Chapter 4

Vehicle and Traffic considerations

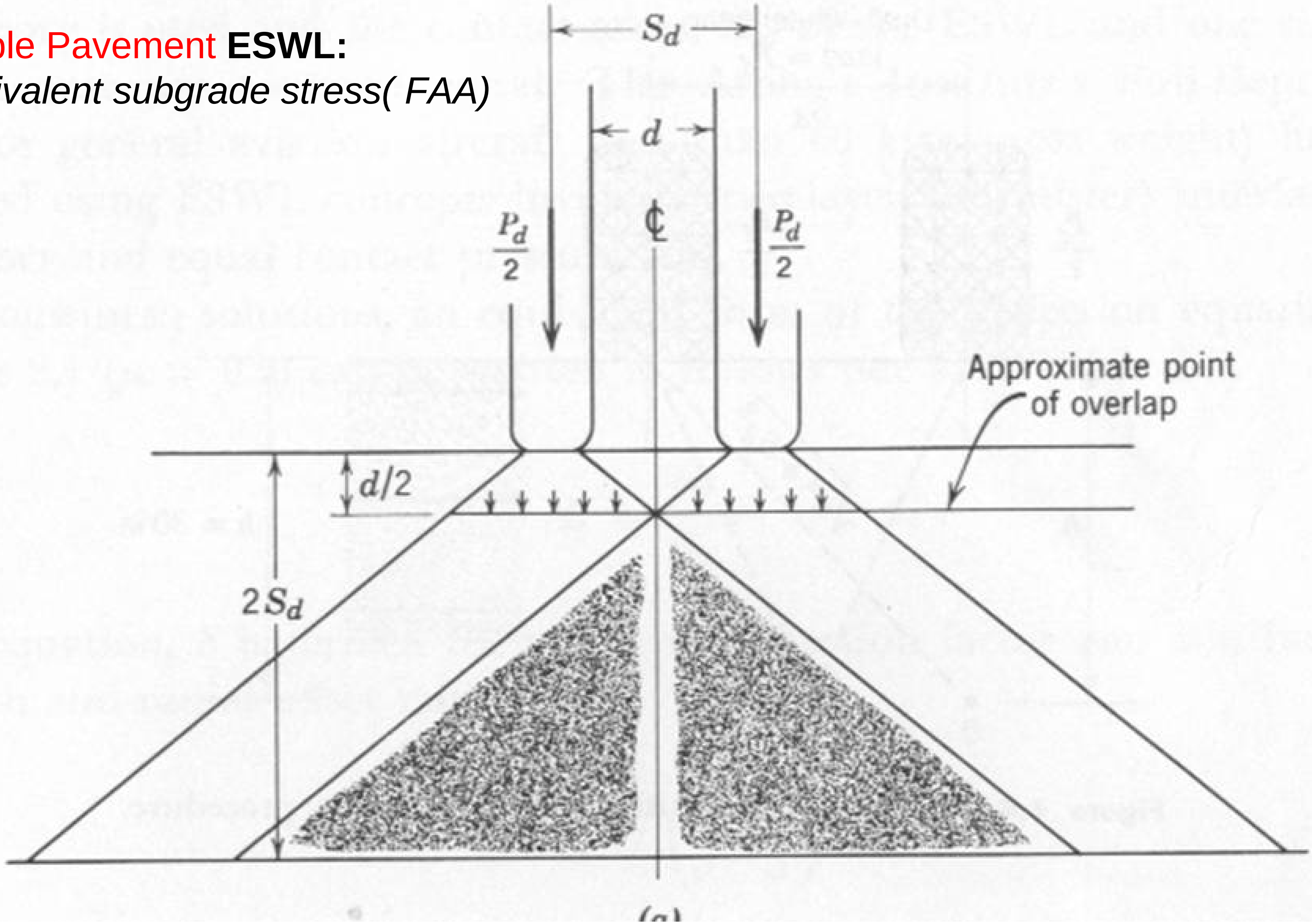
APPROACHES:

1. Airports: **ESWL** (critical vehicle)
   - Load on a single tire that will cause similar effect (stress, strain or deflection) at a selected point in the pavement to that of multiple wheel load.

2. Highways: **EWLF** (standard vehicle)
   - The damage per pass caused to a pavement by vehicle in question compared to a pre-selected standard vehicle.

Flexible Pavement **ESWL:**

Equivalent subgrade stress(FAA)




