Practical Conclusions from ODOT Research Projects

2008 Ohio Asphalt Paving Conference
ODOT Pavement Research

- 20 active research projects
  - Pavement Design
  - Pavement Rehabilitation
  - Pavement Management
  - Preventive Maintenance
Rational Approach to Base Type Selection

Truck/Pavement/Economic Modeling & In-Situ Field Data Analysis Application

FHWA/OH-2006/3A

Drs. Sargand, Wu, & Figueroa
Ohio University
Rational Approach to Base Type Selection

LOG-33-17.82

Figure 1 – Layer Configurations of Test Sections
Rational Approach to Base Type Selection

SHRP Test Pavement*
DEL-23-17.48

* 390 prefix has been omitted from this diagram

- Seasonal-Pavement Response
- Pavement Response
- SPS-1
- SPS-2
- SPS-8
- SPS-9
- No Instrumentation

S.B. RAMP
804 803 809 810
## Rational Approach to Base Type Selection

### Asphalt Concrete Studies

#### SPS-1

<table>
<thead>
<tr>
<th>Section</th>
<th>Thickness (in)</th>
<th>Base Thickness (in)</th>
<th>Base Type</th>
<th>Drain</th>
</tr>
</thead>
<tbody>
<tr>
<td>390101</td>
<td>7</td>
<td>8</td>
<td>DGA8</td>
<td>NO</td>
</tr>
<tr>
<td>390102</td>
<td>4</td>
<td>12</td>
<td>DGA8</td>
<td>NO</td>
</tr>
<tr>
<td>390103</td>
<td>4</td>
<td>8</td>
<td>ATB</td>
<td>NO</td>
</tr>
<tr>
<td>390104</td>
<td>7</td>
<td>12</td>
<td>ATB</td>
<td>NO</td>
</tr>
<tr>
<td>390105</td>
<td>4</td>
<td>8</td>
<td>4&quot;ATB/4&quot;DGAB</td>
<td>NO</td>
</tr>
<tr>
<td>390106</td>
<td>7</td>
<td>12</td>
<td>8&quot;ATB/4&quot;DGAB</td>
<td>NO</td>
</tr>
<tr>
<td>390107</td>
<td>4</td>
<td>8</td>
<td>4&quot;PATB/4&quot;DGAB</td>
<td>YES</td>
</tr>
<tr>
<td>390108</td>
<td>7</td>
<td>12</td>
<td>4&quot;PATB/8&quot;DGAB</td>
<td>YES</td>
</tr>
<tr>
<td>390109</td>
<td>7</td>
<td>16</td>
<td>4&quot;PATB/12&quot;DGAB</td>
<td>YES</td>
</tr>
<tr>
<td>390110</td>
<td>7</td>
<td>8</td>
<td>4&quot;ATB/4&quot;PATB</td>
<td>YES</td>
</tr>
<tr>
<td>390111</td>
<td>4</td>
<td>12</td>
<td>8&quot;ATB/4&quot;PATB</td>
<td>YES</td>
</tr>
<tr>
<td>390112</td>
<td>4</td>
<td>16</td>
<td>12&quot;ATB/4&quot;PATB</td>
<td>YES</td>
</tr>
<tr>
<td>390159</td>
<td>4</td>
<td>25</td>
<td>15&quot;ATB/4&quot;PCTB/6&quot;DGAB</td>
<td>YES</td>
</tr>
<tr>
<td>390160</td>
<td>4</td>
<td>15</td>
<td>11&quot;ATB/4&quot;DGAB</td>
<td>YES</td>
</tr>
</tbody>
</table>

#### SPS-8

<table>
<thead>
<tr>
<th>Section</th>
<th>Thickness (in)</th>
<th>Base Thickness (in)</th>
<th>Base Type</th>
<th>Drain</th>
</tr>
</thead>
<tbody>
<tr>
<td>390803</td>
<td>4</td>
<td>8</td>
<td>DGA8</td>
<td>NO</td>
</tr>
<tr>
<td>390804</td>
<td>7</td>
<td>12</td>
<td>DGA8</td>
<td>NO</td>
</tr>
</tbody>
</table>

#### SPS-9

<table>
<thead>
<tr>
<th>Section</th>
<th>Thickness (in)</th>
<th>Base Thickness (in)</th>
<th>Base Type</th>
<th>Drain</th>
</tr>
</thead>
<tbody>
<tr>
<td>390901</td>
<td>4</td>
<td>22</td>
<td>AC-20 12&quot;ATB/4&quot;PATB/6&quot;DGAB</td>
<td>YES</td>
</tr>
<tr>
<td>390903</td>
<td>4</td>
<td>22</td>
<td>PG-64-28 12&quot;ATB/4&quot;PATB/6&quot;DGAB</td>
<td>YES</td>
</tr>
<tr>
<td>390902</td>
<td>4</td>
<td>22</td>
<td>PG-58-28 12&quot;ATB/4&quot;PATB/6&quot;DGAB</td>
<td>YES</td>
</tr>
</tbody>
</table>
Rational Approach to Base Type Selection

