National Exams December 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 a CLOSED BOOK EXAM.
   One of two calculators is permitted any 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 the key geometric design elements that are essential to ensure a safe driving condition.

2. 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	2.370	2.390	2.410	55%
Sand	2.390	2.410	2.440	15%
Fines	2.390	2.410	2.440	30%
Mineral Filler	2.600	2.620	2.630	0%

Table 3a

Marshall Data	Value
Mass of Compacted Surface Dry Soaked Sample	1375.0
Mass of Compacted Sample in Water	745.0
Asphalt Content by mass of mix	3.75%
Specific Gravity of Asphalt	1.010

3. It is essential to provide adequate drainage for a paved structure to ensure longevity and performance. Discuss in detail the steps you would take to determine the quantity of water to be accommodated, the facilities you would need to accommodate the water and how you would design those facilities.

4. Answer both 4.a and 4.b

4.a. An existing pavement has a structural cross section consisting of 90 mm of Hot Mix Asphalt (HMA), 250 mm of granular base and 300 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 500 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 sub base, design appropriate structural cross sections for a conventional, a deep strength and a full depth pavement.

4.b. Determine the Equivalent Single Axle Load for a tractor trailer of the following configuration

4.b.i. Tractor

4.b.i.(1) 1 Single Axle of 25 kN

4.b.i.(2) 1 Tandem Axle of 70 kN

4.b.ii. Trailer

4.b.ii.(1) 3 Tandem Axles, each of 160 kN

4.b.ii.(2) 1 Tridem Axle of 250 kN

Given that

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

Where: Axle Load is the load in kN
Number of Axles is 1 for Single, 2 for Tandem and 3 for Tridem
n is equal to 4.0

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. Bleeding

5.b. Map Cracking

5.c. Longitudinal Edge Cracking

5.d. Shoving

5.e. Stripping

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

6.a. For a two lane highway with a design speed of 100 kph, determine the minimum radius of circular curve given that the maximum rate of superelevation, e, is 0.06 and the design value for lateral friction, f, is 0.12 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 225,

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

6.c.iv. normal cross fall of 2%,

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

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

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

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

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

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

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

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