P=160,000 lb
p=150 psi
60 in
31 in

P=160,000 lb

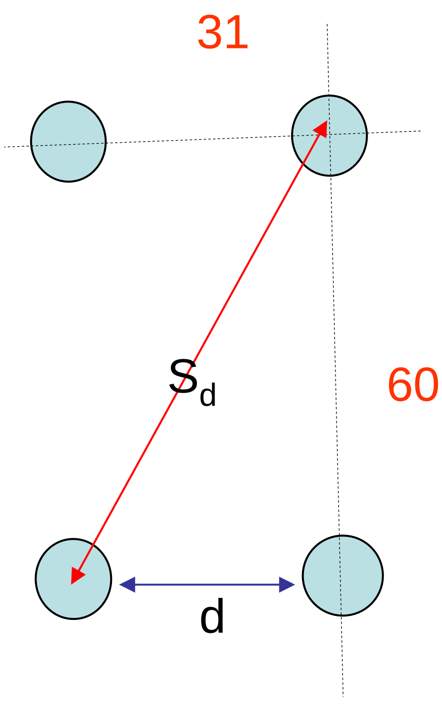
p=150 psi

$A = 160000 / (4*150) = 266.7\ in^2$

$a = (266.7/\pi)^{0.5} = 9.2\ in$

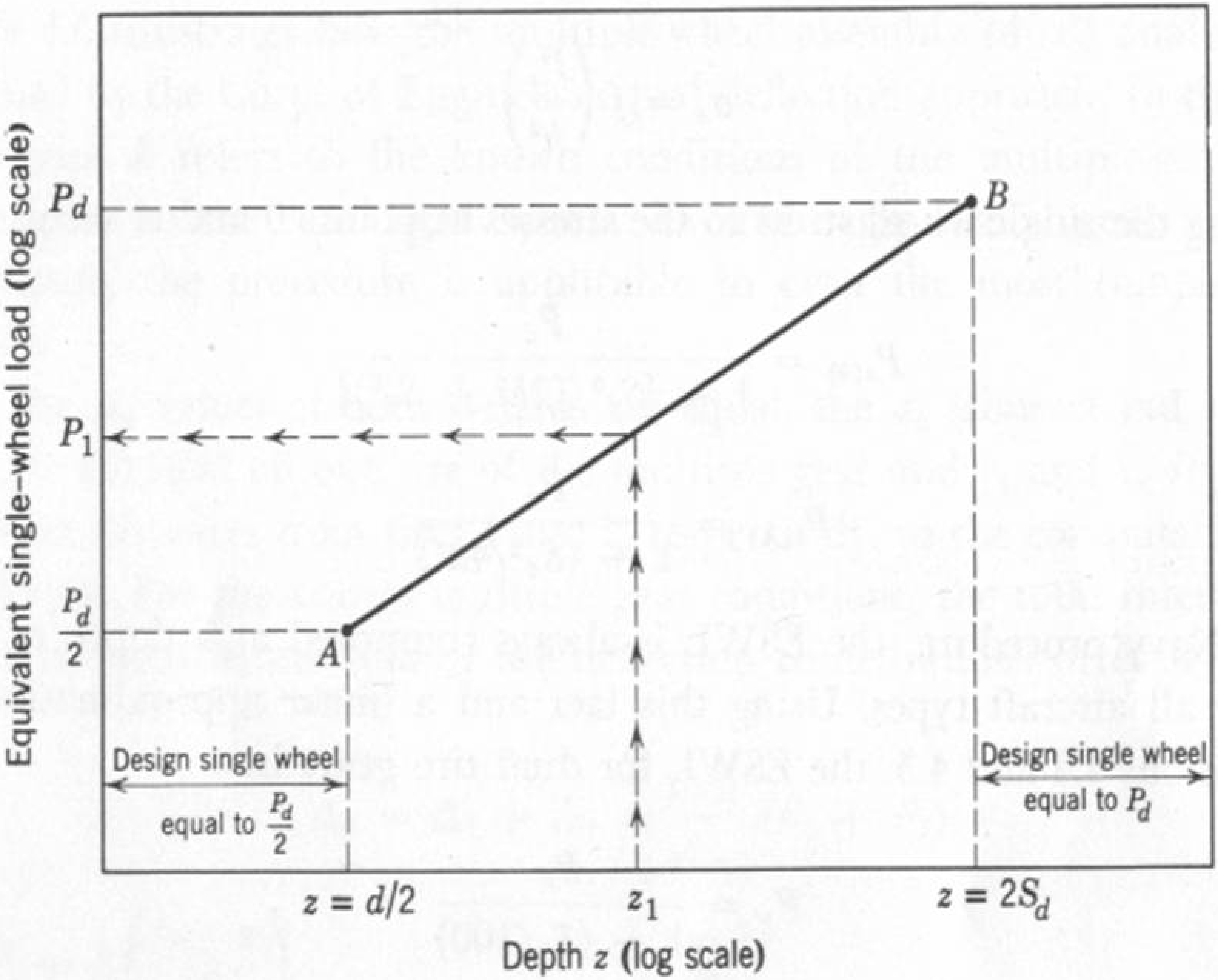
d = minimum spacing = 31- 2(9.2) = 12.6 in

S_d = maximum spacing = $(31^2 + 60^2)^{0.5} = 67.5\ in$



@ d/2 = 6.3 in ....ESWL = 160000/4

@ 2 S_d =135 in ....ESWL = 160,000



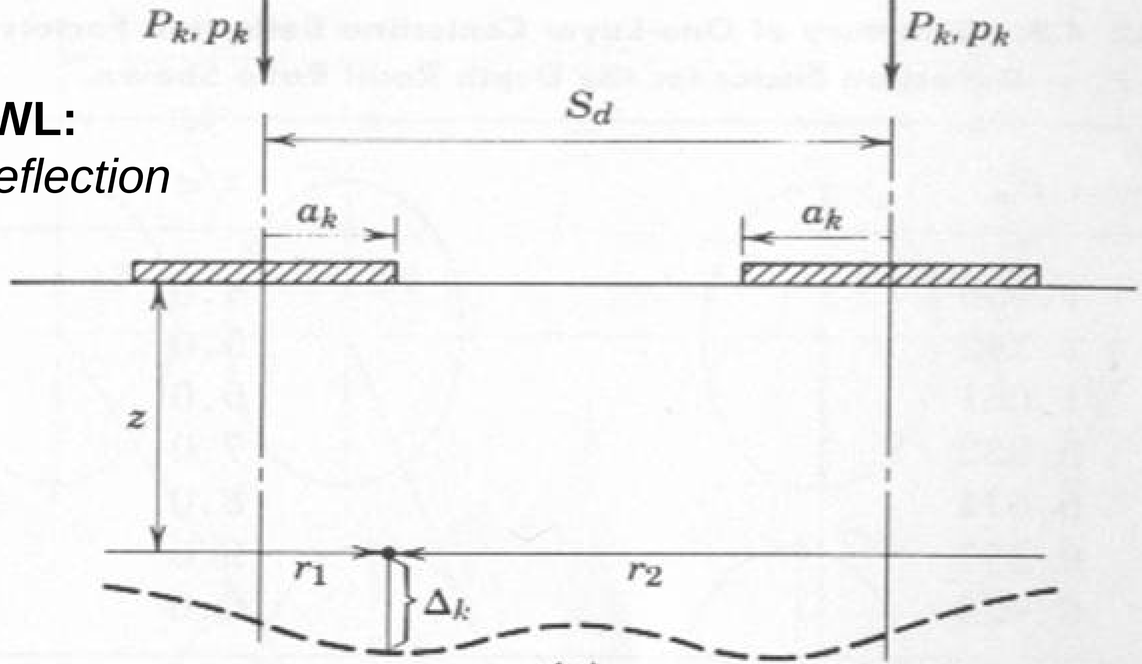
Equivalent single-wheel load (log scale)
P_d
B
P_1
$\frac{P_d}{2}$
A
Design single wheel
equal to $\frac{P_d}{2}$
Design single wheel
equal to P_d
$z = d/2$
z_1
$z = 2S_d$
Depth z (log scale)

(b)

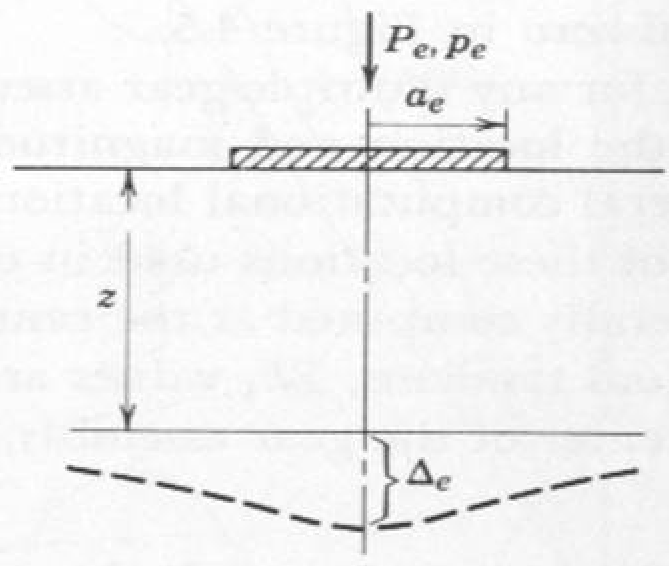
Flexible Pavement **ESWL:**

Equivalent subgrade deflection

(corps of engineers)



(a)



