Subgrades and Subbases

Municipal Streets Seminar
November 18, 2015
Dale S. Harrington, P.E., Representing the National CP Tech Center
Iowa Local Roads Environment

- It is common for Iowa streets and local roads to be constructed from PCC supported on a natural subgrade.

- Aggregate support layers typically serve as:
  - Construction platform
  - Improve stability and uniformity
  - Result in increased performance and thus increased pavement life.

- Aggregate subbases can also improve the drainage.

**Question:**

How much do aggregate bases benefit the pavement, and is the benefit worth the costs, particularly if the pavement is meeting the design life?
Project Purpose

- Purpose of the IHRB, TR-640 - better understand how to optimize local pavement foundation support layers for improved pavement performance.

- Project consisted of a field study of 16 sites.

- Findings and conclusions apply also to concrete and asphalt pavements.
- Improved foundation improves performance & level of service

- How to improve foundation:
  - Improve drainage
  - Provide separation from weak layer

- Sustainability
  - Condition of base layers may reduce rehabilitation effort
• PCC pavements were tested to capture range of conditions statewide. (Sites were random based on location throughout the state and not by age)

• Turned out:
  – Pavement Age: 30 days to 42 years
  – Surface Distress Conditions: Poor to Excellent (PCI = 35 to 92)
  – Support Conditions:
    ▪ Natural Subgrade
    ▪ Fly Ash Stabilized Subgrade
    ▪ 6 in. to 12 in. Granular Subbase
  – Pavement Thickness: 6 to 11 in.
  – Traffic (AADT): 110 to 8900
## TR-640- Subgrade Test Data

### Sites with Pavement on Subgrade

<table>
<thead>
<tr>
<th>Site Location</th>
<th>Year Constructed</th>
<th>Traffic (ADT)</th>
<th>Traffic (ADTT)</th>
<th>PCC Thickness</th>
<th>Subgrade</th>
<th>Subbase</th>
<th>Measured Subgrade CBR</th>
<th>Measured Subbase CBR</th>
<th>Calculated Static $k_c$ (FWD)</th>
<th>Calculated C_d (min.)</th>
<th>LOS (Avg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NW Greenwood &amp; 3rd St. Ankeny</td>
<td>1989</td>
<td>2000</td>
<td>30</td>
<td>8.5</td>
<td>A-2-6</td>
<td>none</td>
<td>5.9</td>
<td>-</td>
<td>39</td>
<td>0.71</td>
<td>1.8</td>
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<tr>
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<td>2000</td>
<td>30</td>
<td>8.3</td>
<td>A-7-6</td>
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<td>-</td>
<td>33</td>
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<td>1.0</td>
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<tr>
<td>E63 Story Co.</td>
<td>1990</td>
<td>1040</td>
<td>52</td>
<td>8</td>
<td>A-4 &amp; A-7-6</td>
<td>none</td>
<td>9.9</td>
<td>-</td>
<td>53</td>
<td>0.77</td>
<td>1.6</td>
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<td>1970</td>
<td>560</td>
<td>16.8</td>
<td>6</td>
<td>A-4</td>
<td>none</td>
<td>6.8</td>
<td>-</td>
<td>51</td>
<td>0.83</td>
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<td>1986</td>
<td>150</td>
<td>7.5</td>
<td>6.8</td>
<td>A-6</td>
<td>none</td>
<td>11</td>
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<td>1.8</td>
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<tr>
<td>9th Ave. Council Bluffs</td>
<td>1989</td>
<td>7600</td>
<td>380</td>
<td>7.75</td>
<td>A-5 to A-7-5, fly ash (1&quot; sand)</td>
<td>8.8</td>
<td>-</td>
<td>29</td>
<td>0.7</td>
<td>1.9</td>
<td></td>
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<tr>
<td><strong>Averages</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td>7.6</td>
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<td></td>
<td></td>
<td>7.32</td>
<td>0.75</td>
<td>1.6</td>
</tr>
</tbody>
</table>
## TR640 Subbase Test Data

