Chapter 15

Design of Flexible Highway Pavements

METHODS

I. Ministry of Transport Method

II. AASHTO Design Method

I. Ministry of Transport Method

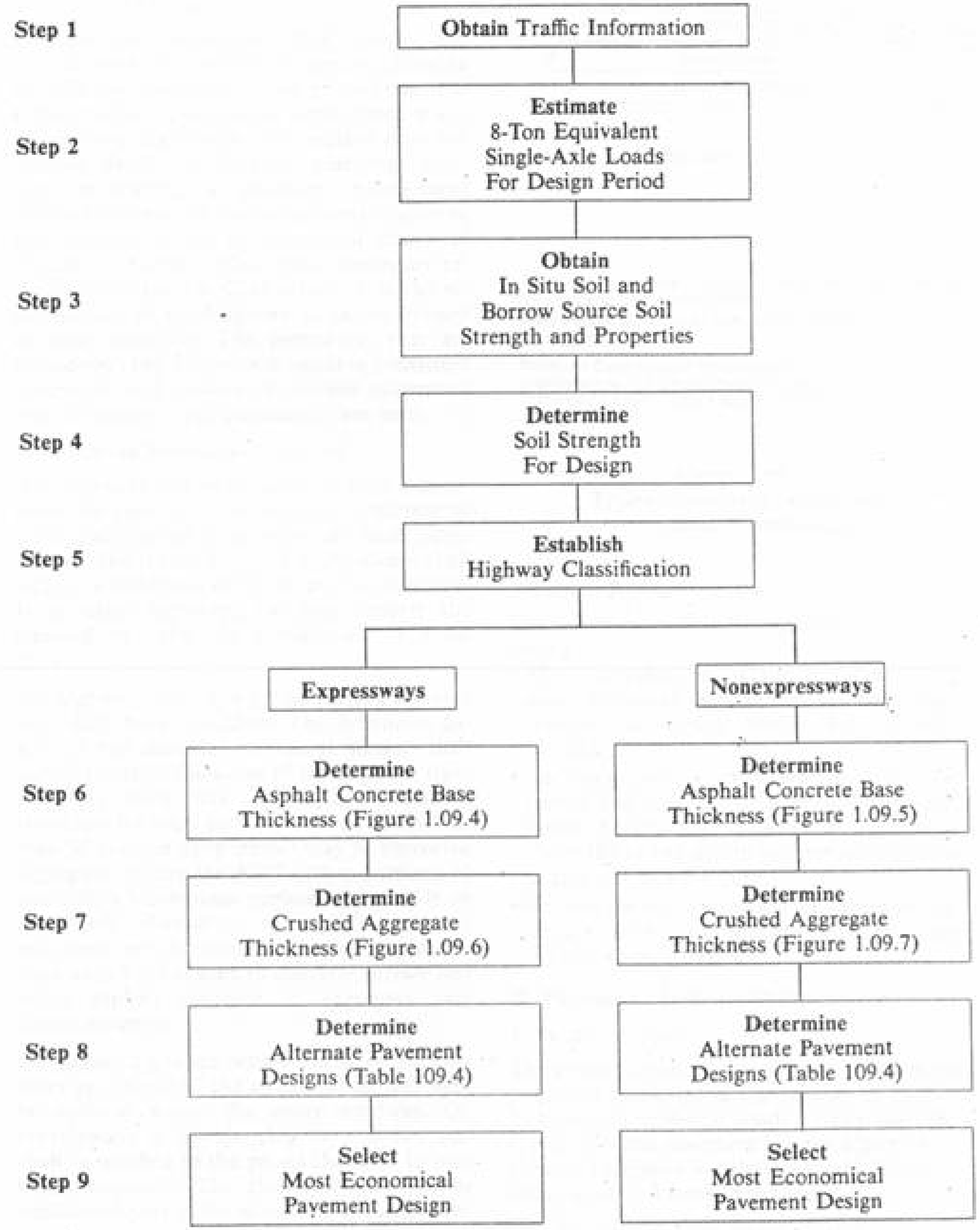


Figure 1.09.9
Design and Pavement Structure Selection

وزارة المواصلات

MINISTRY OF COMMUNICATIONS

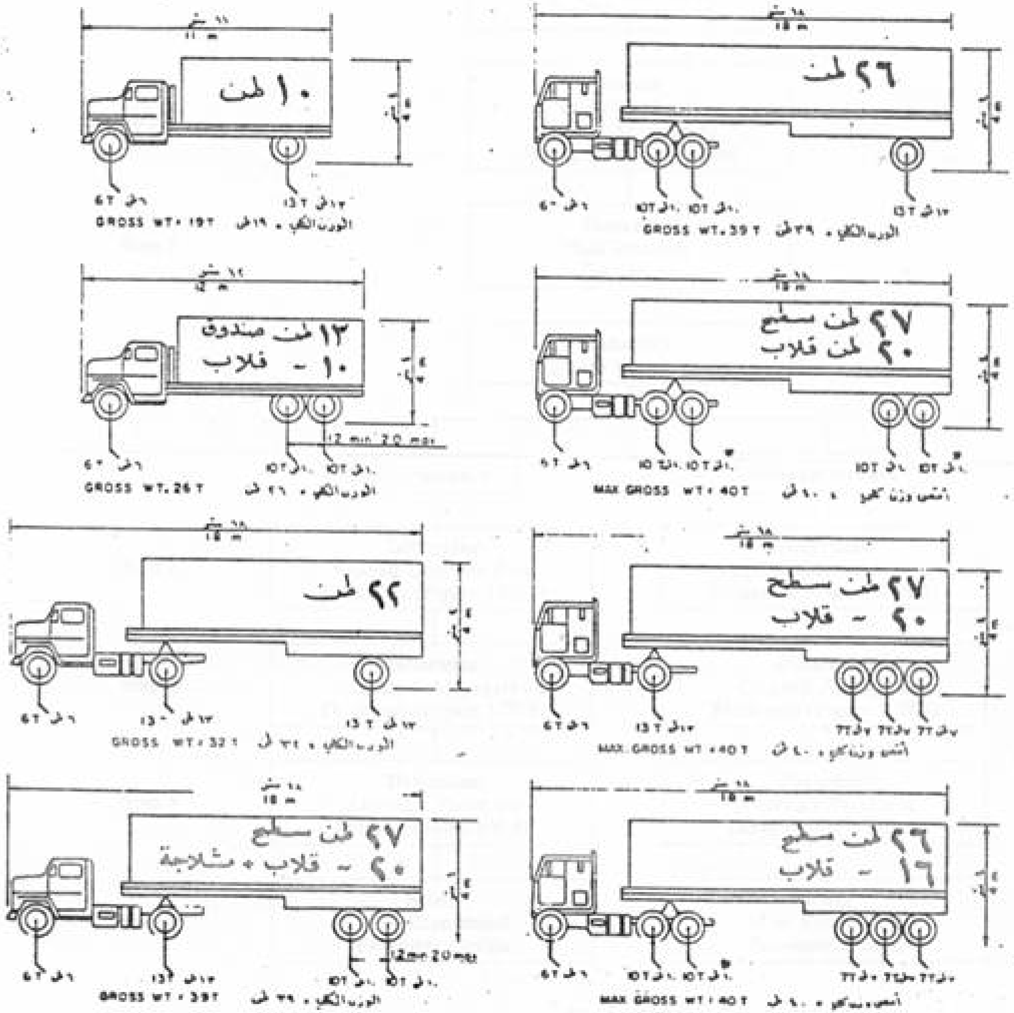
الأوزان القانونية للشاحنات

LEGAL TRUCK WEIGHTS

الأرقام على صندوق الشاحنة ترمز إلى الحمولة الصافية للشاحنة .

WIDTH FOR ALL TRUCKS = 2.5 m MAX

العرض لجميع الشاحنات كحد أقصى = ٢,٥ متر



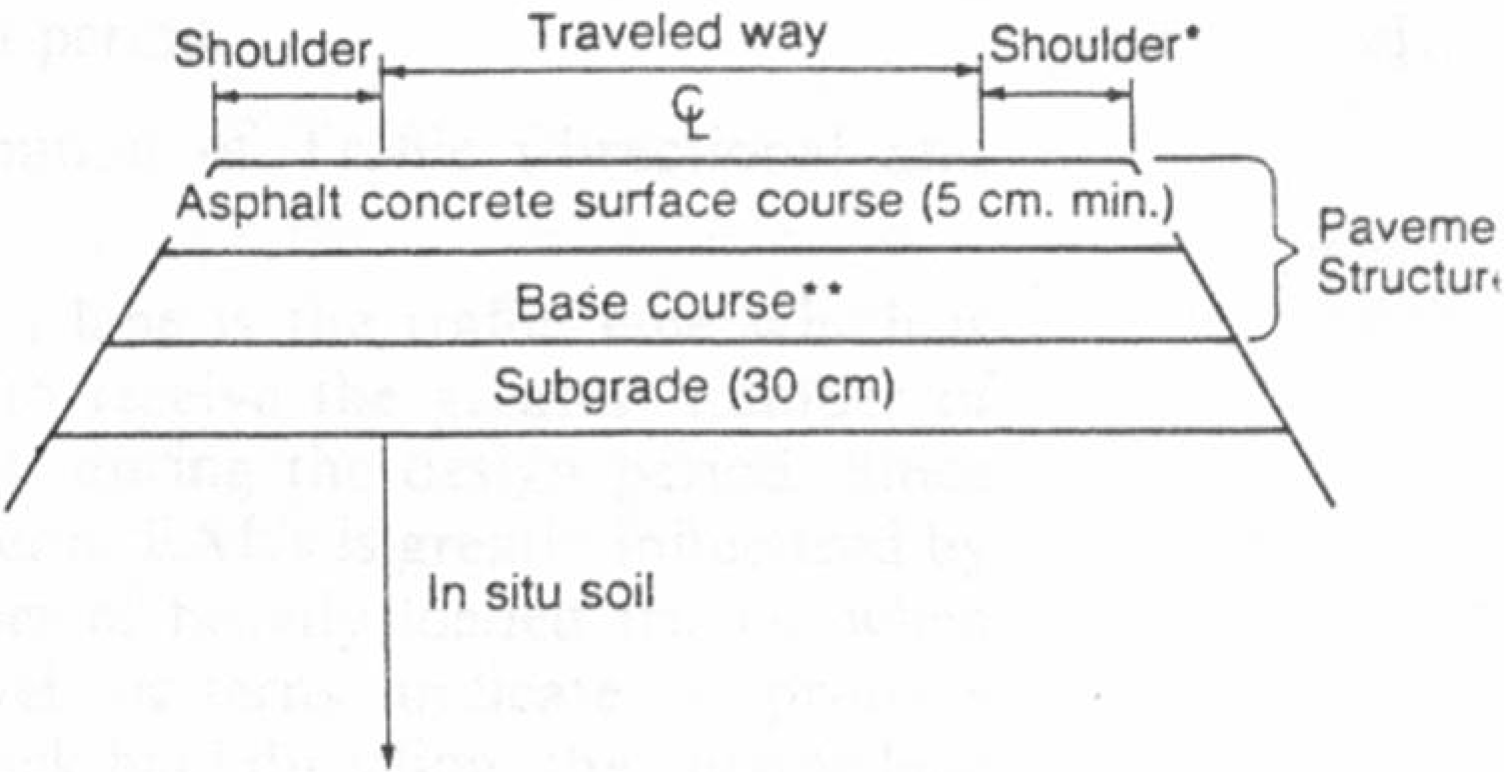
إن معلومات هذا الرسم البياني مبنية على أساس أنظمة المرور لعام ١٣٩٠ هـ

INFORMATION ON THIS CHART IS BASED ON TRAFFIC REGULATIONS (1390 H.)

* الأحمال المحورية القصوى المسموح بها على أن لا تتجاوز الوزن الإجمالي ٤٠ طن

* MAXIMUM ALLOWABLE AXLE LOADS. GROSS WEIGHT NOT TO EXCEED 40 TONS

RAJAB 1404
APRIL 1984



* Asphalt concrete not required on shoulder surface courses for local and low volume roads.

** Base course can include both asphalt concrete and aggregate base.

Minimum Base Course Requirements:
Expressways—15 cm asphalt concrete
Nonexpressways—5 cm asphalt concrete

Table 1.09.1
ADT (20) Growth Factors

$$\left(1 + \frac{AG}{100}\right)^{20}$$

Annual Growth (AG) %	0	2	4	5	6	7	8	10
Growth Factor (GF)	1.00	1.49	2.19	2.65	3.21	3.87	4.66	6.93

Table 1.09.2
Percentage of Total Truck Traffic In Design Lane

Number of Traffic Lanes (two directions)	Percentage of Trucks In Design Lane
2	50
4	45
6 or more	40

Table 1.09.3
Typical*
Truck Class and Weight Distributions

Truck Class	Type SAL-Single Axle TAL-Tandem Axle	Percentage Total Trucks	** Percent of ADT In Design Lane	Gross Vehicle Weight (Ton)	Typical Axle Loads (Tons) EAL Per Axle			EAL Per Vehicle
N.1	Single Unit 2 Axle (2 SAL)	66	14.8	12	2.5	9.5		1.82
					0.01	1.81		
N.2	Single Unit 3 Axle (1 SAL, 1 TAL)	13	2.9	18	3.5	14.5		0.86
					0.03	0.83		
N.3	Multiple Unit 4 Axle (2 SAL, 1 TAL)	11	2.5	21	2.5	8.0	10.5	1.16
					0.01	0.93	0.22	
N.4	Multiple Unit 5 Axle (1 SAL, 2 TAL)	10	2.3	25	3.5	10.0	11.5	0.53
					0.03	0.18	0.32	
Totals/Average		100	22.5					1.48

**Based upon 1977 Truck Study by Italconsult and a survey by Italconsult/Rio/DarHandash, Ministry of Communication 1981.*

