Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2018/2019

COURSE NAME	:	PAVEMENT ENGINEERING
COURSE CODE	:	BFT 40203
PROGRAMME CODE	:	BFF
EXAMINATION DATE	:	DECEMBER 2018/JANUARY 2019
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS

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THIS QUESTION PAPER CONSISTS **SIXTEEN (16)** PAGES

Q1 (a) Pavement performance is an important factor of pavement design because it provides a framework upon which a judgement on the road sucess or failure, which is associated with ability of the pavement to carry out the design loading. Based on that statments, discuss a distinction between two different types of failure.

(4 marks)

(b) The first stage for the road construction is the preparation of the sub-grade layer. It is important to construct a strong sub-grade layer, then the road that to be constructed will expand its lifespan. List and explain the methods that can be conducted to increase the sub-grade strength.

(5 marks)

(c) There are two categories of pavement namely are flexible pavement and rigid pavement. Briefly discuss **THREE (3)** differences among these categories.

(6 marks)

(d) Asphalt concrete pavement is becoming the most popular type of pavement used in highway construction. Discuss the structural components of a flexible pevement.

(10 marks)

Q2 (a) Briefly discuss an environment factor as a one of design considerations procedure to evaluate the pavement performance according to the American Association of State Highway and Transportation Officials (AASHTO) for flexible pavements guide line.

(4 marks)

(b) The Sand cone replacement test method was conducted to determine the density during the construction of the road base layer. The result of the laboratory test showed that a soil has a bulk density of 1939.67 kg/m^3 and a dry density of 1648.82 kg/m^3. According to the Specification of Roadwork by Jabatan Kerja Raya (JKR, 2008), the road base layer must be compacted at least 95% of maximum dry density.

As a project engineer, identify the maximum dry density of this road base layer that complies to the degree of compaction according to Standard Roadworks Specification (JKR, 2008).

(5 marks)

(c) Flexible pavement consist of series of layers with high quality material to distribute the vehicle load over the subgrade. Discuss the factors affected on the strength of soil as road subgrade foundation.

(5 marks)

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(d) The projected vehicle mix for a proposed two-lane major collector rural highway constructed with the road surface, base and subbase layers using the following design parameters:

Equivalent Single Axle Load (ESAL) $= 1 \times 10^5$
Design Serviceability Loss = 3.0
Resilient modulus of asphalt concrete, M_{R1} = 450,000 psi
Resilient modulus of crush stone base = 30,000 psi
Resilient modulus of subgrade = 6,800 psi
Quality of drainage: Surface layer – Good
Base layer – Fair
Subbase layer – Fairly poor
Reliability, R = 99%
Standard deviation, $S_o = 0.35$

By referring to **FIGURE Q2(d)(i)** to **FIGURE Q2(d)(v)**, and **TABLE 2(d)(i)** to **TABLE 2(d)(iii)**, design the thickness of flexible pavement and draw the structure thickness layers, if the levels of pavement approaching to saturation condition is 30%.

(11 marks)

Q3 (a) Discuss the phenomenon of pumping and its effects on rigid pavements.

(4 marks)

(b) Describe the types of stresses that are developed in rigid pavements.

(6 marks)

(c) A 6 in. (152 mm) layer of cement-treated granular material is to be used as sub-base for rigid pavement. **TABLE 3(c)(i)** shows the monthly values for the roadbed soil resilient modulus and the sub-base elastic (resilient) modulus. The rock depth is located 5 ft. below the sub-grade surface and the rigid pavement slab thickness is 9 in. (229 mm).

Using the American Association of State Highway and Transportation Officials (AASHTO) method, estimate the effective modulus of sub-grade reaction by referring to **FIGURE Q3(c)(i)** to **FIGURE Q3(c)(iii)** and **TABLE 3(c)(i)** to **TABLE 3(c)(ii)**.

(9 marks)

(d) **FIGURE Q3(d)(i)** shows a rigid pavement slab 25 ft. (7.62 m) long, 12 ft. (3.66 m) wide and 8 in. (203 mm) thick, subjected to a temperature differential of 20°F (11°C). Due to temperature change, the modulus of sub-grade reaction, k = 54.2 MN/m^3 (200 psi) and coefficient of thermal expansion of concrete, $\alpha_t = 5 \times 10^{-6}$ in./in./°F (9×10^6 mm/mm/°C). Analyze the maximum curling stress in the interior of the slab, if the modulus of concrete, $E = 4 \times 10^6$ psi and Poisson ratio is 0.15.

(6 marks)

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Q4 (a) Discuss the purposes and compare the following types of road maintenance:

(i) Preventive maintenance.

(3 marks)

(ii) Corrective maintenance.

(3 marks)

(iii) Emergency maintenance.

(3 marks)

(b) Discuss the techniques or methods of hot recycling asphalt pavement and state the factors to be considered in the selection of the methods.

(5 marks)

(c) Differentiate between corrective and preventive rehabilitation techniques and give **THREE (3)** examples of surface treatments in each category. State the best preventive maintenance technique for subsurface maintenance.

(5 marks)

(d) An asphalt overlay is placed on an existing asphalt pavement that is subjected to an Equivalent Standard Axle Load (ESAL) of 7×10^6. The horizontal tensile strains at the bottom of the asphalt layer are 1×10^{-4} before overlay and 7×10^{-5} after overlay. By using Asphalt Institute fatigue criteria assuming an Elastic Modulus of 5×10^5 psi (3.5 GPa) for the Hot Mix Asphalt (HMA), calculate the allowable number of ESAL on the overlaid asphalt pavement.

