UNIT III-FLEXIBLE AND RIGID PAVEMENT

PART - A (2 mark)

1. How do you calculate the ESWL at a given depth below the pavement for a dual wheel assembly? (APRIL/MAY 10)

Let P be the single wheel load

d be the spacing between the tyres

S be the centre to centre spacing of tyres

A plot is made in log-log scale with depth on z-axis which gives a linear releationship.two coordinates A (d/2, P) and B (2S, 2P).

Let z_1 be the depth at which ESWL is needed. From the plot for a depth of z_1 the ESWL, P_1 read.

2. What is the radius of resisting section? (APRIL/MAY 10)

Westergaard's suggested an equivalent radius of resisting section, b, in terms of radius of load distribution and slab thickness, as

b= $\sqrt{1.6a^2}$ [redacted] ^{2} [redacted] $.675h$

Where a=radius of wheel load distribution, cm

h=slab thickness

When a is greater than 1.72h, the value of b=a

3. State the components of the flexible pavements. (NOV/DEC 13) (APRIL/MAY 11)

Flexible pavement is based on the principle that the wheel load of vehicles is dissipated to the natural soil through successive layers of granular materials.

Highest quality material is placed on the top. The components of the pavement from the top are surface course, base course and sub base course. The strength of sub grade decides the thickness of flexible pavement.

4. How change in temperature produce frictional stresses in rigid pavements? (APRIL/MAY 11)

Temperature in concrete pavement produces warping stresses and frictional stresses.

When the concrete pavement slab experiences different temperatures at top and bottom, the slab tents to warp downwards or upwards including warping stresses.

As the concrete pavement is in contact with the sub grade, the movement of slab at the bottom is restrained due to friction and causing frictional stress.

5. What is rigidity factor in the design of Highway Pavements? (MAY/JUNE 12)

The ratio of contact pressure to tyre pressure is defined as rigidity factor. the rigidity factor is equal to unity when the tyre pressure is 7.0 kg/cm^2.this value is higher than unity for low tyre pressure and less than unity for tyre pressure higher that 7kg/cm^2.

6. Define ESWL. (MAY/JUNE 13) (MAY/JUNE 12)

In order to have maximum wheel load, dual wheel assembly is provided to the rear axles of the load vehicle. Because of this the load due to the both the wheels are not to be transferred to the pavement. But there will be overlap pressure after a certain depth. The actual effect is in between a single wheel load and the double the load carried by any one wheel.

7. Explain rigid pavement. (MAY/JUNE 13)

Cement concrete pavements represent the group of rigid pavement. Here the load carrying capacity is mainly due to the rigidity and high modulus of elasticity of the slab itself

9. List the application of rigid pavement. (NOV/DEC 13)

- The rigid pavement load carrying capacity is mainly due to the rigidity and high modulus of elasticity of the slab itself.
- The rigid pavement has the slab action and is capable of transmitting the wheel load stresses through a wider area below.

10. Define Pavement?

The Pavement consisting of a few layers of Pavement material is constructed over a prepared soil sub grade to serve as a carriageway.

One of the objectives of a designed Pavement is to keep this elastic deformation of the Pavement within the Permissible limits.

11. What are the types of Pavement Structure?

Based on the structural behavior, Pavements are generally classified in to two categories.

i) Flexible Pavements.

ii) Rigid Pavements.

12. What are the factors considered in design of pavements?

The various factors to be considered for the design of pavements are given below.

i) Design wheel load

ii) Sub grade soil

iii) Climatic factors

iv) Pavement component materials

v) Environmental factors

vi) Special factors in the design of different types of pavements.

13. Define the three types of pressure?

The types of pressure are:

- Tyre pressure
- Inflation pressure
- Contact pressure

14. How to measure the contact pressure?

Contact pressure can be measured by relationship:

$$\text{Contact pressure} = \frac{\text{Load on wheel}}{\text{Contact area (or) area of imprint}}$$

15. What are the design methods available in flexible pavement?

The following methods are:

i) Group index method
ii) California bearing ratio method
iii) Stabilometer method
iv) Triaxial test method
v) McLeod method
vi) Bur mister method

16. Define critical load positions.

There are three typical locations namely the interior, edge and corner, where differing conditions of slab continuity exist. These are termed as critical load positions.

17. What are the types of loading?

Interior loading --- When load is applied in the interior of the slab surface
Edge loading ----- When load is applied in an edge of the slab.
Corner loading ---- When the center of the load application is located on the bisector of the corner angle formed by two intersecting edges of the slab.

18. What are the major effects in climatic variations?

The climatic variations cause following major effects:

i) Variation in moisture condition
ii) Frost action
iii) Variation in temperature.

19. What is traffic index?

Traffic index is an empirical term used to estimate the traffic volume. This is given as

$$T_1=1.35(EWL)^{0.11}$$

Where EWL is the accumulated sum of the products of the constants and the number of axle loads.

