2049

# Ollscoil na hÉireann, Gaillimh
## National University of Ireland, Galway

## Semester I Examinations, 2005/2006

| | |
|---|---|
| Exam Code(s) | 4BE, 4BV |
| Exam(s) | 4th Civil Engineering<br>4th Environmental Engineering |
| Module Code(s) | CE418 |
| Module(s) | Highway & Traffic Engineering II |
| Paper No. | 1 |
| Repeat Paper | Special Paper |
| External Examiner(s) | Professor M. O'Mahony |
| Internal Examiner(s) | Professor P. E. O'Donoghue<br>Dr. M. J. Brennan<br>S. Breathnach, M.E. |

*Instructions*: Answer all questions. The allocation of marks is noted in the questions. This is a computer-based examination that must be held in room E 305. Use a separate answer book for Question 1 and insert the required printouts into it with your name and exam number clearly marked.

Duration: 2hrs
No. of Answer books:

**Requirements**:
Handout
MCQ
Statistical Tables
Graph Paper
Log Graph Paper
Other Material

No. of Pages: 4
Department(s): Civil Engineering

# OLLSCOIL na hÉIREANN, GAILLIMH
*NATIONAL UNIVERSITY OF IRELAND, GALWAY*
**FIRST SEMESTER EXAMINATIONS, 2005/2006**

**B.E. DEGREE**
Civil Engineering and Environmental Engineering
**HIGHWAY AND TRAFFIC ENGINEERING II**
(CE 418)

Professor M. O'Mahony;
Professor P. E. O'Donoghue;
Dr. M. J. Brennan;
S. Breathnach, M.E.

Time allowed: two hours. Answer all questions.
Table 3 and Figure 24 of the NRA Road Geometry Handbook are attached.
Use a separate answer book for Question 1 and insert the required printouts into it with your name and exam number clearly marked.

1. (a) (3%) Other than Novapoint, name three road design software programs that are used in Ireland.

(b) (27%) Using the triangulation model that you have already created in advance, use Novapoint to design a roadway for a design speed of 100 km/h with the following cross section: 7.3m single carriageway (i.e. one 3.65m lane in each direction), 2.5m hard shoulders, 3.0m verges and 1 vertically to 2 horizontal side slopes.
The eastings and northings of horizontal IP points are:

| | |
|---|---|
| First IP: | 6235.115, 23880.294 |
| Second IP: | 6674.704, 23752.960 |
| Third IP: | 7412.305, 23772.891 |
| End IP: | 7652.854, 23651.048 |

Select the minimum curve radius on the first curve which will allow right hand curve overtaking.
Select the mid range radius on the second curve which will not allow overtaking.
Select suitable transition length lengths.

The vertical profile should be as follows:
The first and last points should be locked onto the existing ground levels at the ends of the horizontal alignment. The second VIP should be at station 407m and elevation 90.000. Using the minimum K value for the sag curve, determine the length of the curve. The third VIP should be at station 1275m and elevation 103.500. Using the minimum K value for the crest curve, determine the length of the curve.

Determine the superelevation for a design speed of 100 km/h and ensure that this superelevation rate is used in your design. Ensure also that any transitions that are chosen are the correct length.
Design the hard shoulders, verges and side slopes.
Plot the horizontal alignment and produce a horizontal and vertical alignment report.
Plot the vertical alignment using a 10:1 vertical exaggeration
Print the road surface data for stations 1200 to the end of the alignment.

**Put your name on the drawing and on the reports.**

2. The structural parameters of a 4-layer pavement are given below:

| Layer | Thickness | Modulus | Poisson's ratio |
|---|---|---|---|
| HRA | 100 mm | 3500 MPa | 0.35 |
| Wet-mix | 200 mm | 500 MPa | 0.35 |
| Sub-base | 225 mm | 150 MPa | 0.45 |
| Subgrade | ∞ | 50 MPa | 0.45 |

A 40 kN single wheel load with a radius of contact of 151 mm is applied to the pavement.

