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UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2019/2020

COURSE NAME	:	HIGHWAY ENGINEERING
COURSE CODE	:	BFC31802
PROGRAMME CODE	:	BFF
EXAMINATION DATE	:	DECEMBER 2019 / JANUARY 2020
DURATION	:	2 HOURS 30 MINUTES9
INSTRUCTION	:	ANSWER **ALL** QUESTIONS

THIS QUESTION PAPER CONSISTS OF **EIGHTEEN (18)** PAGES

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Q1 (a) Differentiate between pavement management system at network level and project level.

(5 marks)

(b) There are two categories of pavement evaluation that are functional evaluation and structural evaluation. In accordance, explain briefly **TWO (2)** pavement characteristic for each categories.

(5 marks)

(c) A horizontal curve is designed for a two-lane road in mountainous terrain. The following data are for geometric design purposes; Intersection angle = 40 degrees, Tangent length = 130 m, Station of *PI*: 2700 + 32, f= 0.12, e = 0.08. Based on the information, determine;

(i) Design speed.

(4 marks)

(ii) Length of arc and middle of ordinate.

(4 marks)

(iii) Long chord and station of the PC.

(4 marks)

(iv) Station of the PT.

(3 marks)

Q2 (a) The flexible pavement of rural road is planned to be constructed with the design life of 20 years. Based on the traffic conducted by Highway Planning Unit (HPU) for 16 hours survey, the Average Daily Traffic for one direction (ADT) is 2,000 whereas 12% are commercial vehicles with un-laden weight > 1.5. The additional project information are Lane distribution factor = 1.0, Terrain factor = 1.1, Annual traffic growth = 4%, CBR mean = 16.7%, CBR standard deviation = 4.5 %. Based on the information,

(i) Determine the thickness of the proposed road. Refer **Table Q2(a)(i)** to **Table Q2(a)(iv)** and **Figure Q2(a)(i)** to **Figure Q2(a)(v)** for your calculation.

(11 marks)

(ii) Based on the calculation in **Q2(a)(i)**, briefly discuss a suitability of using full depth asphalt concrete base.

(4 marks)

(b) The construction of a new road has a number of implications for the environment, consuming large amount of materials and energy. Therefore, the paving industry has been striving for sustainability in road construction.

(i) List **FIVE (5)** examples of sustainable road contruction materials.

(5 marks)

(ii) "The Waste Strategy 2000" establishes the waste hierarchy to promote recycling and reuse at the highest level possible to sustainable waste. Elaborate the waste hierarchy.

(5 marks)

Q3 (a) One types of bituminous surface treatment is Mill & Pave. In accordance;

(i) Explain briefly the treatment.

(2 marks)

(ii) State the **THREE (3)** conditions in which Mill & Pave can be used.

(3 marks)

(b) State the types of road recycling techniques which is available in the road rehabilitation industry.

(5 marks)

(c) A section of flexible pavement will be constructed from Sri Gading to Bukit Banang, Batu Pahat, Johor. As a consultant, determine a suitable thickness of the flexible pavement using the AASHTO thickness design method. Refer T**able Q3(c)** and **Figure Q3(c)(i)** to **Figure Q3(c)(v)** for your calculation. The design parameters of the proposed pavement are as follows:

Equivalent Single Axle Load (ESAL) = 1.5×10^6
Initial Present Serviceability Index, $PSI_i = 4.5$
Terminal Present Serviceability Index, $PSI_t = 2.5$
Resilient modulus of asphalt concrete, M_{R1} = 400,000 psi
CBR of crushed stone base = 100%
CBR of gravel subbase = 30%
CBR of subgrade = 7%
Exposure to moisture = 30% of the time
Quality of drainage: Surface layer – Good
Base layer – Fair
Subbase layer – Fair
Reliability, R = 99%
Standard deviation, $S_o = 0.35$

(15 marks)

(d) Using the suitable diagram or sketches, summarizes the construction sequence and procedure of Hot Plant Mix Recycling

(5 marks)

Q4 (a) Define clearly an asphalt paving overlay and list **THREE (3)** functions of overlay construction.

(5 marks)

(b) Using the suitable diagram or sketches, summarizes the construction sequence and procedure of Hot Plant Mix Recycling

(5 marks)

(c) **Table Q4(c)** shows ground levels and formation levels for proposed 800 m road A. **Figure Q4(c)** shows the cross section of the soil cutting and embankment. Given that shrinkage factor = 0.9 and bulking factor = 1.1. In accordance;

(i) Determine the cummulative volume of the soil.

(10 marks)

(ii) Plot the mass haul diagram.

