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UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION (ONLINE) SEMESTER II SESSION 2020/2021

COURSE NAME	:	HIGHWAY ENGINEERING
COURSE CODE	:	BFC31802
PROGRAMME CODE	:	BFF
EXAMINATION DATE	:	JULY 2021
DURATION	:	2 HOURS AND 30 MINUTES
INSTRUCTIONS	:	ANSWER **ALL** QUESTIONS

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

Q1 (a) Differentiate between tack coat and prime coat.

(6 marks)

(b) Discuss about a quality patching work.

(4 marks)

(c) In a Marshall test, the percentage of asphalt binder by total weight of aggregate is 5.26%. The bulk specific gravity of aggregate (Gsb) = 2.455, the specific gravity of asphalt binder (Gb) = 1.020, and the density of water (γw) = 1.000 g/cm^3. If 1 m^3 of an asphalt concrete mixture will be produce that having 2000 g and the asphalt absorbed into the aggregate is 24 gram;

(i) Calculate asphalt content, effective asphalt content and asphalt absorption.

(7 marks)

(ii) Calculate void in mineral aggregate and void filled with asphalt.

(8 marks)

Q2 (a) Recycling of asphalt material for sustainable in road pavement construction industry can be one of the largest economic and material consumption industries in the world. The use of Reclaimed Asphalt Pavement (RAP) in roadway construction fits with the overall objective of sustainable development. Explain or illustrate the use of Reclaimed Asphalt Pavement

(5 marks)

(b) Jalan Raja is suffering from widespread area of pavement distress such as raveling and bleeding. The road authority plans to rehabilitate this road at minimal cost but attempts to avoid built-up layers as it will cause pavement edge drop-off (elevation change or vertical distance between the travel lane and its adjacent shoulder, exceeds acceptable limits).

(i) Propose a suitable pavement rehabilitation method for this scenario and discuss the way to apply it to the pavement.

(3 marks)

(ii) Given that the road shoulders were raised up so that the pavement drop-off issue is resolved and the road authority eventually decides to keep the old asphalt surface as base layer. Suggest a new pavement rehabilitation method for this current scenario.

(2 marks)

(c) An urban road between two towns is being considered to be constructed as the alternative for the current road in servicing. A traffic count and the soil properties that has provided is as follows:

Daily total traffics : 10000 (40% is a commercial vehicles)

(15 marks)

Commercial vehicles (CV)	:	CV1=45%, CV3=17%, CV4=20%, CV6=16%, CV7=2%.
Subgrade CBR	:	20 %
Lane distribution factor	:	0.9
Terrain factor	:	1.0

According to the data,

(i) Calculate the ESAL and its traffic category if the total growth rate of the traffic is actually 2%.

(11 marks)

(ii) By using **Table Q2(c)(i)** to **Table Q2(c)(iv)** and **Figure Q2(c)(i)** to **Figure Q2(c)(v)** in your design, identify subgrade category and design input value of subgrade soil.

(2 mark)

(iii) Based on your finding in **Q2(c)(ii),** is it possible to use conventional flexible? Justify your answer.

(2 marks)

Q3 (a) Pavement Condition Index (PCI) Survey is developed by US Army Corps of Engineers to quantify the condition of pavement section so it will enable decision-makers to decide on the most suitable maintenance method for the pavement section. Through the fieldwork survey and then the deskwork, the PCI values, which is used to indicate the general condition of a pavement section are obtained.

List **FIVE (5)** factors that influence the PCI values and elaborate briefly the relationship of each factor with the PCI values

(5 marks)

(b) The Pavement Management System (PMS) is a series of tools that assists decision-makers in evaluating the best solutions for existing pavement conditions through assessment and maintenance of the pavement in order to ensure appropriate serviceability for a set period of time.

Generally, there are two levels of management system in PMS where they are different in implementation. Name and discuss the differences between them.

