: Traffic Engineering :

According to Institute of traffic Engineering (USA)

"Traffic engineering is that phase of engineering which deals with the planning and geometric design of street, highway, abutting land & traffic operation releated to safe convenient and economic transportation of people and goods."

↳ Traffic engineering is that branch of engineering which deals about the improvement and traffic performance of road networks and terminals.

↳ It also deals with the regulation, direction and control of vehicular and pedestrian traffic on highway to ensure safe and free use of road.

Objective of traffic engineering:

(I) To achieve easy and smooth flow of traffic at intersection.

(II) To have safe, easy, rapid and economic transport of people and goods.

(III) To improve the speed of vehicle.

(IV) To increase the traffic carrying capacity of road.

(V) To reduce chances of road accidents.

(VI) To reduce traffic congestion.

(VII) To improve sufficient parking area for vehicles.

*: Scope of traffic Engineering:-

a. Traffic characteristics:
   i. Vehicular characteristics.
   ii. Road user's characteristics.

b. Traffic study and analysis.
   i. Volume study
   ii. speed study
   iii. O & D study
   iv. Traffic flow characteristics
   v. Parking study
   vi. Accident study.

c. Traffic operation:
   i. control devices. (sign, signals, marking, Bland)
   ii. Regulation.

d. Design:
   i. Intersection
   ii. Parking
   iii. Terminals
   iv. Lighting.

e. Traffic planning:
   i. Mass transit facilities.
   ii. Traffic management.
   iii. Priotization of public transportation.

f. Traffic administration and management.
   i. 3 E (Engineering, Enforcement, & Education)

g. Research and development works.:

Note:

Traffic administration and management:

a. Enforcement:

↳ Enforcement is made through law, regulation and control.

b. Education:

↳ Made by publicity through school, television etc.
↳ Aims at improving human factor in traffic performance.

c. Engineering:

↳ Engineering phase deals with construction.
↳ deals with improvements of road geometrics, providing additional road facilities and installation of suitably designed traffic control device.

* Traffic characteristics:-

a. Road user's characteristics:

(i) Physical characteristics

↳ includes vision, hearing, smelling, fatigue, illness etc.

(ii) Mental characteristics

↳ includes knowledge skills, intelligence, experience, and literacy of road users.

(iii) Psychological characteristics:

↳ includes fear, anger, superstition, impatience, attitude toward traffic, maturity etc.

(iv) Environmental factors:

↳ includes environmental factors such that atmospheric condition, and locality.

b. Vehicular characteristics:

(i) static characteristics

↳ length, width, height and weight of vehicle.

↳ height of head light.

↳ height of drivers seat.

(ii) Dynamic characteristics

↳ speed, acceleration and braking characteristics of vehicle.

↳ skid resistance, $f = \frac{a}{g}$.

↳ extra widening, we.

↳ off tracking distance = $\frac{l^2}{2R}$

Q. A vehicle travelling at a speed at 60 kmph was stopped within 2 sec after application of brakes, calculate avg. skid resistance:

solution

initial velocity (u) = 60 kmph = $\frac{5}{18} \times 60 = 16.67$ m/s.

time (t) = 2 sec

final velocity (v) = 0

let retardation be, a

$v = u + at$

$0 = 16.67 + a \times 2$

$\Rightarrow a = -8.33$ m/s²

Also, skid resistance = $\frac{a}{g} = \frac{8.35}{g} = \frac{8.33}{9.81} = 0.85$

Q. A vehicle has a wheel base of 6.5m. What is the off-tracking while negotiating a curve of mean radius 32m.

solution:

$l = 6.5$ m

$R = 32$ m

off tracking = $\frac{l^2}{2R} = \frac{6.5^2}{2 \times 32} = 0.66$ m. Ans.

Traffic study and analysis:

↳ It is carried out to analyse traffic characteristics.

↳ Traffic study includes:

1. Traffic volume study
2. speed study
3. Origin and destination study
4. Traffic flow characteristics
5. Traffic capacity study
6. Parking study
7. Accident study.

1. Traffic volume study:

↳ Traffic volume is the number of vehicles crossing a road per unit time at any selected point.

↳ Traffic volume is used as quantity measure of flow.

↳ commonly used units: vehicles per day or vehicles per hour.

Objective or importance of traffic volume study:

(i) It measures the relative importance and uses of road for improvements and maintenance.

(ii) Traffic volume is used in planning, traffic operation and control of existing facility.

(iii) This study is used in traffic patterns and trends.

(iv) It is used in design of intersection, planning signal.

(v) Also used in planning and design of side walks, cross walks.

*: Counting of traffic volume:

① Mechanical counting

② Manual counting

(i) Mechanical counting:

↳ automatically records number of vehicle crossing a section of road in a defined period.

↳ traffic count is recorded by electrically operated counters.

Advantage:

① can work throughout the day or night for defined period

Disadvantage:

① It is not possible to get traffic volume of various classes of traffic in the stream and details of turning movements.

(ii) Manual counting:

↳ In this method, a field team is employed to record traffic volume on prescribed record sheet.

↳ selected typical short count periods, the traffic volume study is made by manual counting.

Advantages:

① vehicle classification, details of turning movement are known.

Disadvantages:

① It is not practicable to have manual count for all the 24 hrs of the day and on all days round the years.

Presentation of traffic volume data:

↳ Traffic volume data are presented in following forms:

① Average daily traffic.
② Annual average daily traffic.
③ Trend chart
④ Variation chart.
⑤ Traffic flow map along the route
⑥ volume flow diagram at intersection.
⑦ Thirtieth highest hourly volume.

I. Average daily traffic (ADT):

↳ It is the average daily traffic of two days (5 to 7 days)

II. Annual average daily traffic (AADT):

↳ It is the average daily traffic of 365 days.

↳ The different vehicle classes are converted into a common unit known as passanger car unit (PCU).

III. Trend chart:

↳ Trend chart shows the trend of volume over period of years which are used for traffic planning, future expansion, design and regulation.

iv. Variation chart:

↳ It gives hourly, daily and seasonal variation of flow.

↳ It helps in deciding the facilities and regulations needed during peak traffic period.

v. Traffic flow map along the route:

↳ Traffic volume is represented by thickness of line.

↳ It helps to find traffic volume distribution at a glance.

vi. Thirtiest highest hourly volume:

↳ The thirtiest hourly volume is the hourly volume that will be exceeded only 29 times in a year.

↳ congestion will be only 29 hours in a year. Thus thirtiest hourly volume is taken as design volume.

2. Speed study:

purpose of speed study:

(i) To determine speed trends.

(ii) To plan traffic control measures like,

- traffic signals
- traffic signs
- Road markings
- Islands etc.

(iii) To carryout accident studies.

Types of speed:

① Spot speed
② Average speed
   a. space-mean speed.
   b. time-mean speed.
③ Running speed and
④ Travel speed.

① Spot speed:

↳ Spot speed is the instantaneous speed of a vehicle at a specified section or location.

② Average speed:

↳ Average speed is the average of all the spot speed of vehicles passing a given point on the highway.

↳ Average speed are of two types:

a. space-mean speed
b. time-mean speed

a. space-mean speed:

↳ Space mean speed represents the average speed of vehicles in a certain road length at any time.

↳ Space mean speed is slightly lower than time mean speed.

$$\text{Space-mean speed } (V_s) = \frac{n}{\frac{1}{v_1} + \frac{1}{v_2} + \frac{1}{v_3} + \cdots + \frac{1}{v_n}}$$

6. Time mean speed:

↳ Time mean speed is the average speed of all vehicles passing a point over some specified time.

↳ It is nothing but arithematic mean of all speed.

$$\text{time-mean speed } (V_t) = \frac{V_1 + V_2 + \cdots + V_n}{n}$$

Numerical:

Q. Three vehicles are travelling at 1 km segment in a highway and the following observation is made. vehicle A = 1.2 min. vehicle B = 1.5 min and vehicle C = 1.6 min. what are the average speed of all three vehicles?

solution:

length (ℓ) = 1 km. = 1000 m.

time mean speed

$$V_A = \frac{1}{1.2} \times 60 = 50 \text{ kmph.}$$

$$V_B = \frac{1}{1.5} \times 60 = 40 \text{ kmph.}$$

$$V_C = \frac{1}{1.6} \times 60 = 37.5 \text{ kmph.}$$

$$V_t = \frac{V_A + V_B + V_C}{3} = \frac{50 + 40 + 37.5}{3} = 42.5 \text{ kmph.}$$

space mean speed

$$V_s = \frac{3}{\frac{1}{50} + \frac{1}{40} + \frac{1}{37.5}} = 41.86 \text{ kmph.}$$

(iii) Running speed:

↳ Average speed maintained by a vehicle over a particular road.

$$\text{Running speed } (V_R) = \frac{\text{distance travelled}}{\text{time taken}}$$

(iv) Travel speed:

↳ Average speed considering total travel time (running time + delay time) is called travel speed.

$$\text{Travel speed } (V_o) = \frac{\text{distance travelled}}{\text{total journey time.}}$$

↳ Speed study is carried out by these two methods.

a. spot speed study
b. speed and delay study.

a. Spot speed study:

Purpose:

(i) To use in accident study.
(ii) To study traffic capacity.
(iii) To decide speed trends.
(iv) To analyse driver characteristics.