20. Define CBR.

California bearing ratio is an adhoc property of a material which shows relative significance and do not provide absolute measure.

PART B (16 MARKS)

1. i)State the limitations of CBR method of pavement design. (APRIL/MAY 10)

- CBR is an adhoc penetration test which does not consider any of the sub grade properties directly.
- As the method is empirical, it is not essentially related to any particular value of axle load or wheel load repetitions.
- The design curves provided in the method are not meant to be made use of on the basis of traffic immediately carried by the road or that anticipated (in the case of new constructions).
- This method gives the total thickness requirement of the pavement above a sub grade and the thickness is same irrespective of the quantity of materials used in the component layers.

ii) Using the following data, design the flexible pavement layers:

CBR of the subgrade soil = 5%

CBR of poorly graded growel sub-base = 15%

CBR of WBM = 80 %

Design life = 15 years

Annual rate of increase in the heavy vehicles = 7.5%

No. of heavy vehicles per day during last count = 200

No. of years between the year of completion and year of last count = 3 years

Assume any other data found required.

Solution:

Number of vehicles for design is given by,

$$A = P[1+r]^{n+10} = 1200\left[1+\frac{7.5}{100}\right]^{(3+10)} = 3172 \text{ veh/day}$$

Hence from Fig. 6.9 the design curve F may be used.

CBR of subgrade = 5%

Hence the total pavement thickness for a CBR of 5% is read from Fig. 6.9 aganist curve F as 48 cm.

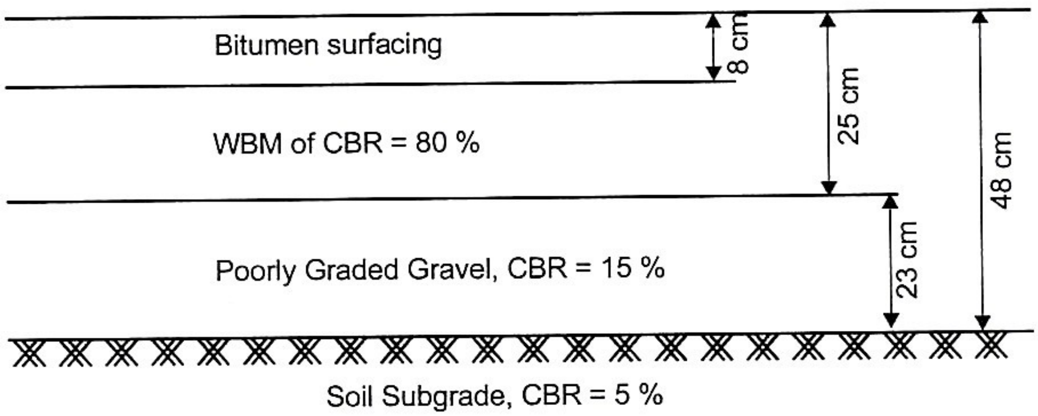
Poorly graded gravel with a CBR of 15 is placed over the subgrade.

Again from Fig. 6.9 for a CBR of 15, the thickness of poorly graded needed for the same traffic is 25 cm.

Over this the WBM layer with a CBR of 80 % is placed.

Thickness of WBM layer is read in Fig. as 8 cm.

The pavement section is shown in Figure given below.



2. i) what are the objectives of joints in cement concrete pavements? Sketch the different types of joints used in pavement construction. Indicate the principle of design.

In general, joints are provided in cement concrete pavements to reduce temperature stresses.

- Expansion joint is provided to permit increase in the length of a slab due to temperature increase.
- Contraction joints are provided (i) to control cracking of the slab resulting from contraction and (ii) to relieve warping stresses.
- Longitudinal joints are provided to prevent the formation of irregular longitudinal cracks and to allow for transverse warping and unequal settlement.
- Construction joints are provided at the abrupt end of a day's work unexpectedly interrupted due to breakdown of plant or onset of bad weather.
- Warping joints are provided if expansion joint and contraction joints are not effective.

Expansion joint is designed based on the maximum temperature variations expected and the width of joint. The design of contraction joint is governed by the anticipated frictional resistance and allowable tensile stress in concrete. Longitudinal joints are designed with tie bars.

