Solution

Internal Assessment Test 1 – March 2019

Sub:	PAVEMENT DESIGN					Sub Code:	15CV833/10CV833	Branch:	CIVIL
Date:	07.03.2019	Duration:	90 min's	Max Marks:	50	Sem / Sec:	VIII A, VIII B and Exit Scheme		

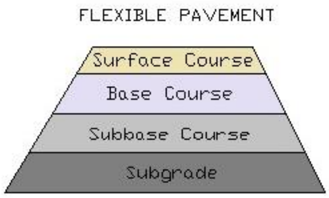
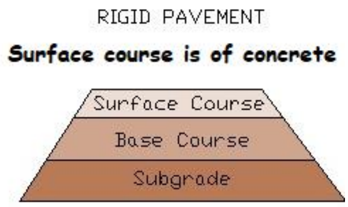
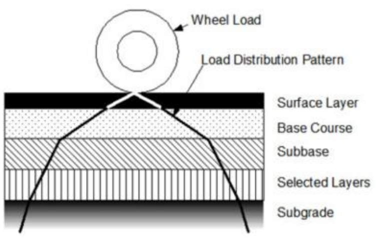
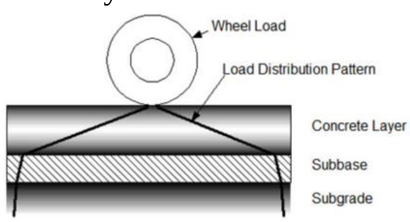
<u>Part A</u> <u>is</u> **<u>compulsory</u>** <u>and Answer any</u> **<u>one question from Part B</u>**

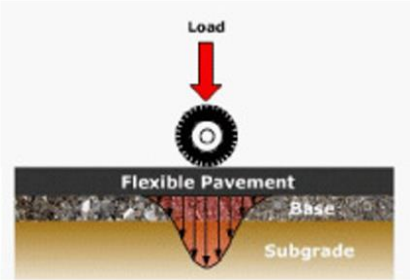
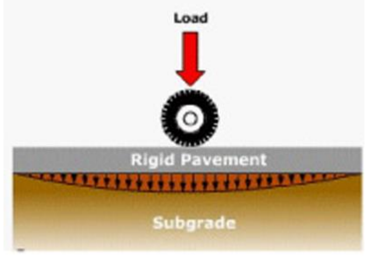
<u>Assume any missing data suitably. Provide neat sketches wherever necessary</u>

MARKS

<u>PART A</u>

1 **(a) Critically compare flexible pavement and rigid pavement.** **[08]**

S. N	Particulars	Flexible pavement	Rigid pavement
1	Cross section	It consists of a series of layers with the highest quality materials at or near the surface of pavement. 	It consists of one layer Portland cement concrete slab or relatively high flexural strength. 
2	Characteristic	It **reflects the deformations of subgrade** and subsequent layers on the surface.	It is able to bridge over localized failures and area of inadequate support.
3	Load transfer	Its stability depends upon the **aggregate interlock, particle friction and cohesion** or by **means of grain to grain contact**	Its structural strength is provided by the pavement slab itself by its **beam action**.
4	Design parameter	Pavement design is greatly influenced by the **subgrade strength.**	**Flexural strength of concrete** is a major factor for design.
5	Distribution of load	It functions by a way of **load distribution through the component layers** 	It distributes load over a **wide area of subgrade** because of its rigidity and high modulus of elasticity. 

6	Distribution of stresses		
7	Design life	15-20 years	20-40 years
8	Temperature stresses	**No thermal stresses** are induced as the pavement have the ability to contract and expand freely	Thermal stresses **are more vulnerable** to be induced as the ability to contract and expand is very less in concrete
9	Deformations	Flexible pavements have self healing properties. **Settlements due to heavier wheel loads are recoverable** to some extent.	Any excessive deformations occurring due to heavier wheel loads are not recoverable, i.e. **settlements are permanent.**
10	Overall cost	Have **low completion cost** but repairing cost is high	Have low repairing cost but **completion cost is high**
11	Maintenance cost	Have low life span (**High Maintenance Cost)**	Life span is more as compare to flexible (**Low Maintenance Cost**)
12	Effect of oil spills	**Damaged by Oils and Certain Chemicals**	**No Damage** by Oils and Greases
13	Curing period	Road can be used for traffic **within 24 hours**	Road cannot be used **until 14 days of curing**
14	Colour and visibility	**Poor visibility** at night due to its black colour	**Better visibility** at night owed to its white/gray colour
15	Design parameter of subgrade	**CBR value**	**Modulus of subgrade reaction (k)**

