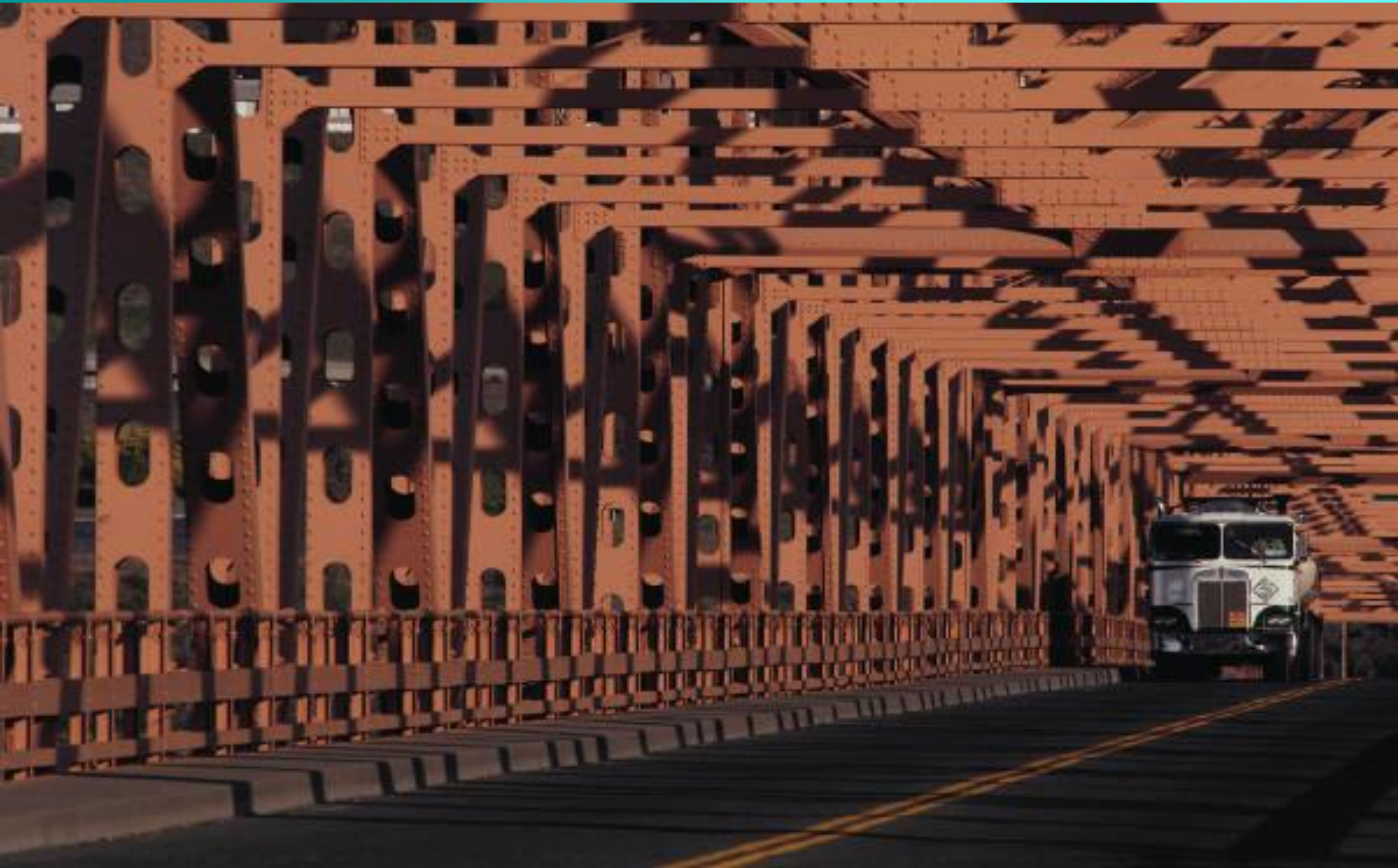
Traffic Terms and Concepts

Why do we need to concern ourselves with traffic when we design pavements?

