BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI
CE -F244 HIGHWAY ENGINEERING
SEMESTER II, 2021-22
COMPREHENSIVE EXAMINATION (OPEN BOOK*)

Date : 07-05-2022 **Time : 180 minutes**
Max. Marks: 90

INSTRUCTIONS:

- *Assume any missing data suitably, if required, and* ***justify*** *your assumption(s).*
- ***IRC:37-2018 (till Page 42) and IRC:58 – 2015 are ONLY allowed. (Highlighting and underlining the code are ONLY allowed).***

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1. Why the maximum pavement temperature is computed at a depth of 20 mm from the surface and not at the surface in Superpave mix design ? ***[6 MARKS]***

2. Why is Falling Weight Deflectometer technique preferred over Benkelman Beam Deflection technique for pavement evaluation ? ***[5 MARKS]***

3. A Major District Road section from 0 + 000 km chainage to 27 +450 km chainage in the coastal area of Thane, Maharashtra is proposed to be constructed as a 2-lane dual carriageway (2 way) with earthen shoulders. The road section consists of 2 tangent sections (bituminous pavement type) having their point of vertical intersect below the road level with a deviation angle of 11 in 300. The traffic and axle load survey were conducted on 07.05.2019 revealed 775 cvpd travelling in each direction with a traffic growth rate of 5.25 % and proposed to finish the construction by 07.05.2021. The curve section is designed as a plain jointed rigid pavement with 125μm PVC sheet between Pavement Quality Concrete surface layer (M40 Grade concrete) and the upper subbase layer to reduce the frictional stresses with an effective CBR of subgrade of 12%. Whereas, for the tangent sections, the in-situ CBR of 500 mm compacted subgrade layer and 500 mm layer below the subgrade were found to be 15% and 5%, respectively.

(i) Determine the maximum tensile stress and fatigue life due to bottom – up and top-down cracking for the Pavement Quality Concrete slab having thickness of 250 mm for Type 3 vehicle whose rear axle weight is precisely equal to the legal axle load limit as per IRC: 58 -2015. Load transfer was achieved only through aggregate interlocking in the concerned pavement. Take the lower subbase layer as granular with thickness of 200 mm for drainage and filter purpose. Also draw the cross section of the designed pavement. ***(20 MARKS)***

(ii) Determine the length of the curve section such that a Type 3 vehicle can safely travel along the curve during night. ***(5 MARKS)***

(iii) If the vertical compressive strain and horizontal tensile strain at top of subgrade and bottom of bituminous layer came up to be 0.535×10^{-3} and 0.685×10^{-3} respectively during the pavement analysis in IITPAVE, determine whether the pavement design is safe or not if unreinforced granular base and unreinforced granular subbase are provided along the tangent sections. Also determine and report the input material properties for IITPAVE. The bituminous mixture has an effective bitumen content of 10% and air voids of 4% using conventional bitumen. The pavement is expected to reach an annual ***(23 MARKS)***

average pavement temperature of 38^0C. Take design life of 20 years. Round-off the effective CBR of this section to next higher whole number and take indicative values if needed.

(iv) Explain in detail, the procedure to find the effective resilient modulus for the pavement at the tangent section if the granular layers are reinforced. ***(7 MARKS)***

4. Marshall stability tests were conducted for five specimens, each of 101.6 mm diameter and 63.5 mm height. The test results are given in Table 1. Find the optimum binder content of the mix. Use a single graph sheet for plotting (i.e., Required plots in one graph paper, Write your name & BITS ID on the graph sheet). ***(7 MARKS)***

5. During the alignment of a National Highway in a mountainous terrain with a design gradient of 4.95%, a horizontal curve of radius 140 m was encountered. If a Type 3 vehicle travels along the curve turning the steering wheel at an angle of 35^0 counter clockwise direction with a tractive force of 125 kN in the rear axles, then,

(i) Determine the curve resistance. ***(2 MARK)***

(ii) Is compensation in gradient required for the curve? If yes, determine the compensation in gradient and compensated gradient. If not, justify your answer. ***(5 MARKS)***

6. True/ False: ***(5x1MARKS)***

(i) Space mean speed is slightly lower than time mean speed.

(ii) Tar is less sensitive (susceptible) to moisture than bitumen.

(iii) Emulsions do not require any heating while cutback bitumen requires.

