National Examinations – Dec 2016

98-Civ-B7, Highway Engineering

<u>3 Hour Duration</u>

NOTES

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper a clear statement of any assumptions made.
2. Any data, not given but required, can be assumed.
3. This is an **"OPEN BOOK"** examination. Any non-communicating calculator is permitted.
4. A total of **five** solutions is required. Only the first five as they appear in your answer book will be marked.
5. All questions are of equal value.
6. For non-numerical questions, clarity and organization of the answer are important.

Marking Scheme

1. 20 marks.
2. (a) 8 marks.
   (b) 12 marks
3. 20 marks.
4. (a) 10 marks
   (b) 10 marks
5. (a) 8 marks.
   (b) 12 marks.
6. (a) 10 marks
   (b) 10 marks.
7. 20 marks

1. A two-lane highway UAU80 of 7.5 m width and a cross-slope of 0.02 m/m. A point of intersection (PI) exists at station 50+000.000 with a deflection angle of 20°. A horizontal circular curve with a radius of 800 m with an e_{max} of 0.06 is chosen to connect the two tangents.

 a. Check is the chosen radius is appropriate for this horizontal curve. If not, select an appropriate value
 b. Determine the spiral parameter and length of the transition curve, and the superelevation
 c. Using a horizontal scale of 1 to 500 and a vertical scale of 1:5, show the development of superelavation along the spiral and the circular curves with rotation around centerline.
 d. Show and calculate the stations at the following points:
    - Tangent to spiral
    - Spiral to curve
    - Curve to spiral

    (the distance between stations is 1000 m)

2. a. The corner of a building is located next to a horizontal curve with a radius of 500 m measured to the centre of the inside lane. The inside lane is 3.30 m wide and the inside edge of the road is 3 m from the corner of the building. Calculate the required speed limit to maintain a safe stopping sight distance.

 b. A vertical curve is to be designed to join a -2.0% and +1.0% grade along a two-lane highway RCU80. Calculate the minimum length of the curve based on minimum required stopping sight distance (SSD). Assume the height of the head lamps to be 0.60 m and the angle of the light beam from the plane of the vehicle to be 1°.

3. Using the AASHTO method, design a flexible pavement section for a four-lane highway (two lanes in each direction) with a one-way average daily traffic (ADT) of 10000, truck volume of 6%, and an annual growth in traffic volume of 2% over the design period of 20 years. The pavement is to be constructed on a subgrade with modulus of resilience of 35 MPa (5000 psi). Assume a truck factor of 1.8 ESAL, a reliability of 95%, an overall standard deviation S_o of 0.49, an initial serviceability of 4.5, and a terminal serviceability of 2.6.

 Use the attached AASHTO chart and return it with the answer booklet.
 Draw a cross section showing the thickness of each layer of the pavement structure.

4. a. The bulk density of a compacted asphalt mixture was determined and found to be 2400 kg/m^3. Using the basic volumetric properties, calculate the air voids, VMA and VFB of this sample given the following:

 Bulk relative density of the combined aggregate = 2.67
 Specific Gravity of the binder = 1.03
 Binder content = 5.5% (% of total mix, aggregates + binder)
 Binder absorbed (% of combined aggregates) = 0.60%

 b. In a relative density test on a coarse aggregate sample, the following measurements were recorded:

 SSD Mass: 2029 g

Submerged mass: 1272 g
Dry mass: 2016.1 g
Find the SSD relative density and the absorption

5. a. The following is a gradation of subgrade. Determine the D_{15} and D_{85} of a soil filter for this subgrade.

Sieve (mm)	% Passing
4.75	98
2.36	93
1.18	85
0.60	65
0.30	35
0.15	15
0.075	10

b. A drainage layer of 200 mm thick, a cross slope of 4%, a porosity n_e of 25%, and a permeability k of 3.5 cm/s. Determine the steady state capacity of the drainage layer and the time for 50% and 95% drainage based on a drainage length of 6 m.

6. a. Specification for a highway requires that the soil be compacted to 95% of the modified laboratory dry density which was found to be 1960 kg/m^3 at an optimum moisture content of 11.0%. A field density test is carried out and the following results were obtained:

Total Density: 2080 kg/m^3
Water content: 13%

Is compaction satisfactory? Should water be added? Or should the road be allowed to dry? Why?

b. List five types of distress that are used to evaluate conditions of asphalt pavements. Explain the reason(s) for each type of distress.

7. An asphalt overlay with a layer coefficient a1 of 0.44 is to be placed on an existing asphalt concrete pavement. The existing pavement has an AC surface of 40 mm (1.5 in) and a stabilized base of 150 mm (6 in). Assume the modulus of resilience of the soil to be 35 MPa (5000 psi). Condition survey was carried out on the existing pavement and showed the asphalt concrete layer to have < 5% medium- and high-severity transverse cracking, and the stabilized base to have >10% high-severity alligator cracking.

   a. Calculate the effective structural number of the pavement (state any assumptions you made or reference you used).
   b. Calculate the required future structural number if the ESAL on the design lane is 100,000, reliability R = 95%, Overall standard deviation S_o= 0.45, initial serviceability = 4.5, and final serviceability = 2.5 (use the attached AASHTO chart and submit it with the answer booklet).
   c. Calculate the thickness of the overlay.

