TRANSPORTATION ENGINNERING – 1

UNIT – 1

1. What are the functions of transition curve?

- Introduce super elevation gradually from zero at the tangent point to the value on the circular curve.
- Maintains a constant proportionality between super elevation and the rate of change of curve.
- Eliminates discomfort and overturning.
- Eliminates discomfort to passenger.

2. Define simple curve.

Simple curve is a curve consists of a single arc with a constant radius connecting two straights or tangents.

3. Define horizontal curve.

Horizontal curve is one which is provided in the horizontal plane connecting two straight alignments.

4. Define vertical curve.

In a highway a change in the rate of grade or direction may cause the vehicle a sudden impact. So far a smooth and safe running of vehicles the change in gradient or direction is smoothened by a curve called a vertical curve.

5. Define transition curve.

It is also called as an easement curve, is an arc introduced between a straight and a circular curve or between two arcs of a compound curve. The radius of a transition curve varies from infinity to a fixed value.

6. Define reverse curve.

When two curves of different or equal radius are bending in opposite directions then it is called a reverse curve. Reverse curves have one common tangent.

7. Define compound curve.

When a curve consists of more than one radius connecting two intersecting straights it is called as a compound curve.

8. Define valley or sag curve.

A vertical curve, concave upwards, is called as a valley or sag curve. This occurs when,

- A descending gradient meets another descending gradient
- A descending gradient intersects an ascending gradient
- An ascending gradient meets another ascending gradient
- A descending gradient meets a horizontal

9. Distinguish between summit and valley curves.

For a smooth and safe running of vehicles the change in gradient or direction is smoothened by a curve called a vertical curve. The vertical curves adopted in highway may be classified as summit curve or valley

curve. A curve with convexity upwards is called a summit curve. A curve with concave upwards is called a valley curve.

10. Define gradient.

Gradient is the rate of rise or fall along the length of the road with respect to the horizontal. It is expressed as a percentage rise or fall or a rate of rise or fall with respect to horizontal distance. A gradient of 1 in 20 or 5% represents that there is an ascending or descending of road profile by one meter for every twenty meters. It is denoted by the symbol 'n'.

11. What is meant by exceptional gradient?

In some field conditions it will be unavoidable to provide a gradient steeper than limiting gradients. Such gradients are referred to as exceptional gradients. Such situations may rise in approaches to causeways, near hair-pin bends, etc. They should be limited for short stretches not exceeding about 100 meters at a stretch. At hair-pin bends, the gradient is restricted to 2.5%.

12. What is meant by minimum gradient in highway? Why it is provided?

A road with less gradient or level may not be in a position to drain easily. The surface water may be drained to the side drain due to the camber. But a longitudinal slope is needed to drain the water on the surface and from the side drain. Hence, it is essential to have a certain minimum gradient on roads from drainage point of view provided topography permits. The minimum gradient depends on the factors like rainfall, run-off, type of soil, topography and other site conditions.

13.Define ruling gradient.

This is the desirable upper limit of gradient adopted in the normal course of design. This adoption of ruling gradient should balance the cutting and filling of earth work which will give an economical design. Different factors which are to be considered in the choice of ruling gradient is type of terrain, the length of the grade, the speed, pulling capacity of vehicles and the presence of horizontal stretches of road.

14.State the factors controlling the alignment of highway.

The various factors, which control the highway alignment, may be listed as:

- Economy
- Geometric design
- Obligatory points
- Traffic
- Other considerations

In hill roads additional care has to be given for

- Stability
- Drainage
- Geometric Standards
- Resisting Length

15.List the details to be collected during ground reconnaissance.

The following are the details to be collected during ground reconnaissance:

- Climatic conditions
- Crossings
- Economic factors

- Geometrics
- Obligatory points
- Resource
- Roads
- Soil type
- Topography

16. List the type of surveys and details to be taken during a conventional preliminary survey.

- Hydrological data
- Leveling work
- Primary traverse
- Soil survey
- Topographical features

17. Name the detailed survey to be conducted.

- Construction material investigation
- Cross-section and profile
- Investigation on crossings
- Right of way investigation
- Soil investigation
- Surface drainage area

18. What is called super elevation?

To counterbalance the centrifugal force the outer edge of the road is raised which is known as the super elevation or cant or banking. This transverse slope is provided throughout the length of the horizontal curve.

The super elevation 'e' is expressed as the ratio of the height of the outer edge with respect to the horizontal width.

19. Define sight distance.

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. The computation of sight distance depends on the following factors.

- Efficiency of brakes
- Reaction time of the driver
- Speed of the vehicle

20. Define stopping sight distance.

Stopping Sight Distance (SSD) or absolute minimum sight distance is the sight distance needed when the visibility should be such that a driver travelling at the design speed has sufficient length of the road ahead to stop vehicle after seeing the object without collision or accident. It is also called non-passing sight distance.