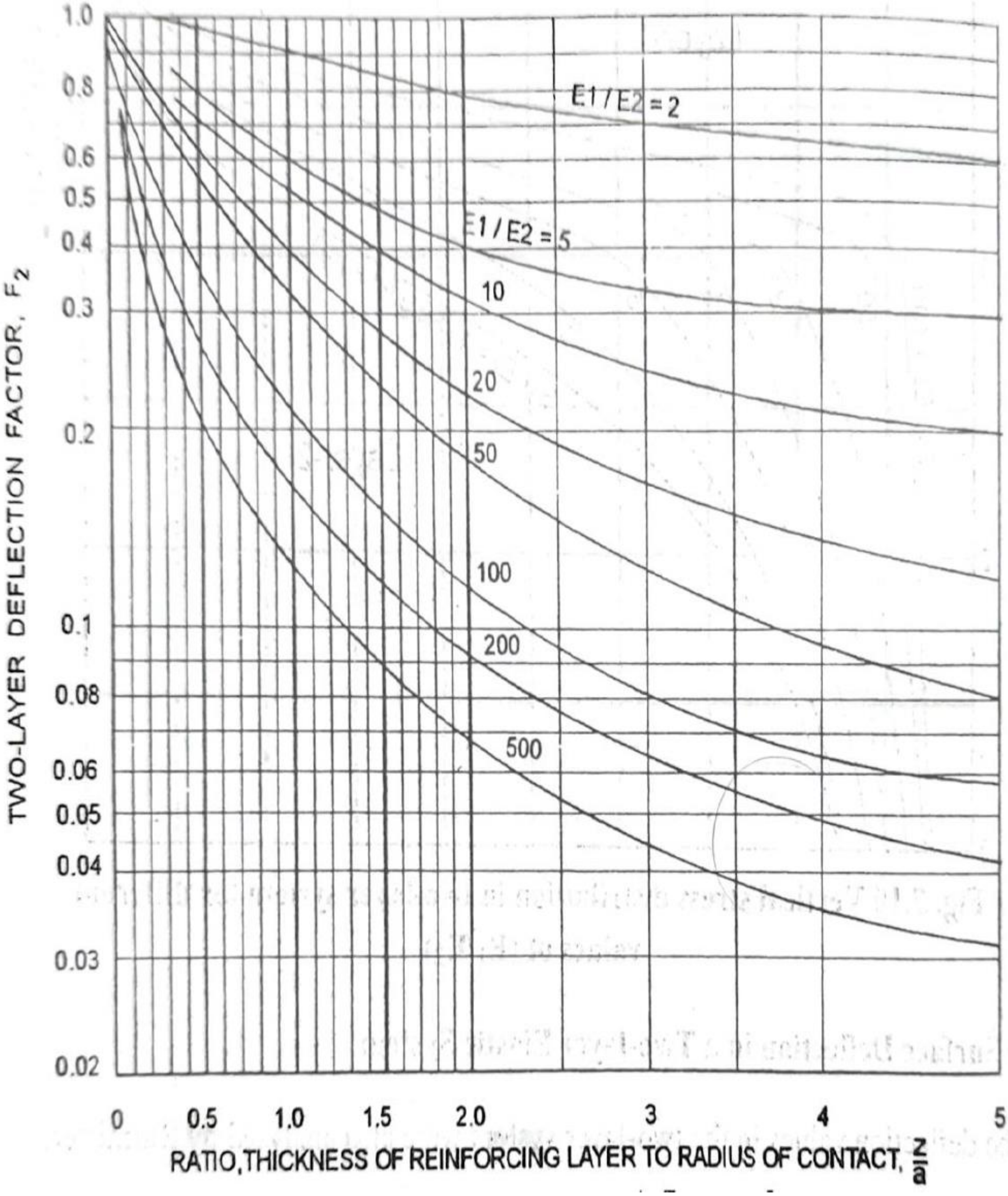
(iv) Bitumen A and bitumen B have 6 mm and 10 mm as penetration values, respectively. So, in general, softening point of A is greater than softening point of B.

(v) Bitumen A and Bitumen B has softening points of 45^0C and 60^oC, respectively. So, bitumen A is less susceptible to temperature than B.

