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CONTENTS

CHAPTER - 1
INTRODUCTION

1.1 DEVELOPMENT OF HIGHWAY

1.1.1 Roman Roads

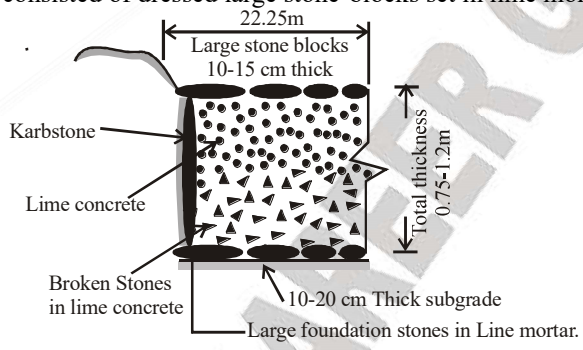
During this period of Roman civilization many roads were built of stone blocks of considerable thickness. Main features of the Roman roads

1.They were built straight regardless of gradients.

2.They were built after the soft soil was removed and a hard stratum was reached.

3.The total thickness of the construction was *as* high as 0.75 to 1.2 metres at some places even though the magnitude of wheel loads of animal drawn vehicles was very low.

4.The wearing course consisted of dressed large stone-blocks set in lime mortar.

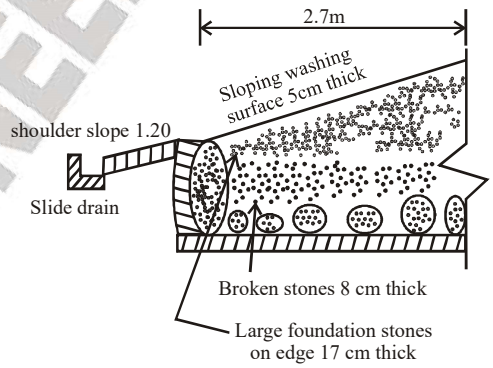


1.1.2 Tresaguet Construction

1. Pierre Tresaguet (1716-1796) developed an improved method of construction in Prance by the year 1764, A.D.

2. The-main-feature of his proposal was that the thickness of construction need to be only in the order of 30 cm.

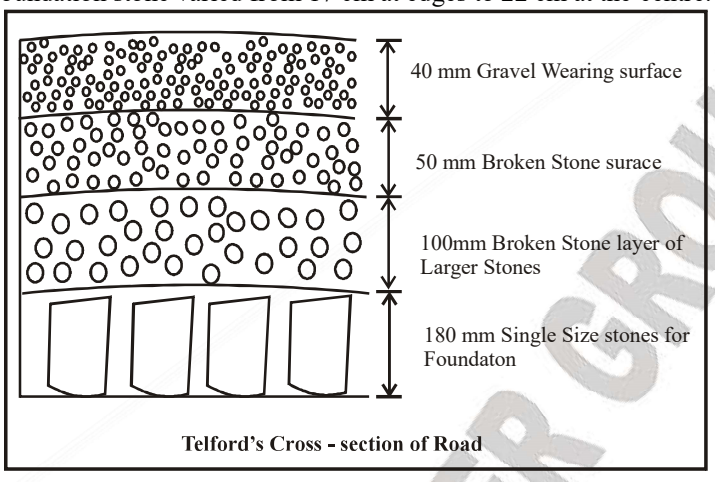
3. Due consideration was given by him to subgrade moisture condition and drainage of surface water.



1.1.3 Telford Construction

1.Telford provided level subgrade of width 9 meters

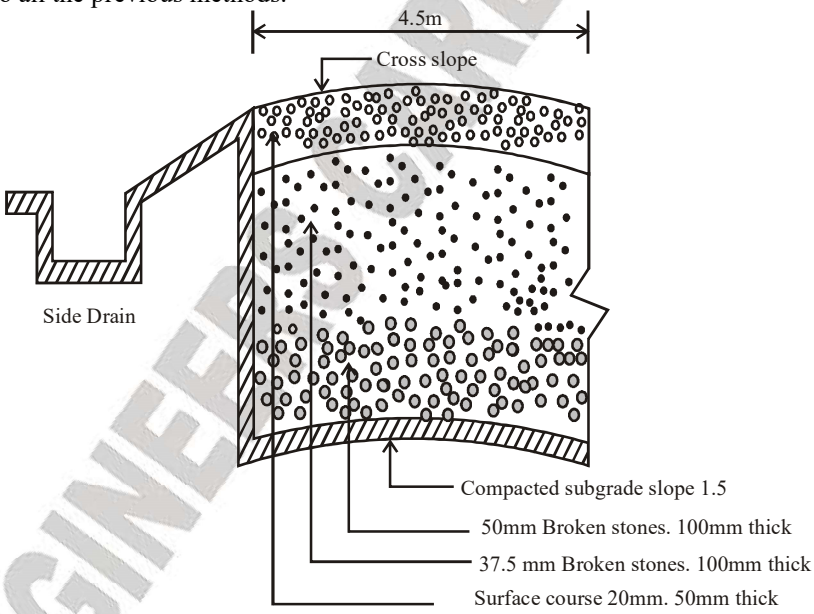
2.A binding layer of wearing course 4 cm thick was provided with cross slope of 1 in 45.
3.Thickness of foundation stone varied from 17 cm at edges to 22 cm at the centre.



Telford's Cross - section of Road

1.1.4 Macadam Construction

1.John Macadam (1756-1836) put forward an entirely-new method of road construction as compared to all the previous methods.



British Roads

2. Macadam was the first person who suggested that heavy foundation stoues are not at all read to be placed at the bottom layer. He provided stones of size less than 5 mm to a uniform thickness of 10 cm. The importance to subgrade drainage and compaction was given so the subgrade was compacted and 'prepared with cross slope of 1 in 36.

3. The size of broken stone for the top layers was decided on the basis of stability under animal drawn vehicles.
4. The pavement surface was also given the cross slope of 1 in 36.
5. Total thickness was kept uniform form edge to centre to a minimum value of 25 cm.

1.2 EARLY DEVELOPMENTS IN HIGHWAY PLANKING IN INDIA

1.2.1 Jayakar Committee

Since 1853, rail transport was mainly used for long distance transportation, and roads acted as a feeder service to the railways. After First World War, as the motor cars came on the roads, the inadequacy of the existing road network came into light.
Hence, in 1927, the government appointed a Road Development Committee headed by. Mr. M.R. Jayakar

1.2.1.1 Recommendations of the Jayakar Committee

1.Committee suggested that Central government should take the proper charge of road considering it as a matter of national interest.
2.They gave more stress on long term planning programme, for a period of 20 years (hence called twenty year plan).
3.They suggested the holding of periodic road conferences to discuss about road construction and development. This paved the way for the establishment of a semi-official, technical body called Indian Road Congress (IRC) in. 1334.
4.They suggested imposition of additional taxation oh motor transport which included duty on motor spirit, vehicle taxation, license fees for vehicles plying for hire. This led to the introduction of a development fund called Central toad fund (CRF) in 1929. Road development in the country was beyond the financial capacity of local governments; and .therefore, the central revenue should support it.
5.They suggested a dedicated research organization to carry out research and development work. This resulted in the formation of Central Road Research Institute (CRRI) in 1950.

1.3 INDIAN ROADS CONGRESS

Indian Roads Congress (IRC) was established in 1934 with the following objectives
1.To promote and encourage the science and practice of road building and maintenance.
2.To provide a forum for expression of collective opinion of its members on matters affecting roads.
3.To promote the use of standard specifications and practices.
4.To advise regarding education, experiment and research connected with roads.
5.To hold periodic meetings to discuss .technical questions regarding roads.
6.To suggest legislation for the development, improvement and protection of roads.
7.To suggest improved -methods of administration, planning, design, operation, use and maintenance of "roads.
8.To establish, furnish and maintain libraries and museums for furthering the science of road making.

