# How to Design Concrete Parking Lots - ACI 330R-08

Luke McHugh, PE
Senior Director, Local Paving
National Ready Mixed Concrete Association

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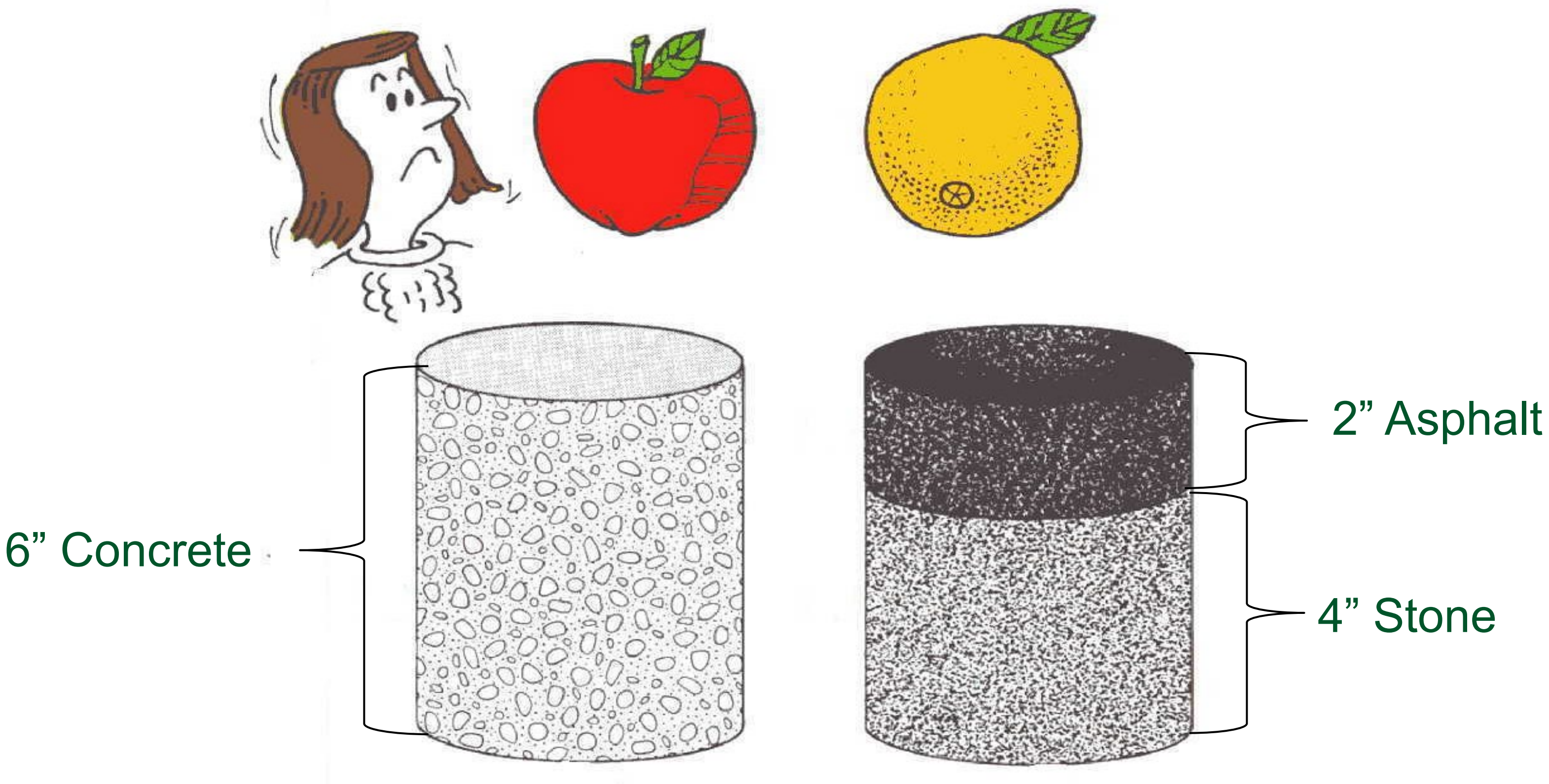
# National Ready Mixed Concrete Association

- National Trade Association – Established in 1930
- HQ in Alexandria, VA
- 1,400+ 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 (PaveAhead.com)*
  - *Structures and Sustainability: Build With Strength™ Initiative*

# NRMCA Disclaimer

- This presentation has been prepared solely for information purposes. It is intended solely for the use of professional personnel, competent to evaluate the significance and limitations of its content, and who will accept full responsibility for the application of the material it contains. The National Ready Mixed Concrete Association and any other organizations cooperating in the preparation of this presentation strive for accuracy but disclaim any and all responsibility for application of the stated principles or for the accuracy of the content or sources and shall not be liable for any loss or damage arising from reliance on or use of any content or principles contained in this presentation.

# These are NOT equal!



# Problems with Under-designing Pavements

*"Under-designing roads can mean more expensive repairs for local towns and counties in the long run."*

Cornell's Dr. David Orr, PE.

"When an agency does not prepare a specific pavement design, what ends up getting built is often times underbuilt. ***While they might have saved some money at the time of building, the cost comes back to bite when the road then needs to be rebuilt earlier than expected."***

Reference: Rutgers Center for Advanced Infrastructure and Transportation

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# What do engineers currently use to design concrete pavements?

Nothing…we only design asphalt pavements

What we've always used

Whatever the Geotechnical Engineer recommends

If it works for the DOT, it's good for me

AASHTO Design Guide – '72, '86, '93

IDOT Pavement Design

# IDOT Pavement Design

Chapter Fifty-four

PAVEMENT DESIGN

BUREAU OF DESIGN AND ENVIRONMENT MANUAL

- ***IDOT***
- ***Chapter Fifty-Four***
- ***Pavement Design***

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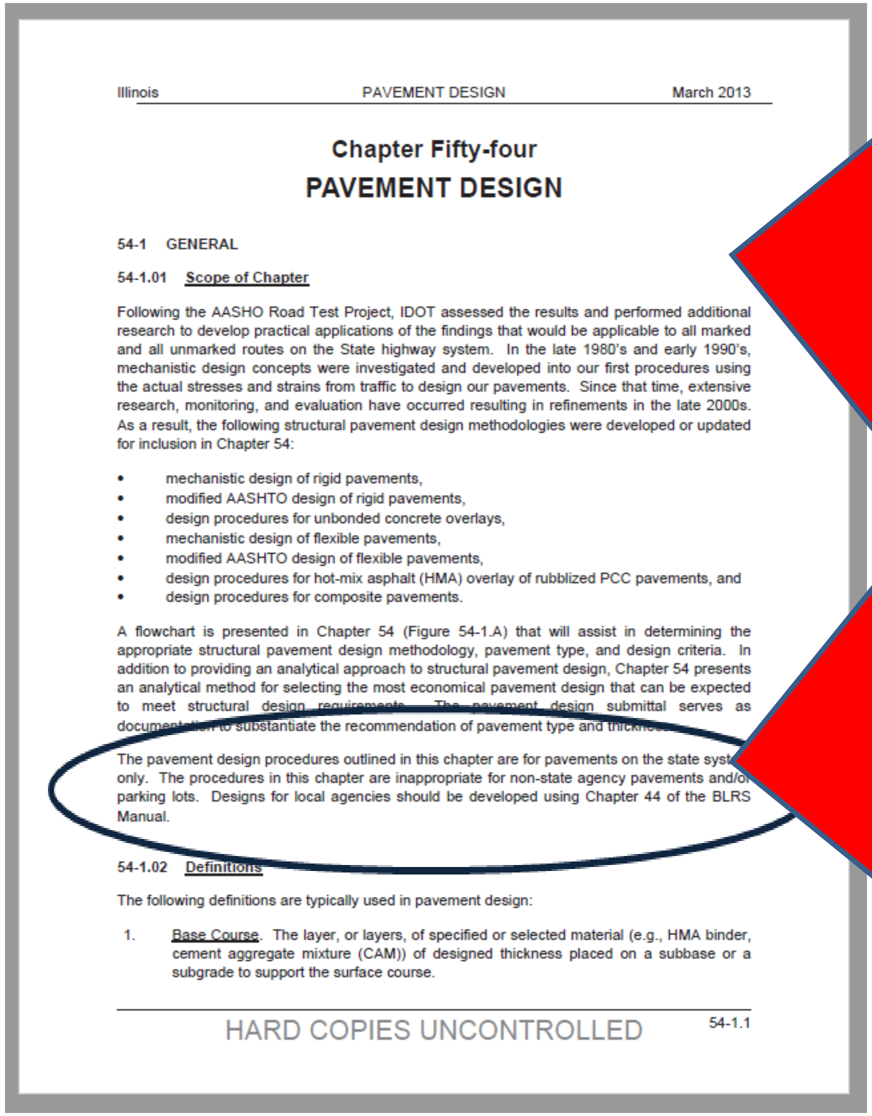
# First Page…


Illinois PAVEMENT DESIGN March 2013

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 additional research to develop practical applications of the findings that would be applicable to all marked and all unmarked routes on the State highway system. In the late 1980's and early 1990's, mechanistic design concepts were investigated and developed into our first procedures using the actual stresses and strains from traffic to design our pavements. Since that time, extensive 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 determining the appropriate structural pavement design methodology, pavement type, and design criteria. In addition to providing an analytical approach to structural pavement design, Chapter 54 presents an analytical method for selecting the most economical pavement design that can be expected to meet structural design requirements. The pavement design submittal serves as 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.

HARD COPIES UNCONTROLLED 54-1.1

- “The pavement design ...cedures outlined in this ...er are for pavements on ... state system only.”
- ...he procedures in this ...pter are inappropriate for ...tate agency pavements ... ***parking lots.”***

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# IDOT Mechanistic Design Method



**54-1.03 <u>Pavement Design Methodologies</u>**

**54-1.03(a) Mechanistic**

Since the completion of the AASHO Road Test Project, the Department has developed many new highway materials and procedures to improve pavement construction. This effort has resulted in improved material usage, construction procedures, and pavement designs which, although common practice today, were neither envisioned nor included in design procedures at the time of the AASHO Road Test. Therefore, to supplement the AASHO Road Test Project and better address modern pavement design, mechanistically based structural pavement design procedures were developed using structural mechanical analysis, computer modeling, and actual performance and response of existing pavement sections.

Mechanistic pavement design procedures are applicable to JPCP designs with nominal 15-ft panels and full-depth HMA designs with HMA surface and binder. The procedures use the actual stresses, strains, and deflections experienced by the pavement to determine its expected fatigue life. Factors that are considered in mechanistic designs include:

- design HMA strain,
- design pavement HMA mixture temperature,
- design HMA mixture modulus ($E_{HMA}$),
- subgrade support ratio (SSR),
- design reliability of 95% (HMA and PCC),
- degree of PCC edge support,
- degree of PCC base erosion,
- PCC joint spacing, and
- PCC stresses.

See Section 54-1.02 for definitions of these factors.

An Excel spreadsheet which will perform the mechanistic pavement design calculations is available on the IDOT website.

**54-1.03(b) Modified AASHTO**

The modified AASHTO design procedures are based on the AASHO Road Test pavement performance equations, which correlate performance of test sections with pavement design, the magnitude and configuration of the axle load, and the number of axle-load applications. The AASHTO equations are necessarily limited to the following factors:

- physical environment of the Road Test Project,
- materials used in the test pavements,
- range of pavement thicknesses included in the experiments,
- axle loads used and number of axle-load applications experienced,
- specific times and rates of application of the test traffic,
- construction techniques employed, and

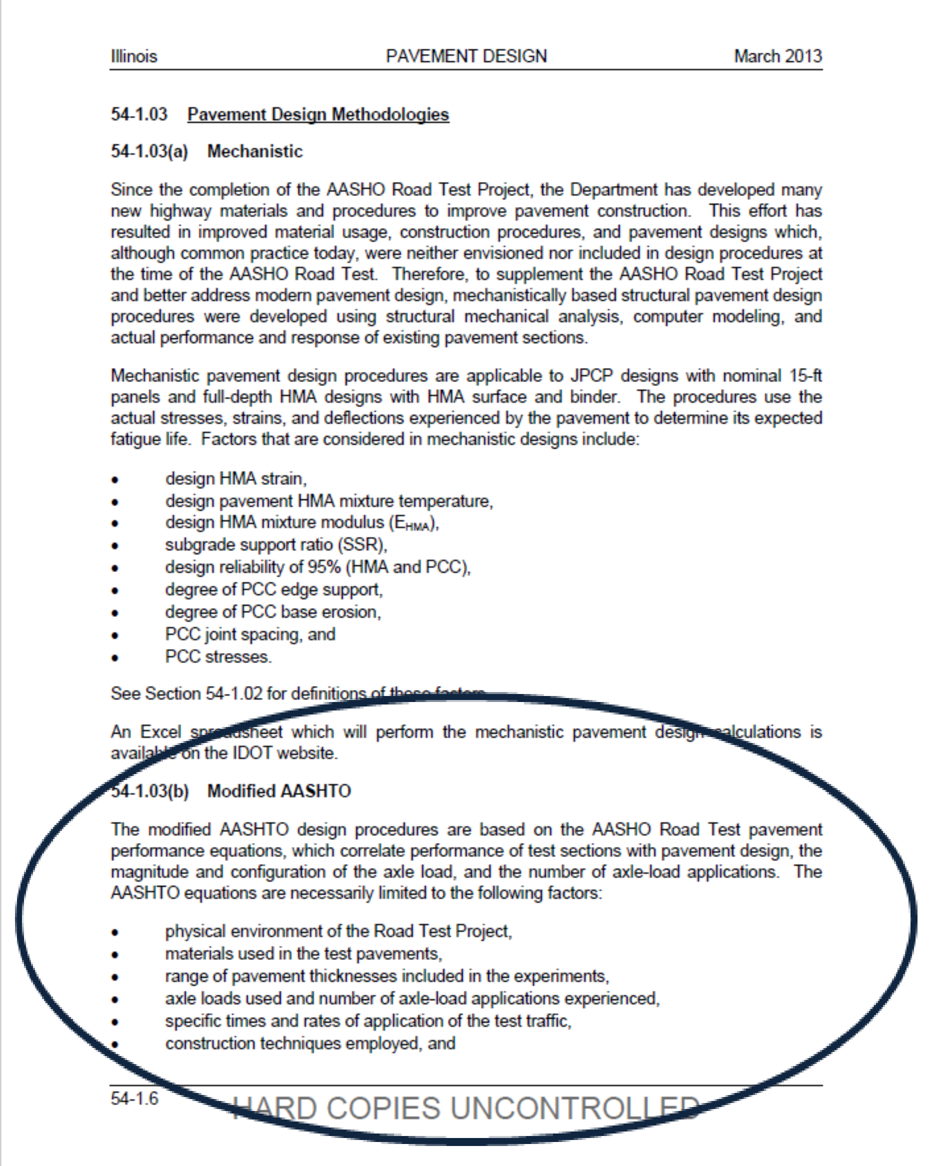


ment design procedures are

ap CP designs with nominal 15-ft

par

# IDOT Modified AASHTO Method





54-1.03 Pavement Design Methodologies

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- physical environment of the Road Test Project,
- materials used in the test pavements,
- range of pavement thicknesses included in the experiments,
- axle loads used and number of axle-load applications experienced,
- specific times and rates of application of the test traffic,
- construction techniques employed, and
- climatic cycles experienced during construction and testing of the experimental facility."