Methods to calculate spot speed:

(i) Enoscope
(ii) Graphic recorder
(iii) Electronic meter
(iv) Radar gun.
(v) speed meter
(vi) photographic method.

6. Speed and delay study:

↳ speed and delay speed gives running speed, overall speed and delay between two stations.

↳ It gives information such as.

- amount of delay
- location of delay
- duration of delay
- causes of delay.

*! Uses of speed and delay study:

(i) Find the cost of journey during economical studies.

(ii) Evaluate congestion, capacity and improvements needed.

(iii) Delay study for traffic control device at intersections.

Types of delay:

(i) fixed delay

(ii) operational delay.

Methods to calculate speed and delay study:

(i) Floating car method.

(ii) Liscence plate method.

(iii) Interview technique.

(iv) Elevated observations.

(v) Photographic techniques.

3. Origin and Destination study: (O & D study)

↳ O and D study is carried to collect information about desired line of traffic travel.

↳ O and D study is essential for planning new facilities and improving existing facilities.

Application of O and D study:

(i) To judge adequacy of existing route.
(ii) To locate major routes along desire line
(iii) To locate new bridge as per traffic demand.
(iv) To locate intermediate stops of public transport.
(v) To determine the need of bypass.
(vi) To estimate future traffic.

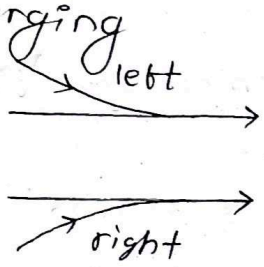
Methods of collecting O and D data:

(i) Road side interview method
(ii) Liscence plate method
(iii) Return postcard method
(iv) Tag on car method
(v) Home interview method.
(vi) Work spot interview method.

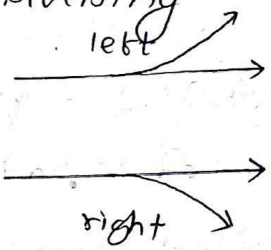
4. Traffic flow characteristics study:

↳ The basic traffic movements are:

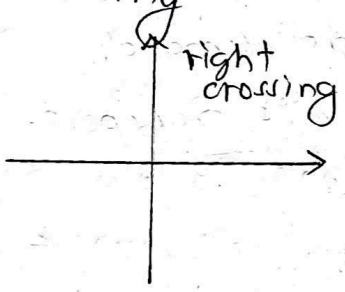
a. Merging



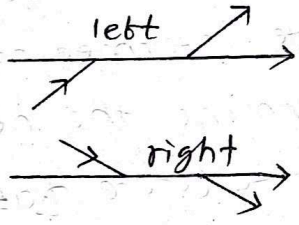
b. Diverging



c. Crossing



d. Weaving:



↳ Merging is the process of mixing the vehicles from left or right of existing lane.

↳ Diverging is the process of leaving the vehicles and gaining either left or right of the existing lane.

↳ Crossing is the movement of one lane perpendicular to other lane.

↳ Weaving is the process of merging and diverging.

Types of traffic flow:

(i) Uninterrupted traffic flow.

(ii) Interrupted traffic flow.

5. Traffic capacity study:

↳ Traffic capacity is ability of ~~the~~ roadway to accomodate traffic volume.

capacity (C) = $\frac{1000\ V}{S}$

; V = speed in mph.

S = c/c spacing of vehicles.

Note:

Difference between traffic volume and traffic capacity:

	Traffic volume	Traffic capacity (C)
(i)	No. of vehicle on a lane that passes a given point during specified time.	No. of vehicle on a lane that passes a given point during specified time per unit lane.
(ii)	Units: veh/hour, veh/day etc.	Units: veh/hr/lane, veh/day/lane etc.
(iii)	volume = $\frac{\text{No. of vehicle crossing in specified time}}{\text{time duration}}$	capacity, C = $\frac{1000\ V}{S}$

*! Passanger car unit:(PCU):

↳ Different class of vehicles such as bus, truck, rickshaw, bullock carts etc. are found on developing countries like Nepal.

↳ Different vehicle class has different static characteristics and dynamic characteristics.

↳ Thus traffic volume count becomes difficult.

↳ In order to resolve above difficulty a standard unit is derived to convert all class of vehicles into a common unit called passanger car unit.

Example of PCU:

→ car, light van, pickup = 1

→ Bicycle, motorcycle, scooter, moped = 0.5

→ mini truck, tractor without tailor, rickshaw = 1.5

→ Bus, truck, tractor, tipper = 3

→ Non-motorized vehicles (bullock carts) = 6

Factors affecting PCU:

(I) Vehicle characteristics

(II) Transverse and longitudional gaps

(III) Traffic stream characteristics

(IV) Roadway characteristics

(V) Regulation and control devices.

(VI) environmental and climatic conditions.

6. Parking study:

↳ Parking is a place where leisure vehicles are kept.

Types of parking:

(i) On street parking.

(ii) Off street parking.

(i) On-street parking:

↳ Also known as kerb parking.

↳ Vehicles are parked on kerb which are designed for parking.

Types of on-street parking:

a. Angular parking

b. Parallel parking

a. Angular parking:

↳ Maximum vehicle can be parked at 90°.

↳ Drivers prefer to park at 75°.

↳ Most economical parking is 45°.

fig

b. Parallel parking:

↳ Parallel parking is preferred when width of road is limited.

fig

(ii) Off-street parking:

↳ When the parking facility are preferred away from road they are known as off-street parking.

Types of off-street parking:

(i) surface car parking
(ii) Multi-storey car parking
(iii) Underground parking
(iv) Roof parking
(v) Mechanical parking
(vi) Composite parking.

styles of off-street parking:

(i) self parking:

↳ vehicles are parked by the drivers or owners.

(ii) Attendant parking:

↳ vehicles are parked by the attendant.

Ill effects of parking:

(i) congestion
(ii) capacity of street is reduced
(iii) Obstruction to emergency vehicles
(iv) Environmental pollution.
(v) Accident occurs.
(vi) Journey speed delays caused high operational cost.

7. Accident studies:

↳ An accident is an undesirable or unfortunate that occurs unintentionally and result in harm, damage or loss of properties & life.

↳ Accidents may involves
- property damage
- personal injuries
- causalties etc.

Objective of accident studies:

(i) To study about cause of accidents.
(ii) To evaluate existing design.
(iii) To support the proposed design.
(iv) For computation of financial losses.
(v) For giving economic justification.

Causes of accidents:

a. Drivers cause:

↳ Expressive speed and rash drivin
↳ violation of rules and regulatio
↳ failure to see traffic situation
↳ temporary effects due to fatig

b. Pedestrian cause:

↳ violating rules and regulatio
↳ careless in using carriageway

c. Passanger cause:
↳ Alighting or getting into moving vehicles.

d. Vehicle defects:
↳ Failures of brakes, steering system or lighting syste
↳ tyre brust, and other defects.

e. Road condition:
↳ slippering or skidding road surface
↳ pot holes, ruts and other damaged conditions of road.

f. Road design:
↳ Defective geometric design like inadequate sight distance, improper curve design.
↳ improper lighting and improper traffic control device.

g. Weather and environment:
↳ Unfavourable weather conditions like mist, fog, snow, dust, smoke or heavy rainfall which restrict normal visibility and render driving unsafe.

h. Animals:
↳ stray animals on roads.

Accident studies and record:

(i) collection of accident data.
(ii) Accident report.
(iii) Accident record.

1. collection of accident data:

a. General information:

> Date, time and person involved in accidents
> classification of accidents like fatal, serious, minorets.

b. Location:

> Description and details of accidents location.

c. Vehicle details:

> Registration number, loading details, vehicular defects.

d. Nature of accidents:

> conditions of vehicle involved, details of collision, damages, injuries etc.

e. Road traffic condition:

> Details of road geometry; straight or curved,
> characteristics such as dry, wet or skidding.

f. Accidents costs:

> property damage, personal injuries.

II. Accident Report:

↳ The accidents should be reported to police authorities for legal actions.

