CHAPTER 5
DESIGN CRITERIA

5-1. Damage Factor.

The damage factor is defined as DF = n/N where n is the number of effective stress or strain repetitions and N is the number of allowable stress or strain repetitions. The cumulative damage factor is the sum of the damage factors for all vehicles. The value of n is determined from the number of vehicle operations, and the value of N is determined from the computed stress or strain and the appropriate criteria. The pavement thickness is determined when the cumulative damage factor equals one.

5-2. Vehicle Operations.

When vehicle operations (passes) are given, an operation-per-coverage ratio is needed for the particular design vehicle to convert operations to coverages. The operation-per-coverage ratios for the representative configurations are shown in tables 5-1 and 5-2 for rigid and flexible pavements, respectively. In LEDROAD computer program, the operations-per-coverage ratio is computed based on the standard deviations listed in the tables. The computations are based on the assumption that the wheels wander in a normal distribution across the traffic lane. The operations-per-coverage ratio computed in LEDROAD will be different from those listed in the tables and consequently the values computed using LEDROAD may be slightly different from those presented in this manual.

5-3. Concrete Pavement.

The limiting stress (fatigue) criteria are the basis for the design of concrete pavements. The thickness of the portland cement concrete slab is selected so that the maximum tensile stress at the bottom of the slab does not exceed the preselected value. The criteria are presented as a relationship between design factor and allowable coverages by the equation:

$$N = 10^{x} \qquad \text{(eq 5-1)}$$

where

N = allowable coverages

$$X = \frac{(R/\sigma - A)}{B}$$

A = 0.2967 + 0.002267 (SCI)

B = 0.3881 + 0.000039 (SCI)

R = flexural strength, psi

σ = 1.33 times the maximum tensile stress at bottom of the slab computed with elastic layered method

SCI = Structural condition index. SCI = 80 for the first-crack condition, and SCI = 50 for the shattered slab condition

5-4. Flexible Pavement.

Basically, there are two criteria for determining the allowable stress (or strain) repetitions N. The first is the allowable number of operations as a function of the vertical strain at the top of the subgrade. The second is the allowable number of operations as a function of the horizontal strain at the bottom of the asphalt layer. There is no strain criteria for unbound base. In developing the procedure, it was assumed that unbound base and subbase that meet CE guide specification for quality will perform satisfactorily.

a. Asphalt strain criteria.

(1) The primary means recommended for determining the limiting horizontal tensile strain for bituminous concrete is the use of the repetitive load flexural beam test on laboratory-prepared specimens. Procedures for the test are presented in detail in appendix C. Several tests are run at different stress levels and different sample temperatures such that the number of load repetitions to fracture can be represented as

Table 5-1. Operations Per Coverage Ratio, Flexible Pavements.

Configuration	(1) Load Range kips	(2) Contact Width* in.	(3) Wander** in.	(4) Standard Deviation† in.	(5) Operations per Coverage
		Passenger Cars, Trucks, Buses, etc.			
Pneumatic tires					
single axle,	0-5	5.63	64.37	21.46	9.59
single wheels	5-10	7.14	52.86	17.62	6.25
Single axle,	0-10	6.75	44.25	14.75	2.95
dual wheels	10-20	7.20	41.20	13.73	2.64
	20-30	7.77	39.60	13.20	2.37
Tandem axle,	0-10	5.63	54.37	18.13	4.05
single wheels	10-15	7.50	48.50	16.16	2.73
Tandem axle,	10-15	5.63	49.38	16.46	1.93
dual wheels	15-20	8.25	38.75	12.92	1.23
	20-50	9.00	37.00	12.34	1.03
		Forklift Trucks			
Pneumatic tires					
Single axle,					
dual wheels	10-35	5.63	44.88	14.93	3.52
Solid rubber tires					
Single axle,	0-5	5.00	51.00	17.00	8.36
single tires	5-10	6.00	50.00	16.67	7.00
	10-20	7.00	49.00	16.34	5.90
		Tracked Vehicles			
Solid rubber					
grousers	0-20	11.22	56.75	18.92	1.43
	20-35	12.00	37.00	12.34	0.89
	35-50	12.00	21.00	7.00	0.55
	50-70	14.25	17.75	5.92	0.43
	70-120	17.25	4.75	1.58	0.33

Note: Traffic lane width (P_w) = 11 ft (except for solid-rubber-tired forklift trucks; P_w = 7 ft), T_w = average tire width from table 3-1. Spacing between dual wheels(s) = 2 in., W_s = average wheel spacing from table 3-1.

*Contact width (C_w) = 0.75 T_w (except for solid-rubber-tired forklift truck where $C_w = T_w$).

**Wander (B_w) for single wheels or track = $P_w - (W_s + C_w)$; for dual wheels, $B_w = P_w - (W_s + 1.75\ T_w + S)$.

†Standard deviation (δ) = $B_w/3$.

a function of temperature and initial stress. The initial stress is converted to initial strain in order to yield criteria based on the tensile strain of the bituminous concrete.

