
INDIAN RAILWAYS
भारतीय रेल
RRB JE CBT 2
Marathon Class
Highway Engineering
wifistudy

ROAD ENGINEERING

- **Road transport is one of the most common mode of transport. Roads in the form of trackways, human pathways etc. were used even from the pre-historic times.**
- **Since then, many experiments were going on to make it more safer and comfortable. Thus road construction became an inseparable part of many civilizations and empires.**

INVESTIGATION OF ROAD PROJECT

OBJECTIVE OF ROAD INVESTIGATION:

- **To locate the alignment of a road which provides maximum transportation facilities with minimum cost of construction and maintenance.**
- **It is mainly done in three stages:**
  - **Reconnaissance Survey**
  - **Preliminary Survey**
  - **Location**

Reconnaissance Survey

It examines the general character of land between the terminal stations in the field, along the proposed alternative alignments marked on the map. In this survey, simple survey instruments like prismatic compass, may be used to collect the additional details.

OBJECTIVES:

1. To collect details of obstruction along the route which are not available in the map.
2. To collect geological features of field.
3. To collect information regarding the availability of local construction material, water and labor.
4. To determine the approximate values of gradient and length of gradient.
5. To determine approximate estimate of construction of road.
6. To determine two or three best possible routes.

Preliminary Survey

- In order to find the details of alternative alignments found suitable during the reconnaissance survey.
- In this survey, the survey instruments used such as chain, tape, prismatic compass, plane table, theodolite etc.
- To collect all necessary information & details of topography, drainage and soil of various alignments found after the reconnaissance survey.
- To compare different alignments as per the requirements of a good road alignment.
- To estimate the cost of construction the road.
- To finalize the best alignment from construction, maintenance and traffic operation point of view.

Location

- **The detailed examination of the alignment finally recommended during the preliminary survey is known as 'Location survey'.**
- **In this survey, the survey instruments are used such as chain, tape, plane table, theodolite etc.**
- **The detailed survey should be carried out for collecting information necessary for the preparation of plans and construction details for highway project.**
- **To determine total cost of the road project**

History of highway engineering

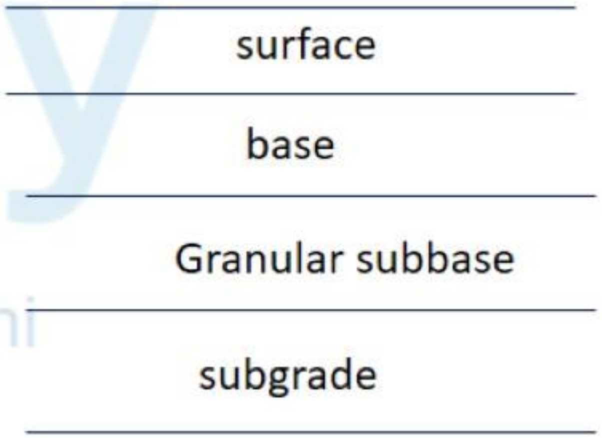
- The history of Highway Engineering gives us an idea about the roads of ancient times.
- Roads in Rome were constructed in a large scale and it radiated in many directions helping them in military operations. Thus they are considered to be pioneers in road construction.

History of highway engineering

- **Ancient Roads**
  - **The first mode of transport was by foot. These human pathways would have been developed for specific purposes leading to camp sites, food, streams for drinking water etc. The next major mode of transport was the use of animals for transporting both men and materials.**
  - **The invention of wheel in Mesopotamian civilization led to the development of animal drawn vehicles. Then it became necessary that the road surface should be capable of carrying greater loads. Thus roads with harder surfaces emerged**
  - **The earliest authentic record of road was found from Assyrian empire constructed about 1900 BC**

History of highway engineering

- Roman roads
  - Romans constructed an extensive system of roads radiating in many directions from Rome.
  - Romans recognized that the fundamentals of good road construction were to provide good drainage, good workmanship
  - Their roads were very durable and some are still existing
  - Roman roads were always constructed on a firm – formed subgrade strengthened



History of Highway Engineering

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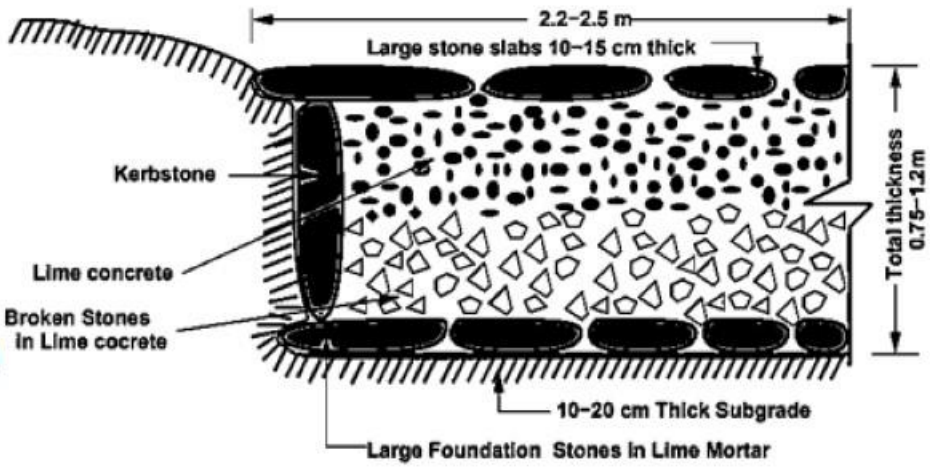
  - The main features of the Roman roads are that they were built straight regardless of gradient and used heavy foundation stones at the bottom.
  - They mixed lime and volcanic pozzolana to make mortar and they added gravel to this mortar to make concrete. Thus concrete was a major Roman road making innovation

surface

base

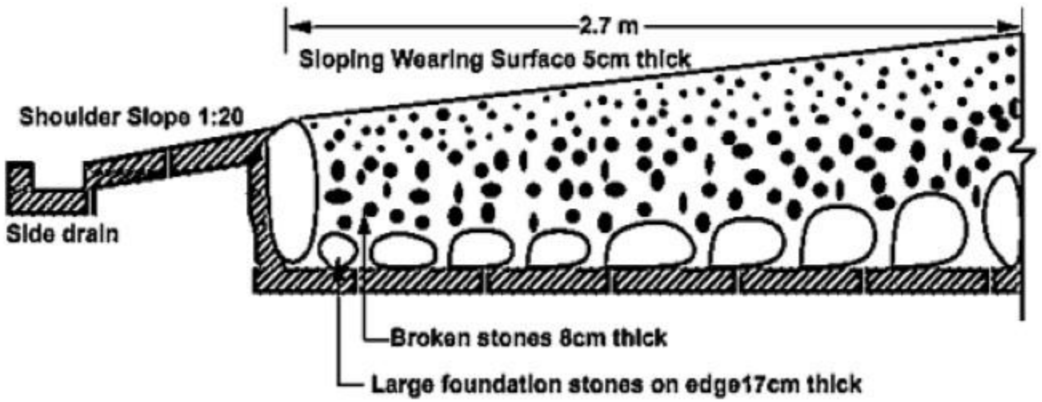
Granular subbase

subgrade



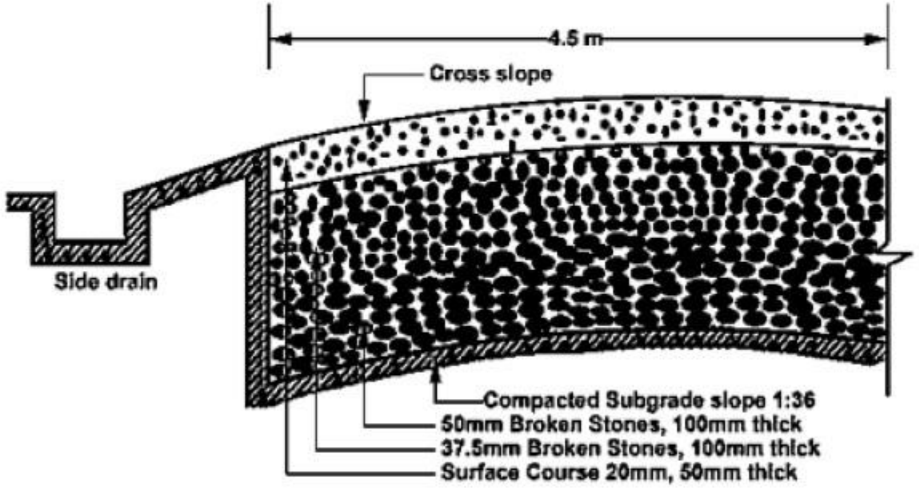
History of Highway Engineering

- French Roads:
  - A cheaper method of construction was developed
  - The pavement used 200 mm pieces of quarried stone of a more compact form and shaped such that they had at least one flat side which was placed on a compact formation
  - Smaller pieces of broken stones were then compacted into the spaces between larger stones to provide a level surface
  - Finally the running layer was made with a layer of 25 mm sized broken stone. All this structure was placed in a trench in order to keep the running surface level with surrounding
  - This created major drainage problems which were counteracted by making the surface as impervious as possible, cambering the surface and providing deep side ditches



History of Highway Engineering

- British Roads:
  - The British government also gave importance to road construction.
  - The British engineer John Macadam introduced what can be considered as the first scientific road construction method.
  - Stone size was an important element of Macadam recipe. By empirical observation of many roads,he came to realize that 250 mm layers of well compacted broken angular stone would provide the same strength and stiffness and a better running surface than an expensive pavement founded on large stone blocks.
  - Thus he introduced an economical method of road construction.



History of Highway Engineering

- Modern Roads:
  - The modern roads by and large follow Macadam's construction method. Use of bituminous concrete and cement concrete are the most important developments. Various advanced and cost-effective construction technologies are used.
  - Development of new equipment help in the faster construction of roads. Many easily and locally available materials are tested in the laboratories and then implemented on roads for making economical and durable pa

Highway planning in India

- After world war 1, the Government of India appointed a committee called Road development Committee in 1927 with Mr.M.R. Jayakar as the chairman.
- This committee came to be known as Jayakar committee.
- They gave more stress on long term planning programme, for a period of 20 years (hence called twenty year plan) that is to formulate plans and implement those plans with in the next 20 years.
- One of the recommendations was the holding of periodic road conferences to discuss about road construction and development. This paved the way for the establishment of a semi-official technical body called Indian Road Congress (IRC) in 1934
- The committee suggested imposition of additional taxation on motor transport which includes duty on motor spirit, vehicle taxation, license fees for vehicles plying for hire. This led to the introduction of a development fund called Central road fund in 1929. This fund was intended for road development.
- • A dedicated research organization should be constituted to carry out research and development work. This resulted in the formation of Central Road Research Institute (CRRI) in 1950.

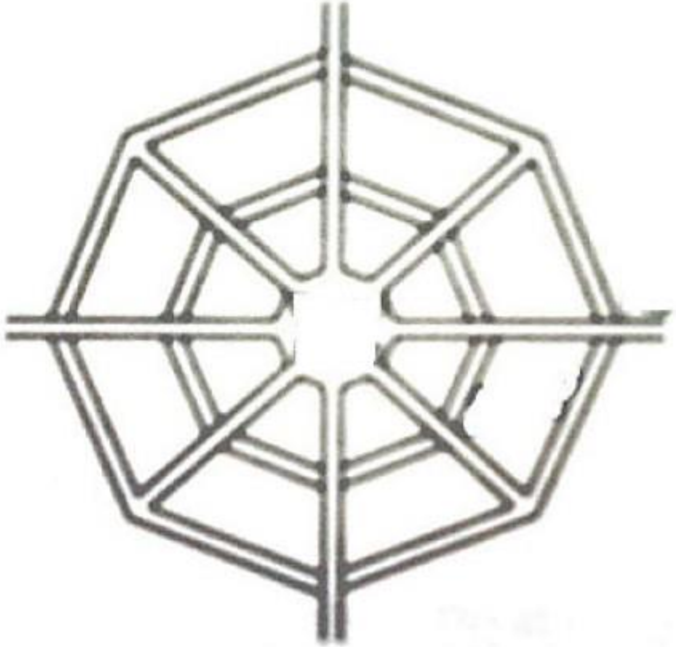
Highway planning in India

- **Nagpur road congress 1943**
  - To discuss about improving the condition of roads, the government convened a conference of chief engineers of provinces at Nagpur in 1943. The result of the conference is famous as the Nagpur plan
  - A twenty year development programme for the period (1943-1963) was finalized. It was the first attempt to prepare a co-ordinated road development programme in a planned manner.
  - The roads were divided into four classes:
    1. National highways which would pass through states, and places having national importance for strategic, administrative and other purposes.
    2. State highways which would be the other main roads of a state.
    3. District roads which would take traffic from the main roads to the interior of the district . According to the importance, some are considered as major district roads and the remaining as other district roads.
    4. Village roads which would link the villages to the road system

Highway planning in India

- **Nagpur road congress 1943**
  - **The committee planned to construct 2 lakh kms of road across the country within 20 years**
  - **One of the objective was that the road length should be increased so as to give a road density of 16kms per 100 sq.km**
  - **They recommended the construction of star and grid pattern of roads throughout the country.**

Start and Grid Pattern



Highway planning in India

- Bombay road congress 1961
  - The length of roads envisaged under the Nagpur plan was achieved by the end of it, but the road system was deficient in many respects. The changed economic, industrial and agricultural conditions in the country warranted a review of the Nagpur plan. Accordingly a 20-year plan was drafted by the Roads wing of Government of India, which is popularly known as the Bombay plan.
  - **It was the second 20 year road plan (1961-1981)**
  - The total road length targeted to construct was about 10 lakhs.
  - Rural roads were given specific attention.
  - They suggested that the length of the road should be increased so as to give a road density of **32kms/100 sq.km**
  - The construction of 1600 km of expressways was also then included in the plan.

Highway planning in India

- Lucknow road congress 1984
  - This was the third 20 year road plan (1981-2001). It is also called Lucknow road plan.
  - It aimed at constructing a road length of 12 lakh kilometres resulting in a road density of 82kms/100 sq.km
  - It aims at improving the transportation facilities in villages, towns etc. such that no part of country is farther than 50 km from NH.

GEOMETRIC DESIGN OF HIGHWAYS

- **The geometric design of highways deals with the dimensions and layout of visible features of the highway.**
- **The emphasis of the geometric design is to address the requirement of the driver and the vehicle such as safety, comfort, efficiency, etc.**
- **The features normally considered are the cross section elements, sight distance consideration, horizontal curvature, gradients, and intersection.**
- **Proper geometric design will help in the reduction of accidents and their severity.**
- **Therefore, the objective of geometric design is to provide optimum efficiency in traffic operation and maximum safety at reasonable cost.**

MAIN COMPONENTS OF GEOMETRIC DESIGN

- **Factors affecting the geometric design**
  - **Highway alignment, road classification**
  - **Pavement surface characteristics**
  - ***Cross-section elements* including cross slope, various widths of roads and features in the road margins.**
  - ***Sight distance elements* including cross slope, various widths and features in the road margins.**
  - ***Horizontal alignment* which includes features like super elevation, transition curve, extra widening and set back distance.**
  - ***Vertical alignment* and its components like gradient, sight distance and design of length of curves.**
  - **Intersection features like layout, capacity, etc.**

FACTORS AFFECTING GEOMETRIC DESIGN

1. **TYPE OF ROADS**
   1. **Rural roads –**

- **National highways (joins various states)**
- **Expressways (speed upto 120km/h)**
- **State highways (joins various districts)**
- **Major district roads (joins area of population)**
- **Other district roads (joins rural areas to market place)**
- **Village roads (joins various villages)**

FACTORS AFFECTING GEOMETRIC DESIGN

1. **TYPE OF ROADS**

   2. **Urban roads –**

   - **Expressways**
   - **Arterial roads**
   - **Sub arterial roads**
   - **Collector roads**
   - **Local streets**

FACTORS AFFECTING GEOMETRIC DESIGN

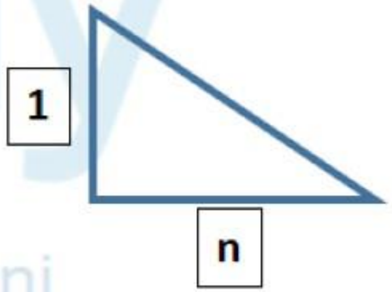
2. TYPE OF VEHICLE

- The vehicle for which road elements are designed is called ***DESIGN VEHICLE*.**
- **The length, width and height of design vehicle are used as design parameters for the roads.**
- **Width of non transport vehicle = 2.5m**
- **Width of transport vehicle = 2.7m**
- **Height of double decker bus = 4.75m**

FACTORS AFFECTING GEOMETRIC DESIGN

3. TOPOGRAPHY

- The next important factor that affects the geometric design is the topography.
- It is easier to construct roads with required standards for a plain terrain.
- It is classified on the basis of general country slope across the road alignment.
- It is generally expressed as 1 in n or x%
- $x\% = \frac{1}{n} \times 100$



FACTORS AFFECTING GEOMETRIC DESIGN

3. TOPOGRAPHY

CROSS SLOPE	CLASS
0 – 10 %	Plain
10 – 25 %	Rolling
25 – 60 %	Mountaneous
> 60 %	Steep

FACTORS AFFECTING GEOMETRIC DESIGN

4. TRAFFIC CAPACITY

- **Traffic capacity is the ability of road to accommodate the maximum traffic volume.**
- **Traffic volume is the number of vehicles crossing a given point on section in unit time.**
- **Both traffic volume and traffic capacity are expresses in *'vehicles per hour'* or *PCU/hr where PCU is passenger car unit.***
- ***PCU =*** $\dfrac{\textit{Capacity with passenger cars only}}{\textit{Capacity with the corresponding vehicle only}}$
  - ***PCU for Pedal cycle,motorcycle,scooter = 0.5***
  - ***PCU for cars, vans, autorikshaw = 1.0***
  - ***PCU for Cycle Rikshaw = 1.5***
  - ***PCU for truck, bus = 3.0***
  - ***PCU for bullock cart = 6***

FACTORS AFFECTING GEOMETRIC DESIGN

4. TRAFFIC CAPACITY

- Generally design capacity is taken as 30th highest hourly volume.
- For Indian conditions, 30th highest hourly volume comes around 8-10% of AADT.
- Here AADT is average annual daily traffic.
- ***AADT =*** $\frac{Total\ Yearly\ Traffic}{365}$

FACTORS AFFECTING GEOMETRIC DESIGN

5. DESIGN SPEED

- It is decided theoretically as the 98th percentile speed, that is the speed at or below which 98% vehicles are moving.
- From economical point of view, IRC has limited the design speed on the basis of topography.
- Ruling speed should be the guiding criteria, however minimum speed can be adopted in localized sections where cost considerations does not permit ruling speed.

FACTORS AFFECTING GEOMETRIC DESIGN

5. DESIGN SPEED

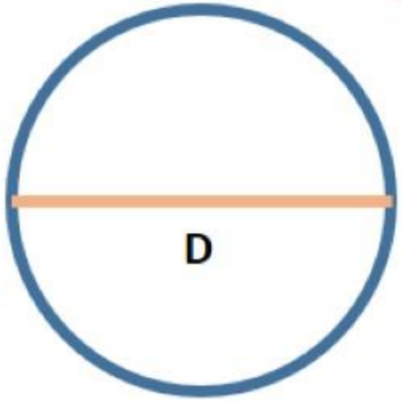
TYPE OF ROAD	RULING SPEED	MINIMUM SPEED
Expressway	120 km/h	100km/h
NH/SH	100 km/h	80 km/h

FACTORS AFFECTING GEOMETRIC DESIGN

6. SURFACE CHARACTERISTICS

➢ **Friction –**

- **Longitudinal friction coefficient – 0.35 to 0.40**
- **Lateral friction coefficient – 0.15**
- **Lack of friction causes skidding and slipping.**
- ***SKIDDING – If one revolution of wheel leads to longitudinal movement greater than πD.***
- ***SLIPPING – If one revolution of wheel leads to longitudinal movement less than πD.***



skidding

slipping

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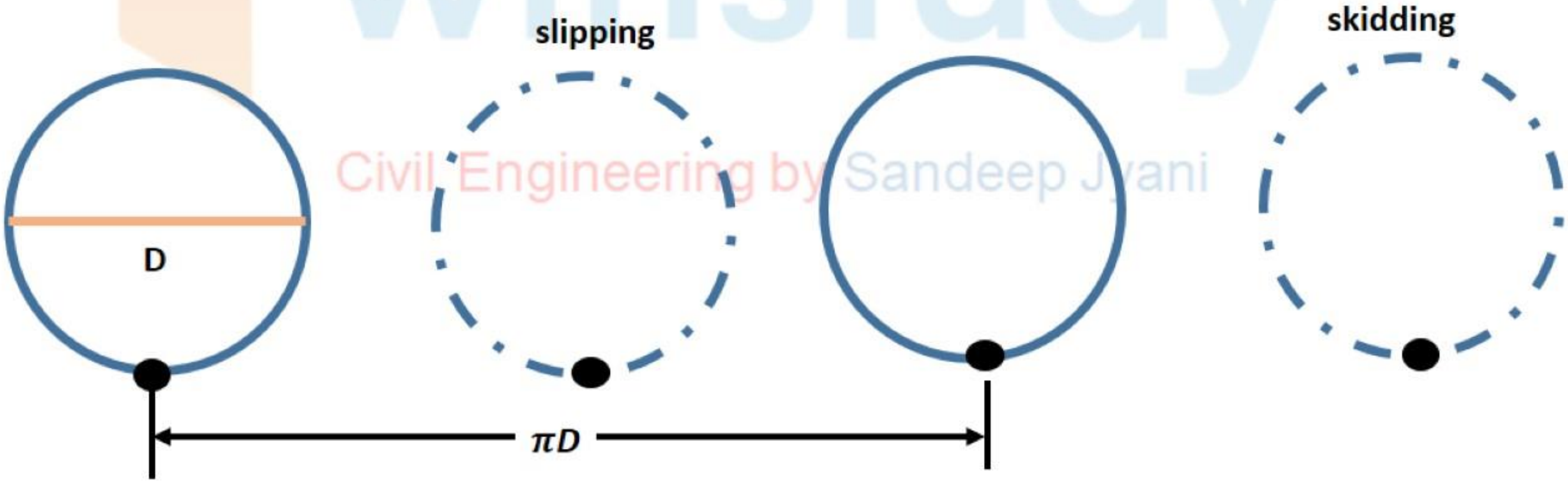


FACTORS AFFECTING GEOMETRIC DESIGN

6. SURFACE CHARACTERISTICS

➢ **Unevenness index –**

- ***It is a cumulative measure of vertical undulations of pavement per unit length of the road.***
- ***It is measured using BUMP INTEGRATOR.***

CLASSIFICATION OF ROAD SURFACE

- **ACCORDING TO UNEVENNESS INDEX**

TYPE OF SURFACE	UNEVENNESS INDEX
Good surface	<1500mm per km
Satisfactory surface	upto 2500mm per km (for speed upto 100km/h)
Unsatisfactory surface	>3200mm per km (for speed upto 55km/h)

CLASSIFICATION OF ROADS

- **ACCORDING TO TRAFFIC VOLUME**

TYPE OF ROADS	VEHICLES PER DAY
Very heavy traffic roads	>600
Heavy traffic roads	251 - 600
Medium traffic roads	70 - 250
Light traffic roads	<70

CLASSIFICATION OF ROADS

- **ACCORDING TO TONNAGE**

TYPE OF ROADS	VEHICLES PER DAY
Very heavy traffic roads	>1524
Heavy traffic roads	1017 - 1524
Medium traffic roads	508 - 1017
Light traffic roads	<508

NAGPUR CLASSIFICATION

In Nagpur road classification, all roads were classified into five categories as

1. **National highways**
2. **State highways**
3. **Major district roads**
4. **Other district roads**
5. **Village roads.**

IRC 73 is concerned with the design of rural highways.

NATIONAL HIGHWAYS

- They are main highways running through the length and breadth of India connecting major ports , foreign highways, capitals of large states and large industrial and tourist centers including roads required for strategic movements.
- It was recommended by Jaykar committee that the National highways should be the frame on which the entire road communication should be based.
- All the national highways are assigned the respective numbers.
- They are constructed and maintained by CPWD (Central Public Works Department).
- The total length of National highway in the country is 58,112Kms, and constitute about 2% of total road networks of India and carry 40% of total traffic.

STATE HIGHWAYS

- They are the arterial roads of a state, connecting up with the national highways of adjacent states, district head quarters and important cities within the state.
- They also serve as main arteries to and from district roads.
- Total length of all SH in the country is 1,37,119 Kms.

- **Major district roads :** Important roads with in a district serving areas of production and markets , connecting those with each other or with the major highways. India has a total of 4,70,000 kms of MDR.
- **Other district roads :** Roads serving rural areas of production and providing them with outlet to market centers or other important roads like MDR or SH.
- **Village roads :** They are roads connecting villages or group of villages with each other or to the nearest road of a higher category like ODR or MDR.

India has 26,50,000 kms of ODR+VR out of the total 33,15,231 kms of all types of roads

MODERN LUCKNOW CLASSIFICATION

- **Primary roads**
  1. **Expressways**
  2. **National highways**
- **Secondary roads**
  1. **State highways**
  2. **Major district roads**
- **Tertiary roads**
  1. **Other district roads**
  2. **Village roads**

GEOMETRIC DESIGN ELEMENTS

- **Cross section elements**
- **Sight distance considerations**
- **Horizontal alignment details**
- **Vertical alignment details**
- **Intersection element.**

❖ HIGHWAY CROSS SECTION ELEMENTS

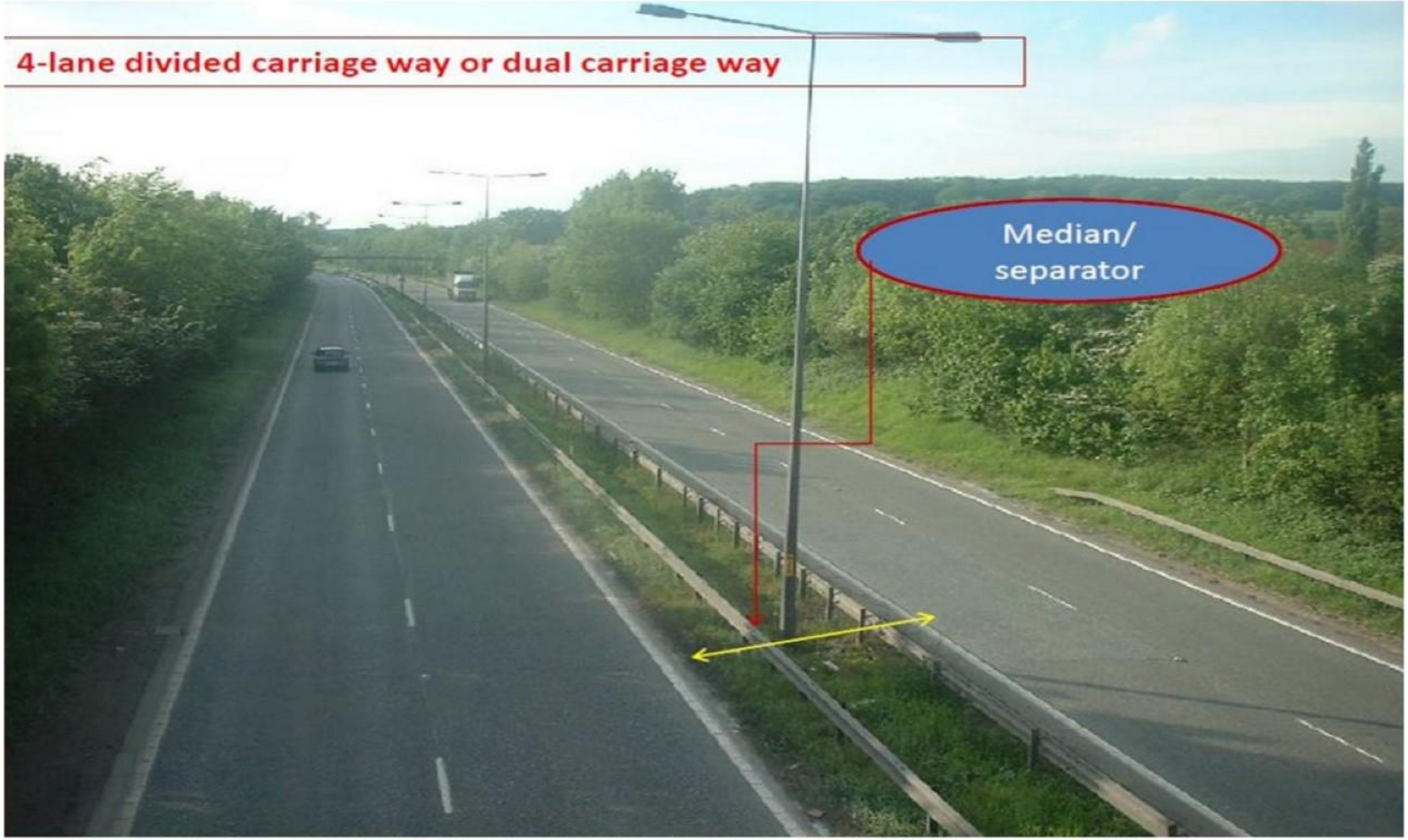
1. **Carriageway**
2. **Shoulder**
3. **Kerbs**
4. **Median**
5. **Road margin**

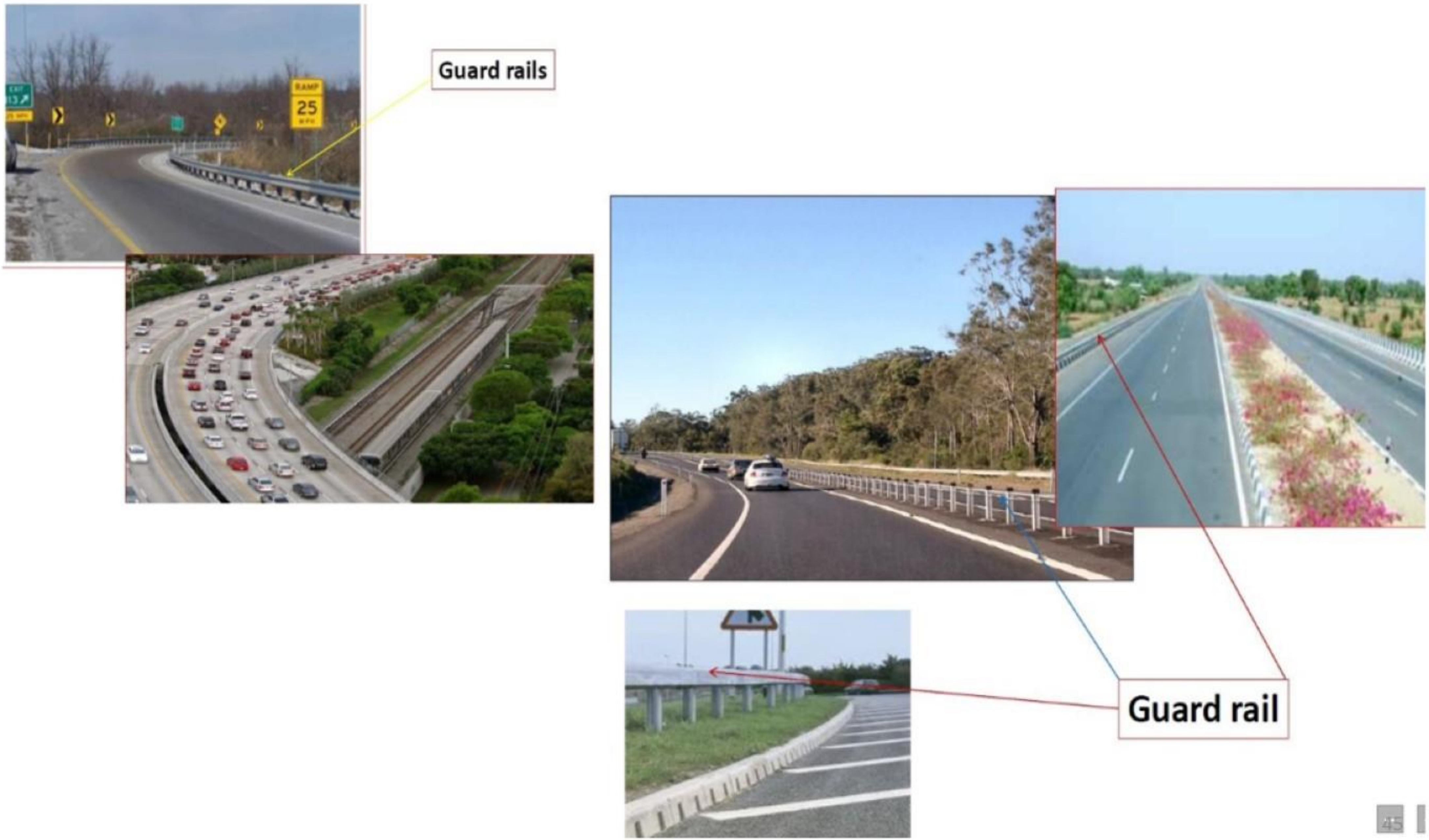

Two lane two-way road
carriageway

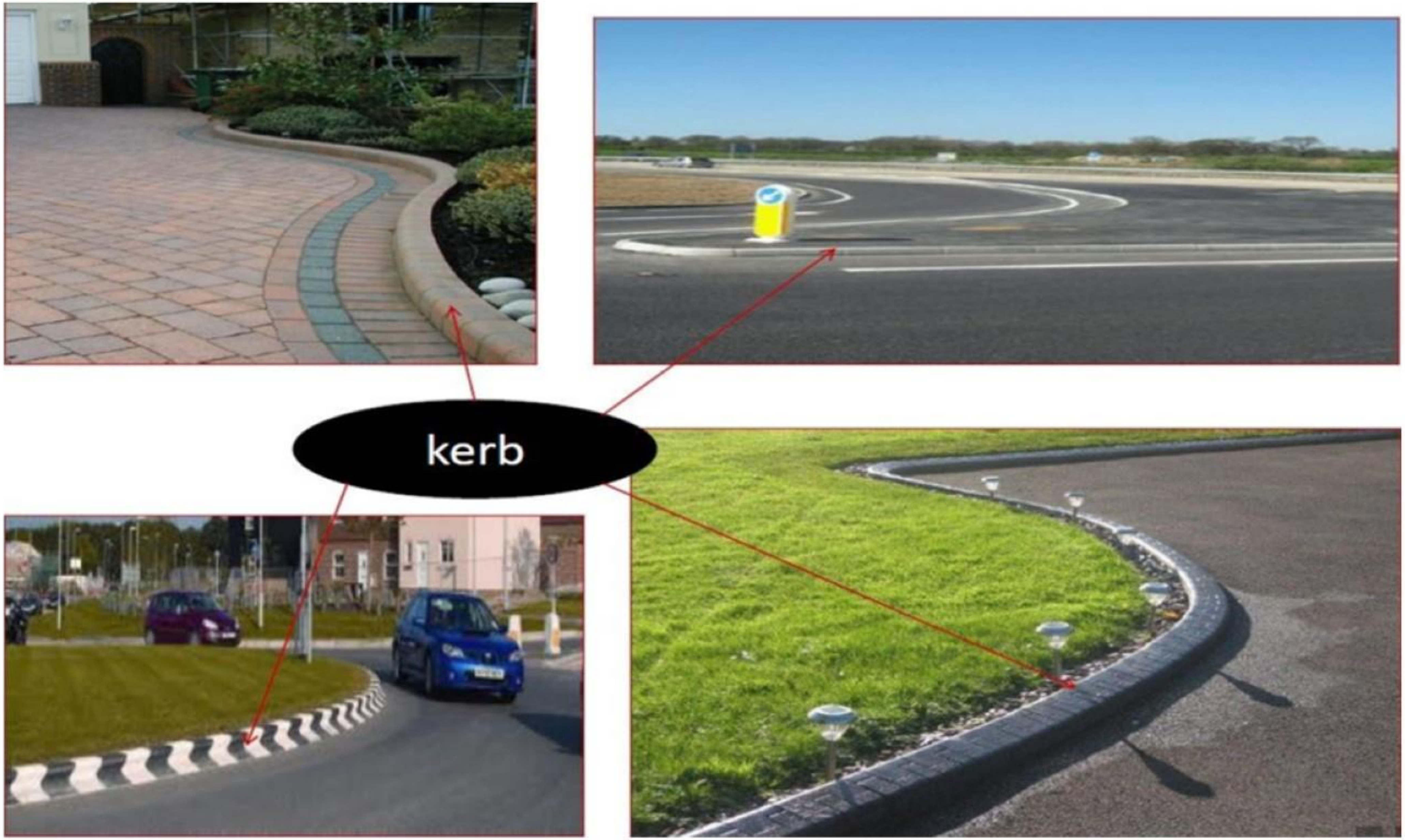

unTreated shoulder
Treated shoulder


shoulder


Cycle track
Footpath


4-lane divided carriage way or dual carriage way
Median/
separator


Guard rails
RAMP
25
Guard rail


kerb

HIGHWAY CROSS SECTION ELEMENTS

1. CARRIAGEWAY: It carries traffic

TYPE OF ROAD	WIDTH OF CARRIAGEWAY
Single Lane	**3.75m**
Dual lane (no kerb)	**7m**
Dual lane (with raised kerb)	**7.5m**
Multi lane	**3.5m per lane**
Intermediate lane	**5.5m**

HIGHWAY CROSS SECTION ELEMENTS

2. SHOULDER

- Shoulder are provided to accommodate stopped vehicles and to provide lateral confinement to the pavement layers.
- Desirable width of shoulder is 4.5m with a minimum of 2.5m on a two lane rural highway.

3. KERBS

- It indicates the boundary between pavement and shoulder or footpath or median.

HIGHWAY CROSS SECTION ELEMENTS

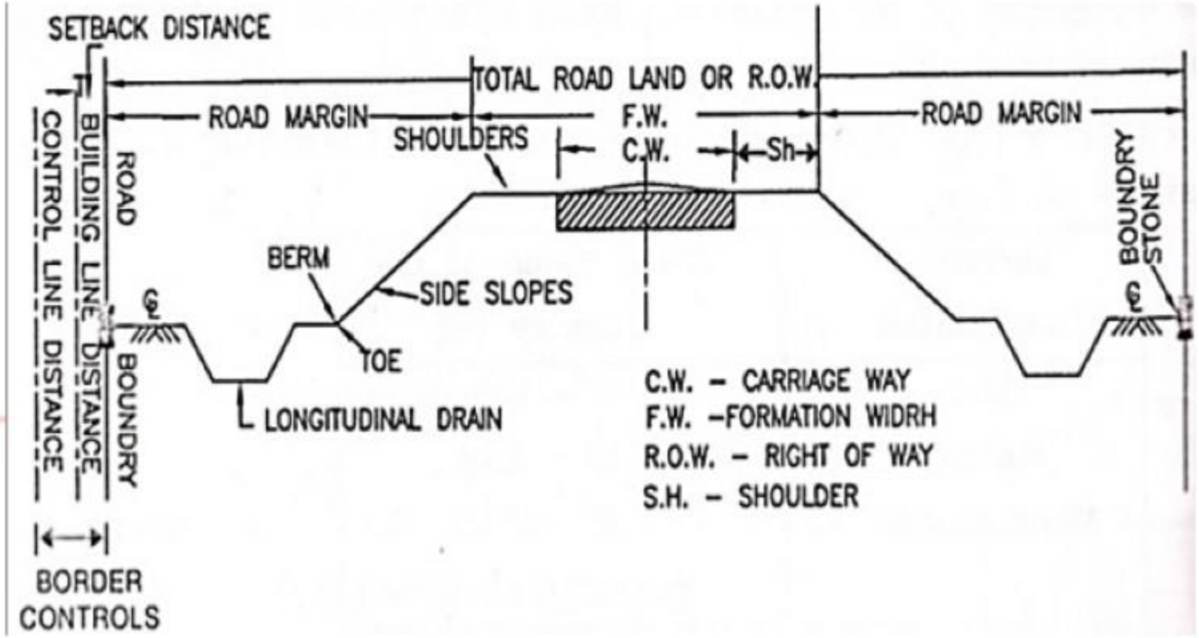
4. MEDIAN

- The process of median is to prevent head on collision of vehicles.
- It is also known as '*traffic separator*'.
- Minimum desirable width for rural highway is 5m and if lane width is restricted then the value maybe reduced to 3m.
- Width of median for bridges should be between 1.2m – 1.5m.
- Transition in median should be 1 in 20 (milder) and 1 in 15 (steeper).

HIGHWAY CROSS SECTION ELEMENTS

5. ROAD MARGINS

- ➢The portion of the road beyond the carriageway and on the roadway can be generally called road margin.
- ➢Various elements of road margin are bus bays and service roads, cycle track, footpath and guard rails.



HIGHWAY CROSS SECTION ELEMENTS

6. RIGHT OF WAY

- Right of way (ROW) or land width is the width of land acquired for the road, along its alignment.
- It should be adequate to accommodate all the cross-sectional elements of the highway and may reasonably provide for future development.
- To prevent ribbon development along highways, control lines and building lines may be provided.
- Control line is a line which represents the nearest limits of future uncontrolled building activity in relation to a road.
- Building line represents a line on either side of the road, between which and the road no building activity is permitted at all.

CROSS SLOPE OR CAMBER

It is the slope provided to the road surface in the transverse direction to drain off the rain water from the road surface.

