UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2012/2013

COURSE NAME	:	HIGHWAY ENGINEERING
COURSE CODE	:	BFC 31802 / BFC 3042
PROGRAMME	:	3 BFF
EXAMINATION DATE	:	JUN 2013
DURATION	:	2 HOURS 30 MINUTES
INSTRUCTION	:	ANSWER ANY **FOUR** FROM FIVE QUESTIONS

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

Q1 (a) The road base layer will be constructed using the crushed rock aggregate. The works include the transportation of material from the quarry until completion of the compaction work. Your plan consists of physical testing of the aggregate and in-situ density testing.

(i) List **FOUR (4)** tests that should be conducted to the road base layer material.

(4 marks)

(ii) Using a suitable diagram, name and briefly explain in-situ density testing method.

(5 marks)

(b) (i) Chip seal is also known as surface dressing or surface treatment. List the technique in chip sealing.

(4 marks)

(ii) Using a suitable diagram, explain the effect of chips spread rate.

(4marks)

(c) A laboratory California Bearing ratio test (CBR) specimen was prepared using 7,000 g dry soil and 3% moisture content. From previous laboratory compaction test, it was found that the optimum moisture content was 11 %.

(i) Determine the amount of water to be added to achieve the optimum moisture content.

(4 marks)

(ii) Briefly describe the purpose of laboratory compaction test.

(4 marks)

Q2 (a) There are four different types of joint placed in concrete pavements. List and briefly describe the **TWO (2)** type of joints used in concrete pavements

(4 marks)

(b) A six-lane concrete pavement designed with doweled joints and concrete shoulders have been constructed for a metropolitan area. This concrete pavement was laid on a 150 mm thick cement-stabilized subbase, which the single axel and tandem axles stress ratio factors were designed as 0.28 and 0.24, and erosion factors as 2.28 and 2.31, respectively.

The expected single and tandem axles load are given in **Table Q2(a).** The following data have been provided;

Concrete modulus of rupture, M_R = 4.21 MPa
Load safety factor = 1.2
Design period = 20 years

Table Q2(a): Expected repetitions

	Axle load (kN)	Expected Repetitions
Single Axle	133	2,100
	125	5,800
	115	18,900
	107	44,200
	98	106,500
	89	168,000
	80	235,500
Tandem Axles	231	1,900
	213	12,800
	195	105,400
	178	275,000
	160	607,700
	142	811,300
	125	1,125,000

(i) Based on equivalent stress value; determine the *k*-value for the subgrade - subbase reaction.

(3 marks)

(ii) Determine the thickness of concrete pavement.

(4 marks)

(iii) Conduct fatigue and erosion damage analyses on this proposed concrete pavement. Based on your analyses, comment on the adequacy of the concrete slab thickness.

(14 marks)

Q3 (a) The embankment of a proposed alternative road from Batu Pahat to Ayer Hitam is 5 km long. The cross section of the embankment is shown in **Figure Q3(a).** The specifications require 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(a)** presents the density of fill 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)

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

(5 marks)

(b) List **FOUR (4)** materials which are suitable for sub-base.

(2 marks)

(c) 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.

(3 marks)

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

(2 marks)

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

(3 marks)

Q4 (a) In a pavement condition survey the following distresses were observed at a 500 m section of a road:

There was large number of pot holes, many places where alligator cracks and deflection discernible to the naked eye were observed when heavy vehicles passed over the depressed area.

(i) What are the possible causes of the defects?

(4 marks)

(ii) Suggest the appropriate treatment for the road section.

(4 marks)

(b) Evaluation on the current pavement condition of a section of road indicates that single bituminous surface treatment (SBST) is suitable treatment. The road is a two lane two direction. Traffic data, sand patch test results, and the size of aggregate to be used are as follow:

Average Daily Traffic, ADT = 600 vpd
Average Least Dimension of aggregate, ALD = 15 mm

Table Q4(a): Sand patch test results:

No	Diameter of sand circle, D (mm)
1	200
2	225
3	230
4	210

(i) Elaborate what is "the current condition" that warrants the application of SBST in this case.

(5 marks)

(ii) Based on average diameter of sand circle, determine the residual binder and aggregate rate of application.

(5 marks)

(c) (i) Explain how Pavement Management System (PMS) can assist road authority in maintaining the road network.

(3 marks)

(ii) Explain the difference between network and project levels pavement management.

(4 marks)

Q5 (a) What are the effects of moisture on roads to the following:

(i) Road traffic and safety

(2 marks)

(ii) Pavement structure

(2 marks)

(iii) Subgrade soil

(2 marks)

(b) Highway drainage can be categorized as surface, subsurface and cross drainage. State the function and sketch **ONE (1)** example for each type of those drainages.

(6 marks)

(c) State **FOUR (4)** common drainage maintenance problems.

