UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2017/2018

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

THIS QUESTION PAPER CONSISTS OF **ELEVEN (11)** PAGES

Q1 (a) 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, so that the constructed will expand its lifespan. List and explain the methods that can be conducted to increase the sub-grade strength.

(4 marks)

(b) Flexible pavement is constructed of bitumen and granular materials utilizing mechanistic-empirical method. Based on that statement, explain the method of design and sketch the loading distribution related to the pavement performance.

(5 marks)

(c) 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 shows 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.

Determine the Maximum Dry Density of road base layer that complies with the Standard Roadworks Specification (JKR, 2008).

(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, $\mu = 0.5$ 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 tyre on a semi-infinite elastic space.

(2 marks)

(ii) Compute the vertical normal stress for road pavement.

(2 marks)

(iii) If the Elastic modulus, E decreases to 100 MPa due to heavy rain, determine the vertical deflection under the same tyre and comment the effects of Elastic modulus, E on the surface vertical deflection.

(6 marks)

Q2 (a) Flexible pavement consists of series of layers with high quality material to distribute the vehicle load over the subgrade. Discuss the factors that affect the strength of soil as road subgrade foundation.

(5 marks)

(b) The traffic proposed for four-lane rural interstate highway consists of 40 percent trucks. If classification studies have shown that the truck factor can be taken as 0.45, design a suitable thickness for 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, respectively.

The followings are additional information;

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, and Resilient Modulus (M_r) for asphalt concrete is 450,000 lb/in^2, respectively.

You may refer to **FIGURE Q2(b)(i)** to **FIGURE Q2(b)(iv)**, **TABLE 2(b)(i)** to **TABLE 2(b)(iii)** and the following equations in Appendix, when answering this question.

(20 marks)

Q3 (a) Explain the difference between Pavement Serviceability Index (PSI) and Present Serviceability Rating (PSR).

(4 marks)

(b) With the aid of diagrams, describe Pavement Serviceability Index and Road Maintenance.

(5 marks)

(c) Describe **TWO (2)** types of highway rigid pavements which are constructed with steel reinforcement and state the conditions under which each type will be constructed.

(4 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 and the edge of the slab, if the modulus of concrete, $E = 4 \times 10^{6}$ psi and Poisson ratio is 0.15.

(12 marks)

Q4 (a) Pavement distress is usually caused by three factors such as traffic loading, temperature and moisture. Discuss and state your justification for each factor.

(5 marks)

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

(8 marks)

(c) Differentiate between corrective and preventive rehabilitation techniques and list **THREE (3)** examples of surface treatments in each category. Select 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 strain 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.

(7 marks)

