NEW DESIGN TOOLS FOR CONCRETE STREETS AND PARKING LOTS

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ICPA
IOWA CONCRETE PAVING ASSOCIATION

TODAY'S PRESENTATION

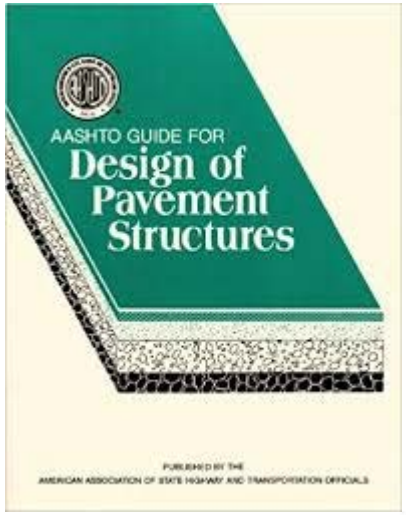
- New tools to design concrete pavements for:
  - Streets and local roads
  - Parking lots
  - Industrial parking and trucking facilities

PavementDesigner.org

American Concrete Institute

BACKGROUND

- There are many existing concrete pavement design guides, methods and software applications…



BACKGROUND

- Design methods use different data and/or models & take many different factors into account
  - Empirical → Mechanistic

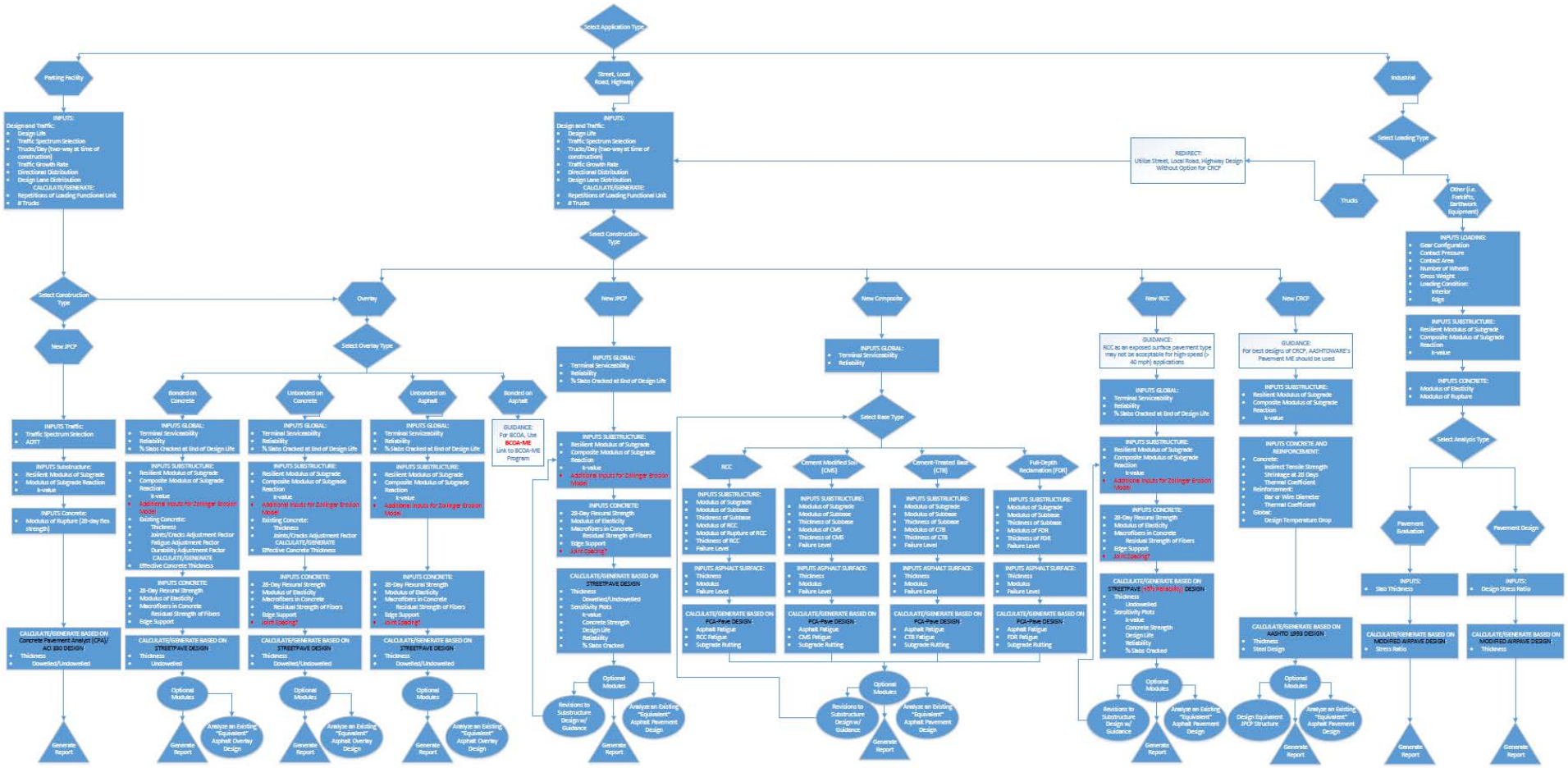
    (Data-Driven) → (Fundamental Properties)
- On a basic level, they are all about designing the **pavement structure**
  - Output: concrete thickness
  - Soil and subbase properties are typically inputs

