Can You Really Afford ***NOT*** to Consider Concrete Pavements?

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Kenneth Justice, P.E., LEED AP, Senior Director, Local Paving
and
Luke McHugh, P.E., Senior Director, Local Paving

National Ready Mixed Concrete Association
www.nrmca.org

Agenda

We are going to hit the high points only!

- What is ACI 330?
- “Guided Tour” of the document
- History of pavement design methodology
- Designing with ACI 330
- Pavement Comparison Using Structural Numbers
- ACI 330 Design in Action

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Concrete Parking Lot Design with ACI 330

What is ACI 330?

Committee within American Concrete Institute

- Leading Industry Experts & Engineers
- Complete and Concise for Design and Construction

✓ACI 330R-08: Guide for Design and Construction of Concrete Parking Lots

✓ACI 330.1-10: Specification for Plain Concrete Parking Lots

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Overview of the Document:

Introduction and Scope – Chapter 1

Notation and Definitions – Chapter 2

Pavement Design – Chapter 3

Materials – Chapter 4

Construction – Chapter 5

Inspection and Testing – Chapter 6

Maintenance and Repairs – Chapter 7

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Materials

Flexural Strength/PSI – key property

Freeze/Thaw – Air Entrainment Necessary?

Well-graded Aggregates/SCM

Workability

Material Specifications

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Construction

- Subgrade
- Paving Equipment
- Placing, Finishing and Texturing
- Curing and Protection
- Jointing
- Parking Lot Geometry
- ACI Certified Finishers

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Inspection and Testing

- Inspection of Subgrade/Subbase
- NRMCA Plant Certification
- Plastic Properties
- Compressive/Flexural Strength
- Construction Checks

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Maintenance and Repairs

Sealing

Full Depth Repair

Undersealing and Leveling

Overlays – Over Asphalt or Existing Concrete

Cleaning

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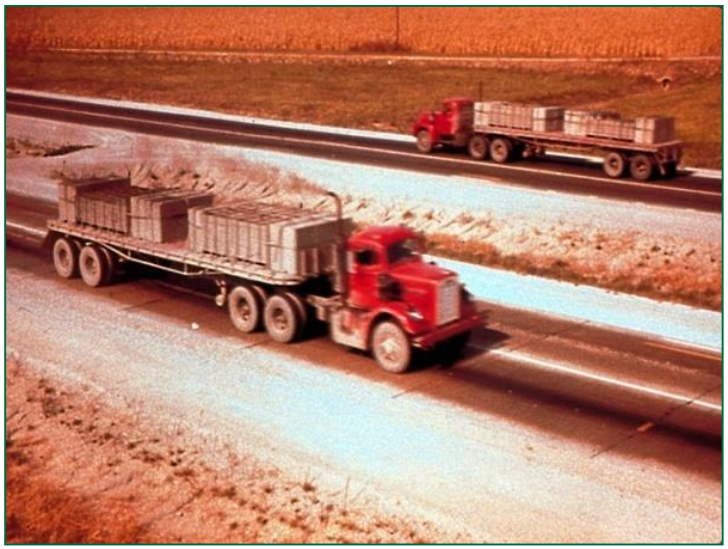
Source of Much of What We Know About Pavement Design

AASHO Road Test

Late 50's and early 60's

Ottawa, Illinois



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ESALS - *Equivalent Single Axle Loads*

- 18,000 lb single axle with dual tires
- Different Axle Loads and Configurations converted into equivalent 18 kip single axle loads

Axle Type (lbs)	Axle Load		Load Equivalency Factor (from AASHTO, 1993)	
	(kN)	(lbs)	Flexible	Rigid
Single axle	8.9	2,000	0.0003	0.0002
	44.5	10,000	0.118	0.082
	62.3	14,000	0.399	0.341
	80.0	18,000	1.000	1.000
	89.0	20,000	1.4	1.57
	133.4	30,000	7.9	8.28
Tandem axle	8.9	2,000	0.0001	0.0001
	44.5	10,000	0.011	0.013
	62.3	14,000	0.042	0.048
	80.0	18,000	0.109	0.133
	89.0	20,000	0.162	0.206
	133.4	30,000	0.703	1.14
	151.2	34,000	1.11	1.92
	177.9	40,000	2.06	3.74
	222.4	50,000	5.03	9.07

One 18,000 lbs. single axle does
over 3,000 times more damage
to a pavement than an 2,000 lbs. single axle

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PCA thickness design method

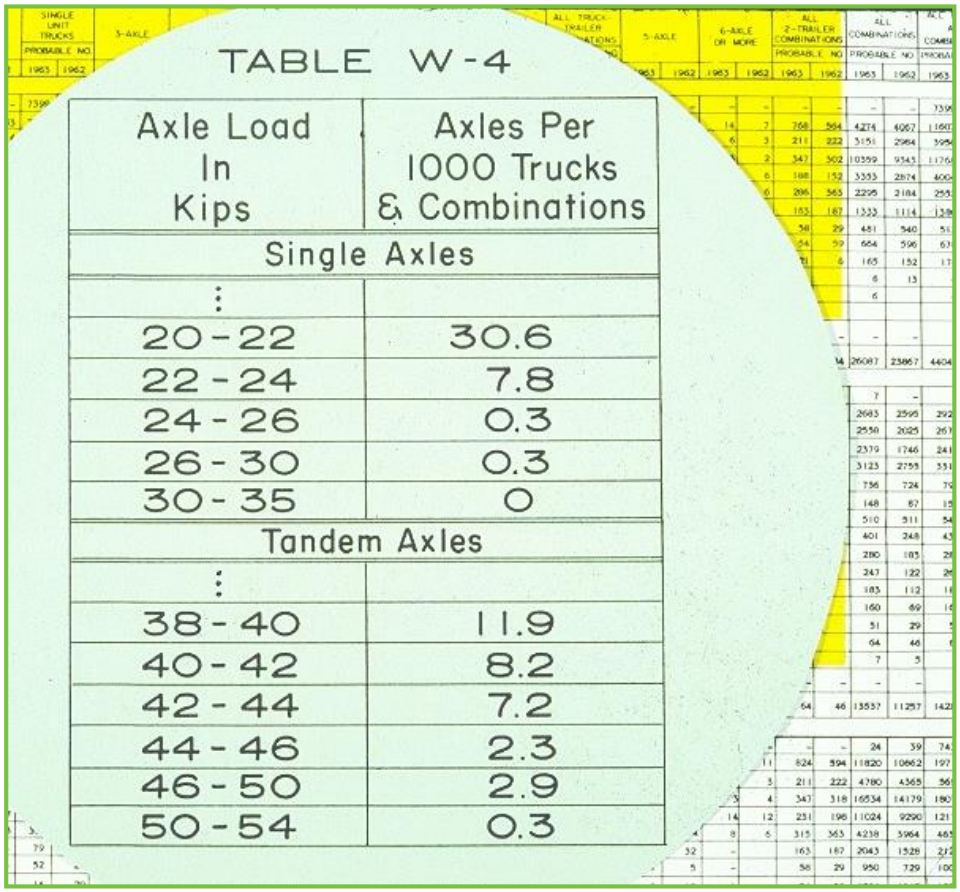

TABLE W-4

Axle Load In Kips	Axles Per 1000 Trucks & Combinations
Single Axles	
⋮	
20-22	30.6
22-24	7.8
24-26	0.3
26-30	0.3
30-35	0
Tandem Axles	
⋮	
38-40	11.9
40-42	8.2
42-44	7.2
44-46	2.3
46-50	2.9
50-54	0.3

- Theoretical, based on calculated pavement stress as a % of MOR
- Traffic input via ADTT (Average Daily Truck Traffic)
- Direct input of data
- Assumed traffic mixes
- Basis of ACPA “Street Pave” and thickness tables in ACI 330R

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What do designers currently use for concrete parking lots?

Nothing – No concrete design. Only design in asphalt

AASHTO Design Guide – ‘72, ‘86, ’93

DOT specifications (Do DOT’s design parking lots?)

“What we’ve always used”

ACI 330!

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Why Use It?

- Economical 20 Year Design
- Addresses All Aspects of Concrete Parking Lots
- Based on Sound *Conservative* Engineering
- Only Document Created Just for Concrete Parking Lots
- **ACI 330 is *The Industry Standard*!**

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Designing with ACI 330

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Key Terminology

k – modulus of subgrade or

CBR – California Bearing Ratio (R and SSV)

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.

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Key Terminology

ADTT – average daily truck traffic

Table 3.3—Traffic categories*

1. Car parking areas and access lanes—Category A		
2. Shopping center entrance and service lanes—Category B		
3. Bus parking areas, city and school buses Parking area and interior lanes—Category B Entrance and exterior lanes—Category C		
4. Truck parking areas—Category B, C, or D		
Truck type	Parking areas and interior lanes	Entrance and exterior lanes
Single units (bobtailed trucks)	Category B	Category C
Multiple units (tractor trailer units with one or more trailers)	Category C	Category D

*Select A, B, C, or D for use with Table 3.4.

Key Terminology

MOR – modulus of rupture/flexural strength

*Concrete Industry uses compressive strength (f’c)

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4,000 psi compressive = 580 psi flexural

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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
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	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

Thickness criteria based on soil support…

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	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

…concrete strength…

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	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

…and Average Daily Truck Traffic (ADTT)

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	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

Recommended Thickness is 4.5 inches

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Traffic Category	A (ADTT =1)	4.0	4.0	4.0	4.5	4.0	4.5	5.0	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	5.5	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

4.5

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Parking Area Quick Reference

From American Concrete Institute Committee 330

Step 1: Determine concrete compressive strength requirement. For all concrete exposed to freeze-thaw cycling and de-icers, use no less than 4000 psi. 4500 psi is recommended.

Step 2: Determine Modulus of Subgrade Reactivity, k. Use guidelines below.

Step 3: Determine Traffic Categories (car parking area, entrances etc.).

Step 4: Determine Average Daily Truck Traffic (ADTT) on the pavement. It is safe to always assume at least one ADTT.

Step 5: Read across row that corresponds to your Traffic Category and ADTT to the column that represents your concrete strength and *k* value.

Example:

- Car parking area truck access lane.
- Traffic Category A, ADTT = 1.
- Concrete strength of 4500 psi.
- Soil is sandy gravel with some clay and silt; *k* value is 130-170; therefore use *k* = 100.
- Under area with *k* = 100, read across row with "Traffic Category A (ADTT = 1)" to column under *f'c* = 4500.
- Thickness necessary for this situation is 4.5.

Modulus of Subgrade Reactivity

Type of Subgrade Soil	*k* Value	CBR
Fine-grained soils in which silt & clay-sized particles predominate	75 - 120	2.5 - 3.5
Sands & sand-gravel mixtures with moderate amounts of silt & clay	130 - 170	4.5 - 7.5
Sands & sand-gravel mixtures relatively free of plastic fines	180 - 220	8.5 - 12

Traffic Categories

Select Category A, B, C or D

Car Parking Areas & Access Lanes *(Autos, pick-ups, & panel trucks only)*		Category A
Shopping Center Entrance & Service Lanes		Category B
City & School Bus Parking Areas: » Parking area & interior lanes. » Entrance & exterior lanes.		Category B Category C
Truck Parking Areas:		
Parking Areas & Interior Lanes	Single-Unit Trucks*	Category B
	Multiple-Unit Trucks**	Category C
Entrance & Exterior Lanes	Single-Unit Trucks*	Category C
	Multiple-Unit Trucks**	Category D

**Single-Unit Trucks = Bobtailed Trucks*

***Multiple-Unit Trucks = Tractor-trailer units with 1 or more trailers*

Twenty-Year Design Thickness Recommendations in Inches (No Dowels)

		k = 500 psi/in. (CBR = 50; *R* = 86)				*k* = 400 psi/in. (CBR = 38; *R* = 80)				*k* = 300 psi/in. (CBR = 26; *R* = 67)			
	f'c	5000	4500	4000	3500	5000	4500	4000	3500	5000	4500	4000	3500
	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)			
	f'c	5000	4500	4000	3500	5000	4500	4000	3500	5000	4500	4000	3500
	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

**ADTT =Average Daily Truck Traffic Trucks are defined as vehicles with at least 6 wheels; excludes panel trucks, pick-up trucks & other 4-wheeled vehicles. Refer to Appendix A.*

k = Modulus of subgrade reaction; CBR =Califomia Bearing Ratio; R=Resistance value & MOR=Modulus of Rupture.

† Thickness of Category D (only) can be reduced by 1.0 in. (25 mm) if dowels are used at all transverse joints (that is joints located perpendicular to direction of traffic). Note: 1in.=25.4mm; 1psi=0.0069 MPa; & 1psi/in.=0.27 MPa/m.

Preparing the Subgrade for Best Performance

Proper subgrade preparation will ensure superior performance of your concrete pavement. While no special subbase is required, it is important that the soil type, moisture content, and density of the subgrade be uniform. Replace non-uniform subgrade areas with materials that are similar to the rest of the area.

The subgrade must also be reasonably smooth and without tire ruts so that the concrete placed over it will be uniform in thickness.

Materials & Proportions

Quality concrete starts with a well chosen mixture using consistently high quality materials.

In regions where the pavement will be subjected to freeze-thaw cycles air entrainment is essential. Air entrainment is so important in providing freeze-thaw durability that it pays to test the concrete frequently for air content at the job site and make the necessary corrections as soon as possible. See the table below for recommended air contents.

Because air entrainment also enhances workability and reduces the amount of bleed water, it is wise to consider its use even where freeze-thaw conditions do not exist.

Compressive strength is the most common and easiest property of concrete to measure, and as such, it is the property most used when specifying concrete. Concrete with a 28-day specified compressive strength of 4000 psi (27.6 MPa), is adequate for most areas of the country.

In areas subjected to freeze-thaw cycles, it is further recommended that the mix contain at least 564 lb of cement per cubic yard. In mild climates a minimum cement content of 520 lb per cubic yard is adequate. A mixture with a maximum slump of 4 inches is acceptable. If a water reducing admixture is specified, slumps can be higher.

Recommended Air Contents for Durable Concrete

	Total Target Air Content Percent*	
Maximum Size Aggregate	Severe Exposure	Moderate Exposure
3/8 in. (9.5 mm)	7-1/2	6
1/2 in. (12.5 mm)	7	5-1/2
3/4 in. (19.0 mm)	6	5
1 in. (25.0 mm)	6	4-1/2
1-1/2 in. (37.5 mm)	5-1/2	4-1/2
2 in. (50.0 mm)	5	4

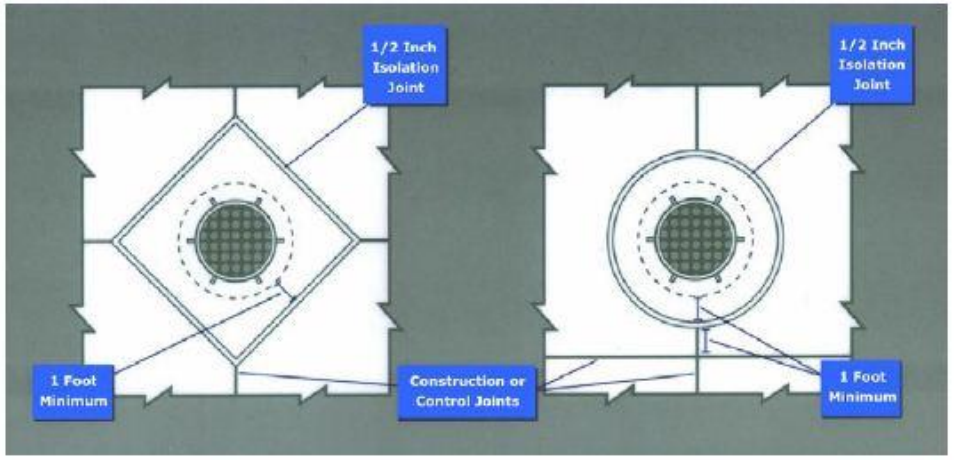
**A reasonable tolerance for air content in field construction is -1 to +2 percentage points*

Jointing Guidelines

It is recommended that you follow these guidelines unless local experience indicates otherwise:

- Joint spacing should not exceed 24 to 30 times the pavement thickness with a maximum spacing of 15 feet.
- Lay out joints to form square panels. When this is not practical, rectangular panels can be used if the long dimension is no more than 1-1/2 times the short.
- Control joints should have a depth of at least one-fourth the slab thickness.

Manhole or Inlet Box



Construction Practices

Procedures that ensure a quality job are:

- Slope pavement 1% or 1/8 inch per foot to drainage.
- Moisten subgrade just prior to placement of concrete.
- Avoid over-finishing slabs. Generally a bullfloat finish is adequate. Sometimes a burlap drag is added in the finishing process to provide a textured finish.
- Cure fresh concrete. Liquid membrane-forming curing compound is usually recommended as the most cost-effective curing agent.
- Keep automobile traffic off the slab for three days and truck traffic off the slab for seven days, unless tests are made to determine that the concrete has gained adequate strength. This is usually 3000 psi.

Concrete Pavement Design Website: Joint Project With ACPA, NRMCA, & PCA

Software Developer: SURGE™

- Designs for Parking, Streets, and Industrial Applications
- Using Jointed Plain Concrete, Continuous Reinforced Concrete, and Roller Compacted Concrete
- With Considerations for Full Depth Reclamation (FDR) and Concrete Overlays

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Common Design Misconceptions

"Concrete pavement requires a subbase"*

*Subbase: a layer of imported or improved material between the natural site material (subgrade) and the concrete.

