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UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2018/2019

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

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

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Q1 (a) State and describe the purpose of using steel (reinforcement) in rigid pavement.
(4 marks)

(b) Explain the function of dowel bar joint in the Joint Plain Concrete Pavement.
(5 marks)

(c) Define the phenomenon of pumping and its effects on rigid pavements.
(6 marks)

(d) Hinge or warping joints is a serious problem that can lead to serve roughness in jointed concrete pavement. Illustrate the methods that can be used to solve the problem.
(10 marks)

Q2 (a) Describe **THREE (3)** factors that need to be considered for structural design of rigid pavement.
(3 marks)

(b) Rigid pavement is the type of pavement normally constructed in Malaysia. Generalize **THREE (3)** types of rigid pavement and briefly discuss their advantages and disadvantages.
(6 marks)

(c) **Figure Q2(c)(i)** shows a rigid pavement slab 300 in. (25 ft) long, 144 in. (12-ft) wide and 8 in. (0.7 ft) thick, subjected to a temperature differential of 25°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, $\alpha_t = 4.5 \times 10^{-6}$ 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, $E = 5 \times 10^6$ psi and Poisson ratio is 0.20.
(6 marks)

(d) A rigid pavement without concrete shoulder is constructed on an untreated sub-base having effective modulus of sub-grade, k = 72 pci (19.5 MN/m^3), Concrete elastic modulus, $E_c = 5.0 \times 10^6$ psi (34.5 GPa), mean concrete modulus rupture, S_c = 650 psi (4.5 MPa), load transfer coefficient, J = 3.3, Drainage coefficient, C_d = 1.0, design serviceability loss, $\Delta PSI = 4.3 - 2.6 = 1.7$, Reliability, R = 95%, S = 0.29.

Calculate the rigid pavement thickness, D if the Equivalent Standard Single Axle Load (ESAL), $W_{18} = 5.1 \times 10^6$. Refer to **Figure Q2(d)(i)** and **Figure Q2(d)(ii)** as reference for your calculation.
(10 marks)

Q3 (a) Briefly discuss the differences between Pavement Serviceability Index (PSI) and Present Serviceability Rating (PSR).

(5 marks)

(b) A full depth asphalt pavement consisting of a 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, estimate the thickness of pavement overlay.

(4 marks)

(c) Rigid pavements are exposed to concrete reinforcement corrosion. Mainly there are **TWO (2)** causes of corrosion in reinforced concrete. With the aid of a diagram, describe the causes of the corrosion.

(6 marks)

(d) **Figure Q3(d)(i)** shows a concrete slab subjected to the slab edge loading. Given the modulus of the subgrade reaction is 120 pci (27.2 MN/m^3), slab thickness is 10 in. (254mm), loading at the corner is 11,000 lb (44.5kN), Poisson Ratio of 0.23 and elastic concrete modulus of 4.5 x 10^6 psi.

Determine the maximum stress and deflection under both circular and semicircular loaded areas.

(10 marks)

Q4 (a) Briefly explain **THREE (3)** importances of road maintenance work.

(6 marks)

(b) Pavement will serve long if the underlying surface is stable and the traffic is light. When a pavement fails earlier than the design life, it is usually a result of general soil issues and engineering. Based on the statement above, briefly discuss **THREE (3)** of soil and engineering factors that may contribute to pavement failures.

(6 marks)

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

(6 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 strains 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), calculate the allowable number of ESAL on the overlaid asphalt pavement.

(7 marks)