- END OF QUESTIONS –

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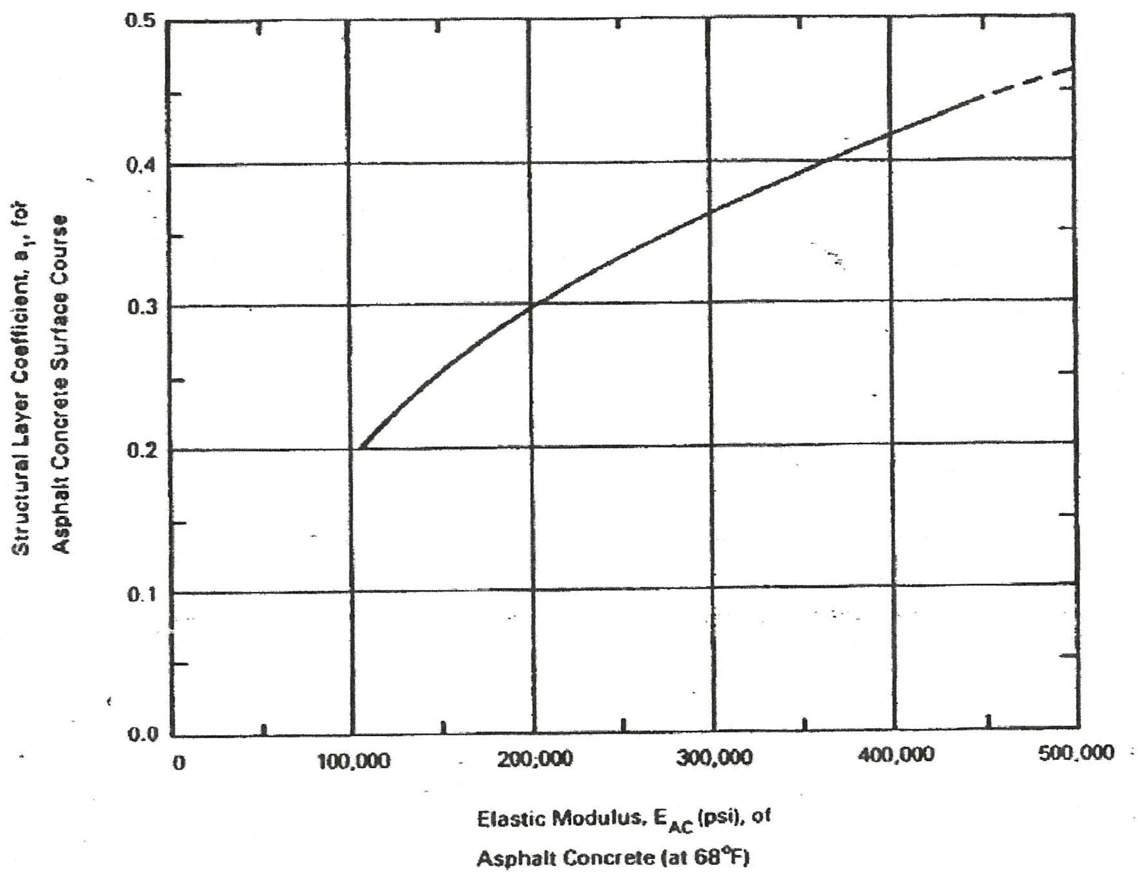

FIGURE Q2(b)(i): Chart for Estimating Structural Layer Coefficient (a_1) of Dense-Graded Asphalt Concrete Based On The Elastic (Resilient) Modulus. *Source: After AASTHO (1986)*