1.3.1 The Nagpur Plan (1943-63)

1.Due to the overall economic depression in the country after First World War, the Road Development Fund was not used for development work, but spent in routine maintenance. This caused further deterioration of the roads under the impact of the heavy war time traffic.
2.At this point of time. Conference of Chief Engineers of the Provinces -was convened at Nagpur In 1843.

CHAPTER - 2
GEOMETRIC DESIGN

2.1 INTRODUCTION

1.A highway has many visible dimensions both in the horizontal plane and in the vertical plane. The art of design of the visible dimensions is known as Geometric Design.

2.Proper geometric design will help in the reduction of accidents and their serverity. Therefore, the objective of geometric design, is the provide optimum efficiency in traffic operation and maximum safety at reasonable cost.

3.Highway Geometric Design covers elements such as design vehicle dimensions, user characteristics, terrain, highway classification, design speed, horizontal curves, vertical curves, gradient, sight distances, cross-sectional features, junctions, interchange etc.

2.2 FACTORS CONTROLLING GEOMETRIC DESIGN

Geometric design is influenced by a number of factors such as.

1. Road user characteristics
2. Vehicle characteristics
3. Safety requirements
4. Environmental considerations
5. Economy in construction, maintenance and operation of vehicles
6. Topography
7. Functional classification of roads
8. Traffic volume and composition
9. Design speed

Safety, environmental needs and economy are built into various elements of design. The remaining factors has been discussed as given below.

1. Road User Characteristics

(i)A driver takes a certain amount of time to respond to a particular traffic situation. This can be called as reaction time.

(ii) The action of applying break on seeing a vehicle or obstruction on the road is not an instantaneous phenomenon. But it is a time-consuming phenomenon based on the psychological process involved.

(iii) We can call these processes, as perception, intellection, emotion and volition (PIEV)

(iv) Perception Time is the time required for transmission of the sensations received through eyes, ears and body to the brain and the spinal chord by the nervous system. After perception intellection occurs, that is the formation of new thoughts and ideas. Recalling old memories of similar occasion.

(v) Linked with these two stages is emotion, based on the situation, tike fear or anger. This has vital influence on the final message or decision sent by the brain to the muscle. This actual act of taking a decision to produce action is done through *volition* time.

(vi) The total time required for PIEV. that is, from the instant the object comes in the line of sight of the driver to the instant he arrives at a decision, sav, to slow down or to overtake under normal circumstance is called *reaction time.*

(vii) This could vary from 0.5 second for simple situations to 3 to 4 seconds for complex situation. The reaction time is affected by the condition of the driver fatigue, disease, alcohol consumption

WORKBOOK

Example 1. According to 1981 census, the area of State of Maharashtra was 308, sq. km. The number of town's population above 5,000 was 567. The total number of towns and village was 35,778 Determine the length of various road categories.

Solution.

Length of National Highway = $\frac{\text{Area}}{50} = \frac{308,000}{50} = 6,160\,\text{km}$

Length of State Highway = $\frac{\text{Area}}{25} = \frac{308,000}{25} = 12,320\text{km}$

Or = 62.5 × No. of towns above = 500 population $- \frac{\text{Area}}{50}$

= 62.5 × 567 – 6,160 = 35,438 – 6,160 = 29.278 km

Length of Major District Roads Length = $\frac{\text{Area}}{12.5} = \frac{308,000}{12.5} = 24,640\text{km}$

Length = 90 × Number of towns and villages with population above = 5000

= 90 × 567 = 51,030 km

Length of Total road = 4.74 × Number of towns and villages

= 4.74 × 35,778 = 1,69,587 km

Length of Rural Road = 1,69,587 – (6,160 + 12,320 + 24,640)

= 1,69,587 – 43,120 = 1,26,467 km

Example 2. Determine the (1) Length of National Highways, State Highways and Major District Roads and (2) Length of other District Roads and village Roads for a state with the following details as per the Nagpur plan

1. Agricultural- Area in sq km = *40,000*
2. Non-agricultural area in sq km = 20,000
3. Number of towns and village

Population over 5000 ---------- 50
Population 200 -5000 ----------75
Population 100 - 2000 ----------120
Population 501 – 1000 ---------- 2000
Population less than 500 --------- 1000

4. Length of Railways = 1500 km

Solution.

Length of NH, SH. MDR

$= \frac{A}{5} + \frac{B}{20} + N + 5T + D - R$

The above formula is in FPS system. The length in km is given by suitably changing the formula as under .

Length (km) = $\frac{A \times 1.6}{(1.6 \times 1.6)5} + \frac{B \times 1.6}{(1.6 \times 1.6)20} + 1.6N + 5 \times 1.6T + D - R$

where A and B are .in sq. km.

Substituting the given values,

Length of HN, SH and MDR = $\frac{40,000 \times 1.6}{1.6 \times 1.6 \times 5} + \frac{20,000 \times 1.6}{1.6 \times 1.6 \times 20} + 1.6N + 5 \times 1.6T + D - R$

= 5000+ 625+ 120 + 400 + D + R

Assume D = 15%

Length = 6145 + 922 – R = (7067 – R) km

= 7067 – 1500 = 5567 km

Length of ODR and VR = $\frac{V}{5} + \frac{Q}{2} + R + 2S + D$

This formula gives length in miles. The length in km is given by

$= 1.6\left(\frac{V}{5} + \frac{Q}{2} + R + 2S\right) + D$

$= 1.6\left(\frac{1000}{5} + \frac{2000}{2} + 120 + 2 \times 75\right) + D$

= 3200 + 1600 + 192′ + 240 + D = 5232 + D

Taking D = allowance for future development as 15%

Length of ODR and VR = 5232 + 785 = 6017 km

CHAPTER - 3
TRAFFIC ENGINEERING

3.1 INTRODUCTION

The basic objective of traffic engineering is to achieve free & rapid flow of traffic with least no. of accidents. For this various studies are carried out. These studies are divided into

1. Traffic characteristics
2. Traffic studies and analysis
3. Traffic control regulation

Based on these studies traffic planning & geometrical design will be done.

3.1.1 Traffic Characteristics

Study of traffic characteristics is the most important, for any improvement of traffic facilities.
In traffic characteristics, we generally study

1. Road user characteristic
2. Vehicular characteristic
3. Breaking characteristic

1. Road User Characteristics

It is important to study the characteristics and limitations of road users because the physical mental and emotional characteristics of human beings affect their ability.
Factors affecting road user characteristics are

(i)Physical. Vision, hearing, strength and General reaction to traffic situations.
(ii)Mental. Knowledge, skill, intelligence, experience and literacy.
(iii)Psychological. Attentiveness, fear, anger, superstition, impatience, general attitude towards traffic and regulations and maturity.
(iv)Environmental. Facilities to the traffic, atmospheric condition and locality.

2. Vehicular Characteristics

The study of vehicular characteristics affects the design and traffic performance.

(i) Vehicle dimensions

(a) Vehicle dimensions mainly considered are the overall width, height, and length of different vehicles, particularly of the largest ones.
(b) The width of the vehicle affects the width of the traffic lanes, shoulders and parking facilities.
(c) Height of the vehicle affects the clearance to be provided under structures such as overbridges underbridges, electric and other service lines.
(d) Length of the vehicle is an important factor in the design of horizontal alignment as it effects the extra width of pavement and minimum turning radius. Length affects the safe overtaking distance, capacity of a road and parking facilities.

(ii) Weight of Loaded Vehicle

The maximum weight of loaded vehicle affects the design of pavement thickness and gradients. In fact the limiting gradients are governed by both the weight and power of the heavy vehicles.