***Based upon Truck Volume = 50% ADT and 45% Truck in Design Lane.*

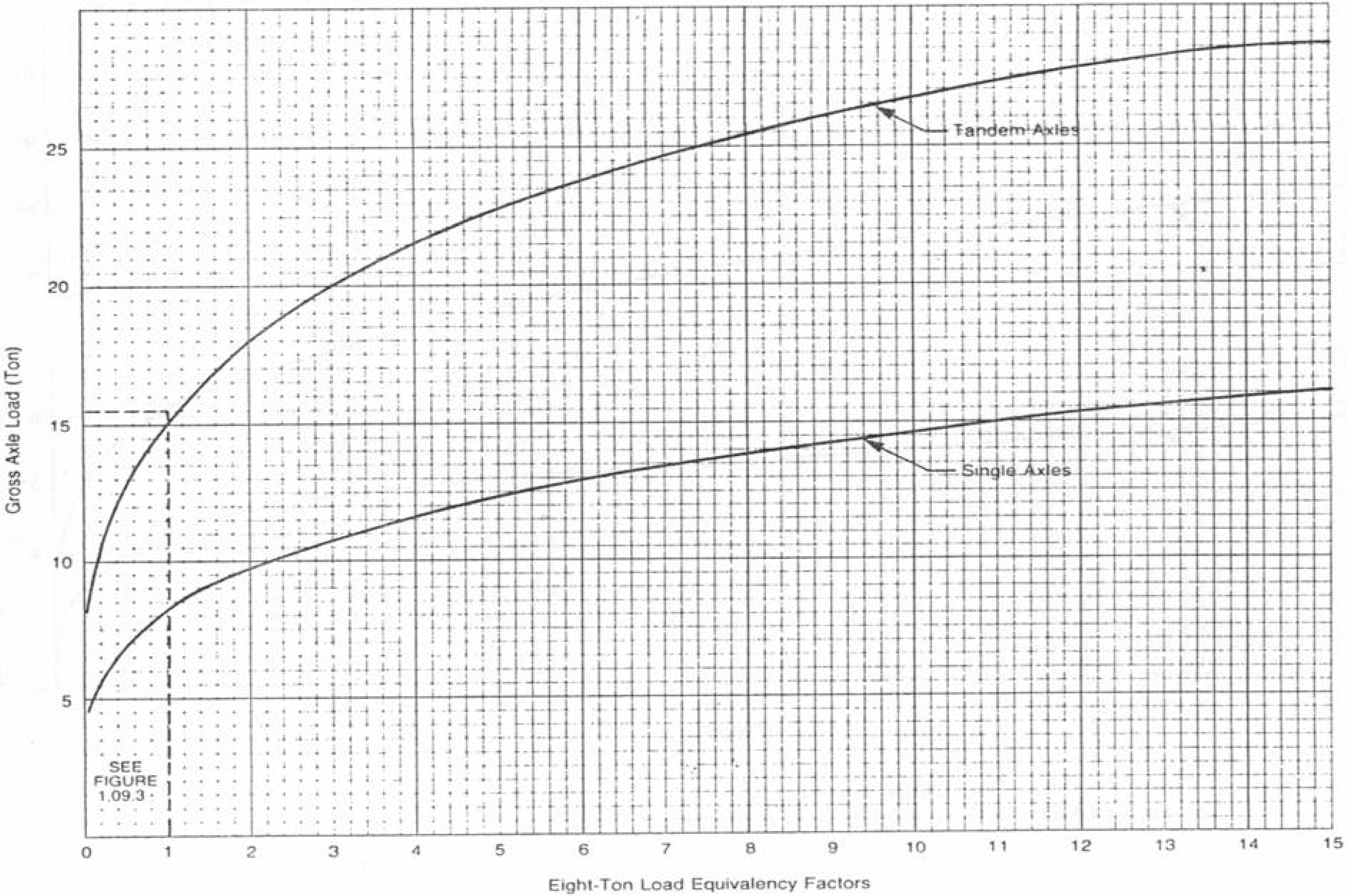


Figure 1.09.2
Eight-Ton, Single-Axle Load Equivalency (EAL) Factors

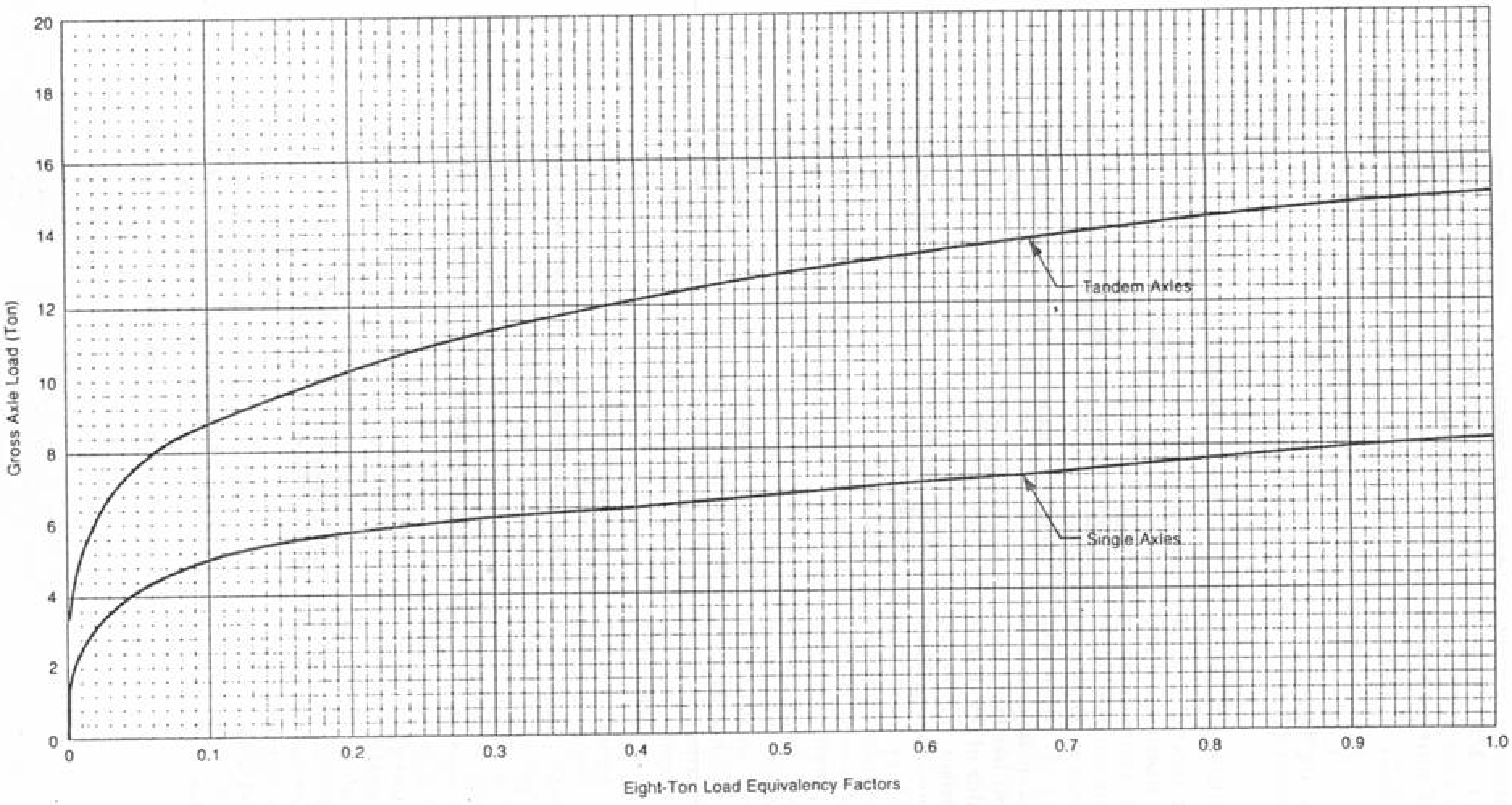


Figure 1.09.3
Eight-Ton, Single-Axle Load Equivalency (EAL) Factors

Problem Statement: A four-lane (two lanes each direction) rural roadway is proposed. Determine the total EAL for pavement design.

Given

From Local Traffic Study (two-way traffic):

Initial Traffic	3,000 Vehicle/Day in 1983
Estimated Traffic	5,000 Vehicle/Day in 2003

50% Trucks 50% pass. cars

Average percentage of trucks through design period is 50 percent.

Truck Type and Axle Load Distribution: use data from Table 1.09.3

Truck Unit	Number of Trucks Units/100 Trucks		Average EAL[1] Per Truck		Total EAL
Single Units					
Two Axle	66	×	1.82	=	120.12
Three Axle or More	13	×	0.86	=	11.18
Multiunit					
Three Axle	11	×	1.16	=	12.28
Four Axle	10	×	0.53	=	5.30
Total EAL/100 Trucks				=	148.88

[1] *Individual values should be obtained from detailed truck traffic and truck weight study and analysis.*

Procedure

For single unit (two axle) average GVW is 12 ton with 2.5 ton (20.8%) on front axle and 9.5 ton (79.2%) on rear axle. From figures 1.09.2 and 1.09.3 EAL's are 0.01 and 1.81 respectively.

EAL/truck is 1.82. The same procedure is then used again to determine the EAL for each of the other travel unit categories, i.e. single unit 3 axle, multiunit 3 and 4 axles.

Average Trucks Per Day =

$$\frac{(3{,}000 + 5{,}000)}{2} \times \frac{50}{100} = 2{,}000 \text{ Trucks/Day}$$

Average Daily Trucks in Design Lane = (2,000) (.45) = 900 Trucks/Day (45% Table 1.09.2)

Total Trucks in Design Lane for Design Period = (900 Trucks/Day) (365 Days/Year) (20 Years) = 6,570,000 Trucks

Total EAL for Pavement Design =
 (6.570×10^6 Trucks) (148.88 EAL/100 Trucks) = 9.781×10^6 EAL

Where detailed traffic analysis is not available and upon approval of the MOC under provisions of HDM-1-1.06B13, the following equation shall be used to determine the total number of equivalent 8-ton loads.

$$EAL = 1{,}220\ ADT\ (0) + ADT\ (20)$$

where EAL = Total number of equivalent 8-ton axle loads
ADT (0) = Initial ADT
ADT (20) = ADT at end of 20-year design period.

2. Soil Considerations

The soils directly below a pavement structure greatly contribute to the overall performance of the pavement. The strength and variability of this material must be considered in the determination of flexible pavement thickness requirements. The material may either be native soils such as in cut sections or may be imported material from designated sources as in fill sections. In either case, representative samples of this material must be collected and tested in the laboratory or in place. A minimum depth of 1.0 m below the top of the subgrade surface should be considered when selecting representative samples. Testing must only be performed on samples that are in a condition that accurately represents the after construction condition of the soil directly beneath the pavement structure. Therefore, density and moisture controls that are required during construction must also apply to remolded samples that are used for strength determinations.

The soil strength input value should be determined by either using the California Bearing Ratio (CBR) MRDTM 213 or the Resilient Modulus (see Asphalt Institute Manual MS-1). The soil support value used in the pavement design shall be equal to the 90th percentile of the representative samples of either the naturally occurring soil below the subgrade or the material proposed for subgrade construction. The lower of these 90th percentile values shall be selected as the soil strength for pavement design. An example illustrating the determination of the soil strength value is given below. The soil strength value may vary between sections within a project dependent upon economic analysis of the entire pavement structure, subgrade, and naturally occurring in situ material.

Example of Selection of Soil Strength Value

Field Samples and Laboratory Test Results	
Borrow for Subgrade CBR	On-Site Material at Subgrade CBR
13	12
25	18
30	8
26	17
32	20

	Highest				Lowest
Borrow CBR	32	30	26	25	13
Percent of Tests Greater Than or Equal	20%	40%	60%	80%	100%
On-Site Material CBR	20	18	17	12	8
Percent of Tests Greater Than or Equal to	20%	40%	60%	80%	100%

CBR Value

90th Percentile Values:
Borrow Material CBR = 20
On-Site Material CBR = 10.5 Soil Strength of CBR = 10 is Used for Design

3. Base Course Thickness Requirements

In addition to satisfying the minimum structural requirements given in 2-1.09A2, all pavements shall meet minimum base course thickness requirements for the local soil or borrow source conditions and estimated traffic loads. Figure 1.09.4 shall be used to determine minimum asphalt concrete base thickness requirements for the soil and traffic on expressways. Figure 1.09.5 shall be used to establish minimum asphalt concrete base requirements for traffic and soil conditions on all roadways other than expressways. Figure 1.09.6 and Figure 1.09.7 shall be used to determine the amount of crushed aggregate base needed to meet requirements. When the asphalt concrete thickness values from Figures 1.09.4 and 1.09.5 exceed 15 cm and 5 cm respectively, 30 cm of aggregate base is required.

Table 1.09.4
Pavement Material Equivalencies

	Substitution Ratio[1]
Base Course	
Asphalt Concrete (Plant Mix)	1
Asphalt Concrete (Road Mix)	1.75
Untreated Aggregates	
Crushed Aggregate	2.5
Natural Gravels	3
Treated Aggregate	
Bituminous-Treated Aggregates	2
Lime-Treated Aggregates	2
Cement-Treated Aggregates	2
Subgrade	
Select Material (Soil)	5
Bituminous-Treated Soil	3.5
Lime-Treated Soil	3.5
Cement-Treated Soil	3.5

[1]*Millimeters of material needed to replace one millimeter of the asphalt concrete pavement.*

Example of Alternative Pavement Designs

Problem Statement: Determine the most cost-effective pavement section that is structurally equivalent to the following:

5 cm asphalt concrete surface (AC)
15 cm asphalt concrete base (AC)
22 cm crushed aggregate base (CAB)
30 cm subgrade borrow
Design soil CBR = 10
Total traffic = 2.25×10^6 EAL

Typical pavement section consists of 3.65 m travel way, 3.00 m shoulders and 4:1 fore-slopes.

Procedure: Since the asphalt concrete surface and base requirements are at minimum levels established by 2-1.09A2, only the crushed aggregate base and subgrade are subject to alternate design.

Determination of which alternate materials are to be compared should be based upon availability, feasibility, and economic analysis. Assume the asphalt concrete (AC) and lime-treated aggregate (LTA) meet these criteria for base material and the lime-treated soil (LTS) meets criteria for alternative subgrade materials.

