Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2015/2016

COURSE NAME	:	PAVEMENT ENGINEERING
COURSE CODE	:	BFT 40203
PROGRAMME	:	BFF
EXAMINATION DATE	:	JUNE/JULY 207
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **FOUR (4)** QUESTIONS ONLY

THIS EXAMINATION PAPER CONSISTS OF **FIFTEEN (15)** PAGES

Q1 (a) Selection of suitable soils is important for the highway foundation. List the **THREE (3)** properties that we can consider as a good sub-grade?

(3 marks)

(b) Describe a consideration in flexible pavement design procedure where the designed was primarily based on empirical or experience.

(6 marks)

(c) Flexible pavement is constructed of bitumen's and granular materials based on mechanistic-empirical method. Based on that statement, discuss the method of design and sketch the loading distribution which relate to the pavement performance.

(6 marks)

(d) An interstate highway construction planned for a full-depth asphalt pavement is carrying 30 kN resting on a semi-infinite elastic space with the Poisson ratio, μ = 0.5 and the Elastic modulus, E = 1400 MPa. If the location of interest is at depth of 0.1 m and radial offset of 0.0 m.

(i) Compute an inflated vehicle tire on a semi-infinite elastic space.
(ii) Compute the vertical normal stress for road pavement
(iii) If the Elastic modulus, E decreases to 100 MPa due to heavy rain, compute the vertical deflection under the same tire and comment the effects of Elastic modulus, E on the surface vertical deflection.

(10 marks)

Q2 (a) How does the Equivalent Single Axle Load (ESAL) differ from a truck factor?

(5 marks)

(b) The traffic on the design lane of a proposed four-lane rural interstate highway consists of 40 percent trucks. If classification studies has shown that the truck factor can be taken as 0.45, design a suitable flexible pavement if the Average Annual Daily Traffic (AADT) on the design lane during the first year of operation is 1000, initial serviceability (Po) = 4.4, and terminal serviceability (Pt) = 2.5.

Growth rate	=	4 percent
Design life	=	20 years
Reliability level	=	95 percent

The pavement structure will be exposed to moisture levels approaching saturation 20 percent of the time, and will take about one week for drainage of water. California Bearing Ratio (CBR) of the subgrade material is 7. CBR of the base and subbase are 70 and 22 respectively, and Resilient Modulus (M_r) for asphalt concrete is 450,000 lb/in^2 (3,102 MN/m^2).

You may refer to **<u>FIGURE Q2(a)</u>** to **<u>FIGURE Q2(c)</u>**, **Table 2(a)** to **Table 2(c)** and the relevant equations given in Appendix, when answering this question.

(20 marks)

Q3 (a) Define the phenomenon of pumping and its effects on rigid pavements.
(5 marks)

(b) A 6 in. (152 mm) layer of cement-treated granular material is to be used as sub-base for rigid pavement. **Table 3(a)** 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.

You may refer to **FIGURE Q3(a)** to **FIGURE Q3(c)** and **Table 3(a)** to **Table 3(b)** in Appendix when answering this question:
(20 marks)

Q4 (a) Describe **TWO (2)** types of highway rigid pavements that are constructed with steel reinforcement. Give the conditions under which each type will be constructed.
(6 marks)

(b) List and describe the types of stresses that are developed in rigid pavements.
(6 marks)

(c) **FIGURE Q4(a)** 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). If the modulus of sub-grade reaction, k = 200 *pci* (54.2 MN/m^3) and coefficient of thermal expansion of concrete, $\alpha_t = 5 \times 10^{-6}$ in./in./°F (9×10^{-6} mm/mm/°C), determine the maximum curling stress in the interior and the edge of the slab.
(13 marks)

Q5 (a) Pavement distresses are usually caused by three factors such as traffic loading, temperature, and moisture. Discuss and give your justification for each factor.
(5 marks)

(b) Describe **FOUR (4)** characteristics of pavement condition used to evaluate whether a pavement should be rehabilitated. If that so, determine the appropriate treatment.
(8 marks)

(c) A full depth asphalt pavement consists of 51 mm Hot Mix Asphalt (HMA) and 152 mm of emulsified asphalt base course with the equivalent factor = 0.83 is to be overlaid. Even though there are cracks on the surface, the crackings are not open, and the pavement appears to be stable. If the pavement has a Pavement Serviceability Index (PSI) of 2.0 and the conversion factor is 0.7, determine the effective thickness.
(4 marks)

