Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2021/2022

COURSE NAME	:	PAVEMENT ENGINEERING
COURSE CODE	:	BFT 40203
PROGRAMME CODE	:	BFF
EXAMINATION DATE	:	JANUARY / FEBRUARY 2022
DURATION	:	3 HOURS
INSTRUCTIONS	:	1. ANSWER **ALL** QUESTIONS. 2. THIS FINAL EXAMINATION IS AN **ONLINE** ASSESSMENT AND CONDUCTED VIA **CLOSE BOOK**.

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THIS QUESTION PAPER CONSISTS OF **FOURTEEN (14)** PAGES

Q1 (a) Pavement performance is an important factor of pavement design because it provides a framework upon which a judgement on the road success or failure, which is associated with ability of the pavement to carry out the design loading. Based on those statements, briefly explain a distinction between **TWO (2)** different types of failure.

(6 marks)

(b) Discuss the concepts of pavement design thickness according to the American Association of State Highway and Transportation Officials (ASSHTO) guide for design of pavement structures 1993.

(6 marks)

(c) A new rural principal arterial road is to be designed to replace an existing highway. The new road properties have an elastic modulus, E as 1400 MPa and the Poisson ratio, μ as 0.5. If the inflated vehicle tire is 601.5 kPa with 0.126 m tire radius is applied on depth of 0.1 m and radial offset of 0.0 m on the road pavement, calculate;

(i) the vertical normal stress

(4 marks)

(ii) the surface vertical deflection

(4 marks)

(iii) If the elastic modulus, E decrease 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.

(5 marks)

Q2 (a) A ride quality rating over a road surface pavement was correlated with the road maintenance or rehabilitation event with amount of traffic using it. With the sketch of diagrams, describe how a maintenance works can improve the serviceability of the road.

(6 marks)

(b) The International Roughness Index (IRI) is a worldwide standard for measuring road smoothness longitudinally in terms of the number of inches per mile. Based on these statements, propose the IRI roughness scale diagram that required for the type of pavement categories based on the World Bank (1980).

(8 marks)

(c) The traffic on the design lane of a proposed 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 flexible pavement if the Average Annual Daily Traffic (AADT) on the design lane during the

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first year of operation is 1000, initial serviceability (P_o) = 4.4, and terminal serviceability (P_t) = 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 (*Mr*) for asphalt concrete is 450,000 lb/in^2.

You may refer to **Table 2(c)(i)** to **Table 2(c)(iii), Figure Q2(c)(i)** to **Figure Q2(c)(iv),** and equations in **Appendix B** when answering this question.

(13 marks)

Q3 (a) A concrete structure is exposes to a variety of environment impacts that directly effects on concrete pavement components. Briefly discuss a causes and possible effect on concrete reinforcement.

(6 marks)

(b) The increasing of load transfer in jointed plain concrete pavement increases the joint deflection and stress on a connection of horizontal joint movement between slabs in the approach and leave slabs. Based on this statement, propose and explain the method with suitable diagram to solve the problem.

(6 marks)

(c) A concrete pavement designed for a four-lane urban express constructed on 6 in. thickness of an untreated sub-base with resilient modulus of 30,000 psi (206.8 MPa) and roadbed resilient modulus of 7,000 psi (48.3 MPa). The road is proposed for a plain concrete pavement with construction joints and load transfer on asphalt shoulder. The initial and terminal serviceability indices are 4.2 and 2.5, respectively. Take the overall standard deviation S_o as 0.29 and the standard normal deviate, Z_R considered as -1.645. The working stress of the concrete is 650 psi (4.5 MPa) and the concrete elastic modulus is 5.0 x10^6 psi (34.5 GPa). The Equivalent Standard Single Axle Load (ESAL) was designed according on **Table Q3(c)(i).** It is estimated that the water removed within 2 hours from a base layer, which pavement exposure to moisture is 30 percent.

Refer **Table Q2(c)(i)** and **Table Q2(c)(ii),** and **Table Q3(c)(i)** to **Table Q3(c)(iv), Figure Q3(c)(i)** to **Q3(c)(iii)** in your calculation. Based on the American Association of State Highway and Transportation Officials (ASSHTO) design method;

(i) Calculate the suitable of concrete slab thickness.

(10 marks)

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(ii) Analyse the relative damage of rigid pavement

(3 marks)

Q4 (a) Discuss the implementing of network level in Pavement Management System (PMS) for a newly development network of pavement works rehabilitation program.