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# AASHTO 93 Design Guide

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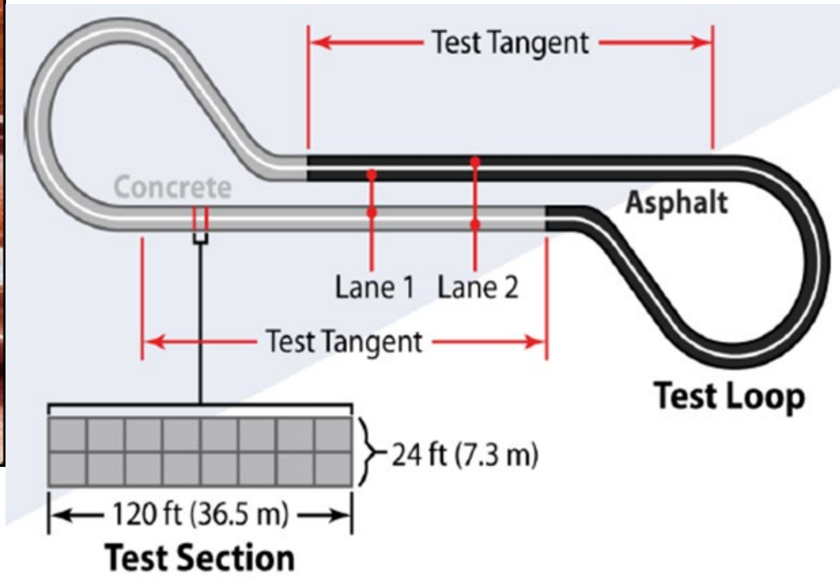
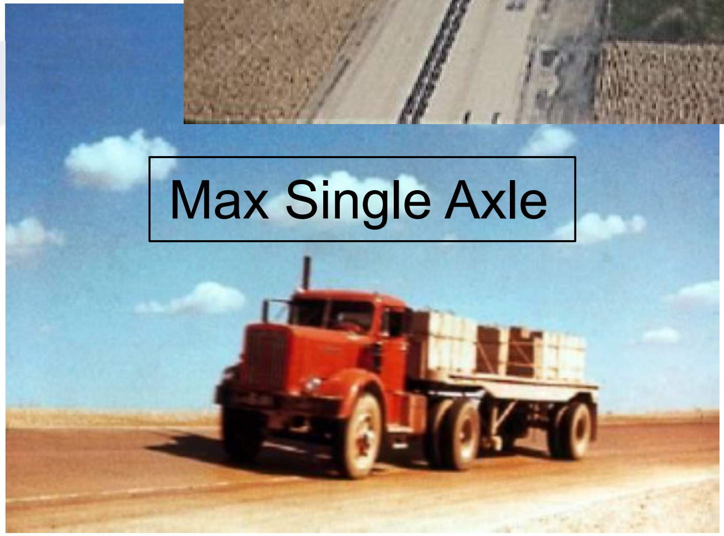
# Source of Much of What We Know About AASHTO Pavement Design

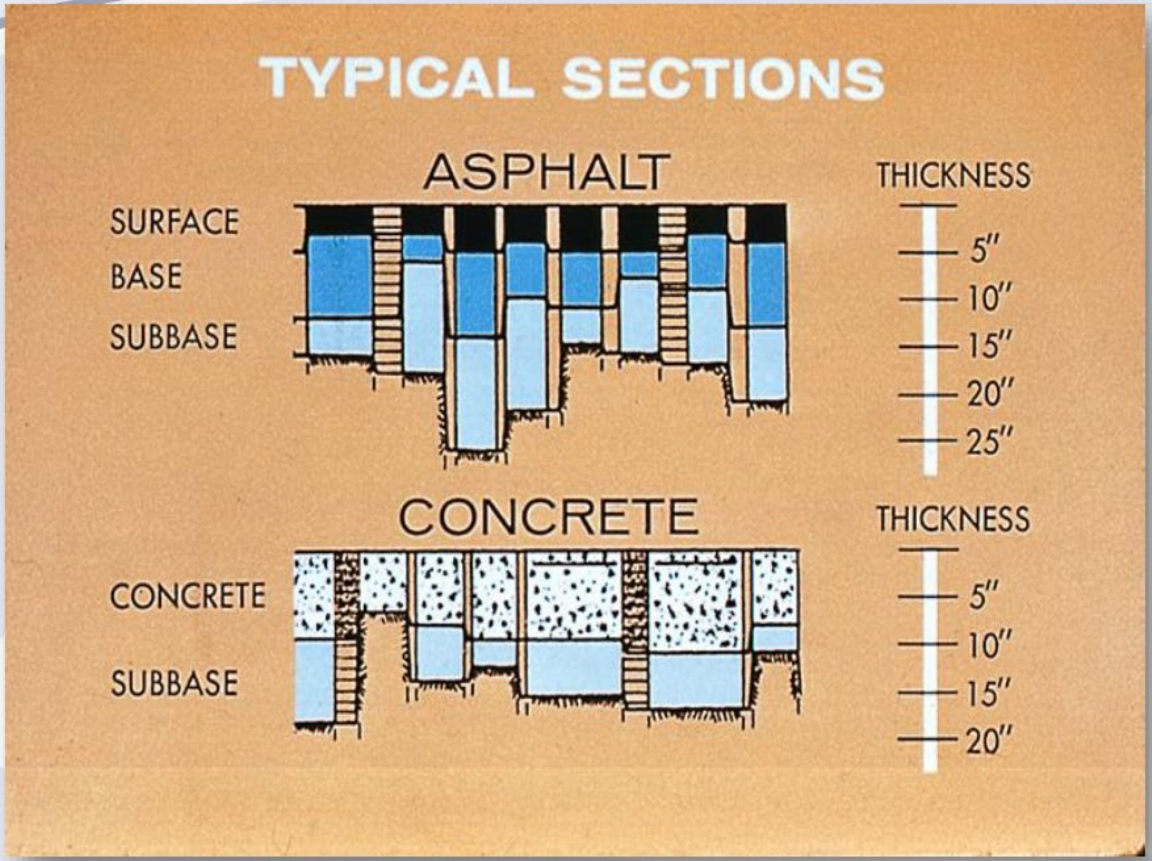
- AASHO Road Test (1958-1960)
- Ottawa, Illinois - 1.1 Mil Reps
- Wholly empirical
- Included 368 concrete and 468 asphalt sections
- Focus was highway pavement

# Test Sections or ***Guessed Sections***

**Necessary Thickness was Guessed!**




***Subgrade = Clay Soil***

Source: Ferrebee ACPA

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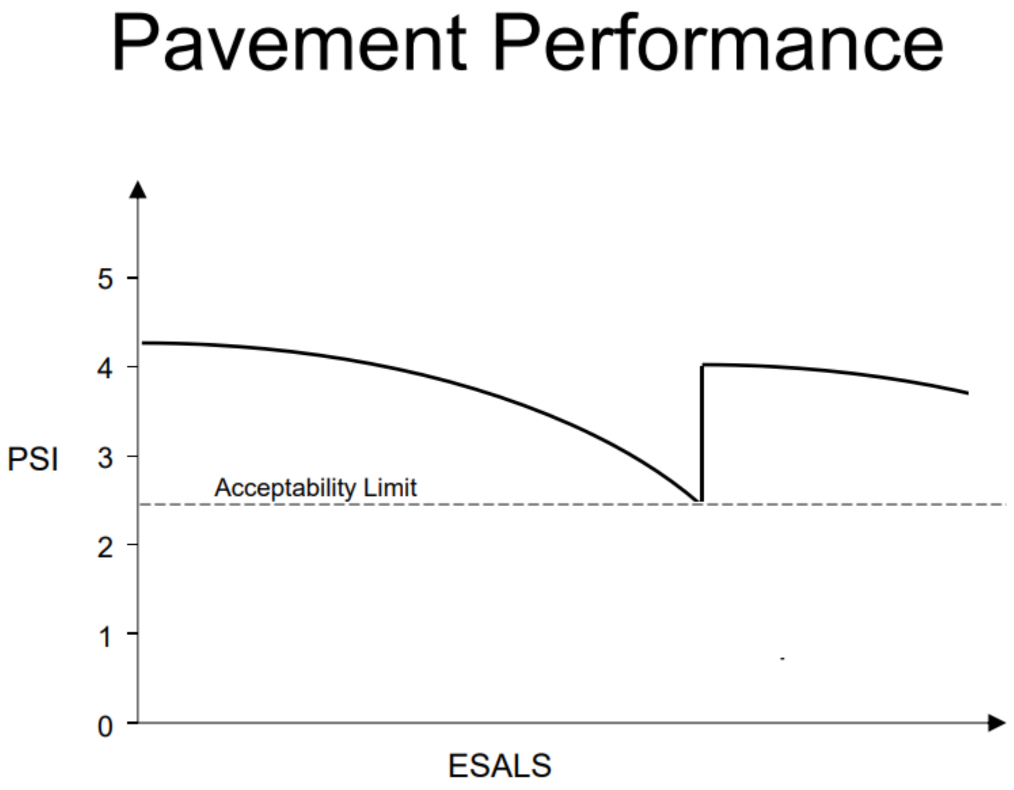
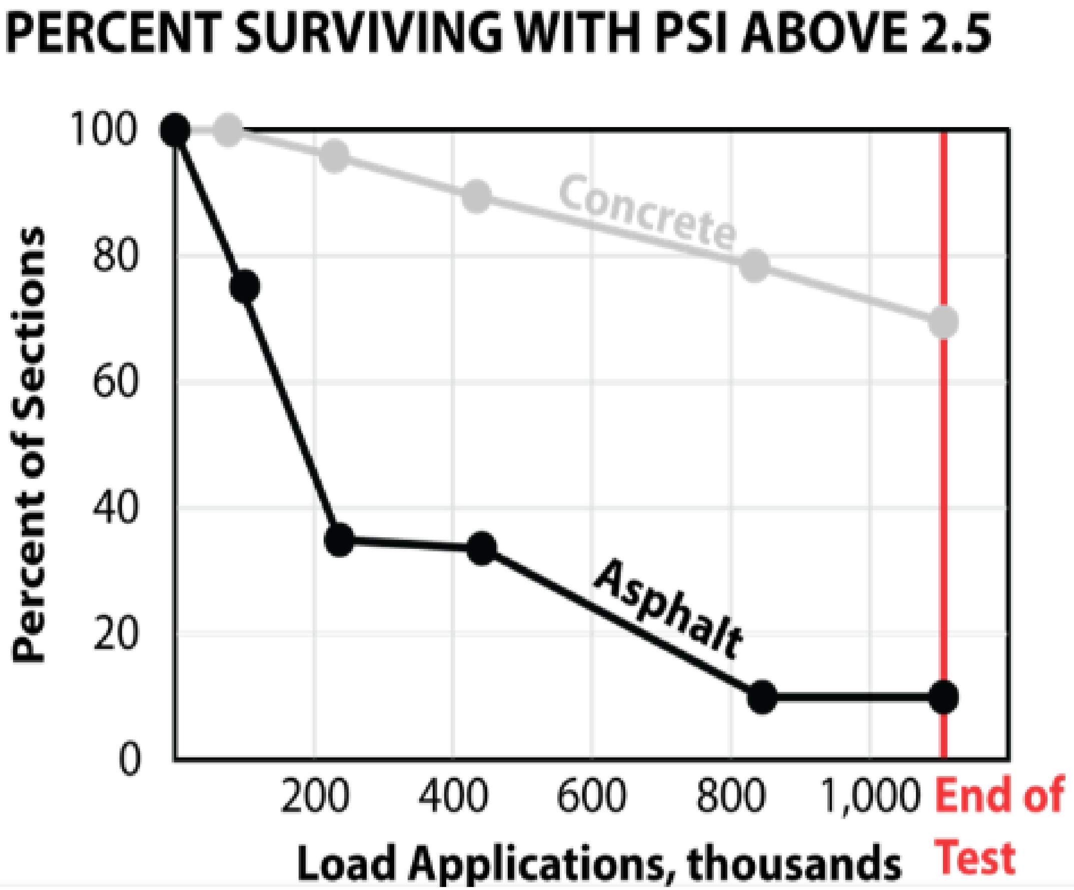
# Serviceability Index

