CONFIDENTIAL

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2015/2016

COURSE NAME	:	HIGHWAY ENGINEERING
COURSE CODE	:	BFC 31802
PROGRAMME CODE	:	BFF
EXAMINATION DATE	:	JUNE / JULY 2016
DURATION	:	2 HOURS AND 30 MINUTES
INSTRUCTION	:	ANSWER **FOUR (4)** QUESTIONS ONLY

THIS QUESTION PAPER CONSISTS OF **TWENTY ONE (21)** PAGES

Q1 (a) Emulsified bitumen is one of the types of bitumen which is available in the industry.

(i) List **TWO (2)** types of this bitumen.

(2 marks)

(ii) Based on the answers in Q1(a)(i), simplify the purpose of having different types of emulsified bitumen.

(2 marks)

(b) An asphalt concrete mix contains 2250 kg of aggregate and 150 kg of asphalt binder per m3. Asphalt absorption of the aggregates is 1.2%. The bulk relative density of the aggregates is 2.67, and the relative density of the asphalt is 1.05. Determine the asphalt concrete:

(i) Density

(ii) Asphalt content, effective asphalt content and asphalt absorption.

(iii) Void in mineral aggregate (VMA) and void filled with asphalt (VFA).

(9 marks)

(c) Asphalt concrete mixture of AC14 will be used to construct the wearing course layer. Prior to the production of the mixture, the blending of aggregate need to be performed and must fulfill the gradation limit according to the specification as shown in Table 1(c)(i). Table 1(c)(ii) shows the results of sieve analysis test for the blending aggregates. Conduct the analysis of the test result and justify whether the gradation of the blended aggregates comply with the specification.

(12 marks)

Q2 (a) The design procedure used in ATJ 5/85 (Amendment 2013) is based on traditional concepts of pavement design, which is on the assumption that two strains are critical to pavement performance. Using the aid of diagram, name the strains and sketch their location.

(4 marks)

(b) Calculate load factor for the following trucks trafficking if equivalent standard axle load (ESAL) is 8.16 tonnes.

(i) A 9 tonnes truck with load 4.2 tonnes weight of wires and cables.

(2 marks)

(ii) A 3 tonnes lorry with unladen.

(2 marks)

(iii) A 5 tonnes articulate lorry without trailers for goods at the back.

(2 marks)

(c) You have been asked to design the pavement for an access highway to a major truck terminal. The design daily truck traffic is 20% from the average daily traffic of 30,000. The daily trafficking on the road as given in Table 2(c)(i). Annual traffic growth rate is 5%. The highway is to be designed with rigid pavement with doweled joints and concrete shoulders. A concrete modulus of rupture is 4137 kPa and subbase-subgrade k value is 33 MPa/m. If a 20 years design life to be used, determine the required slab thickness. Start the calculation with trial thickness of 190 mm. Use the calculation form as shown in Table 2(c)(ii), Figure Q2(a) to Figure Q2(c) and Table 2(c)(iii) to Table 2(c)(vi).

(15 marks)

Q3 (a) Quality has become one of the most important factors in the selection of products and provision of services. For road construction, the quality of the work has been controled by implementing the quality assurance.

(i) List any **THREE (3)** activities commonly carried out in quality assurance in road construction.

(3 marks)

(ii) According to American Association Society Highway Transportation (AASHTO), there are three key components which are designated to define quality assurance. State all the components.

(3 marks)

(b) Excavation increases the volume of material. It is therefore necessary to use a bulking factor to determine the volume of material that will be created by excavation. Based on this statement:

(i) Define the bulking factor.

(2 marks)

(ii) Determine the volume of the soil after an excavation of 300 m^3 of soil. The bulking factor of the soil is 40 %.

(4 marks)

(c) A new road from Parit Hamid to Senggarang (J9) has been constructed by Public Work Department (JKR). Currently, the progress of the work is the construction of the road base layer. This layer use the crushed rock aggregate and has been mechanically stabilized by conducting compaction using the roller compacter. Field density evaluation based on sand replacement test method was conducted to the road base layer. As site engineer, you are required to calculate the degree of the compaction of the road base layer. Based on your calculation, determine whether the compaction work fulfills the requirement, subjected to the dry density of the layer shall be at least 95% of the maximum dry density. The result of sand replacement and moisture content test is shown in Table 3(c)(i) and Table 3(c)(ii).

Useful information:

Bulk density of sand, ρ_s : 1225.71 kg/m^3
Maximum dry density of the crushed rock aggregate : 2141 kg/m^3
Mass of sand in cone (after pouring) : 1.205 kg

(13 marks)

Q4 (a) Differentiate the criteria of selection for rehabilitation work between full depth reconstruction and partial depth reconstruction.

(6 marks)

(b) Prior to conducting pavement maintenance, the distressed road surface is needed to be evaluated. This evaluation is important to identify the appropriate maintenance method.

(i) List **TWO (2)** types of pavement evaluation and state the purpose of each type.

(4 marks)

(ii) Based on the types of evaluation in Q4(b)(i), categorize each evaluation based on its pavement function and characteristics of each function.

(4 marks)

(c) Table 4(c) shows a pavement condition survey for sample Unit 1, Section JPB-KM2 of Jalan Universiti. Determine the Pavement Condition Index for this sample unit. Use Figure Q4(c)(i) to Figure Q4(c)(viii) for the calculation.

(11 marks)

Q5 (a) Drainage is the most important aspect that determines the performance of a road. Failure of roads is often attributed to poor drainage. Based on that statement, list **TWO (2)** main categories of road drainage.

(2 marks)

(b) Road surface should be constructed and maintained with sufficient cross-fall to shed the storm water to the edges and into the side drains. For this purpose the following cross-falls are normally adopted.

(i) State the percentage cross-falls for paved roads, earth and gravel roads and shoulder.

(3 marks)

(ii) If a height of the fall is 18m and the length of the base is 4m, calculate the percentage of this cross-fall and show its diagram.

(4 marks)

(c) Normally roads without paved shoulder will always have defects such as the shoulder is higher than the carriageway. Discuss the main causes of this defect and mention remedial measures.

(6 marks)

(d) Surface drains are designed based on the open channel flow theory by using the Manning formula.

(i) Derive the equation that is used to determine the value of design discharge.

(5 marks)

(ii) The main function of surface drainage is to remove rain water from the road surface and road shoulder. Design a minimum cross section of the drain if the allowable velocity of flow is 0.5 m/sec and quantity of water that is expected to flow in an open channel is 1.5 m^3/sec.

