THE READY MIX USA COMPANIES
READY MIX USA | BLOCK USA | HARDSCAPES USA

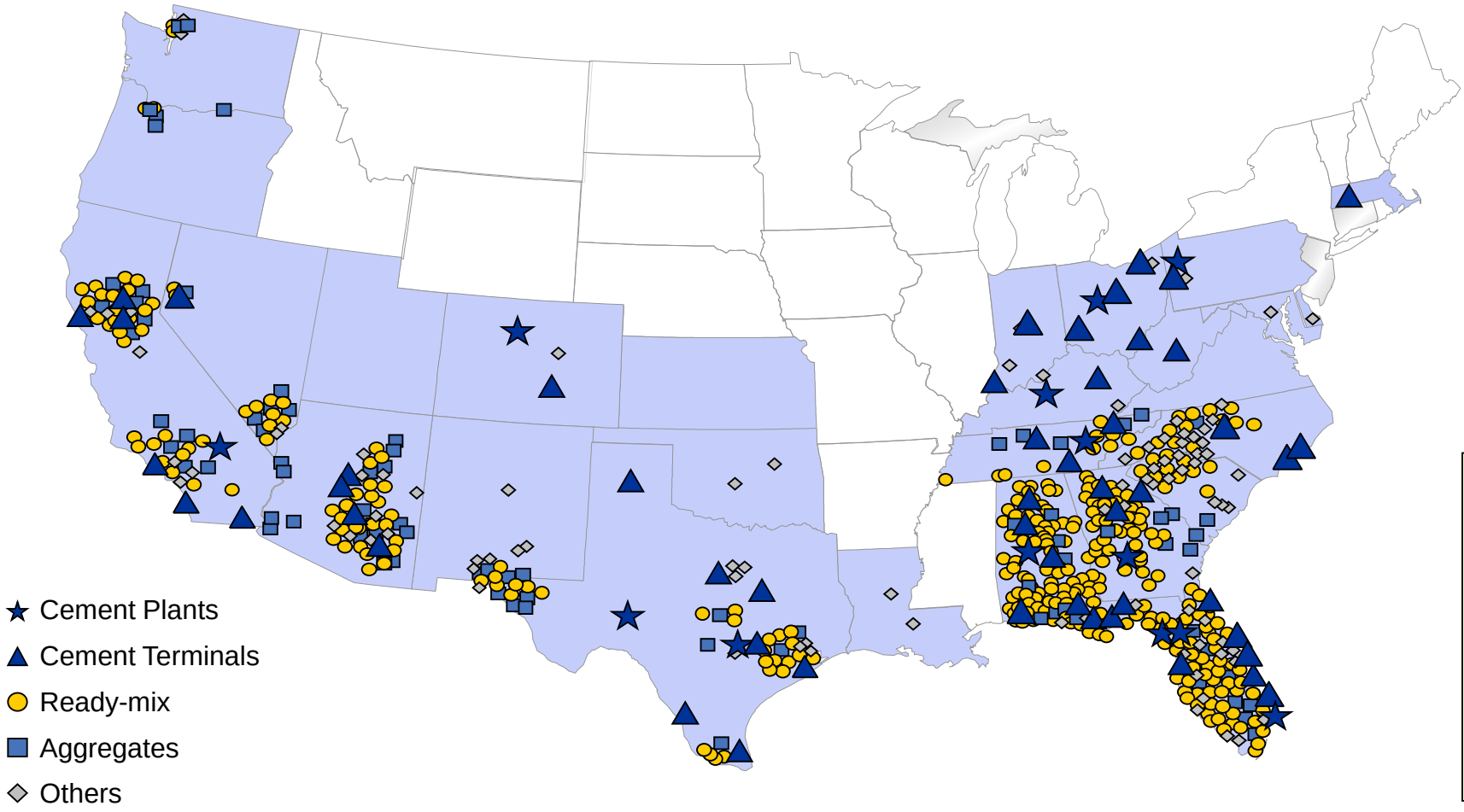
A CEMEX COMPANY

PROVIDING SOLUTIONS THROUGH PAVEMENT DESIGN

# Cement-Based Pavement Solutions

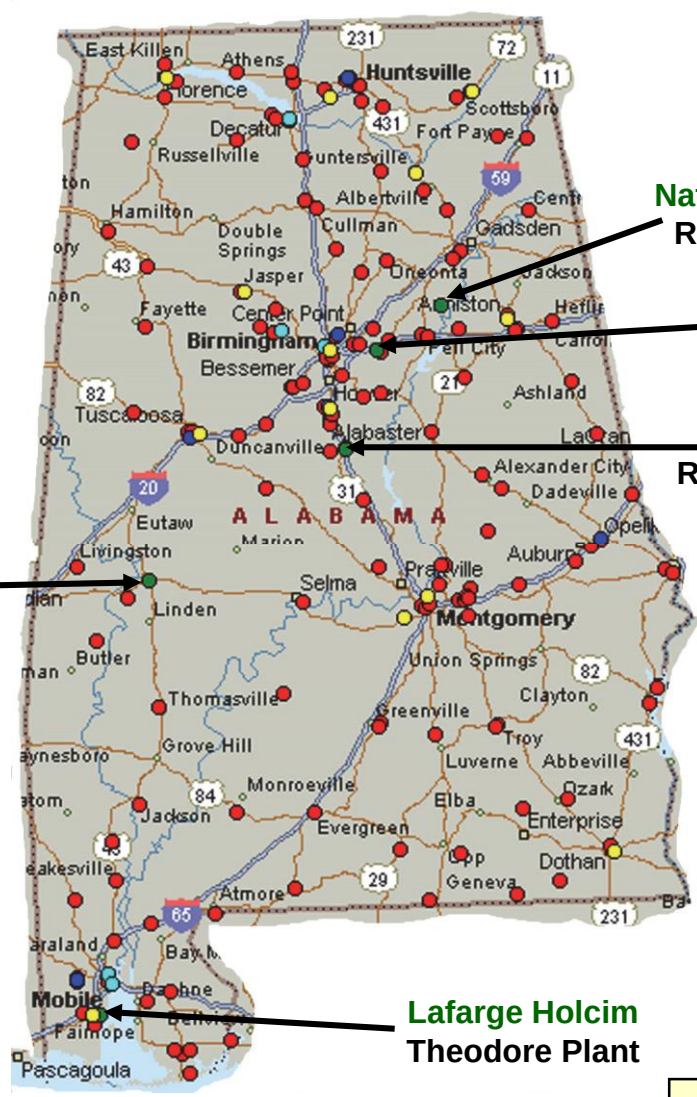
Presented by Shadrack Mboya, P.E.

# CEMEX IS ONE OF THE LEADING BUILDING MATERIALS SUPPLIERS IN THE INDUSTRY




**Plants**
**Cement: 10**
**Ready-mix: 292**
**Aggregates: 61**
**Block: 21**
**Pipe: 29**
**Gypsum: 31**
**Fly Ash: 33**
**Precast: 5**
**Others: 28**

# ALABAMA IS THE FIFTH LARGEST PRODUCER OF CEMENT IN USA[1]




- Cement Plants: 5
- Cement Terminals: 6
- Ready Mix Plants: 156
- Precast/Concrete Pipe Plants: 7
- Block Plants: 13