7. Explain the physical significance of radius of relative stiffness and radius of resisting section. ***(5 MARKS)***

Table 1 : Marshall stability test results

Bitumen content (%)	**Stability (kgf)**	**Flow (mm)**	**Air voids (%)**	**VFB**	**G_m or G_{av} or G_{mb}**
3	500	9	12.5	35	2.10
4	750	9.5	7.5	65	2.20
5	800	12	3.5	85	2.25
6	750	15	2.5	90	2.20
7	650	19.5	2.0	95	2.15



TWO-LAYER DEFLECTION FACTOR, F_2
1.0
0.8
0.6
0.5
0.4
0.3
0.2
0.1
0.08
0.06
0.05
0.04
0.03
0.02
E1 / E2 = 2
E1 / E2 = 5
10
20
50
100
200
500
0
0.5
1.0
1.5
2.0
3
4
5
RATIO, THICKNESS OF REINFORCING LAYER TO RADIUS OF CONTACT, $\frac{z}{a}$

REFERENCE APPENDIX

Table : Ruling and Minimum design speed

Road Classification	Plain terrain		Rolling terrain		Mountainous terrain		Steep terrain	
	R	M	R	M	R	M	R	M
NH & SH	100	80	80	65	50	40	40	30
MDR	80	65	65	50	40	30	30	20
ODR	65	50	50	40	30	25	25	20
VR	50	40	40	35	25	20	25	20

Speed km/h	20 to 30	40	50	60	65	80	100
Longitudinal coefficient of friction, f	0.40	0.38	0.37	0.36	0.36	0.35	0.35

$$\text{SSD} = vt + \frac{v^2}{2g\left(f \pm \frac{n}{100}\right)}$$

$$\text{OSD} = v_b t + v_b T + 2s + v_c T$$

$$e + f = \frac{v^2}{gR}$$

$$W_e = \frac{nl^2}{2R} + \frac{\boldsymbol{V}}{9.5\sqrt{R}}$$

$$m = R - (R-d)cos\frac{\propto}{2} + \left(\frac{S-L_c}{2}\right)\sin\left(\frac{\propto}{2}\right);$$

$$L_s = \frac{Ne(W+W_e)}{2}$$

$$L_s = \frac{2.7\boldsymbol{V}^2}{R};\ L = 2\sqrt{\frac{Nv^3}{C}}$$

$$L_s = Ne(W+W_e) \qquad S_g = vt = 0.278Vt$$

$$\bar{t} = t_w - \frac{n_y}{q}$$

$$m = R - Rcos\left(\frac{\propto}{2}\right)$$

$$m = R - Rcos\frac{\propto}{2} + \left(\frac{S-L_c}{2}\right)\sin\left(\frac{\propto}{2}\right)$$

$$m = R - (R-d)\ cos\left(\frac{\propto}{2}\right)$$

$$L_s = \frac{v^3}{CR} \qquad S = \frac{L_s^2}{24R}$$

$$L_s = \frac{V^2}{R};\quad L = 2S - \frac{2\left(\sqrt{h_1}+\sqrt{h_2}\right)^2}{N}$$

$$q = \frac{n_a + n_y}{t_a + t_w}$$

$$L = \frac{NS^2}{2(h_1 + S\ tan\alpha)}$$

$$L = 2S - \frac{2(h_1 + S\ tan\alpha)}{N}$$

$$L = \frac{NS^2}{2\left(\sqrt{h_1}+\sqrt{h_2}\right)^2}$$

$$S_i = \frac{0.316\,P}{h^2}\left[4\log_{10}\left({}^{l}/_{b}\right) + 1.069\right]$$

$$S_c = \frac{3\,P}{h^2}\left[1 - \left(\frac{a\sqrt{2}}{l}\right)^{0.6}\right]$$

$$S_{ti} = \left(\frac{E\alpha\Delta t}{2}\right)\left[\frac{C_x + \mu C_y}{1 - \mu^2}\right]$$

$$S_e = \frac{0.572\,P}{h^2}\left[4\log_{10}\left({}^{l}/_{b}\right) + 0.359\right]$$

$$S_{te} = Max.\left(\frac{C_x E\alpha\Delta t}{2}, \frac{C_y E\alpha\Delta t}{2}\right)$$

$$S_{tc} = \frac{E\alpha\Delta t}{3(1-\mu)}\sqrt{\frac{a}{l}}$$

VTM or (% air voids) = $\frac{G_t - G_m}{G_t}$ x 100

VMA = [VTM + ($\frac{W_B}{G_B} \times \frac{G_m}{W}$)] x 100

VFB = $\frac{(VMA - VTM)}{VMA}$ x 100

$$G_{se} = \left[\frac{1 - P_b}{\left(\frac{1}{G_{mm}} - \frac{P_b}{G_b}\right)}\right]$$

$$P_{ba} = G_b\left(\frac{G_{se} - G_{sb}}{G_{se} \times G_{sb}}\right) \times 100$$

$$S_g = vt = 0.278Vt$$