University of Technology
Building and Construction Eng. Dept.
Final Exam - First Attempt - 2010/2011

Subject : Highway Engineering — Class: 3rd
Branch : Structural Engineering — Time : 3 Hours
Examiner : A.L. Ahmed Subhi — Date : 6 /6 / 2011

**Only Four Questions are required**

**Q-1/**

(A) What do we mean by the Right of Way (ROW)? Explain and draw a suitable sketch showing it.

(B) Draw a suitable sketch showing the typical layers of a flexible pavement with the range of thicknesses for each layer, and what is the purpose of tack coat and prime coat?

(C) What do we mean by vehicles skidding or slipping? And what are the main factors affecting on friction.

(D) Explain with suitable sketches the spread of the wheel load through the pavement and the pavement deflection under loads. (25 marks)

**Q-2/** An 8 ° (metric) horizontal circular curve turns around a building. The clearance distance from the building to the inner edge of the pavement is 20 meters. The curve is superelvated at a rate of 5cm. per meter. Determine the safe driving speed on this curve, given that length of curve is 300 meters.

- Note: the road consists of two lanes (each lane 4 meters in width).
- Safe coefficient of side friction = 0.15.
- Safe coefficient of skidding friction = 0.3. (25 marks)

**Q-3/**

1- Design a flexible road for a design life of 25 years to carry 2500 heavy commercial vehicles / day in each direction at the time of construction. The traffic is expected to grow at a rate of 3 % per year CBR of subgrade was found to be equal to 9%.

2- And what would be the minimum CBR required for the subbase material?

3- How would the design be altered if the subgrade CBR was 35 %?

| Initial traffic (cm./day | Equivalent factor no. of st. axles /c.v. |
|---|---|
| > 2000 | 2.75 |
| ≤ 2000 & > 1000 | 2.25 |
| ≤ 1000 & > 250 | 1.25 |
| All other (≤ 250) | 0.75 |

(25 marks)

Q-4/

(A) 500 ft. long equal tangent crest vertical curve connects tangents that intersect at station 340 + 00 and elevation 1322 ft. The initial grade is +4.0% and the final grade is -2.5%. Determine the elevation and stationing of the high point, PVC, and PVT. (12 marks)

(B) A pavement of 30 cm. thickness and modulus of elasticity of 3500 $kg/cm^2$. This layer over a subgrade of modulus of elasticity of 700 $kg/cm^2$. Find the surface deflection under the center of a tyre with tyre pressure of 6.0 $kg/cm^2$ and a circular contact area of 707 $cm^2$. (13 marks)

Q-5/ An equal tangent sag vertical curve is designed with the PVC at station 109 + 00 and elevation 950 ft, the PVI at station 110 + 77 and elevation 947.34 ft. and the low point at station 110 + 50 ft. Determine the safe sight distance on this curve.

(25 marks)

$$L = \frac{AS^2}{152.44 + 3.5S} \quad S < L$$

$$L = 2S - \frac{152.44 + 3.5S}{A} \quad S > L$$

$$M = R\left(1 - \cos\frac{28.65S}{R}\right)$$

$$SSD = 2.5V - \frac{V^2}{2fg} \quad \text{Level}$$

$$SSD = 2.5V + \frac{V^2}{254(f - G)} \quad \text{Up grade}$$

$$D = \frac{5729.58}{R} \qquad L = \frac{2\pi R\Delta}{360}$$

$$l = \frac{100\theta}{D} \qquad T = R\tan\frac{\Delta}{2}$$

$$E = R\left(\sec\frac{\Delta}{2} - 1\right) \qquad M = R\left(1 - \cos\frac{\Delta}{2}\right)$$

$$C = 2R\sin\frac{\Delta}{2} \qquad \phi = \frac{\theta}{2} = \frac{lD}{200}$$

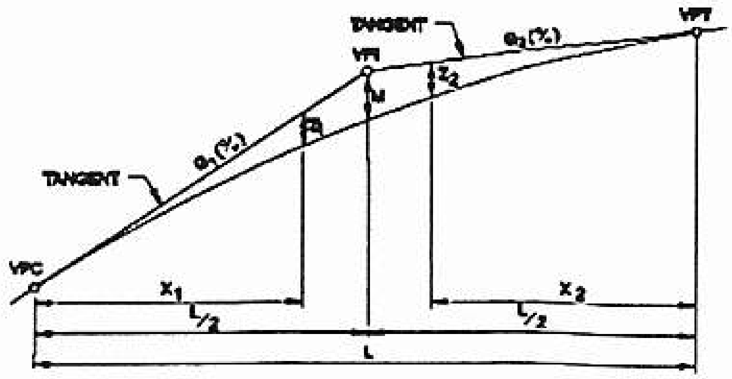
For any tangent distance x:

$$y = R - \left[R^2 - x^2\right]^{1/2}$$

For any arc length:

$$x = R\sin\theta$$
$$y = R(1 - \cos\theta)$$

$$SSD = 2.5V - \frac{V^2}{254 . (f - G)}$$ **Down grade**




M - External distance, ft (m)
Z - Any tangent offset, ft (m)
L - Horizontal length of vertical curve, ft (m)
X - Horizontal distance from VPC or VPT to any ordinate "Z," ft (m)
$G_1$ & $G_2$ - Rates of grade, expressed algebraically, %

NOTE: ALL EXPRESSIONS TO BE CALCULATED ALGEBRAICALLY —
(Use algebraic signs of grades; grades in percent.)

1. Elevations of VPC and VPI:

$$\text{ELEV. OF VPC} = \text{ELEV. VPI} - G_1\left(\frac{L}{200}\right)$$ (Equation 26.4-6)

$$\text{ELEV. OF VPT} = \text{ELEV. VPI} + G_2\left(\frac{L}{200}\right)$$ (Equation 26.4-7)

2. For the elevation of any point "X" on the vertical curve:

CURVE ELEV. = TAN ELEV. – Z (Equation 26.4-8)

Where:

Left of VPI ($x_1$ measured from VPC):

(a) $\text{TAN ELEV.} = \text{VPC ELEV.} + G_1\left(\frac{X}{100}\right)$

(b) $Z_1 = X_1^2 \frac{(G_2 - G_1)}{200\ L}$

Right of VPI ($X_2$ measured from VPT):

(a) $\text{TAN ELEV.} = \text{VPT ELEV.} - G_2\left(\frac{X_2}{100}\right)$

(b) $Z_2 = X_2^2 \frac{(G_2 - G_1)}{200\ L}$

3. Calculating high or low point in the vertical curve:

(a) To determine distance "$x_T$" from VPC: $X_T = \frac{L\ G_1}{G_1 - G_2}$ (Equation 26.4-9)

(b) To determine high or low point stationing: VPC Sta. + $x_T$ (Equation 26.4-10)

(c) To determine high or low point elevation on a vertical curve:

$$\text{ELEV.}_{\text{HIGH OR LOW POINT}} = \text{VPC ELEV.} - \frac{L\ G_1^2}{(G_2 - G_1)\ 200}$$ (Equation 26.4-11)