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

(8 marks)

- END OF QUESTION –

FINAL EXAMINATION

SEMESTER/SESSION	:	II / 2015/16	PROGRAMME	:	BFT
COURSE NAME	:	PAVEMENT ENGINEERING	COURSE CODE	:	BFT 40203

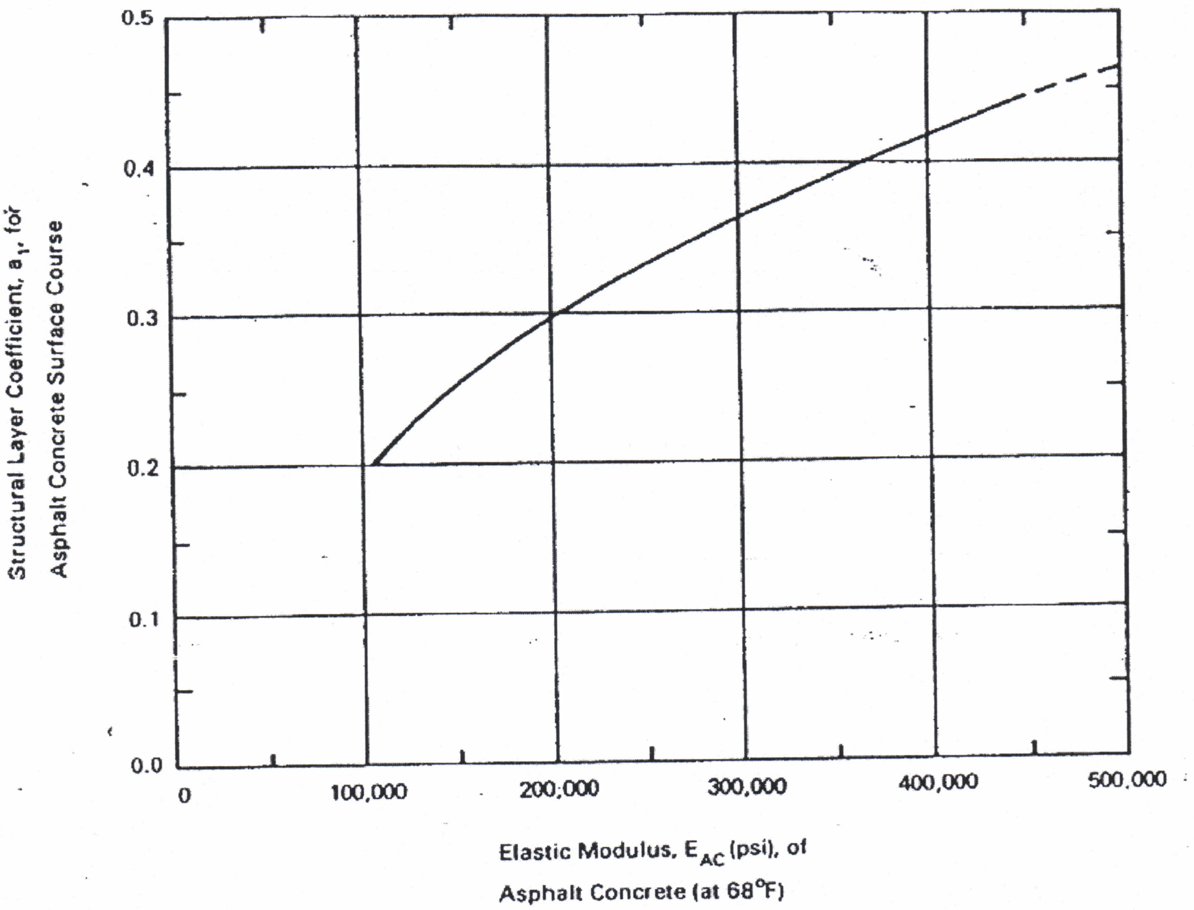
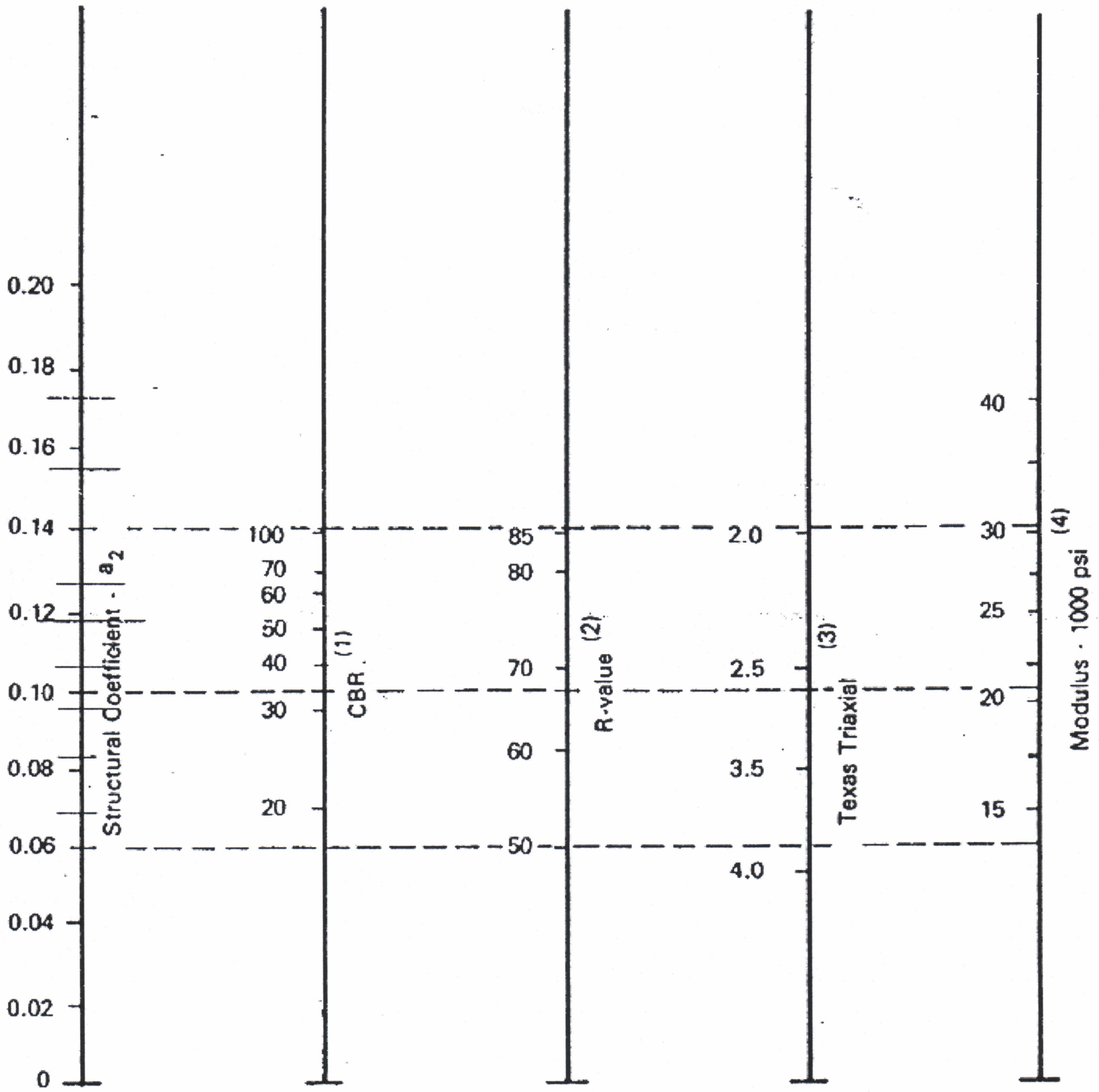