(5 marks)

- END OF QUESTIONS –

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Table 1(c)(i): Gradation limits for asphaltic concrete wearing course (AC 14)

BS Sieve Size (mm)	Percentage passing by weight
20.0	100
14.0	90 – 100
10.0	76 – 86
5.0	50 – 62
3.35	40 – 54
1.18	18 – 34
0.425	12 – 24
0.150	6 – 14
0.075	4 – 8

Table 1(c)(ii): Sieve analysis test result for blend aggregates

BS Sieve Size (mm)	Mass Retained (g)
20.0	0
14.0	440
10.0	625
5.0	1305
3.35	235
1.18	1360
0.425	60
0.150	285
0.075	430
Pan	260

Table 2(c)(i): Axle load of truck trafficking on the road design

Axle load	
SINGLE Axle	TANDEM Axle
125	231
107	213
98	178
80	142

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Table 2(c)(ii): Rigid pavement design spreadsheet

Calculation of Pavement Thickness

Trial Thickness : 190mm
Modulus of Rupture, MR :
Load Safety factor, LSF : 1.2

Doweled joints :
Conrete shoulder :
Design period : 20 years

Axle load (kN)	Multiplied by LSF	Expected repetitions	Fatigue analysis		Erosion analysis	
			Allowable repetitions	Fatigue percent	Allowable repetitions	Damage, percent
1	2	3	4	5	6	7

8. Equivalent stress :
9. Stress ratio factor :

10. Erosion factor:

Single Axle

11. Equivalent stress :
12. Stress ratio factor :

13. Erosion factor:

Tandem Axle

			Total		Total	

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Table 2(c)(iii): Axle Load Data

(1) Axle load, kN	(2) Axles per 1000 trucks	(3) Axles per 1000 trucks (adjusted)	(4) Axles in design period
Single axles			
125-133	0.28	0.58	6,310
115-125	0.65	1.35	14,690
107-115	1.33	2.77	30,140
97.8-107	2.84	5.92	64,410
88.8-97.8	4.72	9.83	106,900
80.0-88.8	10.40	21.67	235,800
71.1-80.0	13.56	28.24	307,200
62.2-71.1	18.64	38.83	422,500
53.3-62.2	25.89	53.94	586,900
44.4-53.3	81.05	168.85	1,837,000
Tandem axles			
213-231	0.94	1.96	21,320
195-213	1.89	3.94	42,870
178-195	5.51	11.48	124,900
160-178	16.45	34.27	372,900
142-160	39.08	81.42	885,800
125-142	41.06	85.54	930,700
107-125	73.07	152.23	1,656,000
88.8-107	43.45	90.52	984,900
71.1-88.8	54.15	112.81	1,227,000
53.3-71.1	59.85	124.69	1,356,000

Columns 1 and 2 derived from loadometer W-4 Table. This table also shows 13,215 total trucks counted with 6,918 two-axle, four-tire trucks (52%).
Column 3: Column 2 values adjusted for two-axle, four-tire trucks; equal to Column 2/(1-52/100).
Column 4 = Column 3 x (trucks in design period)/1000. See sample problem, Design 1, in which trucks in design period (one direction) total 10,880,000.

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Table 2(c)(iv): Equivalent Stress –Concrete Shoulder (Single Axle/Tandem Axle)

Slab thickness (mm)	*k* of subgrade-subbase (MPa/m)					
	20	40	60	80	140	180
100	4.18/3.48	3.65/3.10	3.37/2.94	3.19/2.85	2.85/2.74	2.72/2.72
110	3.68/3.07	3.23/2.71	2.99/2.56	2.83/2.47	2.55/2.35	2.43/2.32
120	3.28/2.75	2.88/2.41	2.67/2.26	2.54/2.17	2.29/2.05	2.19/2.02
130	2.95/2.49	2.60/2.17	2.41/2.02	2.29/1.94	2.07/1.82	1.99/1.78
140	2.68//2.27	2.36/1.97	2.19/1.83	2.08/1.75	1.89/1.63	1.81/1.59
150	2.44/2.08	2.15/1.80	2.00/1.67	1.90/1.59	1.73/1.48	1.66/1.44
160	2.24/1.93	1.97/1.66	1.84/1.53	1.75/1.46	1.59/1.35	1.53/1.31
170	2.06/1.79	1.82/1.54	1.70/1.42	1.62/1.35	1.48/1.24	1.42/1.20
180	1.91/1.67	1.69/1.43	1.57/1.32	1.50/1.25	1.37/1.15	1.32/1.11
190	1.77/1.57	1.57/1.34	1.46/1.23	1.40/1.17	1.28/1.07	1.23/1.03
200	1.65/1.48	1.46/1.26	1.37/1.16	1.30/1.10	1.19/1.00	1.15/0.96
210	1.55/1.40	1.37/1.19	1.28/1.09	1.22/1.03	1.12/0.93	1.08/0.90
220	1.45/1.32	1.29/1.12	1.20/1.03	1.15/0.97	1.05/0.88	1.01/0.85
230	1.37/1.26	1.21/1.07	1.13/0.98	1.08/0.92	0.99/0.83	0.96/0.80
240	1.29/1.20	1.15/1.01	1.07/0.93	1.02/0.87	0.94/0.79	0.90/0.76
250	1.22/1.14	1.08/0.97	1.01/0.88	0.97/0.83	0.89/0.75	0.86/0.72
260	1.16/1.09	1.03/0.92	0.96/0.84	0.92/0.79	0.84/0.71	0.81/0.68
270	1.10/1.04	0.98/0.88	0.91/0.81	0.87/0.76	0.80/0.68	0.77/0.65
280	1.05/1.00	0.93/0.85	0.87/0.77	0.83/0.73	0.76/0.65	0.74/0.62
290	1.00/0.96	0.89/0.81	0.83/0.74	0.79/0.70	0.73/0.62	0.70/0.60
300	0.95/0.93	0.85/0.78	0.79/0.71	0.76/0.67	0.70/0.60	0.67/0.57
310	0.91/0.89	0.81/0.75	0.76/0.69	0.72/0.64	0.67/0.58	0.64/0.55
320	0.87/0.86	0.78/0.73	0.73/0.66	0.69/0.62	0.64/0.55	0.62/0.53
330	0.84/0.83	0.74/0.70	0.70/0.64	0.67/0.60	0.61/0.53	0.59/0.51
340	0.80/0.80	0.71/0.68	0.67/0.62	0.64/0.58	0.59/0.52	0.57/0.49
350	0.77/0.78	0.69/0.66	0.64/0.60	0.61/0.56	0.57/0.50	0.55/0.47

