Introduction to Asphalt Pavement Design and Specifications
Ensuring Good Performance in Flexible Pavement Design and Construction:

accomplished through:

1. Proper structural (thickness) design for the existing soil, anticipated loads and existing pavement condition for overlays.

2. Optimum number of layers to facilitate stability, smoothness and economy.

3. Selection of the appropriate mix types for each of the layers to achieve stability, smoothness and economy.

4. Construction that complies with or exceeds the specifications for uniformity, smoothness and compaction (QC/QA and FQCS).
Goals of Flexible Pavement Design and Construction:

• **Structure** - Provide a structure that has adequate strength to distribute the wheel loads to the soil without undue deflection, compaction or consolidation.

• **Surface** - Provide a surface that is adequately stable so as to not deform under traffic load, is weather resistant, has adequate skid resistance, is adequately smooth and is sufficiently wear resistant.
Function of the Pavement Structure
Designer’s Role

Adequate Structural Design: Asphalt/aggregate thickness adequate for:

- Soil type and drainage
- Expected loads, construction and long term
- Climate conditions

Specifying appropriate combination of mix types, number of layers and layer thicknesses for:

- Loads and speeds
- To provide smoothness and economy
ODOT Construction and Material Specifications (CM&S)

• As modified in SS 800 – current revision
• New edition for 2013
Section 200, Pavement Design Concepts
  300, Rigid Pavement Design
  400, Flexible Pavement Design contains instructions on thickness design, proper mix applications and layer build-ups.
  500, Minor Rehabilitation
Various Structural Design Methods

- AASHTO 93 (DARWin 3.1)/ODOT method (empirical)
- Asphalt Institute methods, SW-1 software (mechanistic/empirical)
- PerRoad software (mechanistic for perpetual pavement design)
- AASHTO MEPDG (DARWin-ME v.2.0)
- Design catalogs
Overview of Asphalt Concrete Pavement Design

- **Design Factors — all design methods**
  - Traffic Loading (heavy trucks)
  - Soil Subgrade Strength
  - Pavement Materials Characteristics
    (strengths of materials comprising the pavement build-up – layer coefficients)
  - Environmental Conditions (Its effect on soil and pavement material strength)
Design Considerations

The method of design provided in the AASHTO 93 Guide includes consideration of the following items:

- Pavement performance,
- Traffic,
- Roadbed soil,
- Materials of construction
- Environment,
- Drainage,
- Reliability,
- Standard deviation

Understanding how to select appropriate input values is necessary for the use of the AASHTO 93 design method or any other design method.
Design Considerations -

**Pavement performance** –

**STRUCTURAL PERFORMANCE** - The expectation of the pavement thickness to provide sufficient structural strength to sustain the traffic loads over the performance period;

**FUNCTIONAL PERFORMANCE** - The expectation of the level of “service” a pavement type will provide to the road user over its life. The dominant component of serviceability is riding comfort or ride quality. Safety is also a consideration.
Pavement performance (continued) – AASHTO Guide...“The serviceability-performance concept is based on five fundamental assumptions, summarized as follows:

- Highways are for the comfort and convenience of the travelling public (User)
- Comfort or riding quality, is a matter of subjective response or the opinion of the User.
- Serviceability can be expressed by the mean of the ratings given by all highway Users and is termed the serviceability rating.
- There are physical characteristics of a pavement which can be measured objectively and which can be related to subjective evaluations. This procedure produces an objective serviceability index.
- Performance can be represented by the serviceability history of a pavement.”
• AASHTO Eqn. Thickness Design Inputs

• **Loss of Serviceability** ($\Delta PSI$) – the amount of serviceability (riding comfort) the agency will tolerate losing before rehabilitation is needed.
Overview of Asphalt Concrete Pavement Design

• **Initial Serviceability**
  • (PSI 4.5 for HMA, 4.2 for PCC)

• **Terminal Serviceability**
  • (PSI 2.5)

\[ \Delta \text{PSI} = P_o - P_t \]
Overview of Asphalt Concrete Pavement Design

• Reference: AASHTO Guide

<table>
<thead>
<tr>
<th>Terminal Serviceability Level ($P_t$)</th>
<th>Percent of People Stating Unacceptable</th>
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<tr>
<td>3.0</td>
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<tr>
<td>2.5</td>
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<td>2.0</td>
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Overview of Asphalt Concrete Pavement Design