FIGURE Q2(a): Chart for Estimating Structural Layer Coefficient of Dense-Graded Asphalt Concrete Based On The Elastic (Resilient) Modulus. *Source: After AASTHO (1986)*

FINAL EXAMINATION

SEMESTER/SESSION	:	II / 2015/16	PROGRAMME	:	BFT
COURSE NAME	:	PAVEMENT ENGINEERING	COURSE CODE	:	BFT 40203



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

FINAL EXAMINATION

SEMESTER/SESSION	:	II / 2015/16	PROGRAMME	:	BFT
COURSE NAME	:	PAVEMENT ENGINEERING	COURSE CODE	:	BFT 40203

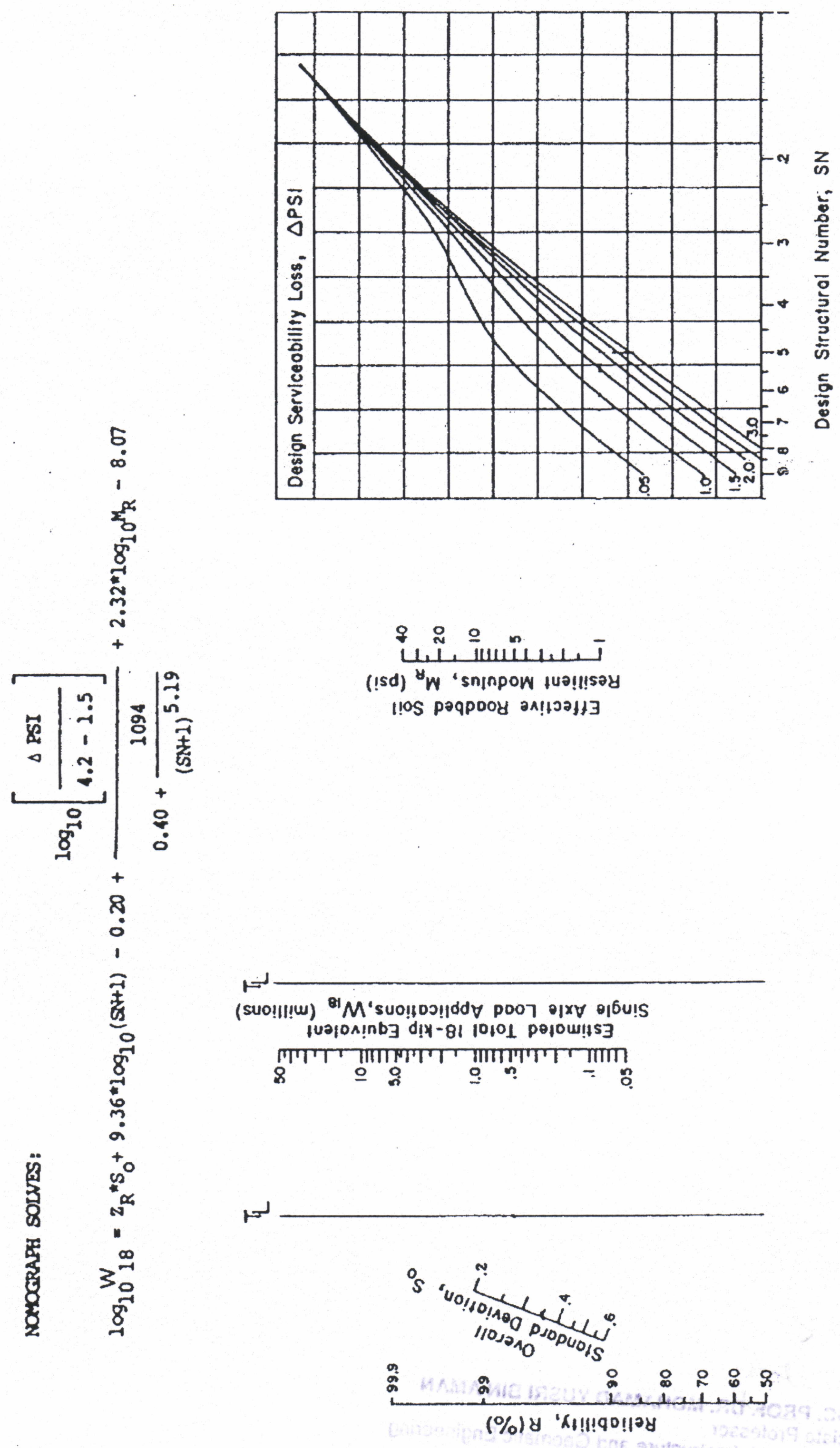


FIGURE Q2(c): Design Chart for Flexible Pavements Based on Using Mean Values for Each Input. *Source: After AASTHO (1986)*

FINAL EXAMINATION

SEMESTER/SESSION	:	II / 2015/16	PROGRAMME	:	BFT
COURSE NAME	:	PAVEMENT ENGINEERING	COURSE CODE	:	BFT 40203

Table 2(a): 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(b): 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(c): 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)

