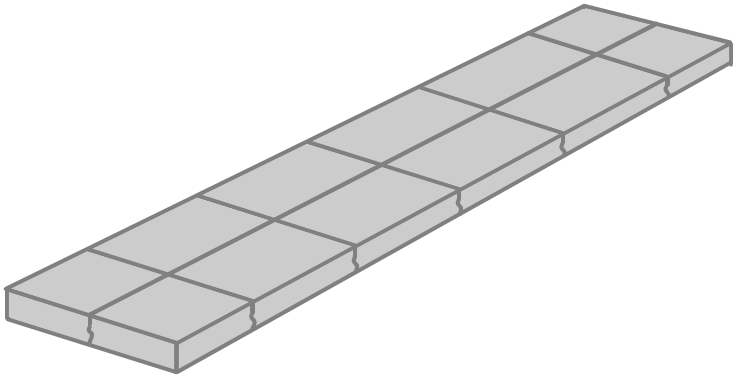
Concrete Jointing

- Joints control natural transverse & longitudinal cracking from internal slab stresses
- Divide pavement into construction lanes or increments
- Accommodate slab movements
- Provide load transfer
- Provide uniform sealant reservoir



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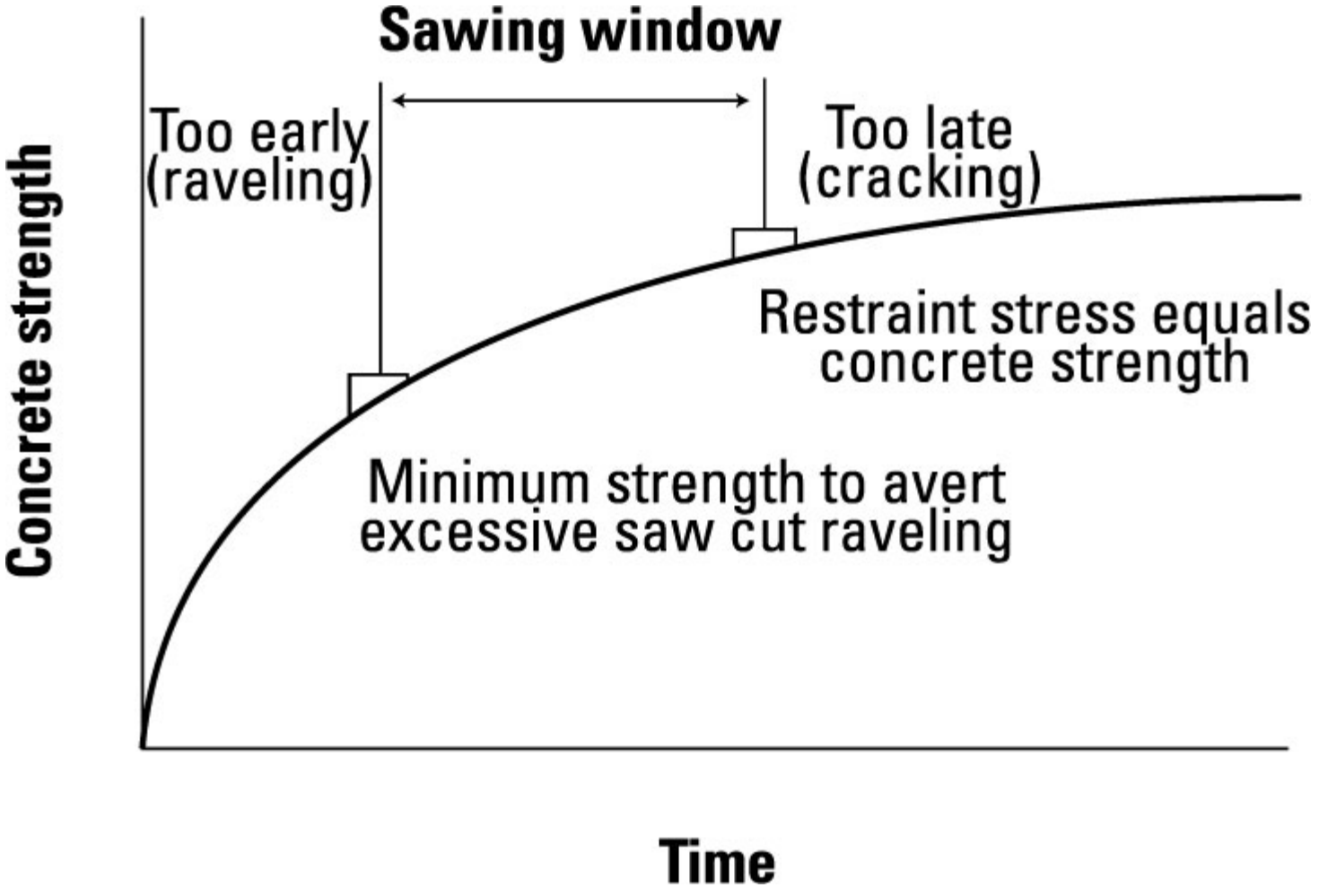