(a) (5%) Using BISAR, determine the vertical, radial and tangential stresses directly below the centre of loading at (i) the bottom of the hot rolled asphalt (HRA) layer; and (ii) the top of the subgrade.

(b) (10%) Using Hooke's generalised law,

$$\varepsilon_x = \frac{1}{E}\{\sigma_x - \mu(\sigma_y + \sigma_z)\} \text{ and } \varepsilon_z = \frac{1}{E}\{\sigma_z - \mu(\sigma_x + \sigma_y)\}$$

show that $\varepsilon_r$ at the bottom of the HRA is 173.5 μm/m and tensile ; and that $\varepsilon_z$ at the top of the subgrade is 412.8 μm/m and compressive.

(c) (5%) Calculate the life of the pavement given the LR 1132 85% probability failure criteria

$$\log N = -9.78 - 4.32 \log \varepsilon_x \text{ and } \log N = -7.21 - 3.95 \log \varepsilon_z$$

and note the mode of failure.

3. A model pavement consisting of a heavy duty macadam (HDM) asphalt layer and a crushed rock granular layer is shown below. The HDM is bound with 50 pen bitumen with a softening point of 51°C. The penetration test temperature is 25°C. It has a bitumen content of 4.2% by mass of the total mix. Its voids content is 5%. It is assumed to have a Poisson's ratio of 0.35. The granular layer has a stiffness of 150 MPa and its Poisson's ratio is 0.45. The subgrade has a stiffness of 50 MPa and a Poisson's ratio of 0.45. The loading time is 0.02 s. The temperature of the asphalt is 20°C.

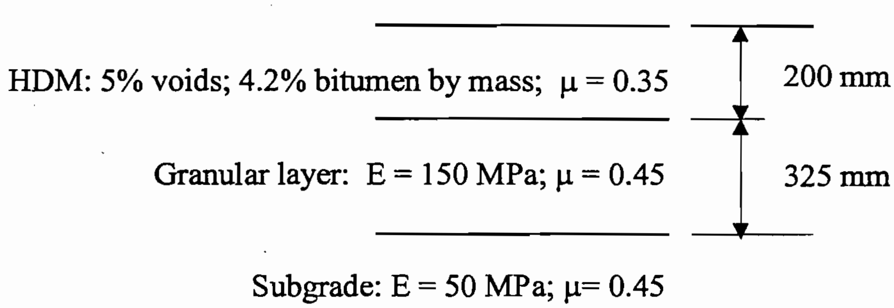
(a) (5%) Show that the volumetric aggregate content of the HDM is 84.9%.

(b) (10%) Using BANDS, establish the stiffness (MPa) of the bitumen, the stiffness (MPa) of the asphalt, the penetration index of the bitumen and the laboratory fatigue life for a strain of 500 micro strains.

(c) (10%) Noting the asphalt fatigue life, $N_f$, the subgrade deformation life, $N_s$, and the mode of failure, use SPDM to establish the life of the pavement (ESALs) by trial and error. The following parameters should be used for the failure criteria:

m=-3.95; *log* l=16.49; n=-4.16 and *log* k=15.58.

The lateral distribution factor and healing factor are both 1.



