CONFIDENTIAL

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER 1
SESSION 2014/2015

COURSE NAME	:	HIGHWAY ENGINEERING
COURSE CODE	:	BFC 31802
PROGRAMME	:	3 BFF
EXAMINATION DATE	:	DECEMBER 2014/JANUARY 2015
DURATION	:	2 HOURS 30 MINUTES
INSTRUCTION	:	ANSWER **FOUR (4)** QUESTIONS

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

Q1 (a) There are several types of bitumen in asphaltic concrete production for pavement.

(i) What is the difference between the production of cutback and emulsified bitumen?

(3 marks)

(ii) What is the suitable type of cutback bitumen to be used as a prime coat and tack coat in the road construction and give the justification for each answer.

(4 marks)

(iii) The road-base layer which consists of limestone aggregate has been completely constructed. What type of emulsified bitumen is suitable for application as prime coat for this layer and give the reason for your answer.

(2 marks)

(b) Briefly describe **THREE (3)** physical properties which are commonly used to characterize the strength of a subgrade.

(6 marks)

(c) Selection of suitable soils to be used as subgrade for pavement is primary importance in the design and construction of highway.

(i) List **FOUR (4)** characteristics of soils those considered as unsuitable material for subgrade and for each mentioned characteristic explain why the soils shall not be used as subgrade material.

(4 marks)

(ii) If the subgrade materials in cut area are found to have California Bearing Ratio (CBR) values of less than that required by JKR specification, what shall be done to the top 300 mm of the subgrade.

(3 marks)

(iii) List **THREE (3)** types of test related to subgrade soil and mention their purposes.

(3 marks)

Q2 (a) List and explain **FIVE (5)** disadvantages of concrete pavement.

(5 marks)

(b) A plain concrete rigid pavement, doweled joint and concrete shoulders is designed for a two-lane two- direction road. Average daily truck traffic is 2500.

Given:

Modulus of subgrade reaction (k)	= 40	MPa/m
Concrete Modulus of Rupture (M_R)	= 4.5	MPa
Safety factor LSF	= 1.2	
Slab thickness	= 240	mm

Using nomograph and tables (PCA method), complete the calculation form as shown in **Table 1** and determine:

(i) Percentage of fatigue.

(ii) Percentage of damage cause by erosion.

(iii) Compare the percentage of fatigue and erosion, give your comment and justification.

(20 marks)

Q3 (a) Explain the following terms that are commonly used in stopping sight distance.

(i) Perception Time

(ii) Reaction Time

(3 marks)

(b) A horizontal curve is to be designed for a section of a highway in rural area which has a design speed of 60 km/h. Calculate the value of superelevation required at this curve if the physical conditions restrict the radius of the curve to 150 m.

(4 marks)

(c) Sign placement involves many issues including the human eye's visual field. Consider the placement of a sign indicating: "TOLL PLAZA AHEAD – BE PREPARED TO STOP." Analyze how far in advance of the toll plaza should such sign be placed to inform the motorists. Given that it can be seen from a distance of 100 m, and that queued vehicles from the toll plaza rarely extend more than 50 m from the gates. Approach speed is 60 km/h, the coefficient of friction is 0.33 and perception-reaction time is 2.5 sec.

(6 marks)

(d) From 2008 to the end of 2011, about fourteen road projects were constructed and widened in Johor especially in areas of Iskandar Malaysia. The vertical curve on that road is a sag vertical curve as shown in **Figure Q3** where the departure grade is -1.75% and the approach grade is +2.25%. Length of the curve is 1200 m and the elevation of vertical intersection point is 591 m.

(i) Design the vertical curve for each 100 m interval

(ii) Calculate the elevations of the minimum point.

(12 marks)

Q4 (a) State **TWO (2)** main objectives of site investigation in the preliminary works of road construction process.

(2 marks)

(b) The following project data for the newly constructed road is listed as follows:

Length of proposed road	= 10 km
Cross-sectional area of embankment	= 36 m^2
Average distance of borrow area from embankment	= 10 km

Results from the laboratory testing for the soil from the borrow pit to construct the embankment are listed as follows:

Maximum Dry Density (MDD)	= 1.95 Mg/m^3
Optimum Moisture Content (OMC)	= 8 %
Bulk density, γ_b	= 1.75 Mg/m^3
Actual moisture content, m	= 6 %

The bulk density and moisture content of borrow material is 1.75 Mg/m^3 and 6 % respectively. According to the specification, the embankment should be compacted at least to 95 % of the MDD. With the bulking factor of 1.30, determine:

(i) Volume of borrow material required for 1 cubic meter of compacted road embankment.

