



MICHIGAN DOT PAVEMENT DESIGN

Justin Schenkel, P.E.

Michigan Department of
Transportation



7/23/2020

OUTLINE

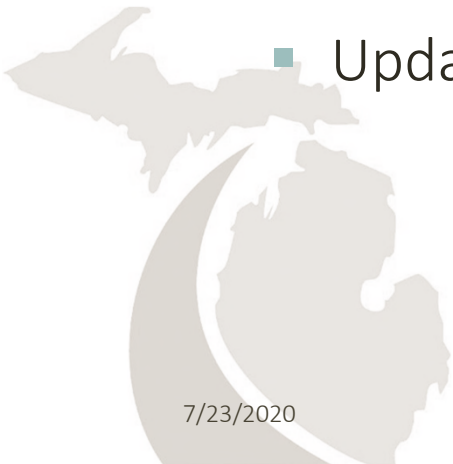
- ❑ AASHTO 1993 design method
(OLD)
- ❑ Mechanistic-Empirical (ME)
design method
(NEW)



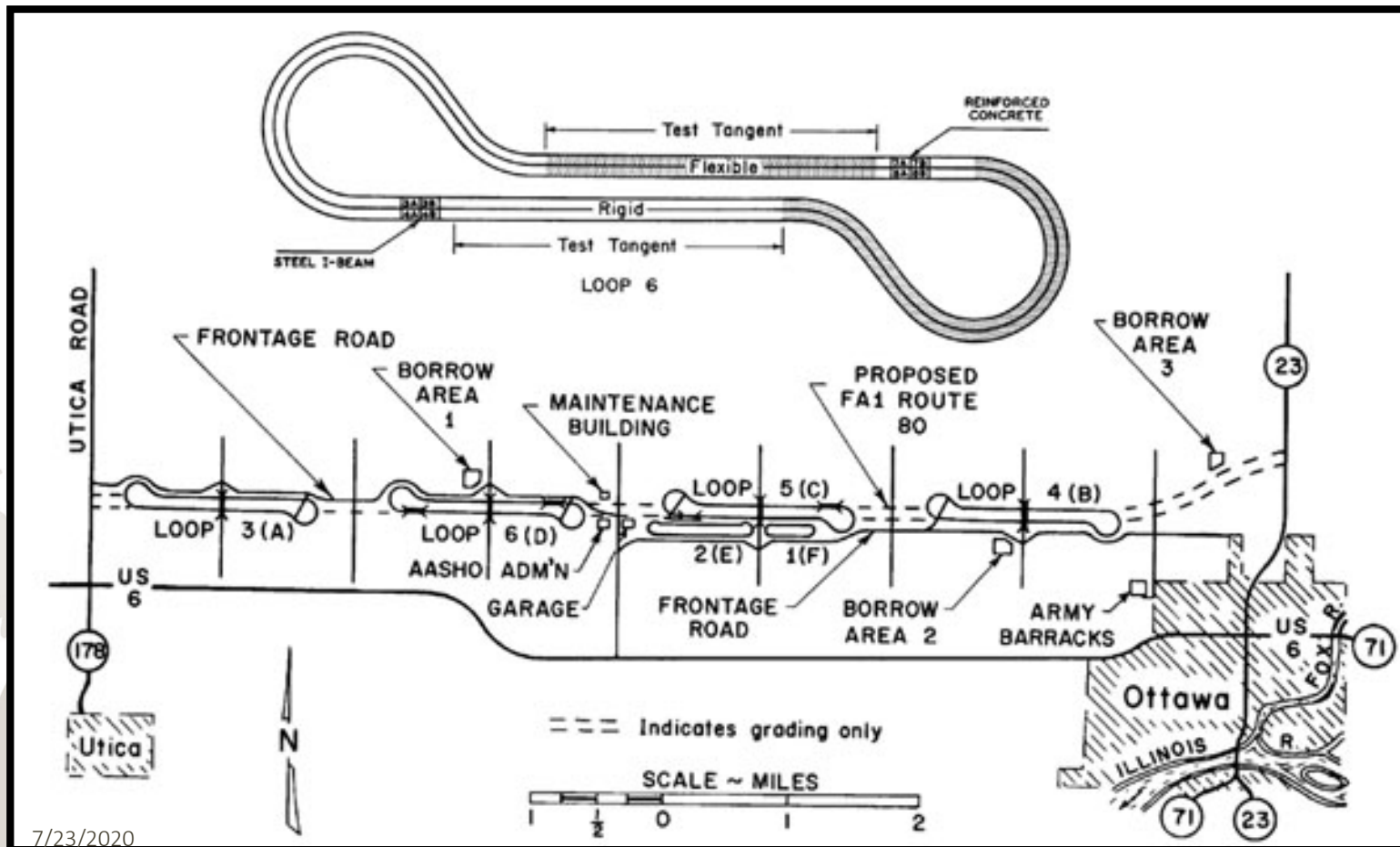
AASHTO 1993 DESIGN METHOD *(OLD)*

AASHTO93 DESIGN METHOD (OLD)

- ❑ *AASHTO 1993 Guide for Design of Pavement Structures*
 - From AASHO Road Test in 1958-1960 in Ottawa, IL
 - Empirical test
 - Interim design method in 1961
 - Official design method in 1972
 - Updates in 1986, 1993, 1998 (PCC only)



AASHTO93 DESIGN METHOD (OLD)



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AASHTO93 DESIGN METHOD (OLD)

Thickness design from an equation:

Flexible

$$\log(W_{18}) = Z_R \cdot S_0 + 9.36 \cdot \log(SN + 1) - 0.20 + \frac{\log \frac{\Delta PSI}{4.2 - 1.5}}{0.4 + \frac{1094}{(SN + 1)^{5.19}}} + 2.32 \cdot \log(M_R) - 8.07$$

Where:

- W_{18} = Equivalent single axle loads (ESAL's)
- Z_R = Reliability
- S_0 = Standard deviation
- SN = Structural number (total for all layers)
- ΔPSI = Change in serviceability
- M_R = Resilient modulus of the subgrade

- *We are solving for SN (which will be used to determine thickness, see slide # 11)*

AASHTO93 DESIGN METHOD (OLD)

Thickness design from an equation (continued):

□ Rigid

$$\log_{10}(W_{18}) = Z_R S_0 + 7.35 \log_{10}(D + 1) - 0.06$$

$$+ \frac{\log_{10}\left(\frac{\Delta\text{PSI}}{4.5 - 1.5}\right)}{1 + \frac{1.64 \times 10^7}{(D + 1)^{8.45}}} + (4.22 - 0.32 p_t) \log_{10}\left[\frac{S_c C_d (D^{0.75} - 1.132)}{215.63 J \left(D^{0.75} - \frac{18.42}{(E_c / k)^{0.25}}\right)}\right]$$

■ *We are solving for D
(which is thickness)*

■ Where:

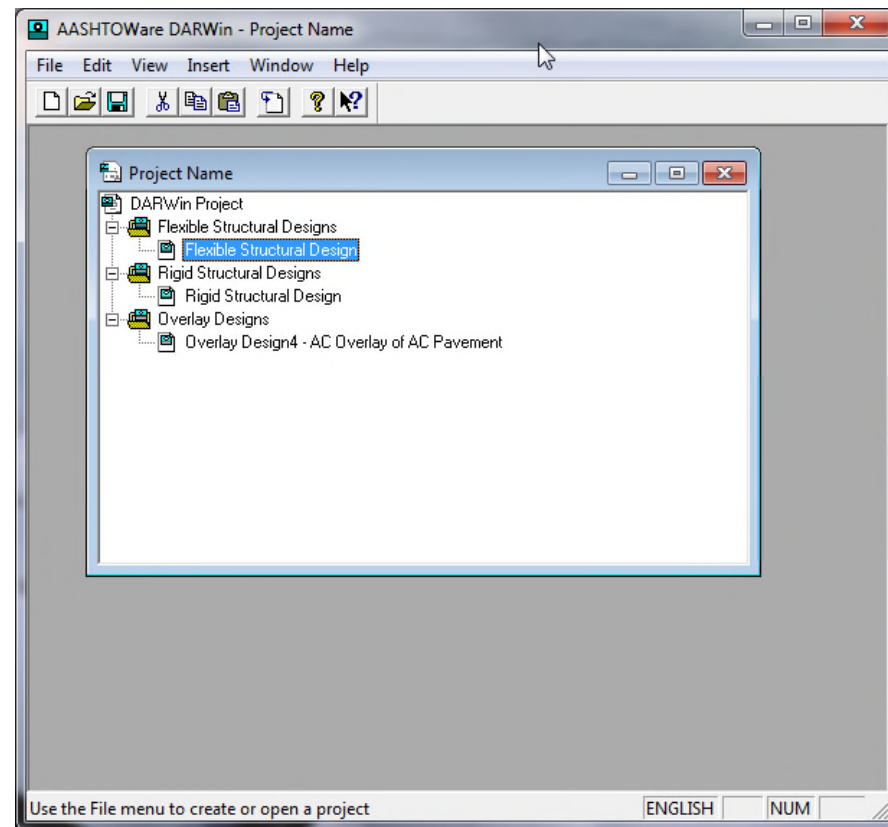
- W_{18} = Equivalent single axle loads (ESAL)
- Z_R = Reliability
- S_0 = Standard deviation
- D = thickness (of the concrete)
- ΔPSI = Change in serviceability
- p_t = Terminal serviceability
- S_c = Modulus of Rupture
- C_d = Drainage coefficient
- J = Load transfer coefficient
- E_c = Modulus of elasticity
- k = Effective modulus of subgrade reaction