GATE QUESTIONS

1. A priority intersection has a single-lane one-way traffic road crossing an undivided two-lane two-way traffic road. The traffic stream speed on the single-lane road is 20 kmph and the speed on the two-lane road is 50 kmph. The perception-reaction time is 2.5 s, coefficient of longitudinal friction is 0.38 and acceleration due to gravity is 9.81 m/s^2. A clear sight triangle has to be ensured at this intersection. The minimum lengths of the sides of the sight triangle along the two-lane road and the single-lane road, respectively will be

[GATE - 2018]

(a) 50 m and 20 m (b) 61 m and 18 m
(c) 111 m and 15 m (d) 122 m and 36 m

2. A 7.5 m wide two-lane road on a plain terrain is to be held along a horizontal curve of radius 510 m. For a design speed of 100 kmph, super-elevation is provided as per IRC : 73-1980. Consider acceleration due to gravity as 9.1 m/s^2. The level difference between the inner and outer edges of the road (in m, up to three decimal places) is _____.

[GATE - 2018]

3. A car follows a slow moving truck (travelling at a speed of 10 m/s) on a two-lane two-way highway. The car reduces its speed to 10 m/s and follows the truck maintaining a distance of 16 m from the truck. On finding a clear gap in the opposing traffic stream, the car accelerates at an average rate of 4 m/s^2, overtakes the truck and returns to its original lane. When it returns to its original lane, the distance between the car and the truck is 16 m. The total distance covered by the car during this period (from the time it leaves its lane and subsequently returns to its lane after overtaking) is

[GATE - 2018]

(a) 64 m (b) 72 m
(c) 128 m (d) 144 m

4. While aligning a hill road with a ruling gradient of 6%, a horizontal curve of radius 50m is encountered. The grade compensation (in percentage, up to two decimal places) to be provided for this case would be ____.

[GATE - 2017]

5. The radius of a horizontal circular curve on a highway is 120m. The design speed is 60km/hour, and the design coefficient of lateral friction between the tyre and the road surface is 0.15. The estimated value of superelevation required (if full lateral friction is assumed to develop), and the value of coefficient of friction needed (if no superelevation is provided) will, respectively, be

[GATE - 2017]

(a) $\frac{1}{11.6}$ and 0.10 (b) $\frac{1}{10.5}$ and 0.37
(c) $\frac{1}{11.6}$ and 0.24 (d) $\frac{1}{12.9}$ and 0.24

6. A motorist traveling at 100 km/h on a highway needs to take the next exit, which has a speed limit of 50 km/h. The section of the roadway before the ramp entry has a downgrade of 3% and coefficient of friction (f) is 0.35. In order to enter the ramp at the maximum allowable speed limit the braking distance (expressed in m) from the exit ramp is_____.

[GATE - 2016]

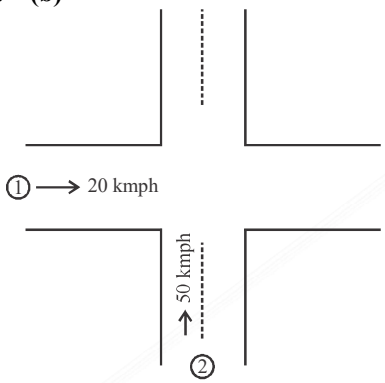
7. A superspeedway in New Delhi has among the highest super-elevation rates of any track on the Indian Grand Prix circuit. The track requires drivers to negotiate turns with a radius of 335 m and 33° banking. Given this information, the coefficient of side friction required in order to allow a vehicle to travel at 320 km/h along the curve is

[GATE - 2015]

(a) 1.761 (b) 0.176
(c) 0.253 (d) 2.530

SOLUTIONS

Sol. 1. (b)

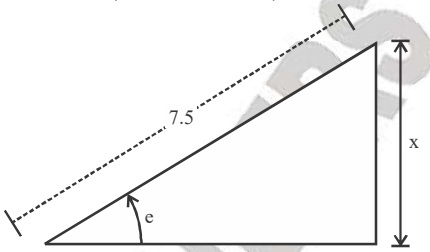


$$SSD_2 = 0.278 \times Vt_R + \frac{V^2}{254f}$$

$$= 0.278 \times 50 \times 2.5 + \frac{50^2}{254 \times 0.38} \simeq 61\,m$$

$$SSD_1 = 0.278 \times 20 \times 2.5 + \frac{20^2}{254 \times 0.38} \simeq 18\,m$$

Sol. 2. 0.525(0.523 to 0.528)



$$e = \frac{V^2}{225R} = \frac{100^2}{225 \times 510} = 0.0871 \not> 0.07 = \tan\theta$$

$\sin\theta \simeq 0.07$

$x = 7.5 \times \sin\theta = 0.525$ m

Sol. 3. (b)

Overtaking time, $T = \sqrt{\frac{4S}{a}} = \sqrt{\frac{4 \times 16}{4}} = 4$ sec.

S = Space heady way = 16 m

a = acceleration = 4 m/s^2

Distance travelled by vehicle = S_2

$$S_2 = uT + \frac{1}{2}aT^2 = 10 \times 4 + \frac{1}{2} \times 4 \times 4^2 = 72\,m$$

Sol. 4. (1.5)

Ruling gradient, G = 6% (> 4% grade compensation is allowed as per 1Rc)

Radius Of curve, R = 50m

Grade compensation, $GC = \frac{30 + R}{R}$

$$= \frac{30 + 50}{50} = 1.6\%$$

$$= = \frac{75}{R} = \frac{75}{50} = 1.5$$

$\therefore$ Use min value of GC = 1.5%

Sol. 5. (c)

Design speed, R = 120m

Design speed, V = 60 km/hr (16.67 m/s)

Coefficient of lateral friction, f = 0.15

(i) Superelevation for the development of full friction

$$e + f = \frac{V^2}{gR} \rightarrow e + 0.15 = \frac{16.67^2}{9.87 \times 120}$$

$$e = 0.086 = \frac{1}{11.63} \simeq \frac{1}{11.6}$$

(ii) For no superelevation coefficient of friction required is $e + f = \frac{v^2}{gR}$

$$0 + f = \frac{16.67^2}{9.81 \times 120}$$

F = 0.236 = 0.24

Sol. 6. (92.14)

Downward gradient, N = - 3%

f = 0.35

$$S_b = \frac{(v_i)^2 - (v_f)^2}{2g(f - N)}$$

ESE OBJ QUESTIONS

1. The rate of equilibrium superelevation on a road is
(1) Directly proportional to the square of vehicle velocity
(2) Inversely proportional to the radius of the horizontal curve
(3) Directly proportional to the square of the radius of the horizontal curve
Which of the above statements are correct?
[ESE - 2018]
(a) 1 and 2 only (b) 1 and 3 only
(c) 2 and 3 only (d) 1, 2 and 3

2. The following purposes served by a trasnistion curve in a highway alignment include.
1.Gradual introduction of the centrifugal force on moving vehicles from zero on the straight alignment to aconstant final value on the circular curve.
2.Enabling the gradual introduction of superelevation on the roadway.
Select the correct answer using the codes givehn below.
[ESE - 2017]
(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) neither 1 nor 2

3. The radius of a horizontal circular curve is 480 m and design speed therein 70 kmph. What will be the equilibrium super elevation for the pressure on the inner and the outer wheels to be equal?
[ESE - 2015]
(a) 5% (b) 6%
(c) 7% (d) 8%

4. Which one of the following items of hill road construction does not help in the prevention of landslides during the monsoon season?
[ESE - 2015]
(a) Breast walls
(b) Hair-pin
(c) Catch-water drains
(d) Retaining walls

5. What will be the non-passing sight distance on a highway for a design speed of 100 kmph when its ascending gradient is 2%? Assuming coefficient of friction as 0.7 and brake efficiency as 50%.
[ESE - 2015]
(a) 176 m (b) 200 m
(c) 150 m (d) 185 m