(8 marks)

(b) Road pavement shall be properly constructed and maintained in order to provide a data maintenance and information for future government decision-makers to the investment strategies. Based on this statement;

(i) Propose with details explanation, a suitable tool analysis to evaluate the investment strategies to maximize performance within constrained funding levels.

(8 marks)

(ii) Based on the answer in **Q4(b)(i)**, discuss in details the benefits of the selected tool analysis.

(9 marks)

- END OF QUESTIONS -

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Table 2(c)(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(c)(ii): Recommended drainage coefficient for untreated bases and sub bases in road 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)(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): Traffic analysis (AASTHO, 1986)

Vehicle Type	Number of Vehicles	Truck Factor	Growth Factor
Single units' trucks			
2 axles (4 tires)	87,700	0.003	29.8
2 axles (6 tires)	53,200	0.25	29.8
3 axles or more	18,800	0.86	29.8
Tractor semitrailers and combinations			
4 axles or less	34,900	0.92	29.8
5 axles	61,200	1.25	29.8
6 axles or more	21,300	1.54	29.8

Table 3(c)(ii): Load transfer coefficient for various pavement types and design conditions *(AASTHO, 1986)*

Type of Shoulder	Asphalt		Tied Portland Cement Concrete	
Load Transfer Devices	Yes	No	Yes	No
JPCP and JRCP	3.2	3.8 – 4.4	2.5 – 3.1	3.6 – 4.2
CRCP	2.9 – 3.2	N/A	2.3 – 2.9	N/A

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Table 3(c)(iii): 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

Table 3(c)(iv): Ranges of loss of support factors for various types of materials
Source: After AASTHO (1986)

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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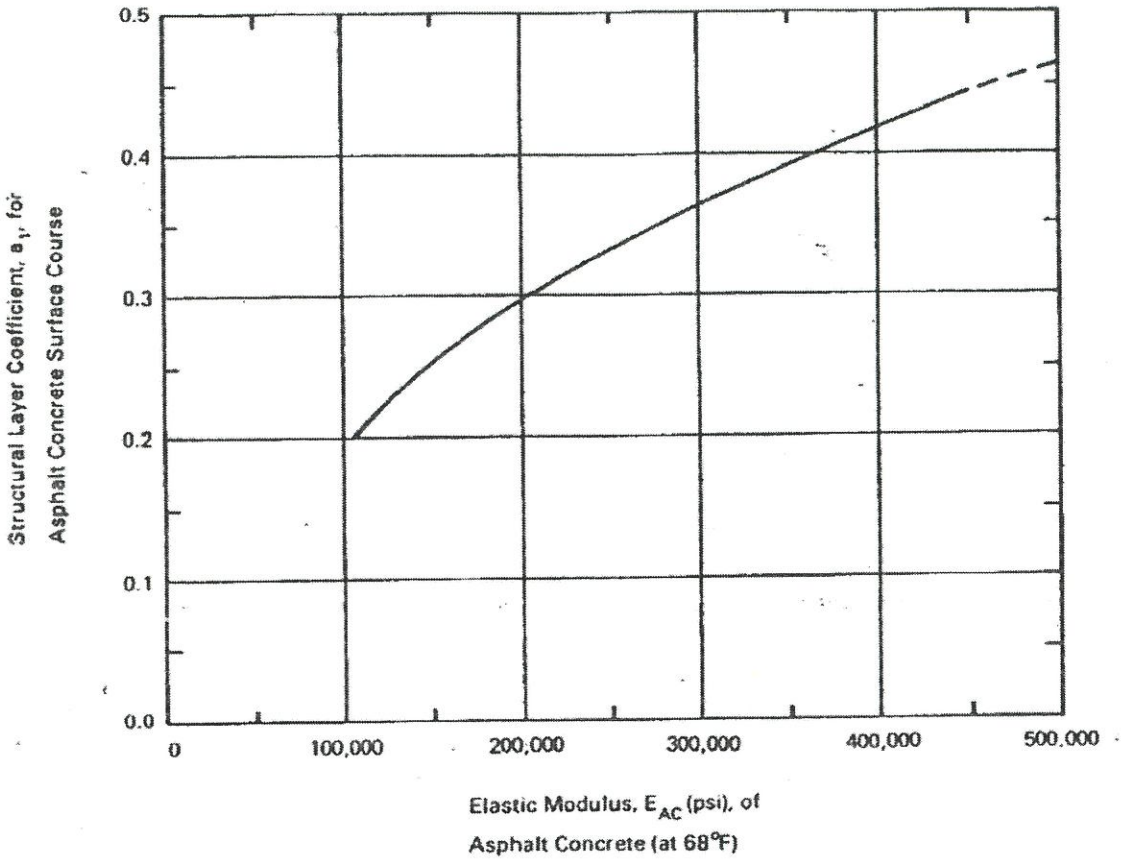