(5 marks)

(c) As an engineer, you are required to design the flexible pavement using AASHTO method for an access highway to a major truck terminal. Details for the design are as follows;

Equivalent Single Axle Load (ESAL)	=	1.0×10^6
Initial Present Serviceability Index, PSI_i	=	4.0
Terminal Present Serviceability Index, PSI_t	=	2.0
Resilient modulus of asphalt concrete, M_{R1}	=	400,000 psi
CBR of subgrade	=	8%
CBR of gravel subbase	=	30%

CBR of crushed stone base	=	100%
Exposure to moisture	=	35% of the time
Quality of surface layer drainage	=	Excellent
Quality of base layer drainage	=	Good
Quality of subbase layer drainage	=	Fairly good
Reliability, R	=	99%
Standard deviation, S_o	=	0.4

Use **Figure Q3(c)(i)** to **Figure Q3(c)(v)** for your calculation, determine:

(i) Resilient modulus for base, subbase and subgrade.
(3 marks)

(ii) Structural number for surface, base and subbase.
(3 marks)

(iii) Structural coefficient for surface, base and subbase.
(1.5 marks)

(iv) Drainage coefficient for surface, base and subbase.
(1.5 marks)

(v) The thickness of surface, base and subbase.
(4.5 marks)

(vi) Sketch the pavement layer profile
(1.5 marks)

Q4 (a) Evaluation of sustainability can help with tracking and assessing progress. List and briefly discuss the main practices of measuring road sustainability.
(5 marks)

(b) Sustainability improvements in highway engineering may not be achieved in short term. However, using a Triple Bottom Line framework to guide planning, policy decisions, and implementation can speed up process toward developing a sustainable outcome.

Draw the intended Triple Bottom Line framework and briefly explain of each one.
(5 marks)

(c) Given the end area of cut and fill of soil as in **Table Q4(c).** If the material bulks after excavation about 10% and shrink 12%. Draw the mass haul diagram and estimate how much excess cut or fill is required.

– END OF QUESTIONS –

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Table Q2(c)(i): Classes of subgrade 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(c)(ii): Traffic categories used in this manual (EAL =80 kN)

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(c)(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:					
○ **5 to 12**	23+15 cm	20+15 cm	20+20 cm	NR	NR
○ **12.1 to 20**	20+15 cm	20+15 cm	20+20 cm	20+20 cm	20+20 cm
○ **20.1 to 30**	20+10 cm	20+10 cm	20+15 cm	20+15 cm	20+15 cm
○ **>30**	20 cm	20+10 cm	20+10 cm	20+10 cm	20+10 cm

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Table Q2(c)(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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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.*

Figure Q2(c)(i): Pavement structure for traffic category T1: <1million ESALs (80 kN)

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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

Figure Q2(c)(ii): Pavement structure for traffic category T2: 1.0 to 2.0 million ESALs

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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

Figure Q2(c)(iii): Pavement structure for traffic category T3: 2.0 to 10.0 million ESALs (80kN)

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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

Figure Q2(c)(iv): Pavement structure for traffic category T4: 10.0 to 30.0 million ESALs (80 kN)

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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

Figure Q2(c)(v): Pavement structure for traffic category T5: >30.0 million ESALs (80 kN)