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Table 2(c)(v): Erosion Factor-Doweled Joints, No Concrete Shoulder (Single Axle/ Tandem Axle)

Slab thickness (mm)	*k* of subgrade-subbase (MPa/m)					
	20	40	60	80	140	180
100	3.76/3.8	3.752/3.79	3.74 /3.77	3.74/3.76	3.72/3.72	3.70/3.70
110	3.63/3.71	3.62/3.67	3.61/3.65	3.61/3.63	3.59/3.60	3.58/3.58
120	3.52/3.61	3.50/3.56	3.49/3.54	3.49/3.52	3.47/3.49	3.46/3.47
130	3.74/3.52	3.39/3.47	3.39/3.44	3.38/3.43	3.37/3.39	3.35/3.37
140	3.31/3.43	3.30/3.38	3.29/3.35	3.28/3.33	3.27/3.30	3.26/3.28
150	3.22/3.36	3.21/3.30	3.20/3.27	3.19/3.25	3.17/3.21	3.16/3.19
160	3.14/3.28	3.12/3.22	3.11/3.19	3.10/3.17	3.09/3.13	3.08/3.12
170	3.06/3.22	3.04/3.15	3.03/3.12	3.02/3.10	3.01/3.06	3.00/3.04
180	2.99/3.16	2.97/3.09	2.96/3.06	2.95/3.03	2.93/2.99	2.92/2.97
190	2.92/3.10	2.90/3.03	2.88/2.99	2.88/2.97	2.86/2.93	2.85/2.91
200	2.85/3.05	2.83/2.97	2.82/2.94	2.81/2.91	2.79/2.87	2.78/2.85
210	2.79/2.99	2.77/2.92	2.75/2.88	2.75/2.86	2.73/2.81	2.72/2.79
220	2.73/2.95	2.71/2.87	2.69/2.83	2.69/2.80	2.67/2.76	2.66/2.73
230	2.67/2.90	2.65/2.82	2.64/2.78	2.63/2.75	2.61/2.70	2.60/2.68
240	2.62/2.86	2.60/2.78	2.58/2.73	2.57/2.71	2.55/2.66	2.54/2.63
250	2.57/2.8	2 2.54/2.73	2.53/2.69	2.52/2.66	2.50/2.61	2.49/2.59
260	2.52/2.78	2.49/2.69	2.48/2.65	2.47/2.62	2.45/2.56	2.44/2.54
270	2.47/2.74	2.44/2.65	2.43/2.61	2.42/2.58	2.40/2.52	2.39/2.50
280	2.42/2.71	2.40/2.62	2.38/2.57	2.37/2.54	2.35/2.48	2.34/2.46
290	2.38/2.67	2.35/2.58	2.34/2.53	2.33/2.50	2.31/2.44	2.30/2.42
300	2.34/2.64	2.31/2.55	2.30/2.50	2.29/2.46	2.26/2.41	2.26/2.38
310	2.29/2.61	2.27/2.51	2.25/2.46	2.24/2.43	2.22/2.37	2.21/2.34
320	2.25/2.58	2.23/2.48	2.21/2.43	2.20/2.40	2.18/2.33	2.17/2.31
330	2.21/2.55	2.19/2.45	2.17/2.40	2.16/2.36	2.14/2.30	2.13/2.28
340	2.18/2.52	2.15/2.42	2.14/2.37	2.12/2.33	2.10/2.27	2.09/2.24
350	2.14/2.49	2.11/2.39	2.10/2.34	2.09/2.30	2.07/2.24	2.06/2.21

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Table 2(c)(vi): Erosion Factor-Doweled Joints, Concrete Shoulder (Single Axle /Tandem Axle)

Slab thickness (mm)	*k* of subgrade-subbase (MPa/m)					
	20	40	60	80	140	180
100	3.27/3.25	3.24/3.17	3.22/3.14	3.21/3.12	3.17/3.11	3.15/3.11
110	3.16/3.16	3.12/3.07	3.10/3.03	3.09/3.00	3.05/2.98	3.03/2.97
120	3.05/3.08	3.01/2.98	2.99/2.93	2.98/2.90	2.94/2.86	2.92/2.84
130	2.96/3.01	2.92/2.90	2.89/2.85	2.88/2.81	2.84/2.76	2.82/2.74
140	2.87/2.94	2.82/2.83	2.80/2.77	2.78/2.74	2.75/2.67	2.73/2.65
150	2.79/2.88	2.74/2.77	2.72/2.71	2.70/2.67	2.67/2.60	2.65/2.57
160	2.71/2.82	2.66/2.71	2.64/2.65	2.62/2.60	2.59/2.53	2.57/2.50
170	2.64/2.77	2.59/2.65	2.57/2.59	2.55/2.55	2.51/2.46	2.49/2.43
180	2.57/2.72	2.52/2.60	2.50/2.54	2.48/2.49	2.44/2.41	2.42/2.37
190	2.51/2.67	2.46/2.56	2.43/2.49	2.41/2.44	2.38/2.35	2.36/2.32
200	2.45/2.63	2.40/2.51	2.37/2.44	2.35/2.40	2.31/2.31	2.30/2.27
210	2.39/2.58	2.34/2.47	2.31/2.40	2.29/2.35	2.26/2.26	2.24/2.22
220	2.34/2.54	2.29/2.43	2.26/2.36	2.24/2.31	2.20/2.22	2.18/2.18
230	2.29/2.50	2.23/2.39	2.21/2.32	2.19/2.27	2.15/2.18	2.13/2.13
240	2.24/2.46	2.18/2.35	2.16/2.28	2.13/2.23	2.10/2.14	2.08/2.10
250	2.19/2.43	2.14/2.31	2.11/2.24	2.09/2.20	2.05/2.10	2.03/2.06
260	2.15/2.39	2.09/2.28	2.06/2.21	2.04/2.16	2.00/2.07	1.98/2.02
270	2.10/2.36	2.05/2.24	2.02/2.18	2.00/2.13	1.96/2.03	1.94/1.99
280	2.06/2.32	2.01/2.21	1.98/2.14	1.95/2.10	1.91/2.00	1.89/1.96
290	2.02/2.29	1.97/2.18	1.93/2.11	1.91/2.06	1.87/1.97	1.85/1.93
300	1.98/2.26	1.93/2.15	1.90/2.08	1.87/2.03	1.83/1.94	1.81/1.90
310	1.95/2.23	1.89/2.12	1.86/2.05	1.84/2.01	1.79/1.91	1.77/1.87
320	1.91/2.20	1.85/2.09	1.82/2.03	1.80/1.98	1.76/1.88	1.74/1.84
330	1.87/2.17	1.82/2.06	1.78/2.00	1.76/1.95	1.72/1.86	1.70/1.81
340	1.84/2.15	1.78/2.04	1.75/1.97	1.73/1.92	1.69/1.83	1.67/1.79
340	1.81/2.12	1.75/2.01	1.72/1.95	1.69/1.90	1.65/1.80	1.63/1.76

