Addressing Myths About Concrete Pavement

Presented By:

National **R**eady **M**ixed **C**oncrete **A**ssociation

PAVE AHEAD

DURABLE. SUSTAINABLE. CONCRETE.

National Ready Mixed Concrete Association

- National Trade Association – Established in 1930
- HQ in Alexandria, VA
- 400+ Member Companies
- NRMCA Represents ~75% of North American Ready Mixed Production
- Mission – Serve Industry and Partners Through:
  - Compliance and Operations
  - Engineering
  - Government Affairs
  - *Local Paving: [Pave Ahead]™ Initiative*
  - *Structures and Sustainability: [Build With Strength]™ Initiative*

Interested in becoming a member?

Visit: [www.nrmca.org/membership/]

NRMCA

Your Instructor Today…

- Luke McHugh, P.E.
  - NRMCA Local Paving, Northeast Region
  - 34 Years in Practice
  - Civil Design – Aviation Emphasis

More information at paveahead.com/experts/

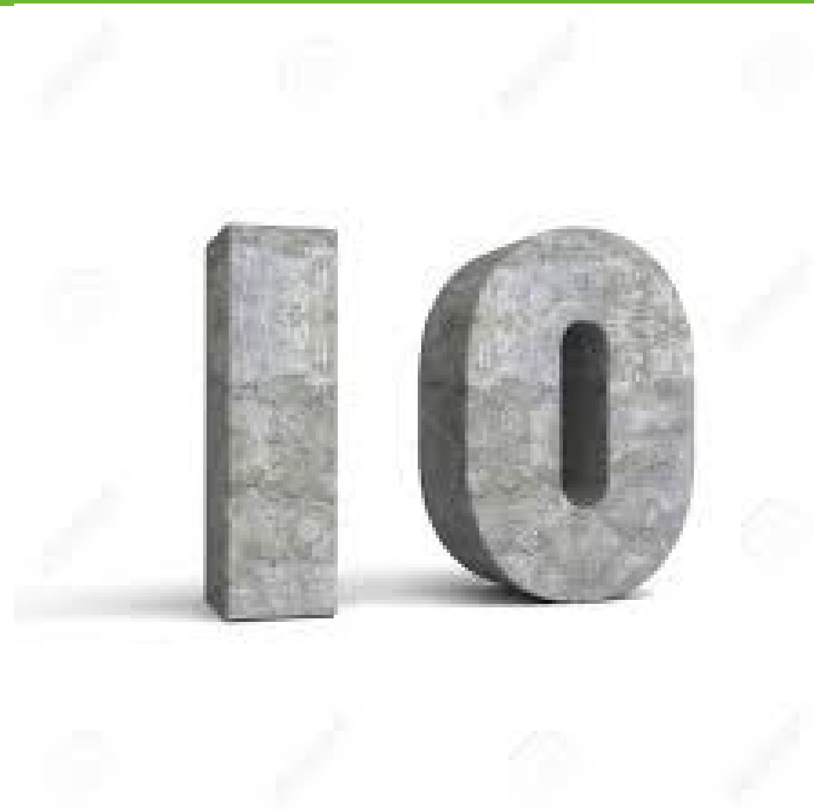
PAVE AHEAD
DURABLE. SUSTAINABLE. CONCRETE.


THE PAVEAHEAD TOP TEN LIST

Number 10

“When I design concrete for local roads and parking lot pavements…

I just use AASHTO 93.”



PAVE AHEAD
DURABLE. SUSTAINABLE. CONCRETE.

1986-93 JPCP AASHTO 93 Equation

$$Log(ESAL) = Z_R * s_o + 7.35 * Log(D+1) - 0.06 + \left[\frac{Log\left[\frac{\Delta PSI}{4.5-1.5}\right]}{1 + \frac{1.624 * 10^7}{(D+1)^{8.46}}} \right]$$

$$+ (4.22 - 0.32 * p_t) * Log\left[\frac{S_c' * C_d * (D^{0.75} - 1.132)}{215.63 * J * \left[D^{0.75} - \frac{18.42}{(E_c / k)^{0.25}} \right]} \right]$$

Standard Normal Deviate

Overall Standard Deviation

Thickness

Change in Serviceability

Traffic

Terminal Serviceability

Modulus of Rupture

Drainage Coefficient

Load Transfer

Modulus of Elasticity

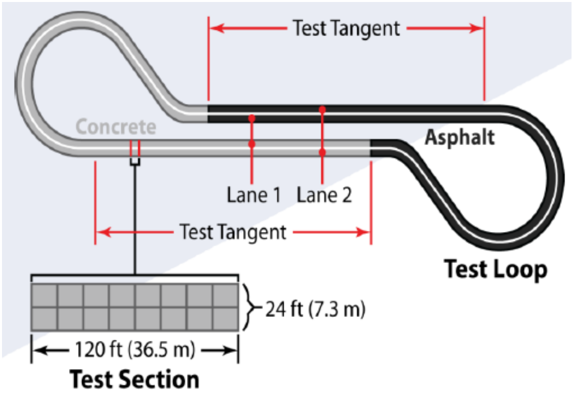
Modulus of Subgrade Reaction

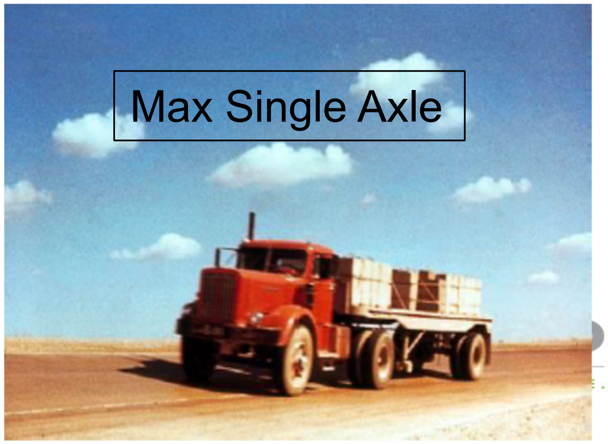
WHAT DO DESIGNERS FOCUS ON?

Source: ACPA

Source of Much of What We Know About Pavement Design

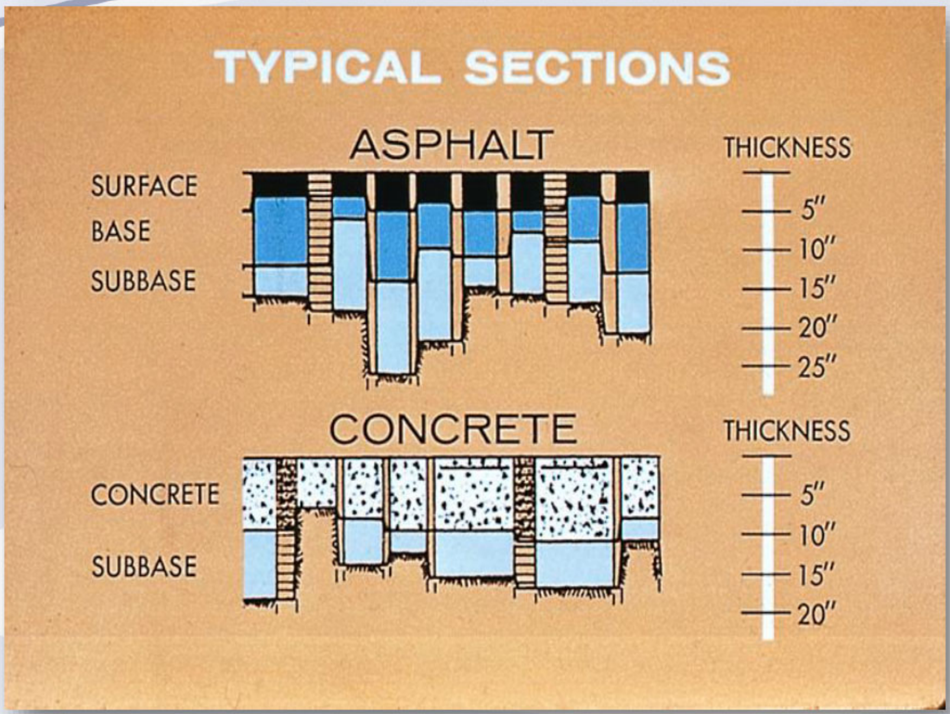
- AASHO Road Test (1958-1960)
- Ottawa, Illinois - 1.1 Mil Reps
- Wholly empirical
- 368 concrete and 468 asphalt sections
- Focus was ***highway pavement***





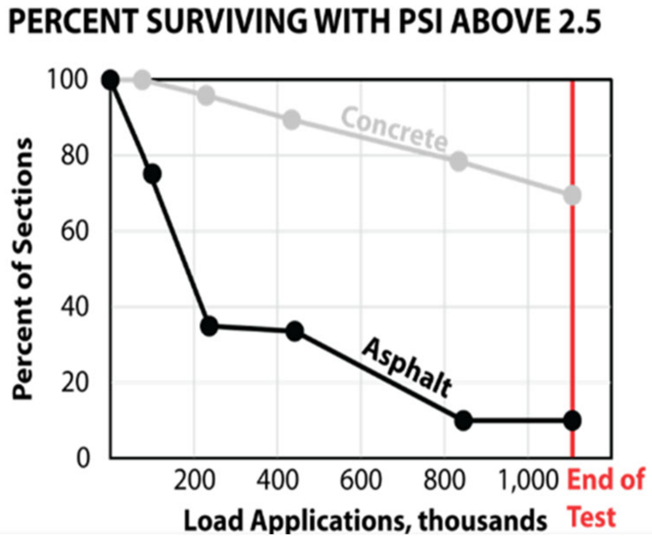
Test Sections or ***Guessed Sections***

Necessary Thickness was Guessed!