AASHTO93 DESIGN METHOD (*OLD*)

DARWin

(Design, Analysis, and Rehabilitation for Windows)

- ❑ 2004 software
- ❑ Based on AASHTO93 design method
- ❑ Solves for previous equations



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AASHTO93 DESIGN METHOD (OLD)

- Typical Hot Mix Asphalt (HMA) inputs
 - Projected ESAL's = Equivalent Single Axle Loads
 - Measure of total damage an axle load does to a pavement in relation to an 18,000 pound axle
 - Is a total derived from the design life (see slide # 20-24)
 - Requested from the Bureau of Transportation Planning.
 - Submit Traffic Analysis Request (TAR) – Form 1730
 - Initial Serviceability = 4.5
 - Terminal Serviceability = 2.5
 - Reliability = 95%
 - Overall Standard Deviation = 0.49

AASHTO93 DESIGN METHOD (OLD)

□ Typical HMA inputs (*continued*)

■ Roadbed Soil (aka subgrade) M_R = Resilient Modulus

- Measure of subgrade material stiffness (psi)
 - MDOT typical values: ~3000 to 5000 psi
- Stress/strain for rapidly applied load
- Estimated by the Region Soils Engineer from:
 - Falling Weight Deflectometer backcalculation
 - Soils identification and known correlations

■ Stage Construction = 1

□ Result is a **Design Structural Number (SN)** that the pavement structure must have to support the projected number of ESAL's over it's life

AASHTO93 DESIGN METHOD (OLD)

□ $SN = a_1d_1 + a_2d_2m_2 + \dots + a_nd_nm_n$

▪ Where

- a = layer structural coeff.
- d = layer thickness
- m = layer drainage coeff.

□ HMA Structural Coefficients (a)

- HMA Top & Leveling Course = 0.42
- HMA Base Course = 0.36
- Cement Stabilized Base = 0.26
- ASCRL = 0.30
- Asphalt/Emulsion Stabilized Base = 0.20
- Crush and Shaped HMA = 0.20
- Rubblized Concrete = 0.18
- Dense-Graded Aggregate Base = 0.14
- Open-Graded Aggregate Base = 0.13
- Sand Subbase = 0.10

□ Drainage Coefficients (m)

- All Layers = 1
- 16" OGDC = 1.1



AASHTO93 DESIGN METHOD (OLD)

Project1 - Flexible Structural Design1

Description:

18-kip ESALs Over Initial Performance Period

Initial Serviceability

Terminal Serviceability

Reliability Level (%)

Overall Standard Deviation

Roadbed Soil Resilient Modulus

Number of Construction Stage

Design Structural Number

in

□ Design SN

AASHTO93 DESIGN METHOD (OLD)

Layer	Material Description	Struct. Coeff. (Ai)	Drain Coeff. (Mi)	Thick. (Di) (in)	One Direct. Width (ft)	Structural Number (in)	Thickness to match Design SN (in)
1							
2							
3							
4							
5							

Thickness Sum

Design SN Source: Flex Design SN

Design SN (in)

Calculated SN (in)

OK Cancel Clear Materials...

Calculated SN must be \geq Design SN

Additional Notes:

- Layered

 - This approach solves for the structural number of a layer based on the elastic modulus of the underlying layer.
 - The elastic modulus is used in the design equation as the resilient modulus.
 - Algorithm starts by solving for the thickness of the bottom layer and working up.
 - A layer with specified thickness isn't considered as part of elastic layered analysis calcs (for purpose of determining thicknesses).
- Specified

 - User supplies all inputs for each layer and DARWin calculates the SN contribution of the individual layers & of the total structure.

AASHTO93 DESIGN METHOD (OLD)

□ Typical Concrete (PCC) inputs

- Projected ESAL's
- Initial Serviceability = 4.5
- Terminal Serviceability = 2.5
- Reliability = 95%
- Overall Standard Deviation = 0.39
- 28-day Modulus of Rupture = 670 psi
- 28-day Elastic Mod. of Slab = 4,200,000 psi
- Load Transfer Coefficient
 - Tied shoulder, tied curb & gutter, or 14' outside lane = 2.7
 - Untied shoulder = 3.2

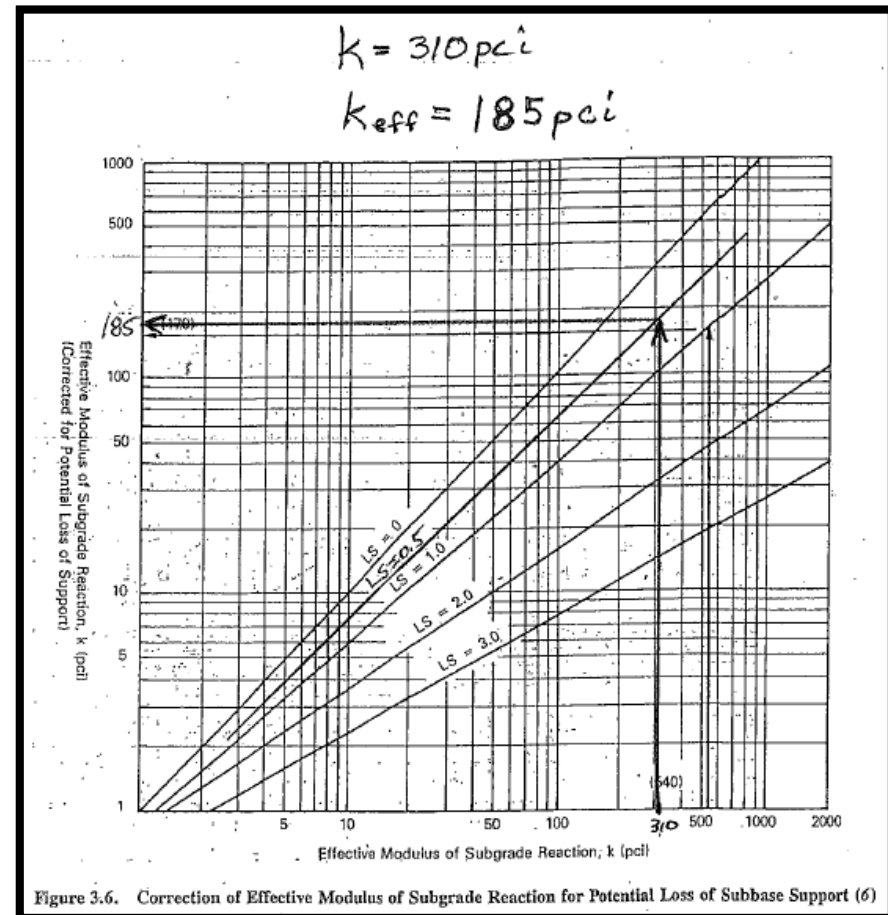
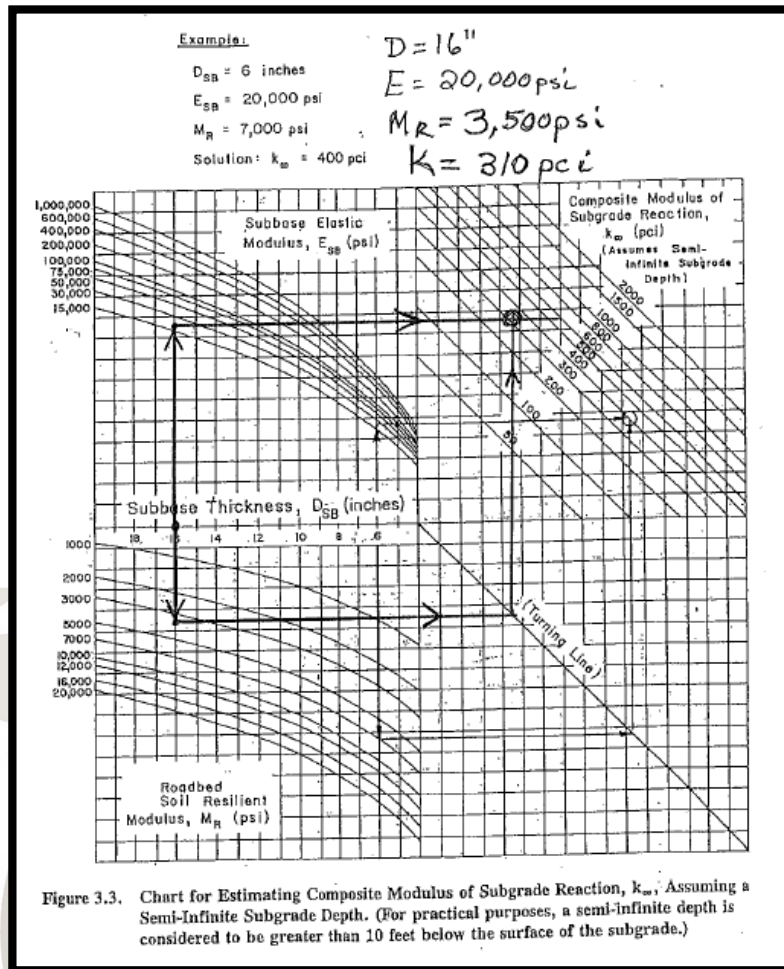
AASHTO93 DESIGN METHOD (OLD)

