SUDAS Concrete Pavement Design – AASHTO 93

ICPA Concrete Pavement Design Seminar

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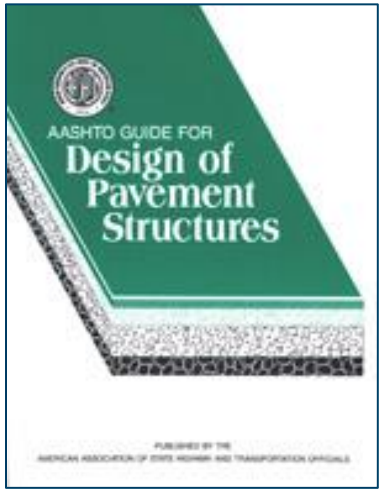
Introduction

- There are many new concrete pavement thickness design tools that are more accessible and user-friendly than ever
- SUDAS also provides pavement thickness design guidance
  - Older design approach with commentary and recommendations geared toward Iowa's cities

Image: ACPA

SUDAS/AASHTO 93 Design

- Section 5F-1 in the *SUDAS Design Manual*
- Based on the AAHSTO 1993 pavement design guide, including methods for both concrete and asphalt pavements
- Provides full commentary and explanation of AASHTO 93 inputs, including recommendations for representative Iowa values



Iowa SUDAS
STATEWIDE URBAN DESIGN AND SPECIFICATIONS

AASHTO Pavement Design

- Initially developed as an empirical design procedure based on the performance of the AASHO road test sections
- Modified over the years to account for additional variables and concepts

AASHO Road Test, 1950s

Q: Where was the AASHO road test?

AASHTO Pavement Design

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- Modified over the years to account for additional variables and concepts

AASHO Road Test, 1950s

A: Ottawa, IL (next to I-80)

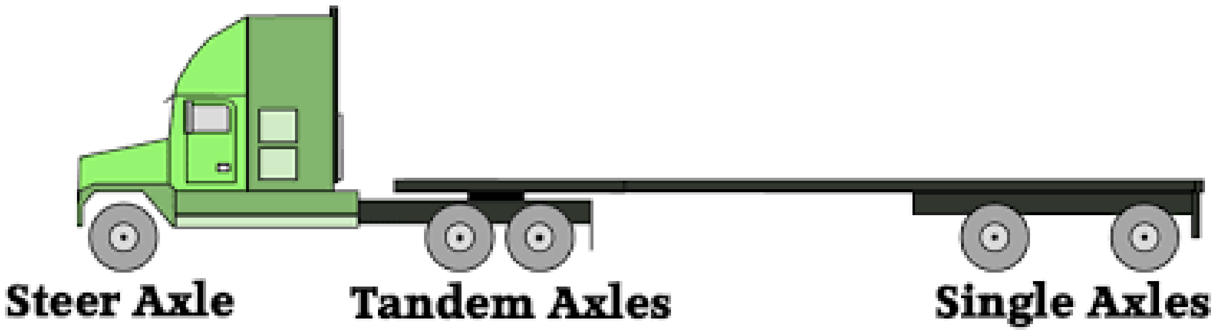
AASHTO Pavement Design

- Shares many of the same design inputs as PavementDesigner.org (PCA Method/StreetPave)
  - There are some differences and unique concepts between the two methods
  - The design equations/models handle some of the same input values differently from each other

PavementDesigner.org

AASHTO Pavement Design

- Differences with AASHTO pavement design:
  - Design traffic is characterized by ESALs
    - Equivalent single axle loads
    - Based on load equivalency factors for different types of trucks
  - Only considers number of load repetitions to failure, calibrated based on AASHO road test results and limited modeling
    - No consideration of separate failure modes like erosion or fatigue as in PavementDesigner.org



AASHTO Pavement Design

- Differences with AASHTO pavement design:
  - End of pavement life: terminal serviceability index
  - Joint spacing does not play any role in concrete pavement thickness design
  - Different terms to account for reliability, standard deviation, etc.