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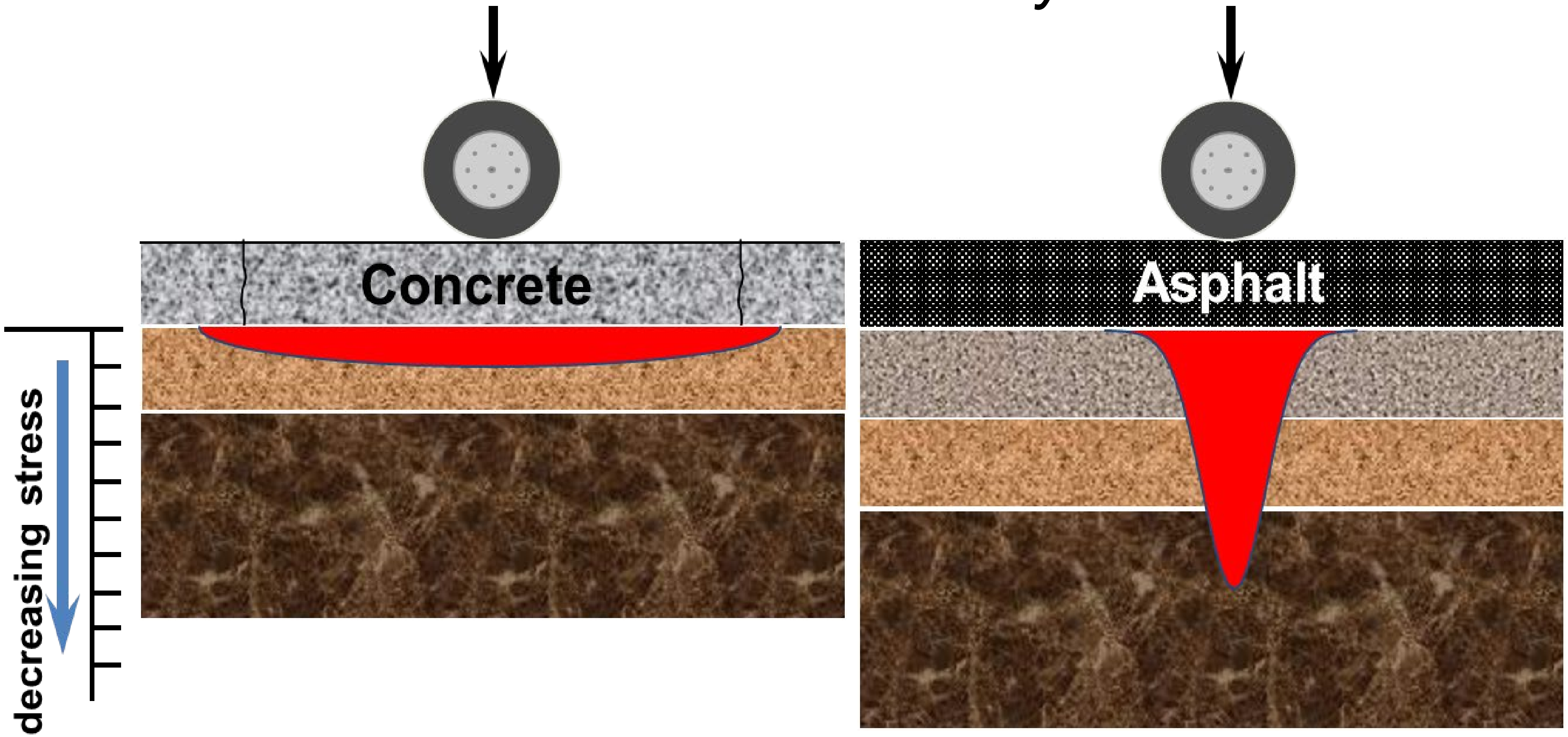
# Design Elements

*Stress dissolution is very different*



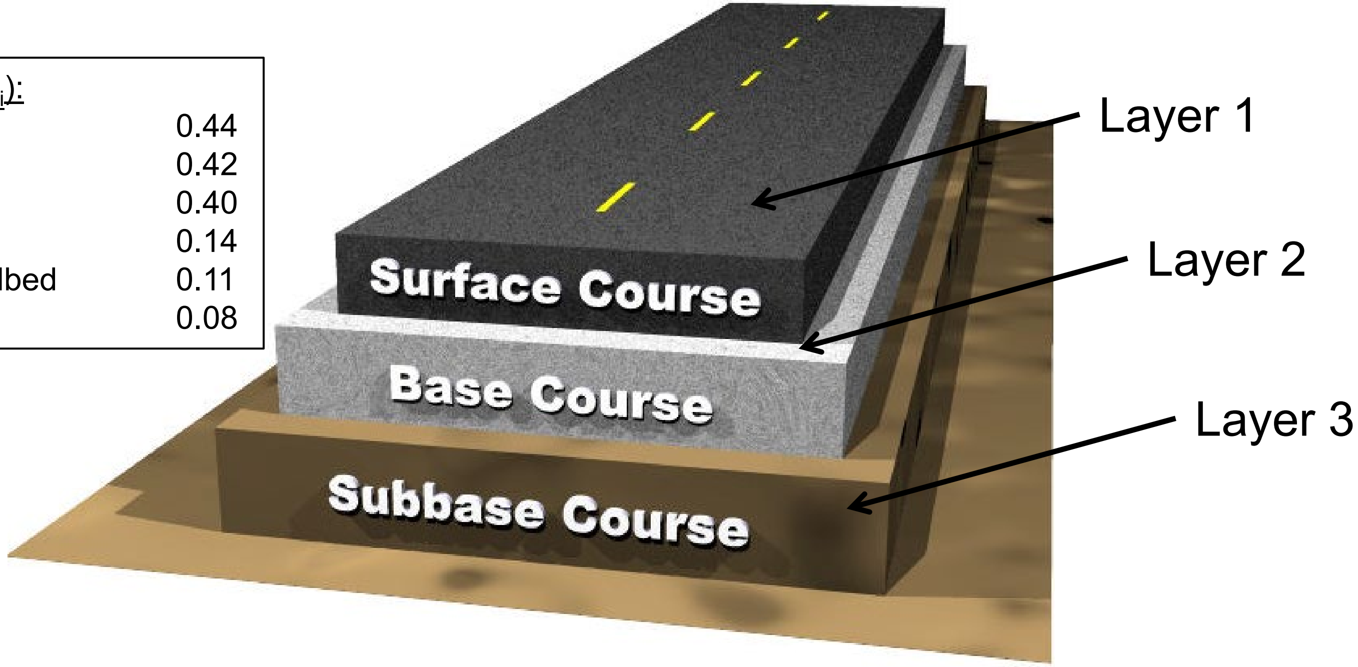
# Design Tools

$$SN = a_1D_1 + a_2m_2D_2 + a_3m_3D_3 + \ldots a_im_iD_i$$

Where:

$a_i$ = structural coefficient representing the relative strength of the pavement layer.
$m_i$ = drainage coefficient representing the ability of the layer to drain.
$D_i$ = layer thickness, in.

| Typical Coefficient Values ($a_i$): | |
|---|---|
| Asphalt Surface | 0.44 |
| Asphalt Binder | 0.42 |
| Asphalt Base | 0.40 |
| Crushed Stone Base | 0.14 |
| Lime/Cement Modified Roadbed | 0.11 |
| Rock Roadbed | 0.08 |



# 1986-93 JPCP AASHTO 93 Equation

Change in Serviceability

Standard Normal Deviate

Overall Standard Deviation

***Thickness***

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

Traffic

Terminal Serviceability

Modulus of Rupture

Drainage Coefficient

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

WHAT DO DESIGNERS FOCUS ON?

Load Transfer

Modulus of Elasticity

Modulus of Subgrade Reaction

# AASHTO Road Test

- All transverse joints were doweled at the same spacing - JPCP @ 15 ft and JRCP @ 40 ft
- AASHTO equation does not address joint spacing
- AASHTO 93 rigid pavement design equation is very sensitive to the joint load transfer coefficient
  - *J Factor for undoweled pavements is simply a guess and based on **very conservative extrapolation***
- Improve load transfer in thinner pavements using short joint spacing
- One of the main reasons we highly encourage **NOT** using AASHTO 93

# There's Another Way

Question:

What should engineers use to design concrete pavements for local roads and parking lots?

***ACI 325***

***&***

***ACI 330!***

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# *What is ACI 325 & 330?*

## Committees within American Concrete Institute

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

  - ✓ **ACI 325.12R-02 (Reapproved 2013): Guide for Design of Jointed Concrete Pavements for Streets and Local Roads**

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

  - ✓ **ACI 325.9R-15: Guide for Construction of Concrete Pavements**

# Overview of ACI 330R-08

- 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
- Appendices –
  - Procedures for Concrete Pavement Design
  - Subgrade
  - Details

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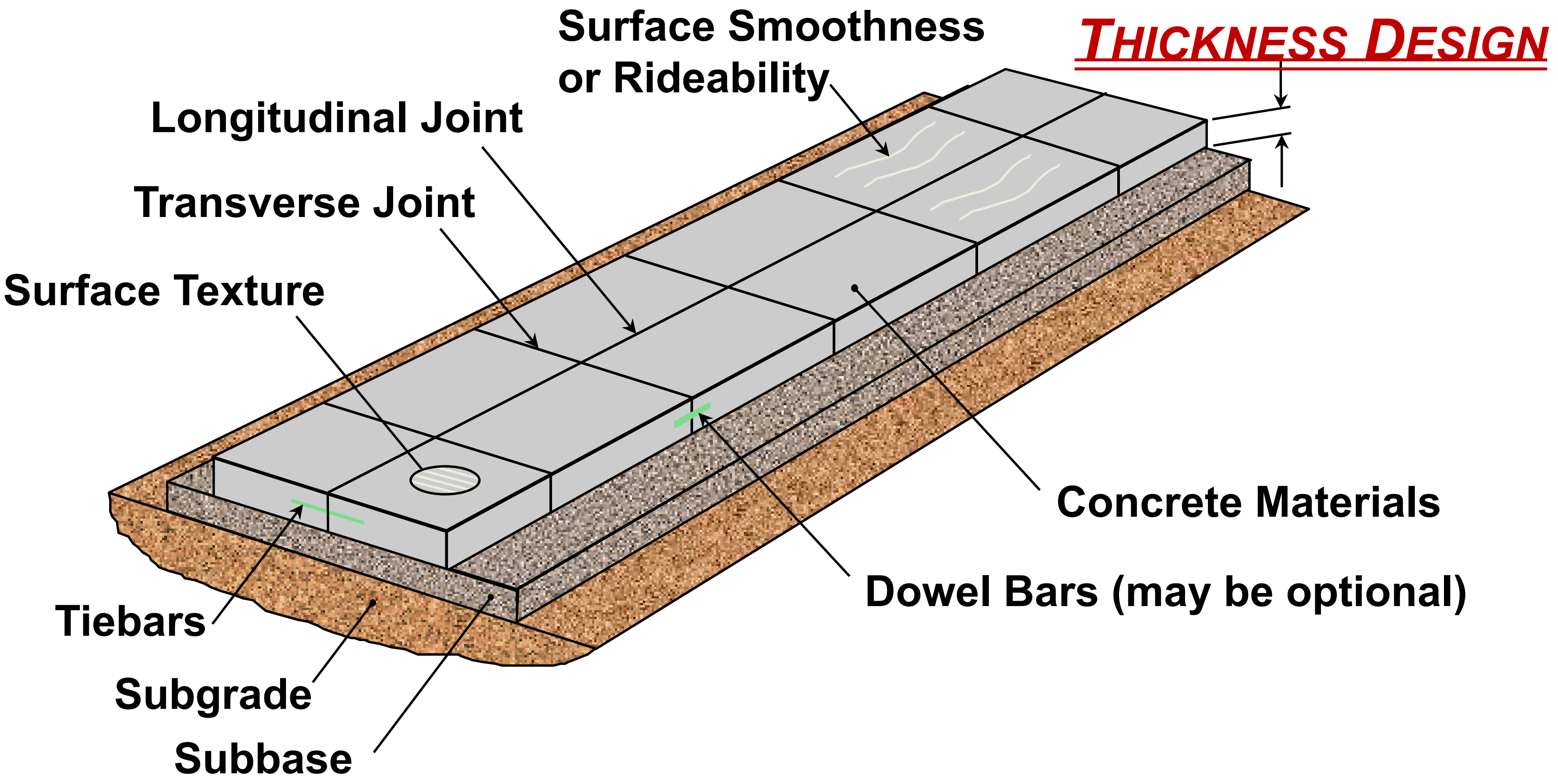
# Design Elements

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# Pavement Design Using ACI 330

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# Concrete Pavement Design

## PCA Design Method

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

# Key Terminology

*k* – modulus of subgrade

ADTT – average daily truck traffic

MOR – modulus of rupture / flexural strength

# 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.

# Key Terminology

**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.

# 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<br>Parking area and interior lanes—Category B<br>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

or

flexural strength

*Concrete Industry uses compressive strength (f’c)

4,000 psi compressive ~ 600 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 |
| | 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 |

