Internal Assessment Test II – June 2021

Sub:	PAVEMENT DESIGN			Sub Code:	17CV833/15CV833	Branch:	CIVIL
Date:	20.06.2021	Duration:	90 min's	Max Marks:	50	Sem / Sec:	8/A & B	OBE

1	Explain (i) Radius of relative stiffness (ii) Equivalent radius of resisting section (iii) Critical load positions (iv) ESWL.	[10]

Radius of relative stiffness:

A certain degree of resistance to slab deflection is offered by the sub-grade. The sub-grade deformation is same as the slab deflection. Hence the slab deflection is direct measurement of the magnitude of the sub-grade pressure. This pressure deformation characteristics of rigid pavement lead Westergaard to the define the term radius of relative stiffness l in cm is given by the equation

$$l = \left[\frac{Eh^3}{12k(1-\mu^2)}\right]^{1/4}$$

Where E is the modulus of elasticity of concrete, kg/cm2

K is the modulus of subgrade reaction, kg/cm3

μ is the Poisson's ratio

h is the thickness of the slab

Equivalent radius of resisting section

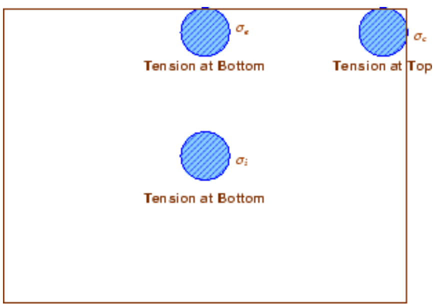
When the interior point is loaded, only a small area of the pavement is resisting the bending moment of the plate. The radius of such an area is called as Equivalent radius of resisting section. Westergaard's gives a relation for equivalent radius of the resisting section in cm

$$b = \sqrt{1.6a^2 + h^2} - 0.675h \; for \; a \leq 1.724\, h$$

Else if a > 1.724 h, b = a

Critical load positions

Since the pavement slab has finite length and width, either the character or the intensity of maximum stress induced by the application of a given traffic load is dependent on the location of the load on the pavement surface. There are three typical locations namely the interior, edge and corner, where differing conditions of slab continuity exist. These locations are termed as critical load positions.



Equivalent single wheel load (ESWL) is the single wheel load having the same contact pressure, which produces same value of maximum stress, deflection, tensile stress or contact pressure at the desired depth. The procedure of finding the ESWL for equal stress criteria is provided below. This is a semi-rational method, known as Boyd and Foster method, based on the following assumptions:

- Equivalency concept is based on equal stress;
- Contact area is circular;
- Influence angle is 45°; and
- Soil medium is elastic, homogeneous, and isotropic half space.

ESWL can be estimated by three ways

(i) By equivalent vertical stress criteria

(ii) By equivalent deflection criterion

By equivalent vertical stress criteria: Boyd and Foster developed a semirational method for determining ESWL. Here it is assumed the ESWL varies with pavement thickness. For thickness smaller than half the clearance between the wheels, ESWL is equal to one half of the total load. For thickness greater than twice the centre to centre spacing of tires, ESWL is equal to the total load indicating the stresses overlap completely. By assuming a straight line relationship between pavement thickness and wheel load on logarithmic scales, the ESWL for any intermediate pavement thickness can be estimated.

Each definition +equation +sketches – 1+1.5
4 such items - 2.5×4 = 10

2	Explain briefly 'CBR method by Cumulative standard axle load' for the design of flexible highway pavements.	[08]

The salient features of this document are

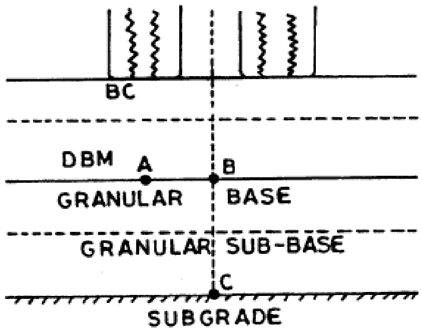
(i) Flexible pavement is designed as a four-layer structure.
(ii) The catalogues cover soils having CBR values in the range of 2-10.
(iii) Traffic upto 150 msa has been considered.
(iv) The damaging factor has to be estimated using load equivalency factors as
Equivalency factor for single axle load = $[Load/8160]^4$
Equivalency factor for tandem axle load = $[Load/14968]^4$
(v) The design catalogues are developed for different CBR value.

The three different types of distresses are considered

(i) Vertical compressive strain at the top of the subgrade
(ii) Horizontal tensile strain at the bottom of the bituminous layer
(iii) Pavement deformation within the bituminous layer

The two important parameters considered for the design are

(i) Design traffic in terms of msa
(ii) CBR value of soil.