(b)

$$\frac{p_k a_k}{E_1} \sum_{i=1}^{n} F_{i_{\max}} = \frac{p_e a_e}{E_1} F_e$$

For equal contact area between systems, $a_e = a_k$, and

$$\pi a_k^2 = \frac{P_k}{p_k} = \frac{P_e}{p_e}$$

Substitution and cancellation of terms yields:

$$P_e = \frac{P_k \sum_{i}^{n} F_{i_{\max}}}{F_e}$$

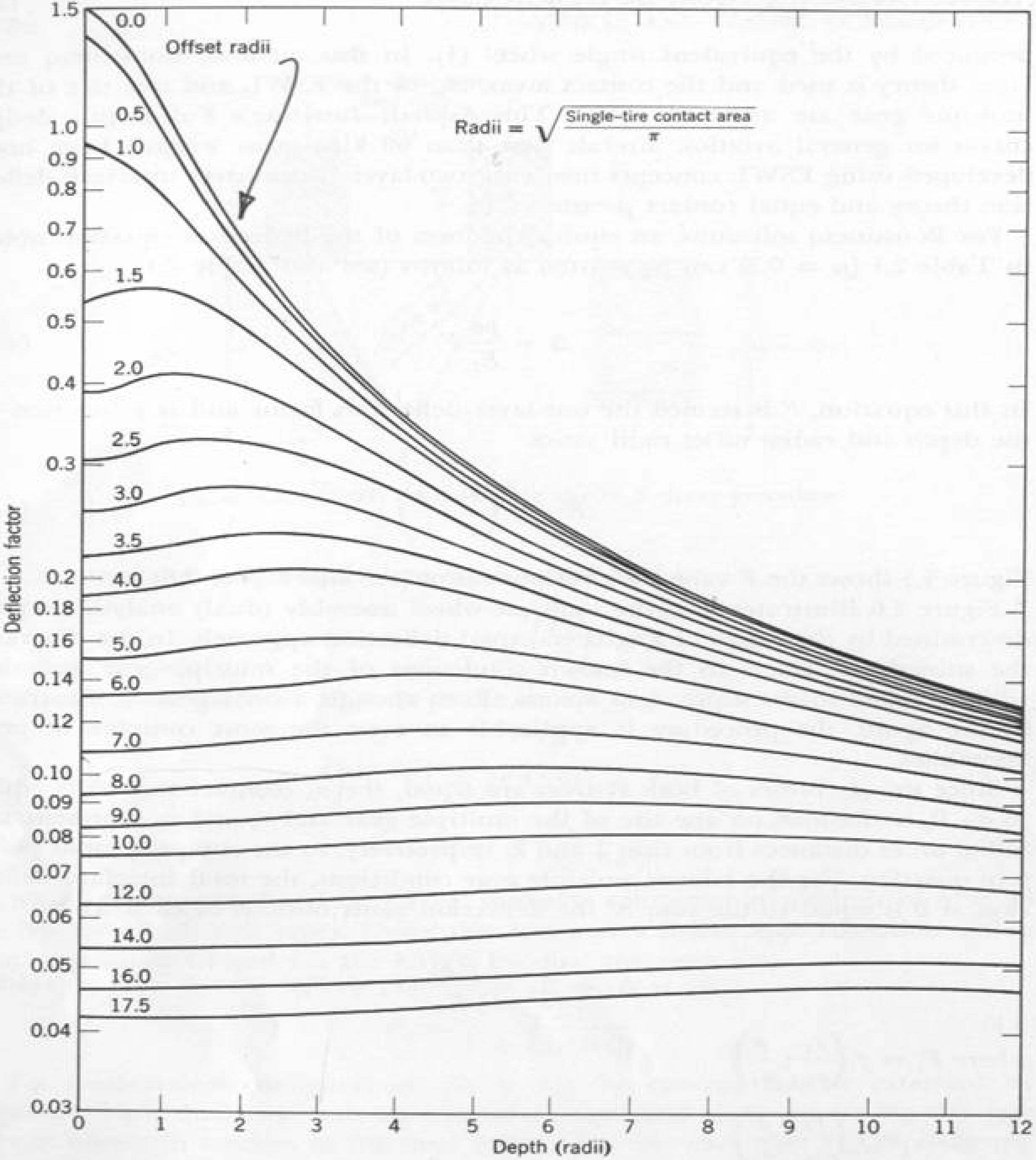

Offset radii
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
5.0
6.0
7.0
8.0
9.0
10.0
12.0
14.0
16.0
17.5
Radii = $\sqrt{\frac{\text{Single-tire contact area}}{\pi}}$
Deflection factor
1.5
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.18
0.16
0.14
0.12
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0
1
2
3
4
5
6
7
8
9
10
11
12
Depth (radii)

TABLE 4.4 C5A ESWL Example Solution

P_k = 30,000 pounds
a_k = 9.54 inches

F—Deflection Factors

Depth Radii (z/a)	Tire Number	1	2	3	4	5	6	7	8	9	10	11	12			
	r =	34 in.	0	53 in.	87 in.	65 in.	82 in.	155 in.	163 in.	223 in.	220 in.	227 in.	236 in.			
	r/a =	3.6	0	5.6	9.1	6.8	8.6	16.3	17.1	23.4	23.1	23.8	24.7	ΣFi	F_e	P_e
0.5		.215	1.350	.141	.083	.112	.088	.046	.043	.027	.028	.027	.025	2.185	1.342	48.8^k
1.0		.220	1.060	.145	.084	.114	.089	.046	.043	.027	.028	.027	.025	1.916	1.061	54.2^k
2.0		.230	.670	.150	.085	.116	.090	.047	.044	.027	.028	.027	.025	1.539	.671	68.8^k
4.0		.220	.360	.152	.088	.122	.094	.048	.045	.027	.028	.027	.025	1.236	.364	101.9^k
6.0		.184	.250	.145	.089	.120	.093	.049	.046	.027	.028	.027	.025	1.083	.247	131.5^k
8.0		.158	.188	.130	.088	.114	.093	.050	.047	.027	.028	.027	.025	1.000	.186	161.3^k
10.0		.131	.152	.116	.086	.108	.089	.051	.049	.027	.028	.027	.025	.880	.149	177.2^k

