Parking lot construction

• Why Concrete?
  – Competitive pricing
  – Good fit with new environmental designs

• Why Parking lots?

• Design is out of whack!

• Construction Practices Today
Why Concrete?

• Pricing of concrete is more competitive than ever.
• Concrete - Numerous sustainability benefits (sri, reflectance savings, savings from heat load, no PAHs).
• Concrete lasts and requires little to no maintenance.
• Owners see overall job costs savings when concrete is specified along with asphalt (equivalent designs).
• By always specifying concrete designed per ACI 330 R-08 you are saving your client money!
A study shows Louisville may be getting hotter at a faster rate than other large U.S. cities. One agency has its own plan to counter the HEAT ISLAND.
51,000 sq ft on red clay
NOW THAT CONCRETE IS COMPARABLE ON INITIAL COST, LONG TERM BENEFITS ARE FREE

**Initial cost Comparison**

<table>
<thead>
<tr>
<th></th>
<th>2004</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Historical</td>
<td>$141</td>
<td>$76</td>
</tr>
<tr>
<td>Current</td>
<td>$154</td>
<td>$120</td>
</tr>
</tbody>
</table>

**Long Term Net Present Value ($K)**

<table>
<thead>
<tr>
<th></th>
<th>2004</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete is 9.5% Lower</td>
<td>$124.0</td>
<td>$137.0</td>
</tr>
</tbody>
</table>

Inflation rate – 4.0%, Discount Rate = 8.0%
Seal coat and stripe application every 5 years, cost $1.50/SY
Concrete cleaning and re-striping every 10 years, cost $0.50/SY
CONCRETE PARKING LOTS CAN BE CONSTRUCTED IN SIMILAR TIME AS ASPHALT

Major Construction Tasks and Production Rates

<table>
<thead>
<tr>
<th>Concrete Surface (5” thick)</th>
<th>Expected Days of Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Form work (800-1200 SY/day)</td>
<td>Concrete</td>
</tr>
<tr>
<td>• Paving (1100 – 1600 SY/day)¹,²</td>
<td>Asphalt</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Asphalt Surface (2” Asphalt / 6”Base)</th>
<th>Concrete</th>
<th>9</th>
<th>Avg Days</th>
<th>12</th>
<th>Max Days</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Granular base preparation (150 - 250 tons/day, minimum 2 day)</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Asphalt paving (500 - 100 tons/day)</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Curb and gutter (250 - 350 LF/day)</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. Based on paving two 25’ wide x 250 ft long sections/day
   Asphalt Design: 2” AC / 6” Granular on compacted subgrade
   Concrete Design: 5” Jointed concrete on compacted subgrade
2. Curb & gutter are integral to concrete paving and included in paving and form work
Sealer abrasion

Fall of 07

Spring of 08
Oils and antifreeze degradation

The problem

The fix?
Dollar General –
Dollar Stores
Sonics
Lighting cost comparison

- Asphalt requires 24% more poles
- Initial costs, maintenance costs, and energy costs are 24% higher

Initial and maintenance costs similar
- Asphalt requires 33% higher energy costs each year.

For One Mile
Assumes: Initial cost = $5,000/pole; Maintenance cost = $100/pole/year; Energy cost = $0.0814/kWh; Operating time = 4,000 hours/pole/year
Spring Street Fire Station Louisville
Henderson Learning Center
Pavement Engineering

...the art of molding materials we do not wholly understand into shapes we cannot precisely analyze so as to withstand forces we cannot assess in such a way that the community at large has no reason to suspect our ignorance.
ACI 330R-08
The Gold Standard for Concrete Parking Lot Design
Why Use It?

- Economical 20 Year Design
- Addresses Many Aspects of Concrete Parking Lot Construction
- Based on Sound Engineering
- Created Just for Concrete Parking Lots!
Overview of the Document:

- Pavement Design – CH 3
- Materials – CH 4
- Construction – CH 5
- Inspection and Testing – CH 6
- Maintenance and Repairs – CH 7

Specifying and requiring the contents of ACI 330 R-08 gives a designer confidence that many aspects of a concrete parking lot are addressed.
What do designers currently use for concrete parking lots?

*Usually follow DOT*

- Nothing – No concrete design; Only design in asphalt
- AASHTO Design Guide – ‘72, ‘86, ’93
- DOT guidelines for roadway design – usually one of the AASHTO guides
- “What we’ve always used”
- ACI 330!
If AASHTO is good enough for the highway, why not the parking lot? Or is it?