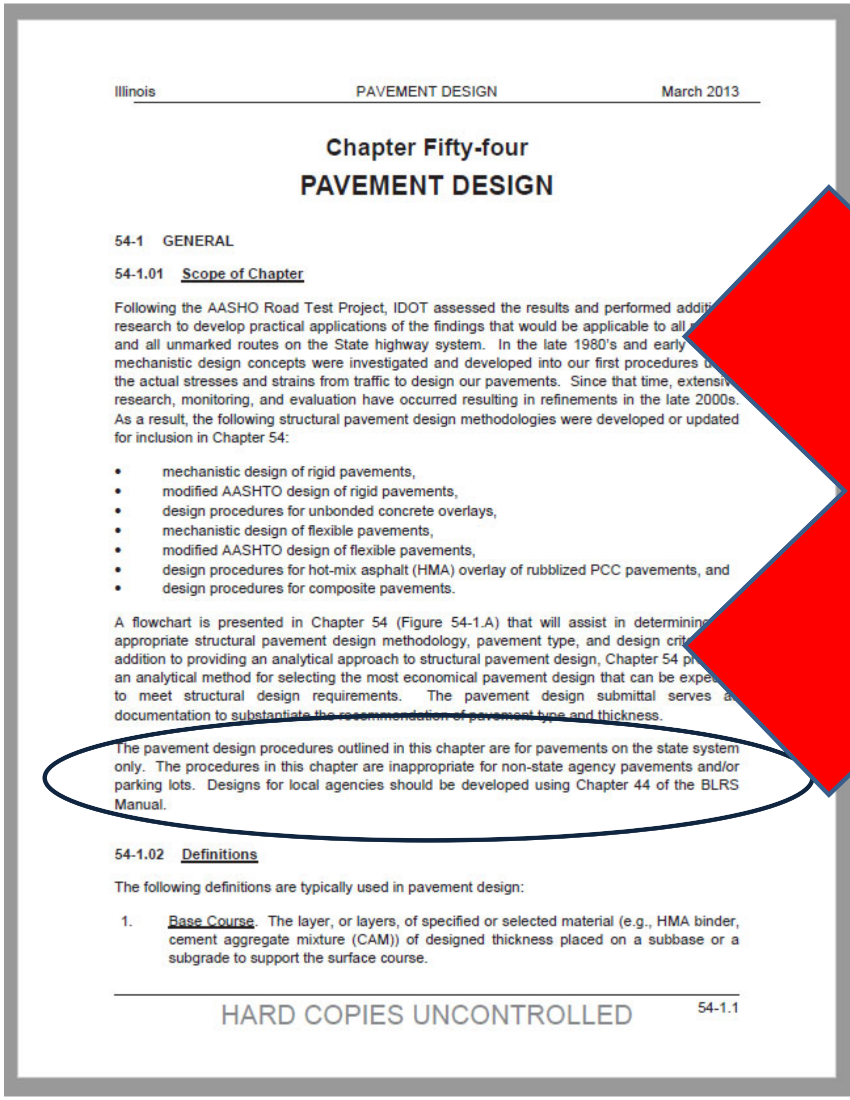
Subgrade = Clay Soil

Source: Ferrebee ACPA



PAVE AHEAD

DURABLE. SUSTAINABLE. CONCRETE.



Chapter Fifty-four
PAVEMENT DESIGN

54-1 GENERAL

54-1.01 Scope of Chapter

Following the AASHO Road Test Project, IDOT assessed the results and performed additi research to develop practical applications of the findings that would be applicable to all r and all unmarked routes on the State highway system. In the late 1980's and early mechanistic design concepts were investigated and developed into our first procedures u the actual stresses and strains from traffic to design our pavements. Since that time, extensiv research, monitoring, and evaluation have occurred resulting in refinements in the late 2000s. As a result, the following structural pavement design methodologies were developed or updated for inclusion in Chapter 54:

- mechanistic design of rigid pavements,
- modified AASHTO design of rigid pavements,
- design procedures for unbonded concrete overlays,
- mechanistic design of flexible pavements,
- modified AASHTO design of flexible pavements,
- design procedures for hot-mix asphalt (HMA) overlay of rubblized PCC pavements, and
- design procedures for composite pavements.

A flowchart is presented in Chapter 54 (Figure 54-1.A) that will assist in determinin appropriate structural pavement design methodology, pavement type, and design crit addition to providing an analytical approach to structural pavement design, Chapter 54 pr an analytical method for selecting the most economical pavement design that can be expe to meet structural design requirements. The pavement design submittal serves a documentation to substantiate the recommendation of pavement type and thickness.

The pavement design procedures outlined in this chapter are for pavements on the state system only. The procedures in this chapter are inappropriate for non-state agency pavements and/or parking lots. Designs for local agencies should be developed using Chapter 44 of the BLRS Manual.

54-1.02 Definitions

The following definitions are typically used in pavement design:

1. Base Course. The layer, or layers, of specified or selected material (e.g., HMA binder, cement aggregate mixture (CAM)) of designed thickness placed on a subbase or a subgrade to support the surface course.

“The pavement design pr dures outlined in this are for pavements on te system only.”

procedures in this chapter ppropriate for non-state pavements or ***parking lot***

Local Roads and Streets

American Concrete Institute
Always advancing

PCA Design Method

- Two failure modes considered:
  - Fatigue failure due to slab flexure
  - Erosion failure due to foundation compression
- Edge loads produce the worst <u>stresses</u>
  - Fatigue based on tensile stress due to edge loads
- Corner loads produce the worst <u>deflections</u>
  - Erosion based on deflections due to corner loads

PavementDesigner.org

NRMCA

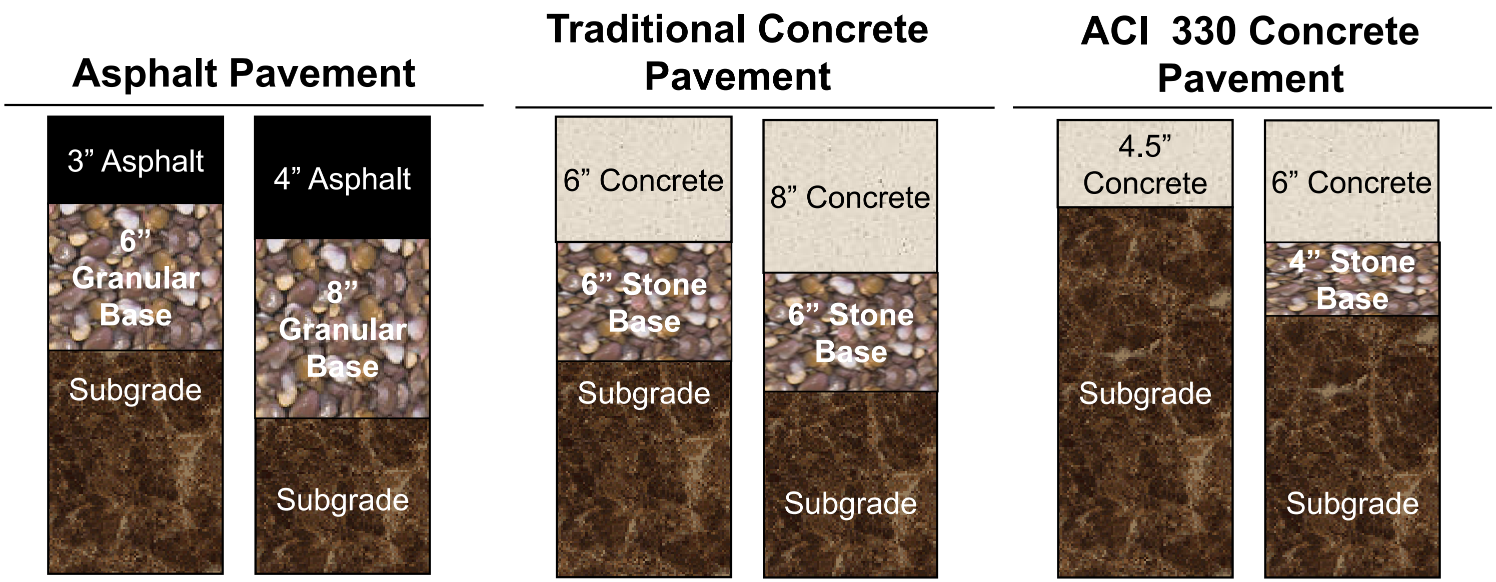
PCA Since 1916 America's Cement Manufacturers™

ACPA AMERICAN CONCRETE PAVEMENT ASSOCIATION

CP Tech Center

PAVE AHEAD
DURABLE. SUSTAINABLE. CONCRETE.