(4 marks)

(ii) Volume of additional water required for the entire volume of embankment.

(4 marks)

(iii) The number of truckloads of soil required if hauling capacity per truck is 8 m^3.

(4 marks)

(iv) Construction cost of embankment with the following costs:
Purchase and borrow pit material at site, haul 2 km round trip, and spread with bulldozer = RM 70/m^3

Extra haul for each km round trip = RM 10/m^3
Compaction = RM 10/m^3

(4 marks)

(c) Quality has become one of the most important factors in the selecting products and provides services. For road construction, the quality of the work has been control by implementing the quality assurance.

(i) List any **FOUR (4)** activities which involve in the quality assurance in road construction.

(4 marks)

(ii) According to American Association Society Highway Transportation Officials (AASHTO), there are **THREE (3)** key components which designated to define quality assurance. State the **THREE (3)** key components.

(3 marks)

Q5 (a) What are the basic purposes of Pavement Management System?

(2 marks)

(b) Surface deformation is one category of pavement distress. Briefly explain the following surface deformation types:

(i) Rutting
(ii) Depression
(iii) Corrugation
(iv) Shoving

(8 marks)

(c) Discuss in detail **ONE (1)** of Non-destructive Deflection Testing (NDT) method for pavement structural evaluation.

(5 marks)

(d) After conducting a pavement condition survey in Jalan Parit Botak (J9), it can be concluded that the average PCI value was 50 and considered as fair, mainly due to the surface defects. As an engineer, propose **TWO (2)** techniques of rehabilitation methods to treat the road. Give your justification for each technique chosen.

(10 marks)

- END OF QUESTION -

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Table 1: Calculation of Pavement Thickness

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

Doweled joints :
Conrete shoulder :
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 :
9. Stress ratio factor :
10. Erosion factor:

Single Axle

133						
125						
115						
107						
98						

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

Tandem Axle

231						
213						
195						
178						
160						
			Total		**Total**	

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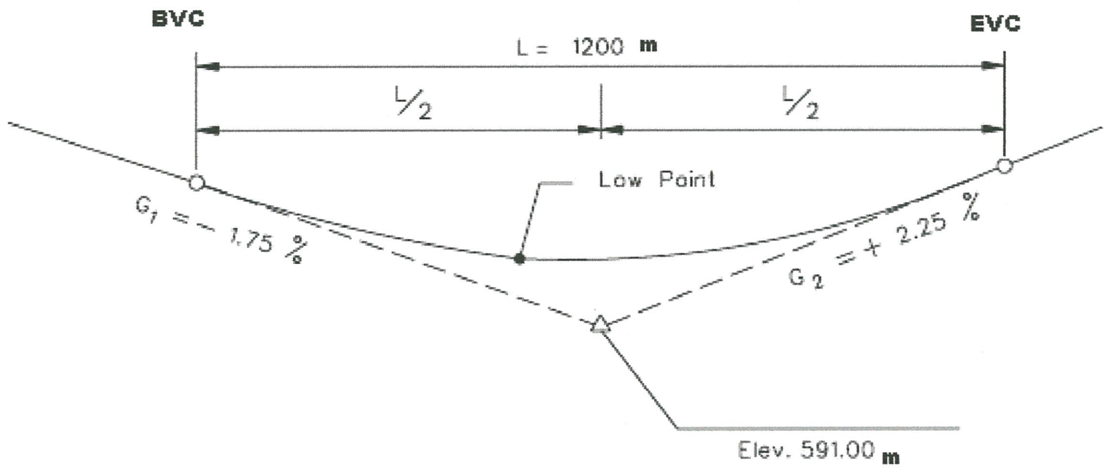

FIGURE Q3

FORMULAE

$$SSD = 0.278tV + V^2/254f$$

$$R_{min} = \frac{V^2}{127(e_{max} + f_{max})}$$

$$x_{min/max} = \frac{G_1 L}{A}$$

$$Y_{min/max} = \frac{G_1 x_{min/max}}{100} - \frac{A}{200L}(x_{min/max})^2$$

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Table 2: Longitudinal Coefficient of Friction Proposed for Certain Design Speeds

