Pavement Design

Sample Question with Solution.

Q.No.1a. List and explain the desirable charectaristics of pavement. (08M)

i. Pavement will provide good and bald suface for vehicle movement from one place to another place.

ii. Pavement suface acts as water proof layer, to the soil suface.

iii. Pavement consist of different layers, with different material and charectaristics.

iv. Distributes loads (various) from top suface to bottom suface and uniformly to ground.

v. Pavement acts as a very important structure for infrastructure development.

Q.No.16. List the difference between Highway pavement and Air feild pavement. (OBM)

Highway pavement:

a. Those pavements which meet for movement of different modes of vehicles, like NH, SH, MDR etc.

b. Cambers are provided in lateral direction with definate proportion.

c. Pavement thickness are moderate and base on vehicle load.

d. Pavement thickness is defined by CBR value & traffic details.

e. Compaction acheived is more than 97% with MDT and SPT methods.

Air feild pavement:

a. Pavements which meet for movement of aircrafts like landing & take off.

b. Longitudinal cambers are provided to avoid unease.

c. Heavy pavement thicknes are provided.

d. Pavement thickness is finalized by aircraft size.

e. compaction achieved is 99.99% with MPT test.

&

Q.No2. a. List out the assumptions made in the burmister theory. (08M)

a. Each layer is homogenous, isotropic and linearly elastic with modulus E and poissons ratio v.

b. The material is weightless and infinite in areal extent.

c. Each layer has finite thickness, except the lower layer is infinite in depth.

d. A uniform pressure q is applied on the surface over a circular area of radius a.

e. Continuity conditions are satisfied at the layer interfaces.

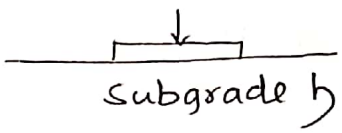
2 b. A plate bearing test conducted with 30cm diameter plate on a subgrade yeilded a pressure of 1 kg/cm² at 5mm deflection. A test is carried out over 18cm base course yelded a pressure of 5 kg/cm² at 5mm deflection. Design the section of pavement for wheel load of 4100 kg with tyre pressure of 6 kg/cm² & allowable deflection 5mm. Use burmister method. (08 M)

Given % $p = 11 kg/cm^2$, $B = 30cm = a = 30/2 = 15cm$,

$F_2 = 1$ @ $h/a = 0$. $\quad Es = \frac{1.18 pa}{\Delta} F_2$

Step 1 :→

$\therefore \quad Es = \frac{1.18 pa}{\Delta} \times f_2$

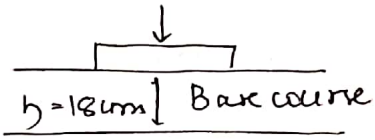


$= \frac{1.18 \times 1 \times 15 \times 1}{0.5} = Es = 35.4 kg/cm^2$

Step 2 :→

$\therefore F_2 = \frac{\Delta Es}{1.18 pa} = \frac{0.5 \times 35.4}{1.18 \times 5 \times 15}$

$F_2 = 0.2 cms$



$Es = \frac{1.18 pa f_2}{\Delta}$

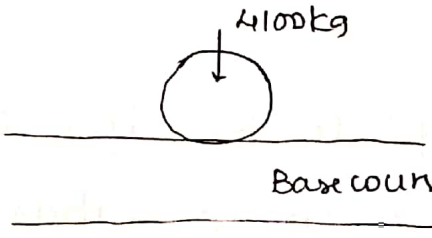
Step 3 :→ $F_2 = 0.2 cm$, $h = 18cm$, $a = 15cm$

$\therefore h/a = 18/15 = 1.2 cms$.

From graph, $Es/Ep = 1/80$

$\therefore Ep = 80 Es \quad \therefore Ep > Es$.