21. Define intermediate sight distance.

When it is not feasible to provide overtaking sight distance, intermediate sight distance is provided to give limited overtaking opportunities to fast vehicles. Intermediate sight distance is taken as twice the stopping sight distance.

22. Define overtaking sight distance.

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.

23. What are the factors on which SSD depends on?

- Features of the road ahead
- Height of the driver's eye above the road surface
- Height of the object above the road surface

24. What are the factors on which OSD depends on?

- Velocities of the overtaking vehicle, overtaken vehicle and of the vehicle coming in the opposite direction.
- Spacing between vehicles, which in-turn depends on the speed
- Skill and reaction time of the driver
- Rate of acceleration of overtaking vehicle

25. Define setback distance.

Setback distance m or the clearance distance is the distance required from the centerline of a horizontal curve to an obstruction on the inner side of the curve to provide adequate sight distance at a horizontal curve. The setback distance depends on:

- Sight distance (OSD, ISD and OSD)
- Radius of the curve
- Length of the curve

26. Define camber.

A convexity provided to the cross section of the surface of carriage way is called camber is also called as cross fall. It is the difference in level between the highest point, known as the crown usually located at the center of the carriage and the edge. Camber is provided so as to,

- Drain the surface
- Separate the traffic in two opposite directions
- Improve the appearance of the road.

27. What camber recommended in WBM road?

2.5to 3% (1 in 40 to 1 in 33)

28. What camber recommended in cement concrete road?

1.7 to 2% (1 in 60 to 1 in 50)

29. What is Kerbs?

Kerbs indicate the boundary between the pavement and shoulders. Sometimes kerbs are also provided on islands or footpaths. Based on their functions, kerbs may be divided into three groups as given below.

- Low or mountable Kerb
- Low speed barrier or urban parking Kerb
- High speed barrier

30. What are the different types of camber?

- Composite camber
- Parabolic camber
- Sloped camber

31. Define design speed.

A road has to be designed for a specific speed known as "Design speed". Thus design speed may be defined as the maximum uniform speed which will be followed approximately by majority of drivers. The choice of design speed depends on terrain condition and load classification.

32. What is called perception time?

Perception time is the time required for an average driver for his/her sensations received by the eyes or ears are to be transmitted to the brain through the nervous system and spinal cord.

33. List the factors controlling geometric design.

The following are the factors which control the geometric design:

- Cross-sectional elements
- Details of vehicles and design speed
- General alignment
- Gradients
- Horizontal alignment
- Sight distance
- Super elevation
- Terrain classification
- Vertical alignment

34. What is remote sensing?

Photogrammetry is often called as remote sensing. This is defined as the science and art of obtaining measurements needed for highway surveys by means of photography. It is intended to encompass procedures for photo

interpretation and converting single photographs into composite over and into maps.

35. What are the requirements of ideal alignment?

The basic requirements of ideal alignment between two terminal stations are that it should be:

- Short
- Easy
- Safe
- Economical

36. What is mean by geometric design?

The geometric design of highway deals with the dimensions and layout of visible features of the highway such as alignment, sight distance and intersections. The geometrics of highway should be designed to provide optimum efficiency in traffic operations.

37. What is meant by highway alignment?

The position or the layout of the centre line of the highway on the ground is called alignment. Highway alignment includes both horizontal and vertical alignments of the roadway. The horizontal alignment includes the straight path, the deviations and horizontal curves. The vertical alignment includes the changes in gradient and vertical curves.

38. Mention the functions of medians in urban roads.

- To avoid the head-on collision between vehicles moving in opposite direction

- To channelize the traffic in to streams at intersections
- To provide protection for pedestrians
- To separate slow moving traffic

39. What are the requirements of ideal transition curve?

- It should meet the straight path tangentially.
- It should meet the circular curve tangentially.
- It should have the same radius as that of circular curve at junction of circular and transition curve.
- The rate of increase of curvature and super elevation should be the same.

40. What are the markings made on the runways?

- Runway centerline marking
- Runway edge strips
- Runway numbering
- Touchdown or landing zone
- Threshold marking
- Two or more parallel runways

41. Mention the main objectives of traffic engineering.

Thus the basic objective of traffic engineering is to achieve efficient, free and rapid flow of traffic, with least number of traffic accidents.

42. State the basic requirement of pavement.

- Functional requirements from the point of view of road users

- Structural requirements from the point of view of the highway engineer

43. What are the objectives of highway planning?

- To plan overall road network for efficient and safe traffic operation, but at minimum cost. Here the costs of construction, maintenance and resurfacing or strengthening of pavement layers and the vehicle operation cost are to be given due consideration.
- To arrive at the road system and the lengths of different categories of roads which could be provide maximum utility and could be constructed within the available resources during the plan period under consideration.
- To divide the overall plan into phases and to decide priorities.
- To fix up date-wise priorities for development of each road link based on utility as the main criterion for phasing the road development program.
- To plan for future requirements and improvements of roads in view of anticipated developments.
- To work out suitable financing system.

