UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
(ONLINE)
SEMESTER II
SESSION 2019/2020

COURSE NAME	:	HIGHWAY ENGINEERING
COURSE CODE	:	BFC 31802
PROGRAMME CODE	:	BFF
EXAMINATION DATE	:	JULY 2020
DURATION	:	5 HOURS AND 30 MINUTES
INSTRUCTIONS	:	ANSWER **ALL** QUESTIONS

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

Q1 (a) Differentiate between corrective and preventive rehabilitation techniques.
(5 marks)

(b) Crocodile crack is one type of pavement distress. Briefly explain **TWO (2)** possible causes and the probable treatments for this type of pavement distress.
(5 marks)

(c) **Table Q1(c)(i)** shows the number of vehicles with different classes in accordance to the traffic count of the proposed road project provided by Highway Planning Unit (HPU). The traffic count covers a time period of 16 hours. Based on this result, determine the Equivalent Standard Axle Load (ESAL) for the base year and after 20 years if a traffic growth factor is 5%. Given lane distribution, L = 1.0 and terrain factor, T = 1.1. Refer **Table Q1(c)(ii)** in your calculation.
(7 marks)

(d) You have been asked to design the flexible pavement for an access highway to a major truck terminal. Given the design traffic over 20 years is 9.7 million. For the sub-grade, a series of CBR tests were conducted. The CBR for subgrade has been analysed with normal distribution and probability of 85%, CBR Mean = 16.7% and Standard Deviation = 4.5 %. Based on the information given, determine the thickness of the proposed road. Use **Table Q1(c)(ii)**, **Table Q1(d)(i)** to **Table Q1(d)(iv)** and **Figure Q1(d)(i)** to **Figure Q1(d)(v)** for your calculation.
(8 marks)

Q2 (a) State the activities involved in Pavement Management System (PMS).
(5 marks)

(b) Briefly discuss **TWO (2)** basic components in Pavement Management System (PMS).
(5 marks)

(c) The Point of Intersection (P.I) of two tangent lines is station 1115+20. The radius of curvature is 275 m, and the angle of deflection is 52°. Based on the information, estimate the following parameters:

(i) Length of the curve (L)
(3 marks)

(ii) Length of the Long Chord (L.C)
(3 marks)

(iii) Length of the Middle Ordinate (M)
(3 marks)

(iv) Length of External Distance (E)
(3 marks)

(v) The station for the Point of Curvature (P.C) and Point of Tangency (P.T)
(3 marks)

Q3 (a) **Figure Q3(a)** shows the longitudinal profile of a site for a proposed highway. The distance and corresponding volume of soil to be cut or filled are indicated in the figure. Assume that the shrinkage and bulking factors are equal to 1.0.

(i) Construct a Mass Haul Diagram.

(8 marks)

(ii) Determine the volume and direction of haul using table in **Figure Q3(a).**

(5 marks)

(iii) Determine the volume of borrow or waste (if any).

(2 marks)

(b) The embankment of a proposed alternative road from Parit Raja to Batu Pahat is 10 km long. The average cross section of the embankment is shown in **Figure Q3(b).** The specification requires the embankment to be compacted to 95% of the maximum dry density according to the B.S 1377 Compaction Test (2.5 kg rammer method). **Table Q3(b)** present the density of laboratory and borrow material at various conditions

(i) Determine the volume of borrow pit material needed for 1 m^3 of the compacted road embankment.

(5 marks)

(ii) Determine the volume of additional water needed for the whole volume of embankment.

(5 marks)

Q4 (a) Pavement performance is an important factor in pavement design because it provides a framework upon which a judgement on the road is either success or failure, which is associated with the ability of the pavement to carry out the design loading. Based on these statements, briefly discuss a distinction between the two different types of failures.

(5 marks)

(b) Discuss on how to evaluate whether a pavement should be rehabilitated or else based on the characteristics of pavement condition. Explain in detail steps of the evaluation.

(10 marks)

(c) A sustainable and environmental friendly construction method includes recycling techniques for road construction. Explain how this technique may benefit both the environment and construction player.