□ Typical Concrete inputs (*continued*)

- Drainage Coefficient = 1 to 1.05, (or 1.1 for 16" of OGDC)
- Effective Modulus of Subgrade Reaction (k-value)
 - Determined from *Subgrade Resilient Modulus, depth of base/subbase, and Elastic Modulus of base/subbase*
 - Figures 3.3 & 3.6 from 1993 AASHTO Guide for Design of Pavement Structures is used to obtain the value
 - Loss of support of 0.5 used in Figure 3.6
 - Subgrade M_R comes from Region Soils Engineer



AASHTO93 DESIGN METHOD (OLD)



AASHTO93 DESIGN METHOD (OLD)

Estimation of Composite Modulus of Subgrade Reaction, Assuming a Semi-Infinite Subgrade Correction of Effective Modulus of Subgrade Reaction for Potential Loss of Subbase Support

CS	JN	D _{SB} (in)	E _{SB} (psi)	M _R (psi)
		16	20000	3500

K _∞ (pci)	LS	K _{LS} (pci)
309	0.5	186

Per MDOT results using the *AASHTO Guide for Design of Pavement Structures 1993*, Part II Figures 3.3 & 3.6, K_∞ and K_{LS} are calculated from the equations below:

$$\ln K_{\infty} = \ln(1.09) * (-2.807 + 0.1253(\ln(D_{SB}))^2 + 1.062(\ln(M_R)) + 0.1282(\ln(D_{SB}))(\ln(E_{SB})) - 0.4114(\ln(D_{SB})) - 0.0581(\ln(E_{SB})) - 0.1317(\ln(D_{SB})\ln(M_R)))$$

$$\log_{10} K_{LS} = 0.8218 \log_{10} K_{\infty} + 0.2234$$

AASHTO93 DESIGN METHOD (OLD)

Project1 - Rigid Structural Design2

Description:

18-kip ESALs Over Initial Performance Period

Initial Serviceability

Terminal Serviceability

28-day Mean PCC Modulus of Rupture psi

28-day Mean Elastic Modulus of Slab psi

Mean Effective k-value psi/in

Reliability Level (%)

Overall Standard Deviation

Load Transfer Coefficient, J

Overall Drainage Coefficient, Cd

Calculated Design Thickness in

AASHTO93 DESIGN METHOD (OLD)

The image shows two overlapping software dialog boxes. The left dialog, titled "Project1 - Overlay Design1", is for "Unbonded PCC Overlay of PCC or AC/PCC Pavement". It contains a "Description" field, a "Future Structural Capacity" section with a "Pavement Thickness for Future Traffic" input, and an "Effective Existing and Overlay Structural Capacity" section. This section has a table with columns for "Existing Pavement Evaluation Methods", "Effective Existing Thickness", and "Overlay Thickness". The "Condition Survey" row has a red box around the "Effective Existing Thickness" input field. A red arrow points from this field to the right dialog.

The right dialog, titled "Effective Thickness--Condition Survey Method", contains several input fields: "Existing PCC Thickness", "Existing AC Thickness", "Milling Thickness", "Durability Adjustment Factor (Fdur)", "Fatigue Damage Adjustment Factor (Ffat)", "AC Quality Adjustment Factor (Fac)", "No. of Unrepaired Deteriorated Joints", "No. of Unrepaired Deteriorated Cracks", "No. of Unrepaired Punchouts", and "No. of Expansion Joints, Exceptionally Wide Joints or AC Full Depth Patches". Below these is a "Calculated Results" section with a red box around the "Effective Existing Pavement Thickness" field. A red arrow points from the "Effective Existing Thickness" field in the left dialog to this field in the right dialog.

Existing Pavement Evaluation Methods	Effective Existing Thickness	Overlay Thickness
Condition Survey	<input type="text"/> in	<input type="text"/> in
Remaining Life	<input type="text"/> in	<input type="text"/> in

AASHTO93 DESIGN METHOD (OLD)

□ Material Elastic Moduli (psi)

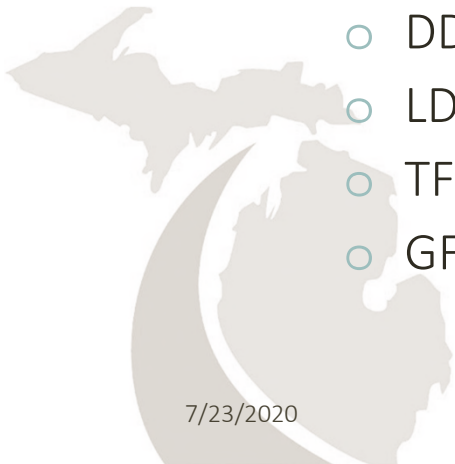
- HMA Top and Leveling Course = 390,000 to 410,000
- HMA Base Course = 275,000 to 320,000
- Cement Stabilized Base = 1,000,000
- ASCRL = 210,000
- Asphalt/Emulsion Stabilized Base = 160,000
- Crush and Shaped HMA = 100,000 to 150,000
- Rubblized Concrete = 45,000 to 55,000
- Dense-Graded Aggregate Base = 30,000
- Open-Graded Aggregate Base = 24,000
- Sand Subbase = 13,500

□ *Elastic Modulus used in HMA layered design or PCC k-value*

AASHTO93 DESIGN METHOD (OLD)

□ Equivalent Single Axle Loads (ESAL's)

- Traffic component that is requested at the preliminary planning stages
- $ESAL's = CADT * 365 * DD * LD * TF * GF$
 - CADT = truck volume
 - DD = directional distribution
 - LD = lane distribution
 - TF = truck factor
 - GF = growth factor



AASHTO93 DESIGN METHOD (OLD)

□ Equivalent Single Axle Loads (ESAL's) (continued)

■ Compound growth factor (GF):

- $GF = ((1+g)^n - 1)/g$

- g = growth rate expressed as a decimal (e.g. 2% = 0.02)
 - Based on review of historic truck volumes
 - May be adjusted (up or down) based on very limited economic information
- n = number of years; (use design life)



AASHTO93 DESIGN METHOD (OLD)

□ Equivalent Single Axle Loads (ESAL's) (continued)

- Truck factors (TF):
 - Average ESAL per truck
 - Different truck types accounted for
 - Different factor used for each FHWA classifications 5-13
 - Overall TF weighted according to the volume of each class
 - Some routes only have vehicle/medium, truck/heavy-truck percentages rather than classification, so only TF for medium/heavy used.
 - Medium = classes 5 though 8
 - Heavy = classes 9 though 13
- “Rule of thumb”: ESAL's for PCC are typically 1.4 to 1.5 times the ESAL's for HMA

AASHTO93 DESIGN METHOD (OLD)

MDOT uses these
truck factors

I. Default values (if no classification counts are available).				
Thickness	Rigid	SN	Flexible	
9.0"	.85	5	.59	
9.5"	.85	6	.57	
10.0"	.85			
10.5"	.86			
11.0"	.86			
11.5"	.86			

II. Classification counts available to determine the mix of heavy and medium trucks.			
Rigid D = 9		Flexible SN = 5	
Heavy	Medium	Heavy	Medium
1.39	.41	.88	.34

III. Classification counts available to determine mix of vehicles by each vehicle type.				
Rigid D = 9		Medium (Under 5 Axles)	Flexible SN = 5	
Class	Factor		Class	Factor
5	.19		5	.19
6	.59		6	.37
7	1.31		7	.80
8	.68		8	.61
9*	1.27		9*	.77
10	2.18		10	1.46
11	1.60		11	1.53
12	1.20		12	1.04
13	2.08		13	1.58

