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UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2023/2024

COURSE NAME	:	PAVEMENT ENGINEERING
COURSE CODE	:	BFT40203
PROGRAMME CODE	:	BFF
EXAMINATION DATE	:	JANUARY / FEBRUARY 2024
DURATION	:	3 HOURS
INSTRUCTION	:	1. ANSWER **ALL** QUESTIONS 2. THIS FINAL EXAMINATION IS CONDUCTED VIA ☐ Open Book ☒ Close 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 **FOURTEEN (14)** PAGES

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Q1 (a) Defined **THREE (3)** tests which utilized in evaluating the strength properties of soil as a road foundation.

(3 marks)

(b) Discuss **SEVEN (7)** factors that are considered in a flexible pavement design according to the American Association of State Highway and Transportation Officials (AASHTO) 1993 pavement design guideline.

(7 marks)

(c) Briefly describe the differences between empirical and mechanistic-empirical approach in designing of pavement structural layer thickness according to the American Association of State Highway and Transportation Officials (AASHTO 1993) and Jabatan Kerja Raya (Arahan Teknik Jalan 5/85) 2013.

(10 marks)

(d) Explain the differences between surface drainage and subsurface drainage and briefly illustrate **THREE (3)** main type for each.

(5 marks)

Q2 (a) The differential shrinkage and variable expansion in rigid pavement are serious problem that can lead to serve roughness in a degree of flexibility concrete, induce critical stresses and cracking in rigid pavement slabs. Based on the statements, sketch a diagram and discuss in detail the phenomenon in jointed concrete pavement.

(9 marks)

(b) A rigid pavement will be constructed and designed based on daily truck traffic consists of 80 single axles at 22,500 kg each, 570 tandem axles at 25,000 kg each, 50 tandem axles at 39,000 kg each and 80 triple axles at 48,000 kg each. Pavement's modulus of rupture is considered as 600 kg/in^2 and the modulus of elasticity as 5 million kg/in^2. The targeted reliability is 95%, with an overall standard deviation of 0.4 and a drainage coefficient of 0.9. Present Serviceability Index (PSI) is 1.7 (with a Terminal Serviceability Index (TSI) of 2.5), and the load transfer coefficient is 3.2, while the modulus of subgrade reaction considered as 200 kg/in3. Based on the statements, calculate the slab thickness required of rigid pavement for 20 years design life. Refer to **Table APPENDIX A.1,** to **APPENDIX A.3**, **Figure APPENDIX B.1**, and **Figure APPENDIX B.3**.

(8 marks)

(c) A flexible pavement is designed with 4 inches hot-mix asphalt (HMA) wearing surface (0.44), 7 inches of dense graded crushed stone bases (0.14), and 10 inches of crushed stone subbase (0.11) constructed on soil with the resilient modulus considered as 5000 kg/in2. The pavement was designed with 90% reliability, an overall standard deviation of 0.4, Present Serviceability Index (PSI) of 2.0 and Terminal Serviceability Index (TSI) of 2.5. The drainage coefficient is 0.9 and 0.8 for the base and subbase, respectively. Determine how many a single axle loads can be carried before the pavement reached its Terminal Serviceability Index (TSI) (with given reliability). Refer to **Table APPENDIX A.4,** for cumulative percent probability, of standard normal distribution (R), corresponding ZR, and pavement Structural Number (SN).

(8 marks)

Q3 (a) Elaborate the appropriate maintenance method that are commonly used to measure the vertical deflection response on flexible pavement layer without destructing the pavement structure.

(9 marks)

(b) **Figure APPENDIX B.3,** illustrates a homogeneous half space subjected to two circular loads application, which each load has a diameter of 10 inches and is spaced 20 inches apart. The pressure on circular areas is 50 psi, and the half space homogeneous has an elastic modulus of 10,000 psi and a Poisson ratio of 0.3. From a provided statements and location of point A that situated 10 inches below the centre of one circular load, compute the following parameters at point A.

i. Vertical Stress. (3 marks)

ii. Strain experienced. (3 marks)

iii. Deflection. (3 marks)

Refer to **Figure APPENDIX B.4** to **Figure APPENDIX B.7.**

(c) Describe the factors that are regularly measured by highway pavement agencies to evaluate the quality and performance for rigid pavements, which included of International Roughness Index (IRI), friction measurements, rut depth, faulting, and punchouts.

