Code No: RR410112 **Set No. 1**

IV B.Tech I Semester Regular Examinations, November 2005
PAVEMENT ANALYSIS DESIGN AND EVALUATION
(Civil Engineering)

Time: 3 hours **Max Marks: 80**

Answer any FIVE Questions
All Questions carry equal marks

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NOTE: IRC 58-2002 & IRC 37-2001 May be used

1. (a) Draw sketches of flexible and rigid pavement cross-sections and show the component parts? [4]
   (b) As a pavement designer, explain various vehicle parameters you would be interested in? [8]
   (c) What is an equivalent single wheel load ? How can it be determined? [4]

2. (a) A single lane two-way road is at present carrying a traffic of 275 commercial vehicles per day. The rate of growth of traffic is 8 % per annum. The period of construction is 3 years. The pavement is to be designed for 15 years after construction. Calculate the design traffic volume? [3]
   (b) Explain various traffic parameters considered in pavement design? Briefly write the IRC recommended traffic considerations? [5]
   (c) Explain and plot atypical relationship between contact pressure and tire pressure? Define and explain rigidity factor? [8]

3. (a) Calculate the horizontal shear stress and vertical pressure due to a point load of 8000 kg, which applied on horizontal surface, for the following cases.
      i. at 2.7 m depth exactly under the axis of loading.
      ii. on the surface, 1.2 m away from the axis of loading.
      iii. at 7.4 m depth and 1.6 m away from the axis of loading. [8]
   (b) Distinguish and discuss the vertical stress distribution of Boussinesq's single layer system and Burmister's two-layer system using a neat sketch. [8]

4. (a) Explain terms, modulus of subgrade reaction, radius of relative stiffness and radius of resisting section of a cement concrete pavement ? [6]
   (b) Calculate wheel load stresses by Westergaard's equations at edge, interior and corner regions of a concrete slab. Given the following details. [10]
      Wheel load = 4080 kg
      Pavement slab thickness = 19 cm
      Modulus of elasticity of concrete = $2 \times 10^5 kg/cm^2$
      Modulus of subgrade reaction = 2.5 kg/cm^3
      Radius of contact of tire = 20 cm.
      Poisson's ratio of concrete = 0.15

5. (a) Explain the effect due to the expansion and contraction of cement concrete slab and discuss the type of stress induced. [8]

(b) Calculate warping stresses at corner and edge region of a concrete pavement of 20 cm thickness with transverse joints spaced at 7 m distance and lane width of the road is 3.7 m. Additional details are given below. [8]

Poisson's ratio of concrete = 0.15

Radius of loaded area = 15 cm

The modulus of subgrade reaction = 6.0 kg/cm^3

Thermal coefficient of concrete = $10 \times 10^{-6} per^oC$

Modulus of elasticity of concrete = $3.0 \times 10^5 kg/cm^2$

Temperature differential for day consideration may be assumed as $1.2^oC/cm$

6. Design the size and spacing of dowel bars at expansion joints of a cement concrete pavement of thickness 31 cm with radius of relative stiffness 90 cm, for a design wheel load of 8000 kg. Assume load capacity of the dowel system as 41 percent of the design wheel load. Take joint width is 2.1 cm, modulus of dowel support is 41500 kg/cm^2, permissible compressive stress of concrete is 400 kg/cm2 and take additional as follows:

Modulus of elasticity of dowel =$2.0 \times 10^6 kg/cm^2$ [16]

Modulus of elasticity of concrete = $3.0 \times 10^5 kg/cm^2$

Poisson's ratio of concrete = 0.15

7. (a) What is meant by functional evaluation of pavements? Briefly discuss the importance of evaluation of pavements? [6]

(b) Briefly outline the IRC:37 recommendations for determining the crust thickness of bituminous pavement. [10]

8. (a) Determine the bituminous overlay thickness required, if Benkelman Beam deflection data is available on 12 selected test sections of a bituminous pavement during summer season using a dual wheel load of 4085 kg, 5.6 kg/cm^2 of tire pressure. After making necessary lag corrections, the deflection values are given below.

test section	1	2	3	4	5	6	7	8	9	10	11	12
Rebound Deflection (mm)	1.41	1.02	1.15	1.83	1.25	1.47	1.73	1.82	1.59	1.55	1.62	1.74

The present traffic volume observed to be 120 commercial vehicles per day. The pavement temperature during the test was 32.3^0 and the correction factor for subsequent increase in subgrade moisture content is 1.2. Assume annual rate of growth of traffic as 7.1 percent and number of years after the last traffic couont before the construction of overlay as 2 years.