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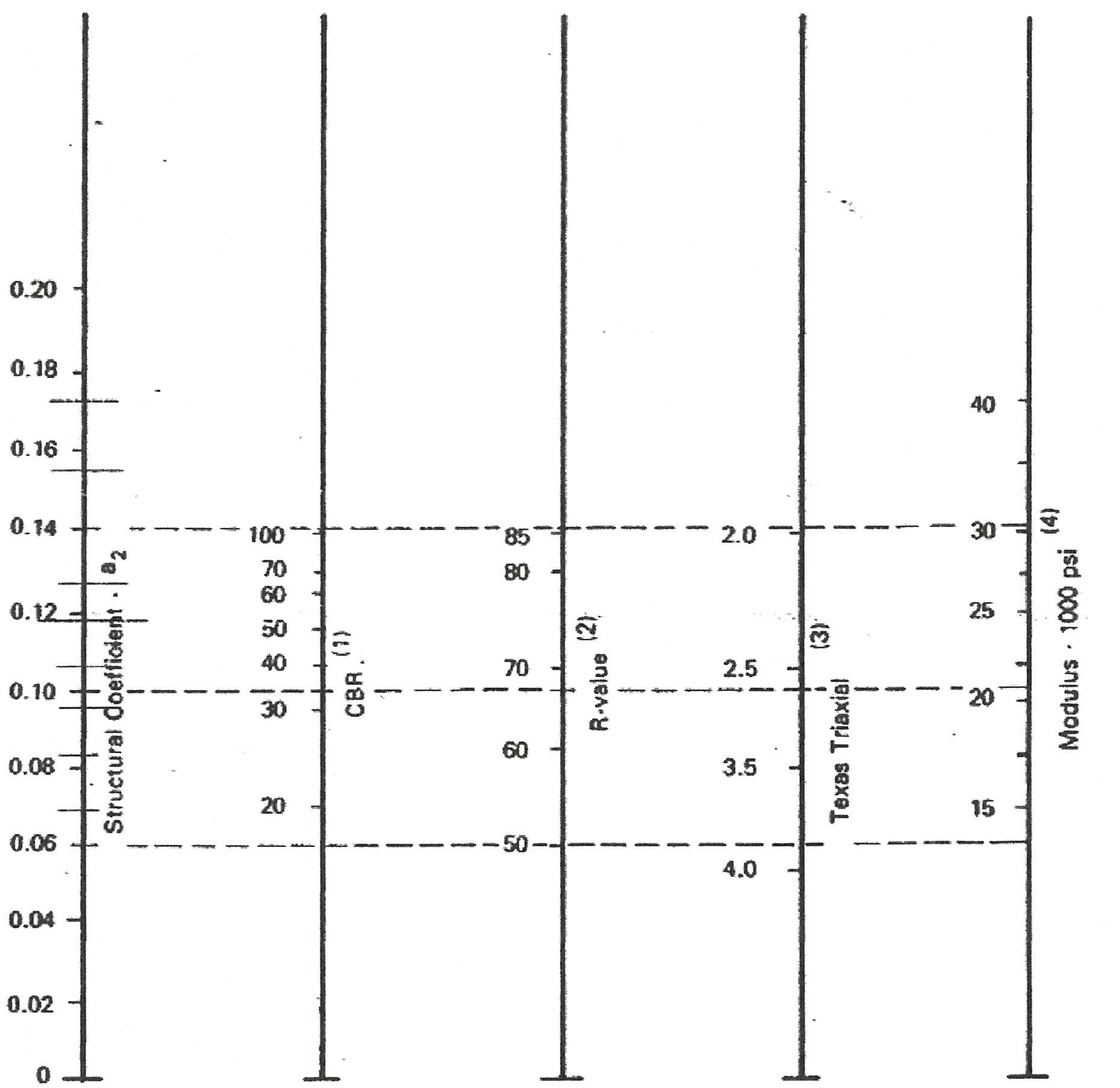

(1) Scale derived by averaging correlations obtained from Illinois.
(2) Scale derived by averaging correlations obtained from California, New Mexico and Wyoming.
(3) Scale derived by averaging correlations obtained from Texas.
(4) Scale derived on NCHRP project *(3)*.