Lowe's Home Improvement
Wilmington, NC



Savings to the owner over traditional concrete design: Undisclosed (reported to be 6-figures!)

PAVE AHEAD
DURABLE. SUSTAINABLE. CONCRETE.

Number 9

“You don’t need to cure the concrete”

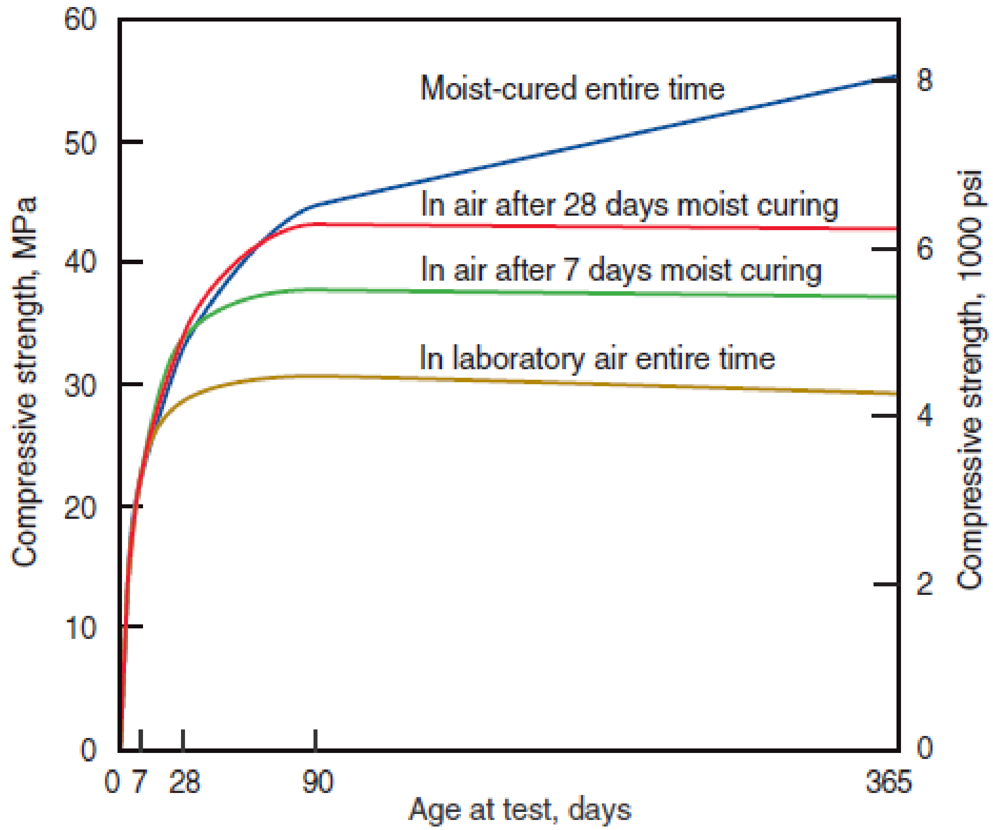
PAVE AHEAD

DURABLE. SUSTAINABLE. CONCRETE.

What is Curing?

It is a **step during construction** that involves **maintaining newly placed concrete** at adequate **moisture** and **temperature** conditions so that it can develop properties, such as **strength and durability**, for which the mixture was **designed** to achieve…

Curing Concrete



Gonnerman and Shuman 1928

Why Cure Concrete

Spray-on curing compound

Curing Blankets

- Predictable Strength Gain
- Improved Durability
- Better Serviceability and Appearance

PAVE AHEAD
DURABLE. SUSTAINABLE. CONCRETE.

CURING MATERIALS

- Liquid Membrane-Forming Compounds
  - waterborne, monomolecular film forming, manufactured for application to fresh concrete
- Absorptive Cover
  - burlap cloth made from jute or kenaf, weighing approximately 9 oz/yd2 (305 g/m2) when dry
- Moisture-Retaining Cover
  - polyethylene film or white burlap-polyethylene sheet

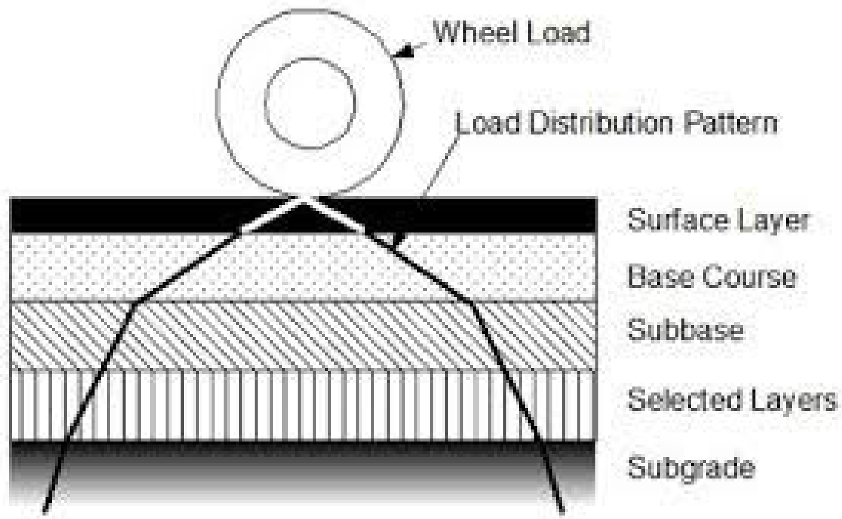
PAVE AHEAD
DURABLE. SUSTAINABLE. CONCRETE.

Number 8

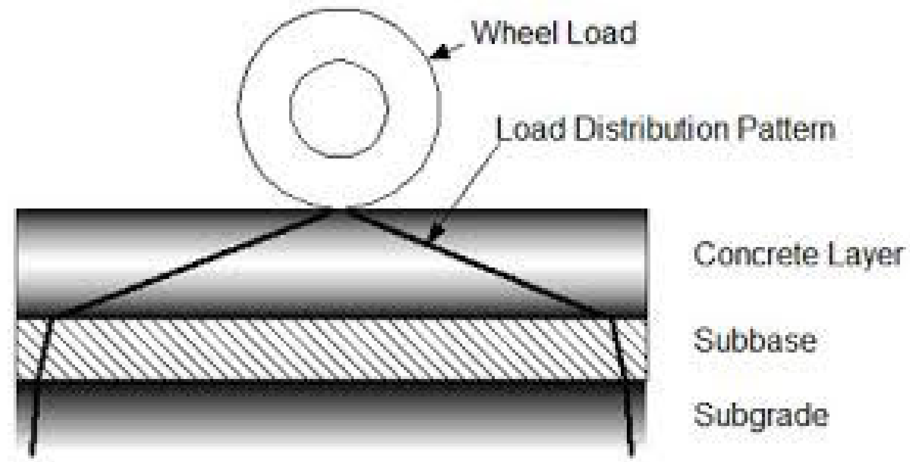
“I have a heavy-duty pavement… so I need a thicker aggregate base course”

PAVE AHEAD
DURABLE. SUSTAINABLE. CONCRETE.

Flexible Pavement



Rigid Pavement



Subgrade Soil

- ***k*** – modulus of subgrade or
- ***CBR*** – California Bearing Ratio

Table 3.1—Subgrade soil types and approximate support values (Portland Cement Association 1984a,b; American Concrete Pavement Association 1982)

Type of soil	Support	*k*, psi/in.	CBR	*R*	SSV
Fine-grained soils in which silt and clay-size particles predominate	Low	75 to 120	2.5 to 3.5	10 to 22	2.3 to 3.1
Sands and sand-gravel mixtures with moderate amounts of silt and clay	Medium	130 to 170	4.5 to 7.5	29 to 41	3.5 to 4.9
Sand and sand-gravel mixtures relatively free of plastic fines	High	180 to 220	8.5 to 12	45 to 52	5.3 to 6.1

Notes: CBR = California bearing ratio; *R* = resistance value; and SSV = soil support value. 1 psi = 0.0069 MPa, and 1 psi/in. = 0.27 MPa/m.

PAVE AHEAD
DURABLE. SUSTAINABLE. CONCRETE.

Table 3.2—Modulus of subgrade reaction *k**

Subgrade *k* value, psi/in.	Sub-base thickness			
	4 in.	6 in.	9 in.	12 in.
	Granular aggregate subbase			
50	65	75	85	110
100	130	140	160	190
200	220	230	270	320
300	320	330	370	430
	Cement-treated subbase			
50	170	230	310	390
100	280	400	520	640
200	470	640	830	—
	Other treated subbase			
50	85	115	170	215
100	175	210	270	325
200	280	315	360	400
300	350	385	420	490

*For subbase applied over different subgrades, psi/in. (Portland Cement Association 1984a,b; Federal Aviation Administration 1978).
Note: 1 in. = 25.4 mm, and 1 psi/in. = 0.27 MPa/m.

ACI 330R-08 Guidelines – Table 3.4

		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

Number 7

"I can't wait 28 days to open the pavement to traffic"

PAVE AHEAD

DURABLE. SUSTAINABLE. CONCRETE.