**Cement Economic Data[2]**
**Cement production: 4.3 million metric tons**
**Cement consumption: 1 million metric tons**

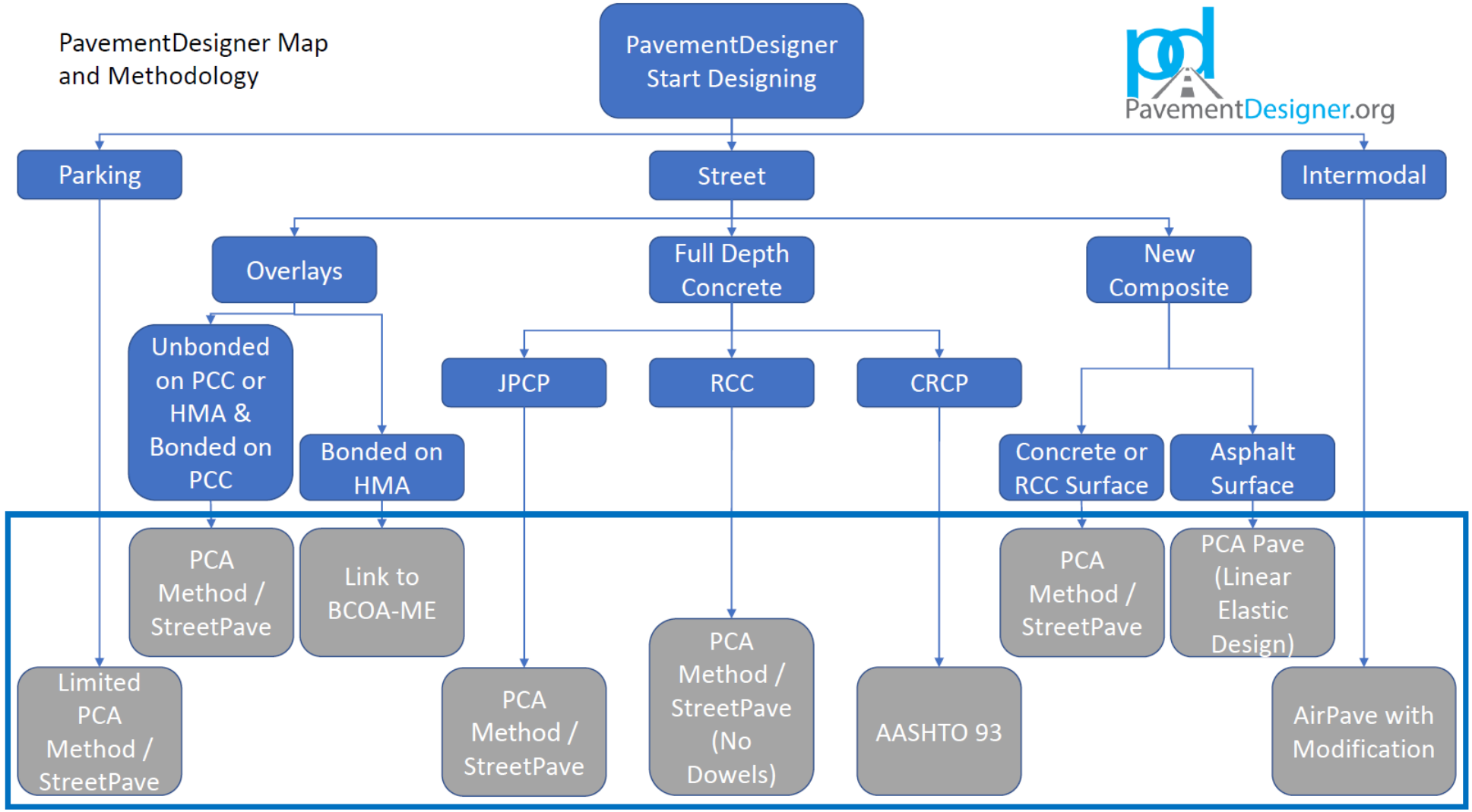
**Widespread raw materials reach and portable batch plants allow our industry to supply most locations**

**Note: Asphalt industry has about 78 Hot Mix Plants in Alabama[3]**


Sources:
1. Cement Industry in the United Sates, Wikipedia, 2013
2. Portland Cement Association, Alabama Cement Industry, 2015
3. Alabama Department of Transportation, Hot Mix Asphalt Plants, 2018

# PavementDesigner.org

PavementDesigner Map and Methodology




**A new, free online resource for the design of roadway, industrial, and parking area pavements**

# THE ADOPTION OF THESE ELEMENTS WILL INCREASE COMPETITION AND LOWER OVERALL COST OF PAVEMENT CONSTRUCTION

**Elements that make Concrete Competitive**

1. **Adoption of Proper Pavement Design Procedure**
   - Removes over-design and lowers initial costs

2. **Accounting for Maintenance Costs**
   - Most owners & engineers do not account for maintenance costs. Maintenance cost will help determine the best pavement alternative.

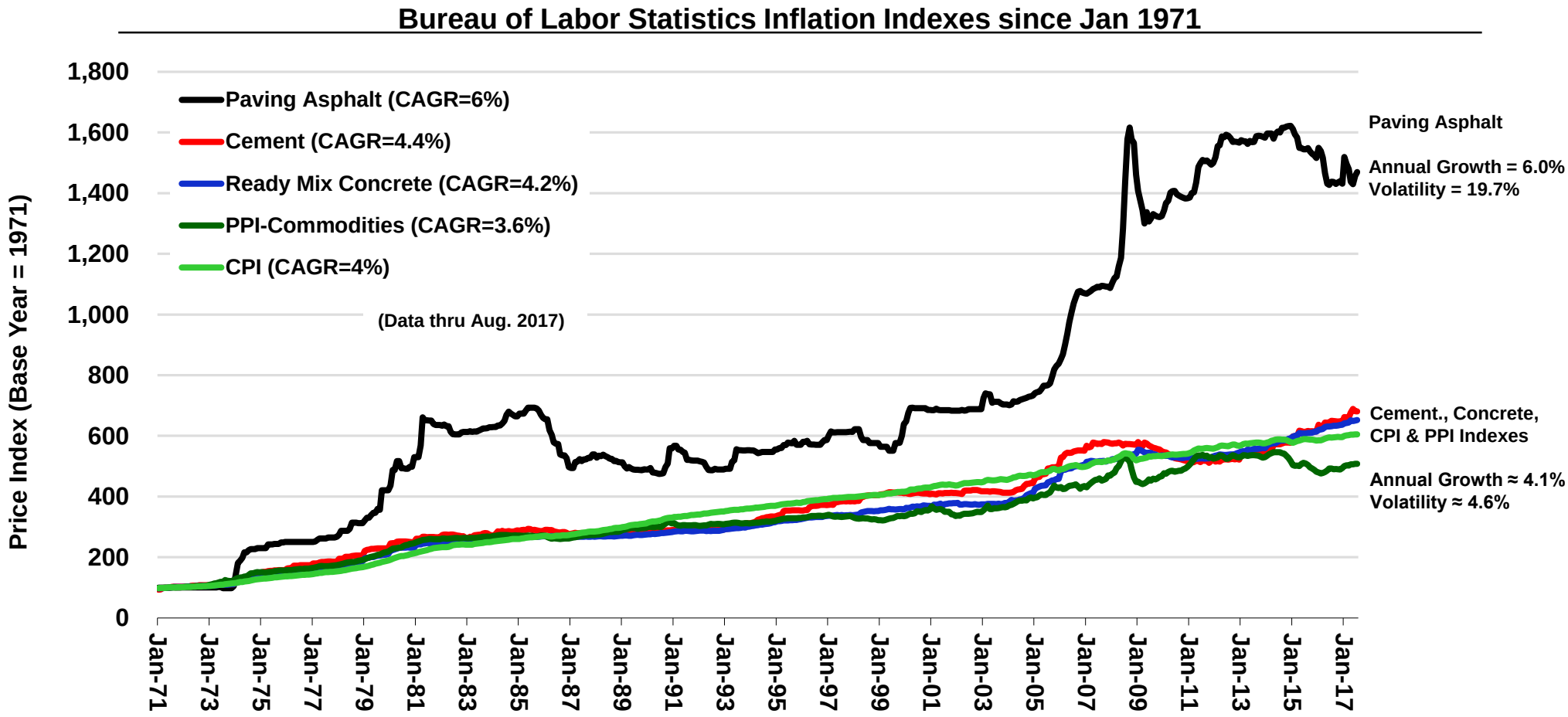
3. **Adoption of Alternate Design / Alternate Bid (ADAB) with Equivalent Design**
   - 90% of projects are designed with Asphalt only
   - Concrete may not even have the chance to bid….
   - ADAB has both asphalt and concrete designs and both are bid

**While there are benefits of each element, when COMBINED there are synergistic effects that have proven to make concrete pavements competitive**

