D AASHO Road Test, PSI, and ESAL Concepts

(資料來源：

1. Carey, W.N., Jr., and P.E. Irick, "The Pavement Serviceability-Performance Concept," Highway Research Board, Bulletin No. 250, 1960.
2. Highway Research Board, "The AASHO Road Test," Report 5, Pavement Research, Special Report 61E, Publication No, 954, National Academy of Sciences - National Research Council, Washington, D.C., 1962.
3. Huang, Y. H., Pavement Analysis and Design, Prentice Hall Inc., 1993.)

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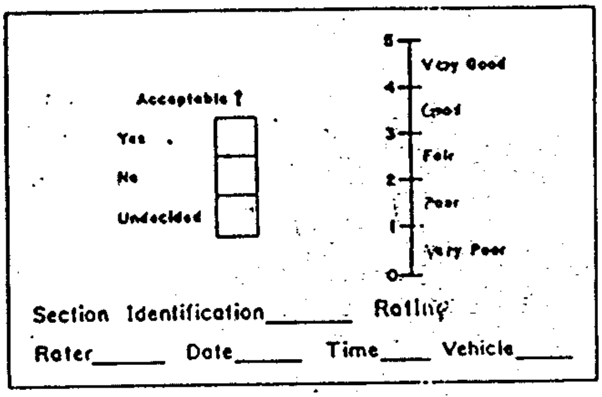


Figure 1. Individual present serviceability rating form.

Measurements for Selected Pavements

Following the acceptability opinion, Tables 1 and 2 give summary values for measurements made on the selected pavements. Measurements are shown in three categories—those that describe longitudinal and transverse roughness, those that summarize surface cracking and, finally, a measurement of the patched area found in the section.

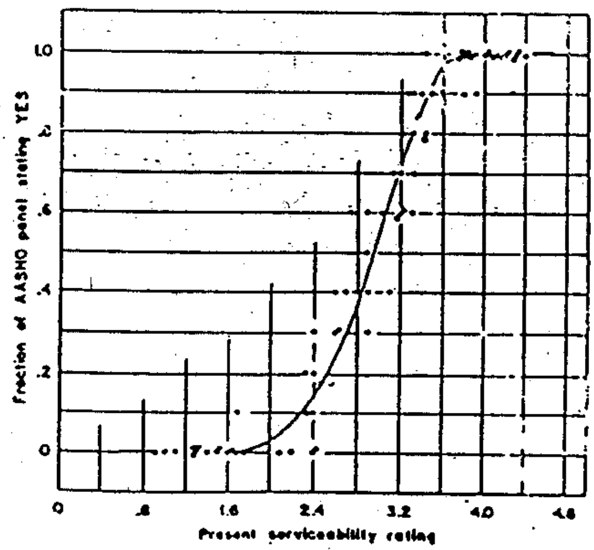


Figure 2. Acceptability vs present serviceability rating; 74 flexible pavements.

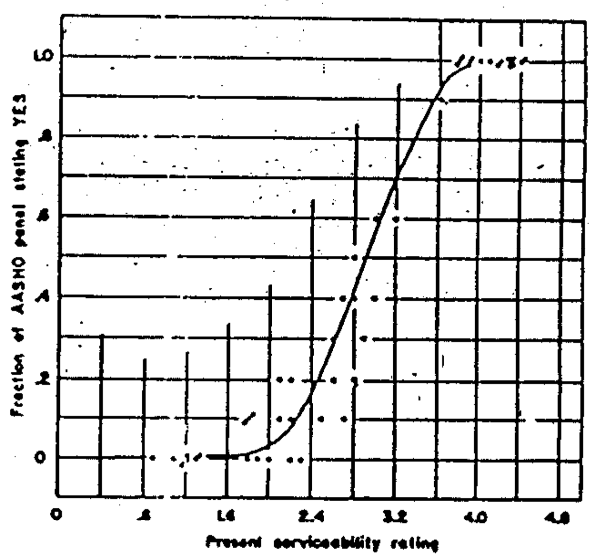


Figure 3. Acceptability vs present serviceability rating; 49 rigid pavements.