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

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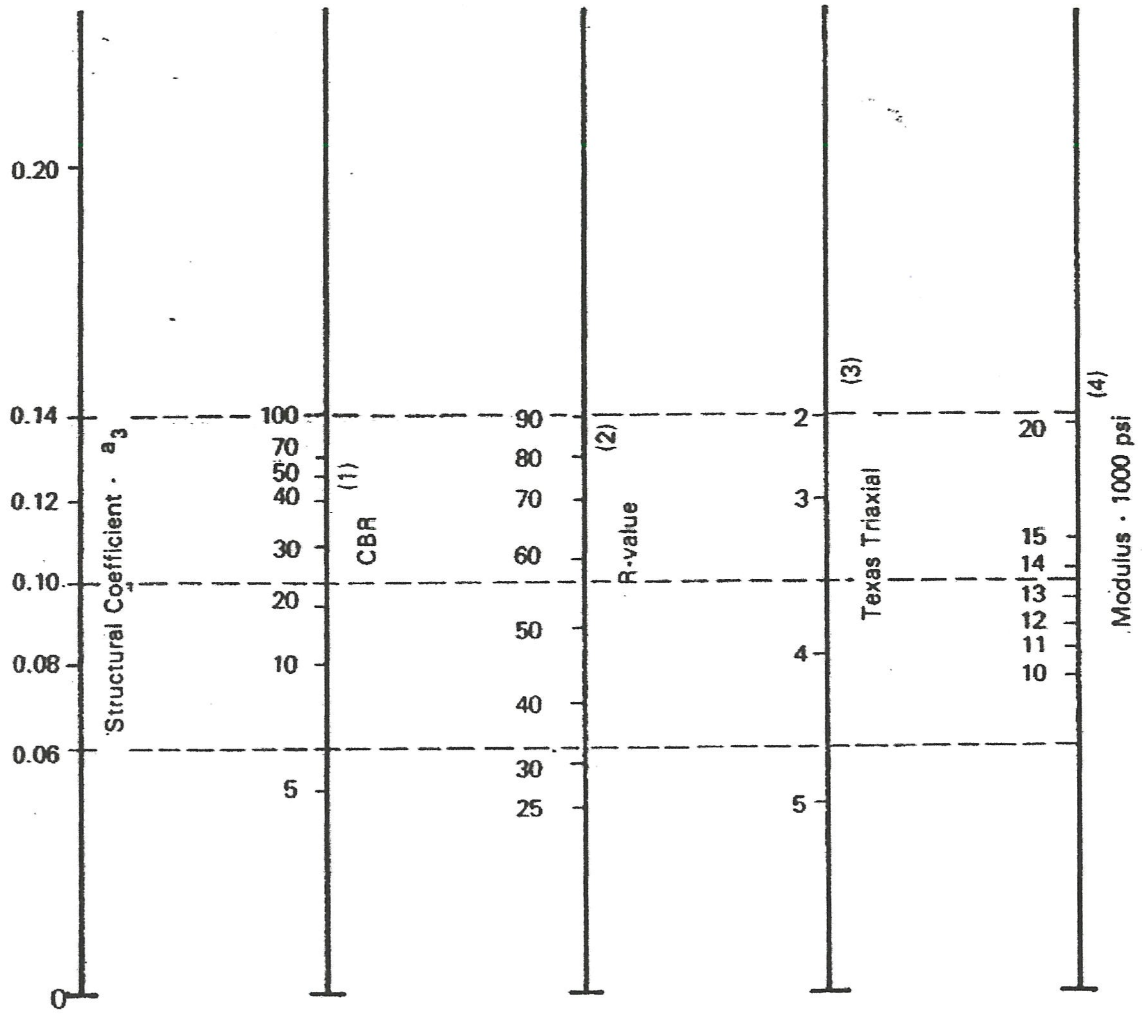

(1) Scale derived from correlations from Illinois.

(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(b)(iii): Variation in Granular Subbase Layer Coefficient (a_3) With Various Subbase Strength Parameters. *Source: After AASTHO (1986)*

