AIR-1 Notes

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Highway

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HIGHWAY

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Highway Engineering

[ESE → 4-6 Ques, Conventional → 30-60 marks, GATE → 3-5 Ques]

1) Geometric Design
2) Traffic Engineering
3) Pavement Design
4) Highway materials

1. Geometric Design

→ Geometric design of highway deals with the visible elements of the road. Various geometric design components depends on:

1) Type of Road

(A) Rural Roads

(i) Expressway: Speed upto 120 kmph
(ii) National Highway: Joins various states
(iii) State Highway: Joins various districts.
(iv) Major District Roads (MDR): Joins areas of population or production with the main highway
(v) Other District Roads (ODR): Joins rural areas to the market place
(vi) Village Roads: Joins various villages

NOTE: IRC:73 deals with the geometric design of rural highways

(B) Urban Roads

(i) Expressway (120kmph) [Divided Arterial Roads]
(ii) Arterial Roads (80 kmph)
(iii) Sub-Arterial Roads (60 kmph)
(iv) Collector Streets (50 kmph)
(v) Local streets (30 kmph)

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2) Type of Vehicle : The vehicle for which road elements are designed is called design vehicle.

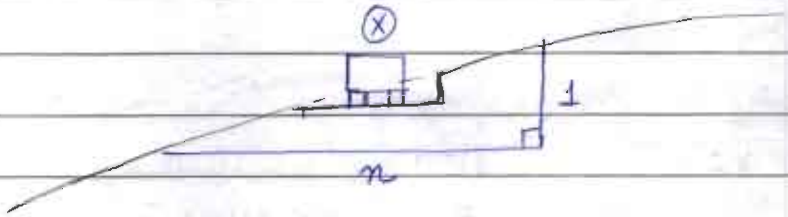
→ Length, width, height of design vehicle are used as design parameters for the roads.

NOTE: IRC:003 deals with the dimension of design vehicle.

→ Width of vehicle = 2.5 m

→ Height of vehicle = 3.8 to 4.75 m [4.75 m is for Double Decker bus]

3) Topography : It is classified on the basis of general country slope across the road alignment. It is expressed as 1 in n or x%.
[x% = x in 100]



Cross-country slope	Class	
0 – 10%	Plain	
10 – 25%	Rolling	
25 – 60%	Mountaneous	Hill Roads.
>60%	Steep	Hill Roads.

→ If cross-slope of the country is large then large expenditure has to be made in altering the alignment for design speed to provide a larger radius of curve to counteract against centrifugal force which causes skidding or overturning problems.

→ Hence when cross-country slope is large, the velocity should be restricted.