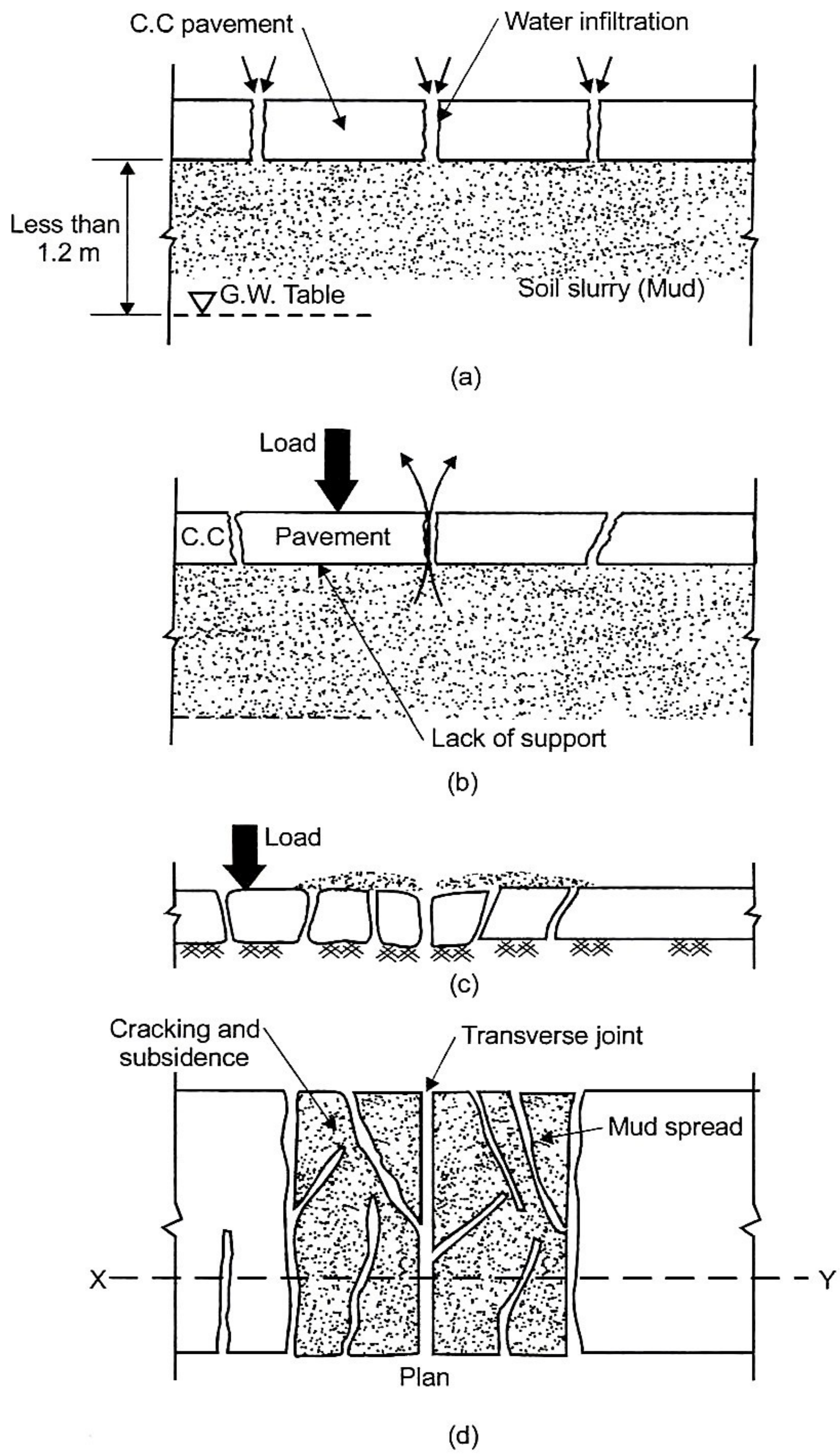
ii) Explain mud pumping. What are the causes for mud pumping and how it can be prevented? (APRIL/MAY 10)

Ejection of soil slurry takes place through cracks formed on the pavement slab due to wheel load or otherwise.mud pumping is caused due to more slab deflection, type of sub grade soil and amount of free water. Pumping is generally noticed in clayey sub grades with soon after the rains.

Due to repeated loading an initial space formed underneath the pavement slab develops and spreads and form a place for collection of water. Since the sub grade soil is clayey which has less permeability retain the water and forms soil slurry or soil suspension in water or the mud.

Subsequent movement of traffic causes the pavement slab to defect at critical location and pushes out the part of mud every time. Continued loosing of sub grade soil due to ejection of mud and application of wheel loads to sub grade support. Ultimately the pavement fails at more places.

