CBCS SCHEME

USN ☐☐☐☐☐☐☐☐☐☐ **18CV825**

Eighth Semester B.E. Degree Examination, June/July 2023
Pavement Design

Time: 3 hrs. Max. Marks: 100

Note: Answer any FIVE full questions, choosing ONE full question from each module.

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.
2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

Module-1

1 a. List and explain the desirable factors to be considered for the design of pavements. (12 Marks)

b. Bring out the points of difference between flexible and rigid pavements. (08 Marks)

OR

2 a. Draw a neat sketch of flexible pavement c/s and show the component parts. Enumerate the functions of each component of its pavement. (12 Marks)

b. Bring out the difference between highway and airport pavement. (08 Marks)

Module-2

3 a. With a neat sketch, explain the ESWL concept of dual wheel assembly. (08 Marks)

b. Calculate the design repetitions for 15 years period equivalent to 2268 kg wheel load, if the mixed traffic in bolt directions is 1974 veh/day. The details of distribution of different wheel load of commercial vehicles are given below:

Wheel load in kg	% in total traffic volume
2268	25
2722	1[illegible]
3175	0[illegible]
3629	06
4082	04
4536	02
4990	01

(12 Marks)

OR

4 a. Write a note on CBR method of pavement design by cumulative standard axle load. (10 Marks)

b. Design the pavement section by triaxial test method using the following data:
Wheel load = 410[illegible] kg
Radius of contact area = 15 cm
Traffic coefficient = 1.5
Rainfall coefficient = 0.9
Design deflection $\Delta = 0.25$ cm
$E_s = 10[illegible]$ kg/cm^2, $E_b = 400$ kg/cm^2
E - value of 7.5 cm thick bituminous concrete = 100 kg/cm^2 (10 Marks)

Module-3

5 a. List the general causes of pavement failures. (06 Marks)

b. Benkelman beam deflection studies were carried out on 15 selected points on a stretch of flexible pavement during summer season using a dual wheel load of 4085 kg, 5.6 kg/cm² pressure. The deflection values obtained in mm after making the necessary lag corrections are given below. If the present traffic consists of 750 CVPD, determine the thickness of bituminous overlay required, if the pavement temperature during the test was 30°C and the correction factor for subsequent increase in subgrade moisture content is 1.3. Assume annual rate of growth of traffic as 7.5%. Adopt IRC guidance 1.40, 1.32, 1.25, 1.35, 1.48, 1.60, 1.65, 1.55, 1.45, 1.40, 1.36, 1.46, 1.50, 1.52, 1.45 mm. (14 Marks)

OR

6 With a neat sketch, explain the following failures of flexible pavement:

a. Alligator cracking
b. Consolidation of pavement layers
c. Shear failure
d. Frost heaving
e. Lack of binding with lower layer (20 Marks)

Module-4

7 a. Write a note on Westergaard's concept for temperature stress. (08 Marks)

b. Determine the warping stress at interior, edge and corner regions in a 25 cm thick concrete pavement with transverse joints at 4.5 m interval and longitudinal joints at 3.6 m. $K = 6.9$ kg/cm³, $t = 0.6$°C per cm slab thickness, $a = 15$ cm, $e = 10 \times 10^{-6}$ per °C, $\mu = 0.15$, $E = 3 \times 10^5$ kg/cm². (12 Marks)

OR

8 a. Design the size and spacing of dowel bars at the expansion joints of a CC pavement of thickness 25 cm with radius of relative stiffness 80 cm, P = 5000 kg. Assume load capacity of the dowel bar system as 40% of the design wheel load. Joint width is 2 cm. $F_s = 1000$ kg/cm², $F_f = 1400$ kg/cm² and $F_b = 100$ kg/cm². (14 Marks)

b. Write note on:
(i) Westergaard's modulus of subgrade reaction
(ii) Relative stiffness of slab to subgrade
(iii) Equivalent radius of resisting section (06 Marks)

Module-5

9 a. With a neat sketch, explain the location of joints. Enumerate the functions of each joints in CC pavements. (12 Marks)

b. The width of expansion joint gap is 2.5 cm in a CC pavement. If the laying temperature is 10°C and the maximum slab temperature in summer is 54°C. Calculate the spacing between expansion joints. $\alpha = 10 \times 10^{-6}$ per °C. (08 Marks)

OR

10 a. With a neat sketch, explain the failures of rigid pavements of mud pumping. (12 Marks)

b. List and explain the properties of concrete. (08 Marks)

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Pavement Design - 18CV825

1a. i) Wheel load and traffic load
ii) Subgrade soil
iii) Climatic factors
iv) Pavement component materials in layers.
v) Drainage and environmental factors.

i) Wheel load: Defines the thickness of pavement. Higher the wheel load more will be the thickness

ii) Subgrade soil: Pavement design also depends upon type of soil and its CBR value. Soil classification for pavement is done through HRB method.

iii) Climatic factor: Like dry or wet and frost and thaw condition defines thickness of pavement

iv) Pavement component material: As per IRC specification if the material used are below than the range then they are weaker materials for construction purpose.

v) Drainage and environmental factors: If the ground water table is nearer to the subgrade then the embankment is constructed. To avoid capillary action in to pavement layer.