Figure Q2(c)(i): Chart for estimating structural layer coefficient (a_1) of dense-graded asphalt concrete based on the elastic (Resilient) Modulus. *Source: After AASTHO (1986)*

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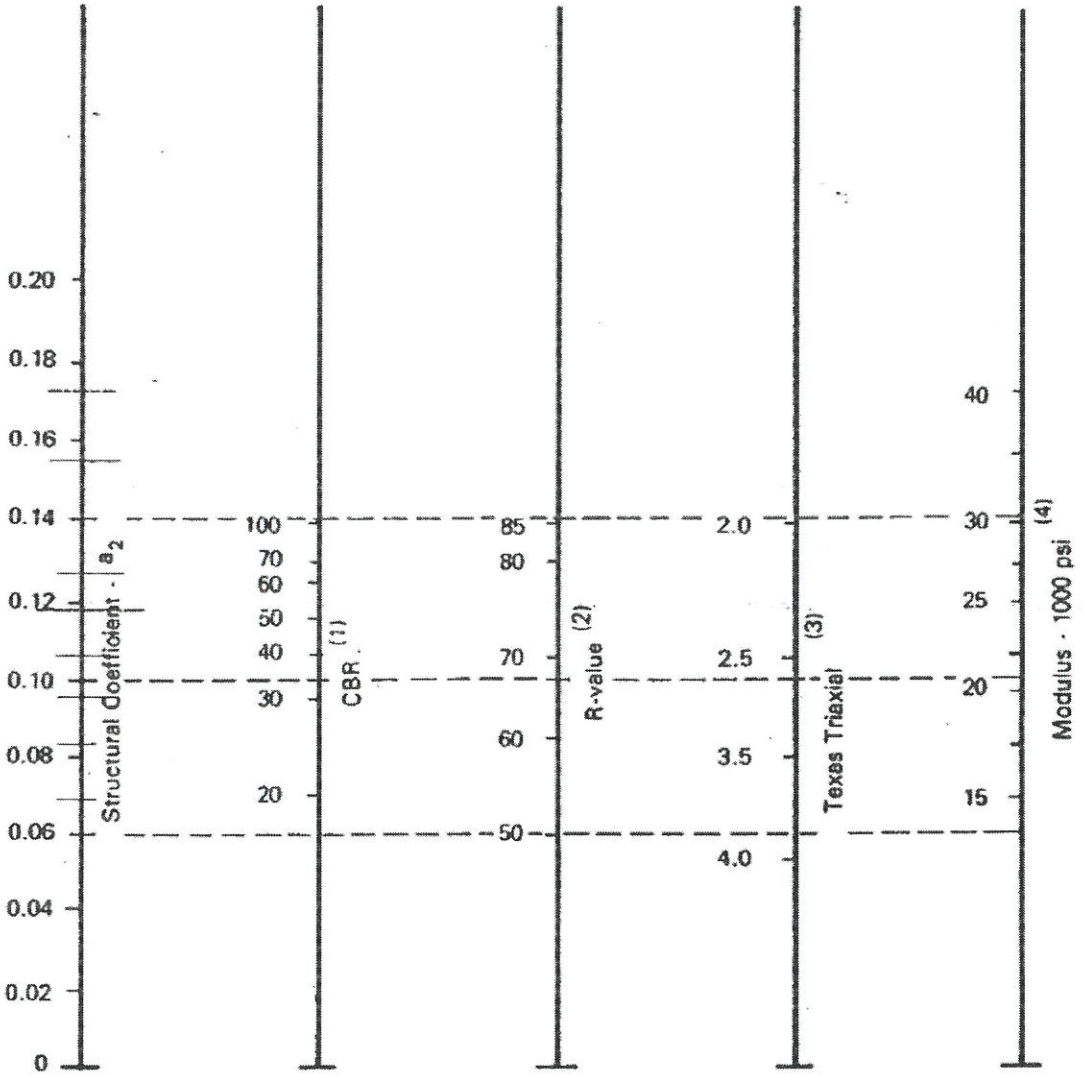

(1) Scale derived by averaging correlations obtained from Illinois.
(2) Scale derived by averaging correlations obtained from California, New Mexico and Wyoming.
(3) Scale derived by averaging correlations obtained from Texas.
(4) Scale derived on NCHRP project *(3)*.