TABLE 1

DATA FOR 74 SELECTED FLEXIBLE PAVEMENTS

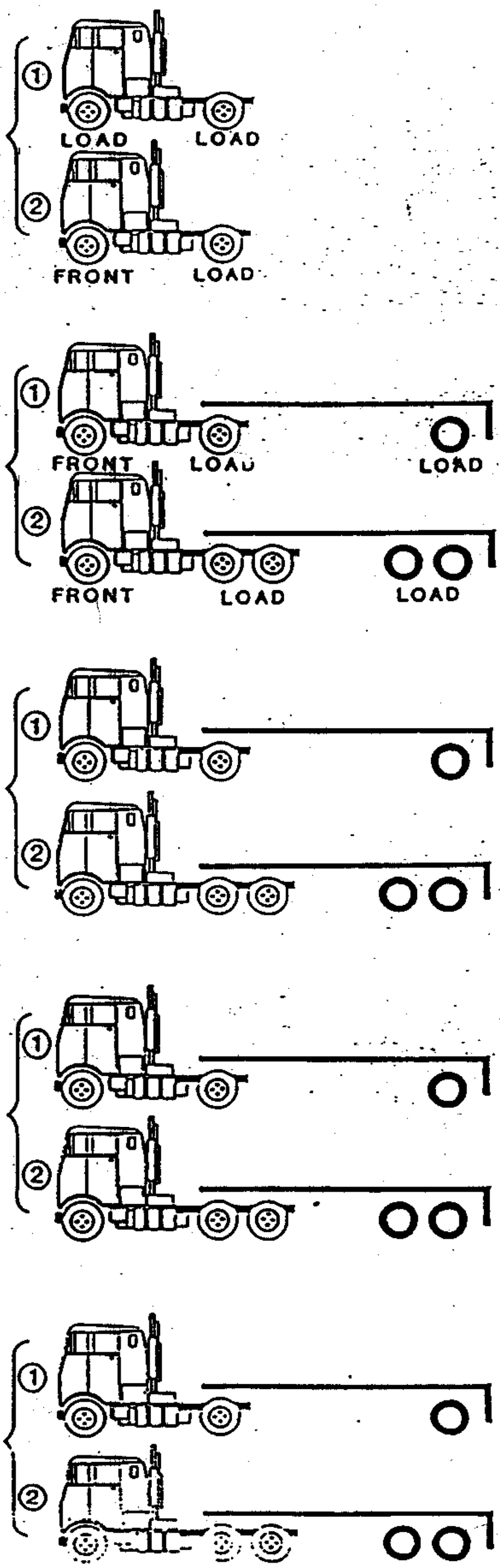
Pvt. Loc.	Sect. Code	Present Serviceability Ratings: AASHO Panel: 1st PSR	AASHO Panel: Replic. diff. in PSR	AASHO Panel: Std. dev. of PSR among raters	Truck DrVrs: PSR	Canad Raters: PSR	Acceptability Opinions: AASHO Panel Fraction: Yes	Fraction: No	$\overline{SV}$ Mean Slope Variance in Whlpths (x10⁶)	$\overline{AR}$ Mean AASHO Rdm'tr in Whlpths in./mi. @10mph	$\overline{RD}$ Mean Rut Depth, (in.)	$\overline{RDV}$ Mean Rut Depth Variance in²x100	Major Cracking: Class 2 + 3 Cracks ft²/1000ft²	Long. & Trans. ft/1000ft²	Patching: P Ft² per 1000 ft²	Transformations: Log (1+$\overline{SV}$)	$\overline{RD}^2$	Sq. rt. C+P	PSI 121 Pres. Serv. Index	Resid. Diff. Betw'n PSR & PSI
Ill.	F 3	4.3		.1	4.5	4.3	1.0	.0	2.8		.10	.7	0	0	0	.57	.01	.0	3.9	.4
	F 4	2.4		.4		2.0	.0	.6	20.5		.22	9.2	343	0	0	1.33	.05	18.5	2.3	.1
	F 5	3.3		.7	3.5	2.6	.6	.2	9.2		.08	3.6	8	0	0	1.01	.01	2.8	3.1	.2
	F 6	4.4	.1	.2	3.5		1.0	.0	3.5		.08	.7	0	0	0	.65	.00	.0	3.8	.6
	F 7	3.8	.1	.6	2.5	3.6	.9	.0	15.5		.06	.4	0	0	0	1.22	.00	.0	2.7	1.1
	F 8	2.6	.2	.7	2.0	2.7	.3	.6	9.5		.08	5.7	64	0	0	1.02	.01	8.0	3.0	.4
	F 9	3.2	.2	.6	3.0	3.0	.6	.2	14.0		.15	3.4	2	0	3	1.18	.02	2.2	2.7	.5
	F10	2.4	.0	.5	3.0	2.2	.1	.6	16.8		.16	3.4	17	0	14	1.25	.03	5.6	2.6	.2
	F11	1.3	.3	.5	1.5		.0	1.0	42.8		.26	10.3	292	0	11	1.64	.07	17.4	1.6	.3
	F12	1.1	.3	.2	1.0	1.7	.0	1.0	56.0		.19	10.9	21	0	2	1.76	.04	4.8	1.6	.5
Minn.	101	3.8	.3	.4			1.0	.0	1.9		.04	.4	0	29	0	.46	.00	5.4	4.1	.3
	102	3.8		.6			1.0	.0	1.5		.09	.3	0	34	0	.40	.00	5.8	4.2	.4
	103	3.8		.4			1.0	.0	1.7		.05	.2	0	14	0	.43	.00	3.7	4.2	.4
	104	3.8	.0	.4			1.0	.0	2.1		.04	.4	0	9	0	.49	.00	3.0	4.1	.3
	105	3.2		.4			.6	.1	7.0		.14	.5	0	0	20	.90	.02	3.2	3.3	.1
	106	1.3		.4			.0	1.0	58.5		.07	6.6	145	22	35	1.77	.00	14.2	1.5	.2
	107	1.3	.2	.4			.0	1.0	58.4		.08	2.9	75	12	55	1.77	.01	11.9	1.5	.2
	108	2.1		.6			.0	.9	17.6		.13	3.2	15	0	5	1.27	.03	4.5	2.5	.4
	109	1.5	.2	.2			.0	1.0	36.2		.37	5.6	30	2	76	1.57	.13	10.4	1.7	.2
	110	2.4	.0	.9			.0	.8	11.4		.07	3.2	2	0	3	1.09	.00	2.2	2.9	.5
	111	4.2		.2			1.0	.0	1.7		.11	.2	0	0	0	.42	.01	.0	4.2	.0
	112	3.9		.4			1.0	.0	1.4		.02	.2	0	0	0	.38	.01	.0	4.3	.4
	113	3.1	.1	.6			.4	.4	7.8		.08	1.3	1	68	66	.94	.01	11.6	3.1	.0
	114	2.2		.7			.0	.9	27.8		.13	5.2	0	1	4	1.46	.02	2.2	2.2	.0
	115	1.5		.6			.0	1.0	33.4		.08	5.4	0	7	6	1.54	.01	2.6	2.0	.5
	116	2.9	.5	.5			.6	.1	6.0		.02	.7	0	180	0	.85	.00	13.4	3.3	.4
	117	1.6	.0	.6			.0	1.0	39.4		.12	4.6	0	0	0	1.61	.01	.0	1.9	.3
	118	4.0	.2	.3			1.0	.0	1.6		.04	.2	0	0	0	.41	.00	.0	4.2	.2
	119	4.2		.5			1.0	.0	1.3		.03	.2	0	0	0	.36	.00	.0	4.3	.1
	120	2.9	.1	.5			.3	.2	5.8		.01	1.4	0	74	0	.84	.00	8.6	3.3	.4
	301	4.1		.6			1.0	.0	4.6	101	.24	.4	44	43	0	.75	.06	9.3	3.4	.7
	302	4.0		.5			1.0	.0	5.4	123	.34	.5	204	75	0	.81	.12	16.7	3.2	.8
Ind.	303	3.2		.5			.6	.1	20.1	146	.02	.4	12	1	0	1.32	.00	3.6	2.5	.7