# USING APPROPRIATE CONCRETE PAVEMENT FEATURES WILL OPTIMIZE THE DESIGN AND CAN MAKE CONCRETE MORE COMPETITIVE

| Element | Objective | Recommendation | Impact |
|---|---|---|---|
| Pavement Thickness | ➢ Design thickness to match expected traffic<br>➢ Most of the design loads are carried by concrete | ➢ Do not use artificial minimums<br>➢ Use of latest design guidelines | ➢ Increases initial cost of pavement |
| Concrete Mix Design | ➢ Determine mix proportion to yield minimum strength and durability | ➢ Use cost effective local material that yield similar design performance period (performance based mixes) | ➢ Increases initial cost of pavement |
| Base Material | ➢ Used to prevent pumping<br>➢ Used as construction platform | ➢ Use appropriate base material based on pavement applications<br>➢ Use cost effective base material and proper thickness that will yield similar design performance period | ➢ Increases initial cost of pavement |
| Dowels | ➢ Used to improve load transfer between slabs | ➢ Typical use on high truck traffic volume and high traffic speed<br>➢ Use cost effective dowels | ➢ Increases initial cost of pavement |
| Fibers | ➢ To add impact resistance<br>➢ Increase durability | ➢ Most effective for thickness < 6 inches<br>➢ Most pavement design do not use fibers | ➢ Increases initial cost of pavement |
| Joint Spacing/ Wide Lanes | ➢ Control crack formation<br>➢ Increase durability | ➢ Use shorter joint spacing ≤ 15 feet<br>➢ Consider widening of design lane (13 feet typical) in lieu of increasing pavement thickness | ➢ Pavement performance |

# CONCRETE PRICES HAVE BEEN MUCH MORE STABLE THAN ASPHALT PRICES

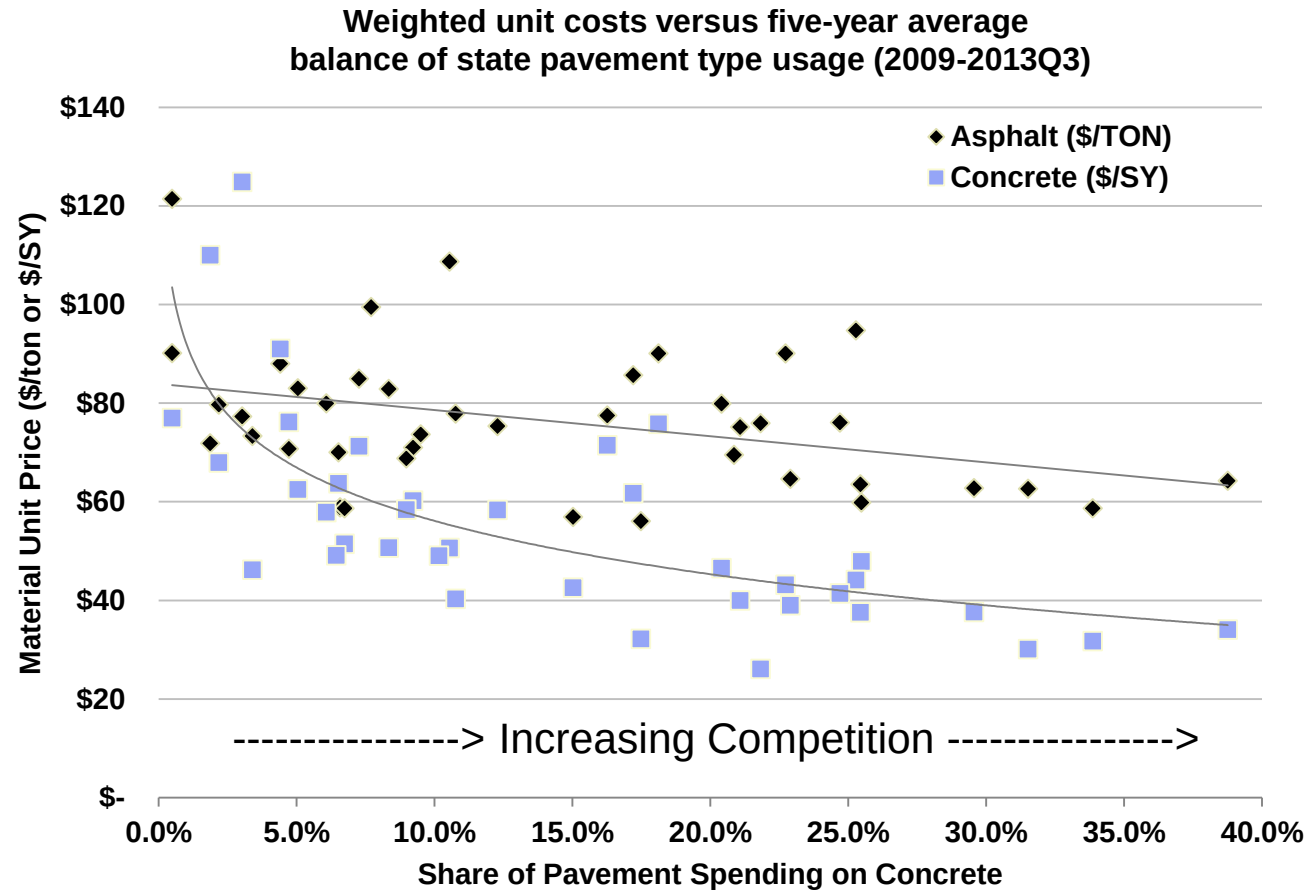



**Asphalt Inflation Rates are significantly higher than Concrete**
**Not accounting for inflation experience will bias the cost estimates and lead to costly overruns**

1. U.S. Department of Labor, Bureau of Labor Statistics, http://www.bls.gov/ppi/home.htm
2. CAGR = Compound Annual Growth Rate

# SUSTAINED COMPETITION BETWEEN THE PAVING MATERIALS INDUSTRIES BRINGS VALUE TO THE TAX PAYERS

- No state spends more than 40% of paving dollar on concrete – on average
  - MAJORITY of states spend less than 15% of paving dollars on concrete pavement
- As competition increases between industries
  - Prices decrease
  - Innovation increases
  - Quality improves
- Allows agencies to build more pavements for same investment!




Source: ACPA - Two Pavement System: Competition Between Industries can Lower Unit Costs and Allow Highway Agencies to do More With Their Budgets

# CEMENT-BASED PAVEMENT SOLUTIONS

| Application | Conventional Concrete Pavements | Thin Concrete Pavements | Roller Compacted Concrete | Concrete Overlays | Full-Depth Reclamation (FDR) with Cement | Soil Stabilization with Cement | Pervious Concrete |
|---|---|---|---|---|---|---|---|
| Interstate/ Highways | ● | | ● | ● | ● | ● | |
| Local Streets | ● | ● | ● | ● | ● | ● | ● |
| County/Rural Roads | ● | | ● | ● | ● | ● | |
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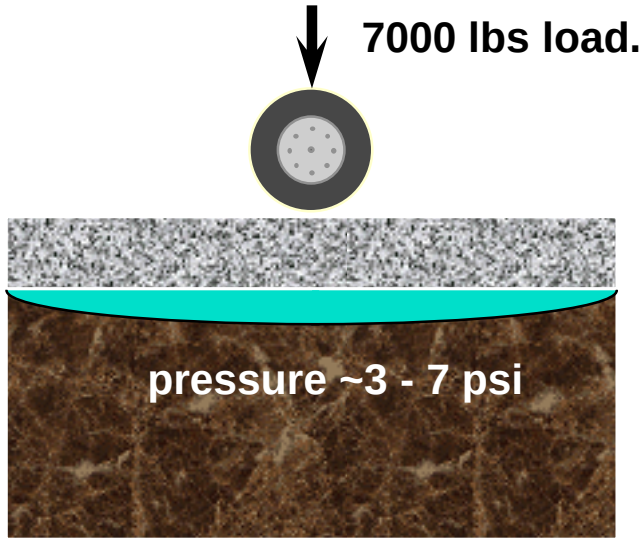
# CONCRETE AND ASPHALT PAVEMENTS ARE DIFFERENT BASED ON HOW THEY DELIVER LOADS TO THE SUBGRADE

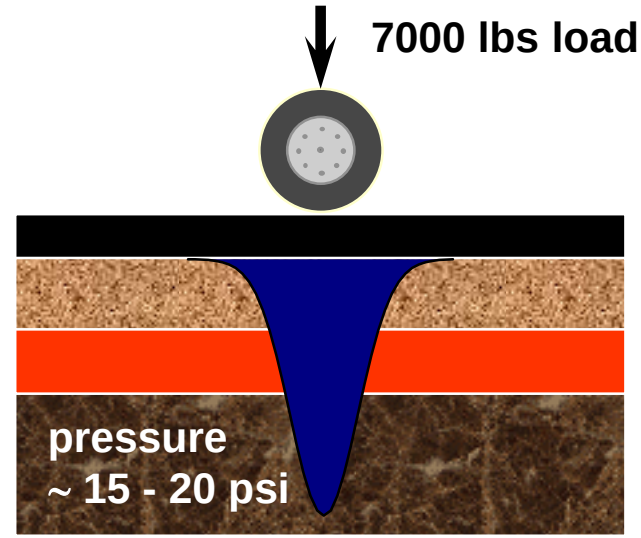
## Concrete Pavements are rigid

- Loads are distributed over a large area through slab action.
- Minor deflections.
- Low subgrade contact pressures.
- Subgrade uniformity is more important than strength.