(4 marks)

(d) In order to reduce the risk of landslides at hill roads, the following elements must be maintained. Describe the maintenance activities of each element listed below and the probable effects that may happen if such activities were ignored.

(i) Slope

(3 marks)

(ii) Drainage

(3 marks)

(iii) Gutters and downspouts

(3 marks)

- END OF QUESTIONS -

TERJEMAHAN SOALAN

S1 (a) Lapisan tapak jalan dibina menggunakan batuan agregat terhancur. Kerja tersebut merangkumi pengangkutan bahan dari kuari sehingga selesai kerja-kerja pemadatan. Pelaksanaan kerja tersebut mengandungi ujikaji fizikal agregat dan ujikaji ketumpatan di tapak.

(i) Senaraikan **EMPAT (4)** ujikaji yang perlu dijalankan ke atas bahan bagi lapisan tapak jalan

(4 markah)

(ii) Dengan bantuan gambarajah, namakan dan huraikan tujuan ujikaji ketumptan di tapak tersebut.

(5 markah)

(b) (i) *Chips seal* juga dikenali sebagai perlindungan permukaan atau rawatan permukaan. Senaraikan teknik dalam kaedah penyediaan *Chips seal.*

(4 markah)

(ii) Dengan bantuan gambarajah, jelaskan kesan keatas kadar hamparan chip

(4 markah)

(c) Sample ujian *California Bearing ratio* (CBR) makmal telah disediakan menggunakan 7,000 g tanah kering dan kandungan lembapan 3 %. Daripada ujikaji pemadatan, didapati kandungan lembapan optimum adalah 11 %.

(iii) Tentukan amaun air yang perlu di tambah untuk mencapai kandungan optimum lembapan.

(4 markah)

(iv) Terangkan secara ringkas tujuan ujikaji pemadatan di makmal.

(4 markah)

S2 (a) Terdapat **EMPAT (4)** perbezaan jenis sambungan yang diletakkan di dalam turapan konkrit. Senarai dan terangkan secara ringkas **DUA (2)** jenis sambungan yang digunakan dalam turapan konkrit tersebut.

(4 markah)

(b) Enam lorong konkrit turapan yang direka dengan sambungan berkebar dan bahu jalan berkonkrit telah dibina bagi kawasan metropolitan. Turapan konkrit diletakkan diatas subtapak setebal 150 mm yang telah disetabilkan menggunakan simen, dimana nisbah faktor tekanan untuk gandar tunggal dan beriring telah direka sebagai 0,28 dan 0.24, dan factor hakisan adalah 2.28 dan 2.31, masing-masing.

Jangkaan beban gandar tunggal dan beriring diberikan dalam **Jadual Q2(a).** Data berikut telah disediakan:

Modulus konkrit pecah, M_R = 4.21 MPa
Beban faktor keselamatan = 1.2
Tempoh reka bentuk = 20 tahun

Jadual Q2(a): Jangkaan pembebanan ulangan

	Beban gandar (kN)	**Pembebanan Ulangan yang dijangkakan**
Gandar tunggal	133	2,100
	125	5,800
	115	18,900
	107	44,200
	98	106,500
	89	168,000
	80	235,500
Gandar beriring	231	1,900
	213	12,800
	195	105,400
	178	275,000
	160	607,700
	142	811,300
	125	1,125,000

(i) Berdasarkan kepada nilai tegangan setara, tentukan nilai *k* bagi tindakan subgred dengan lapisan sub-asas.

(3 markah)

(ii) Tentukan ketebalan lapisan turapan konkrit tersebut.

(4 markah)

(iii) Kendalikan analisis kelesuan dan kerosakan akibat hakisan ke atas turapan konkrit cadangan tersebut. Berdasarkan analisis anda, berikan komen tentang kesesuaian ketebalan turapan konkrit tersebut.

(14 markah)

S3 (a) Penambakan sepanjang 5 km telah dicadangkan di jalan alternatif daripada Batu Pahat ke Ayer Hitam. Keratan rentas tambakan tersebut ditunjukkan di dalam **Rajah Q3.** Spesifikasi memerlukan tambakan dipadatkan sehingga 95% daripada nilai ketumpatan kering maksimum yang diperolehi daripada Ujian Pemadatan B.S 1377 (kaedah hentaman 2.5 kg). **Jadual Q3(a)** menunjukkan ketumpatan bahan tambakan dalam pelbagai keadaan.

(i) Kirakan isipadu bahan pinjam yang diperlukan untuk 1 m^3 penambakan jalan yang telah dipadatkan.

(5 markah)

(ii) Kirakan isipadu tambahan air yang diperlukan untuk keseluruhan isipadu tambakan.

(5 markah)

(iii) Kirakan bilangan lori pengangkut yang diperlukan untuk pembinaan tambak jika kapasiti setiap lori pengangkut adalah 10 m^3.

(5 markah)

(b) Nyatakan **EMPAT (4)** bahan yang sesuai digunakan untuk lapisan sub-tapak.