(7 marks)

Q4 (a) Surface conditions of three highway sections have been assessed and the results are presented in the **Table APPENDIX A.5**. Additionally, the table includes details regarding climatic and traffic data conditions for each section. Evaluate the order of priority for rehabilitation by using rational factorial rating method.

(10 marks)

(b) Discuss the implementing of network level in Pavement Management System (PMS) for a newly development network of pavement works rehabilitation program.

(9 marks)

(c) Explain the differences among the objectives of **THREE (3)** types of road maintenance activities that focused on maintaining roads in their initial or original conditions.

(6 marks)

– END OF QUESTIONS –

APPENDIX A

Table APPENDIX A.1. Axle Load Equivalent Factor for Rigid Pavement, Single Axle, TSI = 2.5

Axle Load (Kips)	Slab thickness, D (inches)								
	6	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
2	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
4	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
6	0.012	0.011	0.010	0.010	0.010	0.010	0.010	0.010	0.010
8	0.039	0.035	0.033	0.032	0.032	0.032	0.032	0.032	0.032
10	0.079	0.089	0.084	0.082	0.081	0.080	0.080	0.080	0.080
12	0.203	0.189	0.181	0.176	0.175	0.174	0.174	0.174	0.174
14	0.376	0.360	0.347	0.341	0.338	0.337	0.336	0.336	0.336
16	0.634	0.623	0.610	0.604	0.601	0.599	0.599	0.599	0.598
18	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
20	1.51	1.52	1.55	1.57	1.58	1.58	1.59	1.59	1.59
22	2.21	2.20	2.28	2.34	2.38	2.40	2.41	2.41	2.41
24	3.16	3.10	3.22	3.36	3.45	3.50	3.53	3.54	3.55
26	4.41	4.26	4.42	4.67	4.85	4.95	5.01	5.04	5.05
28	6.05	5.76	5.92	6.29	6.61	6.81	6.92	6.98	7.01
30	8.16	7.67	7.79	8.28	8.79	9.14	9.35	9.46	9.52
32	10.8	10.1	10.1	107	11.4	12.0	12.3	12.6	12.7
34	14.1	13.0	12.9	13.6	14.6	15.4	16.0	16.4	16.5
36	18.2	16.7	16.4	17.1	18.3	19.5	20.4	21.0	21.3
38	23.1	21.1	20.6	21.3	22.7	24.3	25.6	26.4	27.0
40	29.1	26.5	25.7	26.3	27.9	29.9	31.6	32.9	33.7
42	36.2	32.9	31.7	32.2	34.0	36.3	38.7	40.4	41.6
44	44.6	40.4	38.8	39.2	41.0	43.8	46.7	49.1	50.8
46	54.5	49.3	47.1	47.3	49.2	52.3	55.9	59.0	61.4
48	66.1	59.7	56.9	56.8	58.7	62.1	66.3	70.3	73.4
50	79.4	71.7	68.2	67.8	69.6	73.3	78.1	83.0	87.1

Source: AASHTO Guide for design of pavement structure, Washington, DC, 1993

APPENDIX A

Table APPENDIX A.2. Axle Load Equivalent Factor for Rigid Pavement, Tandem Axle, TSI = 2.5

