Highway development & planning ⟹ Module – I.

- **Road development in India :=**

After the first world war (1914), motor vehicles using the roads increased and this demanded a better road network which can cary both bullock cart traffic & motor vehicles. The existing roads when not capable to withstand the mixed traffic conditions. In response to the resolution, Indian Road Development Committee was appointed by the government with M.R. Jayakar as chairman, in 1927. The Jayakar Committee submitted its report by the year 1928. The most important recomendations made by the Committee are:

(i). The road development in the country should be considered as a national interest as this has become beyond the capacity of provincial governments & local bodies.

(ii). An extra tax should be on petrol form the road users to develop a road development fund called central Road Fund.

(iii). A semi-official technical body should be formed to pool technical know-how from various parts of the country & to act as an advisory body on various aspects of roads.

(iv). A research organisation should be instituted to carry out research & development work & to be available for consultations.

- **central road fund :=** The central road fund (1929) assessed that the consumers of petrol were charged an extra leavy of 2.64 Paisa per litre of petrol to build up the road development fund 20% of the annual revenue is to be retained as a central Reserve for road development & research also by the central Government.

- **Indian roads Congress :=** The Indian roads Congress (1934) was constituted to provide a forum for planning, Construction & maintenance of road in

India.

- **Motor vehicle Act** :- In 1939 the motor vehicle act was brought into effect by Government of India to regulate the road traffic in the form of traffic laws, ordinances & regulations. The three phases primarily covered are control of the driver, vehicle ownership & vehicle operation on roads & in traffic stream. The motor vehicle act has been revised in 1988.
- **National Highway Act** :- In 1956 the national highway act was passed. The main features of the act ~~act~~ are:

(i). The responsibility of development & maintenance of the national highway (NH) to be provisionally taken by the central government.

(ii). The central government to be empowered to declare any other highway as NH or to omit any of the existing national highways from the list.

Classification of Roads ⟹

(a) Depending on weather → (i) All-weather Road.
(ii) Fair-weather Road.

(b) Based on types on pavements →
(i) Pave - road.
(ii) Unpave road.

(c) Road classification based on location & function →
(i) National highway (NH).
(ii) State highway (SH).
(iii) Master district road (MDR).
(iv) Other district road. (ODR).
(v) Village road (VR).

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Formation width / Road way width (As per IRc) :-

Road classification	Plain / Rolling	Mountaneous/Steep
1. NH or SH		
a) Single Lane	12 m	6.25 m
b) Double Lane	12 m	8.8 m
2. MDR		
a) Single lane	9 m	4.75 m
b) Double Lane	9 m	
3. ODR		
a) Single Lane	7.5 m	4.75 m
b) Double Lane	9 m	
4. Village Road	7.5 m	4.0 m

(*) In multilane highways, roadway width should be adequate for the requisite number of traffic lanes besides shoulders & central median.

(*) The minimum roadway width on single lane bridge is 4.25 m.

- Right of way is governed by the following factors:-

i) width of road.
ii) Height of embankment or slope of embankment,
iii) Soil type & side slope.
iv) Drainage system.
v) Sight distance.

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- **Recommended land width for Urban roads :=**

i) Arterial road ⟶ 50–60 m.
ii) Sub-arterial road ⟶ 30–40 m.
iii) Collector Streets ⟶ 20–30 m.
iv) Local Streets ⟶ 10–20 m.

Cross slope or camber ⟹ Camber is a slope provided to the road surface in the transverse direction to drain-off the rainwater from the road surface.

Also used to regulate the vehicles to their proper lane & to improve architectural appearance of the roadway. Camber depends on –
i) Type of road surface.
ii) Amount of rain-fall.

(*) The rate of camber or cross slope is usually designed by 1 in 'n' which means that the transverse slope is in ratio 1 vertical to 'n' horizontal. Camber is also expressed as percentage. If the camber is x%, the cross slope is x in 100.

(*) A flat camber of 1.7 to 2.0% is sufficient for cement concrete or bituminous concrete.

(*) Steeper camber are also provided in areas of heavy rainfall.

(*) The camber is given a parabolic elliptic or straight line shape in the cross section.

(*) When very flat cross slope is provided as in cement concrete pavements, straight line shape of camber may be provided.