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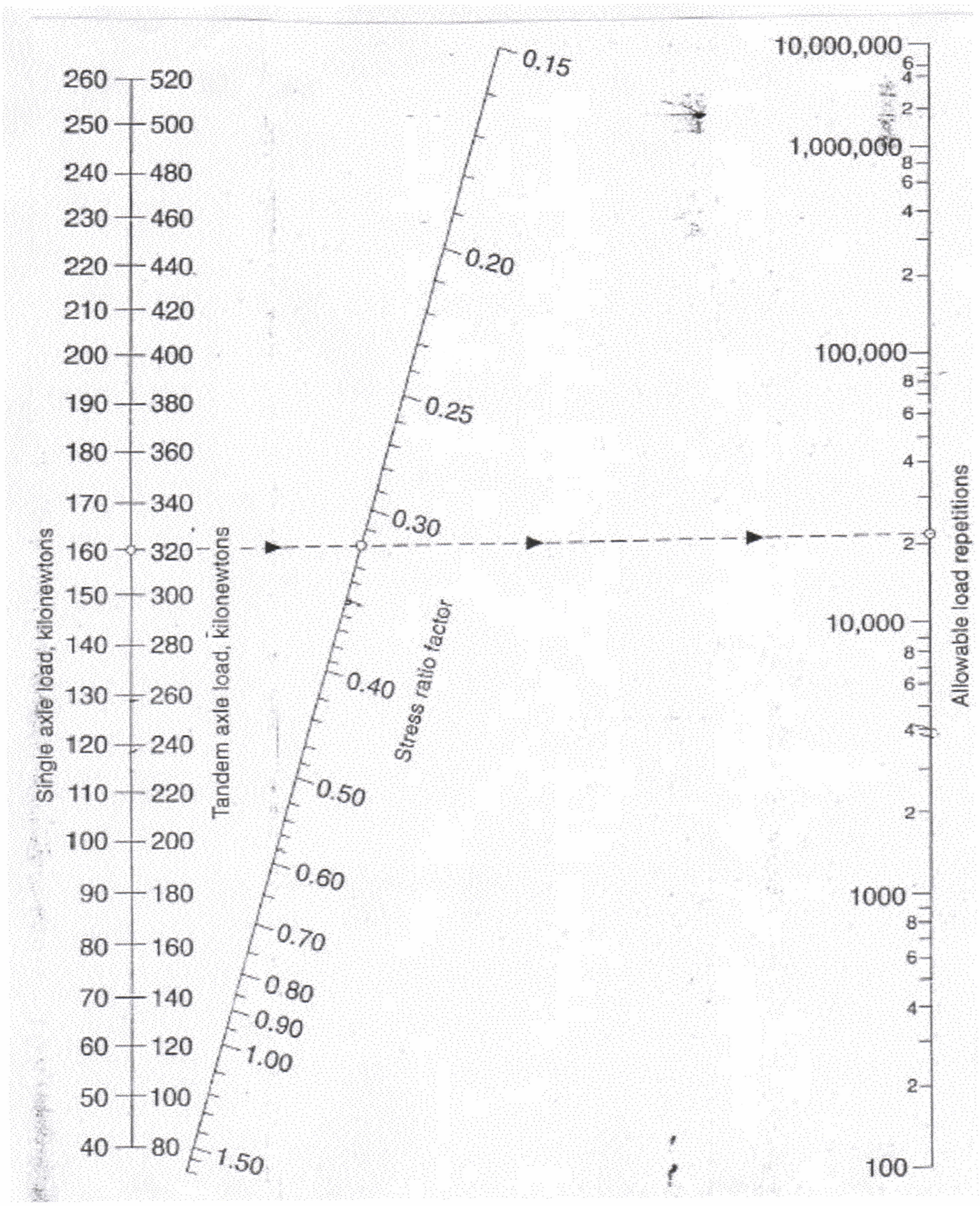

FIGURE Q2(a) : Fatigue analysis-allowable load repetitions based on stress ratio factor (with and without concrete shoulder)

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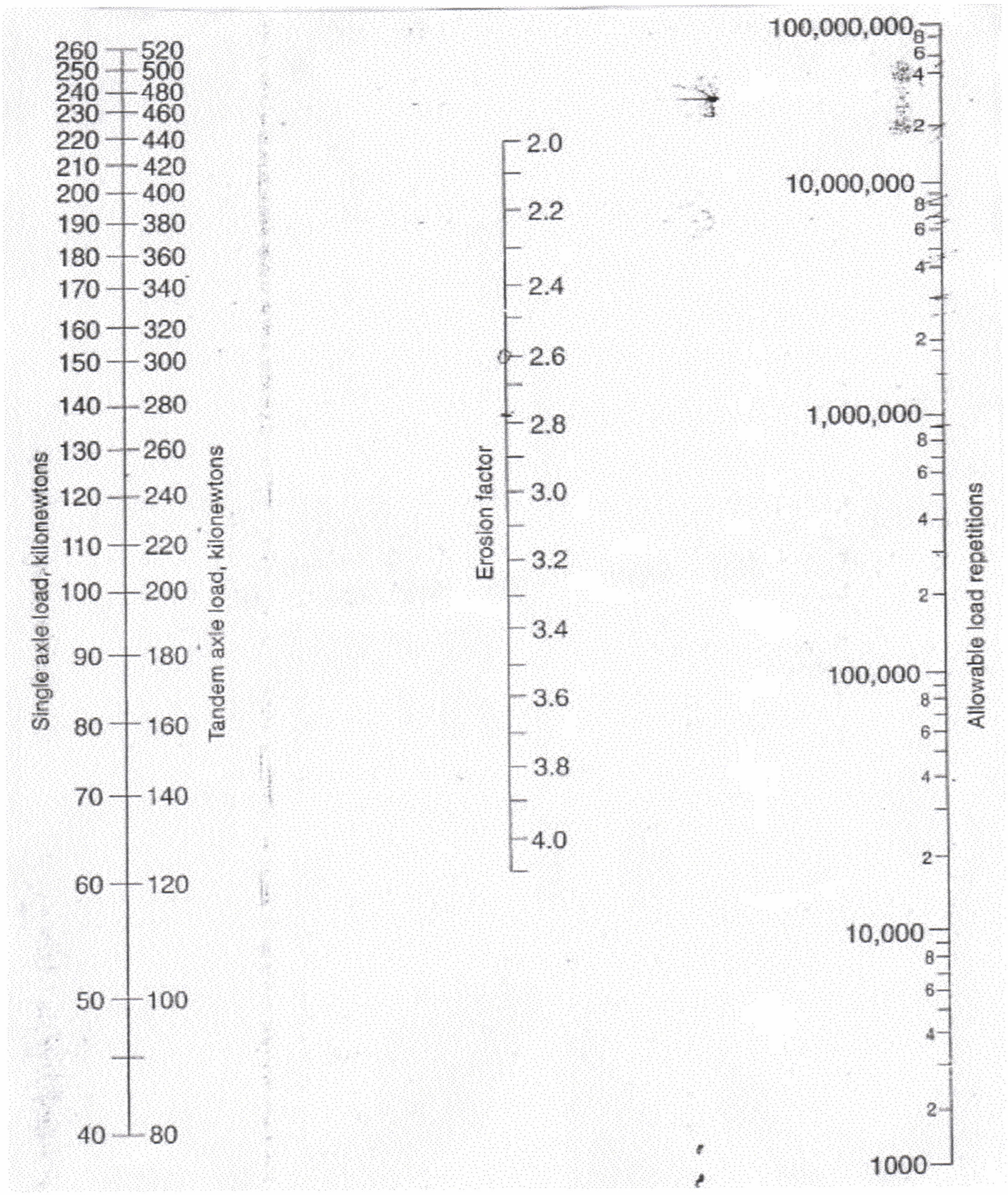