	304	2.4	.0	.4			.2	.5	29.2	134	.17	1.8	455	0	17	1.48	.03	21.7	2.0	.4
	305	2.9	.1	.3			.4	.3	9.1	129	.10	1.2	292	0	32	1.00	.01	18.0	2.9	.0
	306	2.4	.2	.5			.3	.5	20.5	161	.12	2.4	816	0	0	1.33	.01	28.6	2.2	.2
	307	1.7	.3	.6			.1	.9	95.9	383	.02	1.9	719	0	111	1.99	.00	28.8	1.0	.7
	308	1.0		.4			.0	1.0	51.8	296	.03	5.1	691	0	161	1.72	.00	29.2	1.5	.5
	309	1.3		.4			.0	1.0	41.2	233	.14	7.0	613	0	159	1.62	.02	27.8	1.6	.3
	310	3.2		.6			.7	.1	11.5	144	.18	2.0	17	0	0	1.10	.03	4.1	2.8	.4
	311	2.7		.4			.4	.4	15.0	162	.14	.8	45	0	0	1.20	.02	6.7	2.6	.1
	312	1.6		.4			.0	1.0	49.8	217	.23	2.3	502	0	31	1.71	.05	23.1	1.5	.1
	313	1.4		.4			.0	1.0	42.0	182	.27	2.9	437	0	72	1.63	.07	22.6	1.7	.3
	314	2.6		.5			.3	.4	19.0	127	.24	1.2	10	64	2	1.30	.06	8.7	2.4	.2
	315	3.4		.7			.9	.0	6.9	107	.22	.2	283	46	0	.90	.05	15.1	3.1	.3
	316	2.9		.5			.5	.4	11.3	140	.09	.8	177	0	4	1.09	.01	13.4	2.8	.1
	317	4.3	-	.2			1.0	.0	2.9	95	.01	.1	0	0	0	.59	.00	.0	3.9	.4
	318	4.3		.3			1.0	.0	3.3	92	.00	.0	1	0	0	.63	.00	1.0	3.8	.5
	319	4.2	.0	.3			1.0	.0	3.8	92	.12	.2	0	1	0	.68	.01	1.0	3.7	.5
	320	3.9	.3	.4			.9	.0	3.8	105	.16	.4	0	2	0	.68	.03	1.4	3.7	.2
Test Road Sect.	501	3.8		.3			1.0	.0	5.8	132	.08	.3	0	0	0	.83	.01	.0	3.4	.4
	502	3.4		.6			.8	.1	10.3	160	.20	2.2	51	0	0	1.05	.04	7.2	2.9	.5
	503	3.1	.0	.3			.7	.0	7.6	127	.11	.8	17	0	7	.93	.01	4.9	3.2	.1
	504	4.1		.2			1.0	.0	2.6	109	.03	.2	0	0	0	.56	.00	.0	4.0	.1
	505	3.4		.2			1.0	.0	3.8	89	.33	.9	14	0	0	.68	.11	3.7	3.5	.1
	506	3.4		.4			.9	.0	4.8	89	.24	.9	0	0	0	.76	.06	.0	3.5	.1
	507	2.8		.4			.6	.3	7.6	103	.43	1.4	5	0	25	.93	.18	5.4	2.9	.1
	508	3.5		.5			.9	.0	4.0	75	.46	.5	0	0	0	.70	.21	.0	3.4	.1
	509	3.3		.5			.8	.0	2.9	84	.39	.4	9	0	0	.59	.15	3.0	3.7	.4
	510	3.3		.4			.9	.0	5.0	90	.44	1.0	2	0	0	.78	.19	1.3	3.3	.0
	511	3.6		.5			1.0	.0	3.5	90	.47	.6	0	0	0	.65	.22	.0	3.5	.1
	512	3.2		.7			.8	.0	5.1	87	.53	1.3	0	0	0	.79	.28	.0	3.1	.1
	513	3.4		.5			.8	.0	2.6	75	.56	.5	0	0	0	.56	.31	.0	3.5	.1
	514	1.8		.5			.0	.9	11.1	122	.73	5.1	80	0	16	1.08	.53	9.8	2.1	.3
	515	3.3		.7			.9	.0	2.5	79	.38	.5	0	0	0	.54	.14	.0	3.3	.5
	516	2.6		.6			.4	.3	5.4	86	.55	.6	15	0	0	.81	.30	3.9	3.0	.4
	517	3.2		.6			.5	.1	5.4	83	.54	.7	1	0	0	.81	.29	1.2	3.1	.1
	518	1.7		.4			.0	.8	21.0	149	.92	2.8	222	0	0	1.34	.85	14.9	1.2	.5
	519	2.4		.5			.1	.4	6.5	99	.53	3.5	21	0	0	.88	.28	4.6	2.9	.5
	520	3.0	.2	.6			.6	.1	6.8	89	.46	1.1	0	0	0	.89	.21	.0	3.0	.0
Off Site Sect.	521	3.3		.5			.7	.1	4.3	118	.09	.4	0	0	0	.72	.01	.0	3.6	.3
	522	2.7		.4			.6	.1	13.7	185	.11	3.8	300	0	1	1.17	.01	17.4	2.6	.1
	523	2.4		.4			.2	.2	10.8	137	.22	1.3	496	0	52	1.07	.05	23.4	2.7	.3
	524	0.9		.5			.0	1.0	88.1	281	.25	6.2	392	0	60	1.95	.06	21.2	1.0	.1
Sum		215.4	3.9	34.2												75.19	5.59	565.7	215.4*	22.3
Mean		2.91	.16	.46												1.02	.076	7.64	2.91	.30
Sum of Squares		66.85														13.27	1.34	5255	56.42*	10.42*