(3 marks)

(iii) Given that a proposed road B requires an import soil of 1000 m^3. After transferring the extra soil from road A, the required soil is still not enough. Calculate the remaining required soil.

(2 marks)

– END OF QUESTIONS –

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Table Q2(a)(i): Classes of Sub-Grade Strength (based on CBR) used as Input in the Pavement Catalogue of ATJ 5/85 (Amendment 2013) Manual

Sub-Grade	CBR (%)	Elastic Modulus (MPa)	
		Range	Design Input Value
SG1	5 to 12	50 to 20	60
SG2	12.1 to 20	80 to 140	120
SG3	20.1 to 30.0	100 to 160	140
SG4	>30.0	120 to 180	180

Table Q2(a)(ii): Traffic Categories used in this Manual (EAL =80kN)

Traffic category	Design Traffic (ESAL x 10^6)	Probability (Percentile Applied to Properties of Subgrade Material
T1	≤1.0	≥ 60%
T2	1.1 to 2.0	≥ 70%
T3	2.1 to 10.0	≥ 85%
T4	10.1 to 30.0	≥ 85%
T5	>30.0	≥ 85%

Table Q2(a)(iii): Conceptual Outline of Pavement Structures Used in ATJ 5/85 (Amendment 2013)

Pavement Structure	Traffic Category (based on million ESALs@ 80kN)				
	≤ 1	1 to 2	2.1 to 10	10.1 to 30	>30
	T1	T2	T3	T4	T5
Combined Thickness of Bituminous Layers	5 cm	10 cm	18 cm	20 cm	24 cm
Crushed Aggregate Road Base + Sub-base for Subgrade CBR of:					
o 5 to 12	23+15 cm	20+15 cm	20+20 cm	NR	NR
o 12.1 to 20	20+15 cm	20+15 cm	20+20 cm	20+20 cm	20+20 cm
o 20.1 to 30	20+10 cm	20+10 cm	20+15 cm	20+15 cm	20+15 cm
o >30	20 cm	20+10 cm	20+10 cm	20+10 cm	20+10 cm

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Table Q2(a)(iv): Summary of material use In Pavement Structure in Malaysia

NEW PAVEMENT DESIGN AND CONSTRUCTION		
DESIGNATION	**DESCRIPTION**	**ABBREVIATION/ SYMBOL**
DRAINAGE LAYER	Primarily functional granular layer with load distribution capability similar to the Sub-Base	DL
SUB-BASE COURSE	Crushed or natural granular material with maximum 10% fines	GSB
ROAD BASE COURSE		
• Crushed Aggregate	Crushed granular material with maximum 10% fines	CAB
• Wet Mix	Crushed granular material with maximum 10% fines	WMB
• Bituminous	Coarse bituminous mix (AC 28)	BB
• STB 1	Stabilised base with at least 3% Portland cement	STB1
• STB2	Stabilised base with bituminous emulsion and maximum of 2% Portland cement	STB2
BINDER COURSE		
• Binder Course	Coarse bituminous mix (AC 28)	BC
WEARING COURSE		
• Asphaltic Concrete	Medium to fine bituminous mix (AC 10 or AC 14)	BSC
• Polymer Modified Asphalt (PMA)	Medium to fine bituminous mix (AC 10 or AC 14) incorporated with polymer modified bitumen	PMA
• Stone Mastic Asphalt (SMA)	Stone mastic asphalt (SMA 14 or SMA 20)	SMA
• Porous Asphalt	Primarily functional porous asphalt (PA 10 or PA 14)	PA
• Gap-Graded Asphalt	Gap Graded Asphalt GPA I or GPA II	FC

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FIGURE Q2(a)(i): Pavement Structure for Traffic Category T1: <1million ESALs (80 kN)

Pavement Type	Sub-Grade Category			
	SG 1: CBR 5 to 12	SG 2: CBR 12.1 to 20	SG 3: CBR 20.1 to 30	SG 4: CBR > 30
Conventional Flexible: Granular Base	BSC: 50 CAB: 250 GSB: 150	BSC: 50 CAB: 200 GSB: 150	BSC: 50 CAB: 200 GSB: 100	BSC: 50 CAB: 100 GSB: 100
Deep Strength: Stabilised Base	BSC: 50 STB 2: 100 GSB: 200	BSC: 50 STB 2: 100 GSB: 150	BSC: 50 STB 2: 100 GSB: 100	BSC: 50 STB 2: 100 GSB: 100
Stabilised Base with Surface Treatment*	Surface Treatment** GSB: 300 or Surface Treatment** STB 2: 250	Surface Treatment** GSB: 300 or Surface Treatment** STB 2: 250	Surface Treatment** GSB: 250 or Surface Treatment** STB 2: 200	Surface Treatment** GSB: 250 or Surface Treatment** STB 2: 200