Design speed, *V* (km/hr)	30	40	50	60	70	80	90	100	110	120
Coefficient of friction, *f*	0.40	0.38	0.35	0.33	0.31	0.30	0.30	0.29	0.28	0.28

Table 3: Side Friction Factor

Design speed (km/h)	Side friction factor, f
30	0.17
40	0.17
50	0.16
60	0.15
70	0.14
80	0.14
90	0.13
100	0.12

Table 4: Desired minimum horizontal curve radius (JKR)

Design Speed (km/h)	Minimum Radius (m)	
	e = 6%	e = 10%
120	710	570
100	465	375
80	280	230
60	150	125
50	100	85
40	60	50
30	35	30
20	15	15

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APPENDIXES

Table 5. 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 6b: 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 7a. Erosion Factors—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 8a. Erosion Factors–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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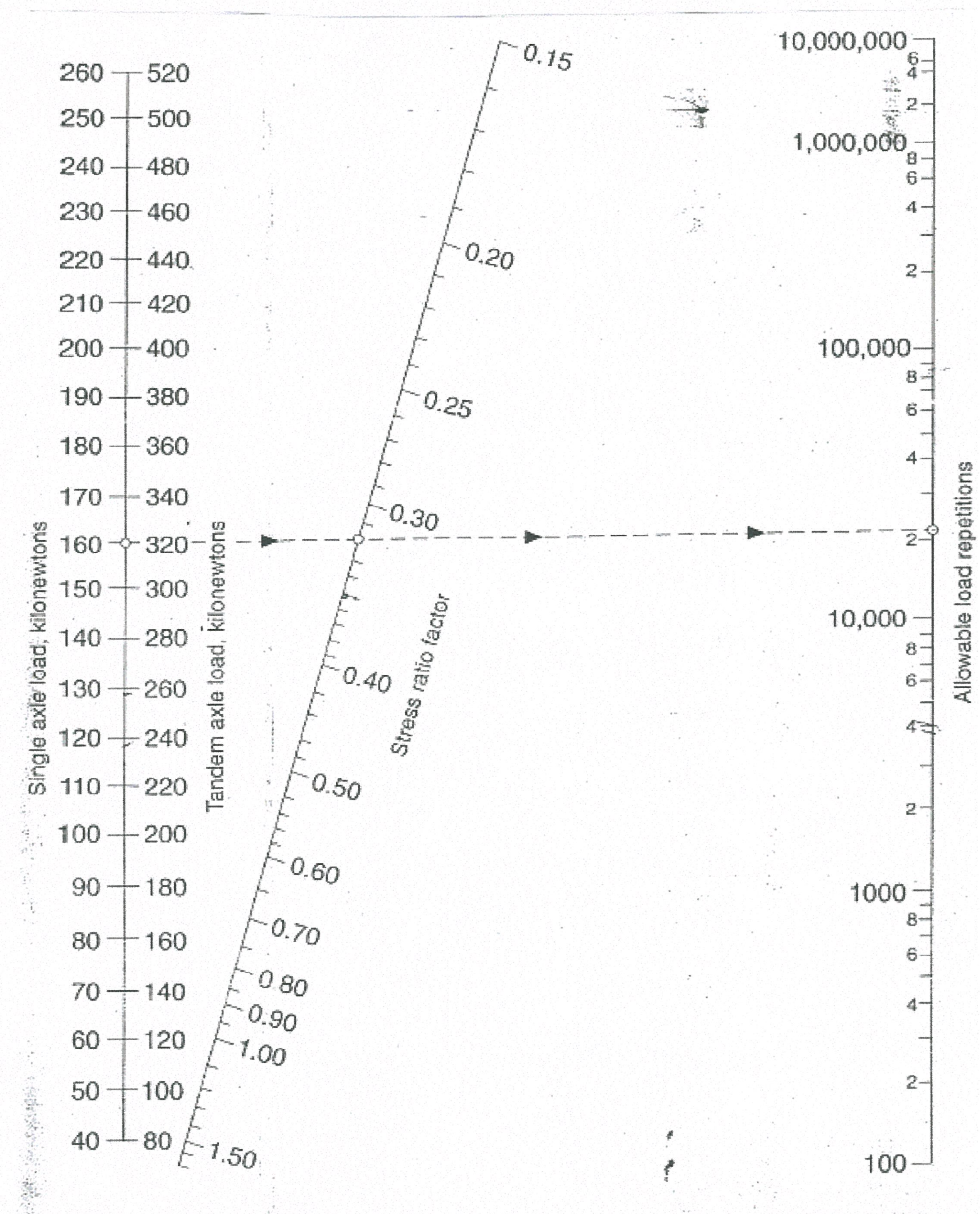

Fig. 5. Fatigue analysis—allowable load repetitions based on stress ratio factor (with and without concrete shoulder).