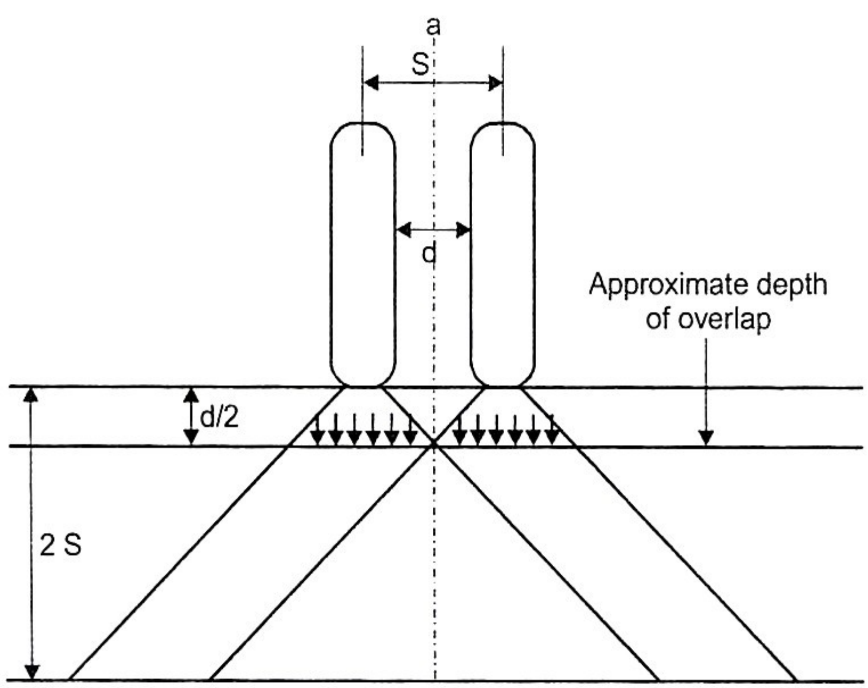
Thus the pavement cracking due to mud pumping is generally a progressive type of pavement failure.



Stages of formation of mud pumping

3. i) define ESWL and lane distribution factor and explain their significance.

In order to have maximum wheel load, dual wheel assembly is provided to the rear axles of the load vehicles. Because of this, the load due to both the wheels is not to be transferred to the pavement. But there will be overlap pressure after a certain depth. The actual effects is in between a single wheel load and double the load carried by any one wheel. Stress overlap is presented in fig below.



Stress overlap due to dual wheels

It is assumed that up to a depth of d/2 the loads act independently beyond which the stresses overlap. The area of overlap becomes more beyond a depth of 2S.hence it may be considered that the load the total stress due to the dual wheels at any depth greater than 2S, is to be equivalent to a single wheel load of 2P magnitude. However, this stress due to 2P is to be slightly greater than the duel wheel assembly which is on the safe side.

This equivalent single wheel load can be determined by equivalent deflection or equivalent deflection or equivalent stress criterion. For example, based on deflection criterion it is to state that the maximum deflection caused at a particular depth z (say, depth equivalent to the thickness of pavement) by a dual wheel load Assembly is also caused by an equivalent single wheel load acting at the surface of the pavement.

Similarly by the stress criterion the ESWL producing the same stress value at a depth z as that produced by a dual wheel load assembly.

A linear relationship is assumed between the ESWL and the depth in a log-log scale. A linear plot is got, as shown in fig. By plotting a point A with coordinates z=d/2 and P and point B with coordinates z=2S and 2P.

Line AB represents the locus of point where any single wheel load is equivalent to a certain set of dual wheels.

In order to use the graph, for an assumed thickness of pavement and ESWL is got from the graph. This ESWL is used in the design calculations and the thickness of pavement is obtained. If this thickness and assumed thicknesses are same then the ESWL assumed is correct. If not the design is repeated and by trial and error the correct thickness of pavement is obtained. This calculation is valid for the given wheel load configuration. For different wheel load assembly different ESWL plots may be made.

ii) Describe the factors influencing the design of flexible pavements. (APRIL/MAY 11)

The various factors to be considered for the design of flexible pavements are given below:

- Design wheel load
- Sub grade soli
- Climatic factors
- Pavement component materials
- Environmental factors
- Special factors

Design wheel load

The thickness design of pavement primarily upon the design wheel load. Higher wheel load obviously need thicker pavement provided other design factors are the same. While considering wheel load, the effects of total static load on each wheel, multiple wheel load assembly, contact pressure, load repetition and the dynamic effects of transient loads are to be taken into account.

As the speed increases the rate of application of the stress is also increased in resulting in a reaction in the pavement deformation under the load: but on uneven pavements, the impact increases with speed. Some of the important design factors associated with the traffic wheel loads have been explained in the subsequent article.

Sub grade soil

The properties of the sub grade soil are important in deciding the thickness requirements of pavements sub grade with lower stability requires thicker pavement to protect it from traffic loads. The variation in stability and volume of the sub grade soil with moisture changes are to be studied as these properties are dependent on the soil characteristics. The stress strain behaviors of the soil under static and repeated loads have also significance. Apart from the design the pavement performance to a great extent depends on the sub grade soil properties and the drainage.

Climate factors

Among the climate factors, rainfall affects the moisture conditions in the sub grade and the pavement layers. The daily and seasonal variation in temperature has significance in the design and performance of rigid pavements. Where freezing temperature is prevalent during winter, the possibility of frost action in the sub grade and the damping effects should be considered at the design stage itself.