To provide structurally equivalent sections, the following equation must be satisfied:

$$\frac{T_A \times SR_B}{SR_A} = T_B$$

where T_A = Thickness of Material A
SR_A = Substitution Ratio of Material A
T_B = Thickness of Material B
SR_B = Substitution Ratio of Material B

The thickness of lime-treated aggregates required for 22 cm of CAB is

$$\frac{(22\text{ cm})\,(2)}{(2.5)} = T_{LTA}$$

T_{LTA} = 17.6 cm, use 18 cm

If asphalt concrete base were substituted, the required thickness would be

$$\frac{(22\text{ cm})\,(1)}{(2.5)} = T_{AC}$$

T_{AC} = 8.8 cm, use 9 cm

The amount of lime-treated soil required to replace 30 cm of borrow soil is

$$\frac{(30\text{ cm})\,(3.5)}{5} = T_{LTS}$$

T_{LTS} = 21 cm

From Figure 1.09.8, a soil strength CBR of 10 requires a 42 cm of cover for 2.25×10^6 EAL. Therefore, any of the following pavement structural sections except Alternative B are acceptable:

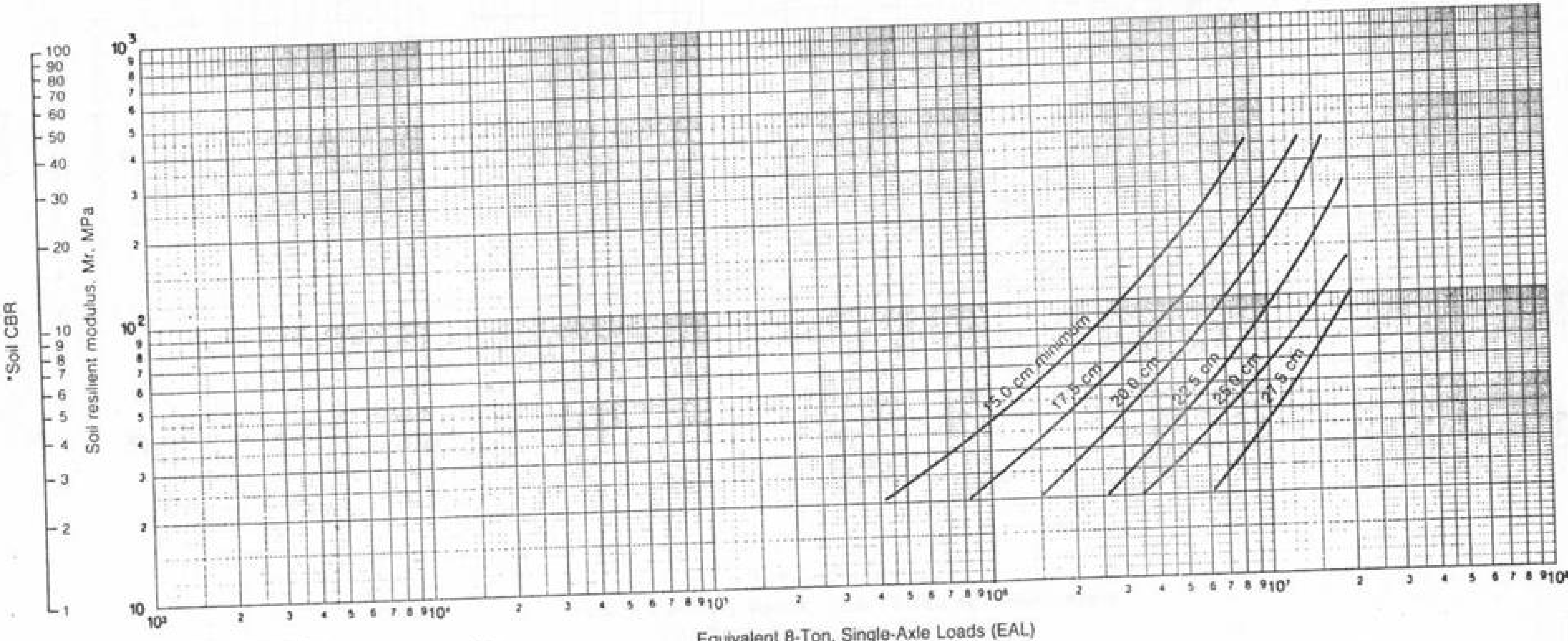
A
5 cm AC surface
15 cm AC base
22 cm CAB
30 cm subgrade borrow

B
5 cm AC surface
24 cm AC base
30 cm subgrade borrow

C
5 cm AC surface
15 cm AC base
18 cm LTA base
30 cm subgrade borrow

D
5 cm AC surface
24 cm AC base
21 cm LTS

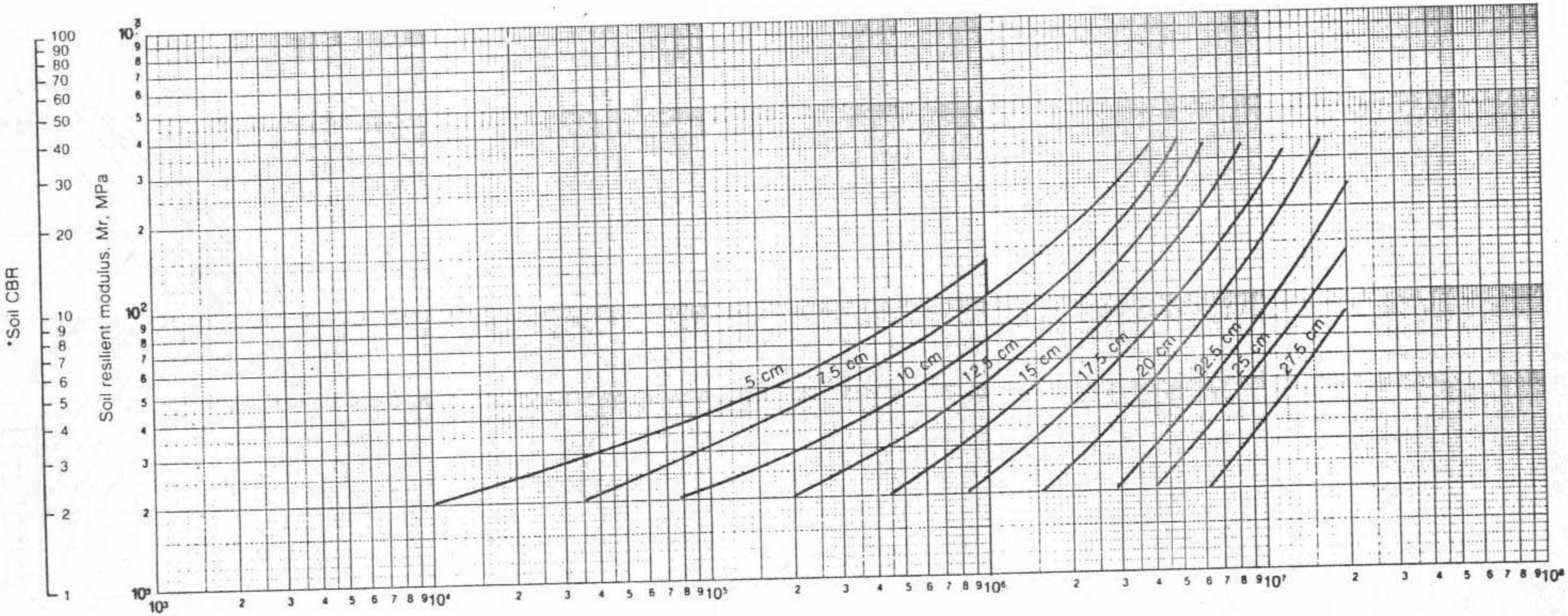
E
5 cm AC surface
15 cm AC base
18 cm LTA base
21 cm LTS



See Figure 1.09.6 for crushed aggregate base thickness

$$^{*}CBR = \frac{Mr}{10.520}$$

Figure 1.09.4
Asphalt Concrete Base Course Thickness Requirements
For Expressways



See Figure 1.09.7 for crushed aggregate base thickness

$$^{*}CBR \cong \frac{Mr}{10.320}$$

Figure 1.09.5
Asphalt Concrete Base Course Thickness Requirements For Roads Other Than Expressways

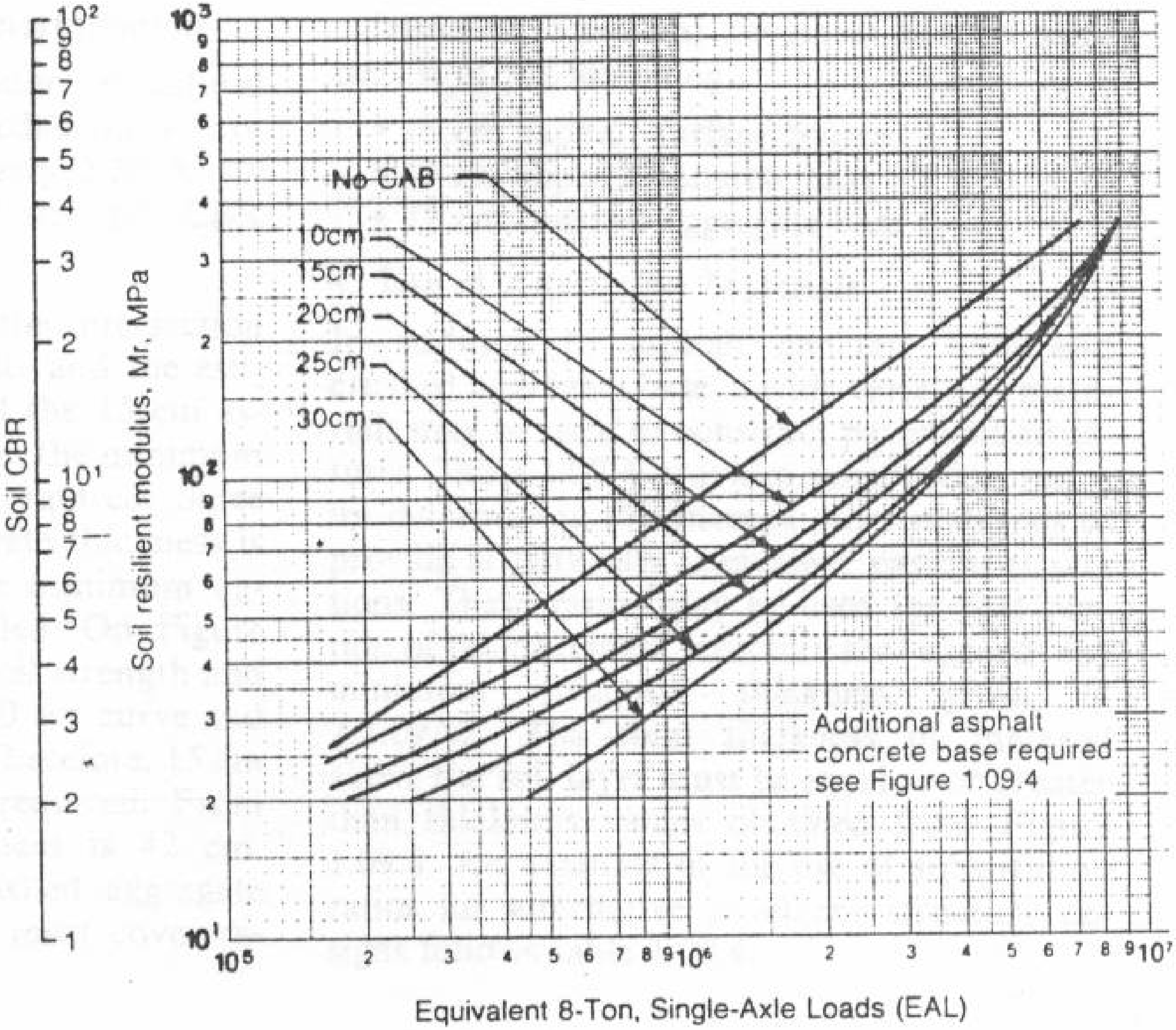


Figure 1.09.6
Crushed Aggregate Base Requirements
For Expressways

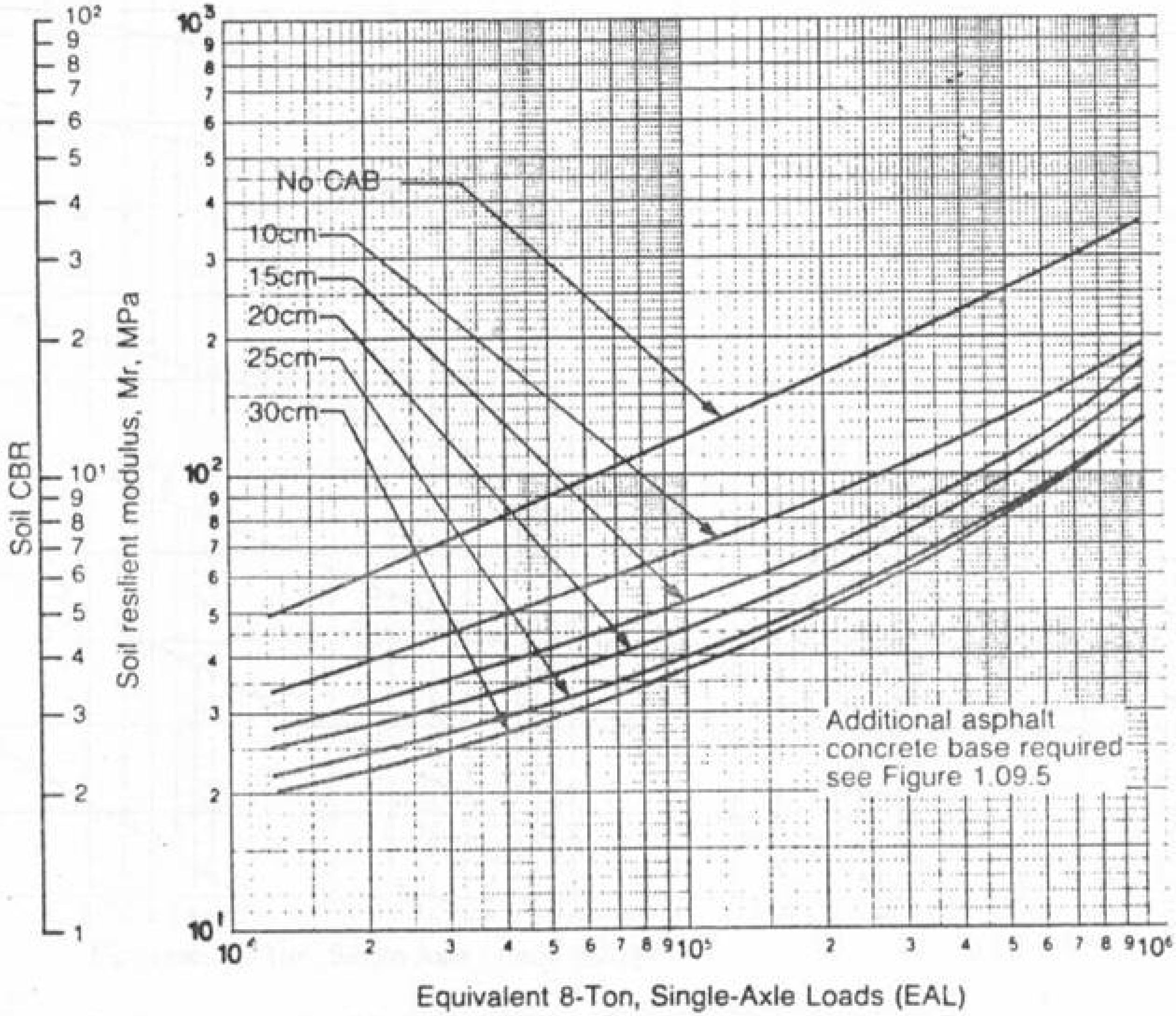


Figure 1.09.7
Crushed Aggregate Base Requirements For Roads Other Than Expressways