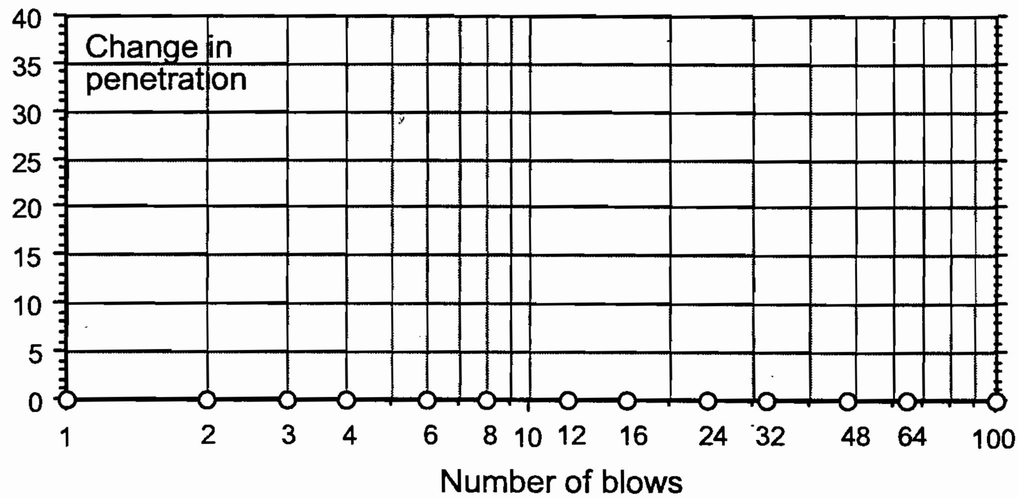
4. (a) (5%) Explain the principle of operation of the Benkelman Beam.
(b) (5%) The Falling Weight Deflectometer (FWD) deflections for two deflection basins subjected to a 40 kN load are tabulated below with the radial distances from the centre of loading. Compute the normalised deflection basin areas and establish whether the pavement or the subgrade is dominating the response in each case using above or below 700 mm as the decision criterion.

| Distance mm | 0 | 300 | 600 | 900 | 1200 | 1500 | 1800 |
|---|---|---|---|---|---|---|---|
| Basin 1 μm | 353 | 296 | 178 | 130 | 90 | 67 | 49 |
| Basin 2 μm | 553 | 280 | 150 | 110 | 70 | 50 | 30 |

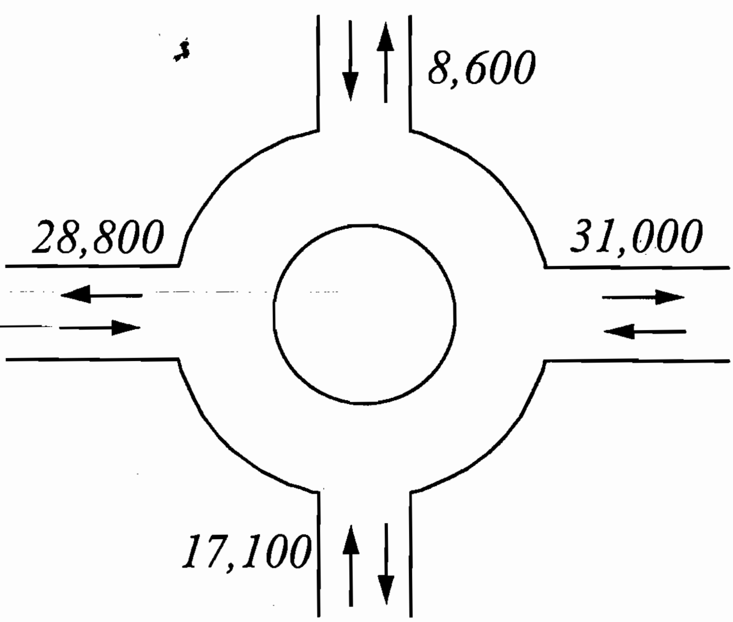
5. (a) (5%) What is the principle underlying the Moisture Condition Value (MCV) test.
(b) (5%) The following results were obtained in assessing the MCV of a heavy clay.

| No. of blows | 1 | 2 | 3 | 4 | 6 | 8 | 12 | 16 | 24 | 32 | 48 | 64 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Penetration (mm) | 34 | 50 | 57 | 65 | 76 | 82 | 89 | 95 | 100 | 100 | 100 | 100 |

Determine the MCV of the clay. Semi-logarithmic paper is provided below.