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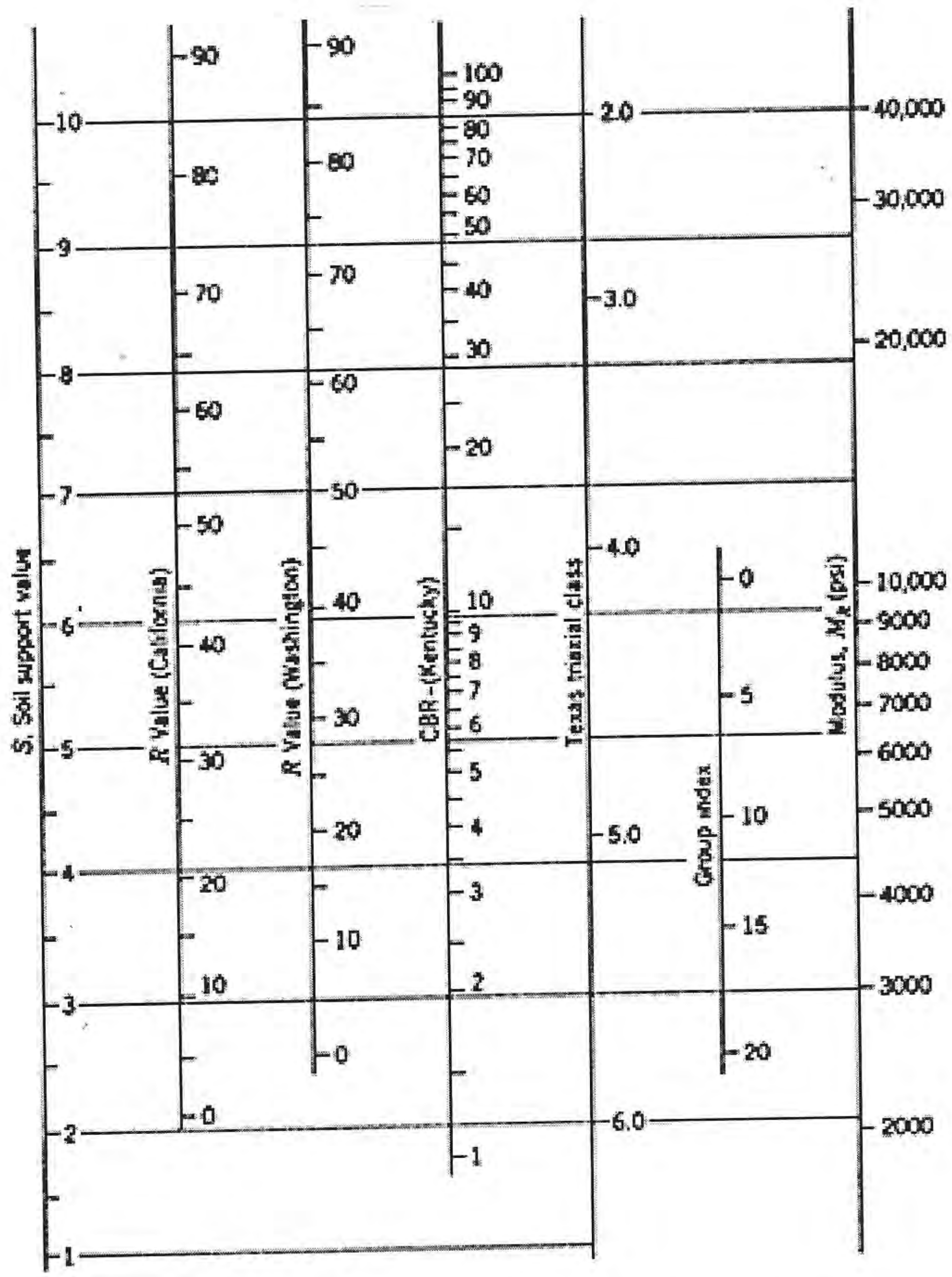

Figure Q3(c)(i): Correlation chart for estimating resilient modulus of subgrade soil

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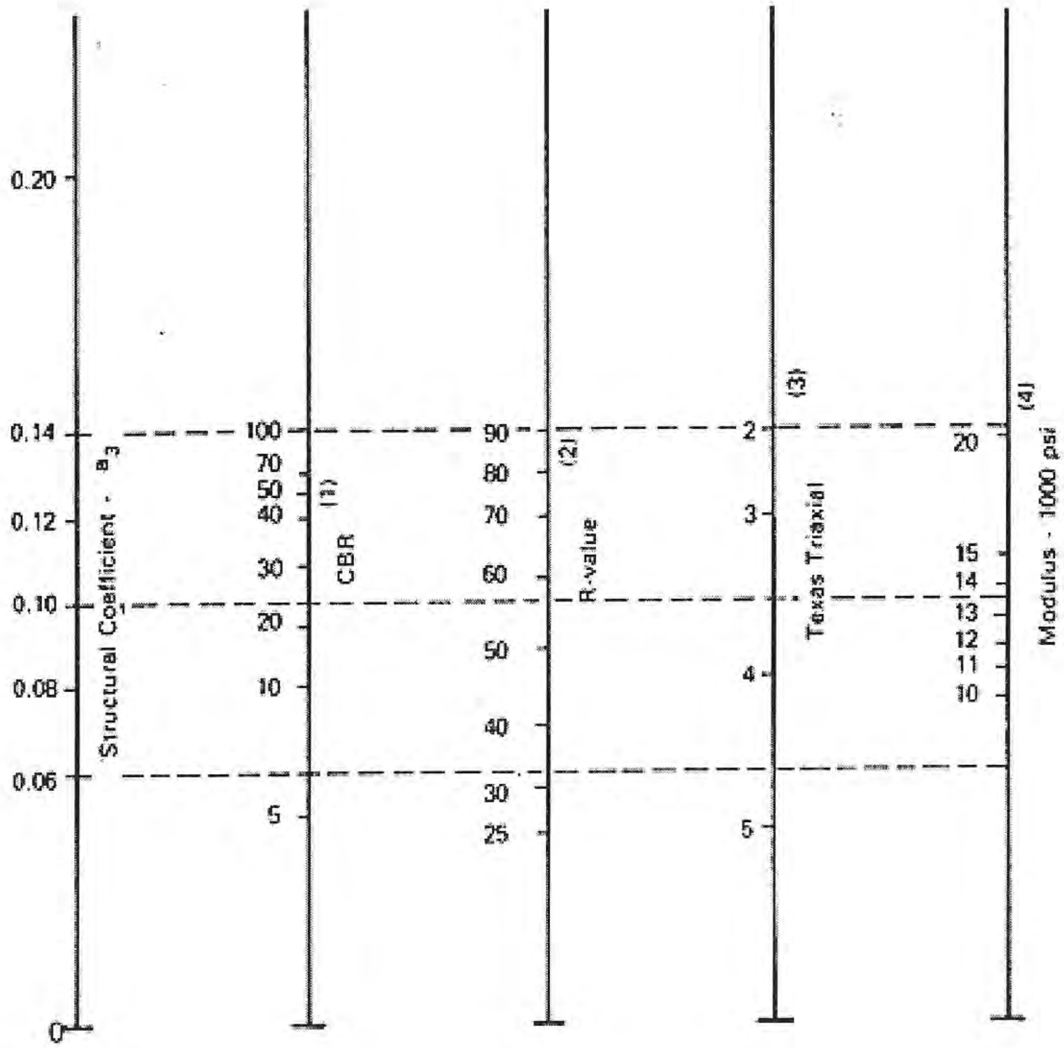