44. What are the classifications of road markings?

- Longitudinal markings
- Transverse markings
- Object markings
- Word messages
- Marking for parking
- Marking at hazardous locations

45. What are the types of traffic signal system?

- Traffic control signals
- Pedestrian signals
- Special traffic signals

46. What are the factors affecting the skid resistance developed at the pavement interface?

- Type of pavement surface namely, cement concrete, bituminous, WBM, earth surface, etc.
- Macro-texture of the pavement surface or its relative roughness
- Condition of pavement namely, wet or dry, smoothened or rough, oil spilled, mud or dry sand on pavement
- Type and condition of tyre
- Speed of vehicle
- Extent of break application or brake efficiency
- Load and tyre pressure
- Temperature of tyre and pavement

UNIT – 2

1. **Mention any four tests for bituminous materials.**
   - **Ductility test**: Ductility is the property of bitumen which permits the material to undergo great deformation without breaking.
   - **Penetration test**: Hardness or softness of bitumen is assessed by penetration of a standard needle.

- **Softening point test**: Softening point is the temperature at which the substance attains a particular degree of softening under specified condition of test.
- **Viscosity test**: Viscosity is a measure of resistance to flow.

2. What is meant by elongation index?

Elongation index of an aggregate is the percentage by weight of the particles whose greater dimension is greater than one and four fifths (1.8 times) their mean dimension. Presence of elongated particles in excess of 10 to 15% is generally considered undesirable. The elongation index test is not applicable to sizes smaller than 6.3 mm.

3. Mention the function of base course.

Base-course is that portion of the roadway which is provided under the wearing course or pavement. Base-courses have to fulfill rigid specifications. They have to satisfy the following requirements:

- Thickness should be adequate to distribute the heavy wheel load pressure gradually to the sub-grade through a sub-base.
- Should have sufficient structural stability so as to resist the vertical pressures and shear stresses due to moving vehicles.
- It should have enough resistance to weathering.
- It should be compacted well to have sufficient density.

4. What do you understand about flash and fire points of bitumen?

The flash point of a material is the lowest temperature at which the vapor of a substance momentarily takes fire in the form of a flash under a specific condition.

The fire point is the lowest temperature at which the material gets ignited and burns under specific conditions.

5. Define flaky aggregate.

Aggregate which pass through the appropriate elongated slot of thickness gauge are called flaky aggregate. Width of elongation slot would be 0.6 times the average of the size range. For example, if the size-range is 16 to 20 mm whose average size is 18mm, the width of the elongated slot is 10.8 mm (0.6×18). Hence in aggregates of 16 to 20 mm size, the aggregate passing through 10.8 mm is called flaky aggregate.

6. Define Flakiness index.

The flakiness index of aggregate is the percentage by weight of particles in it whose least dimension (thickness) is less than three fifths (0.6 times) of their mean dimension.

7. Define angularity number.

It is the amount to the nearest whole number by which the percentage voids exceeds 33%, when an aggregate is compacted in a specified manner in a standardized metal cylinder.

$$Angularity\ number\ =\ 67\ -\ \frac{100\,W}{CGa}$$

8. Write the importance of California Bearing Ratio test.

- It is the best suitable method for evaluating the stability of soil sub-grade and other flexible pavement materials.
- The test results have been correlated, for highways and airfields.

9. What are the limitations of C.B.R test?

- It cannot be used to evaluate the soil properties like cohesion or angle of internal friction or shearing resistance.
- Materials passing through 20mm sieve can only be used for this test.
- If the test sample consists of coarse grained particles, then obtained results are not so suitable for proper designing of pavements.

10. Mention the purpose of conducting softening point test for binder.

Softening point is the temperature at which the substance attains a particular degree of softening under specific condition of test.

Higher softening indicates lower temperature susceptibility and is preferred in areas where warm weather exists. Hard grade bitumen possesses higher softening point than soft grade bitumen. Bitumen used in paving jobs should have softening point varying between 35° to 70°C.

11. What are the desirable properties of soil as highway material?

The desirable properties of soil as a highway material are,

- Adequate drainage
- Easy for compaction
- Incompressibility
- Minimum change in volume
- Permanency
- Stability

12. What are the requirements of a good road aggregate?

- Resistance to impact or toughness
- Resistance to abrasion or hardness

- Resistance from getting polished or smooth/slippery
- Resistance to crushing or crushing strength
- Good shape factors to avoid too flaky and elongated particles of coarse aggregates
- Resistance to weathering or durability
- Good adhesion or affinity with bituminous materials in presence of water or less stripping of bitumen coating from the aggregates.

13. What is called toughness and soundness of stone aggregate?

Toughness or impact susceptibility is one of the necessary properties of an aggregate. Moving vehicles cause some impact on the road aggregate. The magnitude of impact would increase with the roughness of the road surface, the speed of the vehicle and other vehicular characteristics.

