LECTURE 8

AASHTO Design Method

The design procedure recommended by the American Association of State Highway and Transportation Officials

Important Variables used in AASHTO Design Method

1- Pavement Serviceability Index
2- Reliability
3- Standard Deviation
4- Resilient Modulus
5- Drainage Coefficient
6- Layer Coefficient
7- Equivalent Single Axle Load
8- Structural Number

Pavement Serviceability Index (ΔPSI)

Serviceability: the ability at time of observation of a pavement to serve traffic (autos andtrucks); which use the facility.

Based upon Present Serviceability Rating (PSR)

Subjective rating by individual/panel

Initial/post-construction

Various time after construction3. $0 < PSR < 5$

4. PSR < ~2.5: Unacceptable

Trend of serviceability with load application measured by (PSI) present serviceability index.ΔPSI (use in the design equation) = $P_i - P_t$

Where:

P_i = Initial Serviceability, which is a function of pavement type and construction quality

= 4.2 for flexible pavement.

= 4.5 for rigid pavementP_t = Terminal Serviceability

For heavy traffic = 2.5For medium traffic = 2For light traffic = 1.5

The scale of PSI, $1 < PSI < 5$

Reliability (R)

It is the probability that a pavement section designed using the process will perform satisfactory over the traffic and environmental conditions for the design period, Reliability = 90% if not given

The AASHTO guide incorporates in the design procedure a reliability factor R% to account for uncertainties in traffic prediction and pavement performance. R% indicates the probabilitythat the pavement design will not reach the terminal serviceability level before the end of the design 20 years.

Functional Classification	Recommended level of Reliability	
	Urban	Rural
Interstate and other	85 – 99.9	80 – 99.9
Other principles Arterials	80 - 99	75 - 95
Collectors	80 – 95	75 - 95
Local	50 - 80	50 – 80

Standard Deviation (S_o)

Overall standard deviation is a design input for the AASHTO procedure that takes into account uncertainty in traffic estimation and varying construction materials and conditions. AASHTO recommended values shown below:

Rigid pavement: 0.3 – 0.4, Flexible pavement: 0.4 – 0.5

It presents a safety factor for the tolerance occurred due to traffic volumes, traffic characteristics, construction accuracy, temperature, etc.

Standard Deviation = 45% if not given

Resilient Modulus (Mr)

It is a layer strength indication (Elastic Modulus) under dynamic load $M_r = 1500$ CBR Fine soil. $M_r = 3000\ CBR^{0.65}$ Coarse soil

Drainage Coefficient (m)

It is a factor represents the ability of the layer to drain water.

Recommended Drainage coefficient for untreated bases and subbases in Flexible Pavement

Quality of drainage		**% of time pavement structure is exposed tomoisture levels approaching saturation**			
Rating	**Water removed within**	**< 1 %**	**1 - 5 %**	**5 – 25 %**	**> 25 %**
Excellent	2 hours	1.4 – 1.35	1.35 – 1.3	1.3 – 1.2	1.2
Good	1 day	1.35 – 1.25	1.25 – 1.15	1.15 – 1.0	1.00
Fair	1 week	1.25 – 1.15	1.15 – 1.05	1.00 – 0.8	0.8
Poor	1 month	1.15 – 1.05	1.05 – 0.8	0.8 – 0.6	0.6
Very poor	Never drain	1.05 – 0.95	0.95 – 0.75	0.75 – 0.4	0.4

Layer Coefficient (a)

It is a coefficient based on layer type

1- Equivalent Single Axle Load (ESAL W18)

All traffic volumes passing on road is converted to standard axle load which is 18000 lb usingequivalency factors.

W18 = 18000 lb = 18 kip = 8.2 Tons = 80 KN

For pavement designs, a traffic analysis must be performed in order to obtain an expected value for 18 kip (80 KN) equivalent single axle load (ESAL's) over the structural design life of the section. In order to estimate design ESAL's, the designer must know the average daily traffic (ADT), percent trucks, vehicle class distribution and an annual growth rate or expansion factor. To calculate the design ESAL's, the daily truck counts from each axlegroup are multiplied by a conversion factor to arrive at an annual ESAL value. The annual ESAL's from each axle group are summed to arrive at a total annual ESAL value.

$$\boldsymbol{ESAL_i = f_d * G_{rn} * AADT_i * 365 * N_i * F_{Ei}}$$

Where:

$ESAL_i$= equivalent accumulated 18,000*Ib* (80kN) single-axle load for the axle category *i*

f_d= design lane factor.