### Sites with Pavement on Subbase or Stabilized Subgrade

<table>
<thead>
<tr>
<th>Site Location</th>
<th>Year Constructed</th>
<th>Traffic (ADT)</th>
<th>Traffic (ADTT)</th>
<th>PCC Thickness</th>
<th>Subgrade</th>
<th>Subbase</th>
<th>Measured Subgrade CBR</th>
<th>Measured Subbase CBR</th>
<th>Software Static $k_c$ (FWD)</th>
<th>Calculated $C_d$ (min.)</th>
<th>LOS (Avg)</th>
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</thead>
<tbody>
<tr>
<td>Riverside Rd. Story Co.</td>
<td>1994</td>
<td>2910</td>
<td>582</td>
<td>11</td>
<td>-</td>
<td>6&quot; limestone</td>
<td>20</td>
<td>78</td>
<td>73</td>
<td>0.88</td>
<td>1.3</td>
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<tr>
<td>SW Westhavn Ankeny</td>
<td>2008</td>
<td>1000</td>
<td>10</td>
<td>7.3</td>
<td>A-6, woven fabric</td>
<td>8.5&quot; - 10&quot; limestone</td>
<td>11, 1.9</td>
<td>64, 54</td>
<td>38,25</td>
<td>0.84</td>
<td>1.3</td>
</tr>
<tr>
<td>SW Logan Ankeny</td>
<td>2012</td>
<td>500</td>
<td>5</td>
<td>7.5</td>
<td>A-4, fly ash</td>
<td>3.5&quot; limestone</td>
<td>34</td>
<td>60</td>
<td>56</td>
<td>0.72</td>
<td>1.8</td>
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<tr>
<td>W. Main Knoxville</td>
<td>2007</td>
<td>500</td>
<td>15</td>
<td>7</td>
<td>fly ash</td>
<td>12&quot; limestone</td>
<td>11</td>
<td>46</td>
<td>52</td>
<td>0.71</td>
<td>1.2</td>
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<tr>
<td>S. 5th Knoxville</td>
<td>2009</td>
<td>680</td>
<td>13.6</td>
<td>8</td>
<td>fly ash</td>
<td>12&quot; limestone</td>
<td>26</td>
<td>39</td>
<td>104</td>
<td>0.71</td>
<td>1.1</td>
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<tr>
<td>Valley View Dr. Council Bluffs</td>
<td>1997</td>
<td>8900</td>
<td>712</td>
<td>9</td>
<td>A-6 to A-4</td>
<td>6&quot; limestone</td>
<td>24</td>
<td>122</td>
<td>74</td>
<td>0.7</td>
<td>1.5</td>
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<td>Cliff Rd. A Burlington</td>
<td>1993</td>
<td>1120</td>
<td>56</td>
<td>6.5</td>
<td>A-4</td>
<td>5&quot; limestone</td>
<td>8.2</td>
<td>20</td>
<td>65</td>
<td>0.73</td>
<td>1.2</td>
</tr>
<tr>
<td>Cliff Rd B Burlington</td>
<td>1993</td>
<td>1120</td>
<td>56</td>
<td>7.5</td>
<td>A-7-6</td>
<td>4.5&quot; limestone</td>
<td>8.7</td>
<td>20</td>
<td>38</td>
<td>0.92</td>
<td>1.8</td>
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<tr>
<td>Meadowbrook Burlington</td>
<td>2004</td>
<td>300</td>
<td>4.5</td>
<td>6.5</td>
<td>A-6</td>
<td>4&quot; limestone</td>
<td>7.3</td>
<td>22</td>
<td>91</td>
<td>0.94</td>
<td>1.0</td>
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<tr>
<td>W38 Winneshiek Co.</td>
<td>1996</td>
<td>600</td>
<td>36</td>
<td>7</td>
<td>-</td>
<td>12&quot; limestone</td>
<td>56</td>
<td>111</td>
<td>111</td>
<td>0.8</td>
<td>1.0</td>
</tr>
</tbody>
</table>

**Averages**

- **Average Traffic (ADT):** 5350
- **Average Traffic (ADTT):** 89
- **Average PCC Thickness:** 8
- **Average Measured Subgrade CBR:** 64
- **Average Measured Subbase CBR:** 58
- **Average Software Static $k_c$ (FWD):** 73.8
- **Average Calculated $C_d$ (min.):** 0.8
- **Average LOS (Avg):** 1.1
TR-640

Foundation stiffness, permeability, and strength were measured in-situ.
TR-640 - Lowest k-values PCC on Subgrade

PCC: 6 in., Age: 42 years
PCI: 35, AADT: 560 with 3% trucks
Measure of Performance

- **Pavement Condition Index (PCI)** is measured by the pavement’s physical condition.
  - A numerical value that rates the pavement surface condition from 0 to 100.
  - The PCI is determined based on the severity and the amount of distress within the pavement.

