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PART - A

2 Marks Questions

1.
Sol. On the recommendation of Jayaker committee, central Road fund came into existence on 1st march 1929, Upon the authority of a resolution adopted by the Indian legislature.
2.
Sol. In 1956, National Highway act was passed declaring the National Highways and empowering the central Govt to declare any other highway to be NH. This act came into force with effect from 15th April 1957.
3.
Sol. CRRI- The central Road Research Institute located at Delhi founded in 1950. It is an organ of the council of scientific and industrial research, and it performed R&D on highway engineering pavement design, traffic and transportation systems.
4.
Sol. This board was set up by I.R.C in 1973 to give proper direction and guidance to road research work in India.
5.
Sol.
 1. National Highways (NH)
 2. State Highways (SH)
 3. District Roads:
 - (1) Major district Roads
 - (2) Other district Roads
 4. Village roads.
6.
Sol. These roads are of higher way than National highway. There are Such roads on which only font moving vehicles like car and jeeps are classified.
7.
Sol.
 1. Primary System
 2. Secondary System
 3. Tertiary system
8.
Sol.
 1. Rectangular (or) Block pattern.
 2. Radial (or) Star and block pattern.
9.
Sol. The first attempt for proper Scientific planning of roads in India, was made in chief Engineers conference held at Nagpur in 1943. Nagpur conference finalized at 20 years (1943-1963) road development plan.
10.
Sol. A Second road development programmer (1961-81) was finalized by the chief engineers connected with road development, both at centre and State in a meeting held at Mumbai in 1959.
11.
Sol.
 1. Length of road should be shortest
 2. The Proposed road should form a most economical line.
 3. The alignment should provide corny.
12.
Sol.
 1. Volume and type of traffic
 2. Obligatory points
 3. Canal river (or) railway crossings
 4. Geotechnical standard to be adopted
13.
Sol. Obligatory point are such points which act to control points in highway alignment.

14.

Sol. 1. Stability 2. Drainage 3. Geometric standard 4. Deep cutting and heavy fillings should be avoided.

15.

Sol. 1. Map study
2. Reconnaissance survey
3. Preliminary survey
4. Detailed Survey

16.

Sol. Transverse slope given to the road surface is called camber. It is provided mainly to drain off rain water from the road surface.

17.

Sol. The required camber for a road depends on the "type of pavement and the intensity of rainfall in the area".

18.

Sol. The recommended camber for a Water Bound Macadam road is 2.5% (1 in 40) to 3% (1 in 33).

19.

Sol. The recommended camber for a Bituminous surface is 2% (1 in 50) to 2.5% (1 in 40).

20.

Sol. The recommended camber for a Cement concrete Road is 1.7% (1 in 60) to 2% (1 in 50).

21.

Sol. 1. Parabolic camber
2. Sloped camber
3. Composite camber or Combined camber

22.

Sol. Metal led pace strip of road meant for vehicular traffic movement is called carriage way.

23.

Sol. The carriageway width for a two lane state highway without a raised curve is typically 7.0 m.

24.

Sol. Formation width is also called roadway. It is the sum of width of carriageway, shoulders and separations if provided.

25.

Sol. Right of way is the total land area acquired for a road, encompassing its entire cross-section and potential future expansion.

26.

Sol. Sight distance is the actual length of road over which a driver sitting at a specified height in a vehicle can see objects either moving (or) stationary on the road surface.

27.

Sol. 1. Stopping sight distance
2. Overtaking sight distance
3. Sight distance at intersection

28.

Sol. Stopping sight distance is the minimum distance required within which a vehicle moving at designed speed can be stopped without colliding with a stationary object on the road surface.

29.

Sol. IRC recommended height of driver eye is 1.22m.

30.

Sol. It is the time in seconds which a driver can take from the instant the objects visible to him to the instant the brakes are effectively applied.

31.

Sol. Perception period is the time taken by an average driver to realize a danger ahead before actually trying to apply the brake.

32.

Sol. The distance visible to the driver of a vehicle intending to overtake another slow moving vehicle, without causing any inconvenience (or) possibility of accident to the traffic in the opposite direction is called overtaking sight distance (or) safe passing sight distance.

33.

Sol. Design speed can be defined as the speed which is permissible for safe and comfortable driving on a given surface of the highway.

34.

Sol. 1. Tendency to overturn the vehicle.
2. Tendency to skid the vehicle laterally.

35.

Sol. The rise of the outer edge of the pavement with respect to inner edge on a horizontal curve is called super elevation (or) cant (or) banking.

36.

Sol. $e+f = v^2 / gR$

Where, e is the super elevation rate, f is the lateral coefficient of friction, v is the vehicle speed in m/sec, g is the acceleration due to gravity in m/sec² and R is the radius of the curve in m.

37.

Sol. It is a curve in plan to provide change in the direction of the central line by the road surface.

38.

Sol. 1. Design speed of the vehicle
2. Allowable friction
3. Maximum allowable super elevation.
4. Permissible centrifugal ratio.

39.

Sol. It is a curve in the longitudinal section of a highway to provide a easy change of the gradient.

40.

Sol. 1. Circular curve
2. Transition curve
3. Parabolic curve

41.

Sol. The value of radius of simple curve is given by $R = V^2 / g(e+f)$

Where,

R = Radius of curve

V = Speed of vehicle

e = Super elevation

f = Coefficient of friction

42.

Sol. A compound curve consists of a serial of two (or) more simple curve that turn in the same direction and join at common tangent point.

43.

Sol. A reverse curve consist of two simple curve of opposite direction that join at the common tangent point. This common point in called the point of reverse curve _____.

44.

Sol. 1. True spiral (or clothed).
2. Cubic spiral.
3. Cubic parabolic.
4. Lemniscate's.

45.

Sol. A transition curve gradually connects a straight section to a circular curve, featuring characteristics such as a radius that changes from infinity to a finite value. It must be tangential to both the straight and circular parts of the alignment, provide a smooth, gradual change in centrifugal force, and allow for a corresponding gradual increase in super-elevation (banking).



PART - B

5 Marks Questions

46.

- Sol.** (a) In particular for short distance travel by road transport save time.
 (b) Road transport requires a relatively low capital investment for the government.
 (c) Road transport is the only means of transport that offers door-to-door service.

IRC:- A semi official technical body known as "Indian Road Congress" (IRC) was formed in 1934.

Central road fund (CRF):- An extra tax levied on petrol from the road users to develop a road development fund formed in 1929 is called CRF.

47.

- Sol.** **Nagpur road plan (1943-63):-** This is first 20 years road plan, according to this highways are classified as follows (a) NH (b) SH (c) MDR (d) ODR (e) Village Roads (VR)

Length formula according to Lucknow road plan-

I. Length of NH in km = Total area of state (km²)/50

II. Length of SH in km = Area of state (km²)/25 or (62.5 × No. of towns in state - length of NH) whichever ever is max.

III. Length of MDR = $\frac{\text{Area of state (km}^2\text{)}}{12.5}$ or (90 × No. of towns in state) whichever is max.

48.

- Sol.** **Bombay Road plan (1961-81)-** Following are the features of this plan:

- (a) At the end of plan road length aimed was 32 km per 100 km² area
 (b) A development allowance of 5% is provided for future development
 (c) Traffic engineering cell's should be established in each state
 (d) 1600 km express ways have been considered in this plan with in proposed target of NH.
 (e) Max. distance of any place in a developed or agricultural area would be 6.4 km from a metalled road and 2.4 km from any category of roads.

49.

- Sol.** **I.** Length of NH = Total area/50 = $\frac{18400}{50} = 368$ km

II. Length of SH = Total area/20 + $\frac{\text{Developed and agriculture area}}{12.5}$ + undeveloped area/5

$$\text{Length of SH} = 18400/25 + 7500/12.5 + \frac{4800}{5} = 2296 \text{ km.}$$

III. Length of MDR = 90 × no. of towns (more than 5000 population)
 = 90 × (150+80) = 20700 km.

IV. Length of ODR = 90 × no. of towns (Population b/w 1000 to 5000) = 90 × (750 + 360)
 Length of ODR = 90 × 1110 = 99900 km.

V. Length of VR = 4.74 × no. of village (Population b/w < 500 to 1000) = 4.74 × (210 + 350)
 = 2654.4 km

50.

- Sol.** **Preliminary Surveys-** After reconnaissance survey in this Chain survey, Traverse survey, Levelling work and other various survey are done along with soil investigation traffic study, then alignment is finalised.

Detail Surveys- Planning, designing and material costing are to be done and detailed project report (DPR) is finalised.

51.

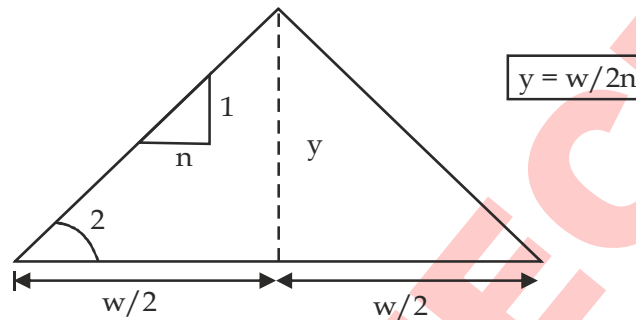
Sol. Following are the c/s elements of the pavement - (a) Right of way (b) width of formation (c) road margins (d) medians (e) kerbs (f) carriageway (g) camber or cross slope etc.

Skid : Translation movement (longitudinal movement) > rotational movement (circumferential movement)

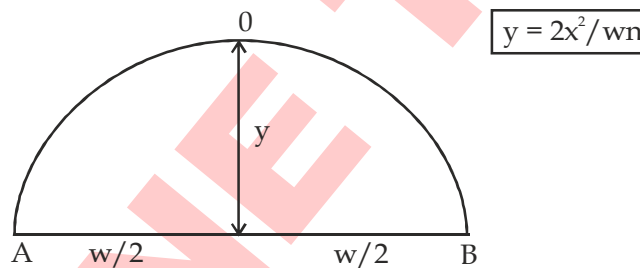
Slip : Rotation movement or circumferential movement > Translation movement or longitudinal movement

52.