PAVEMENT DESIGNER

- With variety of programs, industry wanted to bring state-of-the-art methods together into one package—a unified design tool

PAVEMENT DESIGNER

- **Unified design tool:**



PAVEMENT DESIGNER

- Other key features:
  - Free-to-use
  - Accessible through web browser
  - Modern, streamlined interface
  - Save and share projects, design reports
  - Links to a library of supplemental resources

ACPA

PavementDesigner.org

STREETS & LOCAL ROADS

STREETS & LOCAL ROADS

- Concrete Street Design in PavementDesigner.org
  - Based on ACPA's StreetPave software
  - Underlying method: PCA pavement design method
    - Basis for Iowa DOT concrete pavement design
    - Different from AASHTO 93, SUDAS design guide

ACPA
StreetPave12
Structural Design Software for Street and Road Concrete Pavements

PCA
Portland Cement Association

PCA METHOD

- Developed in 1980s
- Based on finite element modeling and relationship with results of the AASHO road test
  - Calculates critical stresses and deflections in the slab under different axle loading configurations

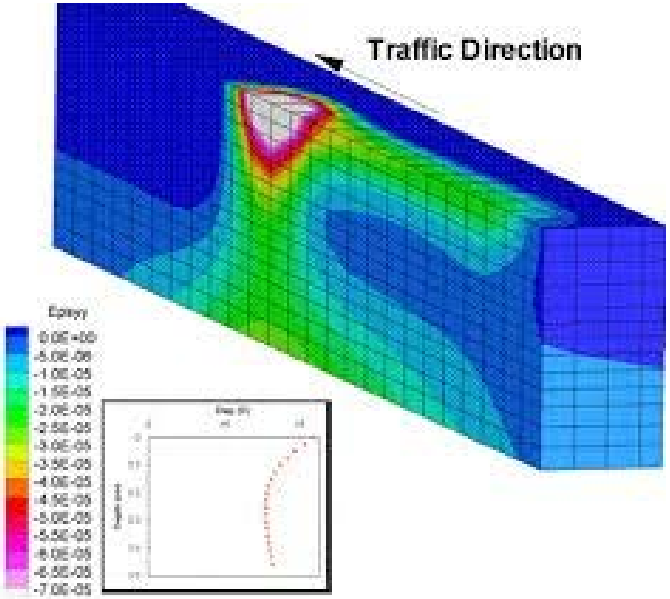


Image: FHWA

PCA METHOD

- Designs concrete pavements based on two design criteria (a.k.a. failure criteria):
  - Fatigue
    - Cumulative damage to the pavement caused by repeated loading at the edge of the slab
  - Erosion
    - Cumulative damage (loss of foundation support, joint faulting) caused by repeated deflections at corner of the slab

DESIGNING STREETS & LOCAL ROADS

- Procedure produces a design concrete slab thickness
  - Different thickness will be provided for doweled and undoweled conditions
  - Depending on number and types of trucks, either the fatigue or erosion criteria will “control” the design
    - Fatigue analysis usually controls design under lighter truck traffic, single-axle loads
    - Erosion analysis usually controls design under heavier truck traffic, tandem axle loads

STREETS & LOCAL ROADS

- User-defined inputs for traffic, concrete design strength, soil properties, subbase layers…
  - SUDAS pavement design guide—good resource for input values you may use