Soundness refers to the ability of aggregate to resist excessive changes in the volume as a result of change in physical conditions. The physical conditions that affect the soundness are,

- Alternate wetting and drying under normal conditions
- Alternate wetting and drying under salt water
- Freezing and thawing
- Variation in temperature

14. Define softening point of bitumen.

Softening point is the temperature at which the substance attains a particular degree of softening under specific condition.

15. List the desirable properties of bitumen.

The desirable properties of bitumen are as follows,

- Attainment of desired stability
- Easy to get mixed
- Even under adverse weather conditions should maintain stability
- Provide sufficient adhesion with the aggregate in the mix in the presence of water
- Sufficient flexibility should be available throughout so as to avoid cracking of bituminous surface.

16. List the tests for road aggregates.

- Abrasion test
- Crushing test
- Impact test
- Shape test
  - Elongation index test
  - Flakiness index test
- Soundness test
- Stone polishing test
  - Deval's test
  - Los Angeles test
- Water absorption test

17. Name the different types of viscometer with their temperature range.

- Capillary tube viscometer (31℃ *to* 160℃)
- Brooke filed syndro-electric viscometer (38℃ *to* 160℃)
- Sliding plate micrometer (25℃ *to* 38℃)

18. Differentiate between tar and bitumen.

FACTORS	BITUMEN	TAR
Source	Derived from naturally occurring petroleum	Obtained from destructive distillation of coal or wood
Solubility	Soluble only in toluene	Soluble in carbon-disulphide and carbon tetrachloride
Colour	Black or brownish black	Black

UNIT – 3

1. What are the components of flexible pavements?

Flexible pavements are based on the principle that the wheel loads of vehicles are dissipated to the natural soil through successive layers of granular materials. Highest quality material is placed on the top. The components of the pavement from the top are surface course, base course and sub-base course. The strength of sub-grade decides the thickness of flexible pavements.

2. Differentiate between flexible and rigid pavement.

S. NO	FLEXIBLE PAVEMENT	RIGID PAVEMENT
1.	Deformation in the sub grade is transferred to the upper layers.	Deformation in the sub grade is not transferred to subsequent layers.
2.	Design is based on load distributing characteristics of the component layers	Design is based on flexural strength or slab action.

3.	Load is transferred by grain to grain contact.	No such phenomenon of grain to grain load transfer exists.
4.	Have low completion cost but repairing cost is high.	Have low repairing cost but completion cost is high.
5.	Have low life span.	Life span is more as compare to flexible.
6.	Surfacing cannot be laid directly on the sub grade but a sub base is needed.	Surfacing can be directly laid on the sub grade.
7.	No thermal stresses are induced as the pavement has the ability to contract and expand freely.	Thermal stresses are more vulnerable to be induced as the ability to contract and expand is very less in concrete.
8.	That why expansion joints are not needed	That why expansion joints are needed
9.	Strength of the road is highly dependent on the strength of the sub grade.	Strength of the road is less dependent on the strength of the sub grade.
10.	Rolling of the surfacing is needed.	Rolling of the surfacing in not needed.
11.	Road can be used for traffic within 24 hours.	Road cannot be used until 14 days of curing.
12.	Force of friction is less.	Force of friction is high.

3. Define pavement.

- Highway pavement is a structure consisting of superimposed layers of processed materials above the natural soil sub-grade, whose primary function is to distribute the applied vehicle loads to the sub-grade.
- The pavement structure should be able to provide a surface of acceptable riding quality, adequate skid resistance, favorable light reflecting characteristics, and low noise pollution.

4. Define plastic deformation.

If applied stress is excessive, than the stability of sub grade and the plastic flow takes place then it is called plastic deformation.

5. Define frost heaving.

Frost heaving is often misunderstood for shear or other types of failure. In shear failure the upheaval of portion of pavement is followed with a depression. In the case of frost heaving, there is mostly a localized heaving up pavement portion depending upon the ground water and climatic conditions.

6. Define Warping.

Warping is the bending of the concrete slab due to uneven expansion or contraction of top and bottom slab surfaces. It is caused by any differences in temperature above and below the slab or caused by moisture differences.

7. What is unevenness index?

Unevenness index is defined as the cumulative measure of vertical undulations of the pavement surface, recorded per unit length of the road. It can be measured by using Bump Integrator.

8. What are the factors to be considered for the design of flexible pavements?

Various factors to be considered for the design of pavements are:

- Design wheel load
- Properties of sub-grade and pavement components
- Other factors

9. What are the factors to be considered for the design of rigid pavements?

- Wheel load
- Temperature variations at the location of the road
- Types of joints and their spacing
- Sub-grade and other supporting layers below the CC pavement slab
- Drainage characteristics

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

- Group index method
- California bearing ratio method
- Stabilometer method
- Tri-axial test method
- McLeod method
- Burmister's method

11. Define perimeter area ratio.

Perimeter-Area, (P/A), where load is P and A is the area which is used in Mc Leod Method. This is used in the computation of radius of contact.