Neither could theses guys…

Houston, TX

PAVE AHEAD
DURABLE. SUSTAINABLE. CONCRETE.

27

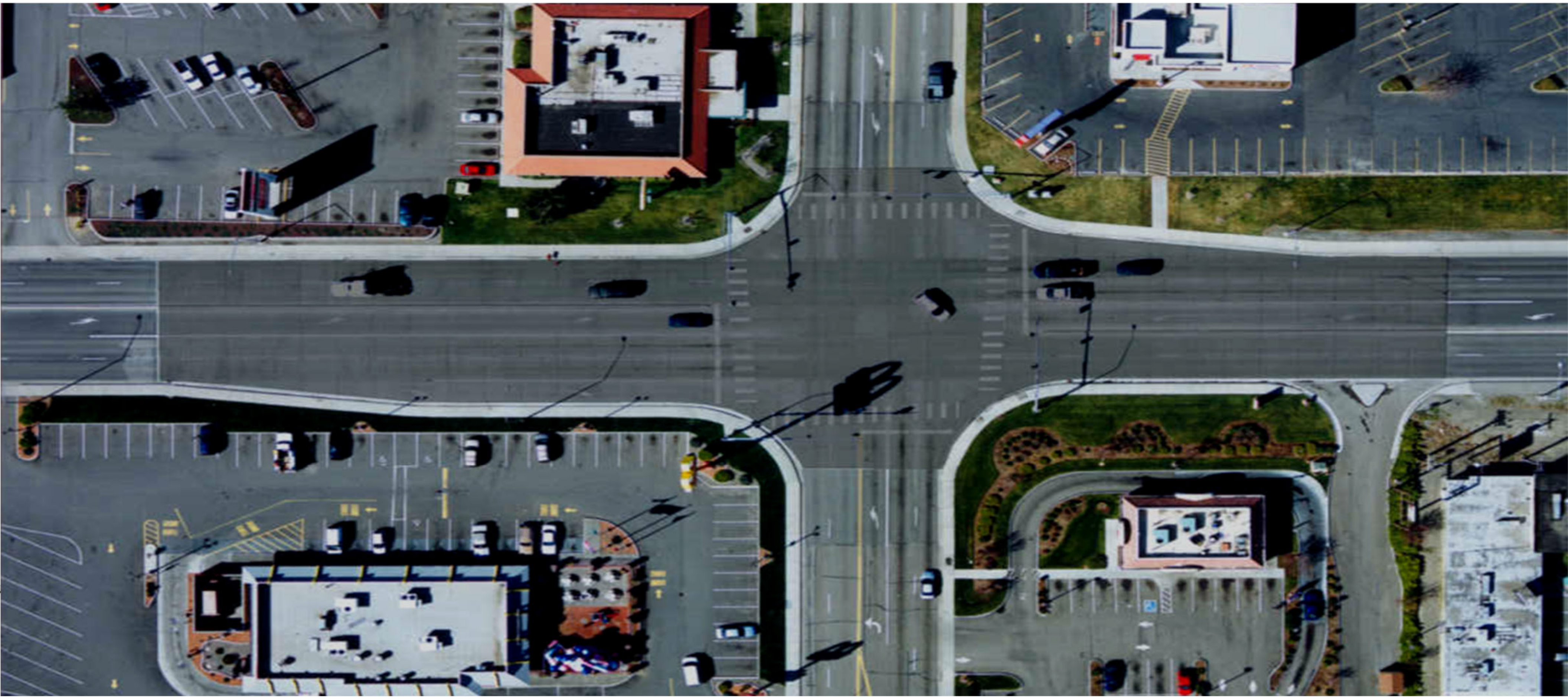
OPENING TO TRAFFIC

- Open to Vehicular Traffic:
  - In-place compressive strength is at least 3,000 psi
  - Or 75% of the specified strength,
  - Or until the pavement is accepted by the Engineer for opening to traffic

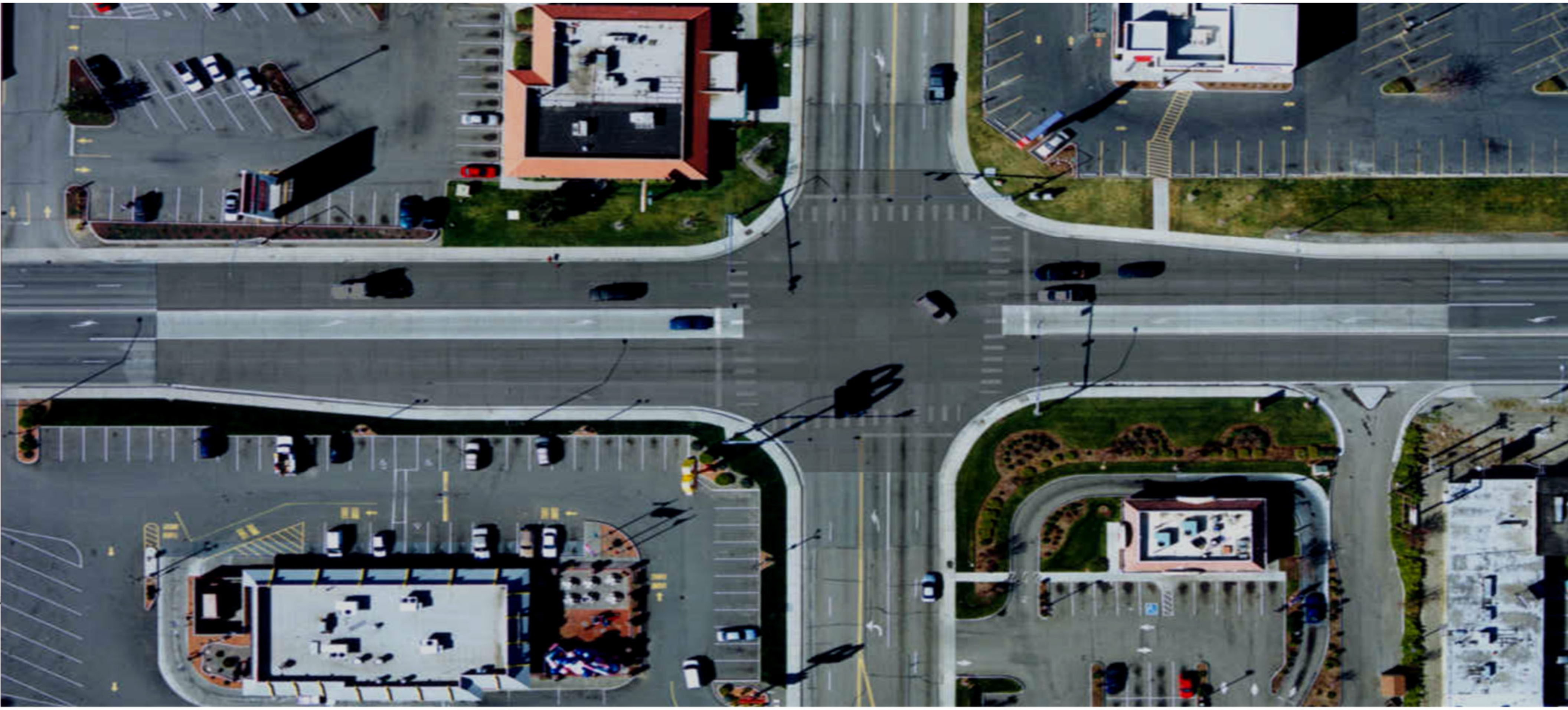
Reconstruction SR 395 Kennewick, WA:

Under Traffic & Full Closure Over 3-Day Weekend

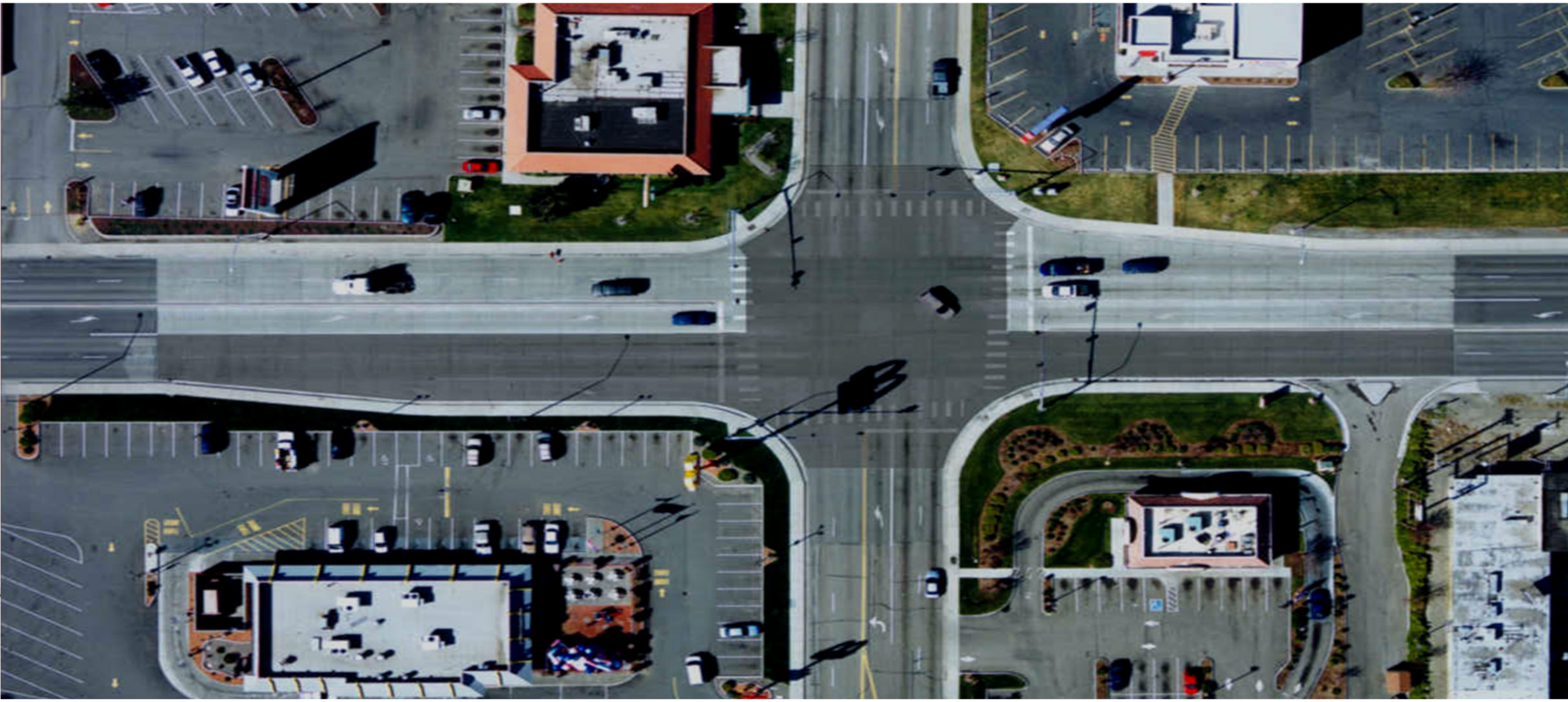
Concrete Intersections – Staging (Start)



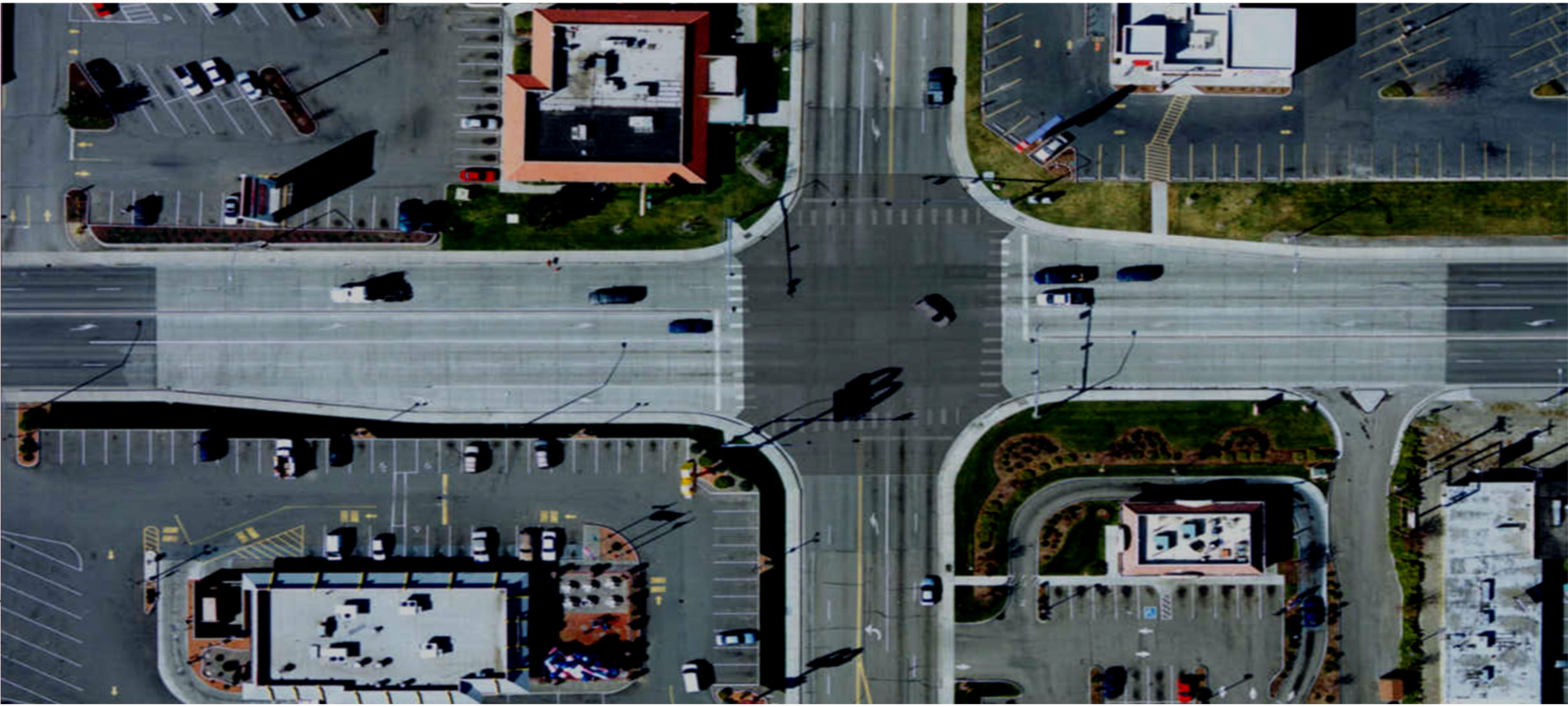
Concrete Intersections – Staging (Stage 1 Under Traffic)



Concrete Intersections – Staging (Stage 2 Under Traffic)



Concrete Intersections – Staging (Stage 3 Under Traffic)



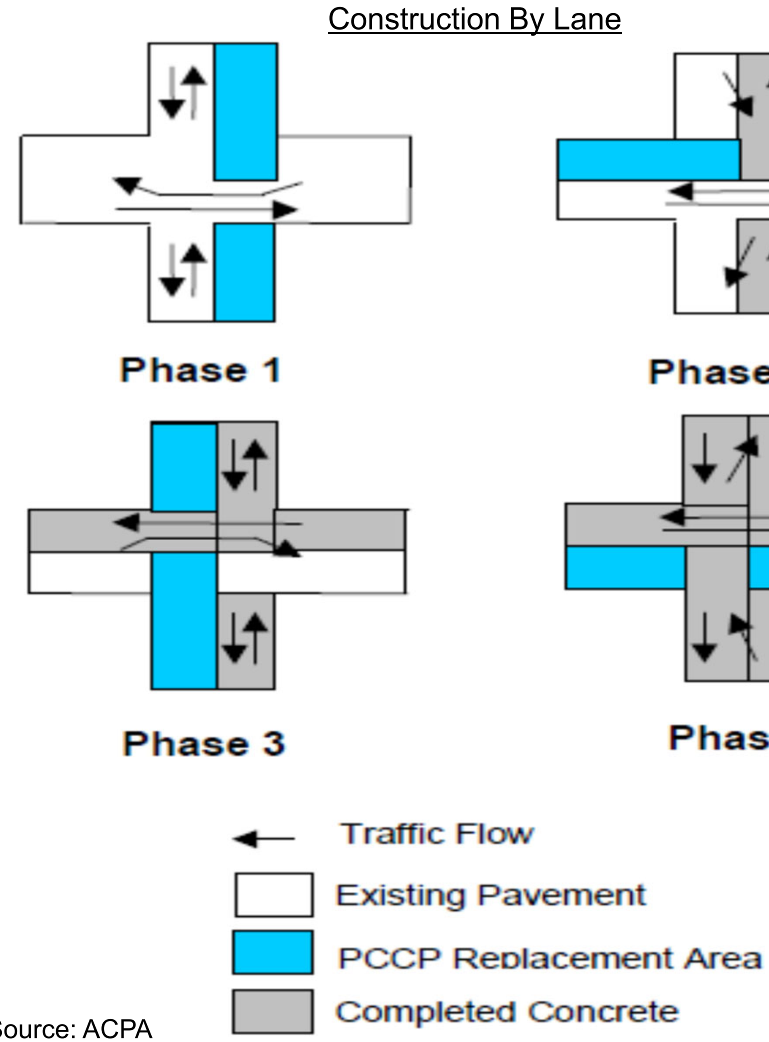
Concrete Intersections – Staging
(Stage 4 Under Closure 3-Day Weekend)