FIGURE Q2(b): Erosion analysis-allowable load repetitions based on erosion factor (without concrete shoulder)

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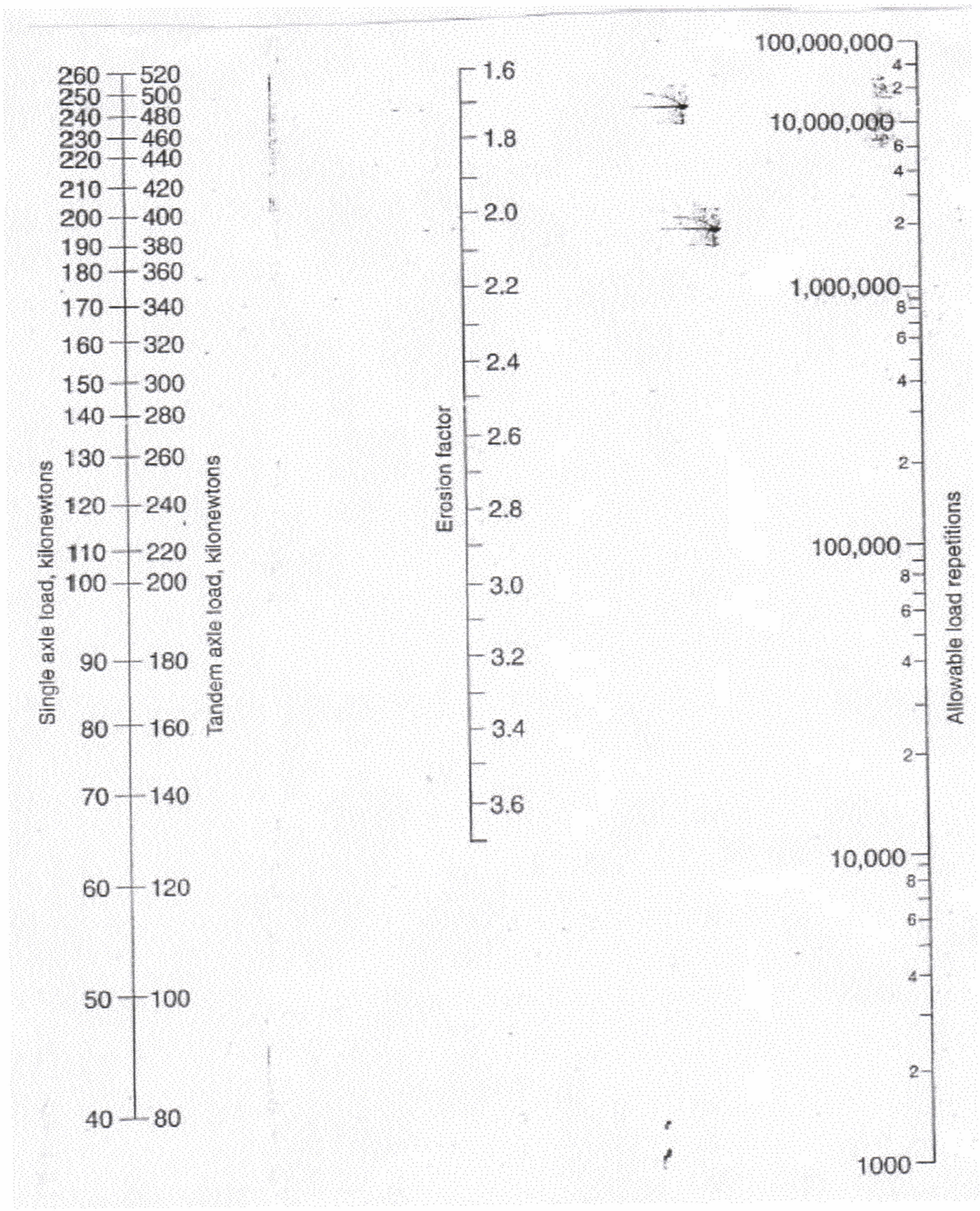

FIGURE Q2(c): Erosion analysis –allowable load repetitions based on erosion factor (with concrete shoulder)

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Table 3(c)(i): Result of the sand replacement test

Mass of sample from hole	kg	6.13
Mass of sand (+ cylinder) before pouring	kg	14.00
Mass of sand (+ cylinder) after pouring	kg	9.12

Table 3(c)(ii): Result of moisture content test

Mass of tray	kg	2.300
Mass of tray + wet sample	kg	8.425
Mass of tray + dry sample	kg	8.230