(2) An alternate method for determining values of limiting tensile strain for bituminous concrete is the use of the provisional laboratory fatigue data employed by Heukelom and Klomp (1964). These data are presented in appendix C in the form of a relationship between stress, strain, load repetitions, and elastic moduli of bituminous concrete. The data may be approximated by the following equation

$$\textit{Allowable coverge} = 10^{-X} \qquad \text{(eq 5-2)}$$

where

$X = 5 \log \mathbf{S_A} + 2.665 \log_{10}(E/14.22) + 0.392$

S_A= tensile strain of asphalt (in./in.)

E = elastic modulus of the bituminous concrete (psi)

The equation used to determine the allowable tensile strain at the bottom of the asphalt layer is:

$$\textit{Allowable Strain } \epsilon_{AC} = 10^{-A} \qquad \text{(eq 5-3)}$$

Table 5-2. Operations Per Coverage Ratio, Rigid Pavements.

Configuration	(1) Load Range kips	(2) Contact Width* in.	(3) Wander** in.	(4) Standard Deviation† in.	(5) Operations per Coverage
		Passenger Cars, Trucks, Buses, etc.			
Pneumatic tires					
single axle,	0-5	5.63	64.37	21.46	9.59
single wheels	5-10	7.14	52.86	17.62	6.29
Single axle,	0-10	6.75	44.25	14.75	2.95
dual wheels	10-15	7.20	41.20	13.73	2.64
	20-30	7.77	39.60	13.20	2.37
Tandem axle,	0-10	5.63	54.37	18.13	8.1
single wheels	10-15	7.50	48.50	16.16	5.46
Tandem axle,	10-15	5.63	49.38	16.46	3.86
dual wheels	15-20	8.25	38.75	12.92	2.46
	20-50	9.00	37.00	12.34	2.06
		Forklift Trucks			
Pneumatic tires					
Single axle,					
dual wheels	10-35	5.63	44.88	14.93	3.52
Solid rubber tires					
Single axle,	0-5	5.00	51.00	17.00	8.36
single tires	5-10	6.00	50.00	16.67	7.00
	10-20	7.00	49.00	16.34	5.90
		Tracked Vehicles††			
Solid rubber					
grousers	0-20	11.22	56.75	18.92	8.58(1.43)
	20-35	12.00	37.00	12.34	5.36(0.89)
	35-50	12.00	21.00	7.00	4.38(0.55)
	50-70	14.25	17.75	5.92	2.59(0.43)
	70-120	17.25	4.75	1.58	2.0 (0.33)

Note: Traffic lane width (P_w) = 11 ft (except for solid rubber-tired forklift trucks; P_w = 7 ft), T_w = average tire width from table 3-1. Spacing between dual wheels(s) = 2 in., W_s = average wheel spacing from table 3-1.

*Contact width (C_w) = 0.75 T_w (except for solid rubber-tired forklift truck where $C_w = T_w$).

**Wander (R_w) for single wheels or track = $P_w - (W_s + C_w)$; for dual wheels, $R_w = P_w - (W_s + 1.75\ T_w + S)$.

†Standard deviation (δ) = $R_w/3$.

††The values shown in the parentheses are for conservative type of design.

where

$$A = \frac{N + 2.665 \log_{10} (E/14.22) + 0.392}{5}$$

N = $1\log_{10}$(coverage)

E = elastic modulus of the bituminous concrete (psi)

b. Subgrade strain criteria. Failure criteria (fig 5-1) for roads and streets are approximated by the equation

Allowable strain $\epsilon_{SUBG} = 10^{-A}$ (eq 5-4)

where

A = $0.1408 \log_{10}$(coverage) + 2.408

Equation 5-5 can also be written as

Allowable coverage = 10^{-A} (eq 5-5)

where

A = $(2.408 + 1\log_{10}(\epsilon_{SUBG}))/0.1408$

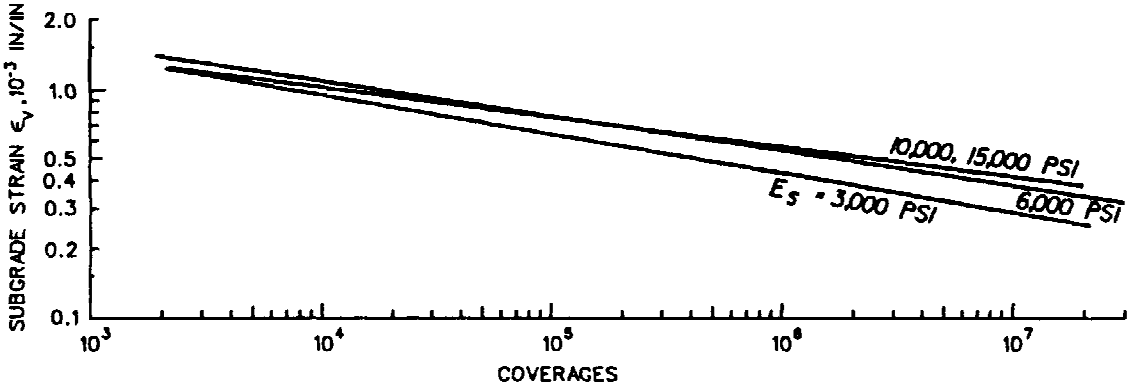

Figure 5-1. Subgrade Strain Criteria for Roads and Streets.