CONFIDENTIAL

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2017/2018

COURSE NAME	:	HIGHWAY ENGINEERING
COURSE CODE	:	BFC 31802
PROGRAMME CODE	:	BFF
EXAMINATION DATE	:	JUNE / JULY 2018
DURATION	:	2 HOURS 30 MINUTES
INSTRUCTION	:	ANSWER **FOUR (4)** QUESTIONS ONLY

THIS QUESTION PAPER CONSISTS OF **SIXTEEN (16)** PAGES

Q1 (a) **Table 1** summarises volumetric data and Marshall test results obtained for five asphaltic concrete mixture for binder course of road pavement. The Jabatan Kerja Raya (JKR/SPJ/2008) requirements for surface course are given in **Table 2.**

(i) Explain the importance of limiting air voids in asphalt concrete

(2 marks)

(ii) Explain the influence of aggregate gradation on optimum bitumen content

(2 marks)

(iii) Plot the graphs used for Marshall mix design analysis in the spaces provided in the **FIGURE Q1(a)(iii).**

(10 marks)

(iv) Determine the optimum bitumen content and check whether the mix meets the JKR/SPJ/2008 requirements.

(11 marks)

Q2 (a) There are two categories of pavements which are flexible pavement and rigid pavement. Briefly discuss **THREE (3)** differences among these categories.

(6 marks)

(b) The load of a vehicle is the total weight of all wheels connected to an axle. If axle load for unloaded and loaded trucks are 9070 kg and 18140 kg respectively, calculate the equivalent factors for each truck.

(4 marks)

(c) Determine the thicknesses rigid pavement using data given;

Number of commercial vehicles on design lane = 3000/day
Dowelled joints and concrete shoulder
Concrete modulus of rupture is 4.14 MPa
Subbase-subgrade *k* value is 35 MPa/m.
Design life = 20 years
Trial thickness = 220 mm.

Use the calculation form as shown in **Table 3.** Refer **Figure Q2(c)(i)** to **Figure Q2(c)(ii)** and 4 to **Table 7** to answer this question.

(15 marks)

Q3 (a) The embankment of a proposed alternative road from Ayer Hitam to Kluang is 10 km long. The average cross section of the embankment is shown in **Figure Q3(a)**. 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 8** 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)

(iii) If capacity of each hauling truck is 10 m^3, determine the number of trucks load required to construct the embankment.

(5 marks)

(b) Compaction is an important process in the preparation of the road surface.

(i) Describe the effect of compaction to Hot Mix Asphalt (HMA) structural layer.

(6 marks)

(ii) State **TWO (2)** pavement distresses which may occur due to inadequate compaction.

(1 marks)

(iii) Name **THREE (3)** types of compaction equipment which are commonly used in the construction of asphalt concrete.

(3 marks)

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

(6 marks)

(b) State **TWO (2)** types of reconstruction techniques

(2 marks)

(c) List the activities that are included in Pavement Management System (PMS).

(5 marks)

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

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

(4 marks)

(ii) Based on the type of the evaluation above, categorize each evaluation based on their pavement function and characteristics of each function.

(8 marks)

Q5 (a) Potholes can damage the pavement surface, causing roughness which can causes vehicle damage, and allows moisture to infiltrate the pavement structure. Describe **TWO (2)** suitable drainage systems that must be made to assure that the moisture in the hole to drain correctly.

(6 marks)

(b) Water is the worst enemy of road. Explain briefly **FOUR (4)** consequences of water ponding due to drainage failure that may happen.

(8 marks)

(c) One of the tasks in highway maintenance is maintaining and repairing drainage systems. Briefly discuss **FOUR (4)** importance of drainage maintenance.

(8 marks)

(d) Road surface should be constructed and maintained with sufficient cross-fall to shed the stormwater to the edges and into the side drains. Based on that requirement, state the percent cross-fall that are normally adopted for paved roads, earth and gravel roads, and shoulders.