	Log (1+$\overline{SV}$)	$\overline{RD}^2$	Sq. rt. C+P
Sum of Products with PSR	-26.69	-1.51	-369.3
Sum of Products with log(1+$\overline{SV}$)		-.166	171.63
Sum of Products with $\overline{RD}^2$			-3.90

*Obtained from Unrounded Calculations

$$PSI\ 121 = 5.03 - 1.91 \log(1+\overline{SV}) - 1.38\overline{RD}^2 - .01\sqrt{C+P}$$

Table 3-2.1 Axle Weights and Distributions Used on Various Loops of the AASHO Road Test (5).



LOOP	LANE	WEIGHT IN KIPS FRONT AXLE	LOAD AXLE	GROSS WEIGHT
2	1	2	2	4
2	2	2	6	8
3	1	4	12	28
3	2	6	24	54
4	1	6	18	42
4	2	9	32	73
5	1	6	22.4	51
5	2	9	40	89
6	1	9	30	69
6	2	12	48	108

Loop 4					
Axle Load					
Lane 1			Lane 2		
18,000-S			32,000-T		
Main Factorial Design Design 1					
Surface Thickness	Base Thickness	Subbase Thickness	Factorial Block	Test Section No. Lane 1	Test Section No. Lane 2
3	0	4	1	633	634
		8	2	607	608
		12	3	571	572
			3	569	570
	3	4	2	599	600
		8	3	573	574
		12	1	617	618
	6	4	3	585	586
		8	1	623	624
		12	2	601	602
4	0	4	3	583	584
		8	1	619	620
		12	2	603	604
	3	4	1	627	628
		8	2	589	590
			2	597	598
		12	3	575	576
	6	4	2	595	596
		8	3	577	578
		12	1	625	626
5	0	4	2	605	606
		8	3	587	588
		12	1	621	622
	3	4	3	579	580
		8	1	631	632
		12	2	593	594
	6	4	1	629	630
			1	615	616
		8	2	591	592
		12	3	581	582

Figure 1-2.1. Pavement Sections Constructed on Loop 4 of the AASHO Road Test.

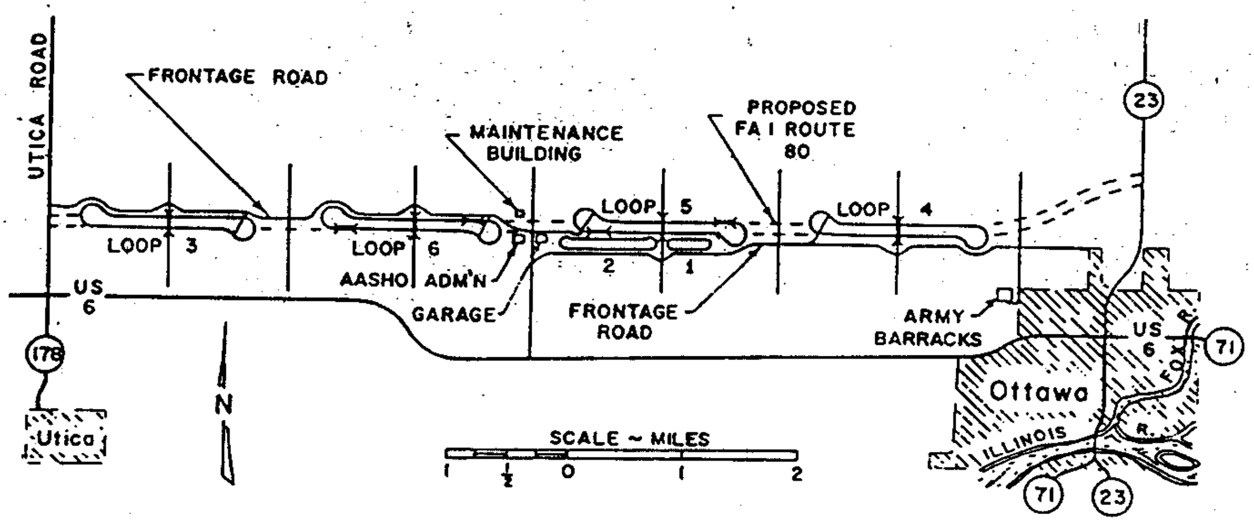


Figure 2. Layout of AASHO Road Test.