16. Bring out the points of difference between the flexible and rigid pavements.

i). Design Precision:

→ A cement concrete pavement design is much more precise structural analysis than the flexible pavement design.

ii). Life: Life span of a rigid pavement is more than 20 years whereas lifespan of flexible pavement is 10-15 years.

iii). Maintenance: Maintenance of a flexible pavement is higher compared to rigid pavement.

iv). Initial cost: Initial cost of a rigid pavement is higher compared to flexible pavement.

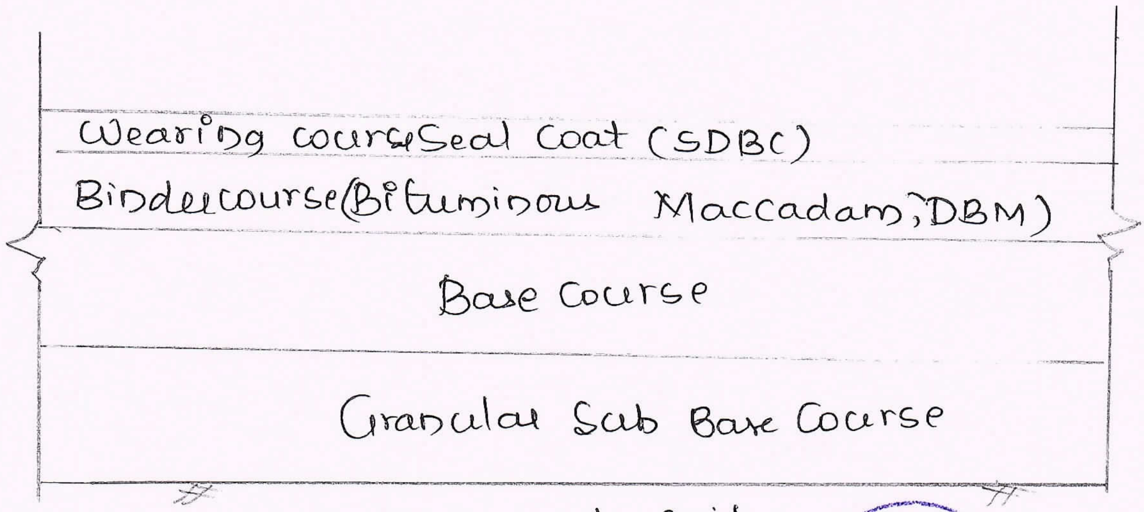
v). Penetration of water: Penetration through CC slab in rigid pavement is less compared to flexible pavement.

vi). Overall economy on a life-cycle basis:

With the overall consideration rigid pavement is considered as the best and economical compared flexible pavement with respect to economy too.

2a. Draw a neat sketch of flexible pavement c/s and show the component parts. Enumerate the functions of each component of its pavement.

Cross-Section of a Flexible pavement



I. Functions of Subgrade:
1). Natural layer with CBR value
2). supports whole pavement structure and distributes load uniformly to the ground.

II. Granular sub base course: Acts a effective drainage layer of pavement structure.
Takes load coming from surface & base course and distributes to subgrade.

III. Base course: Distributes wheel load stresses & disperse through larger area.
Supports bearing of load.
Distributes load coming from surface course to GSB.

IV. Surface course: Acts as seal coat with dense graded bitumen.
Posesses worthy tensile strength.

2b. Bring out the difference between highway and airport pavement.

Highway pavement: i) Pavements which are ment for movement of different modes of vehicles like NH, SH, MDR, ODR and VR.

ii) Cambers are provided with the definate proportions.

iii) Pavement thickness are moderate.

iv) Pavement thickness is defined by CBR value and traffic flow details.

v) Compaction acheived is about 97% with MPT or SPT methods.

Airfeild Pavement:

i) which are ment for movement of aircrafts like landing and take off.

ii) Longitudinal cambers are provided to avoid unease of aircraft movement.