G_{rn}= growth factor for a given rate *r* and design period *n*

$AADT_i$ = first year annual average daily traffic for axle category *i*

N_i = number of axles on each vehicles in category *i*

F_{Ei} = load equivalency factor for axle category *i*

Design Period, Years (n)	*Annual Growth Rate, Percent (r)*							
	No Growth	*2*	*4*	*5*	*6*	*7*	*8*	*10*
1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2	2.0	2.02	2.04	2.05	2.06	2.07	2.08	2.10
3	3.0	3.06	3.12	3.15	3.18	3.21	3.25	3.31
4	4.0	4.12	4.25	4.31	4.37	4.44	4.51	4.64
5	5.0	5.20	5.42	5.53	5.64	5.75	5.87	6.11
6	6.0	6.31	6.63	6.80	6.98	7.15	7.34	7.72
7	7.0	7.43	7.90	8.14	8.39	8.65	8.92	9.49
8	8.0	8.58	9.21	9.55	9.90	10.26	10.64	11.44
9	9.0	9.75	10.58	11.03	11.49	11.98	12.49	13.58
10	10.0	10.95	12.01	12.58	13.18	13.82	14.49	15.94
11	11.0	12.17	13.49	14.21	14.97	15.78	16.65	18.53
12	12.0	13.41	15.03	15.92	16.87	17.89	18.98	21.38
13	13.0	14.68	16.63	17.71	18.88	20.14	21.50	24.52
14	14.0	15.97	18.29	19.16	21.01	22.55	24.21	27.97
15	15.0	17.29	20.02	21.58	23.28	25.13	27.15	31.77
16	16.0	18.64	21.82	23.66	25.67	27.89	30.32	35.95
17	17.0	20.01	23.70	25.84	28.21	30.84	33.75	40.55
18	18.0	21.41	25.65	28.13	30.91	34.00	37.45	45.60
19	19.0	22.84	27.67	30.54	33.76	37.38	41.45	51.16
20	20.0	24.30	29.78	33.06	36.79	41.00	45.76	57.28
25	25.0	32.03	41.65	47.73	54.86	63.25	73.11	98.35
30	30.0	40.57	56.08	66.44	79.06	94.46	113.28	164.49
35	35.0	49.99	73.65	90.32	111.43	138.24	172.32	271.02

SOURCE: *Thickness Design–Asphalt Pavements for Highways and Streets,* Manual Series No. 1, The Asphalt Institute, Lexington, KY, February 1991. Used with permission.

Example 19.1 Computing Accumulated Equivalent Single-Axle Load for a Proposed Eight-Lane Highway Using Load Equivalency Factors

An eight-lane divided highway is to be constructed on a new alignment. Traffic volume forecasts indicate that the average annual daily traffic (AADT) in both directions during the first year of operation will be 12,000 with the following vehicle mix and axle loads.

Passenger cars (1000 lb/axle) = 50%
2-axle single-unit trucks (6000 lb/axle) = 33%
3-axle single-unit trucks (10,000 lb/axle) = 17%

The vehicle mix is expected to remain the same throughout the design life of the pavement. If the expected annual traffic growth rate is 4% for all vehicles, determine the design ESAL, given a design period of 20 years. The percent of traffic on the design lane is 45%, and the pavement has a terminal serviceability index (p_t) of 2.5 and SN of 5.

The following data apply:

Growth factor = 29.78 (from Table 19.4)
Percent truck volume on design lane = 45
Load equivalency factors (from Table 19.3)
Passenger cars (1000 lb/axle) = 0.00002 (negligible)
2-axle single-unit trucks (6000 lb/axle) = 0.010
3-axle single-unit trucks (10,000 lb/axle) = 0.088

Solution: The ESAL for each class of vehicle is computed from Eq. 19.2.

$$\text{ESAL} = f_d \times G_{jt} \times \text{AADT} \times 365 \times N_i \times F_{Ei}$$

$$\text{2-axle single-unit trucks} = 0.45 \times 29.78 \times 12{,}000 \times 0.33 \times 365 \times 2 \times 0.010$$
$$= 0.3874 \times 10^6$$
$$\text{3-axle single-unit trucks} = 0.45 \times 29.78 \times 12{,}000 \times 0.17 \times 365 \times 3 \times 0.0877$$
$$= 2.6343 \times 10^6$$

Thus,

$$\text{Total ESAL} = 3.0217 \times 10^6$$

It can be seen that the contribution of passenger cars to the ESAL is negligible. Passenger cars are therefore omitted when computing ESAL values. This example illustrates the conversion of axle loads to ESAL using axle load equivalency factors.