Pavement component materials

The stress distribution characteristic of the pavement components layers depends on characteristics of the materials used. The fatigue behavior of these materials and their durability under adverse conditions of weather should also be given due consideration.

Environmental factors

The environmental factors such as height of embankments and its foundations details. Depth of cutting, depth of sub surface water table, etc...Affect the performance of the pavement. The choice of the bituminous binder and the performance of the bituminous pavement depending on the variations in pavement temperature with the seasons in the region.

4. Explain the recommended design procedure for the design of rigid pavements by IRC. (APRIL/MAY 11)

Wheel load

The design wheel load may be taken as 4100 kg with a tyre inflation pressure of 5.3 to 6.3 kg/cm^3.

Traffic volume

The growth of traffic volume after 20 years of construction has to be considered in the design. The following formula may be used to estimate the demand

$A_d=P^1(1+r)^{n+20}$

Where

A_d=number of commercial vehicles per day for laden weight greater than 3 tonnes.

P^1=the number of commercial vehicles per day at least count.

r=annual rate of increase in traffic intensity

n=number of years between the last traffic count and the commissioning of new cement concrete pavement.

Traffic classification

Traffic classification	*Design traffic intensity, A_d (number of vehicles of wt> 3 tonnes per day) at the end of design life*	*Adjustment in design thickness of cement concrete pavement, cm*
A	0 to 15	– 5
B	15 to 45	– 5
C	45 to 150	– 2
D	150 to 450	– 2
E	450 to 1500	0
F	1500 to 4500	0
G	> 4500	+2

Annual temperature

The mean daily and annual temperature cycles are to be collected. The temperature difference, depending on the place where the road is intended to be constructed is taken from the standard table provided for various states and regions for a given thickness of slab.

Modulus of sub grade reaction

Modulus of sub grade reaction, K, is determined using a 75 cm diameter plate and the pressure corresponding to 0.125cm deflection. If the pavement is to be laid on the sub grade soil then K should be not less than $5.5kg/cm^3$ otherwise a suitable sub base course is to be provided.

Properties of concrete

The flexural strength of cement concrete to be used for the pavement should be less than 40 kg/cm^3.

The cube strength of concrete should be $280kg/cm^2$, modulus of elasticity $E=3X10^5$ and poisons ratio=0.15.these properties may also be determined experimentally.

Co efficient of thermal expansion may be taken as $10x10^{-6}$per ^oC for design purpose.

Computation of stresses

- Wheel load stresses at the edge and corner regions are calculated as per modified Westergaard's analysis.
- Temperature stress at the edge region is calculated as per Westergaards analysis using Bradbury's coefficient.

Slab thickness

- The length and width of slab are decided based on the joint spacing's and lane width.
- A trial thickness of slab is assumed. The warping stress at edge region is calculated which is deducted from the allowable flexural stress. The resulting strength in the pavement has to support the edge loads.
- The stress due to load at the edge is calculated. The factor of safety is computed comparing the strength and the edge stress. If the factor of safety is less than one, thickness is increased and the calculations are repeated till the factor of safety is above1.this is the design thickness h.
- The stress due to corner load is computed and checked using the above h. if this stress value is less than allowable flexural stress in concrete then the slab thickness h is adequate. If not the thickness may be suitably increased till the above condition is satisfied.
- The design thickness h is then adjusted for traffic intensity as given in table to obtain the final adjusted slab thickness.

Joint spacing

- For all slab thicknesses with rough foundation the maximum spacings recommended for 25mm wide expansion joint ios 140m.for smooth foundation the maximum spacing may be 90m for slab thickness up to 20cm,
- 120m for slab thickness up to 25cm when the construction is made in summer.if the construction is made in winter the spacing may be restricted to 50 and 60m respectively.
- In unreinforced slab for all slab thicknesses the spacing of construction joint is 4.5m.in reinforced slab the spacing is 13m for m15cm thickness slab with steel reinforcement of 2.7kg/cm^2 and 14m spacing for 20cm thick slabs with steel reinforcement of 3.8kg/cm^2.

Dowel bars

- Dowel bars are designed based on Bradbury's analysis for shear, bending and bearing in concrete.
- The minimum dowel length is taken as (L_d+δ).the load bearing capacity of the dowel system is assumed to be 40% of the design wheel load. The dowel bars is considered to be effective 1.8 times the radius of relative stiffness l on the either side of the load position.
- Dowel bars are provided for thickness of slab more than 15cm or more.IRC recommends 2-5cm dia bars of 50cm length with 20cm spacing for 15cm thick slab and spaced at 30cm in case of 20cm thick slab.

Tie bars

Designed for longitudinal joints with permissible bond stress in deformed bars 24.6kg/cm^2 and in plain bars 17.5kg/cm^2.allowable working stress in tensile steel is taken as 1500kg/cm^2.

