Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2019/2020

COURSE NAME	:	PAVEMENT ENGINEERING
COURSE CODE	:	BFT40203
PROGRAMME CODE	:	BFF
EXAMINATION DATE	:	DECEMBER 2019 / JANUARY 2020
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS

THIS QUESTION PAPER CONSISTS OF **FIFTEEN (15)** PAGES

Q1 (a) Soil is important for the foundation of roads, defined **THREE (3)** of the tests used to evaluate the strength properties of soil

(3 mark)

(b) Defined **SEVEN (7)** of the factors considered in AASHTO procedure for the design of flexible pavement as presented in the 1993 guide.

(7 marks)

(c) Briefly describe the differences between empirical and mechanistic-empirical approach in designing the Pavement thickness structural According to (AASHTO 1993 and ATJ 5/85 (2013).

(10 marks)

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

(5 marks)

Q2 (a) The specific gravities and weight proportions for aggregate and bitumen are as under for the preparation of Marshall Mix design. The volume and weight of one Marshall Specimen were found to be 475 m^3 and 1100 g. Assuming the absorption of bitumen in aggregate is zero. Determine Vv, Vb, VMA, and VFB. Refer to the **TABLE 1** for more details

(9 marks)

(b) Design a rigid pavement for daily truck traffic consists of the following: (80 single axles at 22,500 kg each, 570 tandem axles at 25,000 kg each, 50 tandem axles at 39,000 kg each, 80 triple axles at 48,000 kg each), the highway is to be designed with rigid pavement having a Modulus of rupture of 600 kg/in^2, and Modulus of elasticity of 5 million kg/in^2. Reliability is to be 95% the overall standard deviation is 0.4, the drainage coefficient is 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, the modulus of subgrade reaction is 200 kg/in^3, if a 20 years design life is to be used. Calculate the required slab thickness. Refer to **TABLE 2 to 4, FIGURE Q2(a)** and **FIGURE Q2(b)**.

(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). The pavement is on a soil with resilient modulus of 5000 kg/in^2. The pavement was designed with 90% reliability, an overall standard deviation of 0.4, and a Present Serviceability Index (PSI) of 2.0 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 single axle loads can be carried before the pavement reached its Terminal Serviceability Index (TSI) (with given reliability) Refer to **TABLE 5**. For Cumulative percent probability, of standard normal distribution (R), corresponding Z_R, and Pavement Structural Number (SN).

(8 marks)

Q3 (a) A tire with 100 kg/in^2 air pressure distributes a load over an area with circular contact radius, a, of 5 inches (127mm). The pavement was conducted with a material that has a modulus of elasticity of 50,000 kg/in^2 (345,000 kPa) and a Poisson ration of 0.45. Determine the radial horizontal stress and deflection at a point on the pavement surface under centre of tire load. Refer to **TABLE 6 To 10.**

(9 marks)

(b) Calculate the radial horizontal stress and deflection at a point at a depth of 20 inches (508 mm) and a radial distance of 10 inches (245 mm) from the centre of the tire load using the Ahlvin and Uley equation Refer to **TABLE 6 to 10**.

(9 marks)

(c) Describe the factor that are regularly measured by highway pavement agencies to evaluate the quality and performance. Elaborate briefly one of these factors

(7 marks)

Q4 (a) An asphalt overlay is placed on an existing asphalt pavement that is subjected to an equivalent standard axle load (ESAL) of 7×10^6 . The horizontal tensile strain at the bottom of the asphalt layer are 1×10^{-4} before overlay and 7×10^{-5} after overlay. By using asphalt institute fatigue criteria assuming an elastic modulus of 5×10^5 psi (3.5 GPa) for hot mix asphalt (HMA), determine the allowable number of ESAL on the overlaid pavement.

(10 marks)

(b) A full depth asphalt pavement consists of (51 mm) hot mix asphalt (HMA) and (152 mm) type II emulsified asphalt base Couse with the equivalent factor = 0.38 is to be overlaid. Even though there are cracks on the surface, the cracking are not open, and the pavement appears to be stable. If the pavement has a pavement serviceability index (PSI) of 2.0 and the conversion factor is 0.7, determine the effective thickness.

(9 marks)

(c) Distinguish the objective of the following types of road maintenance.