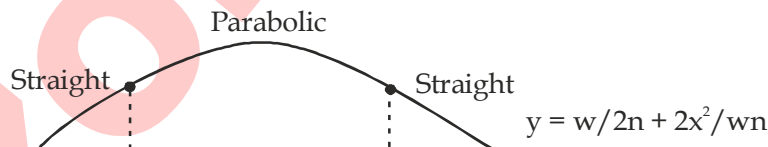
Sol. (a) **Straight camber -**



(b) **Parabolic camber -**



(c) **Combined camber -**



Note:

Camber is provided for the drainage purpose.

53.

Sol. Sight distance is the actual length of road over which a driver sitting at a specified height in a vehicle can see object's either moving or stationary on the road surface.

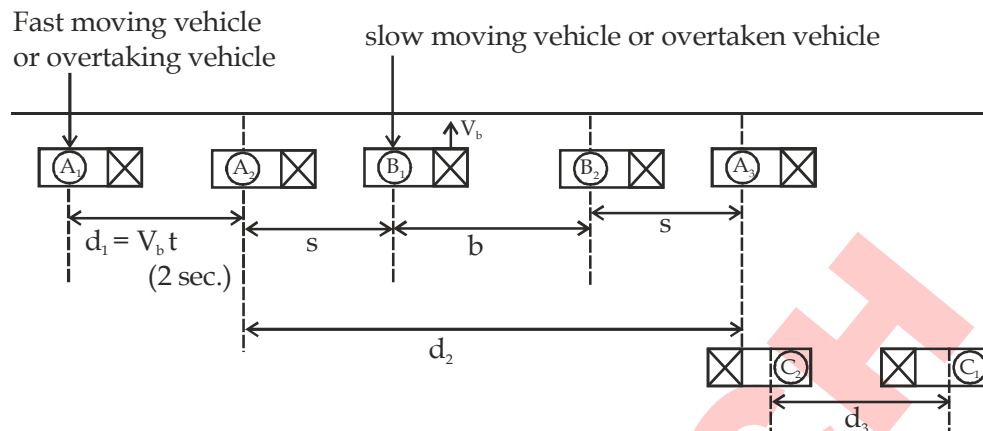
Lag distance (d)- it is the distance travelled by the vehicle in total reaction time if 'v' is the design speed in m/s and 't' is total reaction time in 'sec' then $d = v \cdot t \text{ meters}$ if 'v' in kmph then $d = 0.278 vt$

Braking distance- it is the distance travelled by vehicle after the application of brakes and it is equal

$$\text{to } l = \frac{v^2}{2gf}$$



54.
Sol.



$$\text{O.S.D.} = d_1 + d_2$$

$$\therefore \quad d_1 = V_b t \dots\dots\dots (i)$$

$$d_2 = 2 \times S + b$$

Where, $S \rightarrow$ space headway

$$S = (0.7 V_b + 6) \text{ m}$$

$$\therefore \quad d_3 = V_b \times T$$

$$\text{Where, } T = \sqrt{\frac{4S}{a}} \quad (a \rightarrow \text{m/sec}^2)$$

55.

Sol. $R = 100\text{m}$, Design speed $V_d = 65 \text{ km/hr}$.
For mixed traffic condition, $e = V^2/225R$
Where, V is in km/hr

$$\therefore e = \frac{65 \times 65}{225 \times 100} = 0.187 = 18.7\% > 7\%$$

Now as per IRC the max. limit of super elevation to be provided is 7% for plain terrain.
Hence $e = 7\%$

56.

Sol. Reasons to provide extrawidening

- To avoid offtracking due to rigidity of wheel base.
- To counteract skidding (transverse)
- To increase the visibility
- To encounter psychological tendency

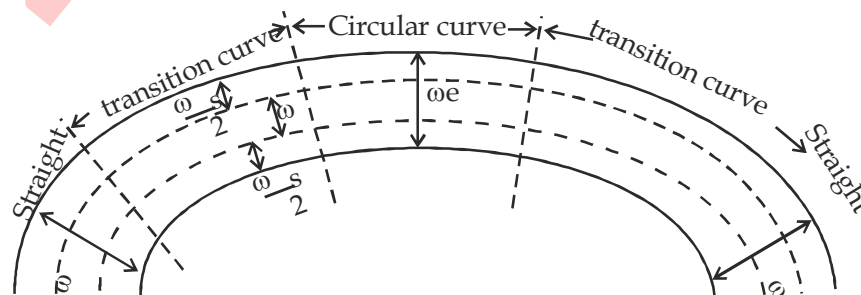


Fig. : Extra widening of povement

57.

Sol. Given :

Design speed $V_d = 90$ km/hr,Reaction time $t_r = 2.5$ sec.,Longitudinal friction $f = 0.31$

As we know that,

Stopping sight distance = length distance + breaking distance

$$S.S.D. = 0.278 V_d t_r + V_d^2 / 254f$$

$$S.S.D. = 0.278 \times 90 \times 2.5 + \frac{90^2}{254 \times 0.31}$$

$$S.S.D. = 165.42 \text{ m}$$

58.

Sol. Vertical curves are provided at the intersections of different grades to smoothen the vertical profile. It reduces the accident due to inadequate visibility, and it also reduces discomfort etc.
Simple circular curve - A simple curve consists of a single arc connecting two straights.

59.

Sol. It is useful to establish -

- (a) relative importance of any route
- (b) trends of a road use
- (c) importance of any route
- (d) distribution of traffic on the road system

Methods to measure traffic volume-

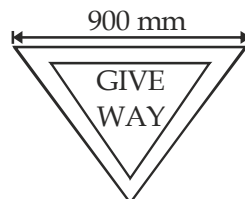
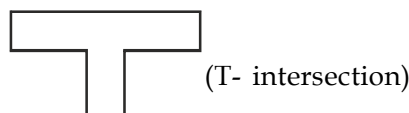
- (a) Manual counting
- (b) automatic counting -
 - I. Magnetic detectors
 - II. Pressure sensitive detectors
 - III. electronic detectors.

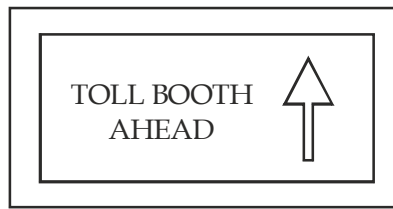
60.

Sol. (I) **Traffic Density** : It is defined as the number of vehicles occupying a unit length of lane of roadway at a given instant is expressed in vehicles per kilometer.
(II) **Traffic Flow** : It is the number of vehicles moving in a specified direction on a given lane that pass a given point during specified unit of time.
(III) **Basic capacity** : Max. no. of vehicles passing a point during one hour under most nearly ideal roadway traffic condition.
(IV) **Practical capacity** : It is also known as design capacity.
(V) **Speed and Delay Study** : It gives the running speed, over all speeds, fluctuation in speeds and delay b/w two stations. It is also useful to find the density of traffic.

61.

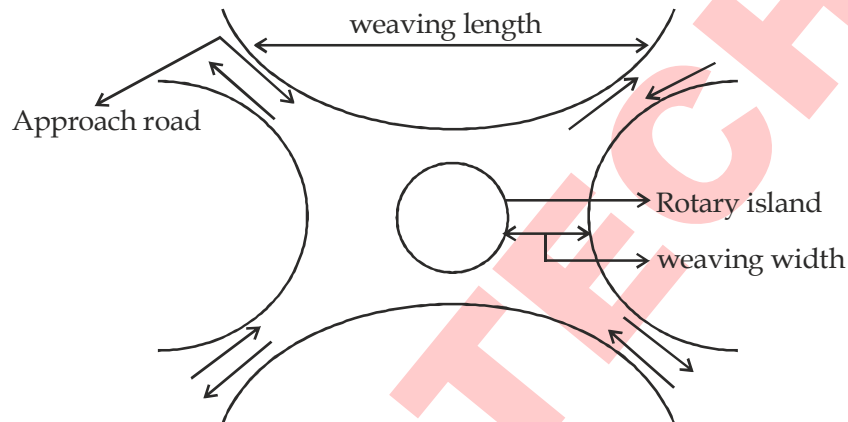
Sol. Traffic signs are meant to regulate, warn, or inform, to road users about the things on the route.

(a) **Regulatory signs**(b) **Warning signs**(c) **informatory sign**



62.

Sol. Rotary are suitable when the traffic entering from all the four approaches are relatively equal. The maximum traffic which a rotary can efficiently handle is 3000 vehicle/hour and a minimum of 500 vehicle/hour.



63.

Sol. Basic material used for construction of roads are

- I. Earth filling
- II. Coarse aggregate (stones)
- III. Filler (dust and fly ash)
- IV. Binding material (Cement, Bitumen, Tar)

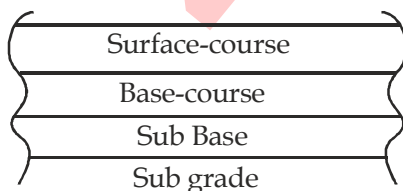
Various tests to be carried out-

- I. For coarse aggregate - aggregate impact, crushing, etc.
- II. For bitumen and tar - softening point test, flash and fire, etc.
- III. For subgrade - CBR test, Group index, plate load test etc.

64.

Sol. **Flexible pavements -**

- * It has very less flexural strength.
- * In this load is transmitted by grain to grain contact.
- * Number of layers = 4.
- * Less cost of construction but has high maintenance cost.



IRC - 37 : 2012 is used for design of flexible pavement

Rigid pavement -

- * It has a worthy flexural strength.
- * In this load transfer is by slab action.
- * Number of layers = 3.
- * Initial cost is high but maintenance cost is low.

Cement concrete surface
Base-course
Soil subgrade

IRC- 58 : is design code for rigid pavement

65.

Sol. **Design factors of pavements-**

(a) **Design wheel load** - Total load influence the thickness requirements of pavements max. axle load by IRC is 8170 kg. with a max. equivalent single wheel load of 4085 kg. The pressure distribution is bulb shaped.

(b) **Contact pressure and tyre pressure** - Low pressure tyre under compression

$$\text{* High pressure - tyre under tension * Contact pressure} = \frac{\text{Load on wheel}}{\text{Contact area}}$$

* Tyre pressure - Top surface effects * Contact pressure → Bottom layer affect

* The ratio of contact pressure to tyre pressure is defined as rigidity factor

(c) **Equivalent single wheel load (ESWL)** - it is defined as load on the single tyre which will cause an equivalent magnitude of stress, strain, deflection etc. (d) equivalent axle wheel load (e) Repetition of load.