(3 marks)

–END OF QUESTIONS–

FINAL EXAMINATION

SEMESTER/SESSION : SEM II / 2017/2018 PROGRAMME CODE : 3 BFF
COUIRSE NAME : HIGHWAY ENGINEERING COURSE CODE : BFC 31802

TABLE 1: Volumetric data and Marshall test results

Bitumen Content (%)	Density (kg/m^3)	Air voids (%)	Voids filled with asphalt (%)	Stability (kg)	Flow (mm)
4.5	2189	10.3	48.5	901	1.2
5.0	2223	8.2	57.1	1058	1.4
5.5	2254	6.0	66.7	1147	1.7
6.0	2261	5.3	71.5	1146	2.1
6.5	2253	4.9	74.4	1045	2.3

TABLE 2: JKR specifications for surface course

Parameter	Wearing Course	Binder Course
Stability (kg)	> 500	> 450
Flow (mm)	> 2.0	> 2.0
Stiffness (kg/mm)	> 250	> 225
Air voids (%)	3 – 5	3 – 7
Voids filled with asphalt (%)	75 – 85	65 – 80

FINAL EXAMINATION

SEMESTER/SESSION	:	II/ 2017/2018	PROGRAMME	:	3 BFF
COURSE NAME	:	HIGHWAY ENGINEERING	COURSE CODE	:	BFC 31802

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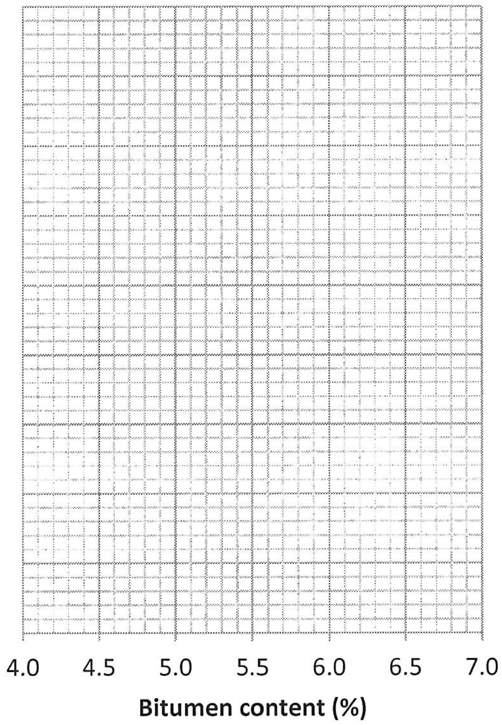
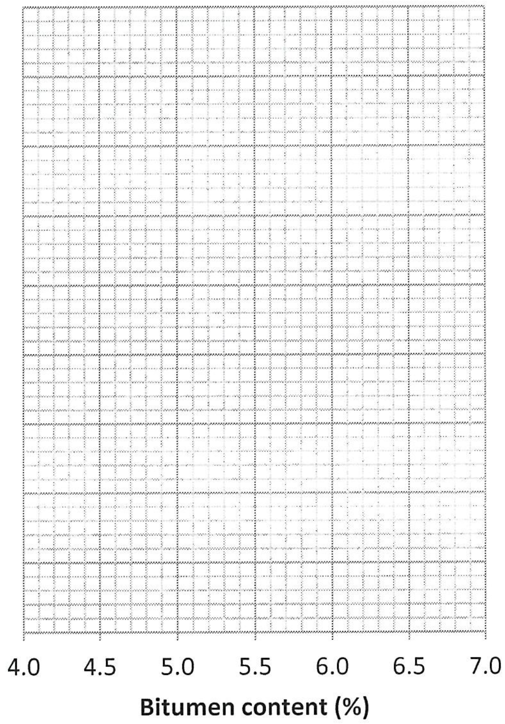
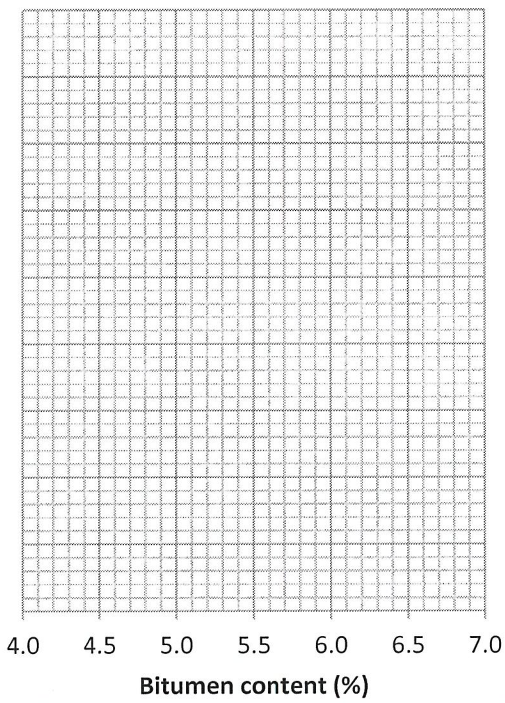
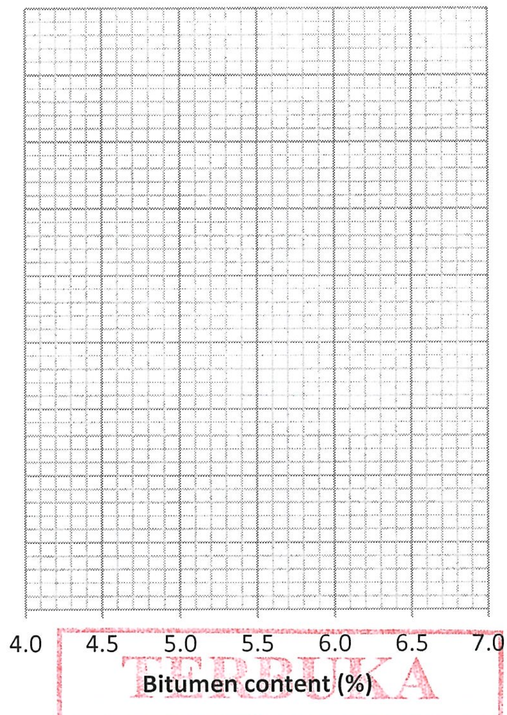
Note: If you are answering **Q1**, please submit this sheet along with your answer script.