# Thickness criteria based on soil support…

| | | $k$ = 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 |

# …concrete strength…

| | | *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 |

# …and Average Daily Truck Traffic (ADTT)

| | | *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 |

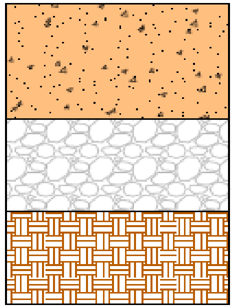
# Recommend… e 4.5 inches

| | MOR, psi: | 650 | 600 | 550 | 500 | 650 | 600 | 550 | 500 | 650 | 600 | 550 | 500 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *k* = 500 psi/in. (CBR = 50, R = 86) | | | | *k* = 400 psi/in. (CBR = 38, R = 80) | | | | *k* = 300 psi/in. (CBR = 26, R = 67) | | | |
| 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 |

| | MOR, psi: | 650 | 600 | 550 | 500 | 650 | 600 | 550 | 500 | 650 | 600 | 550 | 500 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *k* = 200 psi/in. (CBR = 10, R = 48) | | | | *k* = 100 psi/in. (CBR = 3, R = 18) | | | | *k* = 50 psi/in. (CBR = 2, R = 5) | | | |
| 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 | [illegible] | 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 |

## PAVEMENT SECTION 1 – Parking Lot Drive Lanes: car, pickup truck, and SUV with NO garbage or delivery trucks

### CONCRETE SECTION

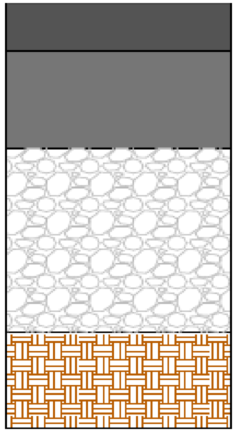


5.5" CONCRETE PAVEMENT

4" AGGREGATE BASE

PREPARED SUBGRADE SOILS

### ASPHALT SECTION A



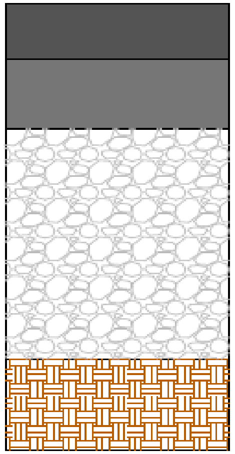
2.5" ASPHALT SURFACE

5" ASPHALT BINDER

8" AGGREGATE BASE

PREPARED SUBGRADE SOILS

### ASPHALT SECTION B



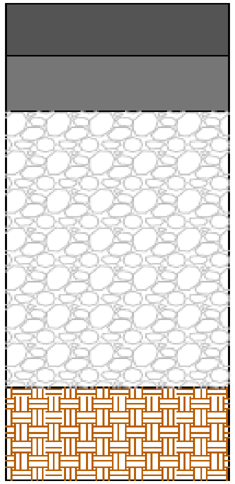
2.25" ASPHALT SURFACE

4" ASPHALT BINDER

10" AGGREGATE BASE

PREPARED SUBGRADE SOILS

### ASPHALT SECTION C



2" ASPHALT SURFACE

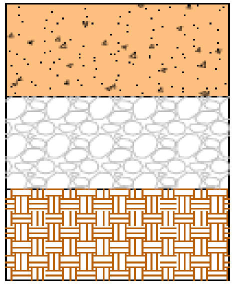
4" ASPHALT BINDER

12" AGGREGATE BASE

PREPARED SUBGRADE SOILS

## PAVEMENT SECTION 2 – Parking Spaces Only: car, pickup truck, and SUV with NO garbage or delivery trucks

### CONCRETE SECTION

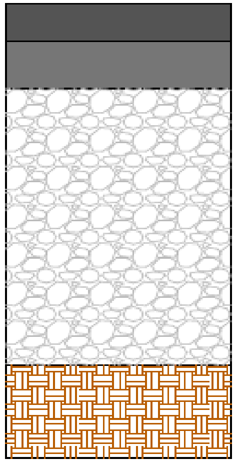


4.5" CONCRETE PAVEMENT

4" AGGREGATE BASE

PREPARED SUBGRADE SOILS

### ASPHALT SECTION A



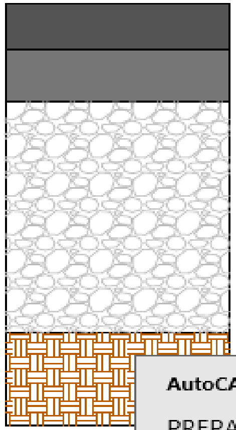
1.75" ASPHALT SURFACE

3" ASPHALT BINDER

12" AGGREGATE BASE

PREPARED SUBGRADE SOILS

### ASPHALT SECTION B



2" ASPHALT SURFACE

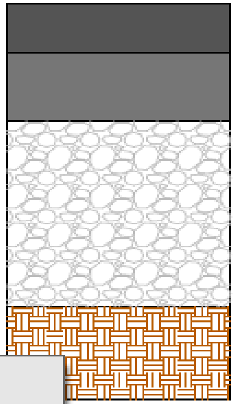
3.5" ASPHALT BINDER

10" AGGREGATE BASE

AutoCAD SHX Text

PREPARED SUBGRADE SOILS

### ASPHALT SECTION C



2.25" ASPHALT SURFACE

4" ASPHALT BINDER

8" AGGREGATE BASE

PREPARED SUBGRADE SOILS

PAVEMENT SECTION COMPARISON 2

FOR: CANTERA SUBAREA G MULTI-FAMILY DEVELOPMENT WARRENVILLE, IL

SCALE: NONE

DRAWN BY: LBM

DATE: 5/14/19

NRMCA NATIONAL READY MIXED CONCRETE ASSOCIATION

LUKE McHUGH, P.E. lmchugh@nrmca.org

# Guide Specifications


NRMCA

Guide Specification for Materials and Construction of Jointed Concrete Pavement for Streets and Local Roads

April 2012

National Ready Mixed Concrete Association • 900 Spring Street, Silver Spring, MD 20910 • 888-84-NRMCA • www.nrmca.org

An ACI Standard

Specification for Unreinforced Concrete Parking Lots and Site Paving

Reported by ACI Committee 330

ACI 330.1-14

aci American Concrete Institute
Always advancing

NRMCA

Guide Specification for Materials and Construction of Jointed Unreinforced Concrete Pavement Parking Lots

January 2012

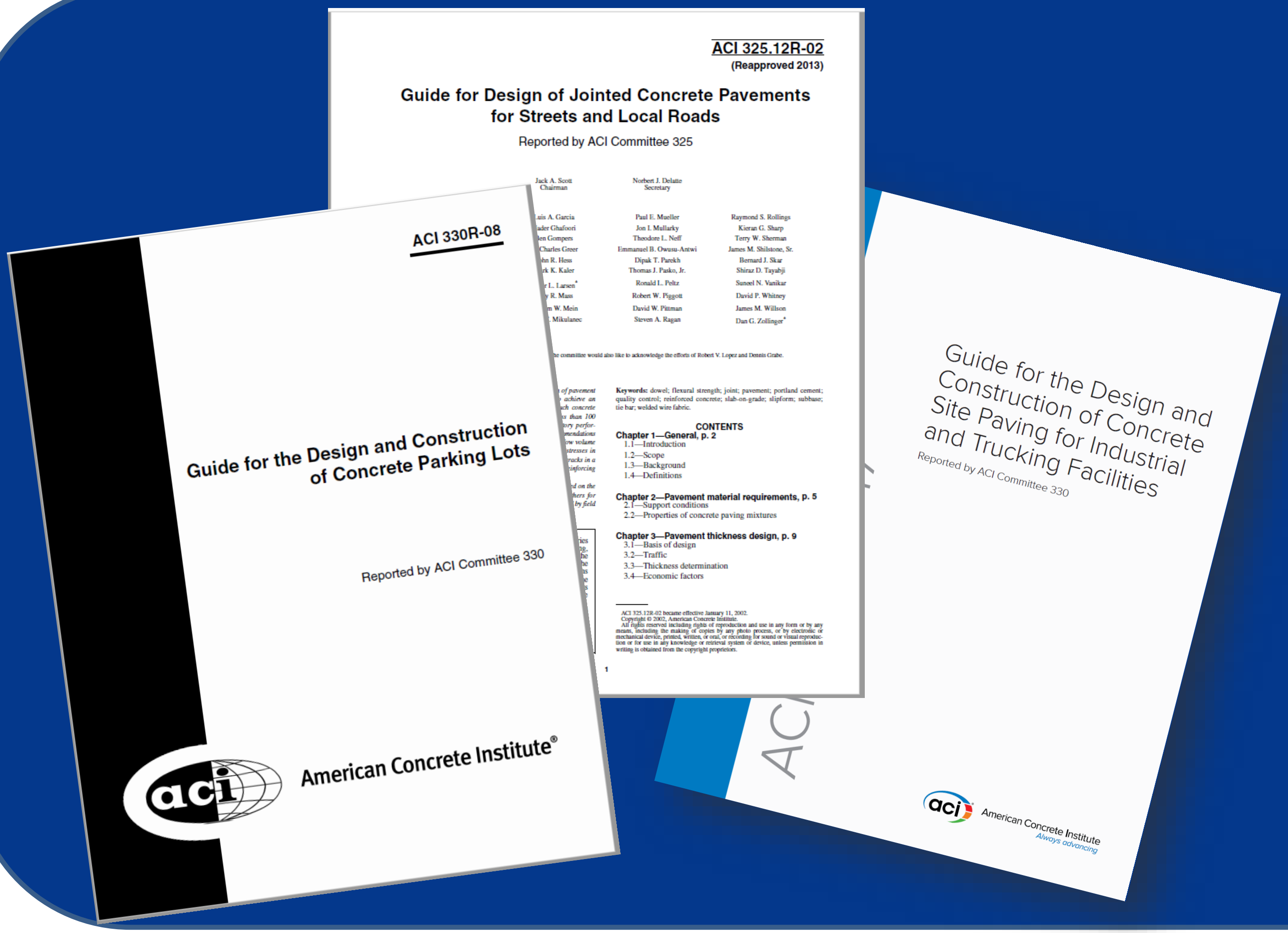
National Ready Mixed Concrete Association • 900 Spring Street, Silver Spring, MD 20910 • 888-84-NRMCA • www.nrmca.org

PAVE AHEAD
DURABLE. SUSTAINABLE. CONCRETE.

# Street Design Using Pavement Designer.org

PAVE AHEAD
DURABLE. SUSTAINABLE. CONCRETE.