6. A descending gradient of 4% meets an ascending grade of 1 in 40 where a valley curve of length 200 m is to be formed. What will be the distance of the lowest point on the valley curve from its first tangent point?
[ESE - 2015]
(a) 100 m (b) 111 m
(c) 125 m (d) 118 m

7. In an area of heavy rainfall, a State Highway of (14.0 m wide) is to be constructed. What will be the height of the crown of the road relative to the edges for a composite camber (i.e. middle half as parabolic and the rest as straight lines)?
[ESE - 2015]
(a) 14 cm (b) 21 cm
(c) 28 cm (d) 7 cm

8. A four-lane divided highway, with each carriageway being 7.0 m wide, is to constructed in a zone of longitudinal slope of 3% and is provided a camber of 2%. What is the hydraulic gradient on this highway in this stretch?
[ESE - 2015]
(a) 4.0% (b) 3.6%
(c) 4.5% (d) 3.0%

9. The maximum super elevation t0 be provided on a road curve is 1 in 15. If the rate of change of super elevation is specified as 1 in 120 and the road width is 10 m, then the minimum length of the transition curve on each end will be
[ESE - 2015]

SOLUTIONS

Sol. 1. (a)
Correct option is (a)
Rate of equilibrium superelevation.

$$e = \frac{v^2}{gR}$$

Thus, statement (3) is incorrect

Sol. 2. (c)
Transition curve in a highway alignment is provided to include
1.Gradual introduction of the centrifugal force between the tangent point on straight curve zero to max on circular curve.
2.To enable the driver turn the steering gradiually for has own comfort and security.
3.To provide gradual introduction of super elevation.
4.To provide gradual introduction of extrawidening.
5.To enhance the aesthetic appearance of the road.

Sol. 3. (d)
Equilibrium super elevation

$$e = \frac{V^2}{127R} = \frac{70^2}{127 \times 480} = 0.08 \text{ i.e. } 8\%$$

Sol. 4. (b)

Sol. 5. (a)

$$SSD = 0.278\ Vt + \frac{V^2}{254(kf + S\%)}$$

$$= 0.278 \times 100 \times 2.5 + \frac{100^2}{254(0.5 \times 0.7 + 0.02)}$$

= 175.9 m

Sol. 6. (b)

$$x = L\left(\frac{n_1}{2N}\right)^{1/2}$$

x = Horizontal distance from end of first tangent point to the lowest point in meters.
n_1 = Natural tangent of first tangent.
$N = n_1 + n_2$

$$= \left|-\frac{4}{10} - \frac{1}{40}\right| = 0.065$$

$$x = 200\left(\frac{0.04}{2 \times 0.065}\right)^{1/2} = 110.94 \simeq 111 \text{ m}$$

Sol. 7. (a)
Camber to be provided for state highway is 1 in 50.
$\therefore$ Height of the crown

$$= \left(\frac{14}{2}\right) \times \frac{1}{50} \times 100 \text{ cm} = 14 \text{ cm}$$

Sol. 8. (a)
Hydraulic gradient is twice of camber.
Given, camber = 2%
$\therefore$ Gradient = 2 × 2% = 4%

Sol. 9. (c)
Length of transition curve based on rate of change of super elevation is,
L = eNw

$$L = \frac{1}{15} \times 120 \times 10 = 80 \text{ m}$$

Sol. 10. (c)
Data given
V = 60 kmph
R = 800 m

$$e = \frac{V^2}{127R} = \frac{(60)^2}{127 \times 800}$$

= 0.03543

and $e = \tan\theta = \frac{y}{x}$

$$\therefore \frac{y}{x} = e = 0.3543$$

CHAPTER - 4
HIGHWAY MATERIALS

4.1 INTRODUCTION

1.CBR test, an empirical test, has been used to determine the material properties for pavement design.
2.Empirical tests measure the strength of the material and are not a true representation of the resilient modules.
3.It is a penetration test wherein a standard piston, having an area of 19.62 cm^2 (or 50 mm dia.) is used to penetrate the soil at a std. rate of 1.25 mm/min. The pressure up to a penetration of 12.5 mm and its ratio to the bearing value of a std. crushed rock is termed as the CBR.
4.In most cases, CBR decreases as the penetration increases.
5.The ratio at 2.5 mm penetration is used as the CBR.
6.In some case, the ratio at 5 mm may be greater than that at 2.5 mm. If this occurs, the ratio at 5 mm should be used if confirmed by repeating the test.
7.The CBR is a measure of resistance of a material to penetration of standard plunger under controlled density and moisture condition. The test may be conducted in re – moulded or undisturbed specimen in laboratory. It is extensively used for filed correlation of flexible pavement thickness requirements.

4.2 TEST PROCEDURE

1.The laboratory CBR apparatus consists of a mould 150 mm dia with a base plate and a collar, a loading frame & dial gauges for measuring the penetration values and the expansion on soaking.
2.The specimen in the mould is soaked in water for four days and the swelling and water absorption values are noted.
3.Load is applied on the sample by a standard plunger with dia of 50 mm at the rate of 1.25 mm/min. A load penetration curve is drawn.
4.The load values on standard crushed stones are 1370 kg (70 kg/cm^2) and 2055 kg (105 kg/cm^2) at 2.5 mm and 5.0 mm penetrations respectively.
5.CBR value is expressed as a percentage of the actual load causing the penetrations of 2.5 mm or 5.0 mm to the standard loads mentioned above. Therefore,

$$\text{CBR} = \frac{\text{load carried by specimen}}{\text{load caried by standard specimen}} \times 100$$

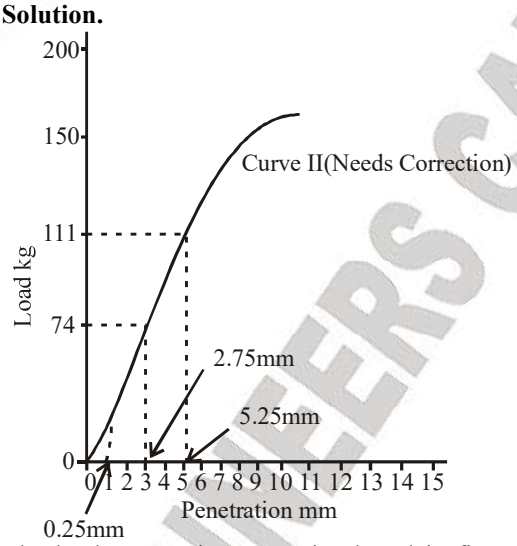
6.Two values of CBR will be obtained. If the value of 2.5 mm is greater than that of 5.0 mm penetration, the former is adopted.
7.If the CBR value obtained from test at 5.0 mm penetration is higher than that at 2.5 mm, then the test is to be repeated for checking.
8.If the check test again gives similar results, then higher value obtained at 5.0 mm penetration is reported as the CBR value.
9.The average CBR value of three test specimens is reported as the CBR value of the sample.

WORKBOOK

Example 1. Load and penetration values from a CBR test are given below. Calculate the CBR value.

Penetration	Load (kg)
0	0
0.5	7
1.0	24
1.5	41
2.0	59
2.5	70
3	81
4	98
5	110
7.5	129
10	143
12.5	150

Solution.



The load penetration curve is plotted in figure (Curve II). The observation need correction. The tangent to the curve meets the x – axis at the value of 0.25 mm. The origin needs shifting by this amount. Thus, the loads at 2.5 mm and 5.00 mm penetration are 74 and 111 kg respectively.

CBR value from 2.5 mm penetration = $\frac{74}{1370} \times 100 = 5.4$

CBR value from 5.00 mm penetration $= \frac{111}{2055} \times 10 = 5.4$

The CBR value is 5.4 percent.

Example 2. Plate bearing tests conducted on a 30 cm dia plate yielded the following observations.