The 1993 AASHTO Guide for Design of Pavement Structures was based on empirical equations derived from the AASHO Road Test. That test was conducted between 1958 and 1960, with limited structural sections at one location, Ottawa, Illinois, and with modest traffic levels compared with those of the present day. As such, designs accomplished with the 1993 AASHTO guide are projected far beyond the inference space of the original data. The JTFP in the

-Gary Sharpe, P.E., AASHTO Chairperson, 6/23/2004
Source of Much of What We Know About Pavement Design

- AASHO Road Test
- Late 50’s and early 60’s
- Ottawa, Illinois
The AASHO road test and AASHTO method

AASHTO design equations:

- Empirical – reproduce actual road test performance data
- Use the “ESAL” concept to quantify loads / repetitions
- Developed Serviceability Factors

\[
\log(\text{ESALs}) = Z_{R} \cdot s' + 7.35 \cdot \log(D + 1) - 0.06R0 + 4.22\cdot p_t* \left[ S_c' \cdot C_d \cdot \left[D^{0.75} - 1.132\right]\right] / \left[ 215.63\cdot J \cdot D^{0.75} - \frac{18.42}{(E_c / k)^{0.25}} \right]
\]
AASHO Test Traffic

Max Single Axle

Max Tandem Axle
Typical AASHO Pavement Sections
Serviceability -

the pavement’s ability to serve the type of traffic (automobiles and trucks) that use the facility

Present Serviceability Index (PSI)

5.0
4.0
3.0
2.0
1.0
0.0

Very Good
Good
Fair
Poor
Very Poor
### AASHO Road Test Results

<table>
<thead>
<tr>
<th>Subbase</th>
<th>Plain</th>
<th>Reinforced</th>
<th>Plain</th>
<th>Reinforced</th>
<th>Plain</th>
<th>Reinforced</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>716</td>
<td>415</td>
<td>353</td>
<td>325</td>
<td>291</td>
<td>592</td>
</tr>
<tr>
<td></td>
<td>343</td>
<td>304</td>
<td>328</td>
<td>175</td>
<td>289</td>
<td>408</td>
</tr>
<tr>
<td>5''</td>
<td>3.8</td>
<td>3.8</td>
<td>4.4</td>
<td>3.4</td>
<td>3.0</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td>687</td>
<td>2.6</td>
<td>3.4</td>
<td>3.4</td>
<td>3.4</td>
<td>1.8</td>
</tr>
<tr>
<td>6 1/2''</td>
<td>3.6</td>
<td>4.3</td>
<td>4.3</td>
<td>1.8</td>
<td>1.8</td>
<td>1.8</td>
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<tr>
<td></td>
<td>793</td>
<td>1000</td>
<td>1000</td>
<td>1000</td>
<td>1000</td>
<td>1000</td>
</tr>
<tr>
<td>8''</td>
<td>4.4</td>
<td>3.9</td>
<td>4.4</td>
<td>4.4</td>
<td>4.3</td>
<td>4.3</td>
</tr>
<tr>
<td></td>
<td>4.1</td>
<td>4.0</td>
<td>4.1</td>
<td>4.1</td>
<td>4.2</td>
<td>4.2</td>
</tr>
<tr>
<td></td>
<td>4.5</td>
<td>3.9</td>
<td>4.2</td>
<td>4.2</td>
<td>3.9</td>
<td>3.9</td>
</tr>
<tr>
<td></td>
<td>4.2</td>
<td>3.8</td>
<td>3.8</td>
<td>3.8</td>
<td>3.8</td>
<td>3.8</td>
</tr>
<tr>
<td>9 1/2''</td>
<td>4.2</td>
<td>4.0</td>
<td>4.5</td>
<td>4.5</td>
<td>4.1</td>
<td>4.8</td>
</tr>
<tr>
<td></td>
<td>4.0</td>
<td>4.0</td>
<td>4.2</td>
<td>4.2</td>
<td>4.2</td>
<td>4.6</td>
</tr>
</tbody>
</table>

**Loop 4**

**Concrete Thickness**

- All sections in second row are replicates.
- Load applications to failure (1,000's)
- Serviceability index at end of test 