III. Accidents' Records:

↳ location files: to check the location of accidents.
↳ spot maps
↳ condition diagram
↳ collision diagram.

*: Accident Investigation:

↳ Following investigations need to be carried out:

I. Recording general observation
II. Driver tests
III. skid resistance and parement surface;
IV. Vehicle test.
V. Probable causes of the accidents
VI. cost analysis.

Measures to be adopted for reduction of accident rates:

I. Engineering
II. Enforcement
III. Education.

(ii) Engineering:

a. Road design:

↳ geometric design features such as sight distance, width of road, horizontal and vertical alignment

↳ pavement surface characteristics such as skid resistance, and friction coefficient should be checked.

b. Preventive maintenance of vehicles.

↳ braking system, steering system, lighting arrangements.

c. Road lighting:

↳ use of proper lights.

d. Before and after studies:

↳ accidents types and patterns, collision diagram etc.

(iii) Enforcement:

a. speed control
b. Traffic control devices
c. Training and supervision.
d. Medical check.
e. Special precaution for commercial vehicle.
f. Implement law and regulation.
g. Control extra modification of bike, specially VR bike.

(iii) Education:

a. Education to road users.

b. Education to drivers

c. Safety drive awareness.

d. Awareness about effect of accidents.

*: Traffic operation:

1. Traffic Regulation:

↳ Traffic regulation are the set of rules and guidelines which guide the behaviors of road users.

↳ Traffic regulation and laws cover the following four phases:

(i) Driver control
(ii) Vehicle control
(iii) Flow regulation
(iv) General control.

(i) Driver control:

↳ It includes driving license, driver tests and minimum requirements for driver.

(ii) Vehicle control:

↳ It includes vehicle registration, maximum dimension and weight, requirements of vehicles, accessories inspection of vehicles etc.

(iii) Flow regulation:
↳ It includes direction, turning, overtaking provision etc.

(iv) General control:
↳ It includes reporting of accidents, recording traffic violation causes etc.

2. control devices:
↳ The device used to control, regulate and guide the traffic is known as traffic control devices.

↳ Types of traffic control devices:
① Traffic signs
② Traffic signals.
③ Markings and
④ Traffic Islands.



1. Traffic sign:
↳ Traffic sign should be backed by law.
↳ shape, size, colour code and symbol used should be specified.
↳ Location of the sign should be specified.

Types of traffic sign:
a. Regulatory sign.
b. Warning sign.
c. Informatory sign.

a. Regulatory sign:

↳ It gives orders.

↳ Also called as mandatory sign.

↳ They are meant for informing road users about law, and rules.

↳ Violation of regulatory sign is a legal offence.

eg: • prohibitory sign.
• no-parking sign.
• speed limit sign
• compulsory direction control sign.

↳ There are A01 to A33 types of regulatory sign.

पार्किंग निषेध

speed limit

रोकण निषेध

↳ Regulatory sign has white background with red circular ring and Black letters.

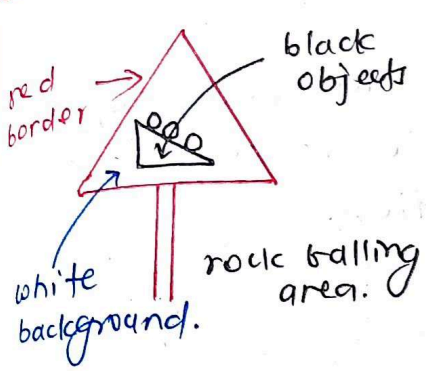
b. Warning signs:

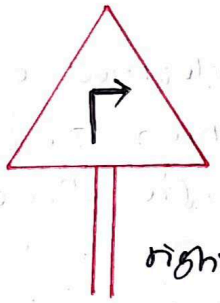
↳ It gives condition ahead.

↳ Used to warn the road users

↳ There are B01 to B48 types of warning signs.

eg: right hand turn, narrow bridge, railway crossing, rock falling area etc.





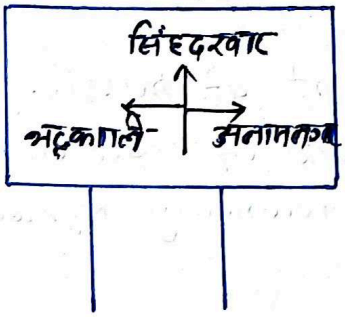
↳ Warning sign are represented by equilateral triangles having apex pointing upward.

c. Informatory sign:

↳ It gives information in travelling.

↳ Used to inform and guide the road users.

eg:
- petrol pump,
- facility information sign
- parking sign
- garage, workshop ahead etc
- road route/alignment.



According to NRS-2070
→ white background & black letters.

According to NURS-20__
→ green background & white letters.

↳ These sign are generally rectangular in shape.

4. Traffic signal:

↳ A traffic signal is defined as the power operated control device by which traffic is warned or directed to some specific direction.

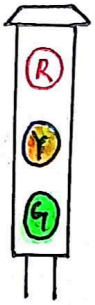


fig: traffic signal:

Requirements of traffic signal are:

↳ Main requirements of signal are:

(i) Draw attention
(ii) To provide meaning
(iii) To provide time to respond
(iv) To have minimum wastage of time.

Purpose of traffic signals:

(i) To provide an order movement of traffic.
(ii) To reduce frequency of accidents of special nature
(iii) To control speed on main and secondary highway.
(iv) To direct different routes.
(v) To control traffic at rail road crossing.

Function / Advantages of traffic signals:

i. Provide orderely movement of traffic.
ii. Increase traffic handling capacity at intersection.
iii. Reduce frequency of certain types of accidents.
iv. Quality of traffic flow is improved.
v. control traffic lane use.
vi. Interrupt traffic for emergency vehicles.

Disadvantages of traffic signal:

i. The rear end collision may be increased.
ii. Failure of signal due to electric power failure.
iii. Excessive delay of vehicles can be caused during off-peak hours.

Types of traffic signals:

1. Traffic control signal
    a. Fixed time signal
    b. Manually operated signal
    c. Traffic actuated (automatic signal)
ii. Pedestrian signal.
iii. special traffic signal.

Types of traffic signal system:

i. Simultaneous system.
ii. Alternate system
iii. Simple progressive system
iv. Flexible progressive system.

3. Road markings:

↳ Road markings are defined as lines, patterns, words or symbols except sign within roadway for controlling warning and guiding road users.

Functions:

① To guide & control traffic on highway.
② To serve as a psychological barrier.
③ To delinate traffic path
④ To aid pedestrian and cyclists movements.

Types of traffic markings are:

a. Parement marking:

↳ generally of white colour.

↳ It includes:

- centreline
- lane line
- turn marking
- stop line at intersection
- cross line for pedestrian crossing.

b. Kerb markings:
c. Object marking.
d. Reflector unit marking.

* Road delinators:

↳ Road delinators are the devices to outline the roadway for providing visual assistance to drivers about the alignment of the road ahead at night.

Types of road delinators:

① Roadway indicators.
② Hazard markers.
③ Object markers.

I. Roadway indicators:

↳ guide posts, 0.8 to 1 m height.
↳ painted black and white strips
↳ with or without reflector units.

II. Hazard markers:

↳ approx. 1.2 m high plates on posts.
↳ three reflectors with yellow or black strips at 45°
↳ define obstruction or object close to road.

III. Object markers:

↳ circular red reflectors arranged to indicate obstruction within path.
↳

4. Traffic Islands:

↳ Island are the raised area provided at road to avoid or minimize the area of major and minor conflicts.

↳ Traffic islands are used to reduce the vehicles speed driving through.

Classification of Islands:

a. Divisional island
b. channelizing island.
c. Rotary island
d. Pedestrian island.

a. Divisional island:

↳ Also known as median island.

↳ provided to separate opposing flow.

b. channelizing island:

↳ Guide the traffic through proper channel.

↳ they are usually triangular in shape.

c. Rotary island:

↳ It is the large central island of rotary intersection.

d. Pedestrian island:

↳ Islands provided bus stops to protect passengers.

Design consideration of islands:

1. Type of island
   ↳ depends on factors such as costs, traffic volume, durability and other requirements.

2. Location of island:
   ↳ based on functional layout and traffic volume.

3. Shape and size of island:
   ↳ function of each island is determined by its shape and size.

4. Road-Intersection:
   ↳ Road intersection is defined as an area where two or more road join or cross each other.

Basic requirements of intersection:

(i) There should be adequate visibility for all approaching vehicles.

(ii) Relative speed of approaching vehicle should be kept small.

(iii) sudden change of path must be avoided.

(iv) Width of pavement at radius of turning should be sufficient enough.

(v) Area of conflict should be minimum

(vi) Good lighting at night is required.