Load	Settlement (mm)
270	0.25
580	0.50
770	0.75
1010	1.00
1260	1.25
1480	1.50
1690	1.75

Determine the k value corresponding to a plate of 75 cm diameter.

Solution.

At a settlement of 1.25 mm, load = 1260 kg

Loading stress, $p = \frac{1260}{0.7854 \times 30^2} \times \frac{9.81}{10^6}$

$= 0.175 MN/m^2/m$

$k = \frac{P}{1.25} \times 1000 MN/m^2/m = 140 MN/m^2/m$

$k_{75} = 0.4\ k_{30} = 0.4 \times 140 = 56\ MN/m^2/m$.

Example 3. The specific gravities and weight proportion for aggregate and bitumen are as under for the preparation of Marshall mix design. The volume and weight of one Marshall specimen was found to be 475 cc and 1100 gm. Assuming absorption of bitumen in aggregate is zero. Find V_a, V_b

Item	CA1	CA2	FA	Filler	Bitumen
Wt(gm)	825	1200	325	150	100
Sp. Gr	2.63	2.51	2.46	2.43	1.05

CHAPTER - 5
PAVEMENT DESIGN

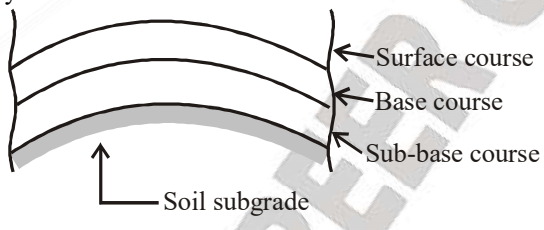
5.1 TYPES OF PAVEMENT

A pavement is the load bearing and load-distributing component of a road. Pavements can be classified as.

1. Flexible
2. Rigid
3. Semi-rigid
4. Composite

5.1.1 Flexible Pavement

1.A flexible pavement is one that is made up of one or more layers of materials, the highest quality material forming the top layer.



Flexible Pavement

2.Loads are transmitted through the layers, care being taken to ensure that the stresses in each layer are within the permissible values and the stress on the sub-grade is within its bearing power.
3.The load carrying capacity of the flexible pavement is derived from the load-distribution property and not from its flexural or bending strength.
4.The flexible pavement layers reflect, the deformation of the lower layer, Thus if the lower layer of the pavement of soil subgrade is undulated, the flexible pavement surface also gets undulated.
5.A typical flexible pavement consists of four components
(i) Soil subgrade
(ii) Sub base-course
(iii) Base course
(iv) surface course

(i) Soil Subgrade

It is a layer of natural soil prepared to receive stress from layers above. It is normally the top natural soil.

(ii) Sub Base Course

It is provided beneath base course. Primary function is to provide structural support, improve drainage and reduce intrusion of fines from subgrade in the pavement structure. A pavement constructed over a high quality stiff subgrade does not require subgrade.

(iii) Base Course.

It is provided immediately below the surface course, provides load distribution & contributes to sub-surface drainage. It is composed of crushed stones.

(iv) Surface Course

CHAPTER - 6
HIGHWAY MAINTENANCE

6.1 INTRODUCTION
By early detection-& repair of defects at initial stages the rapid deterioration of the pavement can be prevented. Such surveys & evaluations should be carried out periodically so as to plan necessary preventive maintenance measures.

6.2 MAINTENANCE OF HIGHWAY

6.2.1 Various Maintenance Operation are
1. Routine Maintenance
These includes filling up of pot holes and patch repairs, maintenance of shoulders and the cross slope and repairing of cracks which are required to be carried out by the maintenance staff almost round the year.
2.Periodic Maintenance
These include renewals of wearing course of pavement surface and maintenance of various items.
3.Special Repairs
The include major restoration or upgrading of the pavement through reconstruction or application of overlays to rectify structural deficiencies.

6.2.2 Symptoms, Causes, And Treatment of Defects
The types of defects in bituminous surfacing are grouped under four categories.
1.Surface Defects
which include fatty surfaces, smooth surfaces, streaking, and hungry surfaces.

2.Cracks
Under which hair-line cracks, alligator cracks, longitudinal cracks, edge cracks. shrinkage cracks, and reflection cracks are dealt with.

3.Deformation
Under this are grouped slippage, rutting, corrugations, shoving, shallow depressions, and settlements and upheavals; and

4. Disintegration
Covering stripping, loss of aggregates, ravelling, pot-holes, and edge breaking.
(i) We will 1st of all describes the symptoms and causes of these defects and indicates the possible types of treatment,
(ii) In each case of pavement distress, the cause or causes of the distress should first be determined. It will be possible to provide suitable maintenance measures which will not only correct the damage but also prevent or delay its recurrence.
(iii) In many situations, lack of proper drainage is the principal cause for stripping loss of materials from the pavement and shoulder, weakening of the pavement layers and siibgrade, resulting in the failure of the pavement.
(iv) In such situations the cause should be completely elimmated before takimgany maintenance measure.

GATE QUESTIONS

1. A bitumen sample has been graded as VG30 as per IS : 73-2013. The '30' in the grade means that

[GATE - 2018]

(a) Penetration of bitumen at 25°C is between 20 to 40
(b) Viscosity of bitumen at 60°C is between 2400 and 3600 Poise
(c) Ductility of bitumen at 27°C is more than 30 cm
(d) Elastic recovery of bitumen at 15°C is more than 30%

2. The initial concavity in the Load-penetration curve of a CBR test is NOT due to

[GATE - 2018]

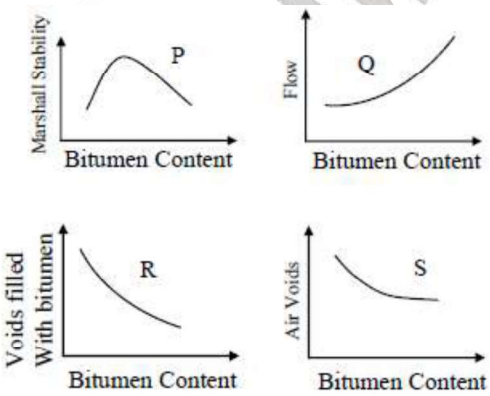
(a) Uneven top surface
(b) High impact at start of loading
(c) Inclined penetration plunger
(d) Soft top layer of soaked soil

3. The following observations are made while testing aggregate for its suitablility in pavement construction
(i)Mass of oven dry aggregate in air = 1000g
(ii)Mass of saturated surface-dry aggregate in air = 1025 g
(iii)Mass of saturated surface-dry aggregate under water = 625 g
Based on the above observations, the correct statement is

[GATE - 2017]

(a)Bulk specific gravity of aggregate = 2.5 and water absorption = 2.5%
(b)Bulk specific gravity of aggregate = 2.5 and water absorption = 2.4%
(c)Apparent specific gravity of aggregate = 2.5 and water absorption = 2.5%
(d)Apparent specific gravity of aggregate = 2.5 and water absorption = 2.4%

4. During a forensic investigation of pavement failure, an engineer reconstructed the graphs P, Q, R and S, using partial and damaged old reports.