12. What is rigidity factor in design for highway pavement?

The ratio of contact pressure to the tyre pressure is called Rigidity Factor.

13. What is traffic index?

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

$T.I = 1.35\ (\ EWL\ )^{0.11}$

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

14. What do you mean by traffic volume?

Traffic flow or volume is measured in terms of number of vehicles per unit time. The common units of time are day and hour. Thus the flows are measured in terms of vehicles per day or vehicles per hour.

15. Define highway capacity.

Highway capacity is defined as the maximum number of vehicles that can pass over a given section of road during a given time period under prevailing roadway and traffic condition.

16. Define traffic density.

Traffic density is defined as the number of vehicles occupying a unit length of roadway at a given instant and is expressed in vehicles per kilometer.

17. Give the deflection equation for rigid and flexible plates.

Burmister's elastic two layer system can be used to compute the elastic modulus of pavement material for a maximum deformation.

$$\Delta = 1.5 \frac{p\,a}{E_s} F_2 \; for \; flexible \; plate$$

$$\Delta = 1.18 \frac{p\,a}{E_s} F_2 \; for \; rigid \; plate$$

Where,

P = pressure on the plates

a = radius of plates

E_s = modulus of elasticity of sub-grade

F_2 = deflection factor

18. What is deflection factor?

In the Burmister's two layer system a deflection factor F_2, has been introduced which is a function of $\frac{E_2}{E_1}$ and $\frac{h}{a}$. Where E_2 and E_1 are the modulus of elasticity of bottom and top layer respectively, 'h' is the thickness of top layer and 'a' is the contact radius.

19. What are the assumptions made in applying Burmister's layer theory on flexible pavements?

The assumptions made in applying Burmister's layer theory to flexible pavements are as follows,

- All the material used in the pavement structure including the sub-grade is isotropic, homogeneous and elastic.
- The surface layer is infinite in horizontal direction and finite in vertical direction. The underlying layer is infinite in both the direction.
- The layers have continuous perfect contact
- The top layer is free of hearing and normal stress outside the loaded area
- Poison's ratio, μ is 0.5 in both layers.

20. Define contact pressure.

The wheel load is assumed to be distributed over a circular area. The distributed load is the tyre pressure which is differently referred to as inflation pressure or contact pressure. Theoretically, all these terms should mean the same thing. Tyre pressure and inflation pressure mean exactly the same. Contact pressure is given by the relationship,

$$Contact\ pressure, p = \frac{L}{A}$$

Where,

p = contact pressure

L = load on wheel

A = contact area or area of imprint

21. Define equivalent single wheel load.

Total stress produced by dual wheel at any depth is produced by a single wheel at that same depth is called the Equivalent Single Wheel Load. This ESWL can be determined by equivalent deflection or equivalent stress criterion.

22. How do you calculate the ESWL at a given depth below the pavement for a dual wheel assembly?

ESWL for any depth can be calculated using the following formula.

$$\log_{10} ESWL = \log_{10} P + \frac{0.301 \log_{10}\left(\frac{z}{d/2}\right)}{\log_{10}\left(\frac{2S}{d/2}\right)}$$

At any depth greater than 2S, the stress due to dual wheel is considered to be equivalent to a single load of magnitude 2P.

23. What is Equivalent Single Axle Load?

- Equivalent Single Axle Load is the equivalent repetitions of standard axle during the design life of the pavement.
- The numbers of repetitions of different types of axles are converted into Equivalent repetitions of standard axle by using Equivalent Axle Load Factors (EALF).

24. List the stresses in concrete pavements.

The stresses in concrete pavement are as follows,

- Stress due to wheel loads
- Stress due to cyclic changes in temperature
- Stress due to change in moisture content

- Stress due to volumetric changes of sub-grade.

25. What is Bradbury's stress coefficient?

Bradbury generalized equation for stress is,

$$S = \frac{P}{h^2} Q$$

Where, Q is the stress co-efficient which is determined by the ratio (l/b) in the case of interior and edge loadings and by the ratio of (a/l) in the case of corner loading.

26. Name the critical load positions. What is more critical?

Three critical locations where the loadings should be considered in the design depth are interior, edge and corner locations on a cement concrete pavement.

Corner loadings are those which are applied at the intersection of transverse joints or cracks. Edge loading is one when the load is applied on an edge of the slab. Interior loading is one when the load is applied in the interior of the slab surface of all the three the critical one is corner loading.

27. What are the reasons for development of edge cracks in flexible pavements?

- Poor drainage
- Inadequate lateral support
- In-sufficient pavement width

28. State the remedial measures in rigid pavement for edge cracks.

- Application of sealants

- Application of epoxy resin
- Proper designing method

29. What are the components of rigid pavements?

The components of a rigid pavement are sub-base and Portland cement concrete. The concrete pavement, if rests directly on the sub-grade, the sub-grade is compacted to a certain level. The special property of a rigid pavement is that it takes minor irregularities in the sub-grade because of its flexural strength and load transfer capacity.