(vii) Proper sign should be provided on roads.

(VIII) Sufficient space should be available for waiting vehicles.

(IX) The layout should follow natural vehicle path.

(X) Minimum number of conflict points.

Design aspect of intersection:

(I) Efficiency of operation.
(II) Safety and less conflict points.
(III) Speed to avoid congestion and delay.
(IV) Cost of operation.
(V) Capacity.

Types of intersection:

↳ Intersection can be broadly classified into two types:

a. Intersection at grade.
b. Grade separated intersection.

a. At grade intersection:

↳ intersection where all road join or cross each other at same level.

Types of at grade intersection:

I. Unchannelized intersection.
   1. Plain intersection
   2. Flared intersection
II. channelized intersection.
III. Rotary intersection.

b. Grade separated intersection:

↳ intersection where roads cross each other at different level.

Types of grade separated intersection:

i. Under pass
ii. over pass
iii. trumplet interchange
iv. diamond interchange
v. cowerleaf interchange
vi. directional interchange
vii. bridged rotary.

Types of at grade intersection:

1. Unchannelized intersection:

↳ intersection where there is no provision of any island for directing traffic is unchannelized intersection
↳ lowest class of intersection.
↳ easiest in design
↳ Most difficult in traffic operation.
↳ Max^n conflict point and accidents.

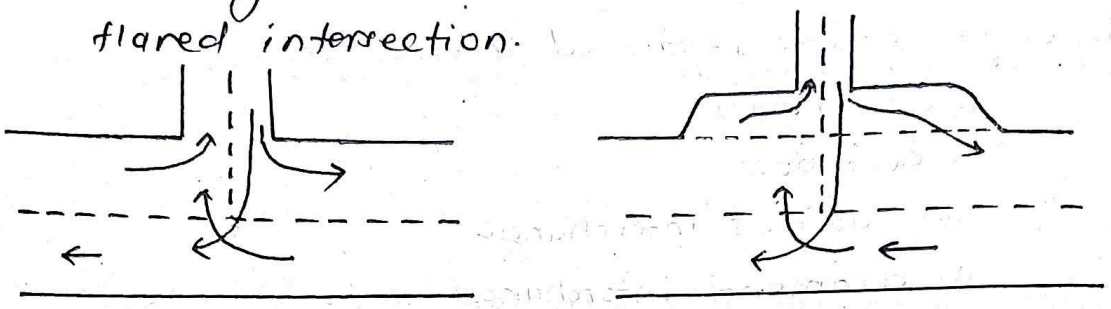
Types of unchannelized intersection:

1. Plain intersection:

↳ When no additional pavement width for turning is provided, it is called plain intersection.

a. Flared intersection:

↳ When the pavement is widened at the intersection area by a traffic lane or more, it is known as flared intersection.



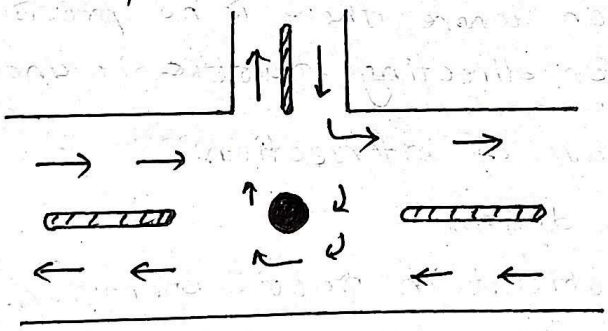
Plain intersection

Flared T-intersection.

11. channelized intersection:

↳ An intersection where there is provision of island for directing traffic is called channelized intersection.

↳ It helps in separation of conflict and control of speed.



channelized intersection.

Advantages:

↳ vehicles are confined to definite path.

↳ conflict area decrease.

↳ speed control of entering vehicles.

↳ place of installation of sign.

↳ blockage for prohibited movement.

Disadvantages:

- Requires large area.
- Difficult design
- One of the crossing vehicle will have to wait while other proceed.

iii. Rotary intersection:

- Rotary intersection is an enlarged road intersection where all converging vehicles are forced to move around the large central island in clockwise direction.

Purpose / objective:

- To eliminate the necessity of stopping even for crossing stream of vehicle.
- To reduce conflict area.

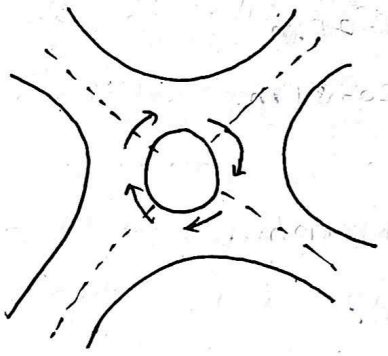


fig: rotary intersection.

Eg: maitighar intersection.

IRC Guidelines for Rotary Intersection:

- RI is selected if volume of traffic is almost equal at all intersecting legs.
- Min^m 500 veh/hr. and maximum 3000 veh/hr. in each intersecting legs.
- High proportion of turning traffic.
- Good for more than 4 approaches at junction.

Factors to be considered for Rotary Intersection Design:

(i) Design speed:
- for urban area: 30 kmph.
- for rural area: 40 kmph.

(ii) Radius of entry:
- for urban area: 15-25m
- for rural area: 20-85m.

(iii) Radius of exit:
- 1.5 to 2 * Radius of entry

(iv) Radius of central Island:
- 1.33 * entry radius.

(v) Weaving length.
- For urban area: 30-60m.
- For rural area: 45-90m

(vi) width of carriageway at entry and exit.
- Min^m 5 + extra widening

(VII) Entry angle 60° and exit angle 30°.

(VIII) super-elevation:
- Maxm 7%.

(IX) cross-slope
- maxm 1:50

(X) Drainage sight distance suitably designed.

Types of grade separated intersection:

1. Overpass:

↳ Major highway is taken above general ground level.

Advantages:

(I) less drainage problem for major road.
(II) Aesthetically better
(III) span of overhead structure is less
(IV) future and lateral expansion is possible for overhead.

Disadvantages:

(I) In rolling terrain, excessive grade may restrict speed.
(II) SD is restricted.
(III)

11. Underpass:

↳ Major highway is taken by depressing it below normal ground level.

Advantages:

① Better load distribution.

⑪ suitable for minor road for speed and same level.

Disadvantages:

① Drainage problem in minor road.

⑪ Not better for stage construction.

*! Highway Lighting:

↳ Highway lighting is a means of providing lights for safety and comfort of night traffic operation.

Importance of road lighting:

① lesser the strain on night driving.

⑪ Avoid glare problem.

⑪ Ensure comfort and confident driving.

⑳ Reduction in accident rates.

⑤ Feeling of security and protection.

⑥ Develop late evening shopping.

Factors affecting night visibility:

(i) Brightness of the object
(ii) Brightness of the background
(iii) Size of the object.
(iv) Glare on eyes of drivers
(v) Reflection properties of pavements.
(vi) Amount of distribution of light.

Factors to be considered for design of light:

(i) Type of lamp:
(ii) luminaire distribution of light.
(iii) Spacing of light unit.
(iv) Height and overhang of mounting.
(v) Lateral placement.
(vi) Lighting layouts.

Extra Note:

Traffic projection and distribution:

↳ Methods are:

(i) Trip generation
(ii) Trip distribution
(iii) Modal split model.
(iv) Trip assignment.

4.1.8 Road pavement:

↳ Road pavement is defined as the layered structure supported by the sub-grade soil to form the carriage way of road.

Components of road pavements.

① Wearing course
② Base course
③ sub-base course
④ sub-grade

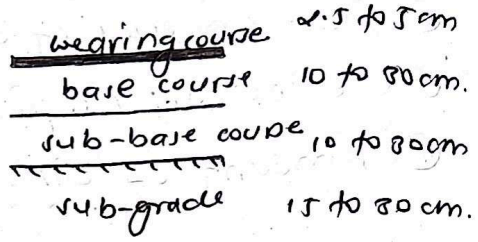


fig: typical components of road pavements.

Functions of components of pavement:

1. surface- course:
   - ↳ to provide smooth and uniform riding surface.
   - ↳ to resist abrassive force of traffic.
   - ↳ to reduce amount of surface water penetration.
   - ↳ to provide skid resistance surface.

2. Base-course:
   - ↳ to receive load from surface course and transfer it to sub-base course.

3. sub-base course:
   - ↳ to receive load from base course and transfer it to sub-grade soil.
   - ↳ to facilitate drainage of free water.

iv. Sub-grade soil:

↳ To resist ultimate load of pavement.

↳ To provide support to the pavement.