Theoretically plausible correct graphs according to the 'Marshall mixture design output' are

[GATE - 2016]

(a) P, Q, R (b) P, Q, S
(c) Q, R, S (d) R, S, P

5. Match the information related to test on aggregates given in List-I with that in List-II.

List-I
A.Resistance to impact
B.Resistance to wear
C.Resistance to weathering action
D.Resistance to crushing

List-II
(i)Hardness
(ii)Strength
(iii)Toughness
(iv)Soundness

[GATE - 2015]

Codes:
(a) A-i, B-iii, C-iv, D-ii
(b) A-iii, B-i, C-iv, D-ii
(c) A-iv, B-i, C-iii, D-ii
(d) A-iii, B-iv, C-ii, D-i

6. In Marshall method of mix design, the coarse aggregate, fine aggregate, fines and bitumen having respective values of specific gravity 2.60, 2.70, 2.65 and 1.01, are mixed in the

SOLUTIONS

Sol 1. (b)

Sol 2. (b)
Initial concavity in CBR test due to
(i) Improper compaction
(ii) Soft top layer
(iii) Inclined plunger

Sol 3. (a)
Bulk specific gravity; G

$$G = \frac{\text{oven dry weight}}{\text{Saturated surface dry weight} - \text{weight in water}}$$

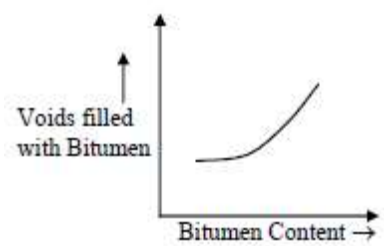
$$= \frac{1000}{1025-625} = 2.5$$

Water absorption; w

$$w = \frac{\text{saturated surface dry weight} - \text{oven dry weight}}{\text{oven dry weight} \times 100}$$

$$= \frac{1025-1000}{1000} \times 100 = 2.5\%\ g$$

Sol 4. (b)
The graph wrong among the given is 'R'
The correct graph should be



Sol 5. (b)

Sol 6. (a)
Theoretical specific gravity

$$G_t = \frac{W_1+W_2+W_3+W_4}{\frac{W_1}{G_1}+\frac{W_2}{G_2}+\frac{W_3}{G_3}+\frac{W_4}{G_b}}$$

$$= \frac{55+35.8+3.7+5.5}{\frac{55}{2.6}+\frac{35.8}{2.7}+\frac{3.7}{2.65}+\frac{5.5}{1.01}} = 2.42$$

Effective specific gravity of aggregates (coarse + fine) is given by

$$G' = \frac{(55\times 2.6)+(35.8\times 2.7)}{55+35.8}$$

= 2.639 = 2.64

Sol 7. (8)
Relationship between penetration and temperature is given by
$P=AT+K$
Where P is penetration
A is temperature susceptibility
K is Constant
With increase in temperature, penetration increases. Hence, we will simply take

Sol 8. (68.79%)

$$V_v = \frac{G_t - G_m}{G_t} \times 100 = \frac{2.441-2.324}{2.441} \times 100$$

= 4.79%

Void filled with bitumen

$$V_b = G_m \times \frac{W_b(\%)}{G_b} = 2.324 \times \frac{5}{1.1}$$

= 10.56%

VMA = $V_v + V_b$ = 4.79 + 10.56 = 15.35%

$$\therefore \text{VFB} = \frac{V_b(\%)}{\text{VMA}} \times 100 = \frac{10.56}{15.35} \times 100$$

= 68.79%

Sol 9. (d)

$$\text{VFB} = \frac{V_B}{V_V} = \left(\frac{15-4.5}{15}\right) \times 100\% = 70\%$$

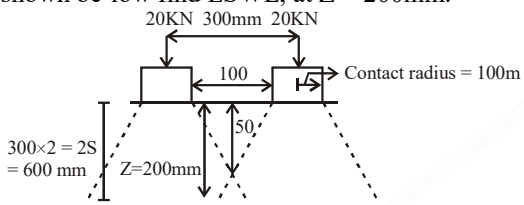
Sol 10. (c)
Since softening point for Y is higher than X.
$\therefore$ Viscosity of Y is high as compared to X and penetration will be more in X, because it will offer less resistance to penetrate.
$\therefore$ Both statement I & II are false.

Sol 11. (c)

Sol 12. (d)

WORKBOOK

Example 1. For the multi-wheel condi-tion shown be-low find ESWL, at Z = 200mm.



Solution.

$$\log(\text{ESQL}) = \log 20 + \frac{\log 40}{\log 600 - \log 50}$$

$$\left[\log(200) - \log\frac{50}{2}\right]$$

$$\log g(\text{ESWL}) = 1.46734$$

ESWL = $10^{1.46734}$ = 29.44kN.

Example 2. The result of 1 day axle load survey of trucks on a road is tabulated as below. Find the no. of repetitions of a standard 80KN axle in a year.

Wt in KN	Frequency (n)	Mid Point (x)	$\text{EALF} = \left(\frac{x}{80}\right)^4$	n_1EALF
0-40	50	20	$\frac{1}{256}$	$\frac{50}{256}$
40-80	250	60	$\frac{81}{256}$	$\frac{(250\times 81)}{256}$
80-120	400	100	$\frac{625}{256}$	$\frac{(400\times 625)}{256}$
120-160	25	140	$\frac{2401}{256}$	$\frac{(250\times 2401}{256}$
				Σ = 3400

No. of repetition of standard axles in one year will be 3400 × 365 = 1.241 MSA

Example 3. If in the previous example, 950 no. no. of axles were surveyed and the no. of vehicles were 400, find the vehicle damage factor.

Solution.

400 vehicle is equivalent to 3400 nos. standard axle.

1 vehicle is equivalent to $\frac{3400}{400}$ = 8.5 st. axle

⇒ 1 commercial vehicle = 8.5 no. of standards axles.

Thus vehicle damage factor = 8.5

VDF for a road traffic is calculated using axle load survey

Example 4.T he no. commercial vehicle per day at present count is 6000. Design life is 15 yrs. Traffic growth rate is 8% VDF is 4.5 lateral distribution factor for 6 lane divided highway = 0.6.

Calculate the no. of standards axles in the design life if the construction period is 2yrs.

Solution.

P = 6000 vehicle/day

Traffic after two year = $P(1 + r)^x$

$(A) = 6000\,(1 + 0.08)^2$

$= 6000(1.08)^2 = 6998$veh./day

⇒ No. of commercial vehicles after the end of construction period is 6998 veh./day.

No. of commercial vehicle in design life

$$N = \frac{365A\left[(1+r)^n - 1\right]}{r}$$

$$= \frac{365\times 6998\left[(1.08)^{15} - 1\right]}{0.08}$$

N = 69.35 × 10^6 vch.

If lateral destribuiton of traffic is accounted for then

GATE QUESTIONS

1. Given the following data : design life n = 15 years, lane distribution factor D = 0.75, annual rate of growth of commercial vehicles r = 6%, vehicle damage factor F = 4 and initial traffic in the year of completion of construction = 3000 Commercial Vehicles Per Day (CVPD). As per IRC : 37-2012, the design traffic in terms of cumulative number of standard axles (in million standard axles, up to two decimal places) is _____.

[GATE - 2018]

2. The radii of relative stiffness of the rigid pavement P and Q are denoted by ℓ_P and ℓ_Q . respectively.The geometric and material properties of the concrete slab and underlying soil are given below.

Pavement	Concrete					Soil
	Length of slab	Breadth of slab	Thickness of slab	Modulus of Elasticity	Poisson's Ratio	Subgrade Reaction modulus
P	L	B	H	E	μ	K
Q	L	B	0.5h	E	μ	2K

The ratio (up to one decimal place) of $\frac{\ell_P}{\ell_Q}$ is

[GATE - 2017]

3. In the context of the IRC 58-2011 guidelines for rigid pavement design, consider the following pair of statements.

I. Radius of relative stiffness is directly related to modulus of elasticity of concrete and inversely related to Poisson's ratio

II. Radius of relative stiffness is directly related to thickness of slab and modulus of subgrade reaction.

Which one of the following combinations is correct?

[GATE - 2016]

(a) I-True; II-True (b) I-False; II-False
(c) I-True; II-False (d) I-False; II-True

4. A traffic survey conducted on a road yields an average daily traffic count of 5000 vehicles. The axle load distribution on the same road is given in the following table.