- Preventive maintenance
- Corrective maintenance
- Emergency maintenance

(6 marks)

– END OF QUESTIONS –

FINAL EXAMINATION

SEMESTER/SESSION : SEM I / 2019/2020 PROGRAMME CODE : 4 BFF
COURSE NAME : PAVEMENT ENGINEERING COURSE CODE : BFT40203

TABLE 1

Item	A_1	A_2	A_3	A_4	B
Wt (g)	825	1200	325	150	100
Sp. Gr	2.63	2.51	2.46	2.43	1.05

TABLE 2. 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	0.097	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	0.173
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	10.7	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 Structures*, The American Association of State Highway and Transportation Officials, Washington, DC, 1993. Used by permission.

FINAL EXAMINATION

SEMESTER/SESSION : SEM I / 2019/2020
COURSE NAME : PAVEMENT ENGINEERING
PROGRAMME CODE : 4 BFF
COURSE CODE : BFT40203

TABLE 3. 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	0.089	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	1.44	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	21.4	20.8	21.4	22.8	24.4	25.7	26.7	27.3
64	27.0	24.6	23.8	24.4	25.8	27.7	29.3	30.5	31.3
66	31.0	28.1	27.1	27.6	29.2	31.3	33.2	34.7	35.7
68	35.4	32.1	30.9	31.3	32.9	35.2	37.5	39.3	40.5
70	40.3	36.5	35.0	35.3	37.0	39.5	42.1	44.3	45.9
72	45.7	41.4	39.6	39.8	41.5	44.2	47.2	49.8	51.7
74	51.7	46.7	44.6	44.7	46.4	49.3	52.7	55.7	58.0
76	58.3	52.6	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

FINAL EXAMINATION

SEMESTER/SESSION : SEM I / 2019/2020 PROGRAMME CODE : 4 BFF
COURSE NAME : PAVEMENT ENGINEERING COURSE CODE : BFT40203

TABLE 4 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	0.151	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	0.265	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