66.

Sol.

- | | | |
|------------------------|---------------------|-------------------------------------|
| (1) Group index method | } empirical methods | (4) Triaxial test - semi empirical |
| (2) CBR method | | (5) Burmister - Theoretical method. |
| (3) McLeod method | | |

(1) **Group index method** -

- It is also called as public road administration classification system, which is generally used for classification of soil used for pavement construction.
- In this method, a parameter "Group Index" (GI) is used to describe the performance of soil when used for pavement construction.
- Higher is the value of GI poorer is the performance of soil when used for pavement construction.
- Group index is dependent upon percentage passing through 75 μ , liquid limit and plasticity index of soil.

$$GI = 0.2a + 0.01bd + 0.005ac$$

a = Portion of % passing through 75 μ sieve greater than 35% but not exceeding 75% expressed as whole no. between 0 to 40.

$$a = \%P - 35 \in [0, 40]$$

b = Portion of % passing through 75 μ sieve greater than 15% but not exceeding 55% expressed as whole number between 0 to 40.

$$b = \%P - 15 \in [0, 40]$$

c = Portion of numerical liquid limit (w_L) greater than 40% but not exceeding 60% expressed as whole no. between 0 to 20.

$$c = w_L - 40\% \in [0, 20]$$

d = Portion of numerical plasticity index (I_p) whole value is greater than 10 but not exceeding 30% expressed as whole no. between 0 to 20.

$$d = I_p - 10 \in [0, 20]$$

Note:

Value of GI varies from 0 to 20.

67.

Sol. Due to temperature variation, rigid pavements undergo expansions and contraction, to prevent cracking and excessive stresses. expansions and contraction joints are provided. Expansion joints allow free movement of slabs during rise in temperature. while constraction joints used to reduced central



cracking when temperature falls and concrete contracts these joints relieve tensile stress maintain slab integrity and ensure smooth riding quality. Joints are usually provided transversely at suitable intervals depending on slab length and temperature range.

68.

Sol. Tie bar -

- I. These are used across longitudinal joint of cement concrete pavements,
- II. Tie bars are not designed to act as a load transfer device.
- III. These are designed to withstand tensile stresses.
- IV. Tie bars are provided at longitudinal joints to hold the slab in position.

Dowel bar -

- I. Dowel bars are provided in the direction of traffic (longitudinal)
- II. Dowel bar transfer the load of wheel from one slab to another
- III. It reduces the differential deflection b/w two slab.
- IV. Half length of this bar is bent in one cement concrete slab and the remaining portion in adjacent but kept free for movement.

69.

Sol. Climatic variations affects in design of pavements in many ways-

- (I) Temperature variation - (seasonal/durnal)- its cause expansion and contraction inducing frictional and warping stress in pavements.
- (II) Rainfall and moisture affect subgrade strength, requiring proper drainage design to avoid water-related failure like water-logging.
- (III) Freeze - Thawing cycles (in cold region)- lead to frost heave & pavement cracks
- (IV) Climatic changes affects material properties like stiffness and durability
- (V) Design must include joints, drainage system and suitable materials based on local climate.

70.

Sol.

- | | | |
|------------------------|---------------------|-------------------------------------|
| (1) Group index method | } empirical methods | (4) Triaxial test - semi empirical |
| (2) CBR method | | (5) Burmister - Theoretical method. |
| (3) McLeod method | | |

(1) Group index method -

- It is also called as public road administration classification system, which is generally used for classification of soil used for pavement construction.
- In this method, a parameter "Group Index" (GI) is used to describe the performance of soil when used for pavement construction.
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- Group index is dependent upon percentage passing through 75 μ , liquid limit and plasticity index of soil.

$$GI = 0.2a + 0.01bd + 0.005ac$$

a = Portion of % passing through 75 μ sieve greater than 35% but not exceeding 75% expressed as whole no. between 0 to 40.

$$a = \%P - 35 \in [0, 40]$$

b = Portion of % passing through 75 μ sieve greater than 15% but not exceeding 55% expressed as whole number between 0 to 40.

$$b = \%P - 15 \in [0, 40]$$

c = Portion of numerical liquid limit (w_L) greater than 40% but not exceeding 60% expressed as whole no. between 0 to 20.

$$c = w_L - 40\% \in [0, 20]$$

d = Portion of numerical plasticity index (I_p) whole value is greater than 10 but not exceeding 30% expressed as whole no. between 0 to 20.

$$d = I_p - 10 \in [0, 20]$$

Note:

Value of GI varies from 0 to 20.

71.

Sol. Given :- $E_{sg} = 90 \text{ kg/cm}^2$, $E_{pm} = 900 \text{ kg/cm}^2$, $P = 5100 \text{ kg}$
 $p = 7.0 \text{ kg/cm}^2$, X (Traffic coefficient) = 1.25, Y (Saturation coefficient) = 0.8
 Thickness of bituminous mat above subgrade is given as

$$T_p(\text{cm}) = \sqrt{\left(\frac{3PXY}{2\pi E_{sg}\Delta}\right)^2 - a^2} \left\{ \frac{E_{sg}}{E_{pm}} \right\}^{1/3} \quad \{\Delta = \text{design deflection} = 0.25 \text{ cm (let)}\}$$

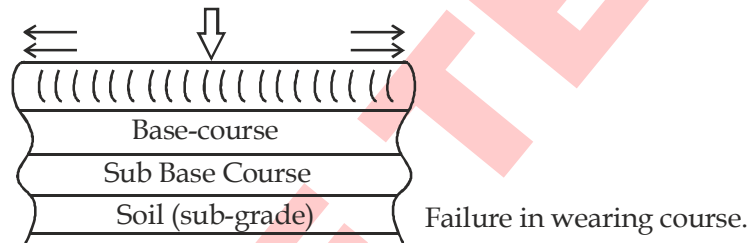
$$T_p = \sqrt{\left(\frac{3 \times 5100 \times 1.25 \times 0.8}{2\pi \times 90 \times 0.25}\right)^2 - \frac{5100}{\pi \times 7} \left\{ \frac{90}{900} \right\}^{1/3} \left\{ a = \text{radius of contact area} \right\}} \\ = \sqrt{P / \pi p}$$

$T_p = 49.73 \text{ cm} \approx 50 \text{ cm}$, so the thickness of bituminous mat above subgrade required is 50 cm.

72.

Sol. Causes of pavement failure are following-

1. Defect's in the quality of material used, construction method and quality control during construction.
2. Inadequate surface or subsurface drainage.
3. Increase in magnitude of wheel load and number of load repetition.
4. settlement of foundation of embankment due to low bearing capacity.



73.

Sol. Construction of WBM roads can be breakdown in given steps.

- (1) Preparation of foundation for receiving WBM course.
- (2) Provision of lateral confinement : Done by constructing shoulder
- (3) Spreading of coarse aggregate : uniformly spreading to even thickness
- (4) Rolling : started from edges and gradually towards center line.
- (5) Application of screening : for filling the interstices left.
- (6) Sprinkling and grouting : sprinkler with water swept and rolled
- (7) Application of binding material
- (8) Setting and drying.

74.

Sol. Given :-

Design speed, $V_d = 80 \text{ kmph}$

As per IRC, taking maximum superelvation, $e_{\max} = 70\% (0.07)$

and friction factor value = $f = 0.15$

Since, only design speed is given considering it as ruling design speed and road as major district road in plain terrain for which min speed = 65 kmph

so $V_{\text{dmin}} = 65 \text{ km/hr}$ & $V_{\text{d ruling}} = 80 \text{ km/hr}$

$$\text{Absolute minimum radius} = \frac{V_{\min}^2}{127(e_{\max} + f)} = \frac{65^2}{127(0.07 + 0.15)} = 151.22 \text{ m}$$

$$\text{Ruling minimum radius} = \frac{V_{\text{Ruling}}^2}{127(e_{\max} + f)} = \frac{80^2}{127 \times (0.22)} = 229.1 \text{ m}$$

75.

Sol. The objectives of providing transition curve-

- (1) To gradually introduce the centrifugal force b/w straight and circular curve.
- (2) To avoid jerk.
- (3) For gradual introduce of superelevation and extra-widening
- (4) To improve aesthetic appearance.

76.

Sol. 1. Aggregate impact value test
2. Los angel abrasion value test
3. crushing value test
4. water absorbtion test

1. Aggregate impact value test - Evaluate toughness of stone.

Dry aggregate passing 12.5 mm sieve and retained on 10 mm sieve is filled in a cylindrical mould in 3 layer's. This sample is a transferd to a cup which is compacted by tamping 25 times. Hammer falls freely from height of 38 cm. after 15 blow's the crushed aggregate is sieved on 2.36 mm siewe.

$$AIV = \frac{\omega_2}{\omega_1} \times 100$$

ω_1 = Total weight of agg.

ω_2 = Weight of agg. passing 2.36 mm sieve.

77.

Sol. The formula for radius of relative stiffness for rigid pavement is-

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

l - Radius of relative stiffness (cm)

h - thickness of pavement (cm)

k - Modulus of subgrade reaction (Kg/cm³)

μ - Poisson's ratio

E - Modulus of elasticity (Kg/cm²)

78.

Sol. The Benkelman beam test procedure involves measuring the rebound deflection of a pavement under a standard wheel load. Deflection measurements are taken at intervals along the road using the Benkelman beam and loaded truck. The results are used to calculate the true rebound deflection and characterize pavement strength statistically based on mean, standard deviation, and characteristic deflection values. Overlay design is then determined based on the statistical analysis.

79.

Sol. As we know that,

Stopping distance = Lag distance + Braking distance

$$= vt + \frac{v^2}{2gf}$$

Where,

$$V = 50 \text{ kmph} \text{ or } v = \frac{50}{3.6} = 13.9 \text{ m/sec}$$

$$t = 2.5 \text{ sec, } g = 9.8 \text{ m/sec}^2, f = 0.37$$

$$\text{Hence, Stopping distance} = 13.9 \times 2.5 + \frac{13.9^2}{2 \times 9.8 \times 0.37}$$

$$= 34.8 + 26.6 = 61.4 \text{ m}$$

Alternatively, the stopping distance may also be calculated as.

$$SD = 0.278Vt + V^2 / 254f$$

$$= 0.278 \times 50 \times 2.5 + \frac{50^2}{254 \times 0.37} = 61.4m$$

- (a) Stopping sight distance for two way traffic on two lane road
= Stopping distance = 61.4 m
- (b) Stopping sight distance for two way traffic with single lane
= 2 [Stopping distance] = $2 \times 61.4 = 122.8$ m

80.

