5
CHAPTER

Pavement Design

Q.1 In cement concrete pavement, the bars are provided
(a) near the top of slab across expansion joints
(b) near the bottom of slab across contraction joints
(c) at mid-depth of slab across longitudinal joints
(d) near the bottom of slab across longitudinal joints

Q.2 The subgrade soil properties of a sample are as follows:
Soil portion passing 0.075 mm sieve = 50%, liquid limit = 40%, plasticity index = 20%.
The group index of the soil is
(a) zero (b) 4
(c) 6.5 (d) 8

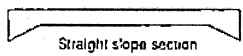
Q.3 If the pressure carried by a CBR specimen at 2.5 mm penetration is 3.5 N/mm^2, the CBR of the soil is
(a) 10% (b) 35%
(c) 50% (d) 70%

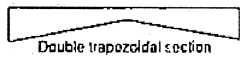
Q.4 Consider the following statements:
The failure of sub-grade of a flexible pavement is mainly attributed to
1. inadequate stability
2. loss of binding action
3. loss of base course materials
4. excessive stress concentration
Which of the statements are correct?
(a) 1 and 2 (b) 1 and 4
(c) 2 and 4 (d) 2 and 3

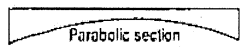
Q.5 Which one of the following statement is correct?
(a) Vertical stress are transmitted to the lower layer through the points of contact in granular structure.
(b) Vertical compressive stress is maximum on the pavement surface directly under the wheel load.
(c) Lower layers have to take lesser magnitude of stress.
(d) Stress on rigid pavements are transmitted to a wider area of sub-grade

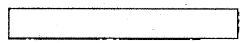
Q.6 The basic formula for determination of pavement thickness was first suggested by
(a) Spanglar (b) Picket
(c) Kelly (d) Goldbeck

Q.7 Pick up the most uncommon cross-section of cement concrete pavement from those shown in figure below:

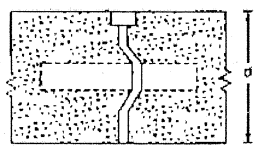
(a) 

(b) 

(c) 

(d) 

Q.8 The figure below shows the cross sectional view of



Q.20 The main drawback of CBR method is
1. it does not take fully into account the damaging effects of heavier wheel loads and their frequency
2. it does not consider whether the road is for multi lane single carriageway or dual carriage way
3. the design curve only gives the value for the total thickness of pavement for different traffic intensity and CBR value of subgrade

The correct answer is
(a) Both 1 and 2 (b) Only 3
(c) Both 2 and 3 (d) 1, 2 and 3

Q.21 The data given below pertains to the design of flexible pavement.
Initial traffic = 1500 cvpd
Traffic growth rate = 8% per annum
Design life = 12 years
Vehicle damage factor = 2.5
Distribution factor = 0.75
The design traffic in terms of million standard axles (msa) to be catered would be
(a) 18.12 msa (b) 194.81 msa
(c) 19.48 msa (d) 21.00 msa

Q.22 The maximum thickness of expansion joint in rigid pavement is
(a) zero (b) 25 mm
(c) 50 mm (d) 100 mm

Q.23 The position of base course in a flexible pavement is
(a) over the sub-base
(b) below the sub-base
(c) over the sub-grade but below the sub-base
(d) over the wearing course when renewal of surface is needed

Q.24 The load transfer to lower layers in flexible pavements is by
(a) bending action of layers
(b) shear deformation
(c) grain to grain contact
(d) consolidation of sub-grade

Q.25 The total thickness of pavement by CBR method depends on the CBR value of
(a) base course (b) surface course
(c) sub-grade (d) all layers

Q.26 The width of expansion joint gap is 2.5 cm in a cement concrete pavement. The spacing between expansion joints for a maximum rise in temperature of 25°C is (assuming coefficient of thermal expansion of concrete as 10×10^{-6} per °C)
(a) 5 m
(b) 50 m
(c) 100 m
(d) 25 m

Q.27 In reinforced cement concrete pavement, steel is placed
(a) near bottom
(b) in the middle
(c) near the top
(d) exactly at neutral axis

Q.28 Consider the following factors :
1. Magnitude of load
2. Thickness of cement concrete slab
3. Temperature distribution in the slab
4. Modulus of sub-grade reaction