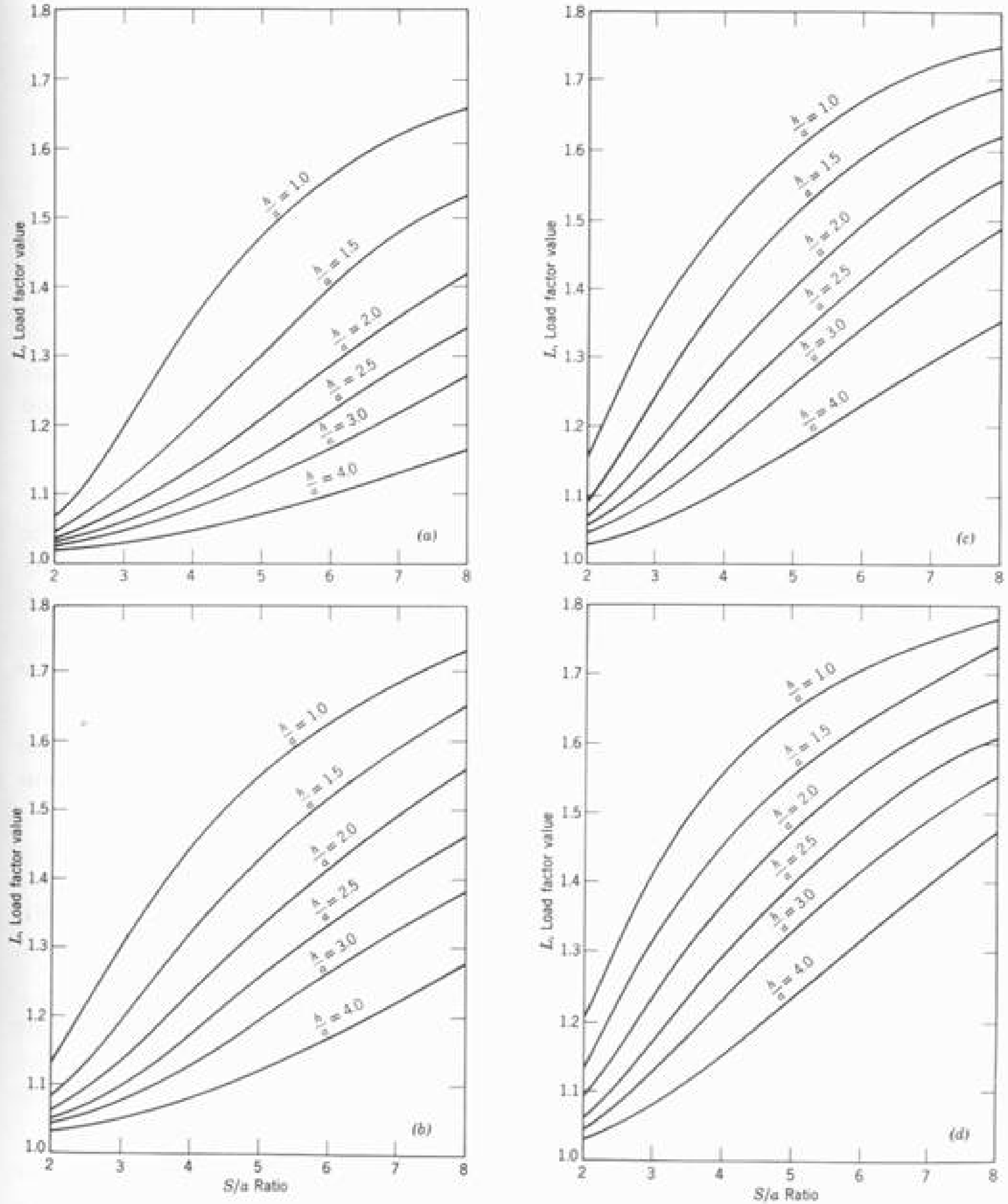
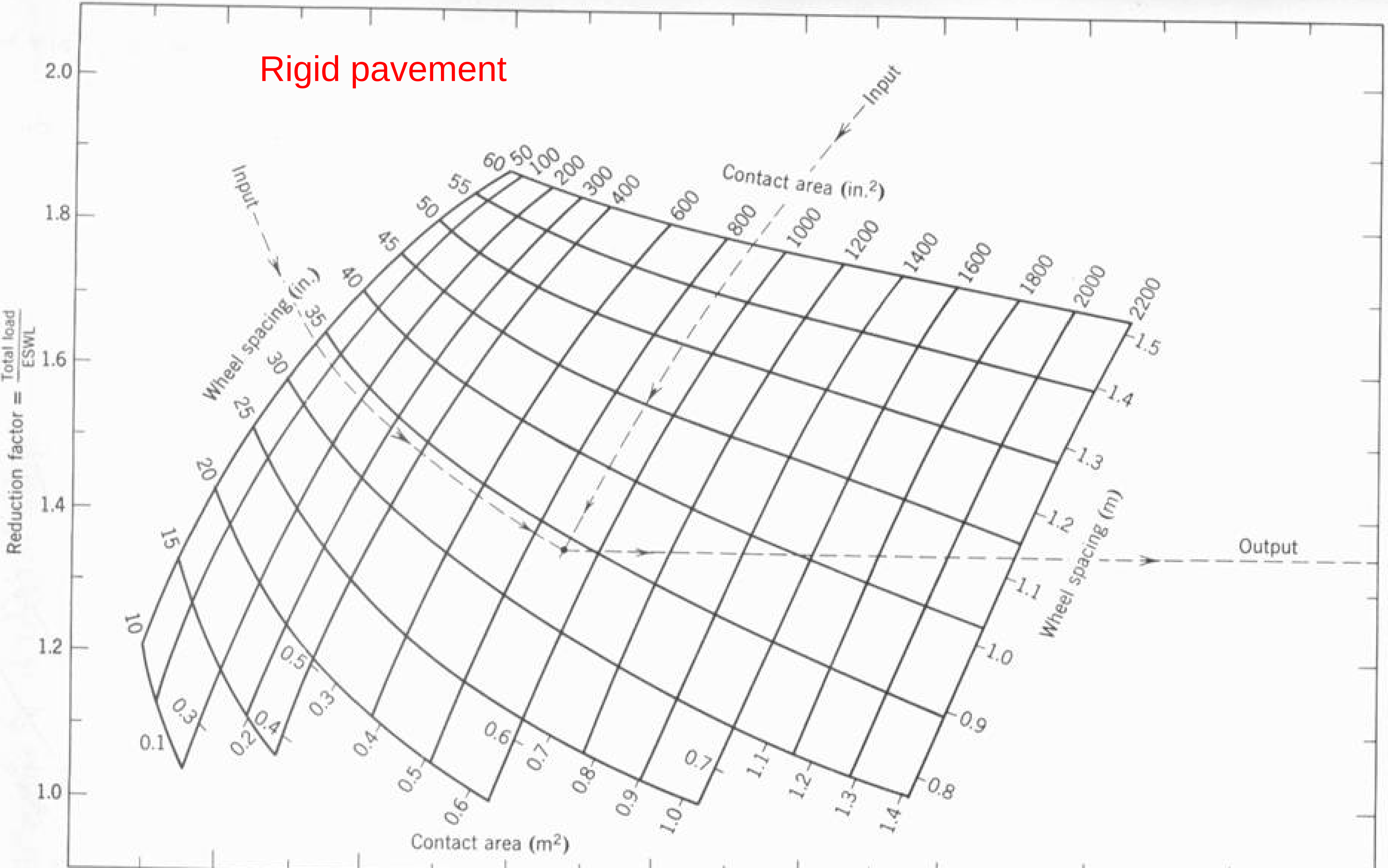


Figure 4.8. Dual wheel load factors (Full Depth asphalt pavement only). (*a*) CBR = 3%; (*b*) CBR = 7%; (*c*) CBR = 15%; (*d*) CBR = 30%.