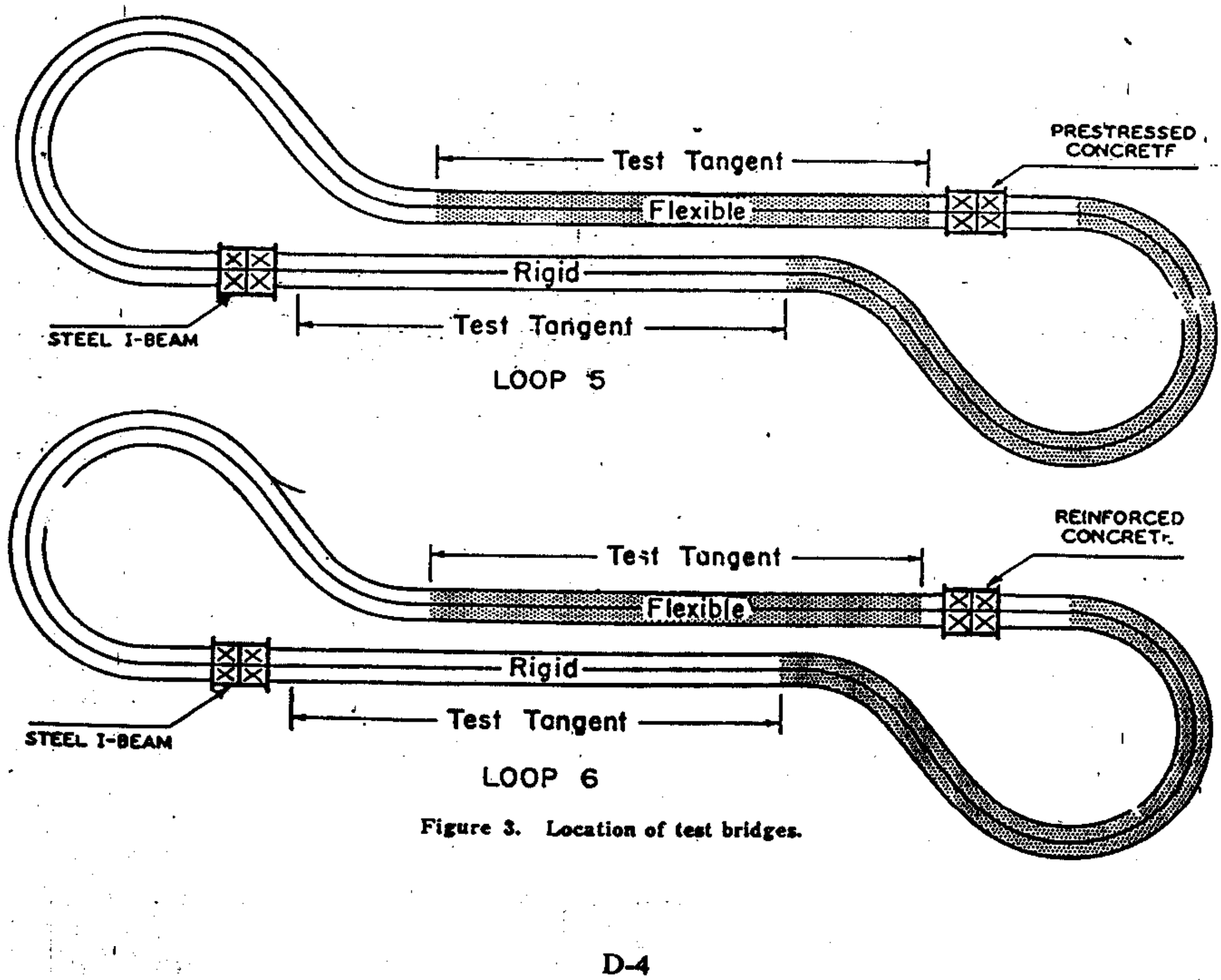


Figure 3. Location of test bridges.

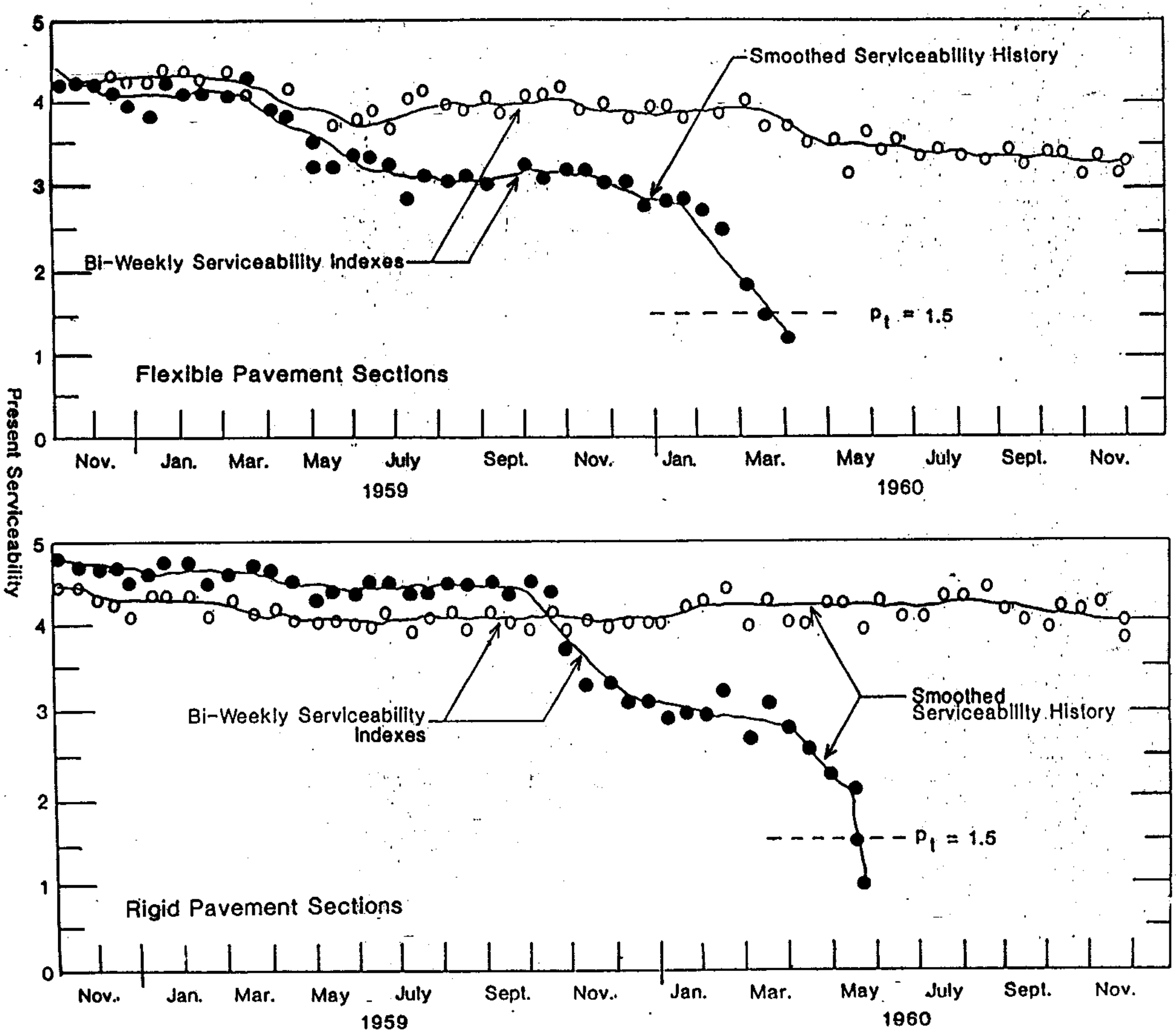


Figure I-2.2. Typical Serviceability Histories from the AASHO Road Test.