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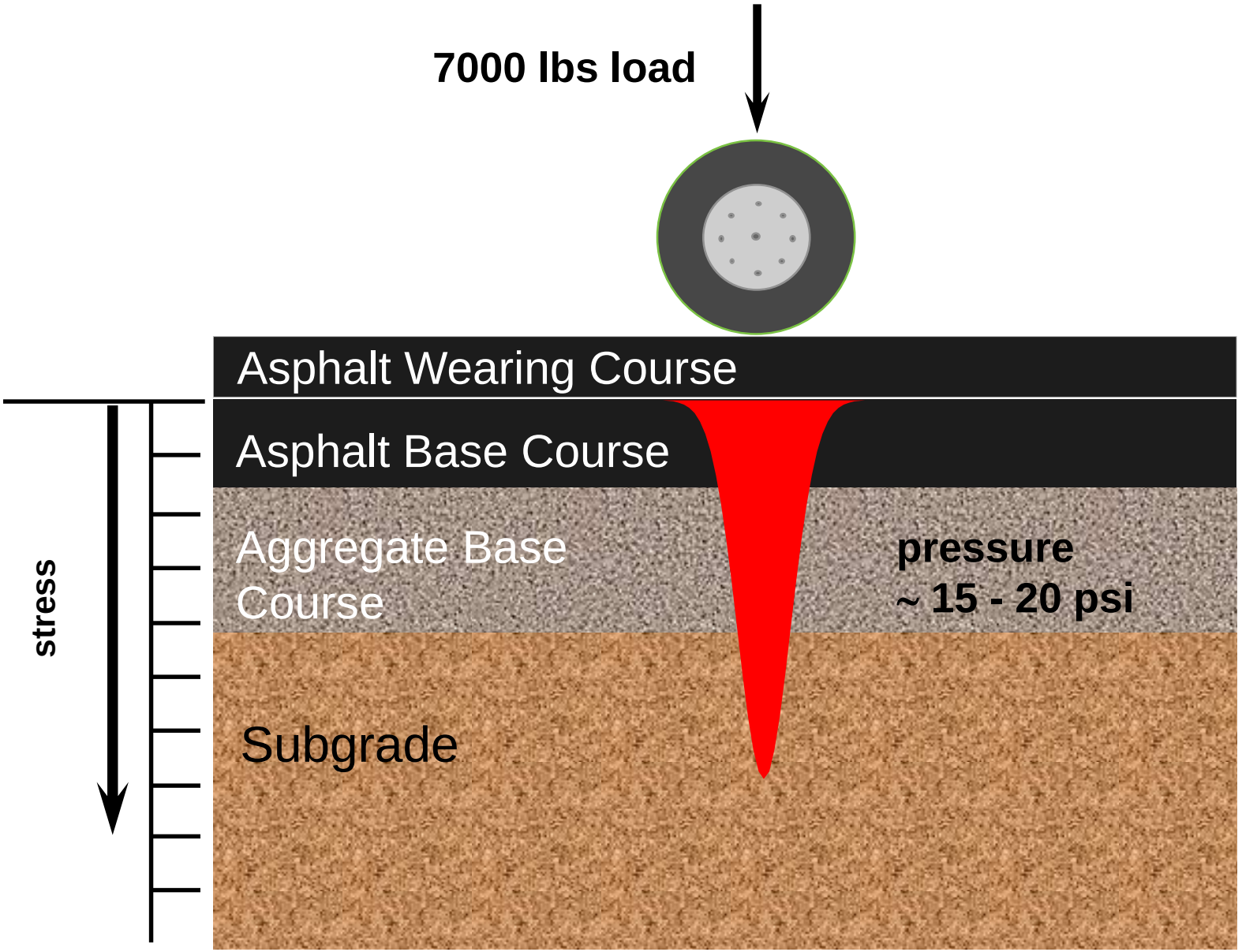
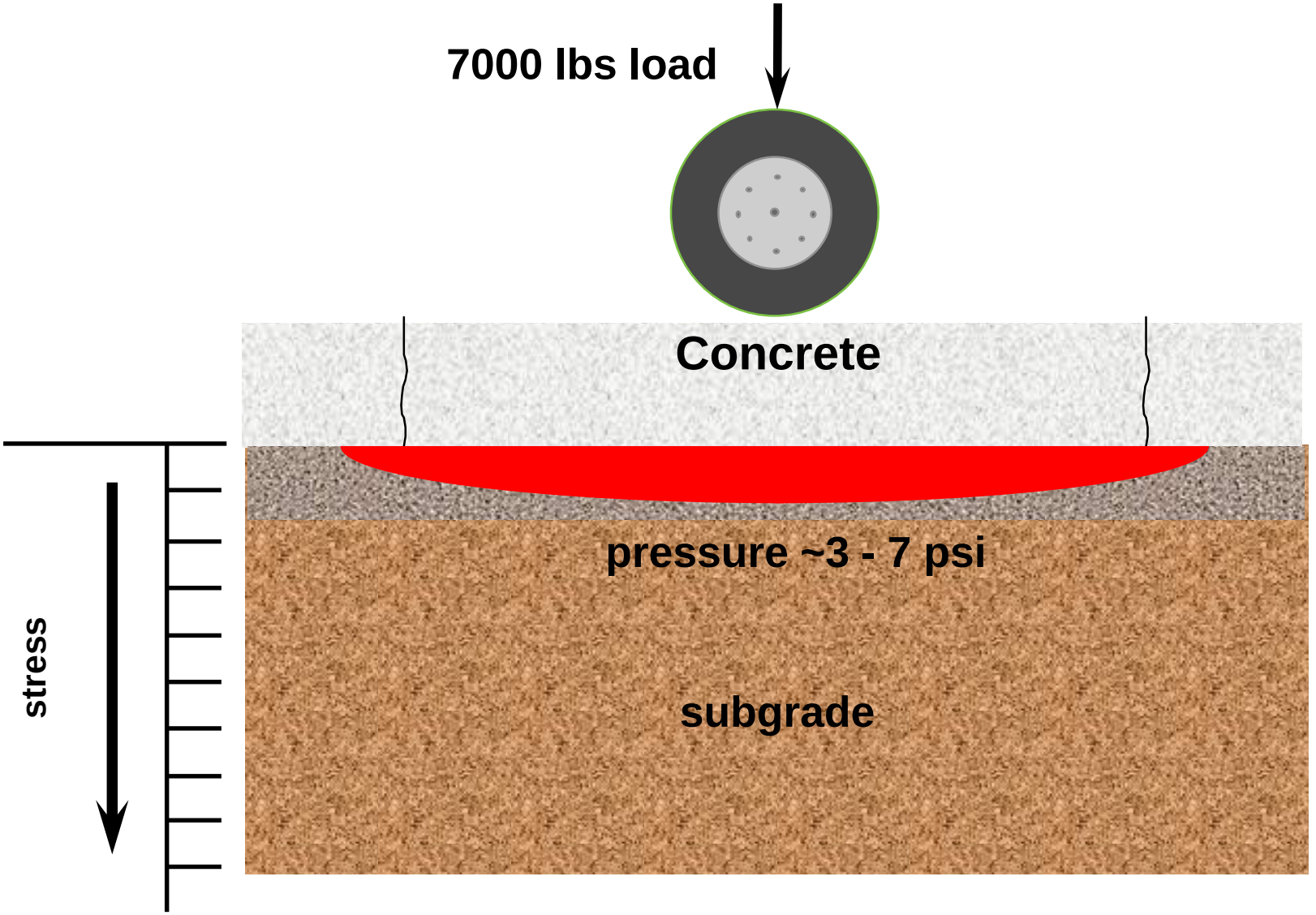

7000 lbs load
Asphalt Wearing Course
Asphalt Base Course
Aggregate Base Course
pressure
~ 15 - 20 psi
Subgrade
stress

The load-carrying structure for concrete pavement is primarily thickness.



ACI 330 position on subgrade/subbase

"A well-prepared, uniform subgrade at the correct elevation is essential to the construction of a quality pavement."

"The subgrade should have a dense, firm, and uniformly smooth surface when concrete is placed on it."

"Granular aggregate subbases are not normally used for concrete parking lots."

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Do you ever need a subbase layer?

May warrant consideration if:

- Construction platform is needed
- Subgrade is very poor quality
- Heavy truck traffic & load transfer concerns
- Pumping of subgrade is likely

Can result in higher *k* value for design and slightly thinner concrete section

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Common Design Misconceptions

Concrete pavements require steel reinforcement!

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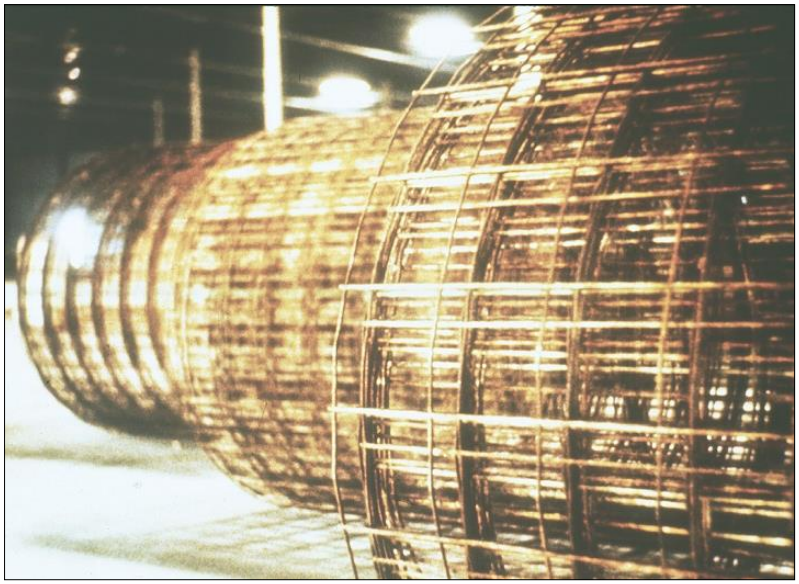
Reinforcing steel in concrete has its place!



Secondary Steel Reinforcement

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

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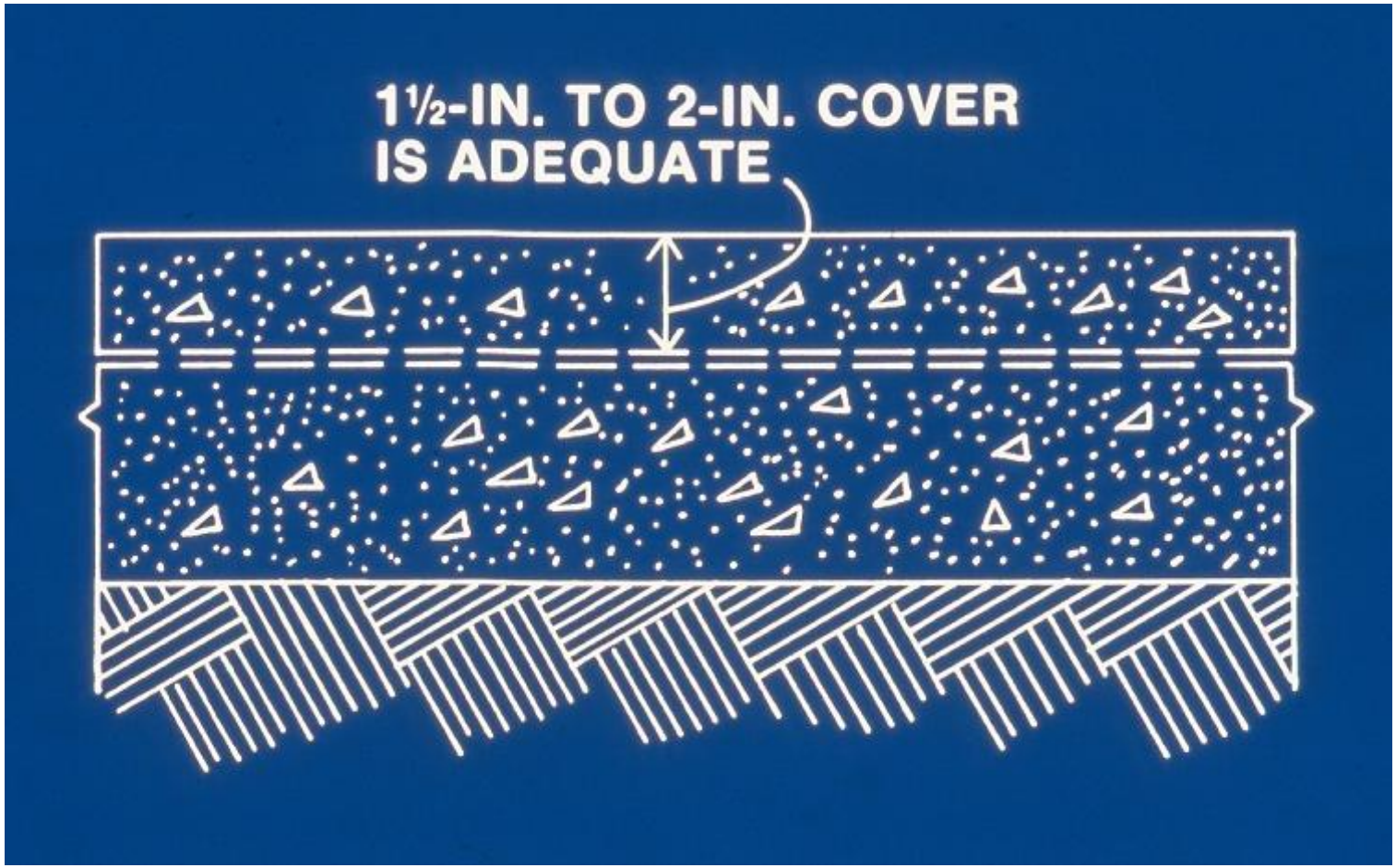
Proper placement of secondary steel reinforcement



When used, the purpose of secondary steel reinforcement is to keep cracks from opening. To do this, it must be located above the mid-thickness.

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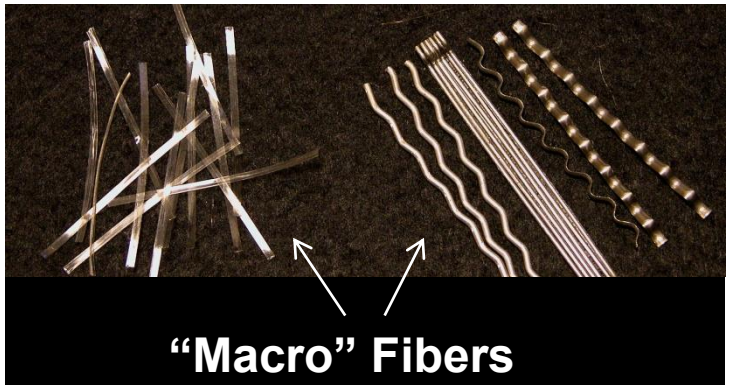
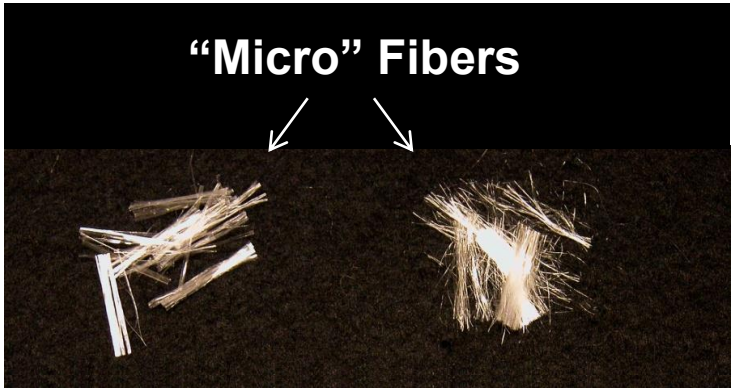
What about Fibers?

Steel & Macro Fibers
(0.008-0.03”)
Secondary Reinforcement



Micro Fibers (<0.004”)
Plastic Shrinkage Crack
Control



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"See how much better it looks Without all those ugly joints?"

How important is jointing?

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Objectives of jointing

- Control the location, width, and appearance of expected cracks
- Facilitate construction
- Accommodate normal slab movements
- Provide load transfer where needed
- Minimize performance implications of any random (unexpected) cracks

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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.

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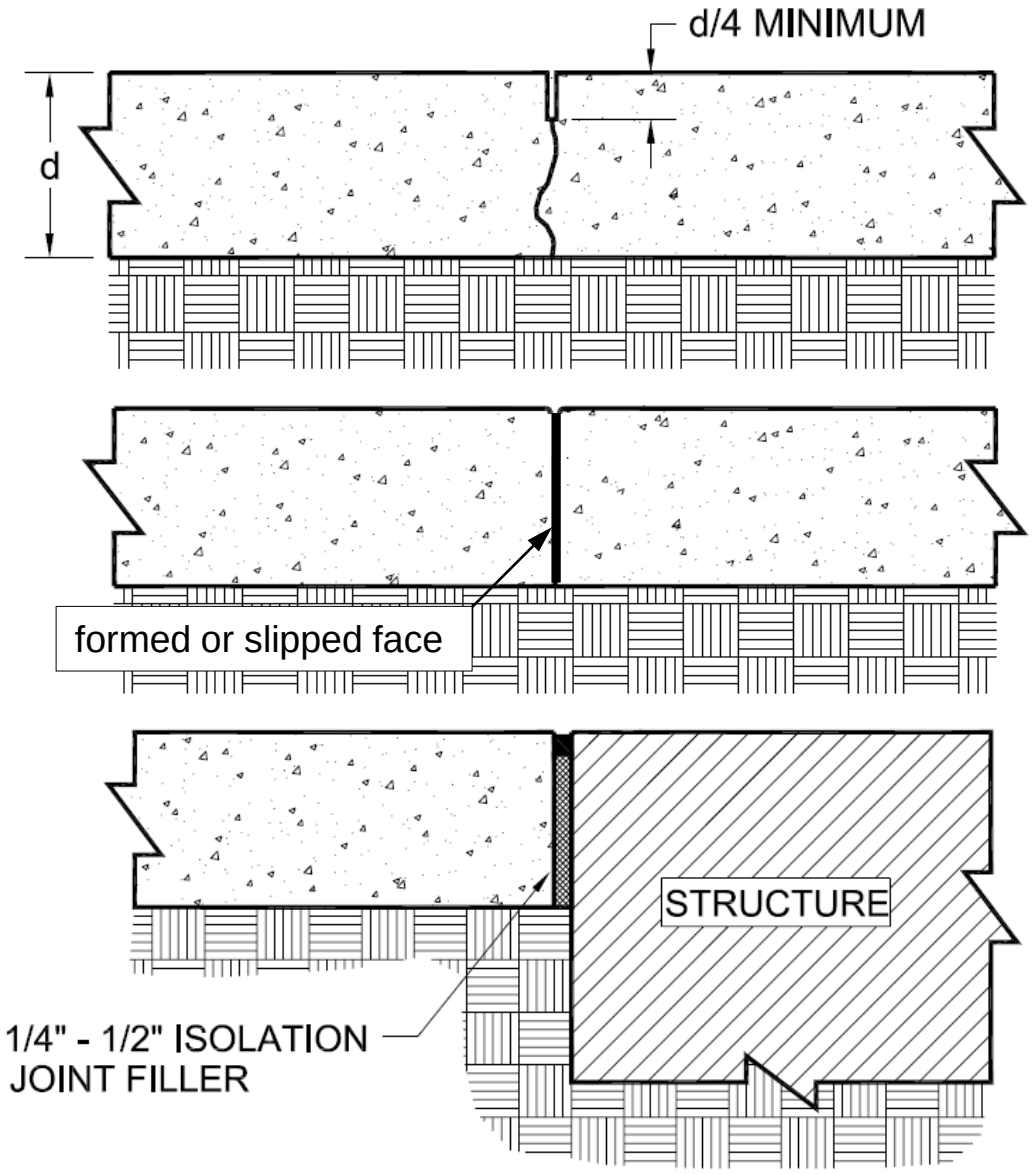
Types of joints in concrete pavement



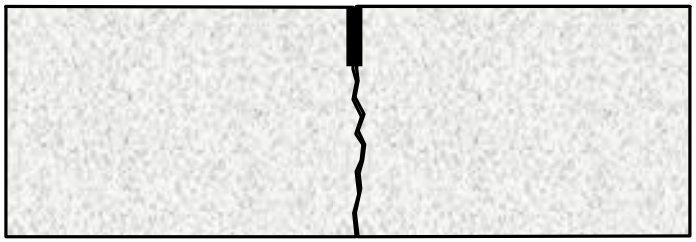
Control joint

Construction joint

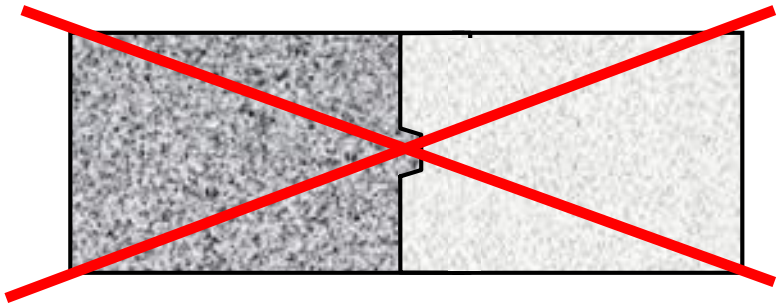
Isolation joint

Load transfer joint details:

Pavements less than 7”



Aggregate Interlock



Keyways

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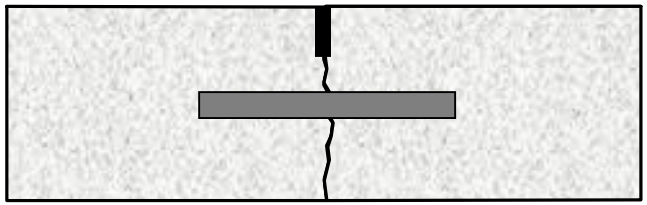
Load transfer joint details:

Pavements greater than 7”



Round Dowels

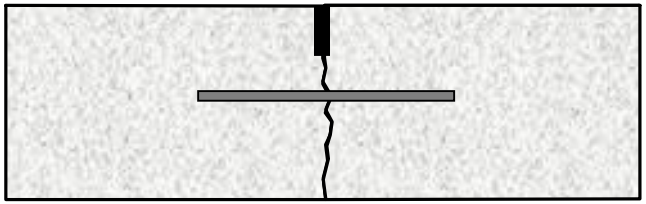
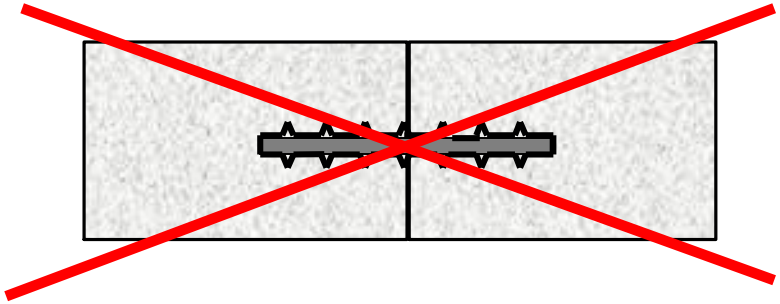


Plate Dowels



Tiebars ≠ Dowels!
(not used for load transfer)

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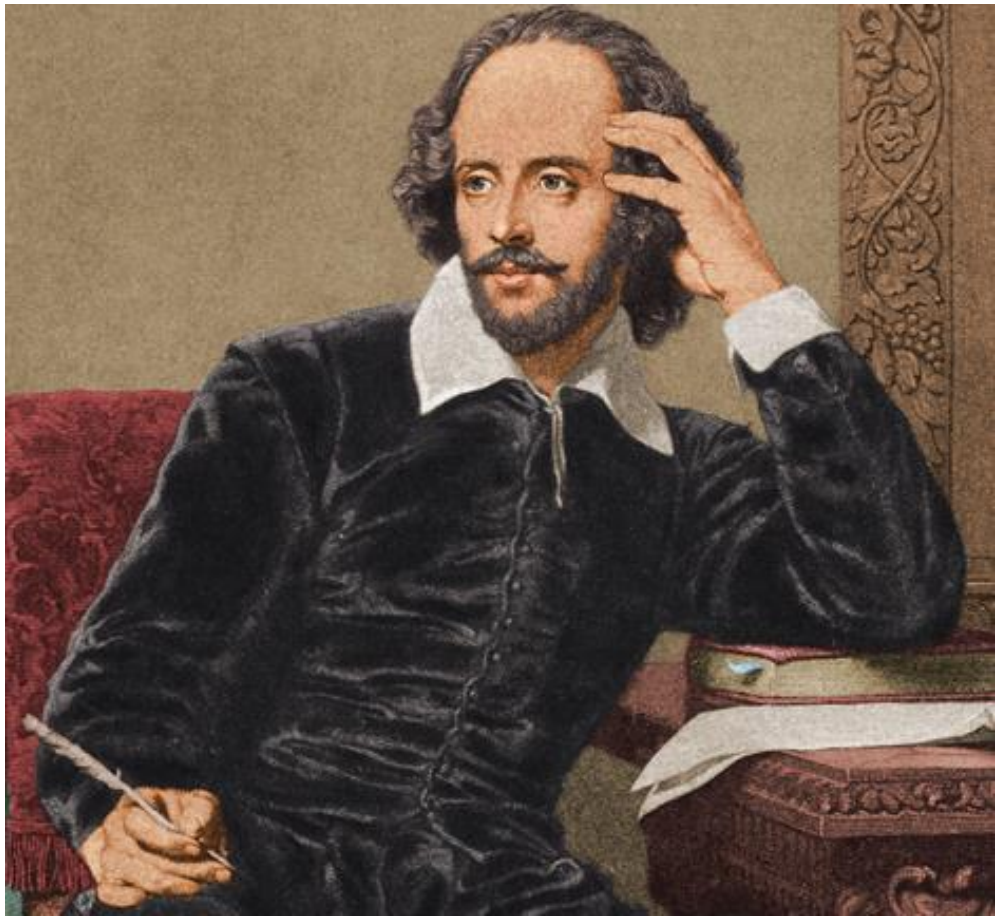

“To seal, or not to seal?”