Axle Load (Kips)	Slab thickness, D (inches)								
	6	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
2	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
4	0.0006	0.0006	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
6	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
8	0.007	0.006	0.006	0.005	0.005	0.005	0.005	0.005	0.005
10	0.015	0.014	0.013	0.013	0.012	0.012	0.012	0.012	0.012
12	0.031	0.028	0.026	0.026	0.025	0.025	0.025	0.025	0.025
14	0.057	0.052	0.049	0.048	0.047	0.047	0.047	0.047	0.047
16	0.097	0.087	0.084	0.082	0.081	0.081	0.080	0.080	0.080
18	0.155	0.143	0.136	0.133	0.132	0.131	0.131	0.131	0.131
20	0.234	0.220	0.211	0.206	0.204	0.203	0.203	0.203	0.203
22	0.340	0.325	0.313	0.308	0.305	0.304	0.303	0.303	0.303
24	0.475	0.462	0.450	0.444	0.441	0.440	0.439	0.439	0.439
26	0.644	0.637	0.627	0.622	0.620	0.619	0.618	0.618	0.618
28	0.855	0.854	0.852	0.850	0.850	0.850	0.849	0.849	0.849
30	1.11	1.12	1.13	1.14	1.14	1.14	1.14	1.14	1.14
32	1.43	1.11	1.47	1.49	1.50	1.51	1.51	1.51	1.51
34	1.82	1.82	1.87	1.92	1.95	1.96	1.97	1.97	1.97
36	2.29	2.27	2.35	2.43	2.48	2.51	2.52	2.52	2.53
38	2.85	2.80	2.91	3.03	3.12	3.16	3.18	3.20	3.20
40	3.52	3.42	3.55	3.74	3.87	3.94	3.98	4.00	4.01
42	4.32	4.16	4.30	4.55	4.74	4.86	4.91	4.95	4.96
44	5.26	5.01	5.16	5.48	5.75	5.92	6.01	6.06	6.09
46	6.36	6.01	6.14	6.53	6.90	7.14	7.28	7.36	7.40
48	7.64	7.16	7.27	7.73	8.21	8.55	8.75	8.86	8.92
50	9.11	8.50	8.55	9.07	9.68	10.14	10.42	10.58	10.66
52	10.8	10.0	10.0	10.6	11.3	11.9	12.3	12.5	12.7
54	12.8	11.8	11.7	12.3	13.2	13.9	14.5	14.8	14.9
56	15.0	13.8	13.6	14.2	15.2	16.2	16.8	17.3	17.5
58	17.5	16.0	15.7	16.3	17.5	18.6	19.5	20.1	20.4
60	20.3	18.5	18.1	18.7	20.0	21.4	22.5	23.2	23.6
63	23.5	24.6	20.8	21.4	22.0	24.4	25.7	26.7	27.3
64	27.0	28.1	23.8	24.4	25.8	27.7	29.3	30.5	31.3
66	31.0	32.1	27.1	27.6	29.2	31.3	33.2	34.7	35.7
68	35.4	36.5	30.9	31.3	32.9	35.2	37.5	39.3	40.5
70	40.3	41.4	35.0	35.3	37.0	39.5	42.1	44.3	45.9
72	45.7	46.7	39.6	39.8	41.5	44.2	47.2	49.8	51.7
74	51.7	52.6	44.6	44.6	46.4	39.3	52.7	55.7	58.0
76	58.3	52.1	50.2	50.1	51.8	54.9	58.6	62.1	64.8
78	65.5	59.1	56.3	56.1	57.7	60.9	65.0	69.0	72.3
80	73.4	66.2	62.9	62.5	64.2	67.5	71.9	76.4	80.2
82	82.0	73.9	70.2	69.6	71.2	74.7	79.4	84.4	88.8
84	91.4	82.4	78.1	77.3	78.9	82.4	87.4	93.0	98.1
86	102.0	92.0	87.0	86.0	87.0	91.0	96.0	102.0	108.0
88	113.0	102.0	96.0	95.0	96.0	100.0	105.0	112.0	119.0
90	125.0	112.0	106.0	105.0	106.0	110.0	115.0	123.0	130.0

APPENDIX A

Table APPENDIX A.3. Axle Load Equivalent Factor for Rigid Pavement, Triple Axle, TSI = 2.5