Figure Q3(c)(ii): Variation in granular subbase layer coefficient (a_3)

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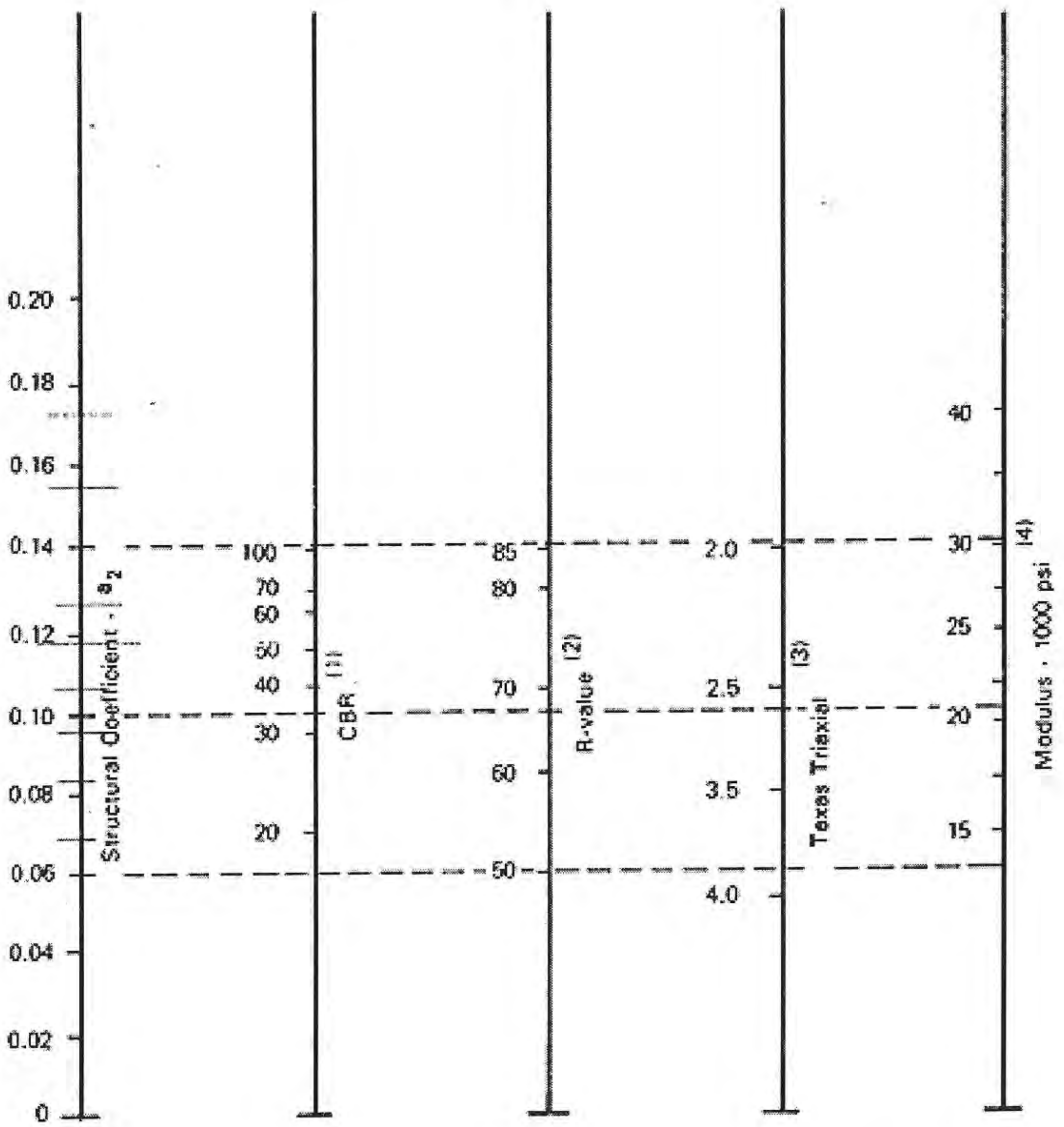