Which of these should be taken into account to determine the wheel load stress at critical location in a cement concrete pavement?
(a) 1, 2 and 3 (b) 1 and 3
(c) 3 and 4 (d) 1, 2 and 4

Q.29 If the CBR value obtained at 5 mm penetration is higher than that at 2.5 mm, then the test is repeated for checking; and if the check test reveals a similar trend, then the CBR value is to be reported as the
(a) mean of the values for 5 mm and 2.5 mm penetration
(b) higher value minus the lower value
(c) lower value corresponding to 2.5 mm penetration
(d) higher value obtained at 5 mm penetration

Q.30 In the design of rigid pavement expansion and contraction joints should respectively be provided at
(a) 50 m and 32 m
(b) 50 m and 10 m
(c) 25 m and 10 m
(d) 25 m and 32 m

Q.31 If the radius of wheel load distribution is 30 cm and slab thickness is 15 cm, then the equivalent radius of resisting section is
(a) $\left(\sqrt{1.6\times(30)^2+15^2}-0.675\times15\right)$cm
(b) $\left(\sqrt{1.6\times(30)^2+15^2}+0.675\times15\right)$cm
(c) 30 cm
(d) None of the above

Q.32 Group index method of design of flexible pavement is
(a) a theoretical method
(b) an empirical method based on physical properties of sub-grade soil
(c) an empirical method based on strength characteristics of sub-grade soil
(d) a semi-empirical method

Q.33 Consider the following pairs
1. Rigid pavements—Temperature warping stress
2. Flexible pavement—Provision of joints
3. CBR chart-Thickness of rigid pavements
4. Burmister analysis—Two layer classic theory

Which of these pairs are correctly matched?
(a) 1 and 4 (b) 1, 3 and 4
(c) 2 and 3 (d) 3 and 4

Q.34 For a given wheel load (p) in kgs, slab thickness (h) (cms), radius of resisting thickness (b) (cms), radius of relative stiffness (l) in cms and if S_i, S_e and S_c are critical stress on a rigid pavement at interior, edge and corner loading's respectively, then
(a) $S_i > S_e > S_c$ (b) $S_c > S_e > S_i$
(c) $S_e > S_i > S_c$ (d) $S_c > S_i > S_e$

Q.35 A pavement is classified as flexible or rigid based on
(a) Wearing course (b) Base course
(c) Sub-base (d) Sub-grade

Q.36 The bulk specific gravity of bituminous mix is 2.33, theoreticate specific gravity is 2.43. The percentage of bitumen in the mix is 4% by weight with specific gravity 1.
The percentage voids in bitumen (VFB) will be
(a) 78% (b) 68%
(c) 62% (d) 60%

Q.37 A new four lane highway (with two lanes on each side of median) is to be constructed on subgrade of CBR 1.8%. The ADT of commercial truck traffic based on the last count was 8000 (in both the directions). The directional split of traffic is 55:45. Vehicle damage factor was 40. Pavement section to be designed for life of 15 years. The last traffic count was taken 1 year back and the project would be completed 2 years from now. Growth rate of traffic = 7%. The design cumulative standard axles on the road will be
(a) 98 MSA (b) 190 MSA
(c) 148 MSA (d) 132 MSA

Q.38 The equivalent radius resisting section of 15 cm slab, if ratio of radius of wheel load distribution to thickness of slab is 0.5 is;
(a) 4.62 cm (b) 6.62 cm
(c) 5.62 cm (d) 7.62 cm

Q.39 The pavement thickness is 20 cm and width of road is 7 m with one longitudinal joint. The unit weight of concrete is 2400 kg/m^3, the coefficient of friction is 1.5, allowable working tensile stress in steel is 1750 kg/cm^2 and bond stress of deformed bars is 24.6 kg/cm^2. The length of bar and spacing of tie bar is:
(a) 36 cm, 45 cm (b) 46 cm, 55 cm
(c) 56 cm, 65 cm (d) 36 cm, 55 cm

Q.40 In case of governing equation for calculating wheel load stress using Westerguard's approach, the following statements are made
1. Load stresses are inversely proportional to wheel load

II. Modulus of subgrade reaction is useful for load stress calculation.

(a) Both statement are true
(b) I is true and II is false
(c) Both statement are false
(d) I is false and II is true

Q.41 In a benkelman beam study, the corrected characteristic rebound deflection on a pavement is found as 3 mm. As per IRC guidelines the allowable deflection is 1 mm. The equivalent granular overlay thickness required for the deflection is

(a) 63 mm (b) 263 mm
(c) 163 mm (d) 183 mm

Q.42 The total cross-sectional area of longitudinal reinforcing steel which is required for a cement concrete pavement slab 3.75 m wide 15 m long and 200 mm thick is
(Assume unit weight of concrete 2400 kg/m^3, working stress in steel is 1400 kg/cm^2, coefficient of friction = 1.5).