- **The IRI value** is typically suited for pavements with higher traffic volume and at higher speeds.
Factors:
- Age
- Drainage coefficient ($C_d$)
- Coefficient of variation for $k$ & CBR
- Weak subgrade layer (CBR)
- Traffic
- Pavement thickness
- Subbase (if or if not)
TR-640 Findings

Field results indicate that the following are key pavement foundation factors affecting performance:

- Low and variable support values (due to low stiffness or CBR)
- Poor drainage (assumed $C_d$ in design is high)
- Seasonal variations (freeze-thaw and frost-heave)
- Loss of support (due to erosion, non-uniform settlement)
- Poorly compacted utility trench backfill
- Overall non-uniformity

Field study recommendation: To improve pavement thickness design reliability and performance: (1) measure and (2) control foundation properties.
User Guide - Approach

• What was understood before the study
  ❑ Subgrades & Subbases
  ❑ Drainage

• What was learned from the study
  ❑ Varied Parameter Values
  ❑ Improved PCI with Subbase
  ❑ CBR Weak Layer

• Guidance for Improving PCC Pavement Performance
  ❑ Treatment Options
  ❑ Benefits of Subbase
  ❑ Geotextiles
What Was Understood Before the IHRB TR-640 Study

Load Equivalency Factors

34,000 lbs.

12,000 lbs. to the subgrade.

pressure = 5 psi

Load applies 24,000 lbs. to the subgrade.

pressure = 30 psi

Concrete

Bituminous

- Smaller pressure on the subgrade means more load is absorbed by concrete.
- Concrete spreads load out over a larger area and thus has a greater ESAL. However, it is subject to changes in soil.
- Because concrete is rigid and has a higher strength than asphalt, it carries more ESALs than asphalt over its lifetime.
What Was Understood Before the IHRB TR-640 Study

• The pavement design life for local roadways (not including heavily traveled arterials or trunk highways) is normally based:
  – pavement thickness
  – less concern is given to the support system.

• Unless there is freeze-thaw damage, ASR, or D-cracking, the normal mode of unacceptable performance is the vertical distortion of the pavement surface from:
  - slab movement
  - joint failures
  - cracking, etc.
  - drop in pavement condition index (PCI).
What Was Understood Before the IHRB TR-640 Study

Subgrade Soils

- In order for a concrete pavement to provide long term performance, its foundation needs to have uniform and stable support.

- At a minimum, this normally includes:
  - Topsoil removal
  - Scarification of subgrade to a depth of one foot
  - Compaction to a specified depth, density and moisture content
  - Differential soils not normally addressed unless wet
What Was Understood Before the IHRB TR-640 Study

Subgrade Soil Key Factors

- When subject to poor drainage and/or poor soils, likely be measurable soil breakdown and movement.
- Subgrade and subbase erosion caused by the intrusion of water can lead to pavement deterioration.
- When limited drainage exists, erosion can begin and weaken the interface.
- Leads to unstable PCC panels.
What Was Understood Before the IHRB TR-640 Study

• Stabilized Subgrades
  – The need to stabilize subgrades is primarily due to excessive moisture in the subgrade itself.
  – High moisture in soils may be encountered during construction:
    ▪ Naturally high water table
    ▪ Changes in drainage conditions during construction.
  – Options (normally not practical)
    ▪ Sub-drains before construction
    ▪ Letting the soil dry out through a natural process
    ▪ Replacement of soils
What Was Understood Before the IHRB TR-640 Study

• Stabilized (Chemical) Subgrades
  – A stabilized subgrade such as soil cement or fly ash stabilization will help:
    ▪ dry out excessively moist soils
    ▪ develop the uniformity
    ▪ construction platform
What Was Understood Before the IHRB TR-640 Study