FINAL EXAMINATION

SEMESTER/SESSION : SEM I / 2019/2020
COURSE NAME : PAVEMENT ENGINEERING
PROGRAMME CODE : 4 BFF
COURSE CODE : BFT40203

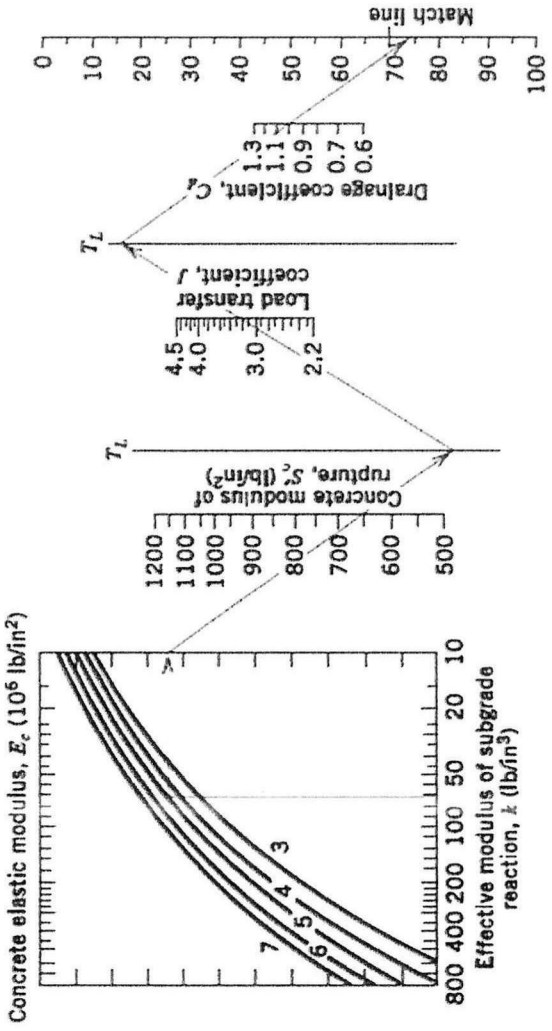

FIGURE Q2 (a). Design Chart for Rigid Pavement

FINAL EXAMINATION

SEMESTER/SESSION : SEM I / 2019/2020
COURSE NAME : PAVEMENT ENGINEERING
PROGRAMME CODE : 4 BFF
COURSE CODE : BFT40203

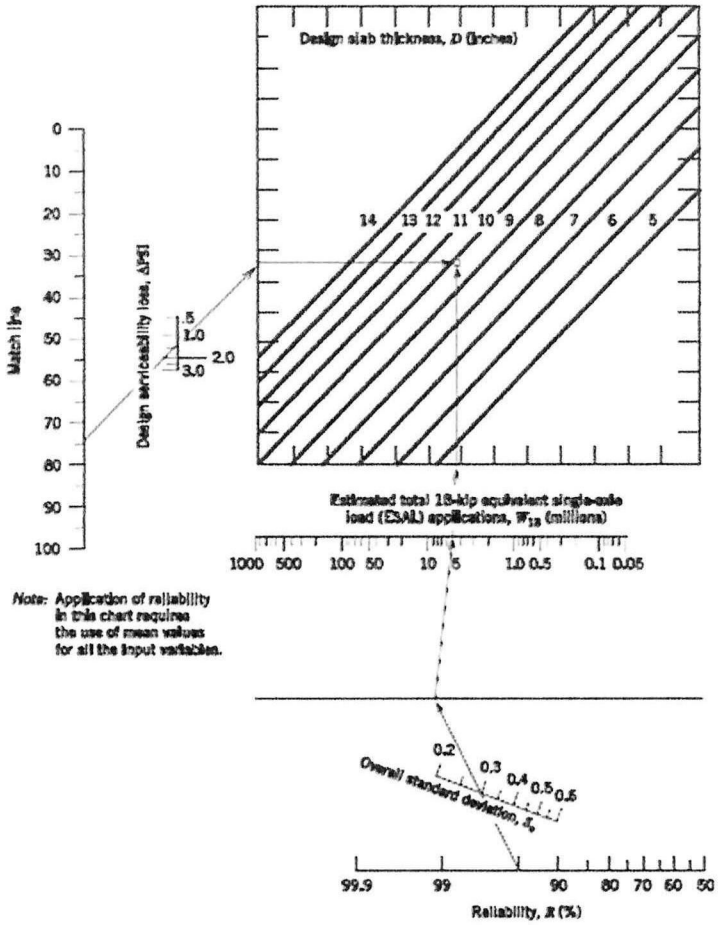

FIGURE Q2 (b). Design Chart for Rigid Pavement

FINAL EXAMINATION

SEMESTER/SESSION : SEM I / 2019/2020 PROGRAMME CODE : 4 BFF
COURSE NAME : PAVEMENT ENGINEERING COURSE CODE : BFT40203

TABLE 5. Cumulative percent probability, of standard normal distribution (R), corresponding Z_R and, Pavement Structural Number (SN).

Cumulative percent probability, of standard normal distribution (R)												
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	**Pavement Structural Number (SN)**					
(Kips)	**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

FINAL EXAMINATION

SEMESTER/SESSION : SEM I / 2019/2020
COURSE NAME : PAVEMENT ENGINEERING
PROGRAMME CODE : 4 BFF
COURSE CODE : BFT40203

TABLE 6. One-layer Elastic Function Values (A)