MAIN PURPOSE

- **To prevent the entry of surface water into the sub grade soil through pavement.**
- **To prevent the entry of water into the bituminous pavement layer.**
- **To remove the rain water from the pavement surface as quick as possible and to allow the pavement to get dry soon after the rain.**
- **It depends on the pavement surface and amount of rainfall.**
- **Camber in shoulder should be 0.5% more than the camber of pavement subjected to a minimum of 3%.**

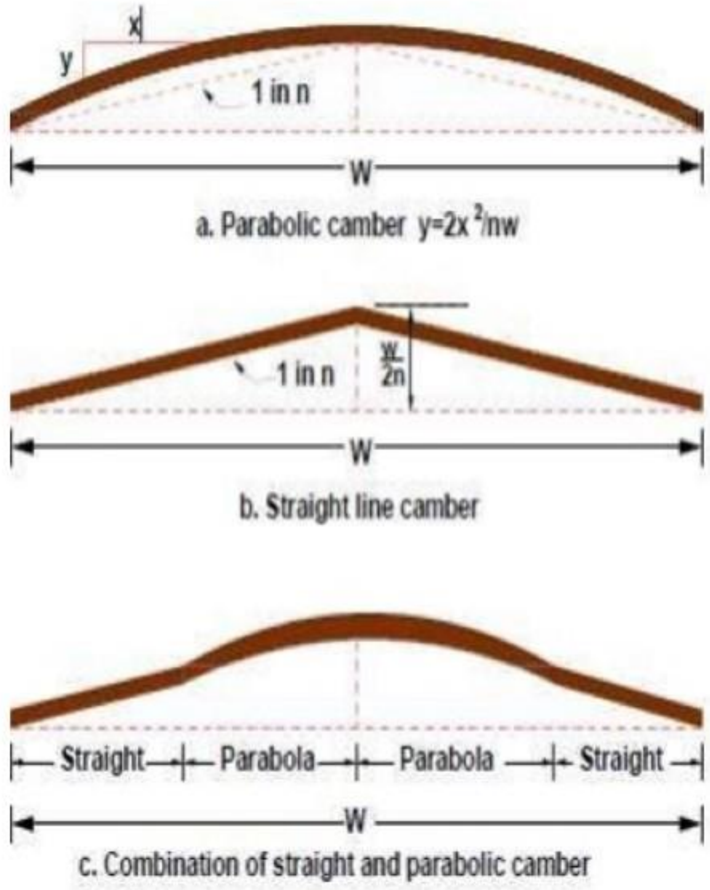
CROSS SLOPE OR CAMBER

- **Types of camber –**

  i) straight camber (bituminous macadam pavement)

  ii) parabolic camber(cement concrete pavement)

SURFACE TYPE	HEAVY RAIN	LIGHT RAIN
	%	%
Concrete/ Bituminous	2	1.7
Gravel/WBM	3	2.5
Earthen	4	4



❖ SIGHT DISTANCE CONSIDERATIONS

- **Sight distance available from a point is the actual distance along the road surface, which a driver from a specified height above the carriageway has visibility of stationary or moving objects.**

OR

- **It is the length of road visible ahead to the driver at any instance.**
- **Geometric design of highway is done in such a way that from every point on highway, the length of view available is sufficient so that the vehicle could be stopped in that visible distance or operations like overtaking could be safely performed.**

TYPES OF SIGHT DISTANCE

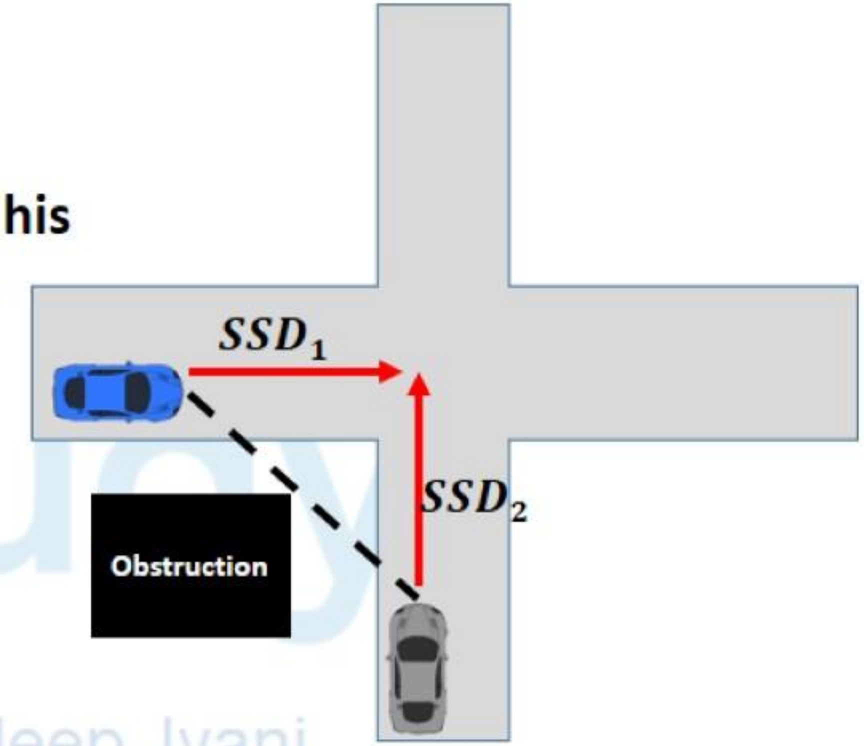
1. Stopping or absolute minimum sight distance (SSD)
2. Safe overtaking or passing sight distance (OSD)
3. Safe sight distance for entering into uncontrolled intersection
4. Intermediate sight distance
5. Head light sight distance

1. **Stopping sight distance SSD:**
    - The minimum sight distance available on a highway at any spot should be of sufficient length to stop a vehicle traveling at design speed, safely without collision with any other obstruction.
    - It is also called *non passing sight distance*.
2. **Overtaking Sight Distance:**
    - The minimum distance open to the vision of the driver of a vehicle intending to overtake slow vehicle ahead with safety against the traffic of opposite direction is known as the minimum overtaking sight distance (OSD) or the safe passing sight distance.
    - It is also called ***passing sight distance***.
3. **Intermediate sight distance:**
    - This is defined as twice the stopping sight distance.
    - When overtaking sight distance cannot be provided, intermediate sight distance is provided to give limited overtaking opportunities to fast vehicles.

ISD = 2 SSD

4. Sight distance at intersection:

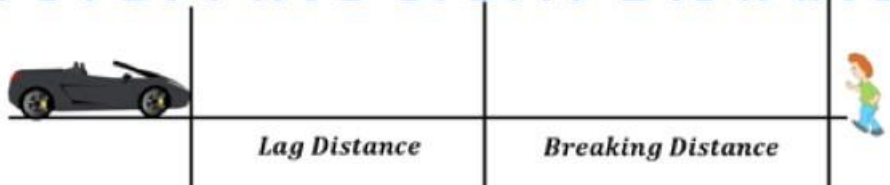
- Driver entering an uncontrolled intersection has sufficient visibility to enable him to take control of his vehicle and to avoid collision with another vehicle.



5. Head light sight distance:

- This is the distance visible to a driver during night driving under the illumination of the vehicle head lights.
- This sight distance is critical at up-gradients and at the ascending stretch of the valley curves.

1. STOPPING SIGHT DISTANCE



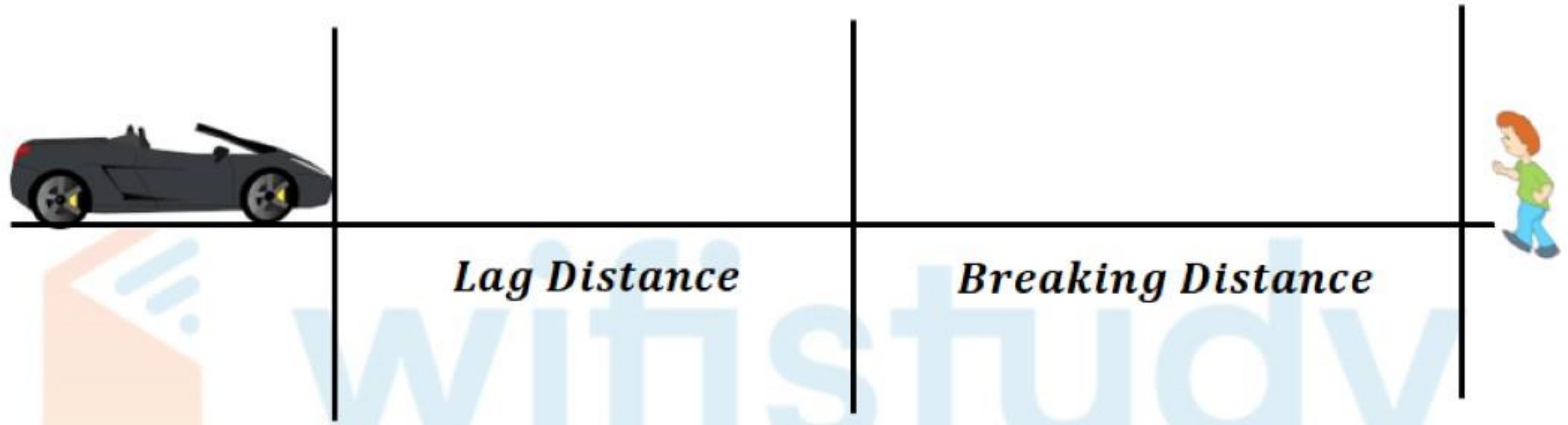
SSD is the minimum sight distance available on a highway at any spot having sufficient length to enable the driver to stop a vehicle traveling at design speed, safely without collision with any other obstruction. It depends on:

1. **Feature of road ahead**
2. **Height of driver's eye above the road surface(1.2m)**
3. **Height of the object above the road surface (0.15m).**

Factors affecting the SSD

1. **Total reaction time of driver (IRC suggests a reaction time of 2.5 seconds)**
2. **Speed of vehicle**
3. **Efficiency of brakes (As per IRC recommended efficiency is 50%)**
4. **Frictional coefficient (IRC recommends longitudinal friction coefficient μ as 0.35 to 0.40)**
5. **Gradient of road**

STOPPING SIGHT DISTANCE



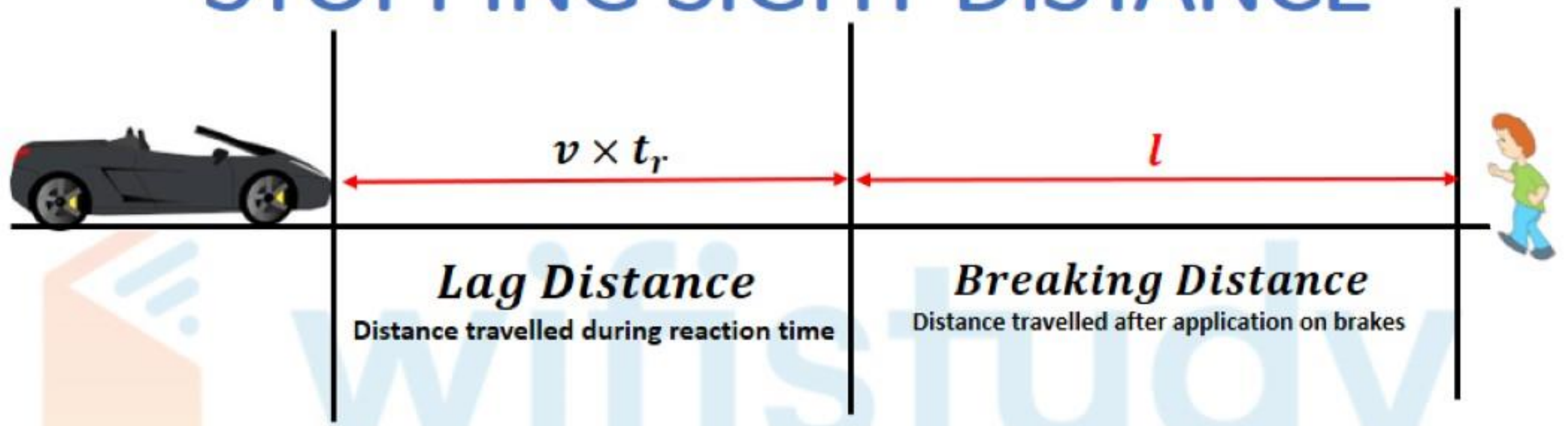
SSD = lag distance + braking distance

- **Lag distance is the distance the vehicle traveled during the reaction time t and is given by $v \times t$, where v is the velocity in m/sec**
- **Braking distance is the distance traveled by the vehicle during braking operation.**
- **If F is the maximum frictional force developed and the braking distance is l, then work done against friction in stopping the vehicle is**

$$Fl = fWl$$

where W is the total weight of the vehicle

STOPPING SIGHT DISTANCE



SSD = lag distance + braking distance

- $Lag\ distance = v \times t_r$
- **The kinetic energy at the design speed is**

$$\Rightarrow \frac{1}{2}\mathrm{m}v^2 = \frac{1}{2g}Wv^2$$

$$\Rightarrow \mu Wl = \frac{1}{2g}Wv^2$$

$$\Rightarrow l = \frac{v^2}{2g\mu}$$

Hence $SSD = vt + \frac{v^2}{2g\mu}$

STOPPING SIGHT DISTANCE

- **When there is an ascending gradient of say +n%, the component of gravity adds to braking action and hence braking distance is decreased.**

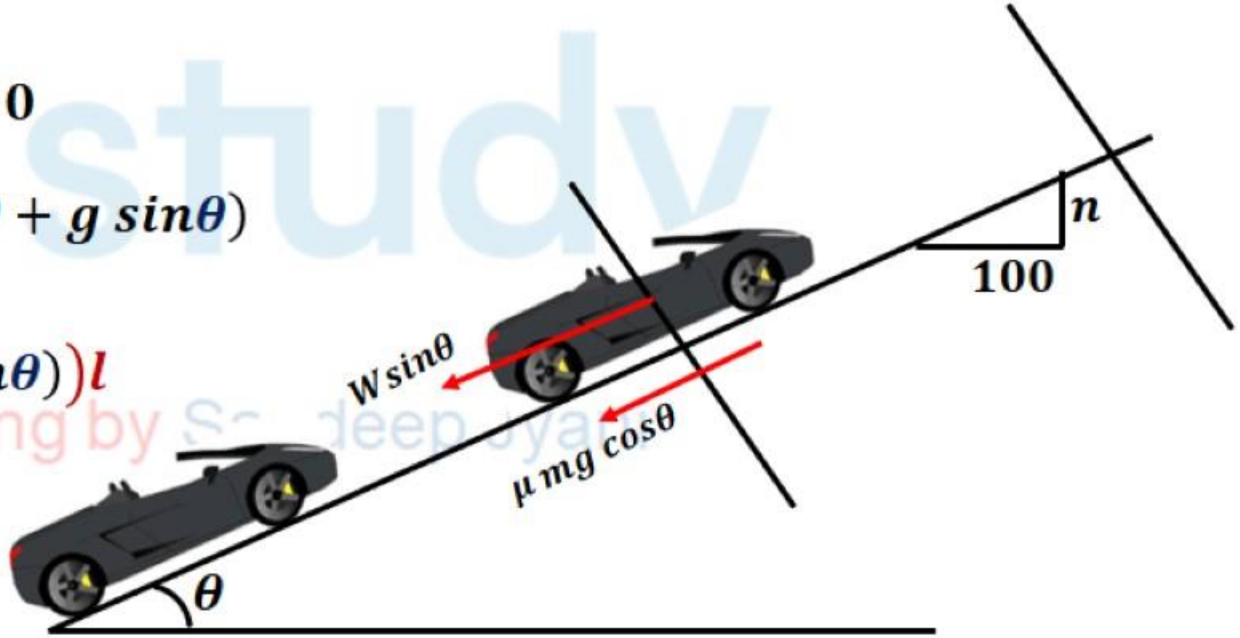
$$W sin\theta \approx W tan\theta = \frac{W\,n}{100} \text{ and } Cos\theta \approx 0$$

$$a = \frac{-(\mu\, mgcos\theta + mg\, sin\theta)}{m} = -(\mu\, gcos\theta + g\, sin\theta)$$

$$V^2 - U^2 = 2as$$

$$0^2 = u^2 + 2\big(-(\mu\, gcos\theta + g\, sin\theta)\big)l$$

$$\Rightarrow l = \frac{v^2}{2g\left(\mu + \frac{n}{100}\right)}$$



- $lag\ distance = vt$, so

$$SSD = vt + \frac{v^2}{2g\left(\mu + \frac{n}{100}\right)}$$

When Vehicle is moving on Levelled Ground

$$SSD = vt + \frac{v^2}{2g\mu}$$

When Vehicle is moving on a Gradient

- For up gradient,

$$SSD = vt + \frac{v^2}{2g(\mu + 0.01n)}$$

- For Down Gradient,

$$SSD = vt + \frac{v^2}{2g(\mu - 0.01n)}$$

STOPPING SIGHT DISTANCE

IRC recommendations for SSD:

1. For single lane road with two way traffic, the minimum SSD should be equal to 2SSD (for same speed).
2. For undivided highway with two way traffic effect of gradient is not considered while calculating SSD. However for divided highway, gradient is considered.
3. SSD on vertical curves is calculated along the centre line of the curve from which a driver with an eye level of 1.2m above the ground surface can see an obstacle 0.15m above the ground.
4. If SSD cannot be provided in a particular stretch of road, proper sign boards with speed restrictions should be provided.

STOPPING SIGHT DISTANCE

IRC recommendations for SSD:

SPEED(km/hr)	20-30	40	50	60	65	80	≥100
Longitudinal friction coefficient	0.40	0.38	0.37	0.36	0.36	0.35	0.35

SPEED (km/hr)	20	25	30	40	50	60	65	80	100
SSD (m)	20	25	30	45	60	80	90	120	180

2. OVERTAKING SIGHT DISTANCE

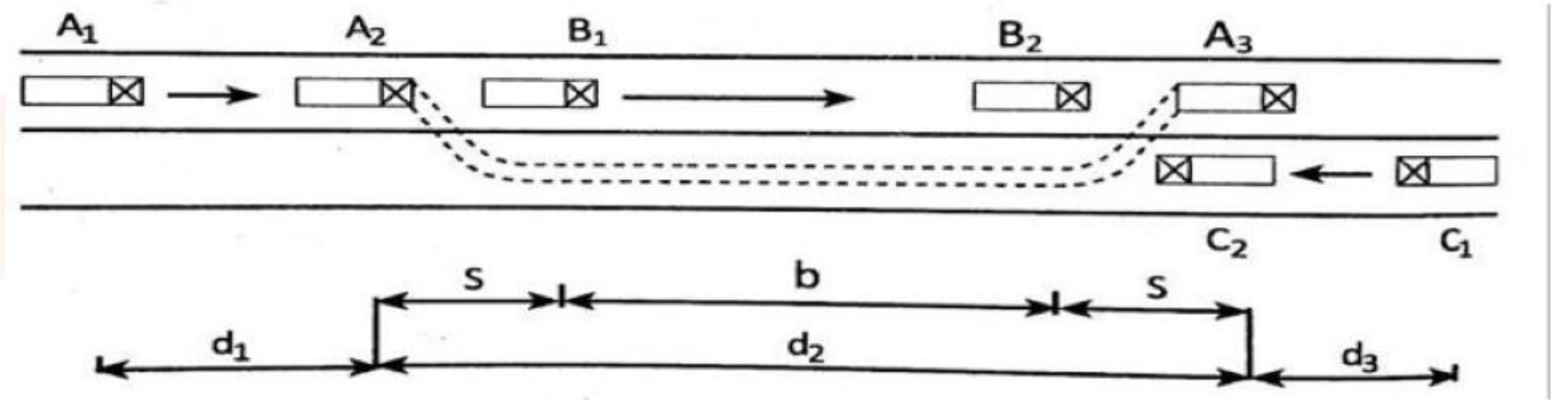
- **The minimum distance available for the driver to safely overtake the slow vehicle in front of him by considering the traffic in the opposite direction is called as the overtaking sight distance.**
- **This distance make us see whether the road is clear to undergo an overtaking movement.**
- **The overtaking sight distance is also called as the passing sight distance that will be measured along the center line of the road.**
- **This is the line level over which the driver keeping an eye level of 1.2 m above the road level can easily see the top of the object 1.2 m above the road surface.**

OVERTAKING SIGHT DISTANCE

Factors Affecting Overtaking Sight Distance

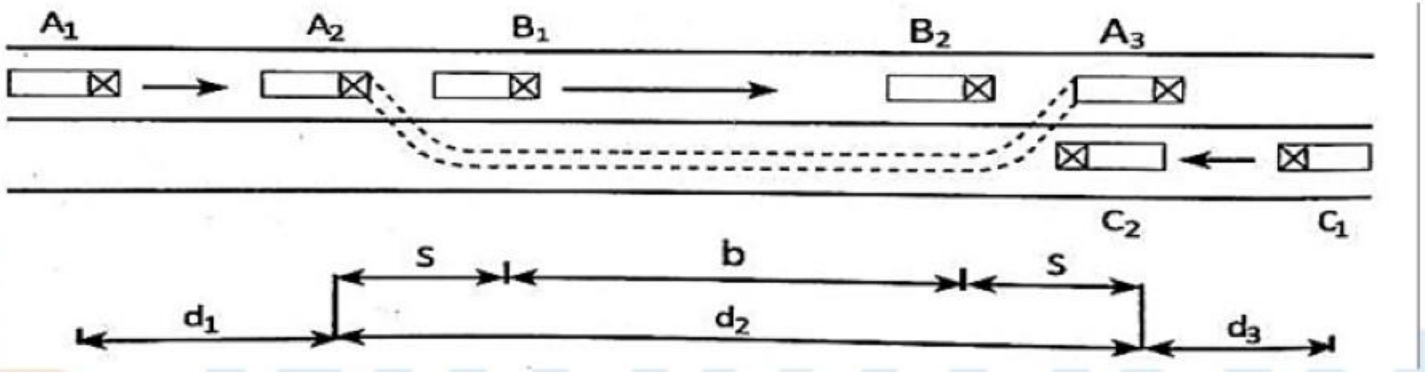
1. Velocities of the overtaking vehicle, overtaken vehicle and of the vehicle coming in the opposite direction.
2. Spacing between vehicles, which in-turn depends on the speed
3. Skill and reaction time of the driver
4. Rate of acceleration of overtaking vehicle
5. Gradient of the road

OVERTAKING SIGHT DISTANCE



$$OSD = d_1 + d_2 + d_3$$

OVERTAKING SIGHT DISTANCE



It is assumed that the vehicle A is forced to reduce its speed to 'v_b,' the speed of the slow moving vehicle B and travels behind it during the reaction time t of the driver.

So d_1 is given by –

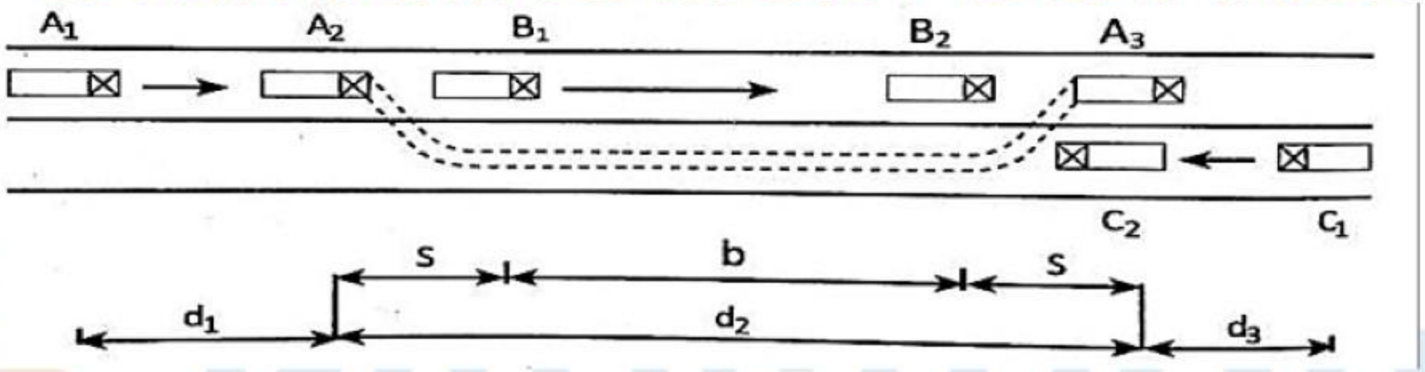
$$d_1 = v_b t$$

Then the vehicle A starts to accelerate, shifts the lane, overtake and shift back to the original lane. The vehicle A maintains the spacing 's' before and after overtaking. The spacing 's' in m is given by

$$s = 0.7v_b + L$$

$$(take\ length\ of\ vehicle\ L = 6m\ is\ not\ given\ and\ reaction\ time = 0.7sec)$$

OVERTAKING SIGHT DISTANCE



- Let 'T' be the duration of actual overtaking.
- The distance traveled by B during the overtaking operation is $2s + V_b T$
- Also, during this time, vehicle A accelerated from initial velocity v_b and overtaking is completed while reaching final velocity 'v'.
- Hence the distance traveled is given by:

$$d_2 = v_b t + \frac{1}{2} a T^2$$

$$2s + v_b t = v_b t + \frac{1}{2} a T^2$$

$$s = \frac{1}{4} a T^2$$

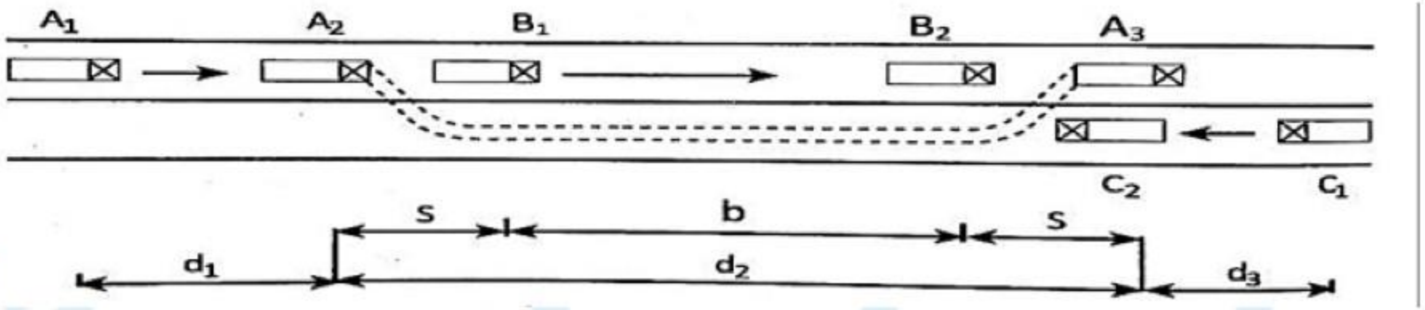
$$\boxed{T = \sqrt{\frac{4s}{a}}}$$

OVERTAKING SIGHT DISTANCE

IRC recommendations for acceleration:

SPEED(km/hr)	Acceleration(m/s^2)
80	0.72
100	0.53

OVERTAKING SIGHT DISTANCE



IRC recommendations for OSD:

1. **On divided highways and on roads with one way traffic regulation –**

   $$OSD = d_1+d_2$$

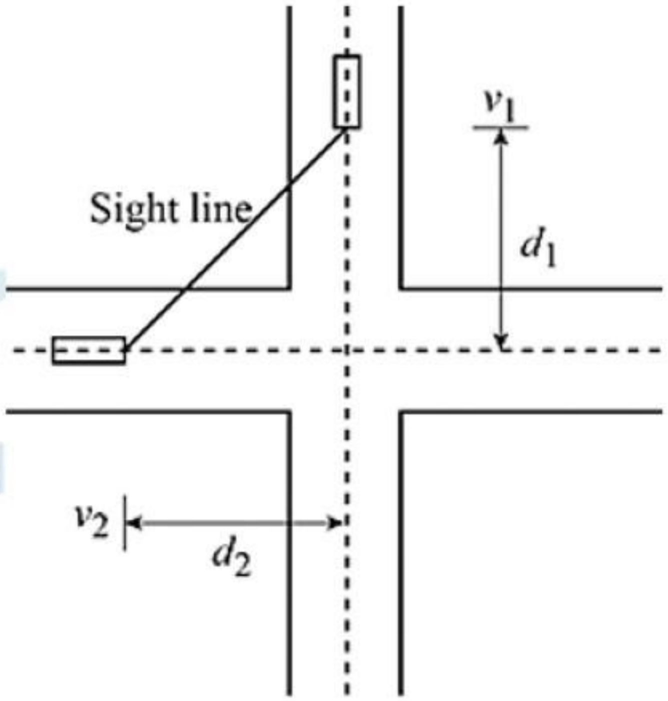
2. **On divided highways with four or more lanes, IRC suggests that there is no need to provide OSD.**

NOTE:

1. **Effect of gradient is not considered while calculating OSD.**
2. **If OSD cannot be provided throughout the length of the road, we provide overtaking zone at certain intervals.**
3. **Desirable length of overtaking zone is 5times OSD, subjected to a minimum of 3times OSD.**

3. SIGHT DISTANCE AT INTERSECTION

- **At intersections where two or more roads meet, visibility should be provided for the drivers approaching the intersection from either sides.**
- **They should be able to perceive a hazard and stop the vehicle if required. Stopping sight distance for each road can be computed from the design speed.**
- **The sight distance should be provided such that the drivers on either side should be able to see each other.**
- **Design of sight distance at intersections may be used on three possible conditions:**
  - **Enabling approaching vehicle to change the speed**
  - **Enabling approaching vehicle to stop**
  - **Enabling stopped vehicle to cross a main road**



HORIZONTAL ALIGNMENT DETAIL

Design elements of horizontal alignments are:

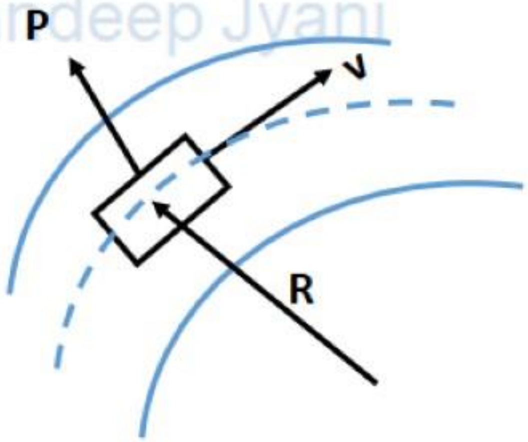
i. **Radius of circular curve**
ii. **Super elevation**
iii. **Extra widening at horizontal curve**
iv. **Design of transition curve**
v. **Set back distance**

HORIZONTAL ALIGNMENT DETAIL

- DESIGN SPEED
  - **The design speed is the single most important factor in the design of horizontal alignment.**
  - **The design speed also depends on the type of the road.**
  - **The design speed also depends on the type of terrain.**

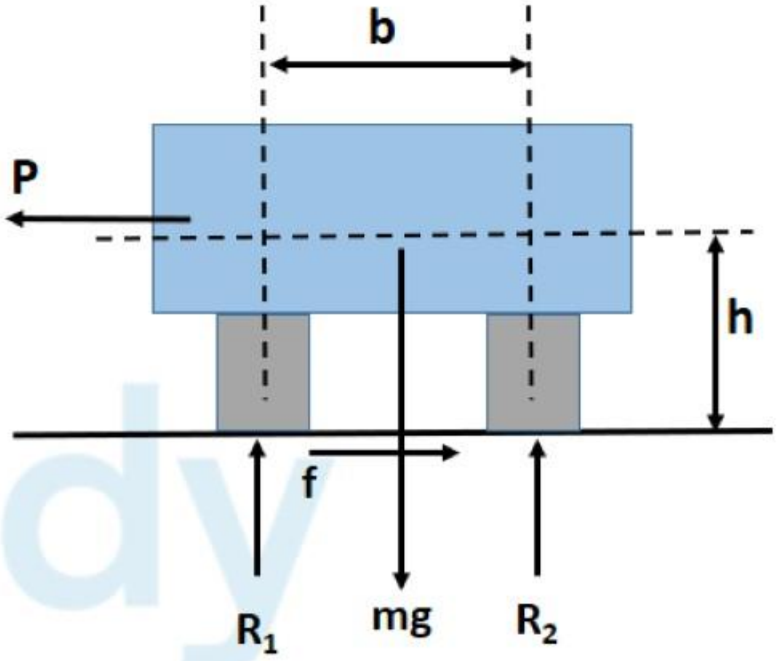
- $P = \frac{mv^2}{R}$
- $\frac{P}{mg} = \frac{v^2}{gR}$

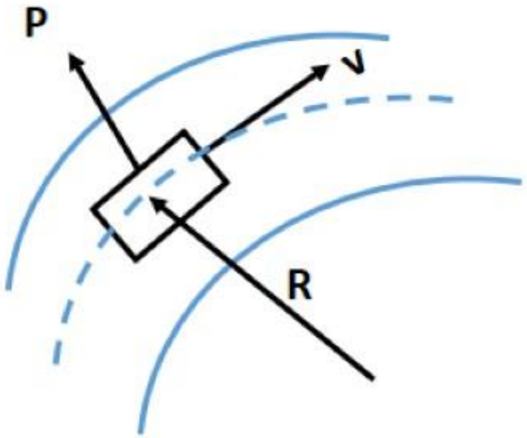
Where v is design velocity
R is radius of curve
P is centrifugal force



HORIZONTAL ALIGNMENT DETAIL

- **HORIZONTAL CURVE**
  - **The presence of horizontal curve imparts centrifugal force which is a reactive force acting outward on a vehicle negotiating it.**
  - **Centrifugal force depends on speed and radius of the horizontal curve and is counteracted to a certain extent by transverse friction between the tyre and pavement surface.**
  - **On a curved road, this force tends to cause the vehicle to overrun or to slide outward from the centre of road curvature.**





HORIZONTAL ALIGNMENT DETAIL

CONDITIONS FOR SKIDDING AND Overturning:

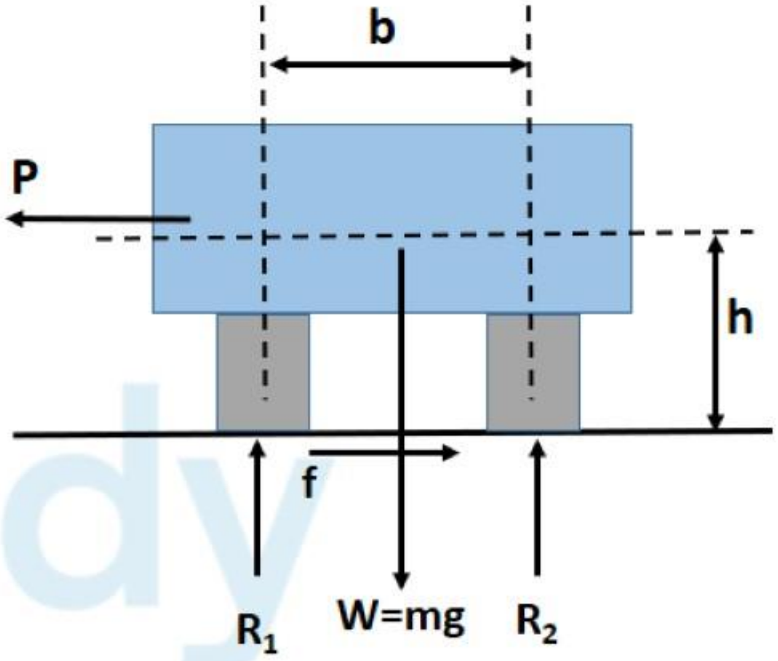
- The centrifugal ratio or the impact factor is given by $\frac{P}{W}$ -

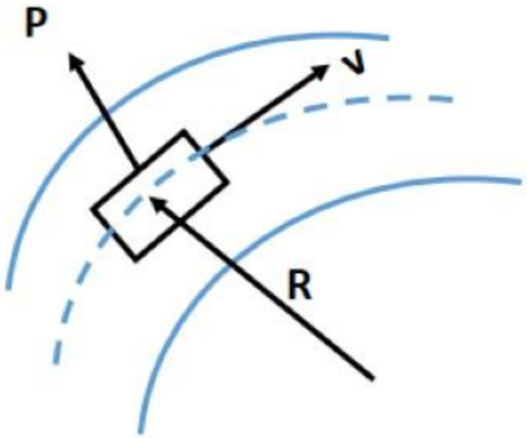
$$\frac{P}{W} = \frac{v^2}{gR}$$

- The centrifugal force has two effects:
  - A tendency to overturn the vehicle about the outer wheels
  - And a tendency for transverse skidding.
  - Taking moments of the forces with respect to the outer wheel when the vehicle is just about to override-

$$\Rightarrow Ph = W\frac{b}{2}$$

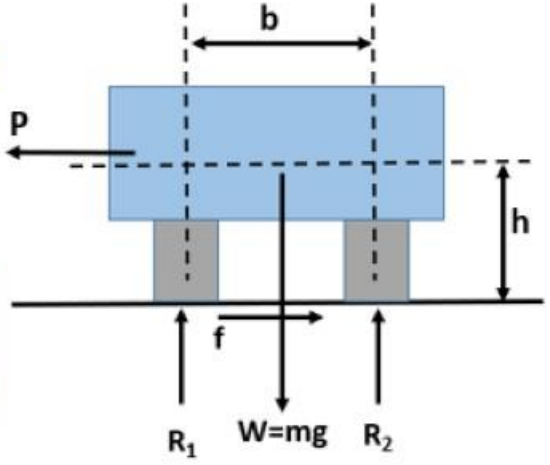
$$\Rightarrow \frac{P}{W} = \frac{b}{2h}$$





HORIZONTAL ALIGNMENT DETAIL

CONDITIONS FOR SKIDDING AND OVERTURNING



- At the equilibrium over turning is possible when

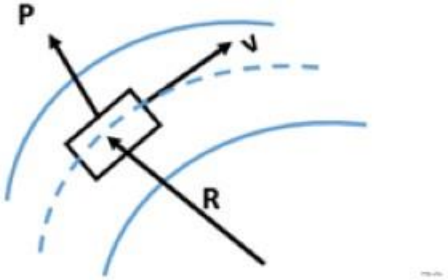
$$\frac{b}{2h} = \frac{v^2}{gR}$$

- For safety the following condition must satisfy

$$\frac{b}{2h} > \frac{v^2}{gR}$$

- Stability factor

$$\frac{v^2}{g\,R} \le \frac{b}{2h}$$



HORIZONTAL ALIGNMENT DETAIL

CONDITIONS FOR SKIDDING AND Overturning:

- **For no skidding:**
  - **In the limiting case, i.e., when the vehicle is just about to skid $(\mathrm{f} = \mu\, n)$, acting forces we have**

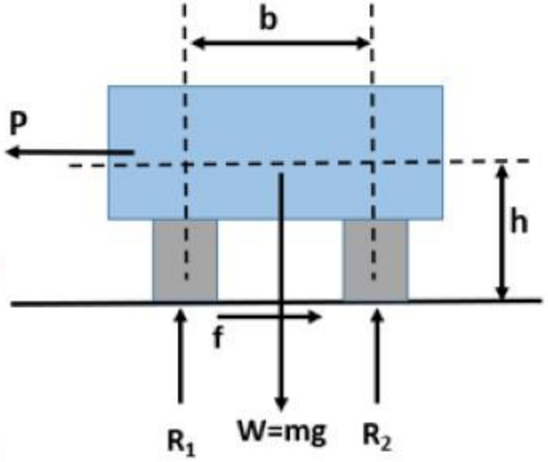
$$P = \mu\, mg$$

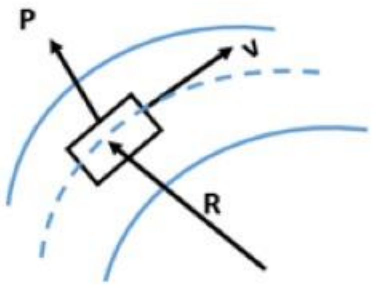
  - **Hence for no skidding, we should have :**

$$P \leq \mu\, mg$$

$$\frac{P}{mg} \leq \mu$$

$$\frac{v^2}{g\,R} \leq \mu$$





HORIZONTAL ALIGNMENT DETAIL

NOTE - To avoid both skidding & overturning

$$\frac{v^2}{g\,R} \leftarrow \frac{P}{mg} \leq \frac{b}{2h} \leq \mu$$

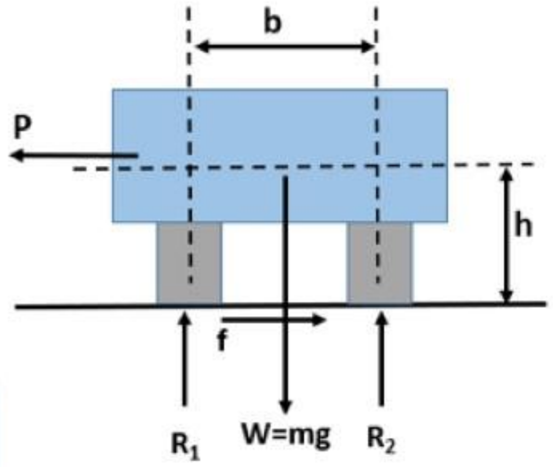
where, v → design speed in m/sec

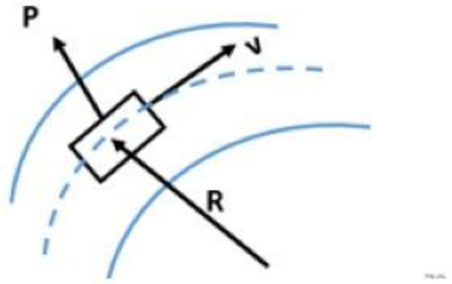
R → Radius of Curve in m

b → distance between inner and outer wheel in m

h → height of C.G. of vehicle above road surface in m

μ → Transverse friction coefficient.





HORIZONTAL ALIGNMENT DETAIL

- **The second tendency of the vehicle is for transverse skidding. i.e. when the centrifugal force is greater than the maximum possible transverse skid resistance due to friction between the pavement surface and tyre. The transverse skid resistance (F) is given by:**

$$\boldsymbol{F = F_A + F_B}$$

$$\boldsymbol{F = fR_A + fR_B}$$

$$\boldsymbol{F = f(R_A + R_B)}$$

$$\boldsymbol{F = f(W)}$$

CONDITIONS FOR SKIDDING AND SLIPPING:

$$F = FA + FB$$

$$F = f(RA + R_B)$$

$$F = fW$$

where F_A and F_B are fractional force at tyre A and B

R_A and R_B are reaction force at tyre A and B

f is the lateral coefficient of friction

W is the weight of the vehicle

- This is counteracted by the centrifugal force (P), and equating:

$$P = fW$$

$$\frac{P}{W} = f$$

- At equilibrium, when skidding takes place

$$\frac{P}{W} = f = \frac{v^2}{gR}$$

- and for safety the following condition must satisfy

$$f > \frac{v^2}{gR}$$

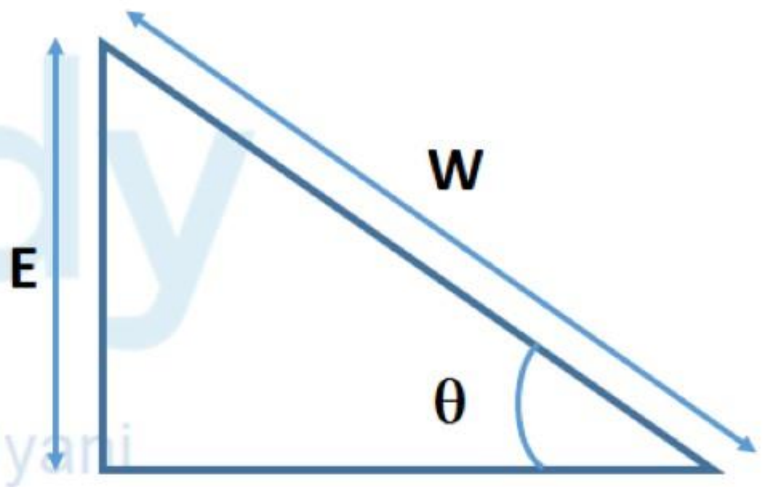
- If $\frac{b}{2h} > f \rightarrow$ vehicle will skid before over turning
- If $f > \frac{b}{2h} \rightarrow$ vehicle will overturn before skidding

NOTE

When vehicle negotiates a horizontal curve without overturning then the Pressure on the outer wheel will be more than the pressure on the inner wheel if friction is mobilized.

SUPER ELEVATION

- Super-elevation or cant is the transverse slope provided at horizontal curve to counteract the centrifugal force, by raising the outer edge of the pavement with respect to the inner edge, throughout the length of the horizontal curve.
- When the outer edge is raised, a component of the curve weight will be complimented in counteracting the effect of centrifugal force.