(10 marks)

- END OF QUESTIONS –

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TABLE Q1(c)(i): Average daily traffic (ADT) of the different vehicle classes

Vehicle		**Average Daily Traffic (ADT)**
HPU class designation	**Class**	
Cars and taxis	C	2640
Small trucks and vans	CV1	100
Large trucks	CV2	120
Articulated trucks	CV3	250

TABLE Q1(c)(ii): Axle configuration and load equivalence factors (LEF)

Vehicle		**Average Daily Traffic (ADT)**
HPU class designation	**Class**	
Cars and taxis	C	0
Small trucks and vans	CV1	0.1
Large trucks	CV2	4
Articulated trucks (3 or more axles)	CV3	4.4
Buses (2 or 3 axles)	CV4	1.8
Motorcycles	MC	0
Commercial Traffic (Mixed)	CV%	3.7

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TABLE Q1(d)(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 Q1(d)(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 Q1(d)(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 Q1(d)(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(d)(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(d)(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(d)(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(d)(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

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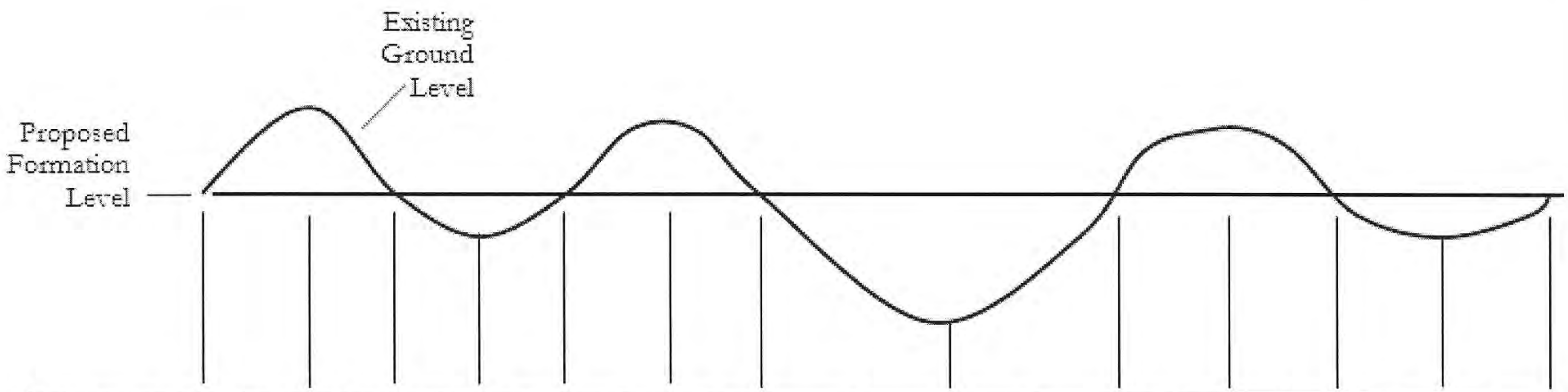

Distance (m)	105	75	70	60	85	80	130	100	80	80	55	80
Volume (m^3)	3,615	3,216	7,012	3,314	9,315	5,622	4,435	4,578	2,077	3,670	4,336	3,282
Cut (m^3)												
Fill (m^3)												
Haul (m^3)												
Borrow (m^3)												
Waste (m^3)												

FIGURE Q3(a): Longitudinal profile of a site for a proposed highway

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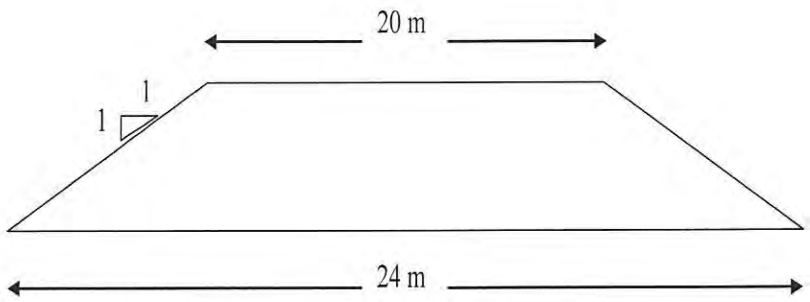

FIGURE Q3(b) Cross section of the embankment

TABLE Q3(b) Density and moisture content of the soil

Laboratory Compaction Test		In-situ (borrow pit)	
Maximum Dry density (Mg/m^3)	Optimum moisture content (%)	Bulk density (Mg/m^3)	Natural moisture content (%)
1.56	12	1.88	9.6

$$\text{Bulking factor} = \frac{\text{Volume before excavation}}{\text{Volume after excavation}} = 1.25$$

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

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

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

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

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

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

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

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

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

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

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

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

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

$$\Delta PSI = PSI_i - PSI_t$$

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

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

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