Figure Q3(c)(iii): Variation in granular base layer coefficient (a_2)

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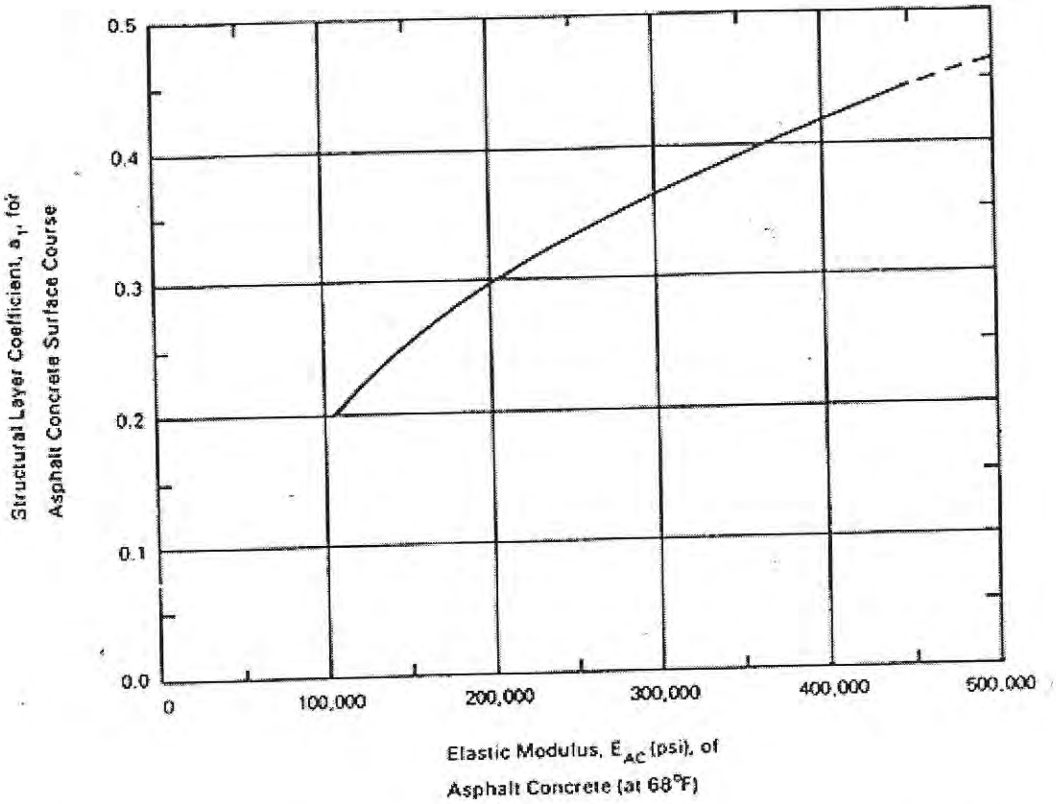

Figure Q3(c)(iv): Chart for estimating structural layer coefficient of dense graded asphalt concrete base on theelastic (resilient modulus)