NOMOGRAPH SOLVES:

$$\log_{10} W_{18} = Z_R{*}S_o + 9.36{*}\log_{10}(SN+1) - 0.20 + \frac{\log_{10}\left[\frac{\Delta PSI}{4.2 - 1.5}\right]}{0.40 + \frac{1094}{(SN+1)^{5.19}}} + 2.32{*}\log_{10}M_R - 8.07$$

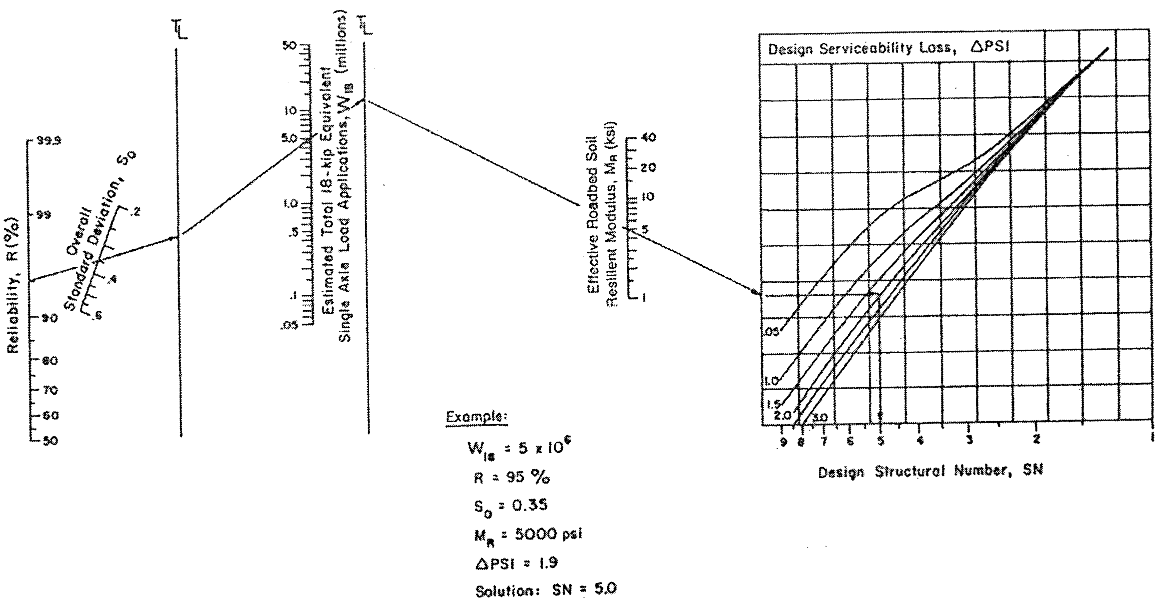

Figure 3.1. Design Chart for Flexible Pavements Based on Using Mean Values for Each Input

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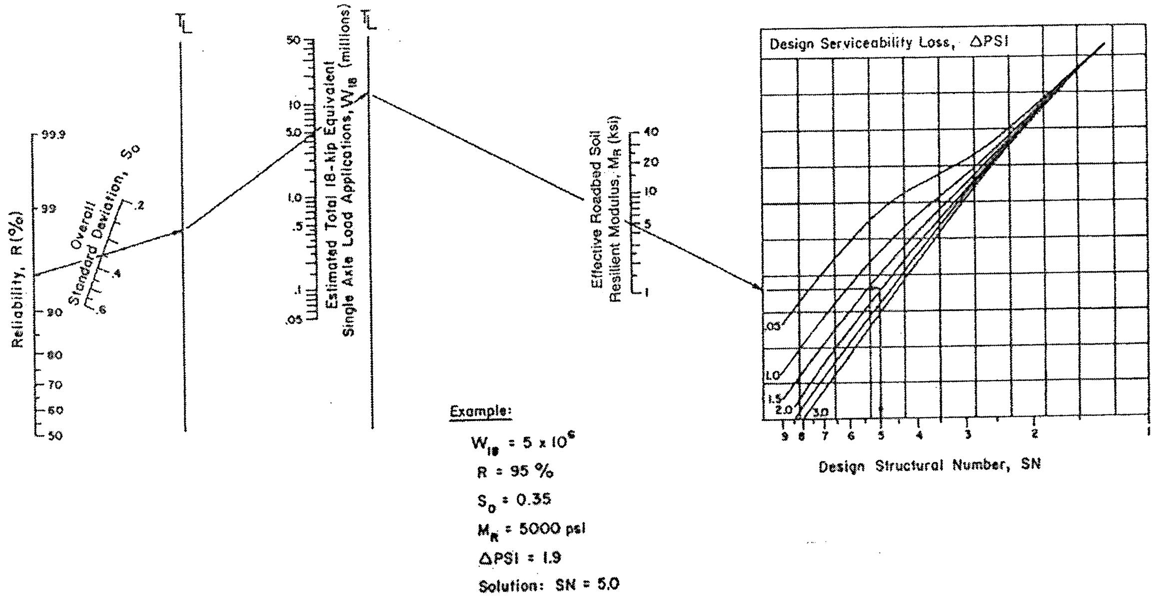