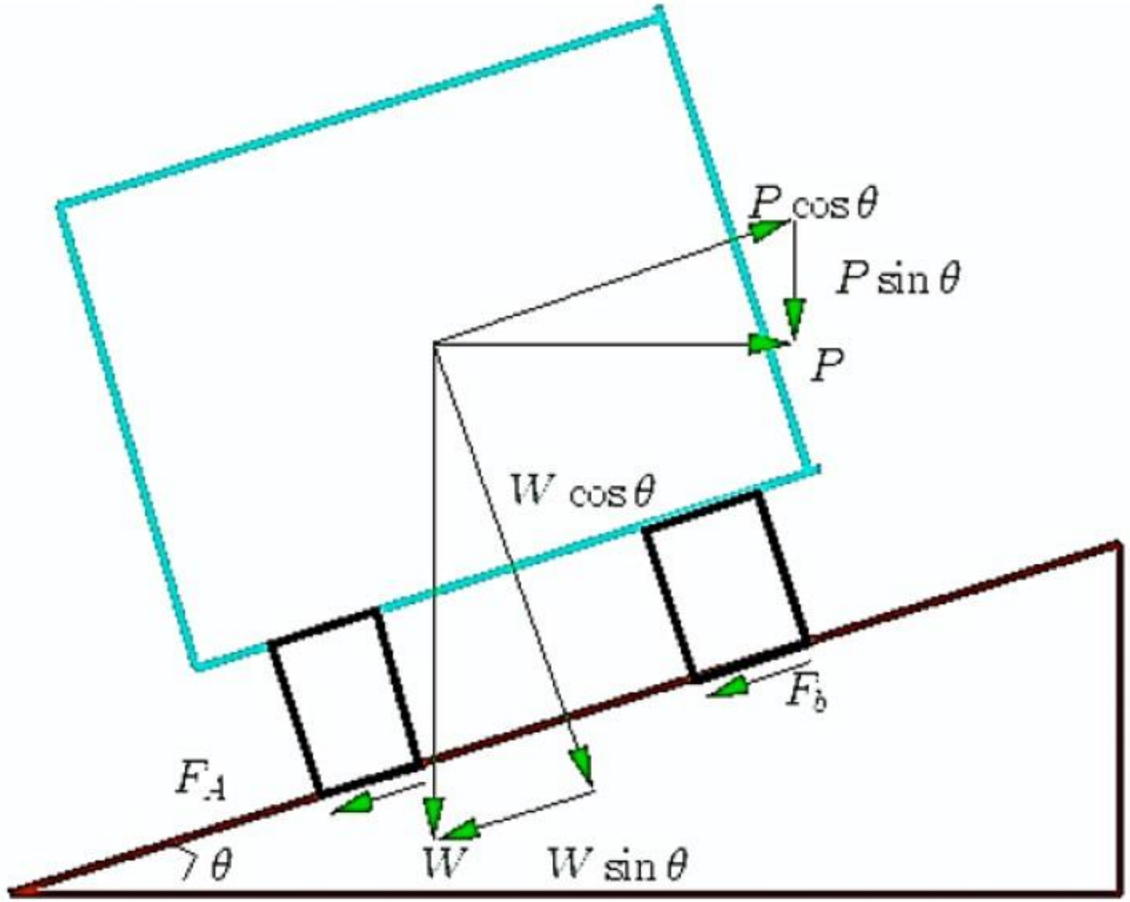
$$tan\theta = \frac{E}{W}$$

SUPER ELEVATION

P $\rightarrow$ the centrifugal force acting horizontally out-wards through the center of gravity

W $\rightarrow$ the weight of the vehicle acting down-wards through the center of gravity

F $\rightarrow$ the friction force between the wheels and the pavement, along the surface inwards



SUPER ELEVATION

At equilibrium, by resolving the forces parallel to the surface of the pavement we get –

$$P\cos\theta = W\sin\theta + F_A + F_B$$

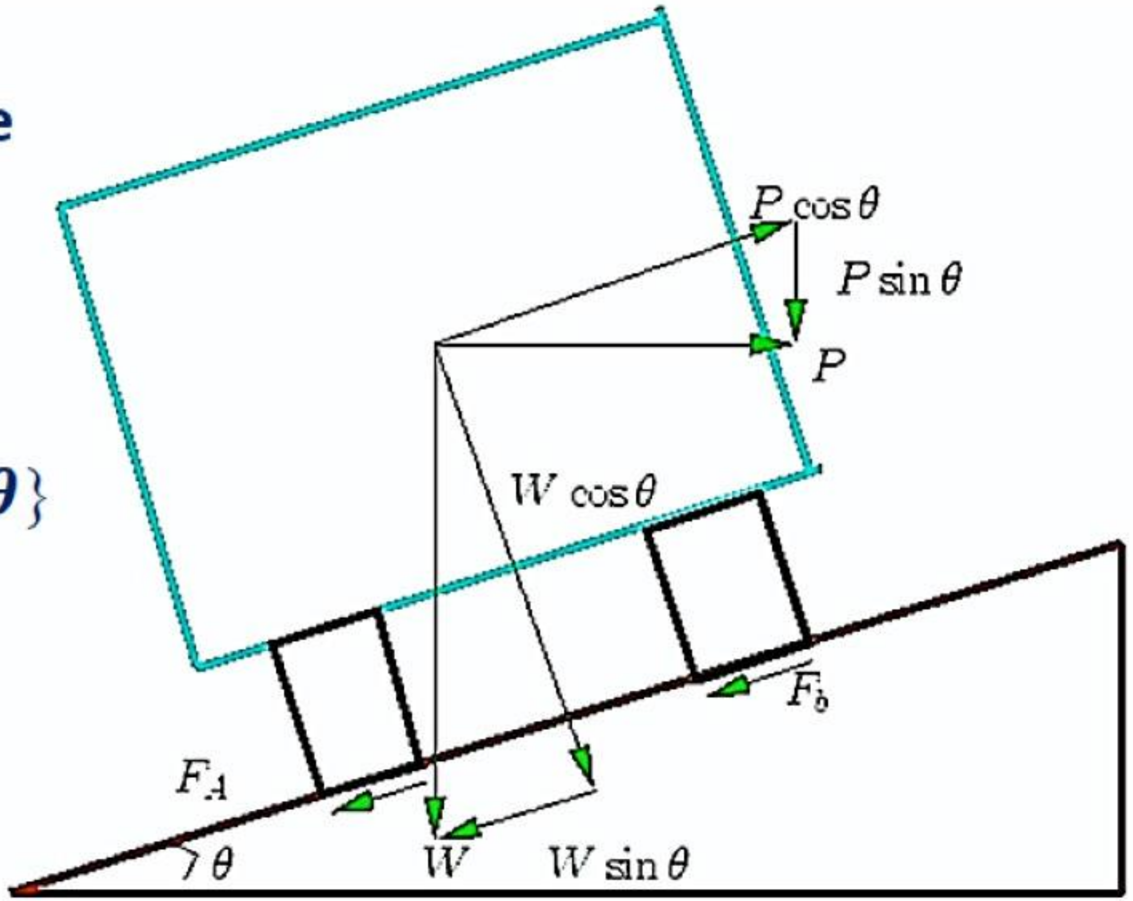
$$P\cos\theta = W\sin\theta + fR_A + fR_B$$

$$P\cos\theta = W\sin\theta + f\{R_A + R_B\}$$

$$P\cos\theta = W\sin\theta + f\{W\cos\theta + P\sin\theta\}$$

Where

- **W is weight of vehicle**
- **P is centrifugal force**
- ***f* is friction coefficient**
- **θ is transverse slope due to superelevation**



SUPER ELEVATION

$$P\cos\theta = W\sin\theta + f\{W\cos\theta + P\sin\theta\}$$

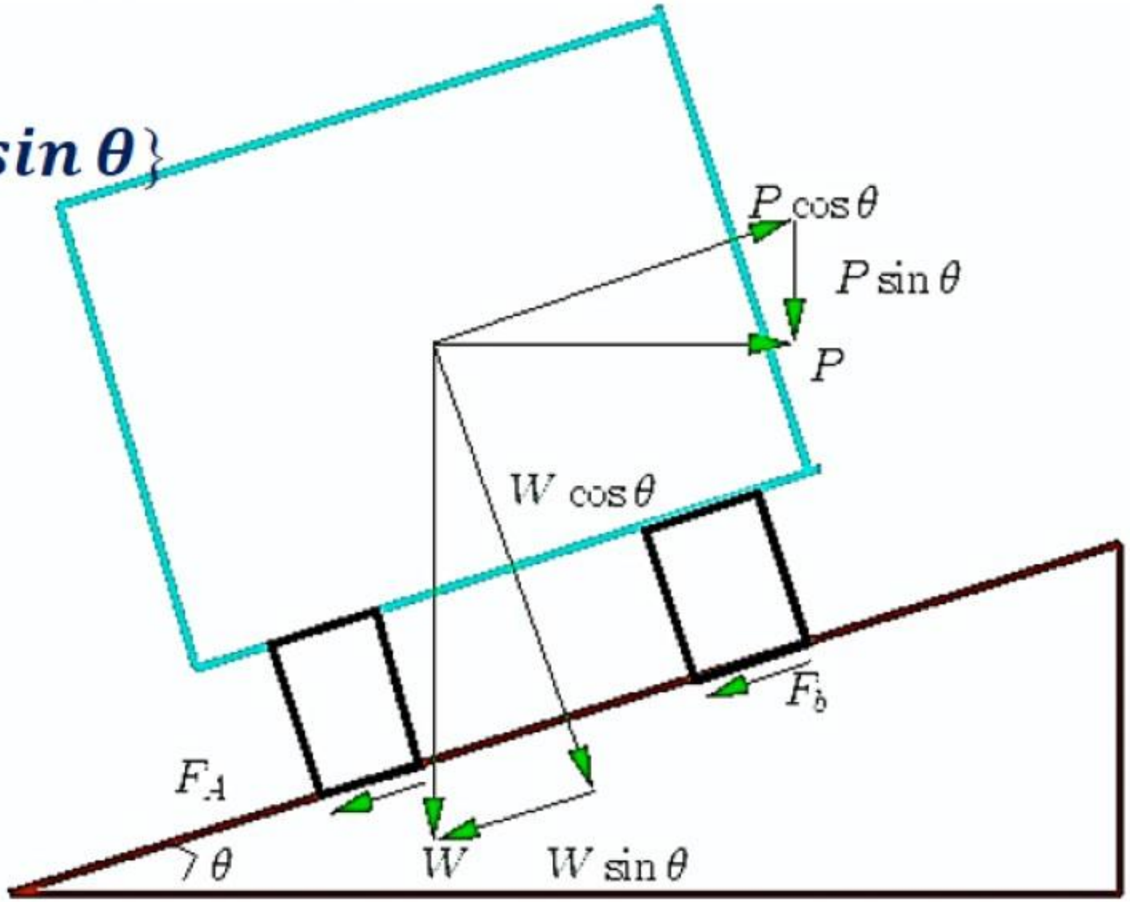
Dividing by $W\cos\theta$, we get

$$\Rightarrow \frac{P}{W} = \tan\theta + f + f\frac{P}{W}\tan\theta$$

$$\Rightarrow \frac{P}{W} = \frac{\tan\theta + f}{1 - f\tan\theta}$$

$$\Rightarrow \frac{v^2}{gR} = \frac{\tan\theta + f}{1 - f\tan\theta}$$

This is an exact expression for superelevation.



SUPER ELEVATION

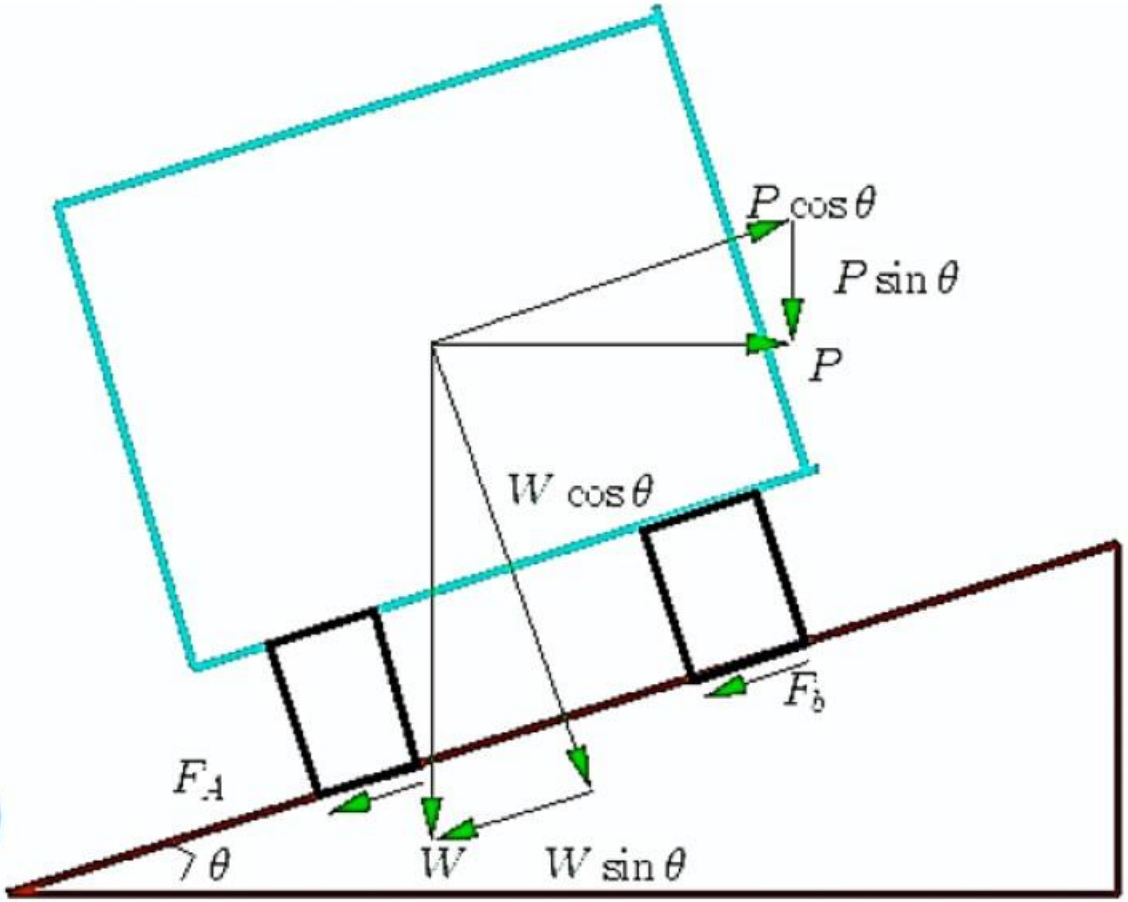
$$\frac{v^2}{gR} = \frac{tan\theta + f}{1 - \mu tan\theta}$$

Normally,

$f \rightarrow$ **0.15**

$\theta \rightarrow$ **less than 4°**

$1 - f tan\theta \approx$ **1**



$tan\theta \approx \sin\theta$ **(for small values of** θ**)**

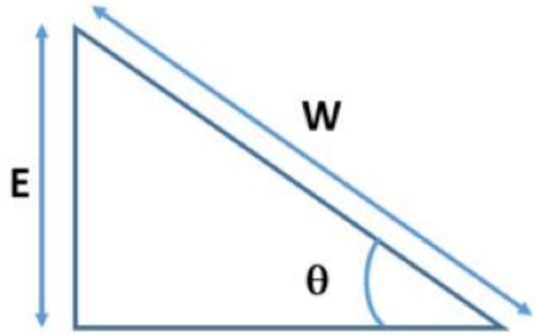
$\Rightarrow tan\theta \approx \sin\theta = \frac{E}{W}$ **= e**

Hence $\boxed{e + f = \frac{v^2}{gR}}$

Guild lines for providing SUPER ELEVATION

Superelevation

$$(e) = tan\theta \approx sin\theta = \frac{E}{W}$$



$$tan\theta = \frac{E}{W}$$

Calculate equilibrium superelevation corresponding to 75% design speed

$$\Rightarrow \mathbf{e} = \frac{(0.75v)^2}{gR}$$

If the value is less than or equal to 7%, then it is correct, but if it exceeds 7% then

$$\frac{v^2}{gR} = \frac{\mu + tan\theta}{1-\mu\, tan\theta}$$

$$= \frac{\mu+e}{1-\mu e}$$

$$\therefore \frac{v^2}{gR} = \mu + e = 0.15 + 0.7 = 0.22$$

$$\Rightarrow v_{max} = \sqrt{0.22gR}$$

$where\ v = design\ speed\ in\ m/sec$

$v_{max} = max\ velocity\ in\ m/sec$

$R = radius\ of\ curve\ in\ m$

Guild lines for providing SUPER ELEVATION

- $\Rightarrow \mathbf{e} = \frac{(0.75v)^2}{gR}$
- $\Rightarrow \mathbf{e} = \frac{(0.75 \times 0.278\,V)^2}{9.81 \times R}$ (V – km/hr)
- $\Rightarrow \mathbf{e} = \frac{V^2}{225R}$
- Similarly, $\mathbf{e}_{\mathbf{eq}} = \frac{(v)^2}{gR}$
- $\Rightarrow \ \mathbf{e}_{\mathbf{eq}} = \frac{(0.278V)^2}{gR}$ (V – km/hr)
- $\Rightarrow \ \mathbf{e}_{\mathbf{eq}} = \frac{V^2}{127R}$

Guild lines for providing SUPER ELEVATION

- **MAXIMUM AND MINIMUM SUPERELEVATION**
  - **Depends on**
    - **(a) slow moving vehicle**
    - **(b) heavy loaded trucks with high CG.**
  - **IRC specifies a maximum super-elevation of 7 percent for plain and rolling terrain, while that of hilly terrain is 10 percent and urban road is 4 percent.**
  - **The minimum super elevation is 2-4 percent for drainage purpose, especially for large radius of the horizontal curve.**

$$e_{max} = \begin{cases} 0.07 \ plain \ and \ rolling \ terrain \\ 0.1 \ Hilly \ terrain \\ 0.04 \ Urban \ road \end{cases}$$

SUPER ELEVATION

IRC RECOMMENDATION

TYPE OF TERRAIN	MAXIMUM SUPERELEVATION
Plain and rolling terrain	7%
Hill roads	10%
Urban road stretches	4%

RADIUS OF HORIZONTAL CURVE

- The maximum comfortable speed on a horizontal curve depends on the radius of the curve.
- Although it is possible to design the curve with maximum superelevation and coefficient of friction, it is not desirable because re-alignment would be required if the design speed is increased in future.
- Therefore, a ruling minimum radius can be derived by assuming maximum superelevation and coefficient of friction.

$$R_{ruling} = \frac{v^2}{g(e+f)}$$

EXTRA WIDENING OF CURVES

- **Extra widening refers to the additional width of carriageway that is required on a curved section of a road over and above that required on a straight alignment.**
- **This widening is done due to two reasons:**
  - **the first and most important is the additional width required for a vehicle taking a horizontal curve, referred as the mechanical widening.**
  - **the second is due to the tendency of the drivers to ply away from the edge of the carriageway as they drive on a curve, referred as the psychological widening.**

EXTRA WIDENING OF CURVES

$$W_e = W_m + W_{ps}$$

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

where n – number of traffic lanes

l – length of wheel base (normally 6m or 6.1m)

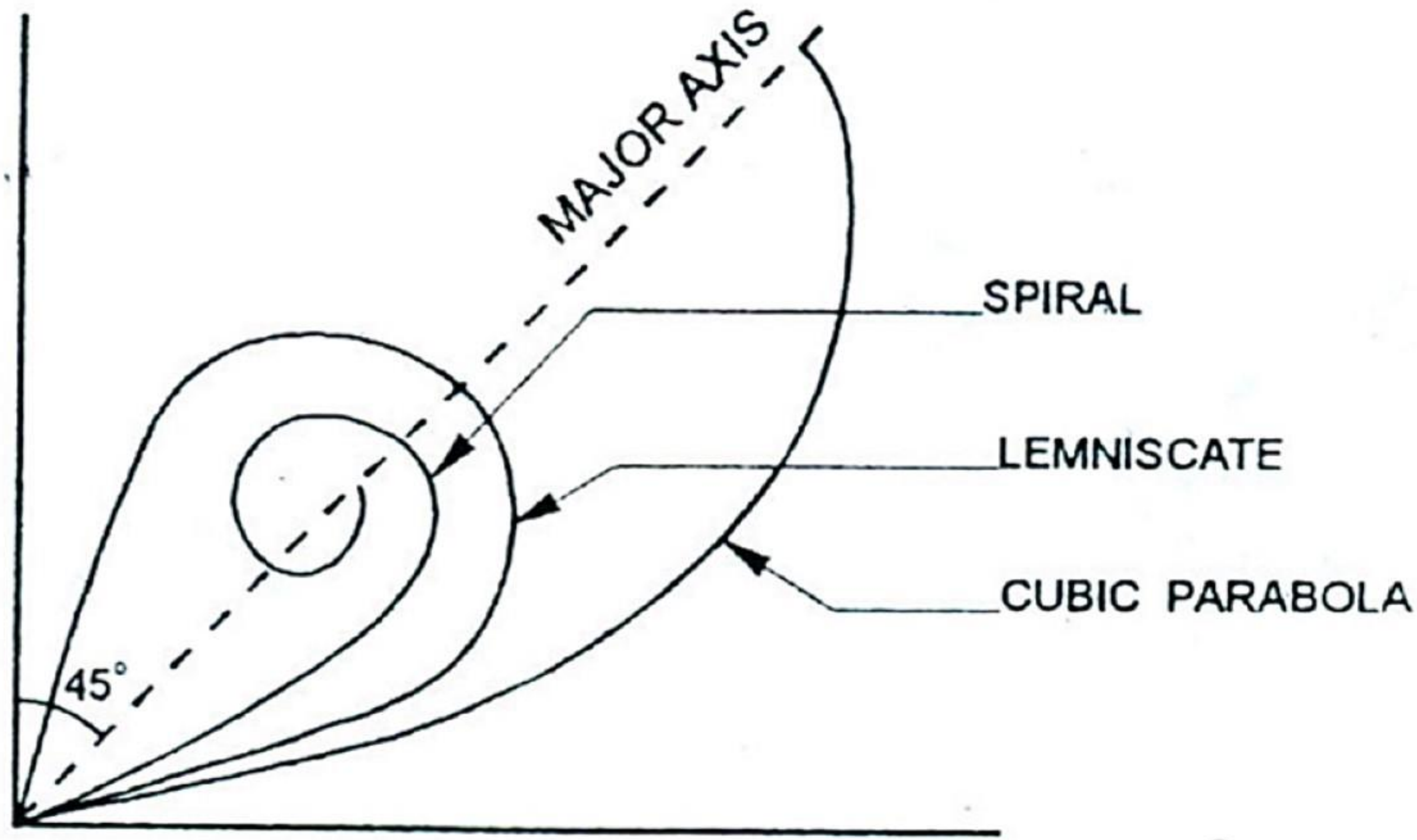
R – radius of horizontal curve (m)

V – design speed (km/hr)

TRANSITION CURVES

- **Transition curve is provided to change the horizontal alignment from straight to circular curve gradually and has a radius which decreases from infinity at the straight end (*tangent point*) to the desired radius of the circular curve at the other end (*curve point*).**
- **Main objectives:**
  - **to introduce gradually the centrifugal force between the tangent point and the beginning of the circular curve, avoiding sudden jerk on the vehicle. This increases the comfort of passengers.**
  - **to enable the driver turn the steering gradually for his own comfort and security,**
  - **to provide gradual introduction of super elevation, and**
  - **to provide gradual introduction of extra widening.**
  - **to enhance the aesthetic appearance of the road.**

TYPES OF TRANSITION CURVES



TRANSITION CURVES

- **Different types of transition curves are**
  - **Spiral or Clothoid**
  - **Cubic parabola**
  - **Lemniscate.**
- **IRC recommends spiral as the transition curve because it fulfills the requirement of an ideal transition curve, i.e.,**
  - **Rate of change or centrifugal acceleration is consistent (smooth) and**
  - **Radius of transition curve is infinite at straight edge and changes to 'R' at curve point (L $\propto \frac{1}{R}$)**

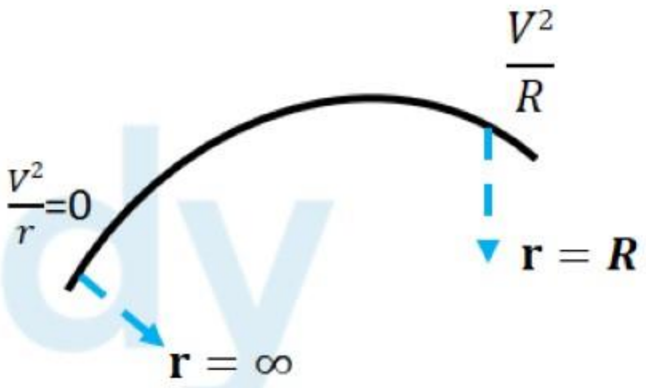
LENGTH OF TRANSITION CURVES

- **The length of the transition curve should be determined as the maximum of the following three criteria:**
  - **rate of change of centrifugal acceleration**
  - **rate of change of superelevation**
  - **an empirical formula given by IRC.**

LENGTH OF TRANSITION CURVES

1. Rate of change of centrifugal acceleration

- **Length of transition curve denoted by L_{s1}**



$$L_{s1} = \frac{v^3}{cR}$$

As per IRC

$$c = \frac{80}{75+3.6v}$$

c_{min} = 0.5

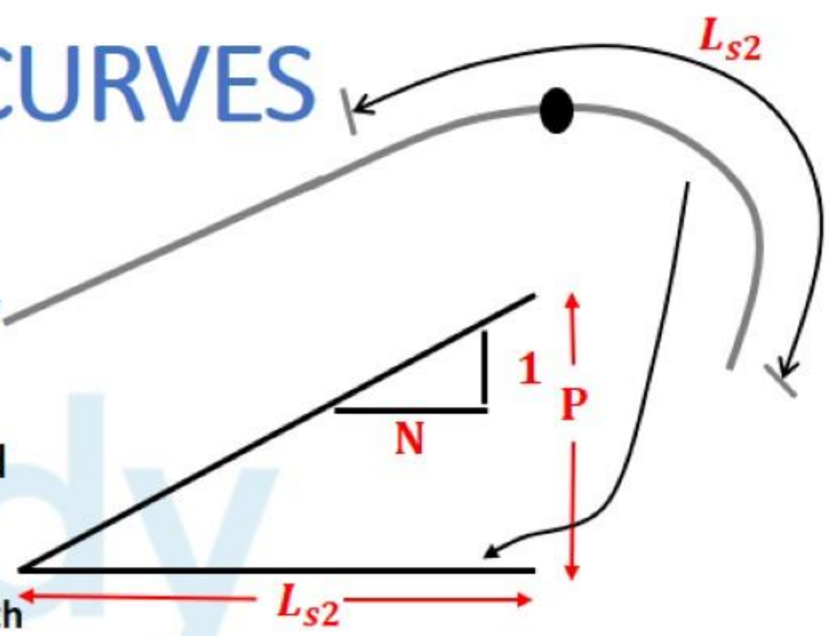
c_{max} = 0.8

LENGTH OF TRANSITION CURVES

2. Rate of change of superelevation

- Length of transition curve denoted by L_{s2}
- Raise(E) of the outer edge with respect to inner edge is given by

  E = eB = e(W+W_e)
- Rate of change should not be steeper than 1 in 150 for plain and rolling terrain,
- And should not be steeper than 1 in 60 for hilly terrain
  - <u>Case 1:</u> When super elevation is provided by raising the outer edge with respect to inner edge



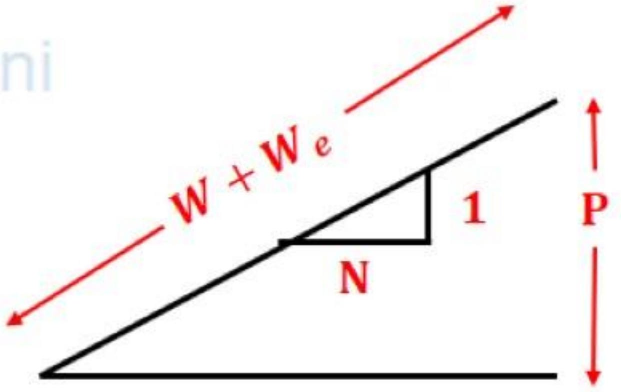
$$\frac{P}{L_{s2}} = \frac{1}{N}$$

$$\Rightarrow P = \frac{L_{s2}}{N} \quad \dots(1)$$

$$Also\ we\ know\ that\ e = tan\theta = \frac{P}{W + W_e} \quad \dots(2)$$

Equating 1 and 2 equations,

$$L_{s2} = \mathrm{Ne}(W+W_e)$$



$\mathrm{N} \geq 60\ for\ hilly\ terrain$

$\mathrm{N} \geq 150\ for\ plain\ terrain$

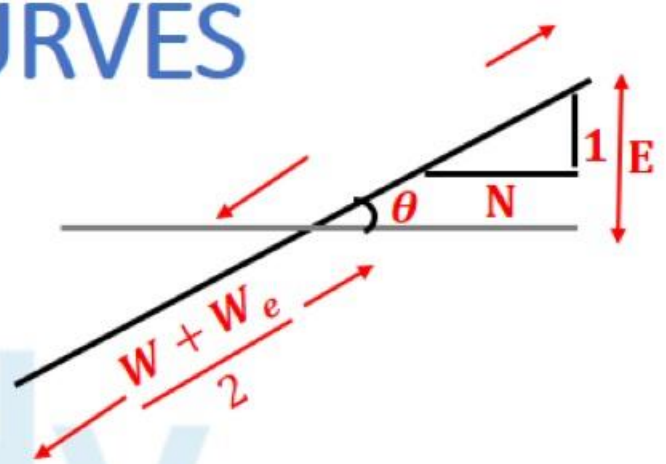
LENGTH OF TRANSITION CURVES

2. Rate of change of superelevation

- **Length of transition curve denoted by L_{s2}**
  - <u>Case 2:</u> When super elevation is provided by rotating about centre

$$we\ know\ that\ e = tan\theta = \frac{E}{\frac{W + W_e}{2}}$$

$$\Rightarrow E = e\left(\frac{W + W_e}{2}\right) \ldots (1)$$

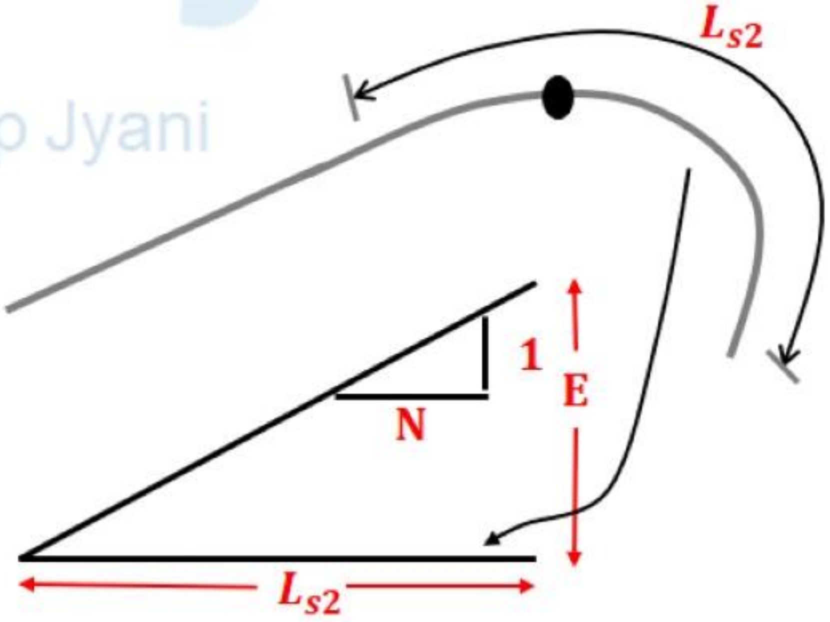


$N \geq 60\ for\ hilly\ terrain$

$N \geq 150\ for\ plain\ terrain$

$$Also\ \frac{E}{L_{s2}} = \frac{1}{N}$$

$$\Rightarrow E = \frac{L_{s2}}{N} \quad \ldots (1)$$



Equating 1 and 2 equations,

$$L_{s2} = \text{Ne}\left(\frac{W + W_e}{2}\right)$$

LENGTH OF TRANSITION CURVES

- **By Empirical Formula of IRC**
  - **Length of transition curve denoted by L_{s3}**
  - **IRC suggest the length of the transition curve is minimum for a plain and rolling terrain**

$$L_{s3} = \frac{35v^2}{R}$$

  - **and for steep and hilly terrain is:**

$$L_{s3} = \frac{12.96v^2}{R}$$

  - **And the shift 's'**

$$s = \frac{{L_s}^2}{24R}$$

LENGTH OF TRANSITION CURVES = MAXIMUM OF $\langle L_{s1} | L_{s2} | L_{s3} \rangle$

SET BACK DISTANCE

- **Set back distance is the distance required from the center line 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.
- **Setback distance controls alignment around obstacles at intersections and curves**

VERTICAL ALIGNMENT

- The vertical alignment of a road consists of gradients(straight lines in a vertical plane) and vertical curves.
- The vertical alignment is usually drawn as a profile, which is a graph with elevation as vertical axis and the horizontal distance along the centre line of the road as the horizontal axis.
- Vertical curves connect two gradients.
- When these two curves meet, they form either convex or concave. The former is called a summit curve, while the latter is called a valley curve.

VERTICAL ALIGNMENT

- *Gradient* is the rate of rise or fall along the length of the road with respect to the horizontal.
- Types of gradient

TERRAIN	RULING GRADIENT	LIMITINGS	EXCEPTION
Plain/Rolling	3.3	5.0	6.7
Hilly	5	6	7
Steep	6	7	8

VERTICAL ALIGNMENT

- **TYPES OF GRADIENT**
  - **Ruling gradient**
    - **The ruling gradient or the design gradient is the maximum gradient with which the designer attempts to design the vertical profile of the road.**
    - **This depends on the terrain, length of the grade, speed, pulling power of the vehicle and the presence of the horizontal curve.**
    - **In flatter terrain, it may be possible to provide flat gradients, but in hilly terrain it is not economical and sometimes not possible also.**

VERTICAL ALIGNMENT

- **TYPES OF GRADIENT**
  - **Limiting gradient**
    - **This gradient is adopted when the ruling gradient results in enormous increase in cost of construction.**
    - **On rolling terrain and hilly terrain it may be frequently necessary to adopt limiting gradient.**
    - **But the length of the limiting gradient stretches should be limited and must be sandwiched by either straight roads or easier grades.**

VERTICAL ALIGNMENT

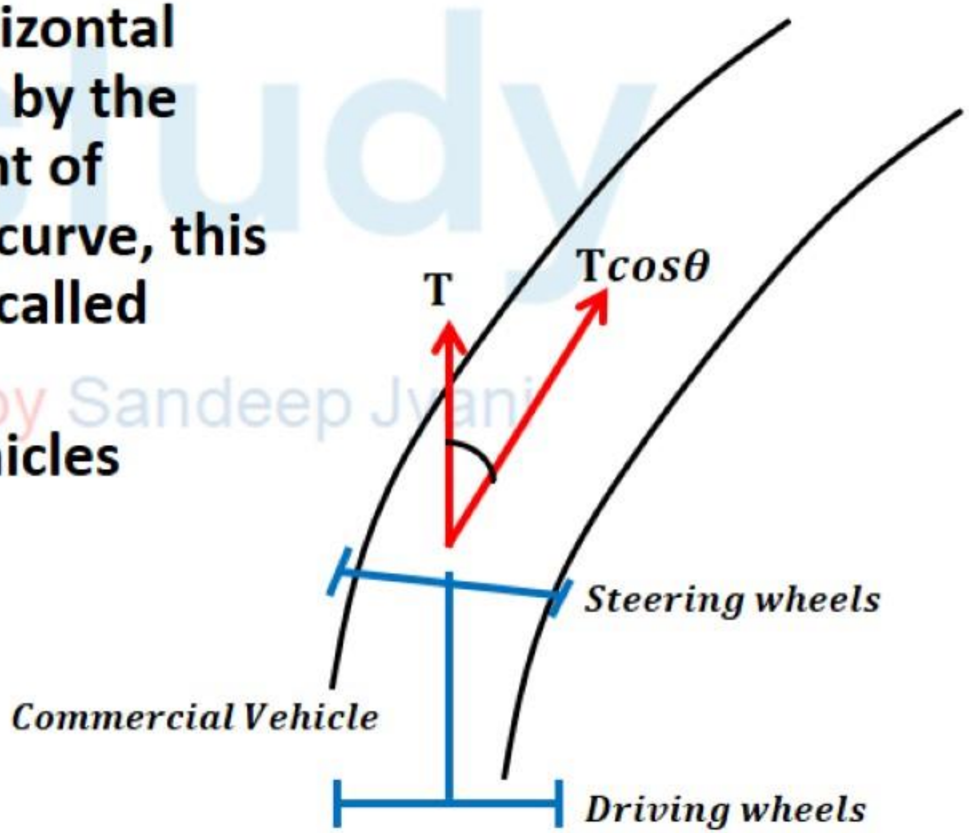
- **TYPES OF GRADIENT**
  - **Exceptional gradient**
    - **Exceptional gradient are very steeper gradients given at unavoidable situations.**
    - **They should be limited for short stretches not exceeding about 100 metres at a stretch.**
    - **In mountainous and steep terrain, successive exceptional gradients must be separated by a minimum 100 metre length gentler gradient. At hairpin bends, the gradient is restricted to 2.5%.**

VERTICAL ALIGNMENT

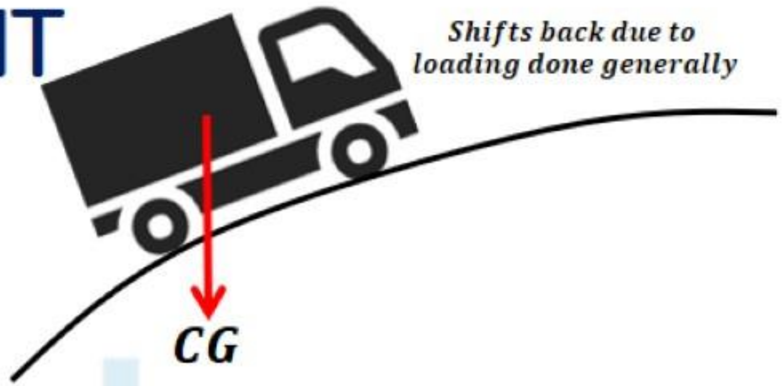
- **GRADIENT**
  - **Critical length of the grade**
    - **The maximum length of the ascending gradient which a loaded truck can operate without undue reduction in speed is called critical length of the grade. A speed of 25 kmph is a reasonable value. This value depends on the size, power, load, grad-ability of the truck, initial speed, final desirable minimum speed etc.**
  - **Minimum gradient**
    - **This is important only at locations where surface drainage is important.**
    - **Camber will take care of the lateral drainage. But the longitudinal drainage along the side drains require some slope for smooth flow of water.**
    - **Therefore minimum gradient is provided for drainage purpose and it depends on the rain fall, type of soil and other site conditions.**
    - **A minimum of 1 in 500 may be sufficient for concrete drain and 1 in 200 for open soil drains are found to give satisfactory performance..**

VERTICAL ALIGNMENT

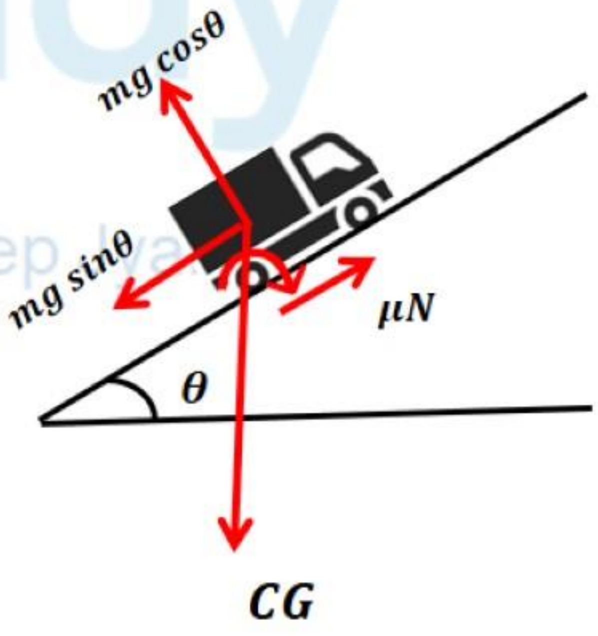
- **CURVE RESISTANCE**
  - **When a vehicle is negotiating a horizontal curve, the front wheels are rotated by the drivers and hence only a component of thrust is available to negotiate the curve, this reduction in thrust ($\mathrm{T} - \mathrm{T}\cos\theta$), is called curve resistance.**
  - **Generally occurs in commercial vehicles having rear wheels.**



VERTICAL ALIGNMENT



- **GRADE COMPENSATION**
  - **When horizontal curve exists together with the up gradient, pulling power of vehicle is reduced, hence to increase the pulling power, the gradient is reduced.**
  - **This reduction in gradient to compensate the loss of tractive effect on horizontal curves is called GRADE COMPENSATION.**
  - **It is not required for grades flatter than 4%**
  - **Grade compensation required is given as $\frac{30+R}{R}\%$ subjected to a maximum of $\frac{75}{R}\%$**
  - **Compensated grade should not be less than 4%**



Que. If the ruling gradient is 1 in 20, what is grade compensation and compensated grade for a radius of 120m.

Que. If the ruling gradient is 1 in 20, what is grade compensation and compensated grade for a radius of 120m.