Depth (z/a)	Function A: Offset (r/a)																			
	0	0.2	0.4	0.6	0.8	1	1.2	1.5	2	3	4	5	6	8	10	12	14			
0	1.0	1.0	1.0	1.0	1.0	0.5	0	0	0	0	0	0	0	0	0	0	0			
0.1	0.90050	0.89748	0.88679	0.86126	0.78797	0.43015	0.09645	0.02787	0.00856	0.00211	0.00084	0.00042								
0.2	0.80388	0.79824	0.77884	0.73483	0.63014	0.38269	0.15433	0.05251	0.01680	0.00419	0.00167	0.00083	0.00048	0.0020						
0.3	0.71265	0.70518	0.68316	0.62690	0.52081	0.34375	0.17964	0.07199	0.02440	0.00622	0.00250									
0.4	0.62861	0.62015	0.59241	0.53767	0.44329	0.31048	0.18709	0.08593	0.03118											
0.5	0.55279	0.54403	0.51622	0.46448	0.38390	0.28156	0.18556	0.09499	0.03701	0.01013	0.00407	0.00209	0.00118	0.0053	0.00025	0.00014	0.00009			
0.6	0.48550	0.47691	0.45078	0.40427	0.33676	0.25588	0.17952	0.10010												
0.7	0.42634	0.41874	0.39491	0.35428	0.29833	0.21727	0.17124	0.10228	0.04558											
0.8	0.37531	0.36832	0.34729	0.31243	0.26581	0.21297	0.16206	0.10236												
0.9	0.33104	0.32492	0.30669	0.27707	0.23832	0.19488	0.15253	0.10094												
1	0.29289	0.28763	0.27005	0.24697	0.21468	0.17868	0.14329	0.09849	0.05185	0.01742	0.00761	0.00393	0.00226	0.00097	0.00050	0.00029	0.00018			
1.2	0.23178	0.22795	0.21662	0.19890	0.17626	0.15101	0.12570	0.09192	0.05260	0.01935	0.00871	0.00459	0.00269	0.00115						
1.5	0.16795	0.16552	0.15877	0.14804	0.13436	0.11892	0.10396	0.08048	0.05116	0.02142	0.01013	0.00548	0.00325	0.00141	0.00073	0.00043	0.00027			
2	0.10557	0.10453	0.10140	0.09647	0.09011	0.08269	0.07471	0.06275	0.04496	0.02221	0.01160	0.00659	0.00399	0.00180	0.00094	0.00056	0.00036			
2.5	0.07152	0.07098	0.06947	0.06698	0.06373	0.05974	0.05555	0.04880	0.03787	0.02143	0.01221	0.00732	0.00463	0.00214	0.00115	0.00068	0.00043			
3	0.05132	0.05101	0.05022	0.04886	0.04707	0.04487	0.04241	0.03839	0.03150	0.01980	0.01220	0.00770	0.00505	0.00242	0.00132	0.00079	0.00051			
4	0.02986	0.02976	0.02907	0.02832	0.02802	0.02749	0.02651	0.02490	0.02193	0.01592	0.01109	0.00768	0.00536	0.00282	0.00160	0.00099	0.00065			
5	0.01942	0.01938				0.01835			0.01573	0.01249	0.00949	0.00708	0.00527	0.00298	0.00179	0.00113	0.00075			
6	0.01361					0.01307			0.01168	0.00983	0.00795	0.00628	0.00492	0.00299	0.00188	0.00124	0.00084			
7	0.01005					0.00976			0.00894	0.00784	0.00661	0.00548	0.00445	0.00291	0.00193	0.00130	0.00091			
8	0.00772					0.00755			0.00703	0.00635	0.00554	0.00472	0.00398	0.00276	0.00189	0.00134	0.00094			
9	0.00612					0.00600			0.00566	0.00520	0.00466	0.00409	0.00353	0.00256	0.00184	0.00133	0.00096			
10								0.00477	0.00465	0.00438	0.00397	0.00352	0.00326	0.00241						

FINAL EXAMINATION

SEMESTER/SESSION : SEM I / 2019/2020
COURSE NAME : PAVEMENT ENGINEERING
PROGRAMME CODE : 4 BFF
COURSE CODE : BFT40203

TABLE 7. One-layer Elastic Function Values (B)