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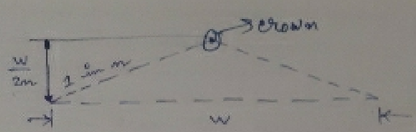
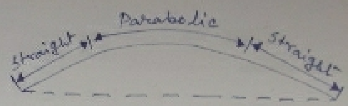
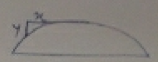


[Straight line camber]





Parabolic shape.

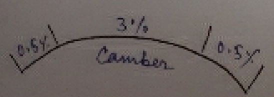
$\left[Y = \frac{2x^2}{nW}\right]$.

[Combination of straight & parabolic slope].

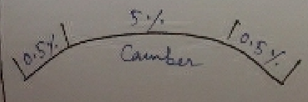
• Type of road surface	Range of camber in area of rainfall range Heavy to Light
i) Cement Concrete & high type bituminous surface	1 in 50 (2%) to 1 in 60 (1.7%)
ii) Thin bituminous surface	1 in 40 (2.5%) to 1 in 50 (2%)
iii) WBM & gravel pavement	1 in 33 (3%) to 1 in 40 (2.5%)
iv) Earth	1 in 25 (4%) to 1 in 33 (3%)

(*) The cross slope for shoulders should be 0.5% steeper than the cross slope of adjoining pavement, subject to a minimum of 3% (and a max. value of 5% for earth shoulders).

Bitumen Road with Concrete shoulder →



Bitumen road with earth shoulder or soil shoulder →



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visible to the driver to the instant the breaks are applied. Higher the reaction time, more is the sight distance.

$\therefore$ Total reaction time = Perception time + Break reaction time

iii) **Efficiency of breaks** → It is an important factor which is affecting the sight distance. The break efficiency is said to be 100% if the wheels are fully locked preventing them from rotating on application of the breaks.

iv) **Co-efficient of friction** → The frictional resistance developed between road and tyres. The skid resistance developed on the type & condition of road surface. The co-efficient of friction depends on the speed of vehicle. Higher co-efficient of friction less the distance.

v) **Ground slope** → Stopping sight distance is on descending grade is higher & it is less for asscending grade.

PIEV Theory :

According to PIEV theory, the total reaction time of the driver is split into four parts time taken by the driver for —

i) **Perception time** → It is the time required for the sensation received by the eyes or ears of driver to be transmitted to the brain through the nervous system and spinal c ord.

ii) **Intellection time** → It is the time required for the driver to understand the situation. It is also the time required for comparing the different thoughts, regrouping & registering new sensations.

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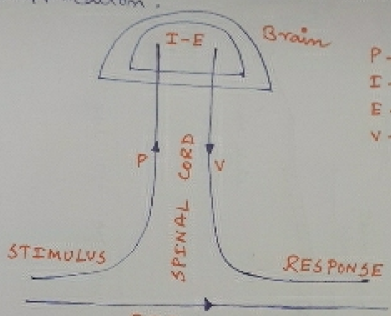
iii) **Emotion time** → It is the time elapsed during emotional sensations & disturbance such as fear, anger or any other emotional feelings such as superstition etc. with reference to the situation. Therefore, the emotion time of a driver is likely to vary considerably depending on the problems involved.

iv) **Volition time** → It is the time taken for the final action, such as break application.



P – Perception
I – Intellection
E – Emotion
V – Volition

(*) The total reaction time of an average driver may vary from 0.5 sec for simple situations to as much as 3 to 4 sec. or more even more in complex problems.

(*) The height of eye level of driver as 1.2 m.

(*) The height of the object as 0.15 m above the ground surface.

(*) Height of the plantation from median area ground surface is about 1.5 m.

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- The distance travelled by the vehicle during the total reaction time is called lag distance.
- The distance travelled by the vehicle after the application of the breaks, to a dead stop position is called breaking distance.

∴ SSD = [Lag distance + Breaking distance].

If 'v' is the design speed in m/sec & 't' is the total reaction time of the driver in seconds, then the lag distance will be 'vt' metres.

If the design speed is 'v' kmph, the lag distance

$$v \times \frac{1000}{60 \times 60} \times t = 0.278\, vt \ (m).$$

[IRC has recommended the value of reaction time $(t) = 2.5$ sec].

Assume break distance = l m

Max. frictional force = F

∴ The total work done against frictional force to stop the vehicle = $F \times l = f \times W \times l$

[f = ~~Acceleration~~, W = weight of vehicle, l = breaking distance (m)].