- Traffic is what LOADS the pavement

- Traffic loads are cyclic (repetitious)

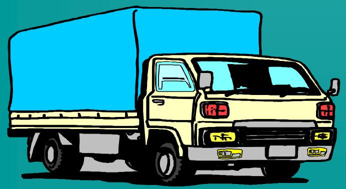
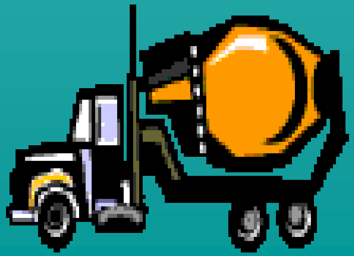
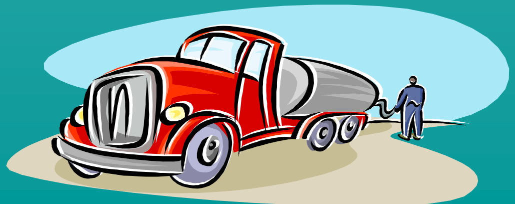
- Repeated, cyclic loads on a structure eventually result in structural fatigue



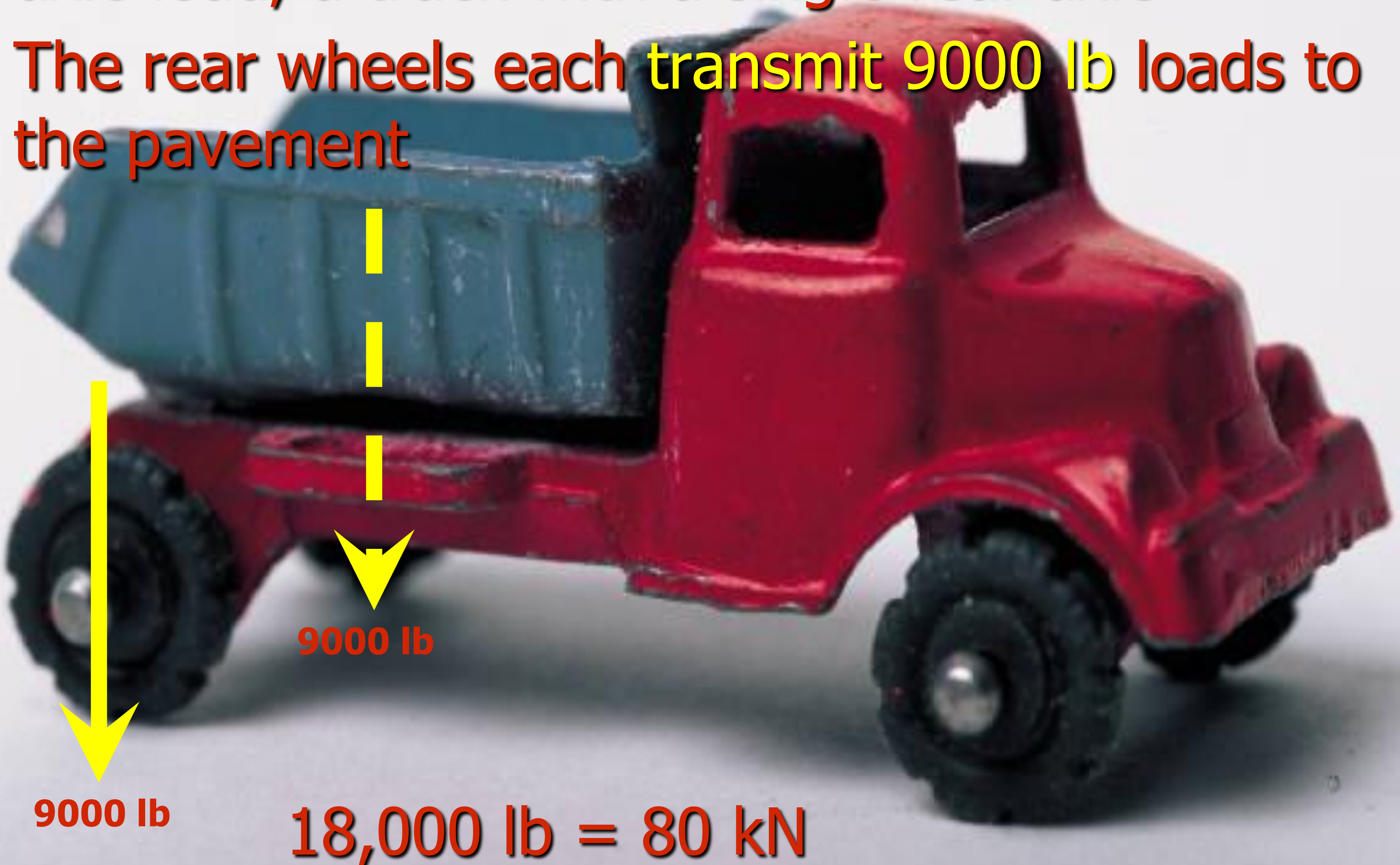
- We see the result of this fatigue as pavement damage or distress

Concept of load equivalency and standard unit load/configuration used in pavement design technology.