Table Q3(c)(i): 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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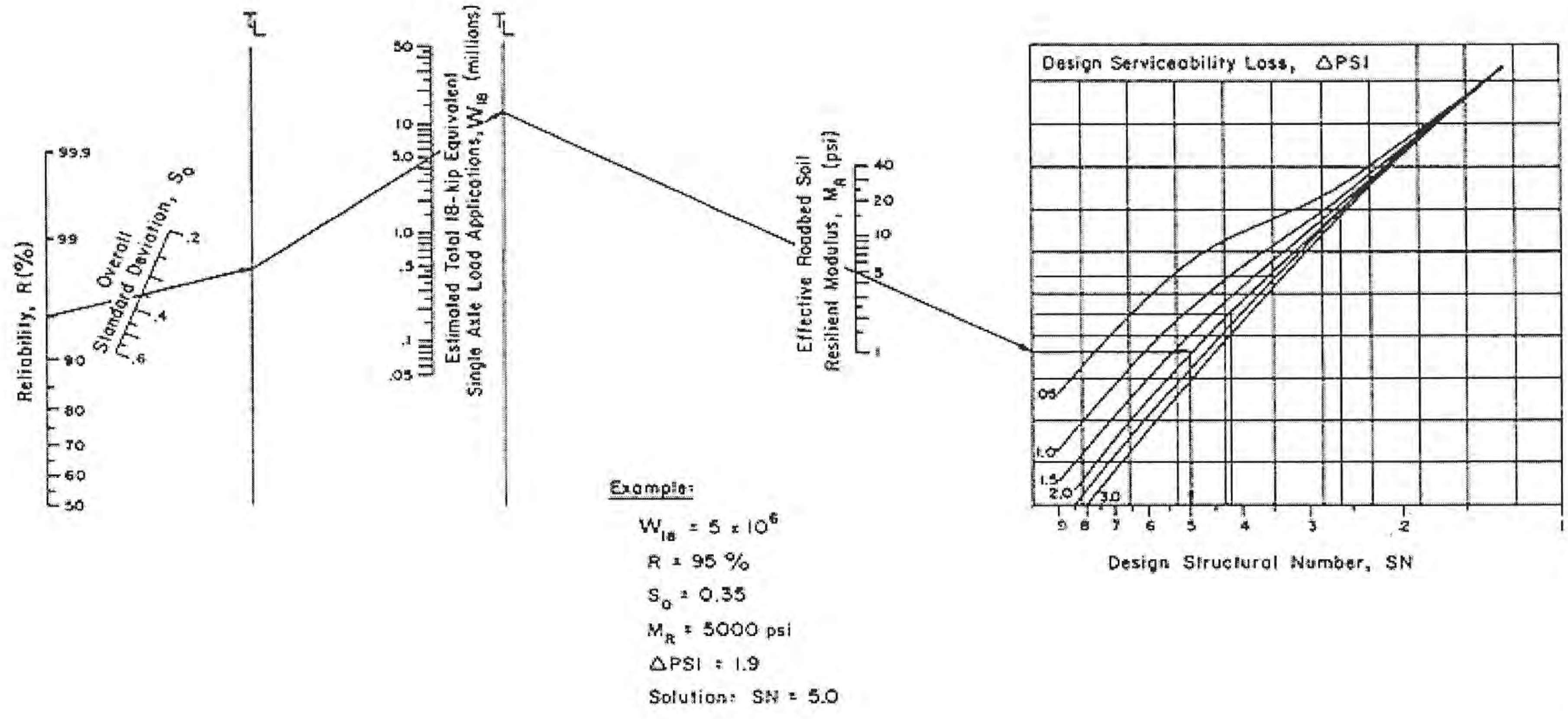

Figure Q3(c)(v): AASHTO design chart for flexible pavement based on using mean values for each input

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Table Q4(c): Cut and fill areas

Chainage	Cut and Fill area (m^2)
0	-26
1	52.28
2	23.58
3	3.73
4	-8.4
5	-63.8
6	-33.34

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

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

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

$$ESAL_{DES} = ESAL_{Y1} \times TGF$$

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

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

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

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

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

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

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

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

$$\Delta PSI = PSI_i - PSI_t$$

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

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

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

$$P_B = \frac{M_B}{M}$$

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$$P_{BA} = \frac{M_{BA}}{M_G} \qquad V_A = V - (V_G + V_{BE})$$

$$VMA = \frac{V_{BE} + V_A}{V}$$