National Examinations – May 2016

98-Civ-B7, Highway Engineering

3 Hour Duration

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. (a) 15 marks.

   (b) 5 marks.
2. 20 marks.
3. (a) 6 marks.

   (b) 14 marks.
4. 20 marks.
5. (a) 10 marks.

   (b) 10 marks.
6. (a) 12 marks

   (b) 8 marks.
7. (a) 7 marks

   (b) 7 marks

   (c) 6 marks

1. (a) A vertical curve is to be designed to join a +1.5% and -2% 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 driver's eye = 1.05 m and the height of object = 0.380 m.

   (b) If the tangents of the above highway intersect at station 200 + 15, calculate the stations of the BVC (beginning of vertical curve) and EVC (End of Vertical Curve)
   (The distance between stations in this problem is 30 m)

2. A two-lane highway UCU80 is 7.5 m wide with a cross-slope of 0.02 m/m. A point of intersection (PI) exists at station 30+000.000 with a deflection angle of 25^0. A horizontal circular curve is required to connect the two tangents (without spiral).

   Design the curve and develop the superelevation (max of 0.04 m/m) by rotating about its center line. Use horizontal scale of 1 to 500 and a vertical scale of 1:5. Show and calculate the stations at
   a) the beginning of the tangent runout
   b) the junction of tangent to transition length
   c) the beginning of the circular curve
   d) the end of the circular curve
   (the distance between stations is 1000 m)

3. (a) A minor road intersects a 7.5 m wide two-lane highway URU80 where the intersection is controlled by a stop sign. Calculate the required minimum sight distance along the major road (URU80) from the intersection based on the following:
   - Perception and reaction time of the driver is 2.5 seconds
   - Distance from the near edge of the pavement of URU80 to the front of the stopped vehicle = 3.0 m
   - Assume single unit trucks or buses (SU-9) with a length of 9.1 m traveling on the minor road

   (b) Describe the possible reasons for each of the following types of pavement distress and state whether the distress is classified as structural or functional:

   <u>For Asphalt Pavement:</u>
   (i) Bleeding
   (ii) Fatigue cracking
   (iii) Polished aggregate
   (iv) Rutting

   <u>For Concrete Pavement:</u>
   (i) D-cracking
   (ii) Pumping
   (iii) Map cracking

Table B.3.1.4a
Superelevation and minimum spiral parameter, e_{max} = 0.04 m/m

design speed, km/h	40			50			60			70			80			90			100		
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
7000	NC			NC			NC			NC			NC			NC			NC		
5000	NC			NC			NC			NC			NC			NC			NC		
4000	NC			NC			NC			NC			NC			NC			NC		
3000	NC			NC			NC			NC			NC			NC			RC	410	410
2000	NC			NC			NC			NC			RC	300	300	RC	315	315	RC	335	335
1500	NC			NC			NC			RC	240	240	RC	260	260	RC	275	275	.022	290	290
1200	NC			NC			NC			RC	215	215	RC	230	230	.021	245	245	.026	260	260
1000	NC			NC			RC	180	180	RC	200	200	.020	210	210	.025	225	225	.030	235	235
900	NC			NC			RC	175	175	RC	190	190	.021	200	200	.027	210	210	.032	225	225
800	NC			NC			RC	165	165	RC	180	180	.023	190	190	.029	200	200	.034	210	210
700	NC			RC	140	140	RC	150	150	.020	165	165	.026	175	175	.032	185	185	.036	200	200
600	NC			RC	130	130	RC	140	140	.023	155	155	.029	165	165	.035	175	175	.039	190	190
500	NC			RC	120	120	.021	130	130	.026	140	140	.033	150	150	.038	160	160	.040	190	190
400	RC	95	95	RC	105	105	.025	115	115	.031	125	125	.037	135	135	.040	160	160	.040	190	190
350	RC	90	90	.020	100	100	.027	110	110	.033	120	120	.039	135	135	.040	160	160	min R=490		
300	RC	80	80	.023	90	90	.031	100	100	.036	110	110	.040	135	135	min R=380					
250	RC	75	75	.026	85	85	.034	90	90	.038	110	110	.040	135	135						
220	RC	70	70	.029	80	80	.036	90	90	.039	110	110	min R=280								
200	.021	65	65	.031	75	75	.038	90	90	.040	110	110									
180	.023	65	65	.033	70	70	.039	90	90	.040	110	110									
160	.025	60	60	.035	70	70	.040	90	90	min R=200											
140	.028	55	55	.037	70	70	.040	90	90												
120	.031	50	55	.039	70	70	min R=150														
100	.034	50	50	.040	70	70															
90	.036	50	50	.040	70	70															
80	.038	50	50	min R=100																	
70	.040	50	50																		
60	.040	50	50																		
	.040	50	50																		
	min R=60																				