Sol. According to this theory the total reaction time of the driver is split into four parts.

- (i) Perception
- (ii) Intellection
- (iii) Emotion, and
- (iv) Volition

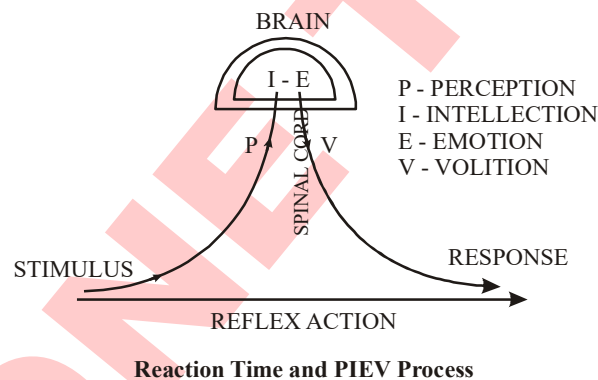
Perception time is the time required for the sensations received by the eyes or ears to be transmitted to the brain through the nervous system and spinal cord. In other words, it is the time required to perceive an object or situation.

Intellection time is the time required for understanding the situation. It is also the time required for comparing the different thoughts, regrouping and registering new sensations.

Emotion time is the time elapsed during emotional sensations and disturbance such as fear, anger or any other emotional feeling with reference to the situation. Therefore the emotion time of a driver vary considerably depending upon the problems involved.

Volition time is the time taken for the final action.

The PIEV process is shown in fig.



The PIEV time of a driver depends on several factors such as physical and psychological characteristics of the driver, type of the problem involved, environmental condition and temporary factors (e.g. travel speed, fatigue, consumption of alcohol, etc.) The total reaction time of an average driver may vary from 0.5 second for simple situations to as much as 3 to 4 seconds or even more in complex problems.

PART - C

20 Marks Questions

81.

Sol. Capacity per lane = $\frac{1800}{2} = 900$ Vehicle / hour

$$\text{Jam density, } k_j = \frac{1000}{5} = 200 \text{ Veh. / km}$$

$$\text{Maximum capacity, } q_{\max} = \frac{V_{st} \times k_j}{4}$$

$$\Rightarrow 900 = \frac{V_{st} \times 200}{4}$$

$$\therefore V_{st} = 18 \text{ kmph}$$

As given in question, the speed v/s density relationship is linear,

$$\text{So, } V = V_{st} \left[1 - \frac{k}{k_j} \right]$$

As we know that, $q = Vk$

Since traffic volume = 1000 vehicle/hour for two lane

So, for single lane, $q = 500$ vehicle/hour

$$q = V_{st} \left[1 - \frac{k}{k_j} \right] k$$

$$\Rightarrow 500 = 18 \left[1 - \frac{k}{200} \right] k$$

$$\Rightarrow 27.77 = k - \frac{k^2}{200}$$

$$\Rightarrow 5554 = 200k - k^2$$

$$\Rightarrow k^2 - 200k + 5554 = 0$$

$$\therefore k = 33.32 \text{ Veh./km for single lane}$$

So, for two lane urban road

$$k = 33.32 \times 2 = 66.64 = 67 \text{ Veh./km}$$

82.

Sol. The various defects occurring in WBM and surface treated asphalt roads in India are as follows :

(i) **Surface Defects :**

These are associated with the surfacing layers and may be due to excessive or deficient quantities of bitumen in these layers.

- **Fatty Surface :**

Fatty surface results when the bituminous binder moves upward in the surfacing and collects as a film on the surface.

Causes :

- Excessive binder in a premix surfacing over filling the voids.
- Non-uniform spreading or loss of cover aggregates in surface dressing.
- Excessive application of binder in surface dressing.

- **Smooth Surface :**

A smooth surface has a very low skid resistance value and becomes very slippery when wet.

Cause :

The primary cause for a smooth surface is the polishing of aggregates under traffic. Also, excessive binder can result in smooth surface.

- **Streaking**

Streaking is characterized by the appearance of alternate lean and heavy lines of bitumen either in longitudinal or transverse direction.

Causes :

- Longitudinal streaking results when alternate longitudinal strips of surface contain different quantities of bitumen due to non-uniform application of bitumen across the surface.
- Some of the common causes are mechanical faults, improper or poor adjustment and careless operation of bitumen distributors.
- Application of bitumen at too low temperature can also result in formation of streaks.

- **Hungry Surface :**

Hungry surface is characterized by the loss of aggregates from the surface or the appearance of fine cracks.



Causes :

- (a) The main cause of hungry surface is the use of less bitumen in the surfacing.
- (b) This condition may also appear due to use of absorptive aggregates in the surfacing.

(ii) Cracks :

A common defect in bituminous surface is the formation of cracks. The crack pattern in many cases, indicate the cause of the defect.

- **Hair-Line Cracks :**

These appear as short and fine cracks at close intervals on the surface.

Causes :

- (a) Insufficient bitumen content
- (b) Excessive filler at the surface
- (c) Improper compaction

- **Alligator Crack or (Map Cracking)**

These appears as interconnected cracking forming a series of small block which resemble the skin of an alligator.

Causes :

- (a) Excessive deflection of the surface over unstable sub-grade, sub-base or base of the pavement, particularly in wheel tracks.
- (b) Excessive overloads by heavy vehicles or inadequate pavement thickness, or both.
- (c) Brittleness of the binder due to ageing of binder or initial overheating. In this case, there will be no deflection of the surface. These cracks are sometimes called '**Crazing**'.

- **Longitudinal Cracks :**

These cracks appear more or less on a straight line along the road. These cracks may appear either at the joint between the pavement and the shoulder, or at the joint between two paving lanes.

Causes :

- (a) The cracking at the shoulder pavement joint may be due to alternate wetting and drying beneath the shoulder surface owing to poor drainage or due to depressions in the pavement edge.
- (b) The lane joint crack is caused by a weak joint between adjoining spreads in the layers of pavement.

- **Edge Cracks :**

Edge cracks are formed parallel to the outer edge of the pavement usually 0.3 - 0.5 m inside the edge.

Causes :

- (a) Lack of lateral support from the shoulder
- (b) Frost-heave
- (c) Settlement or yielding of the underlying material
- (d) Inadequate surface drainage, especially during flooding conditions.

- **Shrinkage Cracks**

These are cracks appearing in the transverse direction, or as interconnected cracks forming a series of large blocks.

Causes :

The primary cause for such cracks is the shrinkage of the bituminous layer itself with age.

- **Reflection Crack or (Sympathetic Crack) :**

It appears in the bituminous surfacing over joints and cracks in the pavement underneath.

Causes :

Reflection cracking is due to joints and cracks in the pavement layer underneath.

(iii) Disintegration :

These are the defects which if not rectified immediately, result in the disintegration of the pavement into small, loose fragments.

- **Stripping :**

This defect is characterized by the separation of bitumen adhering to the surfaces of the aggregates particles, in the presence of moisture.

Causes :

- (a) Inadequate mix composition
- (b) Use of hydrophilic aggregates
- (c) Initial over heating of the binder or aggregate



- (d) Use of improper grade of bitumen
- (e) Ageing of the bitumen leading to the embrittlement of the binder film
- (f) Continuous contact of water with the coated aggregate

- **Ravelling :**

It is characterized by the progressive disintegration of the surface due to the failure of the binder to hold the materials together.

Causes :

- (a) Inadequate compaction during construction
- (b) Improper coating of aggregates by binder
- (c) Insufficient binder in the mix
- (d) Excessively open-graded mix
- (e) Use of inferior quality aggregate resulting in fracture and disintegration of pavement

- **Pot-Hole :**

Pot holes are bowl-shaped holes of varying sizes in a surface layer or extending into the base course caused by localized disintegration of the material.

Causes :

- (a) Most common cause of pot-hole formation is the ingress of water into the pavement through the surfacing course. This makes the pavement soft and under the action of traffic, a depression soon gets formed.
- (b) Lack of proper bond between the bituminous surfacing and the underlying WBM base.
- (c) Insufficient bitumen content in localized areas.
- (d) Too thin bituminous surface which is unable to withstand the heavy traffic.
- (e) In dense graded mix, pot-holes can be caused by too much or too few fines.

- **Edge Breaking :**

The edge of the bituminous surface gets broken in an irregular way.

Causes :

- (a) Worn out shoulders resulting in insufficient side support to the pavement.
- (b) Inadequate strength due to improper compaction at the edge of the pavement
- (c) Lower layer of pavement not being wider than upper layer.

- **Loss of Aggregates :**

The surface presents with round appearance, with some portion having aggregates intact and others where aggregates have been lost.

Causes :

- (a) Ageing and hardening of the binder resulting in loss of its adhesive property.
- (b) Insufficient binder for the size of aggregate used
- (c) Fast traffic over new work whipping of the aggregates
- (d) Cold spraying of bitumen or delaying the spreading of aggregates over sprayed bitumen.

- (iv) **Deformation**

Any change in the shape of the pavement from its original shape is a deformation.

- **Slippage :**

It is the relative movement between the surface layer and the layer underneath.

Causes :

- (a) Unusual thrust of vehicle in a particular direction
- (b) Omission or inadequacy of tack-coat or prime coat
- (c) Failure of bond between two layers due to excessive deflection of the pavement

- **Rutting :**

Rutting is a longitudinal depression or groove on the surface.

Causes :

- (a) Heavy channelised traffic
- (b) Inadequate compaction of the mix at the surface or in the underlying courses.
- (c) Intrusion of sub-grade clay in base-course
- (d) Weak pavement

- **Corrugation :**

It is the formation of fairly regular undulations across the bituminous surface

Causes :

- (a) Lack of stability in the mix
- (b) Oscillations set up by the vehicle springs can cause alternate valleys and ridges
- (c) Faulty laying of surface course

Shoving :

Shoving is a form of plastic movement within the layer resulting in localized bulging of the pavement surface.