FINAL EXAMINATION

SEMESTER/SESSION	:	II/ 2017/2018	PROGRAMME	:	BFC
COURSE NAME	:	HIGHWAY ENGINEERING	COURSE CODE	:	BFC 31802

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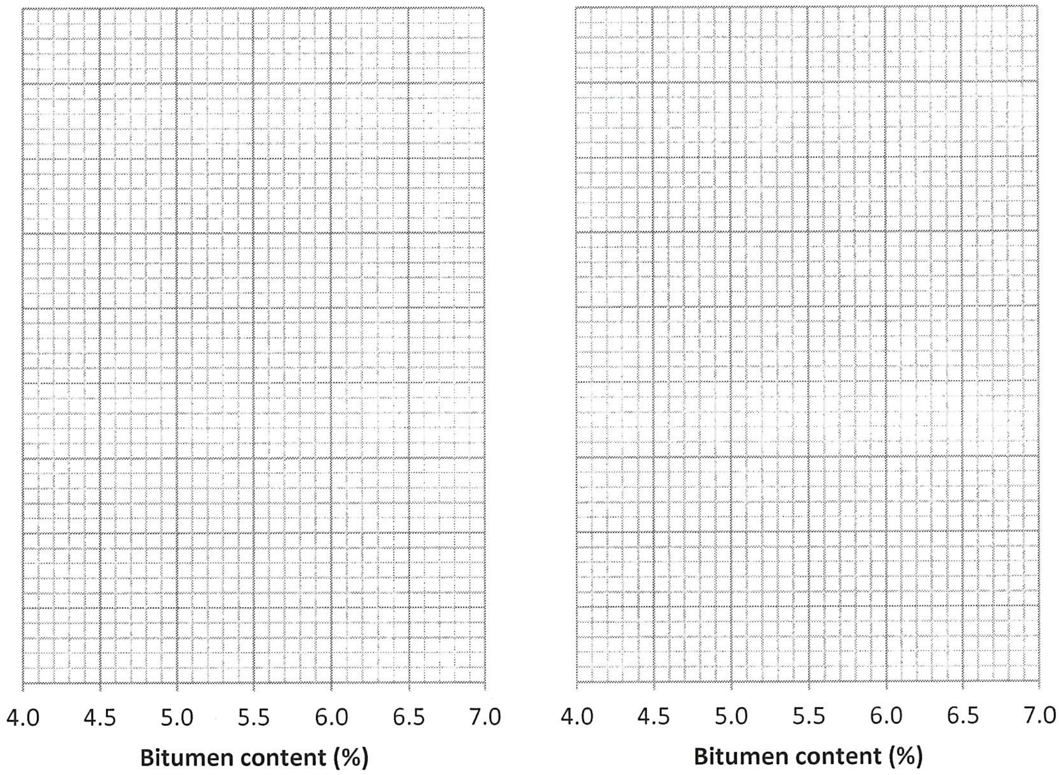