FINAL EXAMINATION

SEMESTER/SESSION : II / 2015/16 PROGRAMME : BFT
COURSE NAME : PAVEMENT ENGINEERING COURSE CODE : BFT 40203

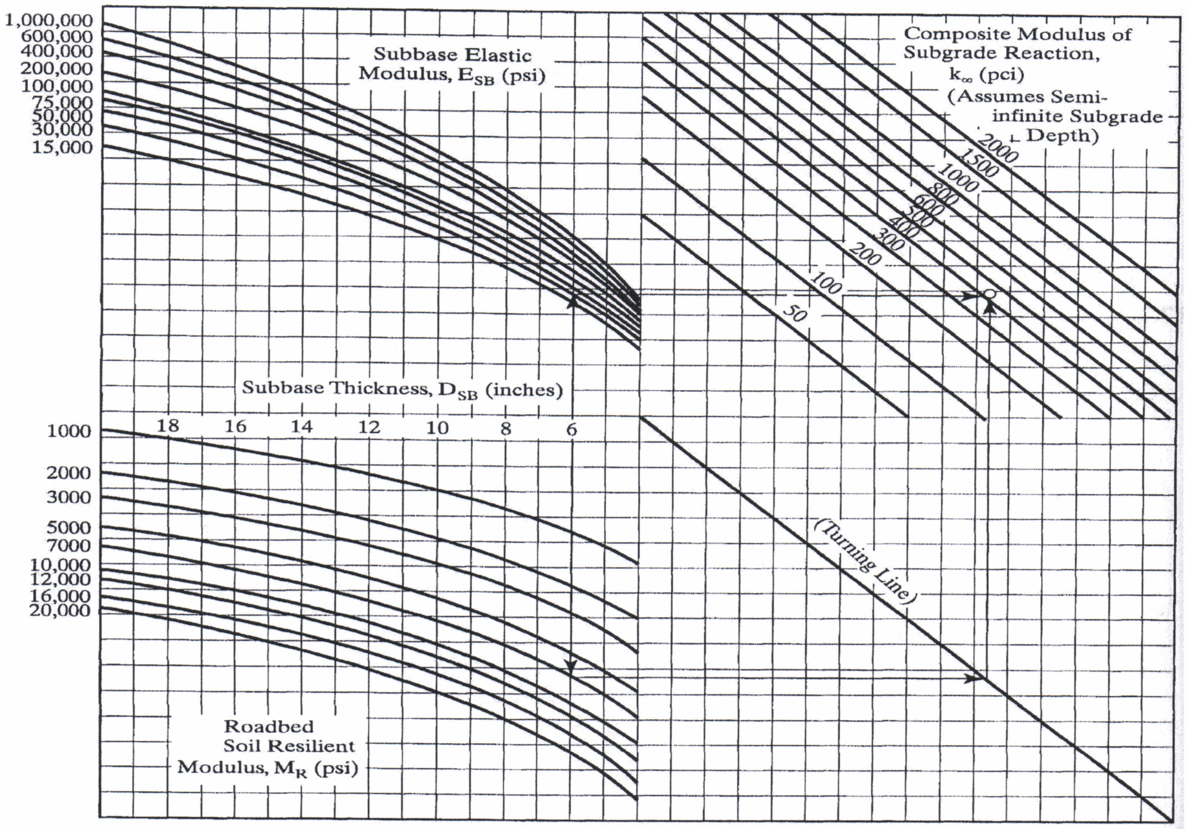


FIGURE Q3(a): Estimating Composite Modulus of Sub-grade Reaction

FINAL EXAMINATION

SEMESTER/SESSION	:	II / 2015/16	PROGRAMME	:	BFT
COURSE NAME	:	PAVEMENT ENGINEERING	COURSE CODE	:	BFT 40203

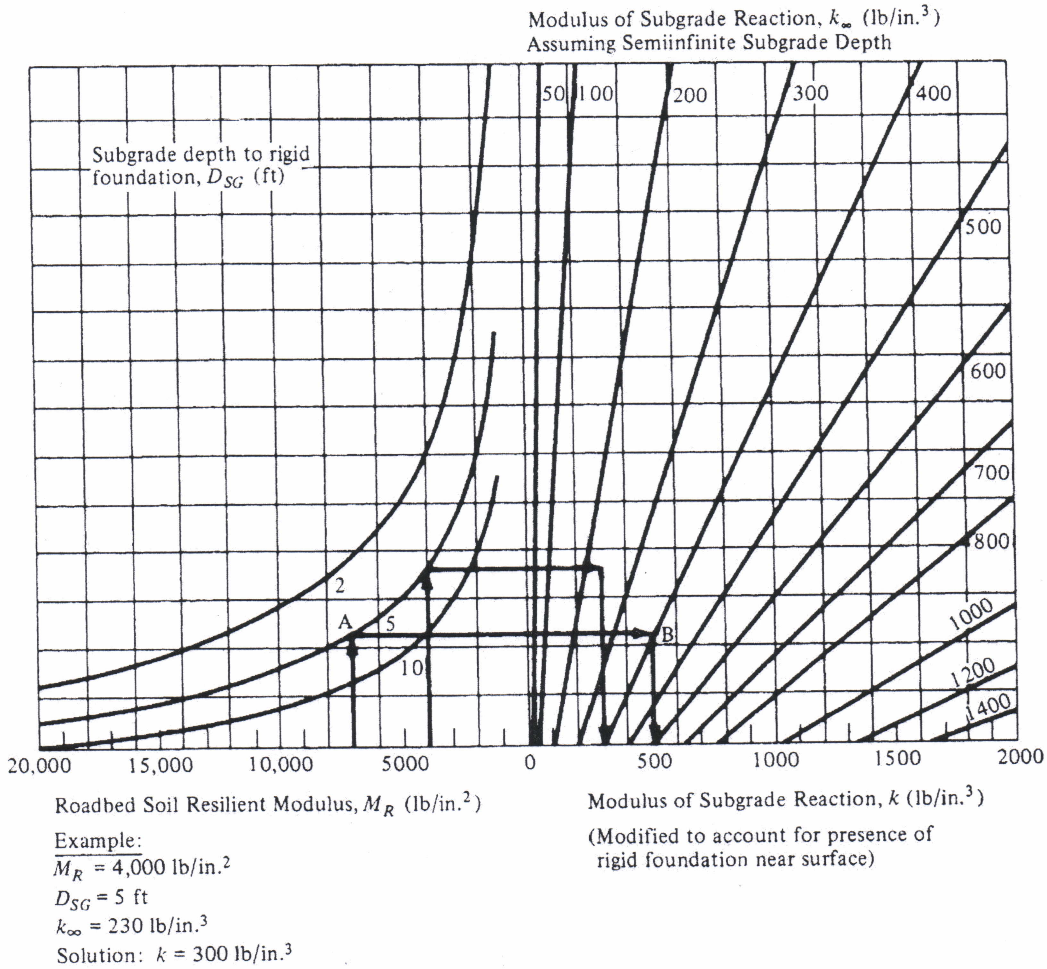


FIGURE Q3(b): Modifying Modulus of Sub-grade Reaction

FINAL EXAMINATION

SEMESTER/SESSION	:	II / 2015/16	PROGRAMME	:	BFT