## Asphalt pavements are flexible

- Loads are more concentrated.
- Deflections are higher
- Subgrade, base and subbase strength are very important.
- Usually require more layers and greater thickness for optimally transmitting load to the subgrade



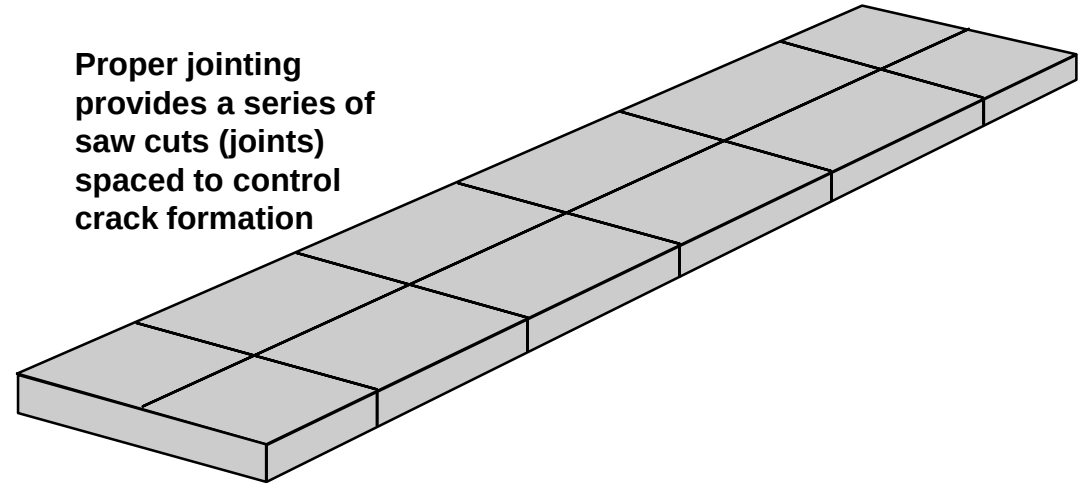




**Concrete's Rigidity spreads the load over a large area & keeps pressures on the subgrade low**

# WHY ARE JOINTS NECESSARY?

- The concrete ***will*** crack after placement
  - Joints tell the concrete where to crack
- Why does concrete crack after placement?
  - Concrete drying shrinkage
  - Changes in temperature and moisture
    - Ambient (contraction)
    - Gradient (curling)
  - Subbase restraint (friction or bond)
  - First applied loads

Proper jointing provides a series of saw cuts (joints) spaced to control crack formation

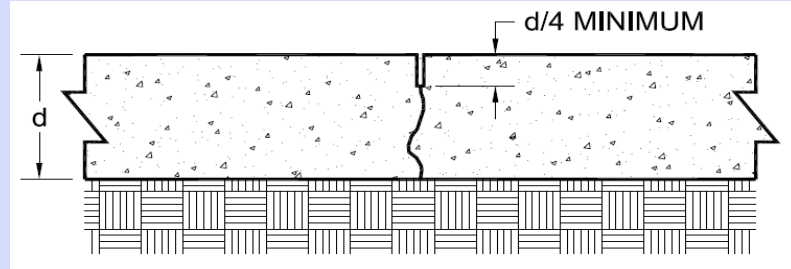
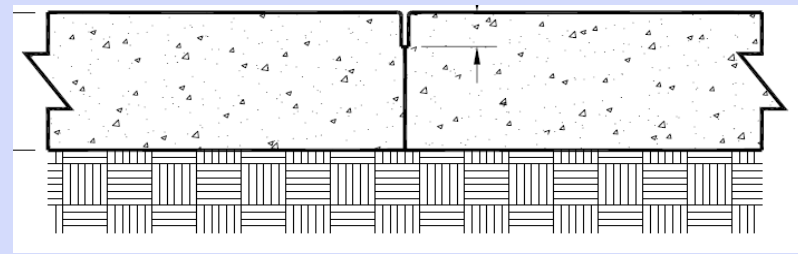
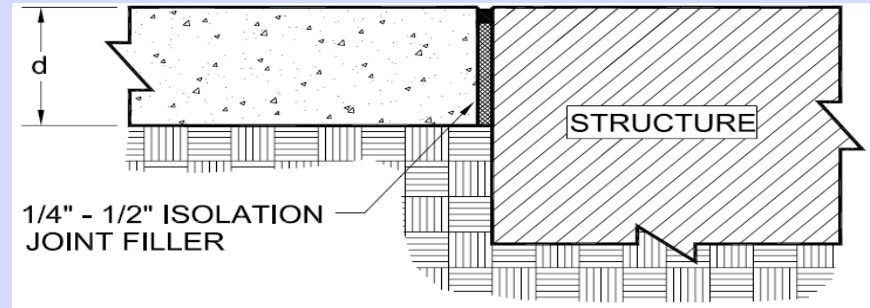


Erratic crack patterns due to no joints

**Recommended Maximum Joint Spacing (2 x thickness in ft)**

| Pavement thickness, in. | Spacing range, ft |
|---|---|
| 4 to 4.5 | 6-10 |
| 5 to 5.5 | 7.5 -12.5 |
| 6 or greater | 10-15 |

# TYPES OF JOINTS IN CONCRETE PAVEMENTS

| | Details For Use | Typical Detail |
|---|---|---|
| **Contraction (Control) Joint** | ➢ Use at short joint spacing<br>➢ Made by saw cut, or tooled<br>➢ Early entry cuts = 1” deep<br>➢ Saw cut within 2 to 6 hours of paving |  |
| **Construction Joint** | ➢ Use at end of construction day<br>➢ Use thickened edge for heavy duty applications<br>➢ Keyways not recommended |  |
| **Isolation (Expansion) Joint** | ➢ Isolate pavement features with differential movements<br>➢ Do not use at regular spaced joints in paving lane<br>➢ Full thickness, vertical joint, sealed with compressible material |  |

1) Jointing recommendations should be based on ACI 330

# STEEL REINFORCEMENT IS NOT NECESSARY FOR CONCRETE PAVEMENTS

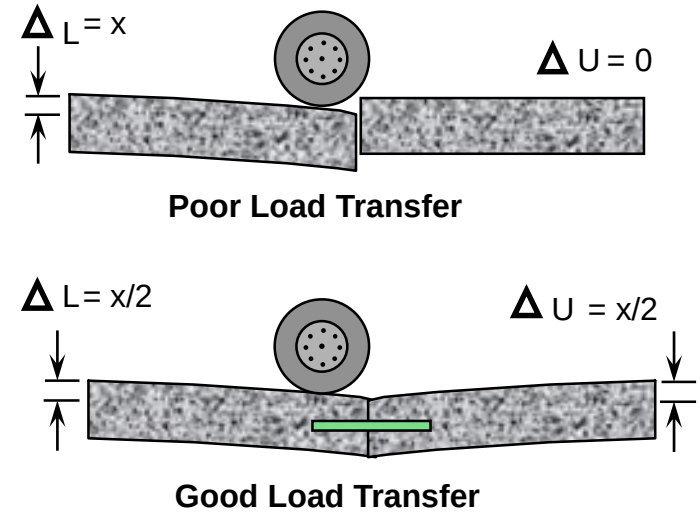
- Steel reinforcement has minor effect on a pavement's load-carrying capacity or thickness
  - It does effect the joint design of the pavement
  - Joints are placed according to the system selected and identifies the "concrete pavement type"
- For all paving applications, industry does not recommend using mesh reinforcing steel
  - Not enough mesh to add strength
  - It is rarely placed at the correct depth
- Cost impact – 7 to 12%
- Save money with tighter joint spacing instead of spending money on reinforcing for similar performance


# DO I NEED DOWELS?

**Dowels are used to improve Load Transfer**

**A slabs ability to share its load with neighboring slabs**

1. **Dowels**




2. **Aggregate Interlock**
   - **Shear between aggregate particles below the initial saw cut**