(6 marks)

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- END OF QUESTIONS –

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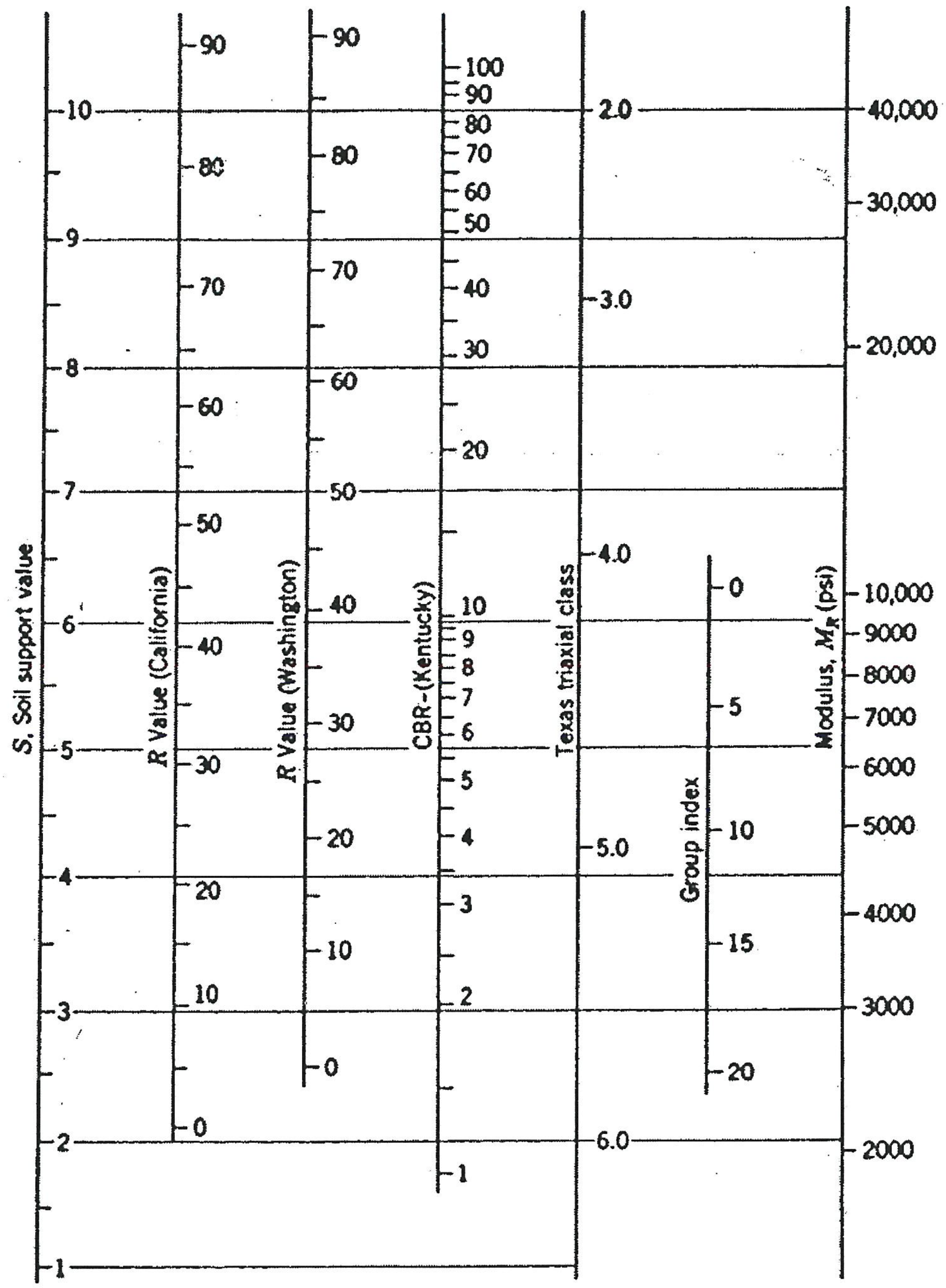

FIGURE Q2(d)(i): Correlation Chart for Estimating Resilient Modulus of Subgrade Soil. Evaluation of AASHTO Interim Guides for Design of Pavement Structures. *Source: After AASTHO (1986)*