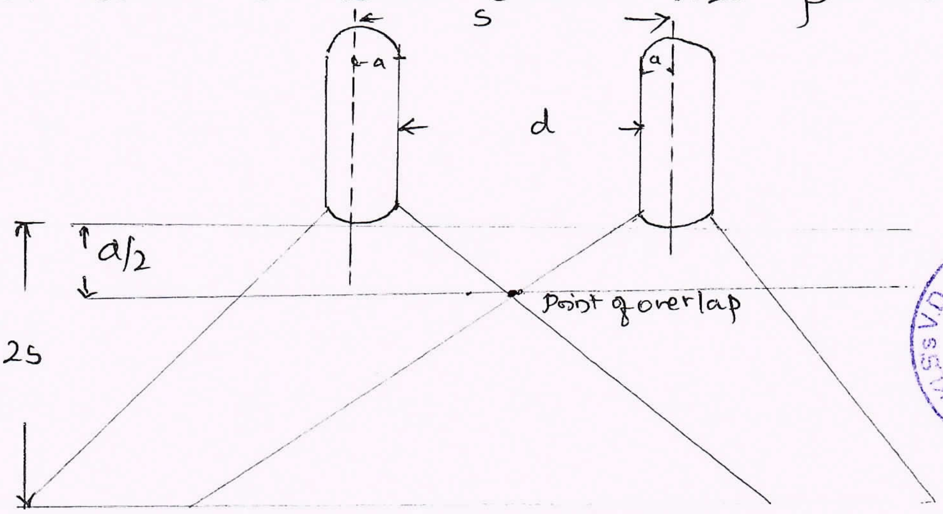
iii) Pavement thickness will be high as aircraft weight is more.

iv) Pavement thickness is finalised by aircraft size type of airport & weight of aircraft.

v) Compaction acheived is 99.99%.

3a. With the neat sketch explain ESWL concept of dual wheel assembly.

Equivalent Single wheel Load: To study the wheel load criteria below the pavement structure.



i). Intensity of load at different pavement depths can be studied.

ii). Quality of the material canbe define.

The above sketch can be explained in the form graphical presentation. which is as follows.

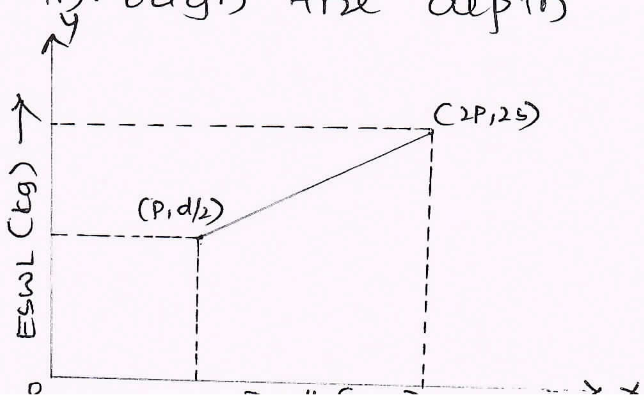
a). Let the wheel load be "P".

b). Inner to inner distance be "d" cms.

c). Centre to Centre distance be "S" cms.

When the load is applied on the pavement surface it acts endivisually i.e "P" up to depth of "d/2".
load will be transmitted through the depth after the depth of "2S".

∴ Co-ordinates are $(P, d/2)$
$(2P, 2S)$



3b. Calculate the design repitation for 15 years period equivalent to 2268 kg wheel load, if the mixed traffic in both directions is 1974 v/day. The details of distribution of different wheel load of commercial vehicles are given.

wheel load in (KN)	Vol. of each wheel load/day	Days in year	No. of years	ECF	Design repitition 22.68KN
22.68	25	365	15	1	136875
27.22	12	365	15	2	157703
31.75	09	365	15	4	275922
36.29	06	365	15	8	420503
40.82	04	365	15	16	630658
45.36	02	365	15	32	700800
49.90	01	365	15	64	770941
			Total	=	3093402

Design repetition equivalent to 22.68 KN

$$= \frac{(\text{Wheeload})}{\text{Lane}}$$

$$= \frac{3093402}{2}$$

$$= 1546701$$

4a. Write a note on CBR method of pavement design by cumulative standard axle method.

According to the CSA method it is considered as ideal method of pavement design. Because of levely factors like traffic data, CBR values etc are considered.

Parameters considered in CSA methods are:

i) vehicle growth rate (r) = %, depends on locality and population. IRC recomended std (r) value as 7.5% per annum

ii) VDF = vehicle damage factor: Mainly depends upon no. of vehicles.