Causes :

- (a) Use of non-volatile oil on roller wheels
- (b) Heavy traffic movement of a start and stop type
- (c) Lack of stability in the mix
- (d) Lack of bond between bituminous and underlying layers

Shallow Depression :

Shallow depressions are low areas of limited size, dipping about 25 mm or more below the desired profile, where water will normally collect.

Cause :

It is caused by the settlement of lower pavement layers due to a pocket of inadequately compacted sub-grade or pavement layers.

83.

Sol. Given,

$$E = 2.5 \times 10^5 \text{ kg/cm}^2$$

$$h = 20 \text{ cm}$$

$$K = 6 \text{ kg/cm}^3$$

$$\mu = 0.15$$

$$P = 5100 \text{ kg}$$

$$a = 15 \text{ cm}$$

Radius of relative stiffness i.e. l is

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

$$= \left[\frac{2.5 \times 10^5 \times 20^3}{12 \times 6(1-0.15^2)} \right]^{1/4} = 73 \text{ cm}$$

$\therefore$ Corner stress i.e. S_c is

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

$$S_c = \frac{3 \times 5100}{20^2} \left[1 - \left(\frac{15\sqrt{2}}{73} \right)^{0.6} \right]$$

$$S_c = 20.03 \text{ kg/cm}^2$$

84.

Sol. In a transportation study, it is often necessary to know the exact origin and destination of the trips. It is not only necessary to know how many trips are made, but also to group these trips with reference to the zones of their origin and destination.

Some More Reasons to conduct O and D studies are as follows :

- (i) To judge the adequacy of existing routes and to use in planning new network of roads.
- (ii) To plan the transportation system and mass transit facilities in cities including routes and schedules of operation.
- (iii) To locate expressways or major routes along the desire lines.
- (iv) To establish preferential routes for various categories of vehicle including by pass.
- (v) To plan the road network and other facilities for vehicular traffic.



Some of the methods for conducting O and D studies are given below :

(1) Road side interview method :

The vehicles are stopped at previously decided interview stations, by a group of persons and the answers to prescribed questionnaire are collected on the spot. The information collected include the place and time of origin and destination, route, locations of stoppages, the purpose of the trip, type of vehicle and numbers of passengers in each vehicle. The main draw-back of this method is that the vehicles are stopped for interview, and there is a delay to the vehicular movement. Also resentment is likely from the road users.

(2) Licence plate method :

The entire area under study is cordoned out and the observers are simultaneously stationed at all points of entry and exit on all the routes leading to and out of the area. Each party at the observation station is given synchronized time pieces and they note the license plate numbers (registration numbers) of the vehicle entering and leaving the cordoned area and the time. Separate recording sheets are maintained for each direction of movement for specified time interval.

(3) Return post card method :

Prepaid business reply post cards with return address are distributed to the road users at some selected points along the route or the cards are mailed to the owners of the vehicles. The questionnaire to be filled in by the road user is printed on the card, along with a request for cooperation and purpose of the study. The distributing stations for the cards may be selected where vehicles have to stop as in case of a toll booth. The method is suitable where the traffic is heavy.

(4) Tag on car method :

In this method a precoded card is stuck on the vehicle as it enters the area under study. When the car leaves the cordon area, the other observations are recorded on the tag. This method is useful where the traffic is heavy and moves continuously.

(5) Home interview method

A random sample of 0.5 to 10% of the population is selected and the residences are visited by the trained personnel who collect the travel data from each member of the household. Detailed information regarding the trips made by the members is obtained on the spot. The data collected may be useful either for planning the road network and other roadway facilities for the vehicular traffic or for planning the mass transportation requirements of the passengers. The problem of stopping vehicle and consequent difficulties are avoided altogether in this method. But to have a complete coverage of the entire cross section of the population is very tedious.

85.

Sol. Given :

Radius, (R) = 550 m

Design speed, (V) = 80 km/hr

Pavement width = 7 meter

Allowable rate of introduction of superelevation = 1 in 150

(i) Based on allowable rate of change of centrifugal acceleration :

$$L_s = \frac{v^3}{CR}; v \rightarrow \text{ms}^{-1}$$

$$C = \frac{80}{75 + V}; V \rightarrow \text{km/hr}, 0.5 < C < 0.8$$

$$C = \frac{80}{75 + 80} = 0.516$$

$$L_s = \frac{\left(80 \times \frac{5}{18}\right)^3}{0.516 \times 550} = 38.67 \text{ m}$$

(ii) Based on allowable rate of introducing of super-elevation :

Calculation of super-elevation

$$e = \frac{(0.75V)^2}{127R}$$

$$e = \frac{(0.75 \times 80)^2}{127 \times 550} = 0.0515 < 0.07, \text{ so OK}$$

Calculation of extra-widening :

As per IRC, for radius above 300 m, there is no requirement of extra widening.

∴ Width of pavement at horizontal curve = 7 m

Let us assume that the pavement is rotated about inner edge after neutralising the camber,

$$L_s = e(w + w_e) \times N$$

$$L_s = 0.0515(7 + 0) \times 150 = 54.08 \text{ m}$$

∴ Length of transition curve = Maximum {38.67, 54.08}
= 54.08 m

∴ Length of transition curve = 54.08 m

86.

Sol. Since it is two-lane undivided highway, vehicles can overtake and there can be a vehicle coming in the opposite direction also.

Minimum overtaking sight distance

$$= d_1 + d_2 + d_3$$

Given that design speed (the speed of overtaking vehicle)

$$v = 22.22 \text{ m/sec}$$

V_B = Speed of slow moving vehicle

$$V_B = 16.67 \text{ m/sec.}$$

$$a = 0.7 \text{ m/sec}^2$$

$$d_1 = (v_B) \times t_1$$

Taking

$$t_1 = 2 \text{ sec. (As per IRC for OSD)}$$

$$d_1 = 16.67 \times 2$$

$$= 33.34 \text{ m}$$

$$S = \text{Space headway} = V_B \times t_r + L$$

As per IRC

$$S = 0.69 V_B + 6$$

$$= 11.50 + 6$$

$$= 17.50 \text{ m}$$

$$T = \sqrt{\frac{4 \times S}{a}} = \sqrt{\frac{4 \times 17.5}{0.7}}$$

$$= 10 \text{ sec}$$

$$d_2 = 2S + v_B T$$

$$= 2 \times 17.5 + 16.67 \times 10$$

$$= 35 + 166.7$$

$$= 201.7 \text{ m}$$

$$d_3 = V \times T$$

$$= 22.22 \times 10$$

$$= 222.2 \text{ m}$$

Minimum overtaking sight distance

$$= d_1 + d_2 + d_3$$

$$= 33.34 + 201.7 + 222.2$$

$$\text{OSD} = 457.24 \text{ m}$$



Say 460 m

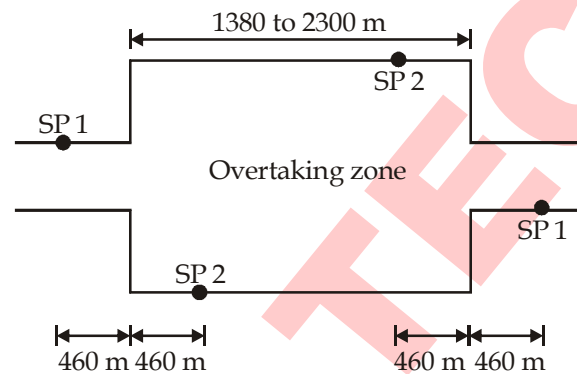
Minimum length of overtaking zone

$$\begin{aligned}
 &= 3 \times \text{minimum overtaking sight distance} \\
 &= 3 \times 460 \\
 &= 1380 \text{ m}
 \end{aligned}$$

Maximum or desirable length of overtaking zone

$$\begin{aligned}
 &= 5 \times \text{minimum overtaking sight distance} \\
 &= 5 \times 460 \\
 &= 2300 \text{ m}
 \end{aligned}$$

The overtaking zone is shown in figure.



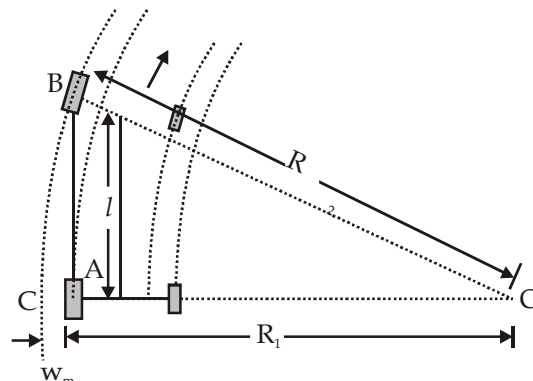
87.

Sol. In case of horizontal curves having sharp radii, it is common to widen the pavement slightly more than normal width.

The objects of providing extra widening of pavements on horizontal curves are due to the following reasons :

- (i) Since, vehicle has a rigid wheel base and only the front wheels can be turned; when this vehicle takes a turn to negotiate a horizontal curve, the rear wheel do not follow the same path as that of front wheels. The phenomenon is known as off tracking.

Normally at low speeds (without lateral slipping of rear wheels); the rear wheels follows the inner path on the curves as compared to that of corresponding front wheels. This means that if inner front wheel takes a path on the inner edge of a pavement, inner rear wheel will be off the pavement on inner shoulder.



- (ii) A vehicle moving at a speed higher than design speed when the superelevation and lateral friction developed are not fully able to counteract the centrifugal force, some transverse skidding may occur and the rear wheels may take paths on the outsides of those traced by the front wheels on horizontal curves.
- (iii) In order to take curved path larger radius and to have greater visibility at curve, the drivers have tendency not to follow the central path of lane, but to use the outer side at the beginning of curve.
- (iv) While two vehicles cross or overtake at horizontal curve, there is psychological tendency to maintain a greater clearance between the vehicles, than on straight road, for increase safety.
- (vi) The path traced by the wheels of a trailer in case of trailer units, is also likely to be either side of the central path of the towing vehicle.

Based on above facts; it is cleared that the required extra widening of the pavement of horizontal curves depends on following factors :

- (a) Length of wheel based of the vehicle (l)
- (b) Radius of curve negotiated (R)
- (c) Psychological factor which is a function of the speed of the vehicle and radius of curve;
- (d) No. of traffic lanes.