Notes:

* *Full Depth Asphalt Concrete Pavement is not recommended for this Traffic Category.*

** *Single or Double Layer Chip Seal or Micro-Surfacing.*

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FIGURE Q2(a)(ii): Pavement Structure for Traffic Category T2: 1.0 to 2.0 million ESALs

Pavement Type	Sub-Grade Category			
	SG 1: CBR 5 to 12	SG 2: CBR 12.1 to 20	SG 3: CBR 20.1 to 30	SG 4: CBR > 30
Conventional Flexible: Granular Base	BSC: 140 CAB: 200 GSB: 150	BSC: 140 CAB: 200 GSB: 150	BSC: 120 CAB: 200 GSB: 100	BSC: 100 CAB: 200 GSB: 100
Deep Strength: Stabilised Base	BSC: 120 STB 2: 150 GSB: 200	BSC: 120 STB 2: 150 GSB: 150	BSC: 100 STB 2: 120 GSB: 150	BSC: 100 STB 2: 120 GSB: 150
Full Depth: Asphalt Concrete Base	BSC: 50 BB: 100 GSB: 250	BSC: 50 BB: 100 GSB: 200	BSC: 50 BB: 100 GSB: 150	BSC: 50 BB: 80 GSB: 150

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FIGURE Q2(a)(iii): Pavement Structure for Traffic Category T3: 2.0 to 10.0 million ESALs (80kN)

Pavement Type	Sub-Grade Category			
	SG 1: CBR 5 to 12	SG 2: CBR 12.1 to 20	SG 3: CBR 20.1 to 30	SG 4: CBR > 30
Conventional Flexible: Granular Base	BSC: 50 BC: 130 CAB: 200 GSB: 200	BSC: 50 BC: 130 CAB: 200 GSB: 200	BSC: 50 BC: 130 CAB: 200 GSB: 150	BSC: 50 BC: 130 CAB: 200 GSB: 100
Deep Strength: Stabilised Base	BSC: 50 BC: 100 STB 1: 150 GSB: 200	BSC: 50 BC: 100 STB 1: 150 GSB: 150	BSC: 50 BC: 100 STB 1: 100 GSB: 150	BSC: 50 BC: 100 STB 1: 100 GSB: 100
Full Depth: Asphalt Concrete Base	BSC: 50 BC/BB: 160 GSB: 200	BSC: 50 BC/BB: 150 GSB: 150	BSC: 50 BC/BB: 130 GSB: 150	BSC: 50 BC/BB: 130 GSB: 100

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FIGURE Q2(a)(iv): Pavement Structure for Traffic Category T4: 10.0 to 30.0 million ESALs (80 kN)

Pavement Type	Sub-Grade Category			
	SG 1: CBR 5 to 12	SG 2: CBR 12.1 to 20	SG 3: CBR 20.1 to 30	SG 4: CBR > 30
Conventional Flexible: Granular Base	Sub-Grade Improvement is Recommended	BSC: 50 BC/BB: 150 CAB: 200 GSB: 200	BSC: 50 BC/BB: 150 CAB: 200 GSB: 150	BSC: 50 BC/BB: 150 CAB: 200 GSB: 100
Deep Strength: Stabilised Base		BSC: 50 BC/BB: 150 STB1: 120 GSB: 200	BSC: 50 BC/BB: 140 STB1: 100 GSB: 150	BSC: 50 BC/BB: 130 STB1: 100 GSB: 100
Full Depth: Asphalt Concrete Base		BSC: 50 BC/BB: 200 GSB: 200	BSC: 50 BC/BB: 180 GSB: 150	BSC: 50 BC/BB: 150 GSB: 100

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FIGURE Q2 (a)(v): Pavement Structure for Traffic Category T5: >30.0 million ESALs (80 kN)

Pavement Type	Sub-Grade Category			
	SG 1: CBR 5 to 12	SG 2: CBR 12.1 to 20	SG 3: CBR 20.1 to 30	SG 4: CBR > 30
Conventional Flexible: Granular Base	Sub-Grade Improvement is Recommended	BSC: 50 BC/BB: 190 CAB: 200 GSB: 200	BSC: 50 BC/BB: 190 CAB: 200 GSB: 150	BSC: 50 BC/BB: 190 CAB: 200 GSB: 100
Deep Strength: Stabilized Base		BSC: 50 BC/BB: 160 STB1: 150 GSB: 200	BSC: 50 BC/BB: 140 STB1: 150 GSB: 150	BSC: 50 BC/BB: 140 STB 1: 150 GSB: 100
Full Depth: Asphalt Concrete Base		BSC: 50 BC/BB: 210 GSB: 200	BSC: 50 BC/BB: 200 GSB: 150	BSC: 50 BC/BB: 180 GSB: 100

