Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2022/2023

COURSE NAME	: PAVEMENT ENGINEERING
COURSE CODE	: BFT 40203
PROGRAMME CODE	: BFF
EXAMINATION DATE	: FEBRUARY 2023
DURATION	: 3 HOURS
INSTRUCTIONS	: 1. ANSWER **ALL** QUESTIONS. 2.THIS FINAL EXAMINATION IS CONDUCTED VIA **OPEN BOOK.** 3.STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUCTED VIA CLOSED BOOK.

THIS QUESTION PAPER CONSISTS OF **TWELVE (12)** PAGES

Q1 (a) Pavement performance is an important factor of pavement design because it provides a framework upon which a judgement on the road success or failure, which is associated with ability of the pavement to carry out the design loading. Based on those statements, briefly discuss a distinction between two different types of failure.

(4 marks)

(b) Providing an appropriate foundation for road pavement structures constitutes a significant problem for designers when the pavement fails earlier than expected during design life. Based on the statement, propose and discuss THREE (3) the most possibility soil and engineering factors that may contribute to pavement failures.

(6 marks)

(c) Roughness index are derived from road profile data and correlated with road users' perceptions of ride quality to indicate the level of pavement roughness. Based on these statements, propose and explain a worldwide standard method to measuring the road smoothness longitudinally based on of the World Bank (1980).

(7 marks)

(d) A riding quality rating over the road surface pavement was correlated with road maintenance or rehabilitation event with amount of traffic using it. With the sketch of diagrams, discuss how a maintenance works can improve the serviceability of the road.

(8 marks)

Q2 (a) The increasing of load transfer in jointed plain concrete pavement increases the joint deflection and stress on a connection of horizontal joint movement between approach slab and leave slabs. Based on this statement, with illustration of relevant diagrams discuss the methods that can be used to solve the problem.

(7 marks)

(b) The basic types of joints are purposefully placed in discontinuities of a rigid pavement in order to take place the deformation. Joints comprised of a filler which separates the slabs, and a sealing compound which is used to prevent the entry of water. Sketch and describe the method that can be used to solve the effect of temperature and subgrade moisture variation on joint construction.

(7 marks)

(c) Propose and explain in detail the appropriate principal responses that are commonly used to evaluate the stresses and deflections analysis in rigid pavement slab.

(11 marks)

Q3 (a) An interlaced cracking pattern caused by a fatigue failure on asphalt surface or a stabilized road base layer are considered as typical pavement deterioration. Discuss THREE (3) possible methods how to control these defects on asphalt pavement.

(6 marks)

(b) A concrete pavement designed with doweled joints and concrete shoulders has been proposed for a four-lane interstate highway. The pavement will be laid onto a combined subbase/subgrade with Modulus of subgrade reaction as 30 MPa/m. The following data have been provided:

- Concrete flexural strength = 4.5 MPa
- Load Safety factor = 1.2
- Design life = 20 years
- Design daily truck traffic is 20% from the average daily traffic of 30,000.

Refer **Table Q3(b)(ii)** to **Table Q3(b)(ix)** and **Figure Q3(b)(i)** to **Figure Q3(b)(iii)** in your calculation.

(i) Predict the design slab thickness by starting the calculation with trial thickness of 190 mm. Do your calculation using **Table Q3(b)(i).**

(15 marks)

(ii) Based on the analysis in **Q3(b)(i),** discuss on the adequacy of the concrete slab thickness.

(4 marks)

Q4 (a) An expression of irregularities in the pavement surface that adversely affect the ride quality of a vehicle, fuel consumption and maintenance costs. Based on those statements, propose and explain a strategy how to improve the serviceability which related to road physical deterioration.

(8 marks)

(b) Road construction and maintenance activities shall be properly providing a maintenance and information data for government decision-makers in future investment strategies within constrained to funding levels. Based on these statements;

(i) Propose and explain a suitable tool analysis to evaluate the different investment strategies to maximize performance in further alternative for road construction and maintenance.

(8 marks)

(ii) Based on the answer in **Q4(b)(i),** discuss the benefits of selected analysis tool selected.

(9 marks)

- END OF QUESTIONS -

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Note: If you are answering **Q3(b)**, please submit this sheet along with your answer script.

