National Exams December 2008

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.
   [illegible] calculator is permitted.
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. A bituminous mix design using the Marshall Mix Design Method was carried out and the following results as shown in Table 1 and 1.a were obtained. Determine the percentage air voids, percentage Voids in the Mineral Aggregate (VMA), percent bitumen absorbed and percent bitumen effective.

Table 1

Aggregate	Bulk Specific Gravity	Effective Specific Gravity	Apparent Specific Gravity	Percent by weight of aggregate blend
Coarse	2.450	2.550	2.600	60%
Sand	2.440	2.500	2.550	20%
Fines	2.480	2.520	2.580	5%
Mineral Filler	2.400	2.420	2.450	15%

Table 1a

Marshall Data	Value
Mass of Compacted Sample in Air	1375.0 g
Mass of Compacted Sample in Water	750.0 g
Asphalt Content by mass of mix	4.75 %
Specific Gravity of Asphalt	1.005

2. Answer both parts a and b

   a. Using the Rational Method, determine the amount of runoff that would occur for a paved parking lot that is 150m x 150m and is uniformly sloped in one direction at a rate of 2.0%. The time of concentration for this parking lot is six minutes. The five-year storm with duration of 6 minutes has an intensity of 12 mm per hour. The runoff coefficient for this parking lot is 0.83.

$$Q = 0.166CIA$$

Where:

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

   b. The runoff from part "***a***" 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	= 0.006m/m
Roughness Coefficient	= 0.070

If the maximum permitted depth of water is 10mm, which gives a cross section area of flow 0.22 m^2 and a wetted perimeter of 2.4 m, using Manning's equation for open channel flow, determine if the ditch will be able to accommodate the flow in part "***a***".

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

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

3. There is a variety of pavement structural design methods currently used in Canada. Discuss any three (3) giving details of the design methodology including design inputs, load estimation, sub-grade strength estimation, and failure criteria.

4. Answer both parts a and b.

   a. An existing pavement has a structural cross section consisting of 130 mm of Hot Mix Asphalt (HMA), 200 mm of granular base and 300 mm of granular subbase. This pavement is to be used as a prototype for a new pavement. It is determined that the new pavement will require the equivalent of an additional 250 mm of granular base. Given that the granular base equivalences for this jurisdiction are 1mm of HMA = 2 mm of granular base = 3 mm of granular subbase, design appropriate structural cross sections for a conventional, a deep strength and a full depth pavement.

   b. Calculate the total Equivalent Single Axle Load for a transport truck that consists of a tractor and a single trailer. The tractor has a single axle which carries a load of 54 kN, and a tandem axle that carries 160 kN. The trailer has a single belly axle that carries 75 kN and a tandem axle that carries 160 kN. The following equation may be used to determine the ESALS for any given axle, where "n" equals 4 for single axles and 2.5 for tandem axles.

$$ESAL = \left(\frac{Axle\ Load}{80} \right)^{n}$$

5. The following results as shown in Table 5 were obtained from a Marshall Mix Design. Determine the optimum asphalt content using the specifications in Table 5a. Assess whether or not the optimum asphalt content satisfies these specifications.

Table 5

Bitumen	Density of Mix	Marshall Stability	Air Voids	Voids in Mineral Aggregate	Flow
%	Kg/m^3	kN	%	%	0.25 mm
4.5	2.375	6	5.2	12.2	4
4.75	2.4	6.7	4.4	11.4	5
5	2.449	5.9	3.4	11.4	7
5.25	2.55	5.3	3	11.8	10
5.5	2.45	4.7	2.8	12.2	14
5.75	2.4	4.1	2.8	12.7	19
6	2.38	3.5	2.8	15	25

Table 5a

Marshall Mix Design Criteria		
Criteria	Min	Max
Stability (N)	6000	-
Flow, (0.25mm)	8	16
Percent Air Voids	2	4
VMA	14	24

6. 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 by each methodology used to arrive at a classification for an asphalt cement. Discuss the meaning of the letters and numbers that make up the classification label. Discuss the advantages and disadvantages of each in the context of building asphalt cement concrete pavements in Canada.