*Most common class type

IV. Commercial volumes				
Volume	Inches	Rigid	SN	Flexible
<2,000	9.0	0.69	6	0.49
2,000-2,499	9.5	0.81	6	0.75
2,500-3,4999	10.0	1.04	6	0.68
3,500-4,499	10.5	1.08	6	0.68
4,500+	11.0	0.85	6	0.56

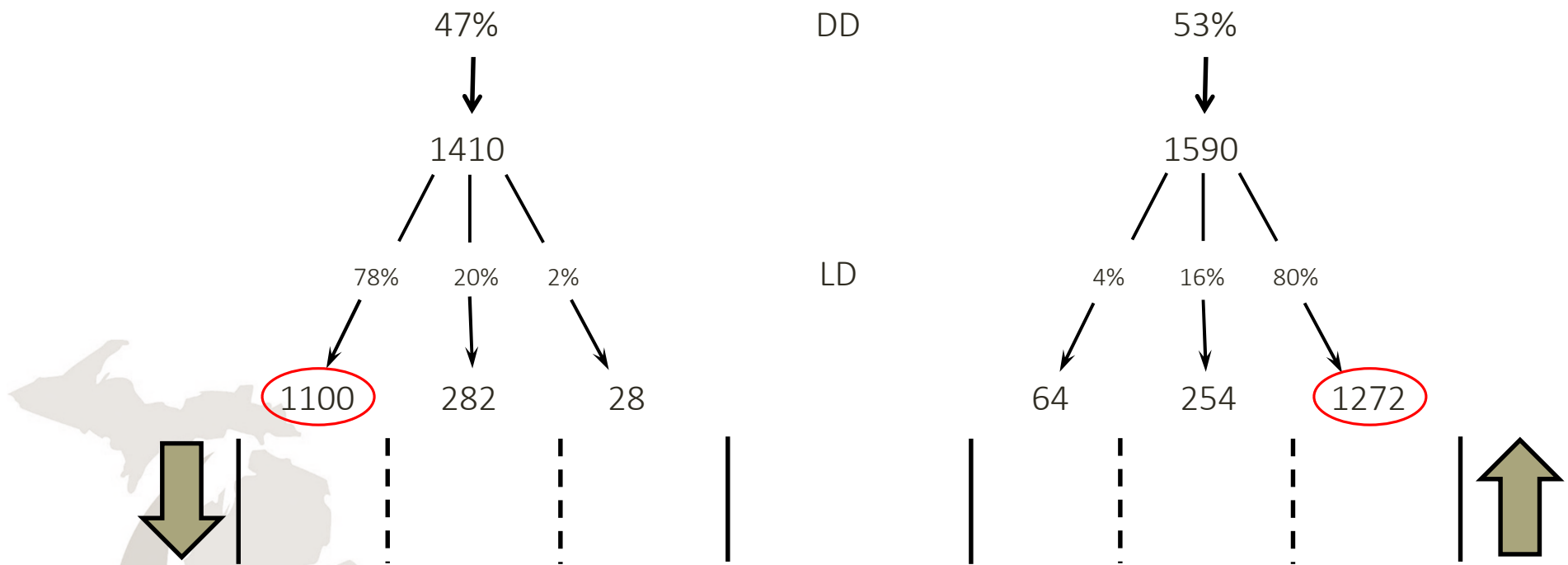


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AASHTO93 DESIGN METHOD (OLD)

Design Lane Example

CADT = 3000





































Lane with highest CADT is known as the Design Lane

AASHTO93 DESIGN METHOD (OLD)

(screenshot from FHWA Traffic Monitoring Guide, April 2013, page 1-18)

FIGURE 1-1 FHWA'S 13 VEHICLE CATEGORY CLASSIFICATION

Class 1 Motorcycles		Class 7 Four or more axle, single unit	
Class 2 Passenger cars		Class 8 Four or less axle, single trailer	
			
			
			
Class 3 Four tire, single unit		Class 9 5-Axle tractor semitrailer	
			
			
Class 4 Buses		Class 10 Six or more axle, single trailer	
		Class 11 Five or less axle, multi trailer	
			
Class 5 Two axle, six tire, single unit		Class 12 Six axle, multi-trailer	
		Class 13 Seven or more axle, multi-trailer	
			
Class 6 Three axle, single unit			
			
			

AASHTO 1993
(ESAL's)

ME adds Class 4

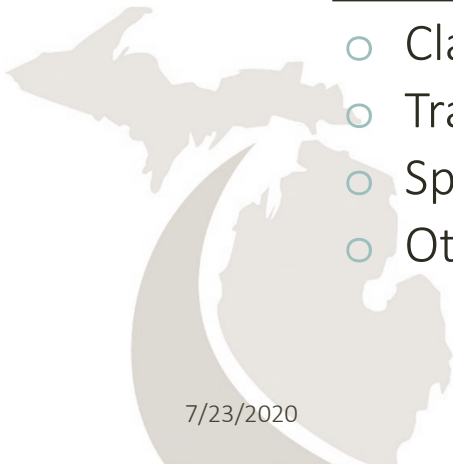
AASHTO 1993
(ESAL's)

7/23/2020

Source: Federal Highway Administration.

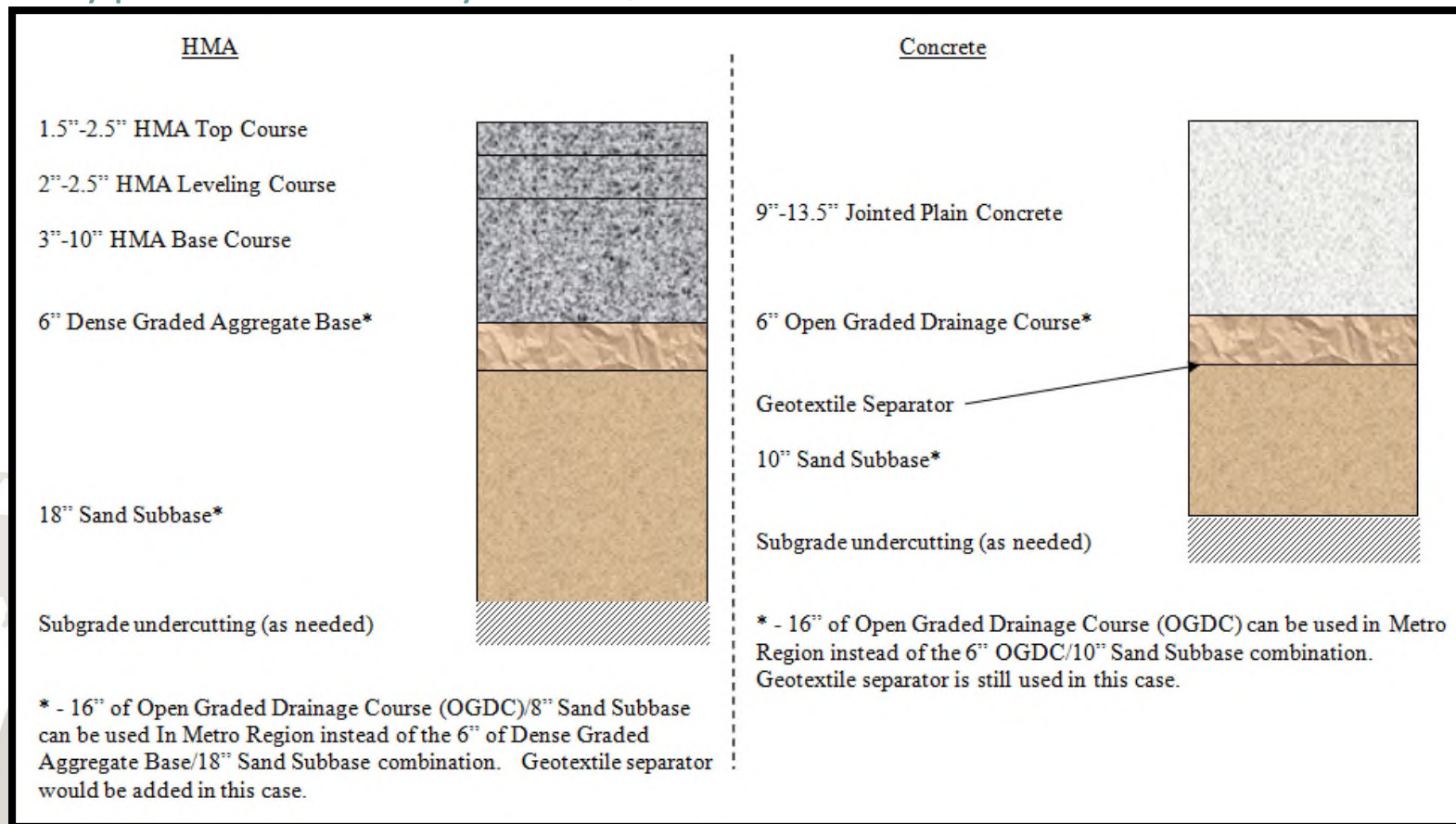
AASHTO93 DESIGN METHOD (OLD)

- Traffic data generally consists of 2 types:
 - Permanent traffic recorders – embedded in the pavement
 - Weigh-In-Motion sites
 - Classification sites
 - Traffic count sites
 - Speed sites (not used for AASHTO 1993)
 - Short term measurements
 - Classification
 - Traffic count
 - Speed
 - Other (turning movements, etc.)