FIGURE Q1(a)(iiii) Marshall mix design plots

FINAL EXAMINATION

SEMESTER/SESSION : SEM II / 2017/2018 PROGRAMME CODE : 3BFF
COURSE NAME : HIGHWAY ENGINEERING COURSE CODE : BFC31802
Student Name: .... Matric No.: ....

Note: If you are answering **Q2**, please submit this sheet along with your answer script.

TABLE 3: Calculation of Pavement Thickness

Trial Thickness :	220 mm	**Doweled joints :**		
Modulus of Rupture, MR :		**Conrete shoulder :**		
Load Safety factor, LSF :	1.2	**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

Axle Load, kN						
133						
125						
115						
107						
98						

11. Equivalent stress :
12. Stress ratio factor :
13. Erosion factor:

Tandem Axle

Axle Load, kN						
231						
213						
195						
178						
160						

FINAL EXAMINATION

SEMESTER/SESSION : SEM II / 2017/2018 PROGRAMME CODE : 3BFF
COURSE NAME : HIGHWAY ENGINEERING COURSE CODE : BFC31802

TABLE 4: 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.

FINAL EXAMINATION

SEMESTER/SESSION : SEM II / 2017/2018
COURSE NAME : HIGHWAY ENGINEERING
PROGRAMME CODE : 3BFF
COURSE CODE : BFC31802

TABLE 5: 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

FINAL EXAMINATION

SEMESTER/SESSION : SEM II / 2017/2018 PROGRAMME CODE : 3 BFF
COURSE NAME : HIGHWAY ENGINEERING COURSE CODE : BFC31802

TABLE 6: 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	2.65/2.62	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