Design Traffic in msa is calculated as

$$N = \frac{365 \times [(1+r)^n - 1]}{r} \times A \times D \times F$$

Where

- r is the traffic growth rate; generally assumed as 7.5%
- n is the design life; Expressways its 20 years; NH and SH its 15 years and for other roads its 10-15 years
- A is the traffic at the end of the construction period= $A = P(1+r)^x$ in CV/day
- Where x is the construction period
- P is the existing traffic
- D is the damage factor
- F is the lane distribution factor
- Design load is generally considered as standard axle load of 80 kN or 8160 kg.
- Damage factor is dependent upon the terrain and the axle load spectrum.
  - Equivalency factor for single axle load = $[Load/8160]^4$
  - Equivalency factor for tandem axle load = $[Load/14968]^4$
  - In the absence of axle load spectrum, it is computed based on terrain and the volume of traffic with a value ranging from 1.5 to 4.5.
- Lane distribution factor accounts for the wandering of traffic given as
  - Single lane road – 1
  - Two lane single CW roads – 0.75
  - Single CW four lane roads – 0.4
  - Dual CW - Three lane roads- 0.6
  - Dual CW - Four lane roads- 0.45

For different traffic repetitions, for different CBR values pavement design catalogues are available in IRC 37, 2001.

Step by step procedure for design
Rutting and fatigue criteria - 3
Estimation of CSA; LDF and VDF -3
Use of charts - 2

3 Calculate the stresses at interior, edge and corner regions of a cc pavement using Westergaard's stress equations (use old equations) for the following data:
Wheel load = 51 kN; Modulus of elasticity of concrete = 0.3×10^8 kN/m^2; Poisson's ratio of concrete = 0.15; Pavement thickness = 18 cm; Modulus of subgrade reaction = 6.0×10^4 kN/m^3; Radius of contact area = 15 cm [08]

$$l = \left[\frac{Eh^3}{12k(1-\mu^2)}\right]^{1/4}$$

$$l = \left[\frac{0.3 \times 10^{11} \times 0.18^3}{12 \times 6 \times 10^7 (1-0.15^2)}\right]^{1/4}$$

$$l = 0.7061\ m$$

a/h = 15/18=0.833 <1.724

$$b = \sqrt{1.6a^2 + h^2} - 0.675h \ \ for\ a \leq 1.724h$$

$$b = a\ for\ a > 1.724h$$

$$b = \sqrt{1.6 \times 15^2 + 18^2} - 0.675 \times 18 = 14.00\ cm$$

Interior loading,

$$Si = \frac{0.316 \times 51000}{0.18^2}\left[4log_{10}\left[\frac{70.61}{14}\right] + 1.069\right] = 1930 \text{ kPa}$$

Edge loading,

$$Se = \frac{0.572 \times 51000}{0.18^2}\left[4log_{10}\left[\frac{70.61}{14}\right] + 0.359\right] = 2854 \text{ kPa}$$

Corner loading,

$$Sc = \frac{3 \times 51000}{0.18^2}\left[1 - \left(\frac{15\sqrt{2}}{70.61}\right)^{0.6}\right] = 2427\text{kPa}$$

l, b, stresses (1+1+2+2+2)

4 Explain EWL factors. Calculate design repetitions for a 20 years period for various wheel loads equivalent to 22.68 kN wheel load using the following survey data on a four-lane road. [08]

Wheel load in kN	ADT, both directions	% of traffic volume
22.68	Total volume of traffic consisting of traffic growth = 215	13.17
27.22		15.30
31.75		11.36
36.29		14.11
40.82		6.21
45.36		5.84

Wheel load, kN	ADT	% of total traffic volume	Traffic volume/day ((3)/100)*(2)	Traffic volume/year (4)*365	Traffic volume for 20 years (5)*20	EWLF	(6)*(7)
22.68	Total volume 215	13.17	28.3155	10335.16	206703.2	1	206703.2
27.22		15.3	32.895	12006.68	240133.5	2	480267
31.75		11.76	25.284	9228.66	184573.2	4	738292.8
36.29		14.11	30.3365	11072.82	221456.5	8	1771652
40.82		6.21	13.3515	4873.298	97465.95	16	1559455
45.36		5.84	12.556	4582.94	91658.8	32	2933082
Sum							7689451

For single lane road = 7689451/4 = 1.9 msa

Column 4, column 7 – 2 marks
Rest 5, 6 and 7 – 3
Single lane road - 1

5	Design a flexible highway pavement section on triaxial method (Kansas method) using the following data: Wheel load = 44 kN; Radius of contact area = 160 mm; Traffic coefficient, X = 1.7; Rainfall coefficient, Y = 0.95; Design deflection =2.8 mm; E value of subgrade soil, $E_s = 100 \times 10^2$ kN/m^2; E value of base course material, $E_b = 400 \times 10^2$ kN/m^2; E value of 75 mm thick bituminous concrete surface course = 1000×10^2 kN/m^2.	[08]

$$T=\left\{\sqrt{\left(\frac{3PXY}{2\pi E_s\Delta}\right)^2-a^2}\right\}\left[\frac{E_s}{E_p}\right]^{1/3}$$