The kinetic energy at the design speed of v m/sec will be

$$\frac{1}{2} m v^2 = \frac{W v^2}{2g}$$

$$\Rightarrow f \times W \times l = \frac{W v^2}{2g}$$

$$\Rightarrow \boxed{l = \frac{v^2}{2gf}}$$

[f = Design co-efficient of friction = 0.4 to 0.35 depending on speed, from 30 to 80 kmph.

g = Acceleration due to gravity = 9.8 m/sec^2].

$$\therefore \boxed{SSD\,(m) = \left[vt + \frac{v^2}{2gf} \right]}$$

$$\therefore \boxed{SSD = \left[0.278\, vt + \frac{v^2}{254 f} \right]}$$

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Important factor for OSD →

(a) Speeds of i) overtaking vehicle.
ii) over taken vehicle.
iii) the vehicle coming from opposite direction.

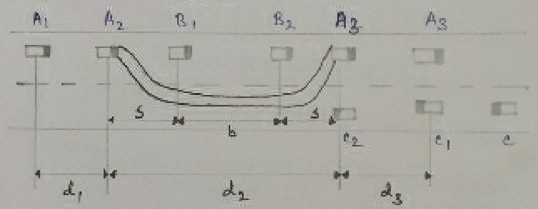
(b) Distance between the overtaking & over-taken vehicles, the minimum spacing depends on the speed.

(c) Skill & reaction time of the driver.

(d) Rate of acceleration of over taking vehicle.

(e) Gradient of the road.

Analysis of OSD ⟹



d_1 = Distance travel by the overtaking vehicle 'A' during the reaction time 't' sec of the driver from position 'A_1' to 'A_2' before starting to overtake the slow vehicle 'B'.

d_2 = Distance travel by the vehicle A during the actual overtaking operation during 'T' sec from position 'A_2' to 'A_3'

d_3 = Distance travel by the oncoming vehicle 'C' during the actual overtaking operation of vehicle 'A' during 'T' sec from position 'C_1' to 'C_2'.

S = Spacing between 'A_2' to 'B_1' & 'B_2' to 'A_3'

b = Distance covered by the vehicle 'B' at 'T' sec.

$$\boxed{OSD = d_1 + d_2 + d_3}$$

- **centrifugal force** is a force that arises from the body's inertia & appears to act on a body that is moving in a circular path which is directed away from the centre around which the body is moving.

∴ centrifugal force 'p' is given by —

$$\boxed{P = \frac{Wv^2}{gR}}$$

[P = centrifugal force (N).
W = weight of vehicle (kg).
R = Radius of circular curve (m).
V = Speed of vehicle (m/sec).
g = Acceleration due to gravity = 9.81 m/sec².]

(*) The ratio of the centrifugal force to the weight of the vehicle that is (P/W) is known as centrifugal ratio or impact factor.

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

(*) The centrifugal force acting on a vehicle negotiating a horizontal curve has two effects —

i) Tendency to overturn the vehicle outwards about the outer wheels.

ii) Tendency to skid the vehicle laterally, outwards.

Super-elevation :⇒ In order to counteract the effect of centrifugal force & to reduce the tendency of vehicle to over-turn or skid, the outer edge of pavement is raised with respect to the inner edge, thus providing a transverse slope throughout the length of the horizontal curve. This transverse inclination to the pavement surface is known as Superelevation or cant or banking.

$$\therefore \frac{P}{W} \approx \tan\theta + f$$
$$= e + f \quad [\because e = \tan\theta]$$

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

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

Here, e = rate of superelevation = $\tan\theta$
f = Coefficient of friction = 0.15
v = Speed of vehicle (m/sec).
R = Radius of horizontal curve (m).
g = Acceleration due to gravity = 9.81 m/sec².

$$\therefore e + f = \frac{(0.278V)^2}{9.81R} = \frac{V^2}{127R}$$

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

(*) If pressure on inner or outer wheels are equal, then we should calculate the e, where taking $f = 0$.

(*) As IRC recommended in plain & rolling terrians & in snow bond areas, maximum values of superelevation is about 7%. In hilly road not bound by snow is about 10%.