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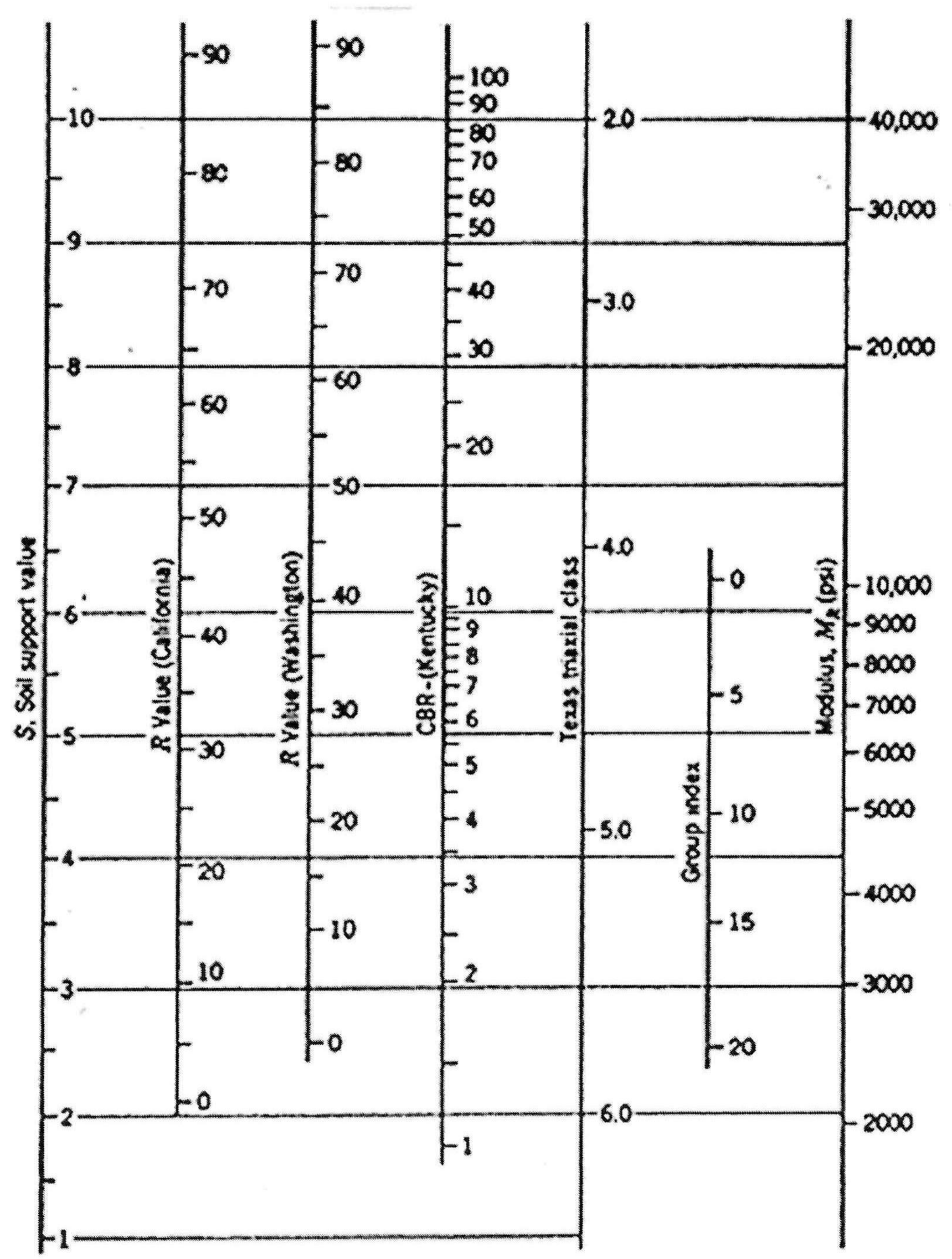

Figure Q3(c)(i) Correlation chart for estimating resilient modulus of subgrade soil