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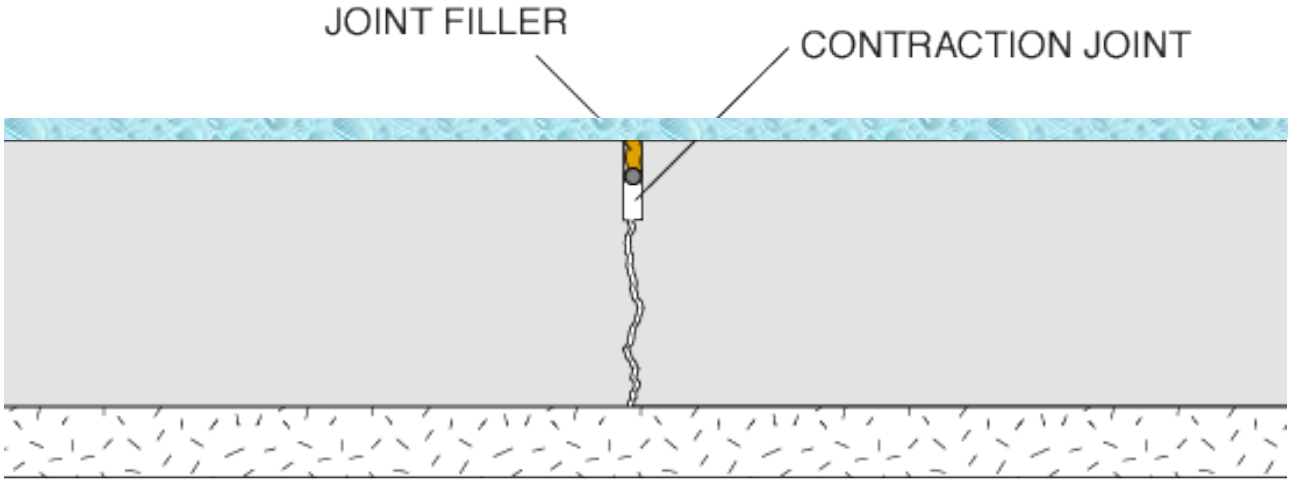

Purpose is to prevent infiltration of water and solids into joint

Factors to consider

- Traffic level
- Soil types & local performance
- Subbase use
- *Saw cut width and method

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Most effective to reduce joint width

1/4 of depth recommended;

1/3 of depth preferred

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Sealants on wide joints extremely ineffective

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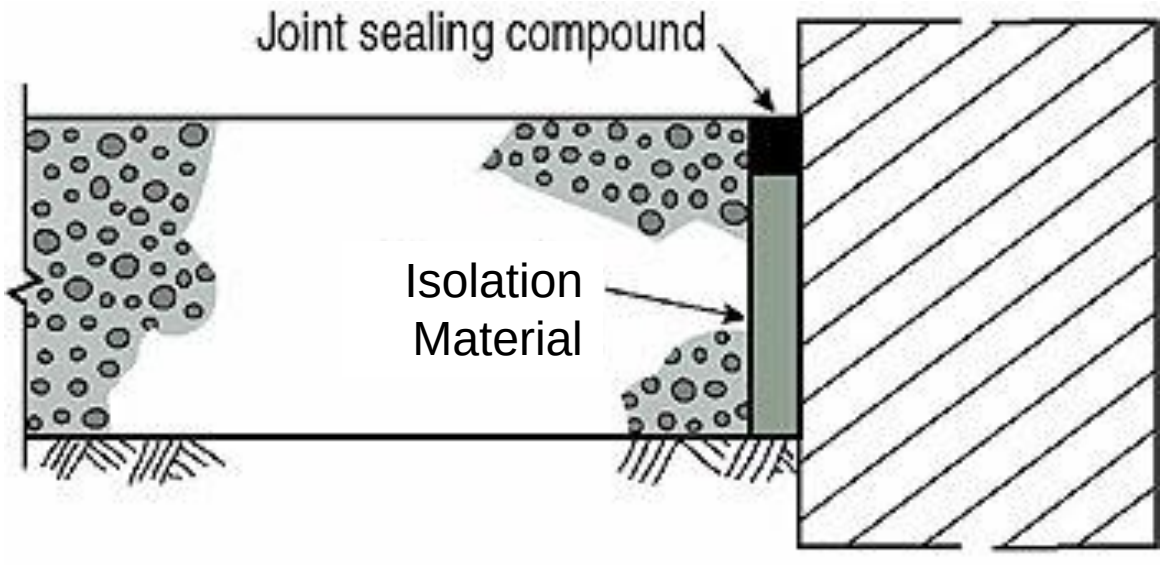
Seal isolation joint against building



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Evaluating Concrete and Asphalt Using Structural Numbers

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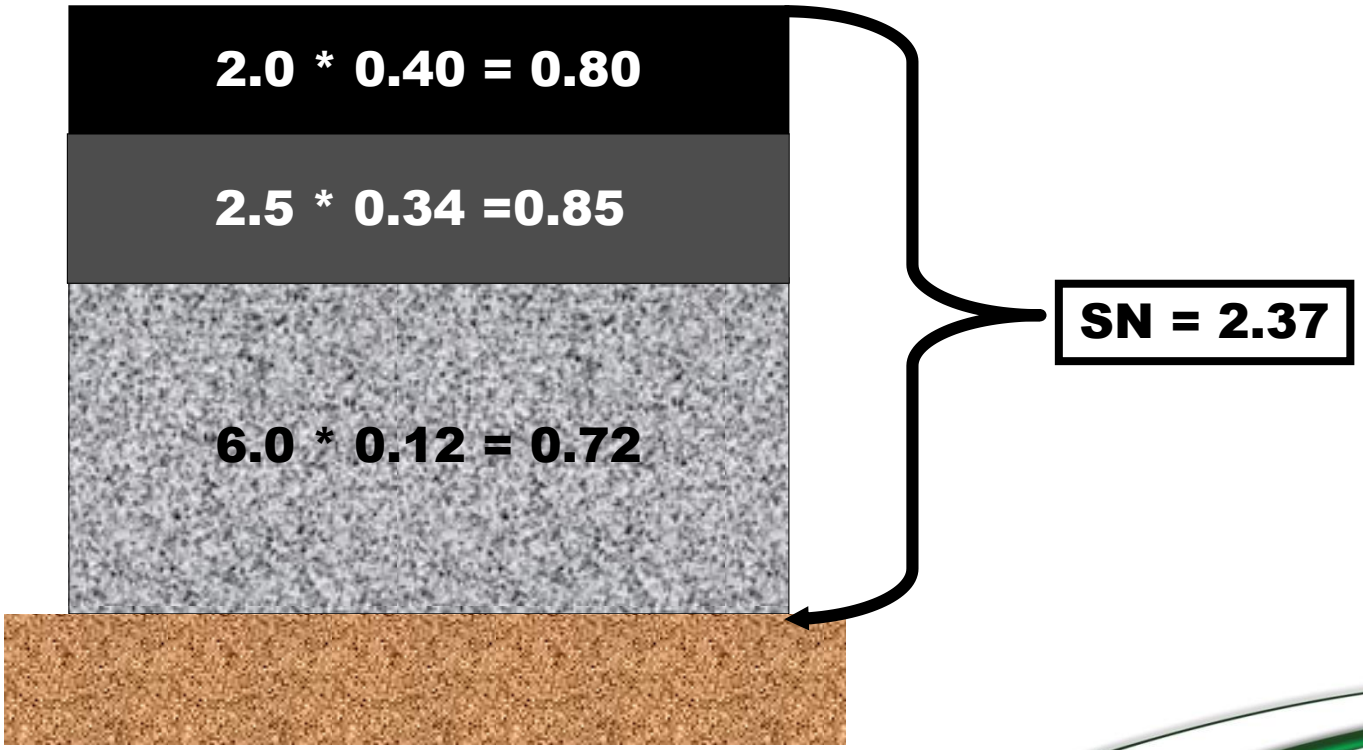
Structural Layer Coefficient

- A relative number assigned for the value of 1” of material
- Using proper values is critical in order to achieve accurate output
- SLC’s for pavement determined from AASHO Road Test for asphalt- 1960

The Structural Number

S.N. = $a_1*t_1 + a_2*t_2 + a_3*t_3 \ldots$



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Bituminous Structural Coefficients

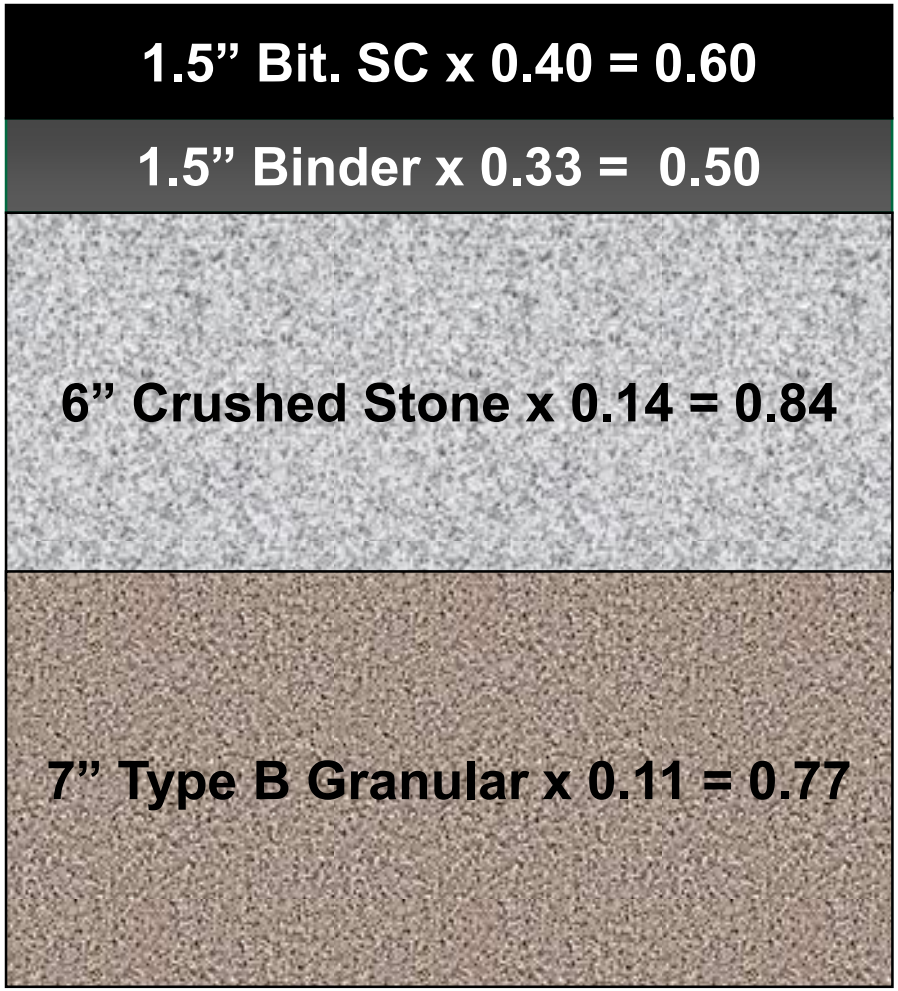
STRUCTURAL MATERIALS	MINIMUM STRENGTH REQUIREMENTS			COEFFICIENTS③		
	MS①	IBR	CS②	a_1	a_2	a_3
Bituminous Surface						
Road Mix (Class B)				0.20		
Plant Mix (Class B)						
Liquid Asphalt				0.22		
Asphalt Cement	900			0.30		
Class I Bituminous Concrete	1700			0.40		
Base Course						
Aggregate, Type B						
Uncrushed		50			0.10	
Crushed		80			0.13	
Aggregate, Type A		80			0.13	
Waterbound Macadam		110			0.14	
Bituminous Stabilized Granular Material	300				0.16	
	400				0.18	
	800				0.23	
	1000				0.25	
	1200				0.27	
	1500				0.30	
	1700				0.33	
Class I Binder	1700				0.33	
Pozzolanic, Type A			600		0.28	
Lime Stabilized Soil			150		0.11	
Select Soil Stabilized			300		0.15	
with Cement			500		0.20	
Cement Stabilized Granular						
Material			650		0.23	
			750		0.25	
			1000		0.28	
Subbase						
Granular Material, Type B		30				0.11
Granular Material, Type A						
Uncrushed		50				0.12
Crushed		80				0.14
Lime Stabilized Soil			100			0.12

Source: Chapter 54, IL D.O.T. Design Manual, 2000

Structural Coefficients for Concrete

- Based on Louisiana AASHO satellite studies
- Used principally for overlay design
- Value set at 0.50 for old concrete
- Calculations from the AASHTO equations incorporating reliability concepts for new pavement show a minimum value of 0.47 to 0.74 depending on strength for plain pavement

Let's Build an Asphalt Section



0.60
\+ 0.50
\+ 0.84
\+ 0.77

S/N 2.71

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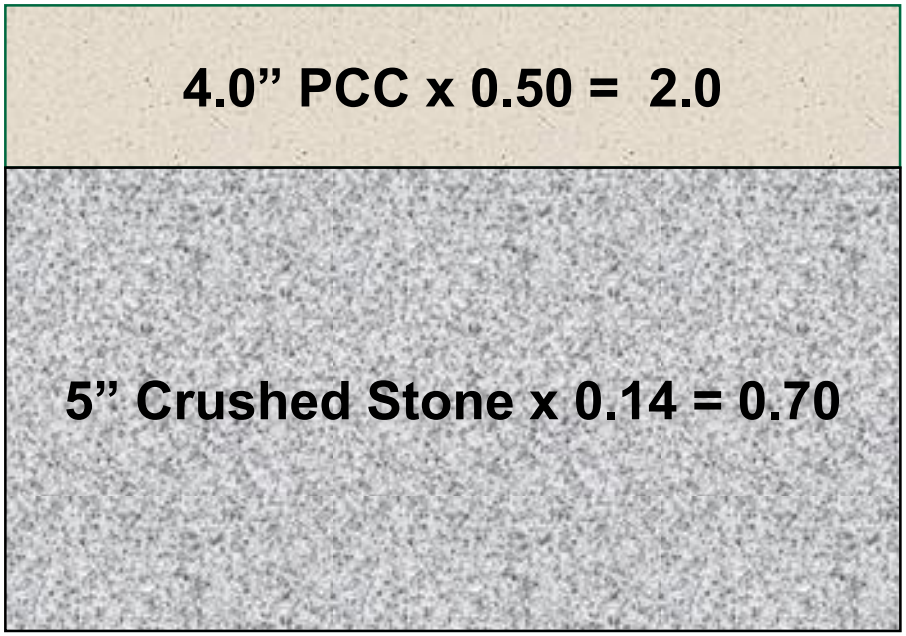
Now Let's Build an Equivalent Concrete Section



2.00

\+ 0.70

S/N 2.70

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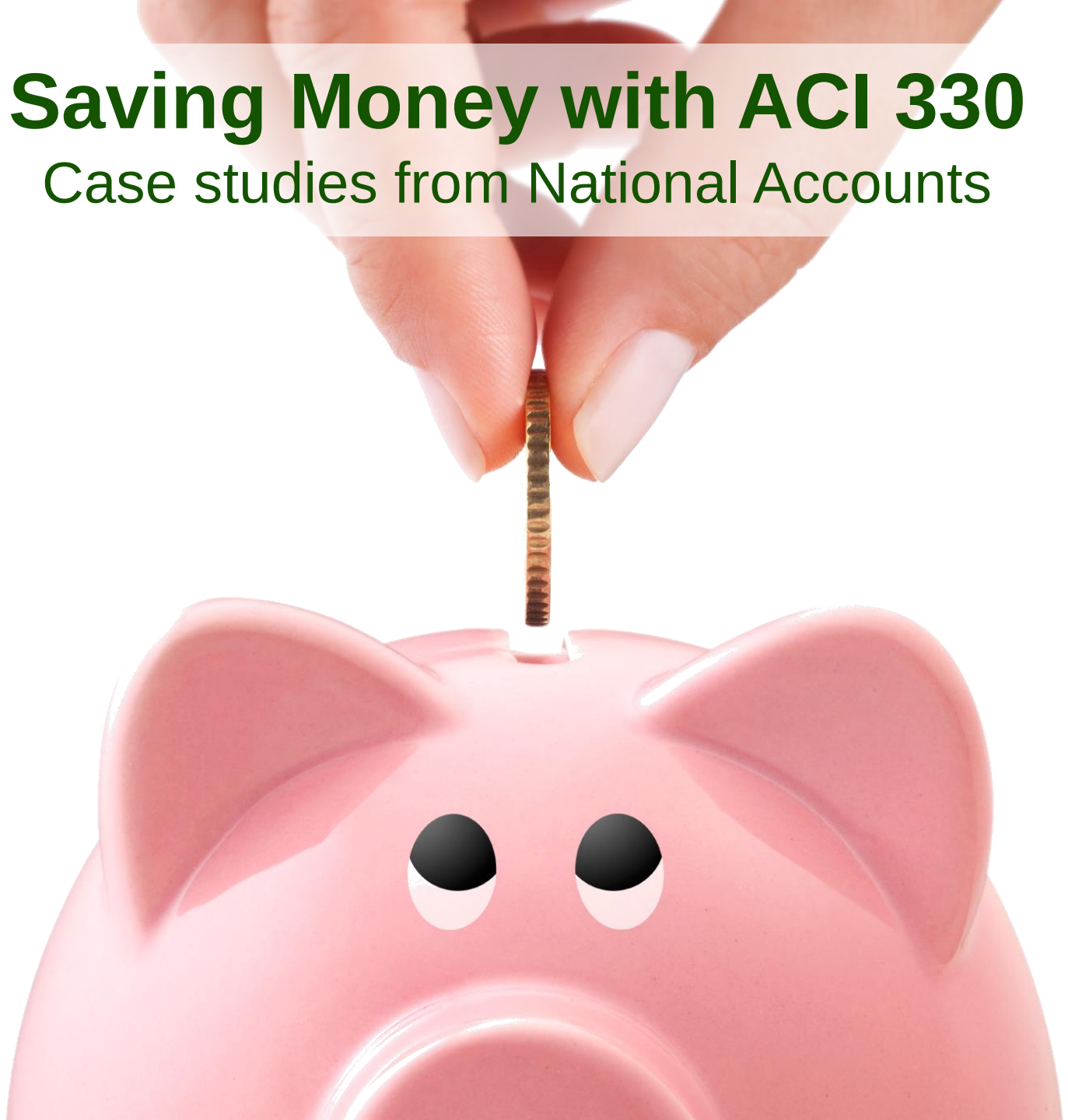
Saving Money with ACI 330