• Cement Modified Soil
  – CMS is soil mixed with a small portion of Portland Cement (3% - 5% of soils dry weight)
  – CMS helps prevent migration of subgrade soil and water into the aggregate subbase
  – Provides some additional strength to the subgrade.
  – CMS modifies fine grained soils such as silts and clays having high plasticity content.
  – Reduces Plastic Index (PI) within a range of 12 to 15.
What Was Understood Before the IHRB TR-640 Study

• Fly Ash
  – Incorporates 10 to 15 percent fly ash (measured by dry weight of the native soil) into the existing subgrade.
  – Fly ash can improve the subgrade CBR from 2 to 3 to as much as 25 to 30.
  – Improve the unconfined compressive strength from 50 psi to 400 psi.
  – Good drying agent for wet soils and provides a working platform during construction.
What Was Understood Before the IHRB TR-640 Study

• Stabilized (Reinforced) Subgrades
  – Typically used when subgrades have an unstable (soft) but not an extremely high moisture content.
  – Geogrid helps prevent localized shear failure of the subgrade.
  – Increase its effective bearing capacity.
  – Reinforce the granular fill through confinement of the particles, stiffening the base layer for improved load distribution.
What Was Understood Before the IHRB TR-640 Study

• Geotextiles
  – Woven geotextiles help reduce localized shear failure of the subgrade.
  – Have higher tensile strength than nonwoven geotextiles and less drainable.
  – Serve as a separation layer between the subgrade and aggregate subbase.
What Was Understood Before the IHRB TR-640 Study

• Unstabilized Aggregate Subbases
  – Used when soil is reasonably stable and not excessively wet.
  – Provide a working platform during construction.
  – Provide uniformity as a support layer.
  – Serve as a drainage system to help drain surface water away from the pavement.
  – Provide a cutoff layer from subsurface moisture.
  – A subdrain and outlet system needs to be provided.
What Was Understood Before the IHRB TR-640 Study

• Subdrains
  – Drainage is important to the long term performance of concrete pavement.
  – Proper maintenance of the subdrain system is imperative.
# TR-640 Test Site Data

## SUBGRADE (Avg. age 24 yrs)

<table>
<thead>
<tr>
<th>Design Parameters</th>
<th>Cd</th>
<th>k</th>
<th>LOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUDAS</td>
<td>1.0</td>
<td>100 psi</td>
<td>1.0</td>
</tr>
<tr>
<td>Field Value (avg. from calculations)</td>
<td>0.75</td>
<td>45 psi (FWD)</td>
<td>1.6</td>
</tr>
</tbody>
</table>

## SUBBASE (Avg. age 12 yrs)

<table>
<thead>
<tr>
<th>Design Parameters</th>
<th>Cd</th>
<th>k</th>
<th>LOS</th>
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</thead>
<tbody>
<tr>
<td>SUDAS</td>
<td>1.1</td>
<td>150-200 psi</td>
<td>0.0</td>
</tr>
<tr>
<td>Field Value (avg. from calculations)</td>
<td>0.8</td>
<td>74 psi (FWD)</td>
<td>1.3</td>
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</tbody>
</table>

Checked Street Pave Using Field Data Value:
- Without Aggregate Subbase- Some Increase in Thickness
- With 4” Aggregate Subbase- No Increase in Thickness
What was Learned from the IHRB-TR640 Study

- CBR and Subgrade Weak Zones
  Impact Modulus of Subgrade Reaction
  
  - Research showed that a majority of the soils had a “weak” layer in the subgrade at depths varying from 6 to 18 inches below the pavement and/or subbase layer.
  
  - Examination of each of the CBR profiles showed that the weak layer in the subgrade did have an impact on the k values as determined by the DCP tests.
What was Learned from the IHRB-TR640 Study
Modulus of Subgrade Reaction-CBR Relationship

- Modulus of Subgrade Reaction - CBR are related
- k-values derived from the DCP are higher than k-values derived from FWD
What was Learned from the IHRB-TR640 Study

Different Values

• Study showed:
  – In situ modulus of subgrade reaction \((k)\) and drainage coefficient \((C_d)\) were variable and lower than typical design parameter values used in thickness design calculations.
  – Loss of Support \((LS)\) values higher than suggested in SUDAS thickness design, but were within range of the AASHTO (1993) design guidelines.
  – Each of the sites were tested at various ages.
  – Over time, the values may have decreased due to degradation of the subbase.
Guidance for Improving PCC Pavement Performance

Geotechnical Investigation

• In order to determine what soils are present and understand their characteristics, it is essential to complete a geotechnical investigation.