Step 4 :→ Flexible plate



$Es = \frac{1.15 pa}{\Delta} F_2$

$\therefore f_2 = \frac{\Delta Es}{1.5 pa}$

$= \frac{0.5 \times 35.4}{1.5 \times 6 \times 14.75}$

$\therefore F_2 = 0.133$

$p = 4100 kg$, $p = 6 kg/cm^2$

$\Delta = 5 mm$

$\therefore A = \frac{P}{p} = \frac{4100}{6}$

$= 683.33 cm^2$

$A = \pi a^2$

Step 5 :- $F_2 = 0.133$, b/a

$$\frac{E_s}{E_p} = \frac{1}{80}$$

from graph, $b/a = 2.8$, $b = 2.8 \times 14.75$ (a)

$b = 42$ cms

∴ Thickness of pavement = $b = 42$ cms.

Q.No 3a. List the design factors considered in the design of flexible pavement ? Explain any 3. (08M)

a. Wheel load.
b. Axle configuration.
c. Tire contact pressure
d. Vehicle speed.
e. Repitation of Loads.
f. Subgrade type.
g. Temprature effect on pavement design.
i. Precipitation.

a. Wheel Load :→ Wheel load on pavement is an important factor to be determine the pavement thickness to be adopted. By providing adequate thickness the load coming from wheels doesn't affect the subgrade soil. The wheel load is acts at particular point on pavement & cause deformation

If the vehicle contains dual wheel on one side of axle, then convert it into equivalent single wheel load. Dual wheeled axle vehicle control the contact pressure with in limit.

b. Axle configuation :-

Axles are important part of vehicles which enables the wheels to rotate while moving, By providing multiple axle, vehicles can carry more load, so the axle load also influence the design of pavement.

c. Vehicle speed :-

If the vehicle is moving at creep speed then also damage occurs to the pavement. If the vehicle speed is gradually increased then it will cause smaller strains in the pavement.

Q.No 3b. Design a highway pavement (08M) for a wheel load of 4100 kg with a tyre pressure of 5kg/cm² by Mc.Leoad method. The plate bearing test carried on a subgrade soil using 30cm ϕ plate yeilded a pressure of 2.5kg/cm² aflee 10 repitations of load as 0.5cm deflection.

∴ Radius of contact $a = \sqrt{\frac{P}{p\pi}} = \sqrt{\frac{4100}{5\pi}}$

$= 16.10 \text{ cms}$

$\ell = 32 \text{ cms}$.

Perimeter over area ratio $= \frac{P}{A} = \frac{2}{a} = \frac{2}{16.1} = 0.124$

∴ The total unit support at 0.5cm deflection using graph is

i.e Plate yeilded a pressure of 2.5 kg/cm^2 @ 10 repitation & 0.5 deflection.

But diameter is 32.2cm

∴ Unit support $= 0.95 \times 2.5 = 2.44 \text{ kg/cm}^2$

where, 0.95 is obtained from graph.

X-axis as perimeter area ratio

Y-axis as Ratio

∴ Design subgrade support on 32.2cm ϕ plate.

$$S = 2.44 \times \frac{\pi}{4} d^2$$

$$= 2.44 \times \frac{\pi}{4} (32.2)^2 = 2100 \text{ kg}.$$

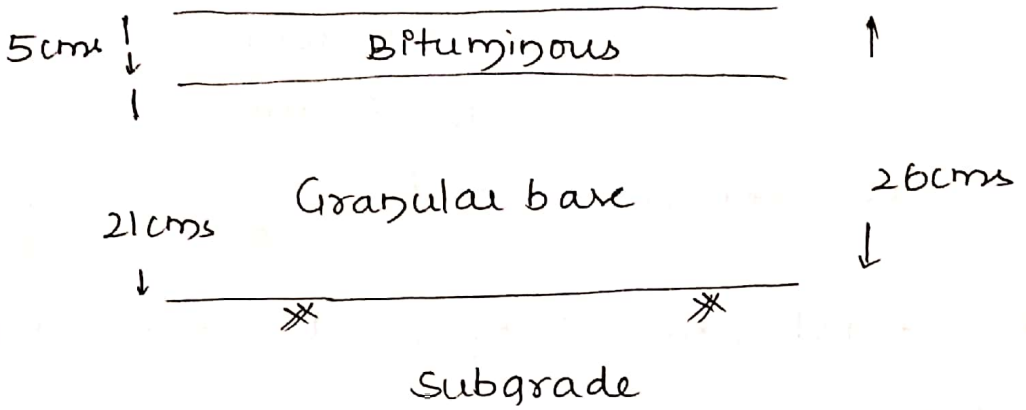
∴ K value of obtained by the graph e 32.2cm