Figure Q2(c)(ii): Variation in granular base layer coefficient (a_2) with various base strength parameters. *Source: After AASTHO (1986)*

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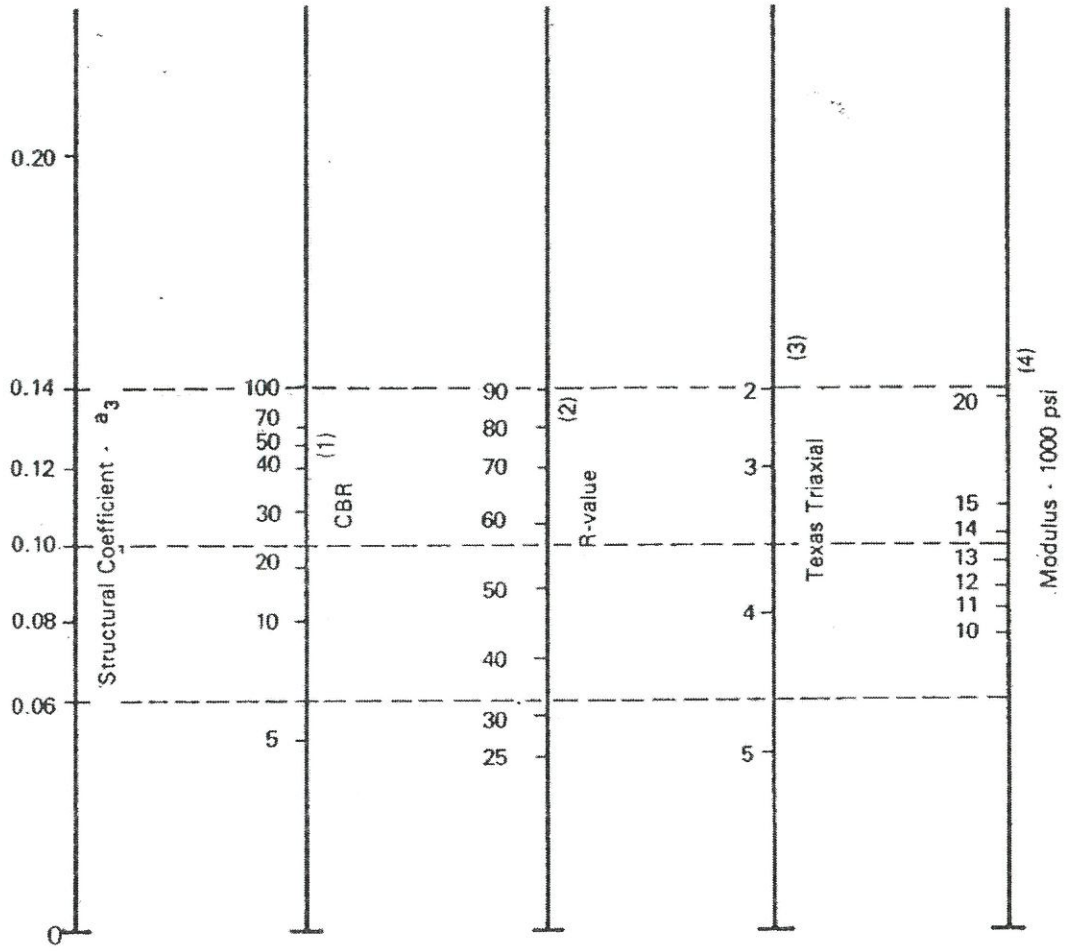

(1) Scale derived from correlations from Illinois.

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

(3) Scale derived from correlations obtained from Texas.

