National Exams May 2009

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 an OPEN BOOK EXAM.
   Any non-communicating 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. Most 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
   a. Spiral curves
   b. Circular curves
   c. Parabolic curves
   d. Super elevation
   e. Cross fall

2. 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 Hot Mix Asphalt (HMA) pavements in Canada.

3. A bituminous mix design using the Marshall Mix Design Method was carried out and the following results as shown in Table 3 and 3.a were obtained. Determine the percentage air voids, percentage Voids in the Mineral Aggregate (VMA), percent bitumen absorbed and percent bitumen effective.

Table 3

Aggregate	Bulk Specific Gravity	Effective Specific Gravity	Apparent Specific Gravity	Percent by weight of aggregate blend
Coarse	2.450	2.460	2.470	35%
Sand	2.440	2.470	2.475	30%
Fines	2.650	2.750	2.800	30%
Mineral Filler	2.900	2.900	2.900	5%

Table 3a

Marshall Data	Value
Mass of Compacted Sample in Air	1350.0
Mass of Compacted Sample in Water	750.0
Asphalt Content by mass of mix	4.54%
Specific Gravity of Asphalt	1.010

4. Using Figure 4, show that the minimum radius of curvature for a circular curve to be used in the horizontal alignment of a highway is given by: (note rate of super elevation is denoted *e*)

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

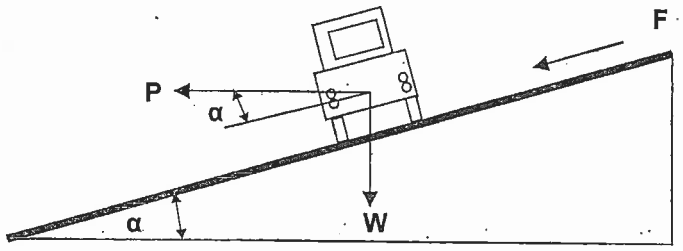

Figure 4

Where:

W=	Weight of Vehicle
M=	Mass of Vehicle
P=	Centripetal force (horizontal)
F=	Friction force between tires and road surface (parallel to road surface
α=	angle of super elevation (tan α = e)
V=	Velocity of vehicle
R=	Radius of Curve

5.

a. An existing pavement has a structural cross section consisting of 90 mm of Hot Mix Asphalt (HMA), 150 mm of granular base and 450 mm of granular sub base. 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 350 mm of granular base. Given that the granular base equivalences for this jurisdiction are 1mm of HMA = 1.5 mm of granular base = 2.5 mm of granular sub base, design appropriate structural cross sections for a conventional, a deep strength and a full depth pavement.
b. The concept of Equivalent Single Axle Load (ESAL) is commonly used to express the structural load that is imparted to pavements. Discuss in detail the meaning of ESAL including how it is defined, how it is calculated and how increases in its value relate to expected damage to a pavement.

6. Discuss each of the following pavement distresses, giving probable causes and the maintenance or rehabilitation procedures most commonly used for rehabilitation of each:

a. Ravelling
b. Rutting
c. Potholes
d. Alligator Cracking
e. Transverse Cracking

SOME USEFUL EQUATIONS

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

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

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

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

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

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

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