Table 4(c): PCI survey data sheet

JALAN UNIVERSITI (ASPHALT SURFACED ROAD)
CONDITION SURVEY DATA SHEET

Branch: Traffic laboratory UTHM	Date: 1 June 2016
Surveyed by: Mr. Mustafa Kamal	Sample unit: 07
Section: JPB-KM2	Sample area: 6 m x 100 m

01. Alligator Cracking (m^2) 02. Bleeding (m^2) 03. Block Cracking (m^2) 04. Bumps and Sags (m) 05. Corrugation (m^2) 06. Depression (m^2) 07. Edge Cracking (m)	08. Joint Reflection Cracking (m) 09. Lane/Shoulder Drop Off (m) 10. Longitudinal & Transverse Cracking (m) 11. Patching & Utility Cut Patching (m^2) 12. Polished Aggregate (m^2)	13. Potholes (no.) 14. Railroad Crossing (m^2) 15. Rutting (m^2) 16. Shoving (m^2) 17. Slippage Cracking (m^2) 18. Swell (m^2) 19. Weathering/Ravelling (m^2)

Distress Survey	Quantity						
1L	1.2	1.92					
1H	1.15	2.21					
7L	5.36	8.2	6.4	8.2	2.8		
8M	5.2	8.1	6.6	7.1	3.6	1.3	2.4
11H	1.15	1.73					
13L	3						
15L	0.24	2.1	2.7				
19L	60						