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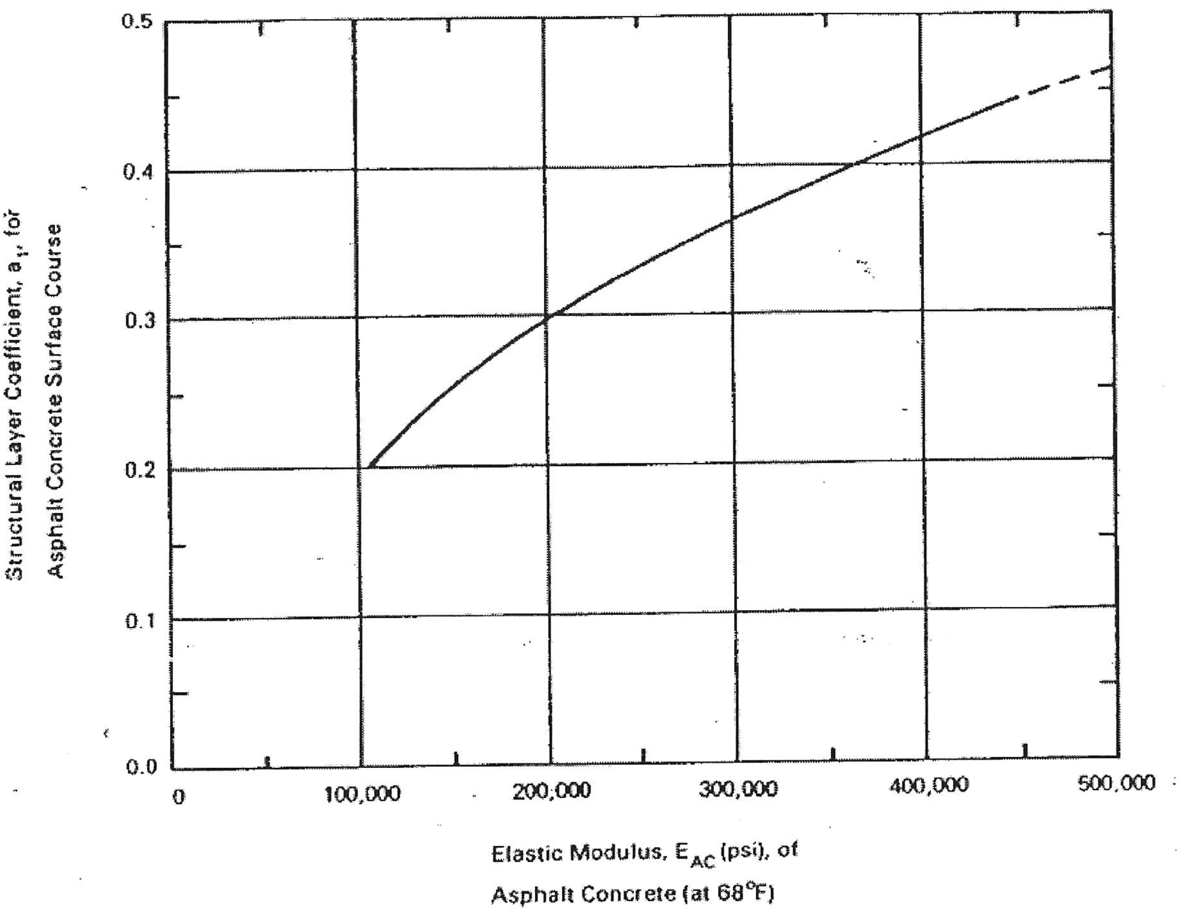

FIGURE Q2(d)(ii): Chart for Estimating Structural Layer Coefficient (a_1) of Dense-Graded Asphalt Concrete Based on the Elastic (Resilient) Modulus. *Source: After AASTHO (1986)*

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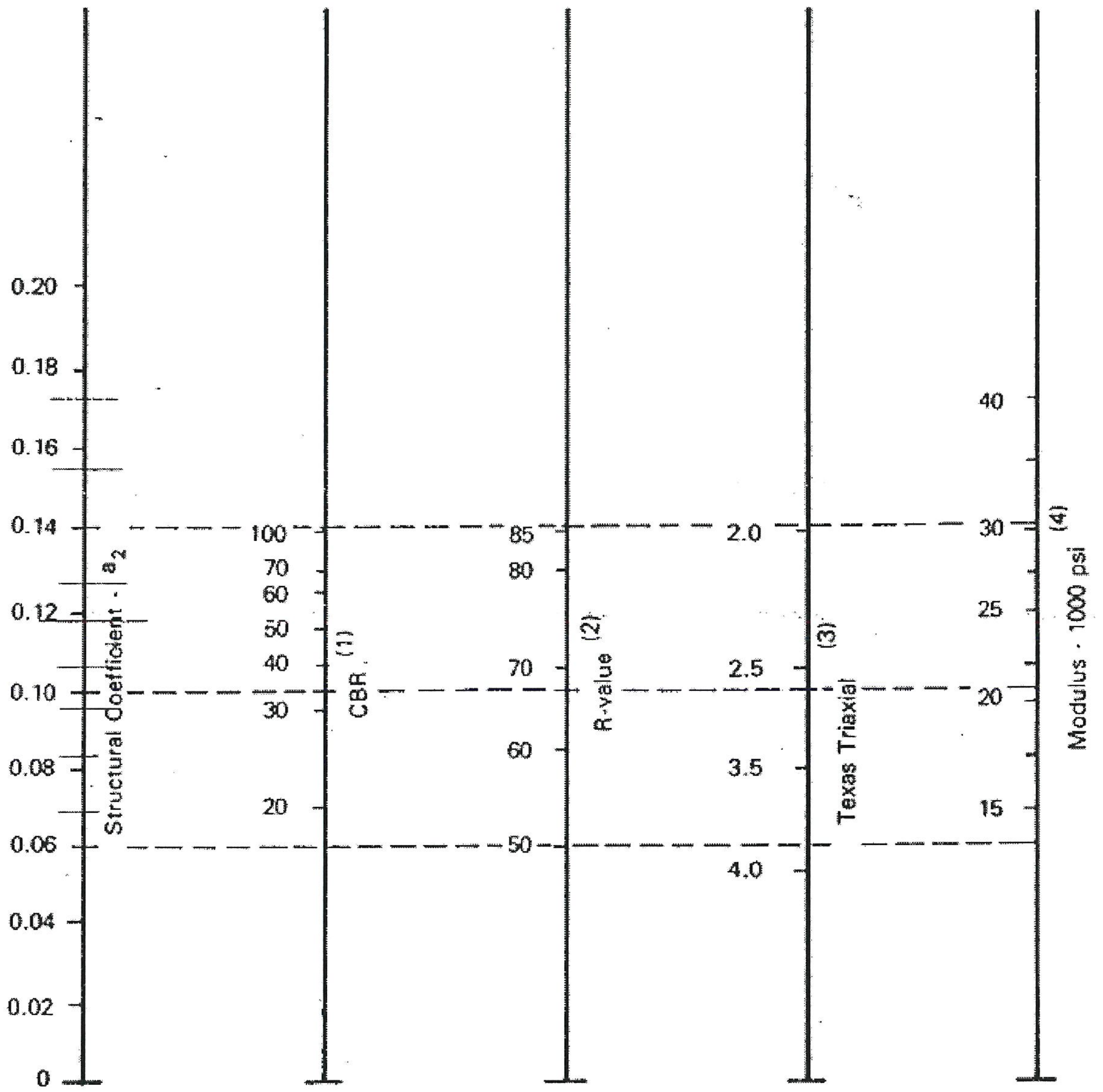

(1) Scale derived by averaging correlations obtained from Illinois.
(2) Scale derived by averaging correlations obtained from California, New Mexico and Wyoming.
(3) Scale derived by averaging correlations obtained from Texas.
(4) Scale derived on NCHRP project *(3)*.

