CrossRef DOI of original article:

Analytical Study & Design of Flexible Pavement

Mousa Ayesh Hussein Al-Asakereh

Received: 1 January 1970 Accepted: 1 January 1970 Published: 1 January 1970

Abstract

Flexible pavement usually constructed of bituminous materials such that they remain in contact with the underlying material even when minor Distortions occur. Flexible pavement usually consists of a bituminous surface underlaid with a layer of granular material and a layer of a suitable mixture of coarse and fine materials.Flexible pavement is the pavement that remains adjacent to the surface soil road, even if the surface is rutting.Provides sufficient thickness for load distribution through a multilayer structure so that the stresses and strains in the Subgrade soil layers are within required limits.The strength of subgrade soil would have a direct bearing on the total thickness of the flexible pavement.

Index terms — flexible design, pavement, asphalt design.

1 Surface Course

Constructed immediately above the base course, usually consists a mixture of aggregates and asphalt. It should be capable of withstanding high tire pressures, resisting abrasive forces due to traffic, providing a skidresistant driving surface, and preventing the penetration of surface water into the underlying layers.

2 I. General Principles of Flexible Pavement Design

Assumed initially that the subgrade layer is infinite in both the horizontal and vertical directions, whereas the other layers are finite in the vertical direction and infinite in the horizontal direction.

In the design of flexible pavements, the pavement structure usually is considered as a multilayered elastic system, with the material that may include the modulus of elasticity (E), the resilient modulus (R), and the Poisson ratio ( ).

Applying of a wheel load causes a stress distribution; the maximum vertical stresses are compressive and occur directly under the wheel load. These decrease with an increase in depth from the surface. In the AASHTO design method, the traffic load is determined in Terms of the number of repetitions of an 18,000-lb (80 KN) the Single-axle load applied to the pavement. This is usually referred to as: Ex 1 : Traffic (AADT) in both directions on the Highway during the first year of operation will be 12,000 with the following vehicle mix and axle loads. Single unit trucks

3 II. AASHTO Design Method Considerations

4 2-axle

AADT1 AADT2 AADT3 N1 N2 N3 F Ei1 F Ei2 F Ei3

Ex 2:

The present AADT (in both directions) of 6000 vehicles is expected to grow at 5% per annum. Assume SN =4 and the percent of the traffic on the design lane is 55%, the design life is 20 years.

If the vehicle mix is:

5 ii. Base Course Construction Materials

Materials selected should satisfy the general requirements for base course materials, A structural layer coefficient, a2, for the material used also should be determined.

6 iii. Surface Course Construction Materials

The structural layer coefficient (a1) relates to a dense graded asphalt concrete surface with its resilient modulus at 68°F. The effects of temperature on asphalt pavements include stresses induced by thermal action and the impact of freezing and thawing water in the subgrade.

The effect of temperature, particularly about to the weakening of the underlying material during the thaw period, is considered a significant factor in determining the strength of the underlying materials used in the design. The effect of rainfall is due mainly to the penetration of the surface water into the underlying material, if penetration occurs, the properties of the underlying materials may be altered significantly.

The resilient modulus of materials susceptible to frost action can reduce by 50 percent to 80 percent during the thaw period, and it is likely that the strength of the material will be affected during the periods of heavy rains.

The AASHTO guide suggests a method for determining the effective, resilient modulus. In this method, a relationship is then used to determine the resilient modulus for each season based on the estimated in situ moisture content and Relative damage during the period of time.

The relative damage ?? ð ??"ð ??" for each period is determined from the following chart, using the vertical scale or the equation given in the chart. The mean comparable damage ?? ð ??"ð ??" then computed, and the effective subgrade resilient modulus is determined using the Chart and value of ?? ð ??"ð ??" . The effect of drainage on the performance of flexible pavement is considered to the effect water has on the strength of the base material and roadbed soil, and The approach used is to provide for the rapid drainage of the water from the pavement structure by providing a suitable drainage layer and by modifying the structural layer coefficient.

7 Ex

The modification is carried out by adding a factor ?? ?? for the base and subbase layer coefficients (?? ?? and ?? ??). The ?? ?? factors are based both on the percentage of time during which the pavement structure will be nearly saturated, and on the quality of drainage, which is dependent on the time it takes to drain the base layer to 50 percent of saturation.

8 Ex1:

A flexible pavement takes U one dayU for water to be drained from within it and the pavement structure will be exposed to moisture levels approaching saturation for 7% of the time. Find the pavement drainage coefficient? The cumulative ESAL is an essential input to any pavement design method. However, the determination of this input is usually based on assumed growth rates which may not be accurate.