TYPICAL EXAMPLES OF PREDICTION MODELS

1. AASHO ROAD TEST:

$$g = \frac{P_i - P}{P_i - P_t} = \left(\frac{W}{\rho}\right)^{\beta}$$

Where:

g	=	"damage" index;
P_i, P_t, P	=	initial, terminal, and present serviceability indices (0-5), respectively;
W	=	number of standard loads, and;
ρ, β	=	functions of pavement thickness, strength, and axle load configurations.

2. NCHRP 1-19 PROJECT (COPES):

$$DISTRESS = (TRAFFIC\ OR\ AGE)^{a} * (b*DESIGN^{c} + d*SUBGRADE^{e} + f*CLIMATE^{g} + h*MATERIALS^{i})$$

WEIGHTED FLEXIBLE PAVEMENT EQUATIONS FROM THE AASHO ROAD TEST:

$$\log_{10} W = \log_{10}\rho + \frac{\log_{10}\left(\frac{4.2 - P}{2.7}\right)}{\beta}$$

$$\beta = 0.4 + \frac{0.081(L_1 + L_2)^{3.23}}{(D + 1)^{5.19} L_2^{3.23}}$$

$$\rho = \frac{10^{5.93}(D + 1)^{9.36} L_2^{4.33}}{(L_1 + L_2)^{4.79}}$$

$$D = 0.44D_1 + 0.14D_2 + 0.11D_3$$

Statistics:

For Predicting $\log_{10}W$: $R^2 = 0.70$, SEE = 0.31, N = 1171

(Mean Replicate Difference of $\log_{10}W = 0.17$, n = 126)

For Predicting W: $R^2 = 0.61$, SEE = 155.3, N = 1171

For Predicting PSI: $R^2 = 0.21$, SEE = 0.62, N = 1083

表10.1　軸重換算常數表（單軸）$P_t=2.5$

軸　重 (千磅)	路面結構數值 (SN) 1	2	3	4	5	6
2	0.0004	0.0004	0.0003	0.0002	0.0002	0.0002
4	0.003	0.004	0.004	0.003	0.003	0.002
6	0.01	0.02	0.02	0.01	0.01	0.01
8	0.03	0.05	0.05	0.04	0.03	0.03
10	0.08	0.10	0.12	0.10	0.09	0.08
12	0.17	0.20	0.23	0.21	0.19	0.18
14	0.33	0.36	0.40	0.39	0.36	0.34
16	0.59	0.61	0.65	0.65	0.62	0.61
18	1.00	1.00	1.00	1.00	1.00	1.00
20	1.61	1.57	1.49	1.47	1.51	1.55
22	2.48	2.38	2.17	2.09	2.18	2.30
24	3.69	3.49	3.09	2.89	3.03	3.27
26	5.33	4.99	4.31	3.91	4.09	4.48
28	7.49	6.98	5.90	5.21	5.39	5.98
30	10.31	9.55	7.94	6.83	6.97	7.79
32	13.90	12.82	10.52	8.85	8.88	9.95
34	18.41	16.94	13.74	11.34	11.18	12.51
36	24.02	22.04	17.73	14.38	13.93	15.50
38	30.90	28.30	22.61	18.06	17.20	18.98
40	39.26	35.89	28.51	22.50	21.08	23.04

表10.2　軸重換算常數表（複軸）$P_t=2.5$

軸　重 (千磅)	路面結構數值 (SN) 1	2	3	4	5	6
10	0.01	0.01	0.01	0.01	0.01	0.01
12	0.02	0.02	0.02	0.02	0.01	0.01
14	0.03	0.04	0.04	0.03	0.03	0.02
16	0.04	0.07	0.07	0.06	0.05	0.04
18	0.07	0.10	0.11	0.09	0.08	0.07
20	0.11	0.14	0.16	0.14	0.12	0.11
22	0.16	0.20	0.23	0.21	0.18	0.17
24	0.23	0.27	0.31	0.29	0.26	0.24
26	0.33	0.37	0.42	0.40	0.36	0.34
28	0.45	0.49	0.55	0.53	0 50	0.47
30	0.61	0.65	0.70	0.70	0.66	0.63
32	0.81	0.84	0.89	0.89	0.86	0.83
34	1.06	1.08	1.11	1.11	1.09	1.08
36	1.38	1.38	1.38	1.38	1.38	1.38
38	1.75	1.73	1.69	1.68	1.70	1.73
40	2.21	2.16	2.06	2.03	2.08	2.14
42	2.76	2.67	2.49	2.43	2.51	2.61
44	3.41	3.27	2.99	2.88	3.00	3.16
46	4.18	3.98	3.58	3.40	3.55	3.79
48	5.07	4.80	4.25	3.98	4.17	4.49