If 0-1500 v/day = VDF = 3.5 Plain & Rolling terrain

VDF = 1.5 Hilly terrain

> 1500 v/day = VDF = 4.5 VDF = 2.5

iii) LDF = Lane distribution factor: Depends mainly on no. of lanes.

for divided highway: 2 lane each side : 0.75

3 lane each side : 0.60

4 lane each side : 0.45

for undivided highway: Single lane : 1.0

Two Lane : 0.75

Four lane : 0.40

$$\therefore CSA = \frac{365A\left[(1+r)^n - 1\right] \times F}{r \times 10^6} \qquad \therefore A = P(1+r)^n = v/day$$

$$= \text{msa}$$

4b. Design a pavement section by triaxial test method using the following data:

Radius of contact area = 15 cm

wheel load = 4100 kg

Traffic co-efficient = 1.5

Rainfall co-efficient = 0.9

Design deflection $\Delta = 0.25$ cm

$E_s = 100$ kg/cm², $E_b = 400$ kg/cm²

E - value of 7.5 cm thick bituminous concrete = 1000 kg/

$$T_b = \sqrt{\left(\frac{3PXY}{2\pi E_s \Delta}\right)^2 - a^2} \times \left(\frac{E_s}{E_b}\right)^{1/3}$$

$$= \sqrt{\left(\frac{3 \times 4100 \times 1.5 \times 0.9}{2\pi \times 100 \times 0.25}\right)^2 - 15^2} \times \left(\frac{100}{400}\right)^{1/3}$$

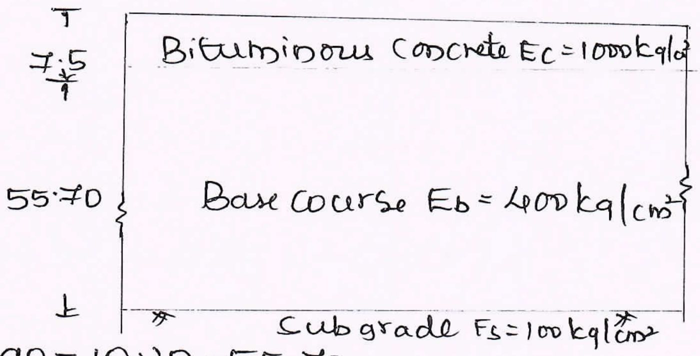
$$= 104.64 \times 0.63 = 65.90 \text{ cms}.$$

∴ Total thickness of pavement is 65.90 cm as said above it's of single base course material

$$\therefore \frac{t_b}{t_c} = \left[\frac{E_c}{E_b}\right]^{1/3}$$

$$\frac{t_b}{7.5} = \left[\frac{1000}{400}\right]^{1/3}$$

$$t_b = 10.20 \text{ cms}$$



Base course thickness = 65.90 − 10.20 = 55.70 cm

Bituminous concrete = 7.5 cm ∴ Total Pavement thickness = 55.70 + 7.50 = 63.20 cms

5a. List the general causes for pavement failures.

General causes for pavement failures are:

i). Potholes: Depressions or holes in the pavement surface caused by the disintegration of asphalt.

ii). Cracks: Long, narrow opening in the pavement surfaces. such as transverse, longitudinal & block cracks.

iii). Rutting: Visible wheel path or grooves in the pavement caused by repetitive heavy traffic loads.

iv). Alligator cracking: A pattern of interconnected cracks resembling the scales of a alligator's skin.

v). Ravelling: Detatchment of aggregate particles from the surface of the pavement, leaving a rough or loose texture.

vi). Bleeding or Flushing: The presence of a thin layer of asphalt on the pavement surface.

vii). Depression or settlement: Sunken areas in the pavement surface.

viii). Deteriorating Joints: Cracks or separations between adjacent pavement sections or slabs.

5b. Benkleman beam deflection were carried out on 15 selected points on a stretch of flexible pavement.