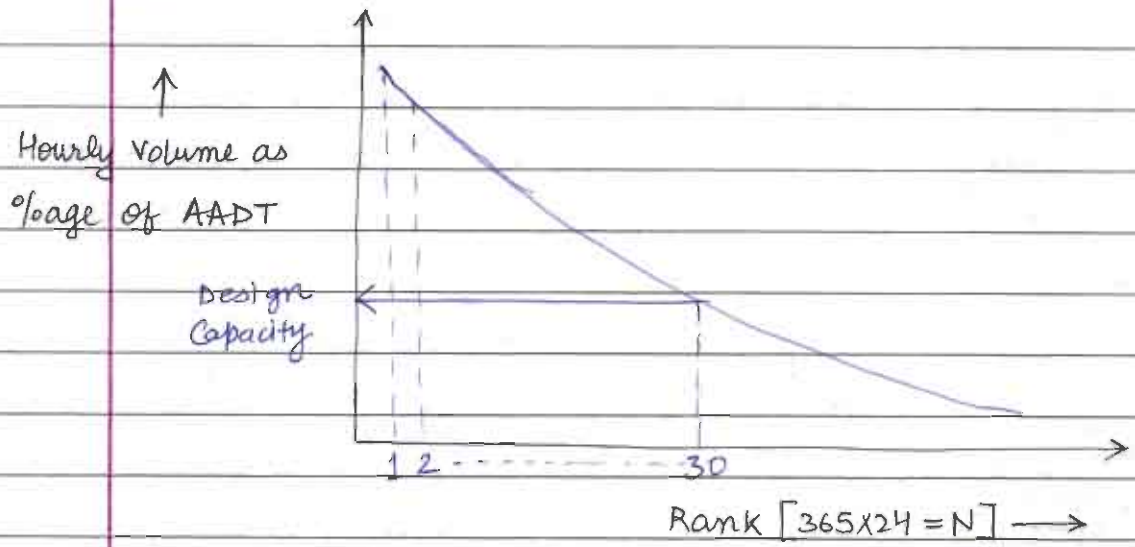
4) ⇒ Traffic Capacity

→ Traffic capacity is the ability of road to accommodate maximum traffic volume.

→ Traffic volume is the no. of vehicles crossing a point or section on the road in unit time.

→ Capacity and volume are both expressed in veh/hr.
[At a particular Level of Service (LOS)]

→ Normally design capacity is taken as 30th highest hourly volume.



AADT → Average annual Daily Traffic i.e. $\left[\frac{\text{Yearly Traffic}}{365}\right]$

→ Generally 30th highest hourly volume for Indian conditions comes around 8-10% of AADT

eg → if AADT = 2000 veh/day
then Design capacity = 160-200 veh/hr
or 30th highest hourly volume

→ Depending upon traffic capacity width of road is decided.

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5) Design speed

→ It is theoretically decided as 98th percentile speed i.e. the speed at or below which 98% of vehicles are moving.

→ However, from economical POV, IRC has limited the design speed based on topography.

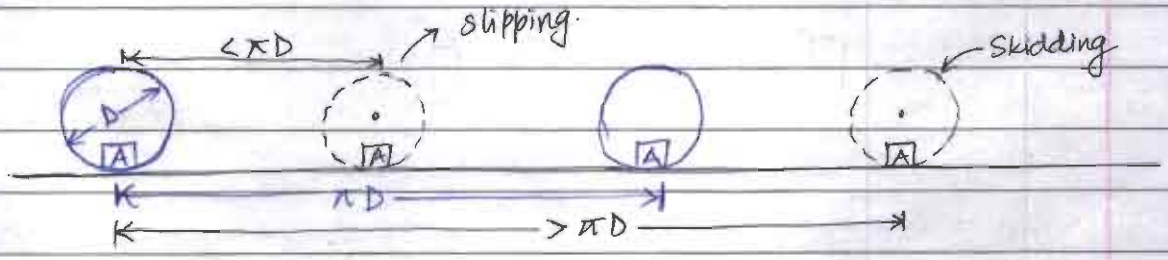
→ Normally ruling speed should be the guiding criteria however, minimum design speed can be adopted in localised sections where cost consideration does not permit ruling speed.

Type of Road	Plain		Rolling	
	Ruling (kmph)	Minimum (kmph)	Ruling (kmph)	Minimum (kmph)
Expressway	120	100	100	80
NH / SH	100	80	80	65

6) Surface characteristics

(i) Friction: Longitudinal friction coefficient as recommended by IRC is 0.35 to 0.40 and lateral friction coeff (or transverse) is 0.15 as recommended by IRC.

→ Lack of friction causes slipping or skidding



→ If one revolution of wheel leads to longitudinal movement less than πD, it is called slipping and if one revolution of the wheel leads to longitudinal movement greater than πD it is called skidding

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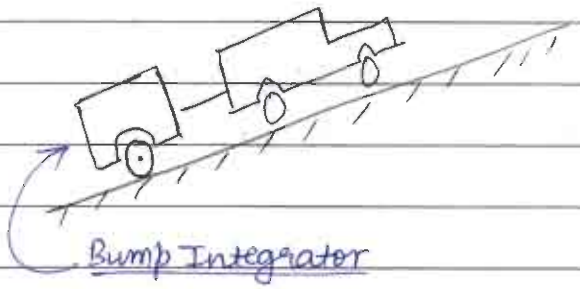
(ii) Unevenness Index

→ This index is a cumulative measure of vertical undulations per unit length of the road.