FINAL EXAMINATION

SEMESTER/SESSION	:	SEM II/ 2015/16	PROGRAMME	:	BFF
COURSE NAME	:	HIGHWAY ENGINEERING	COURSE CODE	:	BFC 31802

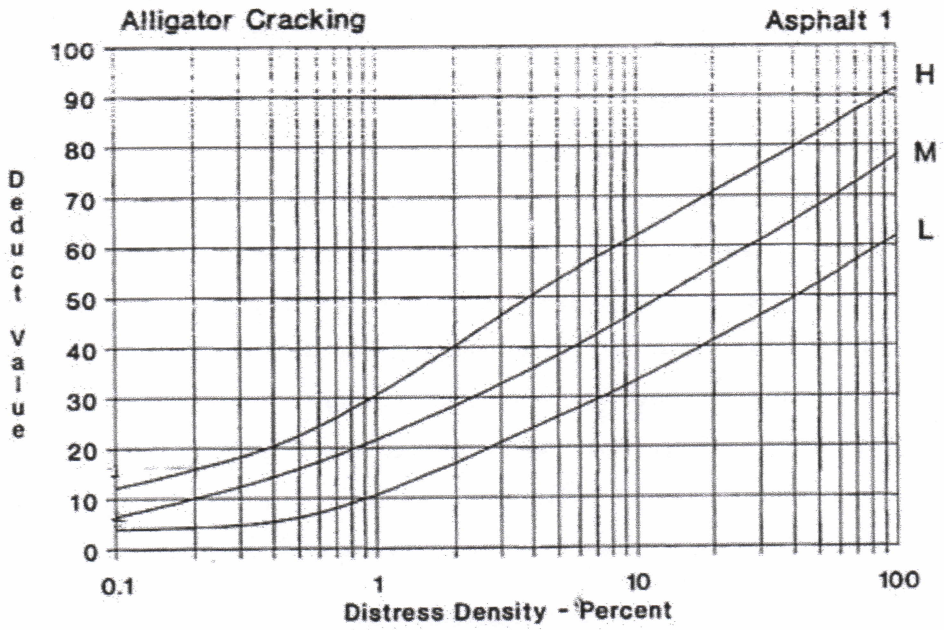

FIGURE Q4(c)(i) : Alligator cracking

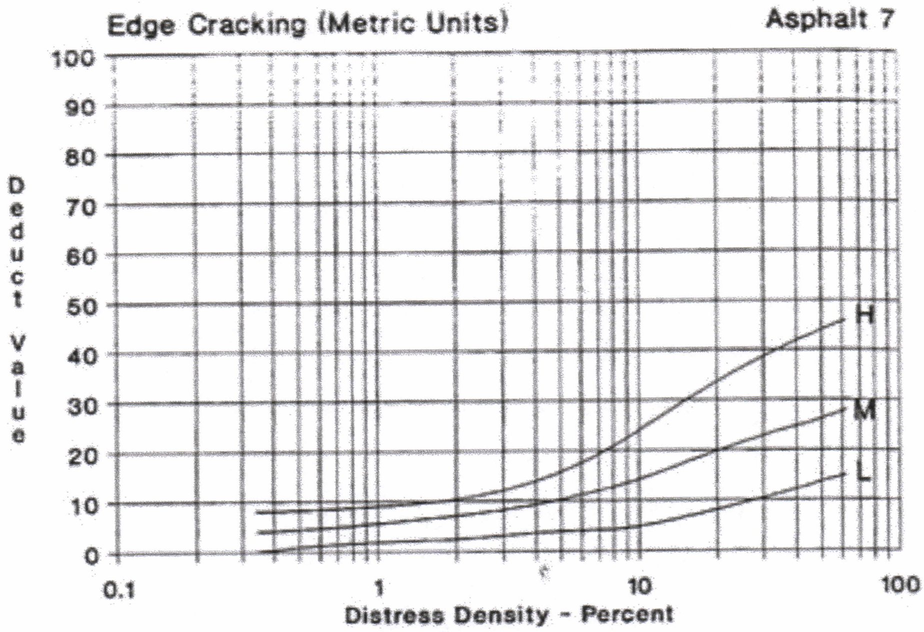

FIGURE Q4(c)(ii) : Edge Crcaking

FINAL EXAMINATION

SEMESTER/SESSION	:	SEM II/ 2015/16	PROGRAMME	:	BFF
COURSE NAME	:	HIGHWAY ENGINEERING	COURSE CODE	:	BFC 31802

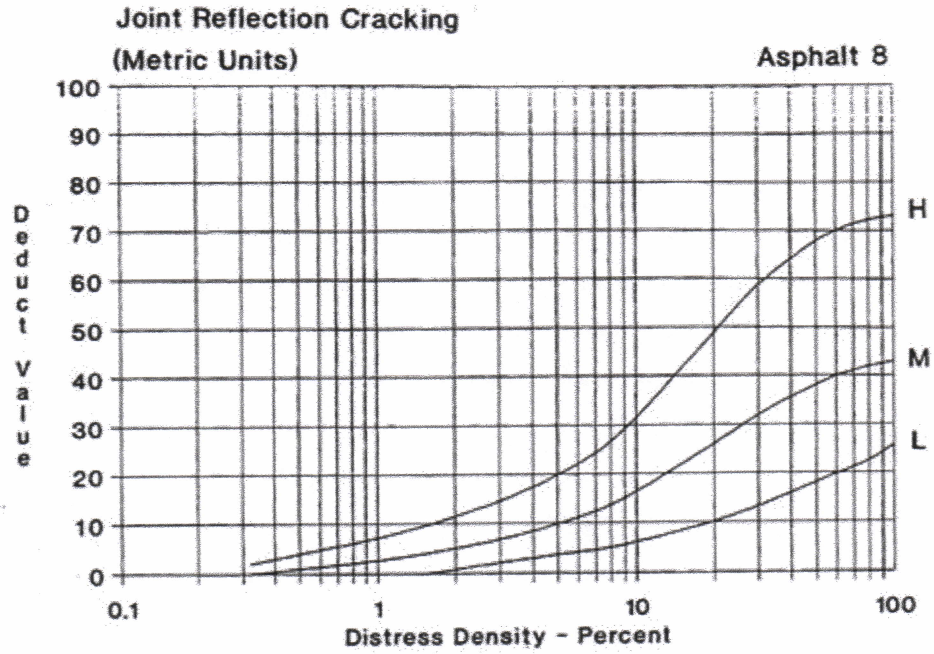

FIGURE Q4(c)(iii) : Joint Reflection Cracking

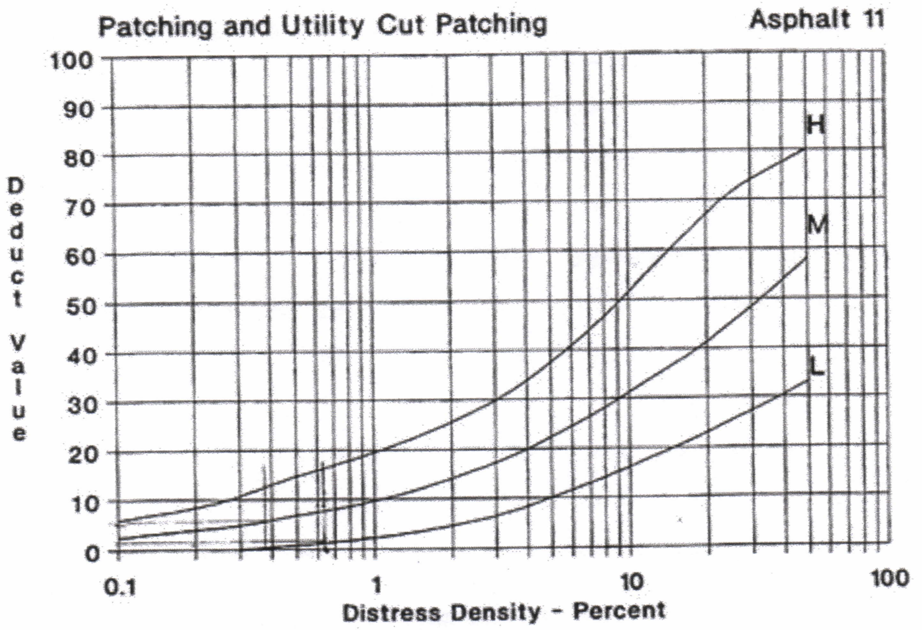

FIGURE Q4(c)(iv) : Patching and Utility Cut Paching

FINAL EXAMINATION

SEMESTER/SESSION	:	SEM II/ 2015/16	PROGRAMME	:	BFF
COURSE NAME	:	HIGHWAY ENGINEERING	COURSE CODE	:	BFC 31802

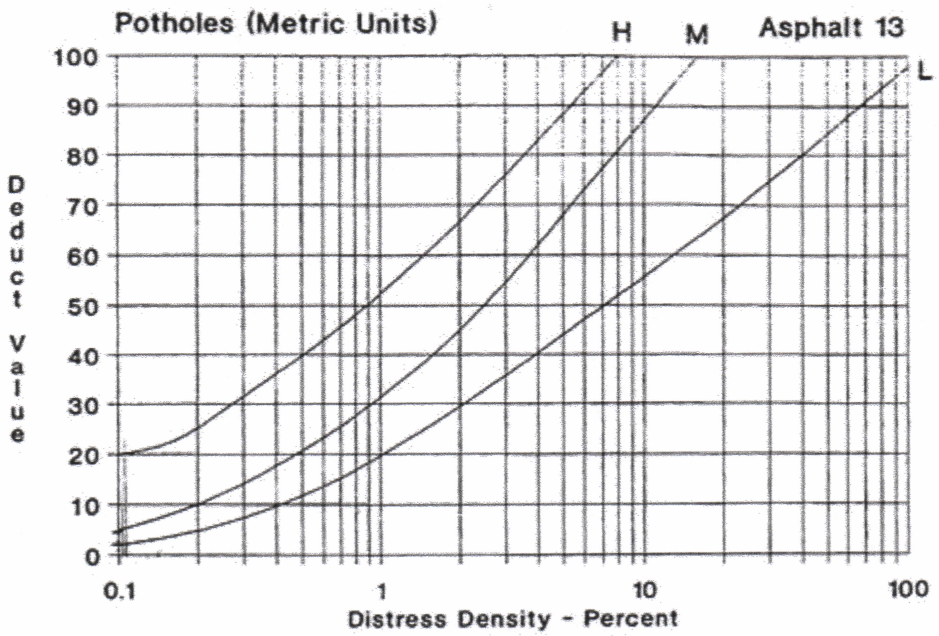

FIGURE Q4(c)(v) : Potholes

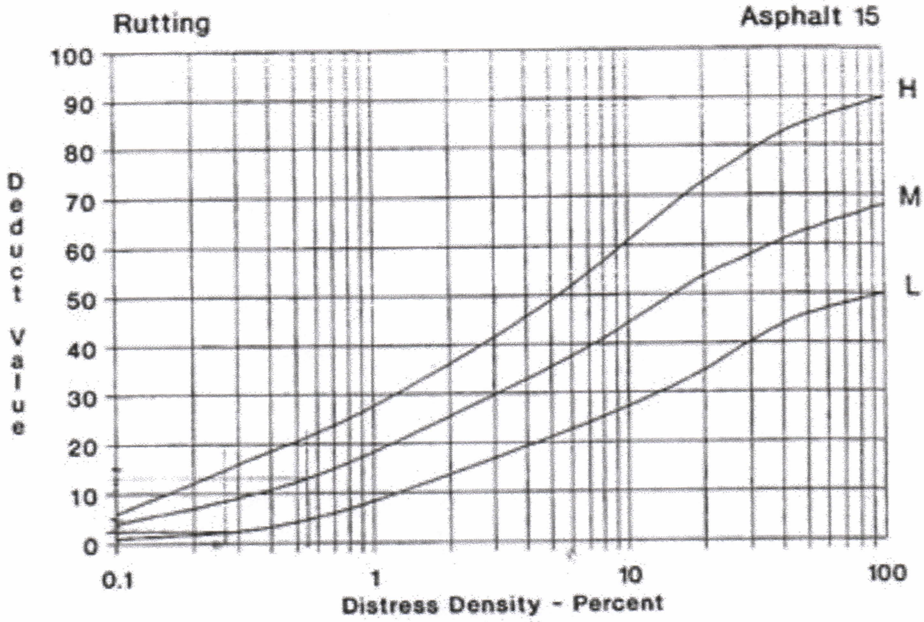