(2 markah)

(c) Pemadatan merupakan proses yang penting dalam penyediaan lapisan permukaan jalan raya.

(i) Nyatakan kesan pemadatan terhadap struktur lapisan asfalt.

(3 markah)

(ii) Berikan **DUA (2)** kerosakan turapan yang mungkin berpunca daripada pemadatan yang tidak sempurna.

(2 markah)

(iii) Namakan **TIGA (3)** jenis peralatan pemadatan yang biasanya digunakan dalam pembinaan lapisan asfalt.

(3 markah)

S4 (a) Satu tinjauan kondisi turapan *(pavement condition survey)* pada jalan sepanjang 500 m mendapati kecacatan permukaan turapan seperti berikut:

Didapati sejumlah lubang, retak buaya dibanyak tempat, dan pesongan permukaan nampak secara ketara apabila kenderaan berat melalui bahagian turapan yang mengendap.

(i) Apakah kemungkinan punca dari kerosakan tersebut?

(4 markah)

(iii) Cadangkan penambah baikan yang sesuai.

(4 markah)

(b) Penilaian kondisi semasa turapan pada satu bahagian jalan mengindikasikan bahawa tindakan pemuliharaan berupa *single bituminous surface treatment (SBST)* adalah sesuai untuk dijalankan. Jalan berkenaan adalah jalan dua halan dengan dua lorong. Data trafik, dan keputusan ujikaji *sand patch* dan saiz agregat yang akan digunapakai adalah sebagi berikut:

Purata trafik harian = 600 kendaraan per hari
Purata ukuran terkecil agregat (ALD) = 15 mm

Jadual Q4(a): Keputusan ujikaji sand patch

No	Diameter bundar pasir, D (mm)
1	200
2	225
3	230
4	210

(i) Terangkan keadaan semasa yang boleh menjustifikasi SBST di dalam kes ini.

(5 markah)

(ii) Berdasarkan purata keputusan ujikaji *sand patch*, dapatkan jumlah penggunaan bitumen dan agregat per satuan luas

(5 markah)

(c) (i) Terangkan bagaimana Sistem Pengurusan Turapan *(Pavement Management System, PMS)* boleh membantu penguatkuasa jalan raya di dalam pemeliharaan rangkaian jalan.

(3 markah)

(i) Terangkan perbezaan di antara pengurusan turapan pada peringkat rangkaian dan projek.

(4 markah)

S5 (a) Apakah kesan-kesan kelembapan pada jalan raya terhadap perkara berikut:

(i) Lalulintas dan keselamatan jalan raya

(2 markah)

(ii) Struktur turapan jalan raya

(2 markah)

(iii) Tanah subgred

(2 markah)

(b) Saliran jalanraya dikategorikan sebagai saliran permukaan, sub permukaan dan melintang, berikan fungsi dan lakarkan **SATU (1)** contoh setiap jenis.

(6 markah)

(c) Nyatakan **EMPAT (4)** masalah yang sering berlaku semasa penyelenggaraan parit jalanraya.

(4 markah)

(d) Bagi mengurangkan risiko tanah runtuh di kawasan jalan berbukit, elemen-elemen berikut perlu disenggarakan. Terangkan aktiviti penyenggaraan setiap elemen yang disenaraikan dibawah dan akibat yang boleh berlaku jika penyenggaraan tersebut tidak dilakukan.

(i) Cerun

(3 markah)

(ii) Sistem Saliran

(3 markah)

(iii) Talang dan saliran penurunan

(3 markah)

- SOALAN TAMAT -

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Table 2(b): Effect of untreated subbase on k-values

Subgrade k value (MPa/m)	*Subgrade-subbase k values (MPa/m)*			
	100 mm	150 mm	225 mm	300 mm
20	23	26	32	38
40	45	49	57	66
60	64	66	76	90
80	87	90	100	117

Table 2(c): Effect of cement-treated subbase on k-values

Subgrade k value (MPa/m)	*Subgrade-subbase k values (MPa/m)*			
	100 mm	150 mm	225 mm	300 mm
20	60	80	105	135
40	100	130	185	230
60	140	190	245	-

Table 2(d): Equivalent stress (with concrete shoulder)