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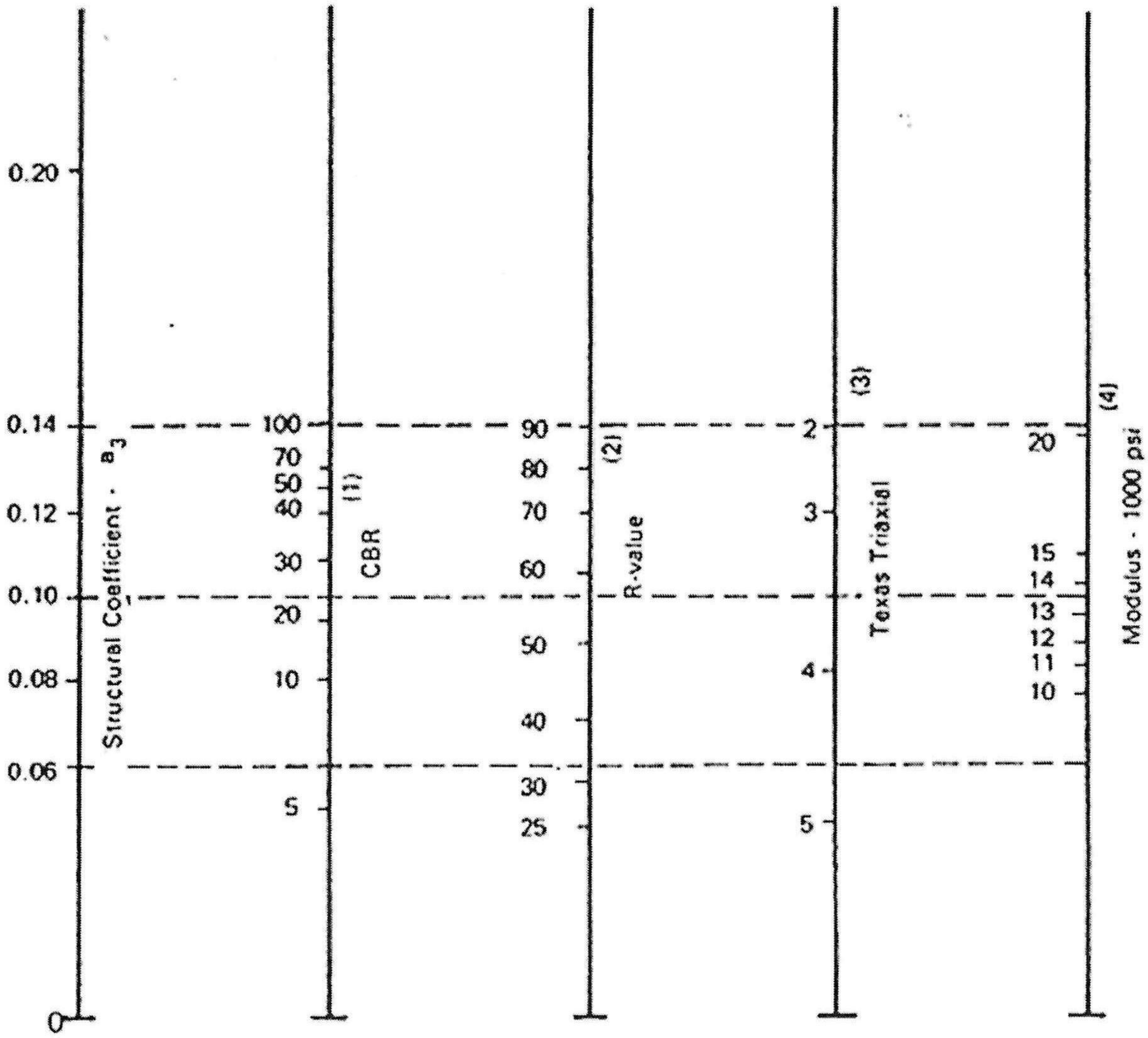

Figure Q3(c)(ii) Variation in granular subbase layer coefficient (a_3)