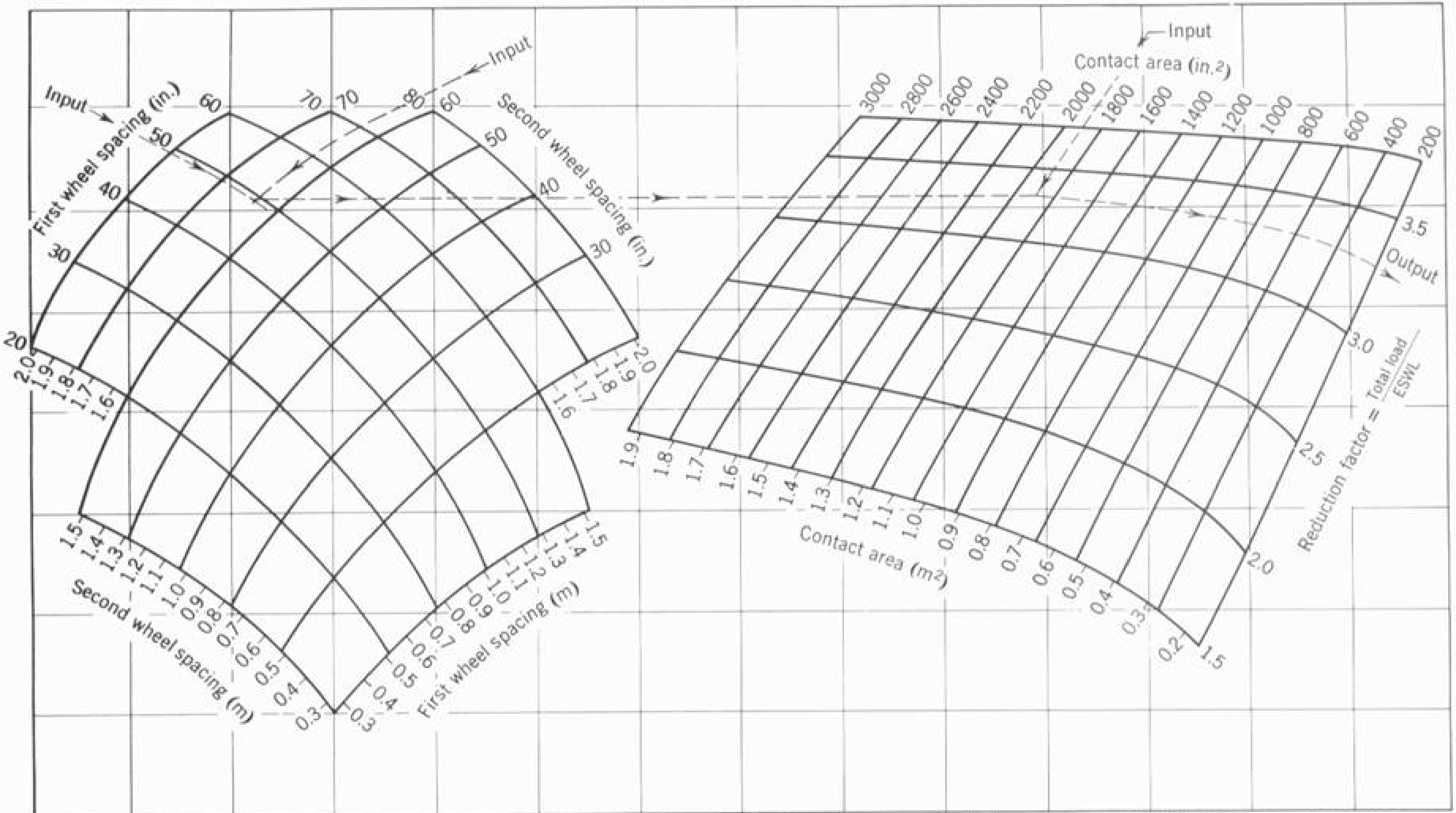
Two layer Dual wheel



Example: Dual-wheel aircraft, wheel spacing 34 in. (0.864 m) c–c, contact area of dual wheels 900 in.² (0.581 m) reduction factor = 1.352

Contact area = Area of all wheels in one undercarriage group

Figure 4.9. EWSL analysis, LCN method, dual wheels. (From Reference 11.)



Example: Dual-tandem wheel aircraft wheel spacing 64 in. x 49 in. (1.626 m x 1.245 m) c-c, contact area of dual-tandem wheels 1900 in.^{2} (1.226 m^2) reduction factor = 3.3

Contact area = Area of all wheels in one undercarriage group

Figure 4.10. ESWL analysis, LCN method, dual-tandem wheels. (From Reference 11.)

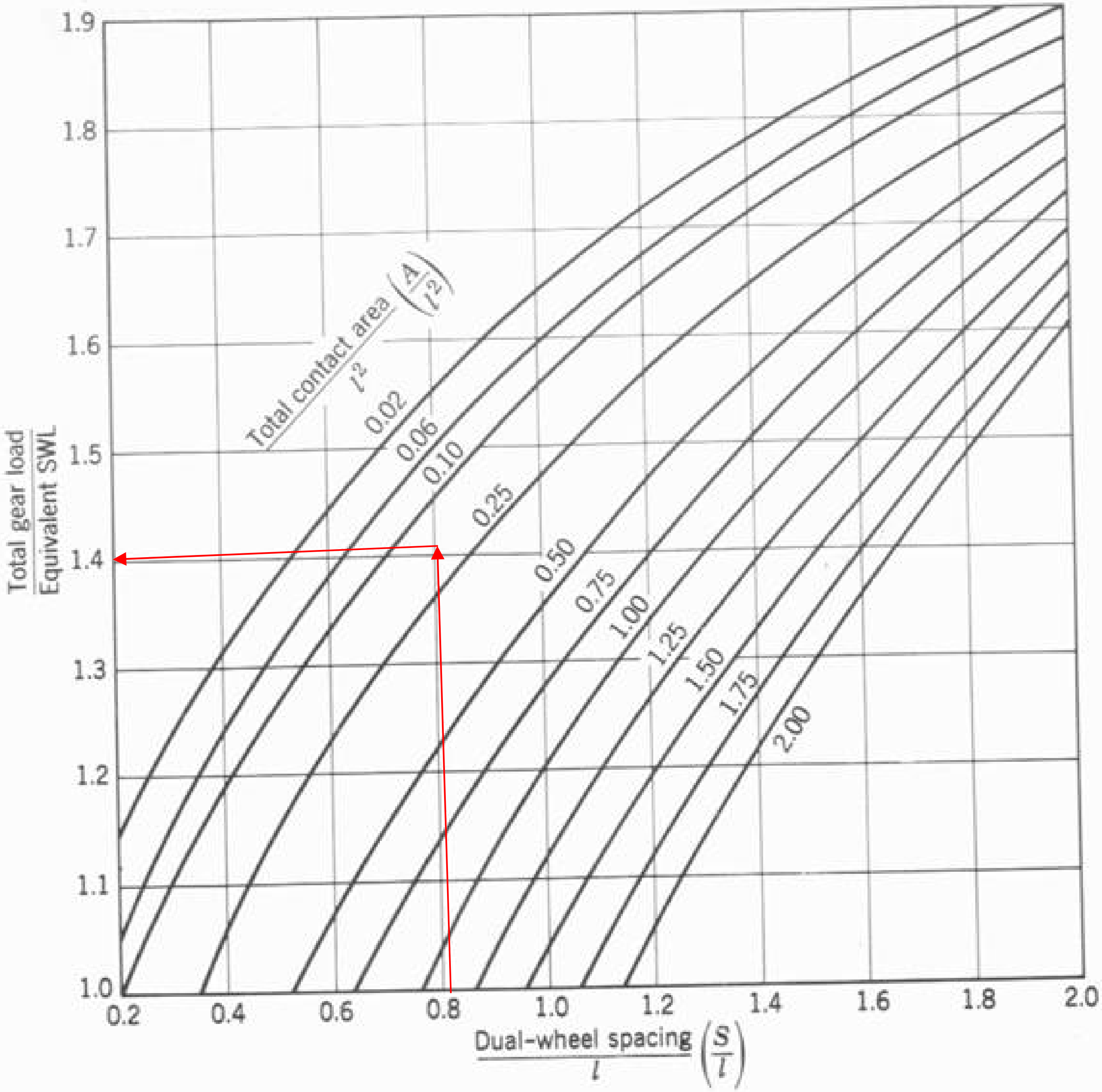


Figure 4.11. ESWL analysis, dual wheel, concrete pavement. (Courtesy FAA.)