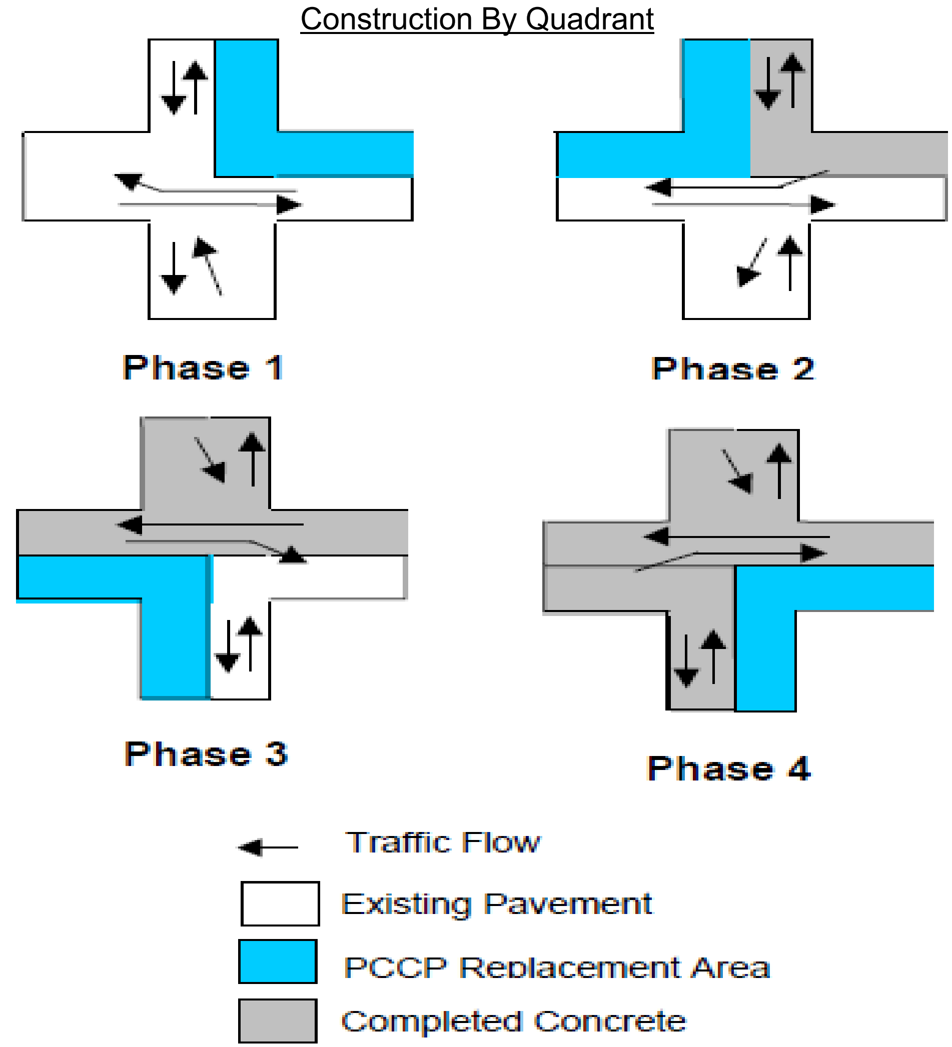
3-Day Weekend Closure

- **Thursday evening to Friday morning**
  - 8:00 pm to 3:30 am – Remove existing surfacing
  - 3:30 am to 7:30 am – Grade, prep base
- **Friday Morning to Friday Evening**
  - 7:30 am to 9:00 pm – Form and pour concrete
  - 3:00 pm – Start joint sawing
- **Saturday Morning to Saturday Evening**
  - 6:30 am – Finish joint sawing
  - 8:00 am to 4:15 pm – Form and pour concrete
  - 4:30 pm to 8:00 pm – Asphalt approaches
  - 6:00 pm to 11:30 pm – Sawcut
- **Sunday Morning to Sunday Afternoon Evening**
  - 5:00 am to 9:00 am – Clean joints/blow dry
  - 9:00 am to 1:00 pm – Joint seal
  - 1:00 pm to 2:00 pm – Clean roadway
  - 2:00 pm to 4:45 pm – Prep roadway (striping)
  - 4:45 pm – Open to traffic

NRMCA
NATIONAL READY MIXED CONCRETE ASSOCIATION

Staging: Intersection Under Traffic





Source: ACPA

Number 6

"It's ok to sprinkle some water on the concrete so it's easier to finish"

PAVE AHEAD
DURABLE. SUSTAINABLE. CONCRETE.

NEVER "*bless*" concrete unless you are an ordained finisher!

PAVE AHEAD
DURABLE. SUSTAINABLE. CONCRETE.

Blessing the concrete surface to facilitate finishing operations will cause dusting

Dusting concrete surface

…or scaling

Scaling on Concrete Slab

Adding Water at the Jobsite

- Water can be added to increase slump
- Only if a portion of design mixing water held back and slump is lower than allowed by design
- When the truck arrives on site
- Slump and/or w/c ratio is not exceeded
- Done in accordance with ASTM C 94

How to Place and Finish Concrete

1. Place the concrete to its’s final location using procedures that avoid segregation
2. Strike off and obtain an initial level surface without sealing the surface
3. Wait for the concrete to stop *bleeding* before starting finishing operations

PAVE AHEAD
DURABLE. SUSTAINABLE. CONCRETE.

How to place and Finish Concrete

4. Texture the surface as required…Don't over finish!
5. Sawcut joints as needed…as soon as possible!
6. Cure!!!

PAVE AHEAD
DURABLE. SUSTAINABLE. CONCRETE.

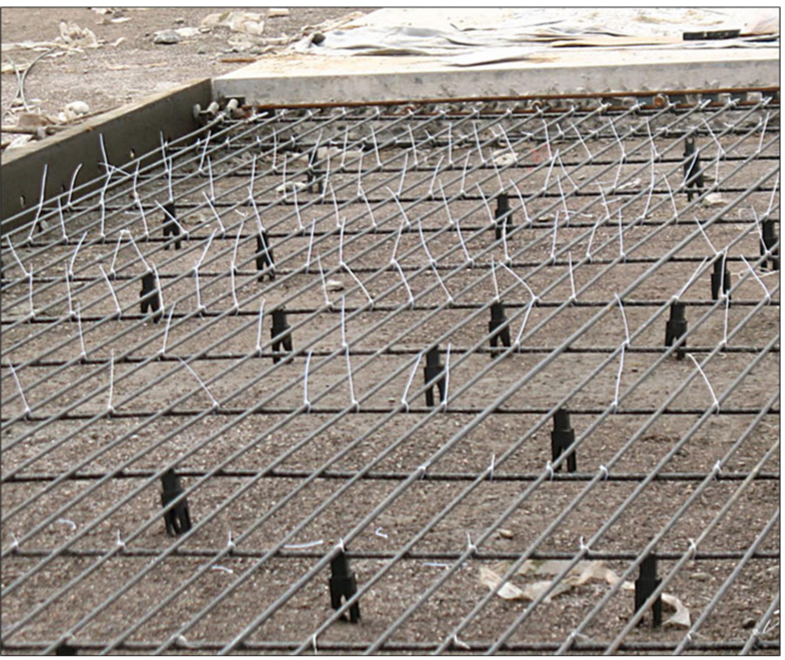
Number 5

“we need reinforcing steel in concrete pavement”

PAVE AHEAD
DURABLE. SUSTAINABLE. CONCRETE.

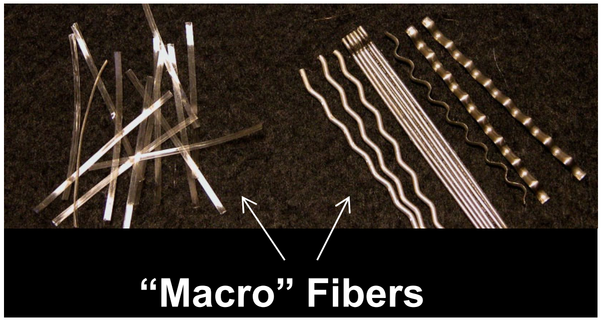
Why do you need steel?

- Does not make concrete stronger!
- Does not stop concrete from cracking!
- Holds concrete together when it cracks

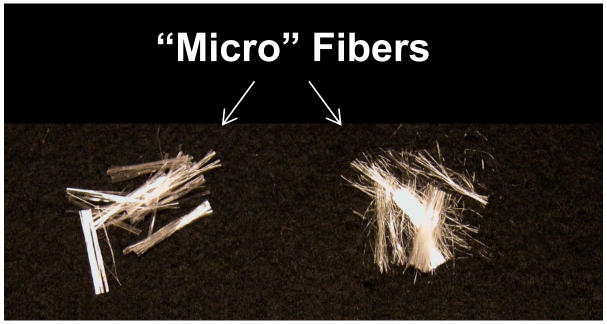


PAVE AHEAD
DURABLE. SUSTAINABLE. CONCRETE.

Fibers are a better way



– Steel & Macro Fibers (0.008-0.03")
Secondary Reinforcement



– Micro Fibers (<0.004")
Plastic Shrinkage Crack Control

PAVE AHEAD
DURABLE. SUSTAINABLE. CONCRETE.