$K = 90$

∴ Granular pavement thickness

$T = K \log_{10} P/S = 26 \text{ cms}$

Provide 5cm bituminous thickness out of this.



Q.No.4a. Significance of ESWL in pavement design? (D&M)

According to the ESWL concept wheel load criteria can be studied below the pavement. As the load "P" is applied it will induces stress in the pavement.

a. With the above study we can easily justify intensity of load at different pavement depths.

b. It also defines quality of material used for construction of pavement.

c. As the stress bearing capacity is more than the material used will be better.

Q.No.46. Design a flexible pavement for two lane undevided carriage way using the following data (OBM)

CBR value = 5%, Initial traffic on completion of construction = 300 cv/day.

Growth rate = 6%/year, Design life = 10yrs

VDF = 2.5 & LDF = 0.75 as for undevided 2 lane carriage way.

$$\therefore CSA = \frac{365 A\,[(1+r)^n - 1] \times VDF \times LDF}{r \times 10^6}$$

$$= \frac{365 \times 300\,[(1+0.06)^{10} - 1] \times 2.5 \times 0.75}{0.06 \times 10^6}$$

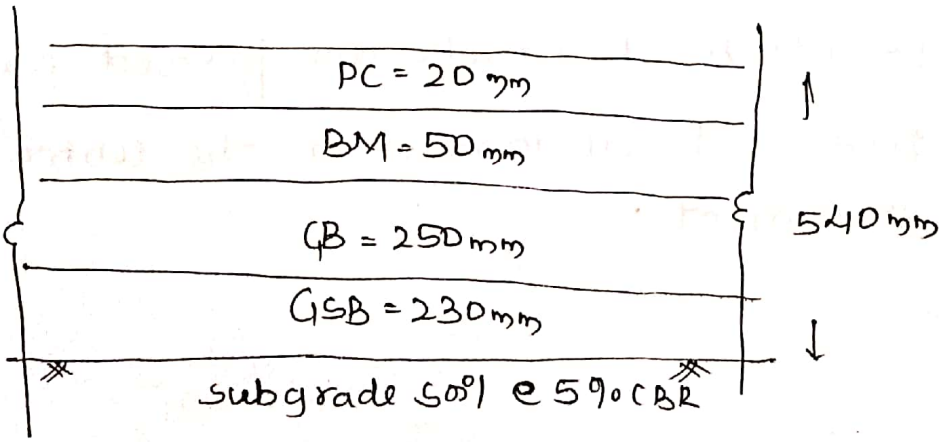
$$= \frac{162370.918}{0.06 \times 10^6} = 2706181.97 = 2.7 \text{ msa}$$

$\simeq 3.0$ msa.