FINAL EXAMINATION

SEMESTER/SESSION : SEM II/ 2017/2018 PROGRAMME CODE : 3BFF
COURSE NAME : HIGHWAY ENGINEERING COURSE CODE : BFC31802

TABLE 7: 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

FINAL EXAMINATION

SEMESTER/SESSION	: SEM II / 2017/2018	PROGRAMME CODE	: 3 BFF
COURSE NAME	: HIGHWAY ENGINEERING	COURSE CODE	: BFC31802

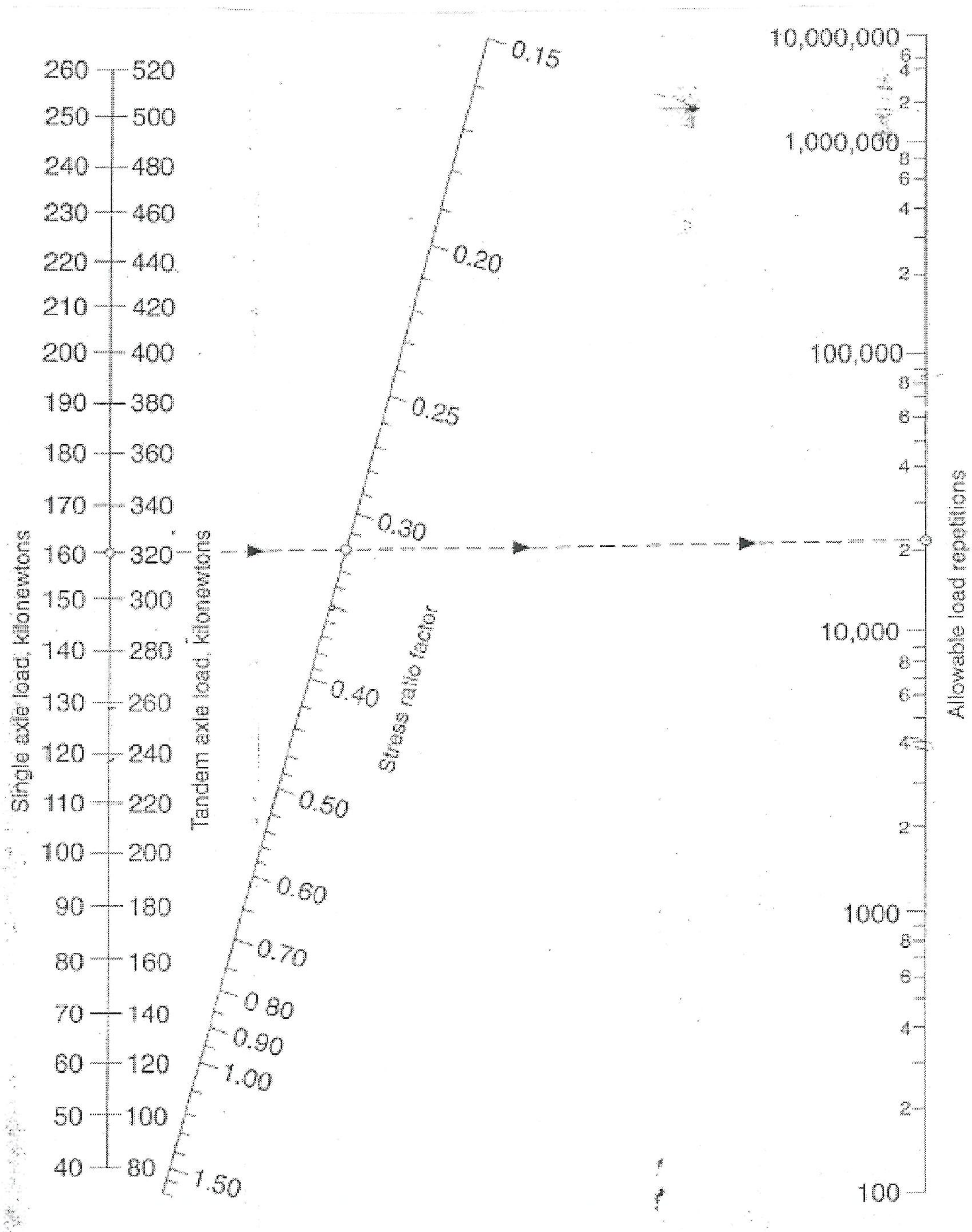

FIGURE Q2(c)(i) : Fatigue analysis-allowable load repetitions based on stress ratio factor (with and without concrete shoulder)