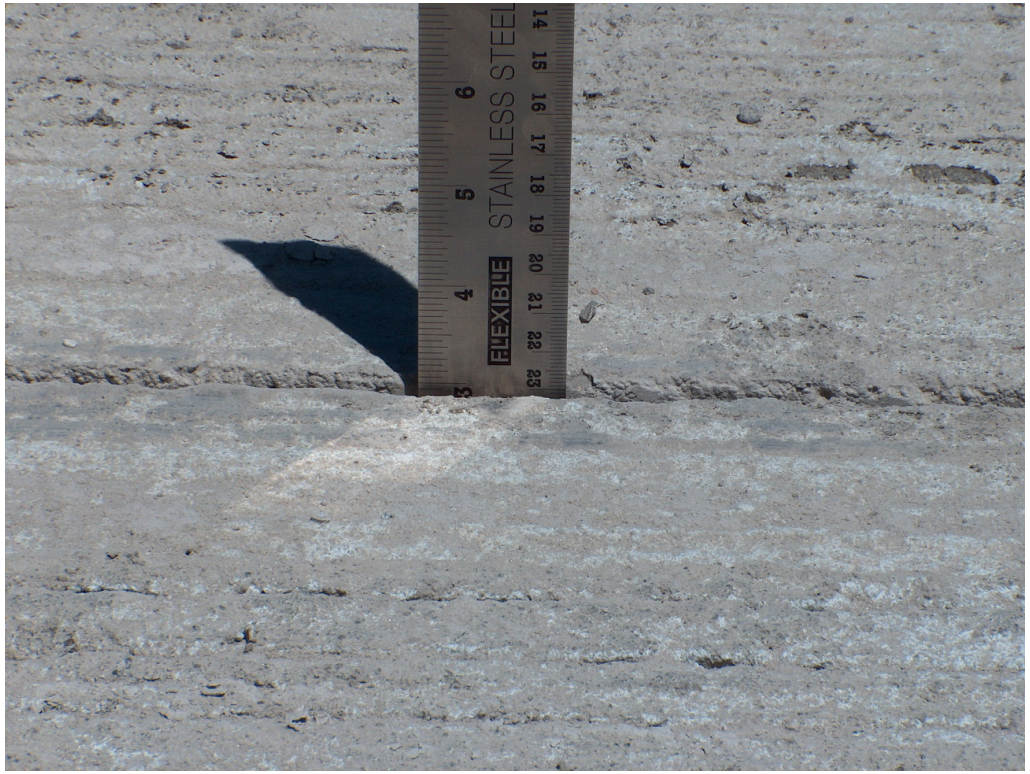
Joint Sawing



Sawcut Depth



- Check saw depth and width daily
- Inadequate depths may lead to cracking
- Check saw blade wear

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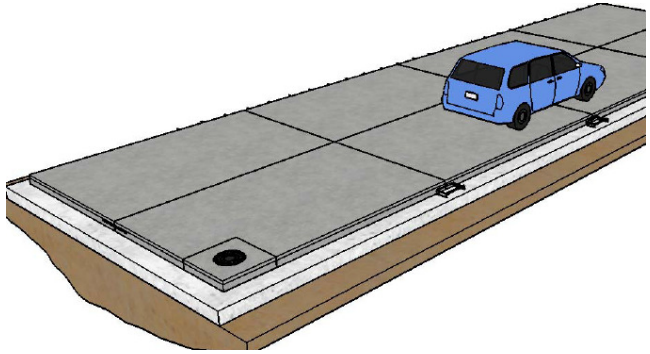
Joint Spacing



- Maximum joint spacing:

  $ML = T \times C_s$

ML = Maximum length between joints (in.)