(a) 1210 mm^2 (b) 1600 mm^2
(c) 1446 mm^2 (d) 1816 mm^2

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Answers Pavement Design

1. (c)	2. (c)	3. (c)	4. (b)	5. (b)	6. (d)	7. (b)	8. (b)	9. (a)	10. (c)
11. (d)	12. (c)	13. (b)	14. (d)	15. (a)	16. (a)	17. (a)	18. (d)	19. (d)	20. (c)
21. (c)	22. (b)	23. (c)	24. (c)	25. (a)	26. (a)	27. (b)	28. (d)	29. (d)	30. (c)
31. (c)	32. (b)	33. (a)	34. (a)	35. (a)	36. (b)	37. (c)	38. (d)	39. (d)	40. (d)
41. (b)	42. (c)								

Explanations Pavement Design

2. (c)
$a = 50 - 35 = 15$
$b = 50 - 15 = 35$
$c = 40 - 40 = 0$
$d = 20 - 10 = 10$
$GI = 0.2\,a + 0.005\,ac + 0.01\,bd$
$= 0.2 \times 15 + 0.005 \times 15 \times 0 + 0.01 \times 35 \times 10$
$= 6.5$

3. (c)
$$CBR = \frac{3.5 \times 100 \times 100}{70 \times 10} = 50\%$$

4. (b)
Two basic reasons for failure of sub-grade are: (i) Inadequate stability (ii) Excessive stress application.

14. (d)
The service life of cement concrete pavement may be assumed to be 20 to 40 years, that of bituminous concrete be 10 to 15 years and other bituminous surfaces including surface dressing be 3 to 10 years. The water bound macadam has a service life of 2 to 6 years and the low cost surfaces, 2 to 4 years.

16. (a)
$$\text{Rigidity factor} = \frac{\text{Contact pressure}}{\text{Tyre pressure}}$$
= 1 for tyre pressure = 7 kg/cm^2
>1 for tyre pressure < 7 kg /cm^2
<1 for tyre pressure > 7 kg/cm^2

21. (c)
Design Traffic = $365\,A((1 + r)^n - 1) \times F$
$$= \frac{365 \times 1500 \times 0.75\left[(1+0.08)^{12} - 1\right] \times 2.5}{0.08}$$
= 19.48 msa

22. (b)
Expansion joints are provided to allow for expansion of the slabs due to rise in slab temperature. The approximate gap width for this type of joint is from 20 to 25 mm.

23. (c)
Flexible pavements are those, which on the whole have low or negligible flexural strength and are flexible in their structural action under the loads. The flexible pavement layers reflects the deformation of the lower layers on-to the surface of the layer. The flexible pavement layers transmit the vertical or compressive stresses to the lower layers by grain to grain transfer through the points of contact in granular structure.

26. (a)
$\delta_1 = 2.5/2 = 1.25$ cm
$t_2 - t_1 = 25°C$
Coefficient of thermal expansion
$C = 10 \times 10^{-6}$ per°C
∴ Spacing of expansion joint,
$$L = \frac{\delta_1}{1000C(t_2 - t_1)}$$
$$= \frac{1.25}{1000 \times 10 \times 10^{-6} \times 25} = 5 \text{ metre}$$

27. (b)
The reinforcement used in cement concrete pavement is in the form of welded wire fabric or bar mats. The function of reinforcement is to hold the cracked slab portions together and thus not to allow them to open up any more. In order to obtain the maximum advantage, it is suggested that greater quantity of the reinforcement should be placed in the longitudinal direction. Further the reinforcement should either be placed in the mid-depth or towards the top of the pavement for better functioning.

28. (d)
To determine wheel load stress at critical location
- Magnitude of load (P)
- Thickness of slab (h)
- Radius of wheel load distribution (a), radius of relative stiffness (l) and radius of resisting section (b) are needed.

'a', 'b' and 'l' depend upon modulus of sub-grade reaction.