Sol. Initial gradient of road = $\frac{1}{20} \times 100$ **= 5%**

Grade compensation required = $\frac{30+R}{R}\%$ **=** $\frac{30+120}{120}\% = 1.25\%$

Grade compensation, maximum = $\frac{75}{R}\%$ **=** $\frac{75}{120}\%$ **= 0.625%**

CHECK – compensated grade $\geq$ 4%

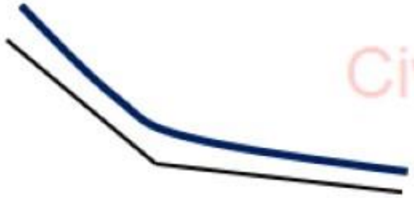
compensated grade = 5 – 0.625 = 4.375 $\geq$ 4%

Vertical Curves

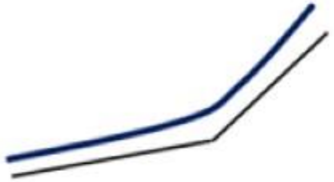
SAG CURVE/Valley Curve

When down gradient is followed by Up gradient

Steep down gradient is followed by mild down gradient



Mild up gradient is followed by steep up gradient



SUMMIT CURVE

When up gradient is followed by down gradient

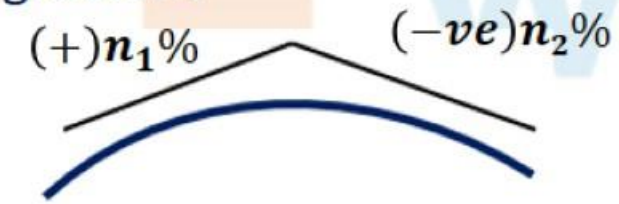
Mild down gradient is followed by steep down gradient

Steep gradient followed by Mild up gradient

Vertical Curves

- SUMMIT CURVES OR CREST CURVES
- Total change of grade:

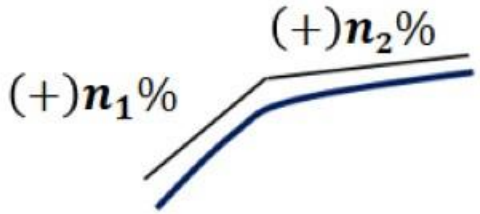
When up gradient is followed by down gradient



$$\boxed{N = n_1 + n_2}$$

$$N = n_1 - (-n_2)$$

Steep gradient followed by Mild up gradient

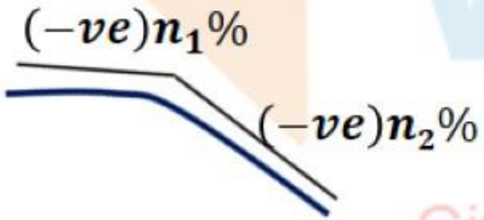


$$\boxed{N = n_1 - n_2}$$

Vertical Curves

- <u>SUMMIT CURVES OR CREST CURVES</u>
- <u>Total change of grade:</u>

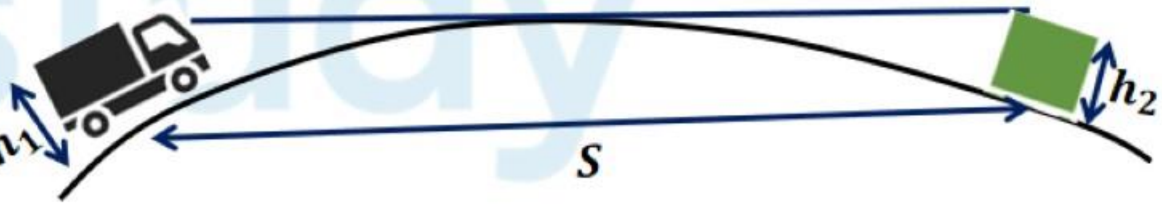
Mild down gradient is followed
by steep down gradient



$$\boxed{N = n_2 - n_1}$$

VERTICAL ALIGNMENT

- **CURVE**
  - **Summit curves are vertical curves with gradient upwards.**
  - **They are formed when two gradients meet.**
  - **Length of summit curve is given by:**
    - **When length of summit curve greater than sight distance:**
      - $L = \frac{NS^2}{2(\sqrt{h_1}+\sqrt{h_2})^2}$
    - **When length of summit curve lesser than sight distance:**
      - $L = 2S - \frac{(\sqrt{2h_1}+\sqrt{2h_2})^2}{N}$



SSD
(h_1= 1.2 m, h_2=0.15m)

OSD/ISD
(h_1= 1.2 m, h_2=1.2 m)

VERTICAL ALIGNMENT

- **SUMMIT CURVE**
  - **When stopping sight distance is considered the height of driver's eye above the road surface (h_1) is taken as 1.2 metres, and height of object above the pavement surface(h_2) is taken as 0.15metres. If overtaking sight distance is considered, then the value of driver's eye height (h_1) and the height of the obstruction (h_2) are taken as 1.2metres.**

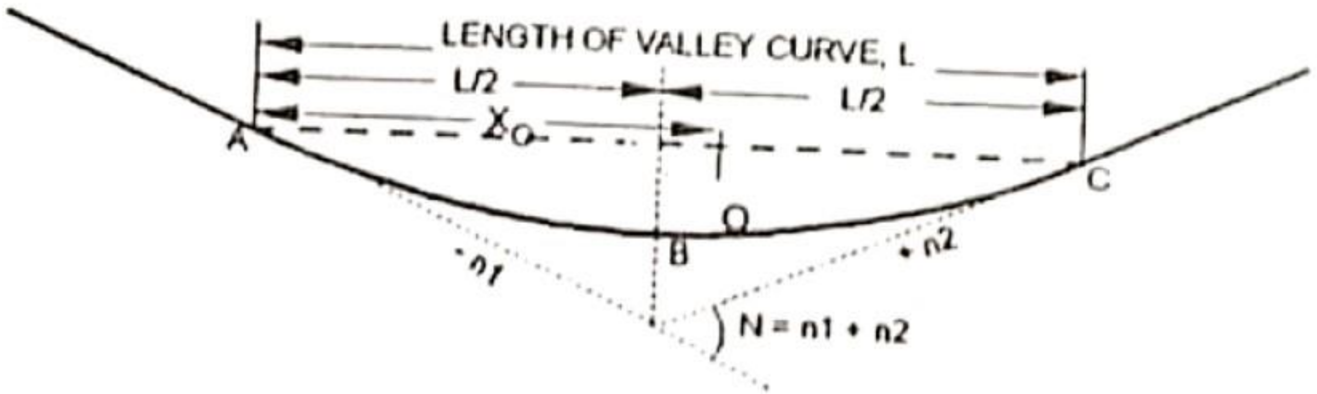
SSD (h_1= 1.2 m, h_2=0.15m)	OSD/ISD (h_1= 1.2 m, h_2=1.2 m)
$L > S \Rightarrow L = \frac{NS^2}{4.4}$	$L = \frac{NS^2}{9.6}$
$L < S \Rightarrow L = 2S - \frac{4.4}{N}$	$L = 2S - \frac{9.6}{N}$

VALLEY CURVE

- **Length of the valley curve is designed to fulfill two criteria:**

  1. **The allowable rate of change of centrifugal acceleration**
  2. **The required head light sight distance for night driving**

- **The higher value of the above two is adopted.(usually 2nd criteria is higher)**
- **The valley curve is made fully transitional by providing two similar transition curves of equal length**
- **The transitional curve is set out by a cubic parabola y = bx^3 where b is the lowest point on the valley curve whose value is b=$\frac{2N}{3L^2}$**



VALLEY CURVE

- **Length of transition curve for comfort condition**
  - **The length of transition curve, L_s fulfilling allowable rate of change of centrifugal acceleration, C is given by**

$$L_s = \frac{v^3}{CR}$$

Value of R (at length L_s) = $\frac{L_s}{N}$ = $\frac{L}{2N}$

The length of valley curve is $2L_s$

Hence $\quad$ $L = 2L_s = 2\sqrt{[\frac{Nv^3}{C}]}$

where L is length of valley curve

N is the deviation angle in radians

v is design speed in m/sec

C is allowable rate of change of centrifugal acceleration

VALLEY CURVE

- **Length of transition curve for head light sight distance**

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

where L is length of valley curve($L>S$) in metres

N is the deviation angle in radians(n_1+n_2), with slopes -n_1 and +n_2

S is SSD (m)

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

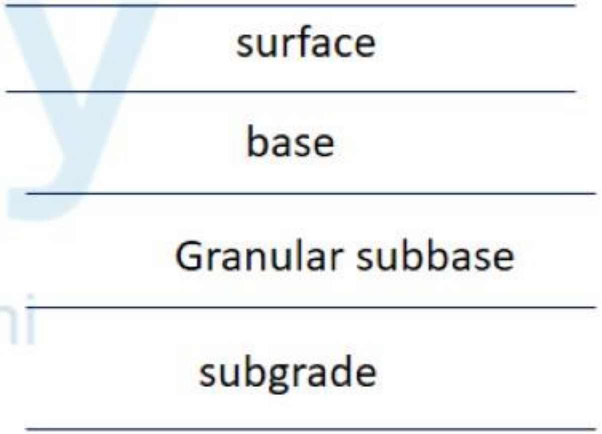
where L is length of valley curve($L<S$) in metres

N is the deviation angle in radians(n_1+n_2), with slopes -n_1 and +n_2

S is SSD (m)

PAVEMENT MATERIALS

- Pavements are a conglomeration of materials.
- These materials, their associated properties, and their interactions determine the properties of the resultant pavement.
- Thus, a good understanding of these materials, how they are characterized, and how they perform is fundamental to understanding pavement.
- The materials which are used in the construction of highway are of intense interest to the highway engineer.



PAVEMENT MATERIALS

- SOIL
  - Soil is an accumulation or deposit of earth material, derived naturally from the disintegration of rocks or decay of vegetation, that can be excavated readily with power equipment in the field or disintegrated by gentle mechanical means in the laboratory.
  - The supporting soil beneath pavement and its special under courses is called sub grade.
  - Undisturbed soil beneath the pavement is called natural sub grade.
  - Compacted sub grade is the soil compacted by controlled movement of heavy compactors.

PAVEMENT MATERIALS

- **SOIL**
  - **The desirable properties of sub grade soil as a highway material are**
    - **Stability**
    - **Incompressibility**
    - **Permanency of strength**
    - **Minimum changes in volume and stability under adverse conditions of weather and ground water**
    - **Good drainage, and**
    - **Ease of compaction**

PAVEMENT MATERIALS

- **SOIL**
  - **The main function of the sub grade is to give adequate support to the pavement and for this the sub grade should possess sufficient stability under adverse climatic and loading conditions. Therefore, it is very essential to evaluate the sub grade by conducting tests.**
  - **The tests used to evaluate the strength properties of soils may be broadly divided into three groups:**
    - **Shear tests**
    - **Bearing tests**
    - **Penetration tests**

PAVEMENT MATERIALS

- **SOIL**
  - Shear tests are usually carried out on relatively small soil samples in the laboratory. In order to find out the strength properties of soil, a number of representative samples from different locations are tested. Some of the commonly known shear tests are direct shear test, triaxial compression test, and unconfined compression test.
  - Bearing tests are loading tests carried out on sub grade soils in-situ with a load bearing area. The results of the bearing tests are influenced by variations in the soil properties within the stressed soil mass underneath and hence the overall stability of the part of the soil mass stressed could be studied.
  - Penetration tests may be considered as small scale bearing tests in which the size of the loaded area is relatively much smaller and ratio of the penetration to the size of the loaded area is much greater than the ratios in bearing tests. The penetration tests are carried out in the field or in the laboratory.

PAVEMENT MATERIALS

- AGGREGATES
  - Aggregate is a collective term for the mineral materials such as sand, gravel, and crushed stone that are used with a binding medium (such as water, bitumen, Portland cement, lime, etc.) to form compound materials (such as bituminous concrete and Portland cement concrete).
  - By volume, aggregate generally accounts for 92 to 96 percent of Bituminous concrete and about 70 to 80 percent of Portland cement concrete.
  - Aggregate is also used for base and sub-base courses for both flexible and rigid pavements

DESIRABLE PROPERTIES OF AGGREGATES

- **Strength**
  - The aggregates used in top layers are subjected to
    (i) Stress action due to traffic wheel load.
    (ii) Wear and tear
    (iii) Crushing.
  - For a high quality pavement, the aggregates should posses high resistance to crushing, and to withstand the stresses due to traffic wheel load.
- **Hardness**
  - The aggregates used in the surface course are subjected to constant rubbing or abrasion due to moving traffic.
  - The aggregates should be hard enough to resist the abrasive action caused by the movements of traffic.
  - The abrasive action is severe when steel tyred vehicles moves over the aggregates exposed at the top surface.

DESIRABLE PROPERTIES OF AGGREGATES

- **Shape of aggregates**
  - **Aggregates which happen to fall in a particular size range may have rounded, cubical, angular, flaky or elongated particles.**
  - **The flaky and elongated particles will have less strength and durability when compared with cubical, angular or rounded particles of the same aggregate.**
  - **Hence too flaky and too much elongated aggregates should be avoided as far as possible.**
- **Adhesion with bitumen**
  - **The aggregates used in bituminous pavements should have less affinity with water when compared with bituminous materials, otherwise the bituminous coating on the aggregate will be stripped off in presence of water.**

DESIRABLE PROPERTIES OF AGGREGATES

- **Toughness**
  - **Resistance of the aggregates to impact is termed as toughness.**
  - **Aggregates used in the pavement should be able to resist the effect caused by the jumping of the steel tyred wheels from one particle to another at different levels causes severe impact on the aggregates.**
- **Durability**
  - **The property of aggregates to withstand adverse action of weather is called soundness.**
  - **The aggregates are subjected to the physical and chemical action of rain and bottom water, impurities there-in and that of atmosphere, hence it is desirable that the road aggregates used in the construction should be sound enough to withstand the weathering.**

DESIRABLE PROPERTIES OF AGGREGATES

- **Freedom from deleterious particles**
  - **Specifications for aggregates used in bituminous mixes usually require the aggregates to be clean, tough and durable in nature and free from excess amount of flat or elongated pieces, dust, clay balls and other objectionable material.**
  - **Similarly aggregates used in Portland cement concrete mixes must be clean and free from deleterious substances such as clay lumps, chert, silt and other organic impurities.**

AGGREGATES TEST

- **Aggregate tests**
  - In order to decide the suitability of the aggregate for use in pavement construction, following tests are carried out:

1. Crushing test
2. Abrasion test
3. Impact test
4. Soundness test
5. Shape test

AGGREGATES TEST

1. **Crushing test-**
   - Load is applied on a sample and then the sample is sieved through 2.36mm sieve
   - This method is used for determining crushing strength.
   - $Aggregate\ Crushing\ Value = \frac{weight\ passing\ through\ 2.36mm\ sieve}{initial\ weight\ of\ the\ sample}$
2. **Abrasion test**
   - It is used to determine hardness.
   - Various abrasion tests conducted are:
     - Los Angeles Abrasion Test

       $$Los\ Angeles\ Abrasion\ Value = \frac{weight\ passing\ through\ 1.7mm\ sieve}{initial\ weight\ of\ the\ sample}$$
     - Devel's Abrasion Test
     - Dorry's Abrasion Test

AGGREGATES TEST

3. Soundness test

- **Soundness test is intended to study the resistance of aggregates to weathering action, (i.e., durability) by conducting accelerated weathering test cycles.**
- **Aggregates of specified size are subjected to cycles of alternate wetting in a saturated solution of either sodium sulphate or magnesium sulphate for 16 - 18 hours and then dried in oven at 105°C - 110°C to a constant weight.**
- **After five cycles, the loss in weight of aggregates is determined by sieving out all undersized particles and weighing.**
- **And the loss in weight should not exceed 12 percent when tested with sodium sulphate and 18 percent with magnesium sulphate solution.**

AGGREGATES TEST

4. Impact Test

- The aggregate impact test is carried out to evaluate the resistance to impact of aggregates or toughness of aggregates.
- Aggregates passing through 12.5 mm sieve and retained on 10 mm sieve is filled in a cylindrical steel cup of internal dia 10.2 mm and depth 5 cm which is attached to a metal base of impact testing machine.
- The material is filled in 3 layers where each layer is tamped for 25 number of blows. Metal hammer of weight 13.5 to 14 kg is arranged to drop with a free fall of 38.0 cm by vertical guides and the test specimen is subjected to 15 number of blows.
- The crushed aggregate is allowed to pass through 2.36 mm IS sieve.
- $$Aggregate\ Impact\ Value = \frac{weight\ passing\ through\ 2.36mm\ sieve}{initial\ weight\ of\ the\ sample}$$

AGGREGATES TEST

5. Shape Test
   - The particle shape of the aggregate mass is determined by the percentage of flaky and elongated particles in it.
   - Aggregates which are flaky or elongated are detrimental to higher workability and stability of mixes.
   - The flakiness index is defined as the percentage by weight of aggregate particles whose least dimension is less than 0.6 times their mean size.
   - The elongation index of an aggregate is defined as the percentage by weight of particles whose greatest dimension (length) is 1.8 times their mean dimension. This test is applicable to aggregates larger than 6.3 mm.

IRC RECOMMENDATIONS

1. Aggregate Crushing Value $< 30\%$ (for surface coarse)
2. Aggregate Crushing Value $\ngtr 45\%$ (for base coarse)
3. Aggregate Impact Value $\ngtr 30\%$ (for bearing coarse)
4. Aggregate Impact Value $\ngtr 40\%$ (for bituminous macadam)
5. Abrasion value Of 40% is allowed for WBM coarse
6. Abrasion value Of 35% is allowed for bituminous and concrete.
7. Loss of weight $\ngtr 12\%$ (for Na_2SO_4)
8. Loss of weight $\ngtr 18\%$ (for $MgSO_4$)

Asphalt/Bitumen

- B**itumen** is a sticky, black, and highly viscous liquid or semi-solid form of petroleum
- **Asphalt** is a composite mix of Bitumen, Sand and aggregate (smoother and durable)
- **Bitumen** - obtained by distillation of crude petroleum or naturally available in asphalt.
- **Coal tar** – by product in destructive distillation of *coke(coal heated in absence of air)*
- At normal range of temp – semi solid state
- For construction of pavements – heated from 130 to 175°C
- Bitumen can be majorly classified into 2 types:
  1. **Paving grade bitumen:** Used for construction of roads and airfields
  2. **Industrial grade bitumen:** Water proofing of structures and industrial floors etc.,

BITUMEN

- Bituminous materials or asphalts are extensively used for roadway construction, because of their excellent binding characteristics and water proofing properties and relatively low cost.
- Bituminous materials consists of bitumen which is a black or dark coloured solid or viscous cementitious substances.
- Tars are residues from the destructive distillation of organic substances such as coal, wood, or petroleum and are temperature sensitive than bitumen.
- Bitumen will be dissolved in petroleum oils where unlike tar.

DIFFERENT FORMS OF BITUMEN

- **Cutback bitumen**
  - In cutback bitumen suitable solvent is used to lower the viscosity of the bitumen.
  - The solvent from the bituminous material will evaporate and the bitumen will bind the aggregate.
  - Cutback bitumen is used for cold weather bituminous road construction and maintenance.
  - There are different types of cutback bitumen like rapid curing (RC), medium curing (MC), and slow curing (SC).
  - Less viscous cutback bitumen means it has more dilutent present and has less bitumen content.
  - More viscous cutback bitumen means it has less dilutent present and has more bitumen content.

DIFFERENT FORMS OF BITUMEN

- **Bitumen Emulsion**
  - **Bitumen emulsion is a liquid product in which bitumen is suspended in a finely divided condition in an aqueous medium and stabilised by suitable material.**
  - **The bitumen content in the emulsion is around 50-60%,emulsifier is around 0.5% and rest is water.**
  - **Emulsifier means bitumen in suspended form.**
  - **Uses of bitumen emulsion**
    - **Maintenance and patch work of roads.**
    - **Can be used in wet weather as well.**
    - **Soil stabilization in desert areas.**

DIFFERENT FORMS OF BITUMEN

- **Tar**
  - It is made by destructive distillation(burning in absence of air/oxygen) of coal/wood.
  - 5 grades of tar are found:
    - RT-1, RT-2, RT-3, RT-4 AND RT-5.
  - RT-1
  - For surface dressing under cold weather conditions and use on hill roads at high altitude as well as for priming the base;
  - RT-2
    - For surface painting in normal climatic conditions;
  - RT-3
    - a) For surface painting and renewal coat;
    - b) For premix chipping carpet (top course and light carpets);
  - RT-4
    - For premix tar macadam (base course) and dense tar surfacing; and
  - RT-5
    - For grouting and water proofing.

DIFFERENT FORMS OF BITUMEN

- **Tar**
  - **It is made by destructive distillation(burning in absence of air/oxygen) of coal/wood.**
  - **5 grades of tar are found:**
    - **RT-1, RT-2, RT-3, RT-4 AND RT-5.**
- **Bituminous primers**
  - **Bitumen primers are useful on the stabilised surfaces and water bound macadam base courses.**
  - **Bituminous primers are generally prepared on road sites by mixing penetration bitumen with petroleum distillate.**

DIFFERENT FORMS OF BITUMEN

- **Modified Bitumen**
  - **Certain additives or blend of additives called as bitumen modifiers can improve properties of Bitumen and bituminous mixes.**
  - **Bitumen treated with these modifiers is known as modified bitumen.**
  - **Advantages of modified bitumen:**
    - **Lower susceptibility to daily and seasonal temperature variations**
    - **Higher resistance to deformation at high pavement temperature**
    - **Better age resistance properties**
    - **Higher fatigue life for mixes**
    - **Better adhesion between aggregates and binder**
    - **Prevention of cracking and reflective cracking**

COMPARISON OF BITUMEN AND TAR

BITUMEN

1. Petroleum biproduct.
2. Pure bitumen is completely soluble in CCl_4 or CS_2
3. Superior durability and water resisting capacity.
4. Less temperature susceptible.
5. Less free carbon

TAR

1. Destructive distillation of coal and wood.
2. Tar is only soluble in toluene.
3. Low quality
4. More temperature susceptible
5. More free carbon

REQUIREMENTS OF BITUMEN

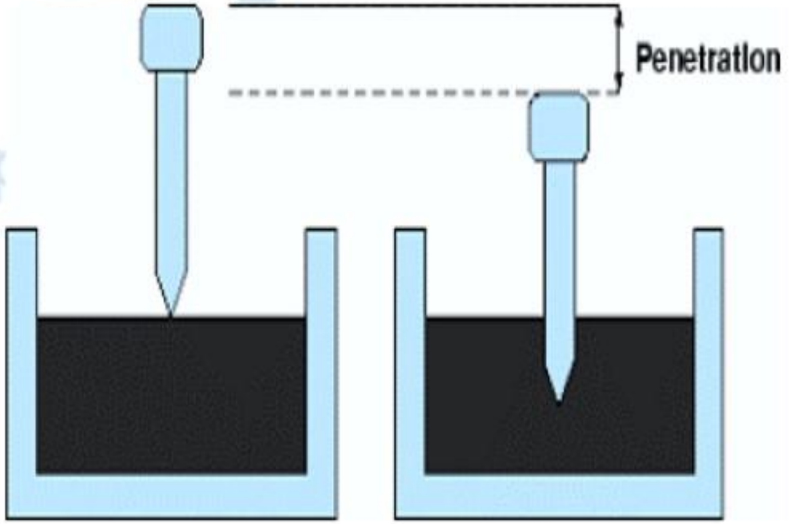
- **Bitumen should posses following desirable properties.**
  - The bitumen should not be highly temperature susceptible: during the hottest weather the mix should not become too soft or unstable, and during cold weather the mix should not become too brittle causing cracks.
  - The viscosity of the bitumen at the time of mixing and compaction should be adequate. This can be achieved by use of cutbacks or emulsions of suitable grades or by heating the bitumen and aggregates prior to mixing.
  - There should be adequate affinity and adhesion between the bitumen and aggregates used in the mix.

TESTS ON BITUMEN

- **Penetration test**
- **Ductility test**
- **Softening point test**
- **Specific gravity test**
- **Viscosity test**
- **Flash and Fire point test**
- **Solubility test**
- **Water content test**
- **Loss on heating test**

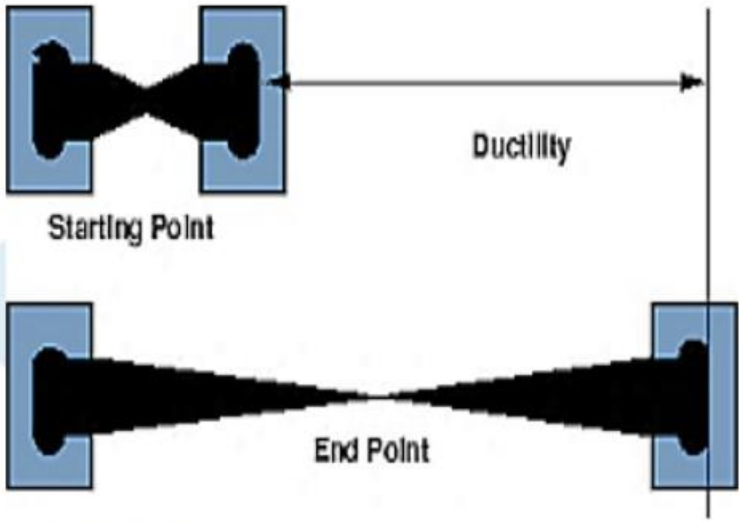
TESTS ON BITUMEN

- **Penetration test**
  - It measures the hardness or softness of bitumen by measuring the depth in *tenths of a millimeter* to which a standard loaded needle will penetrate vertically in 5 seconds.
  - PENETROMETER is used here.
  - Waterbath is kept at 25°C, because the properties of bitumen will change as the temperature changes. At T = 25°C, needle is allowed to penetrate for 5 seconds.
  - The distance which the needle penetrate into bitumen is called 'penetration of bitumen' and is measured in 'gauge.'
  - A grade of 30/40 bitumen(preferred for hot climate) means the penetration value is in the range 30 to 40 at standard test conditions.
  - A grade of 80/100 bitumen(preferred for cold climate) means the penetration value is in the range 80 to 100 at standard test conditions.



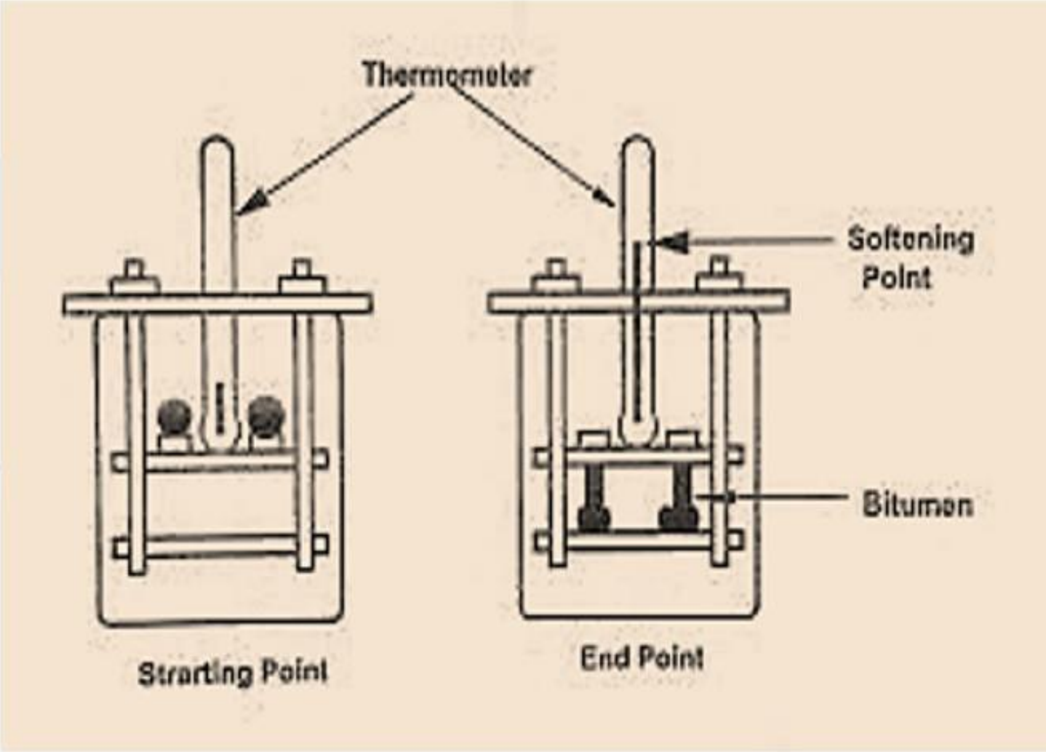
TESTS ON BITUMEN

- **Ductility test:**
  - **Ductility is the property of bitumen that permits it to undergo great deformation or elongation.**
  - **Ductility is defined as the distance in cm, to which a standard sample or briquette of the material will be elongated without breaking.**
  - **ELASTOMER is used here.**
  - **Ductility will be measured at the point where bitumen breaks.**
  - **Temperature maintained = 27°C**
  - **A minimum ductility value of 75 cm has been specified by the BIS.**
  - **Good quality of bitumen has more ductility while low quality of bitumen has less ductility.**



TESTS ON BITUMEN

- **Softening Point test:**
  - Softening point denotes the temperature at which the bitumen attains a particular degree of softening under the specifications of test.
  - It is performed to know the temperature susceptibility of bitumen, i.e., how properties of bitumen vary with temperature.
  - The test is conducted by using Ring and Ball apparatus.
  - Constantly 5°C - 6°C temperature is increased per minute.
  - Temperature at which ball drops is called "softening point of bitumen"
  - Generally softening point of bitumen = 35°C - 70°C



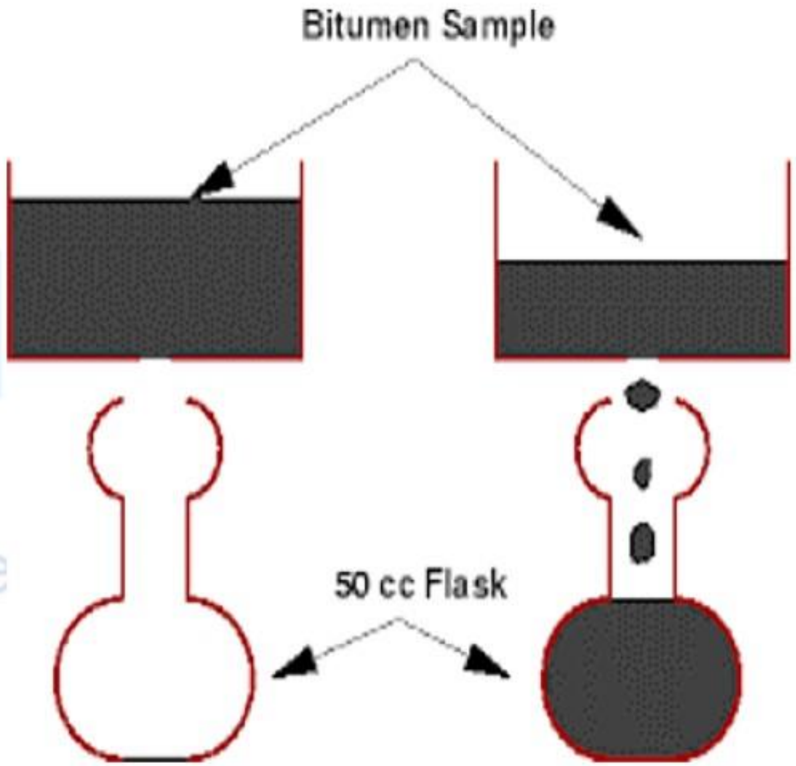
TESTS ON BITUMEN

- **Specific Gravity test:**
  - It is done to determine the density of bitumen.
  - $Specific\ Gravity\ of\ bitumen = \frac{weight\ of\ bitumen\ of\ given\ volume}{weight\ of\ same\ volume\ of\ water}$ (@27°C)
  - PYCNOMETER is used here.
  - Specific gravity of :

1. Bitumen = 0.97 – 1.02
2. Tar = 1.10 – 1.29

TESTS ON BITUMEN

- **Viscosity test:**
  - **Viscosity is a measure of resistance to flow.**
  - **This test is conducted to check *consistency and flow resistance of bitumen.***
  - **Orifice type viscometers are used to indirectly find the viscosity of liquid binders like cutbacks and emulsions.**
  - **The viscosity expressed in seconds is the time taken by the 50 ml bitumen material to pass through the orifice of a cup, under standard test conditions and specified temperature. Viscosity of a cutback can be measured with either 4.0 mm orifice at 25°C or 10mm orifice at 25°-40°C**
  - **Bitumen shall not be too viscous nor less viscous.**



TESTS ON BITUMEN

- **Flash and Fire Point Test:**
  - It is basically safety test which means till what temperature bitumen can be used without any difficulty.
  - The flash point as the temperature at which the vapour of bitumen momentarily catches fire in the form of flash under specified test conditions.
  - The fire point is defined as the lowest temperature under specified test conditions at which the bituminous material gets ignited and burns.
  - PENSKY MARTENS APPARATUS is used here.

TESTS ON BITUMEN

- **Solubility Test:**
  - **This test is done to know the purity of bitumen.**
  - **Pure bitumen is completely soluble in CCl_4 or CS_2.**
  - **99% purity bitumen is required.**
- **Water content test:**
  - **Water content in bitumen should not exceed 0.2% by its weight.**
- **Loss on Heating test:**
  - **Loss allowed on heating of bitumen = 1% BY WEIGHT**

MARSHAL MIX DESIGN

- **Marshal Mix Design is used to design pavement mix.**
- **Desirable properties for mix design:**
  - **Sufficient stability**
  - **Sufficient durability**
  - **Sufficient flexibility**
  - **Sufficient skid resistance**
  - **Sufficient workability**
  - **Sufficient air voids(generally 4%)**

MARSHAL MIX DESIGN

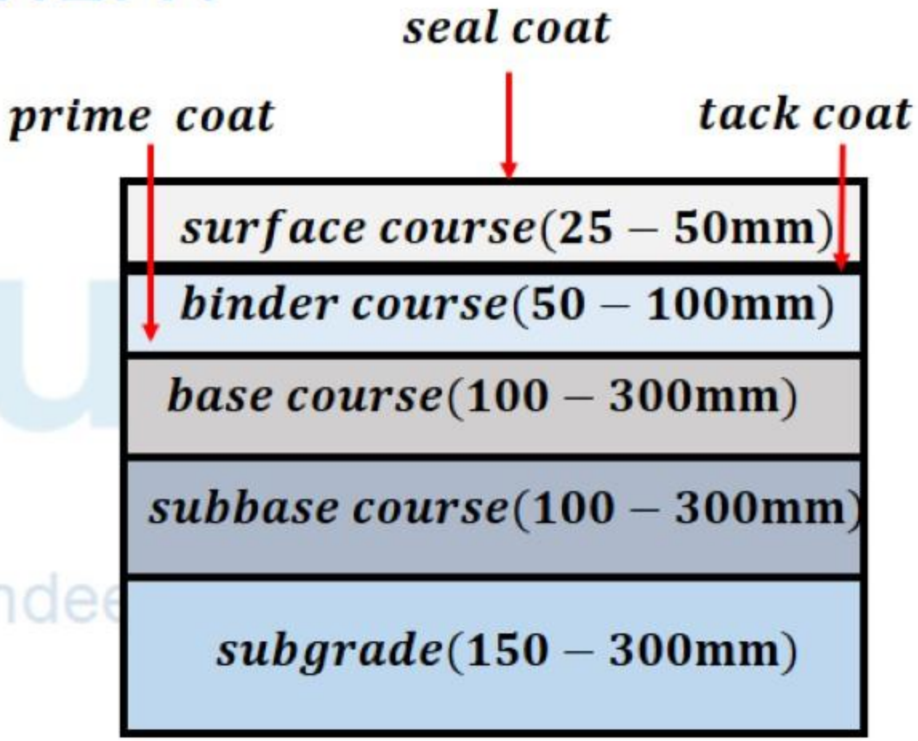
- The Marshall stability and flow test provides the performance prediction measure for the Marshall mix design method.
- The stability portion of the test measures the maximum load supported by the test specimen at a loading rate of 50.8 mm/minute. Load is applied to the specimen till failure, and the maximum load is designated as stability. During the loading, an attached dial gauge measures the specimen's plastic flow (deformation) due to the loading.
- The flow value is recorded in 0.25 mm (0.01 inch) increments at the same time when the maximum load is recorded.

PAVEMENT

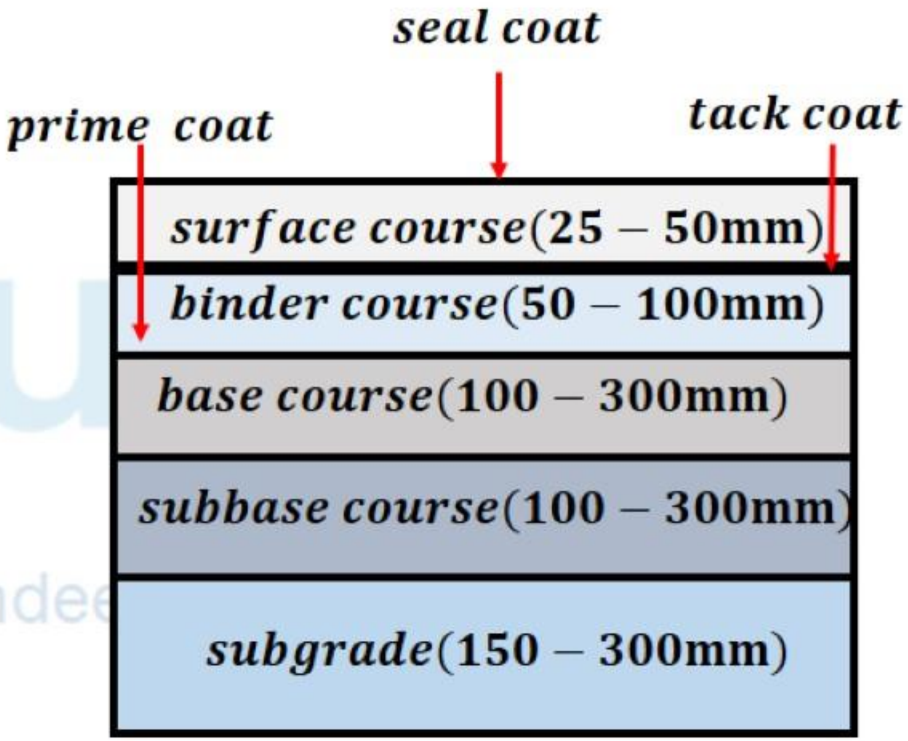
- A highway pavement is a structure consisting of superimposed layers of processed materials above the natural soil sub-grade, whose primary function is to distribute the applied vehicle loads to the sub-grade.
- The pavement structure should be able to provide a surface of acceptable riding quality, adequate skid resistance, favorable light reflecting characteristics, and low noise pollution.
- The ultimate aim is to ensure that the transmitted stresses due to wheel load are sufficiently reduced, so that they will not exceed bearing capacity of the sub-grade.
- Two types of pavements are generally recognized as serving this purpose, namely flexible pavements and rigid pavements.

FLEXIBLE PAVEMENT

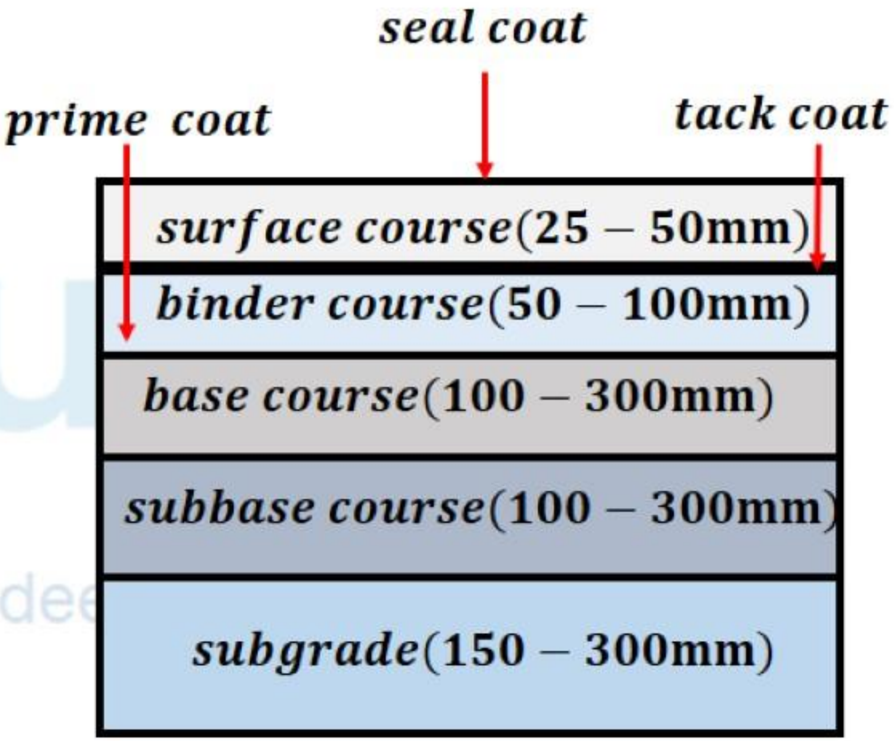
- Flexible pavement, load from top layer is distributed to the bottom layer through grain-grain contact, hence we need to use better quality material the top layer as compare to the bottom layer, since the stresses in the bottom layers will be lower than the top layers.
- The pavement layer thickness is decided in such a way that the stresses in each layer does not exceed its maximum permissible value.
- In flexible pavements any deformation in the bottom layer is reflected the top layers.



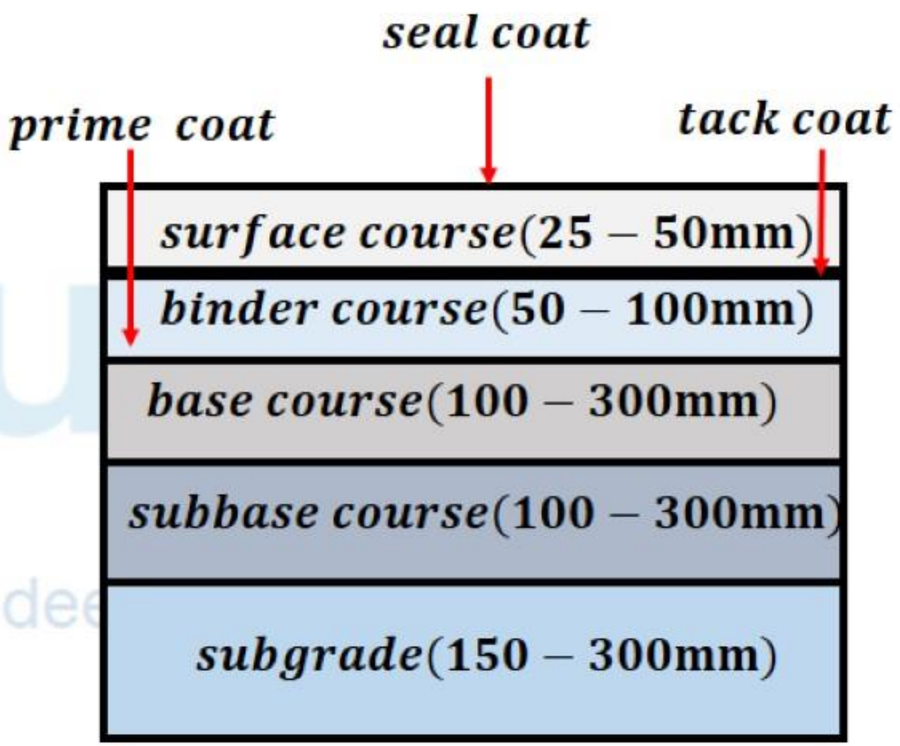
- **FUNCTIONS OF LAYERS:**
  - **Seal Coat:**
    - Seal coat is a thin surface treatment used to water-proof the surface and to provide skid resistance.
  - **Tack Coat:**
    - Tack coat is a very light application of asphalt, usually asphalt emulsion diluted with water.
    - It provides proper bonding between two layer of binder course and must be thin, uniformly cover the entire surface, and set very fast.
  - **Prime Coat:**
    - Prime coat is an application of low viscous cutback bitumen to an absorbent surface like granular bases on which binder layer is placed.
    - It provides bonding between two layers.
    - Unlike tack coat, prime coat penetrates into the layer below, plugs the voids, and forms a water tight surface



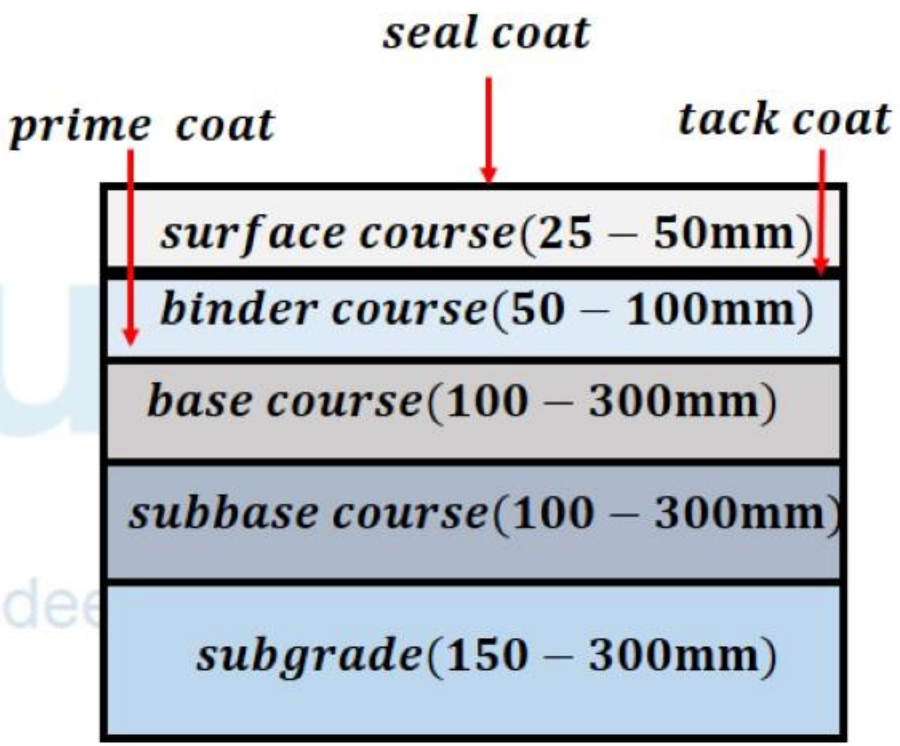
- **FUNCTIONS OF LAYERS:**
  - **Surface course**
    - Surface course is the layer directly in contact with traffic loads and generally contains superior quality materials.
    - They are usually constructed with dense graded asphalt concrete(AC).
    - The functions and requirements of this layer are it provides friction, smoothness, drainage, etc.
    - Also it will prevent the entrance of excessive quantities of surface water into the underlying base, sub-base and sub-grade,
    - It must be tough to resist the distortion under traffic and provide a smooth and skid- resistant riding surface,
    - It must be water proof to protect the entire base and sub-grade from the weakening effect of water.