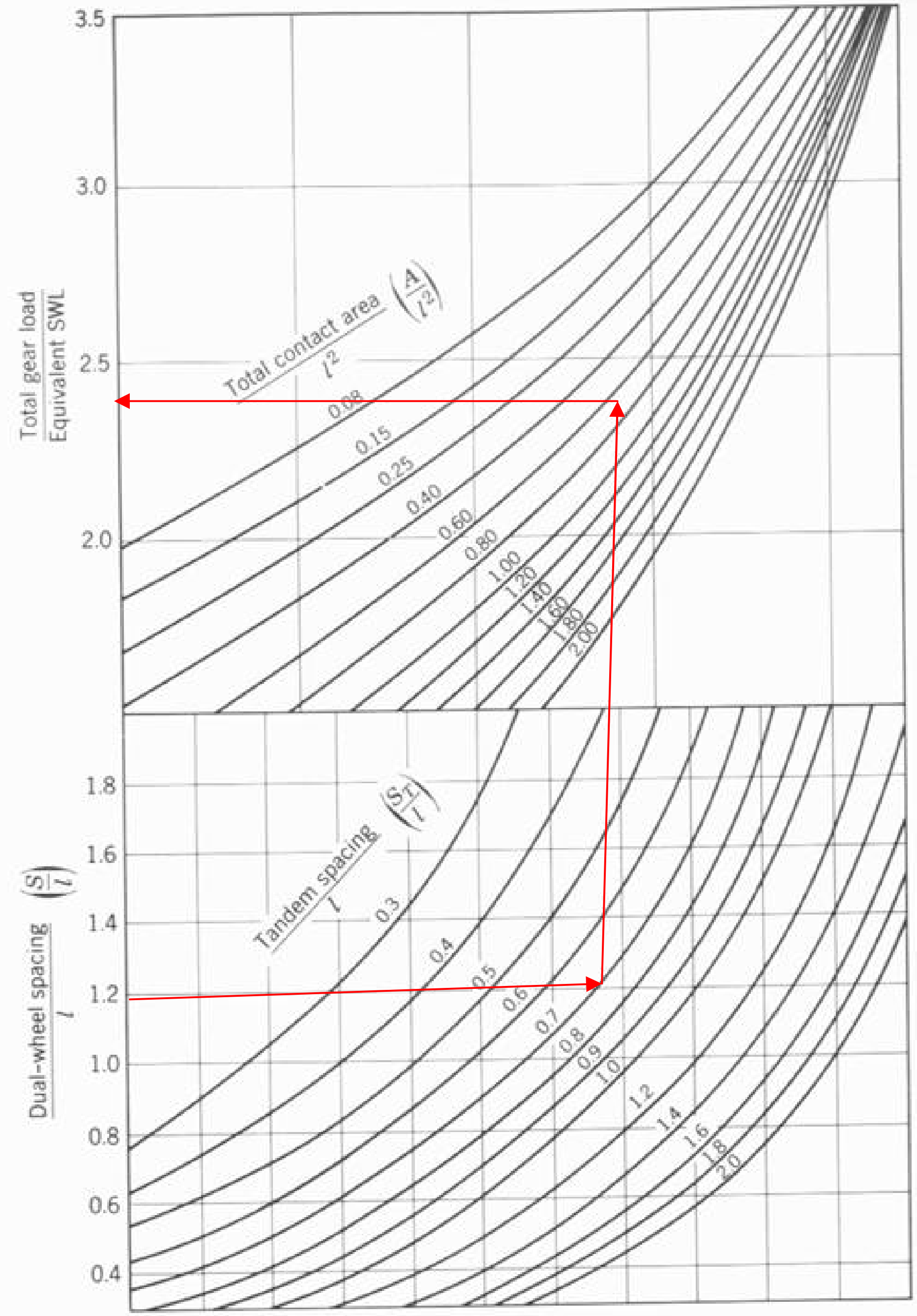


Figure 4.12. ESWL analysis, dual-tandem wheels, concrete pavement. (Courtesy FAA.)

Highways:

EWLF (standard vehicle)

The damage per pass caused to a pavement by vehicle in question compared to a pre-selected standard vehicle.

$Nf = k\,(1/\varepsilon_t)^c$ **................** flexible pavement, c = 4.5

Damage Factor = Fj = $(\varepsilon_j / \varepsilon_s)^c$

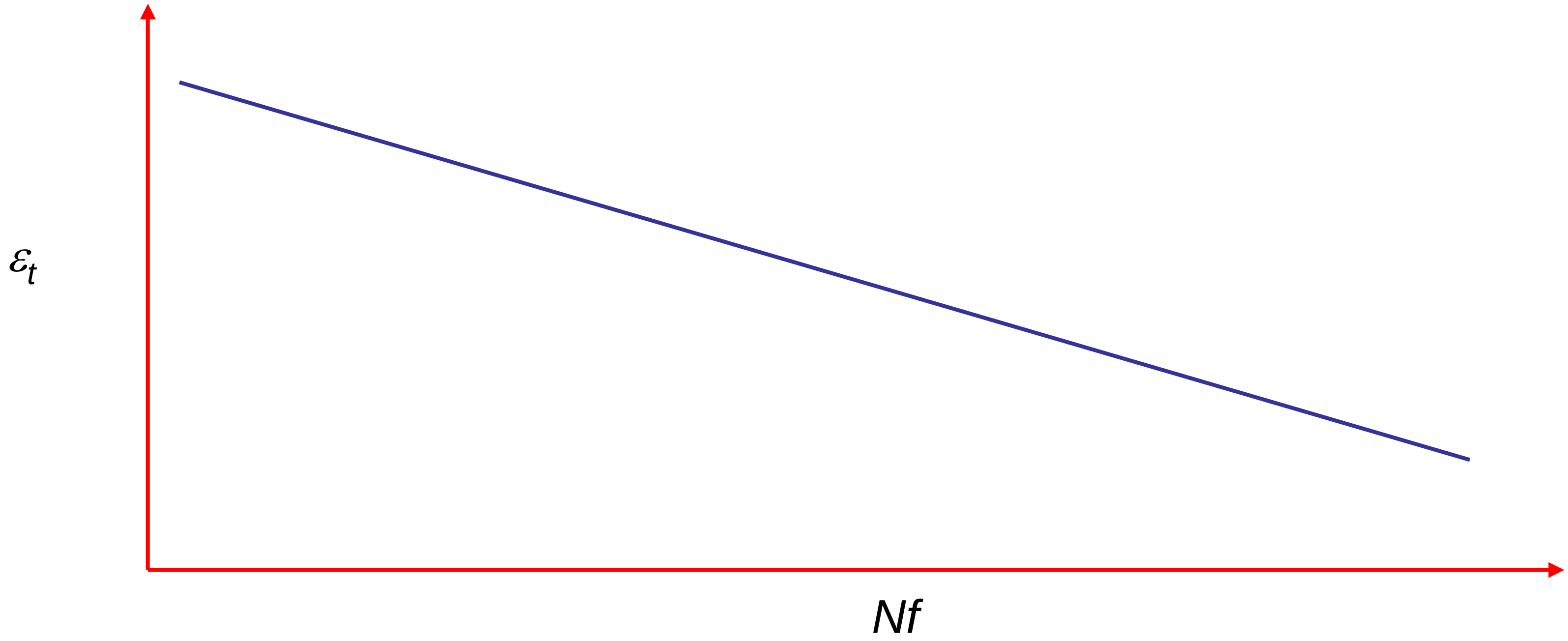


TABLE 4.9. AASHO Equivalence Factors—Flexible Pavement

Single Axles, $p_t = 2.0$

Axle Load (kips)	Structural Number, SN 1	2	3	4	5	6
2	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
4	0.002	0.003	0.002	0.002	0.002	0.002
6	0.01	0.01	0.01	0.01	0.01	0.01
8	0.03	0.04	0.04	0.03	0.03	0.03
10	0.08	0.08	0.09	0.08	0.08	0.08
12	0.16	0.18	0.19	0.18	0.17	0.17
14	0.32	0.34	0.35	0.35	0.34	0.33
16	0.59	0.60	0.61	0.61	0.60	0.60
18	1.00	1.00	1.00	1.00	1.00	1.00
20	1.61	1.59	1.56	1.55	1.57	1.60
22	2.49	2.44	2.35	2.31	2.35	2.41
24	3.71	3.62	3.43	3.33	3.40	3.51
26	5.36	5.21	4.88	4.68	4.77	4.96
28	7.54	7.31	6.78	6.42	6.52	6.83
30	10.38	10.03	9.24	8.65	8.73	9.17
32	14.00	13.51	12.37	11.46	11.48	12.17
34	18.55	17.87	16.30	14.97	14.87	15.63
36	24.20	23.30	21.16	19.28	19.02	19.93
38	31.14	29.95	27.12	24.55	24.03	25.10
40	39.57	38.02	34.34	30.92	30.04	31.25