(b) Differentiate between the following. [6+10]

i. Longitudinal cracking and reflection cracking

ii. Alligator cracking and temperature cracking

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1. (a) Determine ESWL of a dual wheel assembly carrying 4160 kg for pavement thickness of
   i. 18 cm,
   ii. 23 cm and
   iii. 33 cm

   Center to center distance between tires is 32 cm and clear distance between the walls of the wheels is 12 cm. [9]

   (b) Enumerate the functions of various pavement layers of flexible and rigid pavements using sketches? [7]

2. (a) Determine the design wheel load repetitions per lane for 12 years period for various wheel loads equivalent to 2270 kg wheel load using the following traffic data on a four lane road. Average daily traffic volume on both directions observed to be 350.

   (b) Define and explain the relationship between contact pressure and inflation pressure? [10+6]

Sl.No.	Wheel load (kg)	Equivalent load factors	percentage of total traffic volume
1	2270	1	10
2	2722	2	14
3	3175	4	15
4	3629	8	17
5	4082	16	02
6	4536	32	02

3. (a) Design thickness of a flexible pavement for 7500 kg single wheel load, 9.1 kg/cm^2 of tire pressure, if the limiting deflection is 0.120 cm, given the following test results and use below give design chart. (figure 1)
   i. Plate load test was conducted on subgrade using 75 cm diameter steel plate, at 0.78 kg/cm^{2}pressure and 0.120 cm deflection.
   ii. Another plate load test was conducted on 15 cm thick base course, with 75 cm diameter steel plate, at 2.16 kg/cm^{2}pressure and 0.120 cm deflection.

   (b) Briefly explain how Burmister's and Boussinesq theories are useful for analysis of pavements in spite of their limitations? [10+6]

4. (a) Write the assumptions and limitation of Westergaard's analysis of wheel load stresses in rigid pavements? [8]

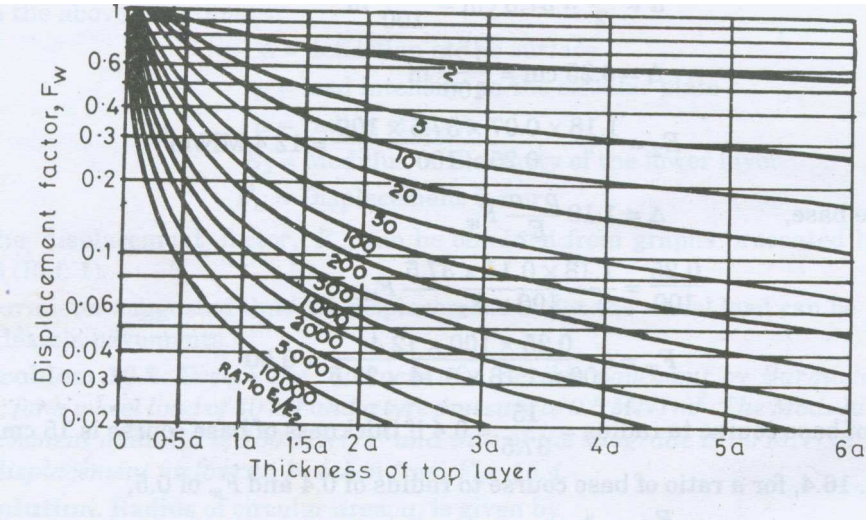

Figure 1:

(b) Define and explain the significance of the following terms in rigid pavement analysis? [8]

i. Radius of relative stiffness,

ii. Equivalent radius of resisting section

iii. Modulus of subgrade reaction and

iv. Poisson's ratio of cement concrete

5. Write short notes on the following parameters which are recommended by IRC for the design of rigid pavements. [16]

(a) Coefficient of thermal expansion of cement concrete

(b) Critical combination of stresses

(c) Design strength of concrete

(d) Temperature differential

6. (a) State the factors that are considered in the design of slab thickness of a cement concrete road and explain briefly how they influence the design? [11]

(b) If the radius of relative stiffness is 95 cm and if the dowels are placed at every 30 cm, calculate the maximum load carried by an outer dowel, which is just below the wheel. Assume that a wheel of 8100 kg is placed at the joint corner and 45 % of the load is transferred through the joints. [5]

7. (a) A two-lane two-way road is at present carrying traffic of 1250 commercial vehicles per day. It is to be strengthened for the growing traffic needs. The VDF has been found to be 3.3. The rate of growth of traffic is 7.8 per cent per annum. The period of construction is four and half years. The pavement is to be designed for 16years after completion. Calculate the cumulative standard axles to be used in design?