Depth (z/a)	Function B — Offset (r/a)															
	0	0.2	0.4	0.6	0.8	1	1.2	1.5	2	3	4	5	6	8	10	12	14
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.1	0.09852	0.10140	0.11138	0.13424	0.18796	0.05388	-0.07899	-0.02672	-0.00845	-0.00210	-0.00084	-0.00042					
0.2	0.18857	0.19306	0.20772	0.23524	0.25983	0.08513	-0.07759	-0.04448	-0.01593	-0.00412	-0.00166	-0.00083	-0.00024	-0.00010			
0.3	0.28362	0.26787	0.28018	0.29483	0.27257	0.10757	-0.04316	-0.04999	-0.02166	-0.00599	-0.00245						
0.4	0.32016	0.32259	0.32748	0.32273	0.26925	0.12404	-0.00766	-0.04535	-0.02522								
0.5	0.35777	0.35752	0.35323	0.33106	0.26236	0.13591	0.02165	-0.03455	-0.02651	-0.00991	-0.00388	-0.00199	-0.00116	-0.00049	-0.0025	-0.0014	-0.00009
0.6	0.37831	0.37531	0.36308	0.32822	0.25411	0.14440	0.04457	-0.02101									
0.7	0.38487	0.37962	0.36072	0.31929	0.24638	0.14986	0.06209	-0.00702	-0.02329								
0.8	0.38091	0.37408	0.35133	0.30699	0.23779	0.15292	0.07530	0.00614									
0.9	0.36962	0.36275	0.33734	0.29299	0.22891	0.15404	0.08507	0.01795									
1	0.35355	0.34553	0.32075	0.27819	0.21978	0.15355	0.09210	0.02814	-0.01005	-0.01115	-0.00608	-0.00344	-0.00210	-0.00092	-0.00048	-0.00028	-0.00018
1.2	0.31485	0.30730	0.28481	0.24836	0.20113	0.14915	0.10002	0.04378	0.00023	-0.00995	-0.00632	-0.00378	-0.00236	-0.00107			
1.5	0.25602	0.25025	0.23338	0.20694	0.17368	0.13732	0.10193	0.05745	0.01385	-0.00669	-0.00600	-0.00401	-0.00265	-0.00126	-0.00068	-0.00040	-0.00026
2	0.17889	0.18144	0.16644	0.15198	0.13375	0.11331	0.09254	0.06371	0.02836	0.00028	-0.00410	-0.00371	-0.00278	-0.00148	-0.00084	-0.00050	-0.00033
2.5	0.12807	0.12633	0.12126	0.11327	0.10298	0.09130	0.07869	0.06022	0.03429	0.00661	-0.00130	-0.00271	-0.00250	-0.00156	-0.00094	-0.00059	-0.00039
3	0.09487	0.09394	0.09099	0.08635	0.08033	0.07325	0.06551	0.05354	0.03511	0.01112	0.00157	-0.00134	-0.00192	-0.00151	-0.00099	-0.00065	-0.00046
4	0.05707	0.05666	0.05562	0.05383	0.05145	0.04773	0.04532	0.03995	0.03066	0.01515	0.00595	0.00155	-0.00029	-0.00109	-0.00094	-0.00068	-0.00050
5	0.03772	0.03760				0.03384			0.02474	0.01522	0.00810	0.00371	0.00132	-0.00043	-0.00070	-0.00068	-0.00049
6	0.02666					0.02468			0.01968	0.01380	0.00867	0.00496	0.00254	0.00028	-0.00037	-0.00047	-0.00045
7	0.01980					0.01868			0.01577	0.01204	0.00842	0.00547	0.00332	0.00093	-0.00002	-0.00029	-0.00037
8	0.01526					0.01459			0.01279	0.01034	0.00779	0.00554	0.00372	0.00141	0.00035	-0.00008	-0.00025
9	0.01212					0.01170			0.01054	0.00888	0.00705	0.00533	0.00386	0.00178	0.00066	0.00012	-0.00012
10									0.00924	0.00879	0.00764	0.00631	0.00501	0.00382	0.00199		

FINAL EXAMINATION

SEMESTER/SESSION : SEM I / 2019/2020
COURSE NAME : PAVEMENT ENGINEERING
PROGRAMME CODE : 4 BFF
COURSE CODE : BFT40203

TABLE 8. One-layer Elastic Function Values (C)