Axle Load (Kips)	Slab thickness, D (inches)								
	6	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
2	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
4	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
6	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
8	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
10	0.006	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
12	0.011	0.010	0.010	0.009	0.009	0.009	0.009	0.009	0.009
14	0.020	0.018	0.017	0.017	0.016	0.016	0.016	0.016	0.016
16	0.033	0.030	0.029	0.028	0.027	0.027	0.027	0.027	0.027
18	0.053	0.048	0.045	0.044	0.044	0.043	0.043	0.043	0.043
20	0.080	0.073	0.069	0.067	0.066	0.066	0.066	0.066	0.066
22	0.116	0.107	0.101	0.099	0.098	0.097	0.097	0.097	0.097
24	0.163	0.15	0.144	0.141	0.139	0.139	0.138	0.138	0.138
26	0.222	0.209	0.200	0.195	0.194	0.193	0.192	0.192	0.192
28	0.295	0.281	0.271	0.2565	0.263	0.262	0.262	0.262	0.262
30	0.384	0.371	0.359	0.354	0.351	0.350	0.349	0.349	0.349
32	0.490	0.480	0.468	0.463	0.460	0.459	0.458	0.458	0.458
34	0.616	0.609	0.601	0.596	0.594	0.593	0.592	0.592	0.592
36	0.765	0.762	0.759	0.757	0.756	0.755	0.755	0.755	0.755
38	0.939	0.941	0.946	0.948	0.950	0.951	0.951	0.951	0.951
40	1.14	1.15	1.16	1.17	1.18	1.18	1.18	1.18	1.18
42	1.38	1.38	1.41	1.44	1.45	1.46	1.46	1.46	1.46
44	1.65	1.65	1.70	1.74	1.77	1.78	1.78	1.78	1.78
46	1.97	1.96	2.03	2.09	2.13	2.15	2.16	2.16	2.16
48	2.34	2.31	2.40	2.49	2.55	2.58	2.59	2.60	2.60
50	2.76	2.71	2.81	2.94	3.02	3.07	3.09	3.10	3.11
52	3.24	3.15	3.27	3.44	3.56	3.62	3.66	3.68	3.68
54	3.79	3.66	3.79	4.00	4.16	4.26	4.30	4.33	4.34
56	4.41	4.23	4.37	4.63	4.84	4.97	5.03	5.07	5.09
58	5.12	4.87	5.00	5.32	5.59	5.76	5.85	5.90	5.93
60	5.91	5.59	5.71	6.08	6.42	6.64	6.77	6.84	6.87
63	6.80	6.39	6.50	6.91	7.33	7.62	7.79	7.88	7.93
64	7.79	7.29	7.37	7.82	8.33	8.70	8.92	9.04	9.11
66	8.90	8.28	8.33	8.83	9.42	9.88	10.17	10.33	10.42
68	10.1	9.4	9.4	9.9	10.6	11.2	11.5	11.7	11.9
70	11.5	10.6	10.6	11.1	11.9	12.6	13.0	13.3	13.5
72	13.0	12.0	11.8	12.4	13.3	14.1	14.7	15.0	15.2
74	14.6	13.5	13.2	13.8	14.8	15.8	16.5	16.9	17.1
76	16.5	15.1	14.8	15.4	16.5	17.6	18.4	18.9	19.2
78	18.5	16.9	16.5	17.1	18.2	19.5	20.5	21.1	21.5
80	20.6	18.8	18.3	18.9	20.2	21.6	22.7	23.5	24.0
82	23.0	21.0	20.3	20.9	22.2	23.8	25.2	26.1	26.7
84	25.6	23.3	22.5	23.1	24.5	26.2	27.8	28.9	29.6
86	28.4	25.8	24.9	25.4	26.9	28.8	30.5	31.9	32.8
88	31.5	28.6	27.5	27.9	29.4	31.5	33.5	35.1	36.1
90	34.8	31.5	30.3	30.7	32.2	34.4	36.7	38.5	39.8

APPENDIX A

Table APPENDIX A.4. Cumulative percent probability, of standard normal distribution (R), corresponding Z_R and, Pavement Structural Number (SN).

R	Cumulative percent probability, of standard normal distribution (R)										
	0	1	2	3	4	5	6	7	8	9	9.5	9.9
90	-1.282	-1.341	- 1.404	- 1.476	- 1.555	- 1.645	- 1.751	- 1.881	- 2.054	- 2.326	- 2.576	- 3.080
80	- 0.842	- 0.842	- 0.915	- 0.954	- 0.994	- 1.036	- 1.080	- 1.126	- 1.175	- 1.227	- 1.253	- 1.272
70	- 0.524	- 0.553	- 0.583	- 0.613	- 0.643	- 0.675	- 0.706	- 0.739	- 0.772	- 0.806	- 0.824	- 0.838
60	- 0.253	- 0.279	- 0.305	- 0.332	- 0.358	- 0.385	- 0.412	- 0.440	- 0.468	- 0.496	- 0.510	- 0.522
50	0	- 0.025	- 0.050	- 0.075	- 0.100	- 0.125	- 0.151	- 0.176	- 0.202	- 0.228	- 0.241	- 0.251