• The following information should be provided from a geotechnical investigation:
  - Soil classification – (USCS or AASHTO)
  - Soil profile from boring logs
  - Stratification lines and depths of the soil profile
  - Moisture or water content (measured as a percentage)
  - Groundwater level
  - Dry density or dry unit weight
  - Unconfined strength
  - Standard penetration resistance value (N)
  - Liquid and plastic limits and plastic index of the soil
What Was Learned from the IHRB-TR640 Study

Southwest Westlawn Drive (Poor Subgrade)
Woven Geotextiles for Stabilization

• Woven geotextiles used for ground stabilization minimize rutting and prevent intermixing of the aggregate with the soft soils below.

• Think of woven geotextiles as affordable insurance for your aggregate. They save time and money by reducing or eliminating the need for additional rock.
What was Learned from the IHRB-TR640 Study

Aggregate Subbase Loss

• Pavement thickness design software programs cannot reflect actual pavement foundation conditions except immediately after construction.

• This causes some:
  – loss of support (LS)
  – which in turn lowers the overall modulus of subgrade reaction (k-value)
  – can lower the drainage coefficient ($C_d$) of the aggregate subbase.

• The overall average CBR of those sites containing an aggregate subbase was 58 as compared to a CBR of 100 (for a new aggregate subbase).
Loss of Base Aggregate

- Road base aggregate penetrates the subgrade soil.
- Subgrade soil migrates up into the aggregate.
- Mixture only has the strength of the soil—required structural section thickness is lost and the road fails.

Road As Built After Service
## AASHTO - Product Applications

<table>
<thead>
<tr>
<th>Application</th>
<th>Class</th>
<th>Nonwoven</th>
<th>Woven</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subsurface Drainage</td>
<td>Class 1</td>
<td>Geotex 801</td>
<td>Geotex 2x2HF</td>
</tr>
<tr>
<td></td>
<td>15 to 50% <em>in situ</em> Soil passing 0.075 mm</td>
<td>Geotex 801</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>&gt;50% <em>in situ</em> Soil passing 0.075 mm</td>
<td>Geotex 801</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Class 2</td>
<td>Geotex 601</td>
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<td></td>
<td>15 to 50% <em>in situ</em> Soil passing 0.075 mm</td>
<td>Geotex 601</td>
<td>Geotex 104F</td>
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<tr>
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<td>&gt;50% <em>in situ</em> Soil passing 0.075 mm</td>
<td>Geotex 601</td>
<td>Geotex 104F</td>
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<tr>
<td></td>
<td>Class 3</td>
<td>Geotex 401</td>
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<td>15 to 50% <em>in situ</em> Soil passing 0.075 mm</td>
<td>Geotex 401</td>
<td>-</td>
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<tr>
<td></td>
<td>&gt;50% <em>in situ</em> Soil passing 0.075 mm</td>
<td>Geotex 401</td>
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*Use Class 3 only if specified by engineer – see note b of table 2 in M288 spec*

<table>
<thead>
<tr>
<th>Temporary Silt Fence</th>
<th>Supported</th>
<th>Geotex 351</th>
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<tbody>
<tr>
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<td>Unsupported</td>
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<td>Geotex 2130</td>
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<tr>
<td>Separation</td>
<td>Class 1</td>
<td>Geotex 801</td>
<td>Geotex 315ST</td>
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<tr>
<td></td>
<td>Class 2</td>
<td>Geotex 601</td>
<td>Geotex 250ST</td>
</tr>
<tr>
<td></td>
<td>Class 3</td>
<td>Geotex 401</td>
<td>Geotex 200ST</td>
</tr>
</tbody>
</table>

| Stabilization                | Class 2 (Use class 2 only if specified by engineer – see note a of table 5 in M288 spec) | Geotex 601    | Geotex 250ST  |
|                              | Class 3 (Use class 3 only if specified by engineer – see note a of table 5 in M288 spec) | Geotex 401    | Geotex 200ST  |
Geotex® - Woven (Stabilization)