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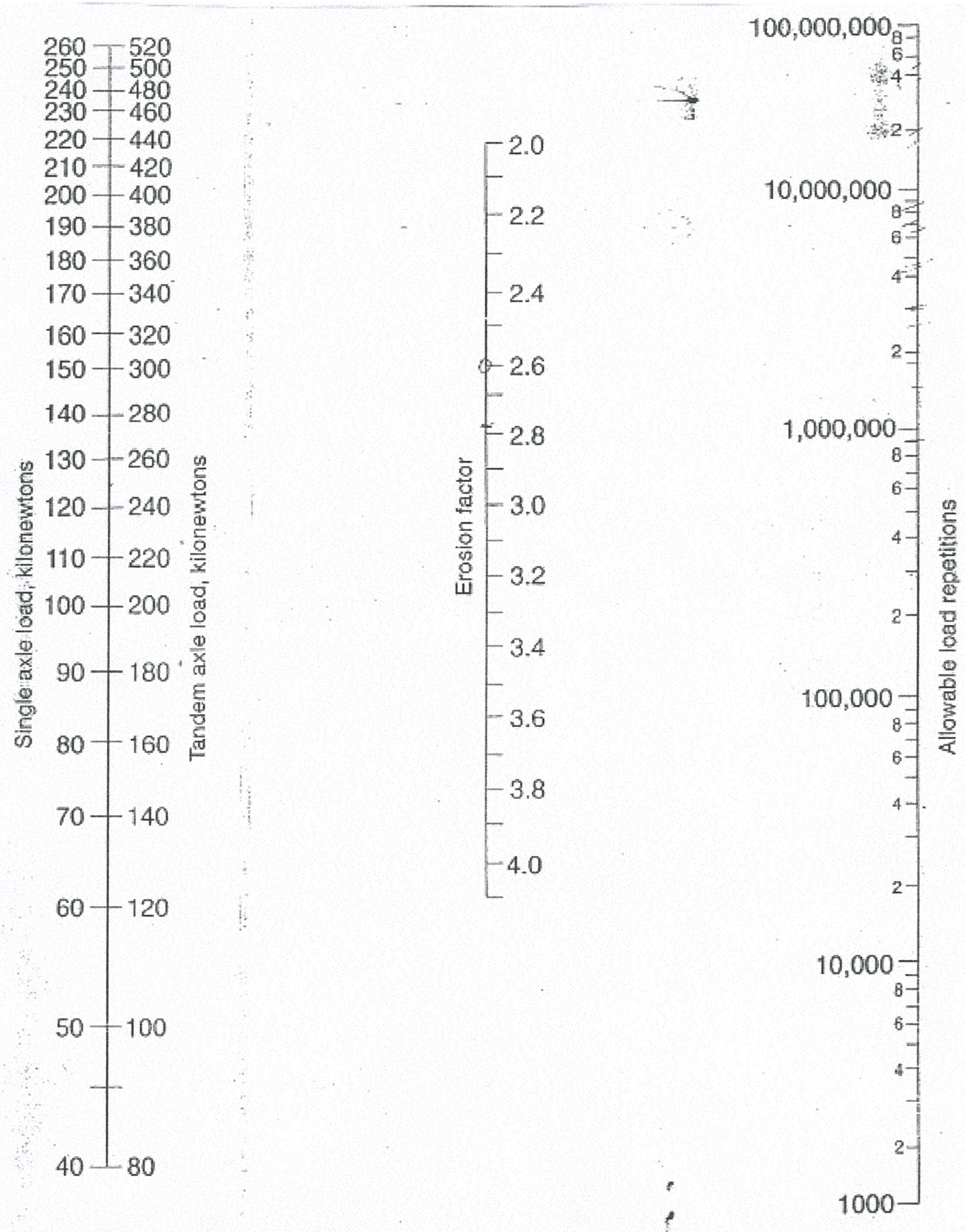

Fig. 6a. Erosion analysis—allowable load repetitions based on erosion factor (without concrete shoulder).