Figure 3.1. Design Chart for Flexible Pavements Based on Using Mean Values for Each Input

Table B.3.1.4b
Superelevation and minimum spiral parameter, e_{max} = 0.06 m/m

design speed, km/h	40			50			60			70			80			90			100			110			120			130		
radius, m	e	A 2 lane	A 3&4 lane	e	A 2 lane	A 3&4 lane	e	A 2 lane	A 3&4 lane	e	A 2 lane	A 3&4 lane	e	A 2 lane	A 3&4 lane	e	A 2 lane	A 3&4 lane	e	A 2 lane	A 3&4 lane	e	A 2 lane	A 3&4 lane	e	A 2 lane	A 3&4 lane	e	A 2 lane	A 3&4 lane
7000	NC			NC			NC			NC			NC			NC			NC			NC			RC			RC	710	710
5000	NC			NC			NC			NC			NC			NC			NC			RC	555	555	RC	580	580	RC	600	600
4000	NC			NC			NC			NC			NC			NC			RC	475	475	RC	495	495	RC	515	515	0.023	540	540
3000	NC			NC			NC			NC			NC			RC	390	400	RC	410	410	0.020	430	430	0.024	450	450	0.020	465	465
2000	NC			NC			NC			RC	275	275	RC	300	300	0.023	300	350	0.022	335	335	0.029	350	350	0.034	365	365	0.040	380	380
1500	NC			NC			RC	225	225	RC	250	250	0.024	250	250	0.029	270	275	0.029	290	290	0.036	305	305	0.042	315	315	0.049	330	335
1200	NC			NC			RC	200	200	0.023	225	225	0.028	225	225	0.033	240	240	0.034	260	260	0.043	270	270	0.049	285	290	0.055	295	320
1000	NC			RC	170	170	0.021	175	175	0.027	200	200	0.032	200	200	0.037	225	225	0.040	235	235	0.048	245	255	0.054	260	280	0.058	280	300
900	NC			RC	150	150	0.023	175	175	0.029	180	180	0.034	200	200	0.039	200	200	0.043	225	225	0.051	235	250	0.057	250	270	0.060	280	300
800	NC			RC	150	150	0.025	160	160	0.031	175	175	0.036	175	175	0.042	200	200	0.046	210	215	0.054	220	240	0.059	250	260	minimum R=950		
700	NC			0.021	140	140	0.027	150	150	0.034	175	175	0.039	175	175	0.045	185	195	0.050	200	210	0.058	220	235	0.060	250	260			
600	NC	120	120	0.024	125	125	0.030	140	140	0.037	150	150	0.042	175	175	0.048	175	185	0.054	190	200	0.060	220	220	minimum R=750					
500	RC	100	100	0.027	120	120	0.034	125	125	0.041	140	150	0.046	150	160	0.052	160	175	0.059	190	190	0.060	220	220						
400	0.023	90	90	0.031	100	100	0.038	115	120	0.045	125	135	0.051	135	150	0.057	160	165	0.060	190	190	minimum R=600								
350	0.025	90	90	0.034	100	100	0.041	110	115	0.048	120	125	0.054	125	140	0.059	160	160	minimum R=440											
300	0.028	80	80	0.037	90	100	0.044	100	110	0.051	120	125	0.057	125	135	0.060	160	160												
250	0.031	75	80	0.040	85	90	0.048	90	100	0.055	110	120	0.060	125	125	minimum R=340														
220	0.034	70	80	0.043	80	90	0.050	90	100	0.057	110	110	0.060	125	125															
200	0.036	70	75	0.045	75	90	0.052	85	100	0.059	110	110	minimum R=250																	
180	0.038	60	75	0.047	70	90	0.054	85	95	0.060	110	110																		
160	0.040	60	75	0.049	70	85	0.056	85	90	minimum R=190																				
140	0.043	60	70	0.052	65	80	0.059	85	90																					
120	0.046	60	65	0.055	65	75	0.060	85	90																					
100	0.049	50	65	0.058	65	70	minimum R=130																							
90	0.051	50	60	0.060	65	70																								
80	0.054	50	60	0.060	65	70																								
70	0.056	50	60	minimum R=90																										
60	0.059	50	60																											
	0.059	50	60																											
	minimum R=55																													

$e_{max} = 0.06$

Notes

e is superelevation
A is spiral parameter in metres
NC is normal cross section
RC is remove adverse crown and superelevate at normal rate
Spiral length, $L = A^2 \div$ Radius
Spiral parameters are minimum and higher values may be used
For 6-lane pavement: above the dashed line use 4-lane values, below the dashed line use 4-lane values × 1.15.
A divided road having a median less than 3 m may be treated as a single pavement.