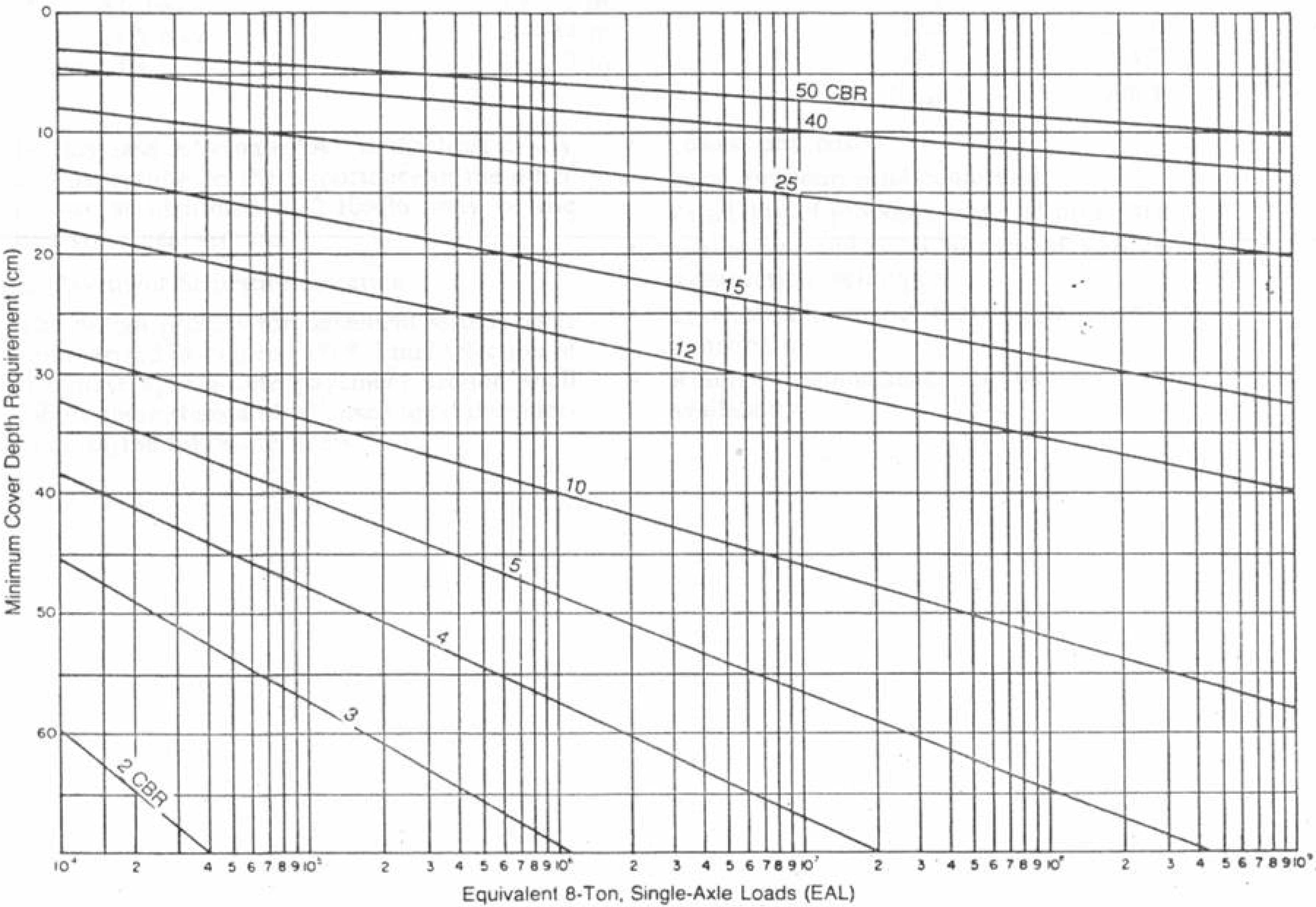


Figure 1.09.8
Cover Requirements

5. Cost Comparison of Acceptable Alternatives

Alternative A	Quantity for One Meter Length	Unit Price (Riyals)	Cost
5 cm AC surface	.6525 m^3	160	104.40
15 cm AC base	1.9875 m^3	150	298.13
22 cm CAB	3.0000 m^3	50	150.00
30 cm subgrade borrow	4.2300 m^3	15	63.45
		Total	615.98

Alternative C	Quantity for One Meter Length	Unit Price (Riyals)	Cost
5 cm AC surface	.6525 m^3	160	104.40
15 cm AC base	1.9875 m^3	150	298.13
18 cm LTA base	2.4444 m^3	110	268.88
30 cm subgrade borrow	4.2180 m^3	15	63.27
		Total	734.68

Alternative D	Quantity for One Meter Length	Unit Price (Riyals)	Cost
5 cm AC surface	.6525 m^3	160	104.40
24 cm AC base	3.2016 m^3	150	480.24
21 cm LTS	2.8959 m^3	80	231.67
		Total	816.31

Alternative E	Quantity for One Meter Length	Unit Price (Riyals)	Cost
5 cm AC surface	.6525 m^3	160	104.40
15 cm AC base	1.9875 m^3	150	298.13
18 cm LTA base	2.4444 m^3	110	268.88
21 cm LTS	2.9337 m^3	80	234.70
		Total	906.11

In this case Alternate "A" is the least costly and depending on the importance of the other factors as identified in 2.109B6, may be the best structural section.

6. Pavement Structure Selection

The design process for pavement structures is summarized in Figure 1.09.9. Final selection of the most appropriate pavement section shall follow these steps and be based upon consideration of the following items:

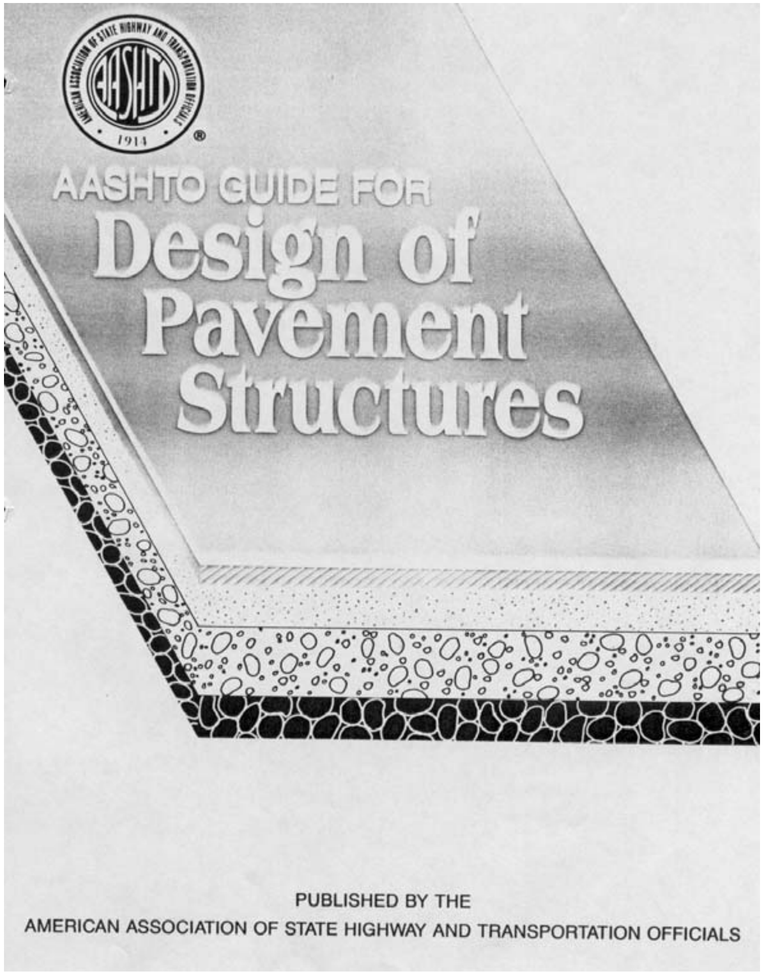
- Lowest unit cost.
- Local environmental conditions.
- Variability of proposed material properties.
- Availability and local history of required construction techniques.
- Level of performance that the pavement is to maintain.
- Routine maintenance requirements and availability.

II. AASHTO Design Method

AASHTO® Guide for
Design of Pavement Structures
1993

Published by the
American Association of State Highway
and Transportation Officials

444 N. Capitol Street, N.W., Suite 249
Washington, D.C. 20001



Highway Conditions	Analysis Period (years)
High volume urban	30 - 50
High volume rural	20 - 50
Low volume paved	15 - 25
Low volume aggregate surface	10 - 20

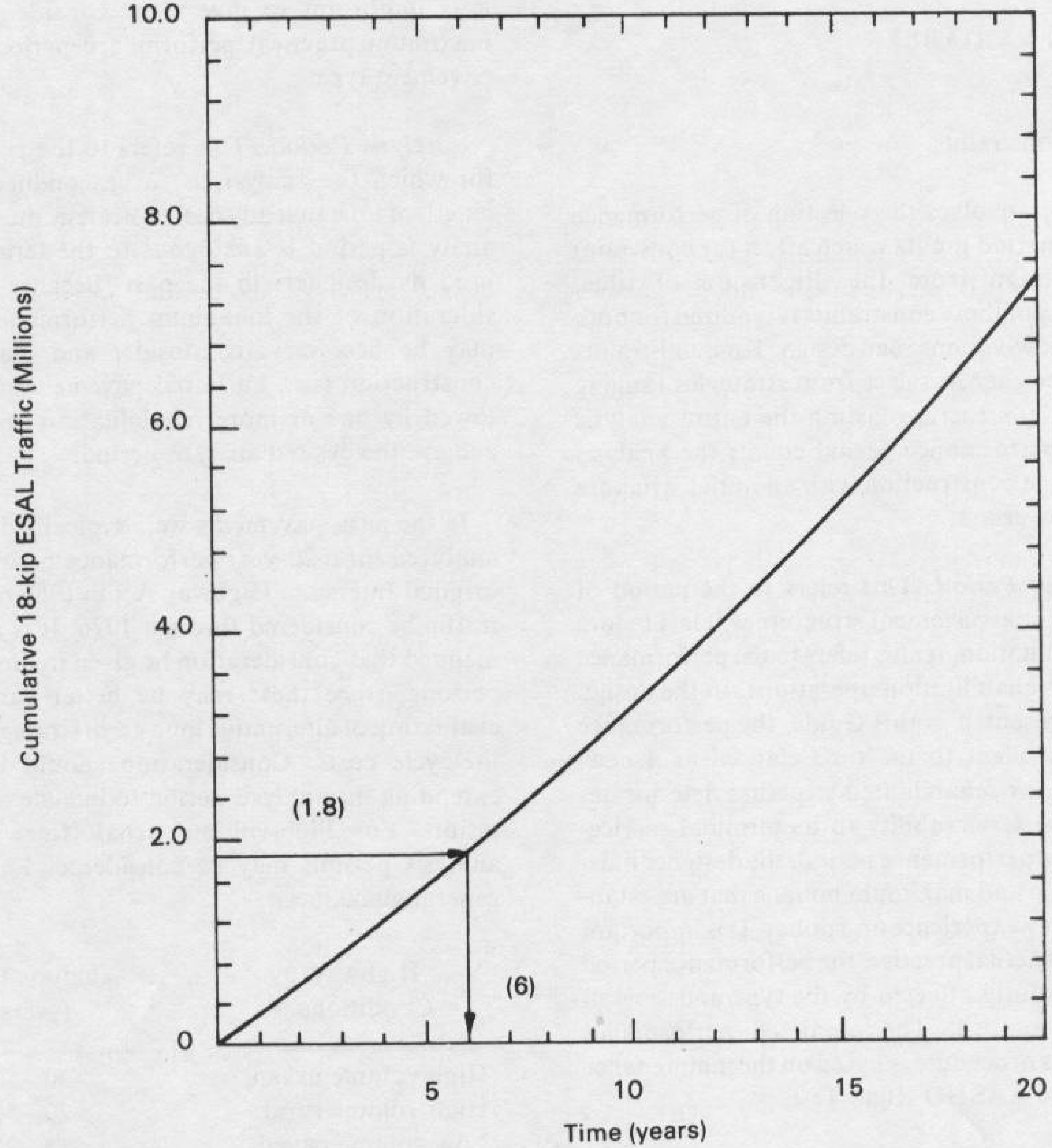


Figure 2.1. Example plot of cumulative 18-kip ESAL traffic versus time.

$$w_{18} = D_D \times D_L \times \hat{w}_{18}$$

where

D_D = a directional distribution factor, expressed as a ratio, that accounts for the distribution of ESAL units by direction, e.g., east-west, north-south, etc.,

D_L = a lane distribution factor, expressed as a ratio, that accounts for distribution of traffic when two or more lanes are available in one direction.

$\hat{w}_{18}$ = the cumulative two-directional 18-kip ESAL units predicted for a specific section of highway during the analysis period (from the planning group).