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

Figure Q2(c)(iii): Variation in granular subbase layer coefficient (a_3) with various subbase strength parameters. *Source: After AASTHO (1986)*

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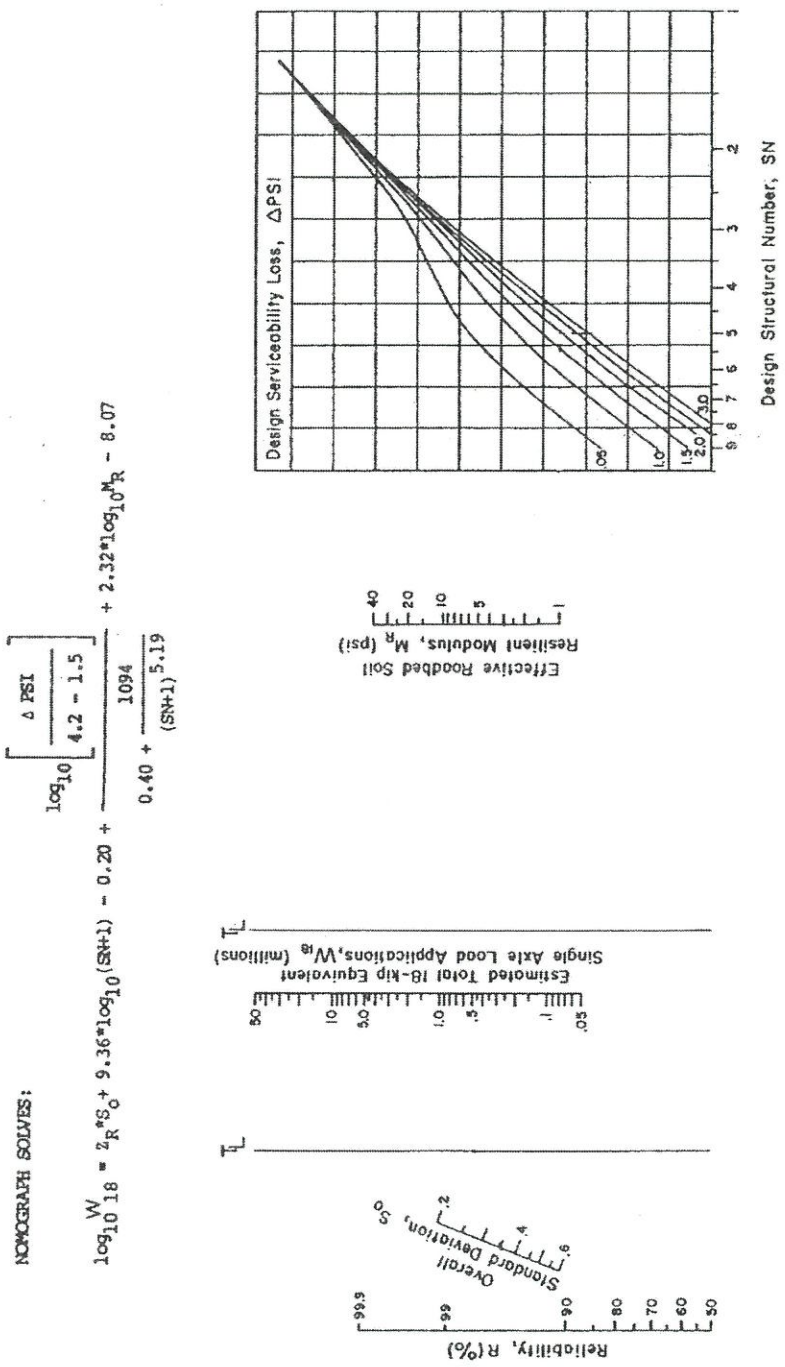

FIGURE Q2(c)(iv): Design chart for flexible pavements based on using mean values for each input. *Source: After AASTHO (1986)*