3. **Concrete shoulders, extended lane, & curb and gutter aid load transfer**

**Trucks Control Thickness and Deflections**

- **Include dowels if:**
  - **Slab thickness > 8.0 inches**
- **Exclude dowels if:**
  - **Slab thickness < 7.0 inches**

**Other issues:**

**Speed of Traffic (Speeds >~30 mph more apt to need dowels)**
**Channelized traffic (more apt to need dowels)**
**Direction (single direction more apt to need dowels**

# A SUBBASE IS PRIMARILY USED TO PREVENT PUMPING/EROSION OF SUBGRADE

- Purposes of the subbase are:
  - To minimize or eliminate the potential for pumping, subgrade expansion due to clay or frost
  - Provide construction platform
- Use a subbase if:
  - Category C, k – value less than 200
  - Multiple truck semi-trailer daily applications
  - Non-uniform soil conditions
  - Wet soil that might hamper construction
- Exclude subbase if:
  - Non-pumpable subgrade soil (< 45% passing #200 sieve & PI <6 )
- It is not economical to use thick subbases to increase structural capacity
  - Cost impact – 15 to 25%

Pumping is the forceful displacement of soil and water from underneath a concrete slab

**Conditions for Pumping**

1. Subgrade soils that are erodible
2. Free water between slab and subgrade
3. Frequent heavy wheel loads

**For parking lots, bases are not usually required, however if required use a <u>Granular Base</u> (or a Cement Stabilized Subgrade)**

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# ROLLER COMPACTED CONCRETE HAS LONG HISTORY OF GOOD PERFORMANCE ON HEAVY DUTY PAVEMENTS

**Roller Compacted Concrete (RCC) Pavements**

- No Slump
- Consistency of damp gravel
- Placed by asphalt pavers
- Compacted with vibratory rollers
- No forms
- No reinforcing steel
- No finishing
- Max lift thick – 8 to 10 in
- Low W/C ratio = limited shrinkage cracks
- High-production rate (typ. 1900 LF/day)
- Typical Traffic Opening within 24 hours
- Typically 5 to 15% cheaper than conventional concrete

Honda Automotive Facility – Lincoln, AL
1.5M Square Yards/ 5” and 7” RCC /4” CTB

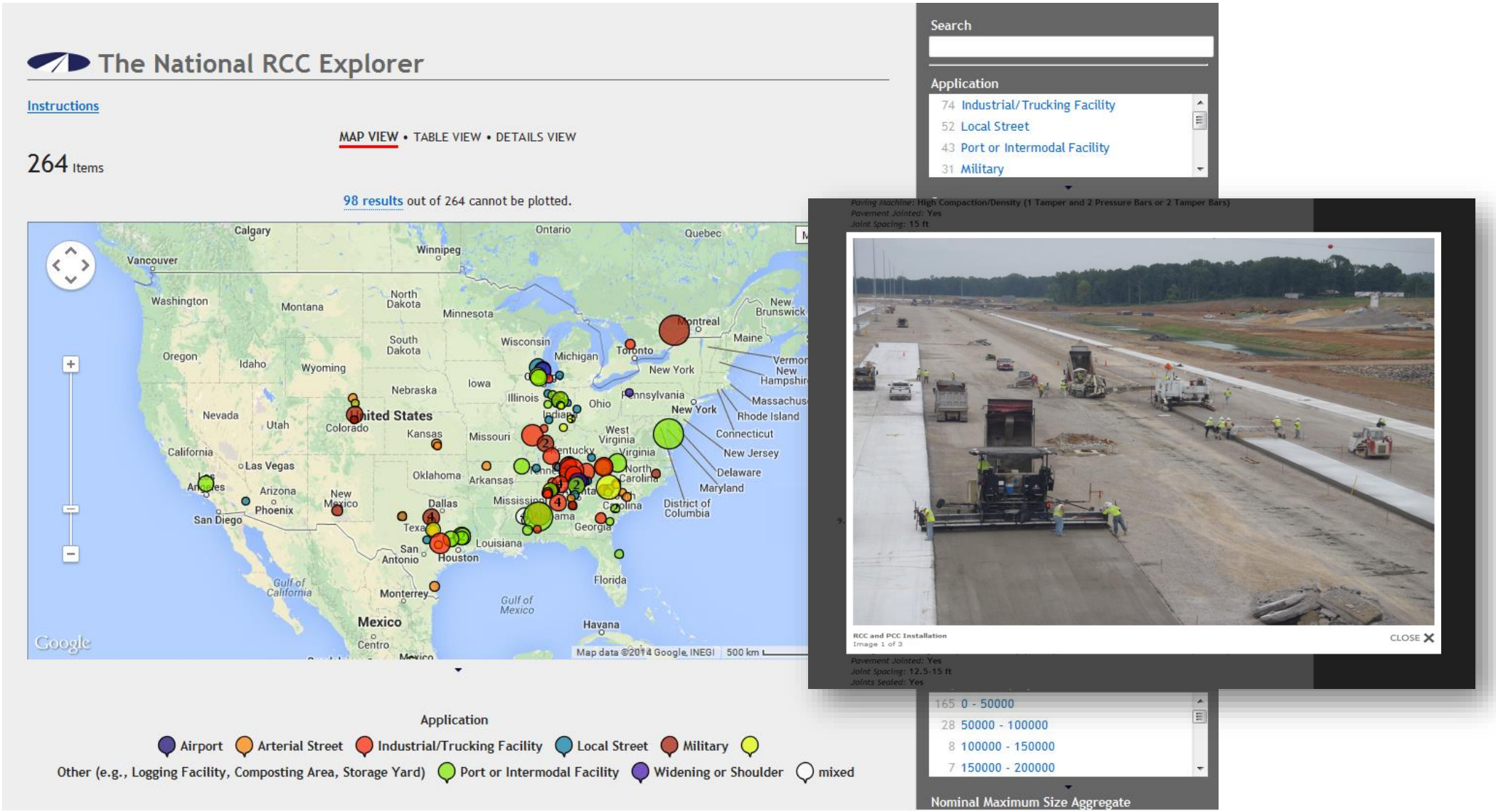
Willow Lane – Hayesville, KS (2011)
5” RCC / 6” recycled base / clay

Birmingham Regional Intermodal Facility
60,000 CY of 9” and 16” RCC

**RCC have been successfully used for intermodal Port / freight / manufacturing yards Its is also used on city streets and Residential subdivisions. Go to rcc.acpa.org for projects examples**