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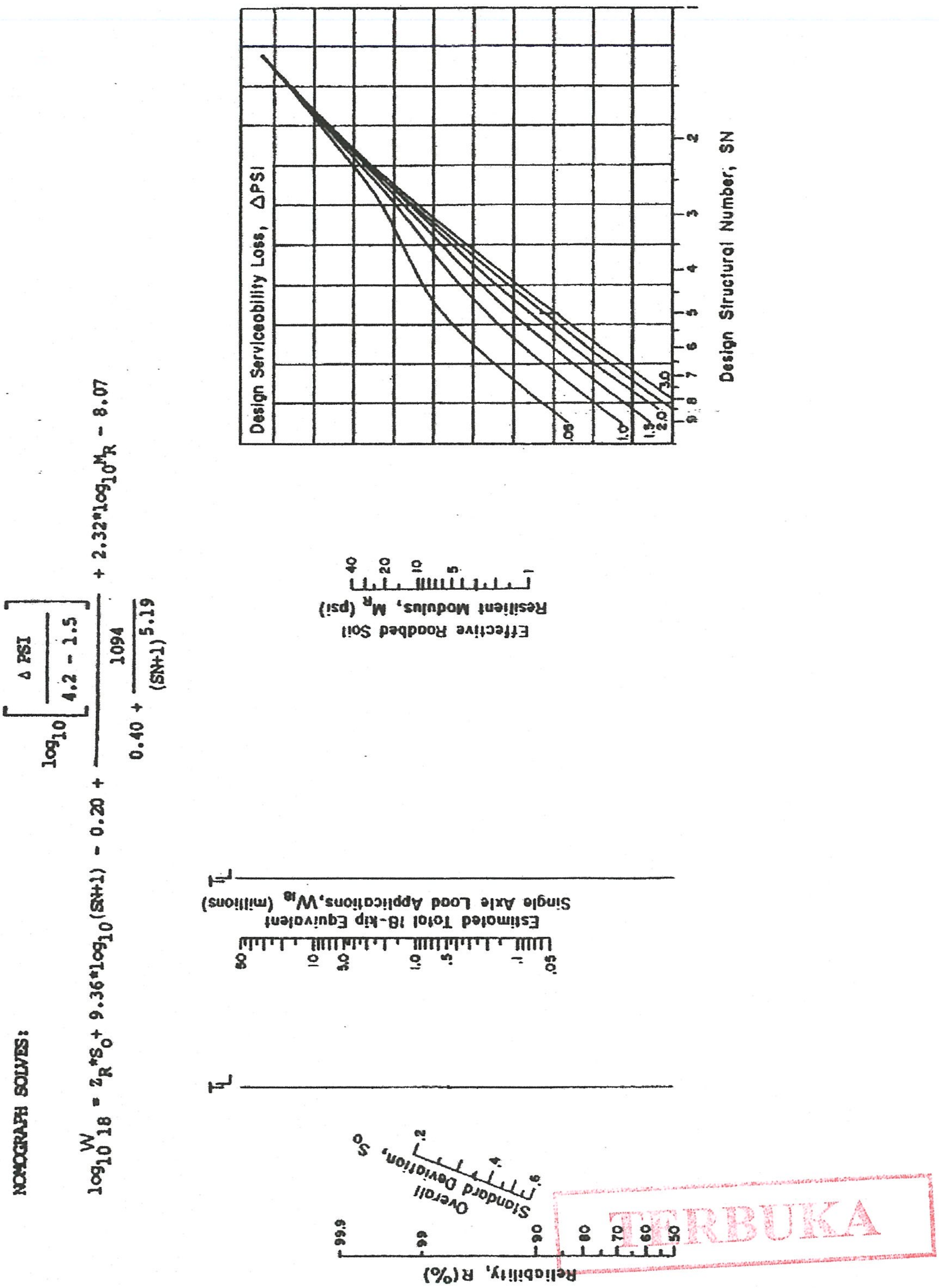

FIGURE Q2(b)(iv): Design Chart for Flexible Pavements Based on Using Mean Values for Each Input. *Source: After AASTHO (1986)*

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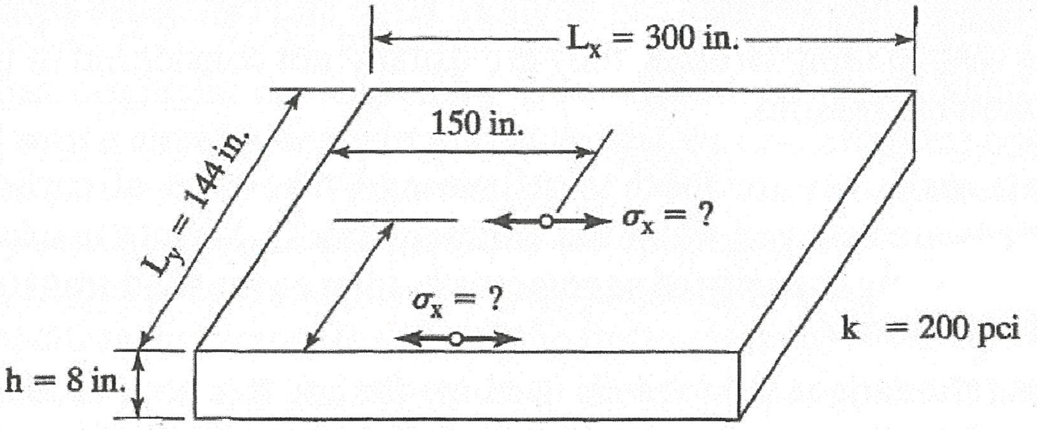