- **Steps for superelevation design :=>**

<i> **Step – I** → The superelevation for 75% of design speed (v m/sec or V kmph) is calculated neglecting the friction – $\boxed{e = \frac{V^2}{225R}}$ —(i)

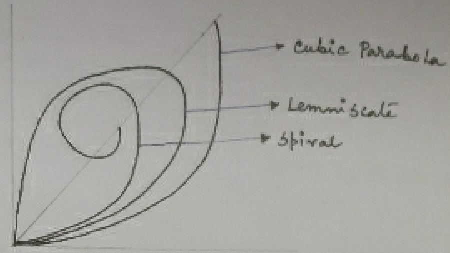
<ii> **Step – II** → (a) If the calculated value of 'e' is less 7%, the value so obtained is provided.
(b) If the value of 'e' as per equation (i) exceeds 7%, then provide the maximum superelevation equal to 7% & proceed with steps III & IV.

$\therefore L = m\sqrt{\theta}$

Here, m is a Constant eqnal to $\sqrt{2RL_s}$ & θ is the tangent deflection angle in radius.

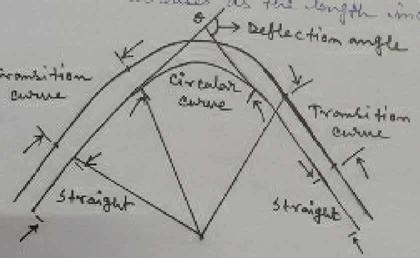
(b) Lemniscate → (a). The radius decreases as the length increases.

(b). Deflection angle higher than 4°.



(c) Cubic parabola → (a). Deflection angle higher than 4°.

(b). The radius decreases as the length increases.



Transition curve in horizontal alignment.

(*) The centrifugal acceleration (c) = $\frac{V^3}{L_s \cdot R}$ (m/sec^3)

The IRC has recommended the eqn (c) = $\frac{80}{75+V}$ m/sec^3,

[0.5 < c < 0.8]

Minimum Value — Maximum Value

(*) Length of transition curve

$(L_s) = \frac{0.0215 V^3}{CR}$, (m)

[R = radius of circular curve (m)].

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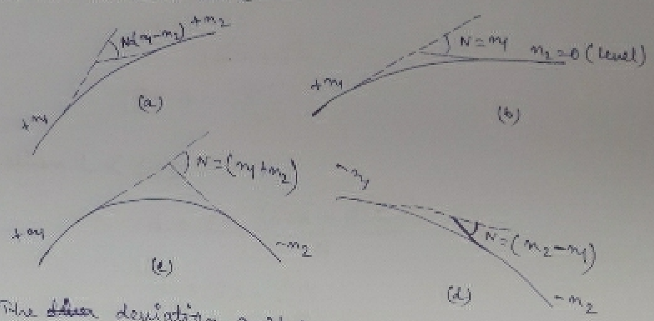
• Summit curves or crest curves :=>

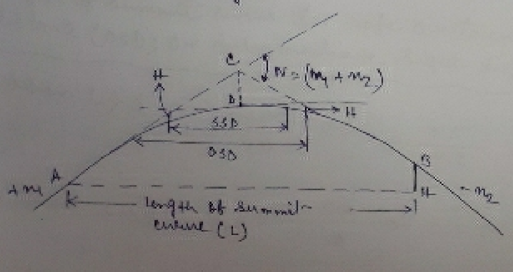
Summit curves with convexity upwards are formed in any one of the case like —



The deviation angle (N) between the two interacting gradients is equal to the algebric difference between them. The deviation angle will be maximum when an ascending gradient meets with the descending gradient i.e. $N=(n_1+n_2)$. Figs represent that the —

(a) when positive gradient meets another positive gradient.
(b) when positive gradient meets flat gradient.
(c) when positive gradient meets another negative gradient.
(d) when negative gradient meets another negative gradient.

Parabolic summit curve generally adopted for construction & design process. For summit curve, SSD & OSD are considered separately.



Length of summit curve.

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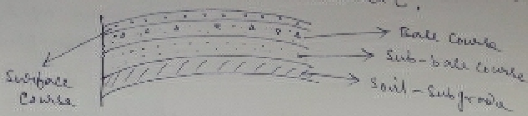
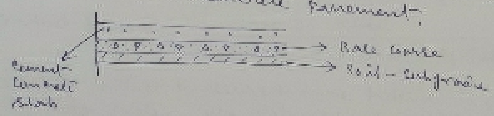
Design Of Highway Pavements.