Tandem Axles, $p_t = 2.0$

Axle Load (kips)	Structural Number, SN 1	2	3	4	5	6
10	0.01	0.01	0.01	0.01	0.01	0.01
12	0.01	0.02	0.02	0.01	0.01	0.01
14	0.02	0.03	0.03	0.03	0.02	0.02
16	0.04	0.05	0.05	0.05	0.04	0.04
18	0.07	0.08	0.08	0.08	0.07	0.07
20	0.10	0.12	0.12	0.12	0.11	0.10
22	0.16	0.17	0.18	0.17	0.16	0.16
24	0.23	0.24	0.26	0.25	0.24	0.23
26	0.32	0.34	0.36	0.35	0.34	0.33
28	0.45	0.46	0.49	0.48	0.47	0.46
30	0.61	0.62	0.65	0.64	0.63	0.62
32	0.81	0.82	0.84	0.84	0.83	0.82
34	1.06	1.07	1.08	1.08	1.08	1.07
36	1.38	1.38	1.38	1.38	1.38	1.38
38	1.76	1.75	1.73	1.72	1.73	1.74
40	2.22	2.19	2.15	2.13	2.16	2.18
42	2.77	2.73	2.64	2.62	2.66	2.70
44	3.42	3.36	3.23	3.18	3.24	3.31
46	4.20	4.11	3.92	3.83	3.91	4.02
48	5.10	4.98	4.72	4.58	4.68	4.83

TABLE 4.9. (continued)

Single Axles, $p_t = 2.5$

Axle Load (kips)	Structural Number, 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	0.004	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	2.61	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

Tandem Axles, $p_t = 2.5$

Axle Load (kips)	Structural Number, 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	5.08	4.80	4.25	3.98	4.17	4.49

$Nf = k\ (1/\sigma_t)^c$ .... Rigid pavement

Damage factor = Fj = $(\sigma_j / \sigma_s)^c$

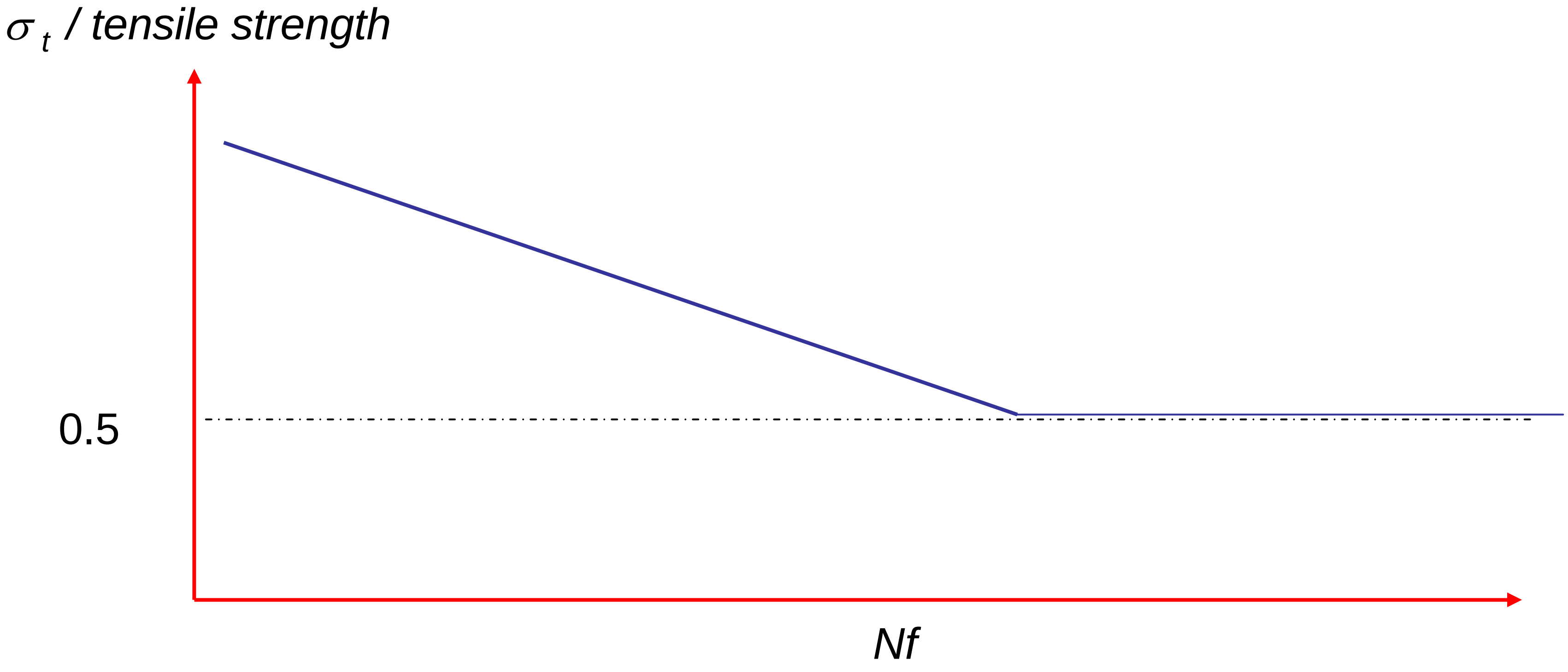


TABLE 4.10. AASHO Equivalence Factors—Rigid Pavement

Single Axles, p_t = 2.0

Axle Load (kips)	D—Slab Thickness (in.)					
	6	7	8	9	10	11
2	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
4	0.002	0.002	0.002	0.002	0.002	0.002
6	0.01	0.01	0.01	0.01	0.01	0.01
8	0.03	0.03	0.03	0.03	0.03	0.03
10	0.09	0.08	0.08	0.08	0.08	0.08
12	0.19	0.18	0.18	0.18	0.17	0.17
14	0.35	0.35	0.34	0.34	0.34	0.34
16	0.61	0.61	0.60	0.60	0.60	0.60
18	1.00	1.00	1.00	1.00	1.00	1.00
20	1.55	1.56	1.57	1.58	1.58	1.59
22	2.32	2.32	2.35	2.38	2.40	2.41
24	3.37	3.34	3.40	3.47	3.51	3.53
26	4.76	4.69	4.77	4.88	4.97	5.02
28	6.59	6.44	6.52	6.70	6.85	6.94
30	8.92	8.68	8.74	8.98	9.23	9.39
32	11.87	11.49	11.51	11.82	12.17	12.44
34	15.55	15.00	14.95	15.30	15.78	16.18
36	20.07	19.30	19.16	19.53	20.14	20.71
38	25.56	34.54	24.26	24.63	25.36	26.14
40	32.18	30.85	30.41	30.75	31.58	32.57