No. of Lanes In Each Direction	Percent of 18-kip ESAL In Design Lane
1	100
2	80 - 100
3	60 - 80
4	50 - 75

$$\Delta PSI_{TR} = \Delta PSI - \Delta PSI_{SW,FH}$$

$$\Delta PSI = p_o - p_t$$

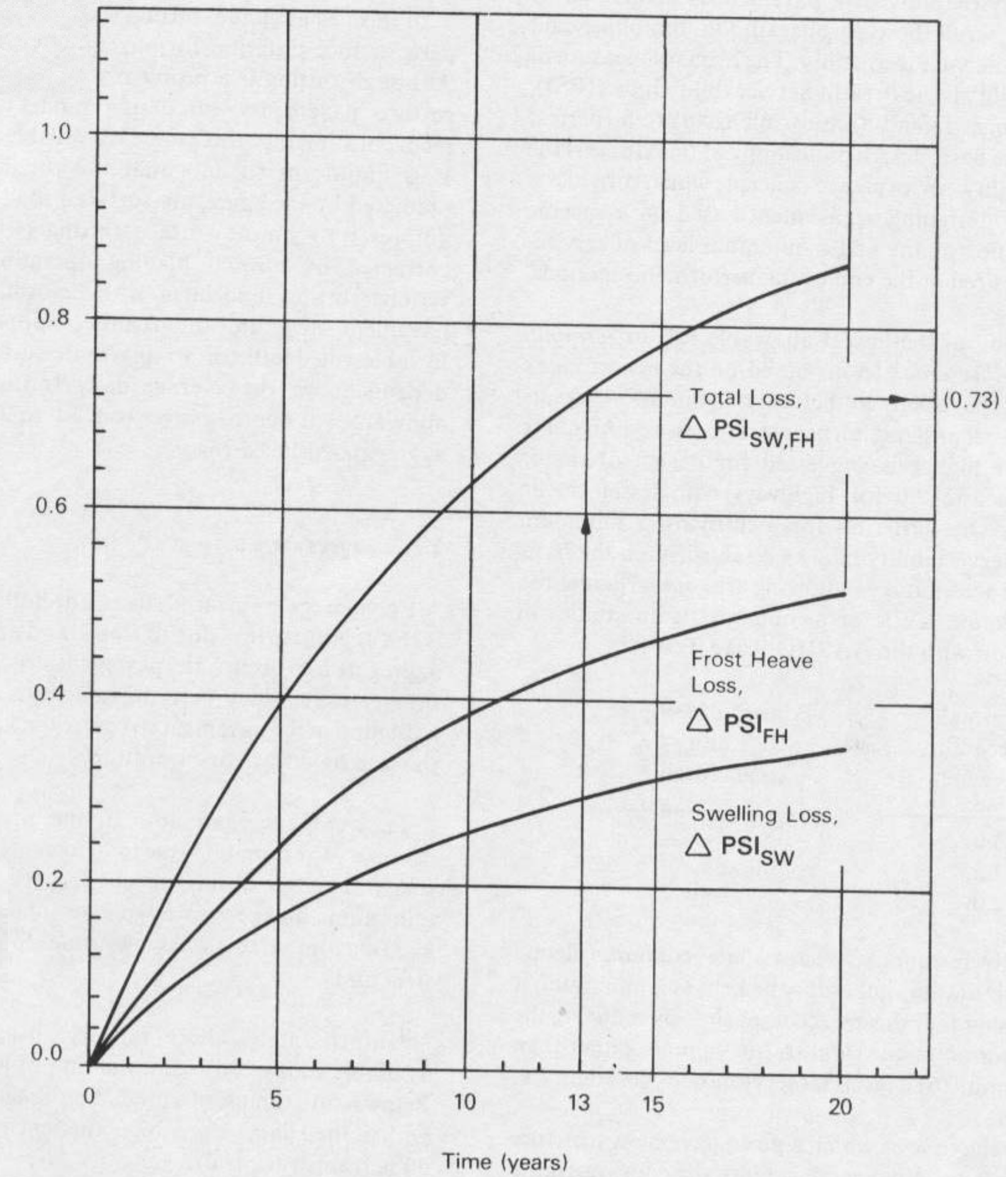


Figure 2.2. A conceptual example of the environmental serviceability loss versus time graph that may be developed for a specific location.

Table 2.2. Suggested levels of reliability for various functional classifications.

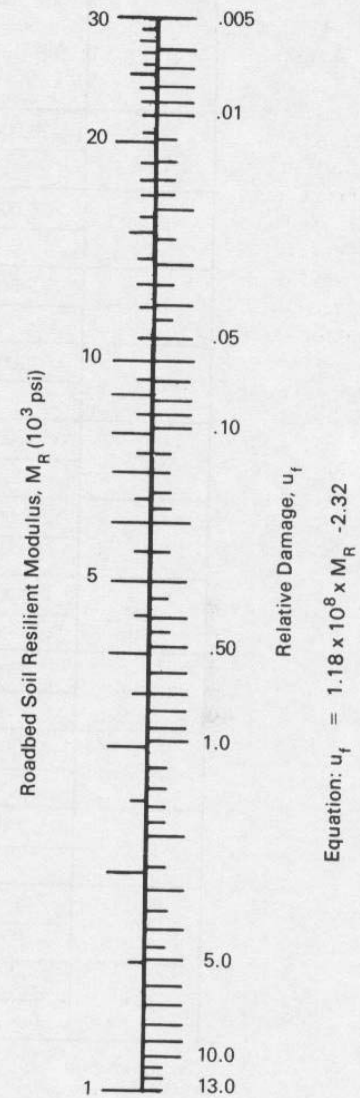
Functional Classification	Recommended Level of Reliability	
	Urban	Rural
Interstate and other freeways	85 - 99.9	80 - 99.9
Principal Arterials	80 - 99	75 - 95
Collectors	80 - 95	75 - 95
Local	50 - 80	50 - 80

Note: Results based on a survey of the AASHTO Pavement Design Task Force

Values of S_o developed at the AASHO Road Test did not include traffic error. However, the performance prediction error developed at the Road Test was .25 for rigid and .35 for flexible pavements. This corresponds to a total standard deviation for traffic of 0.35 and 0.45 for rigid and flexible pavements, respectively.

Month	Roadbed Soil Modulus, M_R (psi)	Relative Damage, u_f
Jan.		
Feb.		
Mar.		
Apr.		
May		
June		
July		
Aug.		
Sept.		
Oct.		
Nov.		
Dec.		

Summation: $\Sigma u_f =$ ______

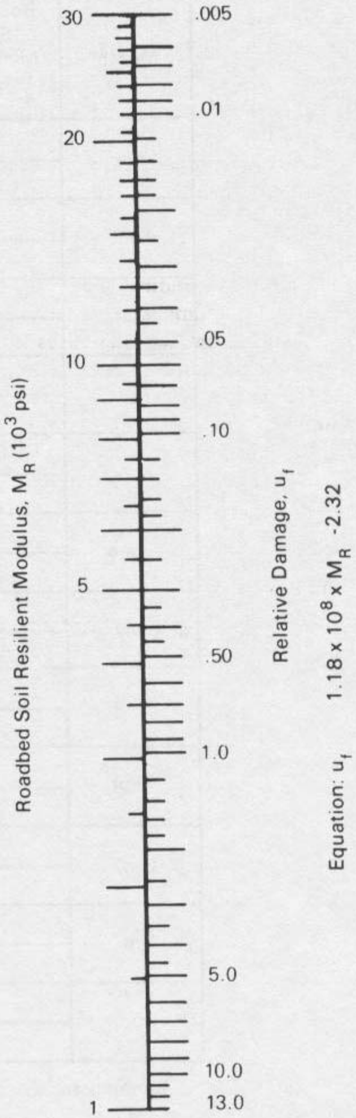


Average: $\bar{u}_f = \frac{\Sigma u_f}{n} =$ ______

Effective Roadbed Soil Resilient Modulus, M_R (psi) = ______ (corresponds to $\bar{u}_f$)

Figure 2.3. Chart for estimating effective roadbed soil resilient modulus for flexible pavements designed using the serviceability criteria.

Month	Roadbed Soil Modulus, M_R (psi)	Relative Damage, u_f
Jan.	20,000	0.01
Feb.	20,000	0.01
Mar.	2,500	1.51
Apr.	4,000	0.51
May	4,000	0.51
June	7,000	0.13
July	7,000	0.13
Aug.	7,000	0.13
Sept.	7,000	0.13
Oct.	7,000	0.13
Nov.	4,000	0.51
Dec.	20,000	0.01
Summation: Σu_f =		3.72



Average: $\bar{u}_f = \frac{\Sigma u_f}{n} = \frac{3.72}{12} = 0.31$

Effective Roadbed Soil Resilient Modulus, M_R (psi) = 5,000 (corresponds to $\bar{u}_f$)

Figure 2.4. Chart for estimating effective roadbed soil resilient modulus for flexible pavements designed using the serviceability criteria.

$$SN = \sum_{i=1} a_i D_i$$

$$SN = a_1 D_1 + a_2 D_2 m_2 + a_3 D_3 m_3$$

where

a_1, a_2, a_3 = layer coefficients representative of surface, base, and subbase courses, respectively (see Section 2.3.5),

D_1, D_2, D_3 = actual thicknesses (in inches) of surface, base, and subbase courses, respectively,

m_2, m_3 = drainage coefficients for base and subbase layers, respectively (see Section 2.4.1).

3.1.1 Determine Required Structural Number

Figure 3.1 presents the nomograph recommended for determining the design structural number (SN) required for specific conditions, including

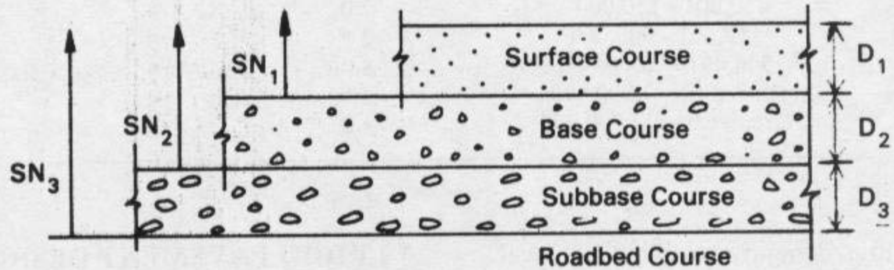
(1) the estimated future traffic, W_{18} (Section 2.1.2), for the performance period,

(2) the reliability, R (Section 2.1.3), which assumes all input is at average value,

(3) the overall standard deviation, S_o (Section 2.1.3),

(4) the effective resilient modulus of roadbed material, M_R (Section 2.3.1), and

(5) the design serviceability loss, $\Delta PSI = p_o - p_t$ (Section 2.2.1).



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

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

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

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

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

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. Procedure for determining thicknesses of layers using a layered analysis approach.