Module – III.

- **Flexible Pavements** → The road pavements which can change their shape of some extent without rupture are known as flexible pavements, examples → All bituminous pavements, gravel pavements, WBM pavements etc.



- **Rigid Pavements** → The road pavements which cannot change their shape without rupture are known as rigid pavements. Example → Cement – Concrete pavement.



- **Semi-rigid Pavements** → When bonded materials like the pozzolanic basic concrete, lean concrete or soil – cement are used to construct the base – course or sub-base course of the pavement, then that is called semi-rigid pavement. Semi-rigid pavement has higher flexural strength.

- **Crocodile cracking** → This is most common type of failure. This may occurs due to relative movement of pavement layer materials. This may be caused by application of heavy wheel load or due to moisture variation.
Result is swelling & shrinkage of sub-grade & other pavement material. Occurs weakness in underlying base course which cause a cracking of surface course.

(...whichever is higher).

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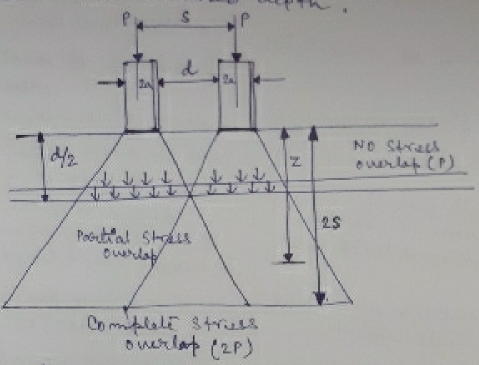
$$\therefore ESWL = \log_{10}(ESWL) = \log_{10}(P) + \frac{0.3011 \log_{10}\left(\frac{z}{d/2}\right)}{\log_{10}\left(\frac{2S}{d/2}\right)}$$

where, P = The wheel load.

S = The center to center distance between two wheels.

d = clear distance between two wheels

z = The desired depth.



Stress overlap due to Dual wheels

Flexible Pavement	Rigid Pavement
(i) Initial cost is low.	(i) Initial cost is high.
(ii) Life span is short.	(ii) Life span is long.
(iii) A reasonably subgrade is required.	(iii) A reasonably subgrade is not needed.
(iv) Moderate skill & less supervision is required.	(iv) High degree of skill & more supervision required.
(v) Joints are not being required.	(v) Joints are so much needed.
(vi) All type of traffic vehicle is suitable.	(vi) Only iron wheeled traffic is suitable.
(vii) Poor visibility at night.	(vii) Night visibility is clear.
(viii) Durability is more.	(viii) Durability is less.
(ix) They do not glare due to reflected sun light in day.	(ix) They are glare due to reflected sun light in day.
(x) Stress is not induced on pavement due to temperature variation.	(x) Stress is heavy that induce in pavement due to temperature variation.

• Design of Rigid Pavements :⇒

cement Concrete pavements represent the group of rigid pavements. Here the load carrying capacity is mainly due to the rigidity & high modulus of elasticity of the slab itself i.e., slab action. H.M. Westergaard Considered the rigid pavement slab as a thin elastic plate resting on soil subgrade which is assumed as a dense limit liquid.

Here it is assumed that the upward reaction is proportional to the deflection, i.e., $\boxed{p = k\Delta}$, where, k = modulus of subgrade reaction (kg/cm³).

Westergaard's Modulus of Subgrade Reaction :⇒

The modulus of subgrade reaction 'k' is proportional to the displacement. The displacement level Δ is taken as 0.125 cm in calculating k as. p is the pressure sustained in kg/cm² by the rigid plate of diameter 75 cm at a deflection Δ = 0.125 cm, the modulus of subgrade reaction k is given by–

$$K = \frac{p}{\Delta} = \frac{p}{0.125} \text{ kg/cm}^3.$$

Relative Stiffness of Slab to Subgrade :⇒

The pressure deformation characteristics of rigid pavement is thus a function of relative stiffness of slab to that of subgrade.
Westergaard defined this term as the Radius of relative stiffness —

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

where,
E = Modulus of elasticity of Cement–Concrete (kg/cm²).
μ = Poisson's ratio for concrete = 0.15.
h = Slab thickness (cm).
k = Subgrade modulus or modulus of subgrade reaction (kg/cm³).