**SYMMETRICAL VERTICAL CURVE EQUATIONS**

**Figure 26.4E**

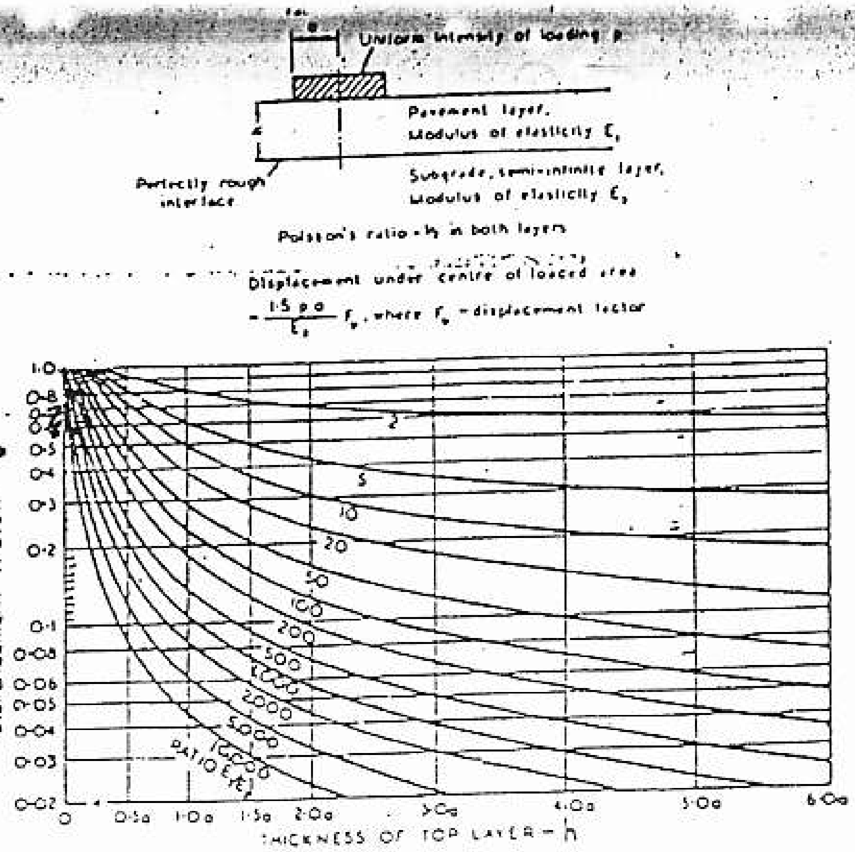



FIG. 20·15 THEORETICAL DISPLACEMENTS IN A TWO-LAYER ELASTIC SYSTEM

(Burmister)