Table Q3(b)(i): Calculation of Pavement Thickness

Trial Thickness : **190.00** 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 : ______
9. Stress ratio factor : ______
10. Erosion factor : ______

Single Axles

Axle Load (kN)	Axle Load by LSF	Expected repetition	Alowable repetition (fatigue)	Fatigue percent	Allowable repetition (erosion)	Damage percent
125						
107						
98						
80						

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

Tandem Axles

Axle Load (kN)	Axle Load by LSF	Expected repetition	Alowable repetition (fatigue)	Fatigue percent	Allowable repetition (erosion)	Damage percent
231						
213						
178						
142						
			Total =		**Total =**	

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Table Q3(b)(ii): Truck Distribution for Multiple-Lane Highways

One-way ADT	Two lanes in each direction		Three or more lanes in each direction		
	Inner	Outer	Inner[a]	Center	Outer
2000	6	94	6	12	82
4000	12	88	6	18	76
6000	15	85	7	21	72
8000	18	82	7	23	70
10,000	19	81	7	25	68
15,000	23	77	7	28	65
20,000	25	75	7	30	63
25,000	27	73	7	32	61
30,000	28	72	8	33	59
35,000	30	70	8	34	58
40,000	31	69	8	35	57
50,000	33	67	8	37	55
60,000	34	66	8	39	53
70,000	—	—	8	40	52
80,000	—	—	8	41	51
100,000	—	—	9	42	49

[a] Combined inner one or more lanes
Source. After Darter et al. (1985).

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Table Q3(b)(iii): 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 Q3(b)(iv): 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 Q3(b)(v): 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 Q3(b)(vi): 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 Q3(b)(vii): 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 Q3(b)(viii): 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 Q3(b)(ix): 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

(Single axle/Tandem axle)

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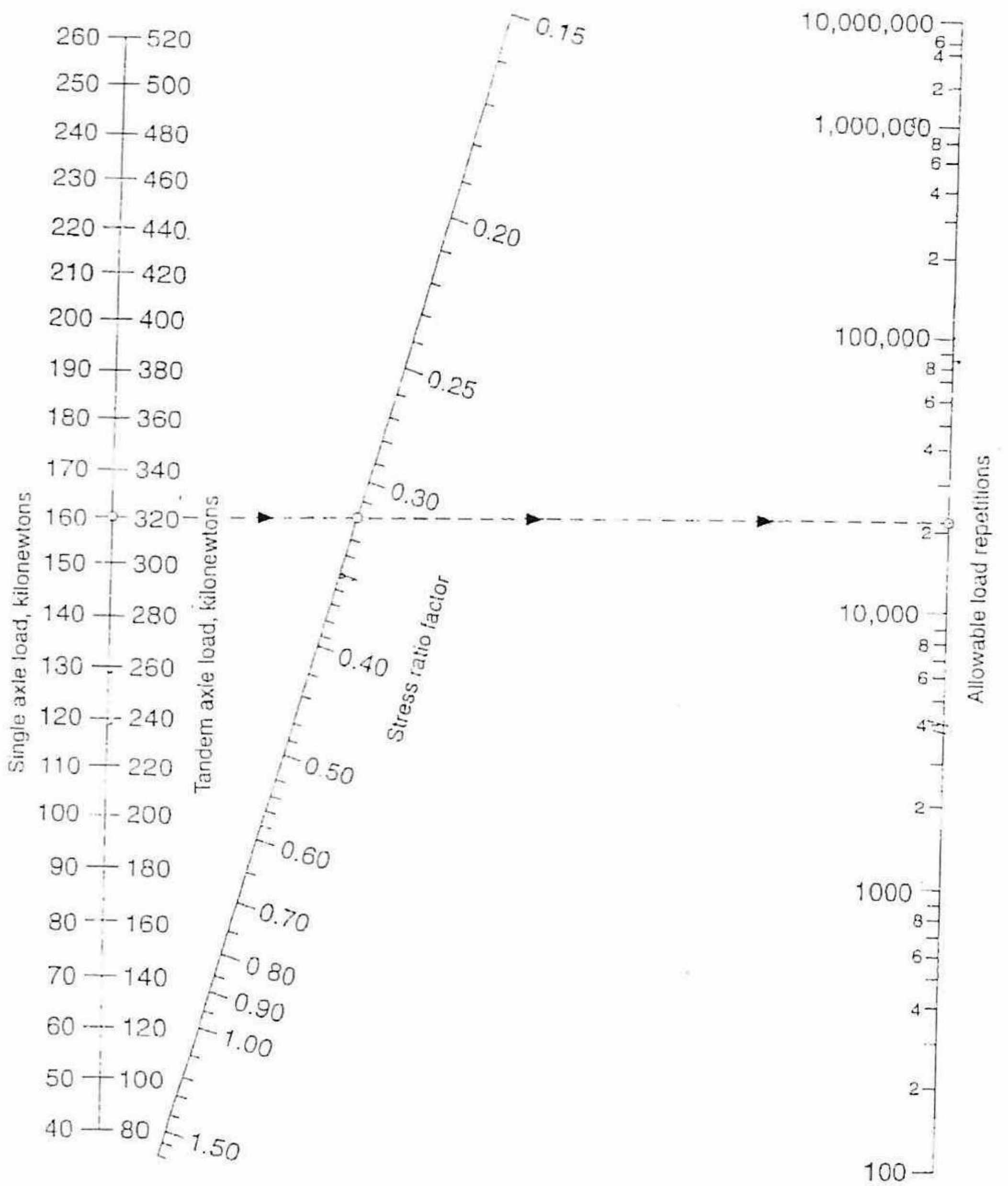