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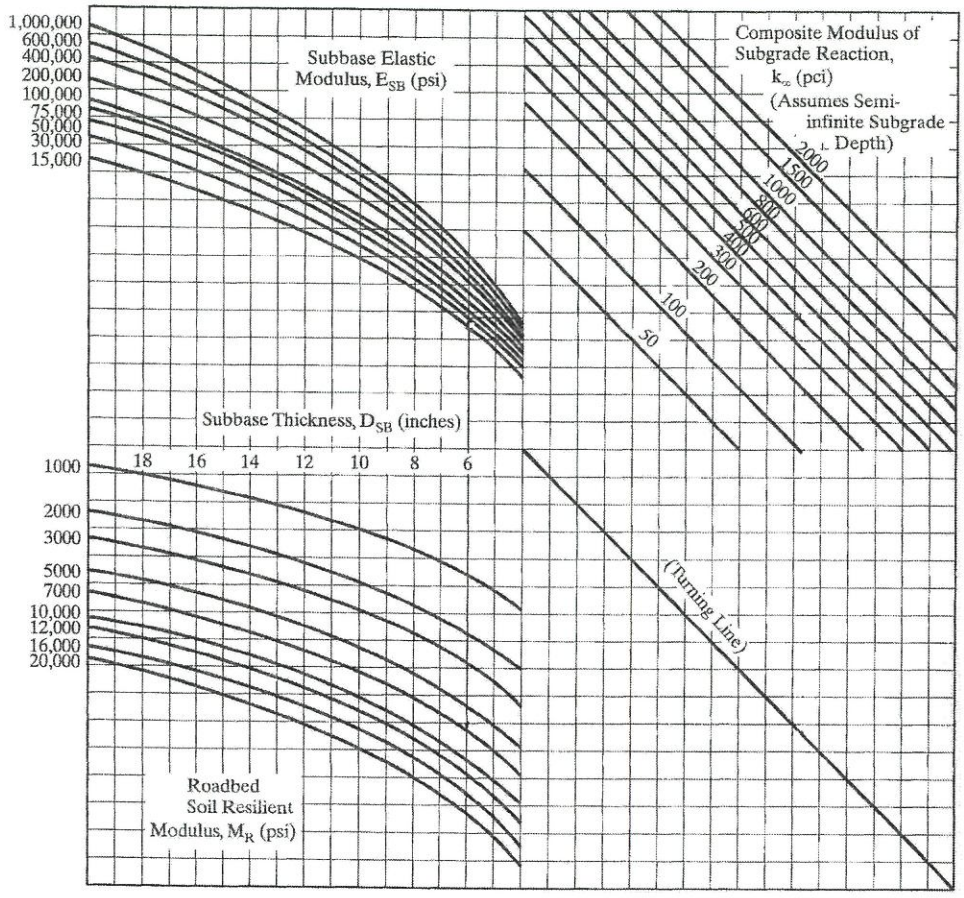

Figure Q3(c)(i): Design chart for estimating composite modulus of sub-grade reaction (AASHTO, 1986)

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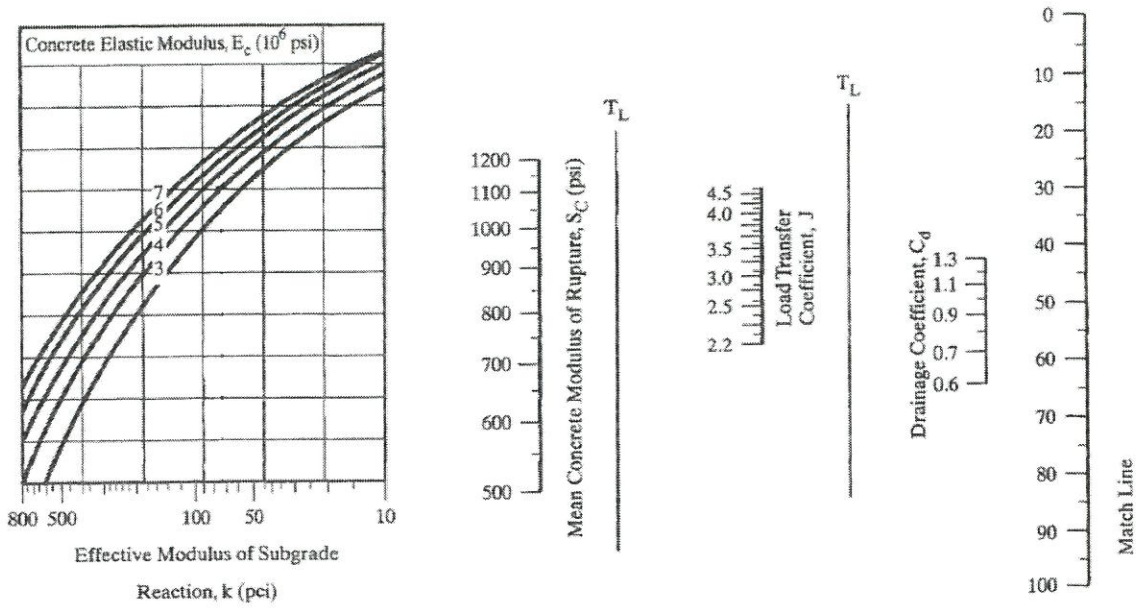