AASHTO93 DESIGN METHOD (OLD)

Typical Freeway New/Reconstruct Cross-Sections



AASHTO93 DESIGN METHOD (OLD)

□ LCCA Analysis (pavt costs > \$1.5 million) – compares PCC vs HMA alternatives:

- New/reconstruction project
 - PCC = Jointed Plain Concrete Pavement (JPCP)
 - HMA = Full-depth (Superpave mix)
- Major rehabilitation project
 - PCC = Unbonded concrete overlay of existing PCC
 - HMA = HMA overlay of rubblized concrete

□ *Note that there are other types of pavement projects, but the above types are what are used in LCCA.*

ME DESIGN METHOD *(NEW)*

ME DESIGN METHOD (*NEW*)

☐ Mechanistic-Empirical (ME) Pavement Design

▪ *ME Pavement Design Guide (MEPDG)*

- Original Version - 1st Edition 2007/2008
- Current Version - 3rd Edition 2020

☐ Mechanistic – Based on the theories of mechanical properties of materials

☐ Empirical – Use observed performance measures to calibrate the performance models

ME DESIGN METHOD (*NEW*)

- ❑ It is AASHTO's recommended pavement design method, replacing AASHTO '93
- ❑ Software name changed in 2013 from:
 - DARWin-ME to Pavement ME Design

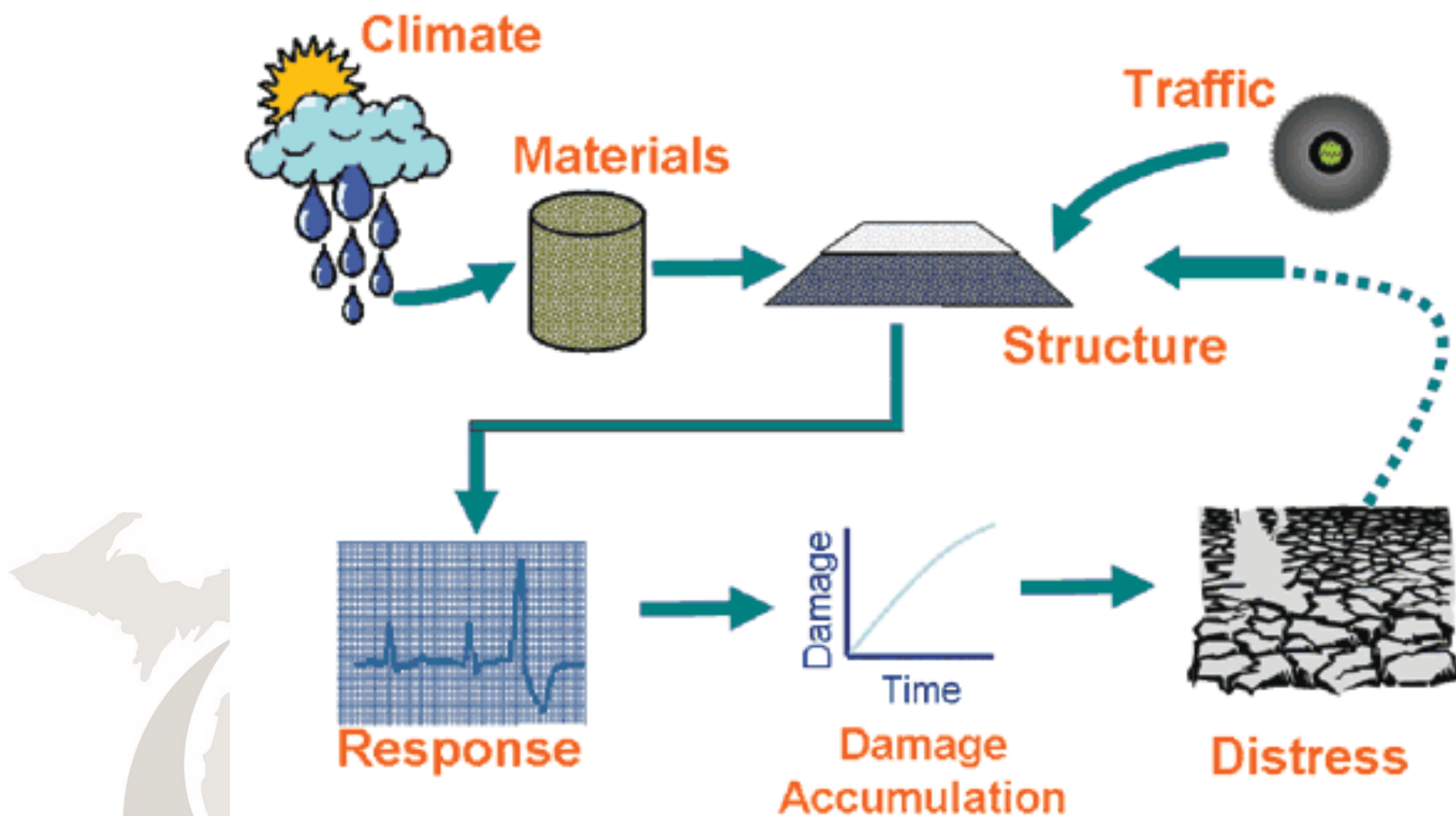


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ME DESIGN METHOD (*NEW*)

- Pavement response for every anticipated axle load is calculated and damage is estimated and summed.
- Result is distress prediction (not a pavement cross-section) for the expected design period
 - Concrete distresses:
 - % slabs cracked, faulting, IRI
 - HMA distresses:
 - transverse cracking, longitudinal cracking, % fatigue cracking, rutting, IRI

ME DESIGN METHOD (*NEW*)



ME DESIGN METHOD (NEW)

The screenshot displays the AASHTOWare Pavement ME Design software interface. The main window is titled "47013_81075_115399 ...Project". The interface is divided into several panes:

- Explorer:** Shows a tree view of project components, including Traffic, Climate, Pavement Structure (Layers 1-6), Project Specific Calibration Factors, Sensitivity, Optimization, and Reports.
- General Information:** Displays project details such as Design type (New Pavement), Pavement type (Flexible Pavement), Design life (20 years), Base construction (July 2017), Pavement construction (August 2017), and Traffic opening (September 2017).
- Performance Criteria:** A table listing various performance metrics with their respective limits and reliabilities.
- Layer Properties:** A detailed view for "Layer 1 Asphalt Concrete: 5E3 Top Course", showing properties for Asphalt Layer, Mixture Volumetrics, Mechanical Properties, Thermal, and Identifiers.
- Visuals:** A central area showing a cross-section of the pavement layers with labels for each layer and a "Click here to edit" link for each.

Performance Criteria Table:

Performance Criteria	Limit	Reliability
Initial IRI (in./mile)	67	95
Terminal IRI (in./mile)	172	95
AC top-down fatigue cracking (ft./mile)	2000	95
AC bottom-up fatigue cracking (percent)	20	95
AC thermal cracking (ft./mile)	1000	95
Permanent deformation - total pavement (in.)	0.5	95
Permanent deformation - AC only (in.)	0.5	95

Layer 1 Asphalt Concrete: 5E3 Top Course Properties:

- Asphalt Layer:** Thickness (in.) = 1
- Mixture Volumetrics:** Unit weight (pcf) = 145.9, Effective binder content (%) = 12.1, Air voids (%) = 5.9, Poisson's ratio = 0.35
- Mechanical Properties:** Dynamic modulus = Input level: 1, Select HMA Estar predictive model = Use Viscosity based model (nationally calibrated), Reference temperature (deg F) = 70, Asphalt binder = Level 1 - SuperPave: 479, Creep compliance (1/psi) = Input level: 1
- Thermal:** Thermal conductivity (BTU/hr-ft-deg F) = 0.67, Heat capacity (BTU/lb-deg F) = 0.23, Thermal contraction = 1.265E-05 (calculated)
- Identifiers:** Display name/identifier = 5E3 Top Course

ME DESIGN METHOD (*NEW*)

☐ Climate:

- Data from 39 weather stations in Michigan
 - Recently completed Michigan Tech project added more years of data to existing stations and additional weather stations from the existing 19 (included in ME package).
- Each weather station over 10 years of monthly climatic data
- Water table depth is an input



ME DESIGN METHOD (*NEW*)