Figure Q3(b)(i): Fatigue Analysis – Allowable repetitions based on stress ratio factor (with or without concrete shoulder)

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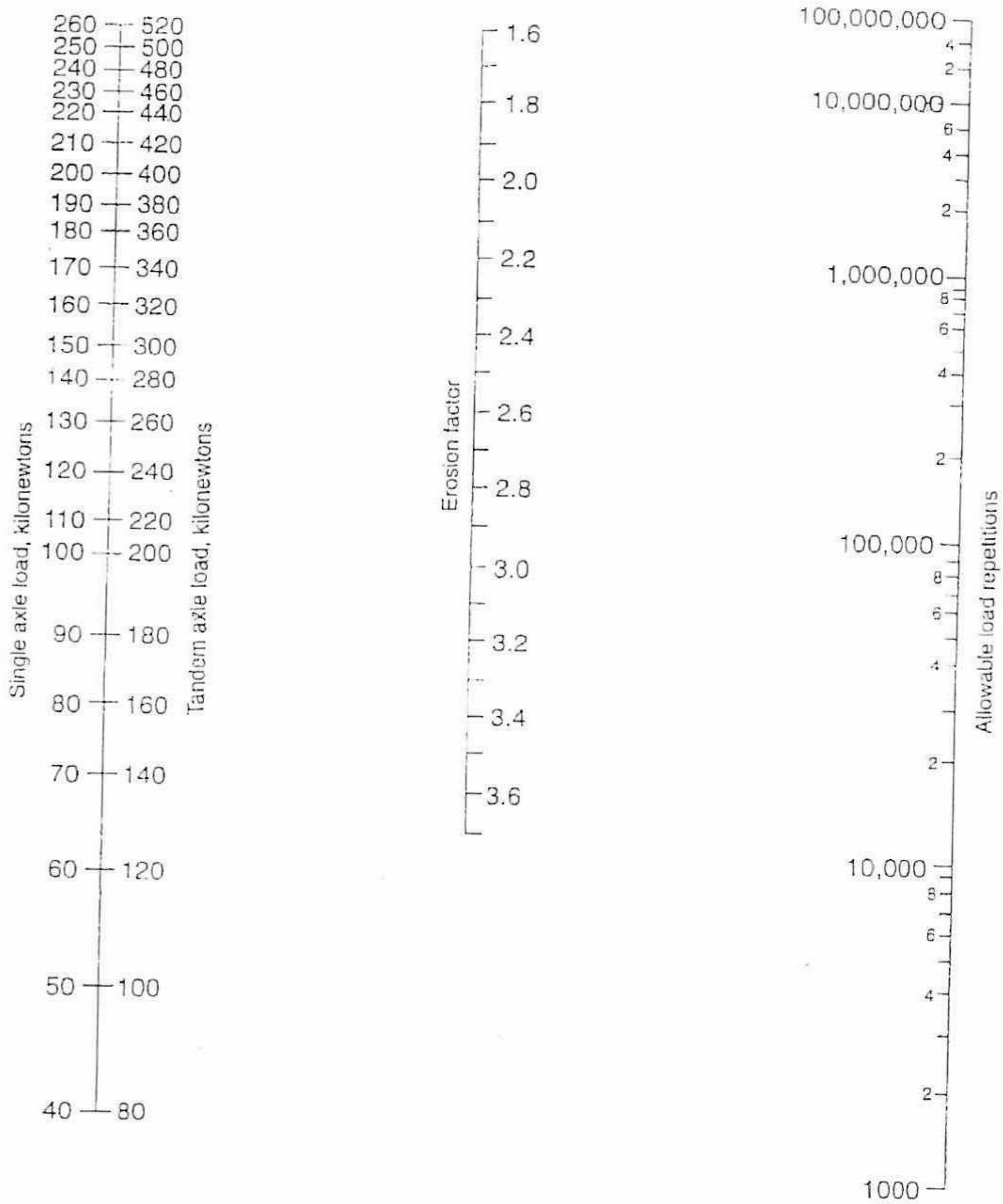