- Reference: ODOT Pavement Design Guide

<table>
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<th>SERVICEABILITY FACTORS</th>
<th>RIGID/COMPOSITE</th>
<th>FLEXIBLE</th>
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<tr>
<td>Initial Serviceability</td>
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<td>4.5</td>
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<tr>
<td>Terminal Serviceability</td>
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<tr>
<td>Design Serviceability Loss</td>
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Design Considerations - Traffic

– consists of the amount, type and weight of vehicles that are expected to use the roadway. Only truck use of a roadway facility is considered since it is these types of vehicles that are sufficiently heavy to damage the pavement.
AASHTO Eqn. Thickness Design Inputs

**Performance Period** (years) –

- *The period of time used in determining pavement thickness and as the basis for forecasting future traffic loads;*
- *In Ohio, typically assumed to be 20 years in length.*
Equivalent Single Axle loads

- Damage (ESAL) is a non-linear relationship to weight on the axle.

Axle load equivalency factor (axle configuration dependent)

\[ \text{ESALs} = 0.49 \]

\[ \text{ESALs} = 2.39 \]

\[ \text{ESALs} = 0.49 \]

\[ \text{ESALs} = 2.39 \]
AASHTO Eqn. Thickness Design Inputs

**Traffic Loading** Over the Performance Period

- Measured in **Equivalent** 18,000 lb. **Single Axle Loads** (ESAL or $W_{18}$);
- ESAL is a means by which the pavement damage caused by different axle configurations and truck weights are **normalized**;
- For determining the pavement thickness use the accumulated ESALs over the Performance Period.
Overview of Asphalt Concrete Pavement Design

- **Traffic Loading** (continued)
  - Consider directional distribution of heavy trucks (i.e. is the truck traffic consistent both directions? If no, design for direction with heaviest traffic.)
  - Lane Factor – for multilane pavements design the thickness based on the lane that carries the greatest number of trucks.
Overview of Asphalt Concrete Pavement Design

**Traffic Loading**
- ODOT Pavement Design Guide, Sec. 200
  - \[ B\text{-ESALs} = ADT \times \%T_{24} \times \%D \times \%LF \times \%B \times CF \]
  - \[ C\text{-ESALs} = ADT \times \%T_{24} \times \%D \times \%LF \times \%C \times CF \]
  - \[ B\text{-ESALs} + C\text{-ESALs} = \text{Total Daily ESALs} \]

- ADT = Average Daily Traffic
- \%T_{24} = 24-hour truck percentage of ADT
- \%D = Directional Distribution
- \%LF = Lane Factor (percent trucks in the design lane)
- \%B,C = % B (tractor trailer) or %C (straight body) trucks of the total trucks
- CF = Truck conversion factor (ESALs per truck) based on
  - Functional Classification of the Roadway
Design Considerations – Soil, subgrade

- roadbed soil is the foundation on which the pavement will be constructed. Soil strength must be known such that the pavement thickness is sufficient to spread the load induced by heavy vehicles on the soil without the soil deforming (rutting).

A mistake on soil strength can be expensive – correcting the soil condition by change order or, worse, premature failure.

Conduct an adequate soils investigation!
Overview of Asphalt Concrete Pavement Design

• **AASHTO Eqn. Thickness Design Inputs**
  • Performance Period (years)
  • **Soil Strength** –
    o AASHTO uses resilient modulus ($M_r$) as
      • the measure of soil strength,
      • accounting for seasonal variation in soil strength;
    o ODOT utilizes Group Index and
      • correlates to California Bearing Ration (CBR). A multiplier is used to estimate
        • “effective” resilient modulus, $EM_r$
    o ($EM_r = CBR \times 1200$)
Design Considerations – environmental and drainage conditions

- addresses the impact of environment on foundation/subgrade strength.
  Seasonal impacts of wet, dry, freeze, non-freeze environments will affect strength of soil and non-stabilized materials (e.g. crushed stone base).