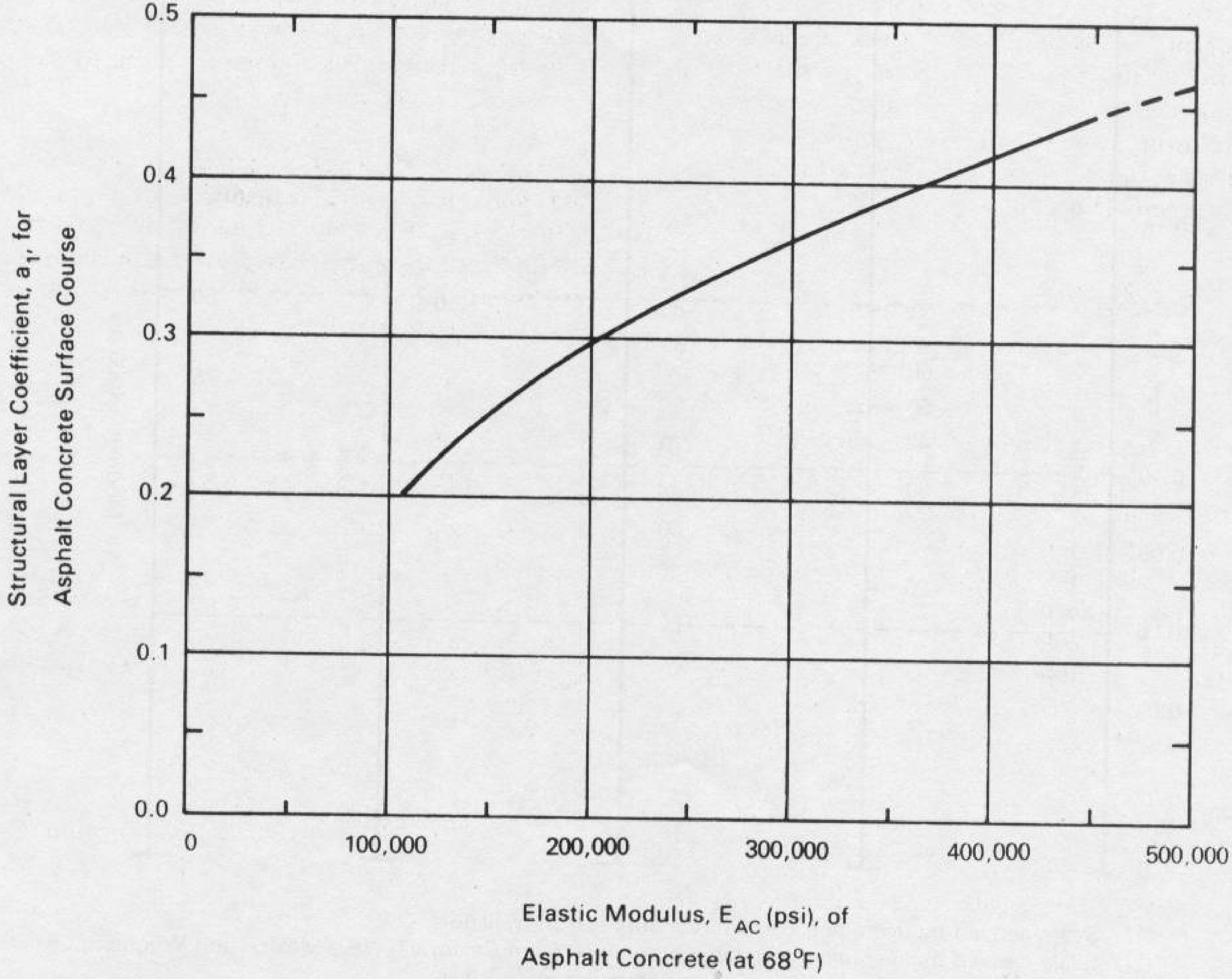
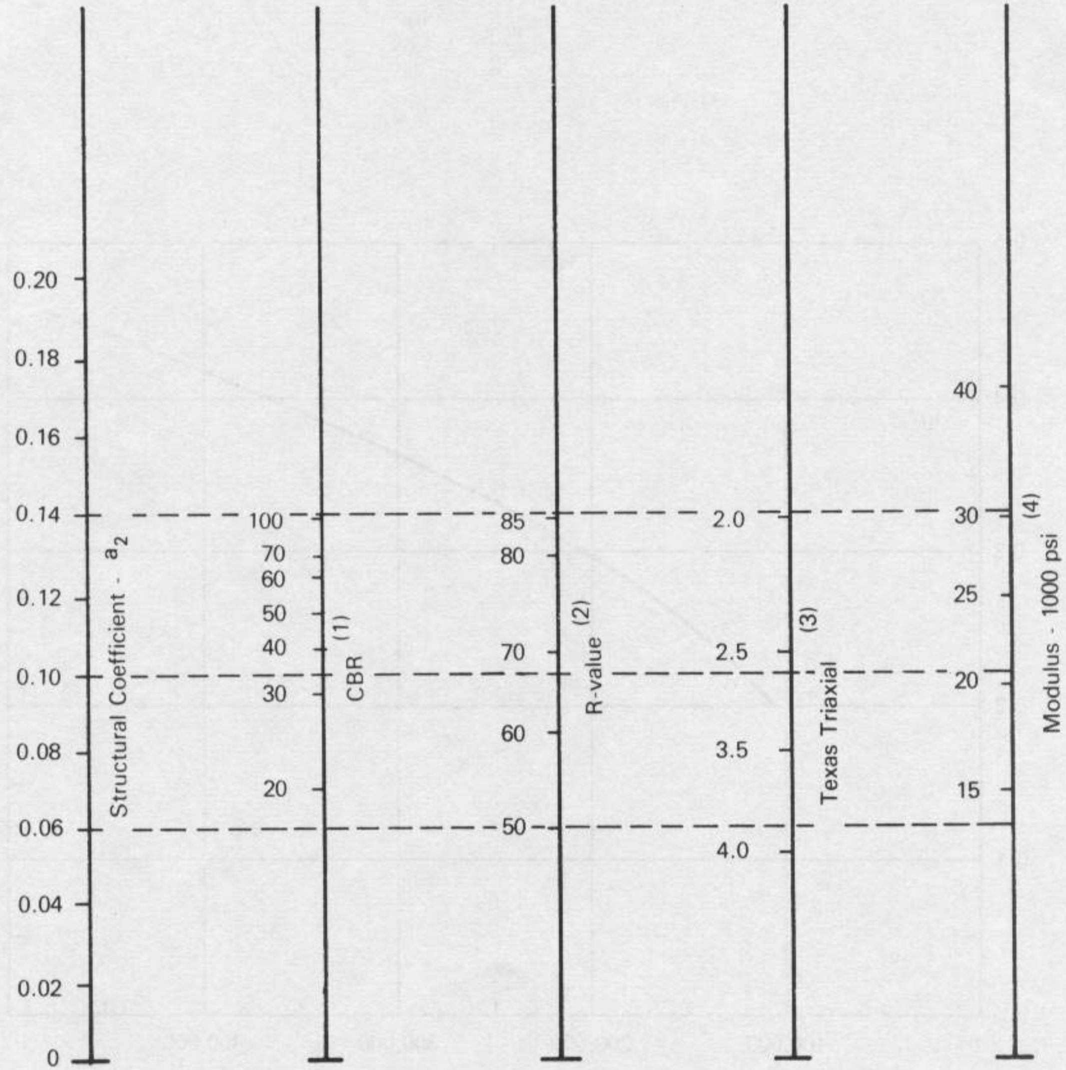
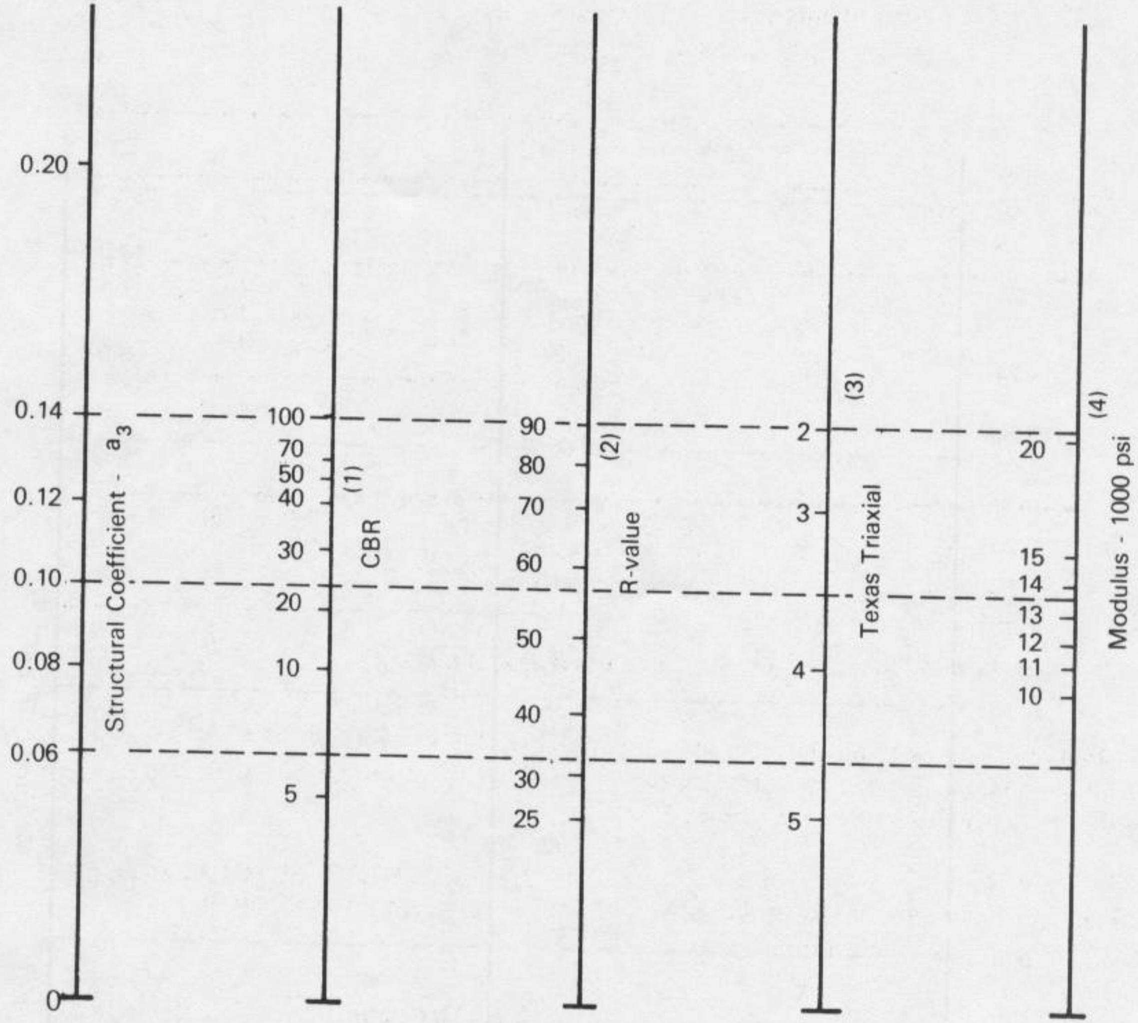


Figure 2.5. Chart for estimating structural layer coefficient of dense-graded asphalt concrete based on the elastic (resilient) modulus (*3*).



(1) Scale derived by averaging correlations obtained from Illinois.
(2) Scale derived by averaging correlations obtained from California, New Mexico and Wyoming.
(3) Scale derived by averaging correlations obtained from Texas.
(4) Scale derived on NCHRP project *(3)*.

Figure 2.6. Variation in granular base layer coefficient (a_2) with various base strength parameters (*3*).



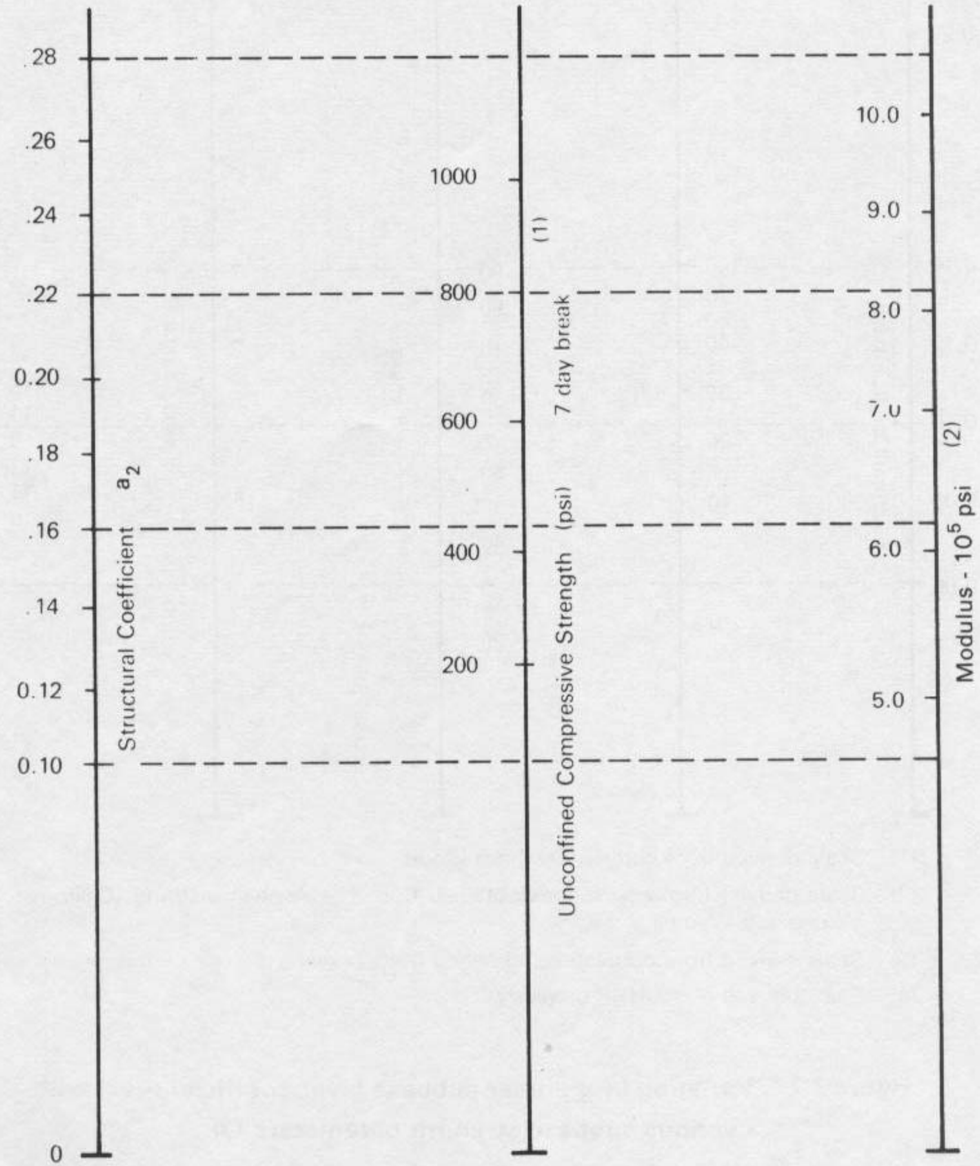
(1) Scale derived from correlations from Illinois.

(2) Scale derived from correlations obtained from The Asphalt Institute, California, New Mexico and Wyoming.

(3) Scale derived from correlations obtained from Texas.

(4) Scale derived on NCHRP project *(3)*.

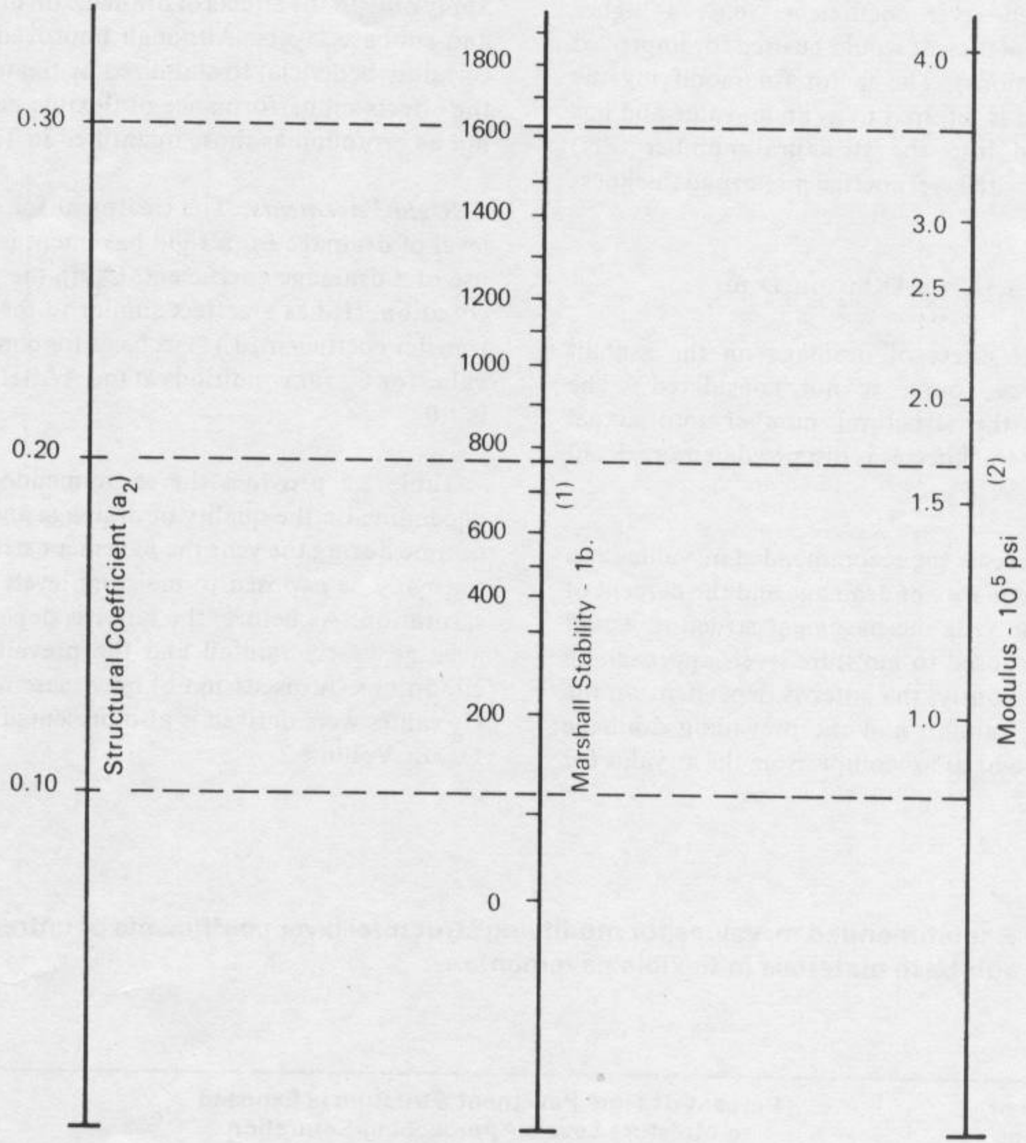
Figure 2.7. Variation in granular subbase layer coefficient (a_3) with various subbase strength parameters *(3)*.



