National Examinations – May 2011

98-Civ-87, 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) 5 marks.
   (b) 15 marks.

2. 20 marks.

3. (a) 10 marks.
   (b) 10 marks.

4. 20 marks.

5. (a) 10 marks.
   (b) 10 marks.

6. (a), 3 (b), 3 (c) 7, (d) 7 - marks.

7. (a) 10 marks
   (b) 10 marks
1. (a) From comfort consideration, what is the minimum length of a parabolic sag vertical curve connecting a -2% and +1% grades?

Running speed of vehicle = 72 km/h  
Permissible centripetal acceleration = 0.3 m/s²

(b) A 1200 m long sag parabolic vertical curve joins a -2.4% grade and a +3.2% grade. The point of vertical intersection is at station 10+300.000 at an elevation of 153.20 m.
   (i) Determine the elevations and slopes at every 100 m along the curve.
   (ii) What is the elevation at the highest point on the curve and at what station does it occur?

(The distance between the stations is 1000 m.)

2. A two-lane highway RCU 100 is 7.5 m wide and has a cross-slope of 0.02 m/m. At station 10+000.000 there is a P.I. (point of intersection) with a deflection angle of 20°. Transition spirals and a horizontal circular curve connect the two tangents.
Design the curve and develop the superelevation by rotating about its center line.

Scale Horizontal: 1 to 500  
Vertical: 1 to 5

Calculate the station at
(i) the beginning of the tangent runout,
(ii) the junction of spiral to curve
(iii) the end of the circular curve,
(iv) the junction of curve to spiral
(v) the end of tangent runout.

3. (a) The cross-sectional areas along a proposed embankment as obtained with a planimeter are as follows:

<table>
<thead>
<tr>
<th>Station</th>
<th>End area (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>46</td>
<td>642</td>
</tr>
<tr>
<td>47</td>
<td>1484</td>
</tr>
<tr>
<td>48</td>
<td>762</td>
</tr>
</tbody>
</table>

Calculate the total volume of fill in cubic metres between stations 46 and 48 using (a) the average end area method and (b) the prismoidal formula.
(Note: The distance between each station is 1000 m.)
(b) The following are notes for an irregular cross-section. Compute the cross-sectional area by dividing it into triangles and trapezoids. The roadway is 14 m wide and the side slopes are 1:2.

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>F4.00</td>
<td>F8.20</td>
<td>F6.60</td>
<td>F8.10</td>
<td>F6.76</td>
</tr>
<tr>
<td>15.00</td>
<td>6.20</td>
<td>0</td>
<td>17.90</td>
<td>20.52</td>
</tr>
</tbody>
</table>

4. A two-lane municipal collector road is to be constructed in concrete. The soils consultant has assigned a CBR of 5.5 to the subgrade material and has recommended that a 100 mm layer of granular material be placed and compacted as a subbase.

The AADT is presently 3000 vehicles per day with truck volumes of 7%. The projected annual growth in traffic volume over the 20-year design period is 2.5%. It is expected that the truck percentage will remain the same over that period.

(a) What k-value corresponds to a CBR of 5.5?
(b) Taking the 100 mm granular layer into account, what k-value will be used for design?
(c) Compute the AADT, ADTT and total truck volume over the design period.
(d) Using the simplified design procedure given in CPCA’s Thickness Design Manual (or any other suitable method), what pavement thickness appears to be adequate?

5. (a) Design a truck climbing lane, given the following:
0% approach at 80 km/h
+2% for 1 km
+4% for 1 km
-2% for 1 km.

Representative design vehicle: 200 g/W truck.

(b) Determine the depth and velocity of flow in a trapezoidal channel with 2:1 side slopes and a 1.2 m bottom width discharging 5m³/s on a 0.5% slope. The channel is covered with some grass and weeds.

6. (a) Los Angeles Abrasion Test Results:
Original mass = 5000 g
Final mass = 4500 g
Calculate the percentage of wear.

(b) Penetration Test results:
Initial reading = 10 mm
Final reading = 15 mm under a loading of 100 g in 5 s at 25°C
What is the penetration grade of the asphalt cement?
(c) CBR Test results:

<table>
<thead>
<tr>
<th>Stress (MPa)</th>
<th>Penetration (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50*0.0069</td>
<td>0.05*25.4</td>
</tr>
<tr>
<td>75*0.0069</td>
<td>0.075*25.4</td>
</tr>
<tr>
<td>125*0.0069</td>
<td>0.1*25.4</td>
</tr>
<tr>
<td>400*0.0069</td>
<td>0.2*25.4</td>
</tr>
<tr>
<td>700*0.0069</td>
<td>0.3*25.4</td>
</tr>
<tr>
<td>860*0.0069</td>
<td>0.4*25.4</td>
</tr>
<tr>
<td>890*0.0069</td>
<td>0.5*25.4</td>
</tr>
</tbody>
</table>

(i) Plot stress-penetration curve; correct for concave upward shape.
(ii) What is the stress corresponding to corrected 0.1*25.4 mm penetration?
(iii) If the standard stress causing 0.1*25.4 mm penetration is 1000*0.0069 MPa, calculate the CBR value of the sample.

(d) Marshall Stability Test results:
Weight in air = 1.306*9.807 N
Weight in water = 0.7986*9.807 N
Saturated surface dry weight in air = 1.3106*9.807 N

(i) What is the bulk volume of the specimen?
(ii) What is the bulk specific gravity of the compacted mix?
7. (a) With respect to Portland cement concrete pavements, describe the following distress conditions giving possible reasons for the distress:

(i) Blowup/Buckling
(ii) Corner break
(iii) Durability (“D”) cracking
(iv) Faulting
(v) Polished aggregate
(vi) Popouts
(vii) Pumping
(viii) Punchout
(ix) Scaling/map cracking/crazing
(x) Spalling, joint

(b) With respect to asphalt cement concrete pavements, describe the following distress conditions giving possible reasons for the distress:

(I) Alligator cracking
(II) Bleeding
(III) Corrugation/washboarding
(IV) Edge cracking
(V) Joint reflection cracking (from Longitudinal and Transverse PCC slabs)
(VI) Lane/shoulder drop-off
(VII) Potholes
(VIII) Rutting
(IX) Shoving
(X) Weathering and ravelling