Reinforcement

Nominal reinforcement in cement concrete pavements is intended to prevent deterioration of the cracks. It is not provided to increase the flexural strength of uncracked slab. The area of longitudinal and transverse steel required per meter width or length of slab is computed using the following formula.

$A=Lfw/(2S)$

Where

A=area of steel required per meter width or length of the slab, cm^2

L=dist6ance between free transverse joints for longitudinal or transverse steel, m.

w=weight of unit area of pavement slab, kg/cm^2.

The reinforcement is to be provided at 5cm below the surface of slab.it is continued across dummy groove joints to serve the purpose of tie bars. The reinforcement is kept at least 5cm away from the face of joint or edge.

5. i) Different between flexible and rigid pavements.

S.no	characteristics	Flexible pavement	Rigid pavement
1	Normal loading	Undergoes deformation under the load	Resists deformation and acts as a cantilever beam.
2	Excessive loading	Local depression take p[lace	A crack on the surface may appear due to rupture
3	After effects of heavy load	Pavement is flexible and thus adjusts itself by deformation.	Permanent rupture or cracks forms and remains
4	Temperature effects	Not affected	Stresses produced based on temperature
5	Sub grade strength	Uniform sub grade is necessary	Sub grade may be non uniform

ii) Explain the design consideration's for spacing of expansion and construction joints. (MAY/JUNE 12)

Expansion joints

The width or gap in expansion joints depends upon the length of slab. Greater the distance between the expansion joints, the greater is the width required of the gap for expansion. The use of wide expansion joint space should be avoided as it would be difficult to keep them properly filled in when the gap widens during winter season. The dowels would develop high bending and bearing stresses with wider openings. It is recommended not to have a gap more than 2.5 cm in any case. The IRC has recommended that the maximum spacing between expansion joints should be not exceeding 140m for rough interface layer.

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

$$\delta = L_e\, C\, (T_1 - T_2)$$

Where

C is the thermal expansion of concrete per degree rise in temperature.

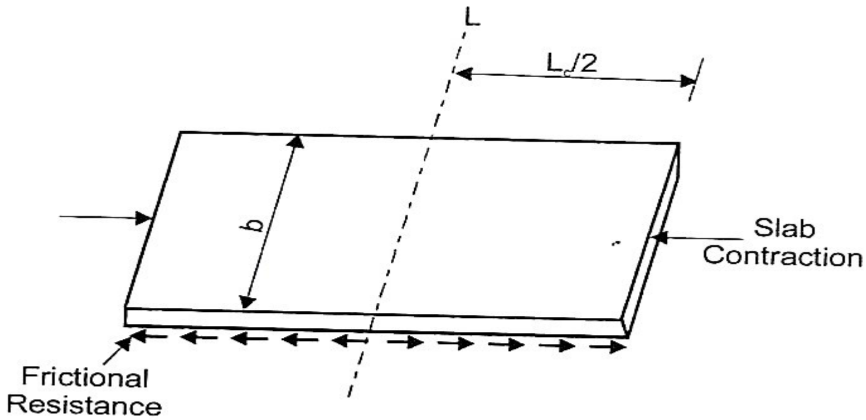
The joint filler may be assumed to be compressed up to 50 percent of its thickness and therefore the expansion joint gap should be twice the allowable expansion in concrete, i.e., 2δ is half the joint width the spacing of expansion joint L_e is given by equation:

$$L_e = \delta / (100C\, (T_1 - T_2))$$

Construction joint

The slab contracts due to fall in slab temperature below the construction temperature. Also during the initial curing period, shrinkage occurs in cement concrete. This movement is resisted by the sub grade drug or friction between the bottom fiber of the slab and the sub grade.

Total frictional resistance up to distance



$L_c/2$=WXbx $L_c/2$x(h/100)xf

Allowable tension in cement concrete=$S_c$xhxbx100

Equating the above two values

WXbx $L_c/2$x(h/100)xf= $S_c$xhxbx100

Length of slab to resists the frictional drag, i.e., spacing of construction joints,

$L_c=(2S_c/(Wf))x10^4$

Here

L_c=slab length or spacing between construction joints, m

H=slab thickness, cm

W=unit weight of cement concrete, kg/m^3

S_c=allowable stress in tension in cement concrete, kg/cm^2

Since the contraction or shrinkage cracks develop mainly during initial period of curing. A very low value of S_c is considered in design. The permissible stresses are generally kept as low as about 0.8kg/cm^2.