Case studies from National Accounts



Lowe's Home Improvement
Wilmington, NC

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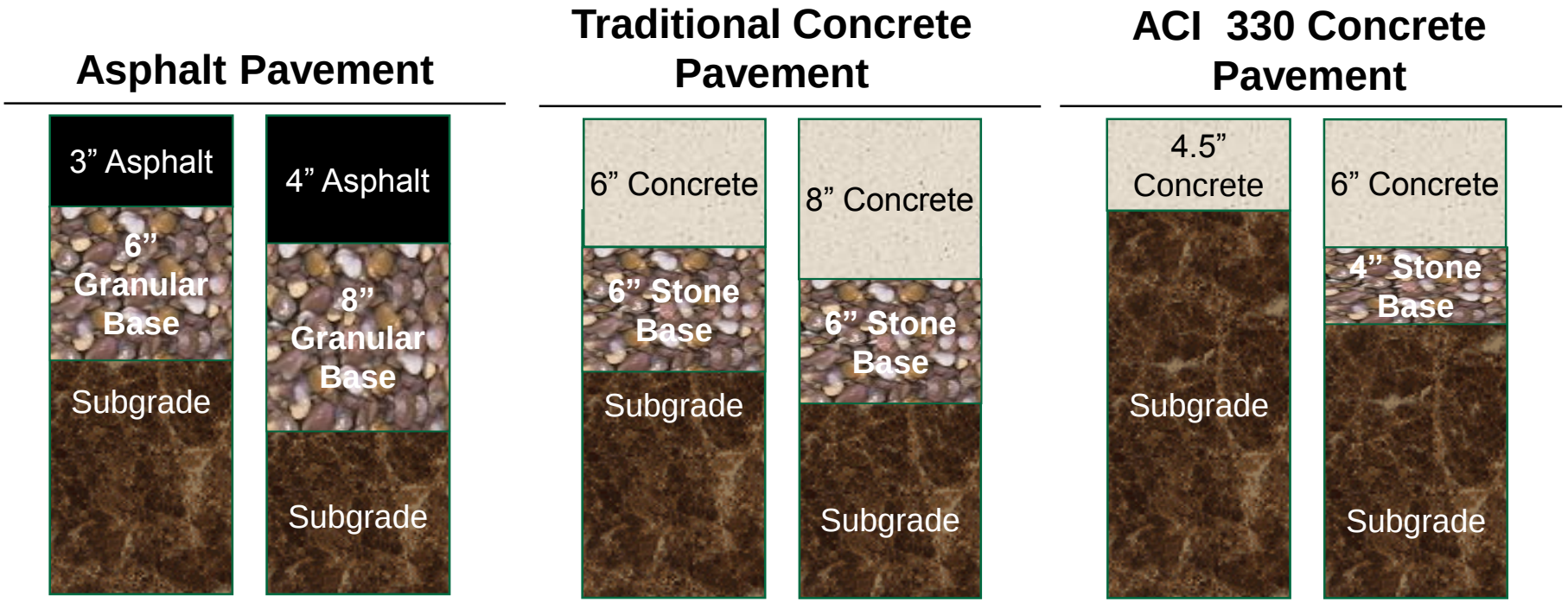
Lowe's Home Improvement
Wilmington, NC



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

Dollar General

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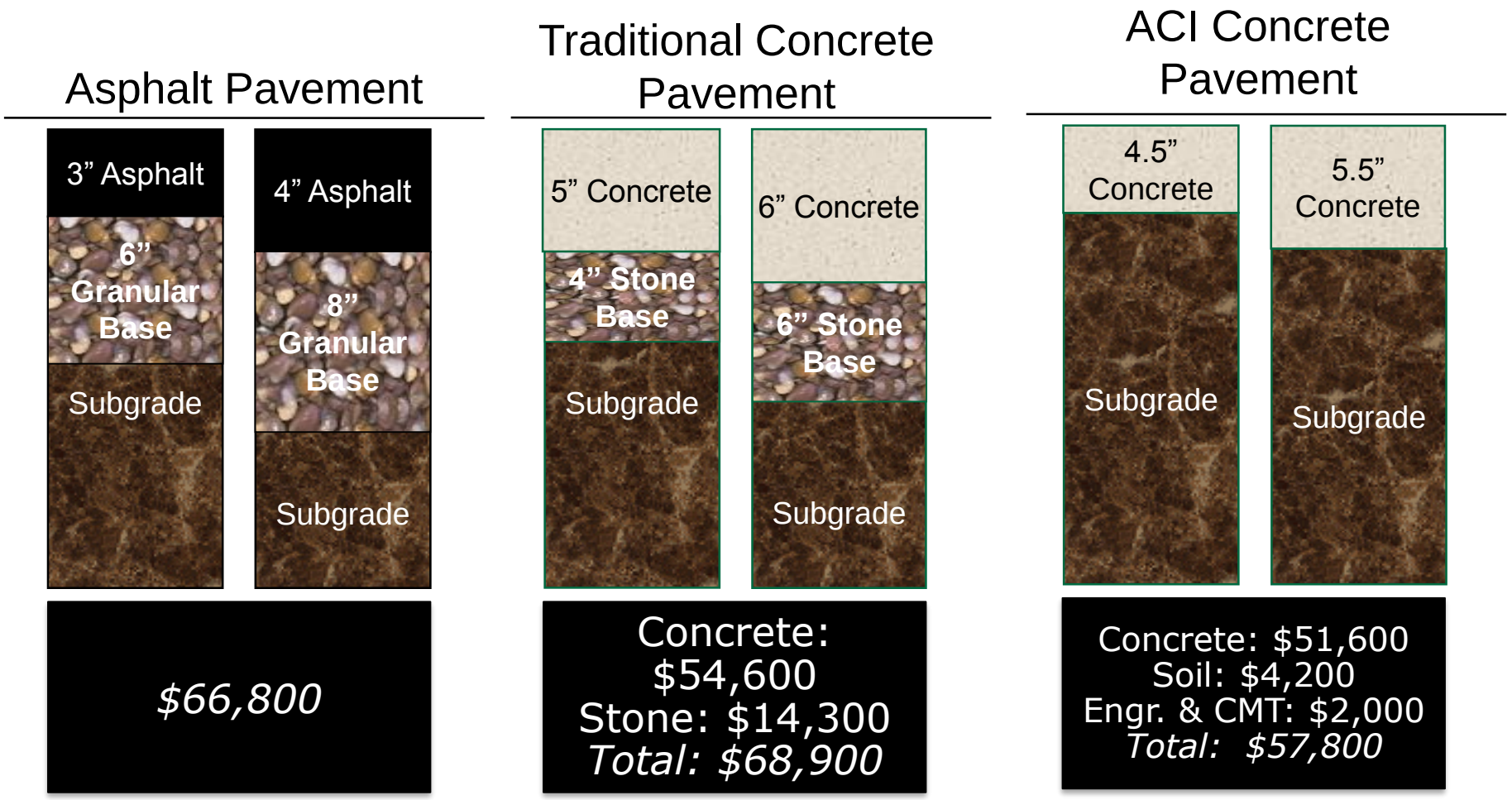
Dollar General



ACI 330 saved developer $9000 paving with Concrete instead of Asphalt

Taco Bell

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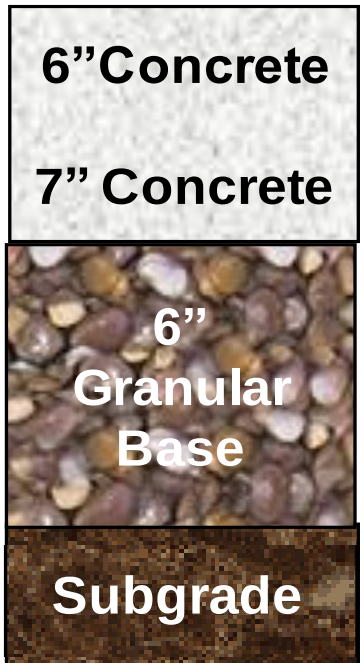
Taco Bell - Lenoir, NC

Asphalt Pavement

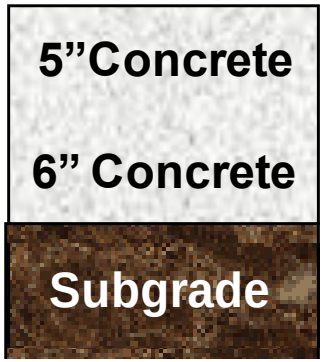
$59,450

Original Concrete Pavement



$88,670

ACI Concrete Pavement



$76,950

The Owners Paid $17,500 ***MORE***
for Concrete vs. Asphalt

Taco Bell - Lenoir, NC

Owner Testimonial:

"We own more than 50 fast food restaurants. This was our first concrete parking lot and it is the best looking pavement at any of our facilities. The small increase in upfront cost is far less than what it will cost us to maintain an asphalt pavement over the life of the restaurant. We will definitely consider concrete in the future."

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Scott Jaguar - Charlotte, NC

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Scott Jaguar - Charlotte, NC

- ACI 330: 20-year design
- Slab Thickness: 4 inches
  - Slab Thickness in front of garage bay doors: 5 inches
- 3,500-psi compressive strength placed using truss screed
- Pavement Condition Rating: Excellent
- Project allowed 20% reduction in light standards

McDonalds

Walgreens

Walmart

FedEx Freight
Northwood, OH

Over 1,000,000 sq ft of Concrete Placed at Northwood, OH FedEx Distribution Facility

After nearly a year of efforts from Michigan contractor, Ray Merlo of Merlo Construction (Milford, MI), and Ohio Concrete, over 1,000,000 sq ft of concrete pavement was placed in Northwood, OH just south of Toledo at a new FedEx distribution facility.

The facility was originally designed with asphalt pavement throughout the yard, minus the trailer staging area. Ray Merlo, the pavement contractor, saw the benefit of offering concrete as an alternative to asphalt throughout the property.

Working with Ohio Concrete Sr. Engineer, Jim Barnhart and the Engineering Services Center, a 6.5" unreinforced 20-year design was presented to the FedEx property owner. This design was developed with the use of ACI 330 principles, StreetPave 12™ and WinPAS 12™ software. This decision was not made hastily or without much discussion and explanation. The owner's main concern was with the concrete design thickness, which was 2.5" less than they had originally designed in the trailer staging area. After much deliberation, the validity of the concrete design was approved and construction was underway.

Aerial view of the new FedEx distribution center in Northwood, OH

The concrete was provided by All Ohio Ready Mix of Sylvania, OH, who set up a portable batch plant on site to allow for the necessary production rate to complete the project on time. Merlo Construction utilized a Somero™ laser screed in the operation of placing and finishing the more than 1,000,000 sq ft of concrete pavement at the FedEx facility.

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Recap-ACI 330R-08

- The only technical document dedicated to concrete parking lots
- Addresses every aspect of a concrete parking lot

The Correct Way to Design!
It Helps You Compete!

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What is your impression/opinion of this parking lot?

Quick Facts:

- It is 25 years old at the time of these photos.
- It was designed using ACI 330, 20 year design life with 85% reliability.
- It is located in Council Bluffs, IA
- It is a shopping center and about 1.5 million SF.
- **Fact: It is about as perfect a design example as you can find.**

Concrete Overlays

- Used extensively across the United States to extend pavement service life (8,000,000 square yards in 2013!)
- Can be designed for a service life of 10 to 40 or more years.
- Can be constructed rapidly and with effective construction traffic management.
- A wide variety of concrete overlay applications for a wide range of pavement conditions.

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National Concrete Overlay Database

- Many examples of successful PCC overlay projects.
- Consult the National Overlay Explorer App on the ACPA website.

http://apps.acpa.org/apps/Overlaypass.html

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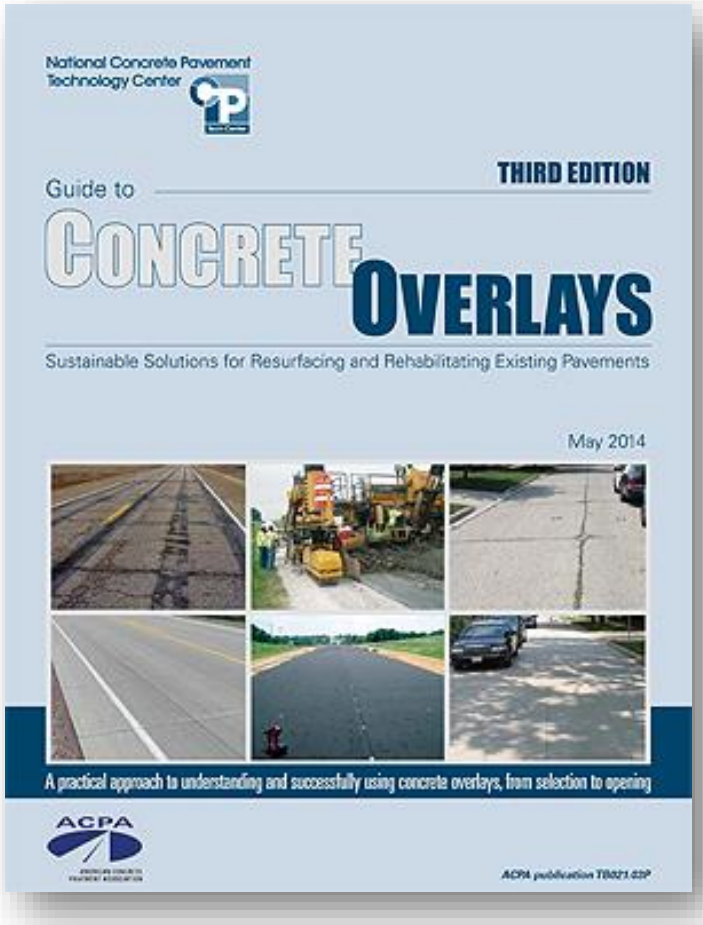
Concrete Overlay Guide, 3rd Ed.

- Overview of Overlay Families
- Overlay types and uses
- Evaluations & Selections
- Six Overlay Summaries
- Design Section
- Miscellaneous Design Details
- Overlay Materials Section
- Work Zones Under Traffic
- Key Points for Construction
- Accelerated Construction
- Specification Considerations
- Repairs of Overlays



Third Edition May 2014

National Concrete Pavement Technology Center

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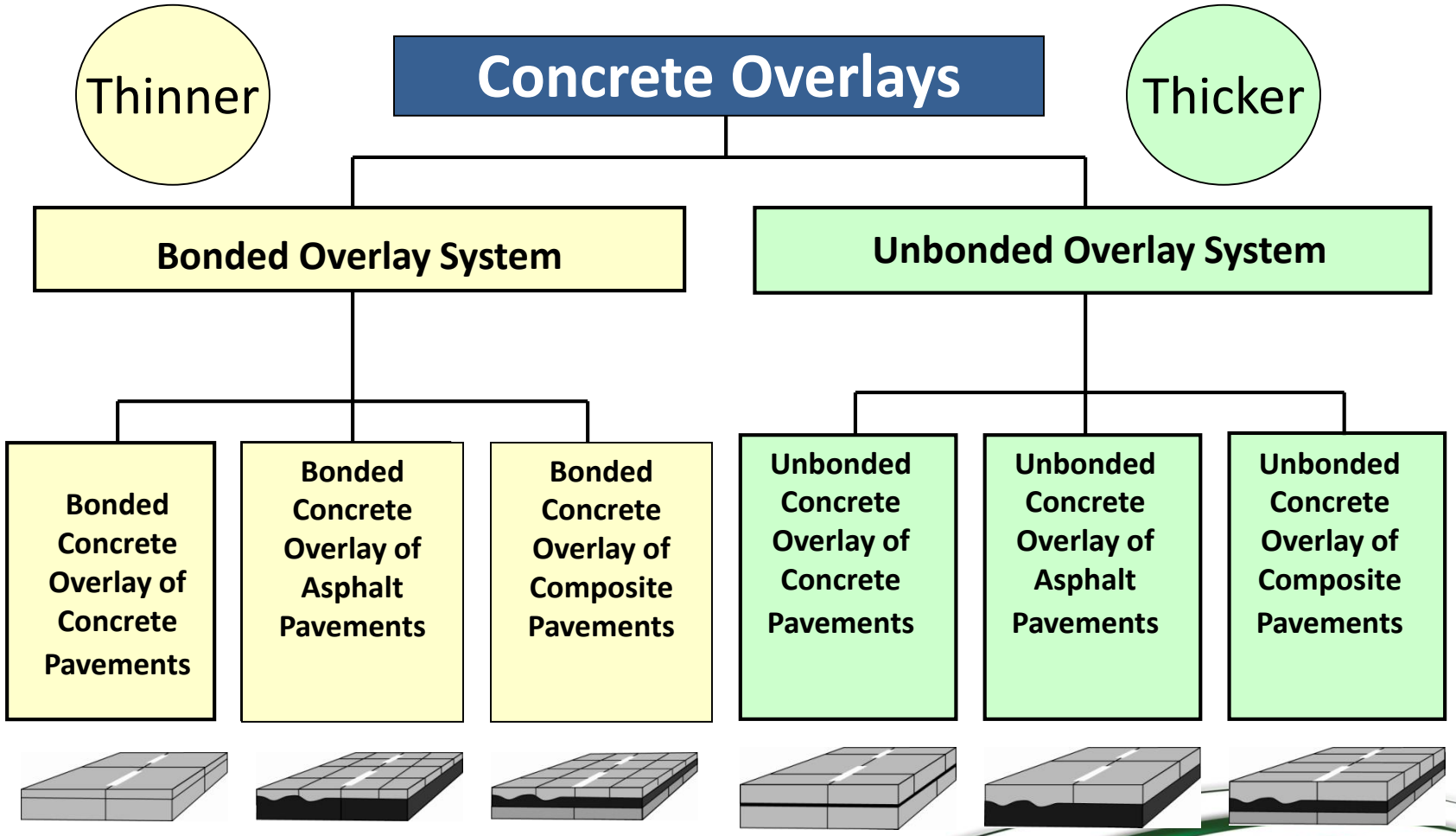
System of Concrete Overlays



Bond is integral to design

Old pavement is base

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Evaluations of Existing Pavements for Overlays

Evaluation establishes if pavement is a good candidate for an Overlay

- Can it provide a uniform and stable support system?
  - Surface defects can be overcome
  - Does the condition of the pavement fit the type of Overlay proposed?
  - Is the existing slab or joints moving?