AASHTO guide proposes the use of a reliability factor that considers the possible uncertainties in traffic prediction and pavement performance prediction. For example, a 50% reliability design level implies 50% chance for successful pavement performance. Table 19.7 shows suggested reliability levels based on the AASHTO guide. [1] [2] [3]

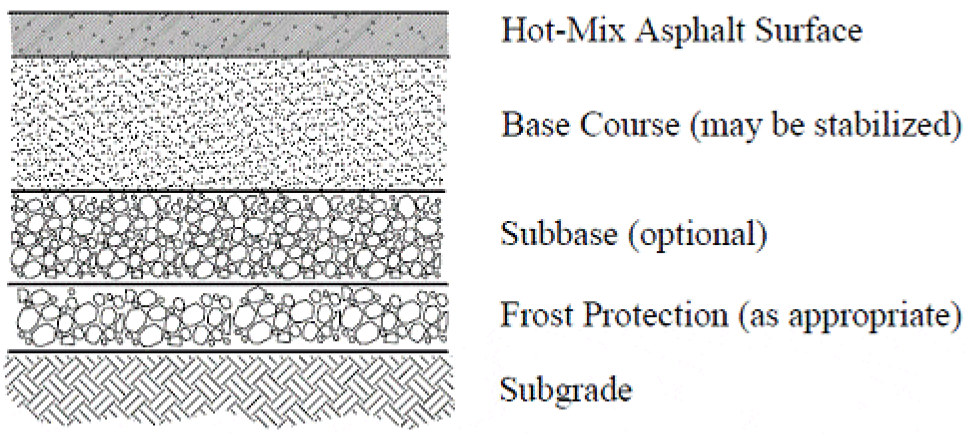


Figure 1:

[1] Analytical Study & Design of Flexible Pavement © 2022 Global Journals

[2] © 2022 Global Journals ( )

[3] © 2022 Global Journals

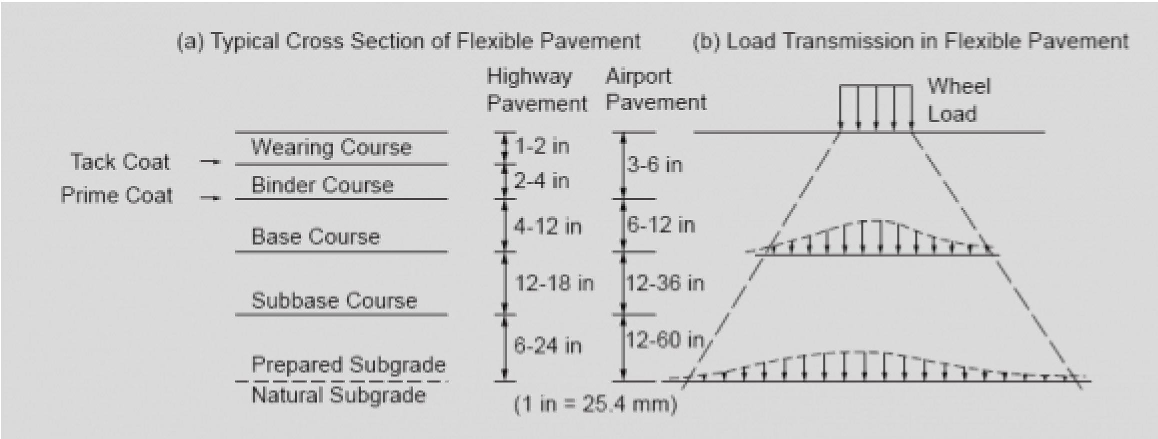


Figure 2:

ν

Figure 3:

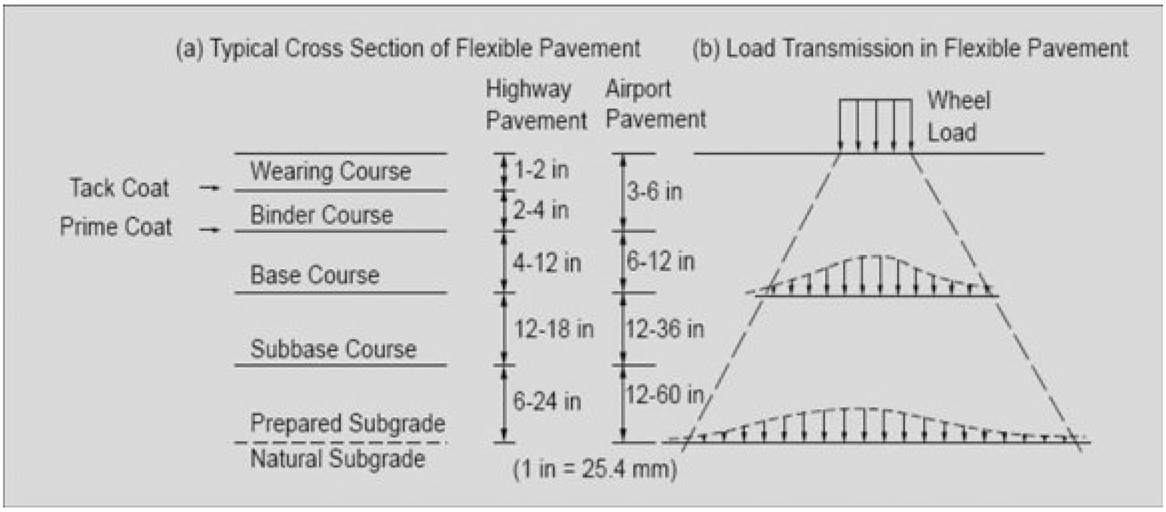
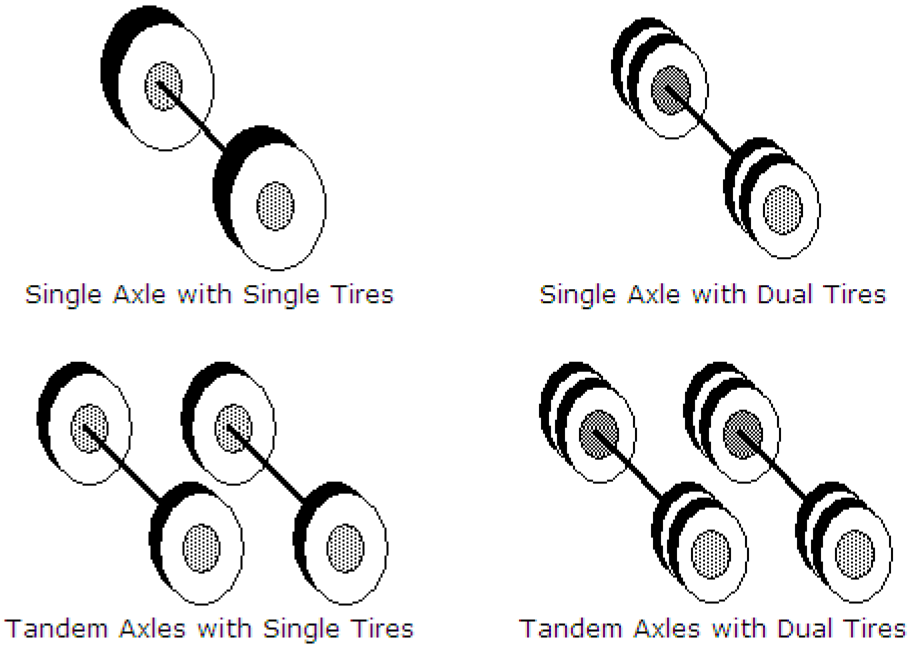


Figure 4: Figure

8 EX1:

Design Period, Years (n)	No Growth	Annual Growth Rate, Percent (r) 2	4	5	6	7	8	
1	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	
3	3.0	3.06	3.12	3.15	3.18	3.21	3.25	
4	4.0	4.12	4.25	4.31	4.37	4.44	4.51	
5	5.0	5.20	5.42	5.53	5.64	5.75	5.87	
6	6.0	6.31	6.63	6.80	6.98	7.15	7.34	
7	7.0	7.43	7.90	8.14	8.39	8.65	8.92	
8	8.0	8.58	9.21	9.55	9.90	10.26	10.64	1
9	9.0	9.75	10.58	11.03	11.49	11.98	12.49	1
10	10.0	10.95	12.01	12.58	13.18	13.82	14.49	1
11	11.0	12.17	13.49	14.21	14.97	15.78	16.65	1
12	12.0	13.41	15.03	15.92	16.87	17.89	18.98	2
13	13.0	14.68	16.63	17.71	18.88	20.14	21.50	2
14	14.0	15.97	18.29	19.16	21.01	22.55	24.21	2
15	15.0	17.29	20.02	21.58	23.28	25.13	27.15	3
16	16.0	18.64	21.82	23.66	25.67	27.89	30.32	3
17	17.0	20.01	23.70	25.84	28.21	30.84	33.75	4
18	18.0	21.41	25.65	28.13	30.91	34.00	37.45	4
19	19.0	22.84	27.67	30.54	33.76	37.38	41.45	5
20	20.0	24.30	29.78	33.06	36.79	41.00	45.76	5
25	25.0	32.03	41.65	47.73	54.86	63.25	73.11	9
30	30.0	40.57	56.08	66.44	79.06	94.46	113.28	16
35	35.0	49.99	73.65	90.32	111.43	138.24	172.32	27

Figure 5: Figure


Single Axle with Single Tires
Single Axle with Dual Tires
Tandem Axles with Single Tires
Tandem Axles with Dual Tires

1

Figure 6: : 1 -

8 EX1:

Axle Load (kips)	Pavement Structural Number (SN)					
	1	*2*	*3*	*4*	*5*	*6*
2	.0004	.0004	.0003	.0002	.0002	.00
4	.003	.004	.004	.003	.002	.00
6	.011	.017	.017	.013	.010	.00
8	.032	.047	.051	.041	.034	.03
10	.078	.102	.118	.102	.088	.08
12	.168	.198	.229	.213	.189	.17
14	.328	.358	.399	.388	.360	.34
16	.591	.613	.646	.645	.623	.60
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	112.0	102.0	79.0	60.0	53.0	55.0