(b) Define ESWL. How ESWL is determined for dual wheel load assembly using equal stress and deflection criteria. Explain briefly. **[08]**

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:

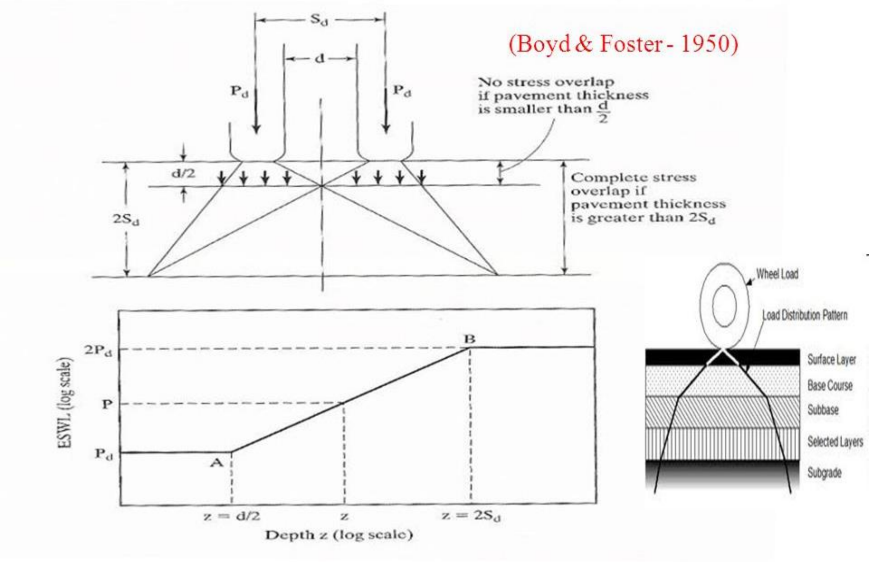
- Equivalency concept is based on equal stress;
- Contact area is circular;
- Influence angle is 45°; and
- Soil medium is elastic, homogeneous, and isotropic half space.

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.



Foster and Ahlvin's chart can also be used to determine the ESWL based on Boussinesq's theory based on the concept of equivalent vertical stresses. Here we compute the vertical stresses developed at three critical points using the charts and the procedure is as follows:

$$[\sigma_z]_{ESWL} = [\sigma_z]_{Dual\,Wheel}$$

$$\left[\left[\frac{\sigma_z}{q_s}\right] \times q_s\right]_{ESWL} = \left[\left[\frac{\sigma_z}{q_d}\right] \times q_d\right]_{Dual\,Wheel}$$

Since area remains constant,

$$\left[\left[\frac{\sigma_z}{q_s}\right] \times P_s\right]_{ESWL} = \left[\left[\frac{\sigma_z}{q_d}\right] \times P_d\right]_{Dual\,Wheel}$$

Or

$$\frac{P_s}{P_d} = \frac{\sigma_z/q_d}{\sigma_z/q_s}$$

Foster and Ahlvin's chart can also be used to determine the ESWL based on Boussinesq's theory based on the concept of equivalent deflection criteria. Here we compute the deflections developed at three critical points using the charts and the procedure is as follows:

$$w_s = \frac{q_s a F_s}{E}$$

And

$$w_d = \frac{q_d a F_d}{E}$$

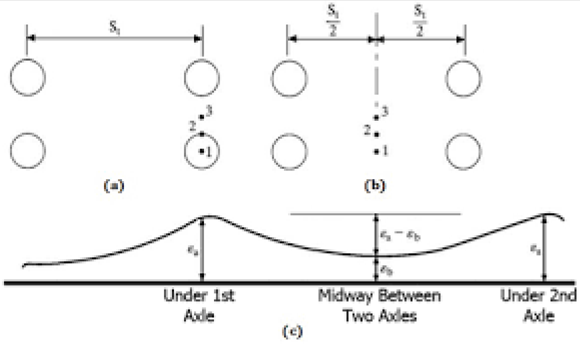
Since a, E and total deflection remains constant,

$$w_s = w_d$$

Or

$$q_s F_{s=} q_d F_d$$

Critical positions for vertical stresses and deflections



(c) Explain the assumptions and limitations of Burmister's theory **[07]**

- The surface of soil is semi-infinite. The soil mass within a layer homogeneous and isotropic. But soil mass is never homogenous and isotropic
- The soil has a linear stress-strain relationship. Soil is non-linear with respect to its properties.
- The soil is weightless. But in real time, soil has a specified density which cannot be neglected
- Wheel load is assumed to be uniformly distributed over a circular area of radius a. But wheel load is not uniform.
- The load acting will not be over a circular area. It will be elliptical in shape. But for simplicity circular shape is assumed.
- The soil below the loading consists of two layers such that top layer has a higher modulus of elasticity in comparison to lower layer.

PART B

2 (a) A plate load conducted with 300 mm diameter plate on subgrade and on a pavement of thickness 400 mm sustained pressure of 0.10 N/mm^2 and 0.40 N/mm^2 respectively at 5 mm deflection. Design the pavement section for 44 kN wheel load and contact pressure of 0.70 N/mm^2 for an allowable deflection of 8 mm using Burmister's approach. Use Chart 1 **[09]**

Since the plate is rigid, it is assumed as a rigid pavement

Determination of E of subgrade

$$\Delta = \frac{1.18pa}{E_2} \times F$$

Assume F=1

$$5 = \frac{1.18 \times 0.1 \times 150}{E_2} \times 1$$

Or E_2 = 3.54 N/mm^2

Determination of E of Surface course

$$5 = \frac{1.18 \times 0.4 \times 150}{3.54} \times F$$

F=0.25

h/a = 400/150 = 2.67

From the graph

E1/E2=**15**

Or E1=53.1 N/mm^2

Design of pavement thickness

p=P/A

Pressure exerted = $\dfrac{\mathbf{44\times10^3}}{\boldsymbol{\pi}/_{\mathbf{4}}\times(\mathbf{2}\boldsymbol{a})^{\mathbf{2}}}$ = 0.7×10^6

Or a= 141.44 mm

$$\mathbf{8} = \frac{\mathbf{1.5\times0.7\times141.44}}{3.54}\times \boldsymbol{F}$$

Or F = 0.19

From the graph, h/a=3.6

Or h= 510 mm

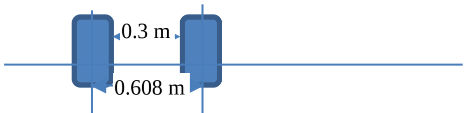
(b) A dual wheel assembly has 52 kN load on each wheel with a contact pressure of 0.7 N/mm2. If the clear gap between the two wheels is 300 mm, using the stress chart and determine the vertical stress values at a depth of 0.60 m due to dual wheel loads at stress points as follows: **[09]**

- **Vertically below the centre of dual wheel load assembly**
- **Vertically below the centre of left wheel**
- **At radial distance of 0.80 m from centre of left wheel towards other wheel. Use Chart 2.**

Pressure exerted = $\dfrac{\mathbf{52\times10^3}}{\boldsymbol{\pi}/_{\mathbf{4}}\times(\mathbf{2}\boldsymbol{a})^{\mathbf{2}}}$ = 0.7×10^6