Figure Q3(c)(ii). Design Chart for Rigid Pavement

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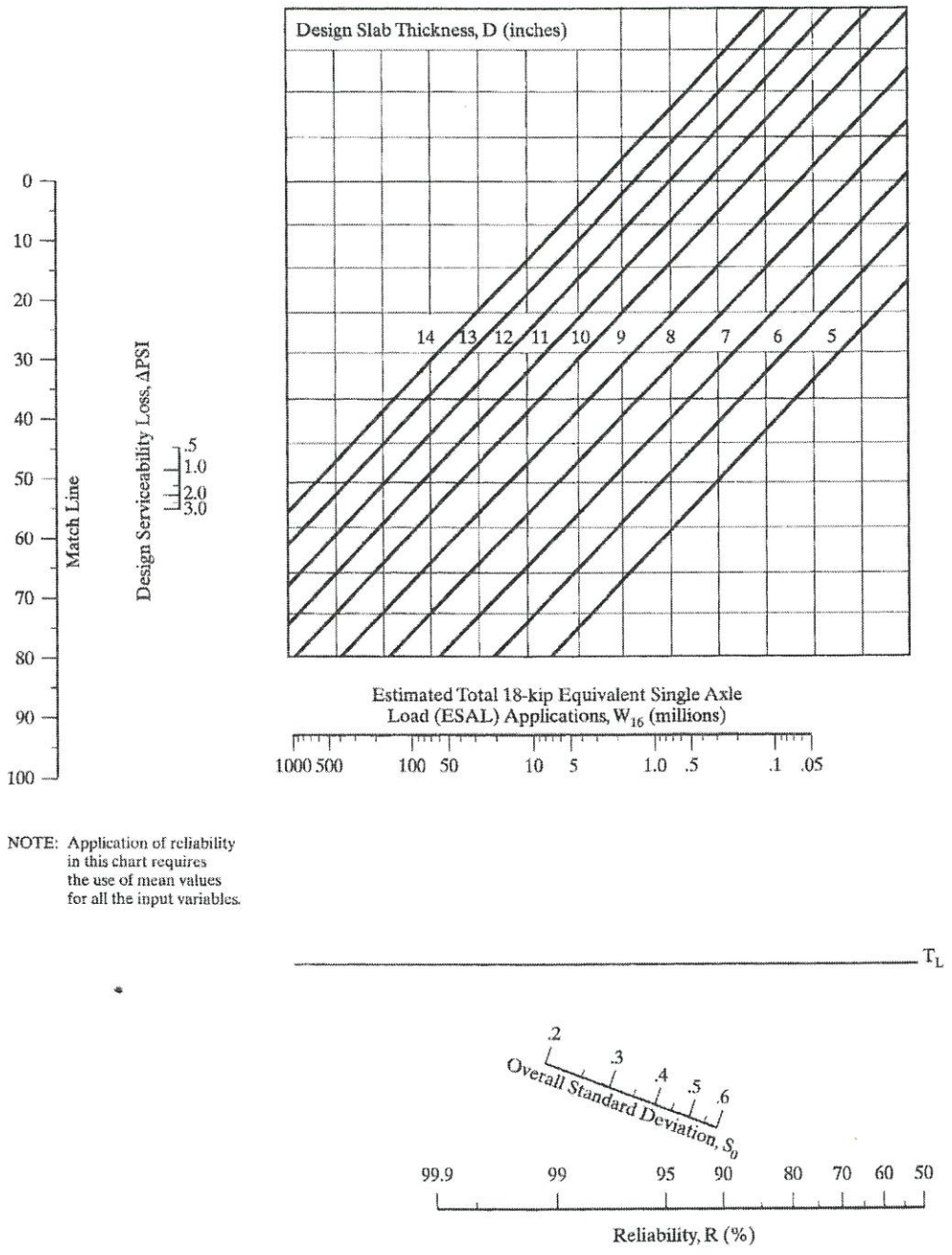

Figure Q3(c)(iii). Design Chart for Rigid Pavement

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