- Heavy vehicles cause damage to pavements
- The heavier the load per axle, the more damage
- In order to assess the damage caused by the many different types/configurations of vehicles, one specific load/configuration has been adopted as the standard


- The standard adopted is the 18,000 lb single axle load, a truck with a single rear axle
- The rear wheels each transmit 9000 lb loads to the pavement



- A load equivalency factor gives the number of repetitions of the standard load/configuration that would cause an equivalent amount of damage as one pass of the specific vehicle;

  e.g., a load equivalency factor of 2.5 means that…

one pass of a specific vehicle

=

causes an equivalent amount of damage as two and a half passes of the standard vehicle

a) ESAL
b) ITN
c) DTN

a) the standard load and axle configuration to which all other load and axle configurations are converted when evaluating traffic loads for pavement structural design

ESAL = **E**quivalent **S**ingle **A**xle **L**oad

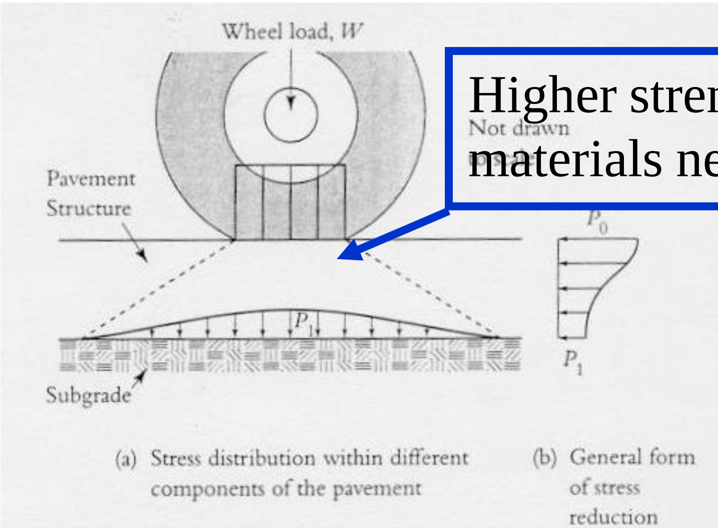
ITN (Initial Traffic Number)

- the average number of ESAL's/day in the first year of a pavement design analysis period

DTN (Design Traffic Number)

- the average number of ESAL's/day over the entire pavement design analysis period
- The total ESAL applications over the design analysis period divided by the number of traffic days
- e.g., 6,000,000 ESAL's over 20 years = 300,000 ESAL's per year or 1,000 ESAL's per day for 300 truck days per year (i.e., DTN = 1000)

Load distribution through the pavement structure

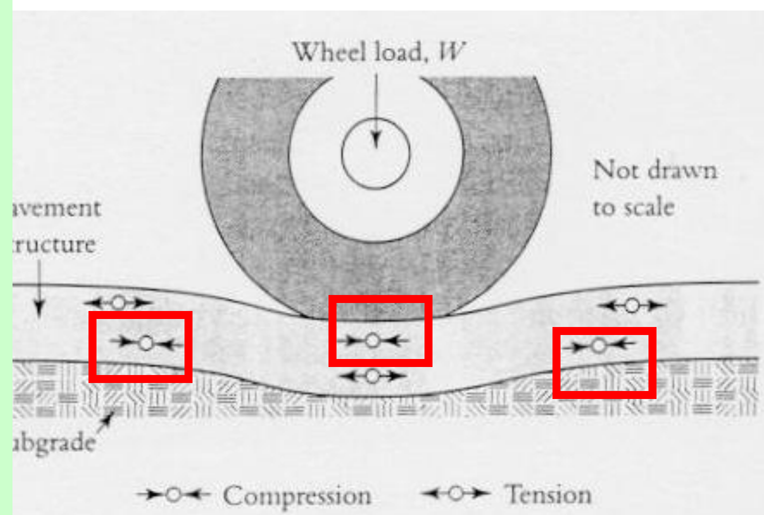


Higher strength materials needed

Typical assumptions:

- Multilayered elastic system
- Subbase, base course, AC surface is infinite in the horizontal direction
- Subgrade is infinite in the vertical and horizontal direction

- Contain both the horizontal and vertical strains below the set values that will cause excessive cracking
- These criteria are considered in terms of repeated load applications because the accumulated repetitions of traffic loads are of significant importance to the development of cracks and permanent deformation of the pavement.