Or a = 0.154 m

Centre to center distance = 0.163+0.3+0.163=0.626 m



Given z = 0.6 m

z/a = 0.6/0.154=3.9

Case 1: r = 0.608×0.5 = 0.304 m

r/a = 0.304/0.154 = 1.97

$$\frac{\boldsymbol{\sigma_z}}{\boldsymbol{q}} = \mathbf{0.04}$$

Or $\boldsymbol{\sigma_z} = \mathbf{0.04\times0.7\times10^6 = 28}\ \boldsymbol{kPa}$

Since, there are to wheels, $\boldsymbol{\sigma_z} = 56\ \boldsymbol{kPa}$

Case 2:

r = 0, from left wheel σ_z/q=0.082 Or σ_z=0.082×0.7×〖10〗^6=57.4 kPa **Total stress = 5.6+43.4 = 49 kPa** Total $\boldsymbol{\sigma_z} = \mathbf{70.7}\ \boldsymbol{kPa}$	For right wheel r = 0.608, from right wheel; r/a = 0.608/0.154 = 3.95 $\frac{\boldsymbol{\sigma_z}}{\boldsymbol{q}} = \mathbf{0.019}$ Or $\boldsymbol{\sigma_z} = \mathbf{0.019\times0.7\times10^6 = 13.3}\ \boldsymbol{kP}$

Case 3:

For left wheel	For right wheel
r = 0.8 m	r = 0.8-0.604 = 0.196 m
r/a = 0.8/0.154 = 5.19	r/a = 0.196/0.154 = 1.27
$\frac{\sigma_z}{q} = 0.008$	$\frac{\sigma_z}{q} = 0.062$
Or $\sigma_z = 0.02 \times 0.6 \times 10^6 = 5.6kPa$	Or $\sigma_z = 0.09 \times 0.6 \times 10^6 = 43.4kPa$
Total stress = 5.6+43.4 = 49 kPa	

(c) Design the flexible pavement by triaxial method using the following data: **[09]**

E-value of subgrade soil = 110 kg/cm2
E-value of base course = 440 kg/cm2
E-value of 8 cm thick bituminous course = 1200 kg/cm2
Design wheel load = 5100 kg
Radius of contact = 16 cm
Traffic coefficient = 1.5
Rainfall coefficient = 0.6
Design deflection = 0.25 cm

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

$$\text{Thickness of pavement} = \left\{\sqrt{\left(\frac{3\times5100\times1.5\times0.6}{2\times\pi\times110\times0.25}\right)^2 - 16^2}\right\} \left[\frac{110}{440}\right]^{\frac{1}{3}}$$

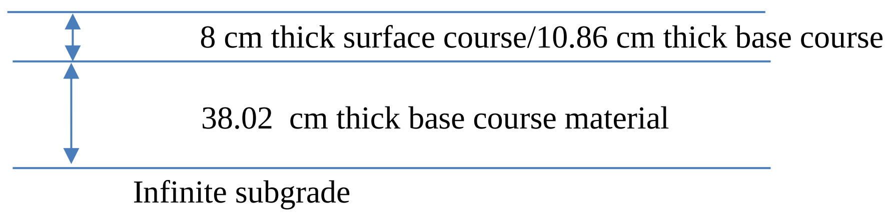
$$= 49.2\ cm$$

$$\frac{t_{surface}}{t_{base}} = \left[\frac{E_{base}}{E_{surface}}\right]^{1/3}$$

$$\frac{8}{t_{base}} = \left[\frac{440}{1200}\right]^{1/3}$$

$$t_{base} = 11.18\ cm = equivalent\ 8\ cm\ thick\ surfacee\ course\ material$$

Actual thickness of base course to be provided = 49.2-11.18 = 38.02 cm



3 **(a) A set of dual tires has a total load of 51 kN and a contact radius of 115 mm with a centre to centre tyre spacing of 350 mm. Determine the ESWL by Foster and Boyd's method and equivalent stress criterion for 340 mm pavement.** **[09]**

Foster and Boyd method

d=350-115×2= 120 mm; log (d/2) = 1.778; log (P)= 1.407
2s = 700; log (2s) = 2.845; log (2P)= log (51)=1.708
log(340)=2.531

$$\frac{\log(ESWL) - 1.407}{1.708 - 1.407} = \frac{2.531 - 1.778}{2.845 - 1.778}$$