30. What is meant by radius of relative stiffness?

Westergaard defined the stiffness property of pavement slab and sub-grade as radius of relative stiffness, l as,

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

Where,

E = modulus of elasticity of cement concrete

μ = Poisson's ratio of cement concrete

h = slab thickness

K = modulus of sub-grade reaction or sub-grade modulus

31. What is equivalent radius of resisting sections?

The maximum bending moment occurs at the loaded area and acts radially in all directions. This bending moment can be effectively resisted by a sectional area of the pavement.

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

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

Where,

a = radius of wheel load distribution

h = slab thickness

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

32. Mention flexible pavement failures.

- Failures in sub-grade
- Failures in sub-base
- Failure in wearing course

33. What are the typical flexible pavement failures?

- Alligator cracking
- Consolidation of pavement layers
- Shear failure
- Longitudinal cracking
- Frost heaving
- Lack of binding
- Reflection cracking
- Formation of waves and corrugation.

34. Give the various defects in cement concrete pavement.

- Disintegration of cement concrete
- Formation of cracking

- Spalling of joints
- Poor riding surface
- Slippery surface
- Formation of shrinkage cracks
- Ingress of surface water and further progressive failures

35. What are the failures in rigid pavement?

- Scalling of cement concrete
- Shrinkage cracks
- Spalling of joints
- Warping cracks
- Mud pumping
- Structural cracks

36. List the steps followed to design the pavement thickness by Group Index method.

- The value of Group Index is found using the details of the soil.
- The anticipated traffic is estimated and classified as light, medium or heavy.
- The appropriate design curve is chosen and the total thickness of pavement is found for the corresponding Group Index.
- The thickness of sub-base or base only is found from appropriate curve, to find the thickness.

UNIT – 4

1. Define the concept of CBR in highway design.

California Bearing Ratio has been used for the design of flexible and rigid pavement thickness. It is a property of the sub-grade which shows relative significance and do not provide absolute measure. It signifies that a particular CBR of a material requires a certain thickness of pavement layer as a cover for a given traffic load.

2. Define CBR.

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

3. Give the IRC recommendation for edge loading.

This equation is basically as that of Westergaard's and modified by Teller and Sutherland.

$$S_e = 0.529 \frac{p}{h^2} (1 + 0.5\mu) \left(4 \log_{10} \frac{l}{b} + \log_{10} b - 0.408 \right)$$

Where,

S_e = stress due to edge loading

p = wheel load

h = thickness of pavement

μ = Poisson's ratio

l = radius of relative stiffness

b = radius of resisting section

4. What are the classifications of flexible pavement design?

The flexible pavement design methods may be classified under three distinct groups:

- **Empirical method**: These are based on soil classification, physical or strength parameters of soils other factors such as climate and moisture.
- **Semi-empirical method**: These are methods based on stress strain functions, performance and serviceability concept.
- **Theoretical method**: These are based on theoretical analysis and mathematical computations considering Stress-Strain behavior of soil.

5. List the steps followed to use the CBR design chart.

In order to use the chart, the following steps are followed,

- CBR value should be found for a soaked specimen of the sub-grade soil.
- Considering the design wheel load or the anticipated traffic, the appropriate design curve is chosen.
- Corresponding CBR value and the chosen curve the total thickness of flexible pavement needed to cover the sub-grade is found.
- If a superior material is to be used as a sub-base, whose CBR value is found. Corresponding to this CBR value of sub-base material the required thickness of construction on the already chosen traffic curve is used.
- Then the thickness of sub-base course is the total thickness minus the thickness over the sub-base.

6. Give the IRC recommendations for traffic volume.

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

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

Where,

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

P' = number of commercial vehicles per day at last count

r = annual rate of increase in traffic intensity

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

7. Give the IRC recommendations on Dowel bars.

- Dowel bars are designed based on Bradbury's analysis for shear, bending and bearing in concrete.
- The minimum dowel length is taken as($L_d + \delta$). The load bearing capacity of the dowel system is assumed to be 40% of the design wheel load. The dowel bar is considered to be effective 1.8 times the radius of relative stiffness l on the either side of the load position.
- Dowel bars are provided for thickness of slab more than 150mm or more. IRC recommends 20 to 50mm diameter bars of 500mm length with 200mm spacing for 250mm thick slab and spaced at 300mm in case of 200mm thick slab.

8. Mention the function of Dowel bar in cement concrete pavement.

Dowel bars are load transfer devices which are usually provided at expansion or contraction joint. These devices are provided to allow the wheel load to reach the end of slab and cross over the joint without any hindrance or difficulty but should be smooth and unnoticeable to drivers and passengers.

9. Briefly explain about control of Ground water table.

There is no necessity for any sub-soil drainage system if the ground water is deeper than 1.5 m below the sub-grade of the road.