∴ From Chart i.e @ CBR = 5% and CSA = 3.0 msa

Total thickness of pavement = 540 mm

GSB = 230mm, GB = 250mm, BM = 50mm & PC = 20mm



Q.No.5a. Explain the different type of flexible pavement failures? (08M)

a. Alligator cracking.
b. Consolidation of pavement layer.
c. Shear failure cracking.
d. Longitudinal cracking.
e. Frost heaving.
f. Lack of binding to the lower course.
g. Reflextion cracking.
h. formation of waves & corrugation.

a. Alligator cracking :→

Also known as fatigue failure. Primary causes for cracks are :

1. Relative movement of pavement layer material
2. Repeated application of heavy loads.
3. Swelling or shrinkage of subgrade.

b. Longitudinal cracking :

This distress can be considered as either as structural or as environmental distress. The longitudinal cracks are formed parallel to the pavement alignment or the centre line of the pavement.

c. Rutting of flexible pavement :→

The depression formed in the surface is called the rutting. This is formed in the wheel path surface. This depression will make the other sides of the wheel to undergo uplift as. The pavement uplift is also called as shearing.

Q.No.5b. List the factors considered in design of runway pavement. (08 M)

1. They must have adequate strength to withstand the heavy loads.
2. Repitation of loads over the design life.
3. High design speed.
4. Anti skid surface.
5. Minimum maintenance cost.
6. Fuel and oil spillage.
7. Cost of pavement should be economical.

Q.No.6a. What are the causes for formation of waves and corrugations in the flexible pavement? Suggest the remedial measures. (08M)

a. Formation of waves and corrugations in the flexible pavement are due to unstable course caused by stop and go traffic.

Remedial measures taken against waves and corrugations are:

a. Lower the water table by providing suitable suitable sub surface drainage system.

b. Avoiding traffic jam situations across the intersections and signals.

c. If it is due to poor mixing surface course then lay another layer of surface course with proper mixing.

Q.No.6b. Explain step by step procedure of conducting Benkelmans beam deflection studies for evaluation of flexible pavement. (08M)

The benkelmans beam measures the deflection under standard wheel load condition. In a well designed road, the deflection is entirely elastical recoverable

The procedure for the measuring rebound deflection is as follows. (OBM)

a. Select 10 points along the outer wheel path for each lane.

b. Bring the rear dual wheel assembly of the truck over the marked point and insert the probe of the beam between the dual wheels so that the probe is placed exactly over the point where the deflection is to be measured.

c. A standard wheel load of 4085 kg is used for the test, the tyre pressure being 5.6 kg/cm^2.

d. The dial guage reading is noted initially (D_0) in the position described under 2 above.

e. The truck is driven forward at a slow speed and dial guage readings (D_1 and D_2) are taken when truck stops at 2.7 m and 9.0 m from the measuring point, and when the rate of recovery is equal to 0.25 mm per minute or less.

f. Pavement temprature is recorded.

g. If $D_1 - D_2 \leq 0.025$ mm, the actual rebound deflection is $2(D_0 - D_2)$. If, however, $D_1 - D_2 > 0.025$ mm correction is needed for the vertical movement of the front leg; the true deflection is obtained by the formula

$$X_T = X_A + 2.91 Y.$$

where,

X_T = True pavement deflection.

X_A = Apparent pavement deflection.

Y = vertical movement of the front leg. i.e twice the difference between the final and intermediate dial reading.

Q.No.7a. Write Westergaard's load stress equation at critical region and discuss critical combination of stress. (08M)

According to Westergaard's stress equation:

CC pavement section can bear much load & even load is taken by subgrade soil.

Westergaard wheel load stresses are:→

∴ Stresses at interior: S_i :→

$$S_i = \frac{0.316P}{h^2}\left[4\log_{10}(l/b) + 1.069\right]$$

Stresses at edge :→

$$S_e = \frac{0.572}{h^2}P\left[4\log_{10}(l/b) + 0.359\right]$$

Stresses at corner :→

$$S_c = \frac{3P}{h^2}\left[1 - \left(\frac{a\sqrt{2}}{l}\right)^{0.6}\right]$$

Q.No-7b. Explain the steps for design of CC pavement using IRC 58-2002. (O&M)

1. Design load on single axle and tandem axles are considered.
2. Trial thickness is assumed, from the given data.
3. K value and E values are considered i.e
   Modulus of K value - kg/cm^3
   E value of concrete - kg/cm^2.
4. Edge stresses are considered using pavement thickness (h) and K value using stress chart for the respective axle loads.
5. Overloaded stress is calculated for different axle loads.
6. Stress ratio for above load is calculated
7. Fatigue analysis is carried out for all types of edge load stresses.
8. Fatigue life CN is calculated it should be less than 1.
9. Both se and ste are calculated.
10. If (se+ste) is less than flexual strength then assumed design and calculation is OK. If riceversa then assume higher thickness.