→ It is measured using Bump Integrator



Bump Integrator

→ Classification of roads based on unevenness Index.

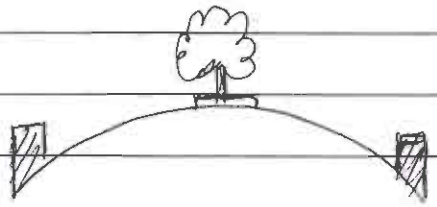
(i) Unevenness Index < 1500 mm/km → good surface

(ii) " " upto 2500 mm/km [100 kmph] → satisfactory surface

(iii) " " > 3200 mm/km [55 kmph] → unsatisfactory surface.

⇒ Various geometric design components of highway

1) Cross-sectional Element



2) Sight Distance

3) Horizontal Alignment details

4) Vertical alignment details

5) Intersection detail

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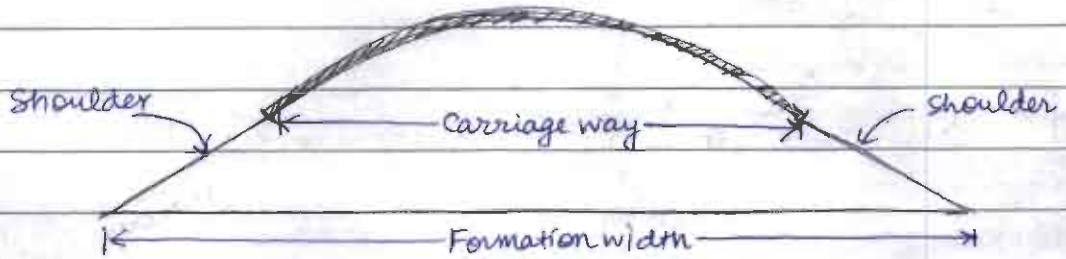
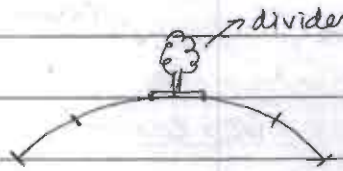
1) Cross-Sectional Elements

(a) Carriage way - It is the part of pavement designed to carry vehicles.



Type of road	Carriage way width
Single Lane	3.75 m
Two lane with no kerb	7.00 m
Two lane with raised kerb	7.50 m
Intermediate Lane	5.50 m
Multi Lane	3.50 m / Lane
Multi lane bridge	3.50 m / Lane + 0.5m per carriage way

3.5 X 4 + 0.5 = 14.5m



3.5 X 4 + 2 X 0.5 = 15m

(b) Shoulder - shoulders are provided to accommodate stopped vehicles and to provide lateral confinement to the pavement layers

→ Desirable width of shoulder is 4.6m with a minimum of 2.5m for 2 lane rural highway.