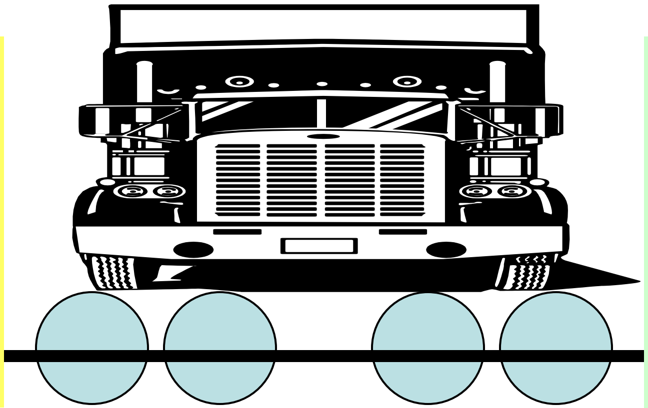


Estimating accumulated wheel load repetitions

Traffic Characteristics: The traffic characteristics are determined in terms of the number of repetitions of an 18,000-lb (80 kilo-newtons (kN)) single-axle load applied to the pavement on two sets of dual tires.

Equivalent single-axle load (ESAL)

- Tire contact area (each 4.51in. (11 cm) radius) and 13.57 (33 cm) in apart
- Contact pressure of 70 lb/in^2



Premise: "the effect of any load on the performance of a pavement can be represented in terms of the number of single applications of an 18,000-lb single axle.

4 tires x π x 4.51^2 = 255.601 in^2, Total single-axle load = 255.601 x 70 lb/in^2 = 17,892 approximately 18,000 lbs.

Load equivalency factors (Table 20.3): Use this if you know axle loads

Gross Axle Load		Load Equivalency Factors		
kN	lb	Single Axles	Tandem Axles	Tridem Axles
4.45	1,000	0.00002		
8.9	2,000	0.00018		
17.8	4,000	0.00209	0.0003	
26.7	6,000	0.01043	0.001	0.0003
35.6	8,000	0.0343	0.003	0.001
44.5	10,000	0.0877	0.007	0.002
53.4	12,000	0.189	0.014	0.003
62.3	14,000	0.360	0.027	0.006
71.2	16,000	0.623	0.047	0.011
80.0	18,000	1.000	0.077	0.017
89.0	20,000	1.51	0.121	0.027

Continued

Obviously the traffic mix (cars, buses, SU trucks, semis, etc.) must be known because their gross axle loads are different. ➔ Vehicle classification counts are needed. Also needed is axle load data – the reason for having truck weighing stations on major highways.

How to estimate the traffic mix if field data are not available (In this case axle loads data must be available).

Table 20.4 can help you estimate break-down of truck types in percentages.

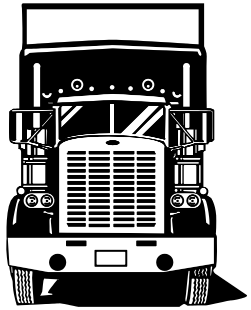
Truck Class	Rural Systems: Interstate	Other Principal	Minor Arterial	Collectors: Major	Collectors: Minor	Range
Single-unit trucks						
2-axle, 4-tire	43 %	60	71	73	80	43–80
2-axle, 6-tire	8	10	11	10	10	8–11
3-axle or more	2	3	4	4	2	2–4
All single-units	53	73	86	87	92	53–92
Multiple-unit trucks						
4-axle or less	5	3	3	2	2	2–5
5-axle**	41	23	11	10	6	6–41
6-axle or more**	1	1	<1	1	<1	<1–1
All multiple units	47	27	14	13	8	8–47
All trucks	100 %	100	100	100	100	

How to estimate ESAL if axle loads are not known

The equivalent 18,000-lb loads can also be determined from the vehicle type, if the axle load is unknown, by using a truck factor for that vehicle type. The truck factor is defined as the number of 18,000-lb single-load applications caused by a single passage of a vehicle.

$$truck\_factor = \frac{\sum (number\_of\_axles \times load\_equivalency\_factor)}{number\_of\_vehicles}$$

Table 20.5 gives truck factors, that is, they were computed based on previous research data. Remember this formula as the definition of the truck factor. You may not actually compute it unless you are determining typical truck factors for your study area. Problem 20-4 let you use this formula.