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

Where, h = Slab thickness, cm.

l = Radius of relative stiffness, cm

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

When, $a > 1.724h \Rightarrow b = a$.

a = Radius of wheel contact (cms).

b = radius of resisting section cms.

Critical combination of stress:→

In the design of cc pavement we have two types of stresses a. Wheel load stress and b. Temperature stress. We calculate above stresses separately when it required as per the type of stress. But during the design of cc pavement all these stresses are combined and calculated based up on conditions.

a. Summer mid day = $S_e + S_{te} + S_f$.

b. Winter mid day = $S_e + S_{te} + S_f$.

c. Summer mid night = $S_c + S_{tc}$.

S_e = Edge wheel load stress,

S_{te} = Edge warping stress.

S_f = Frictional stress

Q.No.8a. Use the following data given below and calculate load stress Load stresses at all positions. (08M)

$P = 5100$ kg, $E = 3\times10^5$ kg/cm^2, $b = 18$ cms, $\mu = 0.15$, $K = 6.0$ kg/cm^3 $a = 15$ cms.

∴ According to Westergaard's Stress equation three basic properties are K, l and b.

∴ $K = 6.0$ kg/cm^3.

$$l = \left[\frac{Eh^3}{12K(1-\mu^2)}\right]^{1/4} = \left[\frac{3.0\times10^5\times18^3}{12\times6\times(1-0.15^2)}\right]^{1/4}$$

$$= \left[\frac{17496\times10^5}{70.38}\right]^{1/4} = 70.61 \text{ cms}$$

∴ Radius of relative stiffness (l) = 70.61 cms.

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

$a/h = 15/18 = 0.833 < 1.724$ $\quad a = 15$ cms.

$$\therefore b = \sqrt{1.6a^2+h^2} - 0.675h$$

$$= \sqrt{1.6\times15^2+18^2} - 0.675\times18 = 14.0 \text{ cms}$$

∴ Radius of resisting section (b) = 14.0 cms

Considering all the above properties.

$$S_l = \frac{0.316P}{h^2}\left[4\log_{10}(l/b)+1.069\right] = 19.29 \text{ kg/cm}^2$$

$$S_e = \frac{0.572P}{h^2}\left[4\log_{10}(l/b)+0.359\right] = 28.45 \text{ kg/cm}^2$$

$$S_c = \frac{3P}{h^2}\left[1-\left(\frac{a\sqrt{2}}{l}\right)^{0.6}\right] = 24.22 \text{ kg/cm}^2$$

Q.No.8b. Design a tie-bar system for a cement concrete pavement, given: (08 M)

1. Slab thickness, h = 20mm
2. Slab width, b = 3.35 m
3. No. of lanes to be tied = 2
4. Co-efficient of friction between slab and subgrade = 1.5
5. Weight of slab = 480 kg/m².
6. Allowable working stress in steel = 1400 kg/cm²
7. Maximum permissible bond stress
   i. Plain bars : 17.5 kg/cm²
   ii. Deformed bars : 24 kg/cm²

$$A_s = \frac{bfw}{S} = \frac{3.35 \times 1.5 \times 480}{1400} = 1.72 \text{ cm}^2/\text{m}$$