Depth (z/a)	Function C: Offset (r/a)														
	0	0.2	0.4	0.6	0.8	1	1.2	1.5	2	3	4	5	6	8	10	12	14
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.1	-0.04926	-0.05142	-0.05903	-0.07708	-0.12108	0.02247	0.12007	0.04475	0.01536	0.00403	0.00164	0.00082					
0.2	-0.09429	-0.09755	-0.10872	-0.12977	-0.14552	0.02419	0.14896	0.07892	0.02981	0.00796	0.00325	0.00164	0.00094	0.00039			
0.3	-0.13181	-0.13484	-0.14415	-0.15023	-0.12990	0.01988	0.13394	0.09816	0.04148	0.01169	0.00483						
0.4	-0.16008	-0.16188	-0.16519	-0.15985	-0.11168	0.01292	0.11014	0.10422	0.05067								
0.5	-0.17889	-0.17835	-0.17497	-0.15625	-0.09833	0.00483	0.08730	0.10125	0.05690	0.01824	0.00778	0.00399	0.00231	0.00098	0.00050	0.00029	0.00018
0.6	-0.18915	-0.18633	-0.17336	-0.14934	-0.08967	-0.00304	0.06731	0.09313									
0.7	-0.19244	-0.18831	-0.17393	-0.14147	-0.08409	-0.01061	0.05028	0.08253	0.06129								
0.8	-0.19046	-0.18481	-0.16784	-0.13393	-0.08066	0.01744	0.03582	0.07114									
0.9	-0.18481	-0.17841	-0.16024	-0.12664	-0.07828	0.02337	0.02359	0.05993									
1	-0.17678	-0.17050	-0.15188	-0.11995	-0.07634	-0.02843	0.01331	0.04939	0.05429	0.02726	0.01333	0.00726	0.00433	0.00188	0.00098	0.00057	0.00036
1.2	-0.15742	-0.15117	-0.13467	-0.10763	-0.07289	-0.03575	-0.00245	0.03107	0.04522	0.02791	0.01467	0.00824	0.00501	0.00221			
1.5	-0.12801	-0.12277	-0.11101	-0.09145	-0.06711	0.04124	-0.01702	0.01088	0.03154	0.02652	0.01570	0.00933	0.00585	0.00266	0.00141	0.00083	0.00039
2	-0.08944	-0.08491	-0.07976	-0.06925	-0.05560	-0.04144	-0.02687	-0.00782	0.01267	0.02070	0.01527	0.01013	0.00321	0.00327	0.00179	0.00107	0.00069
2.5	-0.06403	-0.06068	-0.05839	-0.05259	-0.04522	0.03605	-0.02800	-0.01536	0.00103	0.0134	0.00987	0.00707	0.00569	0.00209	0.00128	0.00083	
3	-0.04744	-0.04560	-0.04339	-0.04089	-0.03642	-0.03130	-0.02587	-0.01748	-0.00528	0.00792	0.01030	0.00888	0.00689	0.00392	0.00232	0.00145	0.00096
4	-0.02854	-0.02737	-0.02562	-0.02585	-0.02421	0.02112	-0.01964	-0.01586	-0.00956	0.00038	0.00492	0.00602	0.00561	0.00389	0.00254	0.00168	0.00155
5	-0.01886	-0.01810				0.01568			-0.00939	-0.00293	-0.00128	0.00329	0.00391	0.00341	0.00250	0.00177	0.00127
6	-0.01333					-0.01118			-0.00819	-0.00405	-0.00079	0.00129	0.00234	0.00272	0.00227	0.00173	0.00130
7	-0.00990					0.00902			-0.00678	-0.00417	-0.00180	-0.00004	0.00113	0.00200	0.00193	0.00161	0.00128
8	-0.00763					-0.00699			-0.00552	-0.00393	-0.00225	-0.00077	0.00029	0.00134	0.00157	0.00143	0.00120
9	-0.00607					-0.00423			-0.00452	-0.00353	-0.00235	-0.00118	-0.00027	0.00082	0.00124	0.00122	0.00110
10								-0.00381	-0.00373	-0.00314	-0.00233	-0.00137	-0.00630	0.00040			

FINAL EXAMINATION

SEMESTER/SESSION : SEM I / 2019/2020 PROGRAMME CODE : 4 BFF
COURSE NAME : PAVEMENT ENGINEERING COURSE CODE : BFT40203

TABLE 9. One-layer Elastic Function Values (F)