Axle load (tonnes)	Frequency of traffic (%)
18	10
14	20
10	35
8	15
6	20

The design period of the road is 15 years, the yearly traffic growth rate is 7.5% and the load safety factor (LSF) is 1.3. If the vehicle damage factor (VDF) is calculated from the above data, the design traffic (in million standard axle load, MSA) is _____.

[GATE - 2014]

5. A pavement designer has arrived at a design traffic of 100 million standard axles for a newly developing national highway as per IRC.37 guidelines using the following data. life = 15 years, commercial vehicle count before pavement construction = 4500 vehicles/day, annual traffic growth rate = 8%. The vehicle damage factor used in the calculation was

[GATE - 2012]

(a) 1.53 (b) 2.24
(c) 3.66 (d) 4.14

6. It is proposed to widen and strengthen an existing 2-lane NH section as a divided highway. The existing traffic in one direction is 2500 commercial vehicles (CV) per day. The construction will take 1 year. The design CBR of soil subgrade is found to be 5 per cent. Given. traffic growth rate for CV = 8 per cent,

SOLUTIONS

Sol 1. 76.45(76.43 to 76.48)

$$N_S = \frac{365A\left[\left(1+\frac{r}{100}\right)^n - 1\right] \times VDF \times LDF}{\frac{r}{100}}$$

$$= \frac{365 \times 3000[1.06^{15} - 1] \times 4 \times 0.75}{0.06} \times 10^{-6}$$

= 76.45 msa

Sol 2. (2)

Westergaard defined the term radius of relative stiffness, ℓ which is expressed as

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

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

$$\ell_Q = \left[\frac{E(0.5h)^3}{12(2k)(1-\mu^2)}\right]^{1/4}$$

$$= \left[\frac{(0.5)^3}{2} \times \frac{Eh^3}{12k(1-\mu^2)}\right]^{1/4}$$

$$\left(\frac{(0.5)^3}{2}\right)^{1/4}\left[\frac{Eh^3}{12k(1-\mu^2)}\right]^{1/4}$$

$$\frac{\ell_P}{\ell_Q} = \frac{\left[\frac{Eh^3}{12k(1-\mu^2)}\right]^{1/4}}{\left(\frac{(0.5)^3}{2}\right)^{1/4}\left[\frac{Eh^3}{12k(1-\mu^2)}\right]^{1/4}}$$

$$= \left(\frac{2}{(0.5)^3}\right)^{1/4} = \frac{\ell_P}{\ell_Q} = 2$$

Sol 3. (b)

Radius of relative stiffness, $l = \left[\frac{Eh^3}{12k(1-\mu^2)}\right]^{1/4}$

Statement -1. False

Directly proportional to modulus of elasticity and also μ

(∴ As μ increases *l* decreases)

Statement-2. False

Sol 4. (309.08msa)

Vehicle damage factor

$$= 0.1\left[\frac{18}{8.2}\right]^4 + 0.2\left[\frac{14}{8.2}\right]^4 + 0.35\left[\frac{10}{8.2}\right]^4$$

$$+0.15\left[\frac{8}{8.2}\right]^4 + 0.20\left[\frac{6}{8.2}\right]^4$$

$$N_s = \frac{365A\left((1+r)^n - 1\right)DF}{r}.$$

$$= \frac{365 \times 5000\left((1.075)^{15} - 1\right) \times 1.3 \times 4.988}{0.075}$$

N_S = 309.08 msa

Sol 5. (b)

Number of commercial vehicles per day,

A = 4500

Annual traffic growth rate, r = 8%

Design life, n =15 years

The cumulative standard axles,

$N_s = 100 \times 10^6$

Vehicle damage factor used,

$$= \frac{N_s \times r}{365A\left[(1+r)^n - 1\right]}$$

$$= \frac{100 \times 10^6 \times 0.08}{365 \times 4500 \times \left[(1+0.08)^{15} - 1\right]} = 2.24$$

Sol 6. (b)

Number of commercial vehicles per day,

A = existing traffic × traffic distribution factor

= 2500 × (1.08) × 0.75 = 2025

Annual growth rate of commercial vehicles = 8%

Vehicle damage factor, F = 3.5

Design life, n = 10 years

ESE OBJ QUESTIONS

1. As per IRC 37 : 2012, the fatigue life of a flexible pavement consisting of granular base and sub-base depends upon
1. Resilient Modulus of bituminous layers
2. horizontal tensile strain at the bottom ofbituminous layer
3. Mix design of birumen
4. Vertical subgrade strain
Which of the above statements are correct?
[ESE - 2018]
(a) 1, 2 and 4 only (b) 1, 3 and 4 only
(c) 1, 2 and 3 only (d) 2, 3 and 4 only

2. In revised CBR design method recommended by the IRC for the design of flexible pavement, the total thickness depends upon
[ESE - 2017]
(a)Only the CBR value of the soil
(b)The CBR value of the soil and the magnitude of wheel load
(c)The CBR value of the soil cumulative standard axle loads
(d)The CBR value of the soil and number of commercial vehicles passing per day

3. Consdier the following statements regarding pavements.
1.Rigid pavements are more suitable than flexible pavements for stage construction.
2.Rigid pavements are more affected by temperature variations than flexible pavements.
3.In a flexible pavement, any deformation in the top layers is transferred to underlaid layers; but in rigid pavements, there is slab or beam action due to which any deformation is only in the top layer of the concrete slab.
Which of the above statemnts are correct?
[ESE - 2017]
(a) 1 and 2 only (b) 2 and 3 only
(c) 1 and 3 only (d) 1, 2 and 3

4. Bankleman beam deflection method is used for design of
[ESE - 2014]
(a) Rigid overlays on rigid pavements
(b) Rigid overlays on flexible pavements
(c) Flexible overlays on flexible pavements
(d) Flexible overlays on rigid pavements

5. In a flexible pavement
[ESE - 2014]
(a)Vertical compressive stresses decrease with depth of the layer
(b)The vertical compressive stress is the maximum at the lowest layer
(c)Tensile stresses get developed
(d)Maximum stress induced by a given traffic load is dependent on the location of the load on the pavement surface.

6. What is the deflection at the surface of a flexible pavement due to a wheel load of 40 kN and a tyre pressure of 0.5 MPa? The value of E for pavement and subgrade is 20 MPa.
[ESE - 2014]
(a) 15 mm (b) 11 mm
(c) 9 mm (d) 6 mm

7. The corrected modulus of sub-grade reaction for standard diameter plate is 6.0 kg/cm^3. What would be the modulus of sub-grade reaction of the soil when tested with a 30 cm diameter pates?
[ESE - 2013]
(a) 15 kg/cm^3 (b) 25 kg/cm^3
(c) 30 kg/cm^3 (d) 60 kg/cm^3

8. Which of the following correspond to the recommendations of IRC for pavement thickness determination by CBR method?
1.CBR tests are to be conducted in situ
2.Static compression is best adopted
3.The top 50 cm of subgrade should be compacted to as near the proctor density as possible
[ESE - 2011]
(a) 1, 2 and 3 (b) 1 and 2 only
(c) 2 and 3 only (d) 1 and 3 only

SOLUTIONS

Sol. 1. (c)
Does not depend on vertical subgrade strain

Sol. 2. (c)
In revised CBR design method recommended by the IRC. For the design of flexible pavement IRC. For the design of flexible pavement IRC has provided charts for different CBR in which relation between pavement thickness and cumulative traffic axle is given.

Sol. 3. (d)
1.Rigid pavements are more suitable than flexible pavements for stage construction.
2.Rigid pavements have more temperature venations.
3.Flexible pavements transfer the load by grain to grain contact which rigid pavements resist the deflection through flexural action.