Assuming diameter of bar to be 10mm

A, Area of cross-section of one bar = 0.785 cm²

P = Perimeter of one bar = 3.142 cm

No. of tie bars required per m,

$$N = \frac{A_s}{A} = \frac{1.72}{0.785}$$

$$\text{Spacing} = \frac{100}{N} = \frac{100 \times 0.785}{1.72} = 45.6 \text{ m} \simeq 45.0 \text{ m}$$

$$\text{Length of tie bar} = \frac{2SA}{BP} = \frac{2 \times 1400 \times 0.7854}{B \times 3.142} = \frac{700}{B}$$

$$= \frac{700}{17.5} = 40 \text{cm for plain bars.}$$

$= \frac{700}{24} = 29.2$ cm for deformed bar

∴ The length can be made 45cm for plain bar and 35cm for deformed bar, keeping as additional 5cm margin for inaccuracy in placing.

Q.No.9a. What are the types of various joints in CC pavement? Explain their functions with neat sketch. (OBM)

Types of joints in CC pavement:

1. Longitudinal joint.
2. Transverse joint.
   a. Contraction joint.
   b. Expansion joint.
   c. Construction joint.

Functions of Joints:

1. Longitudinal joint: Provided along the length of CC pavement with the slab 4.5-5.0 mts. Acts as lane separator.

2. a. Contraction joint: Grooves are made along the width of pavement to avoid shrinkage crack. If bars are used inside the joints then they are provided to avoid expansion joints.

b. Expansion joint: Occurs due to change in temperature CC pavement slab may expand or contract during summer & winter due to this length or width of pavement may change.

c. Construction joint: Provided during the end of the construction. this joint may be expansion joint or contraction joint.

Q.No.9b. Explain briefly the pavement evaluation. (08M)

Pavement evaluation is a technique of assessing the condition of pavement, both structually and from the point of view of suface characteristics.

Iti a handy tool in the hands of highway engineer and serves as a variety of purpose, such as:

a. To research on the pavement performance.
b. To assess maintenance needs such as patches repairs, renewals & resealing.
c. To assess the need for structural overlays on distressed pavements.

Methods of pavement Evaluation:

a. Visual rating.
b. Present serviceability index concept.
c. Roughness measurement.
d. BBM method.

Q.No10.a. Explain the various types of rigid pavement failure with neat sketch. (08M)

a. Scaling of cement concrete.
b. Shrinkage cracks.
c. Joint spalling.
d. Warping crack.
e. Pumping.
f. Faulting.
g. Polished aggregate.
h. Punch out.
i. Linear cracking
j. Durability cracking.
k. Corner break.

a. Faulting:

The difference in elevation between the joints is called faulting.

Causes for the faulting are as follows:
i. Settlement of pavement due to soft foundation
ii. Erosion of material under the pavement.

b. Durability cracking:

They are series of closely placed, cresent-shaped dark coloured cracks.

Causes.
i. Freeze thaw expansion of aggregates in PCC slab.
ii. Some roughness leads to spalling & disintegration

c. Punchout: Broken pieces of the localized area.
i. Heavy repeated loads.
ii. Inadequacy in slab thickness.

Q. NO. 10b. Explain the following :- (08M)

a. Fatigue behaviour of concrete :

i. Fatigue is the important aspect in the rigid pavement design.

ii. Due to application of the heavy loads fatigue occurs in the pavement in the form of micro cracks.

iii. Occurs when a material ruptures under continued repitation of loads.

iv. Load applied by single as well as tandem axle cause maximum flexual stress.

v. Loading at various locations are applied and verified with fatigue behaviour.

b. Maintenance of Joints : (08M)

The joints are the weakest parts of cement concrete pavement and hence, they should be checked periodically and kept in proper order during routine maintenance work.

a. The damaged joint sealer should preferably be replaced before start of mansoon.

b. The expansion and contraction joints are opened up and after cleaning with brush, they are filled up

c. Mud jacking: Holes are cleaned with compressed air. The grout is forced through these holes under pressure. The slab is raised and it is held in position till the grout hardens.

d. Like above, Patch repair, crack treatment like structual and tempreture cracks are maintained.

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