FIGURE Q2(d)(iii): Variation in Granular Base Layer Coefficient (a_2) With Various Base Strength Parameters. *Source: After AASTHO (1986)*

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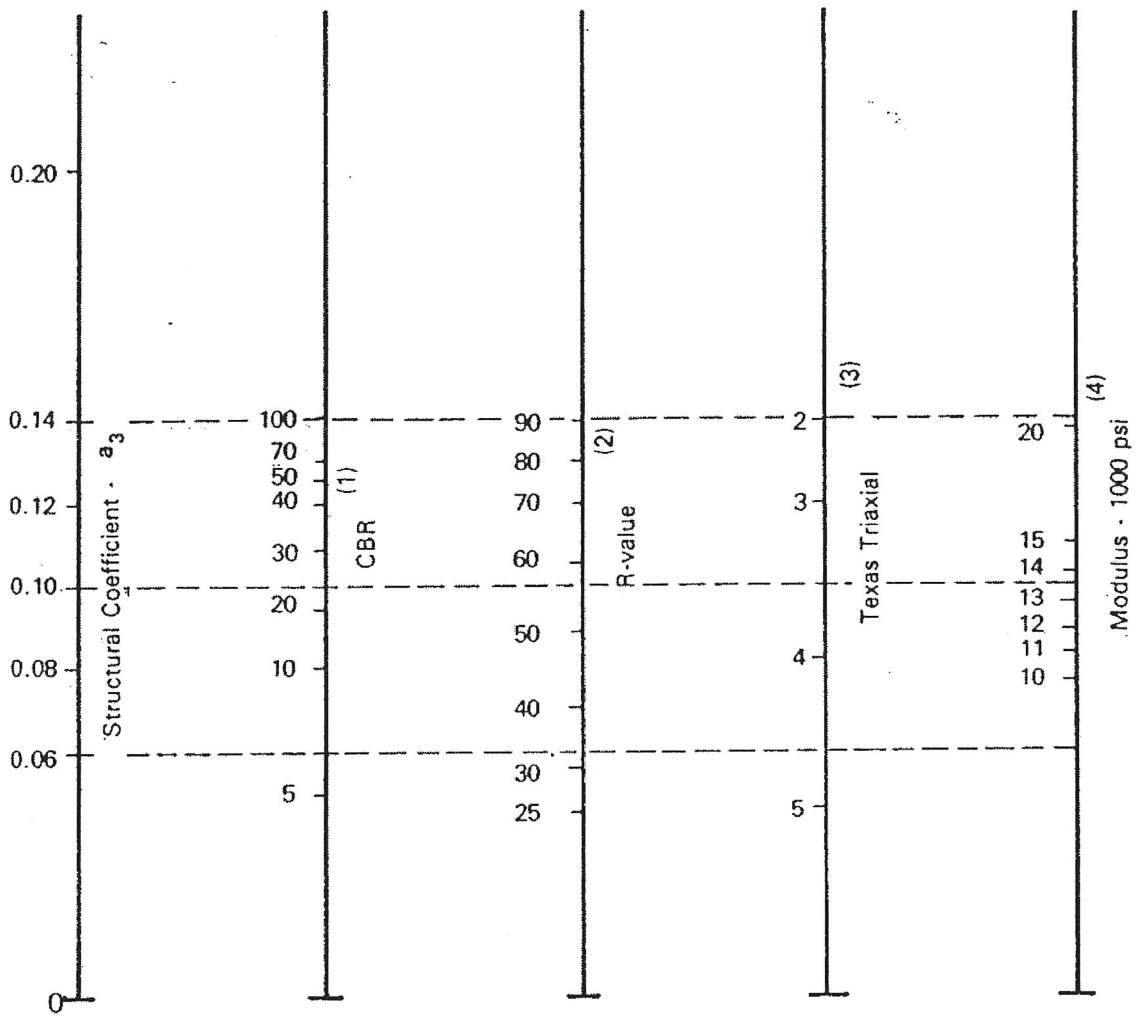

(1) Scale derived from correlations from Illinois.

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

(3) Scale deriv-d from correlations obtained from Texas.

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

FIGURE Q2(d)(iv): Variation in Granular Subbase Layer Coefficient (a_3) With Various Subbase Strength Parameters. *Source: After AASTHO (1986)*