TABLE 6.4 Equivalent Axle Load Factors

Axle load (lb)	Equivalent axle load factor			Axle load (lb)	Equivalent axle load factor		
	Single axles	Tandem axles	Tridem axles		Single axles	Tandem axles	Tridem axles
1000	0.00002			41,000	23.27	2.29	0.540
2000	0.00018			42,000	25.64	2.51	0.597
3000	0.00072			43,000	28.22	2.76	0.658
4000	0.00209			44,000	31.00	3.00	0.723
5000	0.00500			45,000	34.00	3.27	0.793
6000	0.01043			46,000	37.24	3.55	0.868
7000	0.0196			47,000	40.74	3.85	0.948
8000	0.0343			48,000	44.50	4.17	1.033
9000	0.0562			49,000	48.54	4.51	1.12
10,000	0.0877	0.00688	0.002	50,000	52.88	4.86	1.22
11,000	0.1311	0.01008	0.002	51,000		5.23	1.32
12,000	0.189	0.0144	0.003	52,000		5.63	1.43
13,000	0.264	0.0199	0.005	53,000		6.04	1.54
14,000	0.360	0.0270	0.006	54,000		6.04	1.54
15,000	0.478	0.0360	0.008	55,000		6.93	1.78
16,000	0.623	0.0472	0.011	56,000		7.41	1.91
17,000	0.796	0.0608	0.014	57,000		7.92	2.05
18,000	1.000	0.0773	0.017	58,000		8.45	2.20
19,000	1.24	0.0971	0.022	59,000		9.01	2.35
20,000	1.51	0.1206	0.027	60,000		9.59	2.51
21,000	1.83	0.148	0.033	61,000		10.20	2.07
22,000	2.18	0.180	0.040	62,000		10.84	2.85
23,000	2.58	0.217	0.048	63,000		11.52	3.03
24,000	3.03	0.260	0.057	64,000		12.22	3.22
25,000	3.53	0.308	0.067	65,000		12.96	3.41
26,000	4.09	0.364	0.080	66,000		13.73	3.62
27,000	4.71	0.426	0.093	67,000		14.54	3.83
28,000	5.39	0.495	0.109	68,000		15.38	4.05
29,000	6.14	0.572	0.126	69,000		16.26	4.28
30,000	6.97	0.658	0.145	70,000		17.19	4.52
31,000	7.88	0.753	0.167	71,000		18.15	4.77
32,000	8.88	0.857	0.191	72,000		19.16	5.03
33,000	9.98	0.971	0.217	73,000		20.22	5.29
34,000	11.18	1.095	0.246	74,000		21.32	5.57
35,000	12.50	1.23	0.278	75,000		22.47	5.86
36,000	13.93	1.38	0.313	76,000		23.66	6.15
37,000	15.50	1.53	0.352	77,000		24.91	6.46
38,000	17.20	1.70	0.393	78,000		26.22	6.78
39,000	19.06	1.89	0.438	79,000		27.58	7.11
40,000	21.08	2.08	0.487	80,000		28.99	7.45

Note. 1 lb = 4.45 N.

شعبة المواصلات

2- Structural Number (SN)

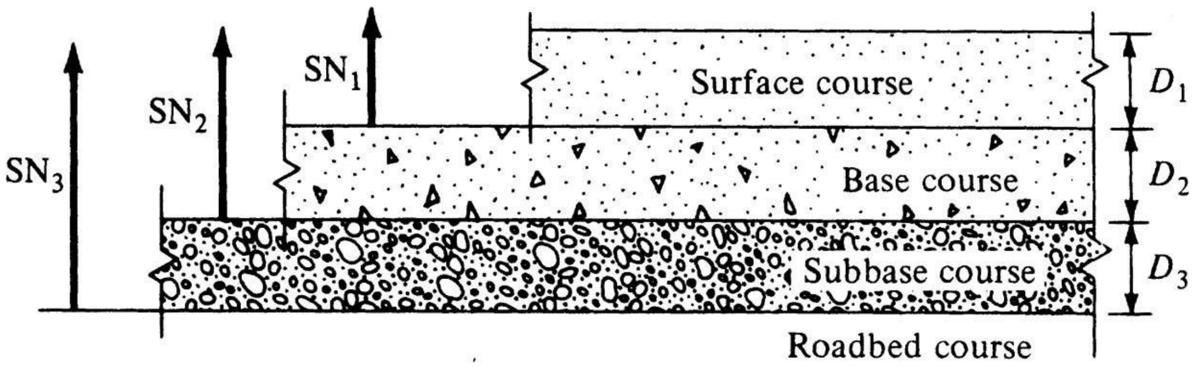
It is a number represents each pavement layer depends on traffic analysis, supporting layerand environmental effect and by which we calculate the thickness of layers.

$$\mathbf{SN = a_1 D_1 + a_2 D_2 m_2 + a_3 D_3 m_3}$$

Where:

a1, **a2** and **a3**: are layer coefficients for the surface, base and subbase, respectively; **D1**, **D2** and **D3: are the thickness of the surface, base and subbase, respectivelym2**: is the drainage coefficient of **base course**

m3: is the drainage coefficient of **subbase course**



Example:

Given: $\mathbf{W_{18}}$ = 5 * 10^6, **R**= 95%, So = 0.35, $\mathbf{M_R}$= 5000 psi (34.5 Mpa) and **ΔPSI** = 1.9

Determine **SN** from design chart.