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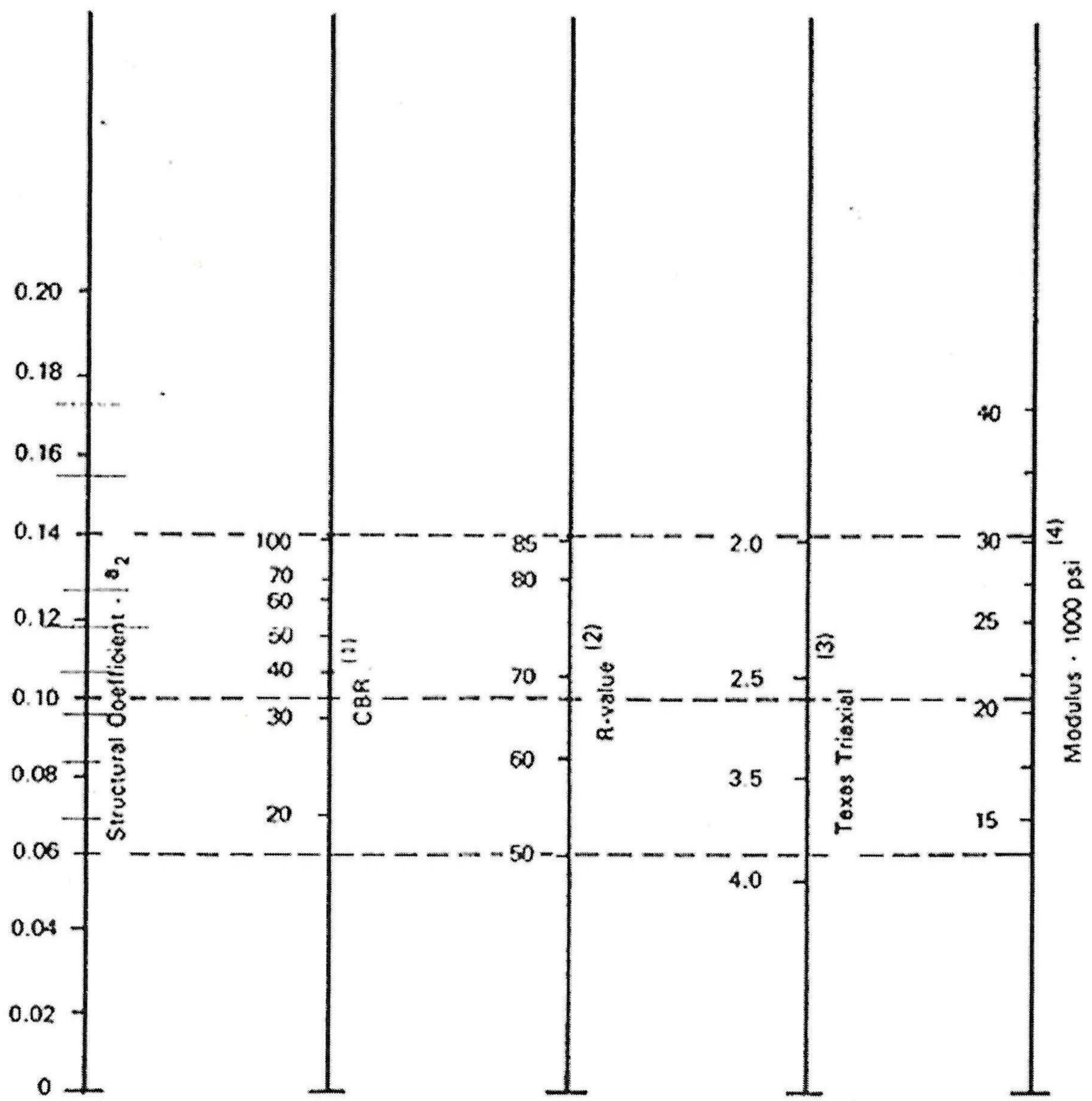

Figure Q3(c)(iii) Variation in granular base layer coefficient (a_2)