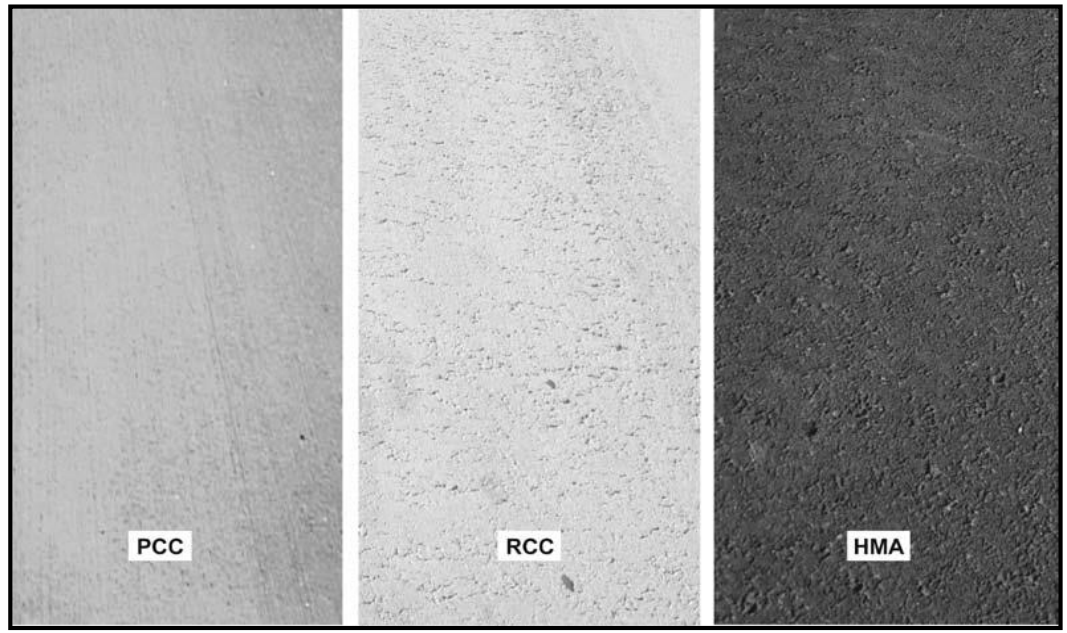
# RCC EXPLORER DATABASE SHOWS WHERE RCC HAS BEEN DONE

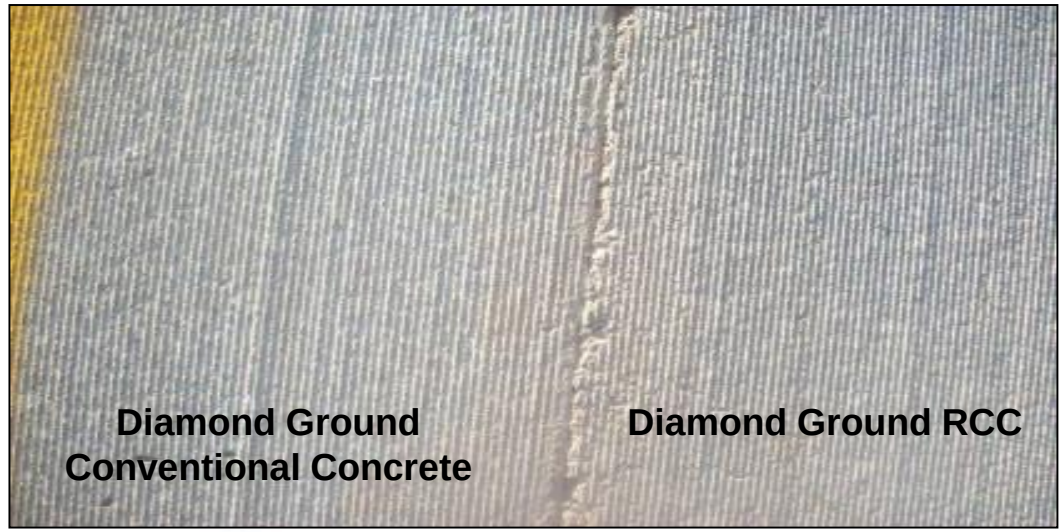
## rcc.acpa.org



# THE SURFACE APPEARANCE AND TEXTURE OF RCC IS SIMILAR TO ASPHALT PAVEMENT

- Similar appearance & texture as asphalt only light grey instead of black
- Surface texture depends on aggregate gradation and paste content
- Diamond ground RCC is similar to diamond ground concrete
- Trowelled RCC similar appearance as conventional concrete



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| Base Course | | | ● | | ● | ● | |
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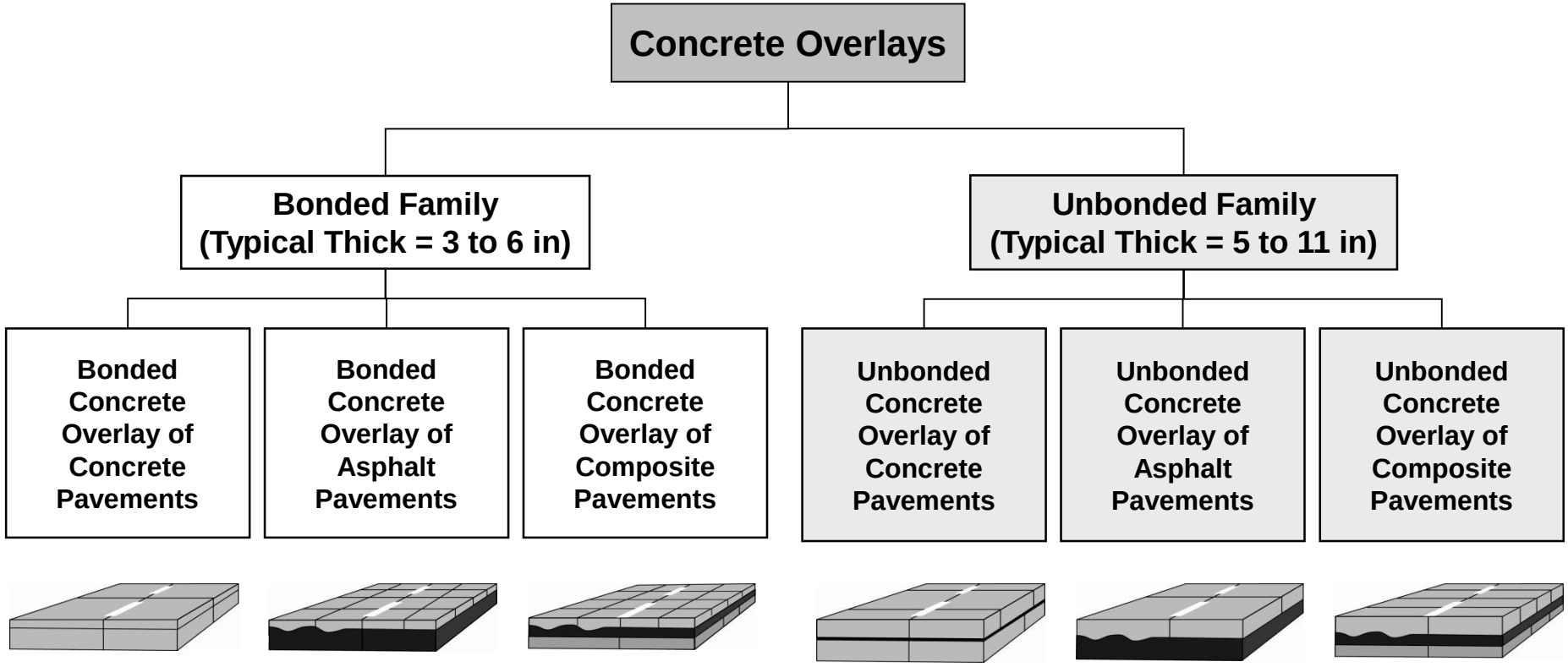
| Airport Runways & Aprons | ● | | | ● | ● | ● | |

# CONCRETE OVERLAYS FALL INTO TWO FAMILIES

## Overlay family is dependent on how the interface between layers is treated




**Bond is integral to design**
(Existing pavement is in relatively good shape)

**Old pavement is base**
(Existing pavement is in poor condition)

# CONCRETE OVERLAYS HAVE SIMILAR LONG-TERM DURABILITY AND COST ADVANTAGES OF TRADITIONAL CONCRETE PAVEMENTS

## Durability & Costs Advantages

**Add strength and durability to an existing pavement**

- Can restore or add design life to existing pavement

**Competitive on Initial & Life Cycle Cost**

- Dollar for dollar, one of most effective long-term options
- A wide range of thicknesses can be used
- Can be designed to last from 10 to 40+ years

**Can be placed on both concrete and asphalt pavements.**

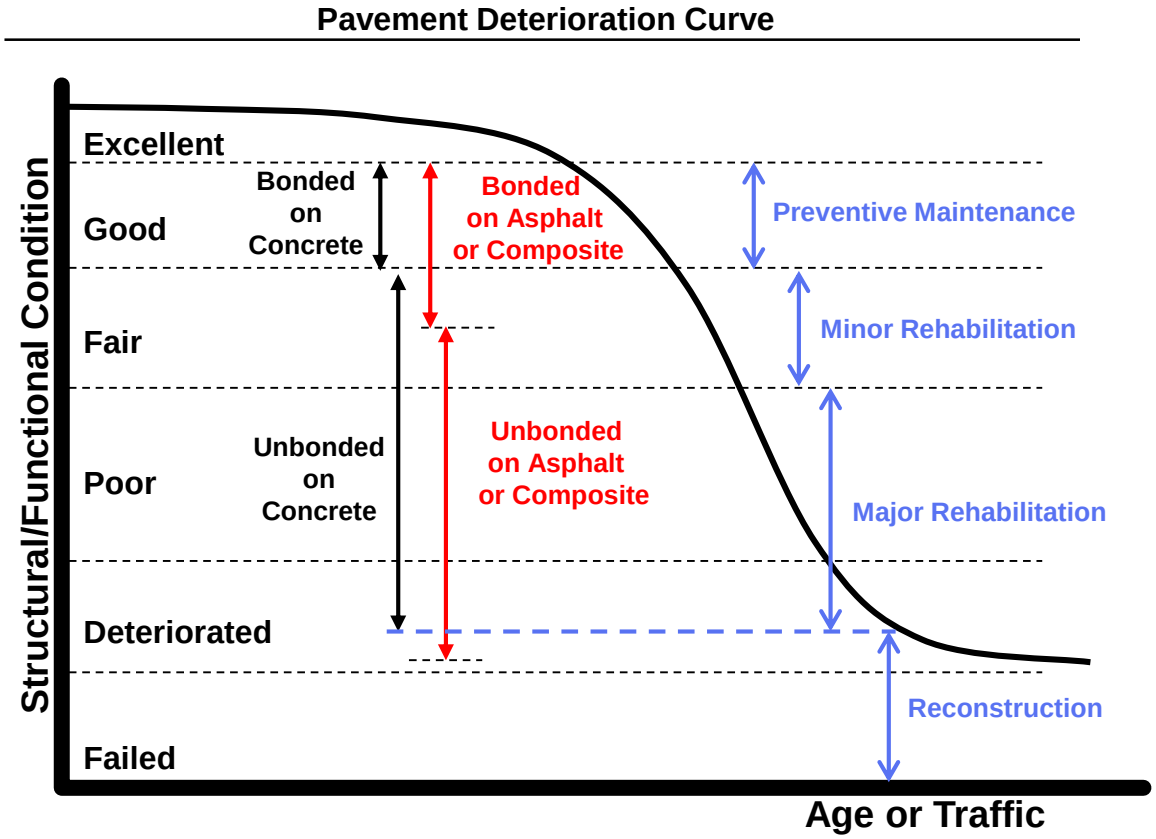
- Existing pavement does not have to be removed
- Few pre-overlay repairs are necessary
- Use normal concrete pavement construction practices