The dependence of these factors can be described using analysis of extra widening on curves. The extra widening is divided into two parts

- (i) Mechanical widening
- (ii) Psychological widening

(i) Mechanical widening : (W_m)

The widening required to account for the off tracking due to rigidity of wheel based is called mechanical widening.

W_m is mathematically calculates as $\frac{nl^2}{2R}$; where

n = No. of traffic lanes

l = Length of wheel bases of the vehicle

R = Radius of horizontal curve.

(ii) Psychological widening (W_{ps}) :

Extra width of pavement is also provided for psychological reasons such as, to provide for greater maneuverability offering at higher speeds, to allow for extra space requirements for overhanging and vehicles and to provide greater clearance for crossing and overtaking on the curves.

W_{ps} is calculated as empirical formula as $\frac{V}{9.5\sqrt{R}}$

Hence the total widening W_e on horizontal curves of radius R , is expressed as

$$W_e(m) = \frac{nl^2}{2R} + \frac{V}{9.5\sqrt{R}}$$

Here, V = design speed in kmph and W_e , l and R in meter.

88.

Sol. Valley curves are formed in case of two gradients of road level meet as a convexity downwards. The most important factors considered of valley curves are :

- (i) Impact-free movement of vehicles at design speed or comfort to passengers.
- (ii) Availability of stopping sight distance under head lights of vehicles for night driving.

Also, at the valley curve, the centrifugal force acts downwards adding to the pressure on the vehicle in addition to that due to weight of vehicle. Hence, the allowable rate of change of centrifugal acceleration govern the design of valley curves.

The length of valley transition is designed based on the two criteria.

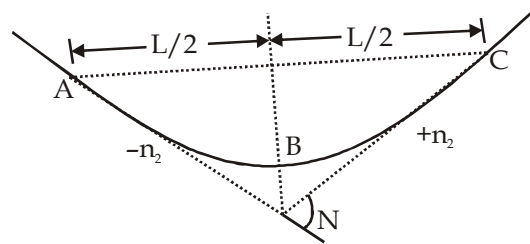
- (a) Allowable rate of change of centrifugal acceleration of 0.6 m/sec^3 .
- (b) The head light sight distance



The higher of the above two values is adopted. Usually the head light sight distance criteria is higher and therefore governs the design.

1. Length of valley curve for comfort condition.

The valley curve is made fully transitional by providing two similar transition curves of equal length.



Here ABC is the valley curve of total length L and AB and BC are two equal transition curves each of length $L_s = L/2$, having the minimum radius R at the common point B.

By transition curve formula,

$$L_s = \frac{V^3}{RC}$$

and

$$R = \frac{L_s}{N} = \frac{L}{2N}$$

$\therefore$

$$L_s = \frac{V^3}{CL_s} \times N$$

$\Rightarrow$

$$L_s^2 = \frac{NV^3}{C}$$

$\Rightarrow$

$$L_s = \sqrt{\frac{NV^3}{C}}$$

and

$$L = 2L_s = 2\sqrt{\frac{NV^3}{C}}$$

Here, N is the deviation angle,

V is the speed m/sec

C is allowable rate of change of centrifugal acceleration = 0.6 m/sec^3

$$\therefore L = 2\sqrt{\frac{N \times (0.278 V)^3}{0.6}} = 0.38\sqrt{NV^3}$$

Here,

L = Total length of valley curve

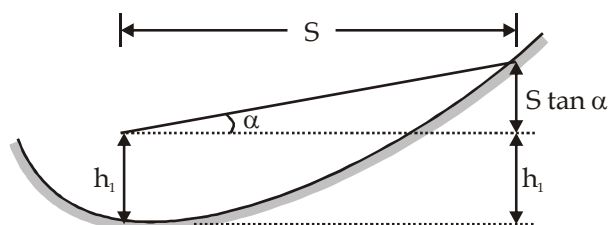
N = deviation angle in radian or tangent of the deviation angle or algebraic differences in grades.

V = design speed in kmph

The minimum radius R of valley curve for cubic parabola

$$R = \frac{L_s}{N} = \frac{L}{2N}$$

2. The length of valley curve for head light sight distance it is determined for two conditions.
 (i) When total length of valley curve L is greater than stopping sight distance SSD .



Let the height of the head light be h_1 and the focussed portion of beam light be inclined at angle α upwards. The sight distance available will be minimum when the vehicle is at the lowest point on the sag curve. It is valley curve is assumed to be parabolic shape with equation

$$y = ax^2$$

where
$$a = \frac{N}{2L}$$

$$\therefore h_1 + S \tan \alpha = aS^2 = \frac{NS^2}{2L}$$

$$L = \frac{NS^2}{2h_1 + 2S \tan \alpha}$$

If the average height of head light is taken as $h_1 = 0.75$ m and the beam angle $\alpha = 1^\circ$, by substituting

$$L = \frac{NS^2}{1.5 + 0.035S}$$

Here,

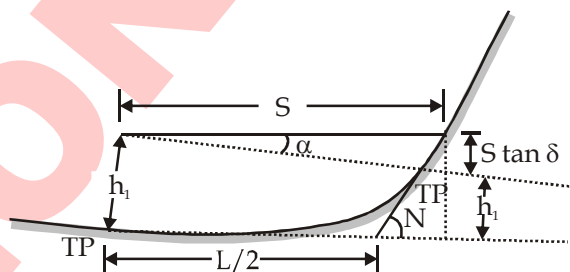
L = Total length of valley curve

S = SSD, m

N = deviation angle = $(n_1 + n_2)$

- (ii) $L < SSD$

Let the vehicle be at the start of the valley curve or at the tangent point T_p , for minimum sight distance.



Here,
$$h_1 + S \tan \alpha = \left(S - \frac{L}{2}\right)N$$

$$L = 2S - \frac{(2h_1 + 2S \tan \alpha)}{N}$$

substituting,

$$h_1 = 0.75 \text{ and } \alpha = 1^\circ$$

$$L = 2S - \frac{1.5 + 0.035N}{N}$$

The lowest point on the valley curve is to be located for providing cross drainage facility. This point on curve will be on the bisector of angle between the grades, if the gradients on either side are equal. When the gradients are not equal, the lowest point lies on the side of flatter grade, and this point is

at a distance $X_0 = L\sqrt{\frac{h_1}{2N}}$ from the tangent point of first grade n_1 . This is obtained by assuming the

valley curve to be a cubic parabola given by equation $y = bx^3$ where $b = \frac{2N}{3L^2}$. This practically coincides with the spiral transition curve for small deflection angles of valley curves; the vertical distance y is differentiated with respect to the horizontal distance x and equated to zero to obtain the lowest point on the curve.

$$\therefore y = \frac{2N}{3L^2} \cdot x^3$$

$$\frac{dy}{dx} = \frac{2N}{3L^2} \cdot 3x^2 = n_1$$

[taking one grade n_1 as dy/dx]

$$x^2 = \frac{n_1 L^2}{2N}$$

$$x = L\sqrt{\frac{n_1}{2N}}$$

(This x gives horizontal distance for lowest point on curve)

89.

Sol. Traffic capacity is the ability of a roadway to accommodate traffic volume. It is expressed as the maximum number of vehicle in a land that can pass a given point in unit time, i.e., vehicles per hour per lane or roadway. The capacity of a roadway depends on a number of prevailing roadway and traffic conditions.

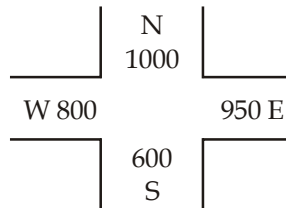
- (a) **Basic Capacity :** It is the maximum number of passenger cars that can pass a given point on a lane or roadway during one hour under the most nearly ideal roadway and traffic conditions which can possibly be attained. Two roads having the same physical factors will have same basic capacity irrespective of traffic conditions, as they are assumed to be ideal.
- (b) **Possible Capacity :** It is the maximum number of vehicles that can pass a given point on a lane or roadway during one hour under prevailing roadway and traffic conditions. The possible capacity of a road is generally much lower than the basic capacity as the prevailing roadway and traffic conditions are seldom ideal. When the prevailing roadway and traffic conditions approach the ideal conditions, the possible capacity would also approach the basic capacity. Thus the value of possible capacity varies from zero to basic capacity.
- (c) **Practical Capacity :** It is the maximum number of vehicle that can pass a given point on a lane or roadway during one hour without traffic density being so great as to cause unreasonable delay, hazard or restriction to the driver's freedom to manoeuvre under the prevailing roadway and traffic conditions. It is the practical capacity which is of primary interest to the designers who strive to provide adequate highway facilities and hence it is also called design capacity.

Factor affecting practical capacity :

1. **Lane width :** As the lane width decreases, the capacity also decreases.
2. **Lateral clearance :** Vertical obstructions such as retaining walls or parked vehicles near the traffic lane reduce the effective width of a lane and thus result in reduction in the capacity of lane. Further, restricted lateral clearance affects driving comfort and increases rates.
3. **Width of shoulders :** Narrow shoulders reduce the effective width of traffic lanes as the vehicles travel towards the centre of pavement. When vehicles in emergency have to park on the shoulder of insufficient width, there is reduction in effective lane width resulting in a great reduction in capacity of the lane.
4. **Commercial vehicles :** Large commercial vehicles occupy greater space and influence the other traffic in the same lane as well as the vehicles along the adjoining lanes. Also, these heavy commercial vehicles may travel at lower speeds especially on grades.

5. **Alignment :** If the alignment and geometrics are not upto the desired standards, the capacity will decrease. Particularly, restrictions to sight distance requirements cause reduction in capacity. Steep and long grades affect the capacity.
6. **Presence of intersections at grade :** Intersections restrict free flow of traffic and thus adversely affect the capacity. The capacity of an intersection of two roads crossing at grade will be slightly less than the road with lower capacity of the two. In order to provide consistent traffic flow and maximum capacity on important highways is necessary to plan them as controlled access highways with grade separated intersections.
7. Other factors which affect the capacity are the stream speed, one or two way traffic movement, number of traffic lanes, vehicular and driver characteristics, composition of traffic and the traffic volume.
- 90.

Sol.