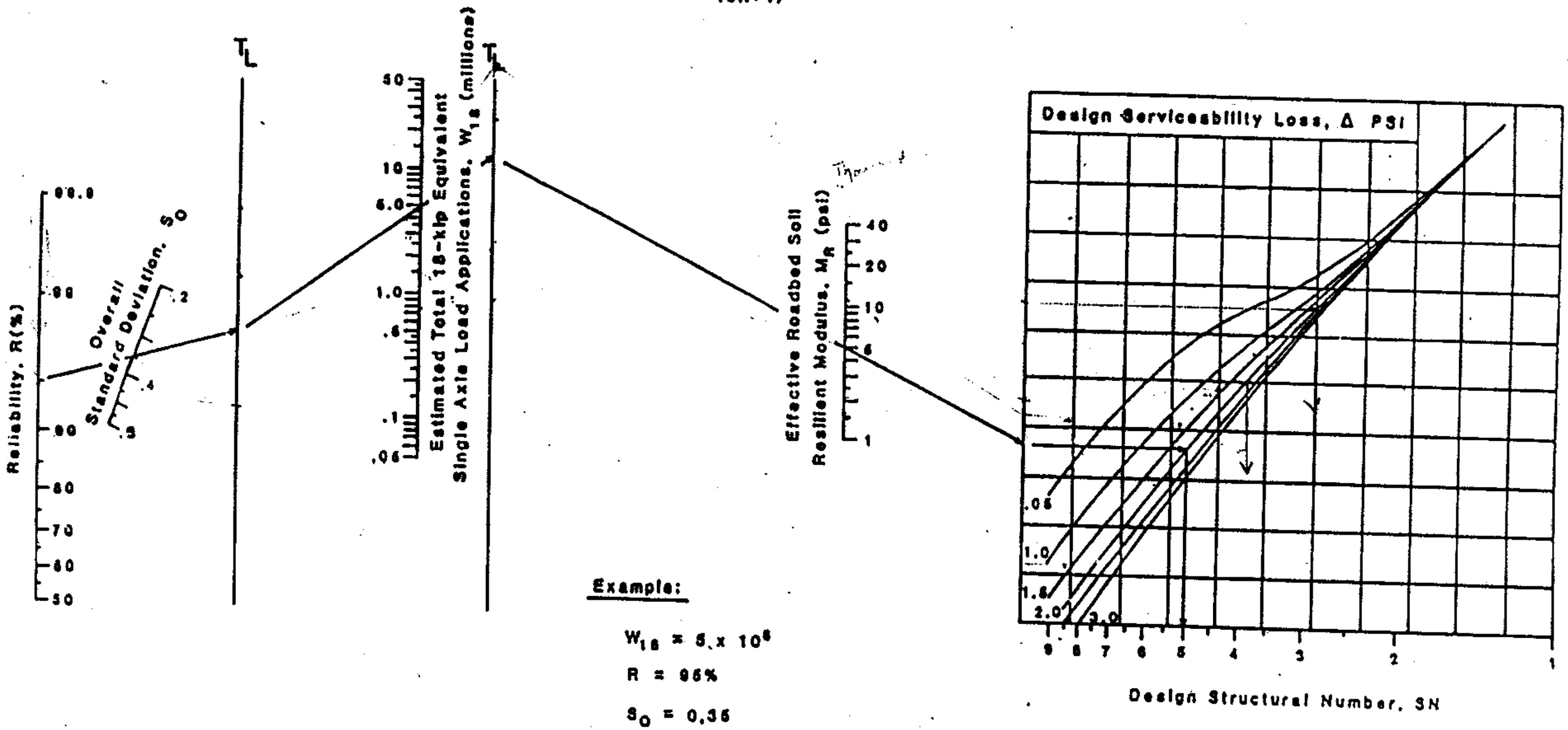
Axle Load	Traffic Equivalency Factor		Number of Axles		A18 Kip EAL's
Single Axles	P = 2.5, SN = 5				
Under 3,000	0.0002	X	0	=	0.000
3,000 - 6,999	0.0050	X	1	=	0.005
7,000 - 7,999	0.0320	X	6	=	0.192
8,000 - 11,999	0.0870	X	144	=	12.528
12,000 - 15,999	0.3600	X	16	=	5.760
26,000 - 29,999	5.3890	X	1	=	5.3890
Tandem Axle Groups					
Under 6,000	0.0100	X	0	=	0.000
6,000 - 11,993	0.0100	X	14	=	0.140
12,000 - 17,999	0.0440	X	21	=	0.924
18,000 - 23,999	0.1480	X	44	=	6.512
24,000 - 29,999	0.4260	X	42	=	17.892
30,000 - 32,000	0.7530	X	44	=	33.132
32,001 - 32,500	0.8850	X	21	=	18.585
32,501 - 33,999	1.0020	X	101	=	101.202
34,000 - 35,999	1.2300	X	43	=	52.890
18 Kip EAL's for all trucks wieghed				=	255.151

$$\text{Truck Load Factor} = \frac{\text{18 Kip EAL's for all trucks weighed}}{\text{Number of trucks weighed 1654}} = \frac{255.151}{165} = 1.5464$$

Figure 10. Computation of the Truck Load Factor for 5-Axle or Greater Trucks on Flexible Pavement (2).

NOMOGRAPH SOLVES:

$$\log_{10} W_{18} = Z_R * S_O + 9.36 * \log_{10}(SN+1) - 0.20 + \frac{\log_{10}\left[\frac{\Delta PSI}{4.2 - 1.5}\right]}{0.40 + \frac{1094}{(SN+1)^{5.19}}} + 2.32 * \log_{10} M_R - 8.07$$



Example:

$W_{18} = 5 \times 10^6$

$R = 95\%$

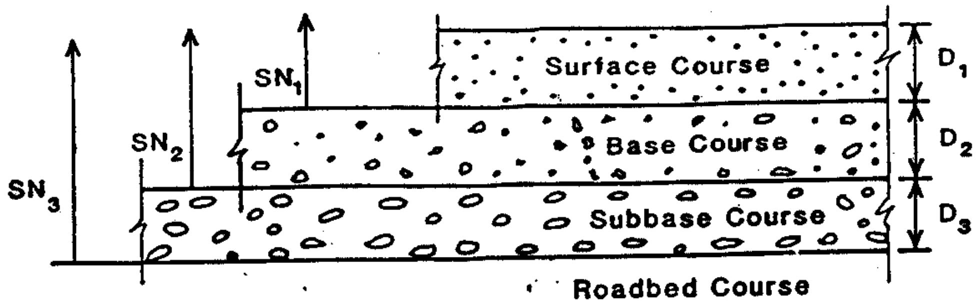
$S_O = 0.35$

$M_R = 5000$ psi

$\Delta PSI = 1.9$

Solution: SN = 5.0

Figure 3-2.11 AASHTO Flexible Pavement Thickness Design Nomograph (4).



$$D^*_1 \geq \frac{SN_1}{a_1}$$

$$SN^*_1 = a_1 D^*_1 \geq SN_1$$

$$D^*_2 \geq \frac{SN_2 - SN^*_1}{a_2 m_2}$$

$$SN^*_1 + SN^*_2 \geq SN_2$$

$$D^*_3 \geq \frac{SN_3 - (SN^*_1 + SN^*_2)}{a_3 m_3}$$

1) a,D,m, and SN are as defined in the text and are minimum required values.