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Westergaard's stress eqvation for wheel loads:

The Concrete cement slab is assumed to be a homogeneous thin elastic plate with subgrade reaction being vertical & proportional to the deflection. After discovered by Grolobeck, westergaard derived the ultimate stress eqvation for wheel loads in interior, edge & corner position of a cement concrete slab pavement. So that —

Interior Loading $\longrightarrow$

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

Edge Loading $\longrightarrow$

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

Corner Loading $\longrightarrow$

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

S_i, S_e, S_c = Maximum stress at interior, edge & corner loading respectively (kg/cm^2).

h = Thickness of slab (cm).

P = wheel load (kg).

a = Radius of wheel load distribution (cm).

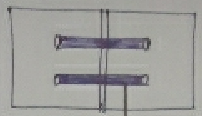
l = Radius of relative stiffness (cm).

b = Radius of resisting section (cm).

(whichever is higher)

(*) Advantage → a) Reduce deflection and stresses.
b) It increase the load-carrying capacity of slab.
c) To increase the initial pavement life.

(*) Longitudinal joints in cement concrete pavements are constructed with suitable tie bars.



(*) The expansion & contraction joints are not to have a gap more than 2.5 cm in any case.

(*) Max. spacing between expansion joints should not exceed 140 m for rough interface layer.

(*) Diameter of dowel bar is 1.25 inch to 1.5 inch.

(*) length of Dowel bar is 18 inch.

(*) c/c spacing of dowel bars are 12 inch.

Dowel bars	Tie bars
i) Placed across transverse joints at the mid-depth of slab.	i) Placed across longitudinal joints at the mid-depth of slab.
ii) Transfer load from one slab to another without preventing joint from opening.	ii) Prevent lanes from separation & differential deflection.
iii) This is round & smooth epoxy coated steel bars.	iii) This is deformed epoxy coated steel bars.
iv) Reduce joint faulting & corner cracking.	iv) Reduce transverse cracking.

Module – IV.

Traffic Engineering

- Traffic characteristics
  - Road user Characteristics
    - Mental
    - Physical
    - Psychological
    - Environmental
  - Vehicular characteristics
    - Static
      - weight
      - Dimension
    - Dynamic
      - Acceleration
      - Power
      - velocity
      - Breaking Test
- Traffic Studies & Analysis
  - Traffic vol. Study
- Traffic Operation
  - Road Signs
  - Road Marking
  - Traffic Islands
  - Road Signals

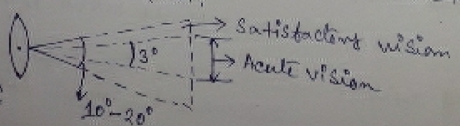
Another part of traffic engg. →

Road Intersection

- Intersection at grade.
- Grade Separated Intersection

(*) In road user characteristics physical characteristics is very important part.

Eye vision



- **Time-mean Speed** represents the speed distributed of vehicles at a point on the roadway & it is the avg. of instantaneous speeds of observed vehicles at the spot.

$$V_t = \frac{\sum_{i=1}^{n} V_i}{n}$$

[V_i = Observed instantaneous speed (kmph).
n = No. of vehicle observed.]

- **Spot speed study** → Spot speed study may be useful for following aspects.

a) To use in planning traffic control & in traffic regulations.

b) To use in geometric design for redesigning existing highway or for deciding design speed for new facilities.

c) to use in accident studies.

d) to study the traffic capacity.

e) to decide the speed trends.

f) to compare diverse types of drivers & vehicles under specified conditions.

- **Traffic volume** → Traffic vol. is the number of vehicles moving in a specified direction on a given lane or roadway that pass a given point or cross section during specified unit time. It is expressed as vehicles per hour or vehicles per day.

- **Traffic density** → Traffic density is the number of vehicles occupying a unit length of roadway at a given instant, usually expressed as vehicle per km.

$$\boxed{\text{Traffic vol.} = \text{Traffic density} \times \text{Traffic speed}}$$

- **Traffic capacity** → It is the ability of a roadway to accommodate traffic vol. It is expressed as the max. number of vehicle in a lane or a road that can pass a given point in unit time (hr) i.e., vehicle per hour per lane.

70

$\therefore T(\text{min}/\text{Km}) = \frac{60}{V}$

or $T(\text{sec}/\text{Km}) = \frac{3600}{V}$

The fundamental relationship between traffic volume, density & speed may be given by the general equation of traffic flow —

$$\boxed{q = K V_s}$$

where, q = the average volume of vehicle passing a point during a specified period of time (vehicle/hr).