Types of Pavement:

↳ Basically pavements are of four types:

i. Flexible pavement.
ii. Rigid pavement.
iii. semi-rigid pavement.
iv. composite pavement.

i. Flexible pavement:

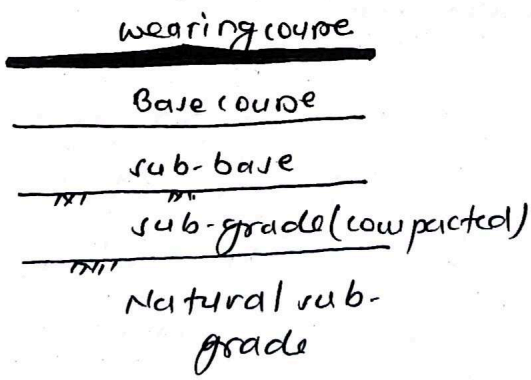
↳ The pavement which have low flexural strength is called flexible pavement.

↳ They are flexible in their structural behaviour.

↳ Vertical loads is transmitted to the lower layers by grain to grain transfers.

↳ made up of bitumen in wearing course.

eg: bituminous road, earthen road, gravel road etc.



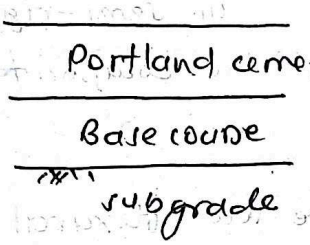
II. Rigid Pavement:

↳ The pavement which posses considerable flexure strength is called rigid pavement.

↳ They are rigid in their structural behaviour.

↳ Vertical load is transmitted through slab action.

↳ made up of portland cement concrete in wearing course.



III. Semi-rigid pavement:

↳ semi-rigid pavement is made up of fly ash, lime, soil stabilization etc. in wearing course.

IV. Composite pavement:

↳ It is the combination of two types of above pavements.

comparision between flexible and rigid pavement:

Governing factor for selection of base course and sub-base course:

(I) Type and intensity of traffic and volume
(II) Funds available.
(III) Type of sub-grade soil available and drainage.
(IV) Availability of construction materials.
(V) climatic conditions
(VI) Plant and equipment available
(VII) Time available to complete the project.
(VIII) Altitude at which road is constructed.

Requirements of wearing course:

(I) High resistance to deformation.
(II) High resistance to fatigue
(III) sufficient stiffness to reduce shear.
(IV) High resistance to environmental degradation.
(V) low permeability
(VI) Good workability
(VII) sufficient surface texture - good skid resistance.

Design of flexible pavements:

↳ following are the factors to be considered for design of flexible pavements:

1. Traffic and loading:

a. Maximum wheel load.

↳ standard axle load for Nepal is 8.2 tonnes.

b. Equivalent factor:

↳ $F = \left(\frac{L_a}{L_s}\right)^n$ where L_a = actual wheel load (kN)

L_s = standard axle load (kN)

n = exponential power.

In Nepal; $n = 4.5$, $L_s = 8.2$ tonnes

c. contact area.

↳ contact area = tyre pressure

d. No. of repititions.

↳ number of repititions cause plastic and elastic deformation.

e. vehicle speed.

↳ speed is directly related to duration of loading

↳ higher speed of vehicle is desirable.

2. Environmental factors:

↳ Temperature

↳ Rainfall.

- greater value of camber in heavy rainfall area.

3. Thawing and freezing:
   ↳ pavement sutter damage due to frost heave.

4. Material properties:
   ↳ CBR - test
   ↳ plate load test
   ↳ elastic modulus test.

5. Failure criteria:
   - Flexible pavement
     ↳ Fatigue cracking
     ↳ Rutting
     ↳ Thermal cracking
   - Rigid pavement:
     ↳ Fatigue cracking
     ↳ Pumping erosion
     ↳ joint deterioration.

fig: frost heave

fig: mud-pumping

Methods of flexible pavement design:

↳ Flexible pavement design method can be categorized into:

Flexible Pavement design method	Example:	Based on:
1. Theoretical methods	• Burmister method • Boussineqs method	• Mathematical method.
2. semi-Empirical or semi-theoritical method.	• Triaxial test method	• stress-strain function.
3. Emperical method	• GI method • CBR method • Mc Leod method • Stabilometer method • Road Note 29 & 31 method.	• Physical property.

Theoretical method:

a. Boussinque's method:

↳ The vertical displacement at surface under centre of applied load is given by,

$$\Delta = \frac{2Pa}{E}(1-\mu^2)$$

where Δ = vertical displacement.

μ = poisson's ratio (bitumen)

E = modulus of elasticity of sub-grade

P = allowable load.

a = contact area

for $\mu = 0.5$

$$\Delta = \frac{2Pa}{E}(1-0.5^2)$$

$$\Delta = \frac{1.5Pa}{E} \leq 5mm \text{ (ok)}$$

↳ This equn is applicable for flexible pavement design.

b. Burmister's method:

↳ special case of boussinque's method.

$$\Delta = 1.5\frac{P \times a}{E} \times f_2$$

f_2 = displacement factor

Note:

Maximum deflection in case of flexible pavement is limited to 5mm.

i.e. $\Delta \leq 5mm$ (ok)

otherwise redesign the pavement.

Semi-theoretical / Semi-emperical method:

a. Triaxial test method:

↳ Equ^n for thickness of pavement,

$$T = \left\{ \sqrt{\left(\frac{3Pxy}{2\pi E_s \Delta}\right)^2 - a^2} \right\} \times \left(\frac{E_s}{E_p}\right)^{1/3}$$

; where

T = thickness of pavement

P = wheel load (kg)

E_s = modulus of elasticity of sub-grade

E_p = modulus of elasticity of pavement material.

x = traffic coefficient

y = rainfall coefficient

a = radius of contact

$\frac{E_s}{E_p}$ = stiffness factor.

Emperical method:

a. Group Index method:

↳ Group index is calculate for soil types having percent fines, liquid limit and plasticity index.

↳ GI is found by, equation,

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

; where GI = group index

a = % of soil passing through 0.075mm sieve in excess of 35% but not exceeding 75%.

b = % of soil passing through 0.075 mm sieve in excess of 15% but not exceeding 55%.

c = liquid limit in excess of 40%.

d = plasticity index in excess of 10%.

Note:

↳ GI of soil lies between 0 to 20.

↳ To design the thickness, estimated traffic is calculated and assumed as light traffic, medium or heavy.

Traffic type	No. of vehicle per day
light	upto 50
medium	50 to 300
heavy	greater than 300.

↳ From GI obtained and estimated traffic, appropriate chart is looked and thickness of pavement is known from chart.

Limitations:

(i) It only considers physical properties of soil.

(ii) It does not consider strength parameter.

b. CBR method:

↳ CBR method is a penetration test method developed by California division of highway.

↳ CBR method is also used to evaluate stability of sub-grade soil.

↳ Design of flexible pavement by CBR method constitutes two steps:

step-1: Calculation of CBR-value

step-2: Calculation of Thickness of pavement.

step-1: calculation of CBR-value:

$$CBR(\%) = \frac{\text{load sustained by specimen at 2.5 or 5mm Penetration}}{\text{load sustained by standard specimen at corresponding value}} \times 100$$

↳ The penetration value of 2.5mm is higher than 5mm.

↳ If the penetration value of 5mm is found higher the test is repeated.

↳ If again the penetration value of 5mm is found higher than its value is taken.

↳ CBR test is done 3-times and its average value is taken.

Step-2: Calculation of thickness of pavement.

↳ thickness of pavement by CBR test is given by

$$t = \left(\frac{1.75P}{CBR\,\% - \frac{A}{\pi}} \right)^{1/2}$$

; where t = thickness of pavement in cm.
P = wheel load (kg)
CBR % = calculated value
A = area of contact (cm^2)

Note:

↳ CBR test method gives overall thickness of pavement.

↳ thickness of successive layers is calculated by subtracting the corresponding thickness calculated from CBR test for each layer.

c. Mcleod Method:

↳ W. Mcleod through canadian Department conducted plate bearing test and developed this method.

↳ emperical formula to calculate thickness.

$$T = K \log_{10} \frac{P}{S}$$

; where T = required thickness of gravel base (cm)
P = gross wheel load (kg)
S = base coupe constant

d. Road Note 29 and Road Note 31 method:

e. IRC method:

↳ IRC method of flexible pavement design consists of two steps:

step-I : calculation of cumulative traffic

step-II: calculation of CBR(%) value.

step-I: calculation of cumulative traffic:

↳ Design traffic is considered in terms of cumulative number of standard axle as:

$$N = \frac{\{365(A+r)^n - 1\}}{r} \times A \times D \times f$$

; where

r = annual growth rate of commercial traffic.

n = design life in years.