Slab thickness (mm)	*k* of subgrade-subbase (MPa/m)				
	20	40	60	80	140
100	4.18/3.48	3.65/3.10	3.37/2.94	3.19/2.85	2.85/2.74
110	3.68/3.07	3.23/2.71	2.99/2.56	2.83/2.47	2.55/2.35
120	3.28/2.75	2.88/2.41	2.67/2.26	2.54/2.17	2.29/2.05
130	2.95/2.49	2.60/2.17	2.41/2.02	2.29/1.94	2.07/1.82
140	2.68/2.27	2.36/1.97	2.19/1.83	2.08/1.75	1.89/1.63
150	2.44/2.06	2.15/2.41	2.00/1.67	1.90/1.59	1.73/1.48
160	2.24/1.93	1.97/1.66	1.84/1.53	1.75/1.46	1.59/1.35
170	2.06/1.79	1.82/1.54	1.70/1.42	1.62/1.35	1.48/1.24
180	1.91/1.67	1.69/1.43	1.57/1.32	1.50/1.25	1.37/1.15
190	1.77/1.57	1.57/1.34	1.46/1.23	1.40/1.17	1.28/1.07
200	1.65/1.48	1.46/1.26	1.37/1.16	1.30/1.10	1.19/1.00
210	1.55/1.40	1.37/1.19	1.28/1.09	1.22/1.03	1.12/0.93
220	1.45/1.32	1.29/1.12	1.20/1.03	1.15/0.97	1.05/0.88
230	1.37/1.26	1.21/1.07	1.13/0.98	1.08/0.92	0.99/0.83
240	1.29/1.20	1.15/1.01	1.07/0.93	1.02/0.87	0.94/0.79
250	1.22/1.14	1.08/0.97	1.01/0.88	0.97/0.83	0.89/0.75

(Single axle/Tandem axle)

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Table 2(e): Equivalent stress (without concrete shoulder)

Slab thickness (mm)	*k* of subgrade-subbase (MPa/m)				
	20	40	60	80	140
100	5.42/4.39	4.75/3.83	4.38/3.59	4.13/3.44	3.66/3.22
110	4.74/3.88	4.16/3.35	3.85/3.12	3.63/2.97	3.23/2.76
120	4.19/3.47	3.69/2.98	3.41/2.75	3.23/2.62	2.88/2.40
130	3.75/3.14	3.30/2.68	3.06/2.46	2.89/2.33	2.59/2.13
140	3.37/2.87	2.97/2.43	2.76/2.23	2.61/2.10	2.34/1.90
150	3.06/2.64	2.70/2.23	2.51/2.04	2.37/1.92	2.13/1.72
160	2.79/2.45	2.47/2.06	2.29/1.87	2.17/1.76	1.95/1.57
170	2.56/2.28	2.26/1.91	2.10/1.74	1.99/1.63	1.80/1.45
180	2.37/2.14	2.09/1.79	1.94/1.62	1.84/1.51	1.66/1.34
190	2.19/2.01	1.94/1.67	1.80/1.51	1.71/1.41	1.54/1.25
200	2.04/1.90	1.80/1.58	1.67/1.42	1.59/1.33	1.43/1.17
210	1.91/1.79	1.68/1.49	1.56/1.34	1.48/1.25	1.34/1.10
220	1.79/1.70	1.57/1.41	1.46/1.27	1.39/1.18	1.26/1.03
230	1.68/1.62	1.48/1.34	1.38/1.21	1.31/1.12	1.18/0.98
240	1.58/1.55	1.39/1.28	1.30/1.15	1.23/1.06	1.11/0.93
250	1.49/1.48	1.32/1.22	1.22/1.09	1.16/1.01	1.05/0.88

(Single axle/Tandem axle)

Table 2(f): Erosion factors (doweled joints, without concrete shoulder)

Slab thickness (mm)	*k* of subgrade-subbase (MPa/m)				
	20	40	60	80	140
100	3.76/3.80	3.75/3.79	3.74/3.77	3.74/3.76	3.72/3.72
110	3.63/3.71	3.62/3.67	3.61/3.65	3.61/3.63	3.59/3.60
120	3.52/3.61	3.50/3.56	3.49/3.54	3.49/3.52	3.47/3.49
130	3.74/3.52	3.39/3.47	3.39/3.44	3.38/3.43	3.37/3.39
140	3.31/3.43	3.30/3.38	3.29/3.35	3.28/3.33	3.27/3.30
150	3.22/3.36	3.21/3.30	3.20/3.27	3.19/3.25	3.17/3.21
160	3.14/3.28	3.12/3.22	3.11/3.19	3.10/3.17	3.09/3.13
170	3.06/3.22	3.04/3.15	3.03/3.12	3.02/3.10	3.01/3.06
180	2.99/3.16	2.97/3.09	2.96/3.06	2.95/3.03	2.93/2.99
190	2.92/3.10	2.90/3.03	2.88/2.99	2.88/2.97	2.86/2.93
200	2.85/3.05	2.83/2.97	2.82/2.94	2.81/2.91	2.79/2.87
210	2.79/2.99	2.77/2.92	2.75/2.88	2.75/2.86	2.73/2.81
220	2.73/2.95	2.71/2.87	2.69/2.83	2.69/2.80	2.67/2.76
230	2.67/2.90	2.65/2.82	2.64/2.78	2.63/2.75	2.61/2.70
240	2.62/2.86	2.60/2.78	2.58/2.73	2.57/2.71	2.55/2.66
250	2.57/2.80	2.54/2.73	2.53/3.69	2.52/2.66	2.50/2.61