29. (d)
The average CBR value of three test specimens is reported to the first decimal place, as the CBR value of the test specimen. If the maximum variation in the CBR values of these specimens exceeds specified limits (3% for CBR up to 10%; 5% for CBR 10 to 30% and 10% for CBR 30-60%), then the design CBR should be the average of at least six specimens.

31. (c)
Because the radius of wheel load distribution is more than 1.724 times slab thickness, hence radius of resisting section is equal to the radius of wheel load distribution.

$\because \frac{a}{h} < 1.724$ or > 1.724
$\therefore$ R = Radius of wheel distribution

32. (b)
The GI method of pavement design is essentially an empirical method based on physical properties of the sub-grade soil. This method does not consider the strength characteristic of the sub-grade soil.

35. (a)
Both flexible and rigid pavements have same base course, subbase course and soil subgrade, but surface (wearing) courses are different. So pavements are classified on the basis of wearing course.

36. (b)
$$\text{Air voids, } V_a = \frac{G_t - G_m}{G_t} \times 100$$
$$= \frac{2.4 - 2.33}{2.43} 100 = 4.11\%$$
% volume of bitumen,
$$V_b = G_m \times \frac{W_b}{G_b}$$
$$= 2.33 \times \frac{4}{1} = 9.32\%$$
Percentage voids in mineral aggregate,
VMA = $V_a + V_b$
= 4.11 + 9.32 = 13.43%

Percentage voids filled with bitumen (VFB)

$$= \frac{100g}{VMA} = \frac{100 \times 9.32}{13.62}$$

$$= 68.43\%$$

37. (c)

4-lane divided carriage way ADT of trucks in the last count = 8000 cvpd

Growth rate = 7%

ADT of commercial trucks in the year of completion of construction.

$$A = 8000(1 + 0.07)^{1+2}$$

$$= 9800 \text{ cvpd}$$

Design life = 15 years

VDF = 4.0

Directional distribution factor,

$$D = 0.55$$

(Use maximum of the two)

Lane distribution factor,

$$L = 0.75$$

Vehicle damage factor = 4

Cumulative number of standard axles during design life of 15 years

$$N = \frac{365\left\{(1+0.07)^{15} - 1\right\}}{r}(9800 \times 0.55) \times 0.75 \times 4$$

$$\Rightarrow \quad N = 148 \text{ msa}$$

38. (d)

$$h = 15 \text{ cm}, \frac{a}{h} = 0.50$$

$$a = 0.5 \times 15 = 7.5 \text{ cm}$$

Now, $b = \sqrt{(1.6a^2 + h^2)} - 0.675h$

$$= \sqrt{1.6(7.5)^2 + (15)^2} - 0.675 \times 15$$

$$\Rightarrow \quad b = 7.62 \text{ cm}$$

39. (d)

Diameter and spacing:

$$A_s = \frac{3.5 \times 20 \times 2400 \times 1.5}{100 \times 1750}$$

$$= 1.44 \text{ cm}^2/\text{m}$$

Assume diameter of steel bar,

$$\phi = 1 \text{ cm}$$

$$A = \frac{\pi}{4}(1)^2 = 0.785 \text{ cm}^2$$

Therefore, spacing is

$$\Rightarrow \quad \frac{100 \times 0.785}{1.44} = 54.57 = 55 \text{ cm}$$

Length of tie bar

$$L_t = \frac{1 \times 1750}{2 \times 24.6} = 36 \text{ cm}$$

40. (d)

Westerguard equation for interior loading

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

$$\Rightarrow \quad \sigma_i \propto P$$

41. (b)

As per IRC guidelines,

Overlay thickness,

$$h = 550\log_{10}\left(\frac{D_c}{D_a}\right)$$

where, D_c = Characteristic corrected deflection

D_a = Allowable deflection

$$= 550\log_{10}\left(\frac{3}{1}\right)$$

$$\Rightarrow \quad h = 263 \text{ mm}$$

42. (c)

$$A_s \times S_s = f \times b \times \frac{L_c}{2} \times \frac{h}{100} \times \gamma$$

$$\therefore \quad A_s = \frac{bhf\gamma L_c}{200 S_s}$$

$$\therefore \quad A_s = \frac{1.5 \times 3.75 \times 20 \times 2400 \times 15}{200 \times 1400}$$

$$= 14.40 \text{ cm}^2$$

where, S_s = Allowable working stress in steel.

A_s = Area of steel/metre length of joint in cm^2

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