Depth (z/a)	Function F: Offset (r/a)																									
	0	0.2	0.4	0.6	0.8	1	1.2	1.5	2	3	4	5	6	8	10	12	14									
0	0.5	0.5	0.5	0.5	0.5	0	-0.34722	-0.22222	-0.12500	-0.05556	-0.03125	-0.02000	-0.01389	-0.00781	-0.00500	-0.00347	-0.00255									
0.1	0.45025	0.44794	0.43981	0.41954	0.35789	0.03817	-0.20800	-0.17612	-0.10950	-0.05151	-0.02961	-0.01917														
0.2	0.40194	0.39781	0.38294	0.34823	0.26715	0.05466	-0.11165	-0.13381	-0.09441	-0.04750	-0.02798	-0.01835	-0.01295	-0.00742												
0.3	0.35633	0.35094	0.34508	0.29016	0.20503	0.06372	-0.05346	-0.09768	-0.08010	-0.04356	-0.02636															
0.4	0.31431	0.30801	0.28681	0.24469	0.17086	0.06848	-0.01818	-0.06835	-0.06684																	
0.5	0.27639	0.26997	0.24890	0.20937	0.14752	0.07037	0.00388	-0.04529	-0.05479	-0.03595	-0.02320	-0.01590	-0.00154	-0.00681	-0.00450	-0.00318	-0.00237									
0.6	0.24275	0.23444	0.21667	0.18138	0.13042	0.07068	0.01797	-0.02479																		
0.7	0.21327	0.20762	0.18956	0.15903	0.11740	0.06963	0.02704	-0.01392	-0.03469																	
0.8	0.18765	0.18287	0.16679	0.14053	0.10604	0.06774	0.03277	-0.00365																		
0.9	0.16552	0.16158	0.14747	0.12528	0.09664	0.06533	0.03619	0.00408																		
1	0.14645	0.14280	0.12395	0.11225	0.08850	0.06256	0.03819	0.00984	-0.01367	-0.01994	-0.01591	-0.01209	-0.00931	-0.00587	-0.00400	-0.00289	-0.00219									
1.2	0.11589	0.11360	0.10460	0.09449	0.07486	0.05670	0.03913	0.01716	-0.00452	-0.01491	-0.01337	-0.01068	-0.00844	-0.00550												
1.5	0.08398	0.08196	0.07719	0.06918	0.05919	0.04804	0.03686	0.02177	0.00413	-0.00879	-0.00995	-0.00870	-0.00723	-0.00495	-0.00353	-0.00261	-0.00201									
2	0.05279	0.05348	0.04994	0.04614	0.04162	0.03593	0.03029	0.02197	0.01043	-0.00189	-0.00546	-0.00589	-0.00544	-0.00410	-0.00307	-0.00233	-0.00183									
2.5	0.03576	0.03673	0.03459	0.03263	0.03014	0.02762	0.02406	0.01927	0.01188	0.00198	-0.00226	-0.00364	-0.00386	-0.00332	-0.00263	-0.00208	-0.00166									
3	0.02566	0.02586	0.02255	0.02595	0.02263	0.02097	0.01911	0.01623	0.01144	0.00396	-0.00010	-0.00192	-0.00258	-0.00263	-0.00223	-0.00183	-0.00150									
4	0.01493	0.01536	0.01412	0.01259	0.01386	0.01331	0.01256	0.01134	0.00912	0.00508	0.00209	0.00026	-0.00076	-0.00148	-0.00153	-0.00137	-0.00120									
5	0.00971	0.01011				0.00905			0.00700	0.00475	0.00277	0.00129	0.00031	-0.00066	-0.00096	-0.00099	-0.00093									
6	0.00680					0.00675			0.00538	0.00409	0.00278	0.00170	0.00088	-0.00010	-0.00053	-0.00066	-0.00070									
7	0.00503					0.00483			0.00428	0.00346	0.00258	0.00178	0.00114	0.00027	-0.00020	-0.00041	-0.00049									
8	0.00386					0.00380			0.00350	0.00291	0.00229	0.00174	0.00125	0.00048	0.00003	-0.00020	-0.00033									
9	0.00306					0.00374			0.00291	0.00247	0.00203	0.00163	0.00124	0.00062	0.00020	-0.00005	-0.00019									
10								0.00267	0.00246	0.00213	0.00176	0.00149	0.00126	0.00070												

FINAL EXAMINATION

SEMESTER/SESSION : SEM I / 2019/2020 PROGRAMME CODE : 4 BFF
COURSE NAME : PAVEMENT ENGINEERING COURSE CODE : BFT40203

TABLE 10. One-layer Elastic Function Values (H)