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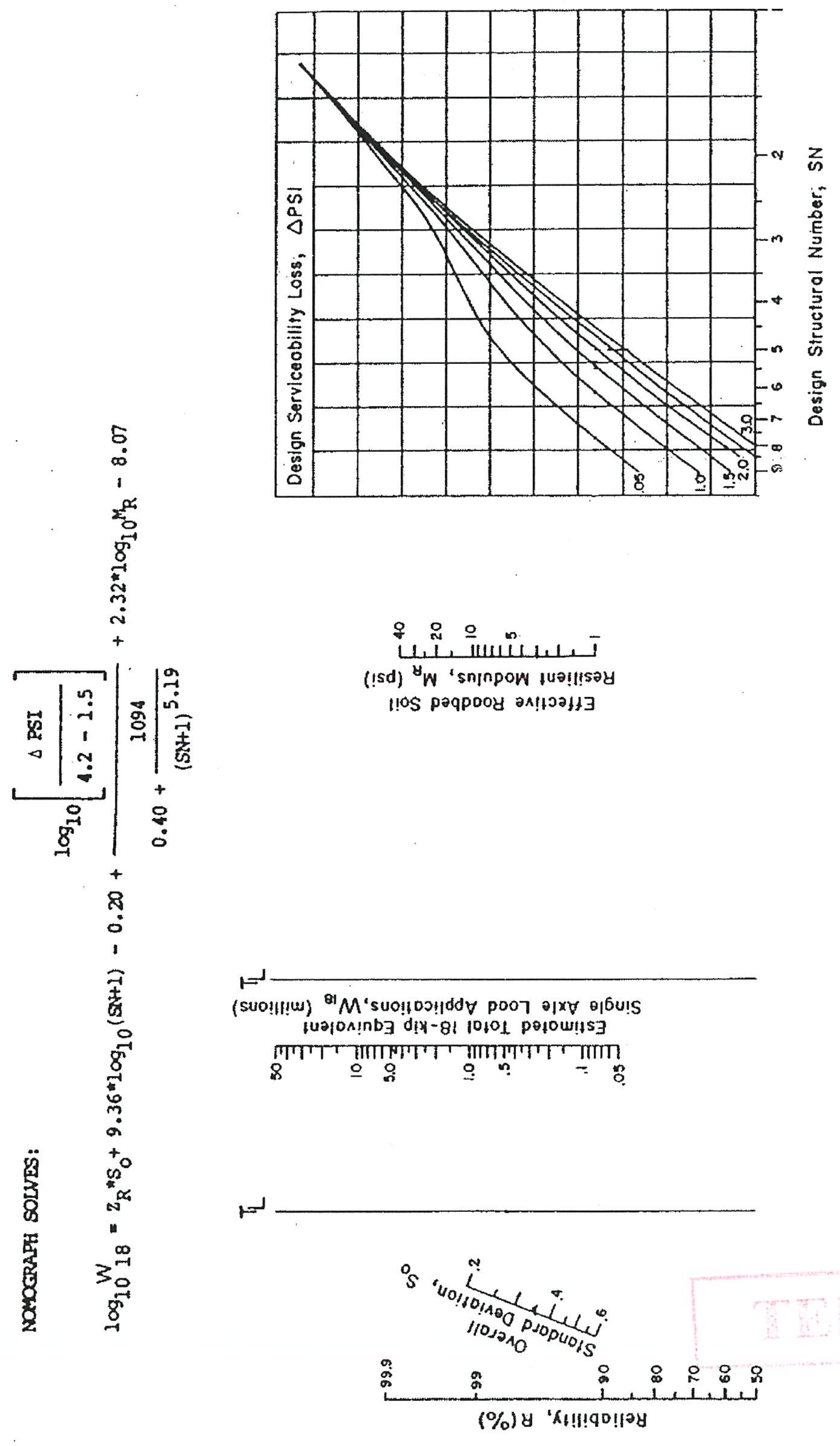

FIGURE Q2(d)(v): Design Chart for Flexible Pavements Based on Using Mean Values for Each Input. *Source: After AASTHO (1986)*

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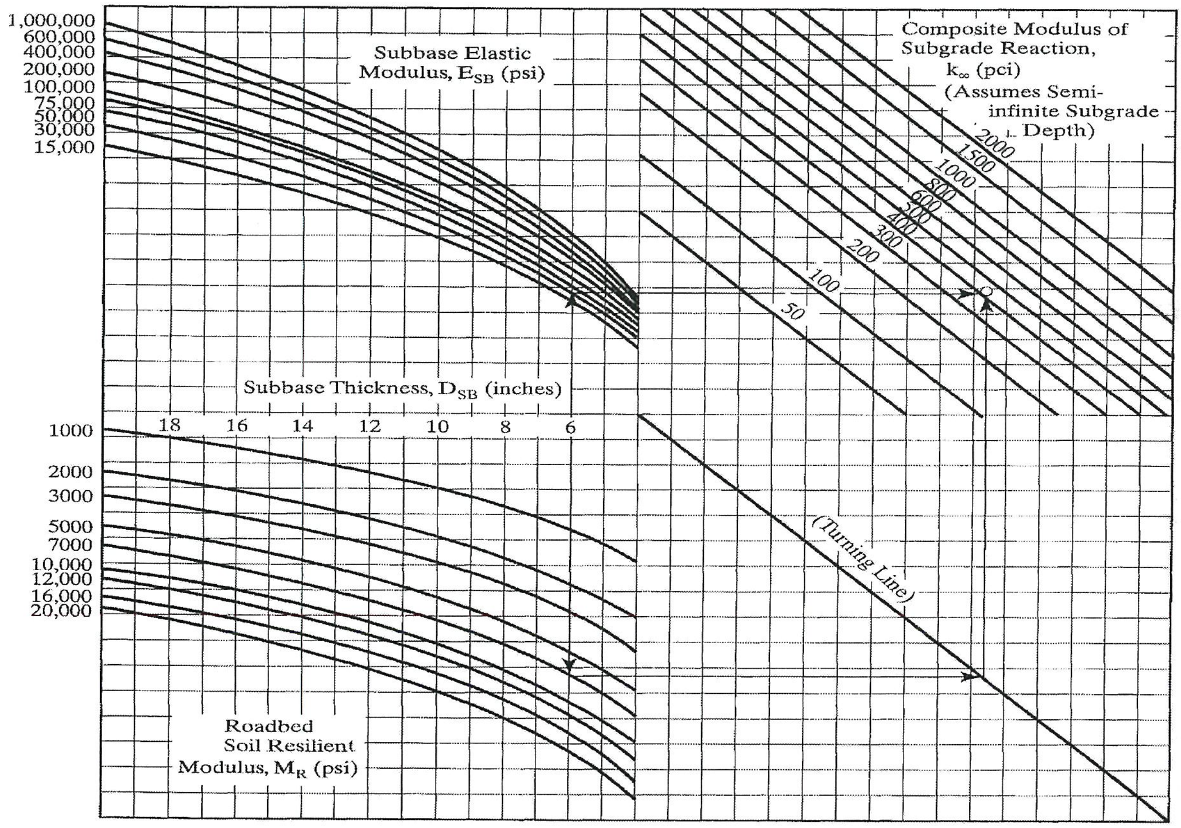