Or ESWL = 41.63 kN

Equivalent stress criterion

	z/a=2.96				
	left wheel		Right wheel		
	r/a	σ/q	r/a	σ/q	Sum
1	0	0.15	3.04	0.03	0.18
2	1	0.12	2.04	0.06	0.18
3	1.52	0.08	1.52	0.08	0.16

$$\frac{P_s}{P_d} = \frac{\sigma_z/q_d}{\sigma_z/q_s}$$

$$or\ P_{ESWL} = \frac{0.18}{0.15} \times 25.5 = 30.6\ kN$$

(b) Calculate the design repetitions for 20 years period for various wheel loads equivalent to 22.68 kN using the following data on a four lane road: **[09]**

Load in kN	**22.68**	**27.22**	**36.29**	**40.82**	**49.90**	**54.43**
Vol per day	**30**	**25**	**20**	**15**	**5**	**1**

Load in kN	22.68	27.22	36.29	40.82	49.9	54.43
Vol per day	30	25	20	15	5	1
ELF	1	2	8	16	64	128
ADT per year	219000	182500	146000	109500	36500	7300
Equivalent repetetions	219000	365000	1168000	1752000	2336000	934400
Total repetetions	67744000	6.77 million				

(c) Plate bearing tests were conducted with a 75 cm diameter plate on soil subgrade and a granular base. The stress noticed, when the deflection was 0.25 cm on the subgrade soil was 0.075 MN/m^2. On the base course, the same plate yielded 0.25 cm deflection under a stress of 0.15 MN/m^2. Design the pavement for an allowable deflection of 0.5 cm under a load of 51 kN and a tyre pressure of 0.4MN/m^2. **[09]**

Since the plate is rigid, it is assumed as a rigid pavement

Determination of E of subgrade

$$\Delta = \frac{1.18pa}{E_2} \times F$$

Assume F=1

$$2.5 = \frac{1.18 \times 0.075 \times 375}{E_2} \times 1$$

Or E_2 = 13.275MN/m^2

Determination of E of Surface course

$$2.5 = \frac{1.18 \times 0.15 \times 375}{13.275} \times F$$

F=0.5

Assume h/a = 2

From the graph

E1/E2=**3.5**

Or E1=56.5 MN/m^2

Design of pavement thickness

p=P/A

Pressure exerted = $\frac{\mathbf{51\times10^3}}{\boldsymbol{\pi}/\mathbf{4}\times(\mathbf{2a})^\mathbf{2}}$ = 0.4×10^6

Or a= 0.201 m

$$\mathbf{5} = \frac{\mathbf{1.5\times0.4\times201}}{13.275}\times \boldsymbol{F}$$