- END OF QUESTIONS -

FINAL EXAMINATION

SEMESTER/SESSION	:	II / 2018/2019	PROGRAMME	:	BFF
COURSE NAME	:	PAVEMENT ENGINEERING	COURSE CODE	:	BFT 40203

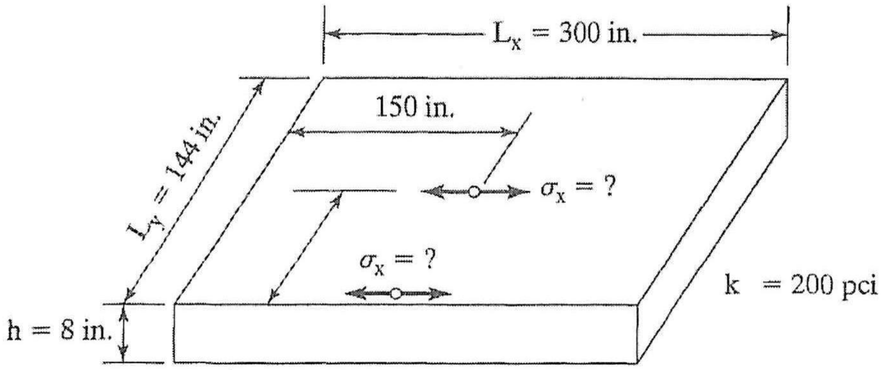

FIGURE Q2(c)(i) : Rigid Pavement Slab

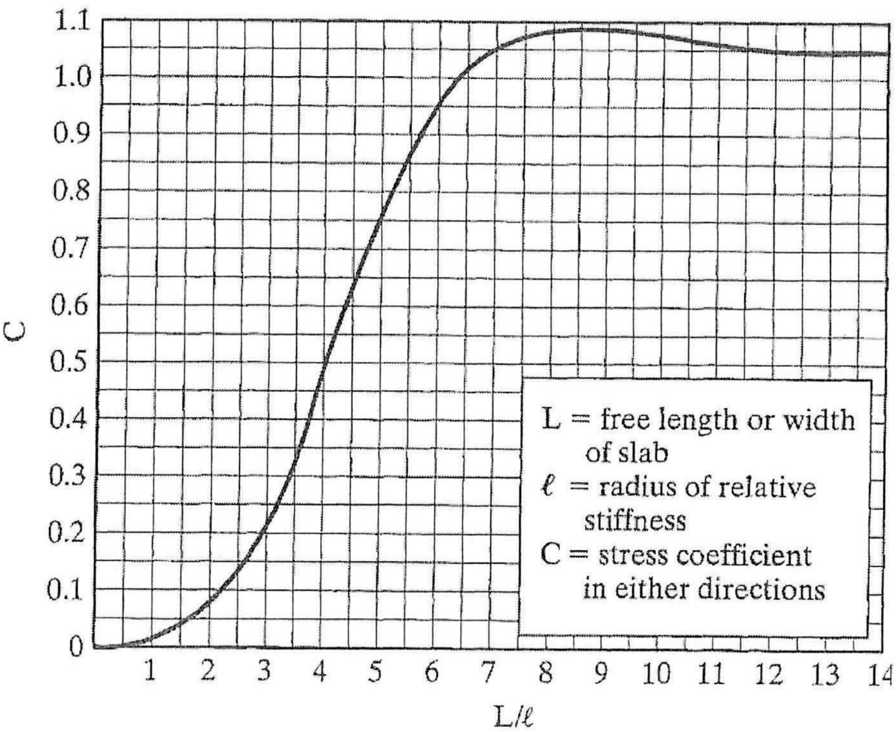

FIGURE Q2(c)(ii) : Stress Correction Factor for Finite Slab (After Bradbury, 1938)