Axle Load (Kips)	Pavement Structural Number (SN)					
	1	2	3	4	5	6
2	0.0004	0.0004	0.0003	0.0002	0.0002	0.0002
4	0.003	0.004	0.004	0.003	0.002	0.002
6	0.011	0.017	0.017	0.013	0.010	0.009
8	0.032	0.047	0.051	0.041	0.034	0.031
10	0.078	0.102	0.118	0.102	0.088	0.080
12	0.168	0.198	0.229	0.213	0.189	0.176
14	0.328	0.358	0.399	0.388	0.360	0.342
16	0.591	0.613	0.646	0.645	0.623	0.606
18	1.00	1.00	1.00	1.00	1.00	1.00
20	1.61	1.57	1.49	1.47	1.51	1.55
22	2.48	2.38	2.17	2.09	2.18	2.30
24	3.69	3.49	3.09	2.89	3.03	3.27
26	5.33	4.99	4.31	3.91	4.09	4.48
28	7.49	6.98	5.90	5.21	5.39	5.98
30	10.3	9.5	7.9	6.8	7.0	7.8
32	13.9	12.8	10.5	8.8	8.9	10.0
34	18.4	16.9	13.7	11.3	11.2	12.5
36	24.0	22.0	17.7	14.4	13.9	15.5
38	30.9	28.3	22.6	18.6	17.2	19.0
40	39.3	35.9	28.5	22.5	21.1	23.0
42	49.3	45.0	35.6	27.8	25.6	27.7
44	61.3	55.9	44.0	34.0	31.0	33.1
46	75.5	68.8	54.0	41.4	37.2	39.3
48	92.2	83.9	65.7	50.1	44.5	46.5
50	112.0	102.0	79.0	60.0	53.0	55.0

APPENDIX A

Table APPENDIX A.5. Condition, Climatic, and Traffic Data for Highway Sections

Section	Rainfall	Freezs	AADT	PSI	Distress
1	10 in / year	5 cycles / year	10,000	2.4	+ 0.5
2	30 in / year	15 cycles / year	5,000	3.2	- 0.2
3	15 in / year	0 cycles / year	20,000	3.0	+ 0.8