COURSE NAME	:	PAVEMENT ENGINEERING	COURSE CODE	:	BFT 40203

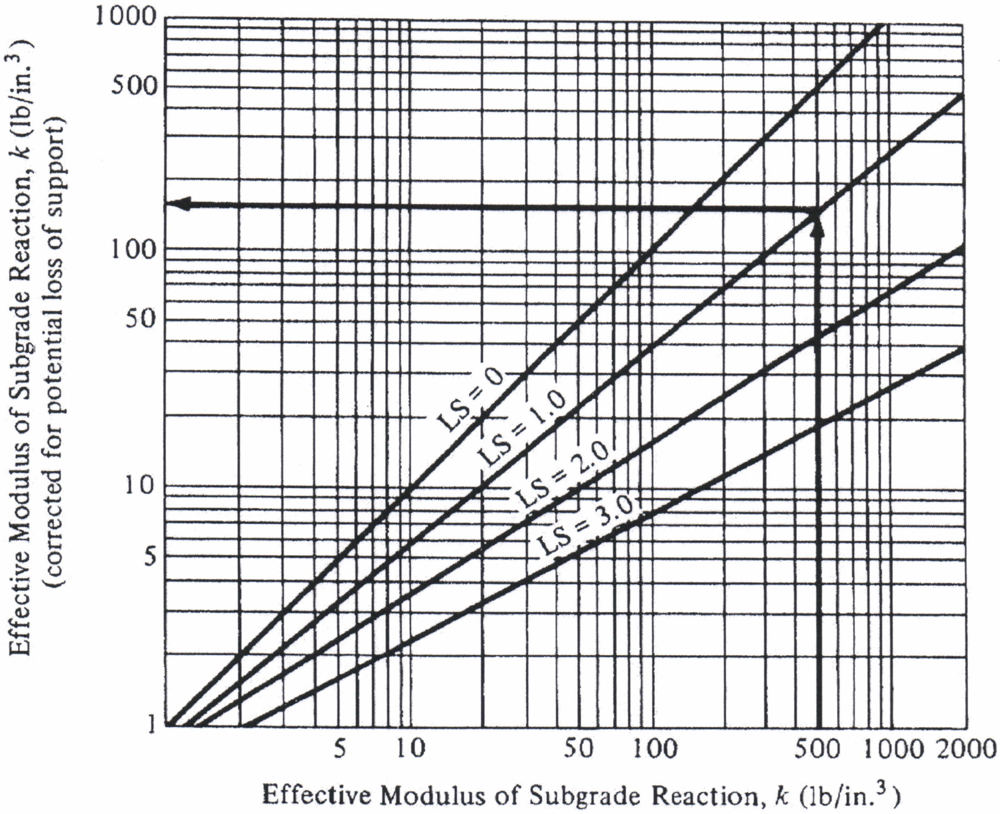


FIGURE Q3(c): Correction of Effective Modulus of Sub-grade Reaction

FINAL EXAMINATION

SEMESTER/SESSION : II / 2015/16
COURSE NAME : PAVEMENT ENGINEERING
PROGRAMME : BFT
COURSE CODE : BFT 40203

Table 3(a): The Modulus of Rigid Pavement

Month	Roadbed Modulus, M_R (Ib/in^2)	Sub-base Modulus, E_{SB} (Ib/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(b): 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.