Or F = 0.55

From the graph, h/a=1.8

Or h= 0.362 m

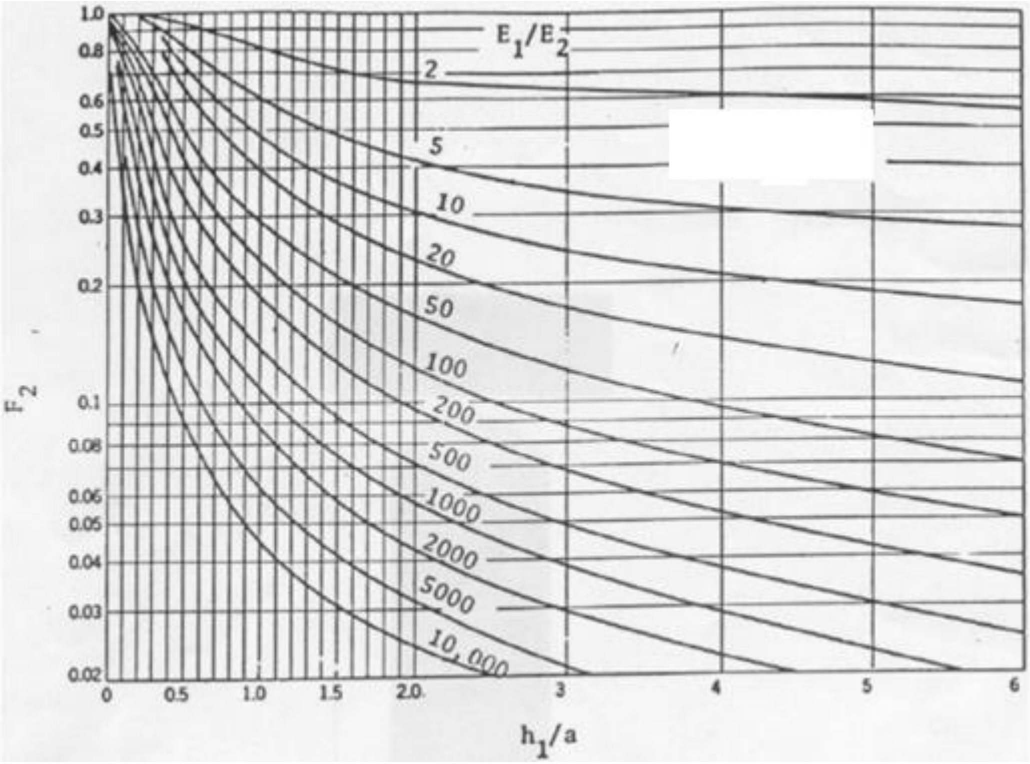


Chart 1.

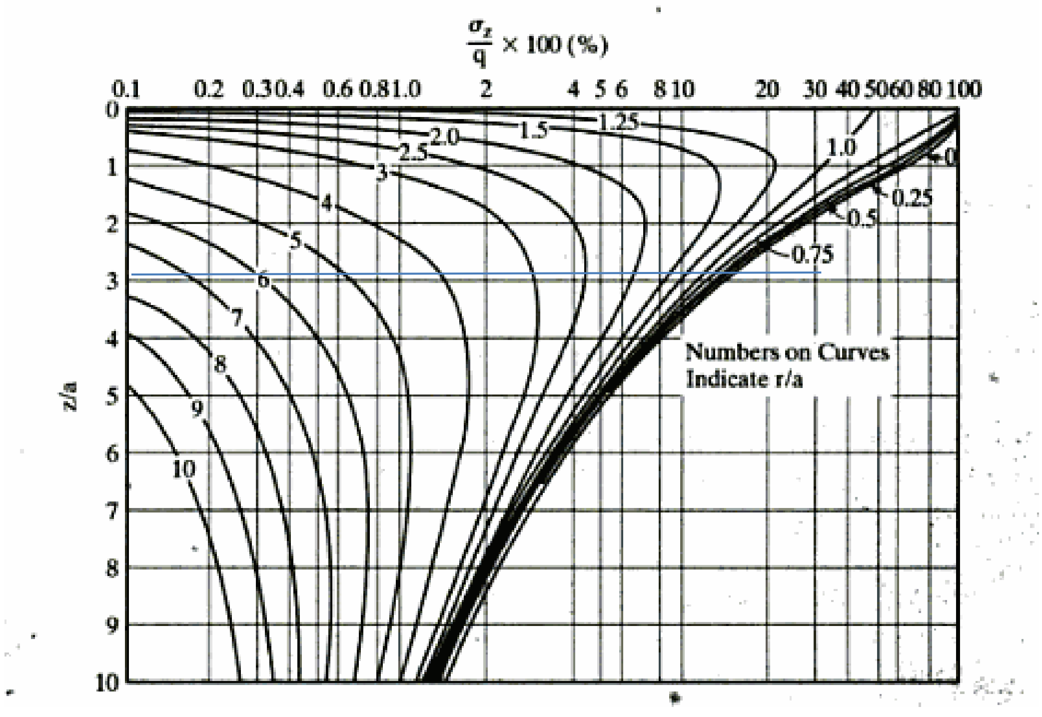


Chart 2

Signature of CI Signature of CCI Signature of HoD