APPENDIX B

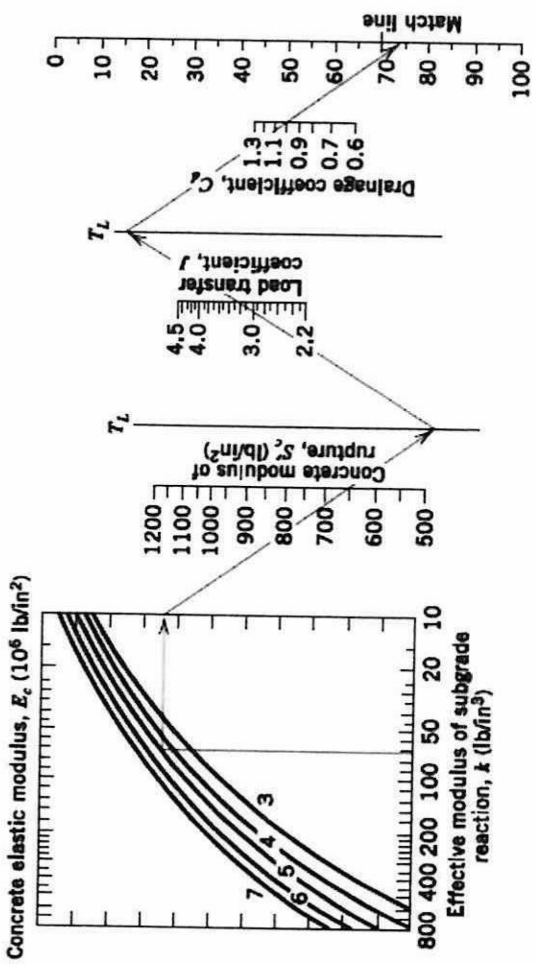

Figure APPENDIX B.1. Design Chart for Rigid Pavement

APPENDIX B

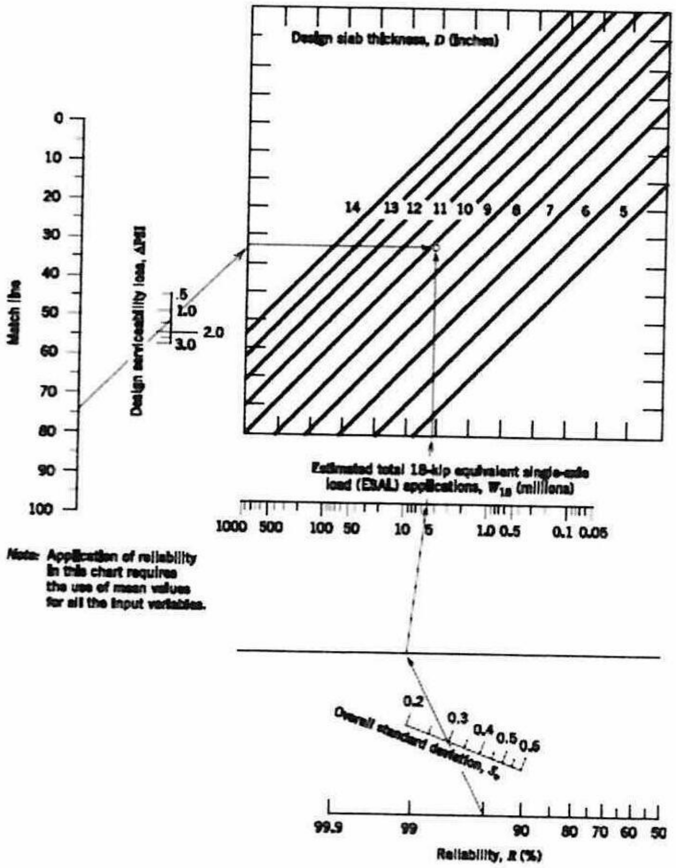

Figure APPENDIX B.2. Design Chart for Rigid Pavement

APPENDIX B

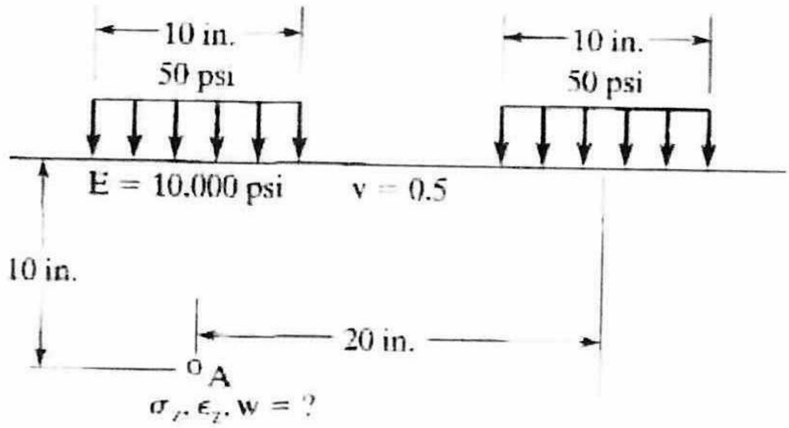

Figure APPENDIX B.3. Homogeneous half space subjected to two circular loads

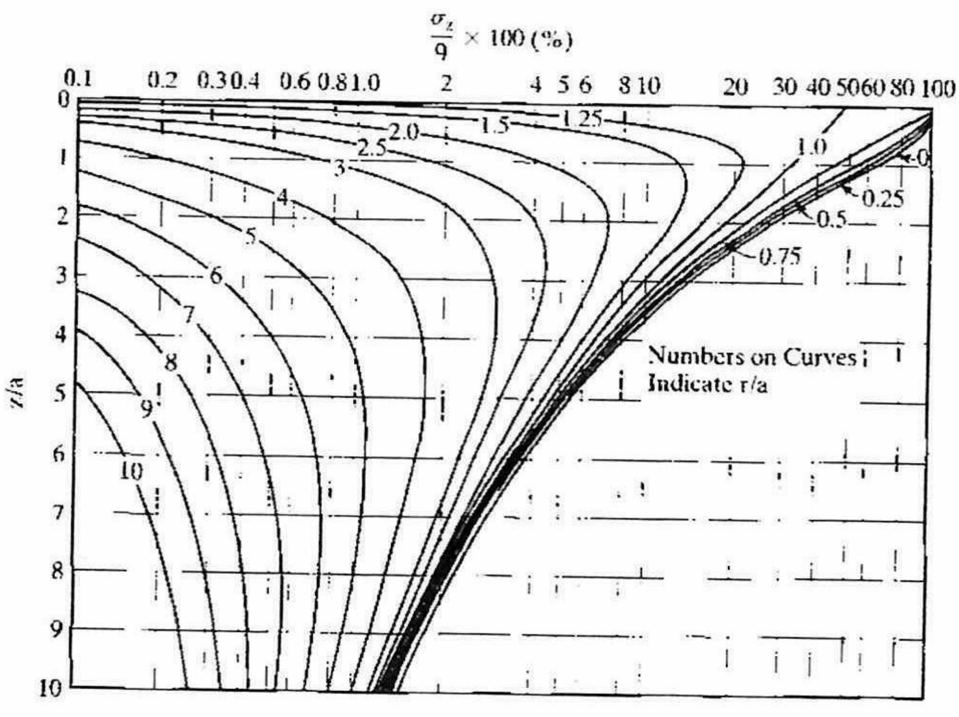

Figure APPENDIX B.4. Vertical stress due to circular load