(Single axle/Tandem axle)

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Table 2(g): Erosion factors (doweled joints, with concrete shoulder)

Slab thickness (mm)	*k* of subgrade-subbase (MPa/m)				
	20	40	60	80	140
100	3.27/3.25	3.24/3.17	3.22/3.14	3.21/3.12	3.17/3.11
110	3.16/3.16	3.12/3.07	3.10/3.03	3.09/3.00	3.05/2.98
120	3.05/3.08	3.01/2.98	2.99/2.93	2.98/2.90	2.94/2.86
130	2.96/3.01	2.92/2.90	2.89/2.85	2.88/2.81	2.84/2.76
140	2.87/2.94	2.82/2.83	2.80/2.77	2.78/2.74	2.75/2.67
150	2.79/2.88	2.74/2.77	2.72/2.71	2.70/2.67	2.67/2.60
160	2.71/2.82	2.66/2.71	2.64/2.65	2.62/2.60	2.59/2.53
170	2.64/2.77	2.59/2.65	2.57/2.59	2.55/2.55	2.51/2.46
180	2.57/2.72	2.52/2.60	2.50/2.54	2.48/2.49	2.44/2.41
190	2.51/2.67	2.46/2.56	2.43/2.49	2.41/2.44	2.38/2.35
200	2.45/2.63	2.40/2.51	2.37/2.44	2.35/2.40	2.31/2.31
210	2.39/2.58	2.34/2.47	2.31/2.40	2.29/2.35	2.26/2.26
220	2.34/2.54	2.29/2.43	2.26/2.36	2.24/2.31	2.20/2.22
230	2.29/2.50	2.23/2.39	2.21/2.32	2.19/2.27	2.15/2.18
240	2.24/2.46	2.18/2.35	2.16/2.28	2.13/2.23	2.10/2.14
250	2.19/2.43	2.14/2.31	2.11/2.24	2.09/2.20	2.05/2.10

(Single axle/Tandem axle)

Table 2(h): Erosion factors (aggregate-interlock joints, without concrete shoulder)

Slab thickness (mm)	*k* of subgrade-subbase (MPa/m)				
	20	40	60	80	140
100	3.94/4.00	3.92/3.93	3.90/3.90	3.88/3.88	3.84/3.84
110	3.82/3.90	3.79/3.82	3.78/3.79	3.76/3.76	3.72/3.72
120	3.71/3.81	3.68/3.73	3.67/3.69	3.65/3.66	3.62/3.62
130	3.61/3.73	3.58/3.65	3.56/3.60	3.55/3.57	3.52/3.52
140	3.52/3.66	3.49/3.57	3.47/3.52	3.46/3.49	3.43/3.43
150	3.43/3.59	3.40/3.50	3.38/3.45	3.37/3.42	3.34/3.36
160	3.35/3.53	3.32/3.43	3.30/3.38	3.29/3.35	3.26/3.28
170	3.28/3.48	3.24/3.37	3.22/3.32	3.21/3.28	3.18/3.22
180	3.21/3.42	3.17/3.32	3.15/3.26	3.14/3.23	3.11/3.16
190	3.15/3.37	3.11/3.27	3.08/3.21	3.07/3.17	3.04/3.10
200	3.09/3.33	3.04/3.22	3.02/3.16	3.01/3.12	2.98/3.05
210	3.04/3.28	2.99/3.17	2.96/3.11	2.95/3.07	2.92/3.00
220	2.98/3.24	2.93/3.13	2.90/3.07	2.89/3.03	2.86/2.95
230	2.93/3.20	2.88/3.09	2.85/3.03	2.83/2.98	2.80/2.91
240	2.89/3.16	2.83/3.05	2.80/2.99	2.78/2.94	2.75/2.66
250	2.84/3.13	2.783.01	2.75/2.95	2.73/2.91	2.70/2.82