**Have good safety and sustainability characteristics**

- Reduced pavement removal / use existing structure
- Uses fewer virgin materials
- High skid resistance and non-rutting
- High reflectivity = greater visibility, lower surface temperature
- Stiff system = better fuel efficiency
- Fewer construction emissions

**Coolidge Road, Michigan**
**5 inch (125 mm) concrete overlay & widening, built September 1983**
***Picture circa 2001***
***First Rehabilitation done in 2015 after 32 years***

# THE CHOICE BETWEEN BONDED OR UNBONDED OVERLAY IS PRIMARILY BASED ON THE EXISTING PAVEMENT CONDITIONS





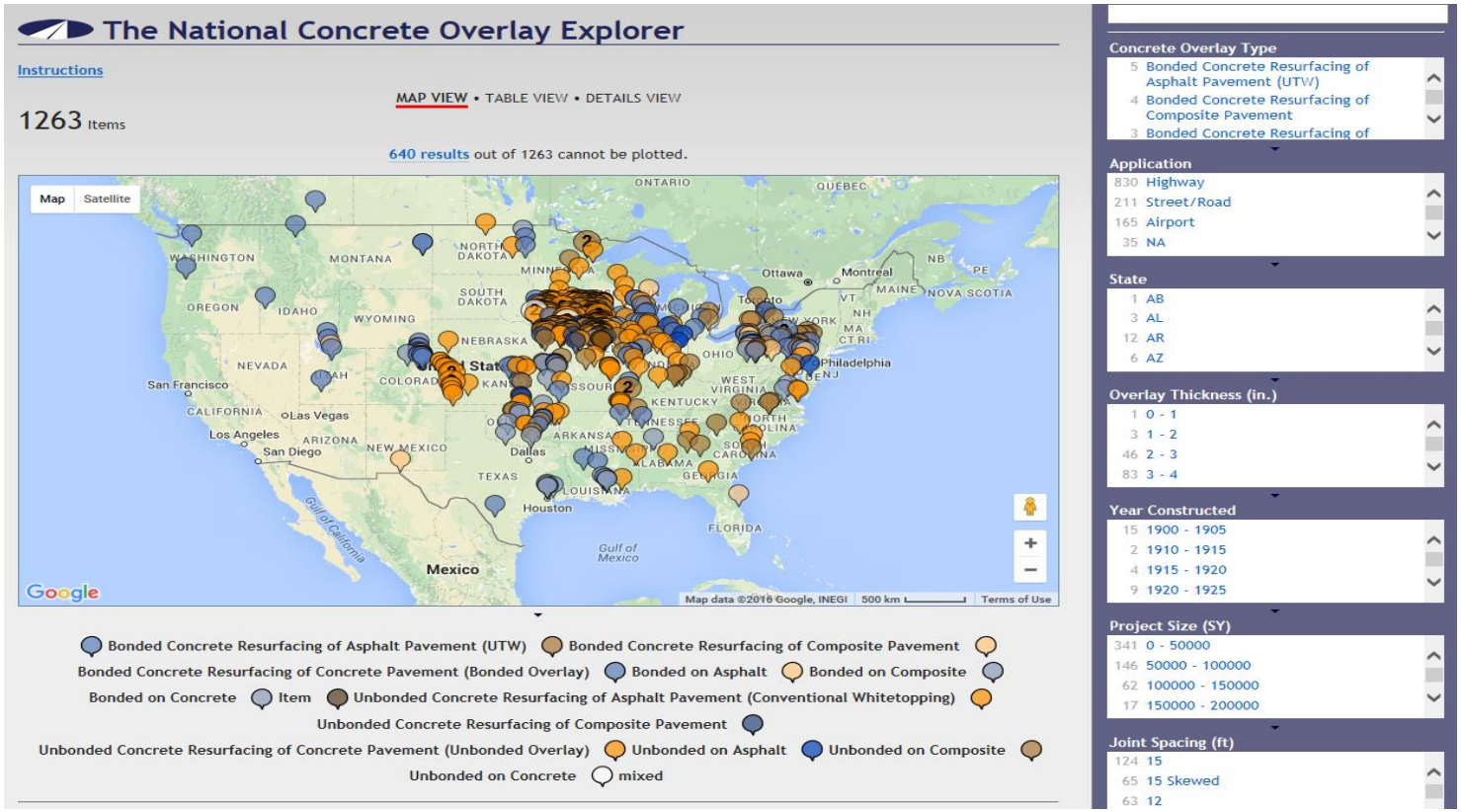
**Other Issues that dictate viability of an overlay**

- Roadway type (Interstate vs Arterial vs Collectors)
- Urban vs Rural
- Site specific considerations
  - shoulder, bridges, and other vertical clearance issues
- Traffic control options & Time to open

# MOST STATES HAVE SOME CONCRETE OVERLAY EXPERIENCE

## ACPA Concrete Explorer database provides details on over 1200 projects

**States with Concrete Overlay Experience**




**http://overlays.acpa.org/webapps/overlayexplorer/index.html**

**Iowa** [1,2]

- **Over 500 different overlay projects**
- **First project in 1960**
- **Most projects on county road system**

**Missouri**

- **Using Alternate Bid/Alternate Designs (concrete vs Asphalt) for high volume highways**
- **Majority of overlay projects have gone concrete**

**Colorado**

- **Has pioneered the use of thin concrete overlays**

**Michigan**

- **Over 18 projects of 6 to 8 in. (150 to 200 mm) concrete overlays on interstate applications**

**Illinois**

- **Has constructed 81 overlays since 1974.**
- **65 been over asphalt or composite pavement**

1. Iowa Concrete Pavement Association
2. National Concrete Pavement Technology Center (CPTech Center)

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# WHAT IS PERVIOUS CONCRETE?