FIGURE 3(d)(i): Rigid Pavement Slab

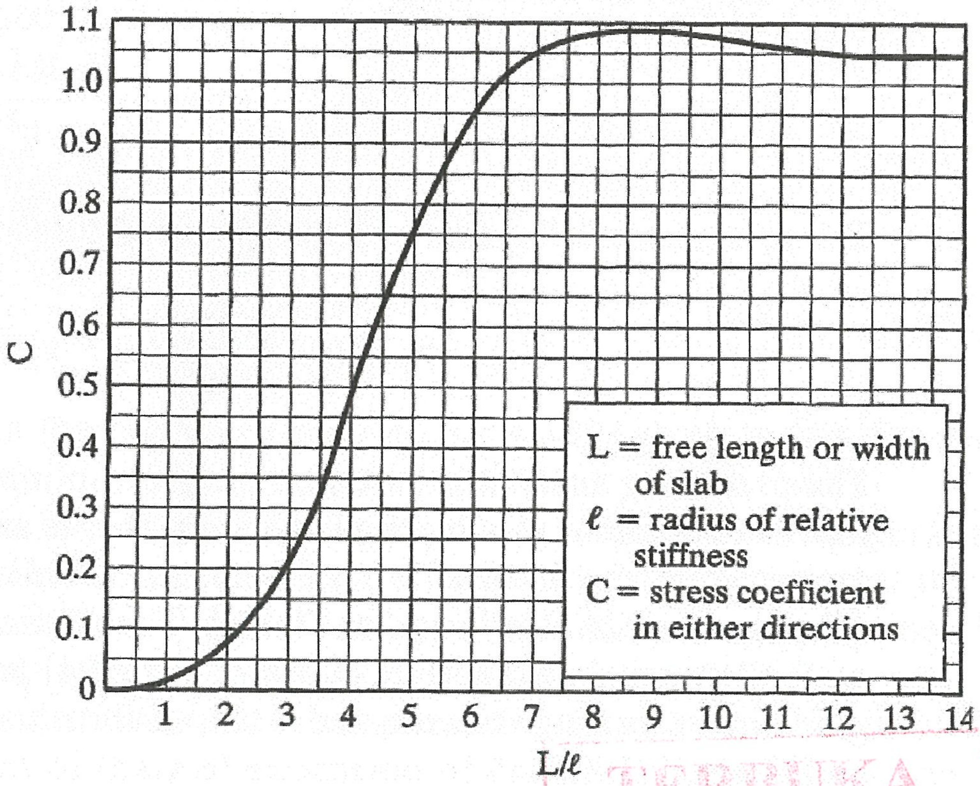

FIGURE Q3(d)(Ii) : Stress Correction Factor for Finite Slab (After Bradbury, 1938)

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TABLE 2(b)(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(b)(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(b)(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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Formulae:

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

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

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

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

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

$$ESAL = (AADT)(T)(T_f)(G)(365), \qquad SN = a_1D_1 + a_2D_2 + a_3D_3$$

$$SN = a_1D_1 + a_2D_2m_2 + a_3D_3m_3$$

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

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

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

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

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

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

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

$$h_e = \sum_{i=1}^{n} h_i C_i E_i, \qquad \frac{\text{Dry density } (\rho_d)}{\text{Maximum Dry Density } (\rho_{max})} \times 100 = 95\%$$