Locations of –
Weather Stations

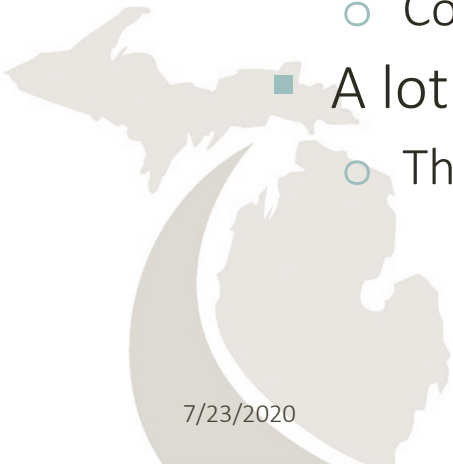


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ME DESIGN METHOD (*NEW*)

☐ Materials:

- Many more material inputs
- Examples:
 - Gradations (for calculating modulus values)
 - Thermal properties of the paved surface (expansion, conductivity, heat capacity)
 - Concrete shrinkage (ultimate, reversible, and time to 50%)
- A lot more material testing has been occurring
 - This will continue into the future



ME DESIGN METHOD (NEW)

Layer 2 Non-stabilized Base: Agg. Base (A-1-a)

Unbound
 Layer thickness (in.) Semi-infinite
 Poisson's ratio 0.35
 Coefficient of lateral earth pressure (k0) 0.5

Modulus
 Resilient modulus (psi) 33000

Sieve
 Gradation & other engineering properties A-1-a

Identifiers
 Display name/identifier: Aggregate Base
 Description of object
 Approver
 Date approved
 Author
 Date created
 County
 State
 District
 Direction of travel
 From station (miles)
 To station (miles)

Sieve Size	Percent Passing
0.001mm	
0.002mm	
0.020mm	
#200	7.7
#100	
#80	
#60	
#50	
#40	
#30	
#20	
#16	
#10	
#8	33.2
#4	
3/8-in.	
1/2-in.	67.7
3/4-in.	
1-in.	94.2
1 1/2-in.	
2-in.	
2 1/2-in.	100
3-in.	
3 1/2-in.	

Liquid Limit	0
Plasticity Index	0
<input checked="" type="checkbox"/> Is layer compacted?	
<input type="checkbox"/> Maximum dry unit weight (pcf)	127.0
<input type="checkbox"/> Saturated hydraulic conductivity (ft/hr)	3.478e-02
<input type="checkbox"/> Specific gravity of solids	2.7
<input type="checkbox"/> Optimum gravimetric water content (%)	5.9
<input type="checkbox"/> User-defined Soil Water Characteristic Curve (SWCC)	

af	5.85967158740529
bf	1.73240110376227
cf	0.689751920445787
hr	100

ME DESIGN METHOD (*NEW*)

Example of materials inputs – Concrete Layer

Layer 1 PCC:JPCP

PropertyGridToolBar

▲ PCC	
Thickness (in.)	<input checked="" type="checkbox"/> 10
Unit weight (pcf)	<input checked="" type="checkbox"/> 145
Poisson's ratio	<input checked="" type="checkbox"/> 0.2
▲ Thermal	
PCC coefficient of thermal expansion (in./in./deg F x 10 ⁻⁶)	<input checked="" type="checkbox"/> 5.8
PCC thermal conductivity (BTU/hr-ft-deg F)	<input checked="" type="checkbox"/> 1.25
PCC heat capacity (BTU/lb-deg F)	<input checked="" type="checkbox"/> 0.28
▲ Mix	
Cement type	Type I (1)
Cementitious material content (lb/yd ³)	<input checked="" type="checkbox"/> 500
Water to cement ratio	<input checked="" type="checkbox"/> 0.42
Aggregate type	Limestone (1)
▶ PCC zero-stress temperature (deg F)	<input type="checkbox"/> Calculated
▶ Ultimate shrinkage (microstrain)	<input type="checkbox"/> 530.8 (calculated)
Reversible shrinkage (%)	<input checked="" type="checkbox"/> 50
Time to develop 50% of ultimate shrinkage (days)	<input checked="" type="checkbox"/> 35
Curing method	Curing Compound
▲ Strength	
PCC strength and modulus	<input checked="" type="checkbox"/> Level:3 Compressive(5600)

ME DESIGN METHOD (*NEW*)

Example of materials inputs – HMA Layer

Layer 1 Asphalt Concrete:5E3 Top Course	
Asphalt Layer	
Thickness (in.)	<input checked="" type="checkbox"/> 1
Mixture Volumetrics	
Unit weight (pcf)	<input checked="" type="checkbox"/> 145.9
Effective binder content (%)	<input checked="" type="checkbox"/> 12.1
Air voids (%)	<input checked="" type="checkbox"/> 5.9
Poisson's ratio	0.35
Mechanical Properties	
Dynamic modulus	<input checked="" type="checkbox"/> Input level:1
Select HMA Estar predictive model	Use Viscosity based model (nationally calibrated).
Reference temperature (deg F)	<input checked="" type="checkbox"/> 70
Asphalt binder	<input checked="" type="checkbox"/> Level 1 - SuperPave:
Indirect tensile strength at 14 deg F (psi)	<input checked="" type="checkbox"/> 479
Creep compliance (1/psi)	<input checked="" type="checkbox"/> Input level:1
Thermal	
Thermal conductivity (BTU/hr-ft-deg F)	<input checked="" type="checkbox"/> 0.67
Heat capacity (BTU/lb-deg F)	<input checked="" type="checkbox"/> 0.23
Thermal contraction	1.265E-05 (calculated)

ME DESIGN METHOD (NEW)

Layer 1 Asphalt Concrete:HMA Top Course	
Asphalt Layer	
Thickness (in.)	<input checked="" type="checkbox"/> 1.5
Mixture Volumetrics	
Unit weight (pcf)	<input checked="" type="checkbox"/> 146
Effective binder content (%)	<input checked="" type="checkbox"/> 11.9
Air voids (%)	<input checked="" type="checkbox"/> 7
▷ Poisson's ratio	0.35
Mechanical Properties	
Dynamic modulus	<input checked="" type="checkbox"/> Input level:3
▷ Select HMA Estar predictive model	HMA Top Course
Reference temperature (deg F)	<input checked="" type="checkbox"/> 70
Asphalt binder	<input checked="" type="checkbox"/> SuperPave:64-28
Indirect tensile strength at 14 deg F (psi)	<input checked="" type="checkbox"/> 400.47
Creep compliance (1/psi)	<input checked="" type="checkbox"/> Input level:3
Thermal	
Thermal conductivity (BTU/hr-ft-deg F)	<input checked="" type="checkbox"/> 0.67
Heat capacity (BTU/lb-deg F)	<input checked="" type="checkbox"/> 0.23
▷ Thermal contraction	1.32E-05 (calculated)
Identifiers	
Display name/identifier	HMA Top Course

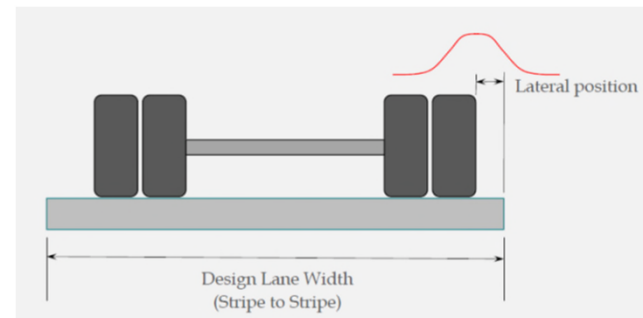
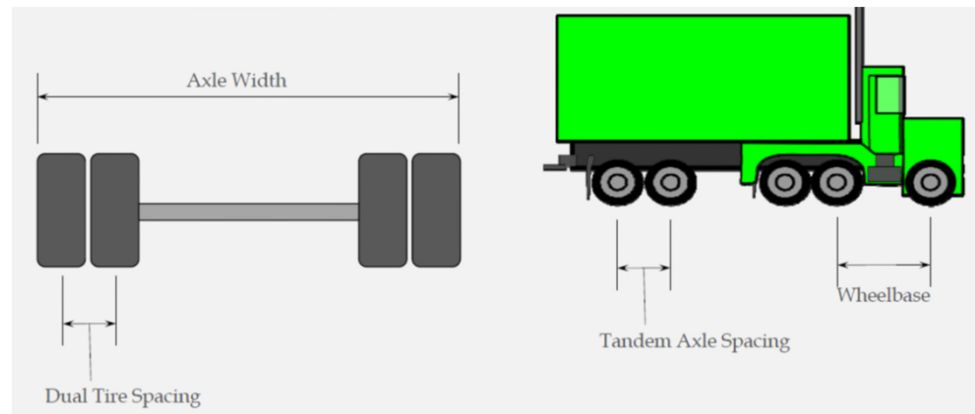
Layer 1 PCC:JPCP	
Thickness (in.)	<input checked="" type="checkbox"/> 10
Unit weight (pcf)	<input checked="" type="checkbox"/> 145
Poisson's ratio	<input checked="" type="checkbox"/> 0.2
Thermal	
PCC coefficient of thermal expansion (in./in./deg F x 10 ⁻⁴)	<input checked="" type="checkbox"/> 4.5
PCC thermal conductivity (BTU/hr-ft-deg F)	<input checked="" type="checkbox"/> 1.25
PCC heat capacity (BTU/lb-deg F)	<input checked="" type="checkbox"/> 0.28
Mix	
Cement type	Type I (1)
Cementitious material content (lb/yd ³)	<input checked="" type="checkbox"/> 500
Water to cement ratio	<input checked="" type="checkbox"/> 0.42
Aggregate type	Limestone (1)
▷ PCC zero-stress temperature (deg F)	<input type="checkbox"/> Calculated
▷ Ultimate shrinkage (microstrain)	<input type="checkbox"/> 530.8 (calculated)
Reversible shrinkage (%)	<input checked="" type="checkbox"/> 50
Time to develop 50% of ultimate shrinkage (days)	<input checked="" type="checkbox"/> 35
Curing method	Curing Compound
Strength	
PCC strength and modulus	<input checked="" type="checkbox"/> Level:3 Compressive(5600)
Identifiers	
Display name/identifier	JPCP