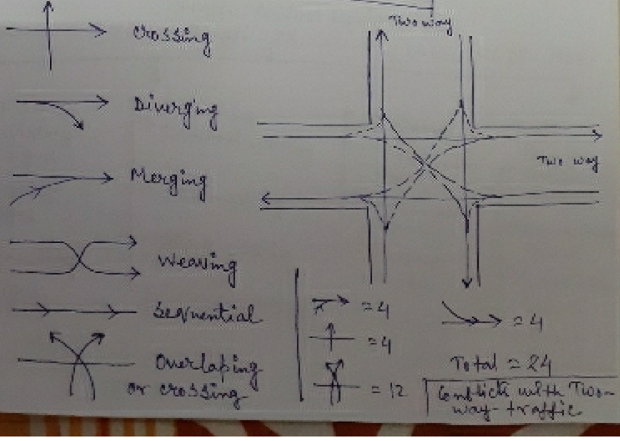
K = the average density or number of vehicles occupying a unit length of roadway at a given instant (vehicle/Km).

V_s = space – mean speed of vehicles in a unit roadway length (Kmph).

(*) The maximum speed value is called free means speed (V_{sf}) and the maximum density at zero speed is called jam density (K_j).

(*) The maximum flow (q_{max}) or the capacity flow (q_c) occurs when the speed is $\frac{V_{sf}}{2}$ & density is $\frac{K_j}{2}$

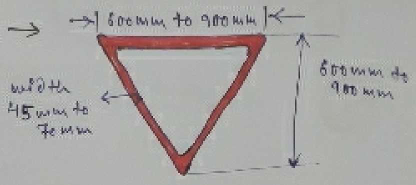
$$\therefore \boxed{q_{max} \text{ or } q_c = \frac{V_{sf} \cdot K_j}{4}}$$



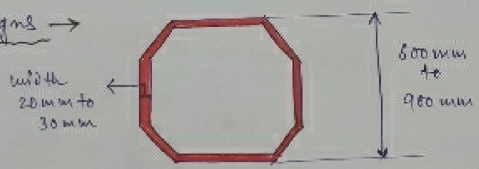
(i) Mandatory or Regulatory signs :→ The road signs used to inform road users of certain laws & regulations to provide safety & free flow of traffic & violation of which is a legal offence are called mandatory or regulatory signs.

- According to IRC : 67 – 1977, mandatory or regulatery signs are of the following types :→

(A) i) Give way signs →

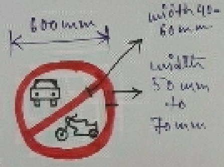


ii) Stop signs →



(B) Probibitory signs →

i) All motor vehicles prohibited →



ii) Bullock cart prohibited →

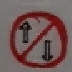
iii) Bullock cart & hand cart prohibited.

iv) cycle prohibited

v) Hand cart prohibited

vi) Horn prohibited →

vii) One way →



viii) Overtaking prohibited →

- **Webster's method** :→ In this method, the optimum signal cycle C_o corresponding to least total delay to the vehicles at the ~~Signif~~ signalized intersection has been worked out. This is a rational approach. The field work consists of finding;

(a) the saturation flow 'S' per unit time on each approach of the water section.

(b) the normal flow 'q' on each approach during the design hour.

Based on the higher value of normal flow, the ratio $y_1 = q_1/S_1$ & $y_2 = q_2/S_2$ are determined on the approach roads in different manner. The approximate value of saturation flow is estimated assuming 160 PCU per 0.3 metre width of the approach.

∴ The optimum signal cycle is given by —

$$C_o = \frac{1.5L + 5}{1 - Y}$$

where, L = Total lost time per cycle (secs)

$= 2n + R$ (n = number of phase & R = All red-time).

∴ Total critical flow ration —

∴ $\boxed{Y = y_1 + y_2}$

Then, $G_1 = \frac{y_1}{Y}(C_o - L)$ & $G_2 = \frac{y_2}{Y}(C_o - L)$

where, G = Phase of traffic signal in green time.

→| cycle length |←

No. of phase			
(I)	G	A	R
(II)	R	G	A

→| cycle length |←

Minimum phase time = 2

& Max. phase time = 4 or 6.

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