Steel for Load Transfer

- Refer to ACI 330R-08 and ACI 325 for sizes and grades.
- Dowels – cut, smooth, square ends, free of burrs
  - Plain
  - Epoxy Coated
  - Plate Dowels

Steel to Hold Slabs Together

- Tie Bars – deformed bars

- Supports - chairs or other devices for spacing, supporting, and fastening reinforcing bars in place

Table 3.7—Lengths and spacings for No. 4, 1/2 in. (13 mm) diameter tie bars

		Tie bar spacing, in. (mm)		
		Distance to nearest free edge or to nearest joint where movement can occur		
Slab thickness, in. (mm)	Tie bar length, in. (mm)	12 ft (3.7 m) or less	14 ft (4.3 m)	16 to 24 ft (4.9 to 7.3 m)
5 (125)	24 (610)	30 (760)	30 (760)	28 (710)
5-1/2 (140)	24 (610)	30 (760)	30 (760)	25 (630)
6 (150)	24 (610)	30 (760)	30 (760)	23 (580)
6-1/2 (165)	24 (610)	30 (760)	30 (760)	21 (530)
7 (180)	24 (610)	30 (760)	30 (760)	20 (510)
7-1/2 (190)	24 (610)	30 (760)	30 (760)	18 (460)
8 (200)	24 (610)	30 (760)	28 (710)	17 (430)
8-1/2 (215)	24 (610)	30 (760)	26 (660)	16 (410)
9 (230)	30 (760)	36 (910)	30 (760)	24 (610)

PAVE AHEAD
DURABLE. SUSTAINABLE. CONCRETE.

Number 4

“my pavement cracked…so it failed”

PAVE AHEAD
DURABLE. SUSTAINABLE. CONCRETE.

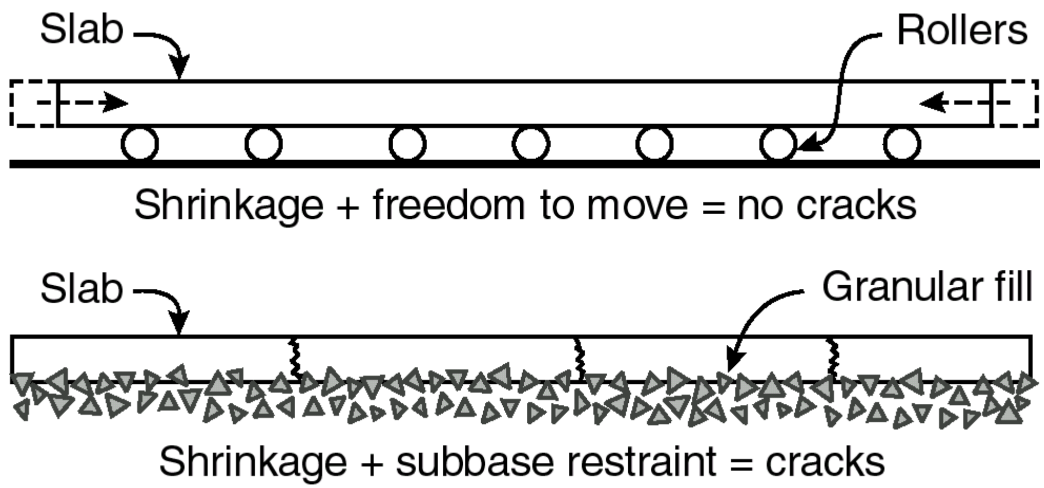
Concrete will crack

The are only 3 things in life that are certain…

- Death
- Taxes
- Concrete will crack

PAVE AHEAD
DURABLE. SUSTAINABLE. CONCRETE.

Drying Shrinkage and Cracking



Shrinkage + Restraint = Cracking

Cracking results from combined effects of restraint and shrinkage (drying and/or thermal)…

…whenever resulting tensile stresses exceed tensile strength.

PAVE AHEAD
DURABLE. SUSTAINABLE. CONCRETE.

Recommended Spacing of Control Joints

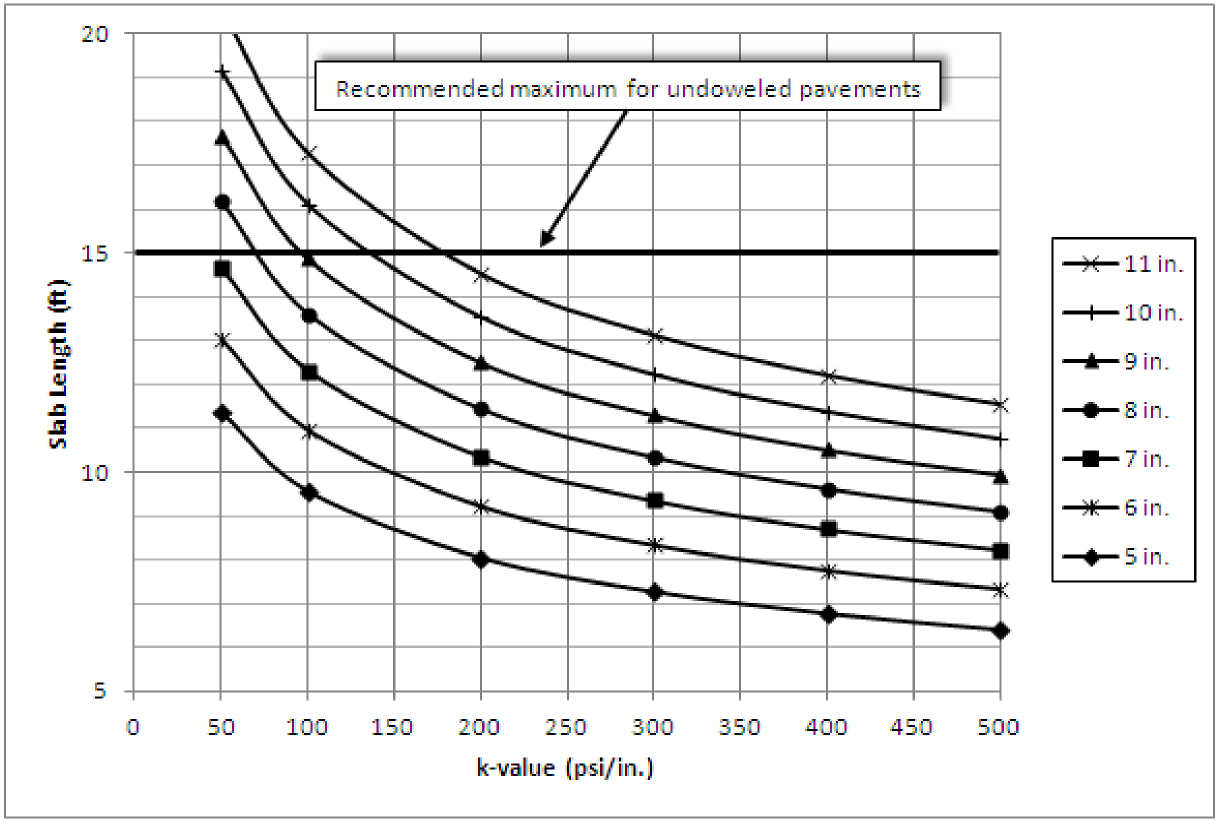
24-30 times the thickness

Thickness (inches)	Spacing (feet)
4	8-10
5	10-12
6	12-15
7	14-15
8+	15

Some designs may call for closer joint spacing due to load transfer considerations.

PAVE AHEAD
DURABLE. SUSTAINABLE. CONCRETE.

Slab Length vs. Pavement Thickness Relationships



Using the criterion of a maximum L/ℓ ratio of 4.44, the allowable joint spacing would increase with increased slab thickness but decrease with increased (stiffer) foundation support conditions.

Rules of Thumb for Jointing & Slab Dimensions

- Spacing:
  - Recommendation of 2.0 to 2.5 times the depth in feet (24 to 30 x thickness gives inches)
  - For example: 4” thick = 10’ maximum (4 x 2.5)
- Panel shall be kept as square as possible
  - L:W of 1½:1 (Maximum length to width ratio)
- Presence of strong base or stiff subgrade affects joint spacing

Jointing Layouts: Corners, acute angles, edges with extreme curvature

Carry joint through curb
(integral curb shown)

Intersect joints
(Avoids acute angles)

Intersect at corners

Jointing Layouts: Corners, acute angles, edges with extreme curvature

Meet structures at corners

Avoids acute angles
(Intersect at perpendicular)

Number 3

"more cement makes the pavement stronger"

Yes, but…

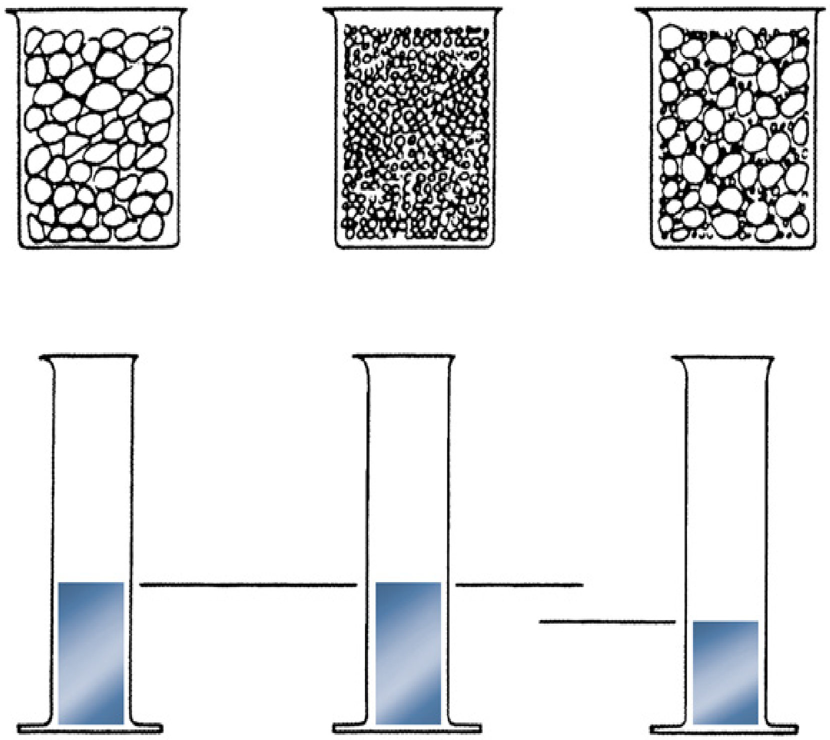
PAVE AHEAD

DURABLE. SUSTAINABLE. CONCRETE.