- When combined with an Overlay can the existing pavement help carry anticipated traffic as
  - An integrated part of the pavement (bonded)
  - Serve as a base or subbase (unbonded)

Evaluations of Existing Pavements for Overlays

- Evaluation is also used to determine:
  - Required repairs where needed
  - Establish the concrete overlay design thickness
- The condition of the existing concrete pavement can be initially assessed through
  - A visual examination of any existing distresses
  - Analysis of cores

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PAVEMENT EVALUATION

- Falling weight deflectometer (FWD) testing can provide
  - Subgrade k-values
  - Variability
  - Concrete modulus
  - Load transfer efficiency
  - Presence of voids

- Normally high volume roads

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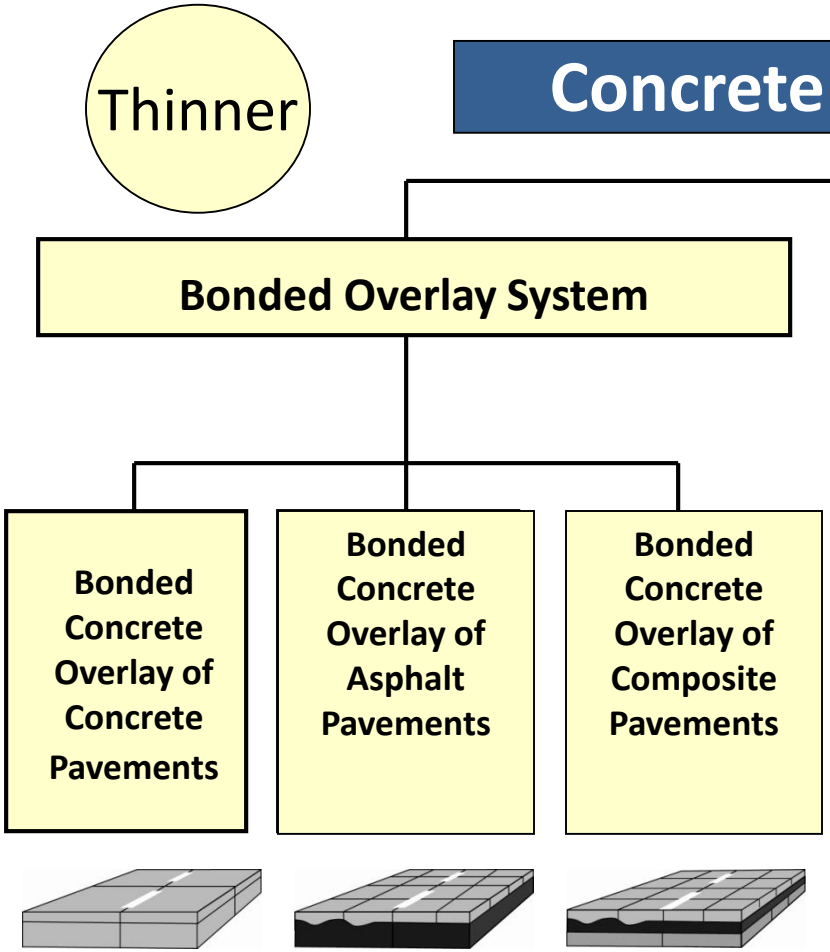
System of Concrete Overlays



Bond is integral to design

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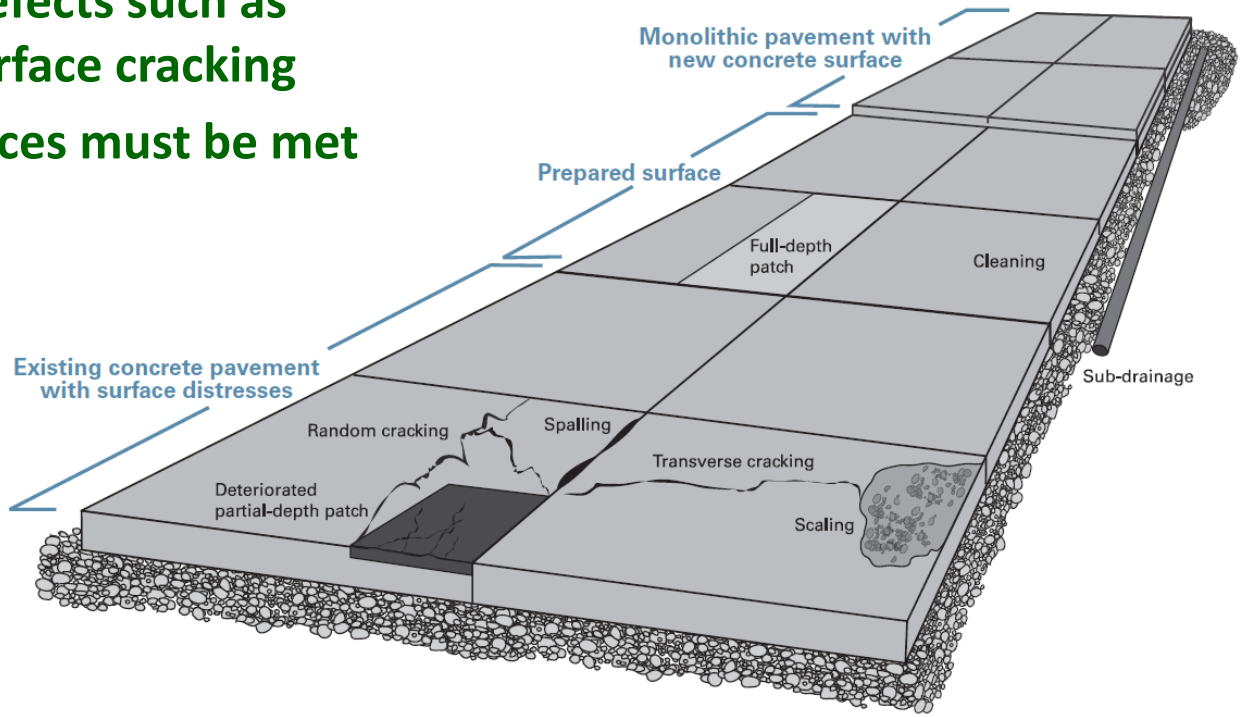
Bonded Concrete Overlays of Concrete Pavement

Good structural condition; some surface distress OK

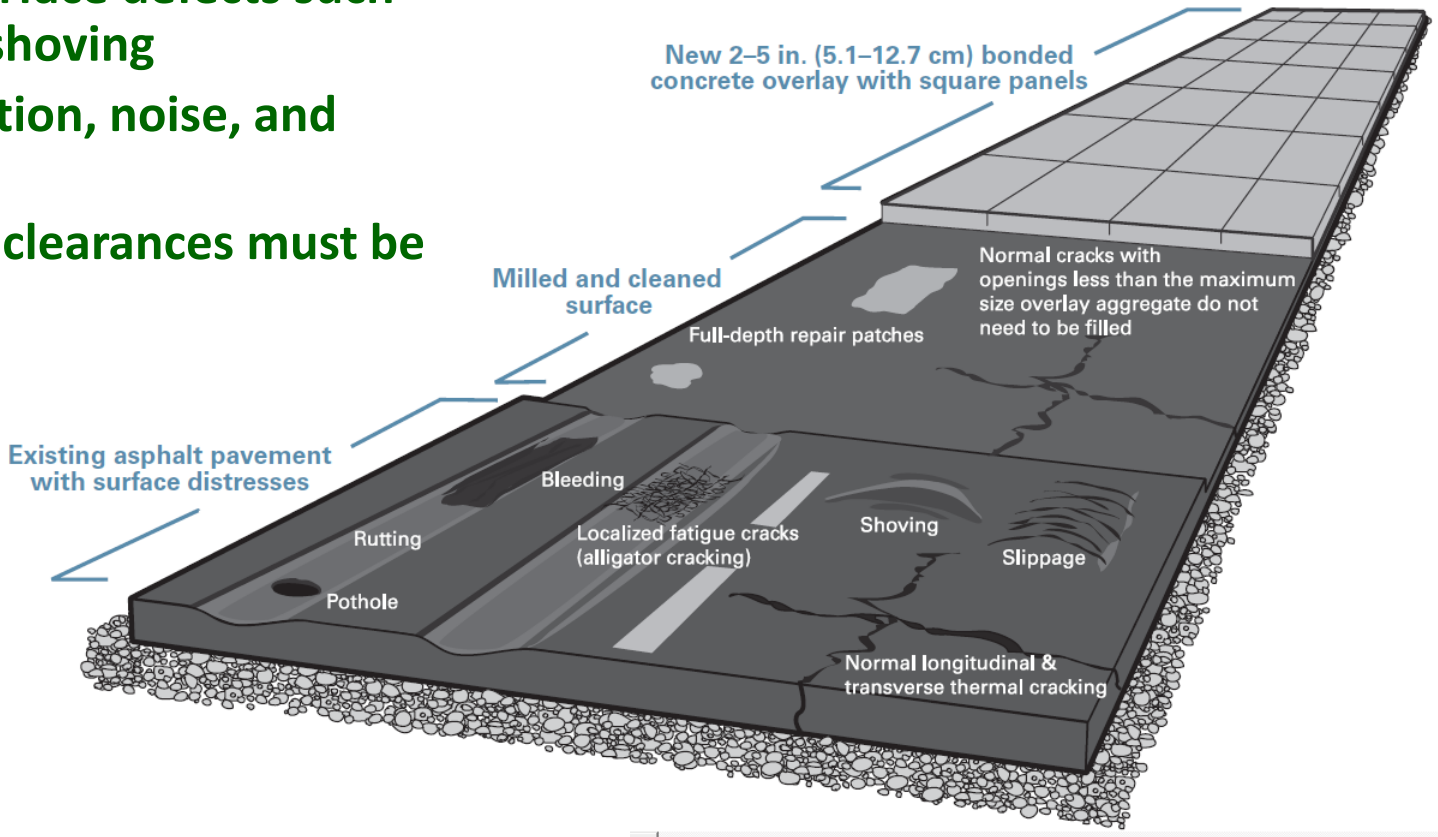
- Where increase in traffic loads requires more structural capacity (related benefit: improves friction, noise, and rideability)
- To eliminate surface defects such as extensive scaling or surface cracking
- Where vertical clearances must be met



Bonded Concrete Overlays of Asphalt Pavement

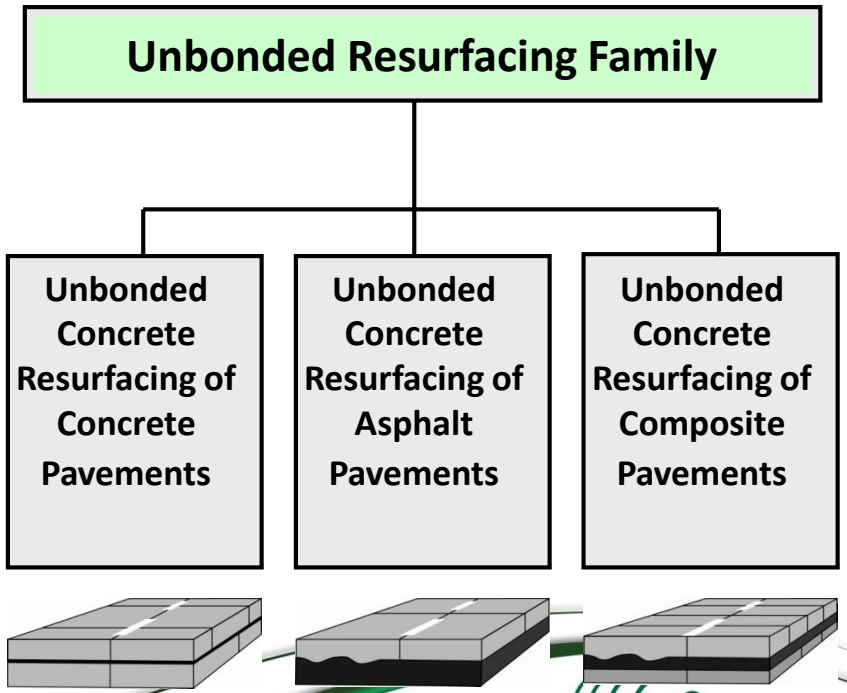
Fair or better structural condition with surface distress

- Where increase in traffic loads requires more structural capacity
- To eliminate surface defects such as rutting and shoving
- To improve friction, noise, and rideability
- Where vertical clearances must be met



Unbonded Resurfacing Family

- Thicker overlays- real pavement
- Over concrete, asphalt, or composite
- Bond is not considered in the design
- Bonding may still be good!



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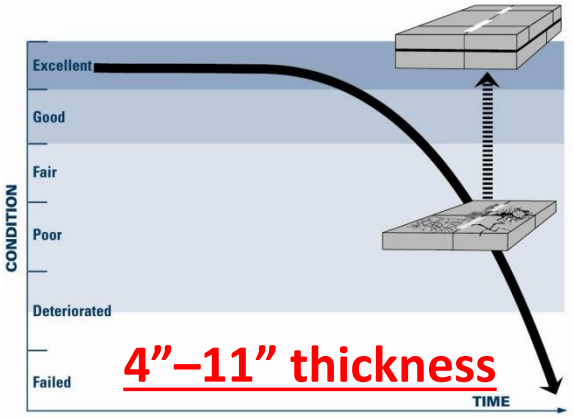
Uses and Advantages

Unbonded | Concrete



- Use when
  - Existing pavement is in poor condition
  - The underlying pavement and subbase are stable and uniform
- Use to restore structural capacity of the existing pavement
- Increase pavement life
  - Often equivalent to full-depth pavement
- Used to improved surface friction, noise, and rideability

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EVALUATION

Unbonded | Concrete

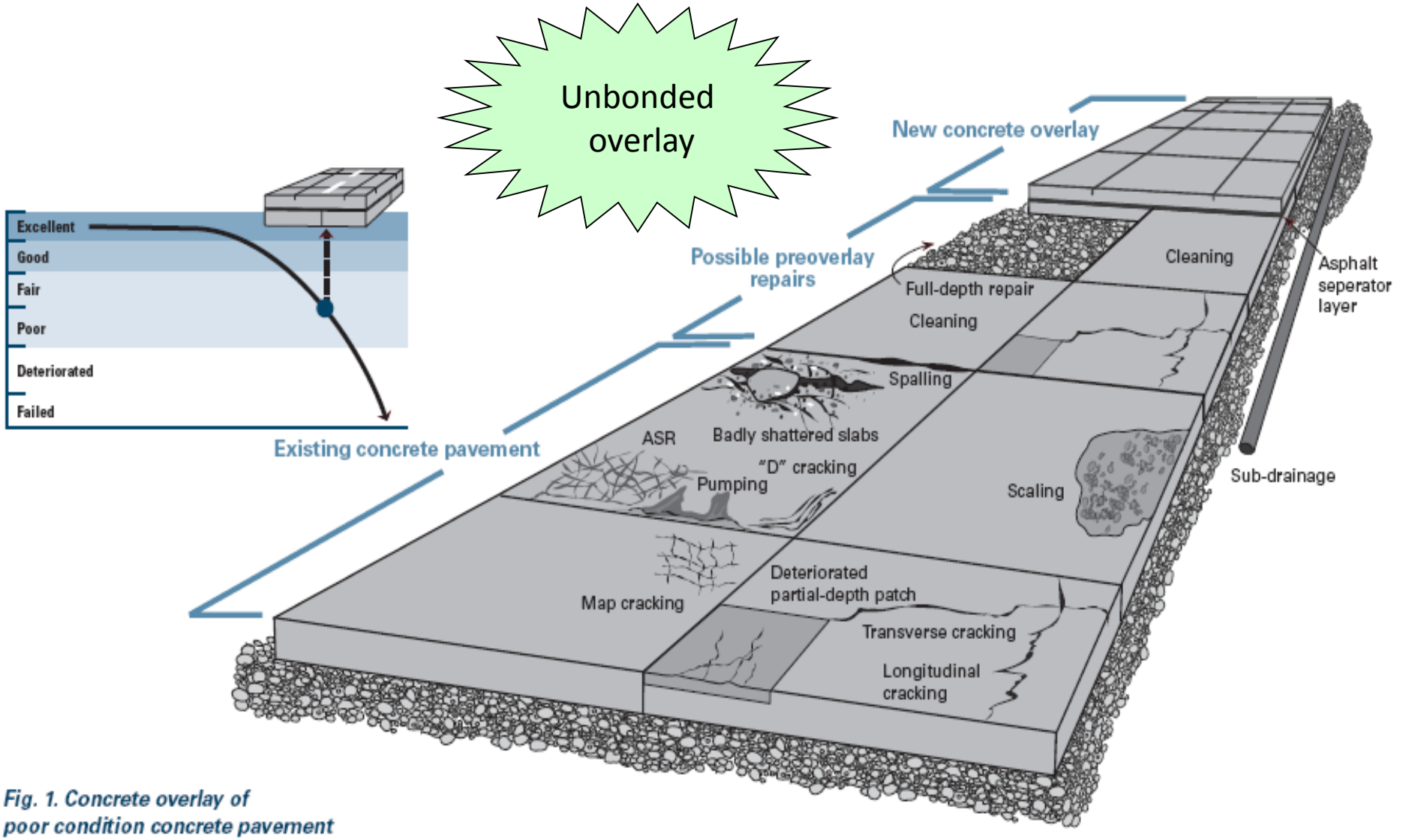

Fig. 1. Concrete overlay of poor condition concrete pavement

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EVALUATION

- The evaluation establishes whether the existing concrete and its subbbase can provide a uniform strength platform and, if not, what actions are necessary to obtain that uniformity
- Look for events of movement in the slab
  - Profile is a good check

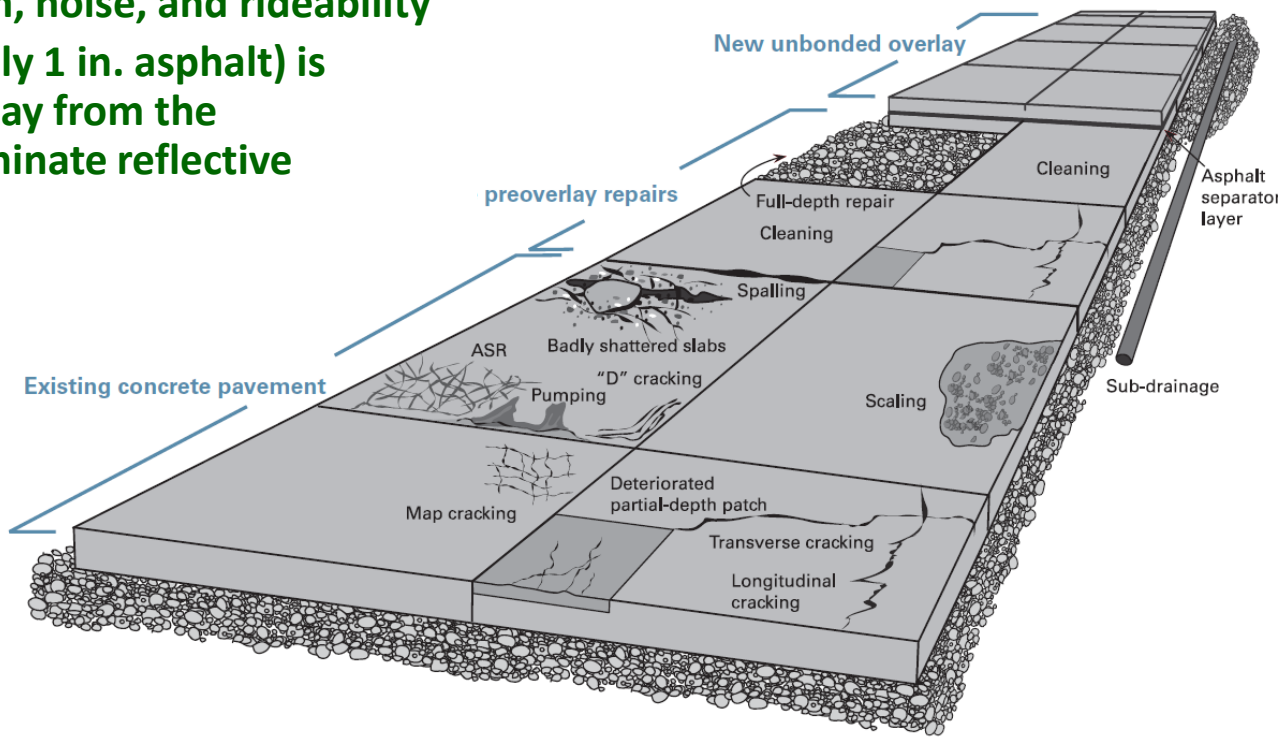
EVALUATION

- If the movement is confined to isolated areas, a full depth patch can solve the problem
- For faulted pavements, if the subgrade is stable, overlays have proven to be adequate
- Faulting is generally not a concern when a separator layer of 1” or greater is used

Unbonded Concrete Overlays of Concrete Pavement

Poor condition, including materials-related distress, but stable and uniform

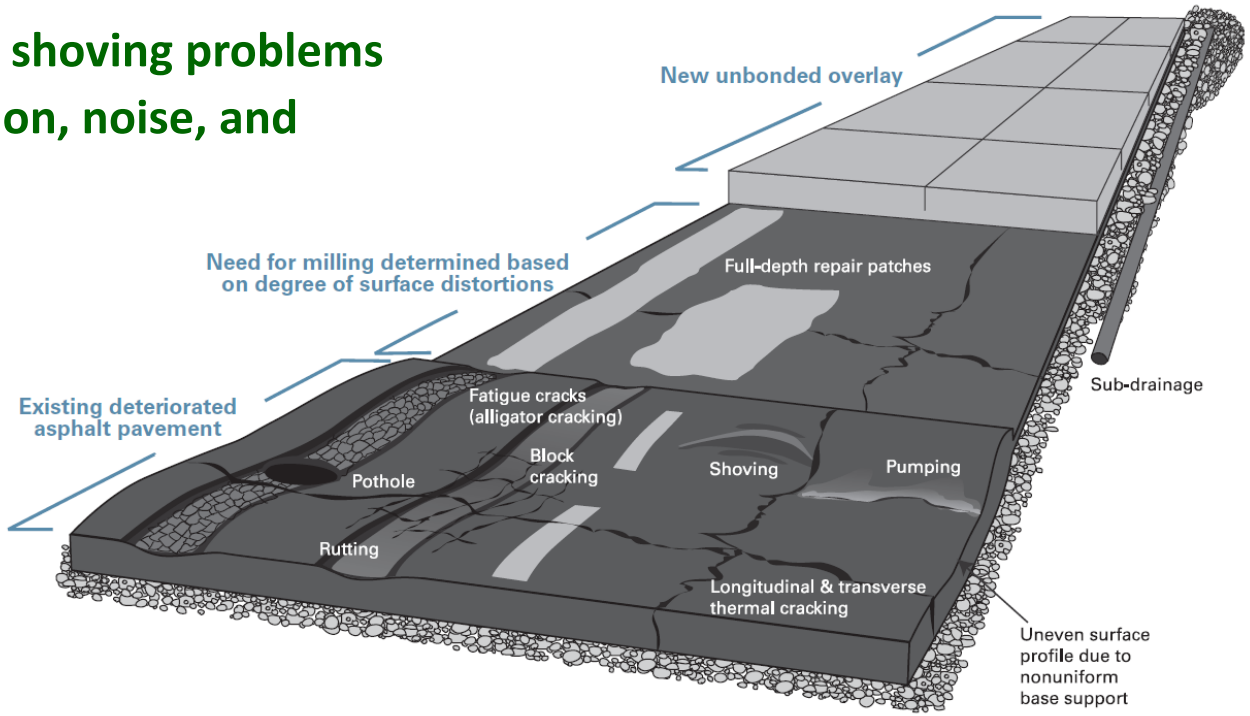
- To restore or enhance pavement's structural capacity
- To increase pavement life equivalent to full-depth pavement
- To improve surface friction, noise, and rideability
- A separation layer (typically 1 in. asphalt) is required to separate overlay from the existing concrete and eliminate reflective cracking



Unbonded Concrete Overlays
of Asphalt Pavement

Deteriorated (severe rutting, potholes, alligator cracking, shoving, and pumping) but stable and uniform

- To restore or enhance pavement's structural capacity
- To increase pavement life equivalent to full-depth pavement
- To eliminate rutting and shoving problems
- To improve surface friction, noise, and rideability



Joint Cutting

	Bonded Resurfacing		Unbonded Resurfacing	
	PCC	HMA	PCC	HMA
Transverse joint saw-cut depth for conventional saws	Full depth + ½"	T/4	T/4 min. – T/3 max.	
Transverse joint saw-cut depth for early-entry saws	Full depth + ½"	Not<1-1/4"	Not<1-1/4"	
Longitudinal joint-saw-cut depth	T/2 (at least)	T/3	T/3	

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Summary - Concrete Overlays

- Add durability and strengthen pavement for extended service life.
- Can be placed on both concrete and asphalt pavements.
- Offer an economically sound solution that will out last any other alternative.
- Increase safety through long-term skid resistance and greater visibility.
- CONCRETE OVERLAYS Are Not Band-Aid Solutions & They Can Stimulate Competition.