Towards North-South;

$$q_A, \text{ Maximum design hour traffic flow} \\ = 1000 \text{ pcu/hr}$$

$$S_A, \text{ Maximum saturation traffic flow} \\ = 3000 \text{ pcu/hr}$$

Toward East-West;

$$q_B, \text{ Maximum design hour traffic flow} \\ = 950 \text{ pcu/hr}$$

$$S_B, \text{ Maximum saturation traffic flow} \\ = 3600 \text{ pcu/hr}$$

Now by Webster's Method

$$y_A = \frac{q_A}{S_A} = \frac{1000}{3000} = \frac{1}{3}$$

$$y_B = \frac{q_B}{S_B} = \frac{950}{3600} = 0.264$$

$$y = y_A + y_B = 0.597$$

Total time lapse

$$L = nt_1 + nt_2$$

Here, t_1 = time lost in starting, per phase

t_2 = All red period per phase

n = no. of phase

$$L = 2 \times 2 + 2 \times 3 = 10 \text{ sec.}$$

$\therefore$ Optimum signal cycle

$$C_0 = \frac{1.5L + 5}{1 - y} = \frac{1.5 \times 10 + 5}{1 - 0.597}$$

$$= 49.63 \text{ sec.}$$

$$\cong 50 \text{ sec}$$

Now, G_A , green time for N-S direction

$$= \frac{y_A}{y} (50 - 10)$$

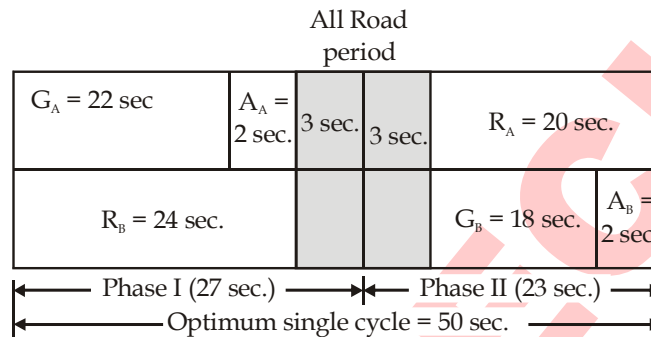
$$= \frac{0.33}{0.597} \times 40 = 22.31 \approx 22 \text{ sec}$$

G_B , Green time for E-W direction

$$= \frac{y_B}{y} (50 - 10)$$

$$= \frac{0.264}{0.597} \times 40 = 17.69 \text{ sec} \approx 18 \text{ sec.}$$

Timing and phase diagram,



Here,

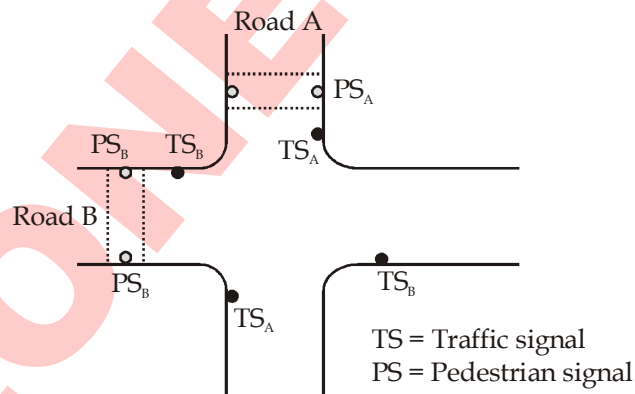
$G \rightarrow$ Green time

$R \rightarrow$ Red time

$A \rightarrow$ Amber time or starting delay

91.

Sol. The layout of traffic and pedestrian signals is shown in figure below



Design of traffic signals :

(i) **Based on the approach speed; amber periods :**

For road A with 55 kmph, amber period,

$$A_A = 4 \text{ secs}$$

For road B with 40 kmph, amber period,

$$A_B = 3 \text{ secs}$$

(ii) **Based on the pedestrian walking speed of 1.2 m/sec, the pedestrian clearance time is calculated.**

$$\text{Road A} = \frac{18}{1.2} = 15 \text{ secs}$$

$$\text{Road B} = \frac{12}{1.2} = 10 \text{ secs}$$

- (iii) Adding 7 secs for initial walk-period, minimum red time for road A is $(15 + 7)$ secs and that for road B is $(10 + 7)$ secs.
- (iv) Minimum green times based on pedestrian criterion :
- Road B = $15 + 7 - 3 = 19$ sec.
- Road A = $10 + 7 - 4 = 13$ sec.
- (v) Based on approach volume, the green time calculated is increased for Road A with higher traffic volume.

$$\text{Use relation } \frac{G_A}{G_B} = \frac{n_A}{n_B}$$

G_A and G_B are green times and n_A and n_B approach volume per land
 G_B is taken as 19 seconds as in (iv) above.
 Green time for Road A,

$$G_A = \frac{n_A}{n_B} G_B = \frac{275}{225} \times 19 = 23.2 \text{ secs}$$

- (vi) Total cycle length

$$\begin{aligned} &= G_A + A_A + R_A \\ &= G_A + A_A + G_B + A_B \\ &= 23.2 + 4 + 19 + 3 \\ &= 49.2 \text{ secs} \end{aligned}$$

Hence adopt cycle length of 50 secs.

The additional period of $50 - 49.2 = 0.8$ secs is distributed to green timings in proportion to approach traffic volume.

$$G_A = 23.2 + 0.44 = 23.64 \text{ secs}$$

$$G_B = 19.0 + 0.36 = 19.36 \text{ secs}$$

$$\begin{aligned} R_A &= G_B + A_B = 19.36 + 3.0 \\ &= 22.36 \text{ secs} \end{aligned}$$

$$\begin{aligned} R_B &= G_A + A_A = 23.64 + 4.0 \\ &= 27.64 \text{ secs} \end{aligned}$$

Design for pedestrian signal

Do not walk (DW) period of pedestrian signal at road A (PS_A) is red period of traffic signal at B.

$$\text{For } PS_A \quad DW_A = R_B = 27.64 \text{ secs}$$

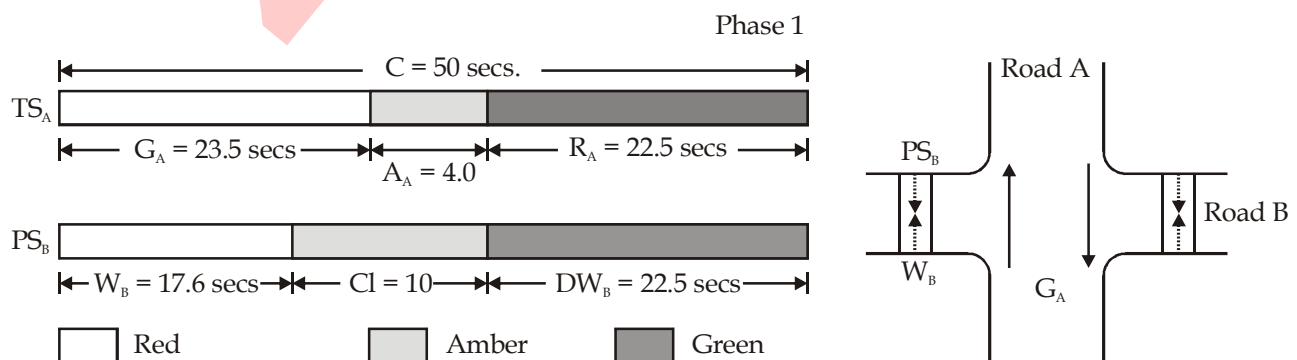
$$\text{For } PS_B \quad DW_B = R_A = 22.36 \text{ secs}$$

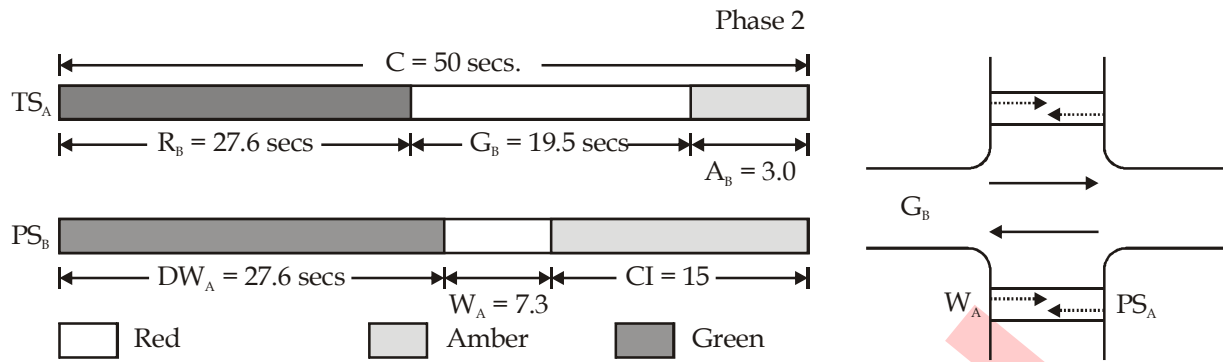
Pedestrian clearance intervals (CI) are of 15 and 10 secs. respectively, for road A and B for crossing from (ii) above. The walk time (W) is calculated from total cycle length.

$$\text{For } PS_A \quad W_A = 50 - (27.64 + 15) = 7.36 \text{ secs}$$

$$\text{For } PS_B \quad W_B = 50 - (22.36 + 10) = 17.64 \text{ secs}$$

Details of design timings are calculated in Table below, Alternatively a phase diagram may be drawn, as shown in figure below.





Interval	Road A		Road A		Time Interval (%)	Pedestrian	Traffic
	Vehicle TS_A	Pedestrian PS_B	Vehicle TS_A	Pedestrian PS_B			
1	G23.64	W 17.64	R 27.64	DW 27.64	35	$DW_A = 27.5$ $\left\{ \begin{array}{l} W_B \ 17.5 \\ \quad \quad 6.0 \end{array} \right\}$	$G_A = 23.5 \} R_A = 27.5$
2		CI 10.00			12		
3	A 4.00				8		
4				W 7.36	15	$DW_A = 27.5$ $\left\{ \begin{array}{l} W_A \ 17.5 \\ \quad \quad 12.0 \end{array} \right\}$	$G_B = 19.5 \} R_A = 22.5$
5	R 22.36	DW 22.36	G 19.36	CI 15.00	24		
6			A 3.00		6		

Traffic Signal

R - Red (Stop),

A - Amber (Clearance), G - Green (Go)

Pedestrian signal

W - Walk

CI - Clearance for pedestrians (may be indicated by flickering of walk signal (W))

DW - do not walk

Note : Amber period of a short interval however be provided in the traffic signal in between red and green periods for getting ready to cross. This period, is a part of the red period itself.