Solution: Mean deflection $\bar{D} = \frac{\Sigma D}{n} = \frac{21.74}{15} = 1.45mm$

Standard deviation $= \sqrt{\frac{\Sigma(\bar{D}-D)^2}{n-1}} = 0.107 mm$

Characteristics deflection $D_c = \bar{D} + \sigma = 1.557 mm$

Deflection after tempreture correction

$= 1.557 - (39-35) \times 0.0065 = 1.531 mm$

Corrected deflection for subgrade moisture

$= 1.531 \times 1.3 = 1.99mm$

∴ Design traffic $A = P(1+r)^{(n+10)}$

$= 750(1+0.075)^{12} = 1768 \, cv/day$

∴ Overlay thickness

$h_0 = 550 \log_{10} \frac{D_c}{D_a} mm$

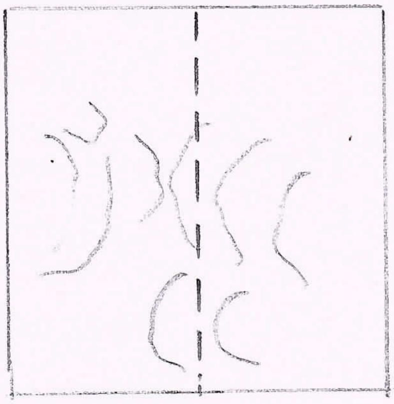
$= 550 \log \frac{1.990}{1.00} = 164.4 mm = 16.5 cm$

∴ Assuming an equivalency factor 2.0 for bituminous concrete overlay, the design thickness of bituminous concrete overlay

$= 16.5 \times 1/2 = 8.25 cm$

6a. With the neat sketch, explain the following failures of flexible pavements.

a). Alligator Cracking: Cracking appears as a series as a series of interconnecting cracks caused by fatigue failure of the AC surface. The fatigue failure is most often the results repeated traffic loading. The cracking initiates at the bottom of the AC surfaces where tensile stress and strain are higher.



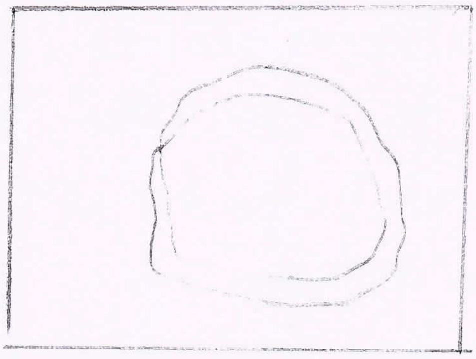
b). Consolidation of pavement layers:

formation of ruts falls in this type of failure. A rut is a depression or groove worn into a road by the travel of wheels. This type of failure is caused due to following reason. Repeated application of load along the same wheel path resulting longitudinal ruts.

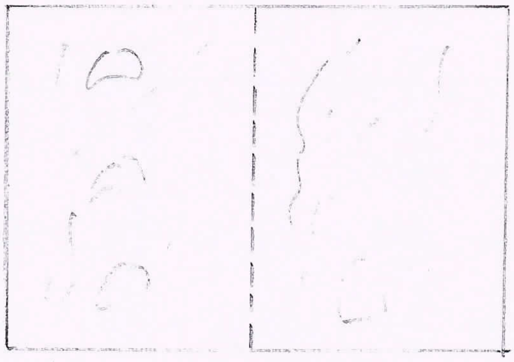
c). Shear failure: Causes upheavel of pavement materials by forming a fracture or cracking. following are the primary causes of shear failure cracking.

a). Excessive wheel loading

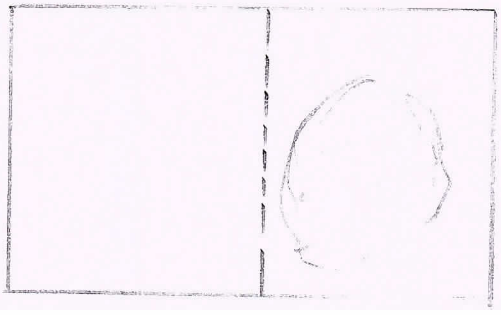
b). Low shearing resistance of pavement mixture.



d). Froast Heaving: Froast heaving causes upheavel of localized portion of a pavement. The extent of froast heaving depends up on the ground water table and climatic condition.



e). Lack of binding with lower layer: When there is lack of binding between surface course and underlaying, some portion of surface course looses up material creating patches and pot holes.



7a. Write a note on Westergaard's concept for tempreture stress.

Tempretcere stresses are of two types

a) Warping stress b) Friction stress

a) Warping stress occurs due to difference in slab tempreture. Stresses at interior, Edge and corners are calculated

$$S_i = \frac{Eet}{2}\left[\frac{C_x + \mu C_y}{1-\mu^2}\right]$$

$S_{Edge} = S_e = \frac{C_x Eet}{2}$ or $\frac{C_y Eet}{2}$ (Highest one)

$S_{corner} = S_c = \frac{Eet}{3(1-\mu)}\sqrt{\frac{a}{l}}$ a = Radius of wheel = cons.