APPENDIX B

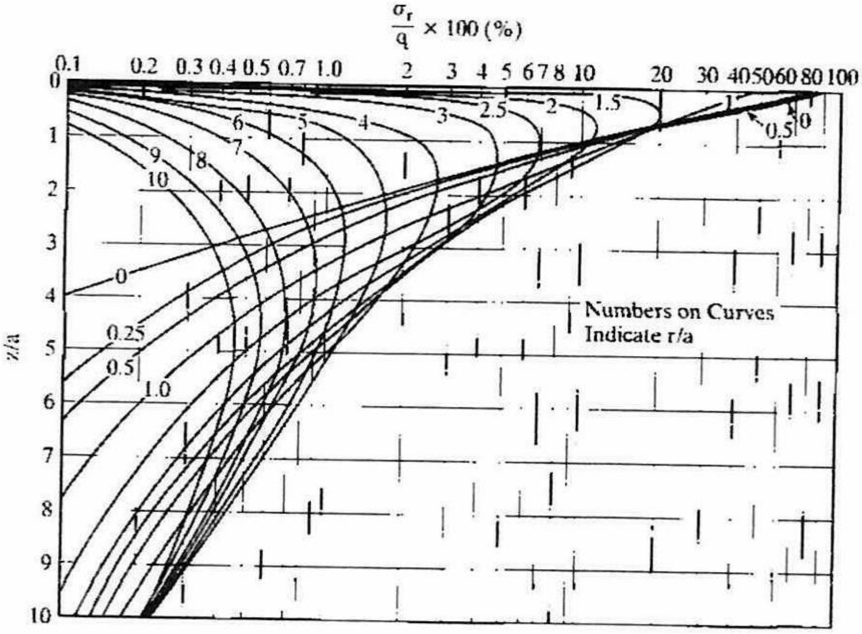

Figure APPENDIX B.5. Radial stresses due to circular load

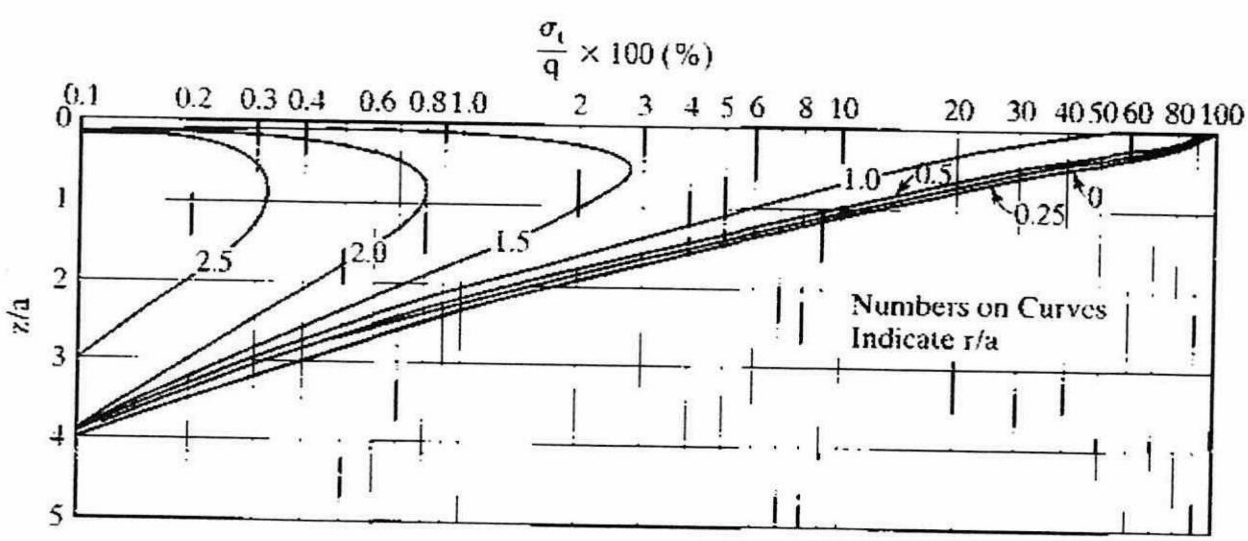

Figure APPENDIX B.6. Tangential stresses due to circular load

APPENDIX B

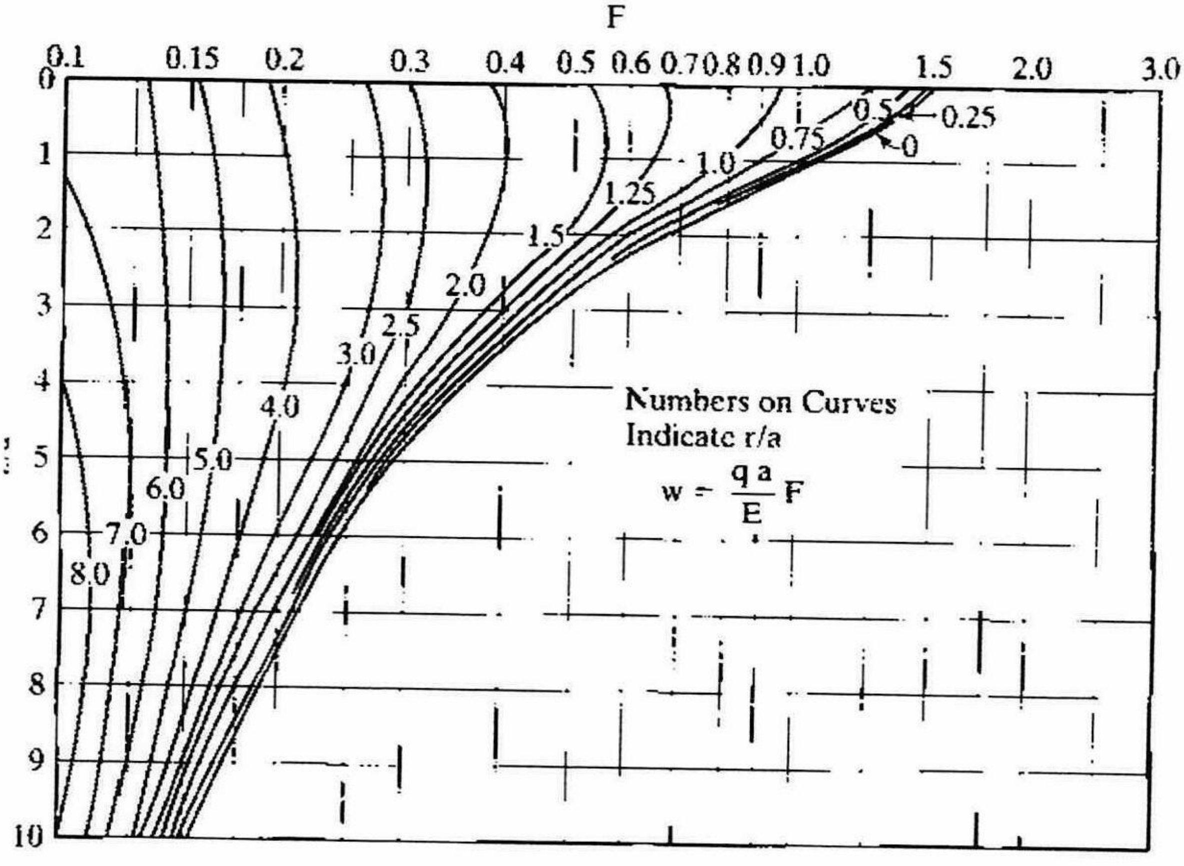

Figure APPENDIX B.7. Vertical deflection due to circular load

APPENDIX C

The following information may be useful. The symbols have their usual meaning.

$$\varepsilon_Z = \frac{1}{E}\left[\sigma_Z - V(\sigma_r - \sigma_t)\right]$$

$$W = \frac{q \times a \times F}{\varepsilon}$$

$$Y = 5.4 - (0.0263x_1) - (0.0132x_2) - [0.4\log(x_3)] + (0.749x_4) + (1.66x_5)$$

$$SN = a_1 D_1 + a_2 D_2 M_2 + a_3 D_3 M_3$$

$$N_f = 0.0796\,(\in_t)^{-3.291}\,(E_1)^{-0.854}$$

$$Log10W18 = ZR\,S0 + 9.36[Log10(SN + 1)] - 0.20 + Log10[DPSI/2.7]/\{0.40 + [1094/(SN + 1)5.19\} + 2.32$$