• Stabilization Products:
  ▪ Applications include:
    – Low to medium volume roads
    – Utility roads
    – Soft subgrades = 0.5<CBR<3
    – Areas of minimal moisture

  ▪ Benefits
    – Gives optimum stabilization performance in the presence of minimal moisture. Performs better than traditional cut and replace methods.
    – Geotextile cost ranges from $0.50 to $1.50 per square yard
    – Install cost ranges from $0.50 to $1.00 per square yard

®- Propex
Geotex® - Woven (Stabilization) – High Strength

• High Strength Stabilization Products:
  - 2x2HF, 3x3HF, 4x4HF, 4x6
  - Applications include:
    - High volume roads
    - Very soft subgrades – CBR<1
    - High water table areas
  - Provide stabilization in areas with very low CBR along with high water tables
    - Material cost ranges from $1.10 - $2.50 per square yard
    - Install cost ranges from $0.50 - $1.00 per square yard
Aggregate Subbase and a Drainage System

- Increases performance and service life
- Provides a construction platform
- Maintains uniform support
- Provides drainage from water infiltration
- Helps reduce shrink and swell of high volume-change soils
- Controls excessive or differential frost heave
- Minimizes mud-pumping of fine-grained soils
- Prevents consolidation of subgrade
- Provides capillary cut off for high water table
With Geotextile, How Thick Should Aggregate Base Be?

• Aggregate Subbase Thickness Limitations (StreetPAVE)
With Geotextile, How Thick Should Aggregate Base Be?

- Aggregate Subbase Thickness Limitations (MEPDG)

![Graph showing IRI vs. Subbase Thickness](image)

- **IRI (Inches/Mile)**
- **Subbase Thickness (Inches)**

*Legend*
- Blue line: 500 AADT 7" PCC
- Red line: 1000 AADT 7" PCC
- Green line: Threshold

**AADT** = Average Daily Traffic (10% Trucks used for ADDTT)
With Geotextile, How Thick Should Aggregate Base Be?

• Aggregate Subbase Thickness Limitations (MEPDG)

![Cracking graph](image)

- **500 AADT 7" PCC**
- **1000 AADT 7" PCC**
- **Threshold**

AADT=Average Daily Traffic (10% Trucks used for ADT&T)
### Guidance for Improving PCC Pavement Reliability

<table>
<thead>
<tr>
<th></th>
<th>1000 AADT</th>
<th>2000 AADT</th>
<th>5000 AADT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Natural Subgrade</td>
<td>5&quot; subbase</td>
<td>Natural Subgrade</td>
</tr>
<tr>
<td>PCC thickness</td>
<td>6&quot;</td>
<td>6&quot;</td>
<td>6&quot;</td>
</tr>
<tr>
<td>Rigid ESALS (5% trucks, 1% growth)</td>
<td>339,259</td>
<td>339,259</td>
<td>678,518</td>
</tr>
<tr>
<td>Overall Standard Deviation</td>
<td>0.35</td>
<td>0.35</td>
<td>0.35</td>
</tr>
<tr>
<td>Flexural Strength</td>
<td>650 psi</td>
<td>650 psi</td>
<td>650 psi</td>
</tr>
<tr>
<td>Modulus of Elasticity</td>
<td>4,400,000 psi</td>
<td>4,400,000 psi</td>
<td>4,400,000 psi</td>
</tr>
<tr>
<td>Load Transfer Coefficient</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Modulus of Subgrade Reaction (k)</td>
<td>100 psi/in.</td>
<td>194 psi/in.</td>
<td>100 psi/in.</td>
</tr>
<tr>
<td>Drainage Coefficient</td>
<td>0.8</td>
<td>0.9</td>
<td>0.8</td>
</tr>
<tr>
<td>Initial Serviceability</td>
<td>4.5</td>
<td>4.5</td>
<td>4.5</td>
</tr>
<tr>
<td>Terminal Serviceability</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Reliability</td>
<td>82%</td>
<td>97%</td>
<td>53%</td>
</tr>
</tbody>
</table>