Distribution of truck factors for different classes of highways and vehicles

Vehicle Type	Rural Systems					
	Interstate	Other Principal	Minor Arterial	Collectors Major	Collectors Minor	Range
Single-unit trucks						
2-axle, 4-tire	0.003	0.003	0.003	0.017	0.003	0.003–0.017
2-axle, 6-tire	0.21	0.25	0.28	0.41	0.19	0.19–0.41
3-axle or more	0.61	0.86	1.06	1.26	0.45	0.45–1.26
All single-units	0.06	0.08	0.08	0.12	0.03	0.03–0.12
Tractor-semitrailers						
4-axle or less	0.62	0.92	0.62	0.37	0.91	0.37–0.91
5-axle**	1.09	1.25	1.05	1.67	1.11	1.05–1.67
6-axle or more**	1.23	1.54	1.04	2.21	1.35	1.04–2.21
All multiple units	1.04	1.21	0.97	1.52	1.08	0.97–1.52
All trucks	0.52	0.38	0.21	0.30	0.12	0.12–0.52

Example: For rural interstates, one single truck is considered to have 0.52 ESAL. Count the total number of trucks and multiply it by 0.52 to find total ESAL for that section.

Determining the accumulated ESAL

Must know: Design period, traffic growth rate, and design lane factor. Usually a 20-year design period is used. Traffic growth rates can be obtained from the planning division of the State DOT.

Table 20.6
Growth Factors

Design Period, Years (n)	No Growth	Annu	
		2	4
1	1.0	1.0	1.0
2	2.0	2.02	2.04
3	3.0	3.06	3.12
4	4.0	4.12	4.25
5	5.0	5.20	5.42
6	6.0	6.31	6.63
7	7.0	7.43	7.90

: Factor = $[(1 + r)^n - 1]/r$, where $r = \frac{\text{rate}}{100}$
d.

G_{jt}

Growth factor for a given growth rate *j* and design period *t*

Table 20.7
Percentage of Total Truck Traffic on Design Lane

Number of Traffic Lanes (Two Directions)	Percentage of Trucks in Design Lane
2	50
4	45 (35–48)*
6 or more	40 (25–48)*

*Probable range.

f_d

Design lane factor: Pavement design is done for the highest loading case (design lane). Typically the outer lane is subject to the highest loading.

Determining accumulated ESAL when axle loads are used

$$ESAL_i = f_d \times G_{jt} \times AADT_i \times 365 \times N_i \times F_{Ei}$$

- $ESAL_i$ = equivalent accumulated 18,000-lb (80kN) single-axle load for the axle category i
- f_d = design lane factor
- G_{jt} = growth factor for a given growth rate j and design period t
- $AADT_i$ = first year annual average daily traffic for axle category i
- N_i = number of axles on each vehicle in axle category i
- F_{Ei} = load equivalency factor for axle category i

Note that AADT used here is the total for both directions.

Determining accumulated ESAL when truck factors are used

$$ESAL_i = f_d \times G_{jt} \times AADT_i \times 365 \times f_i$$

The accumulated ESAL for all categories of axle loads is:

$$ESAL = \sum_{i=1}^{n} \left[ESAL_i\right]$$

- $ESAL_i$ = equivalent accumulated 18,000-lb axle load for truck category i
- f_d = design lane factor
- G_{jt} = growth factor for a given growth rate j and design period t
- $AADT_i$ = first year annual average daily traffic for truck category i
- f_i = truck factor for vehicles in truck category i
- ESAL = equivalent accumulated 18,000-lb axle loads for all vehicles
- n = number of truck categories

Table 20.3

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		6.47	1.66
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	2.67
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.

Table 20.6

Design period (years)	Annual growth rate (%)							
	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