FINAL EXAMINATION

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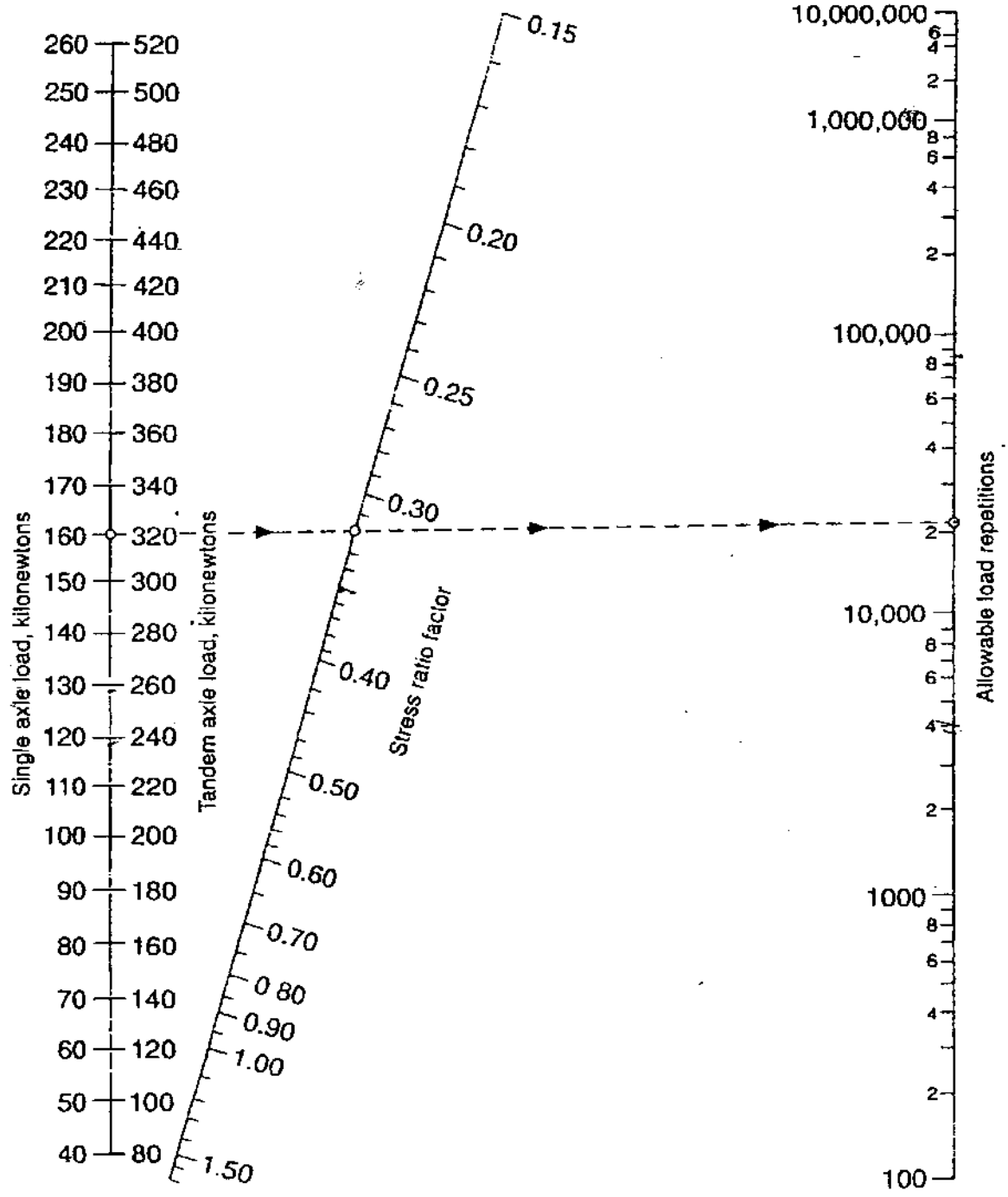

Figure Q2(a) Fatigue Analysis – Allowable repetitions based on stress ratio factor (with or without concrete shoulder)