6. Explain in detail about the IRC method of flexible pavement design. Discuss the limitation of this method. (MAY/JUNE 12)

Indian road congress (IRC: 37-1970) has recommended some important aspects to be considered while using the design chart. Following are the recommendations:

- The specimen to be tested CBR should be remoulded specimen prepared preferably by static compaction wherever possible or dynamic compaction. The standard test procedure should be strictly followed.
- In situ test specimens are not recommended.
- For new roads the sub grade soil specimen should be compacted to proctor density at OMC. If the compaction equipment is not available in the field, the specimen may be compacted to the expected field density.
- For the existing roads the specimen should be compacted to field density of sub grade soil at water content equal to OMC or field moisture content.
- For all new constructions the specimen should be soaked for four days prior to testing. This condition is not mandatory for arid climatic regions or regions with annual rainfall is less than 50cm or the water table is very deep or when thickness of impermeable bituminous surfacing is provided.
- At least three specimens should be tested with identical specimens. If the variation is maximum beyond the norms, then average of six specimens CBR values should be taken.

The specimen limits of maximum variation in CBR values are

3% for CBR value up to 10%
5% for CBR value 10 to 30%
10% for CBR value 30 to 60%

- The top 50cm of sub grade should be compacted with density equal to 95 to 100% of proctor density.
- Keeping in view the existing traffic and the anticipated growth in traffic should be calculated for at least 10 years of life period.

The following formula may be used:

$$A=P\ (1+r)^{n+10}$$

Where

A=number of heavy vehicles per day for design (laden weight>3 tonnes)
P=number of heavy vehicles per day at least count.
r=annual rate of increase of heavy vehicles
n=number of years between the least count and the year of completion of constructions.

The value P has to be found for seven day heavy vehicles obtained from 24 hours count. If a reasonable value of r is not available a value of 7.5% may be assumed for rural roads.

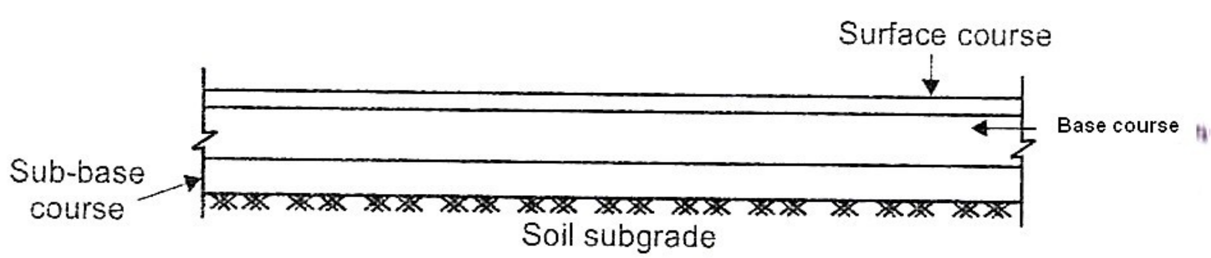
- The traffic obtained from the above equation has to be used in choosing the appropriate design curve (A to G).
- The design thickness corresponding to a single axle load up to 8200kg and tandem axle load up to 14500kg is adopted.
- Substandard sub bases with substantial proportion of aggregates of size above 20mm should not be used in design.
- Thin layers of wearing course such as surface dressing or open graded premixed carpet up to 2.5cm thickness should not be counted towards total thickness as these materials do not contribute to the structural capacity of the pavement.

7. Explain the functions of the components of the flexible pavements. (MAY/JUNE 13)

Flexible pavements are those which on the whole have low or negligible flexural strength and are rather flexible in their structural action under the loads. The flexible pavement layers reflect the deformation of the lower layers on to the surface of the layer. Thus if the lower layer of the pavement or soil sub grade is undulated, the flexible pavement surface also gets undulated. A typical; flexible pavement consists of four components:

Soil sub grade
Sub base course
Base course
Surface course

A typical cross section of a flexible pavement structure is shown in fig.



Flexible pavement

This consists of a wearing surface at the top, below which is the base course followed by the sub base course and the lowest layer consists of the soil sub grade which has the lowest stability among the four typical flexible pavement components. Each of the flexible pavement layers above the sub grade, viz. sub base, base course and the surface courses may consists of one or more number of layers of the same or slightly different materials and specifications.

Flexible pavements are commonly designed using empirical design charts or equations taking into account some of the design factors. There are also semi empirical and theoretical design methods.

According to this the flexible pavement may be constructed in a number of layers and the top layer has to be strongest as the highest compressive stresses are to be sustained by this layer, in addition to the wear and tear due to the traffic.

The lower layers have to take up only lesser magnitude of stresses and there is no direct wearing action due to traffic loads, therefore inferior materials which lower cost can be used in the lower layer.

The lowest layer is the prepared surface consisting of the local soil itself, called sub grade.

The vertical compressive stress is maximum on the pavement surface directly under the wheel load and equal to the contact pressure under the wheel. Due to the ability to distribute the stresses to a longer area in the shape of a truncated cone, the stresses get decreased at the lower layers.