FINAL EXAMINATION

SEMESTER/SESSION	: SEM II / 2017/2018	PROGRAMME CODE	: 3 BFF
COURSE NAME	: HIGHWAY ENGINEERING	COURSE CODE	: BFC31802

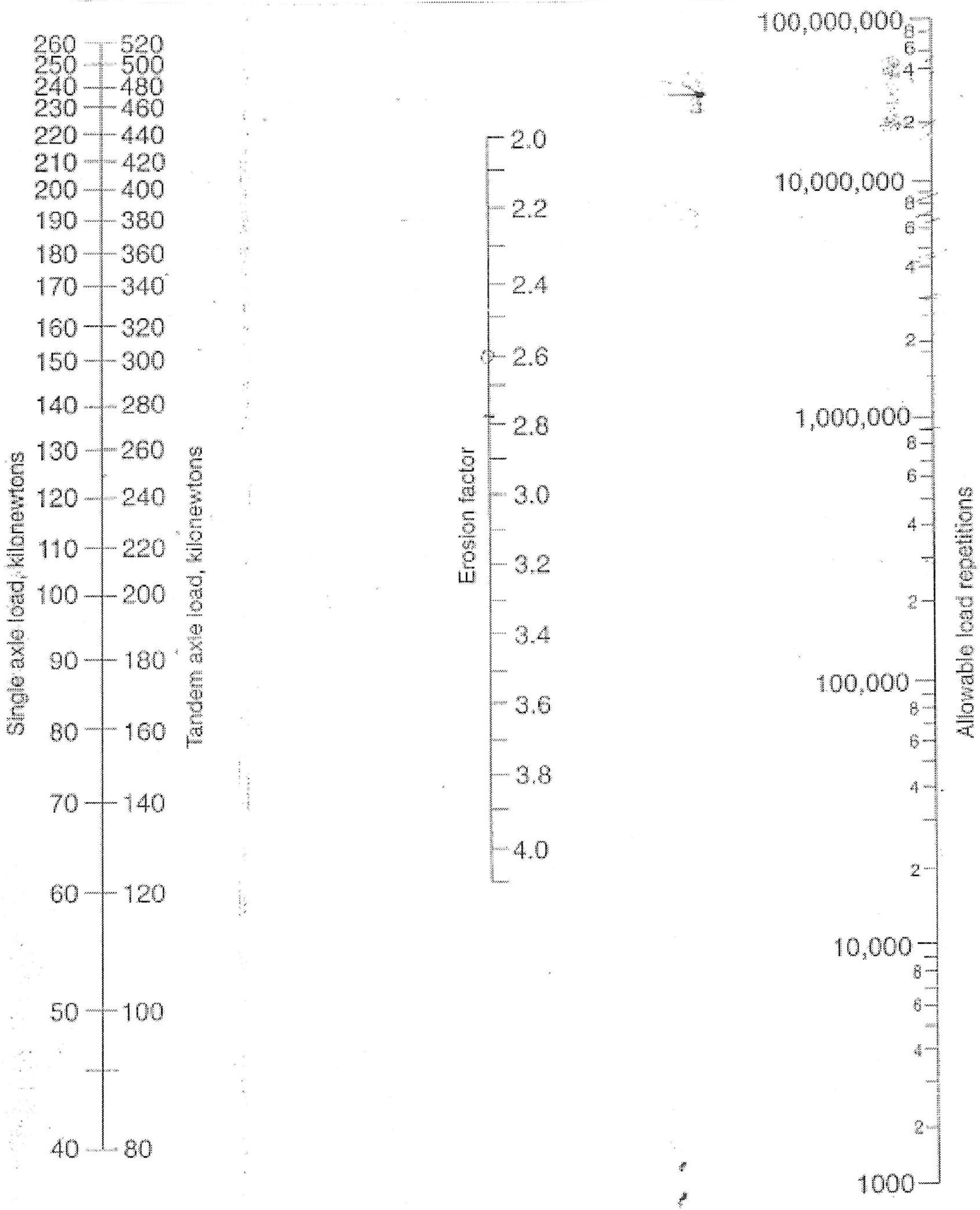

FIGURE Q2(c)(ii): Erosion analysis-allowable load repetitions based on erosion factor (without concrete shoulder)