FINAL EXAMINATION

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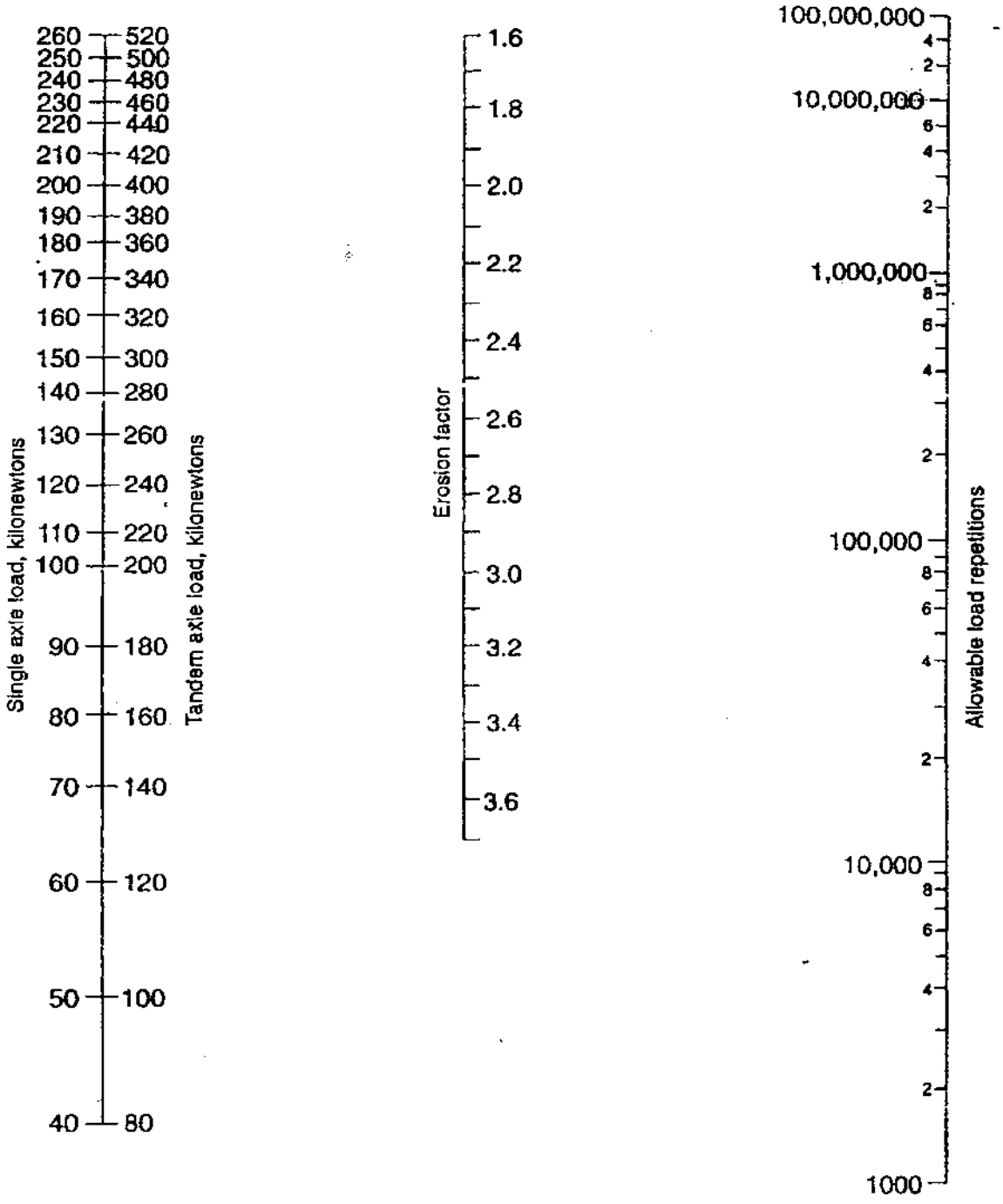

Figure Q2(b) Erosion Analysis – Allowable repetitions based on erosion factor (with concrete shoulder)

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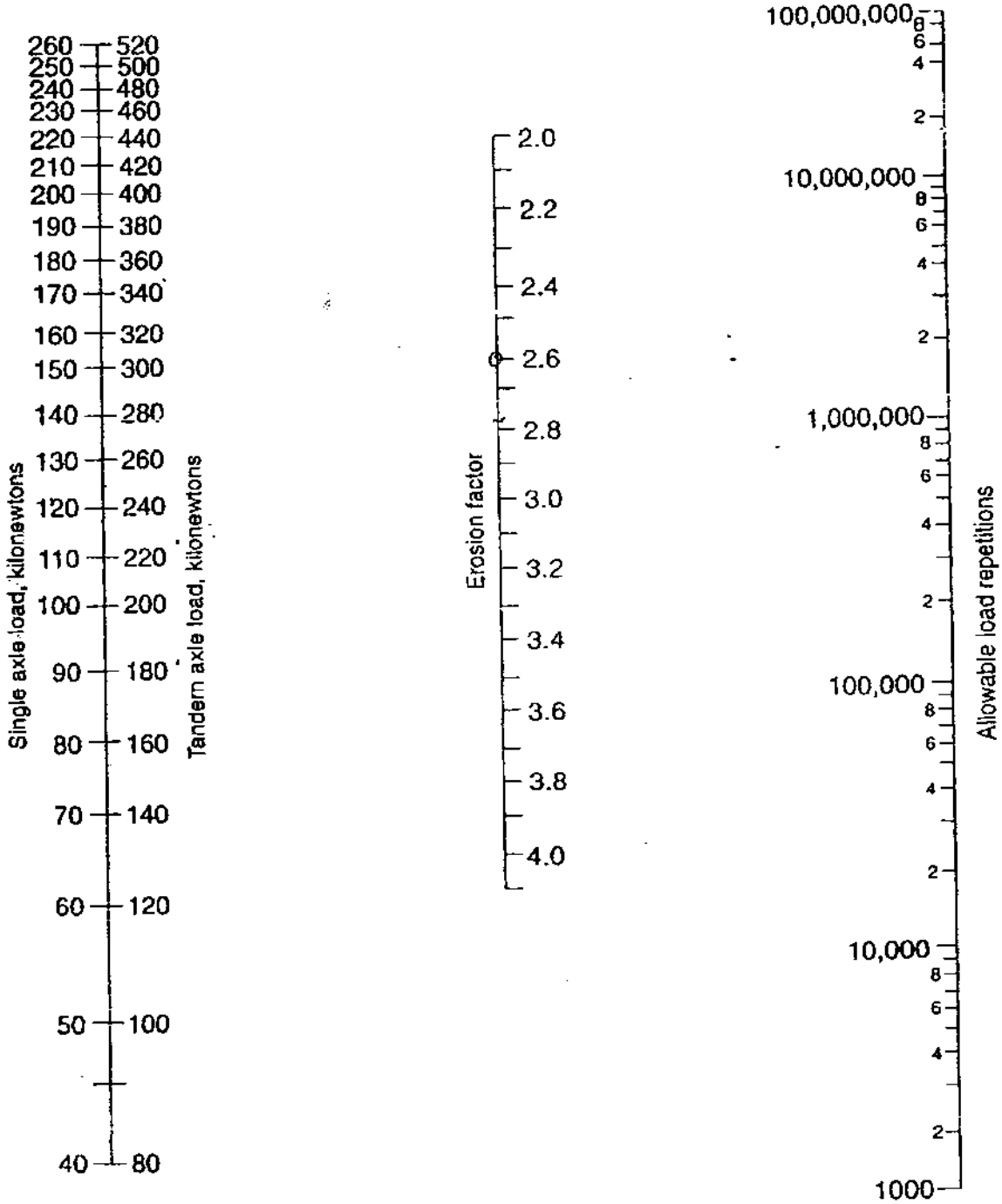