Fig. A growth rate 3

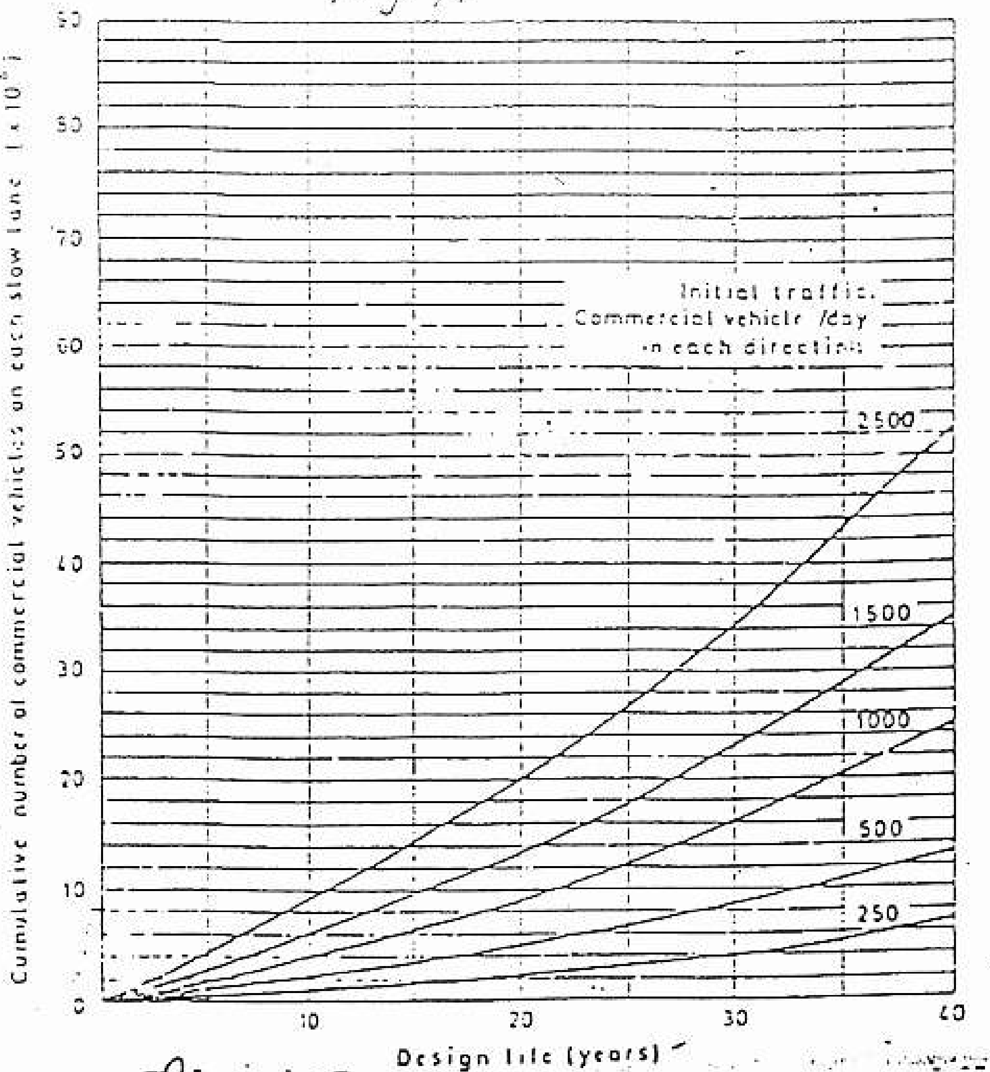
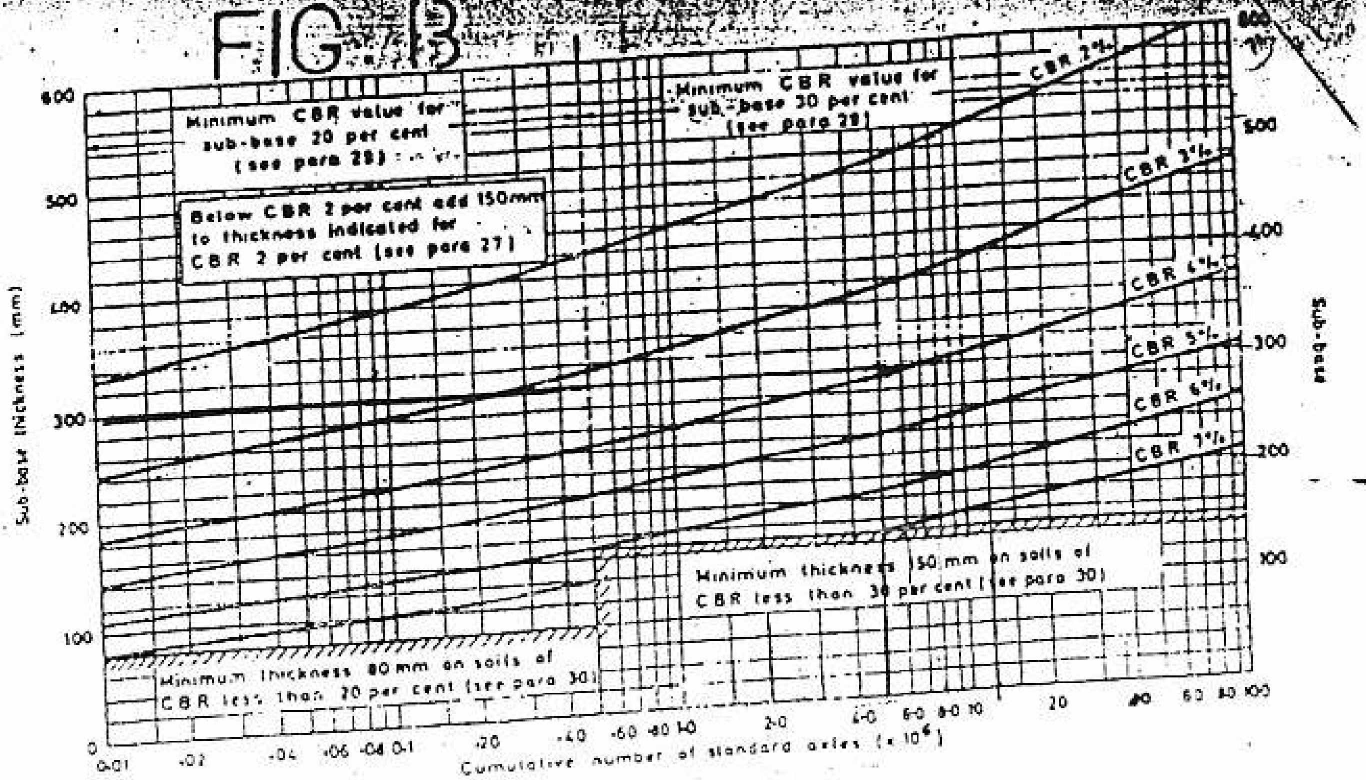
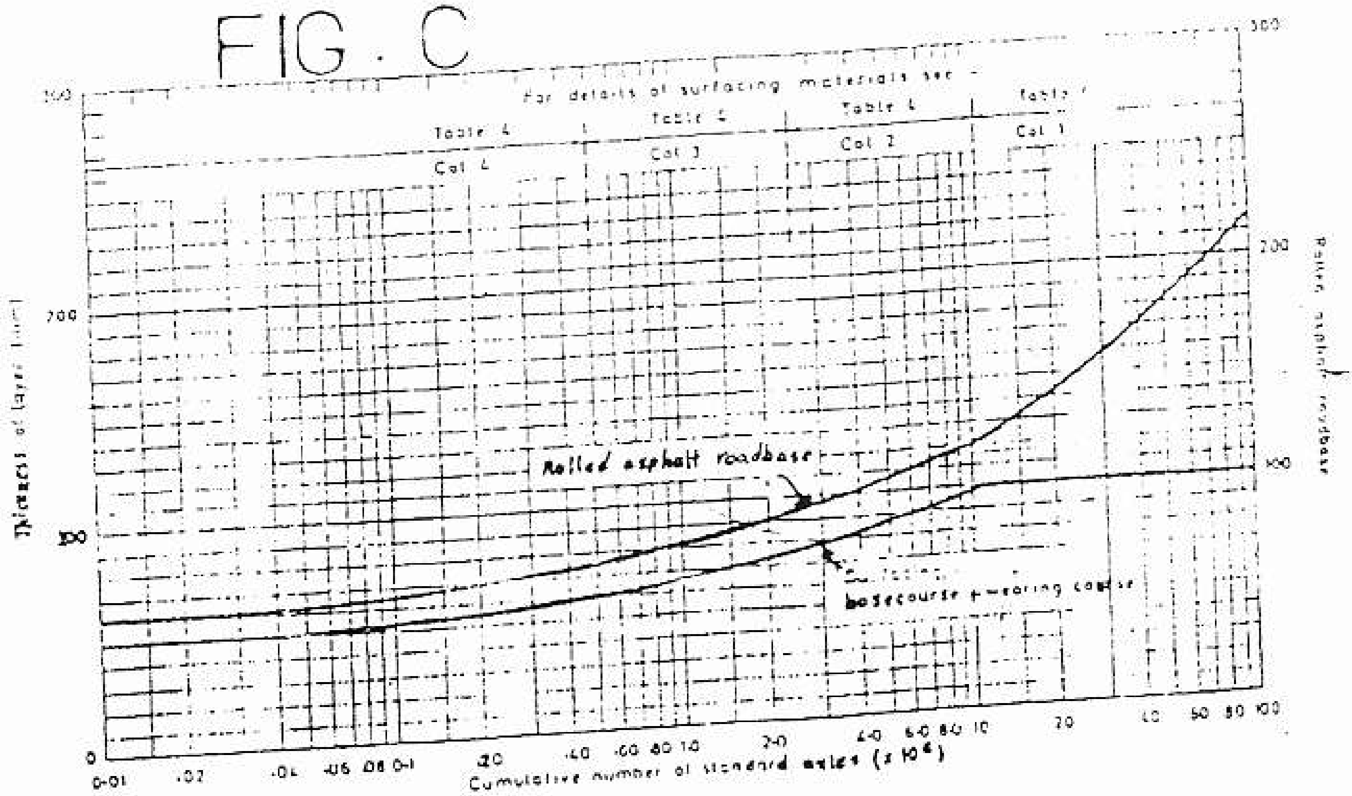


FIG B



Minimum CBR value for sub-base 20 per cent (see para 28)
Minimum CBR value for sub-base 30 per cent (see para 28)
Below CBR 2 per cent add 150mm to thickness indicated for CBR 2 per cent (see para 27)
CBR 2%
CBR 3%
CBR 4%
CBR 5%
CBR 6%
CBR 7%
Minimum thickness 150 mm on soils of CBR less than 30 per cent (see para 30)
Minimum thickness 80 mm on soils of CBR less than 20 per cent (see para 30)
Sub-base thickness (mm)
Sub-base
Cumulative number of standard axles (x 10^6)


FIG. C



For details of surfacing materials see
Table 4 Col 4
Table 4 Col 3
Table 4 Col 2
Table 4 Col 1
Rolled asphalt roadbase
basecourse + wearing course
Thickness of layer (mm)
Cumulative number of standard axles (x 10^6)