(b) Mention the various steps involved in mechanistic pavement design of bituminous pavements as per IRC:37-2001? [7+9]

8. (a) List and describe at least five types of cement concrete pavement distress or failure and describe maintenance practices appropriate for each. [10]

(b) What are the various causes of formation of waves and corrugations in flexible pavements? Suggest remedial measures. [6]

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Time: 3 hours **Max Marks: 80**

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NOTE: IRC 58-2002 &IRC 37-2001 May be used

1. (a) Discuss the necessity of Highway Pavements ? [4]
   (b) Distinguish Flexible and Rigid Pavements ? [8]
   (c) Explain the concept of ESWL? [4]

2. (a) a) What are the traffic loading parameters considered during pavement design? How design traffic intensity is estimated?
   (b) How moisture and climatic variations influence the pavement performance?
   (c) Define fourth power rule? [8+5+3]

3. (a) Calculate the thickness of a flexible pavement for 13250 kg single wheel load, 13.5 kg/cm^2 of tire pressure, if the limiting deflection is 0.125 cm, For the below given test results.
   (i) A plate load test was conducted on subgrade using 75 cm diameter rigid plate, at 0.75 kg/cm^{2}pressure and 0.125 cm deflection.
   (ii) Another plate load test was conducted on 16 cm thick base course, with 75 cm diameter steel plate, at 2.5 kg/cm^{2}pressure and 0.125 cm deflection. Use below give design chart (figure 1). [10]

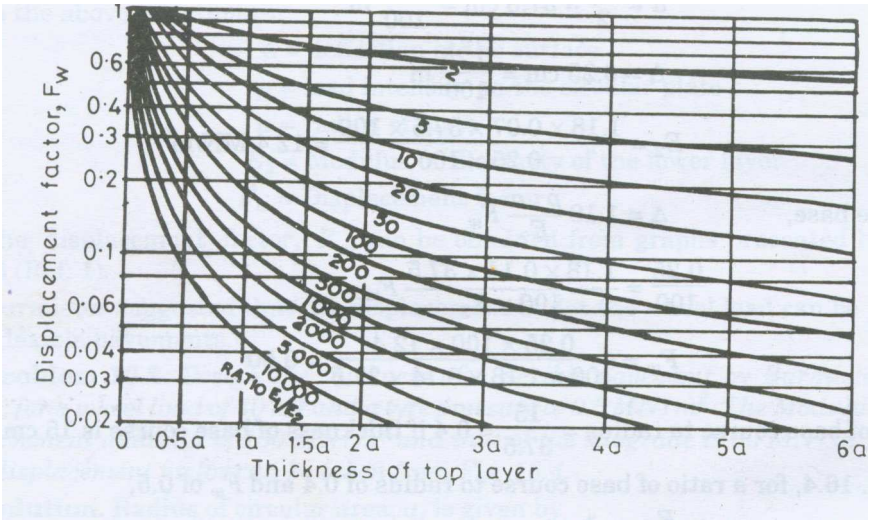

Figure 1:

   (b) Explain the Boussinesq theory of single layer analysis? Discuss limitations of the method? [6]

4. (a) Calculate
   i. radius of relative stiffness,
   ii. equivalent radius of resisting section and
   iii. distance from apex of slab corner to section of maximum stress along corner bisection, using following data. [8]

   Radius of wheel load distribution = 13 cm

   Slab thickness = 24.5 cm

   Modulus of subgrade reaction = 3 kg/cm^3

   Poisson's ratio of concrete = 0.15

   Modulus of elasticity of concrete = 200 000 kg/cm^2

   (b) Briefly describe the Westergaard's concept and assumptions made in his rigid pavement analysis? Explain the nature of stresses due to loading at critical locations on a cement concrete pavement? [8]

5. Determine the worst combination of stresses due to load, warping and friction at the edge and corner regions of a cement concrete pavement from the following data. [16]

   slab thickness = 22 cm

   wheel load I= 4510 kg

   poisson?s ratio of concrete = 0.15

   radius of load contact area = 17 cm

   modulus of subgrade reaction = 6.9 kg/cm^3

   thermal coefficient of concrete = $9.1 \times 10^{-6} per^oC$

   modulus of elasticity of concrete = $2.22 \times 10^5 kg/cm^2$

   spacing of transverse joints = 8 m

   spacing of longitudinal joint = 3.4 m

   temperature differential for day consideration may be assumed as 0.66^oC/cm

6. Design a dowel bar system for a cement concrete slab for the following conditions: [16]

   Design wheel load: 8000 kg

   Design load transfer : 40 percent

   Slab thickness : 34 cm

   Joint width : 2 cm

   Modulus of dowel/concrete interaction : 41000 kg/cm^2

   Modulus of subgrade reaction = 15 kg/cm^3

   Ultimate compressive stress of concrete = 400 kg/cm^2

   Modulus of elasticity of dowel = 2.0×10^6kg/cm^2

Modulus of elasticity of concrete = 3.0×10^5 kg/cm2

Poissons ratio of concrete = 0.15

7. (a) What is meant by functional evaluation of pavements? Briefly discuss the importance of evaluation of pavements? [6]

   (b) Briefly outline the IRC:37 recommendations for determining the crust thickness of bituminous pavement. [10]

8. (a) It has been decided to strengthen an existing bituminous pavement and the pavement is evaluated using a Benkelman Beam with a test vehicle of 8170 kg rear axle load with a tire pressure of 5.6 kg/cm^2. Observations recorded at a pavement temperature of 38.5^oC are given below. Length of test stretch = 600 m.