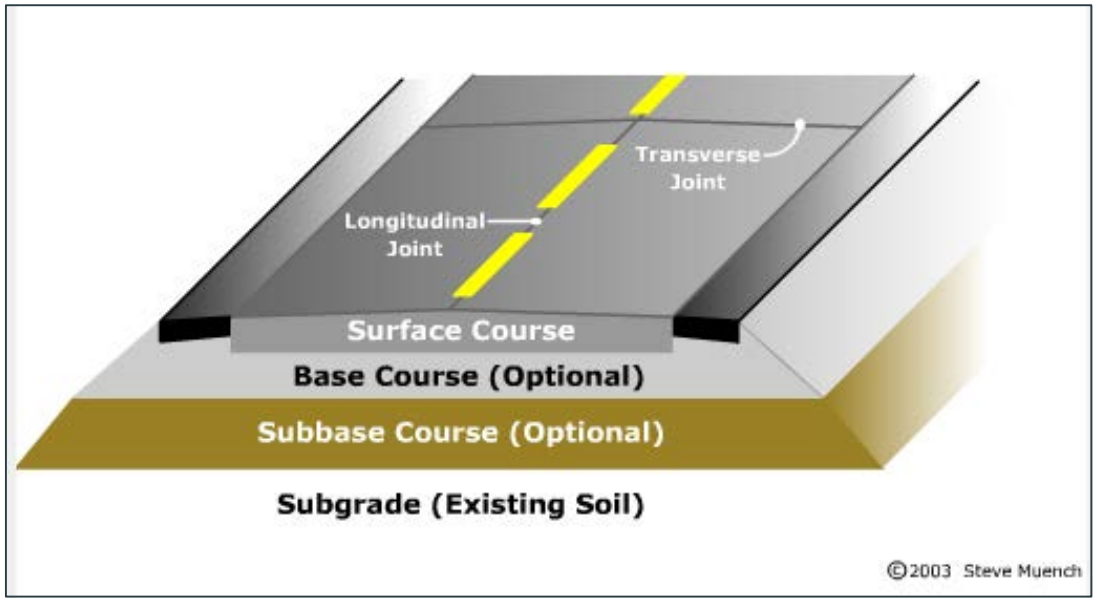


Image: Wikipave

DESIGNING STREETS & LOCAL ROADS

- For new streets in PavementDesigner.org, best to design **Jointed Plain Concrete Pavement (JPCP)**
  - In Iowa cities, Jointed Reinforced Concrete Pavements (JRCP) are designed virtually the same way
  - Reinforcement in Iowa JRCP is generally not considered to contribute to the design thickness and does not affect the joint spacing

PavementDesigner.org

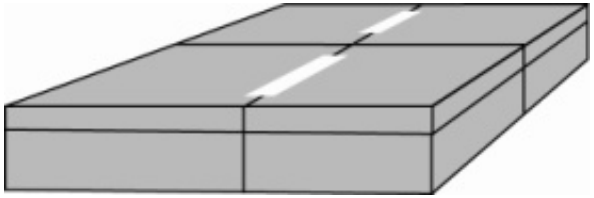
PAVEMENT DESIGNER

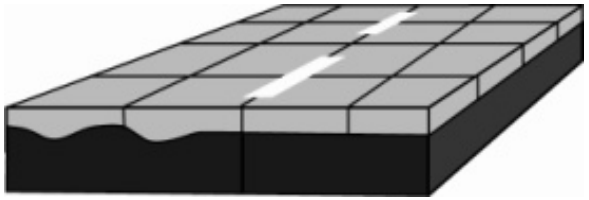
- Demo/walk-through

PavementDesigner.org

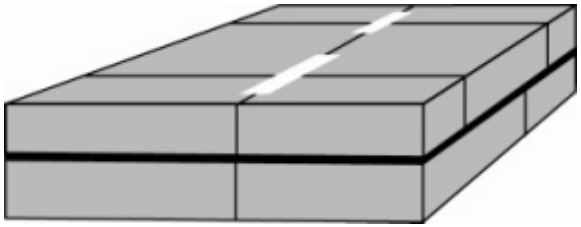
CONCRETE OVERLAYS

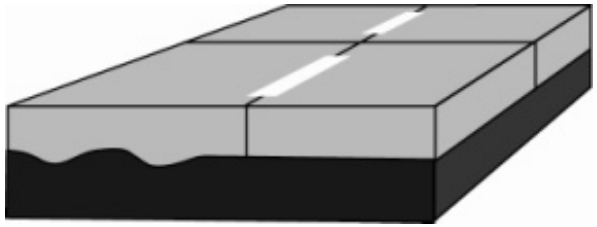
- Concrete Overlay Design in PavementDesigner.org
  - All different types of concrete overlays are included:





Bonded Overlay Family





Unbonded Overlay Family

Image: CP Tech Center

CONCRETE OVERLAYS

- Concrete Overlay Design in PavementDesigner.org
  - Design methods:
    - Unbonded overlays: PCA/AASHTO methods
    - Bonded overlays of asphalt: BCOA-ME (external link)
      - This method incorporates some of the newer mechanistic-empirical pavement design inputs, like climate factors, slab curling, etc.

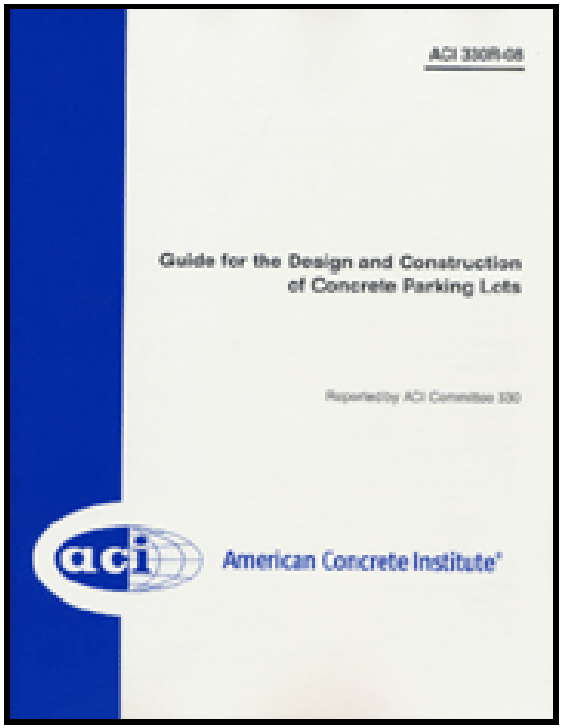
BCOA ME University of Pittsburgh

PavementDesigner.org

ACI PARKING LOT DESIGN GUIDE

ACI PARKING LOT DESIGN

- ACI 330R-08: Guide for the Design and Construction of Concrete Parking Lots
  - Available through ICPA/IRMCA
- Thickness design components are fully incorporated into **PavementDesigner.org**
  - Same StreetPave/PCA design methodology



ACI PARKING LOT DESIGN

- Some things to consider for design of concrete parking lots:
  - Traffic
  - Subbase & Subgrade
  - Jointing
  - Reinforcement

ACI PARKING LOT DESIGN

- Traffic Inputs
  - Choose a category based on chart below
    - Each category is available in PavementDesigner
  - Traffic category dictates assumed axle load distribution for thickness design