FINAL EXAMINATION

SEMESTER/SESSION : II / 2018/2019 PROGRAMME : BFF
COURSE NAME : PAVEMENT ENGINEERING COURSE CODE : BFT 40203

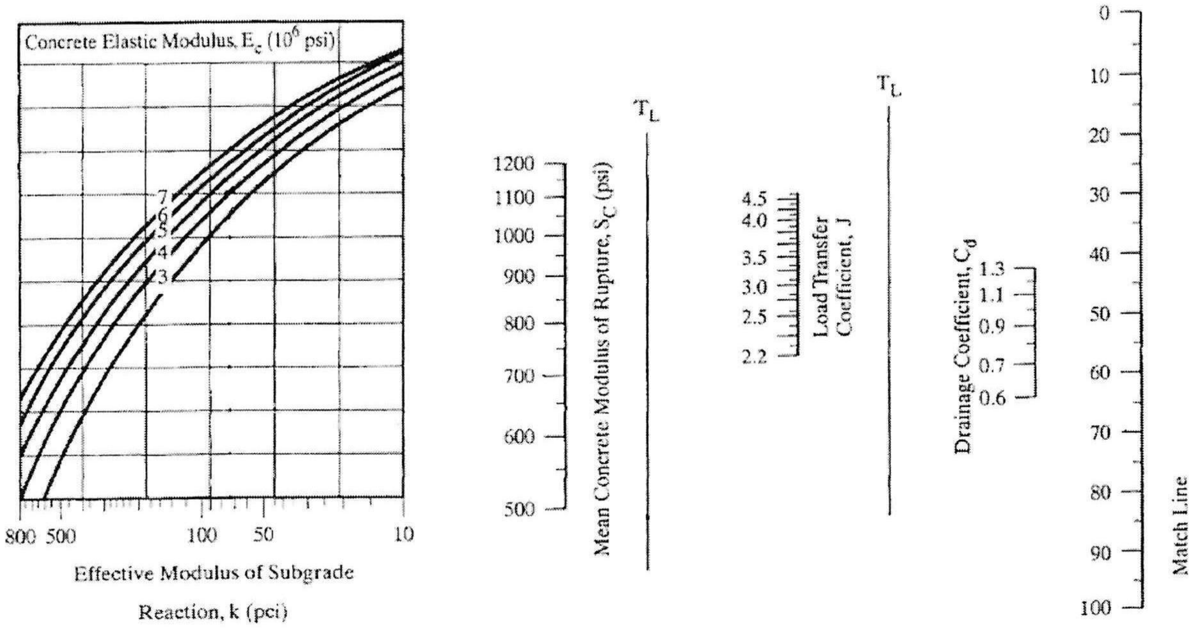

FIGURE Q2(d)(i): Design chart for rigid pavements

FINAL EXAMINATION

SEMESTER/SESSION	:	II / 2018/2019	PROGRAMME	:	BFF
COURSE NAME	:	PAVEMENT ENGINEERING	COURSE CODE	:	BFT 40203

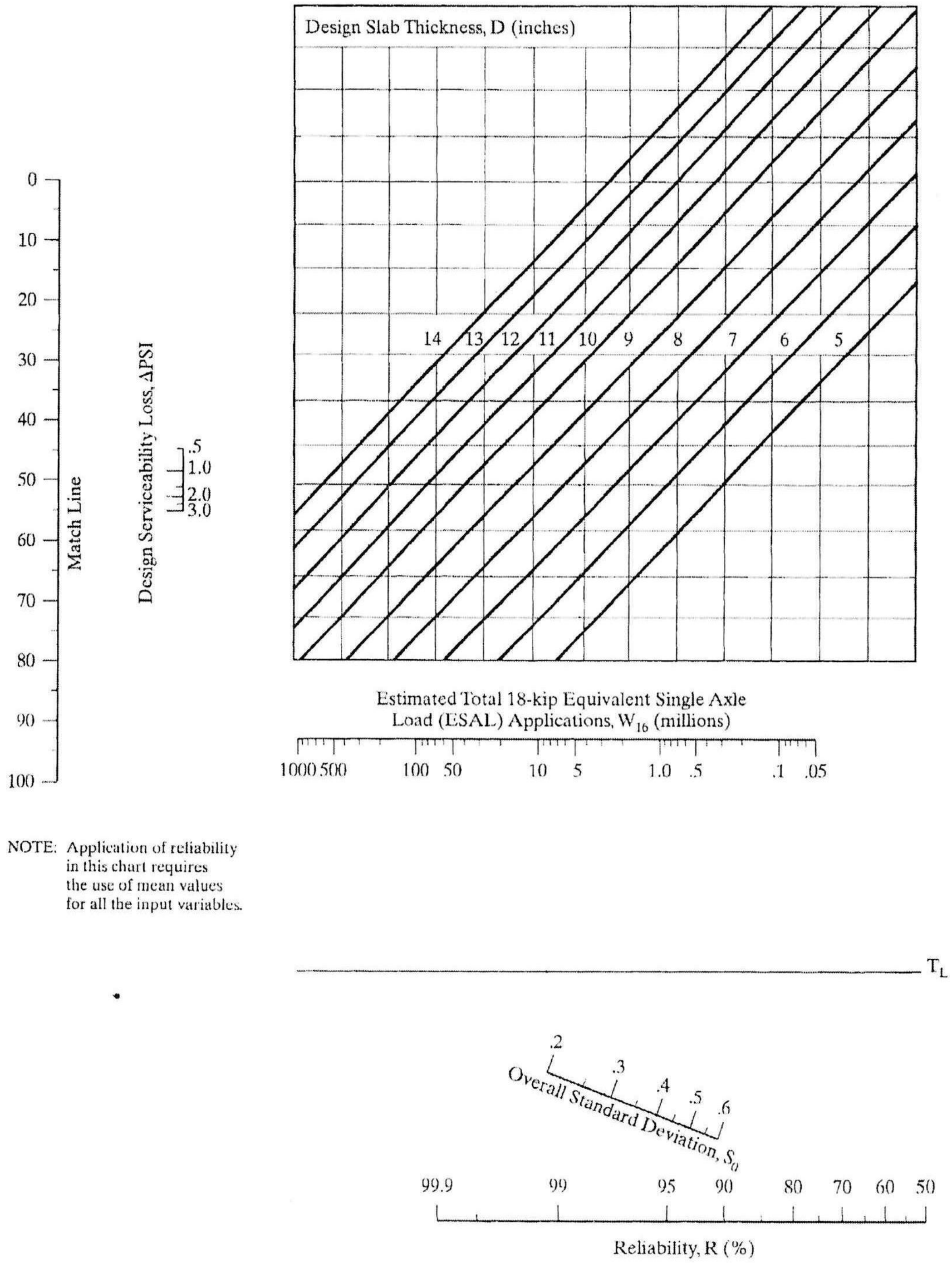

FIGURE Q2(d)(ii): Design chart for rigid pavements (continue)