- **FUNCTIONS OF LAYERS:**
  - Binder course
    - This layer provides the bulk of the asphalt concrete structure.
    - Purpose is to distribute load to the base course
  - Base course
    - The base course is the layer of material immediately beneath the surface of binder course and it provides additional load distribution and contributes to the sub-surface drainage
    - It may be composed of crushed stone, crushed slag, and other untreated or stabilized materials.



- **FUNCTIONS OF LAYERS:**
  - Sub-Base course
    - The sub-base course is the layer of material beneath the base course and the primary functions are to provide structural support, improve drainage, and reduce the intrusion of fines from the sub-grade in the pavement structure.
    - If the base course is open graded, then the sub-base course with more fines can serve as a filler between sub-grade and the base course.
  - Sub-grade
    - The sub grade is the layer of natural soil prepared to receive the stresses from the layers above.
    - It is essential that at no time soil sub-grade is overstressed. It should be compacted to the desirable density, near the optimum moisture content.



- **Failure of flexible pavements**
- The major flexible pavement failures are fatigue cracking, rutting, and thermal cracking.
    - *Fatigue cracking* of flexible pavement is due to horizontal tensile strain at the bottom of the asphaltic concrete. To control fatigue cracking, we limit tensile strain at the bottom of the surface course.
    - *Rutting* occurs only on flexible pavements as indicated by permanent deformation or rut depth along wheel load path.
    - *Thermal cracking* includes both low-temperature cracking and thermal fatigue cracking.

Fatigue cracking –interconnected cracks

Surface depression in the wheel path.

Cracks perpendicular to the pavement's centerline

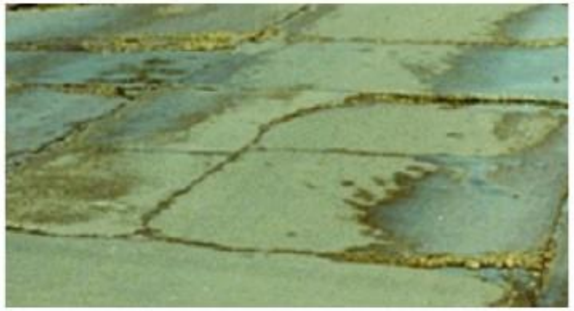
RIGID PAVEMENT

- Rigid Pavement :-
  - In this case load is distributed due to the flexural action of the slab.
  - In rigid pavement, load is distributed by the slab action, and the pavement behaves like an elastic plate resting on a viscous medium.
  - Rigid pavements are designed by Elastic plate theory.
  - The purpose of Base / Sub base course in rigid pavement is to prevent pumping.

***portland cement concrete*(150 – 300mm)**
***base/subbase*(100 – 300mm)**

RIGID PAVEMENT

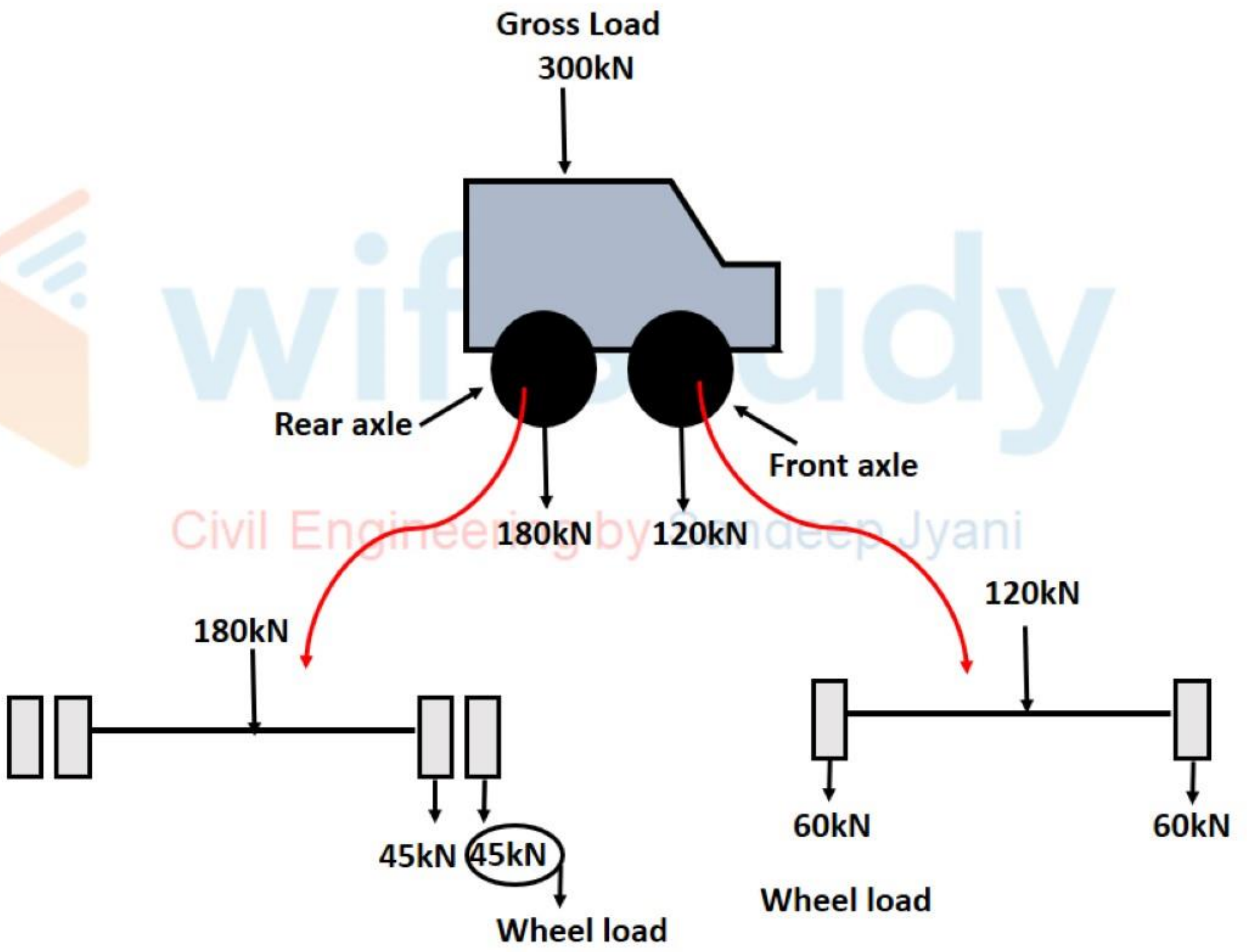
- **Failure criteria of rigid pavements**
  - **Fatigue Failure**
  - **Thermal Cracking**
  - **Mud Pumping**
    - When material present below the road slab ejects out through the joints or cracks, it is called **pumping**. When soil slurry comes out it is called **mud pumping.**



PAVEMENT DESIGN

- **For pavement design, only vehicles having significantly heavy loads are considered, i.e., generally Commercial Vehicles.**
- **As per IRC, vehicles having load greater than 3 tonnes are called as Commercial Vehicles and only these vehicles are considered in design calculations**

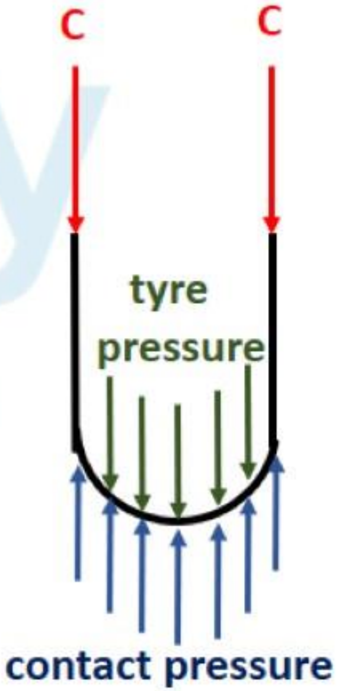
PAVEMENT DESIGN



PAVEMENT DESIGN

- **Contact Pressure and Tyre Pressure**
  - **Tyre pressure is important only for the upper layer of the pavement.**
  - **Contact pressure is responsible for stress at bottom layer.**

$$\textit{Contact Pressure} = \frac{\textit{wheel load}}{\textit{contact area of the wheel}}$$



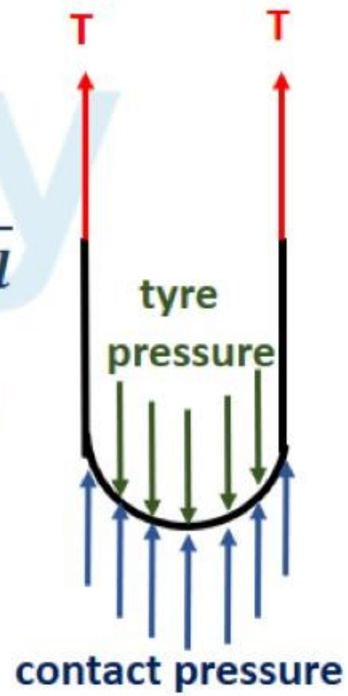
CASE – 1 : when tyre pressure is low

- **In this case, the tyre material comes under compression**
- **In this case, contact pressure > tyre pressure**

PAVEMENT DESIGN

- **Contact Pressure and Tyre Pressure**

$$\textit{Contact Pressure} = \frac{\textit{wheel load}}{\textit{contact area of the wheel}}$$



CASE – 2 : when tyre pressure is high

- **In this case, the tyre material comes under tension**
- **In this case, contact pressure < tyre pressure**

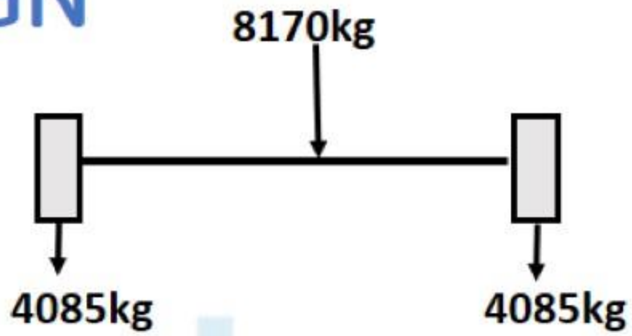
PAVEMENT DESIGN

$$\textit{Rigidity Factor} = \frac{\textit{contact pressure}}{\textit{tyre pressure}}$$

1. **If tyre pressure = 0.7MPa, R.F. = 1**
2. **If tyre pressure < 0.7MPa, R.F. > 1**
3. **If tyre pressure > 0.7MPa, R.F. < 1**

For design purpose, area of contact of wheel is taken as circular.

PAVEMENT DESIGN



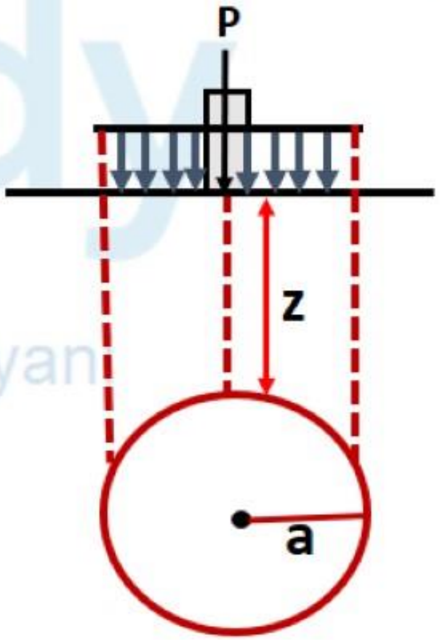
1. Maximum legal axle load

- Legal axle load: The maximum allowed axle load on the roads is called legal axle load. For highways the maximum legal axle load in India, specified by IRC, is 10 tonnes.
- Standard axle load: It is a single axle load with dual wheel carrying 80 KN load and the design of pavement is based on the standard axle load.

- As per IRC, maximum legal axle load = 8170kg

2. Equivalent single wheel load

- Load over one wheel = 4085kg



3. Stress at any point due to wheel load

- Consider load is transferred over a contact area of radius 'a'

$$p = \frac{P}{A} = \frac{P}{\pi a^2}$$

- Stress at a point at 'z' depth below the ground

BOUSSINESQ'S EQUATION

$$p_z = p\left[1 - \frac{z^3}{(a^2 + z^2)^{3/2}}\right]$$

DESIGN LOAD CONFIGURATION

- **The following effects are considered while computing the design load for pavement design:**
  1. **Traffic volume in each year will increase on the road.**
  2. **Wheel loads are applied over different portions of the pavement and not on the same location.**
  3. **Different vehicles have different weight.**

DESIGN LOAD CONFIGURATION

- **TRAFFIC FORECAST:**
  - In this we estimate total number of commercial vehicles that are going to the road over its design time.

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

where **N** is the cumulative number of commercial vehicles during the design life of road

And **A** is the initial design traffic in vehicles per day in the year of construction

And **n** is the design life of pavement

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

Where **P** is traffic per day at last count

x is construction period in year

r is traffic growth rate

DESIGN LOAD CONFIGURATION

NOTE

- **As per IRC 37:2001, r = 7.5%**
- **As per IRC 37:2012, r = 5%**
- **Design life for NH and SH = 15years (flexible pavement)**
- **Design life for expressways/urban roads = 20years (flexible pavement)**

DESIGN LOAD CONFIGURATION

- **LATERAL DISTRIBUTION OF LOAD**
  - **All commercial vehicles counted during the design life are not taken into account and only a certain percentage of cumulative traffic (M) should be considered for design.**
  - **This is accounted for by taking LANE DISTRIBUTION OR LATERAL DISTRIBUTION FACTOR (LDF)**

FOR SINGLE CARRIAGE WAY/UNDIVIDED		FOR DUAL CARRIAGE WAY	
SINGLE LANE	LDF = 1.0	DUAL TWO LANE	LDF = 0.75
TWO LANE	LDF = 0.75 LDF = 0.50 (IRC2012)	THREE LANE	LDF = 0.60
FOUR LANE	LDF = 0.40	FOUR LANE	LDF = 0.45

- **NOTE : As per IRC 2012**
  - **Considering 50% of total traffic, LDF = 0.5**
  - **Considering 100% of total traffic, LDF = 1.0**

DESIGN LOAD CONFIGURATION

- **VEHICLE DAMAGE FACTOR**
  - **Different commercial vehicles will have different weight hence in order to convert number of commercial vehicles per lane during the design life, i.e., (N×LDF) into equivalent number of cumulative standard axle repetition, i.e., (CSA).**
  - **This is done by VDF.**

$$CSA = N \times LDF \times VDF$$

OR

$$CSA = N \times LDF \times VDF \times 10^{-6} msa$$

msa= million standard axle

$$VDF = \frac{total\ number\ of\ standard\ axle}{total\ vehicles\ surveyed}$$

DESIGN LOAD CONFIGURATION

- **EQUIVALENT AXLE LOAD FACTOR**
  - **80kN single axle is considered as 'standard axle'.**

$$EALF = \left(\frac{P_{kN}}{80}\right)^4$$

  - **An equivalent axle load factor (EALF) defines the damage per pass to a pavement by the i^{th} type of axle relative to the damage per pass of a standard axle load.**
  - **The deformation of pavement due to a single application of axle load may be small but due to repeated application of load there would be accumulation of unrecovered or permanent deformation which results in failure of pavement.**
  - $Total\ number\ of\ repetitions = \sum_{i=1}^{m} n_i f_i$
    - **Where m is number of class intervals**
    - **n_i is number of axles in i^{th} class interval**
    - **f_i is equivalent axle load factor for i^{th} class interval**

- **Traffic volume**
  - It is the measure of Annual average daily traffic, peak-hour traffic.
  - It is denominated by commercial vehicles/day or CVPD.
  - Estimate of the initial daily average traffic flow for any road should normally be based on 7-day 24-hour classified traffic counts.

CLASS	CVPD
Light	<50
Medium	50-300
Heavy	>300

CVPD	Minimum % of vehicles surveyed
<3000	20%
3000-6000	15%
>6000	10%

TRAFFIC AND LOADING

- **There are three different approaches for considering vehicular and traffic characteristics, which affects pavement design:**
  - **Fixed traffic:**
    - **Thickness of pavement is governed by single load and number of load repetitions is not considered.**
    - **The heaviest wheel load anticipated is used for design purpose.**
  - **Fixed vehicle:**
    - **In the fixed vehicle procedure, the thickness is governed by the number of repetitions of a standard axle load.**
    - **If the axle load is not a standard one, then it must be converted to an equivalent axle load by number of repetitions of given axle load and its equivalent axle load factor.**
  - **Variable traffic and vehicle:**
    - **In this approach, both traffic and vehicle are considered individually.**
    - **The traffic and loading factors to be considered include axle loads, load repetitions, and tyre contact area.**

DESIGN OF FLEXIBLE PAVEMENT

- **Empirical design**
  - **Eg. CBR test, Group Index Test**
- **Semi-Empirical Design**
  - **Eg. Triaxial Method**
- **Theoretical Approach**
  - **Eg. Burmister Method**

EQUIVALENT SINGLE WHEEL LOAD (ESWL)

- **To carry maximum load with in the specified limit and to carry greater load, dual wheel, or dual tandem assembly is often used.**
- **Equivalent single wheel load (ESWL) is the single wheel load having the same contact pressure, which produces same value of maximum stress, deflection, tensile stress or contact pressure at the desired depth.**
- **Assumptions:**
  - **equalancy concept is based on equal stress**
  - **contact area is circular**
  - **influence angle is 45°**
  - **soil medium is elastic, homogeneous, and isotropic half space.**

CBR TEST

- CBR test is used to determine the material properties for pavement design.
- Maximum value pf CBR for any material is 100.
- It is a penetration test wherein a standard piston, having an area of $3in^2$(or 50 mm diameter), is used to penetrate the soil at a standard rate of 1.25 mm/minute.
- The pressure up to a penetration of 12.5 mm and its ratio to the bearing value of a standard crushed rock is termed as the CBR.
- In most cases, CBR decreases as the penetration increases.
- The ratio at 2.5 mm penetration is used as the CBR.
- The CBR is a measure of resistance of a material to penetration of standard plunger under controlled density and moisture conditions.

CBR TEST

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

PENETRATION	STANDARD LOAD
2.5mm	1370kg
5mm	2055kg

GROUP INDEX TEST

- **Group Index is a number assigned to the soil based on its physical properties like particle size, Liquid limit and plastic limit.**
- **It varies from a value of 0 to 20, lower the value higher is the quality of the sub-grade and greater the value, poor is the sub-grade.**

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

Where

- **a= percentage of soil passing 0.074 mm sieve in excess of 35 per cent, not exceeding 75.**
- **b= percentage of soil passing 0.074 mm sieve in excess of 15 per cent, not exceeding 55**
- **c= Liquid limit in per cent in excess of 40.**
- **d= Plasticity index in excess of 10.**

GROUP INDEX TEST

- **Group index of soil subgrade**
  - Group index value range of different soils is given below
  1. For good soil – 0 to 1
  2. For fair soil – 2 to 4
  3. For poor soil – 5 to 9
  4. For very poor soil – 10 to 20

CALIFORNIA RESISTANCE VALUE METHOD

- This method is based on stabilometer (R) value and cohesionometer (C) value.
- Greater the value of R and C, better the quality of soil.
- These two values are obtained for each layer of pavement material separately from test.
- Thickness of pavement is given by –

$$t = \frac{k(TI)(90 - R)}{C^{1/5}}$$

  - Where t is thickness of pavement in cm

    k is constant having value 0.166

    TI is traffic index $TI = 1.35EWL^{0.11}$

    EWL = Equivalent Wheel Load = $\Sigma AADT(EWL)_{constant}$

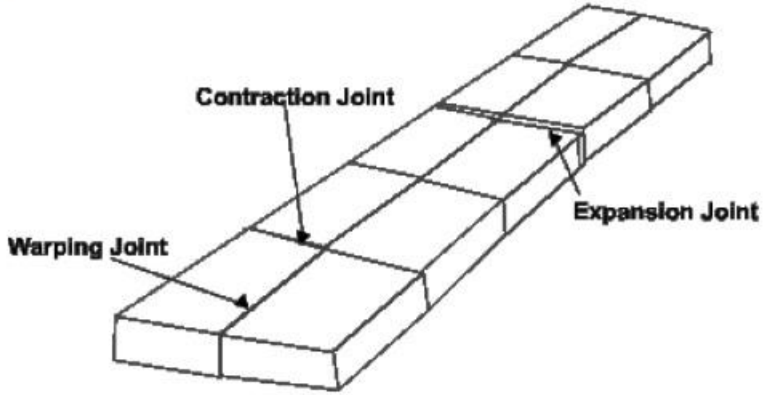
CALIFORNIA RESISTANCE VALUE METHOD

EWL = Equivalent Wheel Load = $\Sigma AADT(EWL)_{constant}$

NUMBER OF AXLE	EWL
2	330
3	1070
4	2460
5	4620

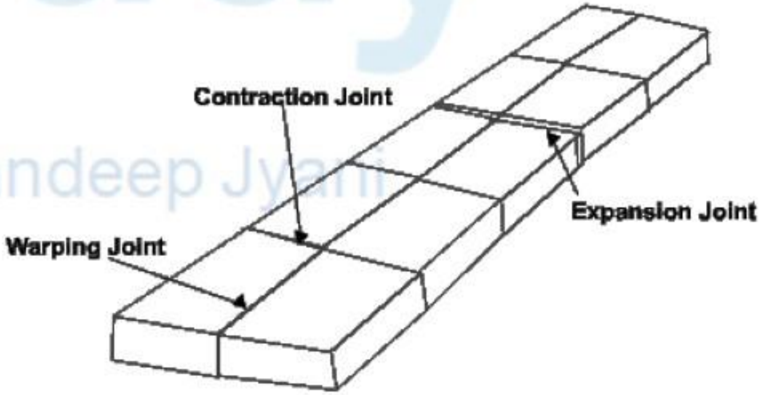
TYPES OF JOINTS IN CEMENT CONCRETE PAVEMENTS

- **Joints are the discontinuities in the concrete pavement slab, and help to release stresses due to temperature variation, subgrade moisture variation, shrinkage of concrete etc.**
- **These joints could be extended to the full or partial depth of the slab. Sometimes iron bars are provided across the joints, the iron bars along the longitudinal joints are called tie bars and along the transverse joints are called dowel bars.**
- **Various types of joints in cement concrete pavement are:**
  1. **Transverse joints**
     1. **Expansion joints**
     2. **Contraction joints**
     3. **Construction joints**
  2. **Longitudinal joints**
     1. **Warping joint**



TYPES OF JOINTS IN CEMENT CONCRETE PAVEMENTS

- **Contraction joint:**
  - Contraction joints are provided along the transverse direction to take care of the contraction of concrete slab due to its natural shrinkage.
- **Construction joint:**
  - Construction joints are provided whenever the construction work stops temporarily.
  - The joint direction could be either along the transverse or longitudinal direction.
- **Expansion joint:**
  - Expansion joints are provided along the transverse direction to allow movement (expansion/ contraction) of the concrete slab due to temperature and subgrade moisture variation.
- **Warping joint:**
  - Warping joints are provided along the longitudinal direction to prevent warping of the concrete slab due to temperature and subgrade moisture variation.



IRC RECOMMENDATIONS FOR JOINTS

Types of Joint	Maximum Spacing between joints
Expansion	140m
Contraction	4.5m

TRAFFIC CHARACTERISTIC STUDY

- **ROAD USER CHARACTERISTICS**
  - **In this mental, physical, psychological and environmental study of road user in carried out.**

1. **PHYSICAL-**
   - **They are either permanent or temporary.**
   - **Permanent characteristics are vision, hearing, strength and general reaction to traffic situations.**
   - **Eg. PIEV Theory (The reaction time is estimated based on PIEV theory)**
   - **P stands for Perception**
   - **I stands for Intellection**
   - **E stands for Emotion**
   - **V stands for Volition**
   - **Temporary characteristics are fatigue, alcohol or drugs and illness.**
   - **All of these reduce alertness and increase the reaction time and also do affect the quality of judgement in some situations.**

TRAFFIC CHARACTERISTIC STUDY

- **ROAD USER CHARACTERISTICS**
  - **In this mental, physical, psychological and environmental study of road user in carried out.**

    2. **MENTAL**
       - **Knowledge, skill, intelligence, experience and literacy of the driver.**
    3. **PSYCHOLOGICAL**
       - **Emotional factors like attentiveness, fear, anger, superstitious impatience etc.**
    4. **ENVIRONMENTAL**
       - **Traffic stream characteristics, roadside features, atmospheric conditions and locality**

TRAFFIC CHARACTERISTIC STUDY

- **Vehicular characteristic study:**
  - **The length, width, height and weight of vehicle is studied.**

- **Braking characteristic study:**
  - **The spacing between two-consecutive vehicles and SSD are effected by braking characteristic.**
  - **To study the braking characteristic braking test is conducted the skid resistance of the pavement.**
  - **BRAKING TEST : Atleast two of the following 3 measurements are required to calculate value of 'u'**
    - **initial velocity (v)**
    - **Braking length (l)**
    - **Actual duration of brake application (t_0)**

TRAFFIC CHARACTERISTIC STUDY

- BRAKING CHARACTERISTICS:
  - When breaking length (l) and initial velocity (v) is known

$$\mu = \frac{v^2}{2gl}$$

  - When initial speed (v) and actual duration (t_o) of brake application is known

$$\mu = \frac{v}{g\, t_0}$$

  - When braking length (l) and actual duration (t_o) of brake application is known

$$\mu = \frac{2l}{g t_0^2}$$

Note:- $\eta_{braking} = \frac{\mu_{braking\ test}}{\mu_{\max\ known}}$

TRAFFIC ANALYSIS AND STUDY

- Traffic engineering studies are carried out to analyze the traffic characteristics and their movements along the identified roads.
- These help in design of geometric features and traffic control measures for safe and efficient traffic movement.
- Traffic survey is carried out to collect traffic data and is called "Traffic seasons"
- Various traffic engineering studies are:
  - Traffic volume studies
  - Spot speed studies
  - Speed and delay studies
  - Origin and destination studies
  - Parking studies
  - Accident studies

TRAFFIC ANALYSIS AND STUDY

- **Traffic volume studies**
  - Traffic volume (or) flow is the number of vehicles crossing a point on a road in unit time.
  - It is used to measure the quantity of traffic flow and is expressed as "Vehicles per hour (or) PCU per hour."
  - Complete Traffic volume study includes:
    - Classified volume study: no. of different type of vehicles are counted.
    - Directional study: distribution of traffic on different lanes is calculated. Turning moment study at intersection
    - Turning moment study: done for intersection design.
    - Pedestrian volume study: helps in planning subways, foot bridge and in pedestrian signal timing.

TRAFFIC ANALYSIS AND STUDY

- **Representation of Traffic volume study data;**
  - **AADT (Average Annual Daily Traffic):**
    - **It is the average 24 hour volume at a location calculated over 365 days.**
    - **It includes seasonal variation of traffic.**
    - **Calculation of AADT:**
      - **AADT is estimated using periodic volume counts and pre established expansion factors-**

1. **Hourly Expansion Factor (HEF) =** $\dfrac{24hour\ traffic\ volume}{hourly\ volume\ of\ that\ particular\ hour}$
2. **Daily Expansion Factor (HEF) =** $\dfrac{weekly\ traffic\ volume}{average\ 24hour\ volume\ of\ that\ day}$
3. **ADT =** $\dfrac{weekly\ volume}{7}$
4. **Monthly Expansion Factor (HEF) =** $\dfrac{AADT}{ADT\ of\ that\ month}$

TRAFFIC ANALYSIS AND STUDY

- **Representation of Traffic volume study data:**
  - ADT (Average daily traffic):
    - It includes weekly variation of Traffic.
    - Minimum 7 days count is done.
  - Trend chart:
    - Volume trend over a period of year is calculated.
    - It is helpful in planning expansion, design and regulation.
  - TRAFFIC FLOW MAP ALONG THE ROUTE:
    - It gives an idea of traffic at a lane.
    - Thickness of line represents traffic volume.
  - 30^{th} HIGHEST HOURLY VOLUME:
    - It is taken as design hourly volume (or) design capacity. It is exceeded or 29 times in a year.

TRAFFIC SPEED STUDY

- TRAFFIC SPEED STUDY
  - Speed of different vehicles varies w.r.t time and space, hence represent these variations, various speeds are defined.

1. **Spot speed :**
   - **It is the instantaneous speed of a vehicle at a particular location**
   - **Spot speed is used in design of horizontal curves, vertical curves, traffic signal, traffic signs (size) and also in accident analysis.**
   - **It is measured wing “Enoscope”, “Pressure contact Tubes”, “Doppler Radar” and “loop deflector”**

TRAFFIC SPEED STUDY

- **TRAFFIC SPEED STUDY**

  2. **Average Speed:**
     - **It is the average of spot speeds of vehicles.**
     - **It is classified as:**

     a) **Time mean speed (V_t)**
        - **It is the average of spot speed of vehicles at a point taken over of time i.e, speed distribution of vehicles at a point on the roadway.**
        - **It is the Arithmetic mean of spot speed of vehicles passing a given point on a Highway in a given interval of time.**
        - $V_t = \frac{\sum_i^n V_i}{n}$
          - **n is no. of vehicles crossing the location in a given interval of time**
          - **V_i is spot speed of i^{th} vehicle at that location**

TRAFFIC SPEED STUDY

- **TRAFFIC SPEED STUDY**

  2. Average Speed:

  b. Space mean speed (V):

  - **It represents the average speed of vehicles in a certain road length at any time.**
  - **This is obtained from the observed travel time of the vehicle over a stretch of road.**
  - $V_s = \frac{3.6dn}{\sum_i^n t_i}$

  Where

  d is the length of road in m

  n is the number of individual vehicle observations

  t_i is the observed time of travel(sec)

TRAFFIC SPEED STUDY

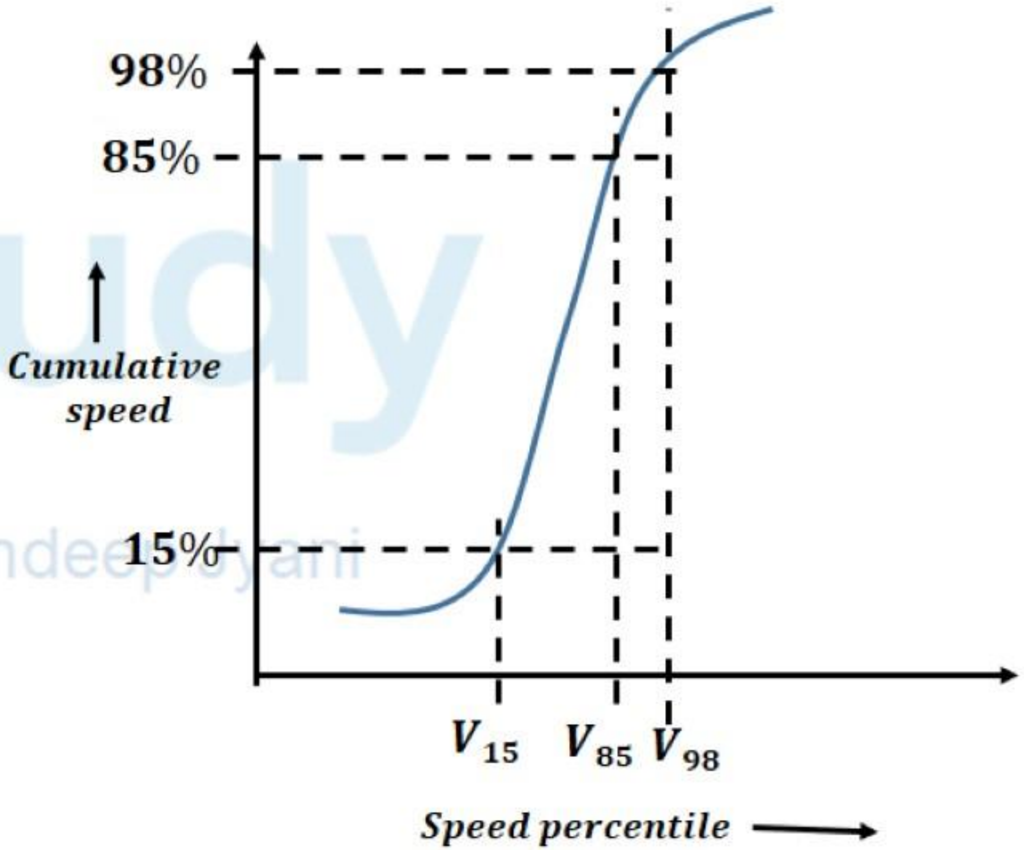
- **TRAFFIC SPEED STUDY**

  3. **RUNNING SPEED**
     - **This speed excludes stop delays.**
     - **It is used to analyse the road condition.**
     - $\boldsymbol{Running\ Speed = \frac{length}{running\ time}}$

  4. **JOURNEY TIME**
     - **This speed includes stop delays**
     - **It is used to analyse traffic flow condition.**
     - $\boldsymbol{Journey\ Speed = \frac{length}{journey\ time}}$

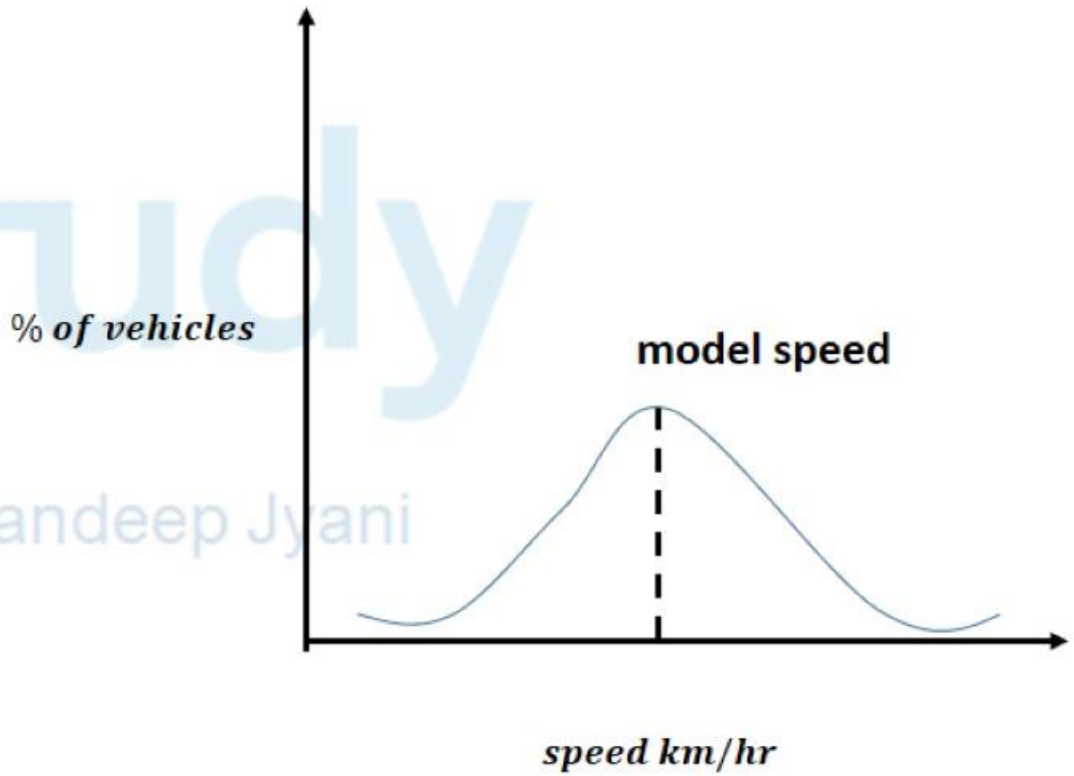
TYPES OF SPOT SPEED STUDIES

1. **CUMMULATIVE SPEED DISTRIBUTION DIAGRAM**
   - In highway geometric design, cumulative speed distribution is drawn and design is checked at 98th percentile.
2. **98th PERCENTILE SPEED**
   - It is the speed at or below which 98% of vehicles are moving.
3. **85th PERCENTILE SPEED**
   - It is the speed at or below which 85% of vehicles are moving.
4. **15th PERCENTILE SPEED**
   - It is the speed at or below which 15% of vehicles are moving.
   - It is taken as lower limit of speed.
   - Efforts are made to segregate traffic moving with a speed lower than V_{15} to avoid congestion.



TYPES OF SPOT SPEED STUDIES

- **FREQUENCY DISTRIBUTION DIAGRAM:**
  - **Speed data can be used to determine the speed at which largest % of vehicles are moving.**
  - **This speed is called model speed.**
  - **It is obtained by plotting the average speed of each speed interval against % of vehicles in that speed interval.**



TRAFFIC SPEED STUDY

- **SPEED AND DELAY STUDIES:**
  - **It is useful in identifying location of congestion, the causes and in arriving at a suitable improvement measures to reduce the delays or increase the travel speed.**
  - **These studies also find the travel time before and after the proposed improvements.**
  - **Methods of conducting speed and delay studies:**
    - **Floating car method**
    - **License plate method**
    - **Interview technique**
    - **Elevated observations**
    - **Photographic technique**

TRAFFIC SPEED STUDY

- **FLOATING CAR METHOD**
  - **Floating car data are positions of vehicles traversing city streets throughout the day.**
  - **In this method the driver tries to float in the traffic stream passing as many vehicles as pass the test car.**
  - **If the test vehicle overtakes as many vehicles as the test vehicle is passed by, the test vehicles should, with sufficient number of runs, approach the median speed of the traffic movement on the route.**
  - **In such a test vehicle, one passenger acts as observer while another records duration of delays and the actual elapsed time of passing control points along the route from start to finish of the run.**

$$q = \frac{n_a + n_y}{t_a + t_w}$$

Where q is flow of vehicles(volume per min) in one direction of stream

- n_a **is average number of vehicles counted in the direction of the stream q when the test vehicle travels in the opposite direction or against the stream**
- n_y **is average number of vehicles overtaking the test vehicle minus the number of vehicles overtaken when tests is in the direction of the stream q**
- t_a **is average journey time (min), when test vehicle is running against the stream q.**
- t_w **is average journey time (min), when test vehicle is running with the stream q.**

TRAFFIC SPEED STUDY

- **LICENCE PLATE METHOD**
  - **In this method, synchronized stop watches/timers or voice recording equipment are used.**
  - **Observers are stationed at the entrance and exit of the test stretch where information of travel time is required.**
  - **The timings and the vehicle numbers are noted by the observers of the selected sample of vehicles in the stream.**
  - **This method does not give the details like causes, number and duration of delays.**

TRAFFIC SPEED STUDY

- **INTERVIEW METHOD**
  - This method may be useful where a large amount of material is needed in minimum time and at little expense for field observation.
  - The work can be completed in a short period of time by interviewing and collecting the required details from the road users on the spot.
- **ELEVATED OBSERVER METHOD and PHOTOGRAPHIC METHOD:**
  - In urban areas, it is sometime possible to station observers in high buildings or other elevated points from which a considerable length of route may be observed.
  - With the help of cameras and video equipment, observations are taken.
  - These investigator select vehicle at random and record; time, location and causes-of-delay.
  - The drawback is that it is sometime difficult to secure suitable points for observation throughout the length of the route to be studied.

TRAFFIC SPEED STUDY

- **ORIGIN AND DESTINATION STUDY:**
  - **It determines the information like duration of travel, selection of route and length of route.**
  - **These studies help in planning new highways and improving the existing services.**
  - **Methods :**
    - **Road side interview method**
    - **License plate method**
    - **Return post card method**
    - **Tag on car method**
    - **Home interview method**
    - **Work spot interview method**
  - **O & D data are represented in the form of desire lines (thickness of line represents number of trips), pie charts (dia of circle represents traffic volume) and contour lines.**

TRAFFIC CAPACITY STUDY

- **TRAFFIC VOLUME(q):**
  - **It is the number of vehicles crossing a given point in unit time.**
  - **It is measured in PCU/hr or Veh/hr.**
- **TRAFFIC DENSITY(k):**
  - **It is the total number of vehicles occupying unit length of road at a given time.**
  - **It is expressed in Veh/km.**
  - **Highest traffic density will occur when the vehicles are practically standing still on a given road or traffic flow is zero.**

TRAFFIC CAPACITY STUDY

- TIME HEADWAY
  - Time interval between the passes of rear bumper of successive vehicles at a point.

$$q = \frac{1}{average\ time\ headway}$$

- SPACE HEADWAY:
  - It is the distance between rear bumpers of successive vehicles.

$$k = \frac{1}{average\ space\ headway}$$

TRAFFIC CAPACITY

- **Traffic Capacity:**
  - It is the ability of the road to accommodate traffic volume.
  - Volume and capacity have same units, but capacity means maximum volume for a particular level of surveys whereas volume represents the actual rate of flow.
  - Traffic capacity is categorized as:
    - Basic capacity
    - Possible capacity
    - Practical capacity

TRAFFIC CAPACITY

- **Basic Capacity**
  - It is the maximum no of vehicles that can pass a given point in a unit time under ideal road ways and Traffic condition.
  - It is also called theoretical capacity.
- **Possible capacity :**
  - It is the capacity under prevailing condition.
- **Practical Capacity**
  - Since the possible capacity can vary between zero and basic capacity, for design purpose we adopt a in between value such that the traffic density is not so high as to cause unreasonable delay & restrictions, such capacity is called practical capacity (or) Design capacity.