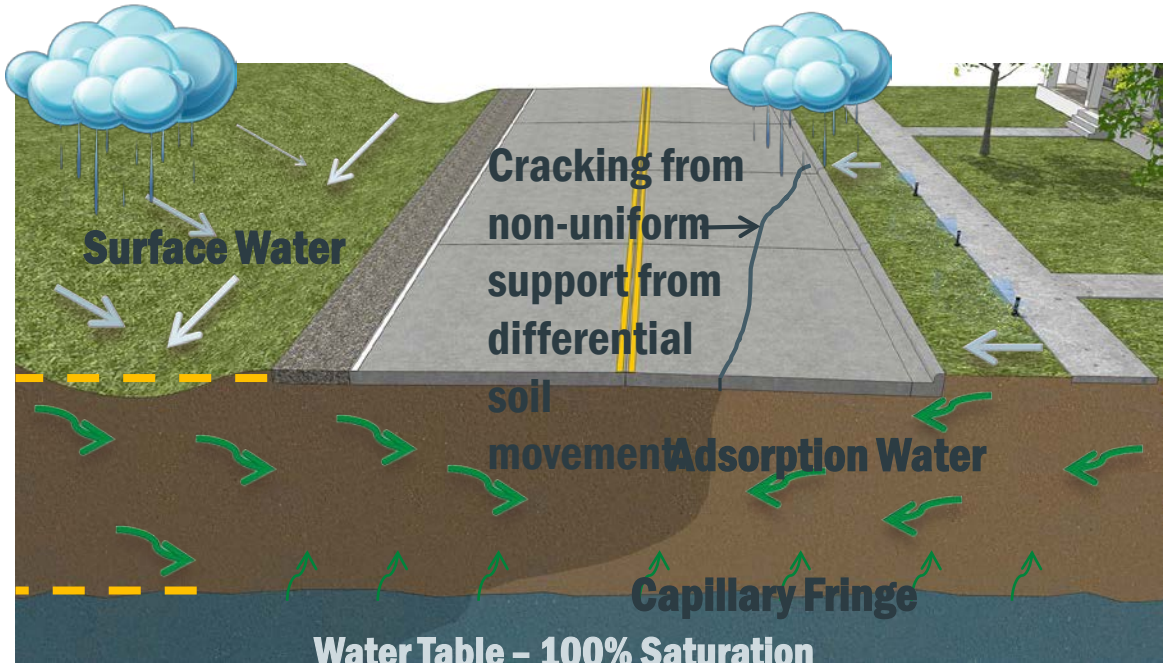
Table 3.3—Traffic categories*

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.

ACI PARKING LOT DESIGN

- Subbase & Subgrade
  - Just like with concrete streets and roads, uniformity of support is more important than strength
  - Subbase more useful to promote good drainage & ensure stable working platform on weak soils



ACI PARKING LOT DESIGN

- Jointing
  - Contraction joints
    - Timely sawing necessary to prevent random cracking
    - Recommended minimum T/4 saw depth with conventional saws
    - Recommended 1” to $1\frac{1}{4}$” saw cut depth with early-entry saws
  - Filling/sealing joints
    - May not be necessary if you have a drainable subbase
    - Recommended 1/8” saw cut width if leaving unsealed
    - Recommended 1/4” to 3/8” saw cut width if filling/sealing

ACI PARKING LOT DESIGN

- Jointing
  - Recommended joint spacing
    - Smaller slabs help control cracking, mitigate curling stresses
    - Panel length should not exceed width by more than 25% (square slabs)
    - Guidelines in ACI guide currently a bit longer than what PavementDesigner may show as an output

Table 3.5—Spacing between joints

Pavement thickness, in. (mm)	Maximum spacing, ft (m)
4, 4.5 (100, 113)	10 (3.0)
5, 5.5 (125, 140)	12.5 (3.8)
6 or greater (150 or greater)	15 (4.5)

ACI PARKING LOT DESIGN

- Reinforcement
  - "Distributed steel reinforcement is not necessary."
    - Stay within recommended joint spacings from table
    - Steel can help prevent cracks from opening
      - Construction difficulties…
      - Proper joint spacing and incorporating subbase may be more proactive way to prevent cracking
      - Consider fiber-reinforced concrete as an alternative to steel
  - Dowel bars generally only needed for load transfer in case of heavy, one-way truck traffic (driving lane)

ACI PARKING LOT DESIGN

- Tie bars recommended for outermost row of panels around the perimeter:
  - Tension Ring
  - Exception for integral curb
  - Also recommended for centerline joint on drive lanes, etc.