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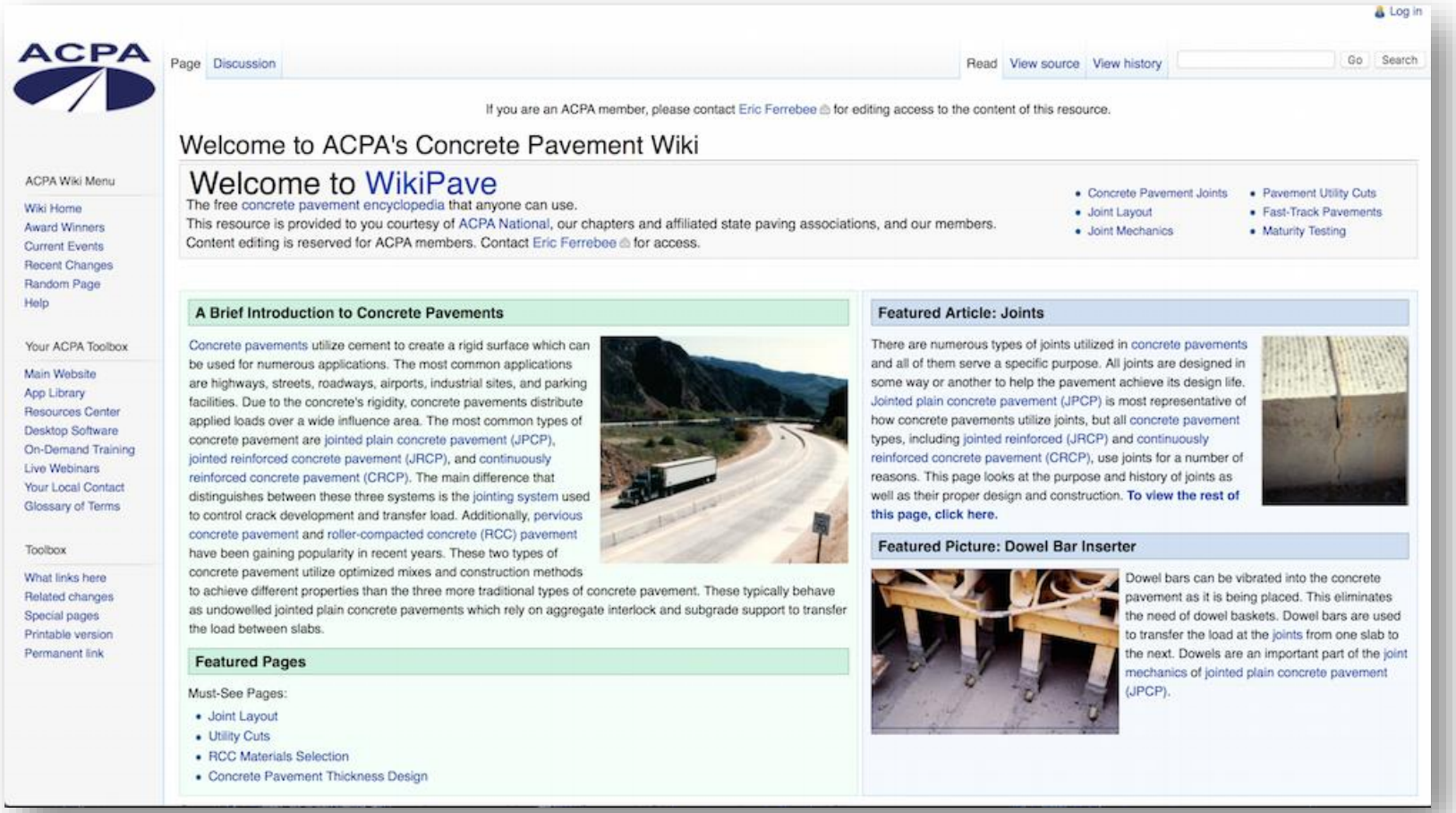
More Tools: ACPA WikiPave



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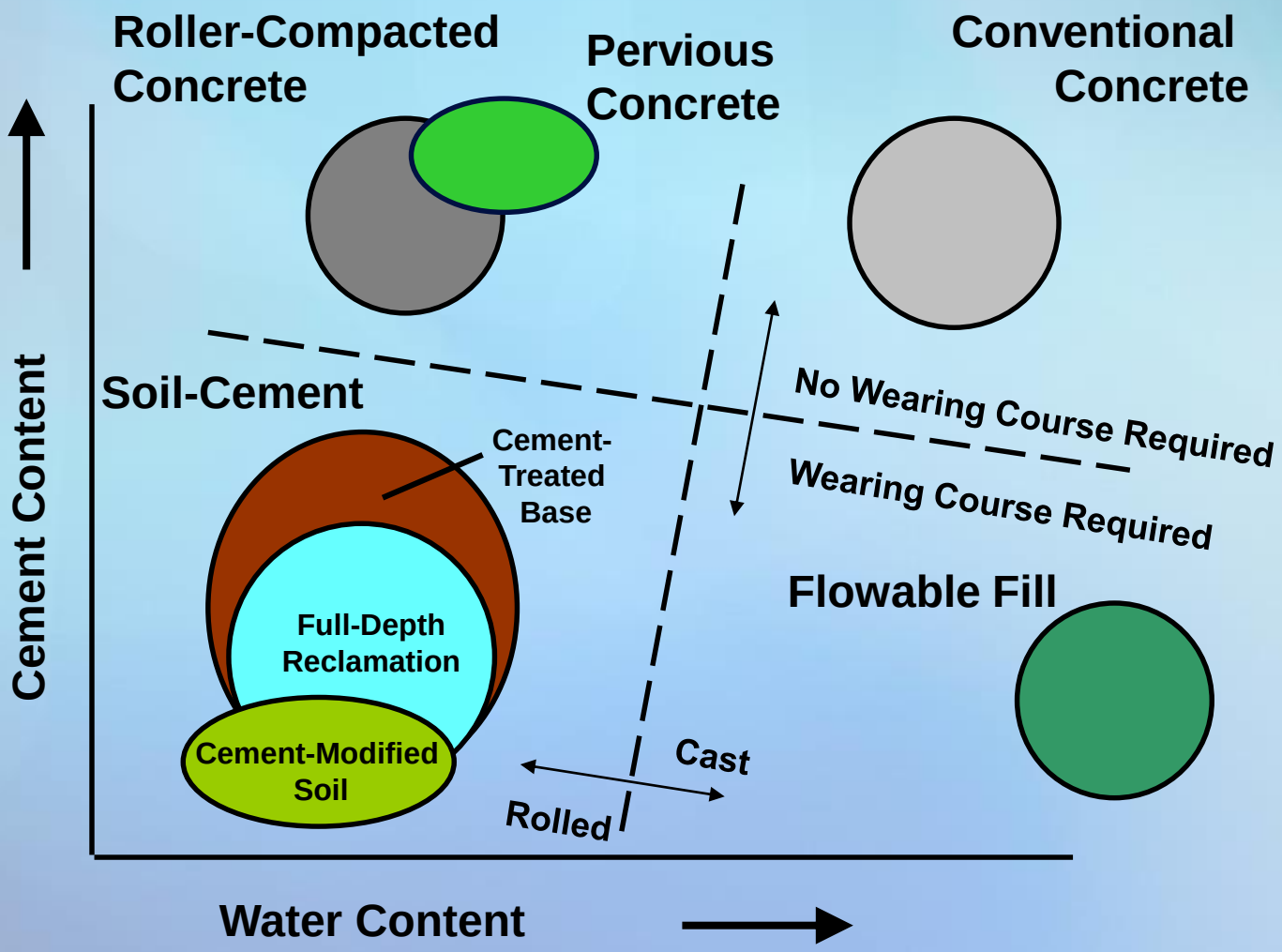
Presentation Outline

- Introduction
- Benefits and Applications
- Mix Design and Construction
- Quality Control

Cement-Based Pavement Materials



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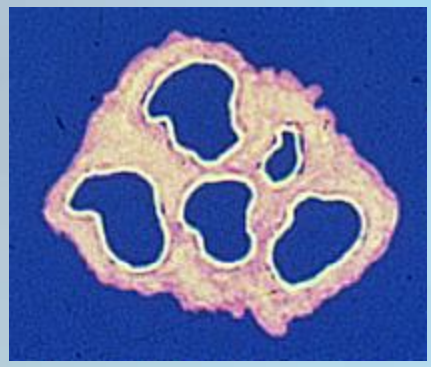
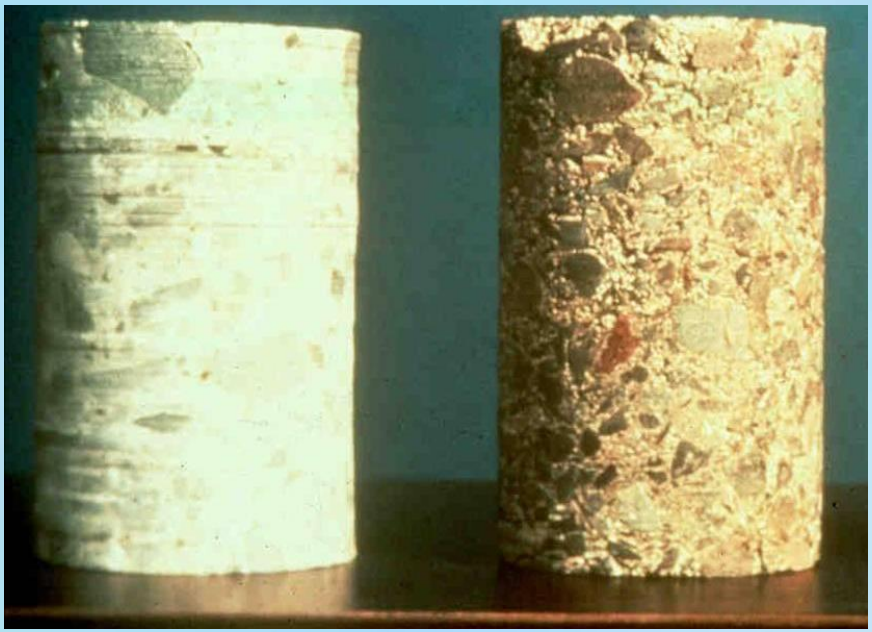
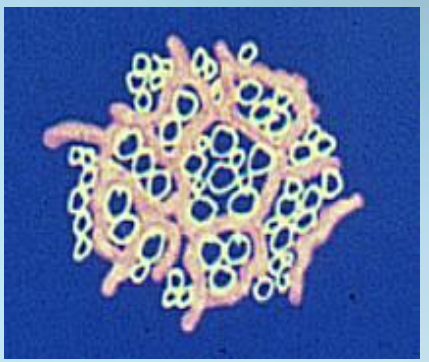
Full-Depth Reclamation (FDR) Introduction







Cementitious Gel or Paste

- coats all particles
- fills voids

Hydration Products

- all particles not coated
- voids not filled
- linkages bind soil agglomerations together

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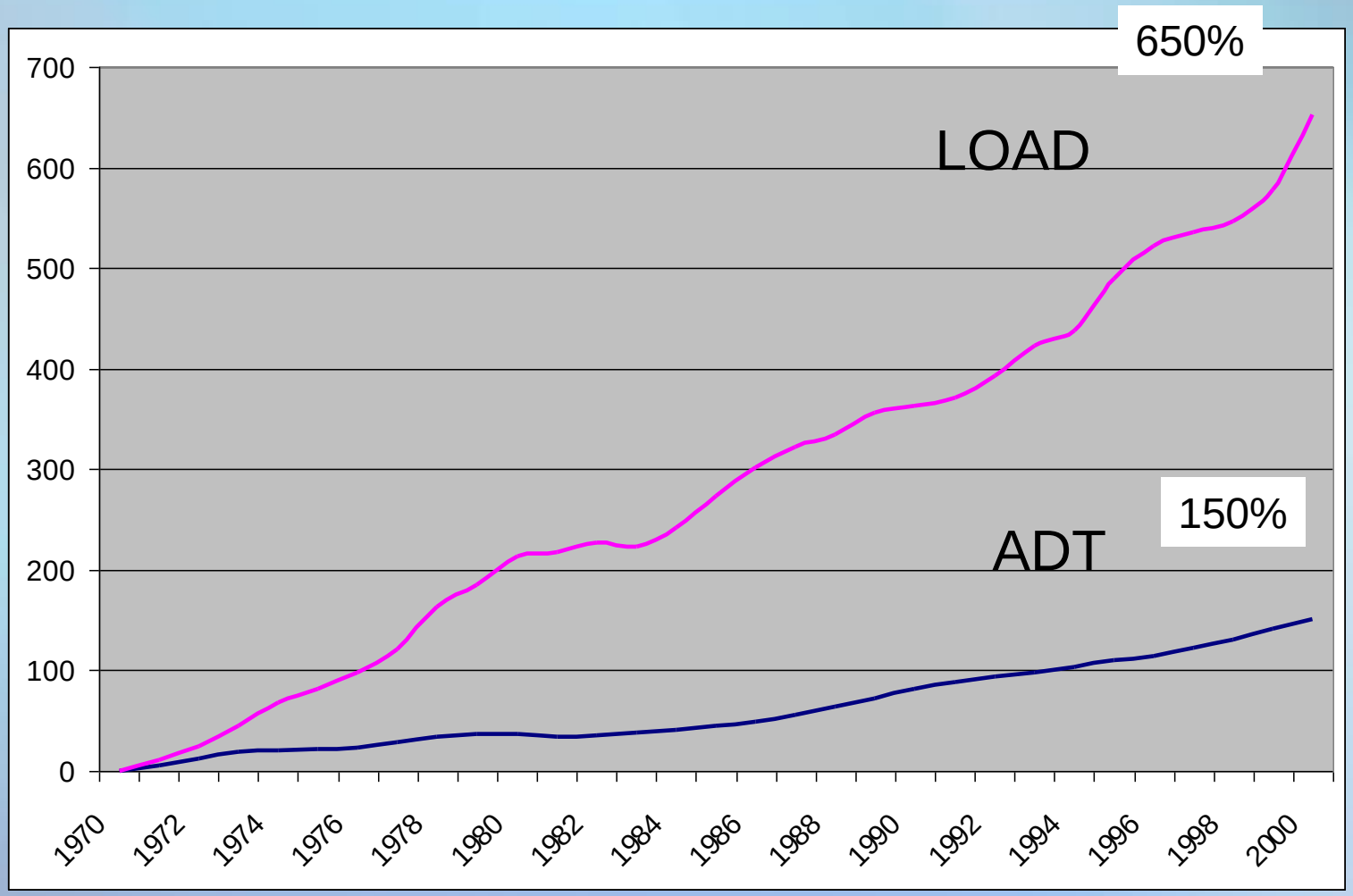
FDR Applications

Challenges Facing America's Roadways

- Continuing Growth
- Rising Expectations from Users
- A Heavily Used, Aging System
- Environmental Compatibility
- Changes in the Workforce
- Funding Limitations

Rural Interstates - Growth



Source: Highway Statistics 2000

Today's Traffic

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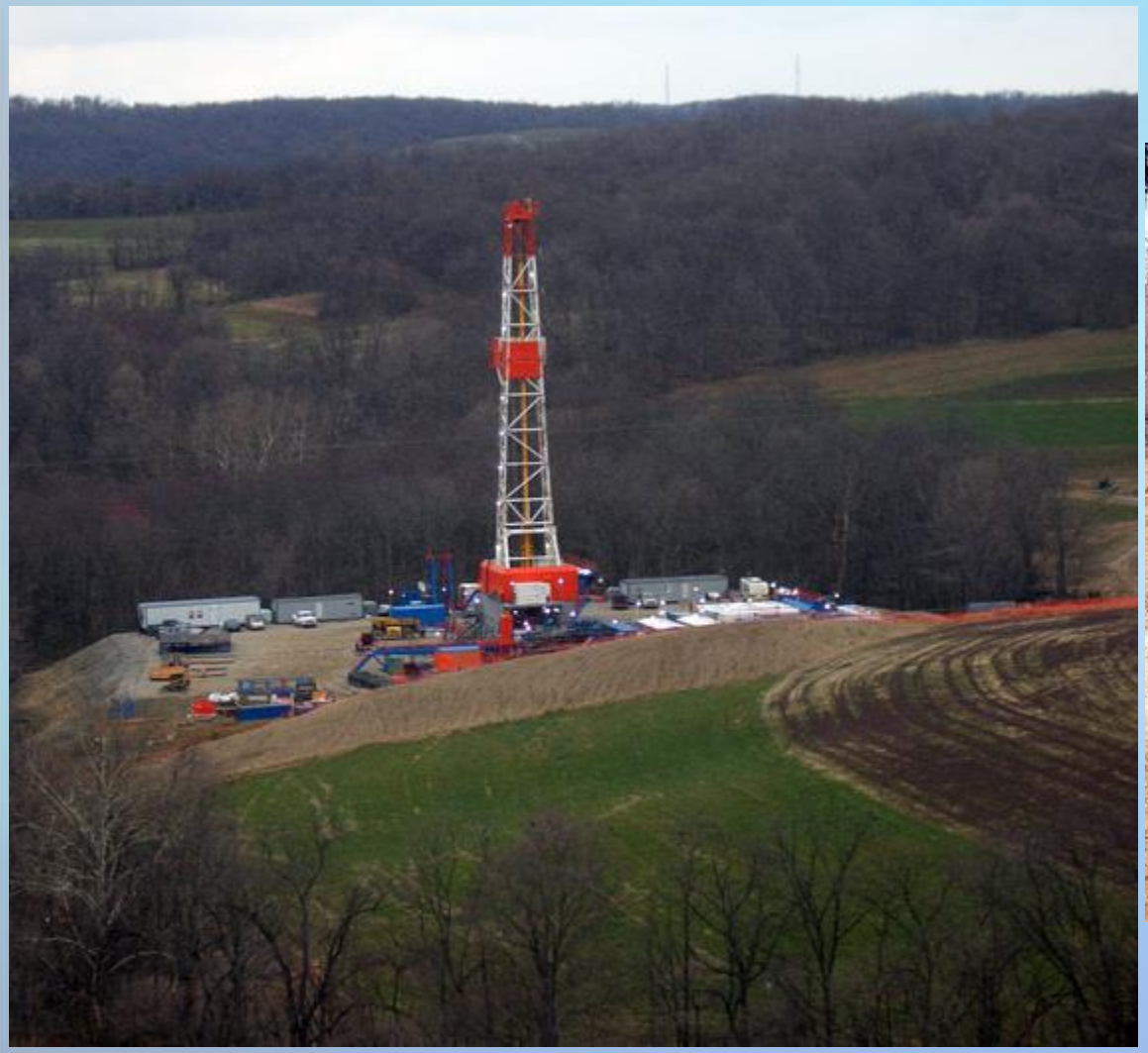