Sol. 4. (c)

Sol. 5. (a)

Sol. 6. (d)

Deflection, $\Delta = \frac{1.5\ P.a}{E_s}$ (For flexible plate)

Where, P is Contact pressure due to wheel load = 0.5 MPa
a is Radius of contact area
Now,

$$\text{Contact area} = \frac{\text{Wheel load}}{\text{Tyre pressure}}$$

$$= \frac{40\times10^3\ N}{0.5\ N/mm^2} = 80 \times 10^3\ mm^2$$

and, area, $\pi \times a^2 = 80 \times 10^3$

$$a = \sqrt{\frac{80\times10^3}{\pi}} = 159.615\ mm$$

$E_s = 250$ MPa

$$\text{So, } \Delta = \frac{1.5\times0.5\times159.617}{20} = 6\ mm$$

Sol. 7. (a)
$k = 6\ kg/cm^3$
When, a = 75 cm

$$k_1 = \frac{6(75)}{30} = 15\ kg/cm^3$$

Sol. 8. (c)
Some of the important points recommended by the IRC for the CBR method of design (IRC. 37-1970) are.
(a) The CBR tests should be performed on remoulded soils in the laboratory. In-situ test are not recommended for design purposes. The specimens should be prepared by static compaction wherever possible and otherwise by dynamic compaction. The standard test procedure should be strictly adhered to.
(b) For the design of new roads, the subgrade soil sample should be compacted at OMC to proctor density whenever suitable compaction equipment is available to achieve this density in the field. In the case of existing roads, the sample should be field density of subgrade soil (at OMC or at a field moisture content).
(c) In new constructions the CBR test samples may be soaked in water for four days period before testing.
(d) Atleast three samples should be tested on each type of soil at the same density and moisture content. The specified limits of maximum variation in CBR are 3% for CBR values upto 10% 5% for values 10 to 30 and 10% for values 30 to 60%.
(e) The top 50 cm of subgrade should be compacted atleast upto 95 to 100 percent of Proctor density.

Sol. 9. (b)
(i) During Summer. Critical combination of stresses = load stress + warping stress – frictional stress, at edges region.
(ii) During winter. The critical stress combination = load stress + warping stress + frictional stress, at edges region.
(iii) At corner region. The critical stress combination = load stress + warping stress, at corner regions

ESE OBJ QUESTIONS

1. Hot bitumen is sprayed over freshly constructed bituminous surface followed by spreading of 6.3 mm coarse aggregates and rolled. Which one of the following is indicated by this type of construction?

[ESE - 2009]

(a) Surface dressing
(b) Gravel-bitumen mix
(c) Liquid seal coat
(d) Seal coat

2. Assertion (A): In water-bound macadam construction, grade I has better load dispersion characteristics as compared to grade III aggregates.

Reason (R): The plasticity index of the binding material should be less than 6%.

[ESE - 2009]

(a)Both A and R are true and R is the correct explanation of A
(b)Both A and R are true but R is not a correct explanation of A
(c)A is true but R is false
(d)A is false but R is true

3. Consider the following statements with reference to Water Bound Macadam (WBM) and Wet Mix Macadam (WMM).
1. WBM is a road mix and WMM is a plant mix.
2. WBM usually has plastic filler, while WMM has non–plastic filler.
3. WBM is modern road mix and WMM is a traditional road mix.
Which of these statements is/are correct?

[ESE - 2008]

(a) 1 and 2 (b) 2 and 3
(c) 1 only (d) 2 only

4. Consider the following bituminous surfacing.
1. SDBM 2. PMC
3. AC 4. SD
5. Mastic Asphalt (MA)

Which one of the following is the correct sequence in increasing order with respect to their performance and wearing qualities?

[ESE - 2008]

(a) 4, 1, 2, 3, 5 (b) 2, 4, 1, 5, 3
(c) 4, 2, 1, 3, 5 (d) 1, 4, 3, 2, 5

5. Match List-I (Type of wall) with List-II (feature) and select the correct answer using the code given below the lists.

List-I
A. Parapet wall
B. Check wall
C. Breast wall
D. Gabion wall

List-II
(i)Constructed with dry stone encased in wire mesh.
(ii)To add the overall stability to the hill face.
(iii)To buttress the uphill slopes of the road cross-section
(iv)To give protection to the motorists.

[ESE - 2007]

Codes:
(a) A-ii, B-iv, C-i, D-iii
(b) A-iv, B-ii, C-i, D-iii
(c) A-iv, B-ii, C-iii, D-i
(d) A-ii, B-iv, C-iii, D-i

6. A road surface is corrected by spreading a layer of dry sand in a thickness varying from 5 mm to 10 mm and rolling the surface by heavy rollers. Which one of the following maintenance works does it apply to?

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(a) Repair of ruts and patches
(b) Repairing of blow ups
(c) Repair of bleeding surface
(d) Sealing of joints and cracks

7. Based on Fuller's maximum density criterion, for 4 mm maximum size of soil particles what is the percentage of particles between 4 mm and 2 mm by weight?

[ESE - 2007]

SOLUTIONS

Sol. 1. (a)

Sol. 2. (d)

Sol. 3. (a)
WBM is a traditional road mix and WMM is a modern road mix.

Sol. 4. (c)

Sol. 5. (c)

Sol. 6. (b)

Sol. 7. (c)
According to Fuller's maximum density criterion the gradation is given by

$$p = 100\left(\frac{d}{D}\right)^n$$

where,
p is per cent finer than diameter 'd' (mm) in the material
D is diameter of largest particle, mm
n is gradation index (taken as 0.5 by Fuller)

$$\therefore \quad p = 100\left(\frac{2}{4}\right)^{0.5}$$

$\Rightarrow$ p = 70.71
Thus, the percentage of particles between 4 mm and 2 mm will be by
$100 - 70.71 = 29.29 \simeq 30\%$

Sol. 8. (c)
The vertical sand drains increase the effective permeability of excess pore pressure in high embankment in soft soils.
Fir urban road surface drainage surface consists of inlets and gratings. The limitation of land width and presence of foot paths, dividing islands and other road facilities necessitates underground longitudinal drains.
In order to intercept and divert water from the hill slope, catch water are provided, running parallel to the roadways. Water from catch water drains is diverted by slopping drain and carried across the road by means of causeways and culverts.
Beside catch water drains, road side drains on one side of hill road are provided. They are angle, saucer, and kerb and channel drain types.
In hill roads where rainfall is heavy, the culverts are needed at 60 to 90 m to facilities drainage of water across the roads. This may be quite costly. Hence often 8 to 10 scuppers (cross-drainage structures) are provided in addition to the bridges and regular culverts.

Sol. 9. (a)
Bituminous premixed carpet is a surfacing course.

Sol. 10. (b)
According to MORST specification bitumen content are as follows.
(i) Bituminous mastic, 14-17%
(ii) Dense bituminous macadam for nominal aggregate size 40 mm minimum 4% and for nominal aggregate size 25 mm minimum 4.5%.
(iii) Bituminous macadam for nominal aggregate size 40 mm, 3.1-3.4% and for nominal aggregate size 19 mm, 3.3-3.5%
(iv) Bituminous concrete for nominal aggregate size 19 mm, 5-6% and for nominal aggregate size 13 mm, 5-7%.

Sol. 11. (a)

Sol. 12. (b)

Sol. 13. (c)
Usually MC (medium curing) or SC (slow curing) cutbacks of suitable grade or viscosity is chosen depending upon the porosity of the surface to be treated.

Sol. 14. (d)

Sol. 15. (d)

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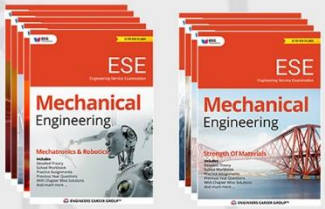

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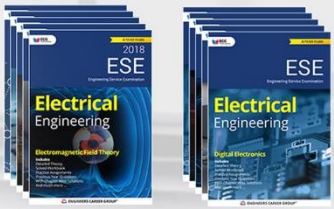

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