Image: Wikipedia

SUDAS/AASHTO 93 Design

- When should I use SUDAS/AASHTO pavement design?
  - It has well-known limitations and it doesn't incorporate the latest pavement design concepts…
  - But it's also been used successfully for many years and is well-understood by many of its practitioners
  - Allows for side-by-side design of concrete and asphalt options
  - The closer you get to the conditions of the AASHO road test, the more applicable those results might be to your design case

SUDAS/AASHTO 93 Design

- When should I use SUDAS/AASHTO pavement design?
  - Climate, materials, and soils in Iowa are similar to those at the road test site in northern Illinois
  - Local agencies often don’t have to design for traffic volumes as high as on state highways
  - Good understanding of the design procedure and customized local design inputs and commentary
    - SUDAS

Iowa SUDAS
STATEWIDE URBAN DESIGN AND SPECIFICATIONS

SUDAS/AASHTO 93 Design

- Section 5F-1 of the *SUDAS Design Manual*
  - Detailed explanation of the AASHTO 93 pavement design process and how to determine design input parameters
  - Design tables are used to calculate design ESALs and pavement thickness using recommended input values for local conditions
  - Allows for easy comparison of equivalent AASHTO 93 concrete and asphalt pavement designs
  - Recommended input values can be plugged into WinPAS software to perform a custom pavement design

Design Parameters

- Parameters required for design:

Table 5F-1.01: Summary of Design Parameters for Pavement Thickness

Section	Description	Flexible HMA	Rigid JPCP/JRCP
5F-1, B, 1	**Performance Criteria**		
	a. Initial Serviceability Index	X	X
	b. Terminal Serviceability Index	X	X
5F-1, B, 2	**Design Variables**		
	a. Analysis Period	X	X
	b. Design Traffic	X	X
	c. Reliability	X	X
	d. Overall Standard Deviation	X	X
5F-1, B, 3	**Material Properties for Structural Design**		
	a. Soil Resilient Modulus	X	
	b. Modulus of Subgrade Reaction		X
	c. Concrete Properties		X
	d. Layer Coefficients	X	
5F-1, B, 4	**Pavement Structural Characteristics**		
	a. Coefficient of Drainage	X	X
	b. Load Transfer Coefficients for Jointed		X
	c. Loss of Support		X

Design Parameters

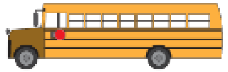
- Table 5F-1.12 contains recommended input values for design parameters
- Section B contains explanation and guidance for selection of input values

Subbase:	Natural		4" Subbase		6" Subbase		8" Subbase		10" Subbase		12" Subbase	
CBR Value:	**3**	**5**	**3**	**5**	**3**	**5**	**3**	**5**	**3**	**5**	**3**	**5**
Rigid Pavement Parameters												
Initial Serviceability Index, P_o	4.5											
Terminal Serviceability Index, P_t	Local Roads = 2.00 Collector Roads = 2.25 Arterials = 2.50											
Reliability, R	Local Roads = 80% Collector Roads = 88% Arterials = 95%											
Overall Standard Deviation, S_o	0.35											
Loss of Support, LS	0											
Soil Resilient Modulus, M_R 1500 x CBR	4,500	7,500	4,500	7,500	4,500	7,500	4,500	7,500	4,500	7,500	4,500	7,500
Subbase Resilient Modulus, E_{SB} *Assumed	Not Applicable		30,000*									
Modulus of Subgrade Reaction k, and Composite Modulus of Subgrade Reaction, k_c Use AASHTO Chapter 3, Table 3.2 and Figures 3.3 - 3.6 to determine	105	148	228	342	239	359	254	380	269	404	285	428
Coefficient of Drainage, C_d	1.00		1.10									
Modulus of Rupture, S'_c $S'_c = 2.3 \times f_c^{0.667}$ *Assumed 4,000 psi concrete	580											
Modulus of Elasticity, E_c $E_c = 6{,}750 \times S'_c$ *Assumed 4,000 psi concrete	3,915,000											
Load Transfer, J	J = 3.1 (Pavement Thickness <8") J = 2.7 (Pavement Thickness ≥ 8")											