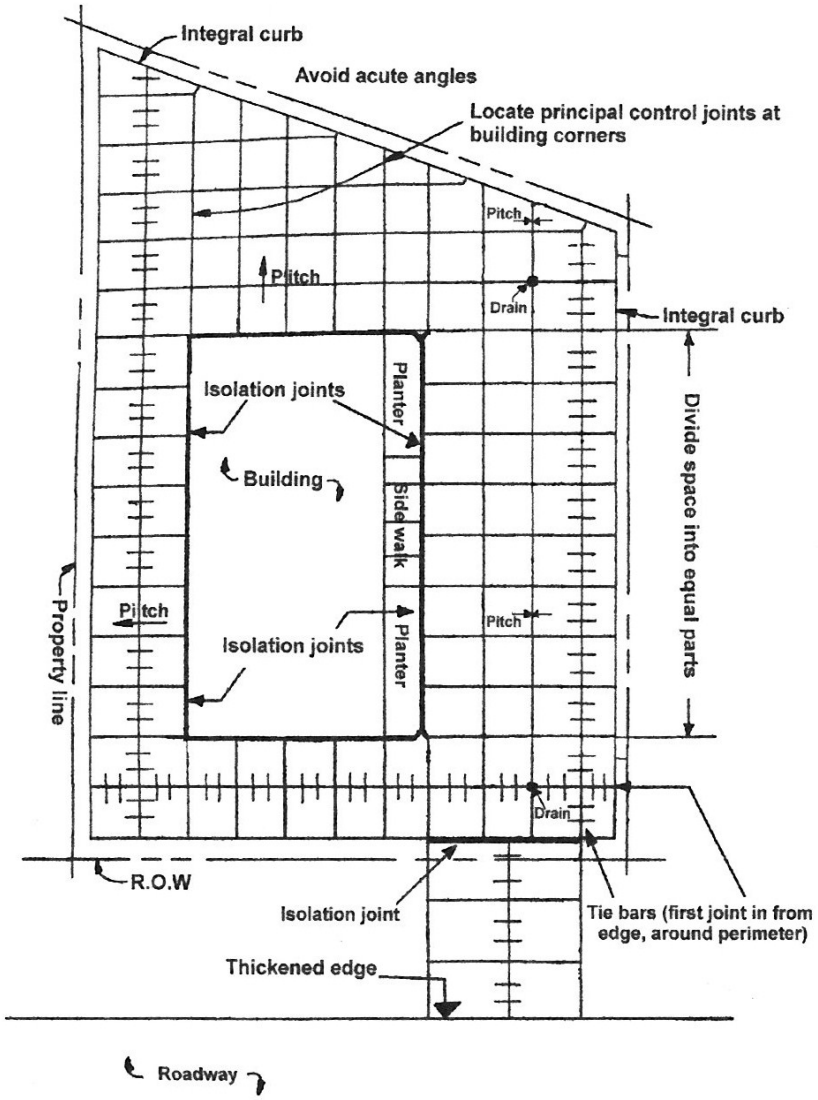


Fig. C.1—Typical joint layout for parking area.

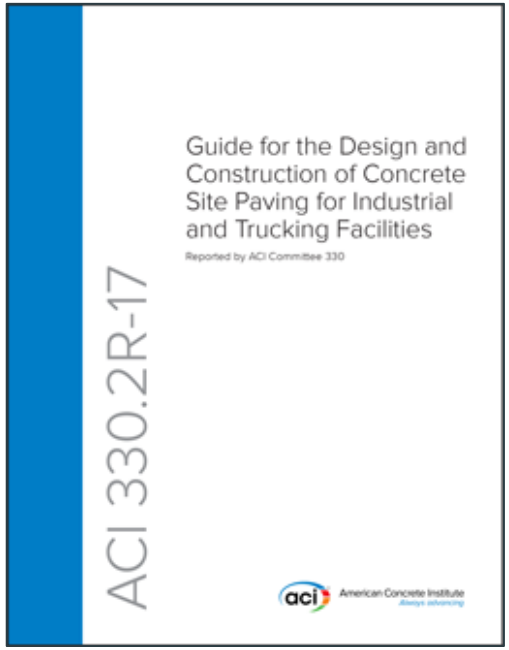
ACI PARKING LOT DESIGN

- In summary:
  - PavementDesigner makes concrete parking lot thickness design simple and easy
  - The ACI guide is still a valuable resource to help with some of the other unique aspects of concrete parking lot design

ACI INDUSTRIAL & TRUCKING FACILITY DESIGN

INDUSTRIAL & TRUCKING FACILITY DESIGN

- ACI 330.2R-17: Guide for the Design and Construction of Concrete Site Paving for Industrial and Trucking Facilities
  - Brand new in 2017!
  - Available through ICPA/IRMCA
- Thickness design components use combination of StreetPave/PCA Methodology + ACPA AirPave
  - Included in PavementDesigner.org