(1) Scale derived by averaging correlations from Illinois, Louisiana and Texas.

(2) Scale derived on NCHRP project (3).

Figure 2.8. Variation in a for cement-treated bases with base strength parameter (*3*).



(1) Scale derived by correlation obtained from Illinois.

(2) Scale derived on NCHRP project (3).

Figure 2.9. Variation in a_2 for bituminous-treated bases with base strength parameter *(3)*.

Quality of Drainage	Water Removed Within
Excellent	2 hours
Good	1 day
Fair	1 week
Poor	1 month
Very Poor	(water will not drain)

Table 2.4 Recommended m_i values for modifying structural layer coefficients of untreated base and sub-base materials in flexible pavements.

Quality of Drainage	Percent of Time Pavement Structure is Exposed to Moisture Levels Approaching Saturation			
	Less Than 1%	1 - 5%	5 - 25%	Greater Than 25%
Excellent	1.40 - 1.35	1.35 - 1.30	1.30 - 1.20	1.20
Good	1.35 - 1.25	1.25 - 1.15	1.15 - 1.00	1.00
Fair	1.25 - 1.15	1.15 - 1.05	1.00 - 0.80	0.80
Poor	1.15 - 1.05	1.05 - 0.80	0.80 - 0.60	0.60
Very Poor	1.05 - 0.95	0.95 - 0.75	0.75 - 0.40	0.40

$$SN = \sum_{i=1} a_i D_i$$

$$SN = a_1 D_1 + a_2 D_2 m_2 + a_3 D_3 m_3$$

where

a_1, a_2, a_3	=	layer coefficients representative of surface, base, and subbase courses, respectively (see Section 2.3.5),
D_1, D_2, D_3	=	actual thicknesses (in inches) of surface, base, and subbase courses, respectively,
m_2, m_3	=	drainage coefficients for base and subbase layers, respectively (see Section 2.4.1).

NOMOGRAPH SOLVES:

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

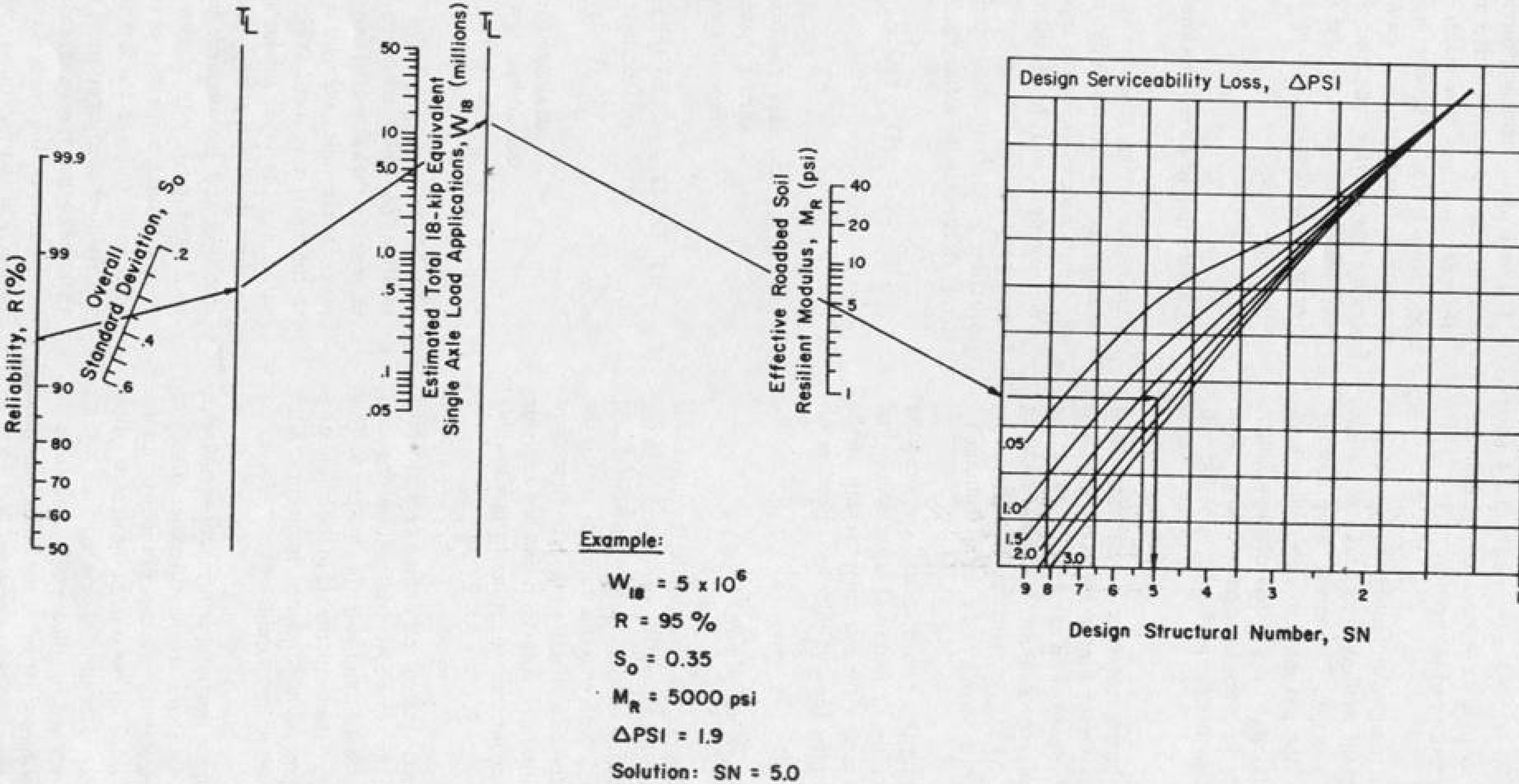
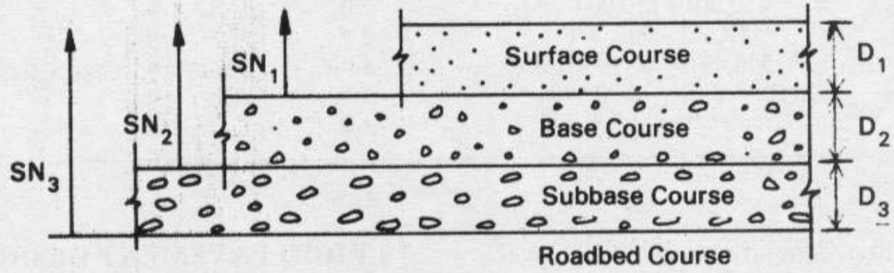


Figure 3.1. Design chart for flexible pavements based on using mean values for each input.



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

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

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

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

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

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. Procedure for determining thicknesses of layers using a layered analysis approach.

Minimum Thickness (inches)

Traffic, ESAL'S	Asphalt Concrete	Aggregate Base
Less than 50,000	1.0 (or surface treatment)	4
50,001 - 150,000	2.0	4
150,001 - 500,000	2.5	4
500,001 - 2,000,000	3.0	6
2,000,001 - 7,000,000	3.5	6
Greater than 7,000,000	4.0	6

Table D.1. Axle load equivalency factors for flexible pavements, single axles and p_t of 2.0.

Axle Load (kips)	Pavement Structural Number (SN)					
	1	2	3	4	5	6
2	.0002	.0002	.0002	.0002	.0002	.0002
4	.002	.003	.002	.002	.002	.002
6	.009	.012	.011	.010	.009	.009
8	.030	.035	.036	.033	.031	.029
10	.075	.085	.090	.085	.079	.076
12	.165	.177	.189	.183	.174	.168
14	.325	.338	.354	.350	.338	.331
16	.589	.598	.613	.612	.603	.596
18	1.00	1.00	1.00	1.00	1.00	1.00
20	1.61	1.59	1.56	1.55	1.57	1.59
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	10.4	10.0	9.2	8.6	8.7	9.2
32	14.0	13.5	12.4	11.5	11.5	12.1
34	18.5	17.9	16.3	15.0	14.9	15.6
36	24.2	23.3	21.2	19.3	19.0	19.9
38	31.1	29.9	27.1	24.6	24.0	25.1
40	39.6	38.0	34.3	30.9	30.0	31.2
42	49.7	47.7	43.0	38.6	37.2	38.5
44	61.8	59.3	53.4	47.6	45.7	47.1
46	76.1	73.0	65.6	58.3	55.7	57.0
48	92.9	89.1	80.0	70.9	67.3	68.6
50	113.	108.	97.	86.	81.	82.

Table D.2. Axle load equivalency factors for flexible pavements, tandem axles and p_t of 2.0.

Axle Load (kips)	Pavement Structural Number (SN)					
	1	2	3	4	5	6
2	.0000	.0000	.0000	.0000	.0000	.0000
4	.0003	.0003	.0003	.0002	.0002	.0002
6	.001	.001	.001	.001	.001	.001
8	.003	.003	.003	.003	.003	.002
10	.007	.008	.008	.007	.006	.006
12	.013	.016	.016	.014	.013	.012
14	.024	.029	.029	.026	.024	.023
16	.041	.048	.050	.046	.042	.040
18	.066	.077	.081	.075	.069	.066
20	.103	.117	.124	.117	.109	.105
22	.156	.171	.183	.174	.164	.158
24	.227	.244	.260	.252	.239	.231
26	.322	.340	.360	.353	.338	.329
28	.447	.465	.487	.481	.466	.455
30	.607	.623	.646	.643	.627	.617
32	.810	.823	.843	.842	.829	.819
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
50	6.15	5.99	5.64	5.44	5.56	5.77
52	7.37	7.16	6.71	6.43	6.56	6.83
54	8.77	8.51	7.93	7.55	7.69	8.03
56	10.4	10.1	9.3	8.8	9.0	9.4
58	12.2	11.8	10.9	10.3	10.4	10.9
60	14.3	13.8	12.7	11.9	12.0	12.6
62	16.6	16.0	14.7	13.7	13.8	14.5
64	19.3	18.6	17.0	15.8	15.8	16.6
66	22.2	21.4	19.6	18.0	18.0	18.9
68	25.5	24.6	22.4	20.6	20.5	21.5
70	29.2	28.1	25.6	23.4	23.2	24.3
72	33.3	32.0	29.1	26.5	26.2	27.4
74	37.8	36.4	33.0	30.0	29.4	30.8
76	42.8	41.2	37.3	33.8	33.1	34.5
78	48.4	46.5	42.0	38.0	37.0	38.6
80	54.4	52.3	47.2	42.5	41.3	43.0
82	61.1	58.7	52.9	47.6	46.0	47.8
84	68.4	65.7	59.2	53.0	51.2	53.0
86	76.3	73.3	66.0	59.0	56.8	58.6
88	85.0	81.6	73.4	65.5	62.8	64.7
90	94.4	90.6	81.5	72.6	69.4	71.3

Table D.3. Axle load equivalency factors for flexible pavements, triple axles and p_t of 2.0.

Axle Load (kips)	Pavement Structural Number (SN)					
	1	2	3	4	5	6
2	.0000	.0000	.0000	.0000	.0000	.0000
4	.0001	.0001	.0001	.0001	.0001	.0001
6	.0004	.0004	.0003	.0003	.0003	.0003
8	.0009	.0010	.0009	.0008	.0007	.0007
10	.002	.002	.002	.002	.002	.001
12	.004	.004	.004	.003	.003	.003
14	.006	.007	.007	.006	.006	.005
16	.010	.012	.012	.010	.009	.009
18	.016	.019	.019	.017	.015	.015
20	.024	.029	.029	.026	.024	.023
22	.034	.042	.042	.038	.035	.034
24	.049	.058	.060	.055	.051	.048
26	.068	.080	.083	.077	.071	.068
28	.093	.107	.113	.105	.098	.094
30	.125	.140	.149	.140	.131	.126
32	.164	.182	.194	.184	.173	.167
34	.213	.233	.248	.238	.225	.217
36	.273	.294	.313	.303	.288	.279
38	.346	.368	.390	.381	.364	.353
40	.434	.456	.481	.473	.454	.443
42	.538	.560	.587	.580	.561	.548
44	.662	.682	.710	.705	.686	.673
46	.807	.825	.852	.849	.831	.818
48	.976	.992	1.015	1.014	.999	.987
50	1.17	1.18	1.20	1.20	1.19	1.18
52	1.40	1.40	1.42	1.42	1.41	1.40
54	1.66	1.66	1.66	1.66	1.66	1.66
56	1.95	1.95	1.93	1.93	1.94	1.94
58	2.29	2.27	2.24	2.23	2.25	2.27
60	2.67	2.64	2.59	2.57	2.60	2.63
62	3.10	3.06	2.98	2.95	2.99	3.04
64	3.59	3.53	3.41	3.37	3.42	3.49
66	4.13	4.05	3.89	3.83	3.90	3.99
68	4.73	4.63	4.43	4.34	4.42	4.54
70	5.40	5.28	5.03	4.90	5.00	5.15
72	6.15	6.00	5.68	5.52	5.63	5.82
74	6.97	6.79	6.41	6.20	6.33	6.56
76	7.88	7.67	7.21	6.94	7.08	7.36
78	8.88	8.63	8.09	7.75	7.90	8.23
80	9.98	9.69	9.05	8.63	8.79	9.18
82	11.2	10.8	10.1	9.6	9.8	10.2
84	12.5	12.1	11.2	10.6	10.8	11.3
86	13.9	13.5	12.5	11.8	11.9	12.5
88	15.5	15.0	13.8	13.0	13.2	13.8
90	17.2	16.6	15.3	14.3	14.5	15.2

Table D.4. Axle load equivalency factors for flexible pavements, single axles and p_t 2.5.