# Design Software

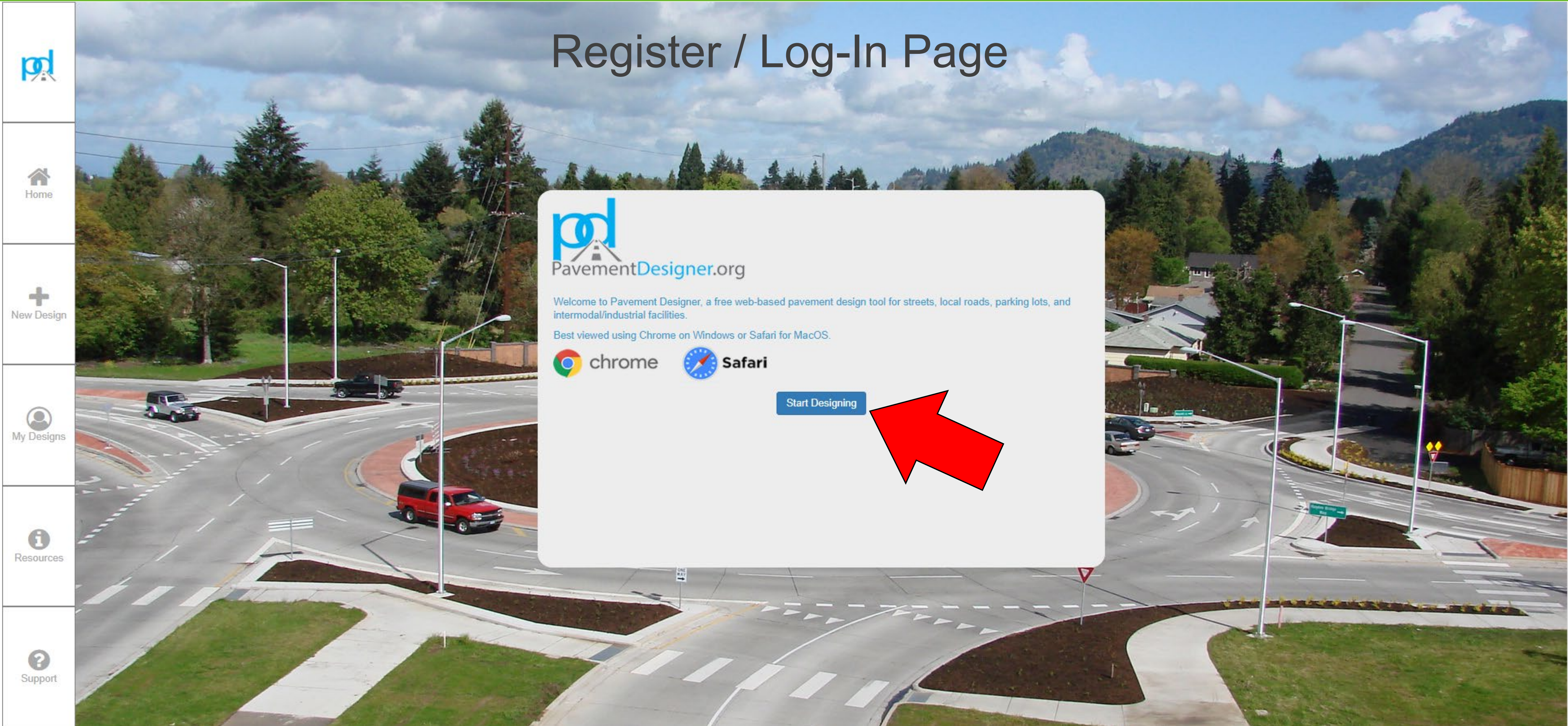



PavementDesigner.org

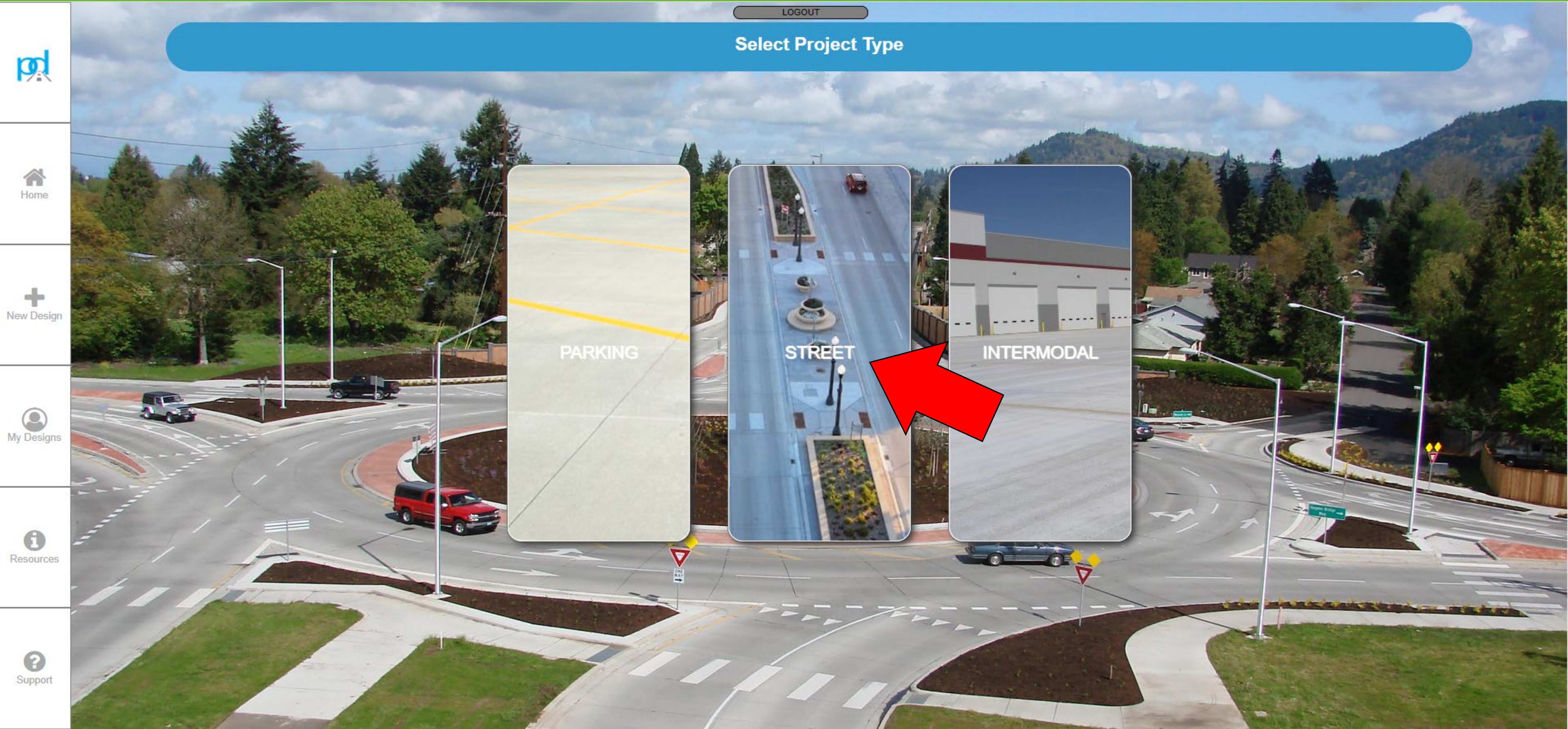
*Recommended for Optimization*

PAVE AHEAD
DURABLE. SUSTAINABLE. CONCRETE.