<table>
<thead>
<tr>
<th>Section</th>
<th>Density (pcf)</th>
<th>Modulus (ksi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>390101</td>
<td>116.8</td>
<td>11.69</td>
</tr>
<tr>
<td>390102</td>
<td>124.6</td>
<td>20.37</td>
</tr>
<tr>
<td>390103</td>
<td>119.8</td>
<td>15.69</td>
</tr>
<tr>
<td>390104</td>
<td>119.7</td>
<td>16.85</td>
</tr>
<tr>
<td>390105</td>
<td>117.6</td>
<td>15.54</td>
</tr>
<tr>
<td>390106</td>
<td>123.4</td>
<td>17.88</td>
</tr>
<tr>
<td>390107</td>
<td>121.3</td>
<td>16.76</td>
</tr>
<tr>
<td>390108</td>
<td>117.4</td>
<td>18.95</td>
</tr>
<tr>
<td>390109</td>
<td>119.7</td>
<td>11.51</td>
</tr>
<tr>
<td>390110</td>
<td>118.0</td>
<td>12.95</td>
</tr>
<tr>
<td>390111</td>
<td>121.3</td>
<td>18.08</td>
</tr>
<tr>
<td>390112</td>
<td>121.9</td>
<td>13.82</td>
</tr>
<tr>
<td>390159</td>
<td>118.9</td>
<td>5.77</td>
</tr>
<tr>
<td>390160</td>
<td>123.1</td>
<td>18.63</td>
</tr>
<tr>
<td>Average</td>
<td>120.3</td>
<td>15.32</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>2.4</td>
<td>3.87</td>
</tr>
<tr>
<td>CV</td>
<td>2%</td>
<td>25%</td>
</tr>
</tbody>
</table>
Rational Approach to Base Type Selection

390108 4”PATB/8”DGAB

Moisture Content (%) vs. Year

- 0.2
- 0.8
- 1.6
Rational Approach to Base Type Selection

<table>
<thead>
<tr>
<th>Depth below subgrade surface</th>
<th>Median Moisture Content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>section</td>
<td>base type</td>
</tr>
<tr>
<td>101</td>
<td>DGAB</td>
</tr>
<tr>
<td>104</td>
<td>ATB</td>
</tr>
<tr>
<td>108</td>
<td>PATB/DGAB</td>
</tr>
<tr>
<td>110</td>
<td>ATB/PATB</td>
</tr>
<tr>
<td>112</td>
<td>ATB/PATB</td>
</tr>
</tbody>
</table>
Rational Approach to Base Type Selection

- Subgrade moisture is not necessary from the surface
- Subgrade density meets specification does not assure uniform subgrade strength
- Base types do not affect subgrade moisture content
Rational Approach to Base Type Selection

Purpose of base
- Construction platform
- Add protection against frost action
- Increase load-supporting capacity of the pavement by providing added stiffness
- Distribute load
- Provide drainage
Rational Approach to Base Type Selection

<table>
<thead>
<tr>
<th></th>
<th>Permeability (ft/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>304</td>
</tr>
<tr>
<td>Fine</td>
<td>206</td>
</tr>
<tr>
<td>Median</td>
<td>1417</td>
</tr>
<tr>
<td>Coarse</td>
<td>5443</td>
</tr>
</tbody>
</table>
Rational Approach to Base Type Selection

LOG-33 Free Draining Bases

- Normalized df1 (mils/kip)
- Station

Graph showing data for different bases (ATFDB, CTFDB, 307NJ, 307IA, 304) over a range of stations from 900 to 1150.
Rational Approach to Base Type Selection

Free Draining Bases, LOG-33

Year
PSI

Rational Approach to Base Type Selection

![PCR, LOG-33](chart)

Year:
- 1994
- 1998
- 1999
- 2000
- 2001

PCR:
- 304
- 307 IA
- 307 NJ
- ATFDB
- CTFDB
CTFDB had much higher $M_R$ than other bases
NJ, IA, 304 about equal
ATFDB had the lowest $M_R$
Roughness – all sections generally similar
Pavement condition – all sections generally similar
  - Decline in rating for ATFDB in 2001
ATFDB cores showed evidence of some stripping of asphalt from aggregate
March, 2001 moratorium on free draining bases.
Rational Approach to Base Type Selection

Free Draining Bases, ERI/LOR-2

Average Number of Transverse Cracks per Slab

Year


CTFDB, 13' section overlaid

304, 13'

307 type IA, 13'

307 type NJ, 13'

ATFDB, 13'