2) An asterisk with D or SN indicates that it represents the value actually used, which must be equal to or greater than the required value.

Figure 3-2.12 Design of Flexible Pavement Layer Thicknesses Using Layer Analysis Concepts.

6.3 EQUIVALENT AXLE LOAD FACTOR

An equivalent axle load factor (EALF) defines the damage per pass to a pavement by the axle in question relative to the damage per pass of a standard axle load, usually the 18-kip (80-kN) single-axle load. The design is based on the total number of passes of the standard axle load during the design period, defined as the equivalent single-axle load (ESAL) and computed by

$$\text{ESAL} = \sum_{i=1}^{m} F_i\, n_i \tag{6.19}$$

in which m is the number of axle load groups, F_i is the EALF for the ith-axle load group, and n_i is the number of passes of the ith-axle load group during the design period.

The EALF depends on the type of pavements, thickness or structural capacity, and the terminal conditions at which the pavement is considered failed. Most of the EALFs in use today are based on experience. One of the most widely used methods is based on the empirical equations developed from the AASHO Road Test (AASHTO, 1972). The EALF can also be determined theoretically based on the critical stresses and strains in the pavement and the failure criteria. In this section, the equivalent factors for flexible and rigid pavements are discussed separately.

6.3.1 Flexible Pavements

The AASHTO equations for computing EALF are described first, followed by a discussion of equivalent factor based on the results obtained from KENLAYER.

AASHTO Equivalent Factors

The following regression equations based on the results of road tests can be used for determining EALF:

$$\log\left(\frac{W_{tx}}{W_{t18}}\right) = 4.79\log(18+1) - 4.79\log(L_x + L_2) + 4.33\log L_2 + \frac{G_t}{\beta_x} - \frac{G_t}{\beta_{18}} \tag{6.20a}$$

$$G_t = \log\left(\frac{4.2 - p_t}{4.2 - 1.5}\right) \qquad (6.20b)$$

$$\beta_x = 0.40 + \frac{0.081(L_x + L_2)^{3.23}}{(\text{SN} + 1)^{5.19}L_2^{3.23}} \qquad (6.20c)$$

in which W_{tx} is the number of x-axle load applications at the end of time t; W_{t18} is the number of 18-kip (80-kN) single-axle load applications to time t; L_x is the load in kip on one single axle, one set of tandem axles, or one set of tridem axles; L_2 is the axle code, 1 for single axle, 2 for tandem axles, and 3 for tridem axles; SN is the structural number, which is a function of the thickness and modulus of each layer and the drainage conditions of base and subbase; p_t is the terminal serviceability, which indicates the pavement conditions to be considered as failures; G_t is a function of P_t; and β_{18} is the value of β_x when L_x is equal to 18 and L_2 is equal to one. The method for determining SN is presented in Section 11.3.4. Note that

$$\text{EALF} = \frac{W_{t18}}{W_{tx}} \qquad (6.21)$$

Equation 6.20 can be used to solve EALF. The effect of p_t and SN on EALF is erratic and is not completely consistent with theory. However, under heavy axle loads with an equivalent factor much greater than unity, the EALF increases as p_t or SN decreases. This is as expected because heavy axle loads are more destructive to poor and weaker pavements than to good and stronger ones. A disadvantage of using the above equations is that the EALF varies with the structural number, which is a function of layer thicknesses. Theoretically, a method of successive approximations should be used because the EALF depends on the structural number and the structual number depends on the EALF. Practically, EALF is not very sensitive to pavement thickness and a SN of 5 may be used for most cases. Unless the design thickness is significantly different, no iterations will be needed. The AASHTO equivalent factors with p_t = 2.5 and SN = 5 are used by the Asphalt Institute, as shown in Table 6.4. The original table has single and tandem axles only but the tridem axles are added based on the AASHTO design guide (AASHTO, 1986). Tables of equivalent factors for SN values of 1, 2, 3, 4, 5, and 6 and p_t values of 2, 2.5, and 3 can be found in the AASHTO design guide.

Example 6.7:

Given p_t = 2.5 and SN = 5, determine the EALF for a 32-kip (151-kN) tandem-axle load and a 48-kip (214-kN) tridem-axle load.

Solution: For the tandem axles, L_x = 32 and L_2 = 2, from Eq. 6.20, $G_t = \log(1.7/2.7) = -0.201$, $\beta_x = 0.4 + 0.081\,(32 + 2)^{3.23}/[(5 + 1)^{5.19}(2)^{3.23}] = 0.470$, $\beta_{18} = 0.4 + 0.081\,(18 + 1)^{3.23}/(5 + 1)^{5.19} = 0.5$, and $\log(W_{tx}/W_{t18}) = 4.79 \log 19 - 4.79 \log (32 + 2) + 4.33 \log 2 - 0.201/0.47 + 0.201/0.5 = 0.067$, or $W_{tx}/W_{t18} = 1.167$. From Eq. 6.21, EALF = 0.857, which is exactly the same as that shown in Table 6.4.

For the tridem axles, L_x = 48, L_2 = 3, from Eq. 6.20, $\beta_x = 0.4 + 0.081(48 + 3)^{3.23}/[(5 + 1)^{5.19}(3)^{3.23}] = 0.470$, and $\log(W_{tx}/W_{t18}) = 4.79 \log 19 - 4.79 \log (48 + 3) + 4.33 \log 3 - 0.201/0.47 + 0.201/0.5 = -0.0139$, or $W_{tx}/W_{t18} = 0.968$. From Eq. 6.21, EALF = 1.033, as shown in Table 6.4.