Cx and Cy values are obtained from graphical sketch.

b) Frictional stress: To avoid contraction and expansion in the CC parement due to seasonal variations in the climate. An opposite force will be acting in the parement i.e frictional force.

$$S_f = \frac{(W \times L_c \times f)}{2\times10^4}$$

W = Unit weight of concrete 2400 kg/m³

f = Co-efficient of friction up to (1.5)

Lc = Slab Cength in mts.

7b. Determine the warping stress

$a = 15 cms, \quad k = 6.9 \, kg/cm^3, \quad e = 10 \times 10^{-6}$ per °C

$E = 3 \times 10^5 \, kg/cm^2, \quad \mu = 0.15, \quad td = 0.6°C$

$$l = \left[\frac{Eh^3}{12k(1-\mu^2)} \right]^{1/4} = \left[\frac{3 \times 10^5 \times 25^3}{12 \times 6.9(1-0.15^2)} \right]^{1/4} = 87.23 \, cms$$

Radius of relative stiffness = 87.23 cms

Temp. difference during day for 25cm thick slab

$= 0.6 \times 25 = 15°C.$

a). Stresses @ interior $\quad S_i = \frac{Eet}{2} \left[\frac{C_x + \mu C_y}{1-\mu^2} \right]$

$C_x = L_x / l = 500/87.23 = 5.73 \qquad C_x = 0.88$

$C_y = L_y / l = 360/87.23 = 4.12 \qquad C_y = 0.54$

$$S_i = \frac{3 \times 10^5 \times 10 \times 10^{-6} \times 15}{2} \left[\frac{0.88 + 0.15 \times 0.54}{1 - 0.15^2} \right]$$

$= 22.11 \, kg/cm^2$

b). Stress @ edge = $S_e = \frac{C_x Eet}{2} = \frac{0.88 \times 3 \times 10^5 \times 10 \times 10^{-6} \times 15}{2}$

$= 19.18 \, kg/cm^2$

$S_e = \frac{C_y Eet}{2} = 12.15 \, kg/cm^2$

$\therefore C_x > C_y \qquad S_e = 19.18 \, kg/cm^2.$

c). Stress @ corner $\quad S_c = \frac{Eet}{3(1-\mu)} \sqrt{a/l}$

$$= \frac{3 \times 10^5 \times 10 \times 10^{-6} \times 10}{3(1-0.15)} \sqrt{15/87.3} = 4.87 \, kg/cm^2$$

8a. Design a size and spacing of a dowel bar

Assume the diameter of the dowel bar, $d = 2.5\,cm$

$P = 5000\,kg$, $l = 80\,cm$, $F_s = 1000\,kg/cm^2$, $F_b = 100\,kg/cm^2$

$H = 25$, $\delta = 2\,cm$, $F_f = 1400\,kg/cm^2$

Capacity of dowel bar $L_d = 5 \times 2.5 \left[\frac{1400}{100} \times \frac{L_d + 1.5 \times 2}{L_d + 8.8 \times 2} \right]^{1/2}$

$$= 12.5 \left[14 \times \frac{L_d + 3}{L_d + 17.6} \right]^{1/2}$$

Solution of this equation by trial method

$\therefore L_d = 45\,cms$

$$L_d = 12.5 \left[14 \times \frac{45 + 3}{45 + 17.6} \right]^{1/2} = 40.95$$

which is less than 45 $L_d = 40.5$

$$L_d = 12.5 \left[14 \times \frac{40.5 + 3}{40.5 \times 17.6} \right]^{1/2} = 40.47$$

$\therefore$ Length of embedment $L_d = 40.5\,cm$

Minimum length of dowel bar $= L = L_d + \delta$

$$= 40.5 + 2.0 = 42.5\,cm$$

$\therefore$ Therefore provide 2.5 cm ϕ dowel bar of length 45 cms

Spacing of a dowel bar

Effective distance up to which there is load transfer

$$= 1.8\,l = 1.8 \times 80 = 144\,cm$$

Assume 30cm between dowel bar

$$= 1 + \frac{144 - 30}{144} + \frac{144 - 60}{144} + \frac{144 - 90}{144} + \frac{144 - 120}{144} = 2.92$$

$\therefore$ provide 2.5 cm ϕ with 45cm length and 30cm spacin

8b. Write a note on:

i). Westergaard's modulus of Subgrade reaction

The property of CC pavement depends upon subgrade soil and it's parameters. So "K" is considered as a important factor related to subgrade

$$K = P/\Delta \quad \text{pressure \& deflection}$$

ii). Radius of relative stiffness: As in the concept two materials are considered. So there should be some relative consideration in stress evaluation as "l" with modulus of elasticity of concrete (E) & poissons ratio.