FIGURE Q4(c)(vi) : Rutting

FINAL EXAMINATION

SEMESTER/SESSION	:	SEM II/ 2015/16	PROGRAMME	:	BFF
COURSE NAME	:	HIGHWAY ENGINEERING	COURSE CODE	:	BFC 31802

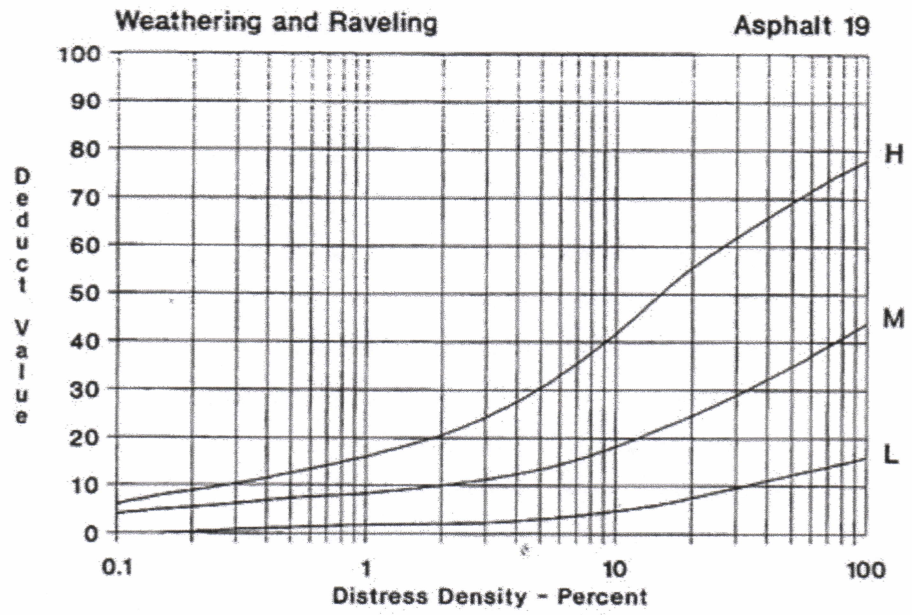

FIGURE Q4(c)(vii) : Weathering and Raveling

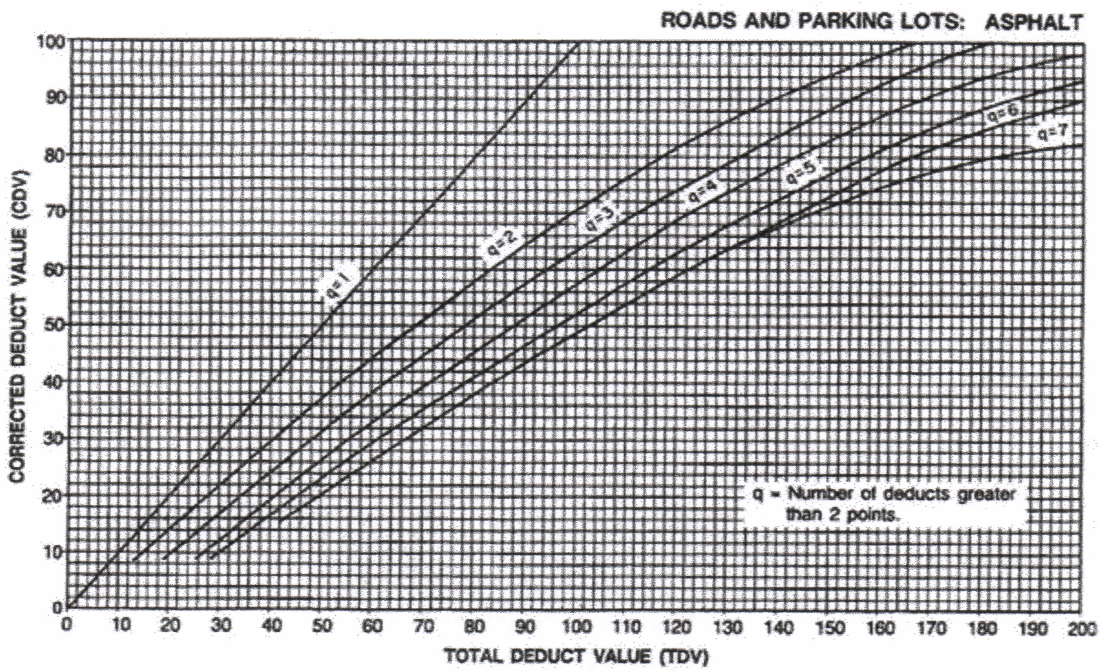

FIGURE Q4(c)(viii) :Corrected Deduct Value

FINAL EXAMINATION

SEMESTER/SESSION	:	SEM II/ 2015/16	PROGRAMME	:	BFF
COURSE NAME	:	HIGHWAY ENGINEERING	COURSE CODE	:	BFC 31802

Formulae:

$$\text{Degree of compaction} = (\rho_d/MDD) \times 100$$

$$\rho_d = \rho_b/(1+m)$$

$$M_{BA} = P_{BA} \times M_G$$

$$V_G = M_G/ (R_{DB}(agg) \times \rho_W)$$

$$V_{BE} = M_{BE}/ (R_{DB}(asp) \times \rho_W)$$

$$V_A = V - (V_G + V_{BE})$$

$$P_{BE} = M_{BE}/M$$

$$PBA = M_{BA}/M_G$$

$$VMA = (V_{BE}+V_A)/V$$

$$VFA = V_{BE}/(V_{BE}+V_A)$$

$$P_B = M_B/M$$

$$m = 1 + (9/98)(100 - HDV)$$