A = initial traffic at the end of construction

$A = P(1+r)^m$

; where P = no. of traffic at beginning of construction

m = construction period

D = lateral distribution factor

f = vehicle damage factor

vehicle damage factor (VDF):

↳ It is the multiplier for converting the number of commercial vehicle to number of standard axle repitition

Step-II: Calculation of CBR(%) value:

↳ CBR(%) = $\frac{\text{load sustained by specimen at 2.5 or 5mm penetration}}{\text{load sustained by standard specimen at corresponding value}} \times 10_0$

↳ After obtaining cumulative traffic, the total thickness of pavement from sub-grade is calculated regarding from the graph given by IRC.

7. Asphalt Institute Method:

↳ It is based on two assumed stress-strain condition.

i. Wheel load is transmitted through tyre at a uniform vertical pressure.

ii. Wheel load caused pavement structure to deflect causing both compressive and tensile stress.

↳ ASTM method is based on multi-layered elastic system

$$\left(\frac{t_b}{t_{sc}}\right) = \left(\frac{E_{sc}}{E_b}\right)^{1/3} \text{ and } \left(\frac{t_{sb}}{t_{sc}}\right) = \left(\frac{E_{sc}}{E_{sb}}\right)^{1/3}$$

; where t_{sc} = thickness of surface course

t_b = thickness of base course

t_{sb} = thickness of sub-base course

E_{sc} = elastic modulus of surface course

E_b = Elastic modulus of base course

E_{sb} = Elastic modulus of sub-base course.

Rigid Pavement Design Method:-

↳ Design of rigid pavement is suggested by Westergaard.

↳ Westergaard method involves

- calculation of sub-grade reaction (K)
- calculation of radius of relative stiffness (ℓ)
- calculation of thickness of pavement (T).

• Modulus of sub-grade reaction (K):

↳ Modulus of sub-grade reaction (K) is the reaction sustained by soil sample under rigid plate at standard diameter per unit of settlement.

↳ load sustained is directly proportional to deflection (Δ).

$$P \propto \Delta$$

$$P = K\Delta$$

$$\Rightarrow K = \frac{P}{\Delta} \text{ and permissible value of } \Delta = 0.125$$

$$\therefore K = \frac{P}{0.125} \text{ kg/cm}^3$$

where P = load sustained (kg/cm²)

Δ = 0.125 cm

• Radius of relative stiffness (ℓ)

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

; where ℓ = radius of relative stiffness (cm)

E = modulus of elasticity of cement concrete (kg/cm²)

μ = poisson's ratio of concrete

h = slab thickness

K = modulus of sub-grade reaction (kg/cm³)

- Thickness of slab (T):

a. According to older theory

$T = \sqrt{\frac{3W}{\sigma}}$; where W = wheel load

σ = unit stress in tension.

b. According to sheet's formula,

$T = \sqrt{\frac{2.4\,WC}{\sigma}}$; where C = coefficient of sub-grade

W = wheel load

σ = unit stress in tension

Numerical:

Q. What are the assumptions made by Wastergaard for analyzing rigid pavement? Calculate the radius of relative stiffness of 15cm thick cement concrete slab from the following data:

$E = 2,10,000\ kg/cm^2$, $K = 3\ kg/cm^3$

$\mu = 0.15$

Ans: Assumption of Wastergaard:

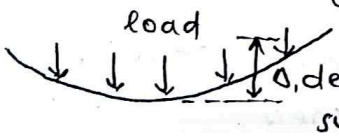
① Concrete slab is homogenous, isotropic & has uniform strength

② sub-grade reaction is vertical only & proportion to slab deflection.

③ sub-grade reaction is proportional to load and deflection.

④ the slab is uniform in thickness.

⑤ The load at interior and corner is circular in shape & positioned as in figure



Temperature stress in Rigid pavement:

↳ Due to effect of temperature, two types of stress occurs in rigid pavement:

i. Warping stress.

ii. Frictional stress.

i. Warping stress:

↳ occurs due to top and bottom surface possesses different temperatures.

↳ slab tends to warp upward or downward.

↳ temperature difference depends on thickness of slab.

ii. Frictional stress.

↳ occurs due to frictional resistance of base or subgrade with slab surface

↳ due to temperature change slab tends to expand & contract and hence friction stress develops.

Types of joint in rigid pavements:

↳ Different types of joints used in cement concrete pavement to reduce temperature stress are:

(i) Expansion joint.

(ii) contraction joint.

(iii) Warping joint.

(iv) construction joint.

(v) Longitudional joint.

	Type of joint	Purpose
1.	Expansion joint	To minimize the effect of temperature increase.
2.	Contraction joint	To minimize the effect of temperature decrease.
3.	Warping joint	To minimize the effect of daily temperature.
4.	Construction joint	To stop work at the end of the day or mechanical problem.
5.	Longitudional joint	When the width of pavement is more than 5m.

Requirements of joints:

(i) Joint must be free to more.

(ii) Joint must be water tight.

(iii) Joint should not protrude out general level of slab.

Properties of joint filler and sealer:

(i) Compressibility

(ii) Elasticity

(iii) Durability

*: Pavement failure:

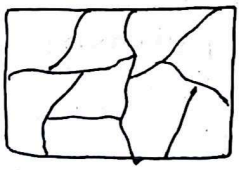
↳ Pavement failures occurs due to several factors such as excessive vehicular stress, sunlight expsure, water intrusion unequal expansion and contraction due to seasonal change

Typical flexible Pavement failures are:

i. Aligator or map cracking
ii. consolidation of pavement layer
iii. shear failure
iv. Longitudional cracking
v. Frost heaving
vi. Lack of binding with lower layer.
vii. Reflection cracking
viii. Formation of wave and corrugation
ix. Edge failure
x. Rise and depression of shoulder.

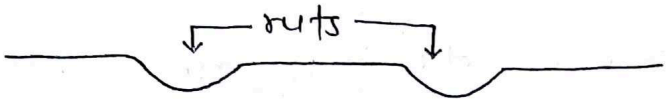
i. Aligator or map cracking:

↳ occurs due to fatigue, moisture variation in sub-grade etc
↳ characterized by hair crack formation and expansion.
↳ Uncomfortable driving.



ii. Consolidation of pavement layer:

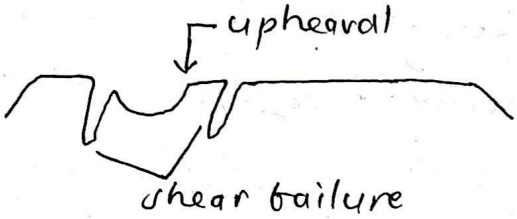
↳ occurs due to repeated action of load on same location.
↳ Formation of ruts



III. Shear failure:

↳ occurs due to low shearing resistance to heavy loading.

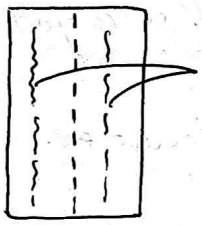
↳ causes upheaval of pavement by causing cracks.



IV. Longitudional cracking:

↳ occurs due to repeated wheel load along same path.

↳ characterized by uneven settlements.



V. Frost heaving:

↳ occurs due to bursting of ice below surface at cold pla

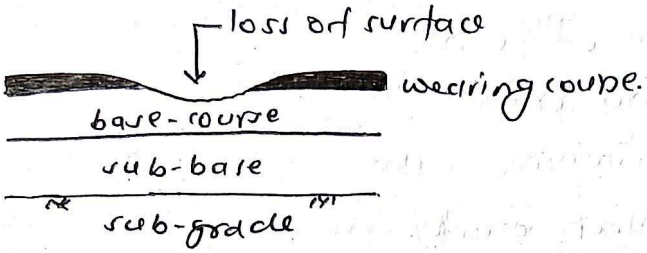
Note:

- shear failure : upheaval of parement portion with a depression.
- Frost heaval: localized heaving without depression.

VI. Lack of binding with lower layers:

↳ occurs due to loss of binding materials.

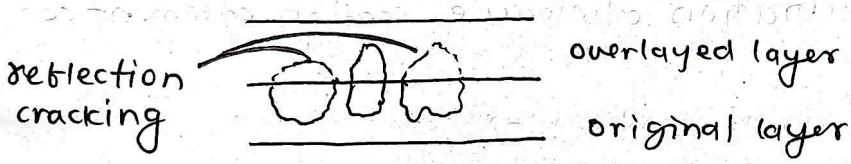
↳ slippage of adjacent layers.



VII. Reflection cracking:

↳ occurs in overlayed pavement layer.

↳ crack pattern is same as below layers.