VALUES FOR THEORETICAL MAXIMUM CAPACITY

- **FROM SPACE HEADWAY:**

$$C = \frac{1000V}{S}$$

  - **Where C is capacity in veh/hr corresponding to speed V km/hr**
  - **S is the minimum space headway in metres.**
  - $S = 0.7v + L$
    - **Where v is speed in m/sec and v=0.278v**
    - **S = SSD + L (from approximation)**

Space Headway increases with velocity

VALUES FOR THEORETICAL MAXIMUM CAPACITY

- **FROM TIME HEADWAY:**

$$C = \frac{3600}{h_t}$$

  - **Where C is capacity in veh/hr corresponding to speed V km/hr**
  - **h_t is minimum time headway(in seconds)**

Time Headway first decreases then increases with velocity

LINE OF SERVICE

- **Capacity is a quantitative measure of flow, where as Line of Service is a qualitative measure of flow.**
- **It tries to explain how good the preset traffic conditions are and is defined from measure of effectiveness which considers 3 parameters:**
  - **Speed and travel time**
  - **Density**
  - **Delay**
- **Highway capacity manual classifies 6 level of service:**
  - **LOS – A**
  - **LOS – B**
  - **LOS – C**
  - **LOS – D**
  - **LOS – E**
  - **LOS – F**

TRAFFIC SPEED STUDY

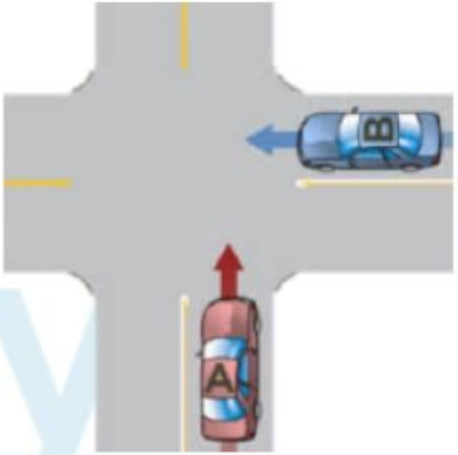
- **PARKING STUDIES:**
  - **Parking surveys are intended to provide all these information. Since the duration of parking varies with different vehicles, several statistics are used to access the parking need.**
  - **Types of parking –**
    - **Off street parking**
    - **In street parking**

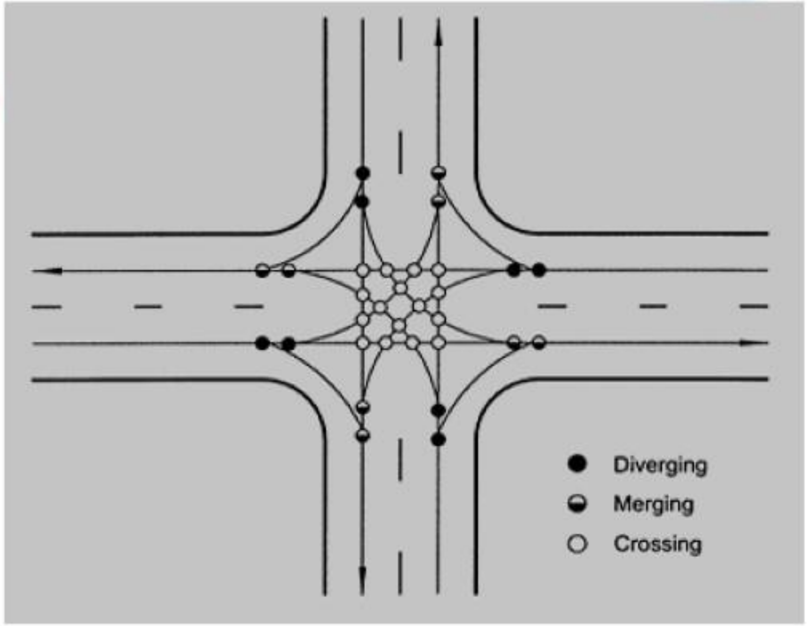
TRAFFIC SPEED STUDY

- **ACCIDENTAL STUDIES**
  - **Some objectives of accident studies are listed below:**
    - **To study the causes of accidents and suggest corrective measures at potential location**
    - **To evaluate existing design**
    - **To compute the financial losses incurred**
    - **To support the proposed design and provide economic justification to the improvement suggested by the traffic engineer**
    - **To carry out before and after studies and to demonstrate the improvement in the problem.**
  - **Various records are maintained in this study-**
    - **Location file**
    - **Spot map**
    - **Conditioned diagram**
    - **Collision diagram**

TRAFFIC CONTROL AND REGULATION

- **TRAFFIC INTERSECTION:**
  - **Intersection is an area where two or more roads joins or crosses.**
  - **In traffic intersection change in direction of movement may occur.**
  - **Various conflicts due to traffic intersection are as follows:**
    - **Crossing conflict**
    - **Merging conflicts**
    - **Diverging conflicts**





TRAFFIC CONTROL AND REGULATION

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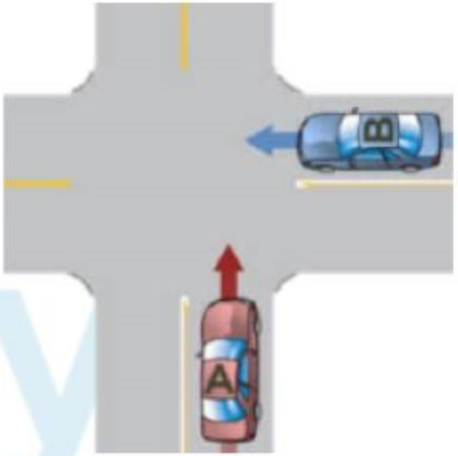
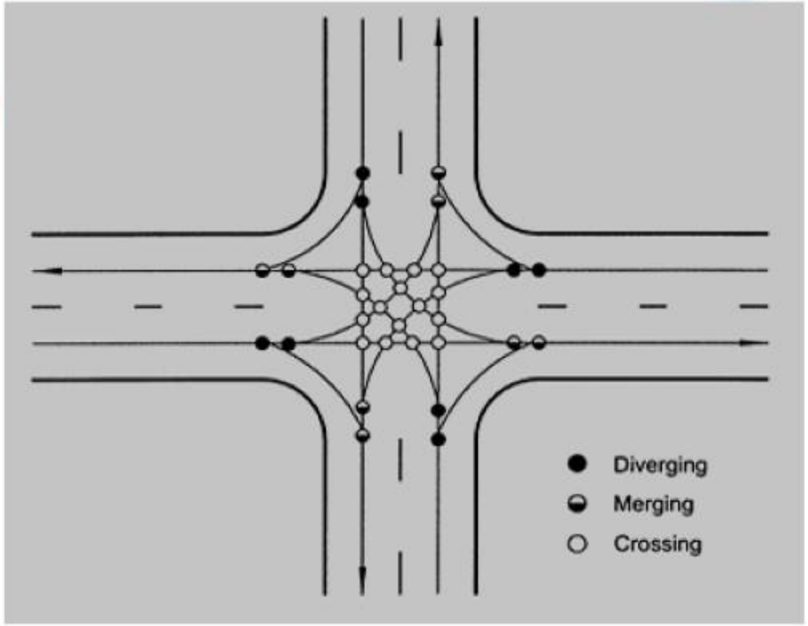
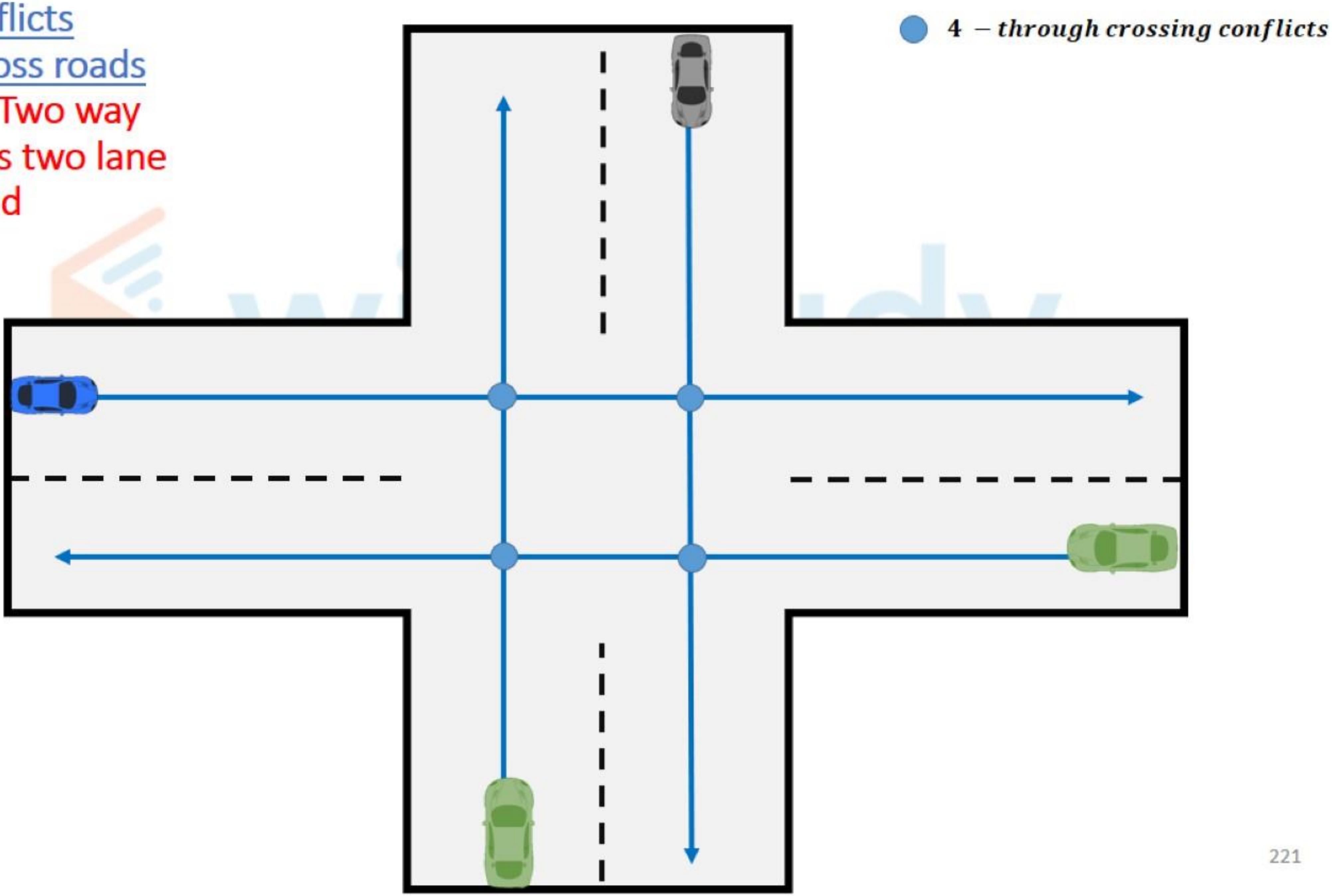




Various Conflicts between Cross roads

1. Two lane Two way Road crosses two lane two way road



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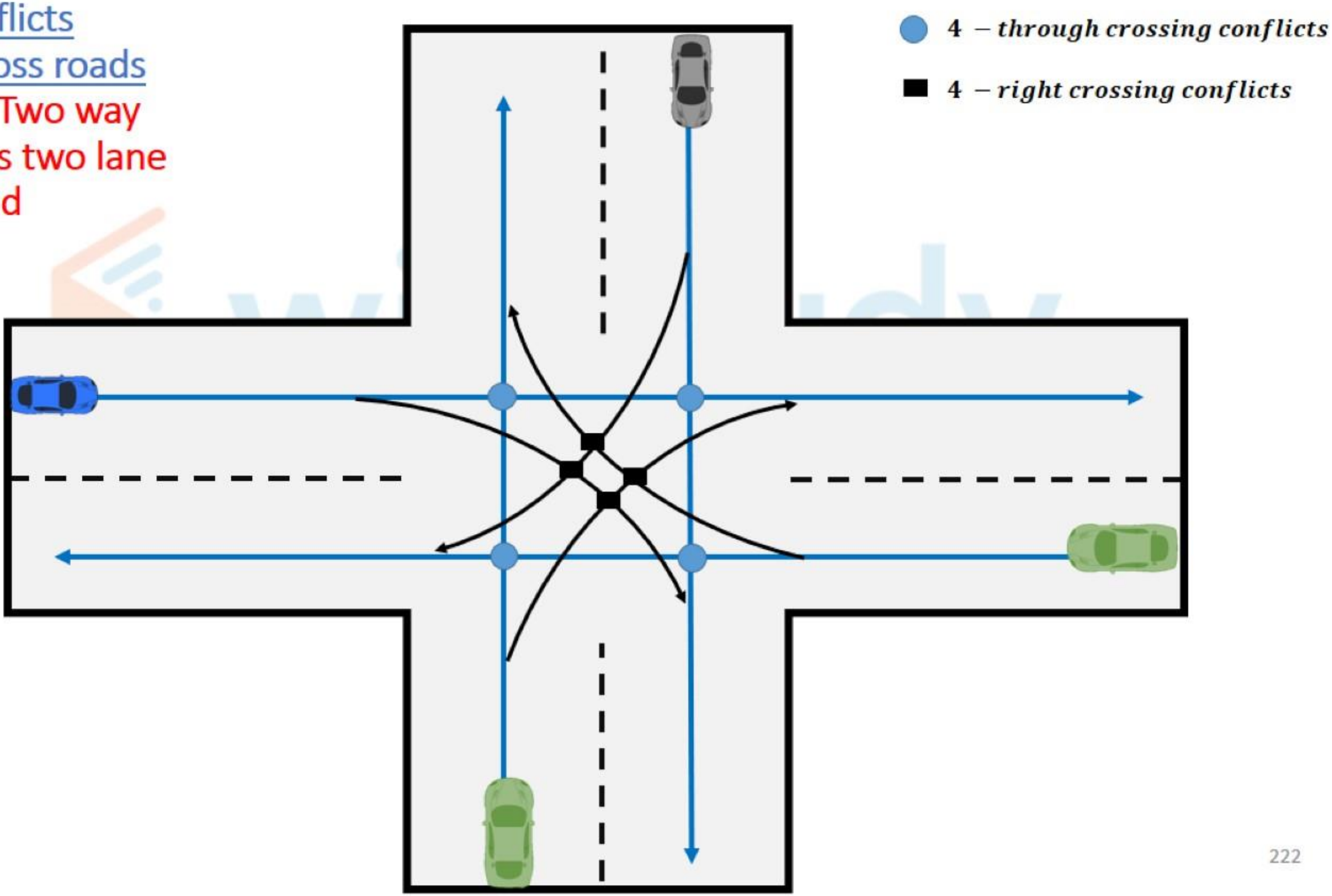

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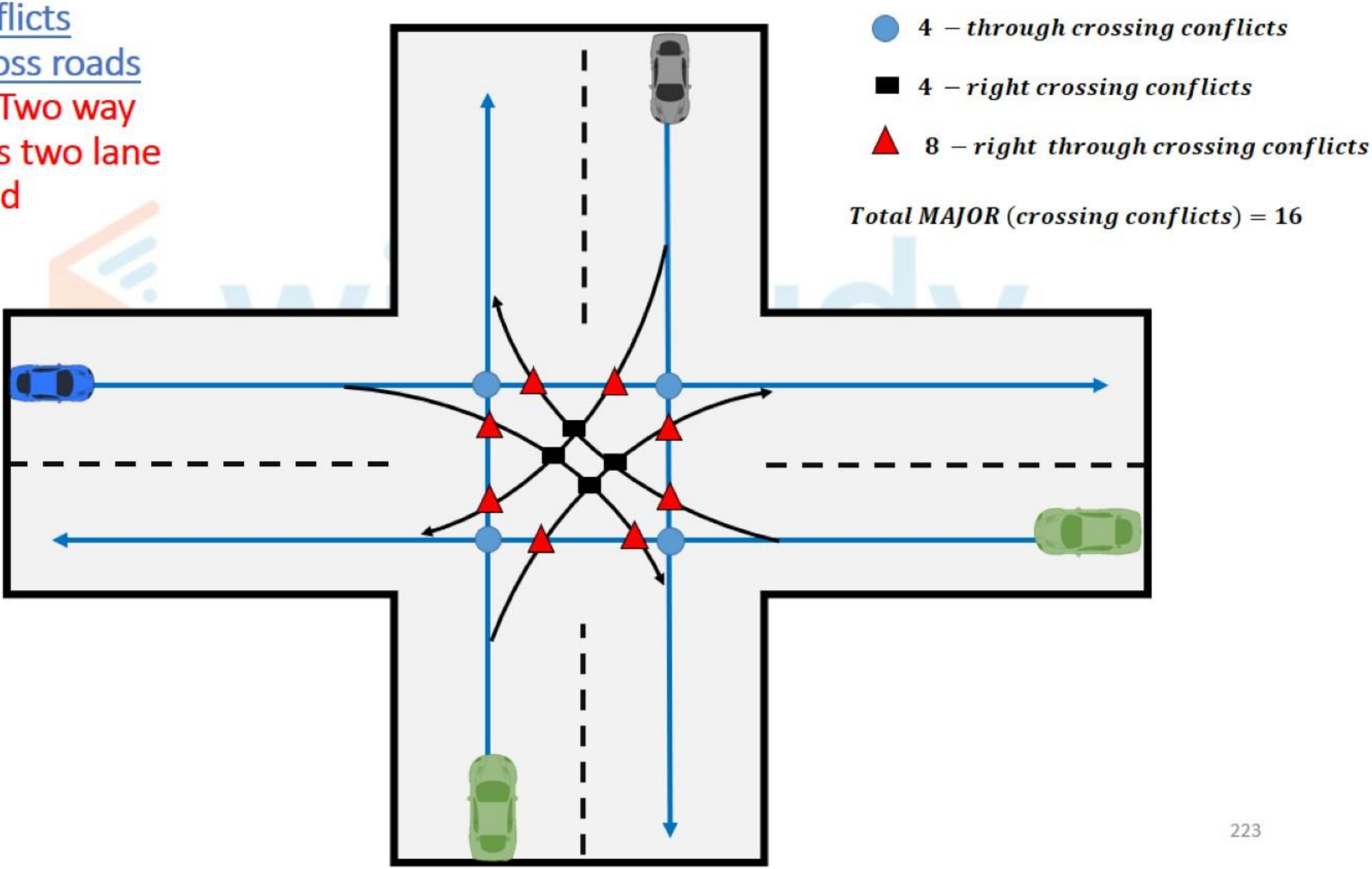

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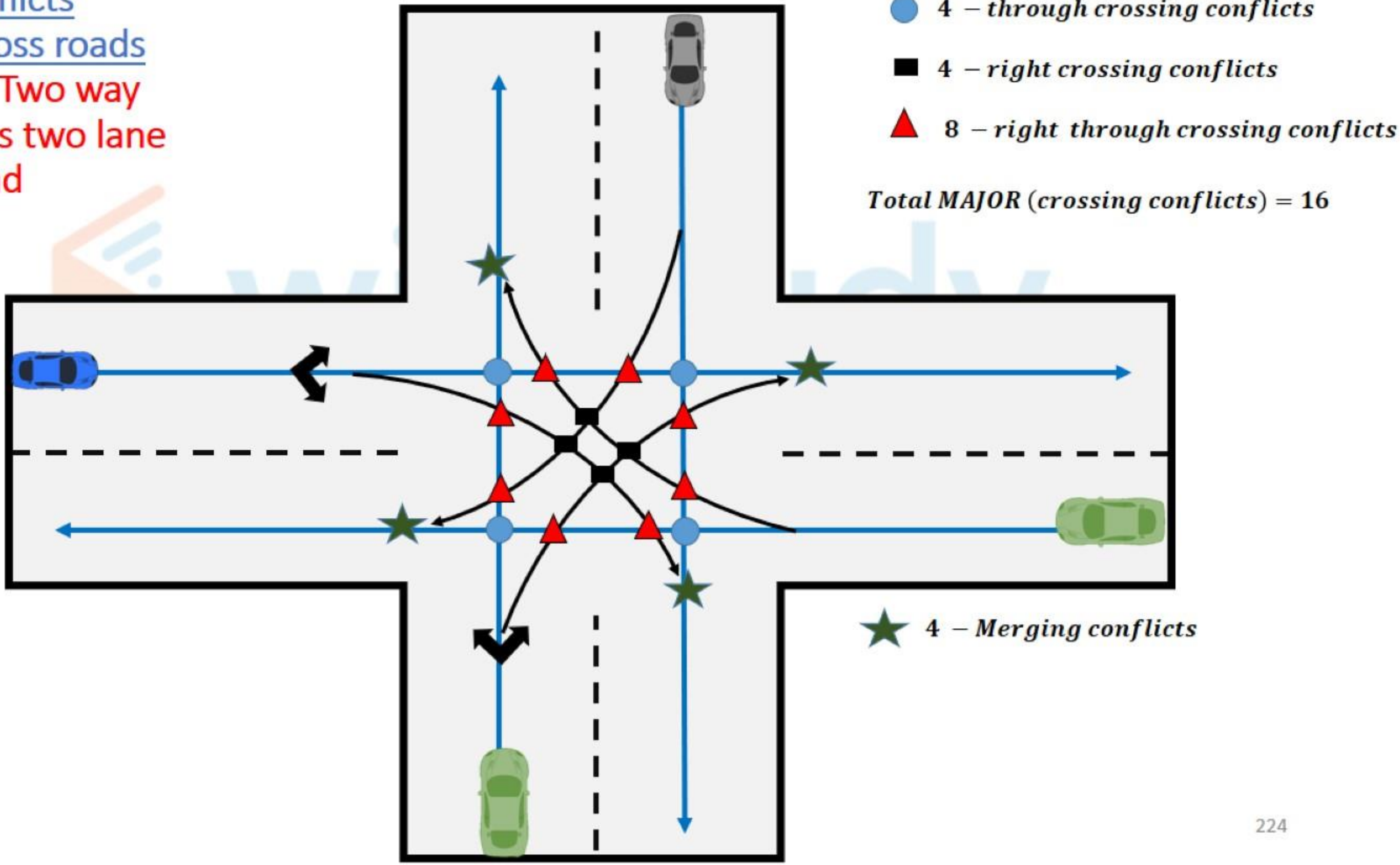

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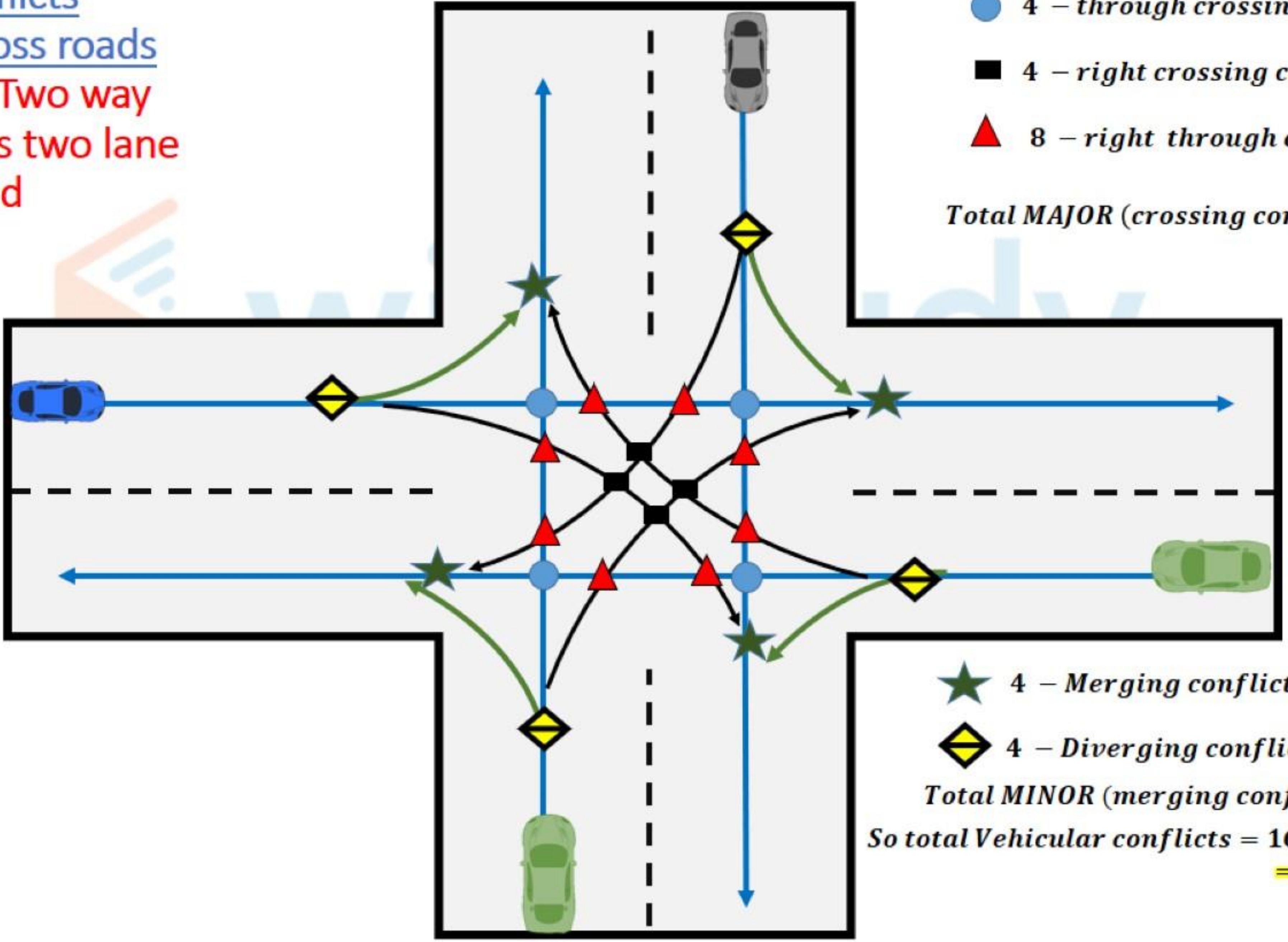


4 – *through crossing conflicts*

4 – *right crossing conflicts*

8 – *right through crossing conflicts*

Total MAJOR (crossing conflicts) = 16

4 – *Merging conflicts*

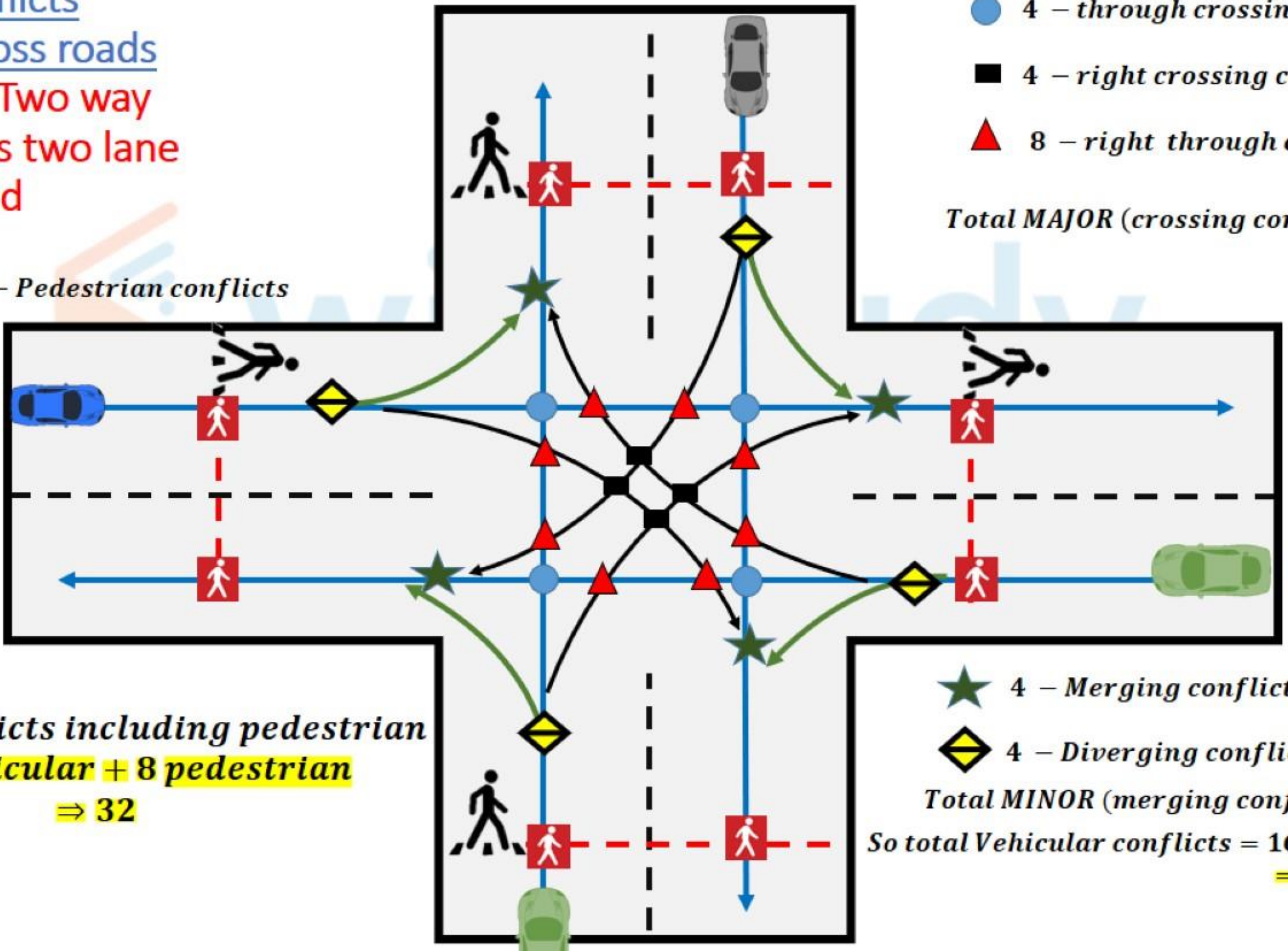
4 – *Diverging conflicts*

Total MINOR (merging conflicts = 8)

So total Vehicular conflicts = 16*major* + 8*minor* = 24

Various Conflicts between Cross roads

1. Two lane Two way Road crosses two lane two way road



8 – *Pedestrian conflicts*

4 – *through crossing conflicts*

4 – *right crossing conflicts*

8 – *right through crossing conflicts*

Total MAJOR (crossing conflicts) = 16

4 – *Merging conflicts*

4 – *Diverging conflicts*

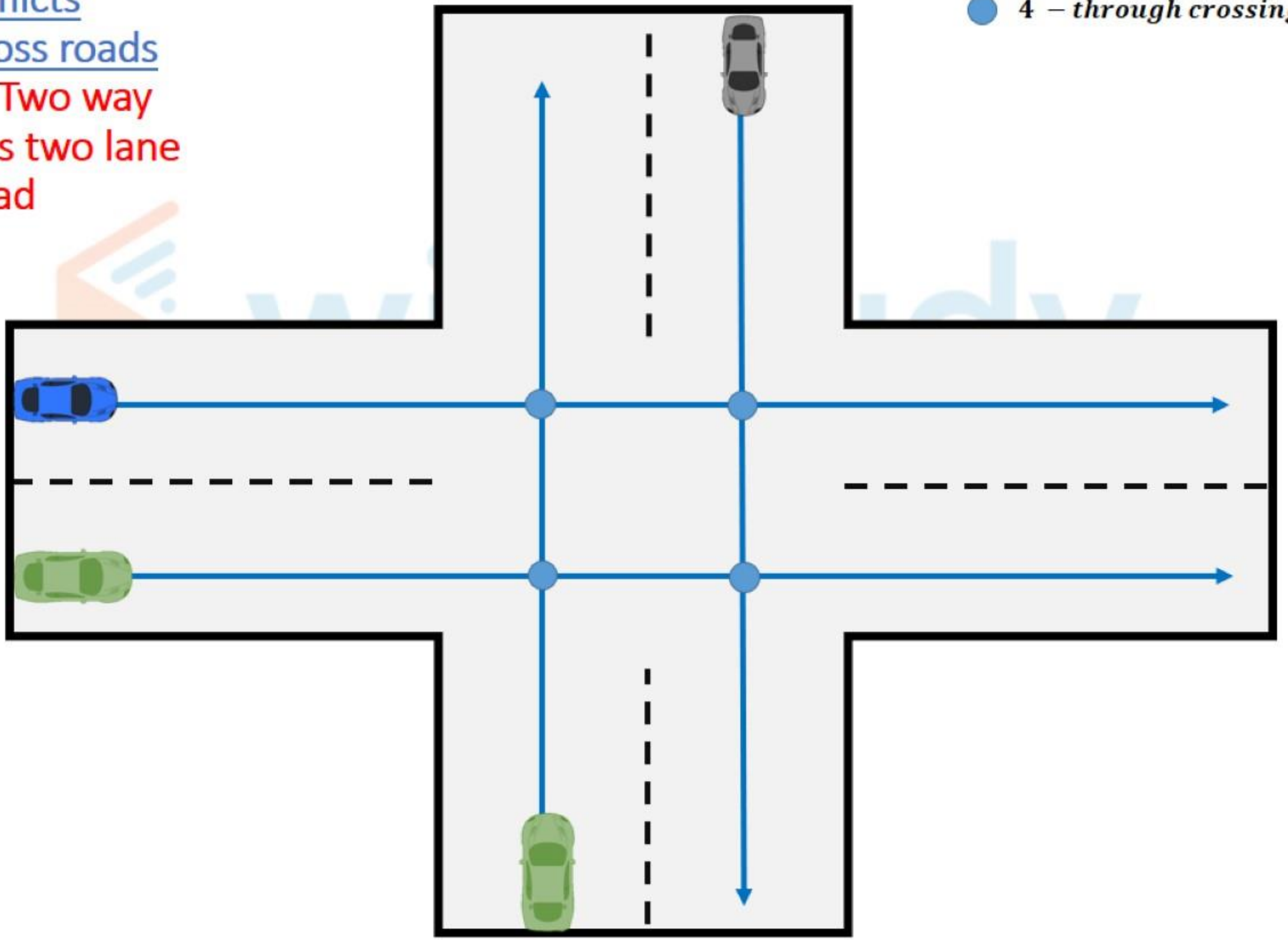
Total MINOR (merging conflicts = 8)

So total Vehicular conflicts = 16major + 8minor
= 24

So total conflicts including pedestrian
⇒ 24 *vehicular* + 8 *pedestrian*
⇒ 32

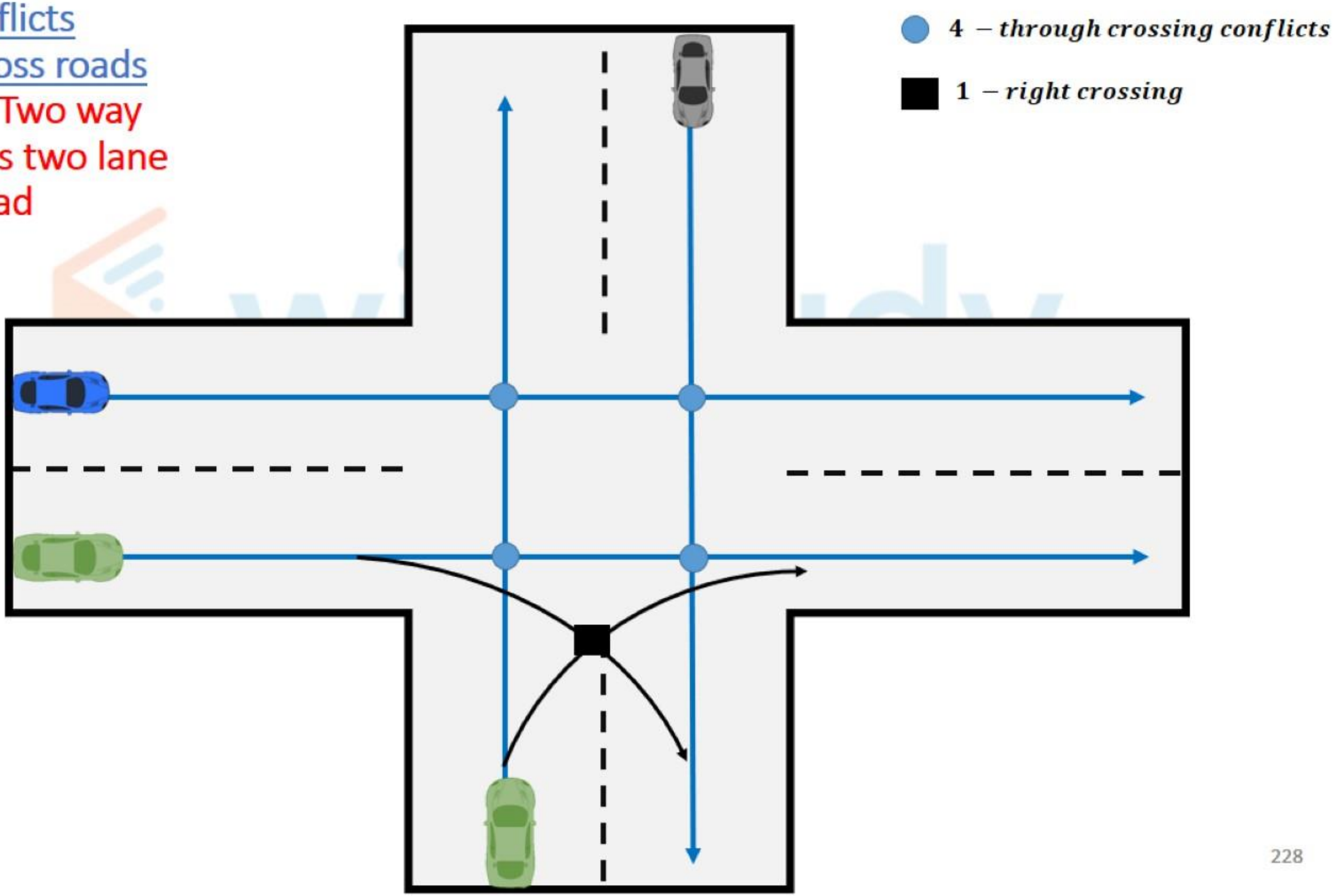
Various Conflicts between Cross roads

2. Two lane Two way Road crosses two lane ONE way road



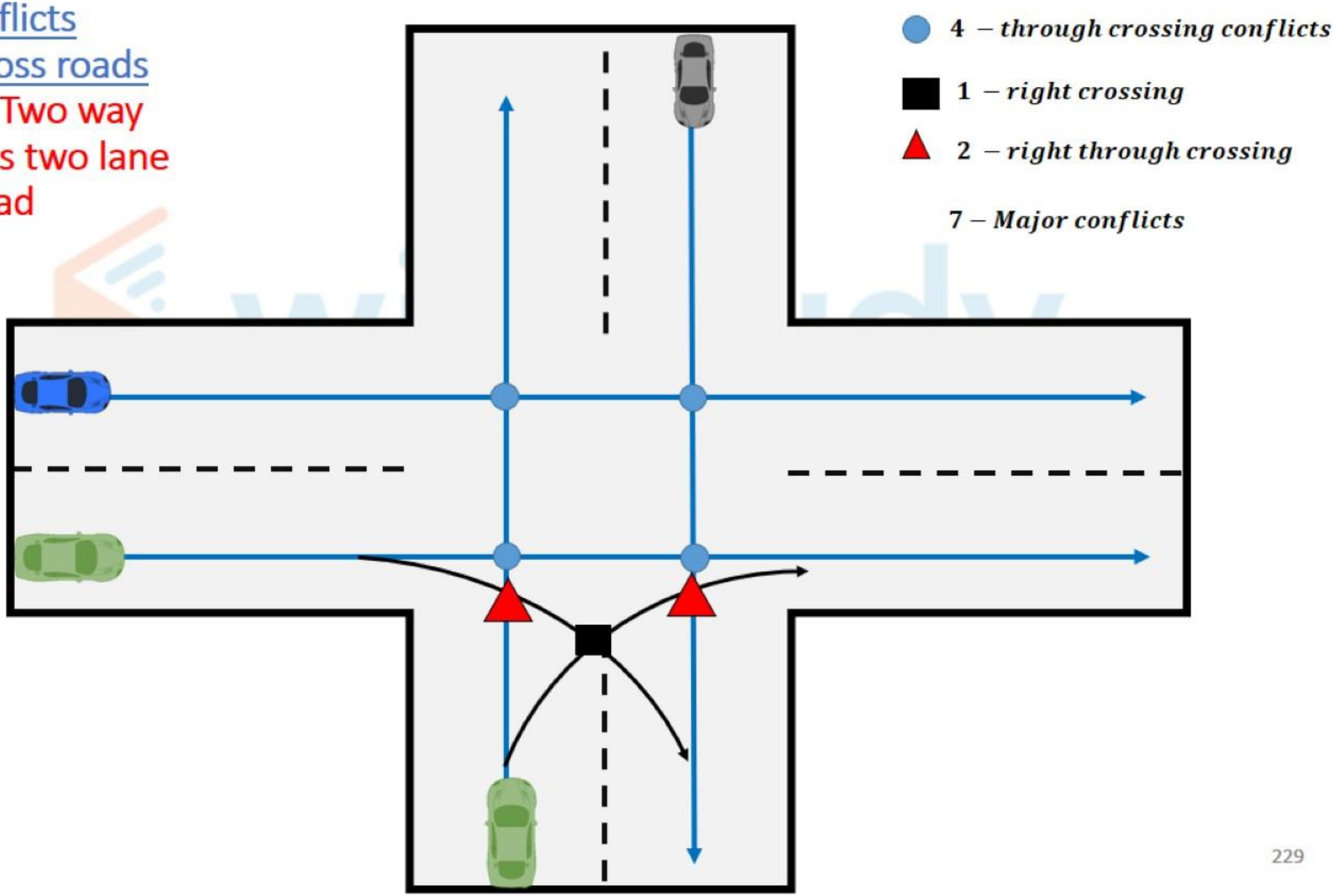
Various Conflicts between Cross roads

2. Two lane Two way Road crosses two lane ONE way road



Various Conflicts between Cross roads

2. Two lane Two way Road crosses two lane ONE way road



Various Conflicts between Cross roads

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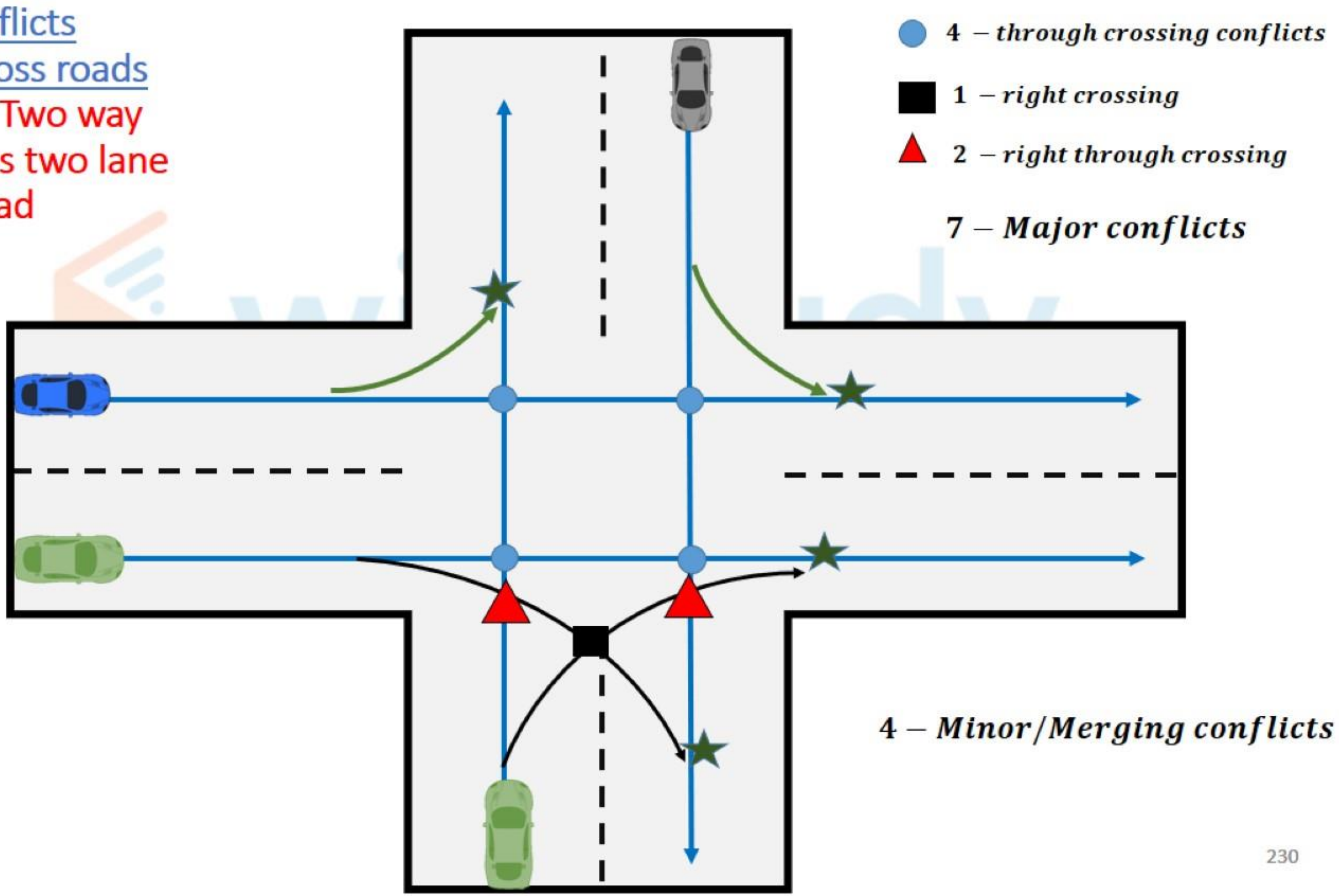
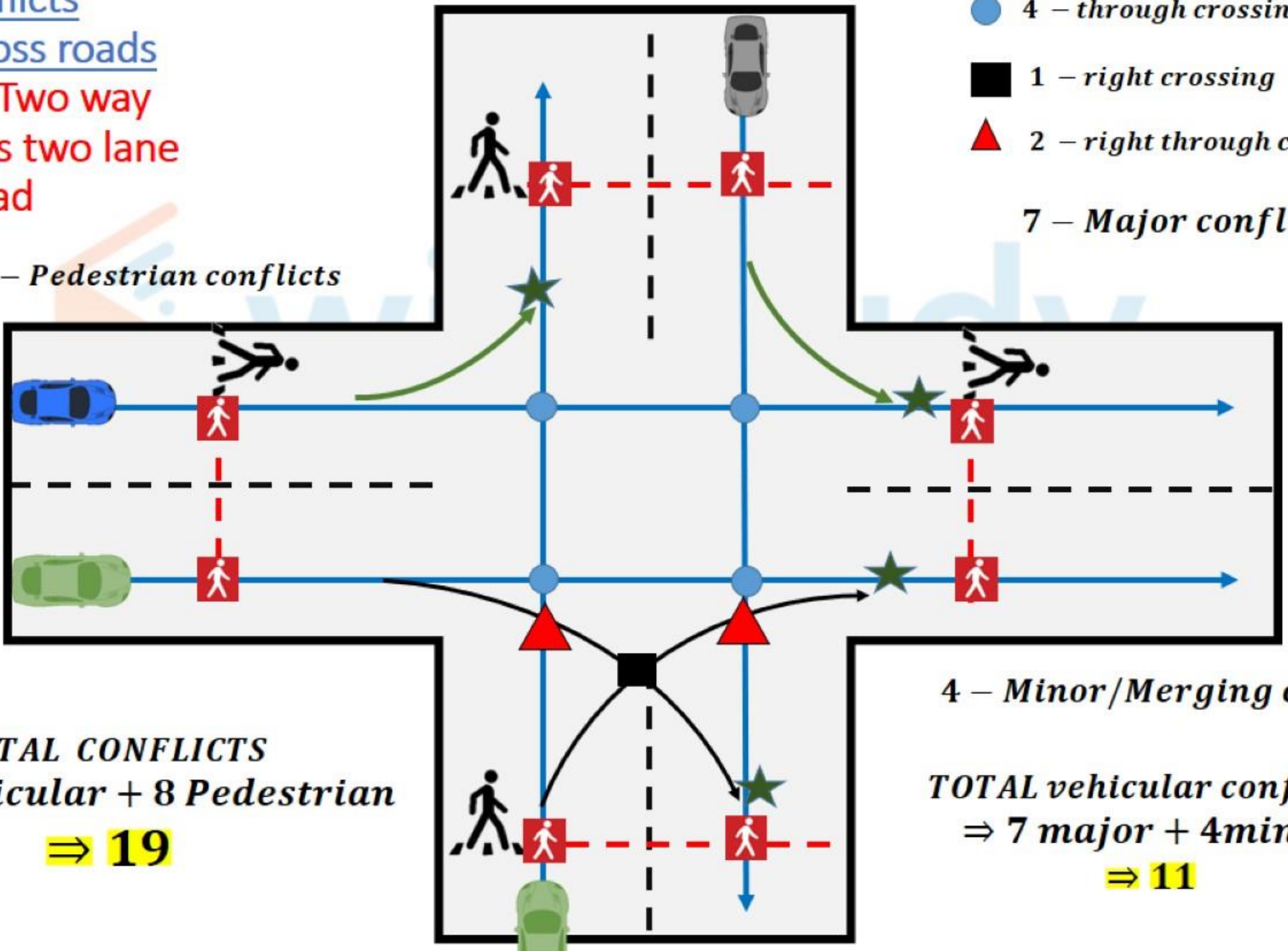