If the ground water is closer than this, the best approach is to go for a road formation such that the sub-grade rests at least 1.2 m above the highest water table.

10. Briefly explain about control of seepage flow.

Seepage flow is likely to exist along a sloping ground. If the seeping zone is at a depth less than 0.6 to 0.9 m from the road surface, it is necessary to intercept the seepage flow.

11. Briefly explain about control of capillary rise.

The sub-grade is likely to be disturbed by capillary water if the sub-grade is near the capillary zone. In this case instead of lowering the water table, the capillary rise can be arrested.

12. What is the importance for highway drainage?

One of the major causes of the failure of highway is water. Water brings about the destruction of highway by:

- Softening the road surface when constructed of soil or sand-clay gravel or Water-Bound Macadam.
- Washing out unprotected areas of the top surface, erosion of side slopes forming gullies, erosion of side drains, etc.
- Softening the sub-grade soil and decreasing its bearing power.

13. State any two techniques for protecting the sub-grade from moist due to capillary rise.

If the water reaches the sub-grade due to capillary rise is likely to be determined. It is possible to solve the problem by arresting the capillary rise instead of lowering the water table.

The capillary rise may be arrested either by a capillary cut-off of any one of the following two types:

- By providing a granular material of suitable thickness, between the sub-grade and the highest level of subsurface water table.
- By inserting an impermeable or a bituminous layer instead of a granular material

UNIT – 5

1. Mention the failures of wearing courses in flexible pavements.

Failure of wearing courses is due to inferior or improper mix design. Inadequate binder cement and inferior duality of binder result in a poor bituminous surfacing. Volatilization and oxidation of binders also makes the bituminous surfacing brittle.

2. What are the different types of pavement roads?

The different types of pavement roads are as follows,

- Bituminous roads
- Cement concrete roads
- Earth roads
- Gravel roads
- Macadam roads
- Soil stabilized roads

3. What is the purpose of dry-rolling in Water Bound Macadam road?

By dry-rolling it is intended to key the coarse aggregate thoroughly. After completing spreading and checking for all irregularities the rolling is done by a three-wheeled power roller of capacity 6 to 10 tonnes.

4. What are the important modifications made in macadam's method of road construction?

- The total thickness of foundation was 250mm.
- Smaller foundation stones are provided.
- A cross slope of 1in 36 was adopted from the sub-grade.

5. What is the purpose of applying prime coat?

- To plug the capillary voids and to act as a water proofing agent for existing base.
- To provide best bonding between existing granular layer and new bitumen layer.

6. Distinguish between "Tack coat" and "Prime coat" in bituminous construction.

PRIME COAT	TACK COAT
Prime coat is the first coat of bituminous surfacing done on an existing pervious texture base.	Tack coat is the bituminous surfacing done over an existing cement concrete top or already existing black top surface road.
Applied to create bonding between base layer and bitumen layer	Applied to create bonding between Bitumen layers.
Application of low viscosity cut backs as primer on existing base layer	Application of low viscosity liquid bitumen to an existing bituminous layer
Sprayed at an uniform rate of 7.3kg to 14.6 kg per 10 sq.m	Sprayed at an uniform rate of 5kg to 10kg per sq.m
Rate of spraying depends on porosity of the surface	Rate of spraying depends on the type of the surface

7. What is the purpose of applying tack coat in bituminous road construction?

Tack coat is a single initial application of bituminous material on surface which has previously been treated or prepared such as existing bituminous, Portland cement concrete, brick or block surface. Tack coat is simply applied to insure adhesion between the existing surface and the new bituminous surface. Since in this case the base is comparatively impervious, the quality of binder required may be less than the primer.

8. State the concept of any one method of pavement evaluation.

Although several methods are used, the two methods categorized below are the basic one,

- Structural evaluation of pavements
- Evaluation of pavement surface condition

The structural evaluation of pavements can be done by plate bearing test can be conducted for both flexible and rigid pavements to assess the structural capacity. The assessment may be made by the load carried at a specified deflection at a plate or by the amount of deflection at a specified load on the plate.

Different equipments are available. Benkelman Beam is the most commonly used. Before conducting the Benkelman beam measurements, a rating survey of the road is performed by dividing the road into homogeneous sections of approximately similar serviceability.

9. Why joints are provided in cement concrete pavements?

- Joints are provided in cement concrete pavements to reduce temporary stress, to prevent longitudinal cracks, to prevent shrinkage cracks, etc.
- Various types of joints are provided in cement concrete pavements, via, expansion joints, contraction joints and warping joint to reduce temperature stresses. Other types of joints are longitudinal joint and construction joint.
- In order to prevent the formation of irregular longitudinal cracks and at the same time to allow for transverse warping and unequal settlement longitudinal joints are provided.

- Construction joints are provided at the abrupt end of a day's work unexpectedly interrupted due to breakdown of plants, onset of bad weather or some urgent repair work has to be carried out.