VIII. Formation of waves and corrugations:

↳ occurs due to poor compaction, poor gradation

↳ excessive deformation in pavement layers.

↳ discomfort driving.

ix: Edge failure:

↳ cracking of edge.

x: Rise and depression of shoulder.

Typical rigid pavement failures:

I. Scaling of cement concrete
II. Shrinkage cracks
III. Spalling of joints
IV. Warping cracks
V. Mud-pumping
VI. Structural cracks.

I. Scaling of ~~cement~~ concrete:

↳ occurs due to deficiency in mix or chemical impurities in cement.

↳ excessive use of vibration also causes scaling of cement concr

II. Shrinkage cracks:

↳ occurs during curing process.

III. Spalling of joints.

↳ dislocation of joints is known as spalling of joints.

IV. Warping cracks.

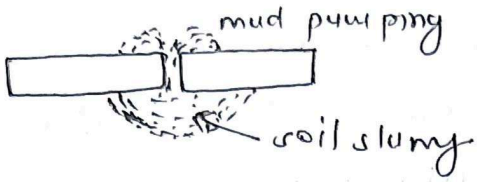
↳ occurs at the edge or corners due to temperature difference.

V. Mud-pumping:

↳ process of ejecting out of soil slurry through joints and cracks.

causes of mud pumping:

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



vi. structural cracks:

↳ occurs due to heavy traffic than considered.

↳ cracks usually develop near edge and corners.

causes:

- heavy traffic.
- insufficient thickness.

4.1.9 Road construction Technology:

↳ Activities and technologies used in road construction are

1. Earth work and site clearance:
   - (i) site clearance
   - (ii) Earth work in filling
   - (iii) Earth work in cutting
   - (iv) Disposal of surplus earth.

2. Drainage works:
   - (i) culverts
   - (ii) Bridge
   - (iii) causeways
   - (iv) surface and sub-surface drainage works.

3. Protection works:
   - (i) Retaining wall
   - (ii) River training works.
   - (iii) landslide stabilization
   - (iv) Bridge protection works.

4. Road works:
   - (i) Preparation of sub-grade.
   - (ii) Preparation of sub-base.
   - (iii) preparation of base course.
   - (iv) Preparation of surface course.

5. Miscellaneous works:

- Installation of traffic sign, signal etc.
- (II) Bio-engineering works.

Tools, Equipments and Plants used in road constr

1. Excavating Equipments:

A. Tools:

- (I) shovel
- (II) spade
- (III) Peak (कुदाली, खन्ती)
- (IV) wheel barrow
- (V) Brushes

B. Equipments:

- (I) Excavator
- (II) Dozer
- (III) calmshell
- (IV) Trench digger
- (V) scrapper
- (VI) Draglines
- (VII) Backhoe loader
- (VIII) Power shovel.

2. Compacting Equipments:

- (I) smooth wheeled roller
- (II) vibrating roller
- (III) Pneumatic tyred roller
- (IV) Tandem roller (अगाडी र पछाडी
- (V) sheep footed roller

3. Transporting equipments:

(i) Tractors
(ii) Trucks
(iii) Trippers
(iv) Mini-dumpers.

4. Lifting equipments:

(i) crane
(ii) Tower crane etc.

5. Paving equipments:

(i) Bitumen boiler
(ii) Bitumen spreader
(iii) Aggregate spreader
(iv) Concrete mixer.

6. Plants:

(i) Aggregate crusher plant
(ii) screening plants
(iii) Asphalt mixing plants
(iv) Batching plant for concrete mix.

7. levelling equipment:

(i) Grader.

construction of roads:

↳ Road construction consists of two major operation:

i. Preparation of sub-grade
ii. construction of overlaying layers.

1. Preparation of sub-grade:

↳ Preparation of sub-grade consists of excavation, filling, grading and compaction.

a. Excavation:

↳ process of cutting and removing earth including rocks from its original position.

↳ Design elements of excavation are:

- Depth of excavation
- stability of foundations
- stability of slopes
- Road side drain
- fill materials.

b. Fillings:

↳ process of depositing earth to raise the level.

↳ granular soil is generally preferred for filling.

c. compaction:

↳ densification of soil by removal of air and air voids.

↳ increases the density and stability.

↳ reduces settlement of foundation.

II. construction of overlaying layers:

↳ it includes construction of,

- sub-base course.
- base course.
- surface/wearing course.

soil stabilization:

↳ process of improving engineering properties of interior soil w.r.to strength, stability, density, bearing capacity etc. is called soil stabilization.

Objective:

(I) Increase stability
(II) Reduce swelling
(III) Increase shear strength
(IV) Reduce permeability

Techniques of soil stabilization:

I. Proportionating technique:

↳ gradation to achieve desired objective.

II. cementing agents:

↳ using cementing agents like ppc, lime, bituminous materials etc.

III. Modifying agents:

↳ use of modifier such as lime, coment etc.

IV. water proofing agents:

↳ use of bituminous material.

v. Heat treatment:

↳ use of heat to reduce swelling properties.

vi. chemical stabilization:

↳ use of chemicals to impart change in soil.

Methods of soil stabilization:

↳ Methods of soil stabilization are:

a. Mechanical stabilization : compaction.
b. soil- cement stabilization.
c. soil- lime stabilization.
d. soil- bitumen stabilization.

a. Mechanical stabilization:

↳ stabilization by compaction.

↳ densification of soil by expulsion of air and air voids.

b. soil- cement stabilization:

↳ 6-12 % cement by volume is mixed in soil. (can be used >12%)

↳ Best application: In sand or sandy soil.

c. soil- lime stabilization:

↳ 3-9 % lime by volume is mixed in soil. (9% max^m)

↳ Best application: In clay (plastic clay)

d. soil- bitumen stabilization:

↳ 3 to 12 l/m^2 is sprayed in soil before compaction.

↳ Best application

① in organic soil ② in dam, reservoir etc.

field row packing control

Field compaction control.

Construction of Asphalt concrete layers:

↳ Types of bituminous construction:

1. Interface treatments
    a. Prime coat
    b. Tack coat
2. Bituminous surface dressing
3. seal coat
4. Penetration macadam
5. Built-up-spray grout
6. Premix method
7. Bituminous macadam
8. Pre-mix carpet
9. Asphalt concrete
10. sheet Asphalt
11. Mastic asphalt.

1. Interface treatment:

a. Prime coat:

↳ It is the first application of low viscosity bituminous material over an existing porous surface like WBM base course.

Objective:

↳ To plug the capillary voids of porous surface and bond the loose particles.

Function:

① To develop adhesion between wearing and base course.

② To bind together loose particles.

③ To seal pores making water proofing.

④ To plug capillary voids.

b. Tack coat:

↳ It is the application of bituminous material over an existing surface before laying new wearing surface.

↳ tack coat is applied by spraying bituminous material of highest viscosity.

Function / objection:

① To develop adherion between pavement layers.

2. Surface dressing:

↳ application of bituminous binder material followed by spreading of aggregate cover and rolling.

↳ provided over an existing pavement to serve as a thin wearing coat.

Functions:

(i) improves skid resistance
(ii) helps to make water proofing.
(iii) protects against frost heaving.

3. seal coat:

↳ seal coat is very thin surface treatment usually applied over an existing ~~black top~~ surface.

Functions:

(i) To seal surface pores
(ii) To develop skid resistance
(iii) To increase the life of surface.

4. Penetration macadam or grouted macadam:

↳ used as a base or binder course.

construction steps:

- coarse aggregates are compacted in dry states.
- high viscosity bituminous binder is sprayed
- bitumen penetrates into the voids and fill up.

↳ Two types:

(i) full grout (ii) semi-grout.

5. Built-up-spray grout:

↳ consists of two layer composite construction.

↳ finished up with key aggregates at top

6. Pre-mix method:

↳ aggregates and bitumen are mixed before spreading and compaction.

Types:

① Dense graded

② Semi-dense graded

③ Open-graded

④ Gap-graded.

7. Bituminous macadam:

↳ open graded mixes

↳ compacted thickness of 50 or 75 mm.

↳ pre-mix construction method.

8. Pre-mix carpet:

↳ consists of C.A. of 12.5mm and 10mm size.

↳ compacted thickness of 20mm.

↳ serve as a surface course.

9. Asphalt concrete:

↳ dense graded bituminous mixes.

↳ well graded aggregates, filler and bituminous material designed by Marshall method.

↳ compacted thickness of 40 to 75 mm.

Construction procedure of Penetration Macadam:

Penetration macadam:

↳ Penetration macadam is used as a base or binder cour

construction techniques:

- coarse aggregates are spread and compacted in dry state
- high viscosity bitumen binder is spread.
- bitumen penetrates into voids and fills up voids.