Various Conflicts between Cross roads

2. Two lane Two way Road crosses two lane ONE way road

8 – *Pedestrian conflicts*



4 – *through crossing conflicts*

1 – *right crossing*

2 – *right through crossing*

7 – *Major conflicts*

4 – *Minor/Merging conflicts*

TOTAL CONFLICTS

$\Rightarrow 11\, Vehicular + 8\, Pedestrian$

$\Rightarrow$ **19**

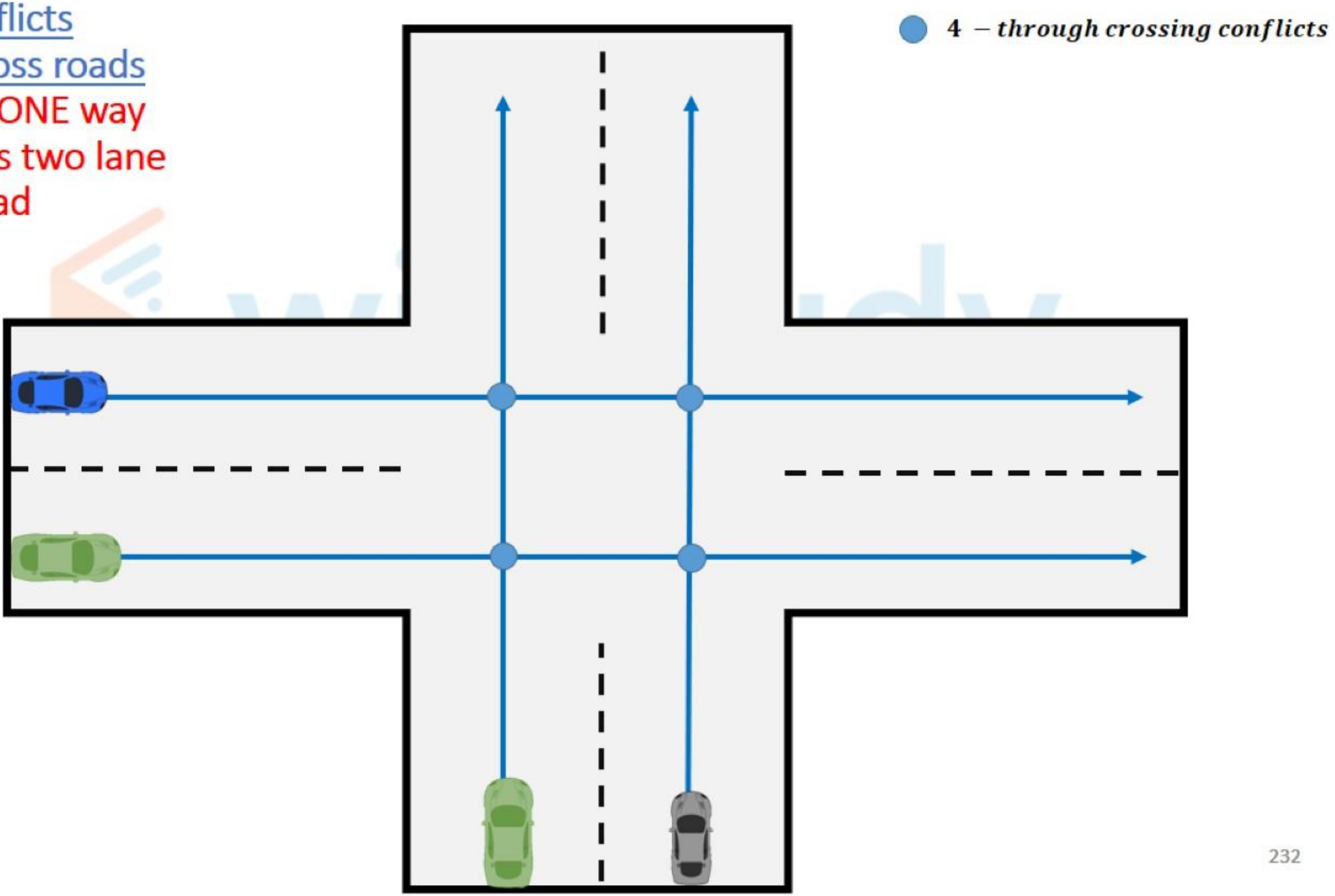
TOTAL vehicular conflicts

$\Rightarrow 7\, major + 4 minor$

$\Rightarrow$ **11**

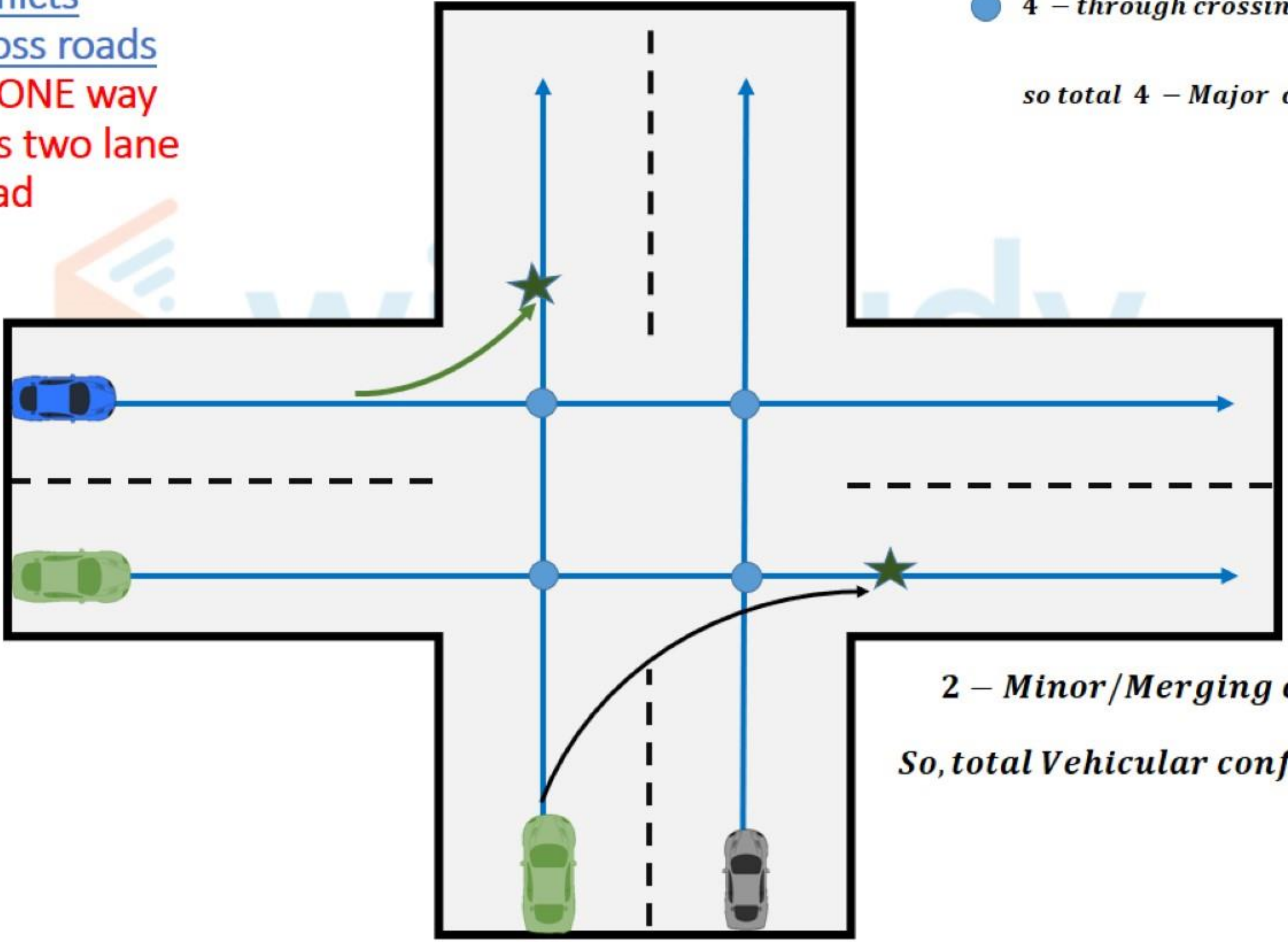
Various Conflicts between Cross roads

3. Two lane ONE way Road crosses two lane ONE way road



Various Conflicts between Cross roads

3. Two lane ONE way Road crosses two lane ONE way road



4 – *through crossing conflicts*

so total 4 – *Major conflicts*

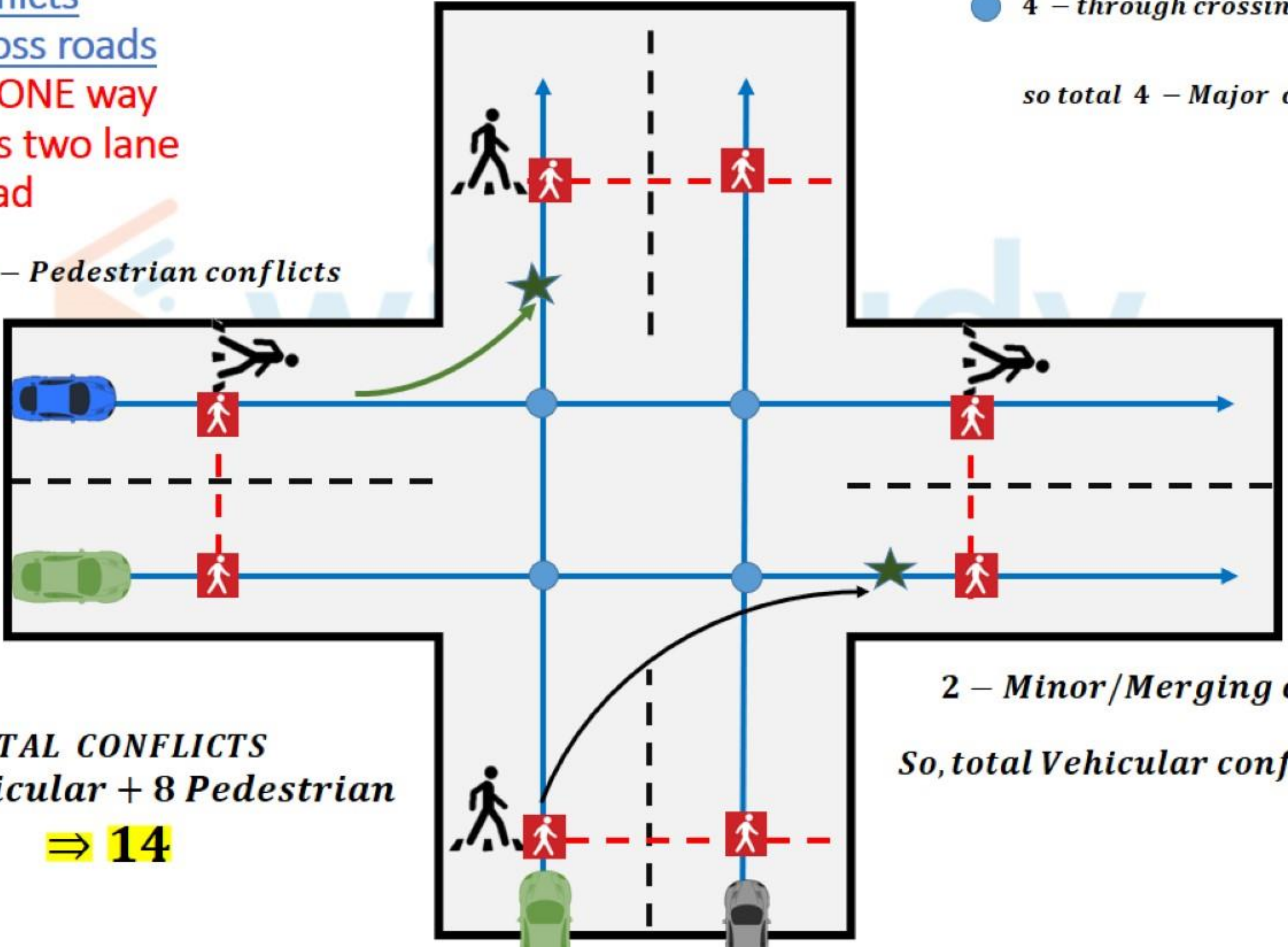
2 – *Minor/Merging conflicts*

So, total Vehicular conflicts $= 6$

Various Conflicts between Cross roads

3. Two lane ONE way Road crosses two lane ONE way road

$8 - \textbf{\textit{Pedestrian conflicts}}$



● $4 - \textbf{\textit{through crossing conflicts}}$

$so\ total\ 4 - Major\ conflicts$

$2 - Minor/Merging\ conflicts$

$So, total\ Vehicular\ conflicts = 6$

$TOTAL\ CONFLICTS$

$\Rightarrow 06\ Vehicular + 8\ Pedestrian$

$\Rightarrow$ **14**

Intersection Control

1. **Passive control**
   - Traffic is less and people follow traffic rules, no exclusive control is required
   - Traffic signs and road markings are used to compliment the control
2. **Semi/Partial Control**
   - Drivers are guided to avoid conflict
   - Channelization and rotary comes under this category
3. **Active Control**
   - Road users are forced to follow the path suggested by the traffic control agency
   - Traffic signals and grade separation intersection comes under this category

TRAFFIC CONTROL AND REGULATION

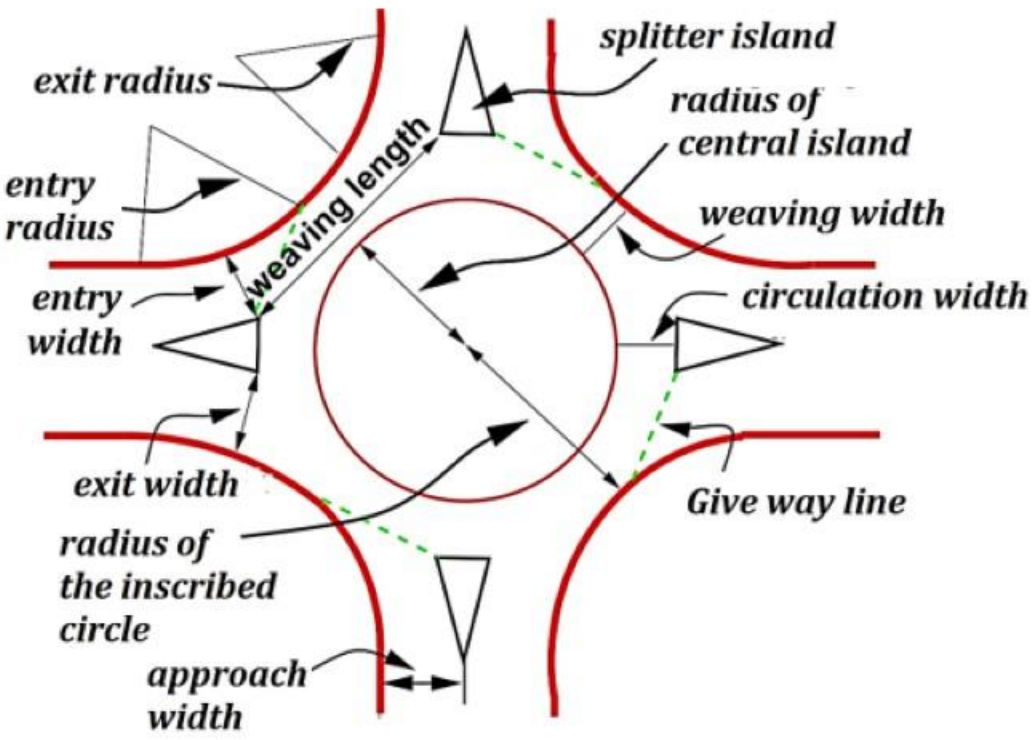
- **ROTARY INTERSECTION**
- **Guidelines for the selection of rotaries**
  - They are suitable when the traffic entering from all the four approaches are relatively equal.
  - A total volume of about 3000 vehicles per hour can be considered as the upper limiting case and a volume of 500 vehicles per hour is the lower limit.
  - A rotary is very beneficial when the proportion of the right-turn traffic is more than 30 percent.
  - Rotaries are suitable when there are more than four approaches or if there is no separate lanes available for right-turn traffic

TRAFFIC CONTROL AND REGULATION

- **DESIGN ELEMENTS OF ROTARY**

1. **Design Speed**
   - The normal practice is to keep the design speed as 30 and 40 kmph for urban and rural areas respectively.

2. **Entry, exit and island radius**
   - The entry radius of about 20 and 25 metres is ideal for an urban and rural design
   - The exit radius is kept as 1.5 to 2 times the entry radius.
   - The radius of the central island which is about 1.3 times that of the entry curve is adequate



TRAFFIC CONTROL AND REGULATION

- **DESIGN ELEMENTS OF ROTARY**

3. Width of the rotary

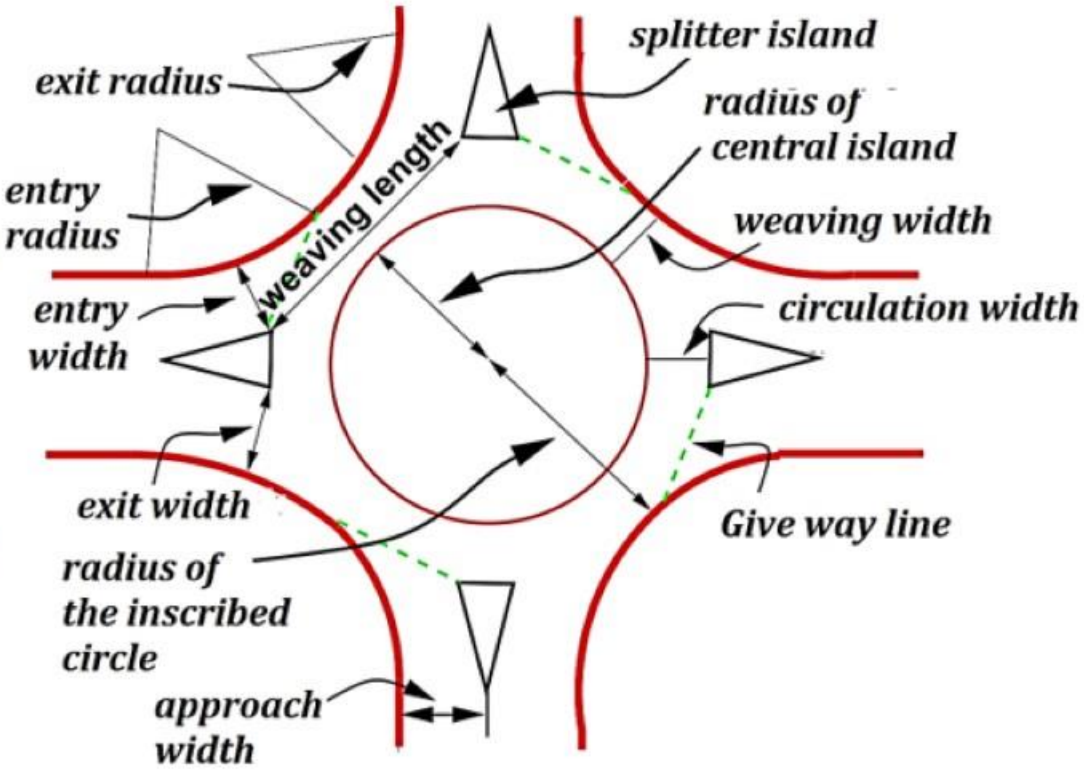
- IRC suggests that a two lane road of 7 m width should be kept as 7 m for urban roads and 6.5 m for rural roads and a three lane road of 10.5 m is to be reduced to 7 m and 7.5 m respectively for urban and rural roads.
- Weaving length is the distance between channelizing islands.
- Width of weaving section is given by-

$$w = \left(\frac{e_1+e_2}{2}\right) + 3.5m$$

Where e_1 is the width of carriageway at entry

And e_2 is the width of carriageway at exit

- Larger the weaving length greater is the tendency of speeding.
- Weaving length is normally taken as 4times of weaving width.



TRAFFIC CONTROL AND REGULATION

- **DESIGN ELEMENTS OF ROTARY**

4. CAPACITY OF ROTARY:

- The capacity of rotary is determined by the capacity of each weaving section.

$$Q = \frac{280w\left(1+\frac{e}{w}\right)\left(1-\frac{p}{3}\right)}{\left(1+\frac{w}{l}\right)}$$

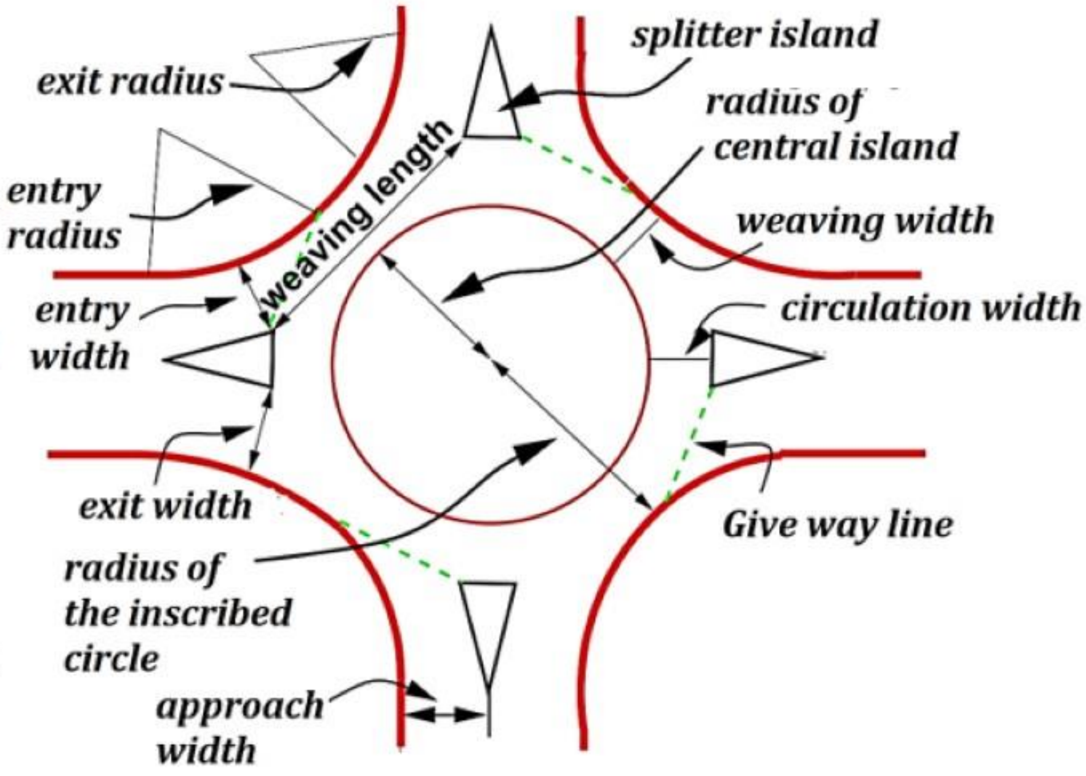
Where e is the average entry and exit width $= \left(\frac{e_1+e_2}{2}\right)$

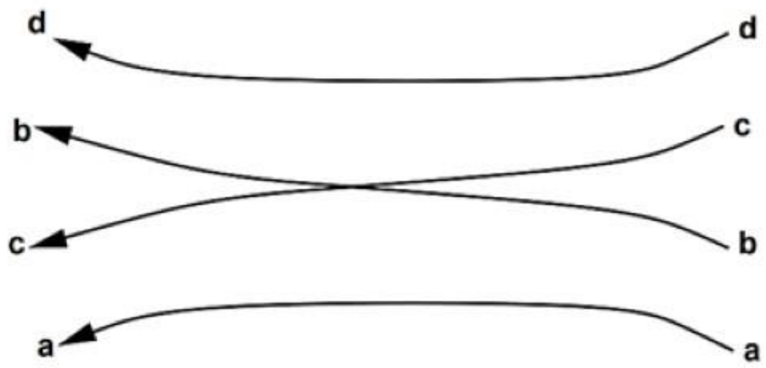
And w is the weaving width = e+3.5m

And p is the proportion of weaving traffic to the non-weaving traffic.

$$p = \frac{b+c}{a+b+c+d}$$

And l is the weaving length = 4w





TRAFFIC CONTROL AND REGULATION

- **DESIGN ELEMENTS OF ROTARY**

4. CAPACITY OF ROTARY:

$$Q = \frac{280w\left(1+\frac{e}{w}\right)\left(1-\frac{p}{3}\right)}{\left(1+\frac{w}{l}\right)}$$

- **This capacity formula is valid only if the following conditions are satisfied.**

1. **Weaving width at the rotary is in between 6 and 18 metres.**
2. **The ratio of average width of the carriage way at entry and exit to the weaving width is in the range of 0.4 to 1.**
3. **The ratio of weaving width to weaving length of the roundabout is in between 0.12 and 0.4.**
4. **The proportion of weaving traffic to non-weaving traffic in the rotary is in the range of 0.4 and 1.**
5. **The weaving length available at the intersection is in between 18 and 90 m.**

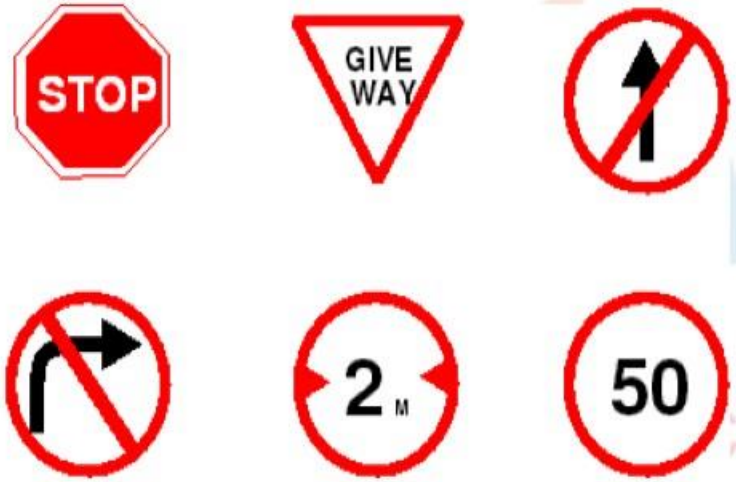
TRAFFIC CONTROL AND REGULATION

- **TRAFFIC CONTROL DEVICES:**
  - **The various aids and devices used to control, regulate and guide traffic are called traffic control devices.**
  - **Most common traffic control devices:**
    - **Traffic signs**
    - **Traffic signals**
    - **Traffic islands**
    - **Road markings**

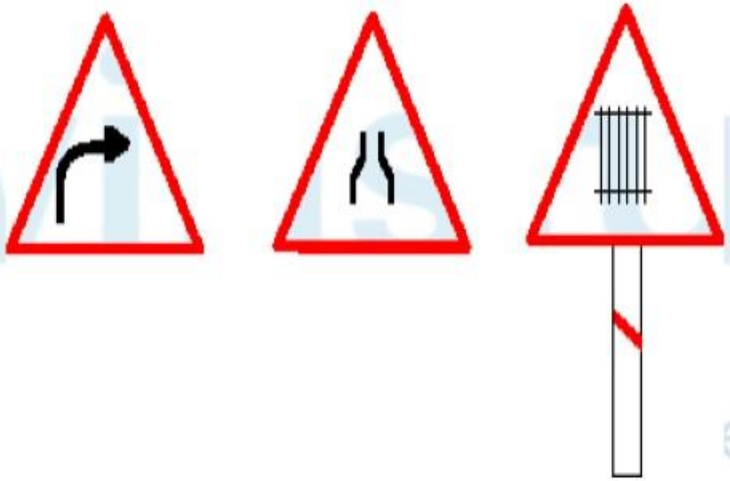
TRAFFIC CONTROL AND REGULATION

- **Traffic signs –**
  - **Regulatory signs-**
  - **These signs require the driver to obey the signs for the safety of other road users.**
  - **These signs have generally black legend on a white background.**
  - **They are circular in shape with red borders.**
  - **Warning signs:**
  - **These signs are for the safety of oneself who is driving and advice the drivers to obey these signs.**
  - **The color convention used for this type of signs is that the legend will be black in color with a white background.**
  - **The shape used is upward triangular or diamond shape with red borders**
  - **Informative signs:**
  - **These signs provide information to the driver about the facilities available ahead, and the route and distance to reach the specific destinations.**
  - **They are written black letters on yellow background.**
  - **They are color coded as white letters with green background.**

TRAFFIC SIGNS



regulatory signs

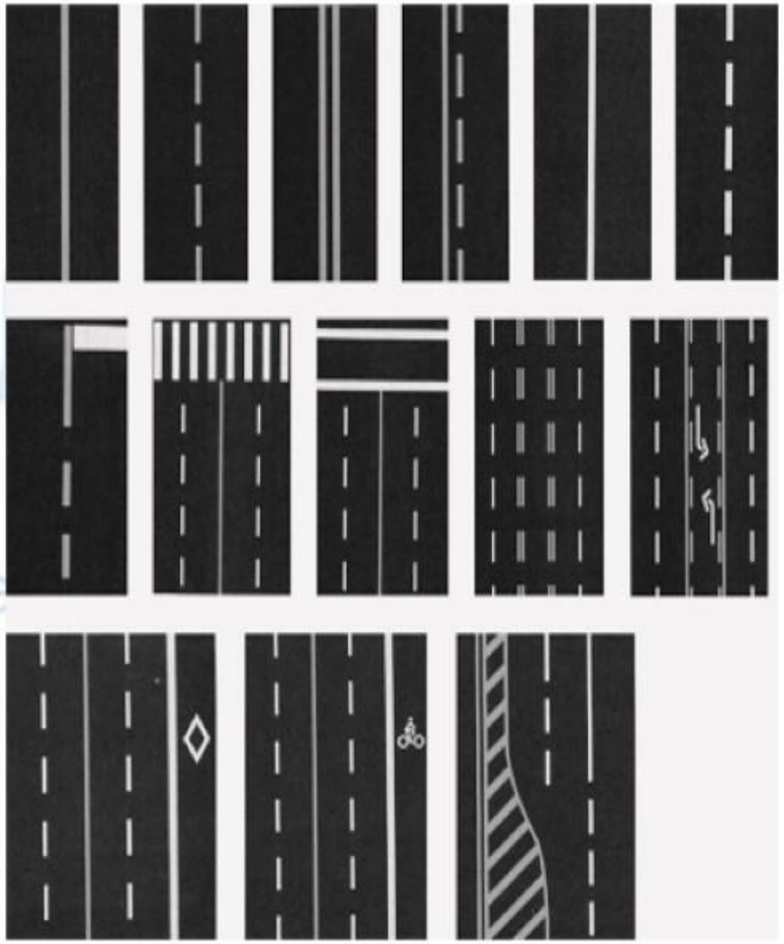


warning signs

informatory signs

TRAFFIC CONTROL AND REGULATION

- ROAD MARKINGS:
  - The essential purpose of road markings is to guide and control traffic on a highway. They supplement the function of traffic signs.
  - They are very important to ensure the safe, smooth and harmonious flow of traffic.
  - Various types of road markings like longitudinal markings, transverse markings, object markings and special markings to warn the driver about the hazardous locations in the road etc.

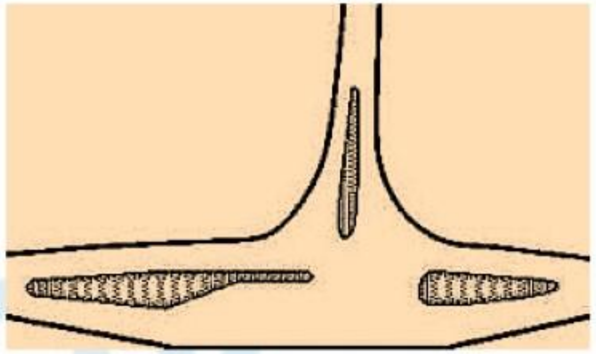


TRAFFIC CONTROL AND REGULATION

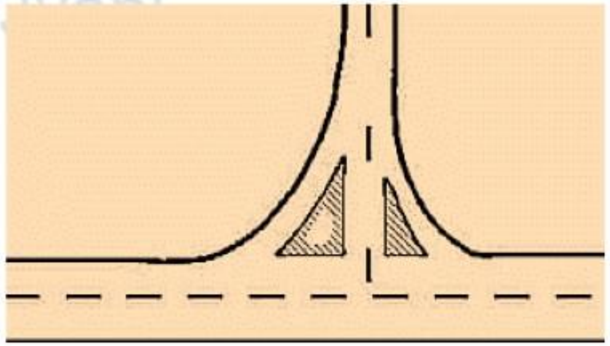
- **TRAFFIC ISLANDS:**
  - An island is a defined area between traffic lanes for control of vehicle movements.
  - Within an intersection area, a median or an outer separation is considered to be an island.
  - Traffic islands are classified as:
    - Divisional islands
    - Channelizing islands
    - Pedestrian loading islands
    - Rotary

TRAFFIC CONTROL AND REGULATION

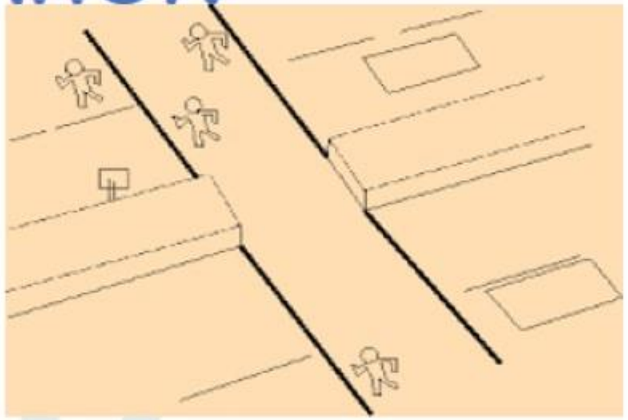
- **Divisional islands**
  - These are designed to divide opposing or same direction traffic streams, usually through movements.



- **Channelizing islands**
  - These are designed to control and direct traffic movement, usually turning.

