

National Exams May 2010
98-Civ-B7, Highway Engineering

3 hours 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. This is a **CLOSED BOOK EXAM**.
Candidates may use one of two calculators; the Casio or Sharp approved models.
3. **FIVE (5)** questions constitute a complete exam paper.
The first five questions as they appear in the answer book will be marked.
4. Each question is of equal value.
5. Some questions require an answer in essay format. Clarity and organization of the answer are important.

1. Discuss each of the following and describe how each is used in the context of the geometric design of roads
 - 1.a. Stopping Sight Distance
 - 1.b. Design Vehicle
 - 1.c. Perception Reaction Time
 - 1.d. Design Speed
 - 1.e. Maximum Lateral Friction, f_{max}

2. The following results as shown in Table 2 were obtained from a Marshall Mix Design. Determine the optimum asphalt content using the specifications in Table 2a. Assess whether or not the optimum asphalt content satisfies these specifications.

Table 2

Bitumen %	Density of Mix Kg/m ³	Marshall Stability kN	Air Voids %	Voids in Mineral Aggregate %	Flow 0.25 mm
4.5	2.58	8.35	3.70	14.70	8.00
4.75	2.59	8.49	2.90	14.30	8.50
5.00	2.61	8.45	1.70	14.20	10.00
5.25	2.61	8.00	1.50	14.60	12.00
5.50	2.60	7.50	1.30	14.90	13.00
5.75	2.59	7.00	1.20	15.50	15.00
6.00	2.58	6.05	1.20	16.00	18.00

Table 2a

Marshall Mix Design Criteria		
Criteria	Min	Max
Stability (N)	6672	-
Flow, (0.25mm)	8	16
Percent Air Voids	2	4
VMA	14	16

3. Answer both parts a and b

- 3.a. Using the Rational Method, determine the amount of runoff that would occur for a paved parking lot that is 100m x 50m and is uniformly sloped from one long edge to the other long edge at a rate of 2.0%. The time of concentration for this parking lot is four (4) minutes. The five-year storm with duration of 4 minutes has an intensity of 10 mm per hour. The runoff coefficient for this parking lot is 0.80.

$$Q = 0.166CIA$$

Where:

Q	=	Rate of Run off (m ³ /min)
I	=	Rainfall Intensity (mm/hr)
A	=	Catchment Area (ha)
C	=	Runoff Coefficient (unit less)

- 3.b. The runoff from part i is to be contained in a trapezoidal drainage ditch with the following properties.

Side Slope	= 2m horizontal run for every 1 m rise
Width of invert	= 2 m
Longitudinal Slope	= 0.005m/m
Manning's number	= 0.080

If the maximum permitted depth of water is 10mm, using Manning's equation for open channel flow, determine if the ditch will be able to accommodate the flow in part i.

$$Q = \frac{AR^{\frac{2}{3}}S^{\frac{1}{2}}}{n}$$

Where:

Q	= rate of flow in m ³ /sec
A	= Cross Section are of flow in m ²
R	= hydraulic radius in m (= A/WP)
WP	= Wetted perimeter in m
S	= Slope of hydraulic gradient in m/m
N	= Coefficient of roughness or Manning's Number

4. There are a number of methods for classifying and grading asphalt cements that are currently used in Canada. Currently these include viscosity-graded asphalts (e.g. AC10), penetration graded asphalts (e.g. PEN 85/100) and performance graded asphalts (e.g. PG 64-22). Discuss the tests required to perform each of these classification methods. Discuss the meaning of the letters and numbers that make up each classification method. Discuss the advantages and disadvantages of each in the context of building asphalt cement concrete pavements in Canada.

5. Discuss each of the following asphalt pavement distresses, giving probable causes and the maintenance or rehabilitation procedures most commonly used for rehabilitation of each:
 - 5.a. Pot Holes
 - 5.b. Frost Boils
 - 5.c. Map Cracking
 - 5.d. Bleeding
 - 5.e. Rutting

6. Answer all of 6.a, 6.b, and 6.c

6.a. For a two lane highway with a design speed of 90 kph, determine the minimum radius of circular curve given that the maximum rate of superelevation, e , is 0.04 and the design value for lateral friction, f , is 0.13 given:

$$R_{\min} = \frac{V^2}{127(e_{\max} + f_{\max})}$$

6.b. For the same highway in Question 7.a, determine the required superelevation for a horizontal curve with twice the minimum radius given that the distribution of e to f is 2:1.

6.c. Given that the

6.c.i. lane widths are 3.75 m,

6.c.ii. the spiral parameter, A is 245,

6.c.iii. the tangent runout is developed using a slope of 1:400,

6.c.iv. normal cross fall of 1.5%,

6.c.v. the lane is rotated around the centre line, and

6.c.vi. a spiral curve is to be used to transition between tangent and circular curve;

6.c.vi.(1) sketch a diagram showing the development of superelevation commencing with the start of tangent runout and ending with spiral to circular curve transition (SC).

6.c.vi.(2) Your sketch should show the elevation of the outside and inside edge of pavement in relation to the centre line elevation at key points including tangent to spiral (TS), removal of adverse crown, start of rotation of full road width, and transition to circular (TC).

$$A^2 = RL$$

Where: A is spiral parameter
 R is radius of circular curve
 L is length of spiral transition curve

SOME USEFUL EQUATIONS

$$VMA\% = \left(1 - \frac{P_{ag} G_{mb}}{G_{sb}} \right) \times 100$$

$$V_a = \frac{G_{mm} - G_{mb}}{G_{mm}}$$

$$P_{be} = \left(\frac{1}{G_{mm}} - \frac{P_{ag}}{G_{sb}} \right) G_b$$

$$G_{se} = \frac{P_{ag}}{\frac{1}{G_{mm}} - \frac{P_b}{G_b}}$$

$$G = \frac{P_1 + P_2 + \dots + P_n}{\frac{P_1}{G_1} + \frac{P_2}{G_2} + \dots + \frac{P_n}{G_n}}$$

$$s^2 = \frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n-1}$$

SOME USEFUL DEFINITIONS

VMA	Voids in the mineral aggregate
V_a	Volume of Air Voids
G_{se}	Effective Specific Gravity of Aggregate
G_b	Specific Gravity of Bitumen
G_{sa}	Apparent Specific Gravity of Aggregate
G_{sb}	Bulk Specific Gravity of Aggregate
G_{mb}	Bulk Specific Gravity of Asphalt Cement Concrete Mix
G_{mm}	Maximum Theoretical Specific Gravity of Asphalt Cement Concrete Mix
P_{be}	Weight of Effective Bitumen as proportion of weight of mix
P_b	Weight of Bitumen as proportion of weight of mix
P_{ag}	Weight of Aggregate as proportion of weight of mix
P_n	Weight of aggregate fraction "n" as proportion of weight of mix
G_n	Specific gravity of aggregate fraction "n"
G	Specific gravity of aggregate blend