Therefore by taking full advantages of the stress distribution characteristic of the flexible pavement, the layer system concept was developed. According to this the flexible pavement is constructed in a number of layers and the top layer has to be strongest as the highest compressive stresses are to be sustained by this layer.

8. Explain the factors governing the structural design of pavements. (MAY/JUNE 13)

The various factors to be considered for the design of pavements are given below:

- Design wheel load
- Sub grade soli
- Climatic factors
- Pavement component materials
- Environmental factors
- Special factors

Design wheel load

The thickness design of pavement primarily upon the design wheel load. Higher wheel load obviously need thicker pavement provided other design factors are the same. While considering wheel load, the effects of total static load on each wheel, multiple wheel load assembly, contact pressure, load repetition and the dynamic effects of transient loads are to be taken into account. As the speed increases the rate of application of the stress is also increased in resulting in a reaction in the pavement deformation under the load: but on uneven pavements, the impact increases with speed. Some of the important design factors associated with the traffic wheel loads have been explained in the subsequent article.

Sub grade soil

The properties of the sub grade soil are important in deciding the thickness requirements of pavements sub grade with lower stability requires thicker pavement to protect it from traffic loads. The variation in stability and volume of the sub grade soil with moisture changes are to be studied as these properties are dependent on the soil characteristics. The stress strain behaviors of the soil under static and repeated loads have also significance. Apart from the design the pavement performance to a great extent depends on the sub grade soil properties and the drainage.

Climate factors

Among the climate factors, rainfall affects the moisture conditions in the sub grade and the pavement layers. The daily and seasonal variation in temperature has significance in the design and performance of rigid pavements. Where freezing temperature is prevalent during winter, the possibility of frost action in the sub grade and the damping effects should be considered at the design stage itself.

Pavement component materials

The stress distribution characteristic of the pavement components layers depends on characteristics of the materials used. The fatigue behavior of these materials and their durability under adverse conditions of weather should also be given due consideration.

Environmental factors

The environmental factors such as height of embankments and its foundations details. Depth of cutting, depth of sub surface water table, etc...Affect the performance of the pavement. The choice of the bituminous binder and the performance of the bituminous pavement depending on the variations in pavement temperature with the seasons in the region

9. Explain the steps involved in the IRC method of design of flexible pavements. (NOV/DEC 13)

The following are the steps involved in design of flexible pavements as per IRC method:

- In situ test specimens are not recommended.
- For new roads the sub grade soil specimen should be compacted to proctor density at OMC. If the compaction equipment is not available in the field, the specimen may be compacted to the expected field density.
- For the existing roads the specimen should be compacted to field density of sub grade soil at water content equal to OMC or field moisture content.
- For all new constructions the specimen should be soaked for four days prior to testing. This condition is not mandatory for arid climatic regions or regions with annual rainfall is less than 50cm or the water table is very deep or when thickness of impermeable bituminous surfacing is provided.
- At least three specimens should be tested with identical specimens. If the variation is maximum beyond the norms, then average of six specimens CBR values should be taken.

The specimen limits of maximum variation in CBR values are

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- The top 50cm of sub grade should be compacted with density equal to 95 to 100% of proctor density.
- Keeping in view the existing traffic and the anticipated growth in traffic should be calculated for at least 10 years of life period.

The following formula may be used:

$$A=P\,(1+r)^{n+10}$$

Where

A=number of heavy vehicles per day for design (laden weight>3 tonnes)
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r=annual rate of increase of heavy vehicles
n=number of years between the least count and the year of completion of constructions.

The value P has to be found for seven day heavy vehicles obtained from 24 hours count. If a reasonable value of r is not available a value of 7.5% may be assumed for rural roads.

- The traffic obtained from the above equation has to be used in choosing the appropriate design curve (A to G).
- The design thickness corresponding to a single axle load up to 8200kg and tandem axle load up to 14500kg is adopted.
- Substandard sub bases with substantial proportion of aggregates of size above 20mm should not be used in design.
- Thin layers of wearing course such as surface dressing or open graded premixed carpet up to 2.5cm thickness should not be counted towards total thickness as these materials do not contribute to the structural capacity of the pavement.

10. Determine the stresses at interior, edge and corner regions of a rigid pavement using Westergaard's method. Take P=4100KG; E=3X10^{5}kg/cm^2, h=20cm, μ=0.15, k=4.0kg/cm^2 and a=15cm. (NOV/DEC 13)

Solution:

Stresses in interior

S_t [redacted]

l [redacted]

b [redacted]

S_t [redacted]

Stress in edge

S_e [redacted]

[redacted]

[redacted] $/ cm^2$

Stress in corner

S_c [redacted]

[redacted]

Result

Stress at interior=13.55kg/cm^2
Stress at edge=20.37kg/cm^2
Stress at corner=23.03kg/cm^2