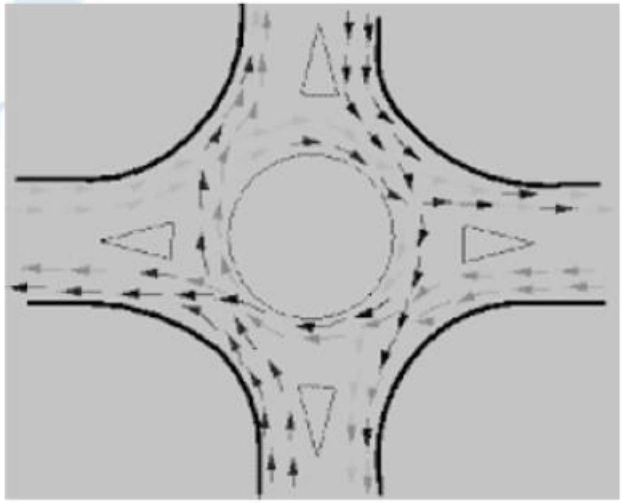


TRAFFIC CONTROL AND REGULATION



- **Pedestrian loading islands**
  - **Pedestrian islands are provided to serve as safety zones for the aid and protection of persons on foot.**

- **Rotary islands**
  - **Rotary intersections or round abouts are special form of at-grade intersections laid out for the movement of traffic in one direction around a central traffic island.**
  - **The traffic operations at a rotary are three:**
    - **Diverging: It is a traffic operation when the vehicles moving in one direction is separated into different streams according to their destinations.**
    - **Merging: Merging is the opposite of diverging. Merging is referred to as the process of joining the traffic coming from different approaches and going to a common destination into a single stream.**
    - **Weaving: Weaving is the combined movement of both merging and diverging movements in the same direction.**

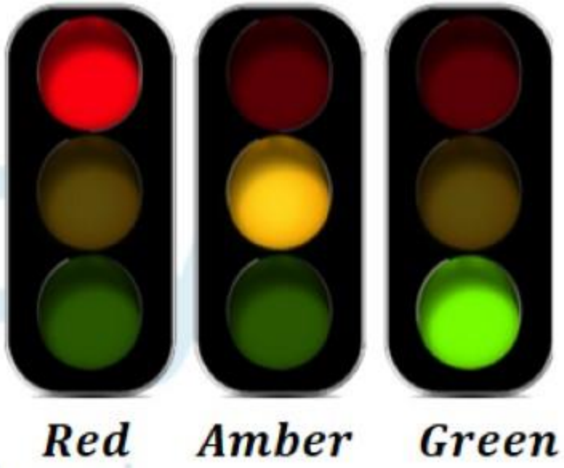


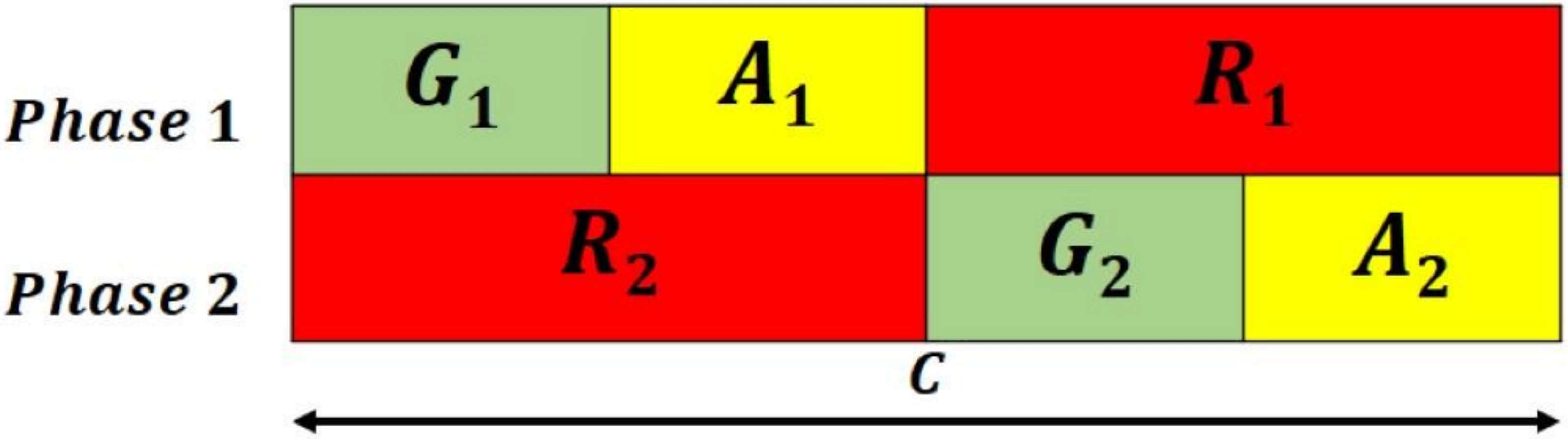
Traffic Signals

- **Traffic signals are one of the most effective and flexible active control of traffic and is widely used in several cities world wide**
- **Cycle: A signal cycle is one complete rotation through all of the indications provided.**
- **Cycle length:**
  - **Cycle length is the time in seconds that it takes a signal to complete one full cycle of indications.**
  - **It indicates the time interval between the starting of of green for one approach till the next time the green starts.**
  - **It is denoted by C**
- **Intervals:**
  - **Interval represents change from one stage to another**
  - **They are of two types:**
    1. **Change interval**
    2. **Clearance interval**

Traffic Signals

- **Intervals:**
  - Interval represents change from one stage to another
  - They are of two types:
    1. Change interval
       - Also known as Yellow time/Clearance amber/amber
       - It is time interval between green time and Red time
       - It serves two purposes-
         - Warns traffic about upcoming red signal
         - It gives time for traffic which has entered the intersection to clear it before the green time for next phase starts

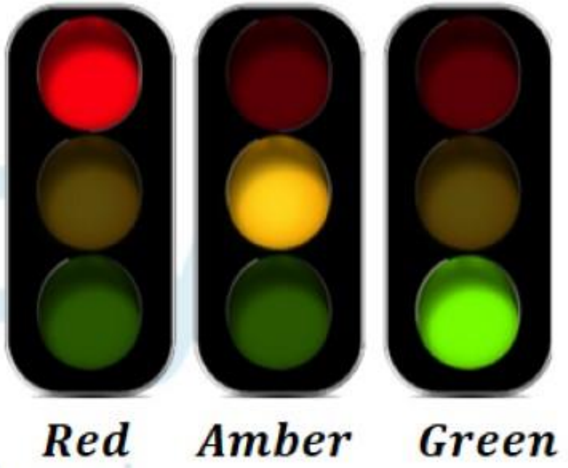


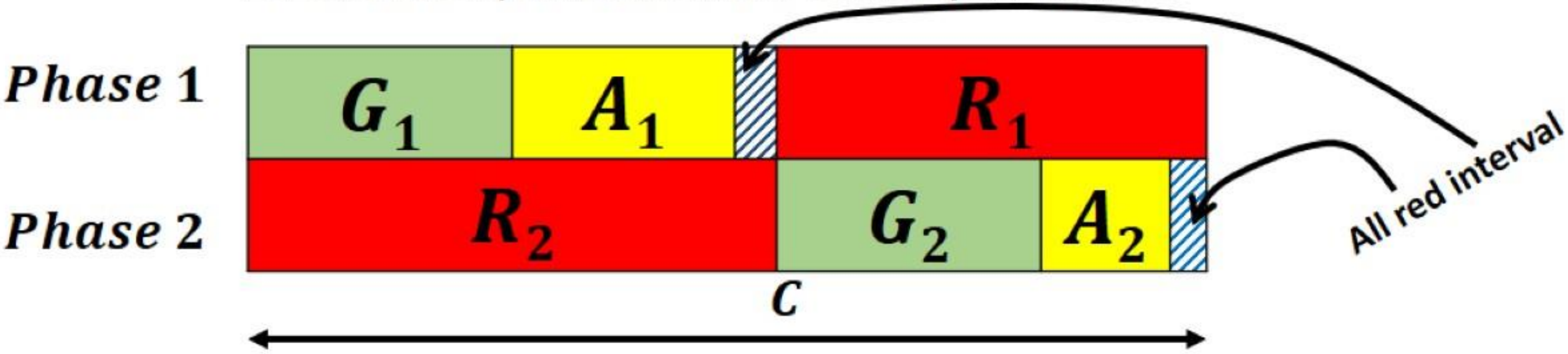


Traffic Signals

- **Intervals:**
  - Interval represents change from one stage to another
  - They are of two types:

    2. Clearance interval
       - Also known as All red interval
       - It is added after each yellow interval and it indicates a period during all phases shown red signs
       - It is used for clearing vehicle from intersection
       - All red interval is optional and generally not provided for small intersections
       - For calculations, all red interval is taken as part of Amber





Traffic Signals

- **Green interval:**
  - It is the green indication for a particular movement or set of movements and is denoted by G_i .
  - This is the actual duration the green light of a traffic signal is turned on
- **Red interval:**
  - It is the red indication for a particular movement or set of movements and is denoted by R_i .
  - This is the actual duration the red light of a traffic signal is turned on.
- **Phase:**
  - A phase is the green interval plus the change and clearance intervals that follow it.
  - Thus, during green interval, non conflicting movements are assigned into each phase. It allows a set of movements to flow and safely halt the flow before the phase of another set of movements start.

TRAFFIC CONTROL AND REGULATION

- **TRAFFIC SIGNALS:**
  - **They are automatic traffic control devices which can alternatively direct the traffic to stop and proceed at intersections using red and green light signals as per pre determined time settings.**
  - **Types of traffic signal:**
    - **Traffic control signals**
    - **Pedestrian signal**
    - **Special traffic signal**

Traffic control signals

Pedestrian signal

Special Traffic signal

Que 1. For the preparation of highways

a) longitudinal sections are required

b) Cross sections are required

c) Both a and b are required

d) None of the above

Que 1. For the preparation of highways

a) longitudinal sections are required

b) Cross sections are required

c) <u>Both a and b are required</u>

d) None of the above

Que 2. The camber of hill roads in case of bituminous surface is adopted as

a) 2%

b) 2.5%

c) 3%

d) 3.5%

Que 2. The camber of hill roads in case of bituminous surface is adopted as

a) 2%

b) <u>2.5%</u>

c) 3%

d) 3.5%

Que 3. In highway construction on super elevated curves, rolling should proceed from

a) Sides towards the centre

b) Centre toward sides

c) lower edge towards the upper edge

d) Upper edge toward the lower edge

Que 3. In highway construction on super elevated curves, rolling should proceed from

a) Sides towards the centre

b) Centre toward sides

c) lower edge towards the upper edge

d) Upper edge toward the lower edge

In highway construction rolling starts from sides and proceeds to center

Que 4. The ruling minimum radius of the curve for a ruling design speed V m/sec, coefficient of friction f, acceleration due to gravity g m/sec^2

And super elevation e is given by

a) $\frac{V^2}{(e-f)g}$

b) $\frac{V^2}{(f-e)g}$

c) $\frac{V^2}{(e+f)g}$

d) $\frac{V^2}{(e+f)2g}$

Que 4. The ruling minimum radius of the curve for a ruling design speed V m/sec, coefficient of friction f, acceleration due to gravity g m/sec²

And super elevation e is given by

a) $\dfrac{V^2}{(e-f)g}$

b) $\dfrac{V^2}{(f-e)g}$

c) $\dfrac{V^2}{(e+f)g}$

d) $\dfrac{V^2}{(e+f)2g}$

SUPER ELEVATION

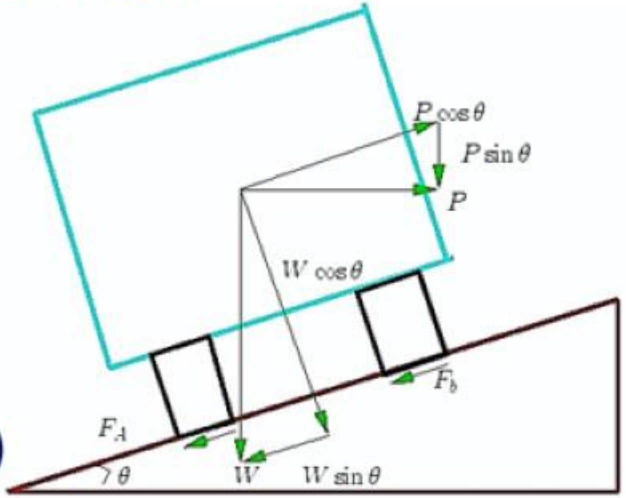
$$\frac{v^2}{gR} = \frac{tan\theta + f}{1 - \mu tan\theta}$$

Normally,

$f \rightarrow 0.15$

$\theta \rightarrow$ less than 4°

$1 - f tan\theta \approx 1$



$tan\theta \approx \sin\theta$ (for small values of θ)

$\Rightarrow tan\theta \approx \sin\theta = \frac{E}{W} = e$

Hence $\boxed{e + f = \frac{v^2}{gR}}$

Que 5. Camber in the road is provided for

a) Counteracting the centrifugal force

b) Effective drainage

c) Having proper sight distance

d) Avoiding overturning

Que 5. Camber in the road is provided for

a) **Counteracting the centrifugal force**

b) **Effective drainage**

c) **Having proper sight distance**

d) **Avoiding overturning**

Que 6. The centrifugal force on a car moving on a horizontal curve is proportional to

a) $\frac{Wv^2}{(gR)}$

b) $\frac{Wv}{(gR)}$

c) $\frac{Wv^2}{(gR^2)}$

d) $\frac{Wv}{gR^2}$

Que 6. The centrifugal force on a car moving on a horizontal curve is proportional to

a) $\frac{Wv^2}{(gR)}$

b) $\frac{Wv}{(gR)}$

c) $\frac{Wv^2}{(gR^2)}$

d) $\frac{Wv}{gR^2}$

Que 7. The shape of STOP sign according to IRC:67-2001

a) Circular
b) Rectangular
c) Triangular
d) Octagonal

Que 7. The shape of STOP sign according to IRC:67-2001

a) Circular
b) Rectangular
c) Triangular
d) <u>Octagonal</u>

Que 8. The shift of transition curve of radius 300m and length 48m is

a) 0.32m

b) 0.42m

c) 0.52m

d) 0.62m

Que 8. The shift of transition curve of radius 300m and length 48m is

a) **0.32m**

b) 0.42m

c) 0.52m

d) 0.62m

L= 48m

R= 300m

Shift $= \frac{L_s^2}{24R} = 0.32$

- **By Empirical Formula of IRC**
  - Length of transition curve denoted by L_{s3}
  - IRC suggest the length of the transition curve is minimum for a plain and rolling terrain

$$L_{s3} = \frac{35v^2}{R}$$

  - and for steep and hilly terrain is:

$$L_{s3} = \frac{12.96v^2}{R}$$

  - And the shift 's'

$$s = \frac{L_s^2}{24R}$$

LENGTH OF TRANSITION CURVES = MAXIMUM OF $\langle L_{s1} | L_{s2} | L_{s3} \rangle$

Que 9. The cumulative speed distribution curve is usually adopted for geometric design of highways. The percentile speed adopted for geometric design is

a) 85^{th} percentile

b) 90^{th} percentile

c) 98^{th} percentile

d) 99.9^{th} percentile

Que 9. The cumulative speed distribution curve is usually adopted for geometric design of highways. The percentile speed adopted for geometric design is

a) 85^{th} percentile

b) 90^{th} percentile

c) 98^{th} percentile

d) 99.9^{th} percentile

5. DESIGN SPEED

- It is decided theoretically as the 98^{th} percentile speed, that is the speed at or below which 98% vehicles are moving.
- From economical point of view, IRC has limited the design speed on the basis of topography.
- Ruling speed should be the guiding criteria, however minimum speed can be adopted in localized sections where cost considerations does not permit ruling speed.

Que 10. The value for lateral coefficient of friction as per IRC is

a) 0.007

b) 0.01

c) 0.15

d) 0.30

Que 10. The value for lateral coefficient of friction as per IRC is

a) 0.007

b) 0.01

c) <u>0.15</u>

d) 0.30

6. SURFACE CHARACTERISTICS

➢ Friction –

- Longitudinal friction coefficient – 0.35 to 0.40
- Lateral friction coefficient – 0.15
- Lack of friction causes skidding and slipping.
- *SKIDDING – If one revolution of wheel leads to longitudinal movement greater than πD.*
- *SLIPPING – If one revolution of wheel leads to longitudinal movement less than πD.*

Que. 11 What will be the shift of transition curve, if the length of transition curve is 80m and radius of the curve is 300m

a) 0.011

b) 0.78

c) 0.89

d) 21.33

Que. 11 What will be the shift of transition curve, if the length of transition curve is 80m and radius of the curve is 300m

a) **0.011**

b) **0.78**

c) **0.89**

d) **21.33**

L= 80m

R= 300m

$$\text{Shift} = \frac{L_s^2}{24R} = 0.89M$$

Que 12. Which of the following are correct values for lateral and longitudinal friction coefficient as per IRC

a) 0.10,0.15

b) 0.15,0.35

c) 0.30,0.10

d) 0.35,0.15

Que 12. Which of the following are correct values for lateral and longitudinal friction coefficient as per IRC

a) 0.10,0.15

b) <u>0.15,0.35</u>

c) 0.30,0.10

d) 0.35,0.15

6. SURFACE CHARACTERISTICS

- **Friction –**
  - Longitudinal friction coefficient – 0.35 to 0.40
  - Lateral friction coefficient – 0.15
  - Lack of friction causes skidding and slipping.
  - *SKIDDING – If one revolution of wheel leads to longitudinal movement greater than πD.*
  - *SLIPPING – If one revolution of wheel leads to longitudinal movement less than πD.*

Que 13. The ruling design speed on a curve is 100kmph and the super elevation on the curve is 7%. Calculate the ruling design radius(m) of the curve. Take coefficient of lateral friction as 0.15

a) 129

b) 189

c) 358

d) 1668

Que 13. The ruling design speed on a curve is 100kmph and the super elevation on the curve is 7%. Calculate the ruling design radius(m) of the curve. Take coefficient of lateral friction as 0.15

a) 129

b) 189

c) <u>358</u>

d) 1668

$$e + f = \frac{V^2}{127R}$$

E= 0.07

F= 0.15(as per irc)

V = 100

Hence r = 358m

Que 14. Right of way is the summation of the width of

a) Carriage way and shoulder

b) Carriage way, shoulder and road margins

c) Carriage way and road margins

d) Road margins and shoulder

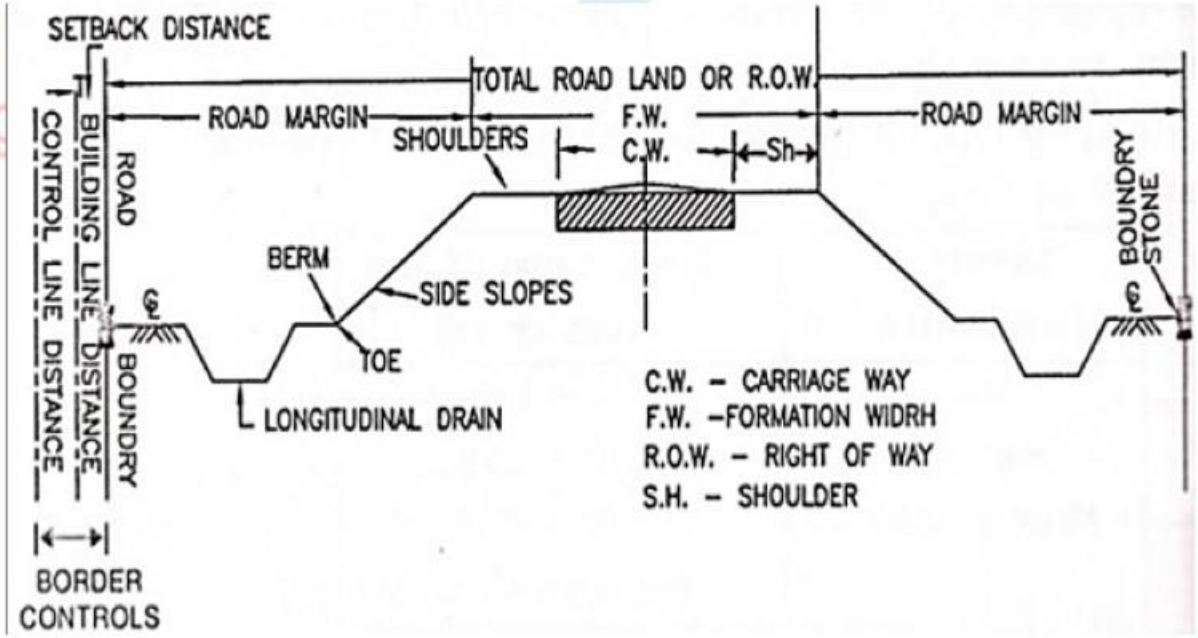
Que 14. Right of way is the summation of the width of

a) Carriage way and shoulder

b) <u>**Carriage way, shoulder and road margins**</u>

c) Carriage way and road margins

d) Road margins and shoulder



Que 15. Gradient on a highway is 1 in 20. Radius of the curve is 200m. Calculate the grade compensation

a) 0.38%

b) 1.15%

c) 4.63%

d) 5%

Que 15. Gradient on a highway is 1 in 20. Radius of the curve is 200m. Calculate the grade compensation

a) <u>0.38%</u>

b) 1.15%

c) 4.63%

d) 5%

%grade comp = (30+R)/R = 1.15%

Max grade comp = 75/R= 0.375%

Que 16. If the SSD and average length of a vehicle are 18m and 6m respectively, then the theoretical maximum capacity on a traffic lane at a speed of 10m/sec is

a) 1500veh/hr

b) 2000veh/hr

c) 2500veh/hr

d) 3000veh/hr

Que 16. If the SSD and average length of a vehicle are 18m and 6m respectively, then the theoretical maximum capacity on a traffic lane at a speed of 10m/sec is

a) **1500veh/hr**

b) 2000veh/hr

c) 2500veh/hr

d) 3000veh/hr

- TIME HEADWAY
  - Time interval between the passes of rear bumper of successive vehicles at a point.

$$q = \frac{1}{average\ time\ headway}$$

- SPACE HEADWAY:
  - It is the distance between rear bumpers of successive vehicles.

$$k = \frac{1}{average\ space\ headway}$$

Time headway = (18+6)/10 = 2.4sec

Theoretical max capacity = 3600/time headway = 3600/2.4 = 1500

Que 17. A flyover segregates traffic in terms of

a) **Direction**

b) **Grade**

c) **Speed**

d) **Class of vehicle**

Que 17. A flyover segregates traffic in terms of

a) **Direction**

b) **Grade**

c) **Speed**

d) **Class of vehicle**

Que 18. The traffic volume of a roadway is defined as the multiplication of

a) Speed and time headway

b) Speed and distance headway

c) Traffic density and speed

d) Time headway and distance headway

Que 18. The traffic volume of a roadway is defined as the multiplication of

a) Speed and time headway

b) Speed and distance headway

c) <u>Traffic density and speed</u>

d) Time headway and distance headway

Que 19. The value of rigidity factor for design purpose, if tyre pressure is greater than 0.7MPa is

a) >1

b) <1

c) =1

d) zero

Que 19. The value of rigidity factor for design purpose, if tyre pressure is greater than 0.7MPa is

a) >1

b) <1

c) =1

d) zero

$$Rigidity\ Factor = \frac{contact\ pressure}{tyre\ pressure}$$

1. If tyre pressure = 0.7MPa, R.F. = 1
2. If tyre pressure < 0.7MPa, R.F. > 1
3. If tyre pressure > 0.7MPa, R.F. < 1

For design purpose, area of contact of wheel is taken as circular.

Que 20. Bitumen is generally obtained from

a) Organic material
b) Synthetic material
c) Petroleum byproduct
d) coal

Que 20. Bitumen is generally obtained from

a) Organic material

b) Synthetic material

c) <u>Petroleum byproduct</u>

d) coal

Que 21. Los Angeles machine is used to test the aggregate for

a) Crushing strength

b) Impact value

c) Abrasion Resistance

d) Water absorption

Que 21. Los Angeles machine is used to test the aggregate for

a) Crushing strength

b) Impact value

c) Abrasion Resistance

d) Water absorption

Que 22. A flaky aggregate is said to be Elongated if its length is

a) Equal to the mean size

b) Twice the mean size

c) Thrice the mean size

d) 4 times the mean size

Que 22. A flaky aggregate is said to be Elongated if its length is

a) **Equal to the mean size**

b) **Twice the mean size**

c) **Thrice the mean size**

d) **4 times the mean size**

- The flakiness index is defined as the percentage by weight of aggregate particles whose least dimension is less than **0.6 times** their mean size.
- The elongation index of an aggregate is defined as the percentage by weight of particles whose greatest dimension (length) is **1.8 times** their mean dimension. This test is applicable to aggregates larger than 6.3 mm.

Que 23. Bitumen Emulsion is

a) A liquid containing bitumen in suspension

b) A Paint

c) Used as anti corrosive paint

d) All of the above

Que 23. Bitumen Emulsion is

a) A liquid containing bitumen in suspension

b) A Paint

c) Used as anti corrosive paint

d) <u>All of the above</u>

Que 24. When the bitumen surfacing is done on already existing black top road or over existing cement concrete road, the type of treatment to be given is

a) Tack coat

b) Spray of emulsion

c) seal coat

d) Prime coat

Que 24. When the bitumen surfacing is done on already existing black top road or over existing cement concrete road, the type of treatment to be given is

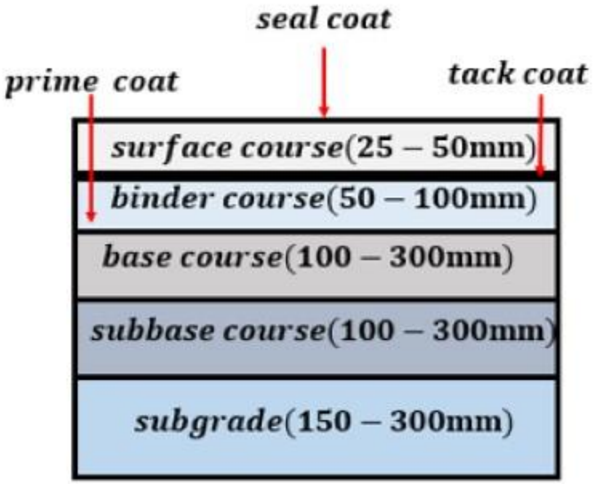
a) <u>Tack coat</u>

b) Spray of emulsion

c) seal coat

d) Prime coat

- **FUNCTIONS OF LAYERS:**
  - Seal Coat:
    - Seal coat is a thin surface treatment used to water-proof the surface and to provide skid resistance.
  - Tack Coat:
    - Tack coat is a very light application of asphalt, usually asphalt emulsion diluted with water.
    - It provides proper bonding between two layer of binder course and must be thin, uniformly cover the entire surface, and set very fast.
  - Prime Coat:
    - Prime coat is an application of low viscous cutback bitumen to an absorbent surface like granular bases on which binder layer is placed.
    - It provides bonding between two layers.
    - Unlike tack coat, prime coat penetrates into the layer below, plugs the voids, and forms a water tight surface



Que 25. Bottom most layer of pavement is known as SSC JE 2012

a) **Sub base coarse**

b) **Sub grade**

c) **Wearing**

d) **Base coarse**

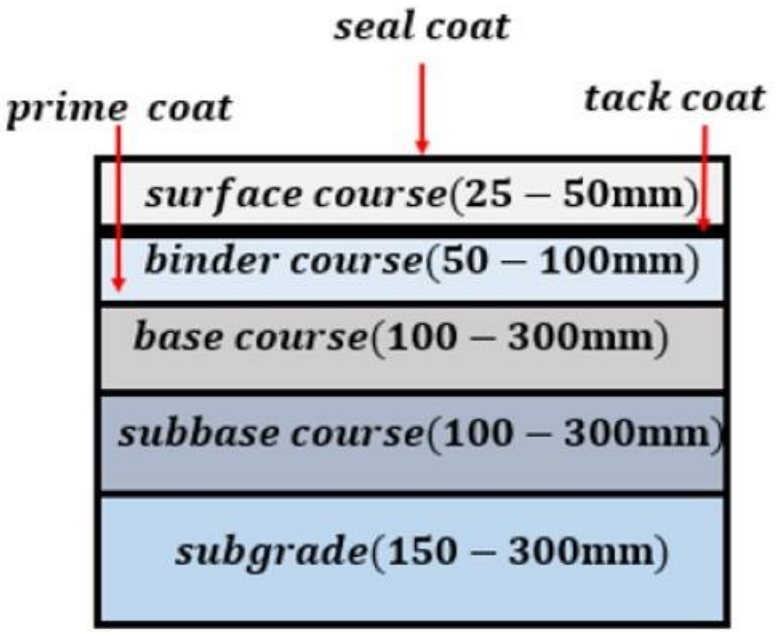
Que 25. Bottom most layer of pavement is known as

a) Sub base coarse

b) <u>Sub grade</u>

c) Wearing

d) Base coarse



Que 26 The resistance of an aggregate to wear is known as

a) Impact value

b) Abrasion resistance

c) Shear Resistance

d) Crushing resistance

Que 26 The resistance of an aggregate to wear is known as

a) Impact value

b) Abrasion resistance

c) Shear Resistance

d) Crushing resistance

Que 27. For constructing road pavements, the type of cement generally used is

a) Ordinary Portland cement

b) Rapid hardening cement

c) Low heat cement

d) Blast furnace slag cement

Que 27. For constructing road pavements, the type of cement generally used is

a) Ordinary Portland cement

b) Rapid hardening cement

c) Low heat cement

d) Blast furnace slag cement

Que 28. Specific gravity of bitumen is

a) 2.09

b) 0.8

c) 0.9

d) 1.02

Que 28. Specific gravity of bitumen is

a) 2.09

b) 0.8

c) 0.9

d) **1.02**

- **Specific Gravity test:**
  - It is done to determine the density of bitumen.
  - $Specific\ Gravity\ of\ bitumen = \frac{weight\ of\ bitumen\ of\ given\ volume}{weight\ of\ same\ volume\ of\ water}$ (@27°C)
  - PYCNOMETER is used here.
  - Specific gravity of :

1. Bitumen = 0.97 – 1.02
2. Tar = 1.10 – 1.29

Que 29. The construction joints in cement concrete

a) Should not be provided at the corner
b) Should be spaced at a distance of 3m apart in case of huge structures
c) Should be located where shear force is large
d) Should be located where bending moment is large

Que 29. The construction joints in cement concrete

a) <u>Should not be provided at the corner</u>

b) Should be spaced at a distance of 3m apart in case of huge structures

c) Should be located where shear force is large

d) Should be located where bending moment is large

Contruction joint is provided where least maximum bending moment and shear force exists
Span 1/3 rd of span length

Que 30. The resistance of an aggregate to the effect of hydration of cement and weather is called

a) **Impact value**

b) **Soundness**

c) **Crushing strength**

d) **Abrasion resistance**

Que 30. The resistance of an aggregate to the effect of hydration of cement and weather is called

a) Impact value

b) <u>Soundness</u>

c) Crushing strength

d) Abrasion resistance

Que 31. Aggregate impact value indicates which of the following properties of aggregate?

a) Durability

b) Toughness

c) Hardness

d) Strength

Que 31. Aggregate impact value indicates which of the following properties of aggregate?

a) Durability

b) <u>Toughness</u>

c) Hardness

d) Strength

Que 32. The resistance of material to penetration is

a) Toughness

b) Hardness

c) Fatigue

d) Roughness

Que 32. The resistance of material to penetration is

a) Toughness

b) <u>Hardness</u>

c) Fatigue

d) Roughness

Que 33. The ductility value of bitumen is

a) Equal to that of tar

b) More than that of tar

c) Less than that of tar

d) None of these

Que 33. The ductility value of bitumen is

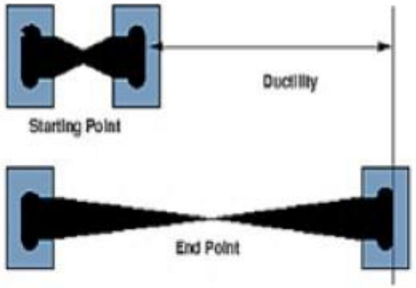
a) Equal to that of tar

b) More than that of tar

c) Less than that of tar

d) None of these

- Ductility test:
  - Ductility is the property of bitumen that permits it to undergo great deformation or elongation.
  - Ductility is defined as the distance in cm, to which a standard sample or briquette of the material will be elongated without breaking.
  - ELASTOMER is used here.
  - Ductility will be measured at the point where bitumen breaks.
  - Temperature maintained = 27°C
  - A minimum ductility value of 75 cm has been specified by the BIS.
  - Good quality of bitumen has more ductility while low quality of bitumen has less ductility.



Que 34. The penetration test on bitumen is used for determining its

a) Grade
b) Ductility
c) Viscosity
d) None of these

Que 34. The penetration test on bitumen is used for determining its

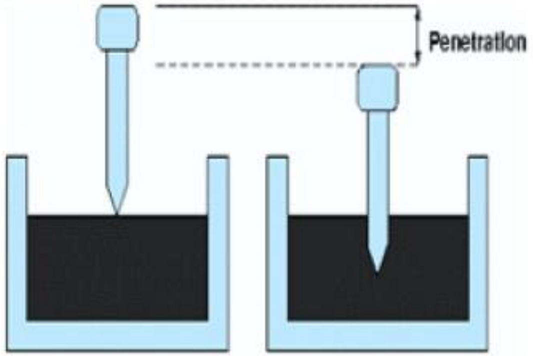
a) <u>Grade</u>

b) Ductility

c) Viscosity

d) None of these

- **Penetration test**
  - It measures the hardness or softness of bitumen by measuring the depth in *tenths of a millimeter* to which a standard loaded needle will penetrate vertically in 5 seconds.
  - PENETROMETER is used here.
  - Waterbath is kept at 25°C, because the properties of bitumen will change as the temperature changes. At T = 25°C, needle is allowed to penetrate for 5 seconds.
  - The distance which the needle penetrate into bitumen is called 'penetration of bitumen' and is measured in 'gauge.'
  - A grade of 30/40 bitumen(preferred for hot climate) means the penetration value is in the range 30 to 40 at standard test conditions.
  - A grade of 80/100 bitumen(preferred for cold climate) means the penetration value is in the range 80 to 100 at standard test conditions.



Que 35. If the ruling gradient on any highway is 5%, the gradient provided on the curve of 300m radius is-

a) 4%

b) 4.25%

c) 4.50%

d) 4.75%

Que 35. If the ruling gradient on any highway is 5%, the gradient provided on the curve of 300m radius is-

a) **4%**

b) **4.25%**

c) **4.50%**

d) **<u>4.75%</u>**

%grade comp = (30+R/R)= 1.1%

Max grade comp = 75/R= 0.25%

Que 36. Width of vehicles affect the width of-

a) Lanes

b) Shoulders

c) Parking spaces

d) All of the above

Que 36. Width of vehicles affect the width of-

a) Lanes

b) Shoulders

c) Parking spaces

d) All of the above

Que 37. Maximum super elevation on hill roads should not exceed

a) 5%

b) 7%

c) 8%

d) 10%

Que 37. Maximum super elevation on hill roads should not exceed

a) 5%

b) 7%

c) 8%

d) <u>10%</u>

TYPE OF TERRAIN	MAXIMUM SUPERELEVATION
Plain and rolling terrain	7%
Hill roads	10%
Urban road stretches	4%

Que 38. The efficiency of brakes of a vehicle depends upon-

a) Condition of the road surface

b) Condition of the tyres

c) Presence of moisture

d) All of the above

Que 38. The efficiency of brakes of a vehicle depends upon-

a) **Condition of the road surface**

b) **Condition of the tyres**

c) **Presence of moisture**

d) **All of the above**

Que 39. The type of transition curves generally provided on hill roads is-

a) Circular
b) Cubic parabola
c) Lemniscate
d) Spiral

Que 39. The type of transition curves generally provided on hill roads is-

a) Circular

b) Cubic parabola

c) Lemniscate

d) <u>Spiral</u>

Que 40. The maximum safe speed on roads depends upon-

a) Type of the highway

b) Type of road surface

c) Sight distance

d) All of the above

Que 40. The maximum safe speed on roads depends upon-

a) Type of the highway

b) Type of road surface

c) Sight distance

d) **All of the above**

Que 41. If cross slope of a country is 10-25%, the terrain is classified as-

a) Rolling
b) Mountainous
c) Steep
d) Plain

Que 41. If cross slope of a country is 10-25%, the terrain is classified as-

a) <u>Rolling</u>
b) Mountainous
c) Steep
d) Plain

Terrain classification	Cross slope (%)
Plain	0-10
Rolling	10-25
Mountainous	25-60
Steep	60

Que 42. On the recommendations of IRC, the ruling gradient in plains is-

a) 1 in 15

b) 1 in 20

c) 1 in 30

d) 1 in 45

Que 42. On the recommendations of IRC, the ruling gradient in plains is-

a) 1 in 15

b) 1 in 20

c) 1 in 30

d) 1 in 45

%

TERRAIN	RULING GRADIENT	LIMITINGS	EXCEPTION
Plain/Rolling	3.3	5.0	6.7
Hilly	5	6	7
Steep	6	7	8

Que 43. While calculating sight distance, the driver's eye above the road surface is assumed –

a) 90cm

b) 100cm

c) 110cm

d) 120cm

Que 43. While calculating sight distance, the driver's eye above the road surface is assumed –

a) 90cm

b) 100cm

c) 110cm

d) <u>120cm</u>

Que 44. When the path travelled along the road surface is more than the circumferential movement of the wheels due to rotation, then it results in-

a) Slipping

b) Skidding

c) Turning

d) Revolving

Que 44. When the path travelled along the road surface is more than the circumferential movement of the wheels due to rotation, then it results in-

a) **Slipping**

b) **Skidding**

c) **Turning**

d) **Revolving**

Que 45. Compared to a level surface, on a descending gradient the stopping sight distance is-

a) Less

b) More

c) Equal

d) Dependent on speed

Que 45. Compared to a level surface, on a descending gradient the stopping sight distance is-

a) Less

b) **More**

c) Equal

d) Dependent on speed

When Vehicle is moving on Levelled Ground

$$SSD = vt + \frac{v^2}{2g\mu}$$

When Vehicle is moving on a Gradient

- For up gradient,

$$SSD = vt + \frac{v^2}{2g(\mu + 0.01n)}$$

- For Down Gradient,

$$SSD = vt + \frac{v^2}{2g(\mu - 0.01n)}$$

Que 46. On a single lane road with two way traffic, the minimum stopping distance is equal to-

a) Stopping distance

b) Two times the stopping distance

c) Three times the stopping distance

d) Half the stopping distance

Que 46. On a single lane road with two way traffic, the minimum stopping distance is equal to-

a) Stopping distance

b) <u>Two times the stopping distance</u>

c) Three times the stopping distance

d) Half the stopping distance

IRC recommendations for SSD:

1. For single lane road with two-way traffic, the minimum SSD should be equal to 2SSD (for same speed).
2. For undivided highway with two-way traffic effect of gradient is not considered while calculating SSD. However for divided highway, gradient is considered.
3. SSD on vertical curves is calculated along the centre line of the curve from which a driver with an eye level of 1.2m above the ground surface can see an obstacle 0.15m above the ground.
4. If SSD cannot be provided in a particular stretch of road, proper sign boards with speed restrictions should be provided.

Que 47. As per IRC, the ruling design speed on a National Highway in a plain terrain is –

a) 60kmph

b) 80kmph

c) 100kmph

d) 120kmph

Que 47. As per IRC, the ruling design speed on a National Highway in a plain terrain is –

a) 60kmph

b) 80kmph

c) <u>100kmph</u>

d) 120kmph

TYPE OF ROAD	RULING SPEED	MINIMUM SPEED
Expressway	120 km/h	100km/h
NH/SH	100 km/h	80 km/h

Que 48. Highway facility are designed for –

a) Annual average hourly volume

b) Annual average daily traffic

c) Thirtieth highest hourly volume

d) Peak hourly volume of the year

Que 48. Highway facility are designed for –

a) Annual average hourly volume

b) Annual average daily traffic

c) Thirtieth highest hourly volume

d) Peak hourly volume of the year

Que 49. Desire lines are plotted in –

a) Traffic volume studies

b) Speed studies

c) Accident studies

d) Origin and destination studies

Que 49. Desire lines are plotted in –

a) Traffic volume studies

b) Speed studies

c) Accident studies

d) Origin and destination studies

- ORIGIN AND DESTINATION STUDY:
  - It determines the information like duration of travel, selection of route and length of route.
  - These studies help in planning new highways and improving the existing services.
  - Methods :
    - Road side interview method
    - License plate method
    - Return post card method
    - Tag on car method
    - Home interview method
    - Work spot interview method
  - O & D data are represented in the form of desire lines (thickness of line represents number of trips), pie charts (dia of circle represents traffic volume) and contour lines.

Que 50. Bitumen of grade 80/100 means

a) Its penetration value is 8mm

b) Its penetration value is 10mm

c) Its penetration value is 8 to 10mm

d) Its penetration value is 8 to 10 cm

Que 50. Bitumen of grade 80/100 means

a) Its penetration value is 8mm

b) Its penetration value is 10mm

c) Its penetration value is 8 to 10mm

d) Its penetration value is 8 to 10 cm

Que 51. Group index method of design of flexible pavement is –

a) A theoretical method

b) An empirical method based on physical properties of sub grade soil

c) An empirical method based on strength characteristics of sub grade soil

d) A semi empirical method

Que 51. Group index method of design of flexible pavement is –

a) A theoretical method

b) An empirical method based on physical properties of sub grade soil

c) An empirical method based on strength characteristics of sub grade soil

d) A semi empirical method

GROUP INDEX TEST

- **Group Index is a number assigned to the soil based on its physical properties like particle size, Liquid limit and plastic limit.**
- **It varies from a value of 0 to 20, lower the value higher is the quality of the sub-grade and greater the value, poor is the sub-grade.**

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

Where

- a= percentage of soil passing 0.074 mm sieve in excess of 35 per cent, not exceeding 75.
- b= percentage of soil passing 0.074 mm sieve in excess of 15 per cent, not exceeding 55
- c= Liquid limit in per cent in excess of 40.
- d= Plasticity index in excess of 10.

Que 52. The recommended grade of tar for grouting purpose is –

a) RT-1

b) RT-2

c) RT-3

d) RT-5

Que 52. The recommended grade of tar for grouting purpose is –

a) RT-1

b) RT-2

c) RT-3

d) RT-5

- Tar
  - It is made by destructive distillation(burning in absence of air/oxygen) of coal/wood.
  - 5 grades of tar are found:
    - RT-1, RT-2, RT-3, RT-4 AND RT-5.
  - RT-1
  - For surface dressing under cold weather conditions and use on hill roads at high altitude as well as for priming the base;
  - RT-2
    - For surface painting in normal climatic conditions;
  - RT-3
    - a) For surface painting and renewal coat;
    - b) For premix chipping carpet (top course and light carpets);
  - RT-4
    - For premix tar macadam (base course) and dense tar surfacing; and
  - RT-5
    - For grouting and water proofing.

Que 53. In CBR test, the value of CBR is calculated at –

a) 2.5mm penetration

b) 5mm penetration

c) 7.5mm penetration

d) Both 2.5mm and 5mm penetration

Que 53. In CBR test, the value of CBR is calculated at –

a) 2.5mm penetration

b) 5mm penetration

c) 7.5mm penetration

d) **Both 2.5mm and 5mm penetration**

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

PENETRATION	STANDARD LOAD
2.5mm	1370kg
5mm	2055kg

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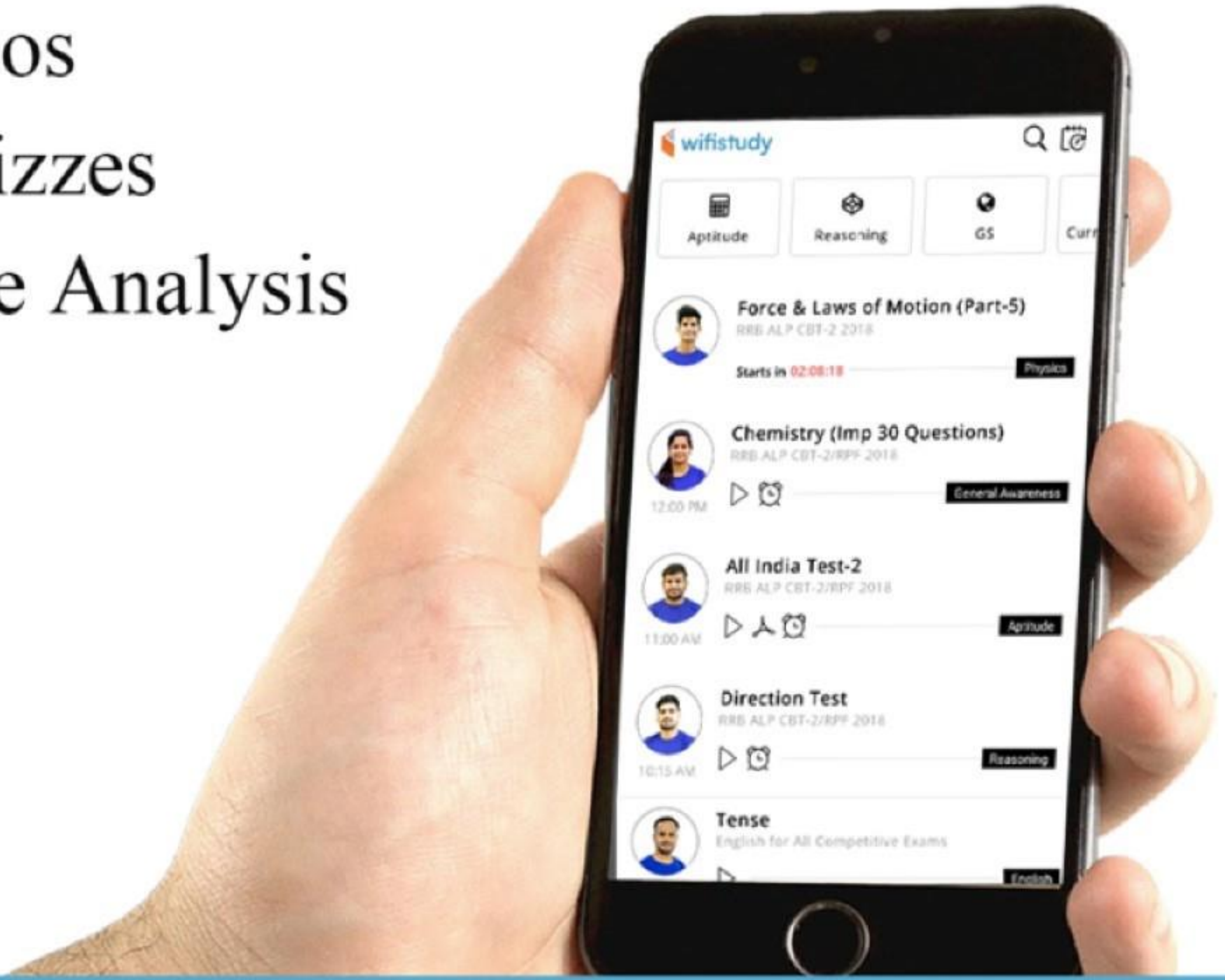

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