INDUSTRIAL & TRUCKING FACILITY DESIGN

- Many of the general principles in this guide follow those of "regular" parking lots
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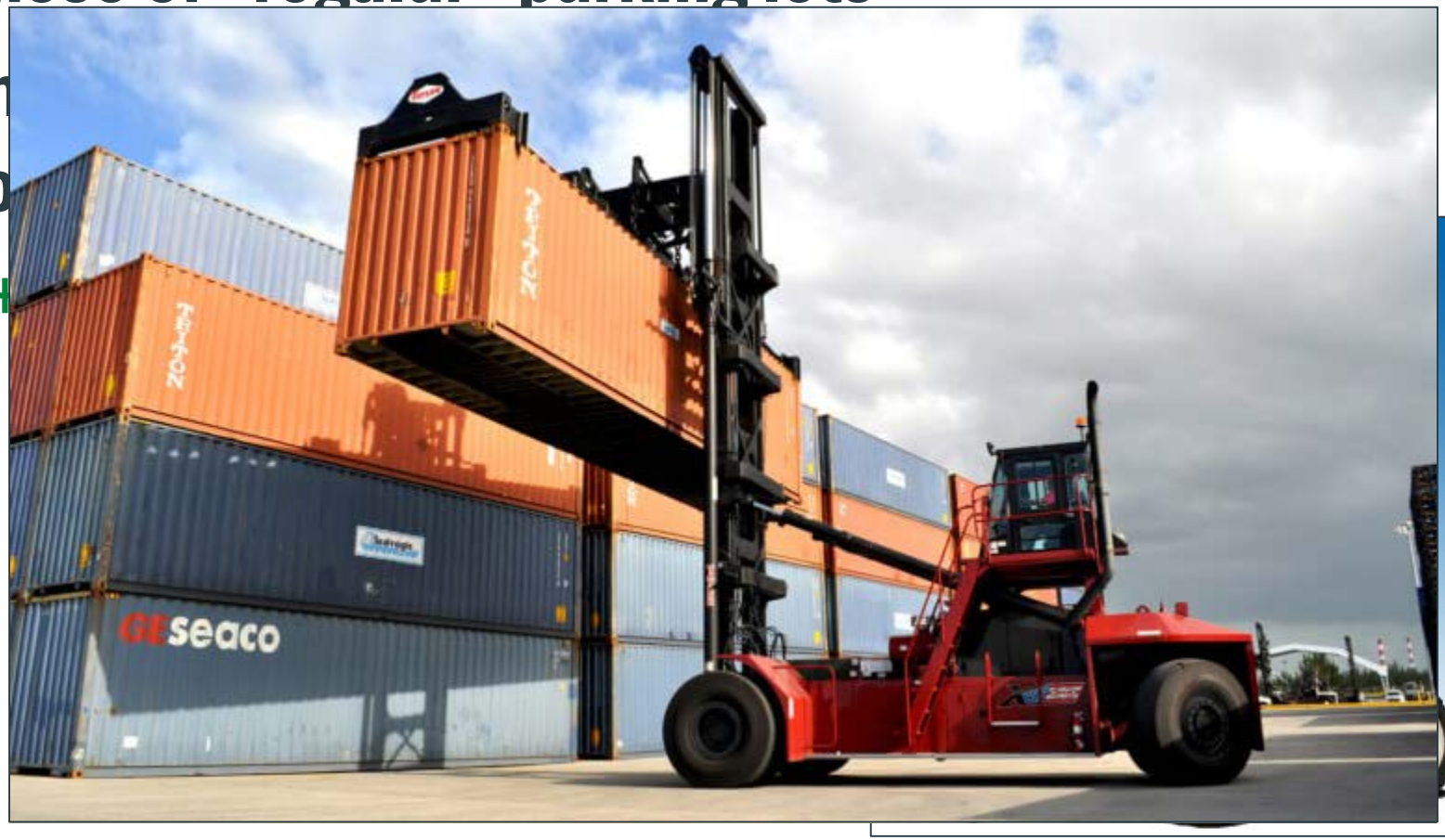
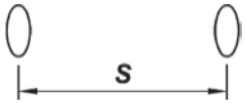


INDUSTRIAL & TRUCKING FACILITY DESIGN

- Thickness design tables are available for over-the-road trucks and various types of lift trucks:

Table 4.7.4a—Thickness in. (mm) for industrial lift trucks with single wheeled drive axle