FINAL EXAMINATION

SEMESTER/SESSION	:	II / 2015/16	PROGRAMME	:	BFT
COURSE NAME	:	PAVEMENT ENGINEERING	COURSE CODE	:	BFT 40203

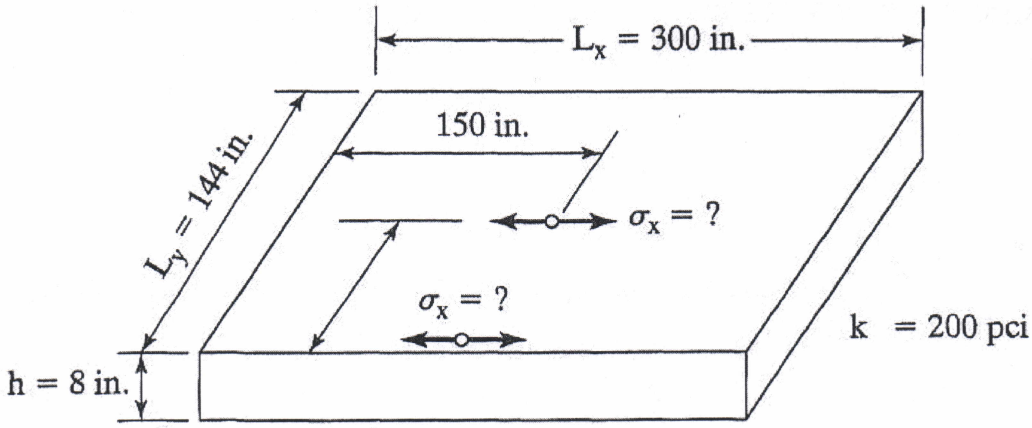


FIGURE Q4(a): Rigid Pavement Slab

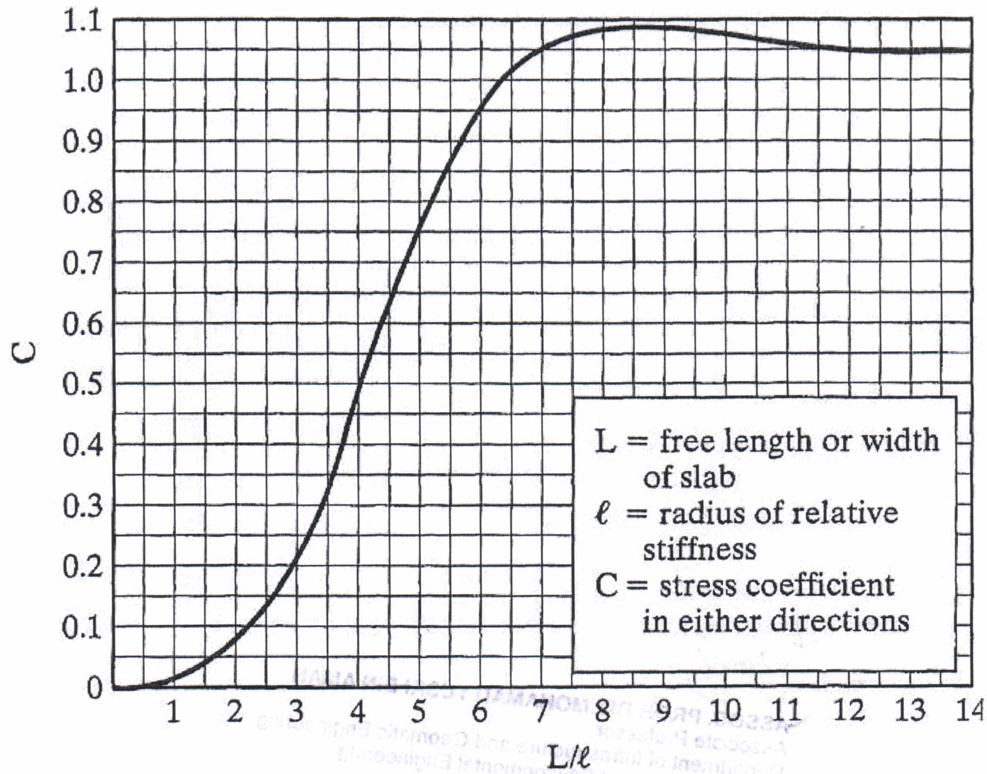


FIGURE Q4(b) : Stress Correction Factor for Finite Slab (After Bradbury, 1938)

FINAL EXAMINATION

SEMESTER/SESSION	:	II / 2015/16	PROGRAMME	:	BFT
COURSE NAME	:	PAVEMENT ENGINEERING	COURSE CODE	:	BFT 40203

Formulae:

$$\log\left(\frac{W_{tx}}{W_{t18}}\right) = 4.79\log(18+1) - 4.79\log(L_x + L_2) + 4.33\log L_2 + \frac{G_t}{\beta_x} - \frac{G_t}{\beta_{18}}$$

$$\beta_x = 0.40 + \frac{0.081(L_x + L_2)^{3.23}}{(SN+1)^{5.19} L^{3.23}}$$

$$u_f = 1.18 \times 10^8 M_R^{-2.32}$$

$$G_t = \log\left(\frac{4.2 - p_t}{4.2 - 1.5}\right)$$

$$ESAL = (ADT)_0(T)(T_r)(G)(365)$$

$$M_r = 1500CBR$$

$$SN = a_1D_1 + a_2D_2 + a_3D_3$$

$$SN = a_1D_1 + a_2D_2m_2 + a_3D_3m_3$$

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

$$\sigma_x = \frac{E\alpha_t\Delta_t}{2(1-v^2)}(C_x + vC_y)$$

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

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

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

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

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

$$h_e = \sum_{i=1}^{n} h_i C_i E_i$$

FINAL EXAMINATION

SEMESTER/SESSION : II / 2015/16
COURSE NAME : PAVEMENT ENGINEERING
PROGRAMME : BFT
COURSE CODE : BFT 40203

$$a = \sqrt{\frac{P}{i\pi}}$$

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

$$\sigma_r = \sigma_{\theta} = \frac{p}{2}\left[-(1+2\mu) + \frac{2(1+\mu)z}{\sqrt{a^2 + z^2}} - \frac{z^3}{(a^2+z^2)^{3/2}}\right]$$

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

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

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

$$w = \frac{3pa^2}{2E\left(a^2 + z^2\right)^{0.5}}$$

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

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