310, 13'

304, 25'

CTFDB, 25'

307 type IA, 25'

307 type NJ, 25'

ATFDB, 25'

310, 25'
Rational Approach to Base Type Selection

- Average
- Maximum
- Minimum

Granular Base Thickness (in) vs. Deflection D0 (mm/9 kips)
Rational Approach to Base Type Selection
Rational Approach to Base Type Selection

Deflection Reduction (mm)

Underneath (D0 in mm)

-0.5 0 0.5 1 1.5 2 2.5 3 3.5

-0.5 0 0.5 1 1.5 2 2.5 3

on SG

on GB
Rational Approach to Base Type Selection

- GB > 200mm (8”) increase subgrade stiffness and uniformity
- Thicker GB increase both stiffness and uniformity
- ATB of 200mm (8”) thick is much more uniform than 100 mm (4”)
Rational Approach to Base Type Selection

Summary

1. Base type has little impact on subgrade moisture and initial pavement performance
2. Choice of base type depends chiefly on three requirements
   - appropriate stiffness
   - sufficient permeability
   - good constructability
Rational Approach to Base Type Selection

- **Recommendations**
  - For uniformly weak or highly variable subgrades, bases with high stiffness or very thick granular base is recommended. Soil stabilization may be used to improve subgrade stiffness.
  - For strong, uniform subgrades, granular base and ATB are suitable choices.
Rational Approach to Base Type Selection

- Technical Notes Published
  - Evaluation of Base Materials under Flexible Pavement (ORITE-8)
    - LOG 33
  - Pavement Design Feature Effects on Subgrade Volumetric Moisture Content (ORITE-9)
    - DEL 23
Fractured Slab Techniques – Break & Seat

Effectiveness of Breaking and Seating of Reinforced PCC Pavement before Overlay  FHWA/OH-95/023
Long Term Monitoring of Broken and Seated Pavement
  FHWA/OH-2002/024
  Drs. Minkarah and Arudi
  University of Cincinnati
Investigation of Pavement Cracking on SR4 and Demonstration of the Multihead Breaker in Fracturing Reinforced Concrete Pavement before Asphalt Overlay  FHWA/OH-2006/12
  Dr. Arudi
  Inframe
FHWA Special Project 202
Fractured Slab Techniques – Break & Seat

- Major rehabilitation technique for jointed reinforced concrete pavement
  - break pavement into small slabs (18”)
  - retards reflective cracking
- 1992 moratorium on break & seat
  - non uniform break pattern
  - partial debonding of steel
Fractured Slab Techniques – Break & Seat

- Special Project 202
  - MUS-70
    - control, 6” pattern, 18” pattern, 30” pattern
    - guillotine pavement breaker
    - 7” asphalt overlay on all sections
    - constructed in 1991
Fractured Slab Techniques – Break & Seat

- University of Cincinnati & Inframe studies
  - FAY/MAD-71
    - control, 18” break pattern
    - guillotine pavement breaker
    - 8 ½” asphalt overlay on all sections
    - constructed in 1992
  - GRE/MOT-4
    - control, 18” break pattern
    - pile hammer pavement breaker
    - 6 ½ “ asphalt overly on all section
    - constructed in 1993
Fractured Slab Techniques – Break & Seat

Special Project 202, Transverse Cracking

% of Joints & Working Cracks

Date


Control
• 6” Pattern
• 18” Pattern
• 30” Pattern

0%
20%
40%
60%
80%
100%
120%
Fractured Slab Techniques – Break & Seat

Special Project 202, High Severity Cracking

<table>
<thead>
<tr>
<th>Date</th>
<th>Control</th>
<th>6” Pattern</th>
<th>18” Pattern</th>
<th>30” Pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aug-91</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dec-91</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aug-92</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dec-92</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aug-93</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dec-93</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aug-94</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dec-94</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aug-95</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dec-95</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aug-96</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dec-96</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apr-96</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aug-96</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dec-97</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apr-97</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

% of Joints and Working Cracks vs Date
Reflective Cracking: I-71 & SR 4

<table>
<thead>
<tr>
<th>Section</th>
<th>Control</th>
<th>B&amp;S</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-71 SB</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SR-4 NB</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SR-4 SB</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

% Joints/Repairs Reflected vs Age (years).
Fractured Slab Techniques – Break & Seat
Fractured Slab Techniques – Break & Seat

- MHB and Pile Hammer do not produce a uniform breaking pattern throughout the depth of concrete slab
- Considerable variability exists in the extent of breaking
- Steel debonding is not consistent
- After 11 years being in service, most of the joints on SR-4 B/S sections reflected; however, their severity is NOT as extensive as that of control sections
Fractured Slab Techniques – Break & Seat

Rehabilitation Performance Trends

PCR

Age (years)