ESAL Calculation

- Start with your design traffic level (ADT and % Trucks)
- Choose from one of three types of truck mixes (A/B/C) meant to correspond to different classes of streets
  - Truck mixes are based on Iowa traffic counts

Type B Truck Mix: Predominantly single axle with some multi-axle trucks

Truck Class (Vehicle Description)	Percent of Total Trucks	Loading	Percent of Truck Class	Vehicle Weight (lbs)	Axle Type S-Single TA-Tandem	Axle Load (lbs)	ESAL Factor (per axle) Rigid	ESAL Factor (per axle) Flexible	LEF (by Vehicle) Rigid	LEF (by Vehicle) Flexible
 Class 4 (2-axle busses, BUS)	5%	Partial Load (80% capacity)	100%	25000	Front-S	9000	0.053	0.066		
					Rear-S	16000	0.607	0.631	0.660	0.697
 Class 5 (2-axle, 6-tire trucks & busses, SU-2)	55%	Partial Load (50% capacity)	100%	20000	Front-S	6500	0.014	0.018		
					Rear-S	13500	0.294	0.326	0.308	0.344
 Class 6 (3-axle trucks, SU-3)	10%	Empty	50%	22000	Front-S	7000	0.019	0.024		
					Rear-TA	15000	0.064	0.044	0.041	0.034
		Fully Loaded	50%	46000	Front-S	12000	0.178	0.206		
					Rear-TA	34000	1.900	1.099	1.039	0.653
 Class 8 (4-axle (or less) single trailer truck, Comb-4)	5%	Empty	20%	24000	Front-S	9000	0.053	0.066		
					Rear-TA	9000	0.009	0.006		
					Trailer-S	6000	0.010	0.013	0.014	0.017
		Partial Load (50% capacity)	40%	44000	Front-S	9500	0.067	0.082		
					Rear-TA	22000	0.310	0.202		
					Trailer-S	12500	0.212	0.242	0.236	0.210
		Fully Loaded	40%	64000	Front-S	10000	0.083	0.101		
					Rear-TA	34000	1.900	1.099		
					Trailer-S	20000	1.558	1.520	1.416	1.088
 Class 9 (5-axle single trailer truck, Comb-5)	25%	Empty	20%	36000	Front-S	11000	0.124	0.147		
					Rear-TA	14000	0.048	0.033		
					Trailer-TA	11000	0.019	0.013	0.038	0.039
		Partial Load (50% capacity)	40%	58000	Front-S	11500	0.149	0.175		
					Rear-TA	24000	0.447	0.284		
					Trailer-TA	22500	0.341	0.220	0.375	0.272
		Fully Loaded	40%	80000	Front-S	12000	0.178	0.206		
					Rear-TA	34000	1.900	1.099		
					Trailer-TA	34000	1.900	1.099	1.592	0.962
					Composite LEF for Type B Truck Mix =				**0.895**	**0.677**