92.

Sol. Speed and Delay Study : This study is made mainly for the following purposes :

- It gives the running speeds, overall speeds, fluctuation in speeds and delay between two stations.
- To find the density of traffic.
- Economic studies utilise travel time and delay data.
- It also gives the information of amount, location, duration frequency and cause of delay in the traffic.

Delay can be categorized into two types :

- Fixed delay :** It is the delay to which traffic is subjected to regardless of the amount of traffic volumes and interferences present on the highway. This is not due to the characteristics of traffic streams. This includes traffic signals, stop signals, railroad crossings, etc. This delay can occur even with only one vehicle on the highway.
- Operational delay :** This is also known as congestion delay. This is caused by interference with other components of traffic. The difference between travel time over a route during an extremely low and during very high traffic volume indicates the amount of operational delay.

There are various methods of carrying out speed and delay study :

- License plate or vehicle number method.
- Interview technique

- Elevated observation
- Photographic technique
- Floating car method or riding check method.

Floating Car Method

In floating car method a test vehicle is driven over a given course of travel, approximately at the average speed of stream. A number of test runs are made along the study stretch and a group of observer records the various readings.

One observer with two stopwatches, notes time at various control points such as intersections and any other fixed point in each trip with one stopwatch and also notes the time of delay at each point with the help of second stopwatch.

Second observer notes the time, location and causes of the delays.

Third observer notes the number of vehicles overtaking the test vehicle and overtaken by the test vehicle.

Fourth observer notes the number of vehicles travelling in opposite direction in each trip.

The average journey time ($\bar{t}$) for all the vehicles in a traffic stream in the direction of flow is given as

$$\bar{t} = t_w - \frac{n_y}{q}$$

Flow of vehicles,

$$q \text{ (vehicle/min)} = \frac{n_a + n_y}{t_a + t_w}$$

where, n_a = Average number of vehicles counted in the direction of stream when the test vehicle travels in the opposite direction.

n_y = The average number of vehicles overtaking the test vehicle-the number of vehicles overtaken when the test is in the direction of flow

q = Flow of vehicles in one direction of the stream

t_a = Average journey time when test vehicle is running against the stream

t_w = Average journey time when the test vehicle is travelling with the stream

q

93.

Sol. The Bituminous Macadam (BM) is a premix laid immediately after mixing and then compacted. It is an open graded construction suitable only a base or binder course. When this layer is exposed as a surface course, at least a seal coat is necessary.

Specifications of Materials

The grades of bitumen used are 30/40 60/70 and 80/100 penetration. Road tar RT-4, cutback and emulsion can also be used in cold mix construction technique. The binder content used varies from 3.0 to 4.5 percent by weight of the mix.

Aggregates used are of low porosity fulfilling the following requirements for the base course.

Los Angeles abrasion value 50% max.

Aggregate impact value 35% max.

Flakiness index 15% max.

Stripping at 40°C after 24 hours 25% max.

immersion (CRRI test)

Loss with sodium sulphate, 12% max.

5 cycles

For binding course the specified maximum abrasion and impact values are 40 and 30 percent respectively.

The quantity of aggregates required for 10 m² of bitumen bound macadam are 0.60 to 0.75 m³ and 0.90 to 1.0 m³ respectively, for 50 and 75 mm compacted thickness. The bitumen quantity would be determined based on the gradings adopted.

Plants and Equipment :

Various plants and equipment required for the job include sprayer, mechanical mixer or improvised hand mixer, spreader (mechanical paver or finisher, grader, or manual methods) and roller.

There are different types of mixer in use. Mechanical mixers include travelling plant or central plant and are employed depending upon the job. Manual hand mixer is also used which is fixed vane type.

Construction Steps :

- (i) **Preparation of existing layer :** The existing layer is prepared to a proper profile. Pot holes are patched and irregularities are made even. The surface is properly cleaned.
- (ii) **Tack coat or prime coat application :** A tack coat is applied of thin layer of bitumen binder on the existing layer either using the sprayer or a pouring can. The quantity of application is 4.0 to 7.5 kg per 10 m² for black top layer and 7.5 to 10 kg per 10 m² for untreated WBM layer.
- (iii) **Premix preparation :** The bitumen binder and aggregates as per recommended gradings are separately heated to the specified temperatures and are then placed in the mixer chosen for the job. The mixing temperature for each grading and the bitumen binder is also specified based on the laboratory results. A tolerance of $\pm 10^\circ\text{C}$ is allowed. The mixing is done till a homogeneous mixture is obtained. The mixture is then carried to the site for its placement through a transporter or a wheel barrow.
- (iv) **Placement :** The bituminous paving mixture is then immediately placed on the desired location and is spread with rakes to a pre-determined thickness. The camber profile is checked with a template. It may be stated here that a compacting temperature also influence the strength characteristic of the resulting pavement structure. It is therefore required that the minimum time is spent between the placement of the mix and the rolling operations.
- (v) **Rolling and finishing the paving mix :** The rolling is done with 8 to 10 tonnes tandem roller. The rolling is commenced from the edges of the pavement construction towards the centre, and uniform overlapping is provided. The finished surface should not show separate lines of markings due to defective or improper rolling. The roller wheels are kept damp otherwise the paving mix may partly stick to the wheels and the finishing may not be good. A variation of 6 mm over 3 m length is allowed in the cross profile. The number of undulations exceeding 10 mm should be less than 30 in 300 m length of pavement.

94.

Sol. Radius of relative stiffness (l) is given by

$$l = \left[\frac{Eh^3}{12K(1-\mu^2)} \right]^{1/4} = \left[\frac{300 \times 10^5 \times 18^3}{12 \times 6(1-0.15^2)} \right]^{1/4}$$

$$= 70.6 \text{ cm}$$

The equivalent of resisting section is given by

$$ah = \frac{15}{18} = 0.833 < 1.74$$

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

$$= \sqrt{1.6 \times 15^2 + 18^2}$$

$$= -0.675 \times 18 = 14.0 \text{ cm}$$

(a) **Stress at the interior**

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

$$= \frac{0.316 \times 5100}{18^2} \left[4 \log_{10} \left(\frac{70.6}{14.0} \right) + 1.069 \right]$$

$$= 19.3 \text{ kg/cm}^2$$

(b) **Stress at the edge**

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

$$= \frac{0.572 \times 5100}{18^2} [4 \times 0.7027 + 0.359]$$

$$= 28.54 \text{ kg/cm}^2$$

(c) Stress at the corner

$$\begin{aligned}
 S_c &= \frac{3P}{h^2} \left[1 - \left(\frac{a\sqrt{2}}{l} \right)^{0.6} \right] \\
 &= \frac{3 \times 5100}{18^2} \left[1 - \left(\frac{15\sqrt{2}}{70.6} \right)^{0.6} \right] \\
 &= 24.27 \text{ kg / cm}^2
 \end{aligned}$$

(d) Location where corner load crack develops

Location where the crack is likely to develop due to corner loading, the distance from the corner of the slab,

$$\begin{aligned}
 X &= 2.58\sqrt{al} = 2.58\sqrt{(15 \times 70.6)} \\
 &= 83.96 = 84 \text{ cm}
 \end{aligned}$$

95.

Sol. Some typical and basic types of failure in rigid pavements which are as under :

- Scalling of Cement concrete :** Scalling is observed in cement concrete pavement showing overall deterioration of the concrete. This is mainly attributed due to the deficiency in the mix or presence of some chemical impurities which damage the mix.
- Shrinkage cracks :** During the curing operation of cement concrete pavements immediately after the construction, the shrinkage cracks normally develop. The placements of cracks are in longitudinal as well as in transverse direction.
- Spalling of joint :** Sometimes when pre-formed filler materials are placed during casting of pavement slabs, the placement is some how dislocated and filler is thus placed at an angle. The concreting is completed without noticing this facility alignment of the filler material. Thus, this forms an overhang of a concrete layer on the top side and the joint later on shows excessive cracking and subsidence.
- Warping cracks :** If the joints are not well designed to accommodate the warping of slabs at edges, this results in development of excessive stress due to warping and the slab develops cracking at the edges in an irregular pattern.
- Mud pumping :** It is recognised when the soil slurry ejects out through the joints and cracks of cements concrete pavements caused during the downward movement of slab under the heavy wheel loads. Pumping is noticed just after the rains in cement concrete pavements that are placed on clayey soil subgrade. Due to applications of repeated loads, initial spaces are developed underneath the pavement slabs and water infiltrates into these spaces through joints, cracks and edges of pavements. Failure of cement concrete pavements are recognized mainly due to following factors :

1. **Deficiency of pavement materials :**

Following are the chief causes which would rise to different defect :

- Soft aggregates
- Poor workmanship in joint construction
- Poor joint filler and scaler material
- Poor surface finish
- Improper and insufficient curing

2. **Structural inadequacy of the pavement system :**

Inadequate subgrade support pavement thickness would be major cause of developing structural cracking in pavements. Following are the causes of failure :

- Inadequate pavement thickness
- Inadequate subgrade support and poor subgrade soil
- Incorrect spacing of joints

To prevent above mentioned cracks cement concrete roads to be done by examining the cracks and causes are ascertained before any remedial measure is adopted.



- A. **Treatment of cracks :** Due to repeated application of heavy wheel loads and variation in temperature and moisture conditions, the cracks get widened. Therefore, before these cracks get wide enough to permit infiltration of water, they should be sealed off to prevent rapid deteriorations. The dirt, sand and other loose particles at the cracks are thoroughly cleaned cracks to facilitate proper bonding of the sealing material. The cracks are then filled by suitable grade bituminous sealing compound, heated to liquid consistency. To remove structural cracks, the maintenance work in such a case involves first remedy of basic causes of failure and then re-casting of failed slabs and also strengthen the concrete pavement by a flexible or rigid overlay expeditiously before cracks develop in other slabs.
- B. **Maintenance of joints :** Atmost case is to be taken to see that the filler and sealer materials are intact at the joints. Periodic maintenance of the joint sealer is essential both at expansion and contraction joints as a part of routine maintenance work. The opened-up joints are cleaned with brush and refilled with suitable joint sealer material before start of the rains.