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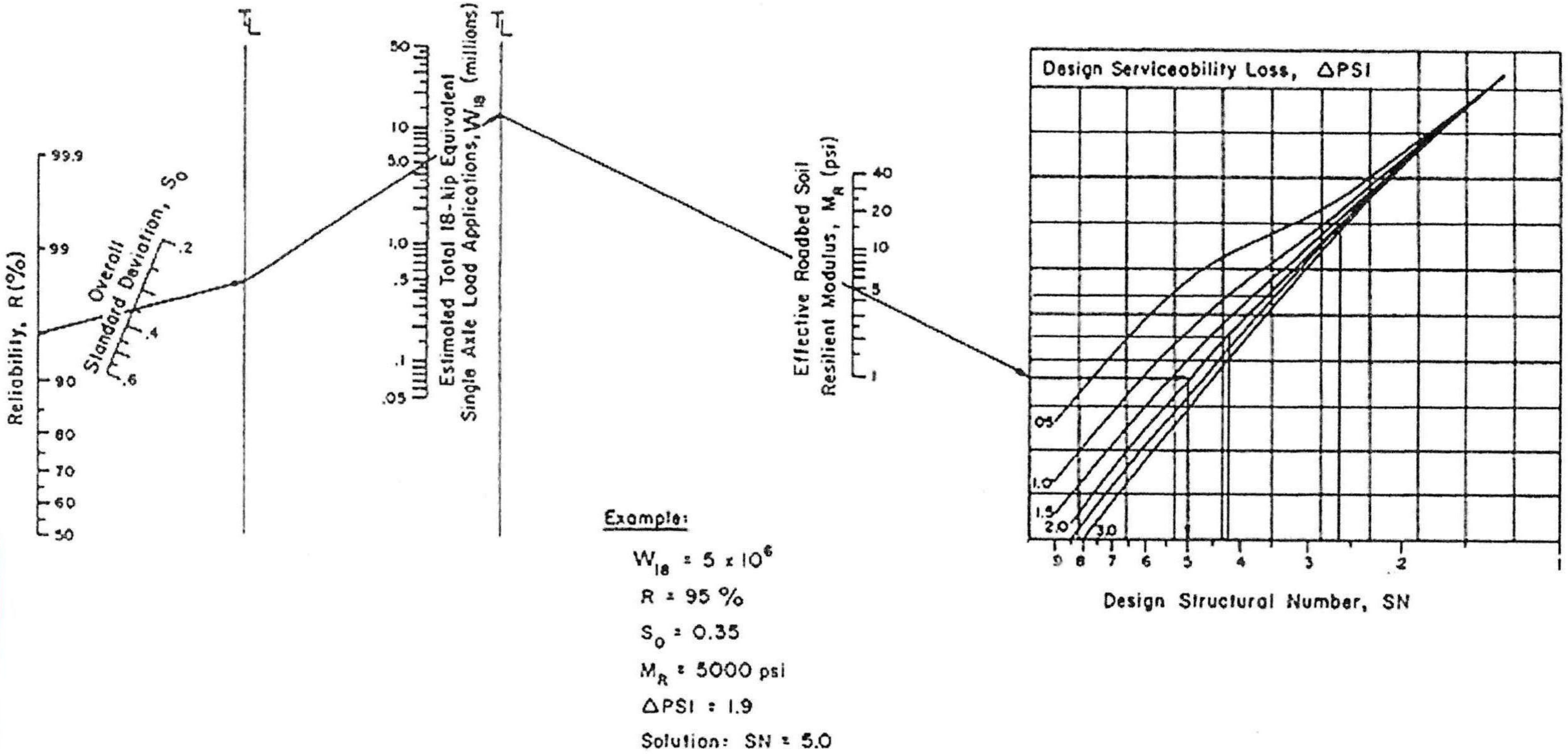

Figure Q3(c)(iv) AASHTO design chart for felxible pavement based on using mean values for each input

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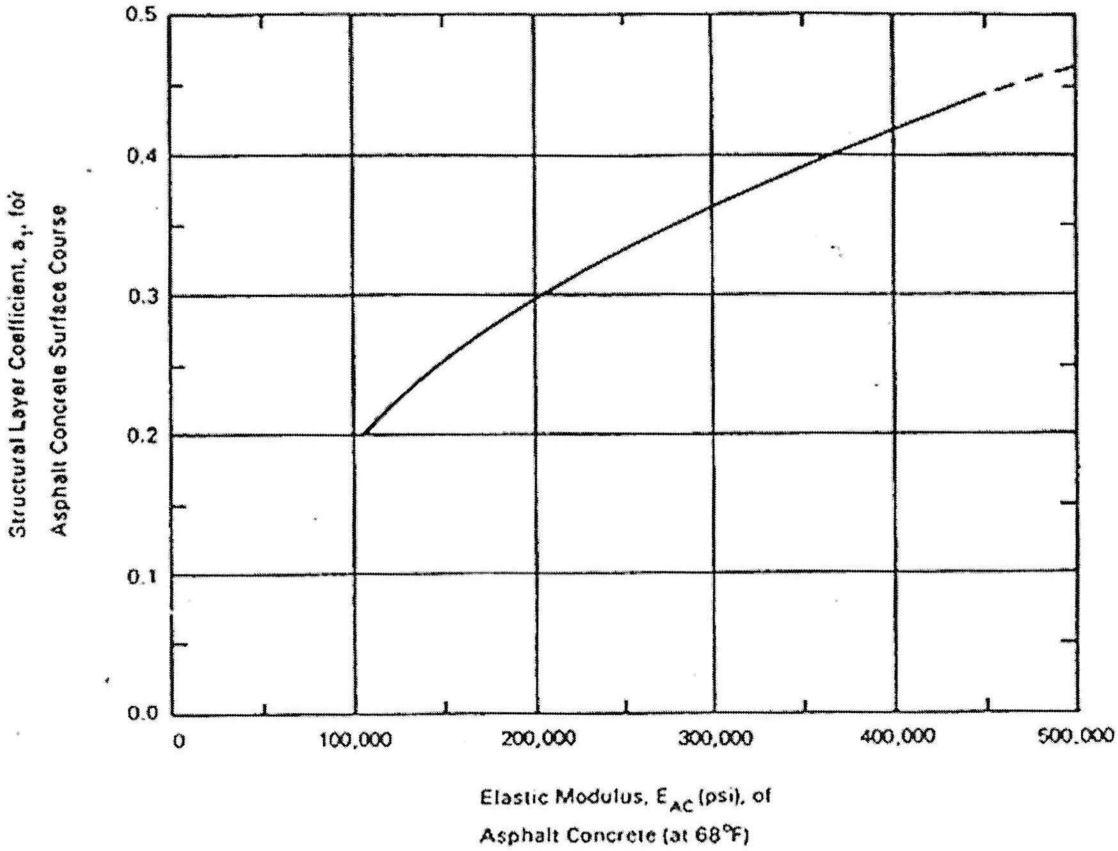