NOTE: Formation width for single / two lane NH section is 12m as per IRC

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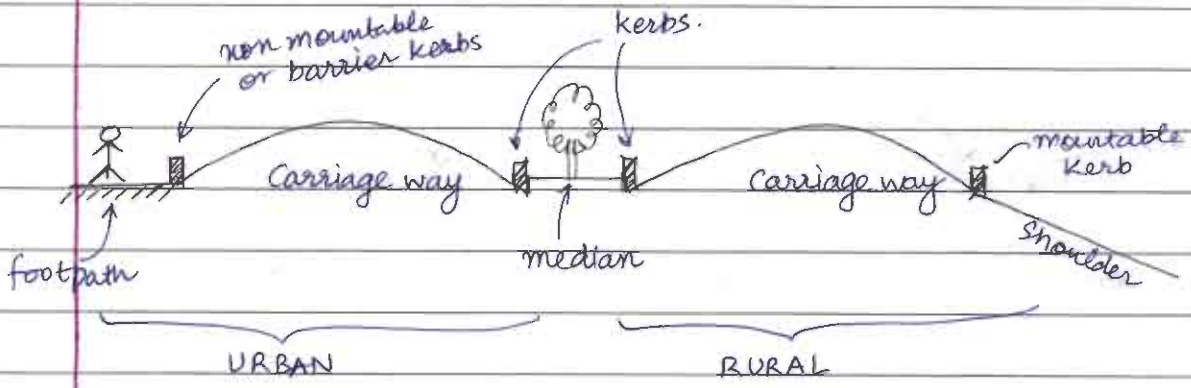
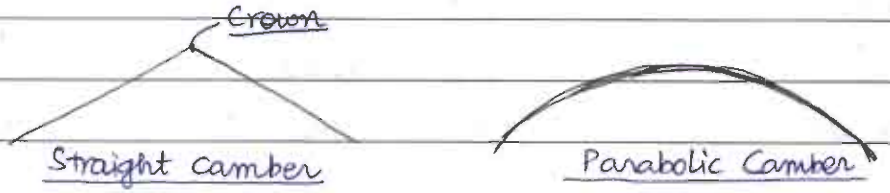
(c) Kerb

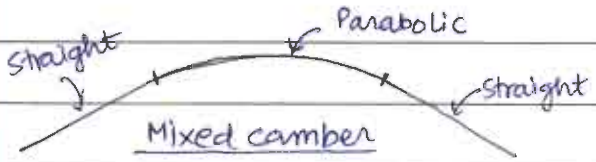
→ It indicates the boundary between pavement and shoulder or median or footpath.



(d) Camber or cross-slope or cross-fall

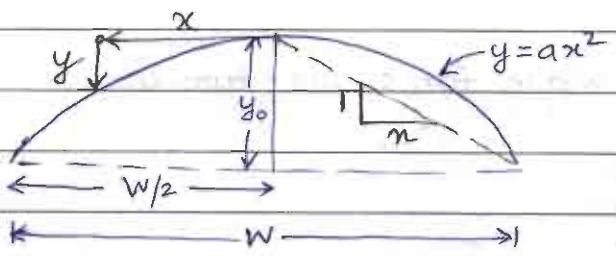
It is the slope provided to the road surface in transverse direction to drain off rain water.





→ For slow moving traffic straight camber can be adopted but for high speed traffic where crown has to be crossed frequently during overtaking, parabolic camber is preferred.

→ Equation of parabolic camber



1 : n → average camber

From similar Δ

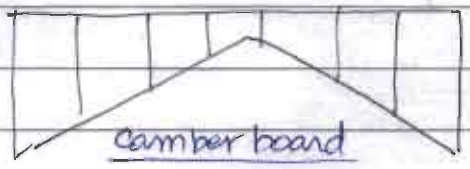
$$\frac{1}{n} = \frac{y_0}{W/2} \Rightarrow \boxed{y_0 = \frac{W}{2n}} \quad -(1)$$

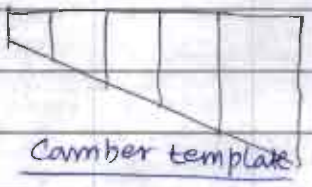
@ $x = W/2$, $y = y_0 \Rightarrow \boxed{y_0 = a\left(\frac{W}{2}\right)^2} \quad -(2)$

From (1) and (2) $\Rightarrow \frac{W}{2n} = \frac{aW^2}{4} \Rightarrow \boxed{a = \frac{2}{nW}}$

So, equation of parabolic camber $\Rightarrow \boxed{y = \frac{2}{nW}x^2}$

→ In field camber is checked by camber boards or templates.