Log. (UBCO)
Log. (New Rigid)
Log. (B&S / C&S)
Log. (R&R)
Log. (Rep & OL)
Log. (New Flex)
Fractured Slab Techniques – Break & Seat

- Not recommended as a major rehabilitation for JRCP in Ohio
- Not recommended for high type routes
- Viable for minor rehabilitation
- Guillotine hammer is not recommended for breaking the pavement
- A minimum overlay thickness of 6” is recommended
Perpetual Pavement

This map is taken from Ohio DOT website
Perpetual Pavement
Perpetual Pavement
Perpetual Pavement

Surface: High Performance
Base: Economical & Durable
Fatigue Resistant Layer

Maximum Tensile Strain for Fatigue Crack
Tensile Strain $< 70$ me
# Design Input: Material’s Properties

<table>
<thead>
<tr>
<th>Material</th>
<th>E (psi)</th>
<th>PR</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMA</td>
<td>500,000</td>
<td>0.35</td>
</tr>
<tr>
<td>19 mm SUPERPAVE</td>
<td>500,000</td>
<td>0.35</td>
</tr>
<tr>
<td>Intermediate (302)</td>
<td>500,000</td>
<td>0.35</td>
</tr>
<tr>
<td>Fatigue Resistant Layer (302)</td>
<td>500,000</td>
<td>0.35</td>
</tr>
<tr>
<td>Aggregate Base (304)</td>
<td>20,000</td>
<td>0.40</td>
</tr>
<tr>
<td>Subgrade</td>
<td>CBR = 4, 5, and 6</td>
<td>0.45</td>
</tr>
</tbody>
</table>
## Perpetual Pavement

<table>
<thead>
<tr>
<th>Thickness (inches)</th>
<th>Material</th>
<th>Design Air Voids (%)</th>
<th>PG Binder</th>
<th>Target Density (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.50</td>
<td>(443) Stone Matrix Asphalt Concr, 12.5mm</td>
<td>3.5</td>
<td>76-22M</td>
<td>93-97</td>
</tr>
<tr>
<td>1.75</td>
<td>(442) Asphalt Concrete Inter. Course, 19mm Type A</td>
<td>4.0</td>
<td>76-22M</td>
<td>93-97</td>
</tr>
<tr>
<td>9</td>
<td>(302) Asphalt Concrete Base</td>
<td>4.5</td>
<td>64-22</td>
<td>93-96</td>
</tr>
<tr>
<td>4</td>
<td>(302) Special Fatigue Resistant Base Layer</td>
<td>3.0</td>
<td>64-22</td>
<td>94-97</td>
</tr>
<tr>
<td>6</td>
<td>(304) Aggregate Base</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Perpetual Pavement

5 mph Test: ODOT 28.2 Kip Single Axle Truck, December, 2005

Longitudinal Strain

Time (sec)

Strain (ue)

3 5 7 9 11

-10 0 5 10 15 20 25 30 35
Perpetual Pavement

Longitudinal Strain in Fatigue Resistance Layer -- Single Axle 20.5 kip 25 mph
AC 876A - Run 3 07/18/2006

Time (sec) vs. Strain (µε)
Perpetual Pavement

Longitudinal Strain in Fatigue Resistance Layer --
Single Axle 20.5 kip 25 mph - AC 876B - Run 3 07/18/2006

Strain (µε) vs Time (sec)

DYN-009
DYN-013
DYN-015
DYN-016
Perpetual Pavement
Perpetual Pavement

Cores Taken from Sites with NO Segregation

Resilient Modulus (ksi)

500 ksi used in Design

Cores Taken from Sites with NO Segregation
Perpetual Pavement

Cores from WAY-30 Segregated Section

Resilient Modulus (ksi)

0 250 500 750 1000

1 2 3 4 5 6 7 8 9 10

Cores from WAY-30 Segregated Section
Perpetual Pavement

Indirect Tensile Strength (psi)

<table>
<thead>
<tr>
<th></th>
<th>Fine Mix</th>
<th>Coarse Mix</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>150</td>
<td></td>
<td></td>
</tr>
<tr>
<td>200</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4” Cores from WAY-30 Segregated Section
Perpetual Pavement
Perpetual Pavement

- Tensile Strain at the Bottom (microstrain)
  - Complete Pavement: 57 microstrain
  - FRL only: 342 microstrain
Perpetual Pavement

**Typical Fatigue (S-N) Diagram**

- **Un-C**: 34 kip on complete pavement
- **Un-I**: 34 kip on FRL
- **SBS-C**, **SBS-I**, **SBS-F**

**Number of Cycles to Failure**

- $1 \times 10^3$ to $1 \times 10^{10}$

**Fatigue Limit**
Research Reports

http://www.dot.state.oh.us/research/default.asp

roger.green@dot.state.oh.us