6. (5%) 16 accidents occurred at a roundabout. The two-way AADT's are given below. What is the annual accident rate per million users?



| DESIGN SPEED (km/h) | 120 | 100 | 85 | 70 | 60 | 50 | $V^2/R$ |
|---|---|---|---|---|---|---|---|
| **STOPPING SIGHT DISTANCE m** | | | | | | | |
| Desirable Minimum | 295 | 215 | 160 | 120 | 90 | 70 | |
| One Step below Desirable Minimum | 215 | 160 | 120 | 90 | 70 | 50 | |
| Two Steps below Desirable Minimum | 160 | 120 | 90 | 70 | 50 | 50 | |
| **HORIZONTAL CURVATURE m** | | | | | | | |
| Minimum R* without elimination of Adverse Camber and Transitions | 2880 | 2040 | 1440 | 1020 | 720 | 510 | 5 |
| Minimum R* with Superelevation of 2.5% | 2040 | 1440 | 1020 | 720 | 510 | 360 | 7.07 |
| Minimum R with Superelevation of 3.5% | 1440 | 1020 | 720 | 510 | 360 | 255 | 10 |
| Desirable Minimum R with Superelevation of 5% | 1020 | 720 | 510 | 360 | 255 | 180 | 14.14 |
| One Step below Desirable Min R with Superelevation of 7% | 720 | 510 | 360 | 255 | 180 | 127 | 20 |
| Two Steps below Desirable Min R with Superelevation of 7% | 510 | 360 | 255 | 180 | 127 | 90 | 28.28 |
| **VERTICAL CURVATURE - CREST** | | | | | | | |
| Desirable Minimum* Crest K Value | 182 | 100 | 55 | 30 | 17 | 10 | |
| One Step below Desirable Min Crest K Value | 100 | 55 | 30 | 17 | 10 | 6.5 | |
| Two Steps below Desirable Min Crest K Value | 55 | 30 | 17 | 10 | 6.5 | 6.5 | |
| **VERTICAL CURVATURE - SAG** | | | | | | | |
| Desirable Minimum Sag K Value | 53 | 37 | 26 | 20 | 13 | 9 | |
| One Step below Desirable Min Sag K Value | 37 | 26 | 20 | 13 | 9 | 6.5 | |
| Two Steps below Desirable Min Sag K Value | 26 | 20 | 13 | 9 | 6.5 | 6.5 | |
| **OVERTAKING SIGHT DISTANCES** | | | | | | | |
| Full Overtaking Sight Distance FOSD m. | N/A | 580 | 490 | 410 | 345 | 290 | |
| FOSD Overtaking Crest K Value | N/A | 400 | 285 | 200 | 142 | 100 | |

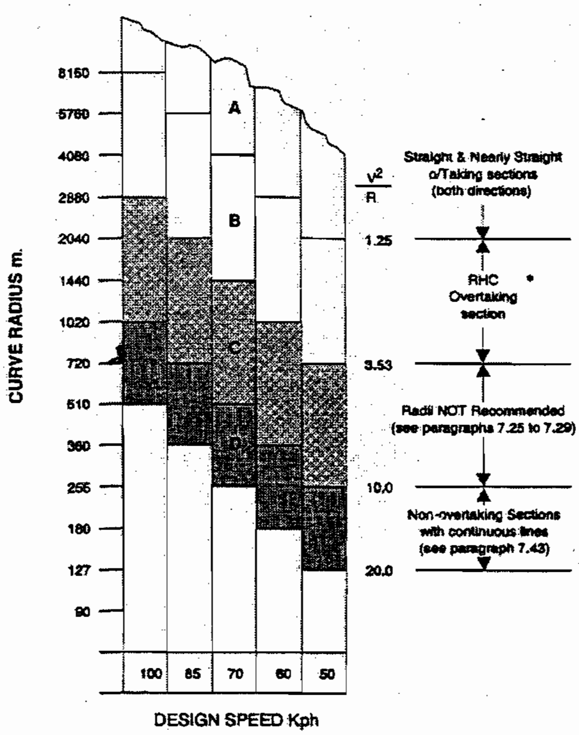
**Notes**

* Not to be used in the design of single carriageways (see Paragraphs 7.25 to 7.30)

The $V^2/R$ values simply represent a convenient means of identifying the relative levels of design parameters, irrespective of Design Speed.

K Value = Curve length divided by algebraic change of gradient %. See Paragraph 4.5.

**Table 3 : Design Speed Related Parameters**




* Note: Verge widening may be necessary. See Paragraph 7.27.

**Figure 24 : Horizontal Curve Design**