Figure Q3(b)(ii): Erosion Analysis – Allowable repetitions based on erosion factor (with concrete shoulder)

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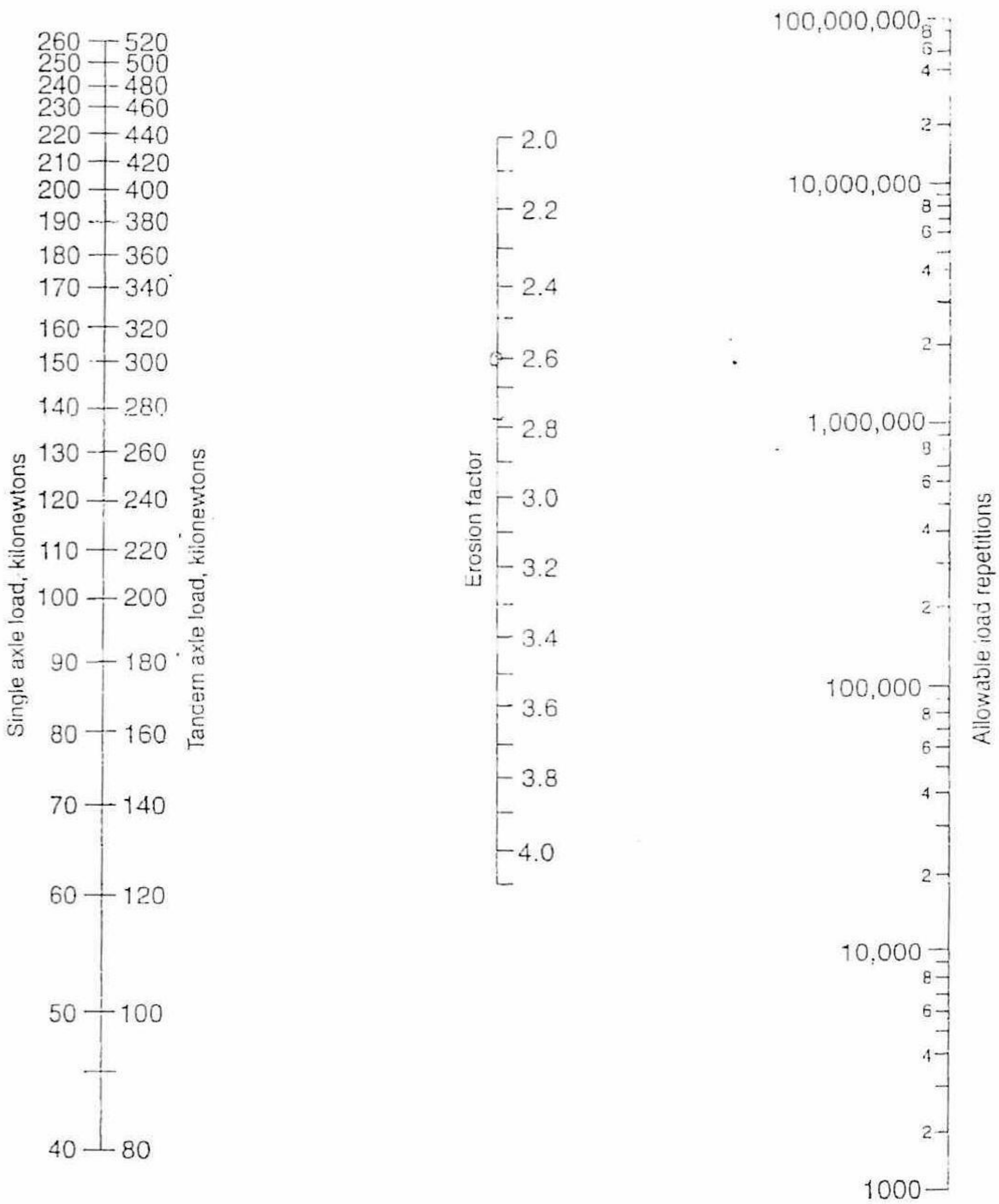

Figure Q3(b)(iii): Erosion Analysis – Allowable repetitions based on erosion factor (without concrete shoulder)