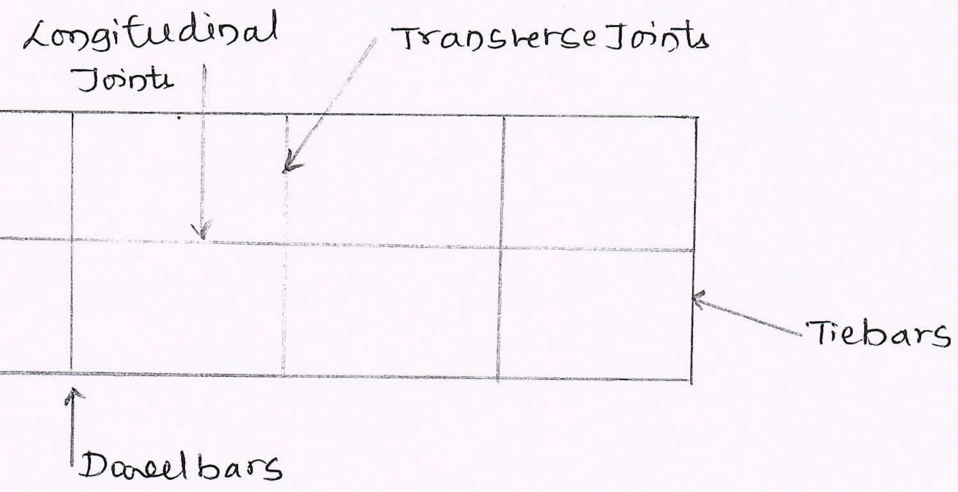
$$l = \left[Eh^3 / 12k(1-\mu^2) \right]^{1/4}$$

iii). Equivalent radius of resisting section: (b):

As a load at interior part causes more bending movement and acts radially in all directions.

$$\therefore b = \sqrt{1.6a^2+h^2} - 0.675h \quad \text{when } a > 1.724h \Rightarrow b = a.$$

9a. With the neat sketch, explain the location of joints. Enumerate the functions of each joints in CC pavement.

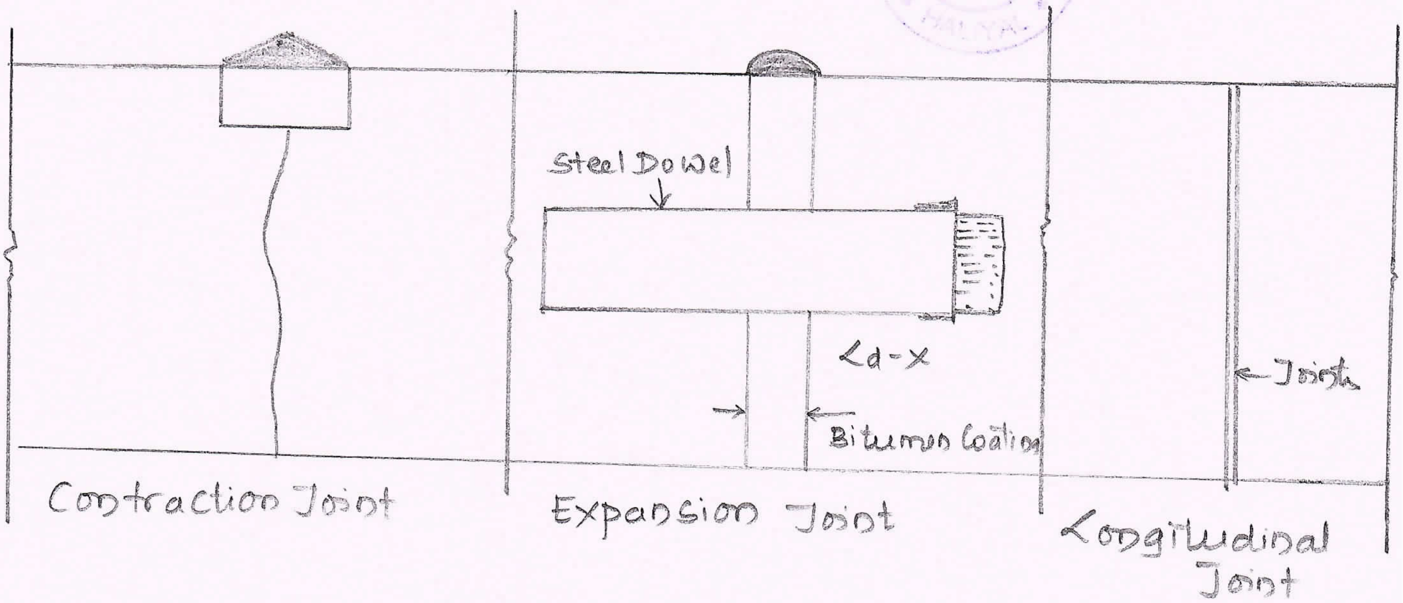


9a. functions of each joints:

a. Longitudinal Joints: Provided at transverse spacing of 3.5 or 3.75m, coinciding with the transverse traffic lane marking. Longitudinal joints are also formed as dummy joints.