**Loop 4**

**Concrete**
## AASHO Road Test Results

**Chart 4**

<table>
<thead>
<tr>
<th><strong>Asphalt</strong></th>
<th><strong>Base</strong></th>
<th><strong>0</strong>°</th>
<th><strong>12</strong>°</th>
<th><strong>4</strong>°</th>
<th><strong>8</strong>°</th>
<th><strong>12</strong>°</th>
<th><strong>4</strong>°</th>
<th><strong>8</strong>°</th>
<th><strong>12</strong>°</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Subbase</strong></td>
<td><strong>4</strong>°</td>
<td><strong>8</strong>°</td>
<td><strong>12</strong>°</td>
<td><strong>4</strong>°</td>
<td><strong>8</strong>°</td>
<td><strong>12</strong>°</td>
<td><strong>4</strong>°</td>
<td><strong>8</strong>°</td>
<td><strong>12</strong>°</td>
</tr>
<tr>
<td>10,000</td>
<td>2</td>
<td>72</td>
<td>82</td>
<td>74</td>
<td>82</td>
<td>583</td>
<td>80</td>
<td>92</td>
<td>1.6</td>
</tr>
<tr>
<td>52,000</td>
<td>12</td>
<td>74</td>
<td>106</td>
<td>76</td>
<td>86</td>
<td>601</td>
<td>80</td>
<td>570</td>
<td>618</td>
</tr>
<tr>
<td><strong>All sections in second row are replicates</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Asphalt surface thickness</strong></th>
<th><strong>4</strong>°</th>
<th><strong>5</strong>°</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>78</td>
<td>107</td>
</tr>
<tr>
<td>83</td>
<td>102</td>
<td>576</td>
</tr>
<tr>
<td><strong>Serviceability index at end of test</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.0</td>
<td>88</td>
<td>119</td>
</tr>
<tr>
<td>102</td>
<td>126</td>
<td>850</td>
</tr>
<tr>
<td><strong>Load applications to failure (1,000's)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.0</td>
<td>621</td>
<td>621</td>
</tr>
</tbody>
</table>
CONVENTIONAL PAVEMENT DESIGN USES THE 1993 AASHTO PAVEMENT DESIGN GUIDE
Based On Old Technology

• AASHTO Guide was developed based on AASHO Road Test in 1950’s
  – Pavement surface: jointed plain or jointed reinforced concrete with dowels (3500 psi)
  – Utilized 1 subgrade and 1 base type (highly erodible)
    • PCC pavements failed by pumping
  – Maximum 1.1 million ESAL applications over 2 yrs
  – Based on 1 climatic zone - Illinois (wet/freeze)
  – Pavement performance measured by human perception of ride quality

Many of the 1993 AASHTO Inputs are not measureable
  • Initial serviceability
  • Terminal serviceability
  • Equivalent Single Axle load - ESAL
  • Load transfer coefficient - J-factor
  • Drainage factor
  • Structural number
  • Layer coefficient

1950's 1960's Today
AASHTO Road Test Data

TYPICAL SECTIONS
ASPHALT
SURFACE BASE SUBBASE
THICKNESS
5’ 10’ 15’ 20’

CONCRETE
CONCRETE SUBBASE
THICKNESS
5’ 10’ 15’ 20’
The New Technology for Roads and Highways:
MEPDG - BASED ON ACTUAL PAVEMENT PERFORMANCE AND LATEST PAVEMENT DESIGN MODELS

- FHWA monitored 2,400 test sections through LTPP program
  - 1,250 test sections constructed for specific studies
    - Structural factors for asphalt pavements
    - Structural factors for concrete pavements
    - Rehabilitation of asphalt pavements
    - Rehabilitation of concrete pavements
    - Environmental effects in absence of heavy loads
  - Performance measured annually
    - Concrete: Cracking, faulting, pumping, roughness
    - Asphalt: Rutting, cracking, roughness
  - Each section is 10-20 yrs old and still counting

Test Section Locations

All Vehicles Considered Individually

Pavement Stresses From Traffic Loading

- All Vehicles Considered Individually
- Pavement Stresses From Traffic Loading
AASHTO PAVEMENT DESIGN GUIDE IS NOT RECOMMENDED FOR CONCRETE PARKING LOT PAVEMENTS

• AASHTO Guide is intended for use on highway pavements
  – Highway pavements are different than parking lots
    • High speed traffic
    • One-directional traffic patterns
    • Loading near edge of pavement
    • Mixed vehicle types
    • Water drains rapidly from pavement
    • Light poles, Islands are not on highways

• AASHTO Guide is currently being revised based on current technology of pavement design
FOLLOWING ACI 330 GUIDELINES RESULTS IN COMPARABLE, SUPERIOR PERFORMING CONCRETE DESIGNS

- **ACI has developed recommended design procedure specifically for parking lots**

<table>
<thead>
<tr>
<th>Given:</th>
<th>Determines:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Soil Strength</td>
<td>• Thickness</td>
</tr>
<tr>
<td>• Concrete Strength</td>
<td>• Jointing</td>
</tr>
<tr>
<td>• Traffic Demand</td>
<td>• Reinforcing (opt.)</td>
</tr>
<tr>
<td></td>
<td>• Subbase (opt.)</td>
</tr>
</tbody>
</table>

- Recognizes construction integrity of rigid pavement materials. Recommends reduction or elimination of granular base:
- Potential Savings = 25-35% of total cost.