T = Slab thickness (in.)

C_s = Support constant (24 for subgrades or subbases; 21 for ATB, CTB, lean concrete, or existing concrete or asphalt)

* Maximum spacing of transverse joints in plain (unreinforced) concrete should be 15 ft for slabs less than 10 in. thick.

Pavement Thickness (T)	Maximum Transverse 'C' Joints	Maximum Transverse 'CD' Joints	Maximum Longitudinal Joint Spacing
< 9"	15'	15'	12-1/2'
9"	15'	15'	14-1/2'
> 9"	15'	20'	14-1/2'*
*16' for Ramps			

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Late Sawcut

- Sawing must be continuous regardless of weather
- Sawing is discontinued if crack develops ahead of saw
- Repair for random transverse cracks

Late sawing crack

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Joint Sealing

- Minimize infiltration of water and incompressible material
- Factors that affect performance
- Reservoir preparation
- Mfg. Recommend procedure

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Maturity Testing

Casting maturity beams at the plant site

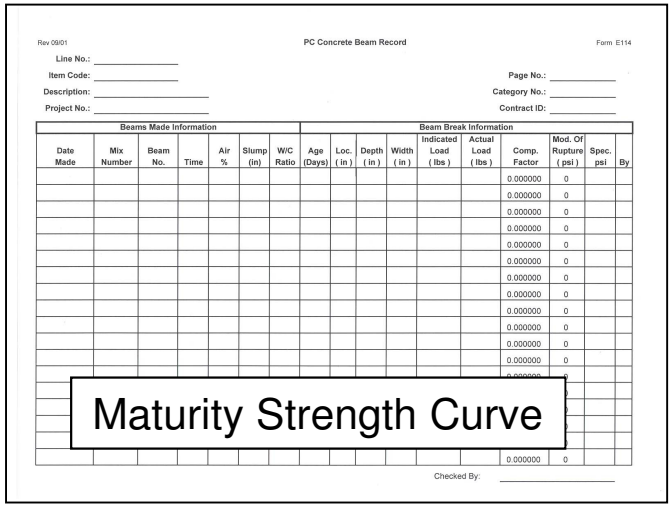
- Strength determines pavement opening (not time)
- Inspector monitors the process
- Maturity involves casting 12 beams & developing a strength/maturity curve

Tech Center

Maturity Testing

- NDT Method for determining concrete strength
- Time-Temperature Factor wires
- Inspector monitors periodically

Maturity probe location with hand held thermometer



Rev 09/01 — PC Concrete Beam Record — Form E114

Line No.: _____ Item Code: _____ Description: _____ Project No.: _____ Page No.: _____ Category No.: _____ Contract ID: _____

Beams Made Information							Beam Break Information								
Date Made	Mix Number	Beam No.	Time	Air %	Slump (in)	W/C Ratio	Age (Days)	Loc. (in)	Depth (in)	Width (in)	Indicated Load (lbs)	Actual Load (lbs)	Comp. Factor	Mod. Of Rupture (psi)	Spec. psi	By
													0.000000	0		
													0.000000	0		
													0.000000	0		
													0.000000	0		
													0.000000	0		
													0.000000	0		
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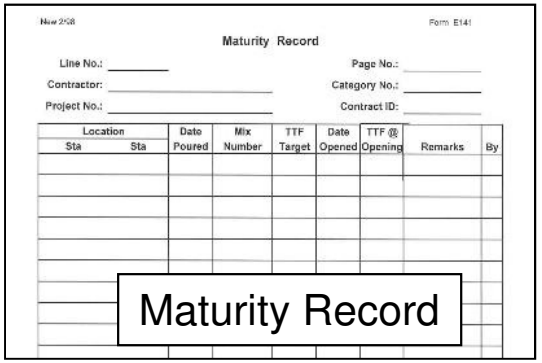
Maturity Strength Curve

Checked By: _____



Rev 2/08 — Form E141

Maturity Record

Line No.: _____ Page No.: _____ Contractor: _____ Category No.: _____ Project No.: _____ Contract ID: _____

Location Sta	Location Sta	Date Poured	Mix Number	TTF Target	Date Opened	TTF @ Opening	Remarks	By

Maturity Record

Minnesota - The Experiment, 6” slab

Concrete Age:

3 hrs. | 5-3/4 hrs. | 8-1/3 hrs. | 10-1/2 hrs. | No Load

124 | **224** | **324** | **424** | **524**

Cell x24 Early Loading Sequence		
Maturity (Deg-Hr)	**Flexural (psi)**	**Loads applied to lanes**
100	**73**	**1st Load on Cell 124 (forward and back)**
200	**196**	**1st Load on Cell 224, 2nd load on Cell 124**
300	**267**	**1st Load on Cell 324, 2nd load on Cell 224, 3rd load on Cell 124**
400	**318**	**1st Load on Cell 424, 2nd load on Cell 324, 3rd load on Cell 224, 4th load on Cell 124**

Starting Day 2, 5 passes per day for first week

Burnham - NCC 2017

Early loading of Cells 124-424

4,000 lb axle vs 14,000 lb axle loads (1st Cell @ 3hrs)

CONCRETE PAVEMENTS DONE RIGHT

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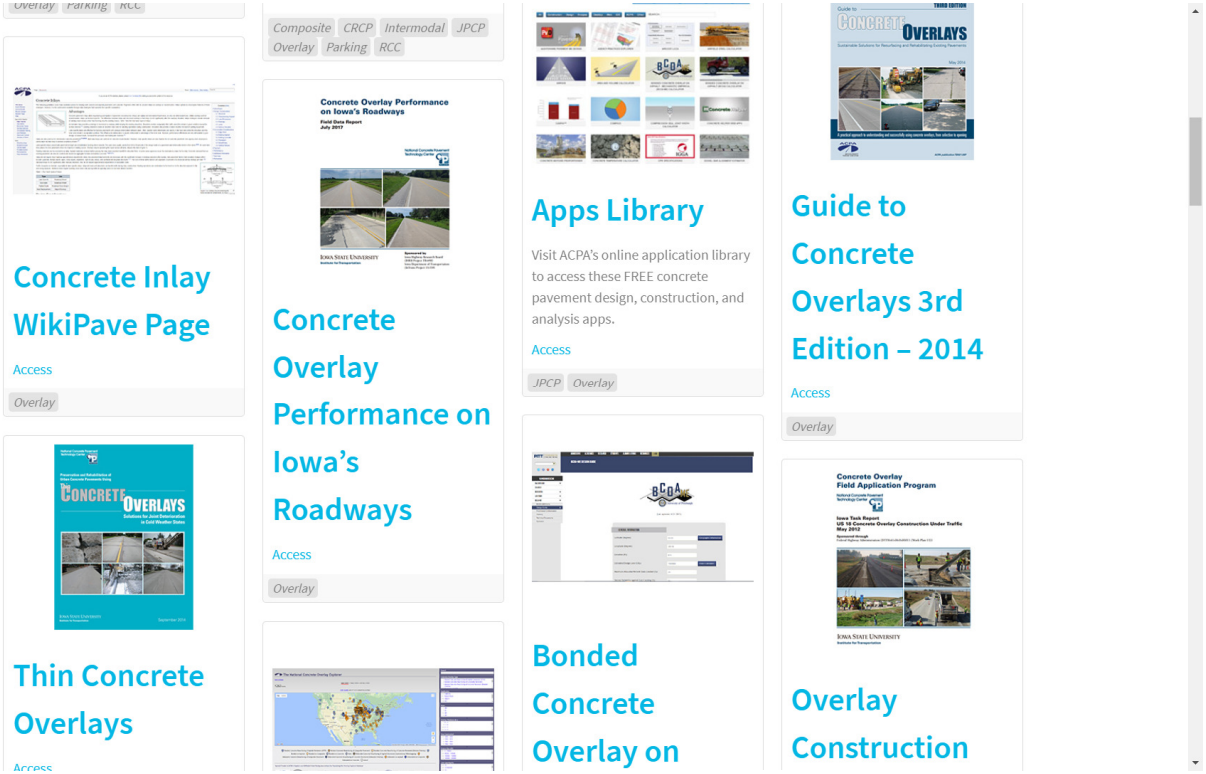
Concrete Pavement Resources



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PCA Portland Cement Association

NRMCA

ACPA AMERICAN CONCRETE PAVEMENT ASSOCIATION Member Company

PavementDesigner.org

Thank you

www.cptechcenter.org

QUESTIONS