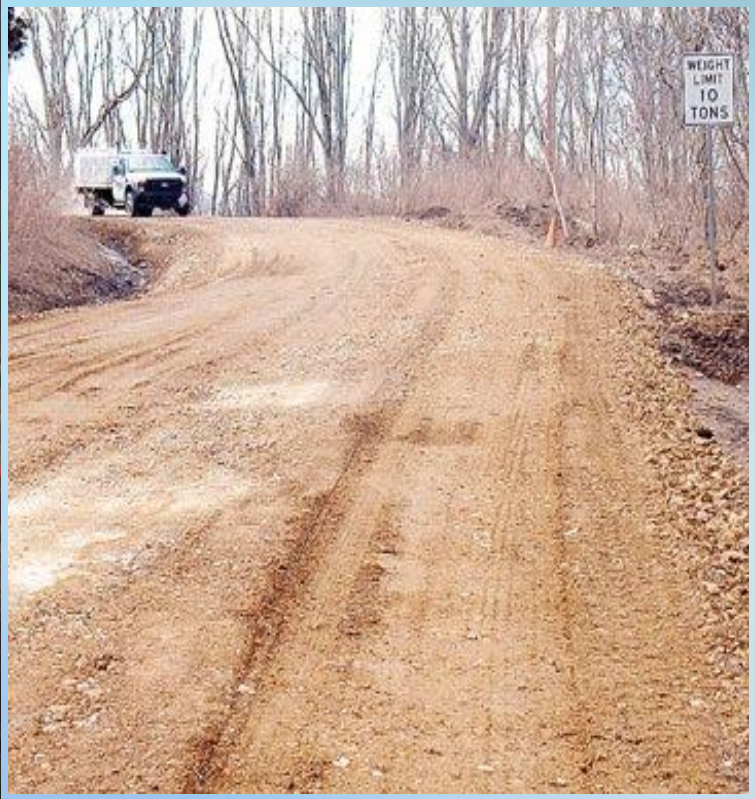

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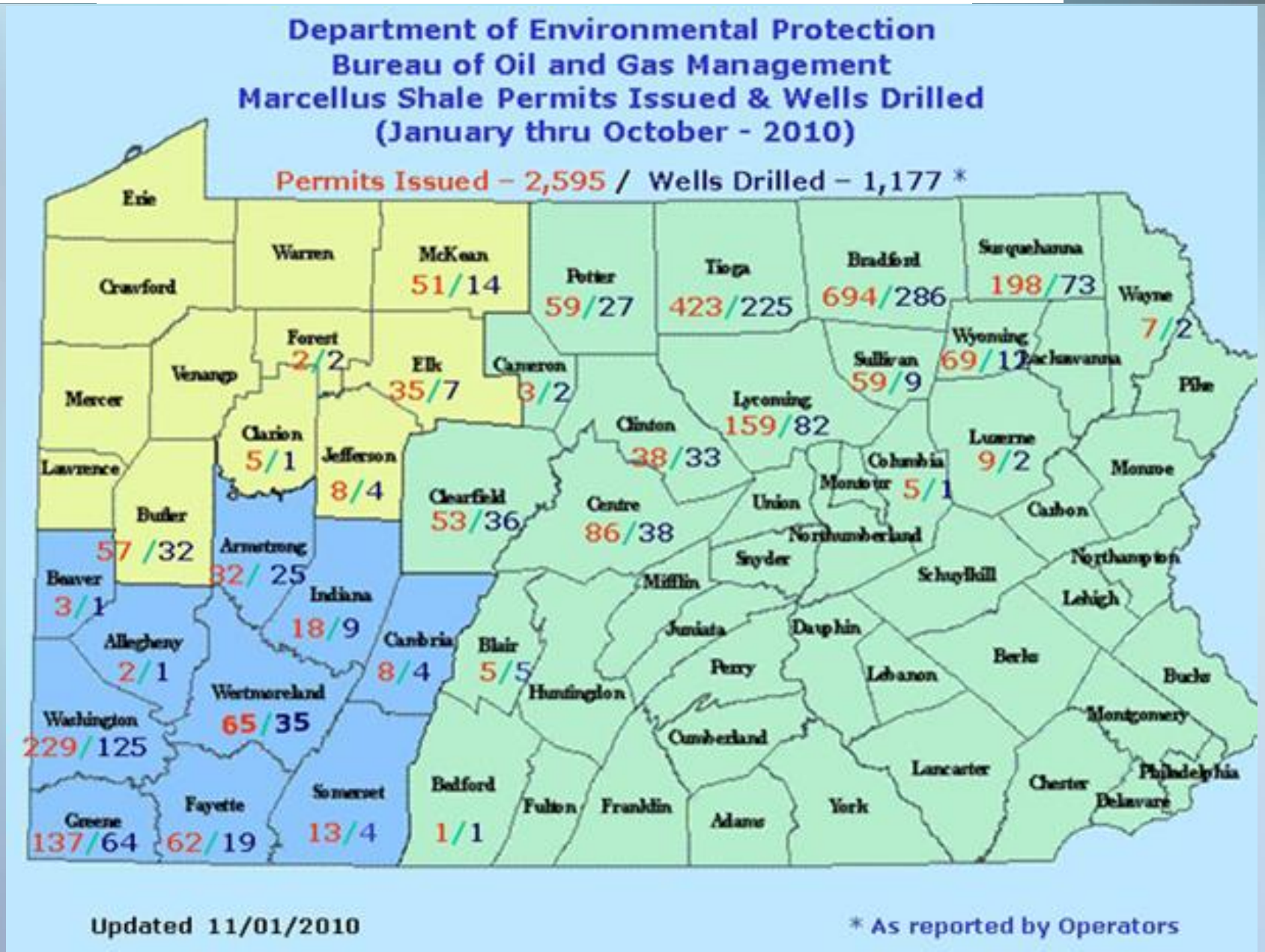


Candidate Roads for FDR

- **Roads with base *AND* surface problems (Pavement Distress)**
- **Roads that need to improve its load bearing capacity (Existing narrow thin paved structure)**
- **Widening projects**
- **Upgrade a dirt / gravel road**
- **Special projects (extreme conditions - fast reconstruction)**

Pavement Distress

Longitudinal Cracking (Wheelpath Cracking)

Causes:

- fatigue from heavy traffic
- an unstable base
- poor construction.

Rutting (Permanent Deformation)

Causes:

- Heavy trucks
- Slow, stopping & standing traffic
- Poor quality materials
- Temperature susceptible asphalt
- Poor construction
- Moisture damage

Pavement Distress

Fatigue Cracking (Alligator Cracking)

Causes

- Inadequate structure
- Accumulated damage
- Age hardening
- Poor drainage

Pushing, Shoving & Delamination

Causes

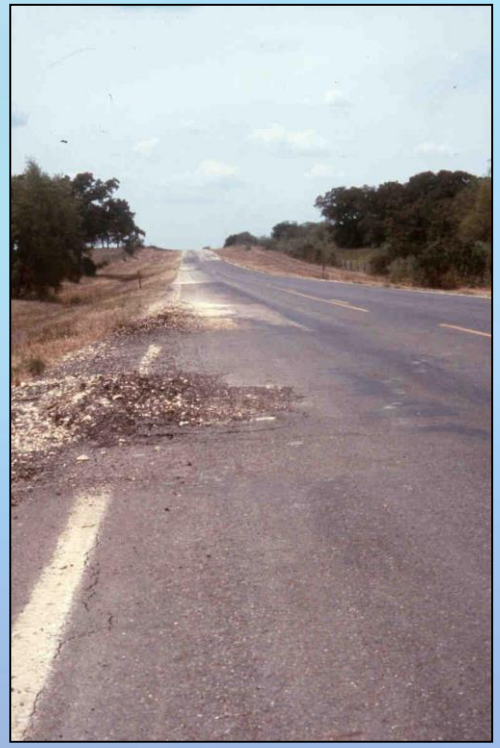
- Unstable Mix
- Braking, stopping, accelerating traffic
- Slippage between layers
- Poor interlayer bond
- Poor construction
- Heavy trucks
- Moisture damage

Pavement Distress

Stripping (Moisture Damage)

Cause

- Poor Asphalt / Aggregate Bond
- Excess Dust
- Clay/ Deleterious Fines
- Lean Mixes
- Poor drainage
- Cracks allowing moisture intrusion



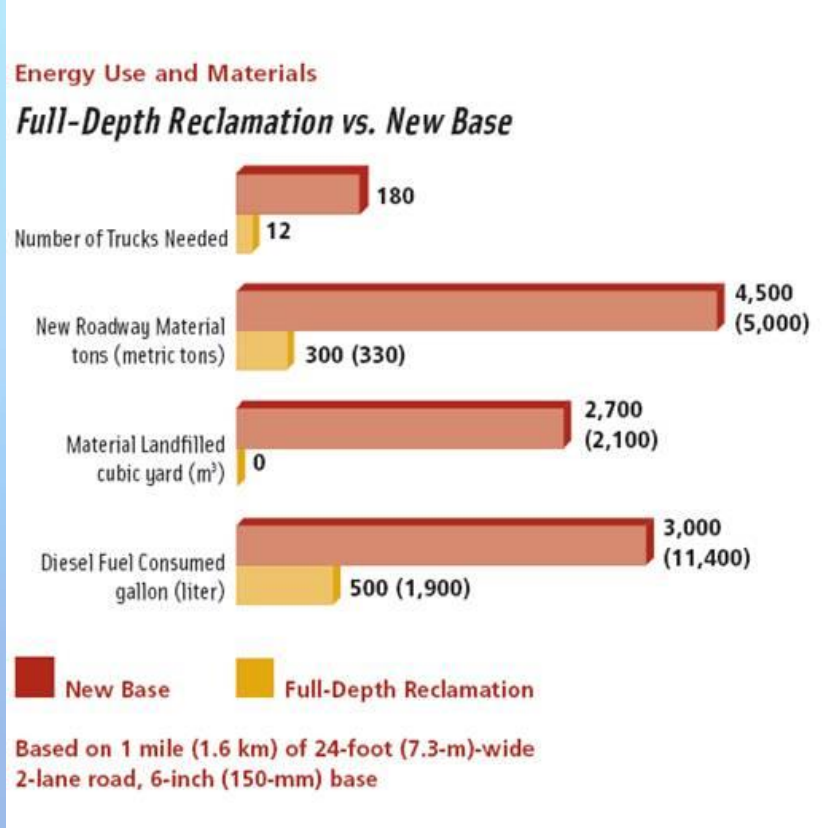
Potholes

Causes

- Inadequate structure
- Accumulated damage
- Age hardening
- Poor drainage

Advantages of Reclamation

- Use of in-place materials
- Little or no material hauled off and dumped
- Maintains or improves existing grade
- Conserves virgin material
- Saves cost by using in-place “investment”
- Saves energy by reducing mining and hauls
- Environmentally friendly



Reclamation: A Logical Choice

- Most highway systems now in place
- Emphasis on maintenance/rehabilitation
- **Most roads are local, low-volume, unpaved or flexible pavements**
- Possible strategies:
  - Thick structural overlays
  - Removal and replacement
  - Reclamation with cement or other additives, with thin overlay

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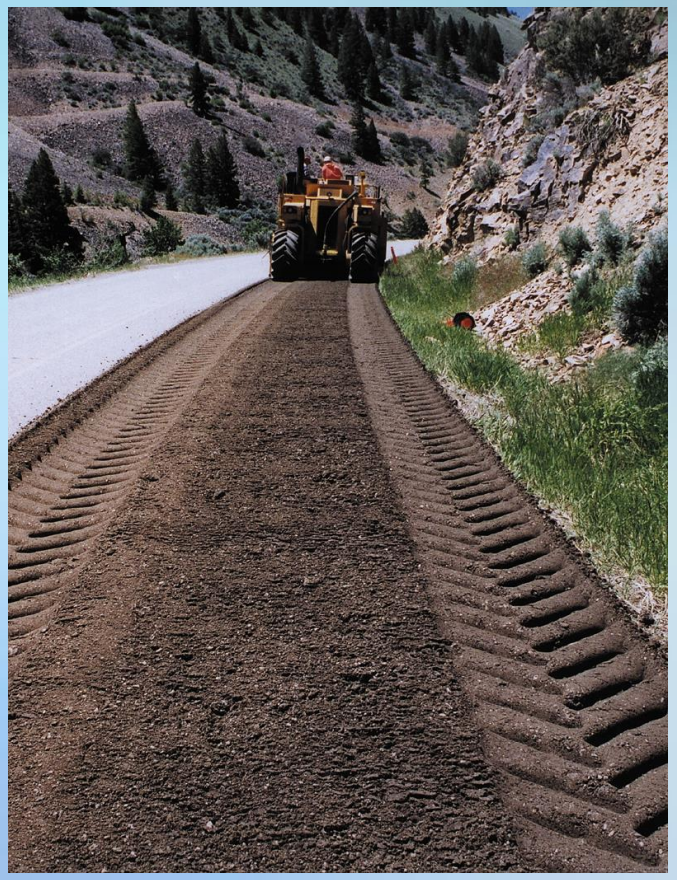
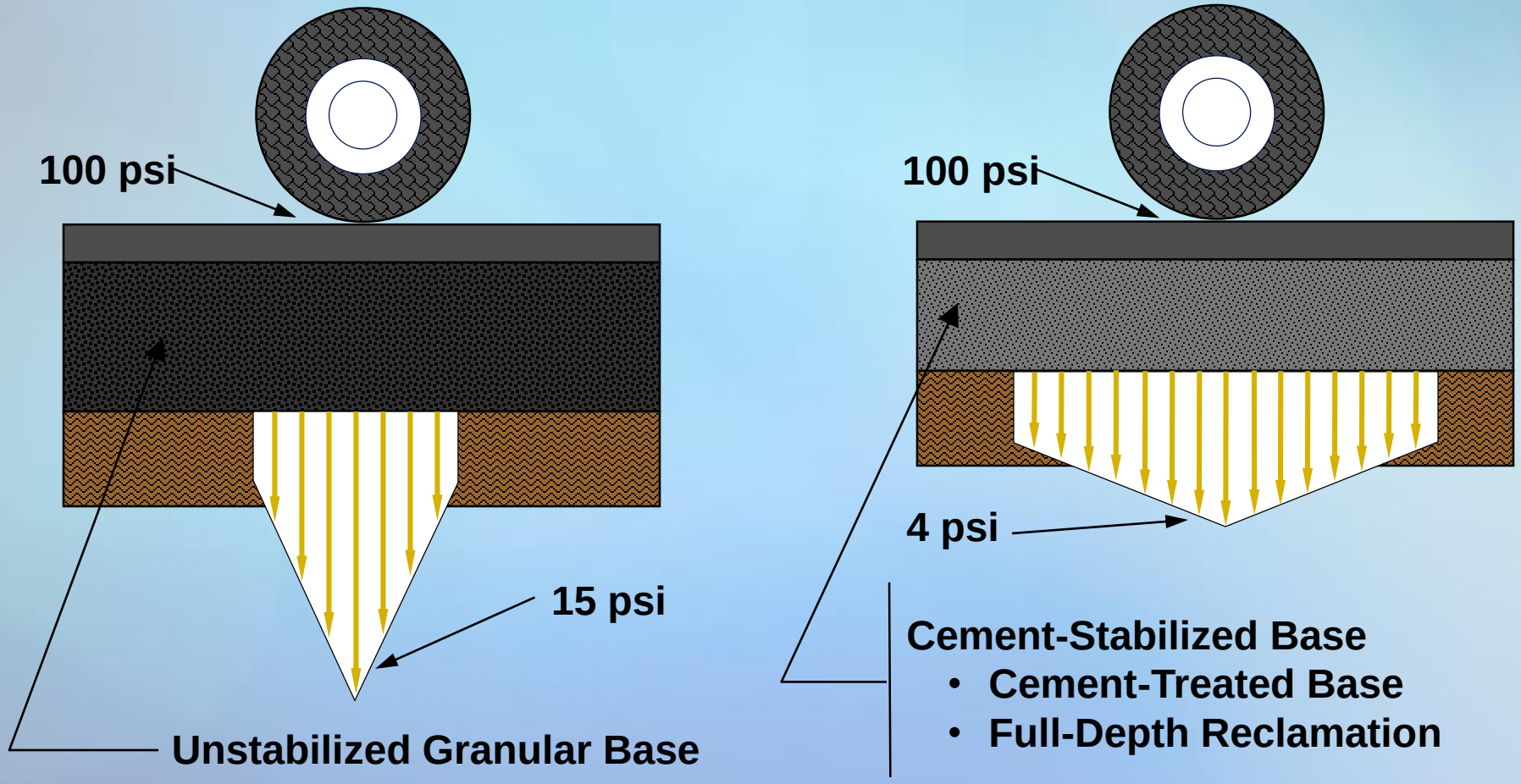
FDR Benefits

Engineering Benefits

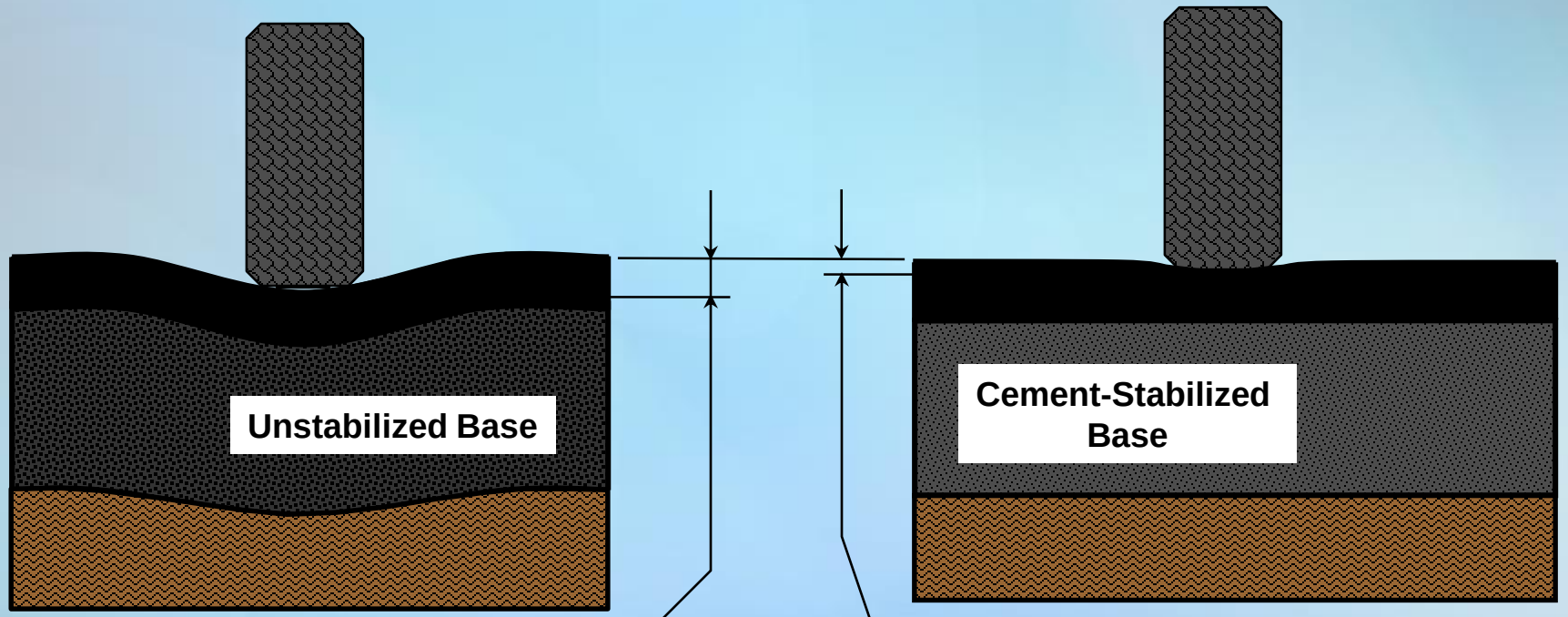
1. Increased Rigidity Spreads Load
2. Eliminates Rutting Below Surface
3. Reduced Moisture Susceptibility
4. Reduced Fatigue Cracking
5. Thinner Pavement Section
6. Retards Reflective Cracking



1. Increased Rigidity Spreads Loads



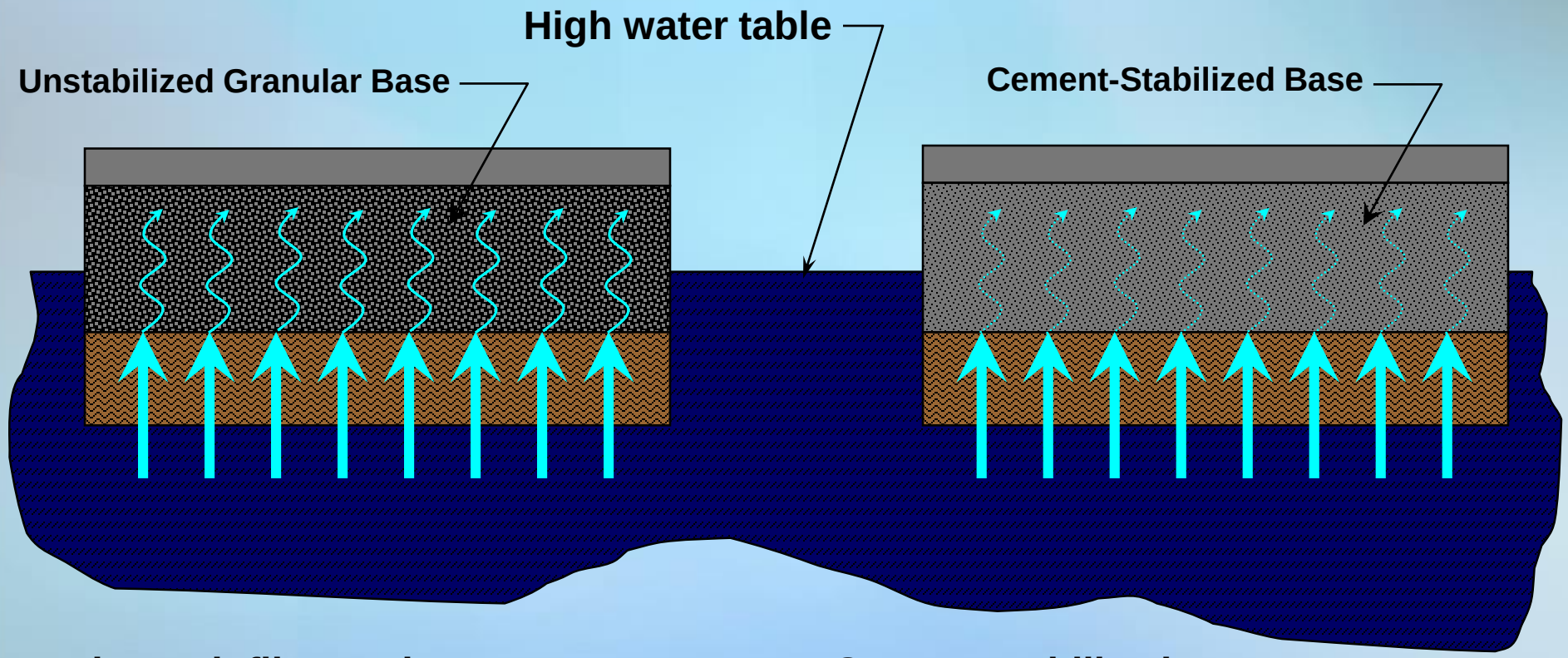
2. Eliminates Rutting Below Surface



Rutting can occur in surface, base and subgrade of unstabilized bases due to repeated wheel loading

Cement-stabilized bases resist consolidation and movement, thus virtually eliminating rutting in all layers but the asphalt surface.