Drainage (or lack thereof) impacts foundation/subgrade strength, and as such, impacts the pavement thickness. Saturated soil is weaker than dry soil. Weak soils require greater thickness.

ODOT always assumes that drainage will be provided in all pavement build-ups.
Design Considerations – materials

the types of materials that will be used in the pavement buildup (asphalt, concrete, crushed stone, rubblized base, etc.) their respective thickness and strengths.

In the AASHTO design method pavement material strengths are represented by layer coefficients that relate the contribution of various materials to satisfying the structural number required.
Overview of Asphalt Concrete Pavement Design

• Reference: ODOT Pavement Design Guide, Plate 401-1

<table>
<thead>
<tr>
<th>Asphalt Concrete Structural Coefficients ($a_i$)</th>
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<tr>
<td>Items 424, 442, 443, 446, 448, 826, 857, 859, 874 — AC Surface</td>
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<td>Items 442, 443, 446, 448, 826, 857 — AC Intermed.</td>
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<td>Items 301, 302 AC Base Course.</td>
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<td>Item 304 — Aggregate Base</td>
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<tr>
<td>Item 320 — Rubblized Concrete</td>
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Design Considerations – reliability

Provides consideration of uncertainties in both traffic predictions and performance predictions. Reliability is used as a safety factor. A higher level of reliability is used in the design computations when greater assurance is needed that the pavement will not fail during its life.
AASHTO Eqn. Thickness Design Inputs

- **Overall Standard Deviation** (variability) –
  - accounts for the chance variation in the traffic prediction and chance variation in actual performance.
AASHTO Eqn. Thickness Design Inputs

- ALWAYS USE THE AVERAGE CONDITION/VALUE for the design!
- USE “RELIABILITY” AS THE MEANS BY WHICH A SAFETY FACTOR IS INCLUDED.
- USING CONSERVATIVE INPUTS AND A HIGH RELIABILITY RESULTS IN EXCESSIVELY THICK PAVEMENTS.
• Overview of Asphalt Concrete Pavement Design

• DETERMINE Structural Number (SN) using AASHTO Equation/nomograph

SN is an abstract number (SN) that represents the structural strength required for a pavement to perform in accordance with the design criteria.

• Definitions, values and an example in the ODOT Pavement manual at http://www.dot.state.oh.us/Divisions/Engineering/Pavement/Pages/Publications.aspx
AASHTO Equation for the design of flexible pavements.

\[ \log_{10}(W_{18}) = Z_R \times S_0 + 9.36 \times \log_{10}(SN + 1) - 0.20 + \log_{10}\left[\frac{4.2 - 1.5}{1094} + \left(\frac{0.40 + \frac{1094}{(SN + 1)^{5.19}}}{\log_{10}(MR)}\right) - 8.07\right] \]
Flexible Pavement Design Chart
Segment 1

Match Line (See 402.3)

Effective Modulus of Susceptible Soils, kPa

Estimated Total Wt./ft. Equivalent
Single axle tandem (ESAL) applications

Reliability, %
"LAYERED DESIGN ANALYSIS"
DETERMINE THE MAXIMUM ALLOWABLE THICKNESS OF EACH UNBOUND LAYER (i.e. aggregate layer), AND DETERMINE THE MINIMUM Thickness of the asphalt layer.

REASON: WE WANT TO AVOID OVER-BENDING THE ASPHALT LAYER — CAUSING IT TO FATIGUE — AND AVOID PUTTING THE AGGREGATE LAYER INTO TENSION (WHY? The strength of the aggregate base layer comes only when it is in compression.)
Introduction to Contract Specifications

• Project dimensions & course thickness
• Item specification under which material will be placed
• Description of material
• Traffic designation
• Grade of binder
• Item quantity
• Language for specifying HMA composition
• Method & point of acceptance
Familiarization with ODOT Asphalt Concrete Specifications

• Use ODOT specs for uniformity and economy – most producers and many contractors are already familiar with ODOT specifications

• ODOT specs must be adapted for use by other agencies
Specification Type

- ODOT “Pay Items” 448, 446 and others refer to acceptance requirements and cross reference other specifications for mix design and construction requirements.
- 448 – Indicates plant QC testing and acceptance and requires density gage testing for uniform courses >1”
- 446 – Indicates both plant QC testing and acceptance based on density testing with cores.
Mix Types