FINAL EXAMINATION

SEMESTER/SESSION : SEM II / 2017/2018
COURSE NAME : HIGHWAY ENGINEERING
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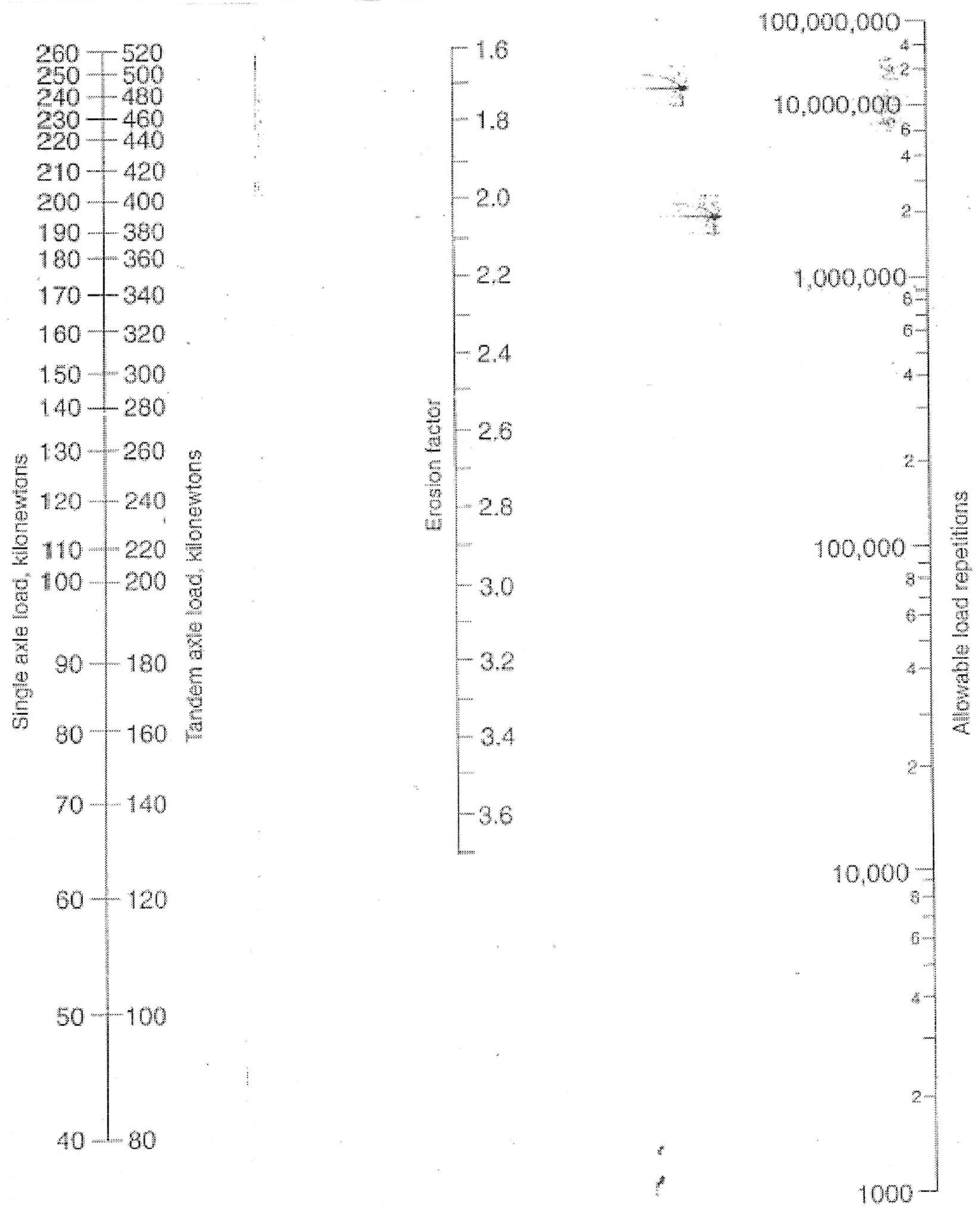

FIGURE Q2(c)(iii): Erosion analysis –allowable load repetitions based on erosion factor (with concrete shoulder)

FINAL EXAMINATION

SEMESTER/SESSION : SEM II / 2017/2018
COURSE NAME : HIGHWAY ENGINEERING
PROGRAMME CODE : 3 BFF
COURSE CODE : BFC31802

TABLE 8: 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 (%)
1.98	13	1.86	9.2

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

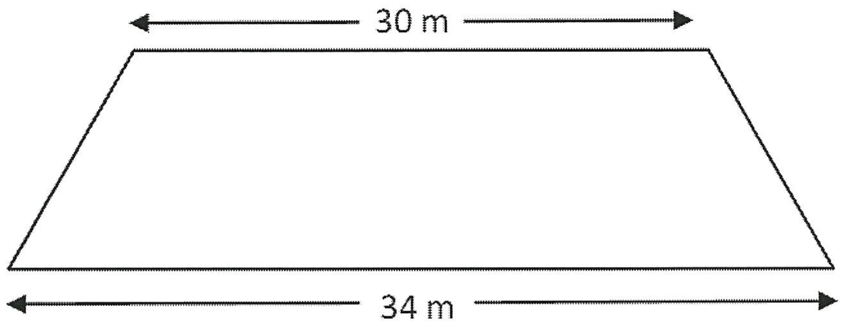

FIGURE Q3(a) : Cross section of the embankment