ESAL Calculation

- Select base year design ESALs from Tables 5F-1.07 through 10

Table 5F-1.09: Base Year Design ESALs for Four Lane *Rigid Pavement*

% Trucks	Truck Mix Type	Two-Way Base Year AADT							
		2,000	**5,000**	**10,000**	**15,000**	**20,000**	**25,000**	**30,000**	**35,000**
1	A	1,000	3,000	6,000	9,000	11,500	14,500	17,500	20,500
	B	2,000	5,000	10,000	14,500	19,500	24,500	29,500	34,500
	C	3,000	7,000	14,500	21,500	28,500	35,500	43,000	50,000
2	A	2,500	6,000	11,500	17,500	23,500	29,500	35,000	41,000
	B	4,000	10,000	19,500	29,500	39,000	49,000	59,000	68,500
	C	5,500	14,500	28,500	43,000	57,000	71,500	85,500	100,000
3	A	3,500	9,000	17,500	26,500	35,000	44,000	52,500	61,500
	B	6,000	14,500	29,500	44,000	59,000	73,500	88,000	103,000
	C	8,500	21,500	43,000	64,000	85,500	107,000	128,500	149,500
4	A	4,500	11,500	23,500	35,000	47,000	58,500	70,500	82,000
	B	8,000	19,500	39,000	59,000	78,500	98,000	117,500	137,000
	C	11,500	28,500	57,000	85,500	114,000	142,500	171,000	199,500
5	A	6,000	14,500	29,500	44,000	58,500	73,000	88,000	102,500
	B	10,000	24,500	49,000	73,500	98,000	122,500	147,000	171,500
	C	14,500	35,500	71,500	107,000	142,500	178,000	214,000	249,500

ESAL Calculation

- Obtain a multiplier for growth factor based on design period (years) and project annual growth in traffic volume
- Calculate a final number for design ESALs for the design period

Table 5F-1.11: Growth Factor

Design Period Years (n)	Average Annual Traffic Growth Rate, Percent					
	No Growth	1%	2%	3%	4%	5%
1	1.0	1.0	1.0	1.0	1.0	1.0
2	2.0	2.0	2.0	2.0	2.0	2.1
3	3.0	3.0	3.1	3.1	3.1	3.2
4	4.0	4.1	4.1	4.2	4.2	4.3
5	5.0	5.1	5.2	5.3	5.4	5.5
6	6.0	6.2	6.3	6.5	6.6	6.8
7	7.0	7.2	7.4	7.7	7.9	8.1
8	8.0	8.3	8.6	8.9	9.2	9.5
9	9.0	9.4	9.8	10.2	10.6	11.0
10	10.0	10.5	10.9	11.5	12.0	12.6

Determining Pavement Thickness

- Final design thickness calculated using Tables 5F-1.13 through 18

Table 5F-1.14: Recommended Thickness for Rigid Pavement - *Collector Roads*

CBR	3						5					
ESAL/ Subbase	Natural	4" Granular	6" Granular	8" Granular	10" Granular	12" Granular	Natural	4" Granular	6" Granular	8" Granular	10" Granular	12" Granular
750,000	7	6	6	6	6	6	7	6	6*	6*	6*	6*
1,000,000	7.5	6.5	6.5	6.5	6.5	6.5	7	6	6	6	6	6
1,500,000	8	7	7	7	7	7	7.5	6.5	6.5	6.5	6.5	6.5
2,000,000	8	7.5	7.5	7.5	7.5	7	8	7	7	7	7	7
3,000,000	8	8	8	8	8	8	8	7.5	7.5	7.5	7.5	7.5
4,000,000	8.5	8	8	8	8	8	8.5	8	8	8	8	8
5,000,000	9	8	8	8	8	8	8.5	8	8	8	8	8
7,500,000	9.5	8.5	8.5	8.5	8.5	8.5	9.5	8.5	8	8	8	8
10,000,000	10	9	9	9	9	9	9.5	8.5	8.5	8.5	8.5	8.5

* Represents the minimum thickness based on established policies of local jurisdictions; the calculated value is less.

WinPAS

- WinPAS = Windows Pavement Analyst Software
- Software to perform AASHTO 93 thickness design calculations
- Includes design of both concrete and asphalt pavements
- Allows for full customization of input values
- Contains a module for life cycle cost analysis (LCCA)
- Older and not the most user-friendly by the standards of 2023… but download and license keys are still available from ACPA

ACPA

Final Thoughts

- Different design procedures can be effective and useful tools, provided:
  - Good understanding by the practitioner
  - Applicable to your design case
  - Quality of data and inputs
  - Ability to customize input values