3. Reduced Moisture Susceptibility



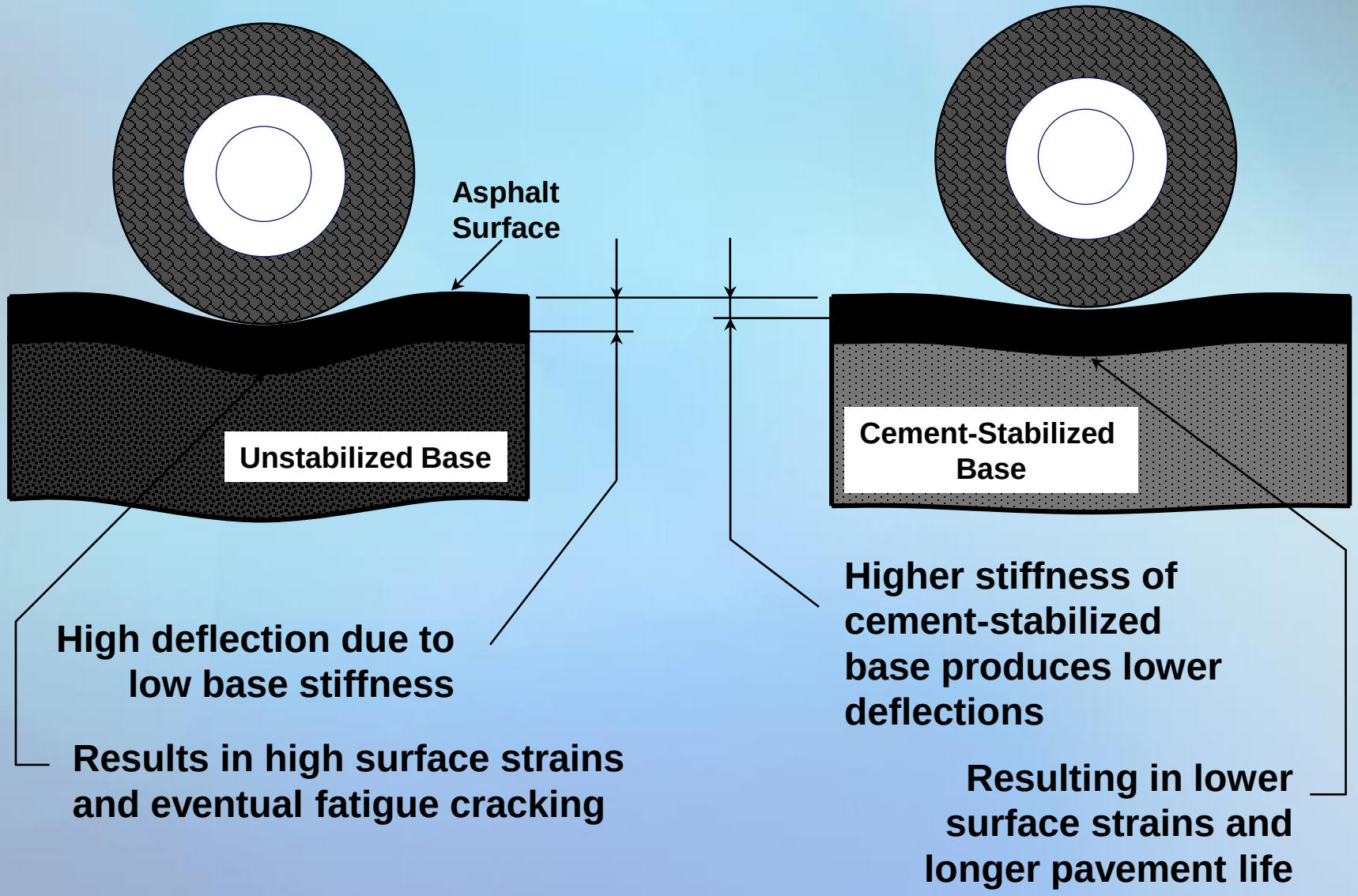
Moisture infiltrates base:

- Through high water table
- Through capillary action
- Causes softening, lower strength, and reduced modulus

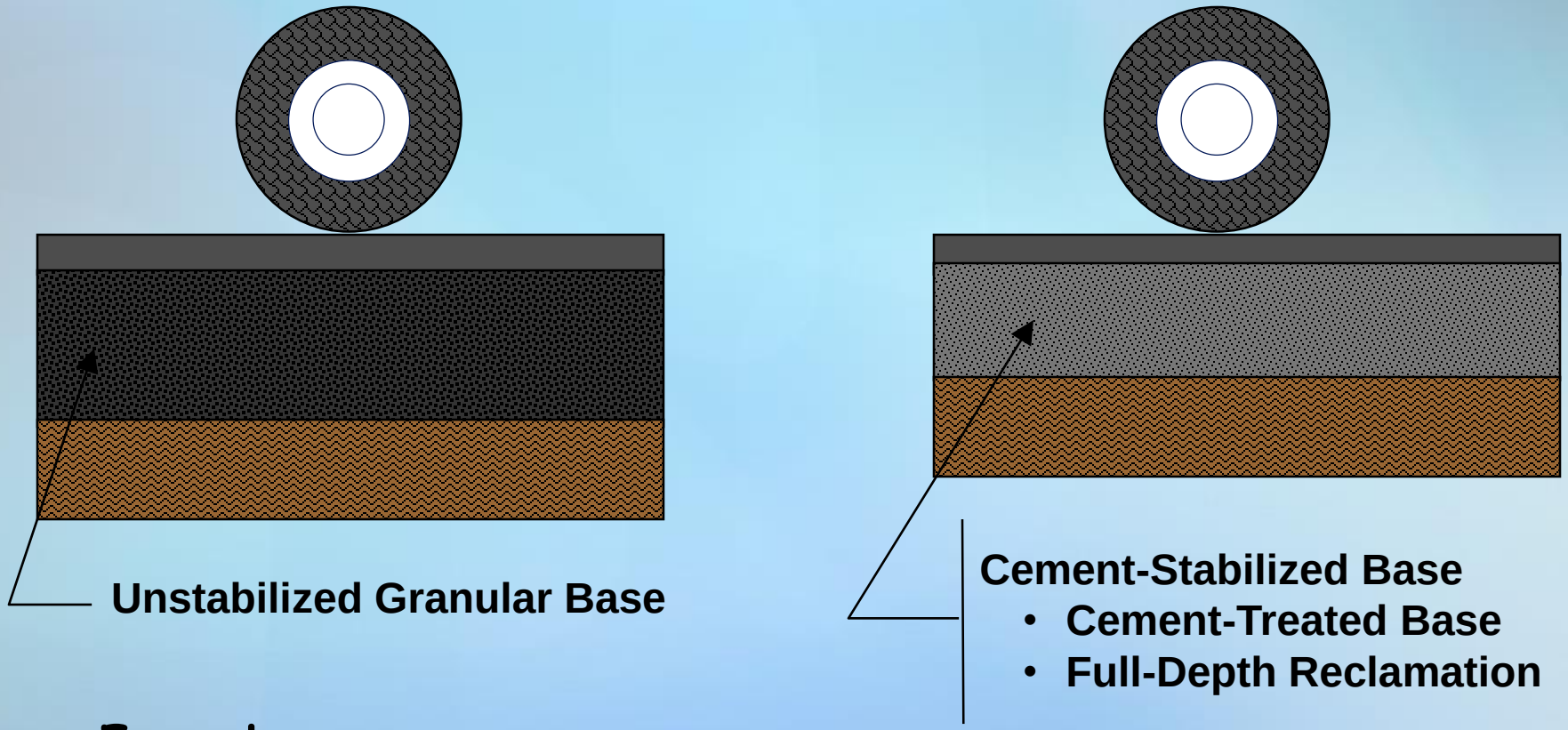
Cement stabilization:

- Reduces permeability
- Helps keep moisture out
- Maintains high level of strength and stiffness even when saturated

4. Reduced Fatigue Cracking



5. Thinner Pavement Section



Example:

A typically accepted rule-of-thumb is that 8 inches of crushed stone base is equal to 6 inches of mixed-in-place FDR/CTB.

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FDR Mix & Thickness Design

Use an *Experienced* Geotechnical Engineer!!!

1. FDR design is NOT the same as traditional roadway / pavement design
2. There is no standard “cookie-cutter” section
3. Obtain all available “as-built” information
4. TAKE CORES!!!!

How is FDR Specified?

All based around for the most part:

- **Quantity of Water**
- **Quantity of Cement**
- **Amount of Compaction**
- **Design Depth**

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FDR Construction

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CONSTRUCTION PROCESS

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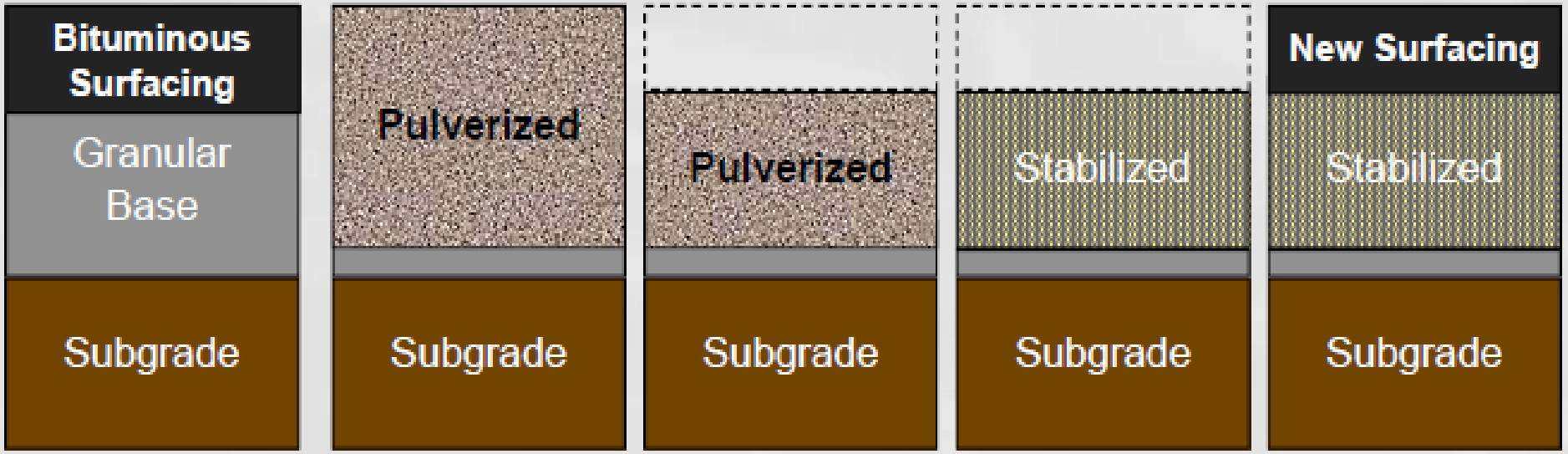
CEMENT SHIPPERS ASSOCIATION

Pulverize, Shape, Add Cement, Mix In Place, Compact, and Surface



Existing road

Pulverization to desired depth

Removal of excess material (if necessary) and shaping

Addition of cement, mixing, reshaping and compaction

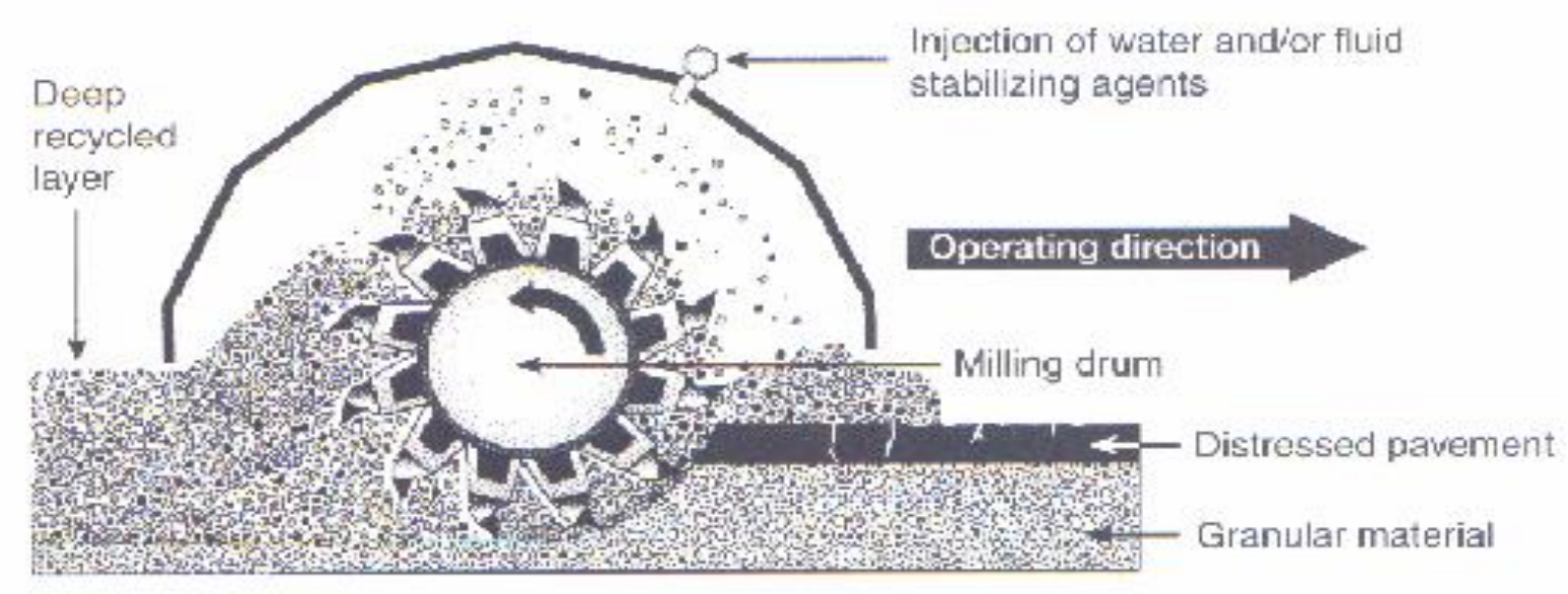
Final surface treatment

Pulverization

Pulverization

- Pulverize mat to appropriate gradation - (Usually <2”)
- Typically 1 or 2 passes

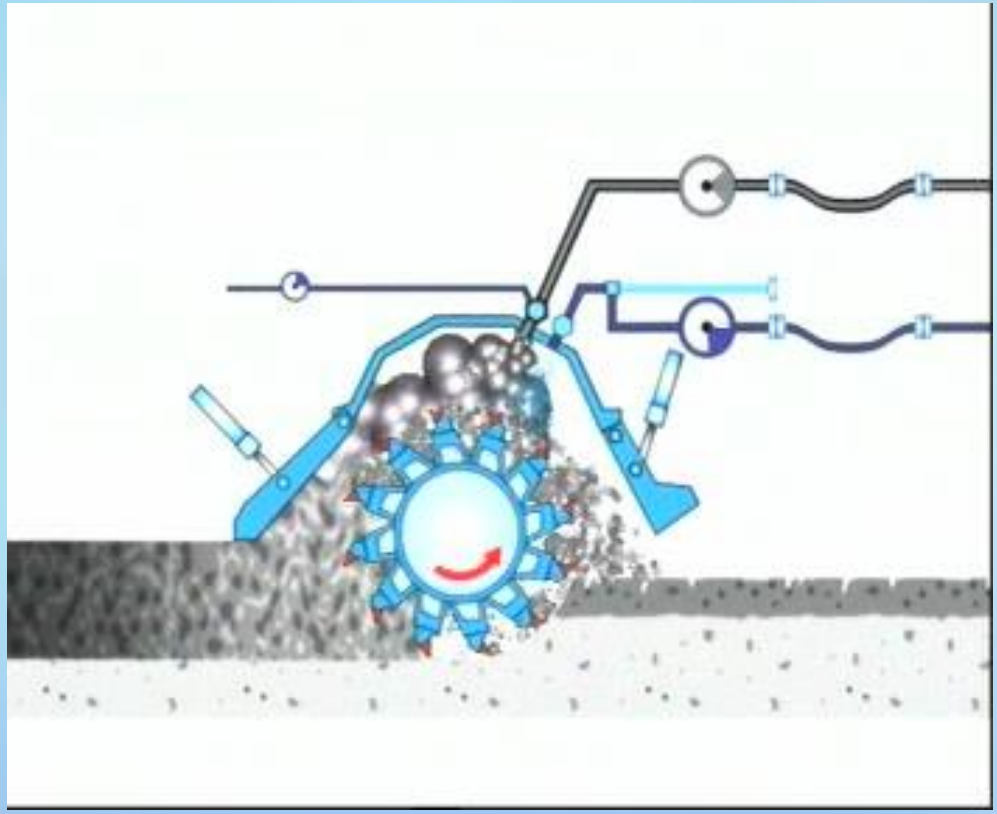
Inside a Reclaimer



Road Recycling Council

New Jersey/Delaware Region

PCA Northeast
CEMENT SHIPPERS ASSOCIATION



Material Removal and Grading

Cement Spreading

Cement is spread on to roadway in

measured amounts


B.O. BOUCHARD
SAINT-HYACINTHE

Portland cement incorporation

Without water

With water

Addition of water

Via drum of mixer

Gravity dump and mix

Compaction

- High density is critical for strength and durability
- Steel-drum
- Rubber-tire roller
- Sheepsfoot roller
- Usually 95% to 98% of standard proctor

Curing

- Ensures surface durability and normal strength gain
- Need of retaining moisture
- Three methods:
  - Moist Cure
  - Concrete Curing Compound
  - Asphalt Emulsion

Moist Cure

- Continuous operation
- Prevent excessive drying

Bituminous Curing Compound

- Excellent moisture barrier
- Good for asphalt cap

Chip Seal

- Excellent moisture barrier
- Can be finished surface

Concrete Curing Compound

- White-pigmented concrete curing compounds
- Apply in two step perpendicular direction
- Not used regularly – unbonded overlays

Paving

- Asphalt binder and wearing courses most common
- Roller compacted concrete (RCC) gaining favor due to durability

Finished Product

Time Limits

- Begin compaction immediately after FDR ingredients are mixed together.
- No material should be left un-compacted for more than 60 minutes
- All compaction operations completed within 2 hours
- All base construction operations completed within 4 hours

Where has it been used in NJ?

- Howell Township
  - 14 miles in 2011 & 2012
  - 6+ miles planned for 2013
- Plainsboro
  - 2,200 LF road to recycling yard
- South Brunswick
  - Subdivision
  - Bids Opening May 9
- Mt. Holly
  - Car Sense Dealership

Questions???

Concrete home survives Hurricane Ike at Gilchrist, Texas

September 2008

Mall of the Bluffs, Council Bluffs, IA

Questions?