Two types:

① full grout ② semi-grout.

↳ Thickness = 50 to 75 mm.

↳ **Materials required:**

a. Bitumen

↳ grade $\frac{80}{100}$, $\frac{60}{70}$, $\frac{30}{40}$

b. Aggregates:

↳ strong, hard, durable and clean with

i. los angles abrasion value = 35 %.

ii. aggregate impact value = 30 %.

iii. water absorptim = 1 %.

↳ plants and Equipments:

a. bitumen heating device
b. Bitumen sprayer
c. Aggregate spreader
d. Aggregate roller.

Construction steps:

I. Preparation of existing surface.
II. spreading of coarse aggregates.
III. Rolling with 8 to 10 tonnes roller.
IV. Bitumen application.
V. spreading of key aggregates.
VI. Seal coating.
VII. Finishing.
VIII. Opening to traffic.

Construction procedure of bitumen bound macadam:

↳ Bitumen macadam is a premix laid immediately after mixing and then compacted.

↳ Open grade mixes suitable only for base or binder course.

↳ thickness : 50 to 75 mm.

Materials required:

a. Bitumen:

↳ grade $\frac{80}{100}$, $\frac{60}{70}$, $\frac{30}{40}$

b. Aggregates:

↳ low porosity aggregates with

i. los angles abrassion value = 50%.

ii. aggregate impact value = 35%.

iii. flakiness index = 15%.

Plants and Equipments:

① Bitumen heating devices

② Bitumen sprayer

③ Mechanical mixer

④ Aggregate spreader

⑤ Roller.

Construction steps:

I. Preparation of existing surface
II. Application of prime coat or tack coat.
III. Premix preparation.
IV. Placement of mix at site.
V. Rolling and finishing.
VI. Application of seal coat.
VII. Opening to traffic.

Construction procedure of plain cement concrete Pavement

↳ Pavement having wearing surface of cement concrete slab is called cement concrete pavement.

Advantages:

① gives excellent riding surface
② maintenance cost is low.
③ design is rational.

Disadvantages:

① high initial cost.
② No. of longitudional and transverse joints.
③ large construction period.

↳ construction of plain cement concrete pavement consists of two steps:

step-1: construction of pavement slab.
step-2: construction of joints.

step-1: construction of pavement slab:

Materials required:

a. cement: opc

b. coarse aggregates:

- Max^m size = $\frac{1}{4}$ th of slab thickness
- Aggregate crushing value = 30%.
- Aggregates impact value = 30%.
- los angles abrassion value = 35%.

c. Fine aggregates:

↳ generally natural sand is preferred.

Plants and Equipments:

i. concrete mixer.
ii. Batching plants.
iii. Vibrator.
iv. Float.
v. Edging tool.
vi. Wheel barrow.
vii. Pan.
viii. Belt.

Construction steps:

i. Preparation of sub-grade and sub-base:
ii. Placing of formwork.
iii. Batching of materials and mixing.
iv. Transporting and placing of concrete
v. compaction and finishing.
vi. curing.
vii. Opening to traffic.

step-2: construction of joints:

↳ provided in cement concrete pavement for expansion, contraction and warping due to temperature variation.

↳ function is to minimize temperature stress induced in slab.

4.1.10 Highway Maintenance, Repair and Rehabilation:

Highway maintenance:

↳ Highway maintenance is defined as the measures adopted to keep the pavement in service condition.

Purpose:

(i) To maintain regular road service.
(ii) Reduction in transport cost and time.
(iii) To reduce accidents.
(iv) To reduce major damage and cost.
(v) To assure long term use of roads.
(vi) To continue social and economical achieverements.
(vii) To accomadate environmental issues.

Types of maintenance:

↳ Maintenance can be divided into five types:

(i) Routine maintenance
(ii) Recurrent maintenance.
(iii) Periodic maintenance.
(iv) Preventive maintenance.
(v) Emergency maintenance.

I. Routine maintenance:

↳ Maintenance work carried out daily on roads.

↳ Regular work to keep road at appropriate standard.

↳ Activities are:

- cleaning drainage, culvert, bridge, road etc.
- Removal of grass from road surface.
- cleaning sign post
- pot hole repair of earthen and gravel road.

II. Recurrent maintenance:

↳ Maintenance work carried out at regular interval of 6 months to 2 years.

↳ Activities are:

- pot hole repair
- road painting, sign board painting
- crack sealing (MCQs) → Lumbini-PPSC
- repair of drainage works.

III. Periodic maintenance:

↳ Maintenance works carried out at interval of several years say (5-7 years).

↳ Activities are:

- surface dressing, sand sealing, slurry sealing etc.
- Bio-engineering
- Installation of cross-drainage structure.
- Road marking

iv. Emergency maintenance:

↳ Maintenance work carried out due to unexpected and sudden blockage of roads due to natural disaster.

↳ Activities are:

- Removal of landslide soil.
- Maintenance of damaged embankment and slope
- Maintenance of bridge/culverts.

v. Preventive maintenance:

↳ Maintenance work carried out to prevent future consequences on road.

↳ Activities are:

- slope stabilization.
- River training works.
- Bio-engineering.

Inspection, prioritization and planning of maintenance activities:

↳ During inspection several defects may be found and they must be maintained.

↳ The maintenance of these defects may or may not be possible due to limited fund, so these defects are arranged according to priorities.

↳ This process is called inspection and prioritization.

Factors to be considered for planning of maintenance system:

(i) Minimum acceptable serviceability.
(ii) Field survey for maintenance requirements.
(iii) Estimation of rate of deterioration of pavements.
(iv) Availability of fund.
(v) Maintenance cost, availability of materials, manpower and equipments.

Q. Differentiate rehabilation, maintenance and re-construction: [3 marks]

Ans: **Maintenance:**

↳ Work performed to keep a pavement in its as constructed condition.

Eg: patch repair, surface treatment.

Rehabilation:

↳ Work performed for improving strength and performance of pavement.

Eg: increasing thickness of layer, resurfacing.

Re-construction:

↳ Work performed to upgrade road condition which may include change in alignment.

Eg: new alignment, re-building of cross-drainage structures etc.

Evaluation of pavement distress and pavement condition:

Pavement Evaluation:

↳ Pavement evaluation is a technique of assessing the conditions of pavement from both structural and surface characteristics point of view.

↳ Also called as pavement condition survey and rating of pavement.

Methods of pavement evaluation:

I. Structural evaluation
II. Evaluation of surface condition.

I. Structural evaluation:

↳ done by measuring deflection ⇐ specified load.

↳ Benkelman Beam method is used for structural evaluation.

- Performance of flexible pavement depends on elastic deformation of pavements.
- Performance of rigid pavement depends on flexural strength of pavements.

II. Evaluation of surface condition:

↳ for flexible pavement:
- measuring surface unevenness, ruts, patches etc.

↳ for rigid pavement:
- measuring surface cracks and faults of joints.

↳ surface condition is expressed by unevenes index.

↳ Measured in cumulative unevenes per km i.e cm/km

Purpose of parement evaluation:

① To research about performance over time.

② To assess the maintenance required.

③ To assess the need of structural overlay.

Parement distress:

↳ physical deterioration of a highway due to structura failure, climatic condition, weathering or environmental factor is known as pavement distress.

IRI value for distress:

- 0 to 3.5 : good to fair → maintenance only needed
- 3.5 to 8.5 : fair to poor → resealing needed
- > 8.5 : poor to very poor → reconstruction needed.

Note: failure can be used as a synonym for dis-tress.

Q. Differentiate prime coat, seal coat and tack coat. [5 marks]

Parameter	Prime coat	Tack coat	Seal coat.
Definition	• First application of low viscosity bituminous material over an existing porous surface like WBM base course.	• Application of bituminous material over an existing surface before laying new wearing course.	• Very thin surface treatment usually applied over an existing black top surface.
Purpose	• provide adhesion between bituminous course and loose bound aggregate • To water proof the layer.	• To provide interface bond between new and existing surface. • To prevent degradation of road.	• To prevent degradation of pavement surface. • To extend pavement life.
Material	• low viscosity asphalt.	• Bitumen emulsion of grade RS-1 & VG-10.	• Type A or type B seal coat.
Rate of application.	• 0.7 to 1 kg/m^2	• 0.2 to 0.35 kg/m^2	• 0.06 m^3 to 0.09 m^3 of F.A. per 10 m^2 area.
Method of application:	• If cut back is used base course should be fully dry. • If emulsion is used base course may be slightly damp.	• RS-1 grade with heating by spraying • VG-10 grade bitumen heated to viscosity 2 poise.	• Type A: premix carpet. • Type B: bitumen and FA heated separately, mixed and sprayed.