NEW DESIGN TOOLS FOR CONCRETE STREETS AND PARKING LOTS

Dan King, E.I.T.
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
BACKGROUND

There are many existing concrete pavement design guides, methods and software applications...
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
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
StreetPave
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
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
User-defined inputs for traffic, concrete design strength, soil properties, subbase layers...

- SUDAS pavement design guide—good resource for input values you may use
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
PAVEMENT DESIGNER

- Demo/walk-through
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.
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
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>
<thead>
<tr>
<th>Table 3.3—Traffic categories*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Car parking areas and access lanes—Category A</td>
</tr>
<tr>
<td>2. Shopping center entrance and service lanes—Category B</td>
</tr>
</tbody>
</table>
| 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 |

<table>
<thead>
<tr>
<th>Truck type</th>
<th>Parking areas and interior lanes</th>
<th>Entrance and exterior lanes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single units (bobtailed trucks)</td>
<td>Category B</td>
<td>Category C</td>
</tr>
<tr>
<td>Multiple units (tractor trailer units with one or more trailers)</td>
<td>Category C</td>
<td>Category D</td>
</tr>
</tbody>
</table>

*Select A, B, C, or D for use with Table 3.4.
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.
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>
<thead>
<tr>
<th>Pavement thickness, in. (mm)</th>
<th>Maximum spacing, ft (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4, 4.5 (100, 113)</td>
<td>10 (3.0)</td>
</tr>
<tr>
<td>5, 5.5 (125, 140)</td>
<td>12.5 (3.8)</td>
</tr>
<tr>
<td>6 or greater (150 or greater)</td>
<td>15 (4.5)</td>
</tr>
</tbody>
</table>
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.
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 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
Many of the general principles in this guide follow those of “regular” parking lots.

Industrial-type facilities can have unique traffic loadings: not only heavy trucks, but forklifts, telehandlers, and lulls...
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

<table>
<thead>
<tr>
<th>Load on drive axle, lb (kN)</th>
<th>Spacing S, in. (mm)</th>
<th>Tire pressure contact, psi (MPa)</th>
<th>Contact area, in.² (cm²)</th>
<th>Subgrade reaction $k = 150$ psi (41 MN/m²)</th>
<th>Modulus of rupture, psi (MPa)</th>
<th>Subgrade reaction $k = 200$ psi (54 MN/m²)</th>
<th>Modulus of rupture, psi (MPa)</th>
<th>Subgrade reaction $k = 300$ psi (81 MN/m²)</th>
<th>Modulus of rupture, psi (MPa)</th>
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</thead>
<tbody>
<tr>
<td>6400 (29)</td>
<td>26 (660)</td>
<td>100 (0.7)</td>
<td>32 (206)</td>
<td>4.5 (115)</td>
<td>4.0 (100)</td>
<td>4.0 (100)</td>
<td>4.5 (115)</td>
<td>4.0 (100)</td>
<td>3.5 (90)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>250 (1.7)</td>
<td>13 (84)</td>
<td>5.0 (130)</td>
<td>4.5 (115)</td>
<td>4.0 (100)</td>
<td>5.0 (130)</td>
<td>4.5 (115)</td>
<td>4.0 (100)</td>
</tr>
<tr>
<td>10,400 (46)</td>
<td>31 (785)</td>
<td>100 (0.7)</td>
<td>52 (336)</td>
<td>5.5 (140)</td>
<td>5.0 (130)</td>
<td>4.5 (115)</td>
<td>5.5 (140)</td>
<td>5.0 (130)</td>
<td>4.5 (115)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>250 (1.7)</td>
<td>21 (136)</td>
<td>6.0 (150)</td>
<td>5.5 (140)</td>
<td>5.0 (130)</td>
<td>6.0 (150)</td>
<td>5.5 (140)</td>
<td>5.0 (130)</td>
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<tr>
<td>14,600 (65)</td>
<td>32 (815)</td>
<td>100 (0.7)</td>
<td>73 (471)</td>
<td>6.5 (165)</td>
<td>6.0 (150)</td>
<td>5.5 (140)</td>
<td>6.5 (165)</td>
<td>6.0 (150)</td>
<td>5.5 (140)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>250 (1.7)</td>
<td>20 (187)</td>
<td>7.0 (180)</td>
<td>6.5 (165)</td>
<td>6.0 (150)</td>
<td>7.0 (180)</td>
<td>6.5 (165)</td>
<td>6.0 (150)</td>
</tr>
<tr>
<td>22,200 (99)</td>
<td>37 (940)</td>
<td>100 (0.7)</td>
<td>111 (716)</td>
<td>8.0 (200)</td>
<td>7.0 (180)</td>
<td>6.5 (165)</td>
<td>7.5 (190)</td>
<td>7.0 (180)</td>
<td>6.5 (165)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>250 (1.7)</td>
<td>44 (284)</td>
<td>8.5 (215)</td>
<td>8.0 (200)</td>
<td>7.5 (190)</td>
<td>8.0 (200)</td>
<td>8.0 (200)</td>
<td>7.5 (190)</td>
</tr>
<tr>
<td>32,500 (145)</td>
<td>37 (940)</td>
<td>100 (0.7)</td>
<td>162 (1045)</td>
<td>9.5 (240)</td>
<td>9.0 (225)</td>
<td>8.0 (200)</td>
<td>9.5 (240)</td>
<td>8.5 (215)</td>
<td>8.0 (200)</td>
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<tr>
<td></td>
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<td>250 (1.7)</td>
<td>65 (419)</td>
<td>10.5 (265)</td>
<td>9.5 (240)</td>
<td>9.0 (225)</td>
<td>10.5 (265)</td>
<td>9.5 (240)</td>
<td>9.0 (225)</td>
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<tr>
<td>42,000 (187)</td>
<td>40 (1015)</td>
<td>100 (0.7)</td>
<td>210 (1355)</td>
<td>11.0 (280)</td>
<td>10.0 (250)</td>
<td>9.0 (225)</td>
<td>10.5 (265)</td>
<td>9.5 (240)</td>
<td>9.0 (225)</td>
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<tr>
<td></td>
<td></td>
<td>250 (1.7)</td>
<td>84 (542)</td>
<td>12.0 (300)</td>
<td>11.0 (280)</td>
<td>10.0 (250)</td>
<td>11.5 (290)</td>
<td>10.5 (265)</td>
<td>10.0 (250)</td>
</tr>
</tbody>
</table>

Note: The values are rounded for simplicity.
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
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
THANK YOU!