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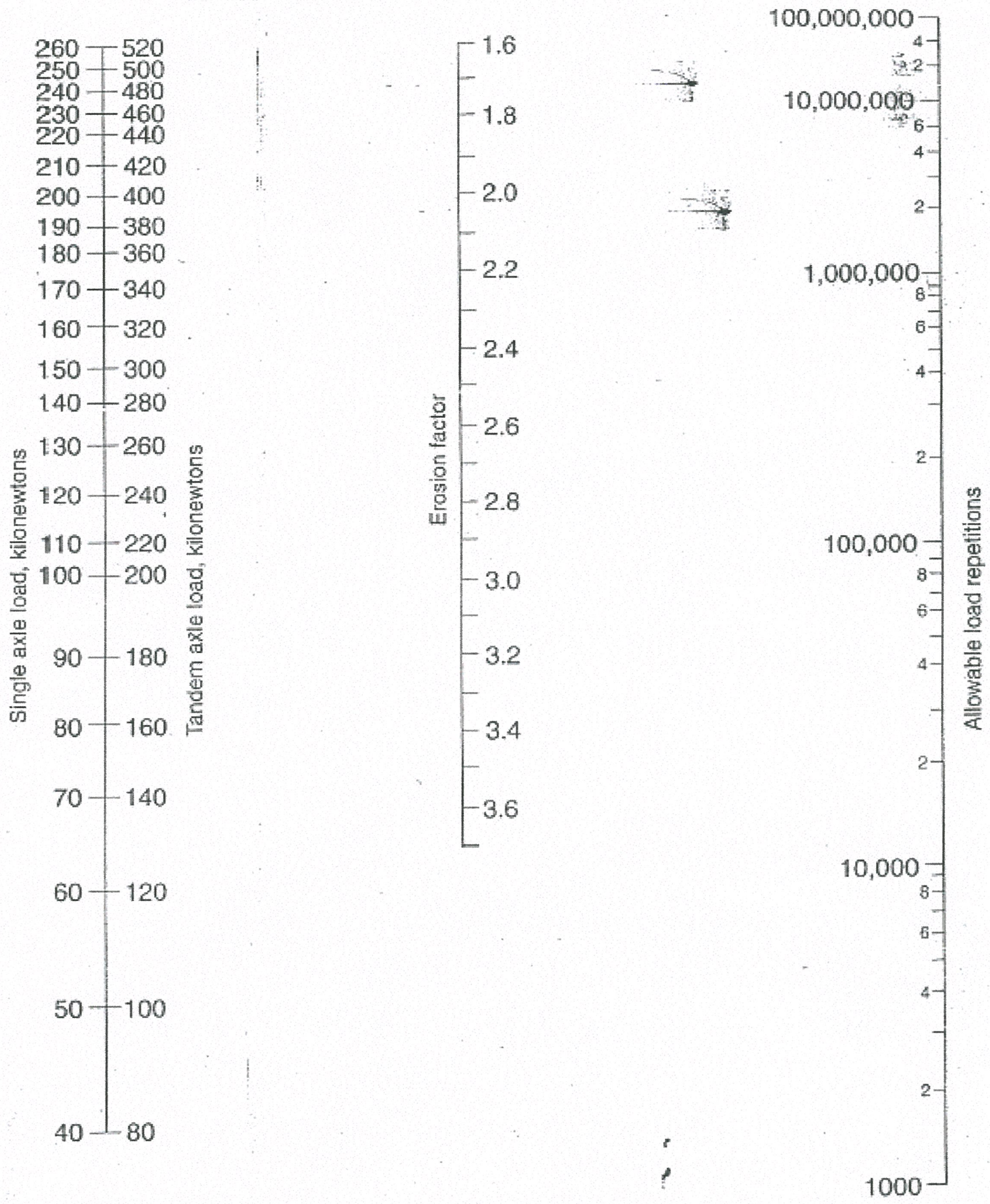

Fig. 6b. Erosion analysis—allowable load repetitions based on erosion factor (with concrete shoulder).