HMA vs JPCP
inputs

ME DESIGN METHOD (*NEW*)

□ Traffic:

- No more ESAL's
- Axle Load Spectra
- Inputs include:
 - Average axle spacing,
 - Typical tire pressures,
 - Average distance from shoulder to closest tire,
 - Monthly and hourly distributions,
 - Vehicle class distribution,
 - etc.



ME DESIGN METHOD (NEW)

Example
of –
Traffic
Inputs

AAADTT

Two-way AAADTT 16300

Number of lanes 3

Percent trucks in design direc 50

Percent trucks in design lane 85

Operational speed (mph) 60

Traffic Capacity

Traffic Capacity Cap Not enforced

Axle Configuration

Average axle width (ft) 8.5

Dual tire spacing (in.) 12

Tire pressure (psi) 120

Tandem axle spacing (in.) 51.6

Tridem axle spacing (in.) 49.2

Quad axle spacing (in.) 49.2

Lateral Wander

Mean wheel location (in.) 18

Traffic wander standard deviat 10

Design lane width (ft) 12

Wheelbase

Average spacing of short axle 12

Average spacing of medium ax 15

Average spacing of long axles 18

Percent trucks with short axle 33

Percent trucks with medium ax 33

Percent trucks with long axles 34

Identifiers

Display name/identifier **Default Traffic**

Description of object **Default Traffic File**

Approver

Date approved **1/1/2011**

Author **AASHTOWare**

Date created **1/1/2011**

County

State

District

Direction of travel

From station (miles)

To station (miles)

Highway

Revision Number 0

User defined field 1

User defined field 2

User defined field 3

Item Locked? **False**

Traffic Capacity Cap

Vehicle Class Distribution and Growth

Vehicle Class	Distribution (%)	Growth Rate (%)	Growth Function
Class 4	1.6	2	Compound
Class 5	6.14	2	Compound
Class 6	5.16	2	Compound
Class 7	0.36	2	Compound
Class 8	2	2	Compound
Class 9	68.99	2	Compound
Class 10	8.21	2	Compound
Class 11	0.78	2	Compound
Class 12	0.2	2	Compound
Class 13	6.56	2	Compound

Monthly Adjustment

Month	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10	Class 11	Class 12	Class 13
January	0.899	0.899	0.899	0.899	0.966	0.966	0.966	0.77	0.77	0.77
February	0.94	0.94	0.94	0.94	1.041	1.041	1.041	0.749	0.749	0.749
March	0.979	0.979	0.979	0.979	1.057	1.057	1.057	0.847	0.847	0.847
April	0.972	0.972	0.972	0.972	0.917	0.917	0.917	0.889	0.889	0.889
May	0.992	0.992	0.992	0.992	0.897	0.897	0.897	0.98	0.98	0.98
June	1.087	1.087	1.087	1.087	1.119	1.119	1.119	1.187	1.187	1.187
July	1.019	1.019	1.019	1.019	0.941	0.941	0.941	1.21	1.21	1.21
August	1.016	1.016	1.016	1.016	1.019	1.019	1.019	1.034	1.034	1.034
September	0.963	0.963	0.963	0.963	0.927	0.927	0.927	1.071	1.071	1.071
October	1.053	1.053	1.053	1.053	1.05	1.05	1.05	1.268	1.268	1.268

Axes Per Truck

Vehicle Class	Single	Tandem	Tridem	Quad
Class 4	1.65	0.36	0	0
Class 5	2	0.05	0	0
Class 6	1	1	0	0
Class 7	1.06	0.06	0.59	0.35
Class 8	2.28	0.74	0	0
Class 9	1.29	1.85	0	0
Class 10	1.54	1	0.31	0.56
Class 11	4.99	0	0	0
Class 12	3.85	0.96	0	0
Class 13	2.03	1.4	0.36	0.61

Hourly Adjustment

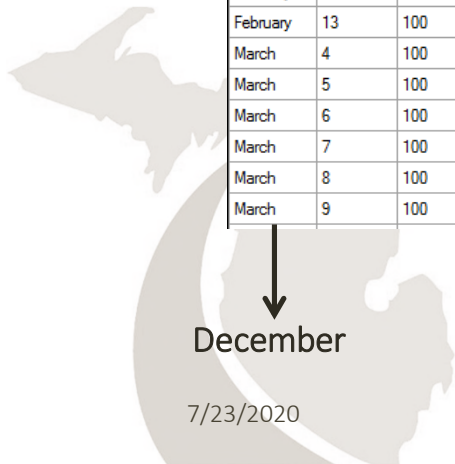
Time of Day	Percentage
12:00 am	2.58
1:00 am	2.42
2:00 am	2.16
3:00 am	2.22
4:00 am	2.4
5:00 am	2.78
6:00 am	3.23
7:00 am	3.61
8:00 am	4.33
9:00 am	5.34
10:00 am	6.15
11:00 am	6.53
12:00 pm	6.42
1:00 pm	6.29
2:00 pm	5.89
3:00 pm	5.3
4:00 pm	5.01
5:00 pm	4.58
6:00 pm	4.48
7:00 pm	4.37
8:00 pm	3.99
9:00 pm	3.63
10:00 pm	3.31
11:00 pm	3
Total	100.0

ME DESIGN METHOD (NEW)

Month	Class	Total	3000	4000	5000	6000	7000	8000	9000	10000	11000	12000	13000	14000	15000	16000
January	4	100	0	0.02	0.1	0.71	2.7	10.18	15.06	15.67	12.43	11.52	8.92	8.03	5.42	3.18
January	5	100	9.98	12.48	16.19	12.7	13.67	8.34	7.8	4.69	3.97	2.24	2.04	1.59	1.07	1.1
January	6	100	0.36	0.42	0.74	1.13	4.17	7.98	15.11	13.56	16.02	9.81	8.36	5.18	3.19	3.14
January	7	100	1.61	1.9	3.14	2.41	5.92	4.09	6.8	5.92	7.68	7.89	9.58	9.73	7.09	7.53
January	8	100	1.44	2.6	4.15	5.88	10.51	15	20.39	9.77	8.13	5.06	4.4	3.31	2.24	2.37
January	9	100	3.1	1.53	1.23	0.86	1.78	4.84	16.68	23.92	26.41	8.24	2.84	1.47	1.44	2.12
January	10	100	0.02	0.06	0.14	0.42	1.25	4.04	13.07	22.18	27.67	14.45	8.97	3.72	1.45	1.15
January	11	100	0.52	1.86	6.17	5.37	6.61	8.38	17.17	11.65	9.86	6.59	7.21	6.49	4.18	3.45
January	12	100	0.74	2.21	5.57	7.4	10.36	10.77	18.41	11.94	10.12	6.56	5.5	3.2	1.9	1.87
January	13	100	2.03	1.76	2.94	3.66	3.62	2.21	6.59	11.17	15.42	9.11	8.94	7.24	5.33	6.18
February	4	100	0.02	0.02	0.19	0.82	3.12	9.95	14	15.3	12.73	11.89	9.45	7.99	5.34	3.23
February	5	100	10.02	11.73	15.97	13.05	13.79	8.49	7.72	4.67	4.05	2.34	2.15	1.66	1.15	1.13
February	6	100	0.28	0.55	0.84	1.18	5.26	8.38	14.32	13.72	16.18	9.44	8.61	5.15	2.88	3.14
February	7	100	1.24	1.86	5.77	4.54	7.29	4.88	6.94	6.25	8.17	5.84	7.7	8.11	6.12	7.29
February	8	100	1.51	2.44	4.54	6.11	10.73	15.36	19.61	9.62	8.01	4.89	4.49	3.46	2.34	2.3
February	9	100	3.3	1.46	1.17	0.83	1.94	4.96	17.38	24.08	25.04	7.73	3.13	1.75	1.58	2.23
February	10	100	0.01	0.04	0.19	0.31	1.65	3.65	14.18	22.66	26.91	14	8.23	3.91	1.65	1.4
February	11	100	0.53	1.92	6.2	5.15	6.81	8.61	17.41	11.4	9.95	6.75	7.08	6.16	4.15	3.38
February	12	100	0.8	2.4	5.98	7.94	9.8	10.88	18.4	11.27	10.13	6.5	5.46	3.16	1.77	1.91
February	13	100	2.16	2.1	3.2	3.52	3.28	2.09	7.33	11.74	14.32	8.64	8.85	7.03	5.39	6.03
March	4	100	0	0	0.08	0.69	2.86	11.21	14.98	14.68	11.97	11.6	9.13	8.21	4.96	3.61
March	5	100	10.35	11.32	15.34	13.09	13.88	8.49	7.93	4.82	4.11	2.28	2.12	1.67	1.19	1.2
March	6	100	0.24	0.5	0.93	1.7	5.33	9.14	15.23	14.78	17.27	9.6	7.7	4.26	2.17	2.16
March	7	100	1.29	1.83	7.52	6.43	10.67	6.97	7.02	5.64	6.53	4.6	8.01	7.91	6.23	5.89
March	8	100	1.8	2.89	4.4	6.29	10.91	15.82	19.99	9.18	7.57	4.7	4.32	3.38	2.15	2.32
March	9	100	3.55	1.47	1.17	0.79	1.71	4.83	17.58	24.87	25.39	6.73	2.71	1.79	1.75	2.43