FIGURE Q3(c)(i): Estimating Composite Modulus of Sub-Grade Reaction

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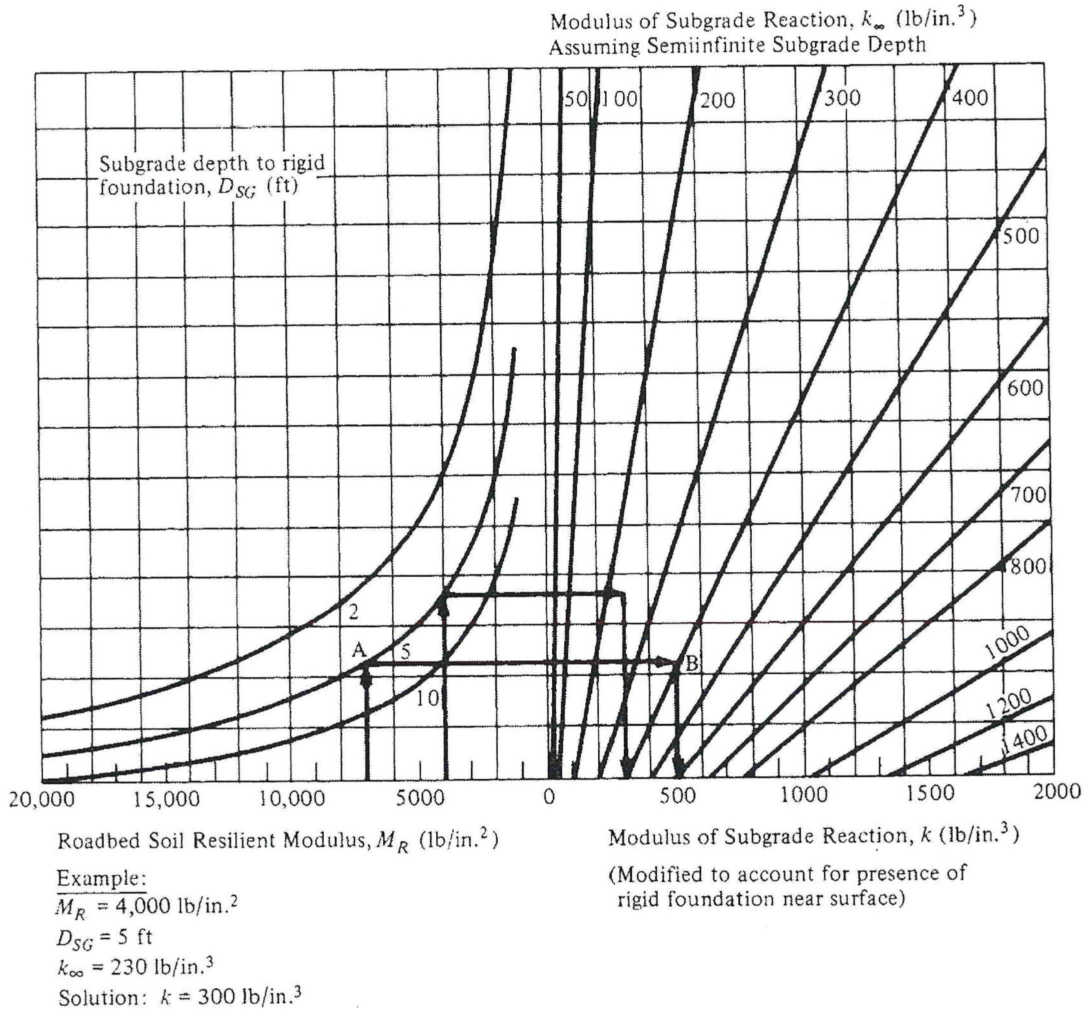

FIGURE Q3(c)(ii): Modifying Modulus of Sub-Grade Reaction

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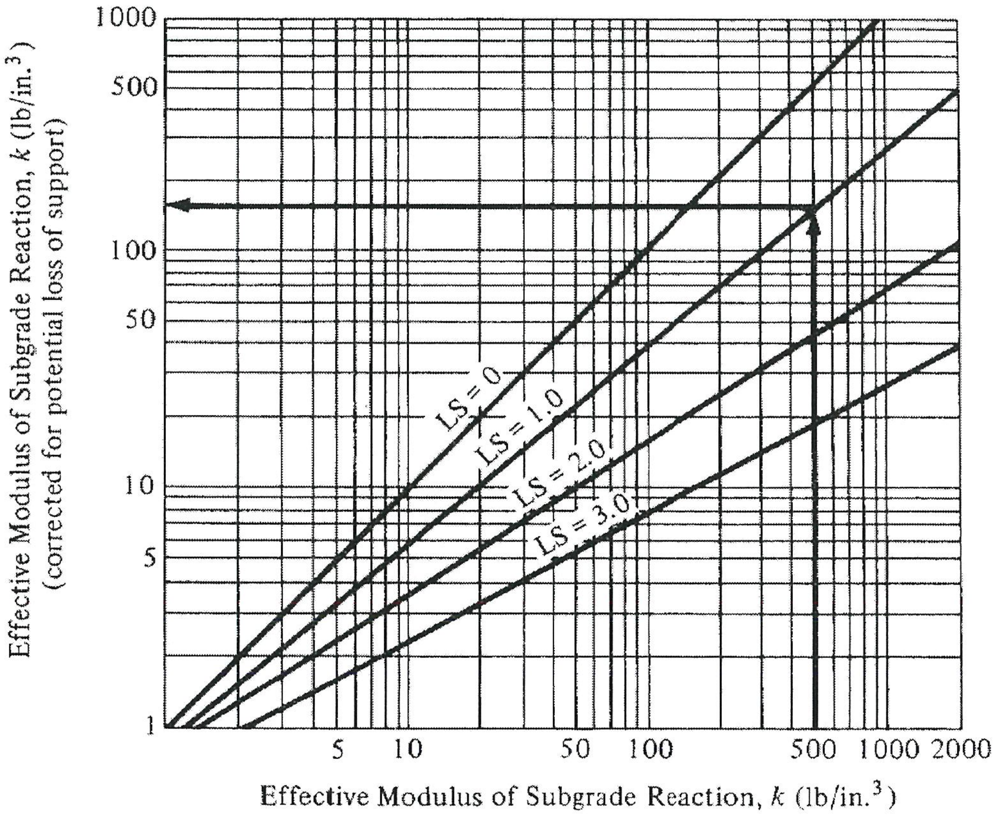