10. What are the requirements of ideal joints?

- Should be easy to maintain
- Moves freely without stress development
- Should not allow infiltration of water
- Should be convenient to road users.
- Should be in level with the surface

11. What is meant by streaking?

Presence of alternate lean and heavy lines of bitumen either in longitudinal or transverse direction is called streaking. This is formed due to non-uniform application of bitumen across the surface.

12. What do you understand about rutting?

Rutting is formation of longitudinal depression or groove in the wheel tracks. Accumulation of water in the ruts can cause skidding. If accompanied by adjacent bulging, it may be a sign of sub-grade movement or weak pavement.

13. What is called raveling in flexible pavements?

Raveling is failure of binder to hold the aggregate show up by pock marks or eroded areas on the surface. It generally starts from the surface downwards or from edge inwards.

There are several causes for raveling, via, inadequate compaction, insufficient binder in the mixture, excessively open graded mix, over heating of mix or binder, improper coating of aggregate by binder, etc.

14. What is called Scalling of pavements?

Presence of chemical impurities in the mixture or due to poor mixture design, scalling of cement concrete generally occur. Further, over finishing at the edges and abrasion action of traffic are other causes.

15. What do you understand by the term "mud pumping"?

Ejection of soil slurry through cracks formed on the pavement slab due to wheel load or otherwise. This is caused due to more slab deflection, type of sub-grade soil and amount of free water.

16. What are the factors considered in mud pumping?

- Amount of free water
- Extent of slab deflection
- Type of sub grade soil

17. State the basic principle of deflection studies using Benkelman beam.

A well designed and constructed flexible pavement which has been well conditioned by traffic deforms elastically under the design load. That is there is an elastic recovery or rebound of the deformed pavement surface. This is the principle on which the Benkelman Beam has been made.

18. Mention the reasons for the development of cracks in rigid pavement.

Cracks formed in rigid pavements are shrinkage cracks, warping cracks and structural cracks. Shrinkage cracks are formed in cement concrete pavements during curing operation. These cracks develop both in the longitudinal and transverse directions.

Formation of excess warping stress at the edge causes the slab to develop cracks at the edges in an irregular pattern. Design of thickness should be made properly considered different aspects like wheel load, temperature, sub-grade condition, etc. If the thickness is inadequate structural cracks are liable to occur.

19. What is spalling in rigid pavement?

Spalling is the breakdown or disintegration of slab edges at joints or at cracks or directly over the reinforcing steel and generally due to the breakdown of pavement joint edges from traffic action.

20. What are the causes of scaling?

- Over vibration of concrete
- Presence of chemical impurities

21. What is mud-jacking?

Mud-jacking is the repairing method of rigid pavements, in which the raising of settled cement concrete slab or filling a void beneath the slab is done with cement grout.

22. How pot holes are formed? How they are repaired?

Most common cause of pot hole formation is the movement of water into the pavement through the surfacing course. This occurs if there is no proper camber and open textured surfacing. Water enters through the cracks.

Because of entry of water and traffic the pavement gets softened. This is followed by information of bowl shaped holes of varying sizes on the surface layer. Pot holes are repaired by filling premix open-graded or dense-graded patching or penetration patching.

23. What are the general problems in earthen roads?

- Formation of ruts in longitudinal direction along the wheel path of slow moving vehicles.
- Formation of dust in dry weather.

24. Mention the types of skidding.

- Straight skidding
- Impending skidding
- Sideway skidding

25. Define pavement roughness index.

Pavement roughness index is defined as the grading of irregularities in the pavement surface that adversely affect the riding quality of a vehicle. It is used to prepare the guidelines for measuring roughness on a standard scale.

26. What is pavement serviceability?

It is defined as the evaluation of pavement in terms of surface unevenness, patching and cracking etc. It is used to analyze the riding quality of pavement.

27. Define overlay.

It means the additional thickness of the pavement of adequate thickness in one or more layers over the existing pavement which is called overlay.

28. Give the various types of overlay.

The overlay combination is divided into four categories based on the type of existing pavement and the overlay.

- Flexible overlay over flexible pavements
- Cement concrete or rigid overlay over flexible pavement
- Flexible overlays over cement concrete or rigid pavement
- Cement concrete or rigid overlay over rigid pavement.

29. What are the main functions of seal coat?

Premised snail bitumen (or) surface dressing type seal coat is applied either immediately (or) after a few days.

30. What is surface dressing?

Bituminous Surface Dressing is provided over a prepared base course or existing pavement to serve as thin wearing coat. Surface dressing work consists of application of suitable grade of bitumen or emulsion by spraying over a prepared base course or existing pavement surface followed by

spreading specified size of hard aggregates at the recommended rate and rolling.

The surface dressing does not add to the structural stability or strength of the pavement nor will it improve the existing riding quality of the pavement surface. Two types of surface dressing are,

- Single coat surface dressing
- Double coat surface dressing