Axle Load (kips)	Pavement Structural Number (SN)					
	1	2	3	4	5	6
2	.0004	.0004	.0003	.0002	.0002	.0002
4	.003	.004	.004	.003	.002	.002
6	.011	.017	.017	.013	.010	.009
8	.032	.047	.051	.041	.034	.031
10	.078	.102	.118	.102	.088	.080
12	.168	.198	.229	.213	.189	.176
14	.328	.358	.399	.388	.360	.342
16	.591	.613	.646	.645	.623	.606
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	10.3	9.5	7.9	6.8	7.0	7.8
32	13.9	12.8	10.5	8.8	8.9	10.0
34	18.4	16.9	13.7	11.3	11.2	12.5
36	24.0	22.0	17.7	14.4	13.9	15.5
38	30.9	28.3	22.6	18.1	17.2	19.0
40	39.3	35.9	28.5	22.5	21.1	23.0
42	49.3	45.0	35.6	27.8	25.6	27.7
44	61.3	55.9	44.0	34.0	31.0	33.1
46	75.5	68.8	54.0	41.4	37.2	39.3
48	92.2	83.9	65.7	50.1	44.5	46.5
50	112.	102.	79.	60.	53.	55.

Table D.5. Axle load equivalency factors for flexible pavements, tandem axles and p_t of 2.5.

Axle Load (kips)	Pavement Structural Number (SN) 1	2	3	4	5	6
2	.0001	.0001	.0001	.0000	.0000	.0000
4	.0005	.0005	.0004	.0003	.0003	.0002
6	.002	.002	.002	.001	.001	.001
8	.004	.006	.005	.004	.003	.003
10	.008	.013	.011	.009	.007	.006
12	.015	.024	.023	.018	.014	.013
14	.026	.041	.042	.033	.027	.024
16	.044	.065	.070	.057	.047	.043
18	.070	.097	.109	.092	.077	.070
20	.107	.141	.162	.141	.121	.110
22	.160	.198	.229	.207	.180	.166
24	.231	.273	.315	.292	.260	.242
26	.327	.370	.420	.401	.364	.342
28	.451	.493	.548	.534	.495	.470
30	.611	.648	.703	.695	.658	.633
32	.813	.843	.889	.887	.857	.834
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
50	6.12	5.76	5.03	4.64	4.86	5.28
52	7.33	6.87	5.93	5.38	5.63	6.17
54	8.72	8.14	6.95	6.22	6.47	7.15
56	10.3	9.6	8.1	7.2	7.4	8.2
58	12.1	11.3	9.4	8.2	8.4	9.4
60	14.2	13.1	10.9	9.4	9.6	10.7
62	16.5	15.3	12.6	10.7	10.8	12.1
64	19.1	17.6	14.5	12.2	12.2	13.7
66	22.1	20.3	16.6	13.8	13.7	15.4
68	25.3	23.3	18.9	15.6	15.4	17.2
70	29.0	26.6	21.5	17.6	17.2	19.2
72	33.0	30.3	24.4	19.8	19.2	21.3
74	37.5	34.4	27.6	22.2	21.3	23.6
76	42.5	38.9	31.1	24.8	23.7	26.1
78	48.0	43.9	35.0	27.8	26.2	28.8
80	54.0	49.4	39.2	30.9	29.0	31.7
82	60.6	55.4	43.9	34.4	32.0	34.8
84	67.8	61.9	49.0	38.2	35.3	38.1
86	75.7	69.1	54.5	42.3	38.8	41.7
88	84.3	76.9	60.6	46.8	42.6	45.6
90	93.7	85.4	67.1	51.7	46.8	49.7

Table D.6. Axle load equivalency factors for flexible pavements, triple axles and p_t of 2.5.

Axle Load (kips)	Pavement Structural Number (SN) 1	2	3	4	5	6
2	.0000	.0000	.0000	.0000	.0000	.0000
4	.0002	.0002	.0002	.0001	.0001	.0001
6	.0006	.0007	.0005	.0004	.0003	.0003
8	.001	.002	.001	.001	.001	.001
10	.003	.004	.003	.002	.002	.002
12	.005	.007	.006	.004	.003	.003
14	.008	.012	.010	.008	.006	.006
16	.012	.019	.018	.013	.011	.010
18	.018	.029	.028	.021	.017	.016
20	.027	.042	.042	.032	.027	.024
22	.038	.058	.060	.048	.040	.036
24	.053	.078	.084	.068	.057	.051
26	.072	.103	.114	.095	.080	.072
28	.098	.133	.151	.128	.109	.099
30	.129	.169	.195	.170	.145	.133
32	.169	.213	.247	.220	.191	.175
34	.219	.266	.308	.281	.246	.228
36	.279	.329	.379	.352	.313	.292
38	.352	.403	.461	.436	.393	.368
40	.439	.491	.554	.533	.487	.459
42	.543	.594	.661	.644	.597	.567
44	.666	.714	.781	.769	.723	.692
46	.811	.854	.918	.911	.868	.838
48	.979	1.015	1.072	1.069	1.033	1.005
50	1.17	1.20	1.24	1.25	1.22	1.20
52	1.40	1.41	1.44	1.44	1.43	1.41
54	1.66	1.66	1.66	1.66	1.66	1.66
56	1.95	1.93	1.90	1.90	1.91	1.93
58	2.29	2.25	2.17	2.16	2.20	2.24
60	2.67	2.60	2.48	2.44	2.51	2.58
62	3.09	3.00	2.82	2.76	2.85	2.95
64	3.57	3.44	3.19	3.10	3.22	3.36
66	4.11	3.94	3.61	3.47	3.62	3.81
68	4.71	4.49	4.06	3.88	4.05	4.30
70	5.38	5.11	4.57	4.32	4.52	4.84
72	6.12	5.79	5.13	4.80	5.03	5.41
74	6.93	6.54	5.74	5.32	5.57	6.04
76	7.84	7.37	6.41	5.88	6.15	6.71
78	8.83	8.28	7.14	6.49	6.78	7.43
80	9.92	9.28	7.95	7.15	7.45	8.21
82	11.1	10.4	8.8	7.9	8.2	9.0
84	12.4	11.6	9.8	8.6	8.9	9.9
86	13.8	12.9	10.8	9.5	9.8	10.9
88	15.4	14.3	11.9	10.4	10.6	11.9
90	17.1	15.8	13.2	11.3	11.6	12.9

Table D.7. Axle load equivalency factors for flexible pavements, single axles and p_t of 3.0.

Axle Load (kips)	Pavement Structural Number (SN) 1	2	3	4	5	6
2	.0008	.0009	.0006	.0003	.0002	.0002
4	.004	.008	.006	.004	.002	.002
6	.014	.030	.028	.018	.012	.010
8	.035	.070	.080	.055	.040	.034
10	.082	.132	.168	.132	.101	.086
12	.173	.231	.296	.260	.212	.187
14	.332	.388	.468	.447	.391	.358
16	.594	.633	.695	.693	.651	.622
18	1.00	1.00	1.00	1.00	1.00	1.00
20	1.60	1.53	1.41	1.38	1.44	1.51
22	2.47	2.29	1.96	1.83	1.97	2.16
24	3.67	3.33	2.69	2.39	2.60	2.96
26	5.29	4.72	3.65	3.08	3.33	3.91
28	7.43	6.56	4.88	3.93	4.17	5.00
30	10.2	8.9	6.5	5.0	5.1	6.3
32	13.8	12.0	8.4	6.2	6.3	7.7
34	18.2	15.7	10.9	7.8	7.6	9.3
36	23.8	20.4	14.0	9.7	9.1	11.0
38	30.6	26.2	17.7	11.9	11.0	13.0
40	38.8	33.2	22.2	14.6	13.1	15.3
42	48.8	41.6	27.6	17.8	15.5	17.8
44	60.6	51.6	34.0	21.6	18.4	20.6
46	74.7	63.4	41.5	26.1	21.6	23.8
48	91.2	77.3	50.3	31.3	25.4	27.4
50	110.	94.	61.	37.	30.	32.

Table D.8. Axle load equivalency factors for flexible pavements, tandem axles and p_t of 3.0.

Axle Load (kips)	Pavement Structural Number (SN)					
	1	2	3	4	5	6
2	.0002	.0002	.0001	.0001	.0000	.0000
4	.001	.001	.001	.000	.000	.000
6	.003	.004	.003	.002	.001	.001
8	.006	.011	.009	.005	.003	.003
10	.011	.024	.020	.012	.008	.007
12	.019	.042	.039	.024	.017	.014
14	.031	.066	.068	.045	.032	.026
16	.049	.096	.109	.076	.055	.046
18	.075	.134	.164	.121	.090	.076
20	.113	.181	.232	.182	.139	.119
22	.166	.241	.313	.260	.205	.178
24	.238	317	.407	.358	.292	.257
26	.333	.413	.517	.476	.402	.360
28	.457	.534	.643	.614	.538	.492
30	.616	.684	.788	.773	.702	.656
32	.817	.870	.956	.953	.896	.855
34	1.07	1.10	1.15	1.15	1.12	1.09
36	1.38	1.38	1.38	1.38	1.38	1.38
38	1.75	1.71	1.64	1.62	1.66	1.70
40	2.21	2.11	1.94	1.89	1.98	2.08
42	2.75	2.59	2.29	2.19	2.33	2.50
44	3.39	3.15	2.70	2.52	2.71	2.97
46	4.15	3.81	3.16	2.89	3.13	3.50
48	5.04	4.58	3.70	3.29	3.57	4.07
50	6.08	5.47	4.31	3.74	4.05	4.70
52	7.27	6.49	5.01	4.24	4.57	5.37
54	8.65	7.67	5.81	4.79	5.13	6.10
56	10.2	9.0	6.7	5.4	5.7	6.9
58	12.0	10.6	7.7	6.1	6.4	7.7
60	14.1	12.3	8.9	6.8	7.1	8.6
62	16.3	14.2	10.2	7.7	7.8	9.5
64	18.9	16.4	11.6	8.6	8.6	10.5
66	21.8	18.9	13.2	9.6	9.5	11.6
68	25.1	21.7	15.0	10.7	10.5	12.7
70	28.7	24.7	17.0	12.0	11.5	13.9
72	32.7	28.1	19.2	13.3	12.6	15.2
74	37.2	31.9	21.6	14.8	13.8	16.5
76	42.1	36.0	24.3	16.4	15.1	17.9
78	47.5	40.6	27.3	18.2	16.5	19.4
80	53.4	45.7	30.5	20.1	18.0	21.0
82	60.0	51.2	34.0	22.2	19.6	22.7
84	67.1	57.2	37.9	24.6	21.3	24.5
86	74.9	63.8	42.1	27.1	23.2	26.4
88	83.4	71.0	46.7	29.8	25.2	28.4
90	92.7	78.8	51.7	32.7	27.4	30.5

Table D.9. Axle load equivalency factors for flexible pavements, tandem axles and p_t of 3.0.

Axle Load (kips)	Pavement Structural Number (SN)					
	1	2	3	4	5	6
2	.0001	.0001	.0001	.0000	.0000	.0000
4	.0005	.0004	.0003	.0002	.0001	.0001
6	.001	.001	.001	.001	.000	.000
8	.003	.004	.002	.001	.001	.001
10	.005	.008	.005	.003	.002	.002
12	.007	.014	.010	.006	.004	.003
14	.011	.023	.018	.011	.007	.006
16	.016	.035	.030	.018	.013	.010
18	.022	.050	.047	.029	.020	.017
20	.031	.069	.069	.044	.031	.026
22	.043	.090	.097	.065	.046	.039
24	.059	.116	.132	.092	.066	.056
26	.079	.145	.174	.126	.092	.078
28	.104	.179	.223	.168	.126	.107
30	.136	.218	.279	.219	.167	.143
32	.176	.265	.342	.279	.218	.188
34	.226	.319	.413	.350	.279	.243
36	.286	.382	.491	.432	.352	.310
38	.359	.456	.577	.524	.437	.389
40	.447	.543	.671	.626	.536	.483
42	.550	.643	.775	.740	.649	.593
44	.673	.760	.889	.865	.777	.720
46	.817	.894	1.014	1.001	.920	.865
48	.984	1.048	1.152	1.148	1.080	1.030
50	1.18	1.23	1.30	1.31	1.26	1.22
52	1.40	1.43	1.47	1.48	1.45	1.43
54	1.66	1.66	1.66	1.66	1.66	1.66
56	1.95	1.92	1.86	1.85	1.88	1.91
58	2.28	2.21	2.09	2.06	2.13	2.20
60	2.66	2.54	2.34	2.28	2.39	2.50
62	3.08	2.92	2.61	2.52	2.66	2.84
64	3.56	3.33	2.92	2.77	2.96	3.19
66	4.09	3.79	3.25	3.04	3.27	3.58
68	4.68	4.31	3.62	3.33	3.60	4.00
70	5.34	4.88	4.02	3.64	3.94	4.44
72	6.08	5.51	4.46	3.97	4.31	4.91
74	6.89	6.21	4.94	4.32	4.69	5.40
76	7.78	6.98	5.47	4.70	5.09	5.93
78	8.76	7.83	6.04	5.11	5.51	6.48
80	9.84	8.75	6.67	5.54	5.96	7.06
82	11.0	9.8	7.4	6.0	6.4	7.7
84	12.3	10.9	8.1	6.5	6.9	8.3
86	13.7	12.1	8.9	7.0	7.4	9.0
88	15.3	13.4	9.8	7.6	8.0	9.6
90	16.9	14.8	10.7	8.2	8.5	10.4