Figure Q2(c) Erosion Analysis – Allowable repetitions based on erosion factor (without concrete shoulder)

FINAL EXAMINATION

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Note: If you are answering **Q2**, utilise this sheet and include it in your answer script.

Project : _____
Trial Thickness : _____ mm
Subbase - subgrade, *k*: _____MPa/m
Modulus of rupture, M_R : _____MPa
Load safety factor, LSF : _____

Doweled joints : **Yes** ____ / **No**____
Concrete shoulder : **Yes** ____ / **No** ____
Design period : ____ 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 : _____ 10. Erosion factor : _____
9. Stress ratio factor : _____

Single Axles

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

Tandem Axles

			Total =		**Total =**	

Figure Q2(d): Concrete Pavement Design Worksheet

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Note: If you are answering **Q3**, utilise this sheet and include it in your answer script.

Table 3(a): Soil density and moisture content

Laboratory Compaction Test		In-situ (borrow pit)	
Maximum Dry density (Mg/m^3)	Optimum water content (%)	Bulk density (Mg/m^3)	Natural moisture content (%)
1.86	12	1.68	8.2

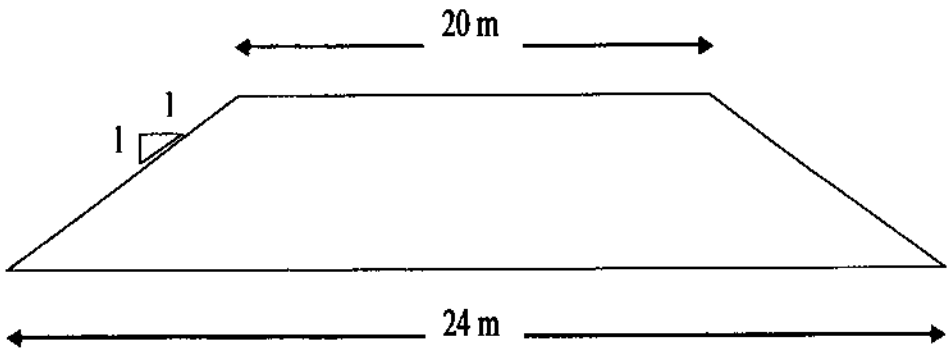

Figure Q3(a): Cross section of the embankment

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Note: If you are answering **Q4**, utilise this sheet and include it in your answer script.

RESIDUAL BINDER RATE OF APPLICATION

$$R = (0.138 \times ALD + e) \times T_f$$

Sand Circle Diameter* (mm), ∅	Bitumen needed o fill surface void (l/m^2), "e"	Traffic in lane (vpd/lane)	T_f
150	0.49	5	1.596
160	0.45	10	1.523
165	0.39	20	1.451
170	0.37	30	1.409
175	0.34		
180	0.32	40	1.379
185	0.30	50	1.356
190	0.29	75	1.314
195	0.27	100	1.284
200	0.25		
210	0.22	150	1.242
220	0.20	200	1.212
230	0.18	300	1.170
240	0.16	400	1.140
250	0.14		
260	0.13	500	1.117
270	0.12	750	1.074
280	0.11	1,000	1.004
290	0.11	1,500	1.002
300	0.09		
325	0.07	2,000	0.972
350	0.05	3,000	0.930
400	0.03	4,000	0.900
500	0.00	5,000	0.877

* Sand Patch Test with 45 ml volume of sand

Figure Q4(a): Residual binder rate of application

FINAL EXAMINATION

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Useful Fomula;

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

Volume of cylinder, $V = \frac{\pi D^2 t}{4}$; $R = (0.138\,ALD + e)\,T_f\ (\ell / m^2)$; $C = \frac{ALD}{666}$ m^3/m^2