FIGURE Q3(c)(iii): Correction of Effective Modulus of Sub-Grade Reaction

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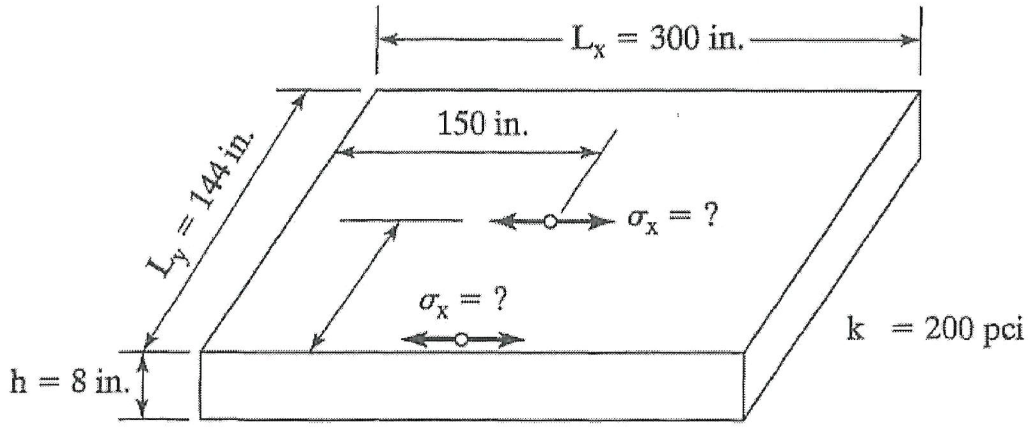

FIGURE Q3(d)(i)): Rigid Pavement Slab

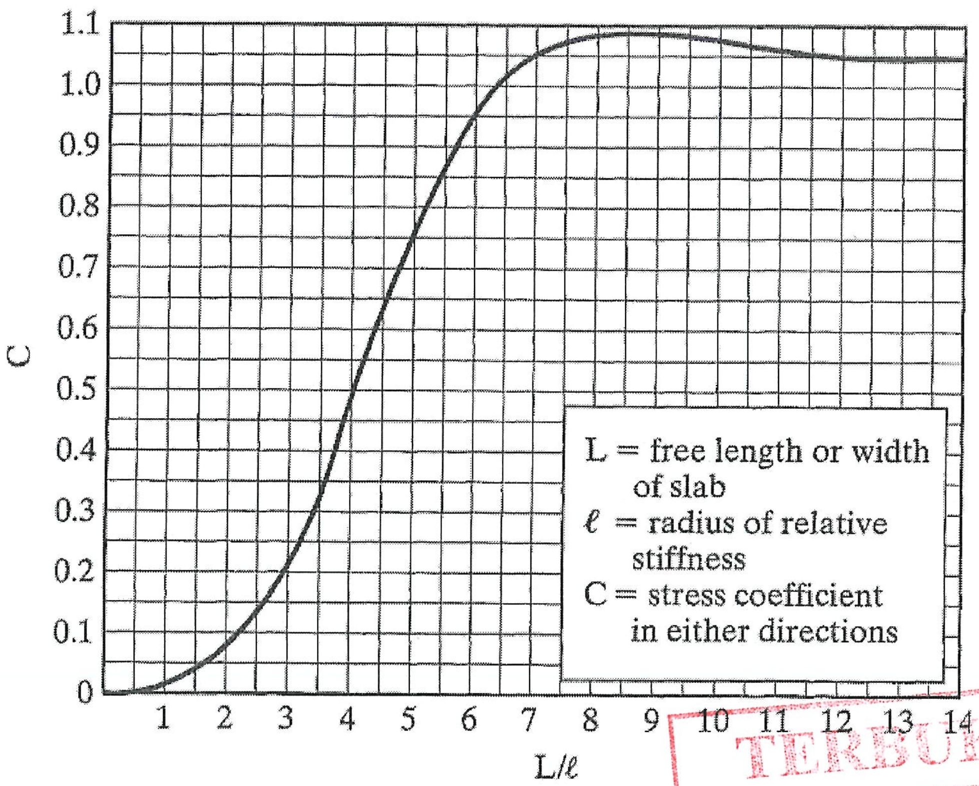

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FIGURE Q3(d)(ii): Stress Correction Factor for Finite Slab (After Bradbury, 1938)

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TABLE 2(d)(i): Suggested Levels of Reliability for Various Functional Classifications