				Subgrade reaction k = 150 pci (41 MN/m³)			Subgrade reaction k = 200 pci (54 MN/m³)			Subgrade reaction k = 300 pci (81 MN/m³)		
				Modulus of rupture, psi (MPa)			Modulus of rupture, psi (MPa)			Modulus of rupture, psi (MPa)		
Load on drive axle, lb (kN)	Spacing S, in. (mm)	Tire pressure contact, psi (MPa)	Contact area, in.² (cm²)	550 (3.8)	650 (4.5)	750 (5.2)	550 (3.8)	650 (4.5)	750 (5.2)	550 (3.8)	650 (4.5)	750 (5.2)
6400 (29)	26 (660)	100 (0.7)	32 (206)	4.5 (115)	4.0 (100)	4.0 (100)	4.5 (115)	4.0 (100)	3.5 (90)	4.0 (100)	4.0 (100)	3.5 (90)
		250 (1.7)	13 (84)	5.0 (130)	4.5 (115)	4.0 (100)	5.0 (130)	4.5 (115)	4.0 (100)	4.5 (115)	4.0 (100)	4.0 (100)
10,400 (46)	31 (785)	100 (0.7)	52 (336)	5.5 (140)	5.0 (130)	4.5 (115)	5.5 (140)	5.0 (130)	4.5 (115)	5.0 (130)	4.5 (115)	4.5 (115)
		250 (1.7)	21 (136)	6.0 (150)	5.5 (140)	5.0 (130)	6.0 (150)	5.5 (140)	5.0 (130)	5.5 (140)	5.5 (140)	5.0 (130)
14,600 (65)	32 (815)	100 (0.7)	73 (471)	6.5 (165)	6.0 (150)	5.5 (140)	6.5 (165)	6.0 (150)	5.5 (140)	6.0 (150)	5.5 (140)	5.0 (130)
		250 (1.7)	29 (187)	7.0 (180)	6.5 (165)	6.0 (150)	7.0 (180)	6.5 (165)	6.0 (150)	6.5 (165)	6.0 (150)	5.5 (140)
22,200 (99)	37 (940)	100 (0.7)	111 (716)	8.0 (200)	7.0 (180)	6.5 (165)	7.5 (190)	7.0 (180)	6.5 (165)	7.5 (190)	6.5 (165)	6.0 (150)
		250 (1.7)	44 (284)	8.5 (215)	8.0 (200)	7.5 (190)	8.0 (200)	8.0 (200)	7.0 (180)	8.0 (200)	7.5 (190)	7.0 (180)
32,500 (145)	37 (940)	100 (0.7)	162 (1045)	9.5 (240)	9.0 (225)	8.0 (200)	9.5 (240)	8.5 (215)	8.0 (200)	9.5 (240)	8.0 (200)	7.5 (190)
		250 (1.7)	65 (419)	10.5 (265)	9.5 (240)	9.0 (225)	10.5 (265)	9.5 (240)	9.0 (225)	10.0 (250)	9.0 (225)	8.5 (215)
42,000 (187)	40 (1015)	100 (0.7)	210 (1355)	11.0 (280)	10.0 (250)	9.0 (225)	10.5 (265)	9.5 (240)	9.0 (225)	10.0 (250)	9.0 (225)	8.5 (215)
		250 (1.7)	84 (542)	12.0 (300)	11.0 (280)	10.0 (250)	11.5 (290)	10.5 (265)	10.0 (250)	11.0 (280)	10.5 (265)	9.5 (240)

INDUSTRIAL & TRUCKING FACILITY DESIGN

- Because of nature of loading at these facilities, dowel bars may be needed for load transfer
  - Two-directional doweling for all-way movements
  - Guidance provided on use of alternative dowel bar types, such as square or plate dowels
    - May better handle stresses, shrinkage, and lateral movement than round dowels when two-directional doweling is needed

Images: PNA Construction

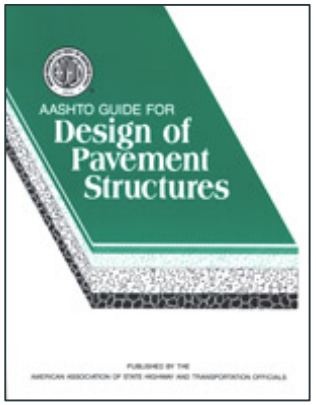
CONCRETE PAVEMENT DESIGN

- Final thoughts
  - Different design procedures can be effective and useful tools, provided:
    - Good understanding by practitioner
    - Applicable to situation you are designing for
    - Quality of data and inputs
    - Ability to customize input values

PavementDesigner.org

American Concrete Institute

Iowa SUDAS
STATEWIDE URBAN DESIGN AND SPECIFICATIONS



THANK YOU!