Depth (z/a)	Function H: Offset (r/a)														
	0	0.2	0.4	0.6	0.8	1	1.2	1.5	2	3	4	5	6	8	10	12	14
0	2.0	1.97987	1.91751	1.80575	1.62553	1.27319	0.93676	0.71185	0.51671	0.33815	0.25200	0.20045	0.16626	0.12576	0.09918	0.08346	0.07023
0.1	1.80998	1.79018	1.72886	1.61961	1.44711	1.18107	0.92670	0.70888	0.51627	0.33794	0.25184	0.20081					
0.2	1.63961	1.62068	1.56242	1.46001	1.30614	1.09996	0.90098	0.70074	0.51382	0.33726	0.25162	0.20072	0.16688	0.12512			
0.3	1.48806	1.47044	1.40979	1.32442	1.19210	1.02740	0.86726	0.68823	0.50966	0.33638	0.25124						
0.4	1.35407	1.33802	1.28963	1.20822	1.09555	0.96202	0.83042	0.67238	0.50412								
0.5	1.23607	1.22176	1.17894	1.10830	1.01312	0.90298	0.79308	0.65429	0.49278	0.33293	0.24996	0.19982	0.16668	0.12493	0.09996	0.08295	0.07123
0.6	1.13238	1.11998	1.08350	1.02154	0.94120	0.84917	0.75653	0.63469									
0.7	1.04131	1.03037	0.99794	0.91049	0.87742	0.80030	0.72143	0.61442	0.48061								
0.8	0.96125	0.95175	0.92386	0.87928	0.82136	0.75571	0.68809	0.59398									
0.9	0.89072	0.88251	0.85856	0.82616	0.77950	0.71495	0.65677	0.57361									
1	0.82843	0.85005	0.80465	0.76809	0.72387	0.67769	0.62701	0.55364	0.45122	0.31877	0.24386	0.19673	0.16516	0.12394	0.09952	0.08292	0.07104
1.2	0.72410	0.71882	0.70370	0.67937	0.64814	0.61187	0.57329	0.51552	0.43013	0.31162	0.24070	0.19520	0.16369	0.12350			
1.5	0.60555	0.60233	0.57246	0.57633	0.55539	0.53138	0.50496	0.46379	0.39872	0.29945	0.23495	0.19053	0.16199	0.12281	0.09876	0.08270	0.07064
2	0.47214	0.47022	0.44512	0.45656	0.44502	0.43202	0.41702	0.39242	0.35054	0.27740	0.22418	0.18618	0.15846	0.12124	0.09792	0.08196	0.07026
2.5	0.38518	0.38403	38098	0.37608	0.36940	0.36155	0.35243	0.33698	0.30913	0.25550	0.21208	0.17898	0.15395	0.11928	0.09700	0.08115	0.06980
3	0.32457	0.32403	0.32184	0.31887	0.31464	0.30969	0.30381	0.29364	0.27453	0.23487	0.19977	0.17154	0.14919	0.11694	0.09558	0.08061	0.06897
4	0.24620	0.24588	0.24820	0.25128	0.24168	0.23932	0.23668	0.23164	0.22188	0.19908	0.17640	0.15596	0.13864	0.11172	0.09300	0.07864	0.06848
5	0.19805	0.19785				0.19455			0.18450	0.17080	0.15575	0.14130	0.12785	0.10585	0.08915	0.07675	0.06695
6	0.16534					0.16326			0.15750	0.14868	0.13842	0.12792	0.11778	0.09990	0.08562	0.07452	0.06522
7	0.14217					0.14077			0.13699	0.13097	0.12404	0.11620	0.10843	0.09387	0.08197	0.07210	0.06377
8	0.12448					0.12352			0.12112	0.11680	0.11176	0.10600	0.09976	0.08848	0.07800	0.06928	0.06200
9	0.11079					0.10989			0.10854	0.10548	0.10161	0.09702	0.09234	0.08298	0.07407	0.6678	0.05976
10									0.09900	0.09820	0.09510	0.09290	0.08980	0.08300	0.07710		

FINAL EXAMINATION

SEMESTER/SESSION : SEM I / 2019/2020
COURSE NAME : PAVEMENT ENGINEERING
PROGRAMME CODE : 4 BFF
COURSE CODE : BFT40203

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

$$G_t = \frac{W_1 + W_2 + W_{3+} W_b}{\frac{W_1}{G_1} + \frac{W_2}{G_2} + \frac{W_3}{G_3} + \frac{W_b}{G_b}}$$

$$\sigma_r = p\,[\,2\mu A + C + (1-2\mu)F]$$

$$G_m = \frac{W_m}{W_m - W_w}$$

$$\Delta_z = \frac{p(1+\mu)a}{E}\left[\frac{z}{a}A + (1-\mu)H\right]$$

$$V_v = \frac{(G_t - G_m)100}{G_t}$$

$$h_e = \sum_{i=1}^{n} h_i\, C_i\, E_i$$

$$V_b = \frac{\frac{W_b}{G_b}}{\frac{W_1 + W_2 + W_\# + W_b}{G_m}}$$

$$\frac{n_r}{N_a} = 1 - \frac{n_e}{N_a}$$

$$VMA = V_v + V_b$$

$$VFB = \frac{V_b \times 100}{VMA}$$

$$\mathrm{SN} = a_1 D_1 + a_2 D_2 M_2 + a_3 D_3 M_3$$

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

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