Serial Number Subsection	Rebound deflection (mm)	Serial number subsection	Rebound deflection (mm)
1	1.33	7	1.14
2	1.21	8	1.11
3	1.16	9	1.14
4	1.16	10	1.33
5	1.11	11	1.41
6	1.64	12	1.23

   Compute the thickness of overlay of bituminous concrete, taking allowable deflection as 1.00 mm, if the factor for subgrade moisture correction is 1.3.

   (b) Write a short note on working principle of Loadman with a neat sketch? [10+6]

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NOTE: IRC 58-2002 & IRC 37-2001 May be used

1. (a) Explain the objectives and requirements of highway pavements? [7]
   (b) Draw sketches of 'flexible and rigid pavement' cross-sections and explain the significance of each layer in detail? [9]

2. (a) Explain how wheel load repetitions and equivalent load factors are useful for pavement design? [8]
   (b) Define 'tire pressure and contact pressure' and discuss their relationship using a neat sketch? [8]

3. (a) Explain the Burmister's theory and how it can be used for design of highway pavements? Discuss the limitations of Burmister's theory ? [9]
   (b) Calculate the horizontal shear stress and vertical pressure due to a point load of 5 tonnes, which applied on horizontal surface, for the following cases.
      i. at 2m depth exactly under the axis of loading.
      ii. on the surface, 2 m away from the axis of loading.
      iii. At 4 m depth and 1 m away from the axis of loading. [7]

4. (a) Define and explain the significance of the following terms in rigid pavement analysis? [8]
      i. Equivalent radius of resisting section
      ii. Modulus of subgrade reaction
      iii. Radius of relative stiffness and
      iv. Poisson's ratio of cement concrete
   (b) Calculate
      i. equivalent radius of resisting section
      ii. radius of relative stiffness, and
      iii. distance from apex of slab corner to section of maximum stress along corner bisection, using following data. [8]

   Slab thickness = 24.5 cm
   Radius of wheel load distribution = 16.5 cm
   Modulus of subgrade reaction = 5.73 kg/cm^3
   Poissons ratio of concrete = 0.15
   Modulus of elasticity of concrete = 230500 kg/cm^2

5. Write short notes on the following parameters of IRC recommendations for the design of rigid pavements. [16]
   (a) Foundation strength
   (b) Foundation surface characteristics
   (c) Design strength of concrete
   (d) Environmental parameters.

6. Design a dowel bar system for a cement concrete slab for the following conditions:
   Design wheel load: 8000 kg [16]
   Design load transfer : 40 percent
   Slab thickness : 34 cm
   Joint width : 2 cm
   Modulus of dowel/concrete interaction : 41000 kg/cm^2
   Modulus of subgrade reaction = 15 kg/cm^3
   Ultimate compressive stress of concrete = 400 kg/cm^2
   Modulus of elasticity of dowel = 2.0×10^6kg/cm^2
   Modulus of elasticity of concrete = 3.0×10^5 kg/cm2
   Poissons ratio of concrete = 0.15

7. Design a bituminous pavement from the following data. [16]
   Design life = 15 years.
   Type of carriageway: dual four lane carriageway
   Initial traffic in the year of completion of construction = 520 CV/day
   Traffic growth rate per annum = 7.1 per cent
   Vehicle Damage Factor = 4.32 sa/CV
   Subgrade CBR values for design
   (a) 7 %,
   (b) 4 % and
   (c) 2 %

   Draw neat sketches showing the design details of the pavement crust and comment on the results obtained.

8. (a) Determine the bituminous overlay thickness required, if Benkelman Beam deflection data is available on 12 selected test sections of a bituminous pavement during summer season using a dual wheel load of 4085 kg, 5.6 kg/cm^2 of tire pressure. After making necessary lag corrections, the deflection values are given below.

test section	1	2	3	4	5	6	7	8	9	10	11	12
Rebound Deflection (mm)	1.41	1.02	1.15	1.83	1.25	1.47	1.73	1.82	1.59	1.55	1.62	1.74

The present traffic volume observed to be 120 commercial vehicles per day. The pavement temperature during the test was 32.3^0 and the correction factor for subsequent increase in subgrade moisture content is 1.2. Assume annual rate of growth of traffic as 7.1 percent and number of years after the last traffic couont before the construction of overlay as 2 years.

(b) Differentiate between the following.

i. Longitudinal cracking and reflection cracking

ii. Alligator cracking and temperature cracking [6+10]

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