NOTE: Bituminous pavement → Parabolic camber
Rigid pavement → Straight camber

→ IRC recommendations for camber

#	Type of Road	RAINFALL: Low (≤100cm)	Heavy (>100cm)
1)	Cement concrete or High type Bituminous pavement	1.7%	2%
2)	Thin bituminous pavement	2%	2-5%
3)	WBM / gravel	2.5%	3%
4)	Earthen	3%	4%

NOTE: Slope of shoulder should atleast be 0.5% steeper than the slope of camber subjected to a minimum of 3%.

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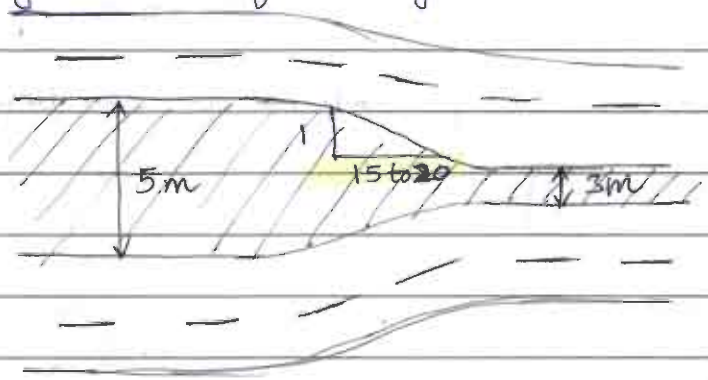
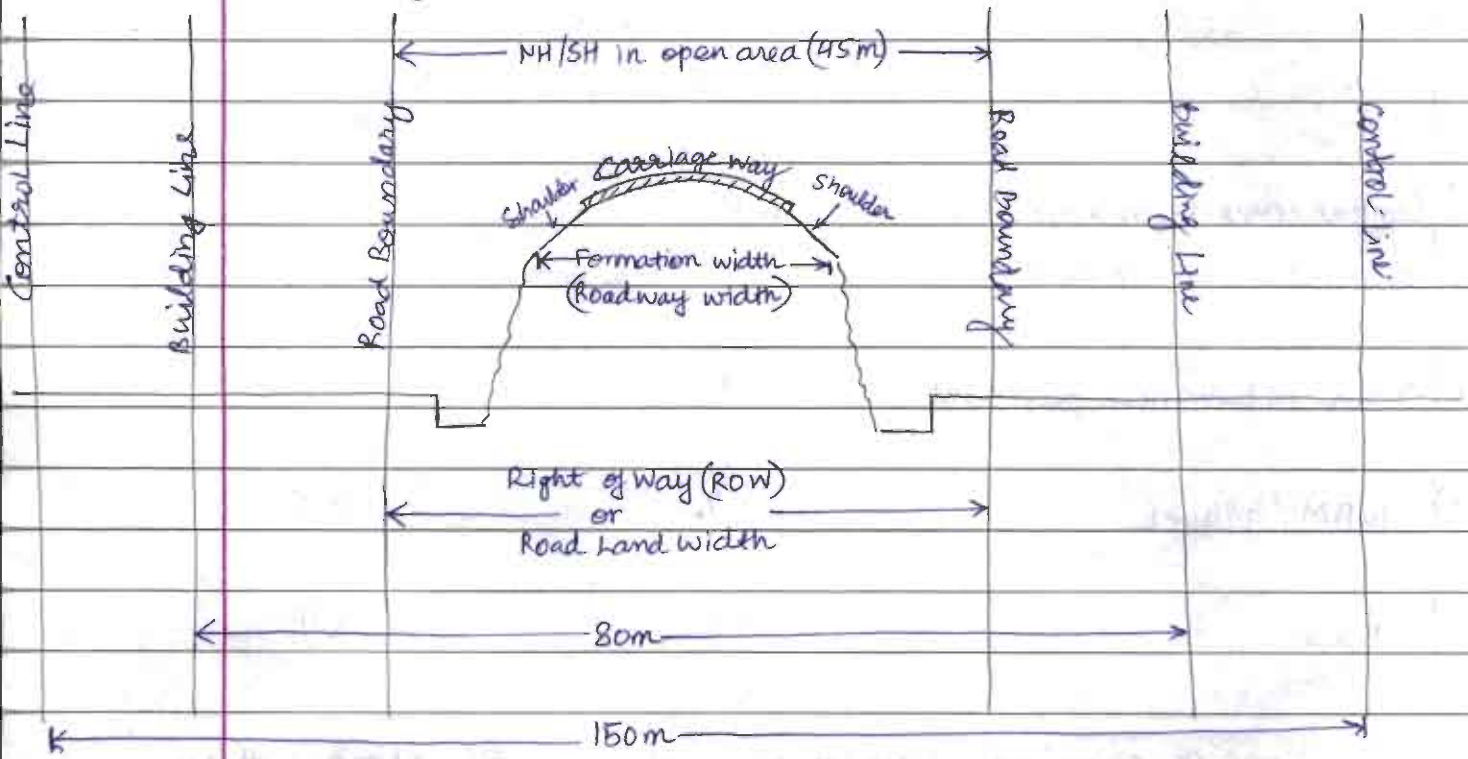
Median