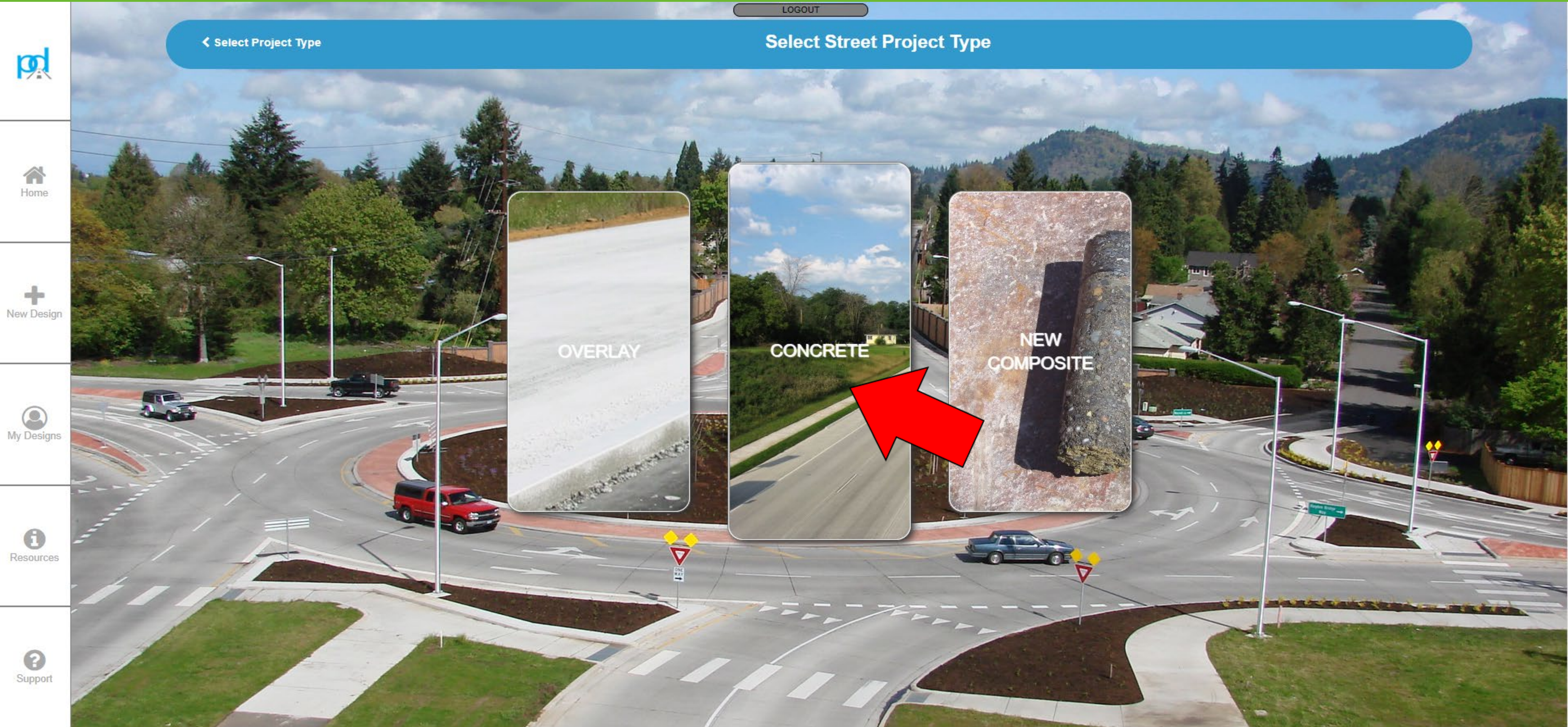
# PavementDesigner.org



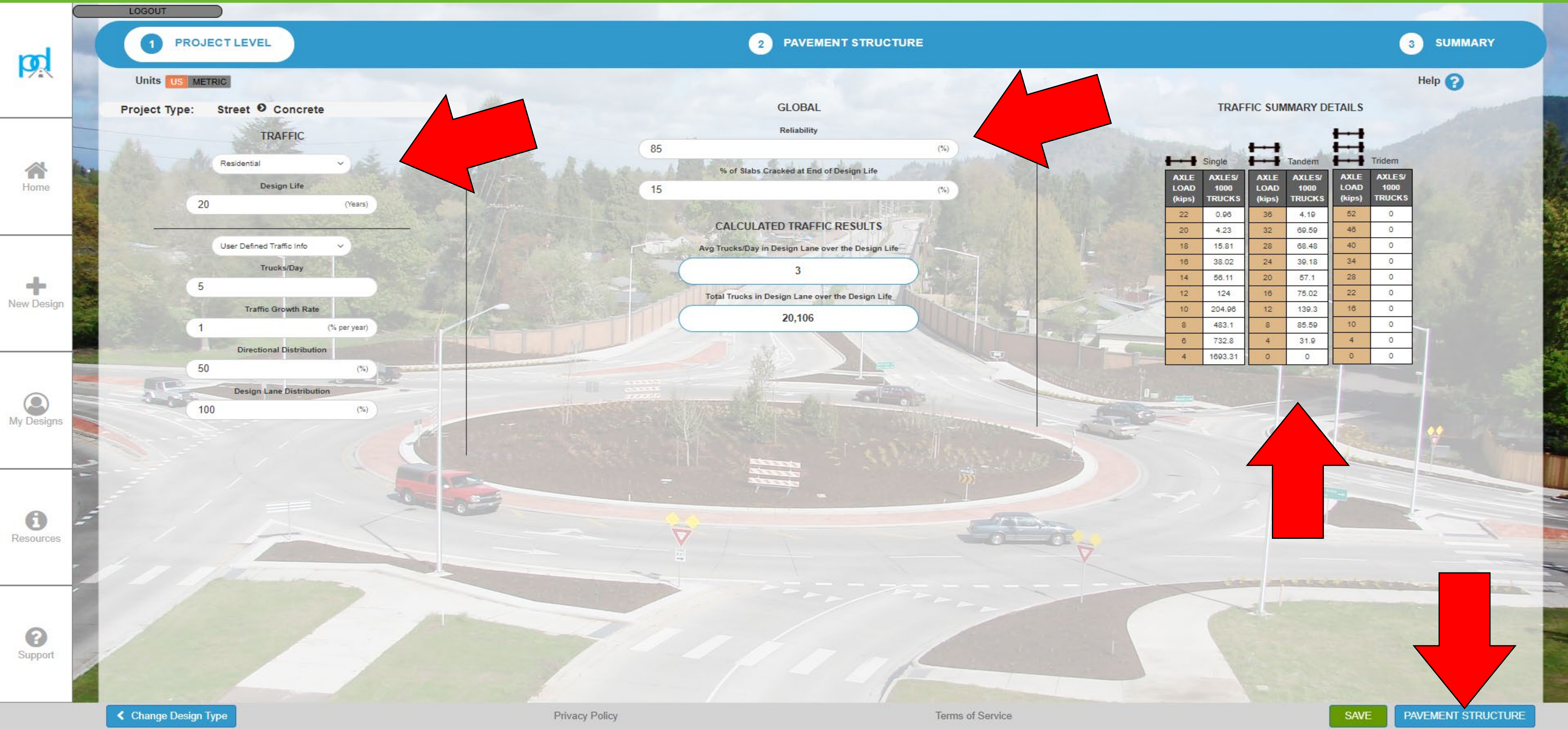
# PavementDesigner.org



# PavementDesigner.org



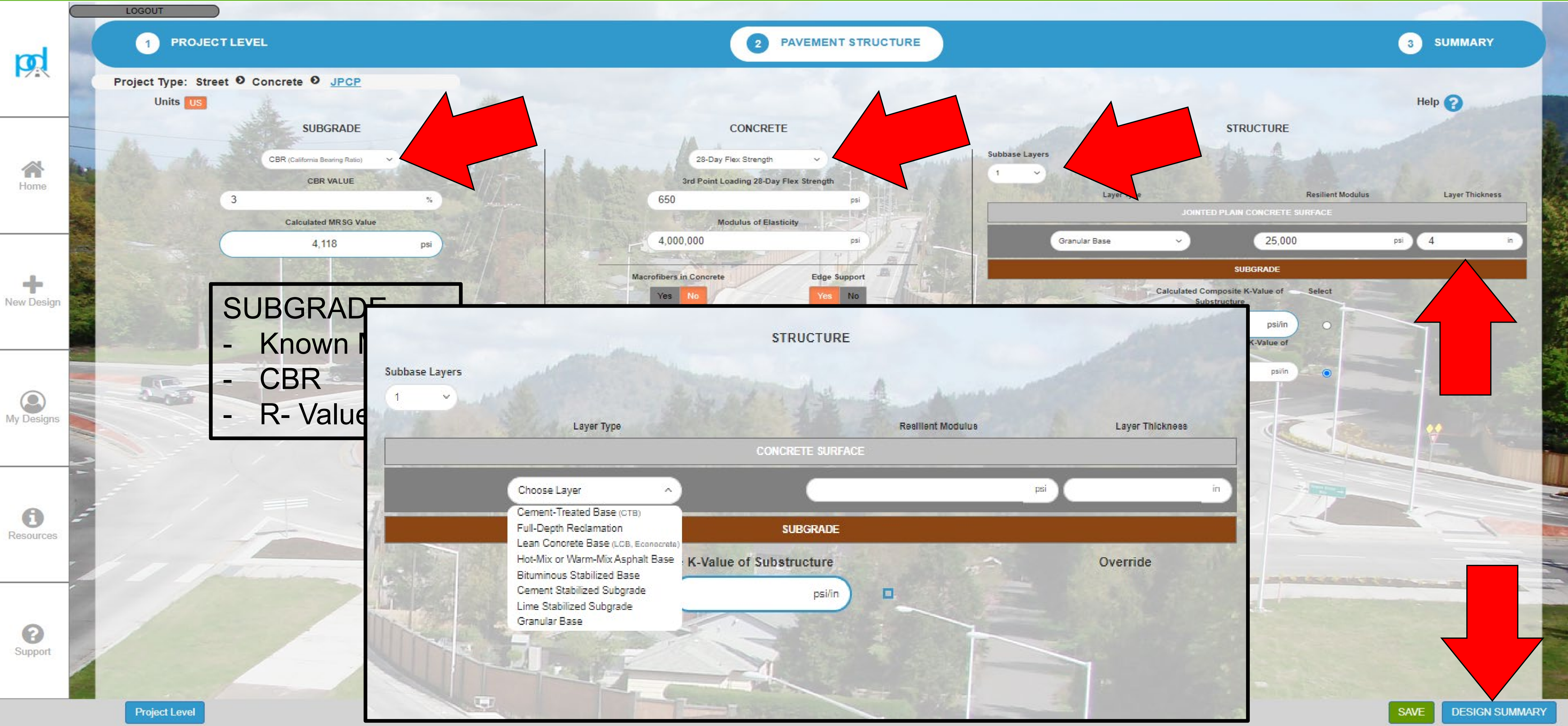
# PavementDesigner.org

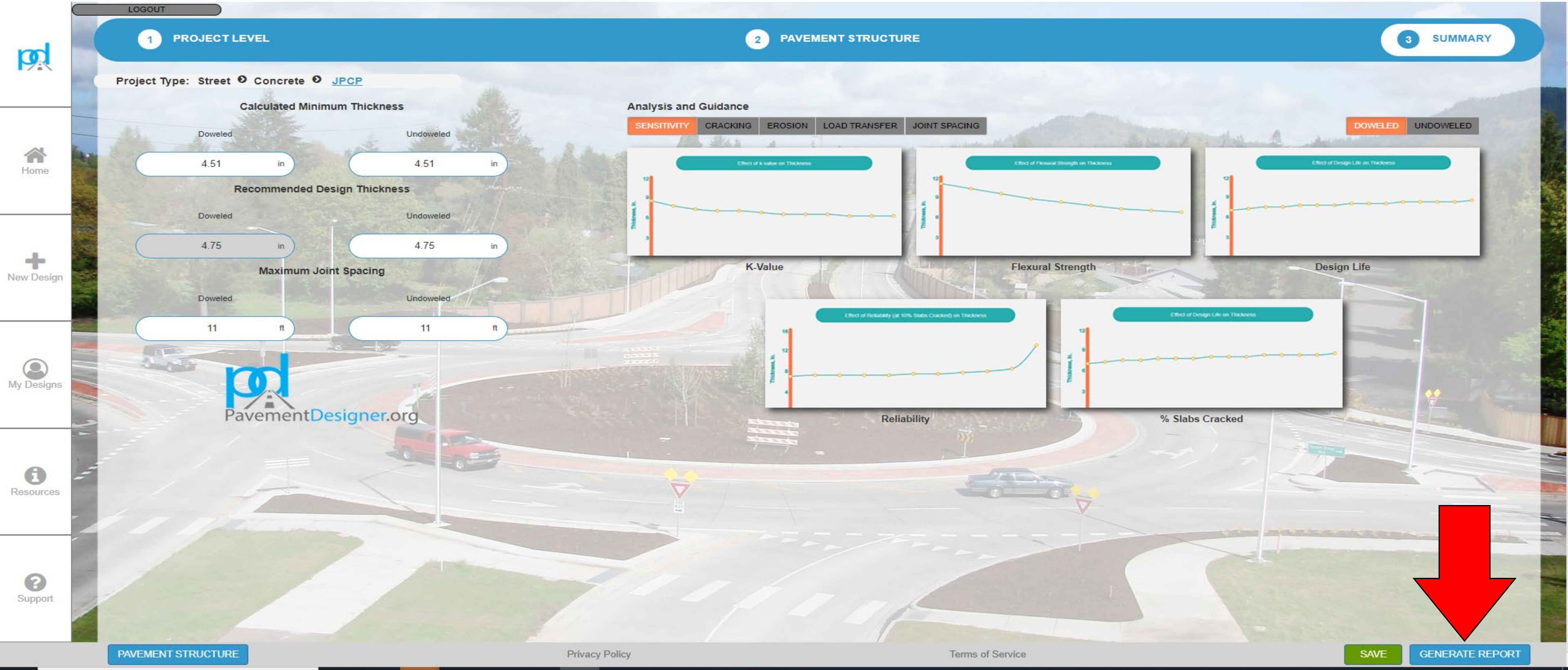



| Single AXLE LOAD (kips) | Single AXLES/ 1000 TRUCKS | Tandem AXLE LOAD (kips) | Tandem AXLES/ 1000 TRUCKS | Tridem AXLE LOAD (kips) | Tridem AXLES/ 1000 TRUCKS |
|---|---|---|---|---|---|
| 22 | 0.96 | 36 | 4.19 | 52 | 0 |
| 20 | 4.23 | 32 | 69.59 | 46 | 0 |
| 18 | 15.81 | 28 | 68.48 | 40 | 0 |
| 16 | 38.02 | 24 | 39.18 | 34 | 0 |
| 14 | 56.11 | 20 | 57.1 | 28 | 0 |
| 12 | 124 | 16 | 75.02 | 22 | 0 |
| 10 | 204.96 | 12 | 139.3 | 16 | 0 |
| 8 | 483.1 | 8 | 85.59 | 10 | 0 |
| 6 | 732.8 | 4 | 31.9 | 4 | 0 |
| 4 | 1693.31 | 0 | 0 | 0 | 0 |

# PavementDesigner.org

# PavementDesigner.org





LOGOUT
1 PROJECT LEVEL
2 PAVEMENT STRUCTURE
3 SUMMARY
Home
New Design
My Designs
Resources
Support
Project Type: Street Concrete JPCP
Calculated Minimum Thickness
Doweled
Undoweled
4.51 in
4.51 in
Recommended Design Thickness
Doweled
Undoweled
4.75 in
4.75 in
Maximum Joint Spacing
Doweled
Undoweled
11 ft
11 ft
PavementDesigner.org
Analysis and Guidance
SENSITIVITY
CRACKING
EROSION
LOAD TRANSFER
JOINT SPACING
DOWELED
UNDOWELED
K-Value
Flexural Strength
Design Life
Reliability
% Slabs Cracked
PAVEMENT STRUCTURE
Privacy Policy
Terms of Service
SAVE
GENERATE REPORT

PavementDesigner.org

**DESIGN SUMMARY REPORT FOR**

**JOINTED-PLAIN CONCRETE PAVEMENT (JPCP)**

**DATE CREATED:**

Thu Dec 03 2020 12:33:04 GMT-0500 (Eastern Standard Time)

## Project Description

| | | | | | |
|---|---|---|---|---|---|
| Project Name: | Sample | **Owner:** | | **Zip Code:** | |
| **Designer's Name:** | | **Route:** | | | |
| **Project Description:** | | | | | |

## Design Summary

| | Doweled | Undoweled | | Doweled | Undoweled |
|---|---|---|---|---|---|
| Recommended Design Thickness: | 4.75 in | 4.75 in | Maximum Joint Spacing: | 11 ft | 11 ft |
| Calculated Minimum Thickness: | 4.51 in | 4.51 in | | | |

## Pavement Structure

**SUBBASE**

User-Defined Composite K-Value of Substructure: 130 psi/in

| Layer Type | Resilient Modulus | Layer Thickness |
|---|---|---|
| JOINTED PLAIN CONCRETE SURFACE | | |
| Granular Base | psi | in |
| SUBGRADE | | |

**CONCRETE**

| | | | |
|---|---|---|---|
| 28-Day Flex Strength: | 650 psi | Edge Support: | Yes |
| Modulus of Elasticity: | 4000000 psi | Macrofibers in Concrete: | No |

**SUBGRADE**

| | |
|---|---|
| CBR: | 3 % |
| Calculated MRSG Value | 4,118 psi |

## Project Level

**TRAFFIC**

| | |
|---|---|
| Spectrum Type: | Residential |
| Design Life: | 20 years |

**USER DEFINED TRAFFIC**

| | |
|---|---|
| Trucks Per Day: | 5 |
| Traffic Growth Rate %: | 1 % per year |
| Directional Distribution: | 50 % |
| Design Lane Distribution: | 100 % |

**GLOBAL**

| | |
|---|---|
| Reliability: | 85 % |
| % Slabs Cracked at End of Design Life: | 15 % |
| Avg Trucks/Day in Design Lane Over the Design Life: | 3 |
| Total Trucks in Design Lane Over the Design Life: | 20,106 |

## Design Method

**The PCA design methodology from StreetPave, was used to produce these results.**

# Design Software

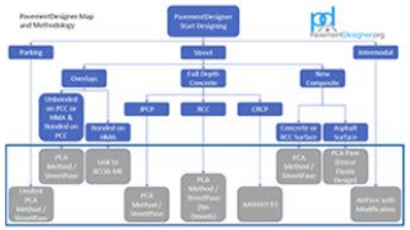
## PavementDesigner.org

### Pavement Designer Intro Video

A quick video introduction to the features of PavementDesigner.org.

Access

Composite CRCP Intermodal JPCP Overlay Parking RCC



### PavementDesigner Map and Methodology

A sitemap listing the solutions contained within PavementDesigner, along the methodologies used and the process flow.

Access

Composite CRCP Intermodal JPCP Overlay Parking RCC

### PavementDesigner JPCP Tutorial

A video tutorial of JPCP design using PavementDesigner.org.

Access

JPCP

### Concrete Overlay WikiPave Page

Access

Overlay

DURABLE. SUSTAINABLE. CONCRETE.

# Concrete Pavement Thickness*

| CBR=3 w/4-inch agg. base | CAT D Semi-Trailers | CBR=3 |
|---|---|---|
| *k=130* | *600 psi* | *k=100* |
| 55 | 6.0 | 35 |
| 115 | 6.5 | 75 |
| 260 | 7.0 | 150 |
| 650 | 7.5 | 320 |
| 1,950 | 8.0 | 725 |
| >10,000 | 8.5 | 2,000 |

***Assumptions:**

- 20-year design life
- 85% reliability
- 15% slabs cracked at the end of design life
- no dowels
- no industrial vehicles

PAVE AHEAD
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# 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 *need* an aggregate base layer?

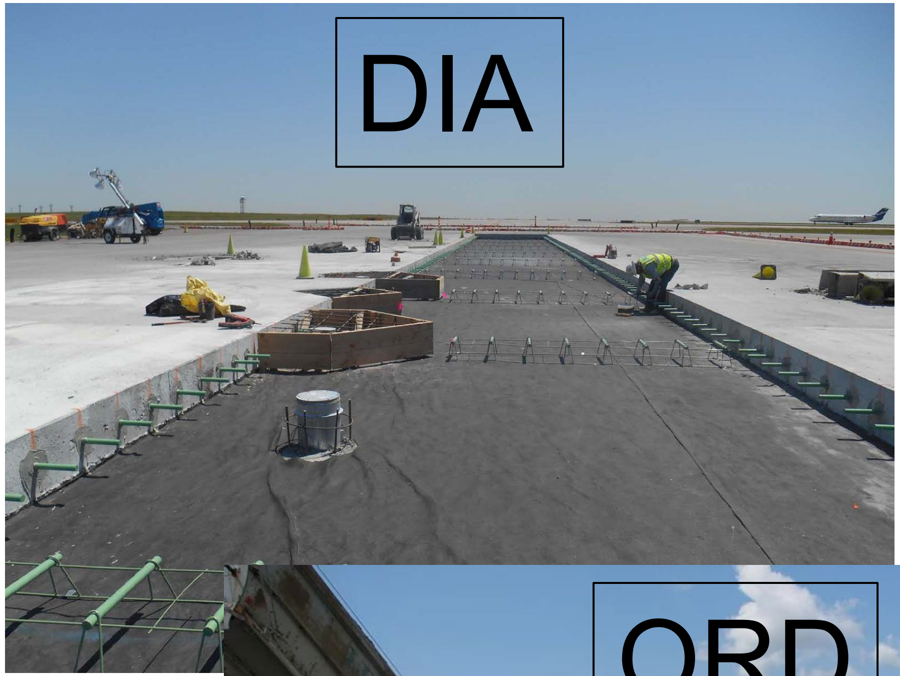
May warrant consideration if:

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

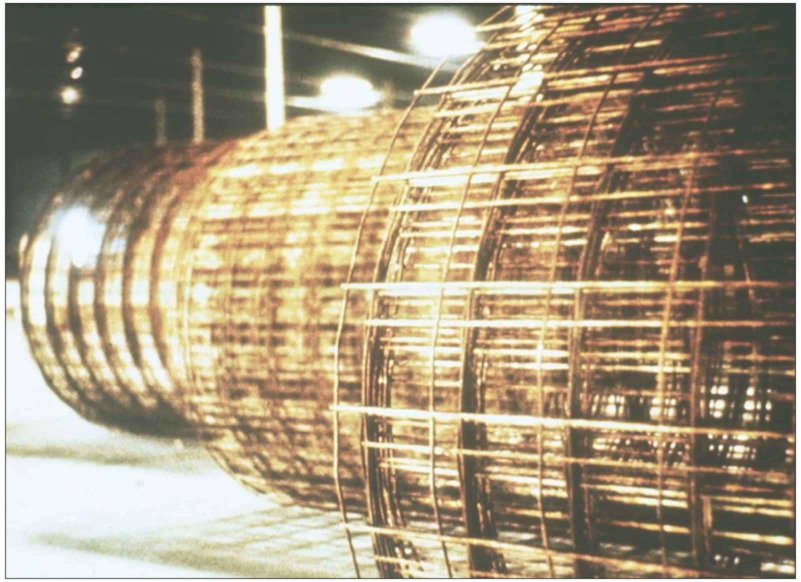
Can result in higher *k* value for design and slightly thinner concrete section

# Do you *need* steel in your mat?

# Airport Pavements are Unreinforced Concrete



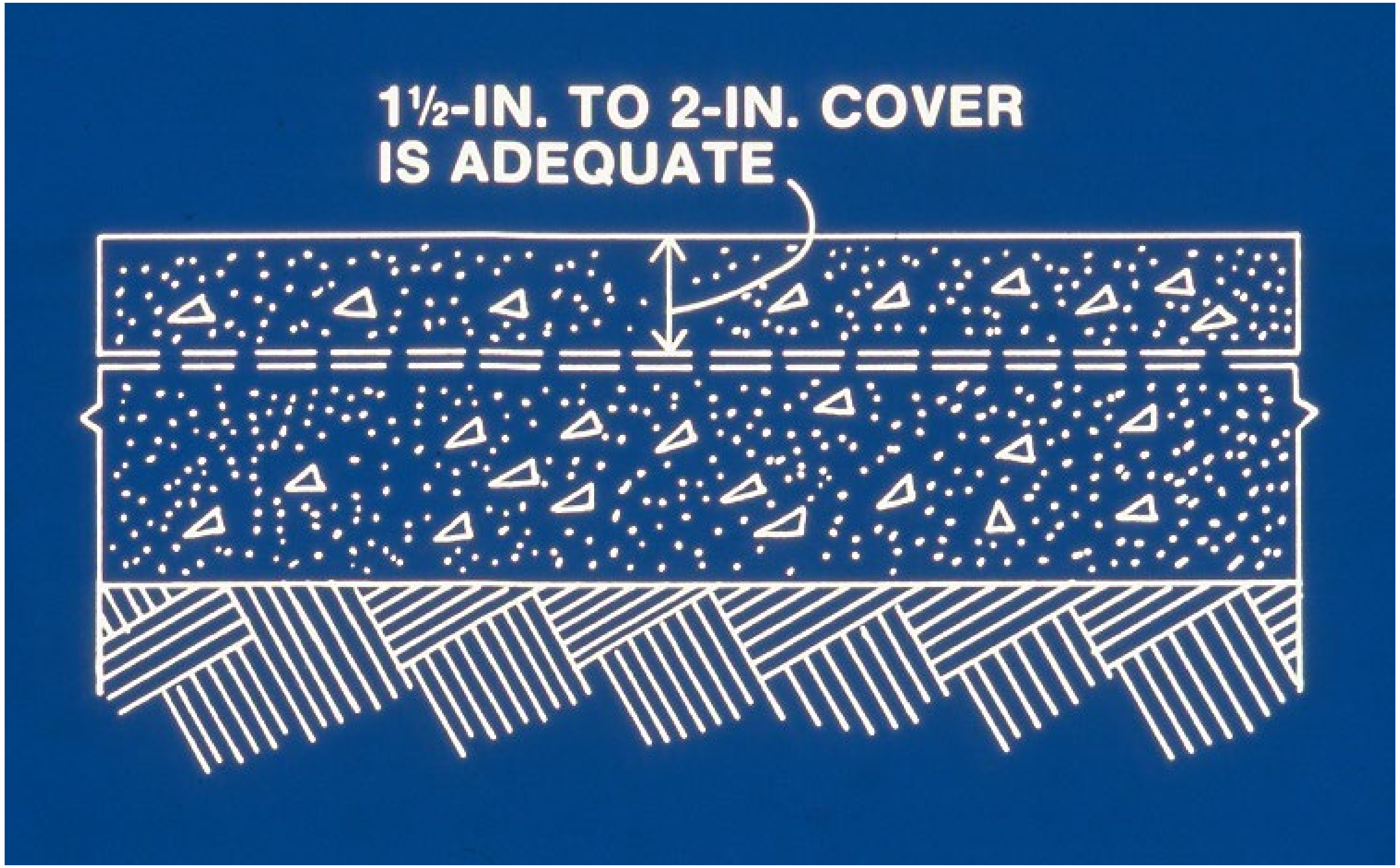




# Secondary Steel Reinforcement

- <u>Does not</u> make concrete stronger!
- <u>Does not</u> stop concrete from cracking!
- Holds concrete together <u>when</u> it cracks

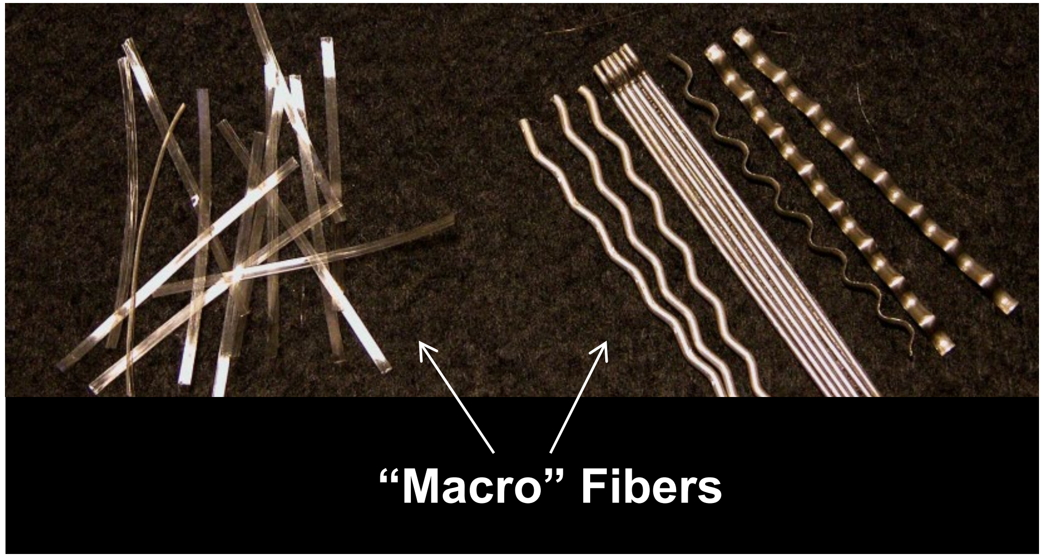
# Proper placement of secondary steel reinforcement

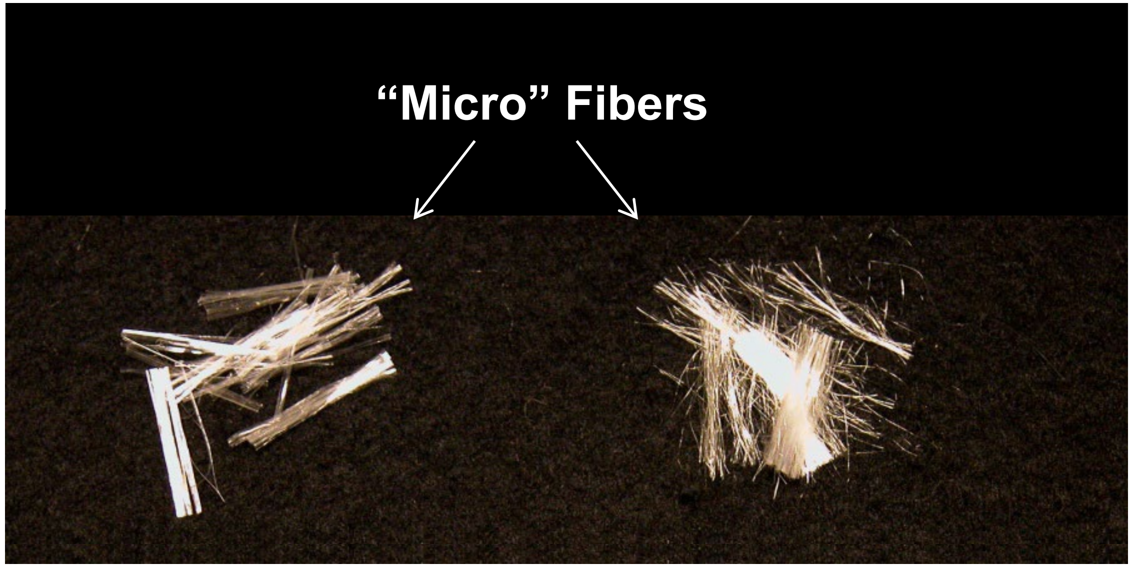



When used, the purpose of secondary steel reinforcement is to keep cracks from opening. To do this, it must be located above the mid-thickness.

# What about Fibers?

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




Micro Fibers (<0.004”)
Plastic Shrinkage Crack Control

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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

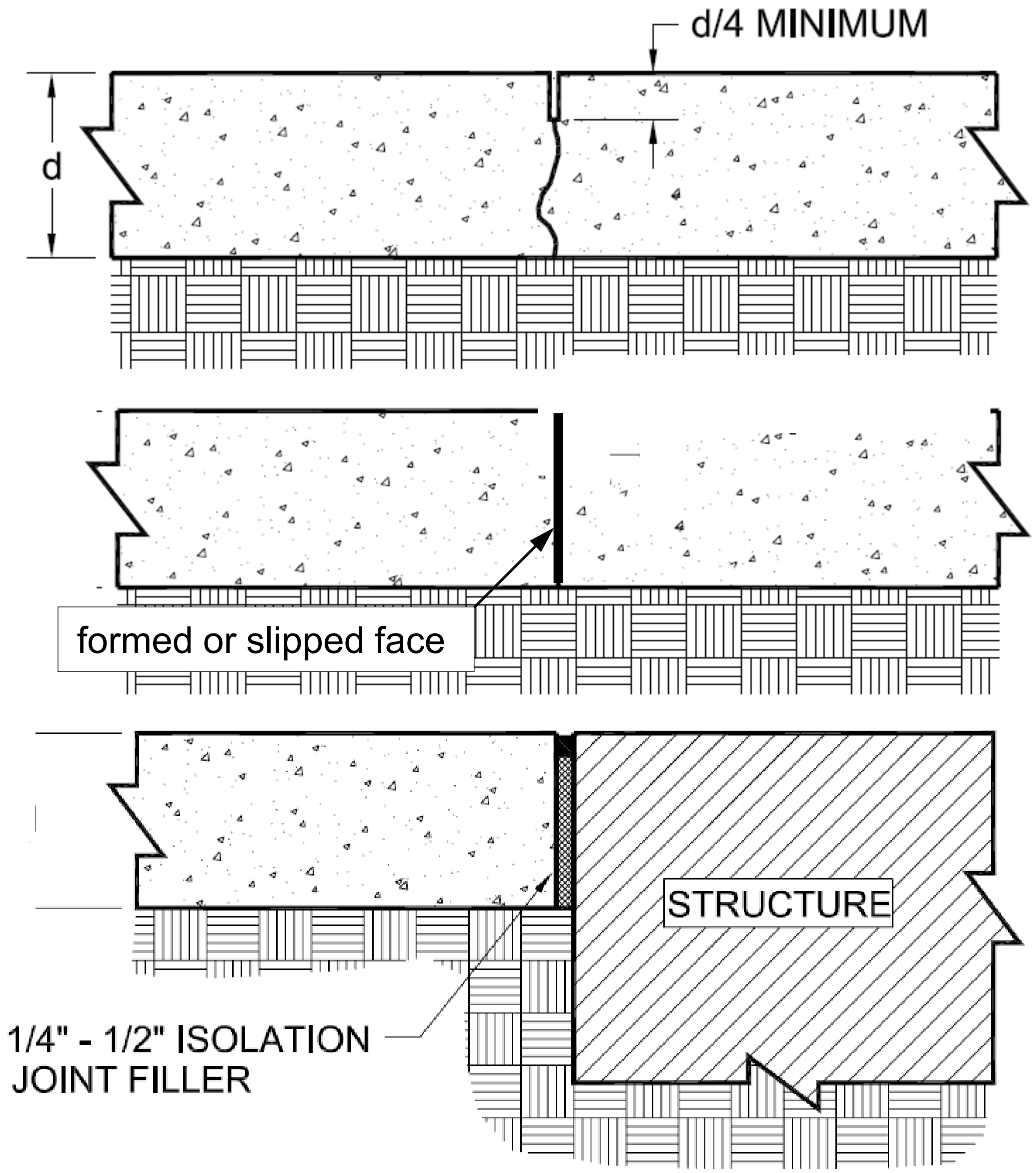
# Recommended Spacing of Control Joints

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.