Figure Q3(c)(v) Chart for estimating structural layer coefficient of dense graded asphalt concrete base on theelastic (resilient modulus)

Table Q3(c) Recommended m value for modifying structural layer coefficient of untreated base and subbase materials in flexible pavement

	Percent of Time Pavement Structure is Exposed to Moisture Levels Approaching Saturation			
Quality of drainage	Less than 1%	1%-5%	5%-25%	Greater than 25%
Excellent	1.40-1.35	1.35-1.30	1.30-1.20	1.20
Good	1.35-1.25	1.25-1.15	1.15-1.00	1.00
Fair	1.25-1.15	1.15-1.05	1.00-0.80	0.80
Poor	1.15-1.05	1.05-0.08	0.80-0.60	0.60
Very Poor	1.05-0.95	0.95-0.75	0.75-0.40	0.40

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Table Q4(c) :- Ground level and formation level of road A

Chainage (m)	Ground level (m)	Formation level (m)
0	21	23
100	20	22
200	19	21
500	17	20
700	20	19
800	23	18

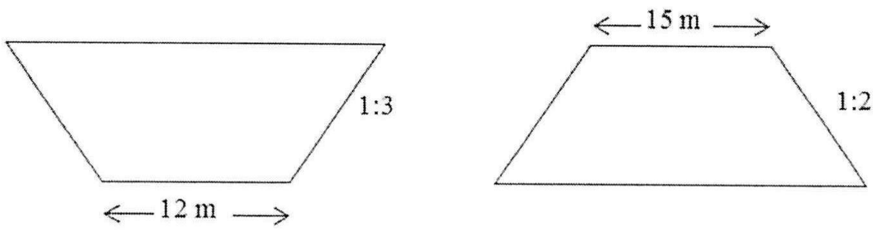

Figure Q4(c): Cross section of cutting and embankment of road A

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The following information may be useful. The symbols have their usual meaning.

$$ESAL_{Y1} = [ADT_{VC1} \times LEF_1 + ADT_{VC2} \times LEF_2 + \cdots + ADT_{VC4} \times LEF_4 +] \times 365 \times L \times T$$

$$ESAL_{Y1} = ADT \times Pc \times 365 \times 3.7 \times L \times T$$

$$ESAL_{DES} = ESAL_{Y1} \times [(1+r)^n - 1]/r$$

Desig input value = Mean – (Normal Deviate x Standard Deviation)

85% Probabilty: Mean -1.000 x STD

60% Probability: Mean -0.253 x STD

70% Probability: Mean -0.525 x STD

$$T = R \tan(\Delta/2)$$

$$C = R \sin(\Delta/2)$$

$$E = R[\sec(\Delta/2) - 1]$$

$$M = R[1 - \cos(\Delta/2)]$$

$$L = (\Delta/360)(2\pi R)$$

$$R_{min} = \frac{V^2}{127(e + f_{\square})}$$

$$A = h(b + nh)$$

$$\Delta PSI = PSI_t - PSI_i$$

$$D_1 = \frac{SN_1}{a_1 m_1}, \qquad SN_1^* \geq SN_1$$

$$D_2 = \frac{SN_2 - SN_1}{a_2 m_2}, \qquad SN_1^* + SN_2^* \geq SN_2$$

$$D_3 = \frac{SN_3 - SN_2 - SN_1}{a_3 m_3}, \qquad SN_1^* + SN_2^* + SN_3^* \geq SN_3$$