b. Expansion joints: A traverse expansion joints are provided in CC pavement at desired intervals or at edentified location during construction of the CC pavement with a gap of 20-25mm.

c. Contraction Joints: contraction joints are dummy joints formed by cutting grooves of specified depth on the top of the slab.



9b. The width of the expansion Joint Gap is 2.5 cm in a CC pavement. If the laying temperature is 10°C and the maximum slab temperature in summer is 54°C. Calculate the spacing between expansion joints. $e = 10 \times 10^{-6}$ per °C.

If 'δ' is the maximum expansion in a slab of length Le with the temperature rise ~~from~~ T_1 to T_2.

$\delta' = LeC(T_2 - T_1)$ ∴ $\delta' = LeC(T_2 - T_1)$

$$\therefore \delta' = \frac{2.5}{2}$$

$$= 1.25\,cm$$

$$\therefore T_2 - T_1 = 54 - 10 = 44°C$$

$$L = \frac{\delta'}{C(T_2 - T_1)}$$

$$= \frac{1.25}{100 \times 10 \times 10^{-6} (44)}$$

$$= 28.5\,m$$

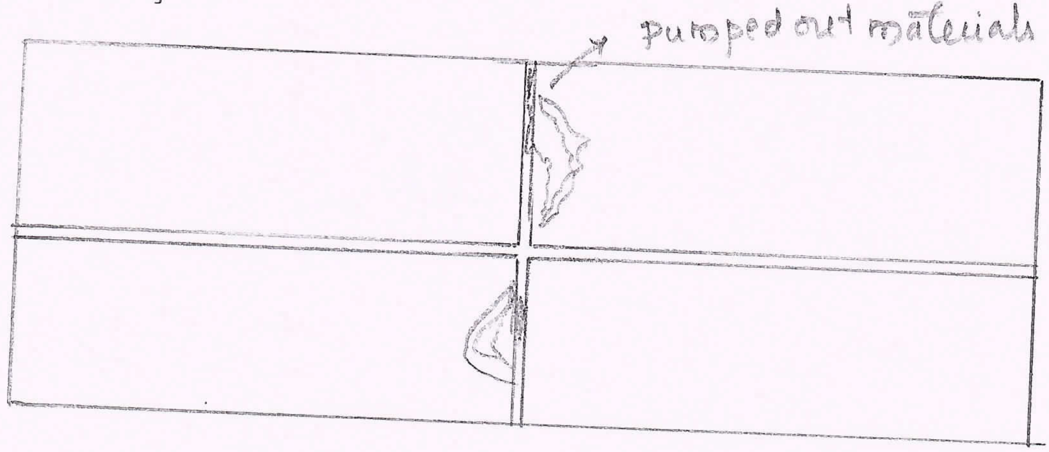
10a. With the neat sketch explain the failure of rigid pavement of mud pumping.

Types of failures in mud pumping:

a). Joint spalling
b). Faulting
c). Polished aggregate
d). Shrinkage Cracking
e). Pumping
f). Punch out
g) Linear cracking
h). Durability Cracking.

Mud pumping in rigid pavements:

The expulsion of water from the under a layer of the pavement is called as pumping. This distress is caused due to the active vehicle loads coming over the pavement in a repetitive manner. This will result the fine materials present in the subbase to move along with water and get expelled out with the water. Larger voids are created under the pavement due to repeated expulsion.



10a List and explain the properties of concrete.

a). Workability : This refers to the ease with which the concrete can be mixed, transported and placed into its final position.

b). Strength : Concrete is known for its strength and can withstand heavy loads and stresses.

c). Creep in concrete : Defined as the plastic deformation under sustained load. Creep strain depends primarily on the duration of sustained loading.

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d). Shrinkage of concrete : The property of diminishing in volume during the process of drying and hardening is termed shrinkage.

e). Modular ratio : Short term modular ratio is the modulus of elasticity of steel to the modulus of elasticity of concrete.

Short term modular ratio = Es/Ec.

Staff Incharge 22-02-2024
(Prof. Harsha D. Jadhav)

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