# Types of joints in concrete pavement



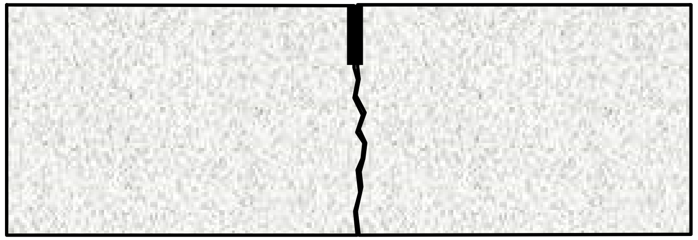

Control joint

Construction joint

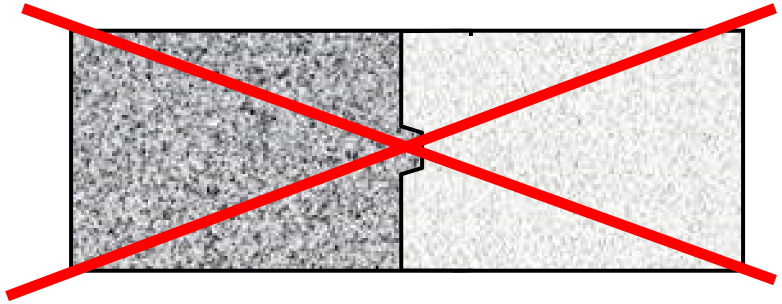
Isolation joint

# Load Transfer Joint Details:

## Pavements <7”



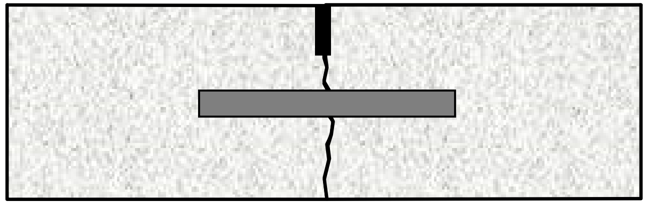
Aggregate Interlock



Keyways

# Load Transfer Joint Details:

## Pavements >7”



Round Dowels

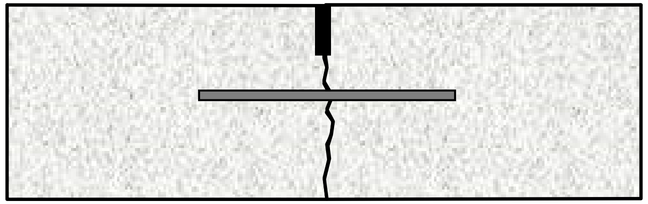
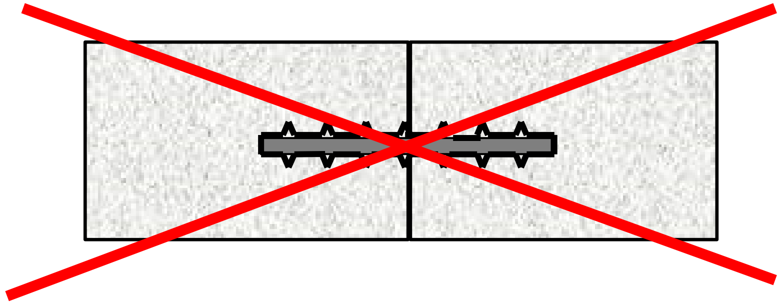
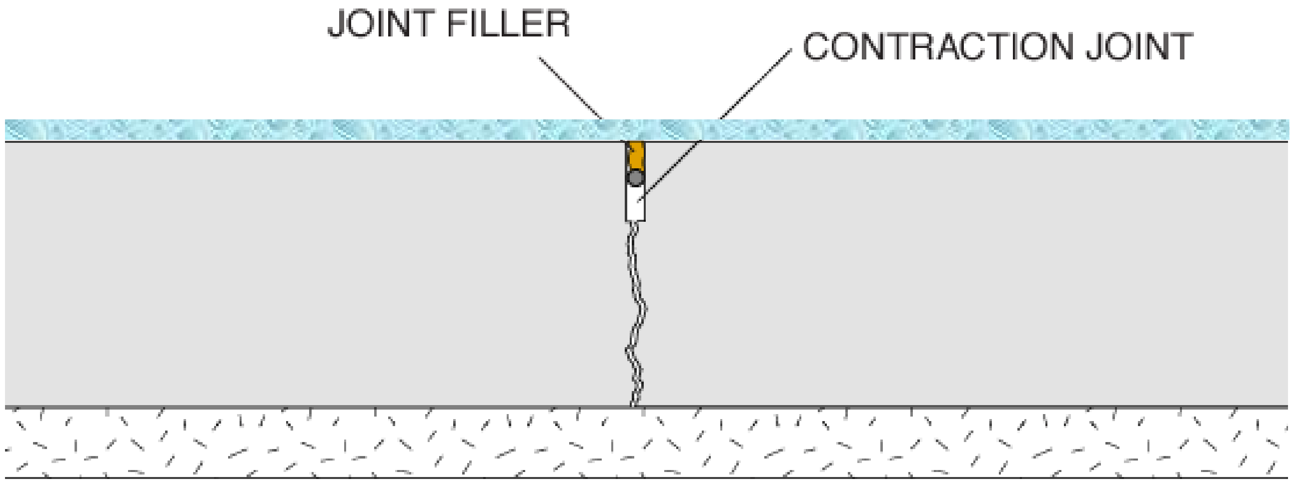


Plate Dowels



Tiebars ≠ Dowels!

(not used for load transfer)




Purpose is to prevent infiltration of water and solids into joint

# Most effective to reduce joint width

1/4 of depth recommended;

1/3 of depth preferred

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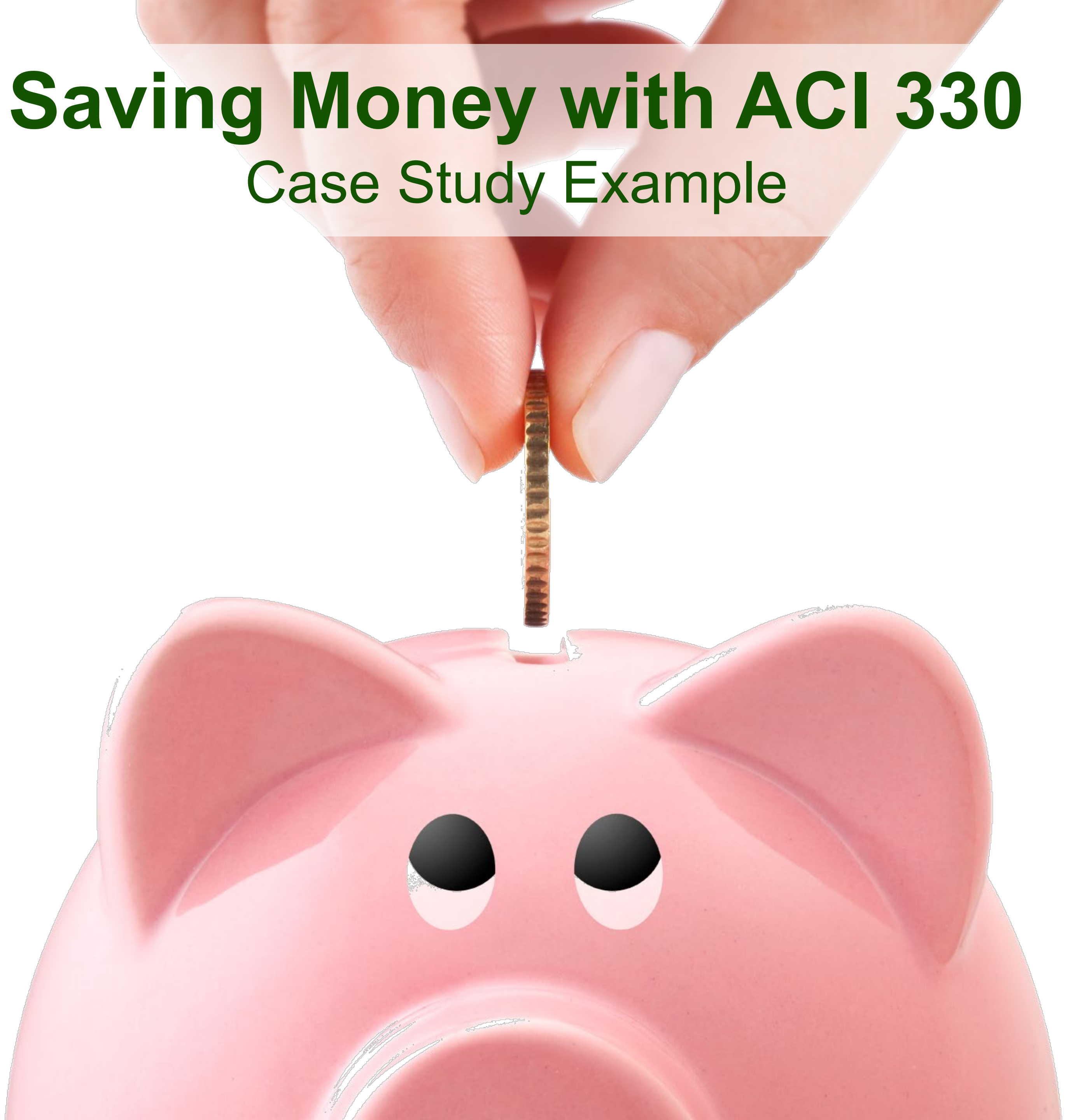
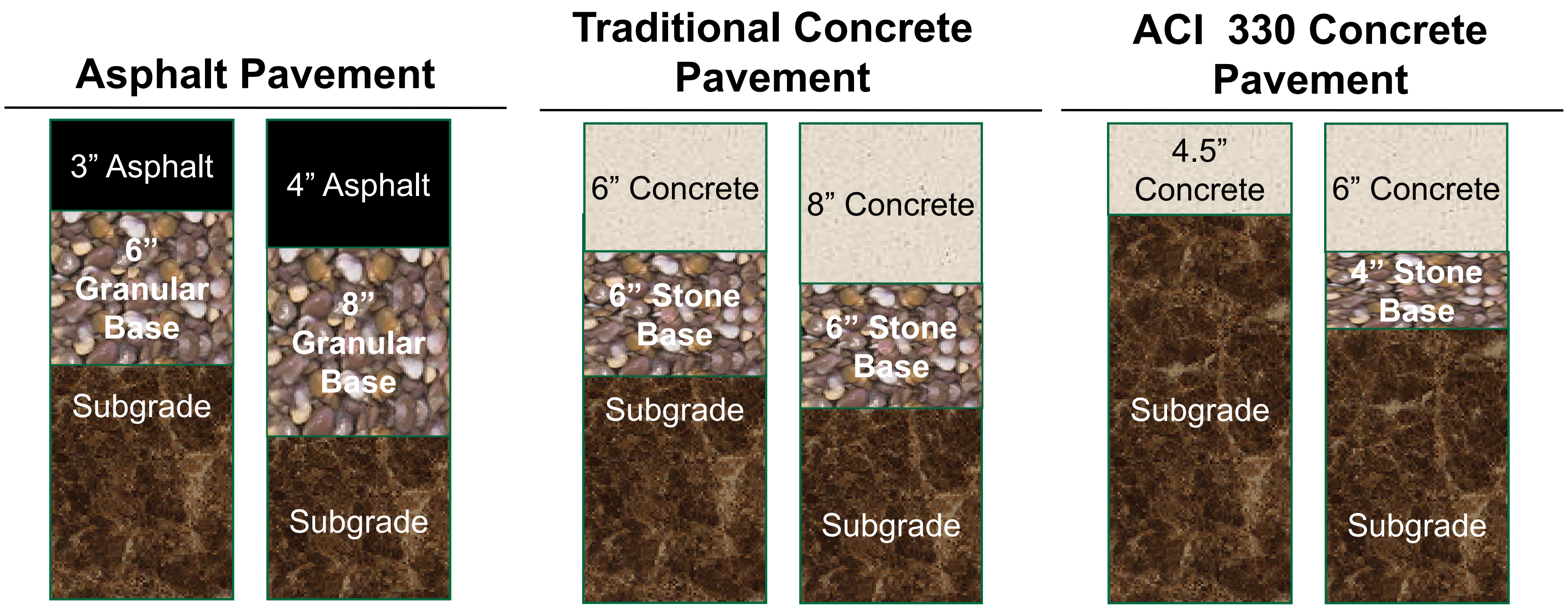
# Saving Money with ACI 330

## Case Study Example



# Lowe's Home Improvement

# Lowe’s Home Improvement - Wilmington,NC




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

# TO DO or NOT TO DO

- **Don't** copy and paste pavement design that have been used on other projects
  - Each project is unique
  - Ask your client about traffic type and design frequency for those loads
- **Don't** have a geotechnical Report…No Problem.
  - USDA Website
  - Make a CONSEREVATIVE Assumption
- **Don't** have traffic data…No Problem.
  - ESTIMATE
  - You're probably right
  - You can always change it

DO
Call, Text, E-Mail
Theron

PAVE AHEAD
DURABLE. SUSTAINABLE. CONCRETE.

# It’s not all concrete…*ALL* the time

PAVE AHEAD
DURABLE. SUSTAINABLE. CONCRETE.

# Give Them a Choice…


Always
Specify
Concrete

It Spurs
Competition!!!


PAVE AHEAD
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# Key Take Aways

Concrete pavement ***has a place***

Concrete pavement is ***durable***

Concrete pavement can be ***cost effective***

Concrete pavement thickness design is ***much easier than I thought an hour ago…***

Concrete pavement questions…**contact Theron Tobolski.**

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# We’re here to help…Questions?…Thank You

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- https://www.concrete.org/
- https://cptechcenter.org/
- https://www.cement.org/
- https://cshub.mit.edu/
- https://www.ascconline.org/
- http://www.acpa.org/

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*Always advancing*

CP Tech Center

CSHub MIT CONCRETE SUSTAINABILITY HUB

NRMCA®

PCA® Since 1916
America's Cement Manufacturers™

ASCC American Society of Concrete Contractors

ACPA AMERICAN CONCRETE PAVEMENT ASSOCIATION

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# Questions???


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