Figure 7: U

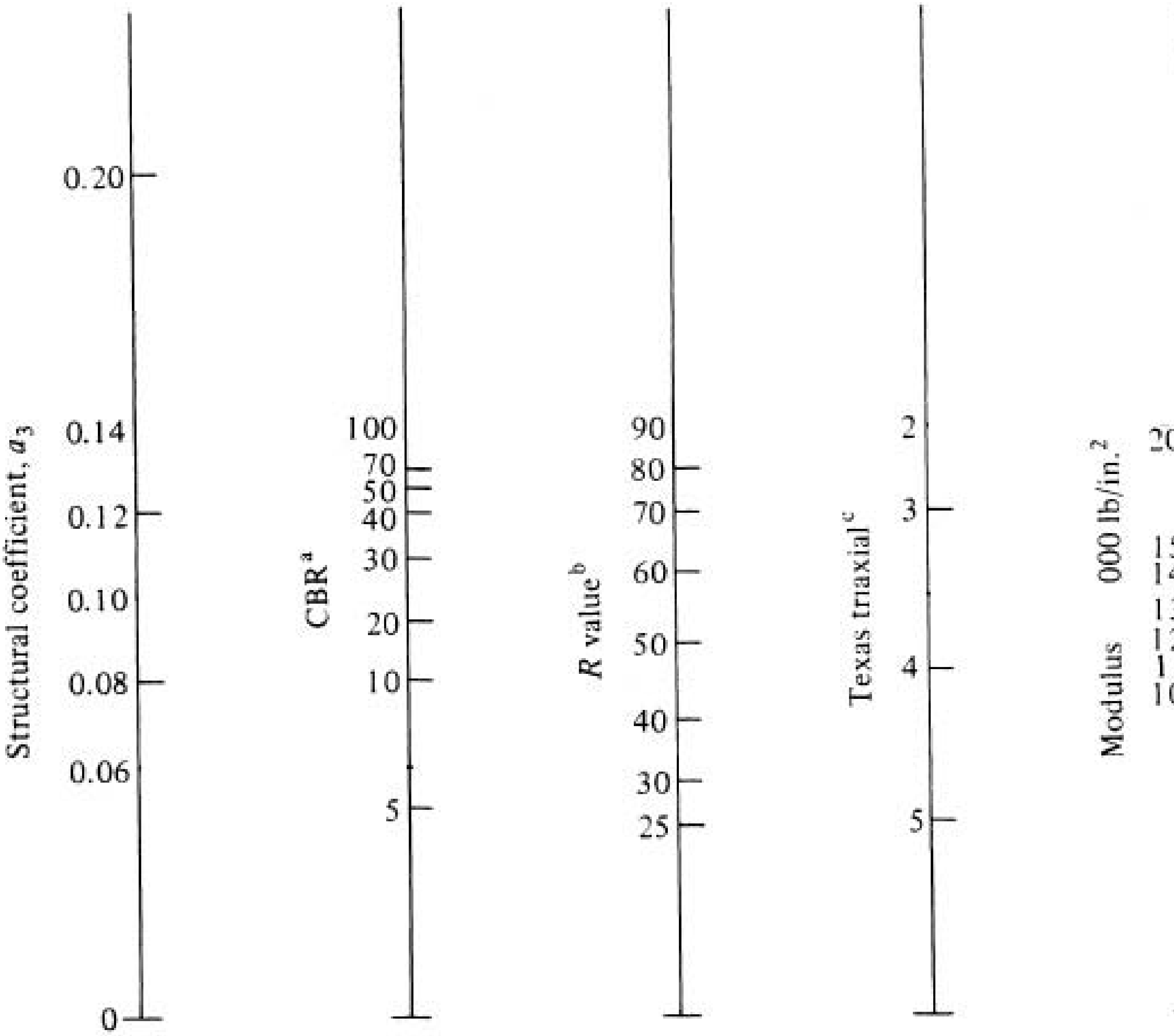

Structural coefficient, a_3
0.20
0.14
0.12
0.10
0.08
0.06
0
CBR[a]
100
70
50
40
30
20
10
5
R value[b]
90
80
70
60
50
40
30
25
Texas triaxial[c]
2
3
4
5
Modulus 000 lb/in.[2]

Figure 8:

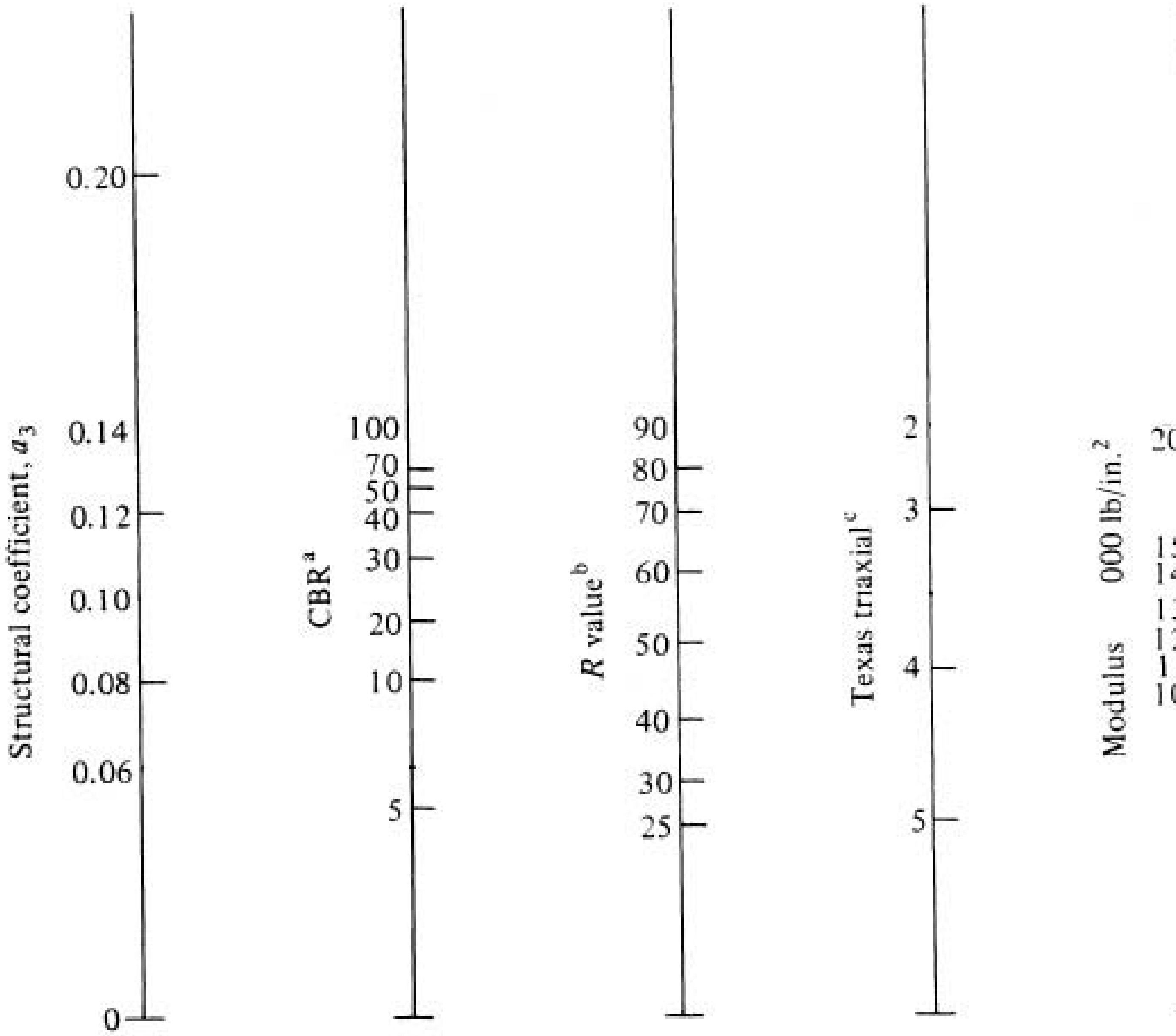

Structural coefficient, a_3
0.20
0.14
0.12
0.10
0.08
0.06
0
CBR[a]
100
70
50
40
30
20
10
5
R value[b]
90
80
70
60
50
40
30
25
Texas triaxial[c]
2
3
4
5
Modulus 000 lb/in.[2]

Figure 9:

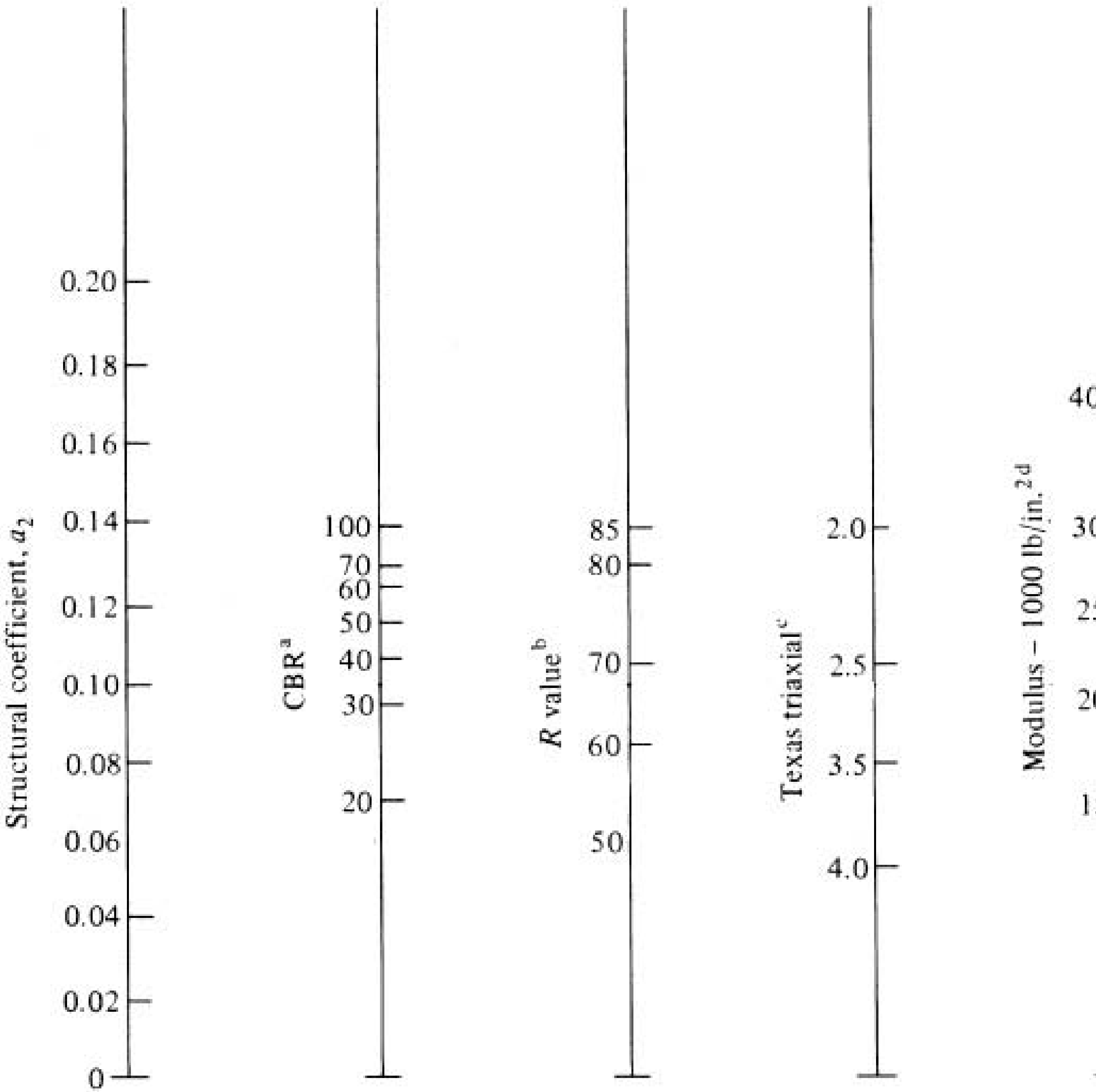

Structural coefficient, a2
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0
CBR a
100
70
60
50
40
30
20
R value b
85
80
70
60
50
Texas triaxial c
2.0
2.5
3.5
4.0
Modulus – 1000 lb/in.2 d

Figure 10:

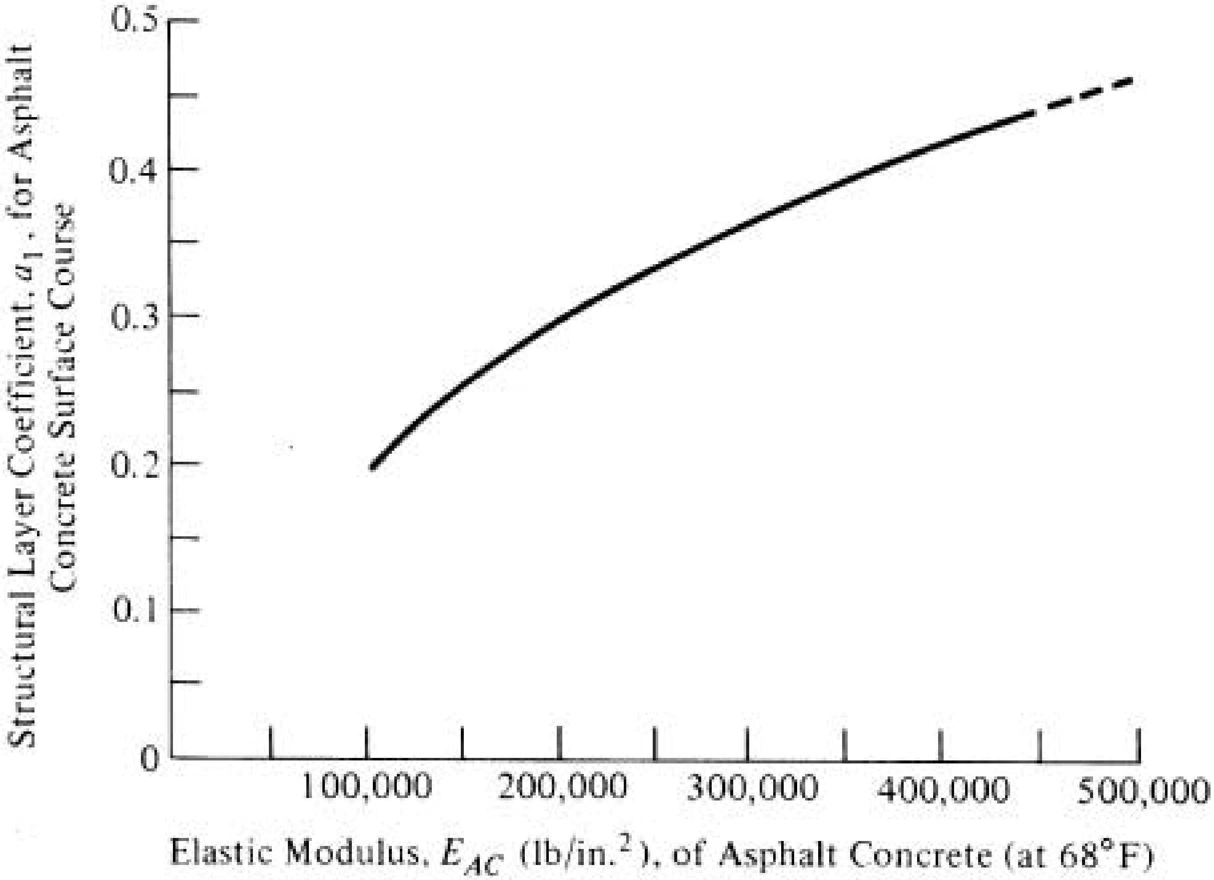
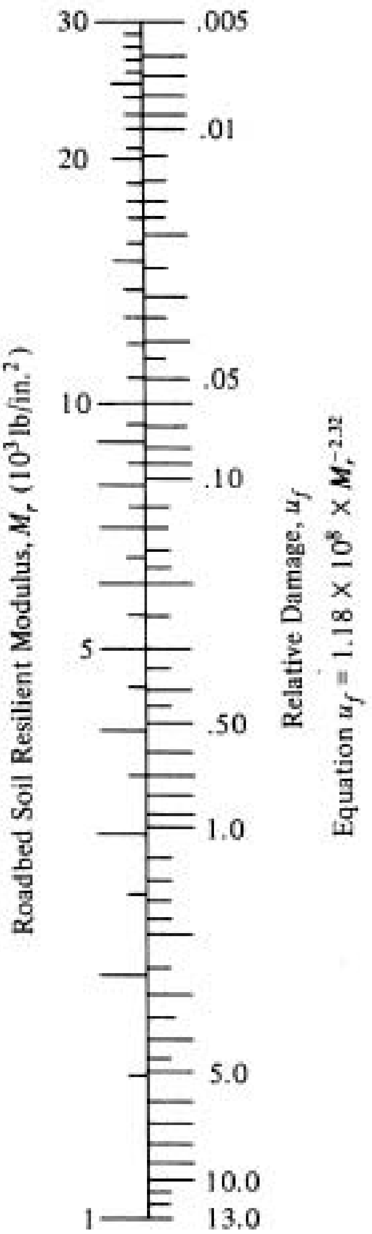

0.5
0.4
0.3
0.2
0.1
0
100,000
200,000
300,000
400,000
500,000
Structural Layer Coefficient, a_1, for Asphalt Concrete Surface Course
Elastic Modulus, E_{AC} (lb/in.^{2}), of Asphalt Concrete (at 68°F)

Figure 11:

Month	Roadbed Soil Modulus M_r (lb/in.^{2})	Relative Damage u_f
Jan.	22000	0.01
Feb.	22000	0.01
Mar.	5500	0.25
Apr.	5000	0.30
May	5000	0.30
June	8000	0.11
July	8000	0.11
Aug.	8000	0.11
Sept.	8500	0.09
Oct.	8500	0.09
Nov.	6000	0.20
Dec.	22000	0.01
Summation: Σu_f =		1.59



$$\text{Average } \bar{u}_f = \frac{\Sigma u_f}{n} = \frac{1.59}{12} = 0.133$$

Effective Roadbed Soil Resilient Modulus, M_r (lb/in.^{2}) = 7250 (corresponds to $\bar{u}_f$)

Figure 12:

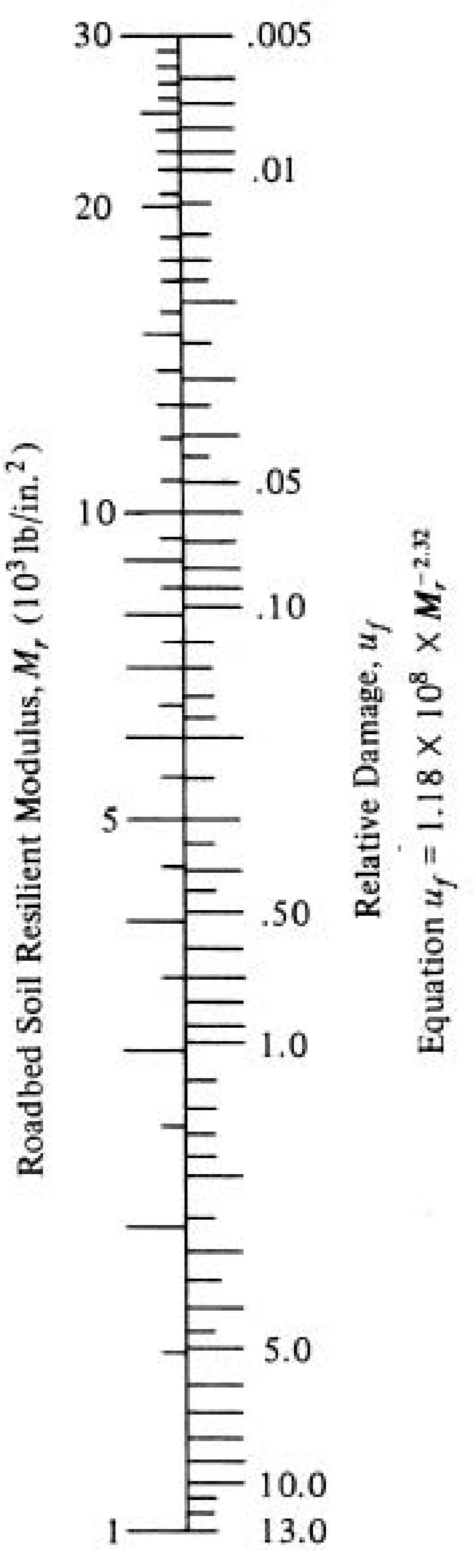

30
20
10
5
1
.005
.01
.05
.10
.50
1.0
5.0
10.0
13.0
Roadbed Soil Resilient Modulus, M_r (10^3 lb/in.^{2})
Relative Damage, u_f
Equation $u_f = 1.18 \times 10^8 \times M_r^{-2.32}$

Figure 13:

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

Figure 14:

Quality of Drainage	*Percent of Time Pavement Structure Is Exposed to Moisture Levels Approaching Saturation*			
	Less Than 1%	*1 to 5%*	*5 to 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

Figure 15:

	Recommended Level of Reliability	
Functional Classification	*Urban*	*Rural*
Interstate and other freeways	85–99.9	80–99.9
Other principal arterials	80–99	75–95
Collectors	80–95	75–95
Local	50–80	50–80

Figure 16:

Analytical Study & Design of Flexible Pavement

Table 19.4: Growth Factors

table 19.3a

FEi Single Axle

when pt = 2.5 ESAL = AADT ×N × ?? ???? × ?? ???? ×

Where:

ESAL = Equivalent Accumulated 18,000-lb (80 KN) single-axle load. AADT = First year annual a

N = Number of axles on each vehicle.

?? ???? = load equivalency factor for Single and Tandem axle. ?? ???? = Growth factor for a give

Year 2022 58 Volume Xx XII Issue II Version I Global Journal of Researches in Engineering ( ) E

EX: If * From Equation

First Year ESAL Design lane Total ESAL First Year Daily ESAL Design Lane Total Daily ESAL ?? ð ??"ð ??"ð ??"ð ??" = (??+ ð ??"ð ??") ð ??"ð ??" ??? ð ??"ð ??" =

AADT × N × ?? ???? × 365 × ð ??"ð ??" ?? AADT × N × ?? ???? × ð ??"ð ??" ?? AADT × N × ?? ???? (??+ ??.????) ?? ??? ??.???? = 11.03 AADT × N × ?? ???? × 365

[Note: -?? ???? From table 19.3a & 19.3b]

Figure 17: the value of design period years n =9, and annual growth rate r = 5%, Find ?? ð ??"ð ??"ð ??"ð ??" ? * From above table ?? ð ??"ð ??"ð ??"ð ??" = 11.03

19

[Note: .3a: Axle Load Equivalency Factors for Flexible Pavements, Single Axles, and p t of 2.5]

Figure 18: Table 19

193b19

Figure 19: Table 19 . 3b Table 19 .

195

Figure 20: Table 19 . 5 :

196

Analytical Study & Design of Flexible Pavement

Figure 21: Table 19 . 6 :

197

1-By Equation

?????? 10 ((???? +1) 5.19 ??????? 2.7) 0.4+ 1094 +2.32?????? 10 (?? ??)-8.07

Where:

[Note: W18 = predicted number of 18,000-lb (80 KN) single-axle load applications ?PSI = ?? ?? -?? ?? SN = structural number indicative of the total pavement thickness ?? ?? = standard normal deviation for a given reliability ?? ?? = overall standard deviation]

Figure 22: Table 19 . 7 :

19

[Note: 8: Standard Normal Deviation (Z R) Values Corresponding to Selected Levels of Reliability Analytical Study & Design of Flexible Pavement © 2022 Global Journals]

Figure 23: Table 19 .

19

[Note: .5: Definition of Drainage QualityTable 19.6: Recommended m i Values Analytical Study & Design of Flexible Pavement]

Figure 24: Table 19

[Highway et al.] , Traffic Highway , N Engineering , Garber . 20 p. 19.

[Principles of Pavement Design Yoder Ej (ch1] *Principles of Pavement Design Yoder Ej (ch1*, 2.