FINAL EXAMINATION

SEMESTER/SESSION : II / 2018/2019 PROGRAMME : BFF
COURSE NAME : PAVEMENT ENGINEERING COURSE CODE : BFT 40203

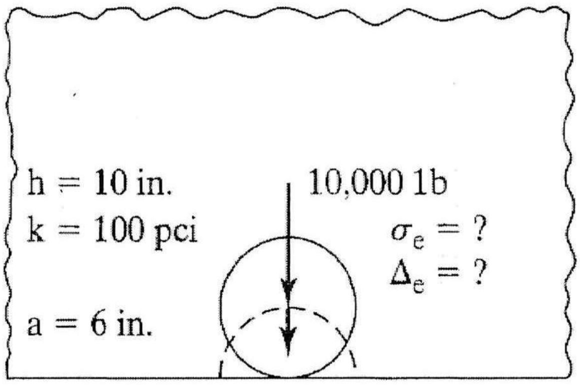

FIGURE Q3(d)(i): Concrete Slab Subjected to Slab Edge Loading

FINAL EXAMINATION

SEMESTER/SESSION : II / 2018/2019 PROGRAMME CODE : BFF
COURSE NAME : PAVEMENT ENGINEERING COURSE CODE : BFT 40203

TABLE 1: Suggested Levels of Reliability for Various Functional Classifications
Source: After AASTHO (1986)

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

TABLE 2: Standard Normal Deviation for Various Levels of Reliability
Source: After AASTHO (1986)

Reliability (%)	Standard normal deviate *(ZR)*	Reliability (%)	Standard normal deviate *(ZR)*
50	0.000	93	-1.476
60	-0.253	94	-1.555
70	-0.524	95	-1.645
75	-0.674	96	-1.751
80	-0.841	97	-1.881
85	-1.037	98	-2.054
90	-1.282	99	-2.327
91	-1.340	99.9	-3.090
92	-1.405	99.99	-3.750

FINAL EXAMINATION

SEMESTER/SESSION : II / 2018/2019
COURSE NAME : PAVEMENT ENGINEERING
PROGRAMME CODE : BFF
COURSE CODE : BFT 40203

TABLE 3: 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)

TABLE 4: 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)

FINAL EXAMINATION

SEMESTER/SESSION	:	II / 2018/2019	PROGRAMME CODE	:	BFF
COURSE NAME	:	PAVEMENT ENGINEERING	COURSE CODE	:	BFT 40203

TABLE 5: 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 / 2018/2019	PROGRAMME	:	4 BFF
COURSE NAME	:	PAVEMENT ENGINEERING	COURSE CODE	:	BFT 40203

Formulae:

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

$$\frac{L_x}{\ell}$$

$$\sigma_c = \frac{3P}{h^2}\left[1 - \left(\frac{a\sqrt{2}}{\ell}\right)^{0.6}\right]$$

$$\sigma_{e\,circle} = \frac{0.803P}{h^2}\left[4\log\left(\frac{\ell}{a}\right) + 0.666\left(\frac{a}{\ell}\right) - 0.034\right]$$

$$\sigma_{e\,semicircle} = \frac{0.803P}{h^2}\left[4\log\left(\frac{\ell}{a}\right) + 0.282\left(\frac{a}{\ell}\right) + 0.650\right]$$

$$\Delta_{e\,circle} = \frac{0.431P}{k\ell^2}\left[1 - 0.82\left(\frac{a}{\ell}\right)\right]$$

$$\Delta_{e\,semicircle} = \frac{0.431P}{k\ell^2}\left[1 - 0.349\left(\frac{a}{\ell}\right)\right]$$

$$\sigma_c = \frac{3P}{h^2}\left[1 - \left(\frac{c}{\ell}\right)^{0.72}\right]$$

$$c = 1.772a$$

$$\Delta_c = \frac{P}{k\ell^2}\left[1.205 - 0.69\left(\frac{c}{\ell}\right)\right]$$

$$\Delta_c = \frac{P}{k\ell^2}\left[1.1 - 0.88\left(\frac{a\sqrt{2}}{\ell}\right)\right]$$

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

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

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

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

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

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