• Referenced in the specifications define the aggregate gradation and mix design parameters

• Type I – Common type of mix used on many surface courses. Coarse aggregates < ½ inch

• Type II – Common type of mix used on many intermediate Courses. Coarse aggregate < ¾ inch
Item Description Example

448, Asphalt Concrete Surface Course, Type 1, medium traffic, PG 64-22
Performance Graded binders

- originated from SHRP research

- performance related, cracking and rutting resistance at high and low pavement temperature

- example: PG 64-22 is tested to perform adequately at a high pavement temperature of 64 degrees Celsius (147F) and at a low pavement temperature of minus 22 degrees Celsius (-8F)
Binder Grade applications

- PG 64-22 (similar to old AC-20) is the most common liquid used in Ohio
- PG 64-28 (default grade for heavy traffic design intermediate courses)
- PG 58-28 (used for blending high RAP mixes)
- PG 70-22M – (polymer modified grade for heavy traffic mixes)
- PG 76-22M (polymer modified graded for high stress applications)
Why know these concepts?

The designer must select and specify an appropriate mix type for each application on the project.

The contractor is required to design and obtain approval of a Job Mix Formula for each mix specified to be used on a project.
Job Mix Formula (JMF)

Think of an asphalt mix as a “recipe”. The ingredients are a combination of aggregates and liquid asphalt binder mixed in an asphalt plant and designed to specific test requirements.

Another word for the recipe – **Job Mix Formula** (JMF)

- Every Mix must have an approved JMF Developed by contractor’s Lab
- Given a specification, The producer must develop a JMF using standard test methods to achieve specification requirements
- Once developed in lab, the JMF used at the plant to produce mix meeting the specifications

Let’s review a Typical **Job Mix Formula**
### AC Content Determination

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<tr>
<th>Sieve</th>
<th>% Passing</th>
<th>AC Content @ Max Unit Weight</th>
<th>AC Content @ Median Voids</th>
<th>AC Content @ Max Stability</th>
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<td>2&quot;</td>
<td></td>
<td></td>
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<tr>
<td>3/8&quot;</td>
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**Optimum AC Content:** 4.9

*Consult applicable spec for method of optimum determination*

**Constituent Analysis**

<table>
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<th>Coarse Aggregate</th>
<th>Type</th>
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<td>American &amp; Buckeye, OH</td>
<td>####</td>
</tr>
<tr>
<td>20</td>
<td>#8</td>
<td>Notre Dame Agg &amp; Heaven, OH</td>
<td>####</td>
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</table>

<table>
<thead>
<tr>
<th>Fine Aggregate</th>
<th>Type</th>
<th>Producer/Location</th>
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<td>30</td>
<td>Sand</td>
<td>Fighting Irish &amp; Neville, OH</td>
<td>####</td>
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<tr>
<td>10</td>
<td>Sand</td>
<td>Notre Dame Agg &amp; Heaven, OH</td>
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</table>

**Recycle**

| Description |%
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</table>

*If taken from state route enter state route and project*

*If non-state route enter size, type and source/loc of fine and coarse aggregate -- also source of information.*

**AC at Optimum AC Content:**

\[
\text{STAB: } 15\% \quad \text{F: } 4.1 \quad \text{VA: } 0.4 \quad \text{VMA: } 139 \quad \text{UNIT WT: } 1.944 \quad \text{Ivy}
\]

**Max Theo:** 2.403

**Design:** 3PT

**Median Air Voids:** X

**Orig. Rec:** 5-10-96

**Resubmit Rec.**

**Date Approved:** 5-18-96

**JMF:** B####

**Calibration #:** #######
Typical Pavement Build-up

- 441, Type 1, 442 etc.
- 441 Type 2, 442 etc.
- 301, 302
- 304 on Prepared Subgrade, item 204 and 206
The ODOT Pavement Design Manual, Section 400, Flexible Pavement Design, contains guidance on appropriate mix applications and layer build-ups for various applications.
Specifying Hot Mix Asphalt (HMA) Pavements in Ohio