#### 30 Year Design

<table>
<thead>
<tr>
<th></th>
<th>1000 AADT</th>
<th>2000 AADT</th>
<th>5000 AADT</th>
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<td>PCC thickness</td>
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<td>6&quot;</td>
<td>6&quot;</td>
</tr>
<tr>
<td>Rigid ESALS (5% trucks, 1% growth)</td>
<td>241,398</td>
<td>241,398</td>
<td>482,797</td>
</tr>
<tr>
<td>Overall Standard Deviation</td>
<td>0.35</td>
<td>0.35</td>
<td>0.35</td>
</tr>
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<td>Flexural Strength</td>
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</tr>
<tr>
<td>Reliability</td>
<td>91%</td>
<td>99%</td>
<td>69%</td>
</tr>
</tbody>
</table>

#### Reliability

- 15% increase in Reliability
- 31% increase in Reliability
- 30% increase in Reliability

---

**Tech Center**
Guidance for Improving PCC Pavement Performance

Factors:
- Age
- Drainage Coefficient ($C_d$)
- Coefficient of variation for $k$ & CBR
- Weak subgrade layer (CBR)
- Traffic
- Pavement thickness
- Subbase (if or if not)
Applications of Prediction Model

Critical Parameters

- Drainage Coefficient
- CBR
- Age
- k

PCI = 5.553 – 1.615 (Age) – 2.009 (CBR_{SG-Weak}) – 1.055 (COV of CBR_{SG-Weak}) + 205.907 (C_d) + 0.004 (AADT) – 1.055 (COV of k_{PSD-Corr}) – 2.395 (PCC Thickness) + a

[a = +6.89] if subbase is present and [-6.89] if subbase is not present
Guidance for Improving PCC Pavement Performance

PCI vs Age
500 AADT, 7" PCC, Prediction Model

- PCI Subbase (using avg field subbase Cd)
- PCI Subgrade (using avg field subgrade Cd)

10 YRS
Guidance for Improving PCC Pavement Performance

**PCI vs Age**

1000 AADT, 7" PCC, Prediction Model

- PCI Subbase (using avg field subbase Cd)
- PCI Subgrade (using avg field subgrade Cd)

9 YRS
- Performance measured by PCI
- Pavements with aggregate subbase are performing better than those without
<table>
<thead>
<tr>
<th>Subgrade Conditions</th>
<th>Approach &amp; Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet &amp; Unstable</td>
<td>Chemically treated soils</td>
</tr>
<tr>
<td></td>
<td>6” Cement Modified Soils = $4.35/ Sq.Yd.</td>
</tr>
</tbody>
</table>
|                                                                                  | 5” aggregate subbase = $6.00/ Sq.Yd.  
|                                                                                  | $10.35/ Sq.Yd.                                      |
|                                                                                  | After compaction, slightly wet & somewhat stable but |
|                                                                                  | will not pass proof rolling                          |
|                                                                                  | Dry out soil, place woven geotextile with           |
|                                                                                  | 5” aggregate subbase                                 |
|                                                                                  | Geotextile = $2.50/Sq.Yd.                           |
|                                                                                  | 5” aggregate subbase = $6.00/Sq.Yd.  
|                                                                                  | $8.50/Sq.Yd.                                        |
| After compaction, slightly wet & somewhat stable but will not pass proof rolling| CMS or Fly Ash $0.75/Sq.Yd/In; Aggregate $1.20 /Sq. Yd; |
| Meets moisture & density control and passes proof rolling                        | Non Woven geotextile                                 |
|                                                                                  | 5” aggregate subbase                                 |
|                                                                                  | $1.75/Sq.Yd.                                        |
|                                                                                  | $6.00/Sq.Yd.                                        |
|                                                                                  | $7.75/Sq.Yd.                                        |
Implementation

• CP Tech Center will develop an expanded User Guide and one-hour PowerPoint presentation for use at the Lunch Hour Forums.

• SUDAS will consider adding supplemental information to the Design Manual. Supplemental information may include:
  - the benefits of using aggregate subbase
  - improvement to the loss of support
  - improvement to drainage
  - increase in service life
Implementation

- Engineers need to examine their agency standard pavement foundation support system based on what long term level of service they want.

- If an agency feels they are reaching a desirable pavement design life - no change.
  - Engineer should be prepared to assign resources for pavement preservation
  - Will be above those required for improved foundation support system if they desire a high level of service
Thank you!

National CP Tech Center
www.cptechcenter.org/