e_{max} = 0.04

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.

4. A flexible pavement section is to be designed for four-lane highway (two lanes in each direction) with a one-way average daily traffic (ADT) of 8000, truck volume of 5%, 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 34.5 MPa or 5000 psi.

   (a) Calculate the total truck volume in the **design lane** over the design period
   (b) If the average Equivalent Single Axle Load (ESAL) per truck is 2 ESAL, calculate the design ESAL
   (c) Assuming a flexible pavement that consist of 100 mm asphalt concrete with a layer coefficient of 0.42, 300 mm road base with a layer coefficient of 0.14, and 400 mm subbase with layer a layer coefficient of 0.10: use AASHTO method to check if this pavement is adequate for the intended traffic and design period. Assume a reliability of 90%, an overall standard deviation S_o of 0.49, an initial serviceability of 4.5 and terminal serviceability of 2.6.

5. (a) The following is a gradation of subgrade soil. The subbase material planned to be used has a D_{15} of 2.1 mm. Check if subgrade intrusion (subgrade intrudes into subbase) will be an issue if this subbase is used

Sieve Size	Passing
2.0 mm	100%
300 um	85%
150 um	60%
75 um	42%
40 um	15%

   (b) Smooth plastic pipe of 4 inches in diameter with roughness coefficient of 0.01 is placed at 2.5% slope in a trench drain. If outlets are provided every 300 ft, what is the maximum allowable lateral inflow into the plastic pipe in ft^3/day/ft.

6. (a) The bulk density of an asphalt concrete mix was determined experimentally and found to be 2366 kg/m^3. The maximum density is 2448 kg/m^3. The specifications require air voids content within the range of 3% to 5% and a percent voids filled with asphalt (VFA) in the range from 65% to 75%. Check if this mix meets the specified volumetric requirements given the following:

   - Asphalt content = 5.5% (expressed as % of total mix)
   - Relative density of combined aggregates = 2.65
   - Relative density of asphalt = 1.04

   (b) Specifications require a 95% subgrade compaction on a project. Maximum dry density and the optimum moisture content were determined in the lab and found to be 1800 kg/m^3 and 9%, respectively. Results from the field test showed a wet density of 1850 kg/m^3 and a moisture content of 12%. Is the compaction satisfactory?

7. (a) Draw a graph to show the effect of traffic or age on serviceability or structural capacity of a flexible pavement with a design period of 20 years. On the same graph, show the effect of an overlay constructed at the end of the 20 years on serviceability, and the effects of traffic over the following 15 years (no values are needed).

(b) A condition survey was carried out on an existing flexible pavements and the following layer coefficients were assigned to each of the layer as follows:

Layer	Thickness	Coefficient
Asphalt concrete	100 mm	0.32
Roadbase	300 mm	0.10
Subbase	400 mm	0.08

- Calculate the effective structural number of the pavement
- Calculate the required thickness of asphalt overlay if the future structural number is 120 mm. Assume a layer coefficient of 0.42 for new asphalt layer.

(c) A concrete mix has a compressive strength of 5000 psi. Estimate the modulus of rupture and the modulus of elasticity of this mix.