**Is a concrete pavement:**

- Has 15-35% air voids to allow water to percolate
- Has minimum or no fines in the mix
- Typically uses single size aggregate
- Has rough surface texture
- Has unit weight less than conventional concrete
- Has typical permeability rate of 3.5 gal/ft2/min (infiltration rate in excess of 340 in/h)
- Provide savings to site owners through storm water management, increased land area use, decrease construction costs, minimal maintenance

**Cemex has pervious concrete brand called Pervia**


# WHERE HAS PERVIOUS CONCRETE BEING USED?

## Streets and Roads

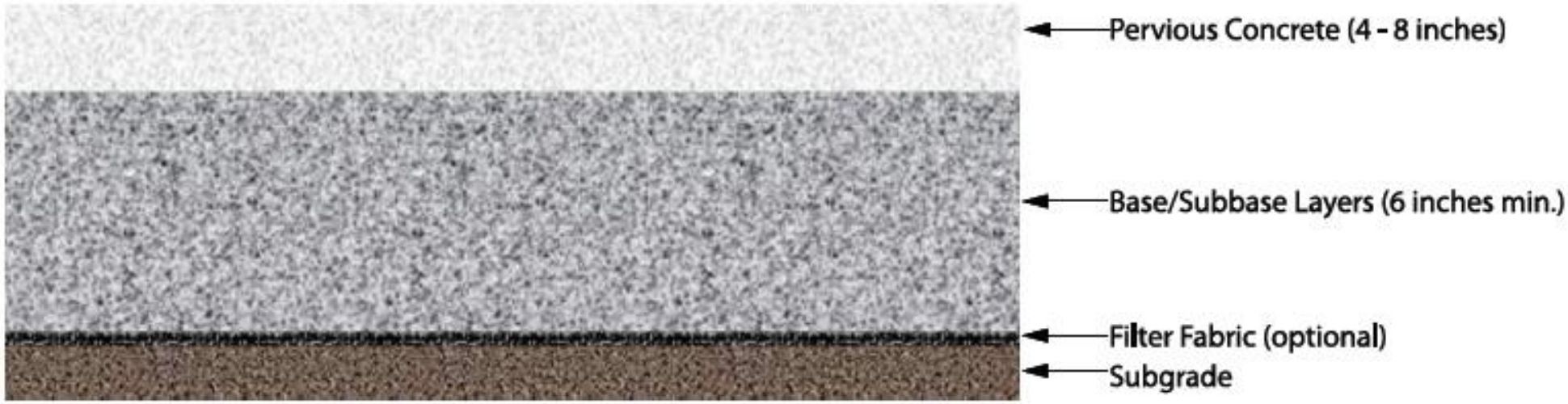
## Parking Lots

## Sidewalks

## Others

Source: National Ready Mixed Concrete Association

# TYPICAL PERVIOUS CONCRETE PROFILE




**Adopted from United States Environmental Protection Agency (EPA) 2010**

1. Technical Brief FHWA-HIF-13-006, Figure 1

# PERVIOUS CONCRETE DESIGN CONSIDERATIONS

**Traffic:**

- **Pedestrian/Sidewalk (typically 4 inches min.)**
- **Standard Duty Traffic (typically 6 inches min.)**
- **Heavy Duty Pavement (typically 8 inches min.)**

**Sidewalk Pavement**

**Standard Duty Pavement**

**Heavy Duty Pavement**

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| Parking Lots | ● | ● | ● | ● | ● | ● | ● |
| Base Course | | | ● | | ● | ● | |
| Industrial | ● | | ● | ● | ● | ● | ● |
| Airport Runways & Aprons | ● | | | ● | ● | ● | |

# SOIL STABILIZATION IS A COST EFFECTIVE TREATMENT OF POOR SOILS THAT ARE INADEQUATE FOR CONSTRUCTION

## 1. What is it?

- Treatment of soil using portland cement
- Soils include gravel, sand, silt, clay, and manufactured sand and aggregate
- Typical cement content is between 2 to 6 percent of soil dry weight

## 2. What does it do?

- Increases workability, strength, compaction of soils
- Reduces moisture susceptibility, mitigating subgrade expansion due to clay or frost
- Provide construction platform
- Provide uniform, stable support
- Eliminating the potential for pumping of the subgrade

## 3. Cost Comparison

- Typically cost less than half of aggregate base materials.


**When soil stabilization is used under light to medium duty pavements, soil erodibility is reduced eliminating the need for granular bases**

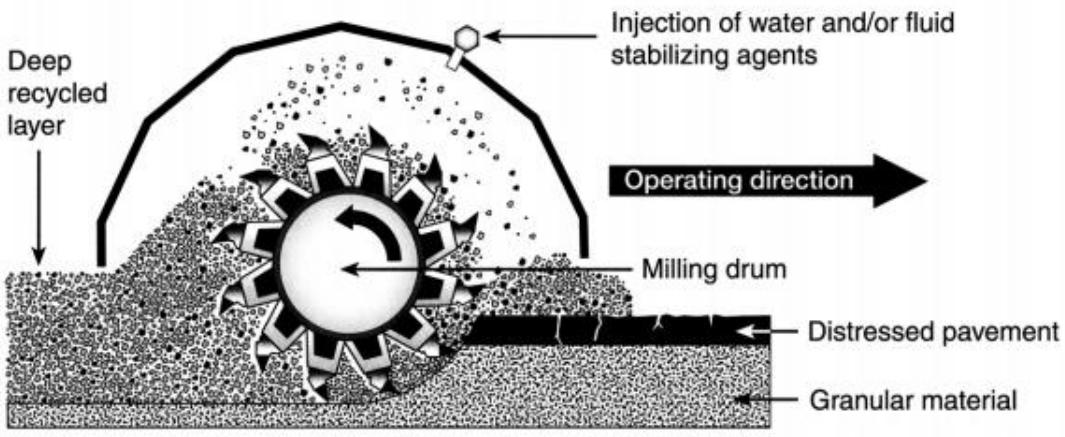
(1) PI – Plasticity index – measure of soil plasticity. Low PI = Sand, High PI = Clay
(2) Majority of soil stabilization is done on mid to high PI soils

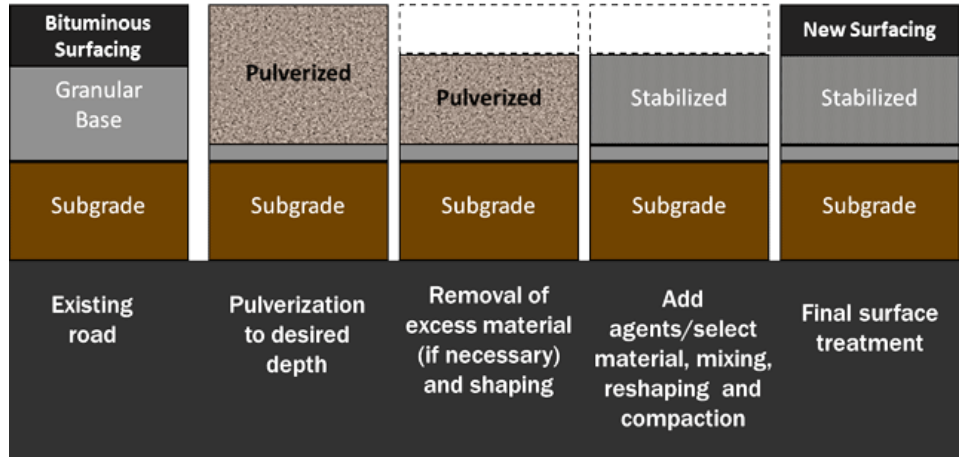
# CEMENT-BASED PAVEMENT SOLUTIONS

| Application | Conventional Concrete Pavements | Thin Concrete Pavements | Roller Compacted Concrete | Concrete Overlays | Full-Depth Reclamation (FDR) with Cement | Soil Stabilization with Cement | Pervious Concrete |
|---|---|---|---|---|---|---|---|
| Interstate/ Highways | ● | | ● | ● | ● | ● | |
| Local Streets | ● | ● | ● | ● | ● | ● | ● |
| County/Rural Roads | ● | | ● | ● | ● | ● | |
| Parking Lots | ● | ● | ● | ● | ● | ● | ● |
| Base Course | | | ● | | ● | ● | |
| Industrial | ● | | ● | ● | ● | ● | ● |
| Airport Runways & Aprons | ● | | | ● | ● | ● | |

# FULL-DEPTH RECLAMATION (FDR) WITH CEMENT

- Pulverizing or recycling of an existing distressed or deteriorated asphalt pavement and its underlying layers with Portland cement to form a new base.
- Underling layers include base, subbase, and/or subgrade (soil)
- Typical pulverized depth is between 6 and 12 inches
- Typical cement content is between 2 to 8 percent of recycled material dry weight
- Typically a rigid or flexible pavement is placed over FDR base material



# FDR WITH CEMENT IS A TRIED AND TRUE REHABILITATION METHOD

- **Low cost: Typical cost savings between 30 and 60% compare to alternative reconstruction such as removal and replace[1]**
- **Can be performed in a short time, benefiting owners or general public**
  - **Typical production rates range from 5,000 to 10,000 square yards depending on contractors experience**
- **Can be performed in airports, residential, industrial, parking lots, streets & local roads, and interstate and highways**
- **Increases structural capacity of the pavement**
- **Reduce carbon footprint**


1. Design of Full-Depth Reclamation with Portland Cement (FDR-PC) Pavements (Halsted 2007)

# Thank You

## & Any Questions?

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