- The purpose of median is to prevent head-on collision b/w vehicles
- Also known as traffic separator
- Minimum desirable width for rural Highway is 5m and if lane width is restricted, then the value may be reduced to 3m
- Width of median for bridges should be between 1.2–1.5m



- transition in median should be b/w 1 in 20 to 1 in 15

Road Margins



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→ Building Line

Represents the road width upto which no building activity is permitted.

→ Control Line

Represents distance upto which nature of building is controlled.

→ Sight Distances

→ 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.

→ Various sight distances are :

(a) Stopping Sight Distance (SSD)

It is also known as absolute minimum sight distance or non-passing sight distance.

(b) Overtaking sight Distance (OSD)

It is also known as passing sight distance.

(c) Intermediate Sight Distance (ISD)

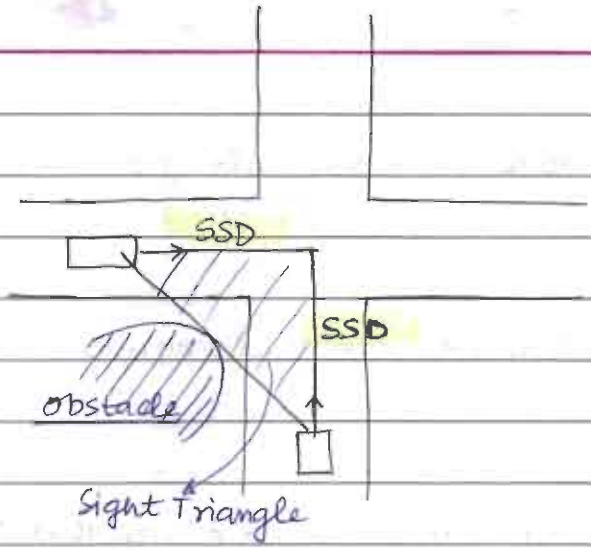
When overtaking sight distance cannot be provided, we provide ISD so as to give some degree of overtaking opportunity.

$$ISD = 2 \times SSD$$

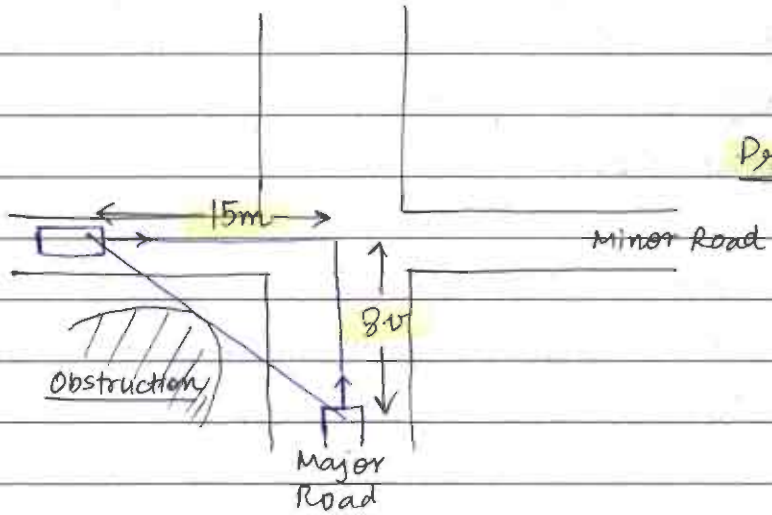
(d) Headlight Sight Distance (HSD)

Distance visible to the driver at night under headlight illumination. The minimum value of HSD should be SSD.