Low Shrinkage Is Best

- What shrinks?
  - Do aggregates shrink?
    - No
- Does paste shrink?
    - Yes
  - Why?
    - Made up of cementitous materials & water
- Remember:
  - Lower paste content = lower shrinkage!

Aggregates Grading and Size Effects



A mixture of particle sizes is more efficient at filling void space than all particles of any one size.

Larger maximum sizes also help graded aggregates fill volume more effectively.

Durability of Concrete

- **Durability** is more important than **strength**
- Withstand freeze / thaw and deicing salts /ASR
- Need quality aggregates, low w/c ratio, adequate cement, and sufficient amount of entrained air.
- Good contractors
- Good curing measures
- Keep water out of the joints

PAVE AHEAD
DURABLE. SUSTAINABLE. CONCRETE.

Number 2

“concrete pavements can’t be built in northern climates”

PAVE AHEAD
DURABLE. SUSTAINABLE. CONCRETE.

Pinwheel Roundabout - Wisconsin

Source – Wisconsin Concrete Association

PAVE AHEAD
DURABLE. SUSTAINABLE. CONCRETE.

McKenzie County, ND

PAVE AHEAD
DURABLE. SUSTAINABLE. CONCRETE.

Washington County, MN

Source – Minnesota Concrete Association

PAVE AHEAD
DURABLE. SUSTAINABLE. CONCRETE.

Burlington International Airport (2012 – 2017)

Super 8 Motel – Cromwell, CT

PAVE AHEAD
DURABLE. SUSTAINABLE. CONCRETE.

Route 20 - Charlton, MA

PAVE AHEAD
DURABLE. SUSTAINABLE. CONCRETE.

Reduce the risk of distress

- Use low w/cm ratio, ~ 0.40 to 0.42 to reduce permeability
- Appropriate use of supplementary cementitious materials
- Adequate air voids

PAVE AHEAD
DURABLE. SUSTAINABLE. CONCRETE.

Reduce the risk of distress (cont'd)

- Pay attention to drainage at all locations so joints can dry out

- Application of penetrating sealants that will slow water and salt penetration into the microstructure (Castro et al. 2011)

- Limiting the use of aggressive salts to times and temperatures (typically <15ºF) when they are necessary for safety

…and the Number 1

"concrete pavement is a lot more expensive than asphalt pavement"

…But it doesn't have to be

PAVE AHEAD
DURABLE. SUSTAINABLE. CONCRETE.

Here’s how…

- I can eliminate steel in the mat $
- I can eliminate steel at the joints $$
- I can decrease or eliminate my base $$$
- I don’t have to improve the subgrade $$$$
- I should use ACI to design my thickness $$$$$
- I can use SCM to reduce cement costs and improve durability $$$$$$
- I can reduce my pavement maintenance costs $$$$$$$
- I can construct concrete pavements ANYWHERE

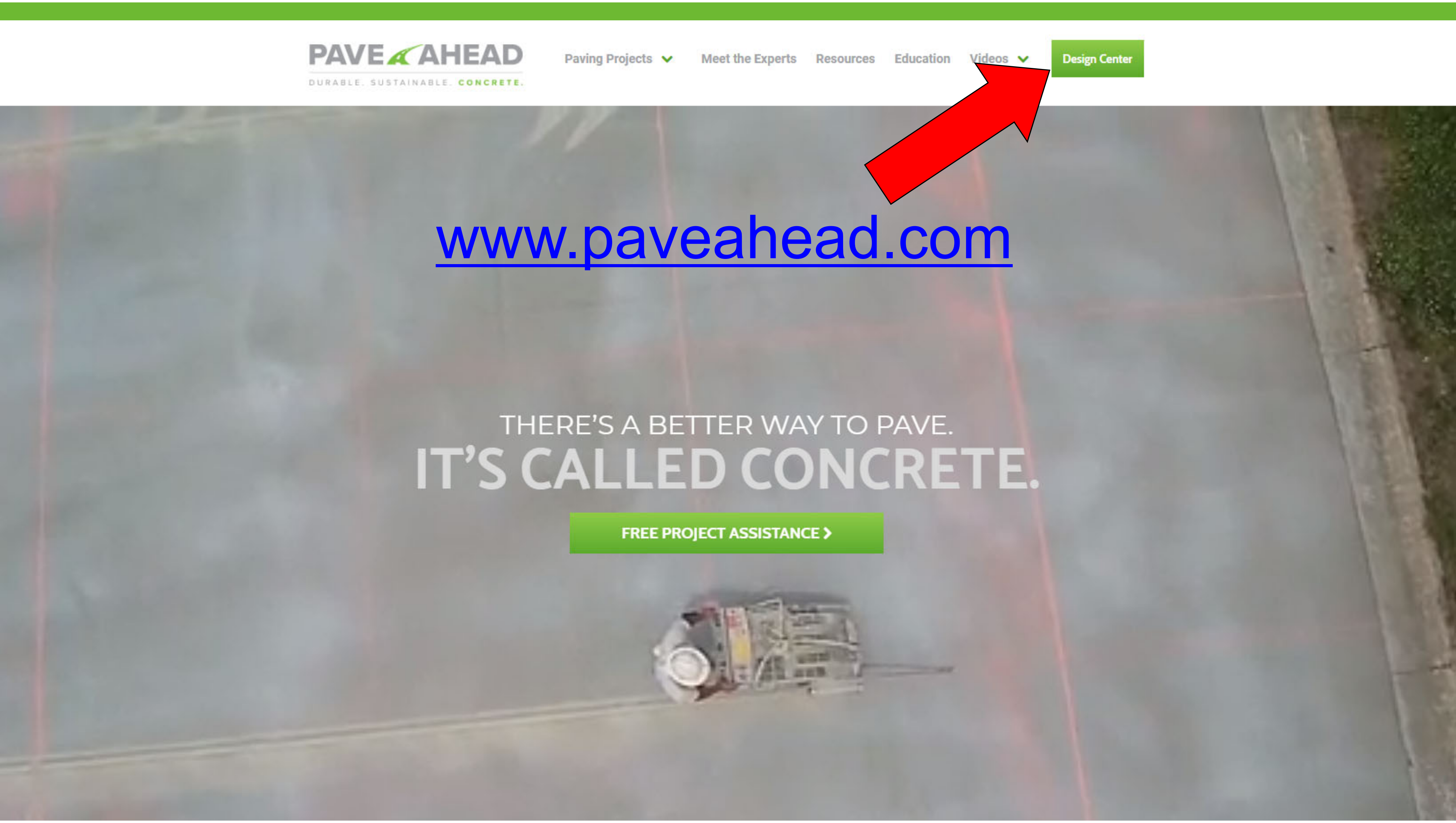
PAVE AHEAD
DURABLE. SUSTAINABLE. CONCRETE.

NRMCA Resources

How Can We Assist You for Free?

PAVE AHEAD

DURABLE. SUSTAINABLE. CONCRETE.


PAVE AHEAD
DURABLE. SUSTAINABLE. CONCRETE.
Paving Projects
Meet the Experts
Resources
Education
Videos
Design Center
www.paveahead.com
THERE'S A BETTER WAY TO PAVE.
IT'S CALLED CONCRETE.
FREE PROJECT ASSISTANCE

paveahead.com/register/

Pave Ahead™ Design Center

- Design and Jointing recommendations and reviews for FREE
- Cost comparisons including life cycle costs
- Specification review
- Ready mixed products:
  - Conventional concrete (full depth and overlays)
  - Pervious concrete
  - Roller compacted concrete
  - Cement slurry for full depth reclamation (FDR)

PAVE AHEAD

DURABLE. SUSTAINABLE. CONCRETE.

NRMCA'S CONCRETEWORKS 2021

September 30–October 4, Kissimmee, FL

CELEBRATE, COMMUNICATE, ELEVATE

Thank You!

NRMCA®

www.nrmca.org/

paveahead.com/experts/

PAVE AHEAD
DURABLE. SUSTAINABLE. CONCRETE.