Tandem Axles, p_t = 2.0

Axle Load (kips)	D—Slab Thickness (in.)					
	6	7	8	9	10	11
10	0.01	0.01	0.01	0.01	0.01	0.01
12	0.03	0.03	0.03	0.03	0.03	0.03
14	0.05	0.05	0.05	0.05	0.05	0.05
16	0.09	0.08	0.08	0.08	0.08	0.08
18	0.14	0.14	0.13	0.13	0.13	0.13
20	0.22	0.21	0.21	0.20	0.20	0.20
22	0.32	0.31	0.31	0.30	0.30	0.30
24	0.45	0.45	0.44	0.44	0.44	0.44
26	0.63	0.64	0.62	0.62	0.62	0.62
28	0.85	0.85	0.85	0.85	0.85	0.85
30	1.13	1.13	1.14	1.14	1.14	1.14
32	1.48	1.45	1.49	1.50	1.51	1.51
34	1.91	1.90	1.93	1.95	1.96	1.97
36	2.42	2.41	2.45	2.49	2.51	2.52
38	3.04	3.02	3.07	3.13	3.17	3.19
40	3.79	3.74	3.80	3.89	3.95	3.98
42	4.67	4.59	4.66	4.78	4.87	4.93
44	5.72	5.59	5.67	5.82	5.95	6.03
46	6.94	6.76	6.83	7.02	7.20	7.31
48	8.36	8.12	8.17	8.40	8.63	8.79

TABLE 4.10. (continued)

Single Axles, p_t = 2.5

Axle Load (kips)	D—Slab Thickness (in.)					
	6	7	8	9	10	11
2	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
4	0.003	0.002	0.002	0.002	0.002	0.002
6	0.01	0.01	0.01	0.01	0.01	0.01
8	0.04	0.04	0.03	0.03	0.03	0.03
10	0.10	0.09	0.08	0.08	0.08	0.08
12	0.20	0.19	0.18	0.18	0.18	0.17
14	0.38	0.36	0.35	0.34	0.34	0.34
16	0.63	0.62	0.61	0.60	0.60	0.60
18	1.00	1.00	1.00	1.00	1.00	1.00
20	1.51	1.52	1.55	1.57	1.58	1.58
22	2.21	2.20	2.28	2.34	2.38	2.40
24	3.16	3.10	3.23	3.36	3.45	3.50
26	4.41	4.26	4.42	4.67	4.85	4.95
28	6.05	5.76	5.92	6.29	6.61	6.81
30	8.16	7.67	7.79	8.28	8.79	9.14
32	10.81	10.06	10.10	10.70	11.43	11.99
34	14.12	13.04	12.94	13.62	14.59	15.43
36	18.20	16.69	16.41	17.12	18.33	19.52
38	23.15	21.14	20.61	21.31	22.74	24.31
40	29.11	26.49	25.65	26.29	27.91	29.90

Tandem Axles, p_t = 2.5

Axle Load (kips)	D—Slab Thickness (in.)					
	6	7	8	9	10	11
10	0.01	0.01	0.01	0.01	0.01	0.01
12	0.03	0.03	0.03	0.03	0.03	0.03
14	0.06	0.05	0.05	0.05	0.05	0.05
16	0.10	0.09	0.08	0.08	0.08	0.08
18	0.16	0.14	0.14	0.13	0.13	0.13
20	0.23	0.22	0.21	0.21	0.20	0.20
22	0.34	0.32	0.31	0.31	0.30	0.30
24	0.48	0.46	0.45	0.44	0.44	0.44
26	0.64	0.64	0.63	0.62	0.62	0.62
28	0.85	0.85	0.85	0.85	0.85	0.85
30	1.11	1.12	1.13	1.14	1.14	1.14
32	1.43	1.44	1.47	1.49	1.50	1.51
34	1.82	1.82	1.87	1.92	1.95	1.96
36	2.29	2.27	2.35	2.43	2.48	2.51
38	2.85	2.80	2.91	3.04	3.12	3.16
40	3.52	3.42	3.55	3.74	3.87	3.94
42	4.32	4.16	4.30	4.55	4.74	4.86
44	5.26	5.01	5.16	5.48	5.75	5.92
46	6.36	6.01	6.14	6.53	6.90	7.14
48	7.64	7.16	7.27	7.73	8.21	8.55

Wander:

For Highways.................Ignore

For Airports ....Consider

TABLE 4.6. Load Repetition Factors for Several Aircraft (from Packard)

Aircraft	Load Repetition Factor (tentative design values)			
	Taxiway		Runway	
	σ = 24 in.	σ = 48 in.	σ = 96 in.	σ = 192 in.
DC-3	0.12	0.07	0.05	0.03
B-727	0.41	0.23	0.13	0.09
DC-8 and B-707	0.83	0.46	0.25	0.17
B-747	0.58	0.38	0.33	0.28
C5A	0.74	0.61	0.37	0.25
B-2707[a]	0.52	0.39	0.22	0.16
Concorde	0.83	0.44	0.23	0.15
DC-10-10 and L1011	0.57	0.40	0.22	0.12
Future #4[b]	1.33	0.84	0.44	0.24

[a] 12-wheel gear, spacing: 3 sets 22 × 44 × 22 at 44 in., 2 post, 265-in. tread.

[b] Projected 1 million pound aircraft, dual-tandem gear 44 × 56 in., 4 post (2 tracking), 426-in. tread.

TABLE 4.7. Example Calculations

Aircraft	n	LRF	(n)(LRF)	σ	(σ/MR)	N_f	(n/N_f)
A (B-747)	2,000	0.38	760	387	.66	6,000	.127
B (DC-8)	25,000	0.46	11,500	336	.57	75,000	.153
C (B-727)	100,000	0.23	23,000	300	.51	400,000	.058
							.338

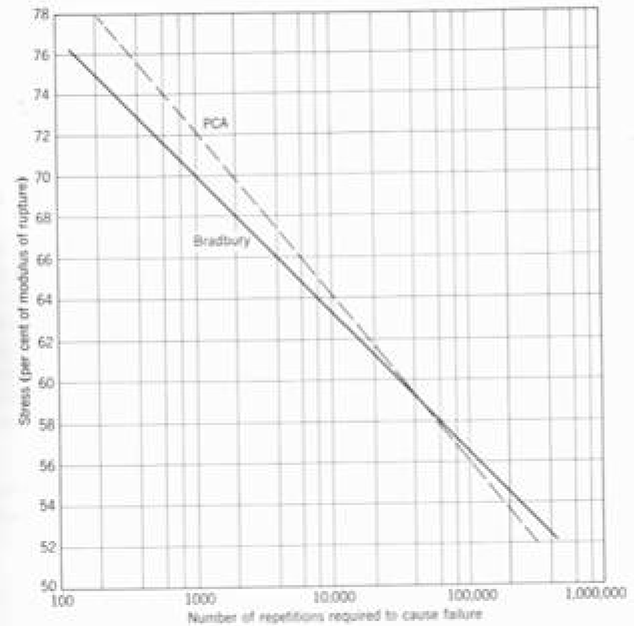


Figure 4.14. Fatigue curves for plain concrete in flexure.

Using identical concepts for that of the asphalt concrete fatigue analysis, the value can be equated to:

$$F_i = \left(\frac{\sigma_f}{\sigma_a}\right)^{c} \tag{4.30}$$