Functional Classification	Recommended level of reliability	
	Urban	Rural
Interstate and other freeway	85 – 99.9	80 – 99.9
Principal arterials	80 – 99	75 – 95
Collectors	80 – 95	75 – 95
Local	50 – 80	50 – 80

Source: After AASTHO (1986)

TABLE 2(d)(ii): Recommended Drainage Coefficient for Untreated Bases and Sub bases in Flexible Pavements

Quality of drainage		Percentage of time pavement structure is exposed to moisture levels approaching saturation			
Rating	Water removed within	Less than 1%	1 – 5%	2 – 25%	Greater than 25%
Excellent	2 hours	1.40 – 1.35	1.35 – 1.30	1.30 -1.20	1.20
Good	1 day	1.35 – 1.25	1.25 – 1.15	1.15 – 1.00	1.00
Fair	1 week	1.25 – 1.15	1.15 – 1.05	1.00 – 0.80	0.80
Poor	1 month	1.15 – 1.05	1.05 – 0.80	0.80 – 0.60	0.60
Very poor	Never drain	1.05 – 0.95	0.95 – 0.75	0.75 – 0.40	0.40

Source: After AASTHO (1986)

TABLE 2(d)(iii): Minimum Thickness for Asphalt Surface and Aggregate Base

Traffic (ESAL)	Asphalt Concrete (in.)	Aggregate Base (in.)
< 50,000	1.0	4
50,000 – 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
> 7,000,000	4.0	6

Source: After AASTHO (1986)

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TABLE 3(c)(i): The Modulus of Rigid Pavement

Month	Roadbed Modulus, M_R (lb/in^2)	Sub-base Modulus, E_{SB} (lb/in^2)	Composite, k value (lb/in.^{2})	k value (E_{SB}) on Rigid Foundation	Relative Damage, u_f
January	20,000	50,000	1100	1350	0.35
February	20,000	50,000	1100	1350	0.35
March	2,500	15,000	160	230	0.86
April	4,000	15,000	230	300	0.78
May	4,000	15,000	230	300	0.78
June	7,000	20,000	400	500	0.60
July	7,000	20,000	400	500	0.60
August	7,000	20,000	400	500	0.60
September	7,000	20,000	400	500	0.60
October	7,000	20,000	400	500	0.60
November	4,000	15,000	230	300	0.78
December	20,000	50,000	1100	1350	0.35

TABLE 3(c)(ii): Ranges of Loss of Support Factors for Various Types of Materials

Type of Material	*Loss of Support (LS)*
Cement-treated granular base (E = 1,000,000 to 2,000,000 lb/in.^{2})	0.0 to 1.0
Cement aggregate mixtures (E = 500,000 to 1,000,000 lb/in.^{2})	0.0 to 1.0
Asphalt-treated base (E = 350,000 to 1,000,000 lb/in.^{2})	0.0 to 1.0
Bituminous stabilized mixtures (E = 40,000 to 300,000 lb/in.^{2})	0.0 to 1.0
Lime-stabilized mixtures (E = 20,000 to 70,000 lb/in.^{2})	1.0 to 3.0
Unbound granular materials (E = 15,000 to 45,000 lb/in.^{2})	1.0 to 3.0
Fine-grained or natural subgrade materials (E = 3,000 to 40,000 lb/in.^{2})	2.0 to 3.0

Note: E in this table refers to the general symbol for elastic or resilient modulus of the material.
SOURCE: Adapted from B.F. McCullough and Gary E. Elkins, *CRC Pavement Design Manual,* Austin Research Engineers, Inc., Austin, Tex., October 1979.

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Formulae:

$$\in_z = \frac{(1+v)p}{E}\left[1-2v+\frac{2vz}{(a^2+z^2)^{0.5}}-\frac{z^3}{(a^2+z^2)^{\frac{3}{2}}}\right]$$

$$\in_r = \frac{(1+v)p}{2E}\left[1-2v-\frac{2(1-v)z}{(a^2+z^2)^{0.5}}+\frac{z^3}{(a^2+z^2)^{\frac{3}{2}}}\right]$$

$$w = \frac{(1+v)pa}{E}\left[\frac{a}{(a^2+z^2)^{0.5}}+\frac{1-2v}{a}\left[(a^2+z^2)^{0.5}-z\right]\right]$$

$$w_0 = \frac{2(1-v^2)pa}{E}$$

$$w_0 = \frac{1.18qa}{E_2}F_2$$

$$SN = a_1D_1 + a_2D_2 + a_3D_3$$

$$SN = a_1D_1 + a_2D_2m_2 + a_3D_3m_3$$

$$D_1 = \frac{SN_1}{a_1m_1},\quad D_2 = \frac{SN_2 - SN_1*}{a_2m_2},\quad D_3 = \frac{SN_3 - SN_2* - SN_1*}{a_3m_3}$$

$$N_f = 0.0796\,(\in_t)^{-3.291}\,(E_1)^{-0.854}$$

$$N_f = 0.0685\,(\in_t)^{-5.671}\,(E_1)^{-2.363}$$

$$\ell = \left[\frac{Eh^3}{12(1-v^2)k}\right]^{0.25}$$

$$\sigma = \frac{CE\alpha_t\Delta_t}{2}$$

$$\sigma_x = \frac{C_xE\alpha_t\Delta_t}{2(1-\upsilon^2)}+\frac{C_y\upsilon E\alpha_t\Delta_t}{2(1-\upsilon^2)}=\frac{E\alpha_t\Delta_t}{2(1-\upsilon^2)}(C_x+\upsilon C_y)$$

$$\frac{n_r}{N_a} = 1 - \frac{n_e}{N_a}$$

$$h_e = \sum_{i=1}^{n} h_iC_iE_i$$

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