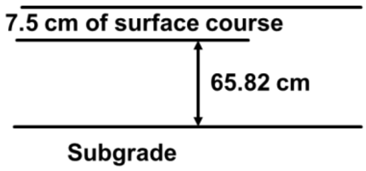
$$T=\left\{\sqrt{\left(\frac{3\times44\times1.7\times0.95}{2\times\pi\times10000\times0.0028}\right)^2-0.16^2}\right\}\left[\frac{100}{400}\right]^{\frac{1}{3}}$$

T=1.2×0.629 =0.76 m

$$\frac{0.075}{t_{base}}=\left[\frac{400}{1000}\right]^{1/3}$$

$t_{base} = 10.18\ cm$

$= equivalent\ 7.5\ cm\ thick\ bituminous\ course\ material$

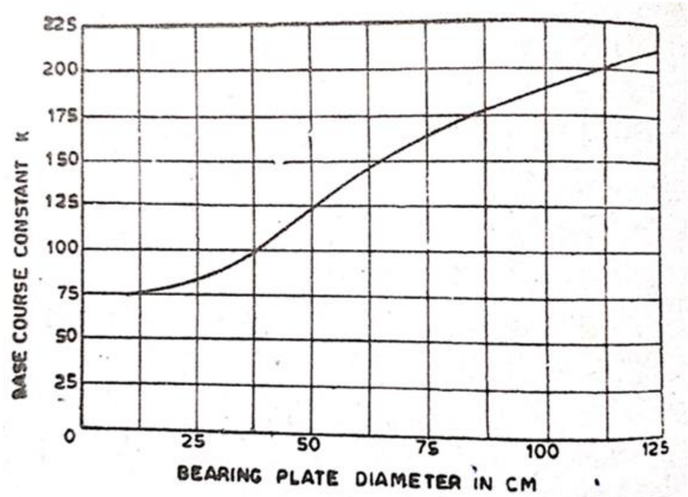


T – 3

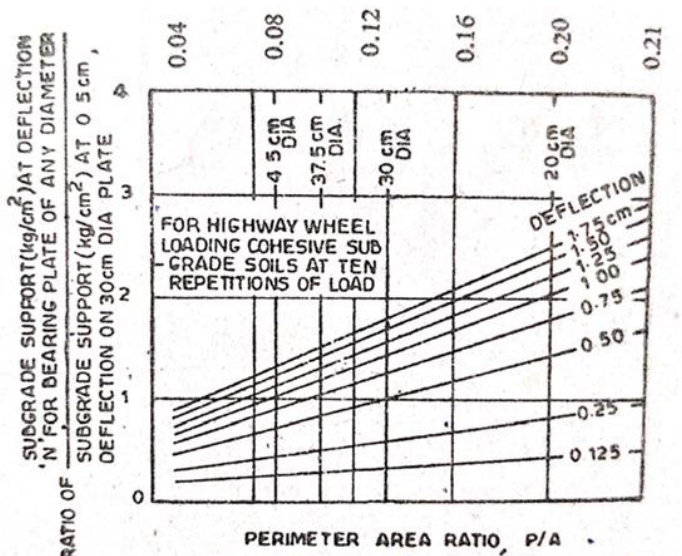
T_{base} – 3

Sketch - 2

6	Design a highway pavement using McLeod method for a wheel load of 5100 kg with tyre pressure of 6.5 kg/cm^2. The plate bearing test conducted on subgrade soil using 30 cm diameter. Plate yielded pressure of 2.5 kg/cm^2 after 10 repetitions at 0.5 cm deflection. What will be the pavement thickness, if design deflection is taken as 0.35 cm? Use given charts.	[08]



Relation between Plate Diameter and Base Course Constant



Relationship between subgrade support with P/A ratio

P gross wheel load, kg = 5100 kg

	Tyre pressure = 7 kg/cm^2 Plate diameter = 30.46 cm k=85 P/A = (π×30.46×4)/(π ×30.46×30.46) = 0.1313 For 30.46 cm diameter plate at 0.5 cm deflection, pressure =1 kg/cm^2 (It's the ratio) $\frac{Subgrade\ pressure}{2.5} = 1$ S is the total subgrade support, kg (for the same contact area, deflection and number of repetitions of load P) = 2.5×1× π ×30.46×30.46/4 = 1821.8 kg $\boldsymbol{T = k\ log\frac{P}{S}\ = 85 \times log\left[\frac{5100}{1821.8}\right] = 38\ cm}$ For 30.46 cm diameter plate at 0.35 cm deflection, pressure =1 kg/cm^2 (It's the ratio) $\frac{Subgrade\ pressure}{2.5} = 0.8$ S is the total subgrade support, kg (for the same contact area, deflection and number of repetitions of load P) = 2.5×0.8× π ×30.46×30.46/4 = 1457.4 kg $\boldsymbol{T = k\ log\frac{P}{S}\ = 85 \times log\left[\frac{5100}{1457.4}\right] = 46.24\ cm}$
	K -2 ***Case 1 -3*** ***Case 2 - 3***

Signature of CI　　　　Signature of CCI　　　　Signature of HoD