Solution:

1- Starting from R=95%;2- S_o = 0.35;

3- W_{18}= 5 * 10^6;

4- M_R= 5000 psi (34.5 Mpa)

5- ΔPSI = 1.9

Finally intersect SN at 5.0

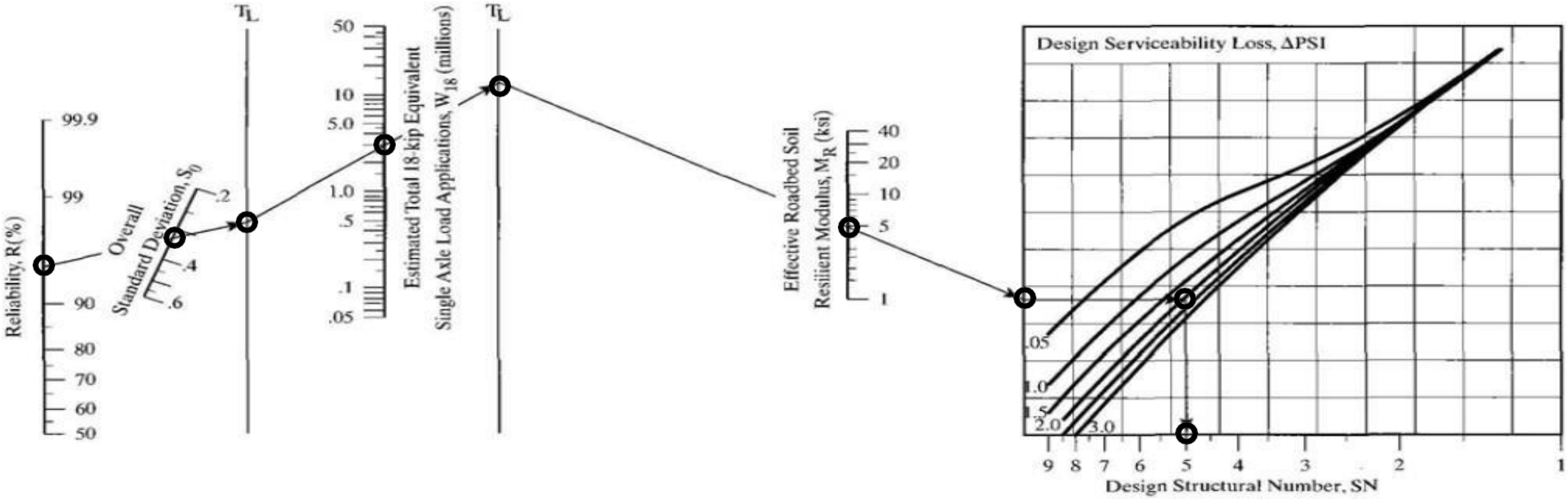


FIGURE 11.25

Design chart for flexible pavements based on mean values for each input (1 ksi = 6.9 MPa). (From the *AASHTO Guide for Design of Pavement Structures*. Copyright 1986. American Association of State Highway and Tranportation Officials, Washington, DC. Used by permission.)

$$log_{10}W_{18} = Z_R S_O + 9.36\, log_{10}(SN+1) - 0.02 + \frac{log_{10}[\frac{\Delta PSI}{4.2-1.5}]}{0.4 + \frac{1094}{(SN+1)^{5.19}}} + 2.32\, log_{10} M_R - 8.07$$

Or from using a chart →nomograph (design chart for flexible pavement).

Where:

W_{18} = Predicted number of 18000 lb (80 KN) single – axle load application

Z_R = standard normal deviation for a given reliability

S_o = overall standard deviation

SN = structural number indicative of the total pavement thickness

ΔPSI = P_i - P_t

TABLE 11.15 Standard Normal Deviates for Various Levels of Reliability

Reliability (%)	Standard normal deviate (Z_R)	Reliability (%)	Standard normal deviate (Z_R)
50	0.000	93	−1.476
60	−0.253	94	−1.555
70	−0.524	95	−1.645
75	−0.674	96	−1.751
80	−0.841	97	−1.881
85	−1.037	98	−2.054
90	−1.282	99	−2.327
91	−1.340	99.9	−3.090
92	−1.405	99.99	−3.750