→ 41,000

1.15% of the class 5 single axles in February are in the 14,000 to 14,999 weight bin



Single Axle Load Spectra
(axle load bin counts)

ME DESIGN METHOD (NEW)

JN 88876 & 90076 & 90077 - JPCP
File Name: C:\Users\jschenkel\Documents\My ME Design\LCCA DESIGN\ME DESIGN\ (NEW CALIB COEF)\Testing\JN 88876 & 90076 & 90077 - JPCP.dgs

Design Inputs

Design Life: 20 years Existing construction: - Climate Data: 43.171, -86.237
 Design Type: Jointed Plain Concrete Pavement (JPCP) Pavement construction: August, 2016 Sources (Lat/Lon)
 Traffic opening: September, 2016

Design Structure

Layer type	Material Type	Thickness (in.)	Joint Design:
PCC	JPCP	9.5	Joint spacing (ft) 14.0
NonStabilized	OGDC	8.0	Dowel diameter (in.) 1.25
NonStabilized	Sand Subbase	10.0	Slab width (ft) 12.0
Subgrade	Poorly Graded Sand/Silty Sand Subgrade	Semi-infinite	

Traffic

Age (year)	Heavy Trucks (cumulative)
2016 (initial)	2,932
2026 (10 years)	4,530,020
2036 (20 years)	9,435,780

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	172.00	137.43	95.00	99.76	Pass
Mean joint faulting (in.)	0.25	0.04	95.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	0.11	95.00	100.00	Pass

Distress Charts

Report generated on: 1/28/2015 3:51 PM Created by: J Schenkel on: 6/16/2014 1:41 PM Approved by: on: 6/16/2014 1:41 PM Page 1 of 15

JN 88876 & 90076 & 90077 - HMA
File Name: C:\Users\jschenkel\Documents\My ME Design\LCCA DESIGN\ME DESIGN\ (NEW CALIB COEF)\Testing\JN 88876 & 90076 & 90077 - HMA.dgs

Design Inputs

Design Life: 20 years Base construction: July, 2016 Climate Data: 43.171, -86.237
 Design Type: Flexible Pavement Pavement construction: August, 2016 Sources (Lat/Lon)
 Traffic opening: September, 2016

Design Structure

Layer type	Material Type	Thickness (in.)	Volumetric at Construction:
Flexible	5E10 Top Course	1.5	Effective binder content (%) 12.1
Flexible	3E10 Leveling Course	3.3	Air voids (%) 5.9
Flexible	3E10 Base Course	3.5	
NonStabilized	OGDC	6.0	
NonStabilized	Sand Subbase	18.0	
Subgrade	Poorly Graded Sand/Silty Sand Subgrade	Semi-infinite	

Traffic

Age (year)	Heavy Trucks (cumulative)
2016 (initial)	2,932
2026 (10 years)	4,530,020
2036 (20 years)	9,435,780

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	172.00	144.94	95.00	99.54	Pass
Permanent deformation - total pavement (in.)	0.50	0.46	95.00	98.38	Pass
AC bottom-up fatigue cracking (percent)	20.00	21.26	95.00	93.40	Fail
AC thermal cracking (ft/mile)	1000.00	346.09	95.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	2000.00	1427.68	95.00	99.71	Pass
Permanent deformation - AC only (in.)	0.50	0.42	95.00	99.49	Pass

Distress Charts

Report generated on: 1/28/2015 3:55 PM Created by: J Schenkel on: 9/4/2014 12:00 AM Approved by: on: 1/1/2001 12:00 AM Page 1 of 25

ME DESIGN METHOD (*NEW*)

Design Comparison

	<u>AASHTO 1993</u>	<u>Mechanistic-Empirical</u>
Basis	Empirical observation from the 1958-59 AASHTO Road Test	Theories of mechanics
Original Calibration	AASHO Road Test – Ottawa, IL	SHRP test sections from around the country
Traffic Characterization	Equivalent Single Axle Load	Axle load spectra
Materials Inputs	Very few	Many
Climatic Effects	Limited – can change inputs based on season	Integral – weather data from 600+ US weather stations included
Performance Parameter	Present Serviceability Index	Various distresses, IRI
Output	Thickness	Performance prediction (distress prediction)

ME DESIGN METHOD (*NEW*)

- ❑ 1st calibration completed fall of 2014 (Michigan State University project)
- ❑ 2nd calibration completed end of 2017 (MSU)
- ❑ 3rd calibration to be completed in 2022 (MSU)
- ❑ Began phase 1 of transition process March 2015
 - Phase 1: Life-cycled reconstruction projects
 - Phase 2: All reconstruct projects (*currently in this phase*)
 - Phase 3: Life-Cycled rehab projects
 - Phase 4: All rehab projects

ME DESIGN METHOD (*NEW*)

MDOT ME Website:

- http://www.michigan.gov/mdot/0,4616,7-151-9623_26663_27303_27336_63969---,00.html

MDOT ME User Guide

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I-275 project updates: www.revive275.com and www.mi.gov/drive

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Mechanistic-Empirical (ME) Pavement Design

The Michigan Department of Transportation (MDOT) is currently working towards implementing the new AASHTOWare ME Pavement Design software. This site will provide progress reports as well as links to other ME-related resources.

ME Pavement Design is the latest generation of pavement design methodologies. It utilizes the theories of mechanics of materials to predict the pavement's response (stresses and strains) to load. The pavement's response is then correlated into damage, which is accumulated over the design life and results in predicted distresses over time. Climatic conditions (temperatures, moisture levels, etc.) are taken into account through the material properties of the constituent pavement layers. Finally, the models used to predict distresses are calibrated using observed distress amounts (the empirical portion of the name).

Contact
Mike Eacker
Phone: 517-322-3474
email: eackerm@michigan.gov

Justin Schenkel
Phone: 517-636-6006
email: schenkelj@michigan.gov
[Receive E-mail Updates](#)

Sign up to receive e-mail updates for ME Pavement Design through MDOT's GovDelivery e-mail system.

Implementation Newsletters

ME - Related Research Reports

Presentations
Operations Executive Staff Oct. 18, 2012
Oversight Committee Kickoff June 18, 2012

Manuals & Software Resources
[Mechanistic Empirical Pavement Design User Guide](#)

Quick Links

- Title VI Nondiscrimination
- Tribal Governments
- Twitter Facebook YouTube
- Mi Drive
- State Map

QUICKLINKS

- AASHTOWare Pavement ME Design
- AASHTOWare Pavement ME Design Webinars
- NCHRP 1-37A Final Report
- FHWA Pavements
- FHWA DGIT Workshops
- Pavement Interactive
- State DOT Search Engine
- TRB Research In Progress
- Transportation Research Database

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7/23/2020

QUESTIONS?



□ Contact Info:

- Justin P. Schenkel, P.E.
P: 517-636-6006
E: schenkelj@michigan.gov



Construction Field Services

Michigan Department of Transportation



7/23/2020