- **ACI 330 recognizes parking lots are different than a street/roadway.**
  - Load is in the Interior
  - Primary purpose is to store & move vehicles
  - Lot may be a water collector
  - May need to accommodate lighting, islands, landscaping
Actual NRMCA National Account Design Situation:

Large Account Default Requirement
Requested AASHTO Design Methodology:
Standard Duty: 7” over 6” subgrade
Heavy Duty: 8” over 6” subgrade

Revised Project Criteria using ACI 330 R-08 Guideline:
Standard Duty: 5” – no subgrade
Heavy Duty: 6” over 4” subgrade

Substantial Cost Savings !!!
Keeping thickness in perspective...

- "Rules of thumb" work fine for many small projects.
- Actual fatigue failures are rare.
- Most thickness design is conservative for assumed loads.
- More critical issues:
  - Subgrade / subbase uniformity
  - Drainage & maintenance
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
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.
Steel reinforcement

It is almost impossible to place rolled wire mesh in the upper thickness where it can function. Rebar on chairs or welded rigid mats perform better if steel is called for. Secondary steel reinforcement is often misunderstood and can rarely be justified in flatwork that is properly jointed.

**If steel is used, it should generally be cut at all joints!**
JOINTED REINFORCED CONCRETE PAVEMENTS (JRCP) ARE NOT RECOMMENDED FOR PARKING LOTS

Plan

Profile

30’ to 90’ joint spacing
PROPER JOINTING PRACTICES AFFECT LONG TERM PERFORMANCE MORE THAN THICKNESS

<table>
<thead>
<tr>
<th>Things to do</th>
<th>Things to avoid</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Match existing joints or cracks</td>
<td>• Slabs &lt; 1 ft. wide</td>
</tr>
<tr>
<td>• Isolate fixed structures</td>
<td>• Slabs &gt; 15 ft. wide</td>
</tr>
<tr>
<td>• Take into account aggregate type</td>
<td>• Angles &lt; 60°</td>
</tr>
<tr>
<td>• Joint locations can be adjusted in the field</td>
<td>• Creating interior corners</td>
</tr>
<tr>
<td>• Match joints in curb</td>
<td>• Odd Shapes (keep slabs square)</td>
</tr>
<tr>
<td>• Be practical</td>
<td>• Avoid “T” joint</td>
</tr>
<tr>
<td>• Detail Joints</td>
<td></td>
</tr>
</tbody>
</table>

**Diagonal**

**Inlet - None**

Isolation joint

Isolation joint
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.

Recommended Maximum Joint Spacing (2 x thickness)

<table>
<thead>
<tr>
<th>Pavement thickness, in.</th>
<th>Spacing range, ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 to 4.5</td>
<td>6-10</td>
</tr>
<tr>
<td>5 to 5.5</td>
<td>7.5 -12.5</td>
</tr>
<tr>
<td>6 or greater</td>
<td>10-15</td>
</tr>
</tbody>
</table>

Erratic crack patterns due to no joints
THE CRITICAL STRESS FOR PARKING LOT DESIGN IS IN THE INTERIOR

Edge Loadings are used for Highway Design

1. Loadings at pavement corners are most severe
2. Loadings at pavement edges are next most severe
3. Parking lot thickness design assumes the loads at some distance from pavement corners and edges
   - Pavement edge without integral curb may need thickened edge
   - Joint design must provide for the proper level of load transfer or a condition approaching free edge loading will occur at joints / cracks.
Expansion Joints
Expansion Joints
ACI 330R-08 – The Gold Standard

ACI 330 is preferred because:

• AASHTO 93 – for roads and highways NOT parking lots
• AASHTO 93 – outdated methodology (1950s)
• AASHTO 93 doesn’t offer construction methodology standards for concrete parking lots
• AASHTO 93 doesn’t allow for cost competitive designs for concrete
70 cubic yards per day pipe screed
City of Frankfort Public Works Department Placed the Pervious Concrete
Porous Concrete Installation May 10, 2005
Installation
Radcliff – using KRMCA Pervious Concrete Equipment
Dry Ridge, KY
60-70 cu yds / day
700 cubic yards laser screed one night Breckinridge County Kentucky
660 cu yds 9 hours
Menards store, Ohio
124,750 sq ft 3 days