(e) Sight Distance at Intersections



Normal Intersection



Priority Intersection

→ At priority intersection [major road crosses a minor road) the sight Δ is formed by providing a minimum visibility of 15m along the minor road and a visibility of 8 seconds travel distance along the major road. (8v) (where v is in m/s)

1) Stopping Sight Distance

→ It is the minimum sight distance (visibility) that should be visible from all spots of highway such that vehicles travelling at design speed could be safely stopped within that distance.

→ SSD depends on

1) Reaction time of driver (Perception reaction time)
IRC recommends 2.5s as the reaction time for SSD calculations.

2) Speed of vehicle

3) Brake efficiency
IRC assumes a brake eff. of 50%. It has already been incorporated in the longitudinal friction coeff. (0.35-0.40) recommended by IRC.

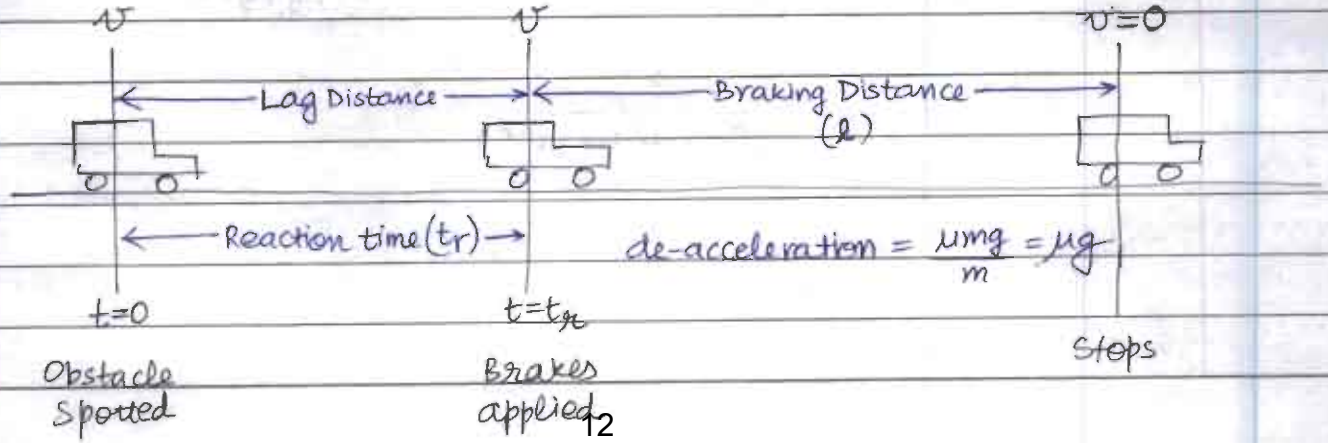
4) Friction coeff of road [Longitudinal]
As per IRC it is taken as 0.35 to 0.4

Speed (kmph)	μ [Design]
≤ 30	0.40
60	0.36
≥ 80	0.35

5) Longitudinal gradient of road
Up gradient will lead to a lower value of SSD and down gradient will lead to a higher value of SSD.

→ Calculation of SSD

Case I - When the vehicle is moving on level road i.e. no longitudinal gradient



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$$\text{Lag Distance} = v t_r$$

$$v^2 = u^2 + 2as$$

$$0^2 = v^2 - 2\mu g l$$

$$l = \frac{v^2}{2\mu g}$$ → Braking distance

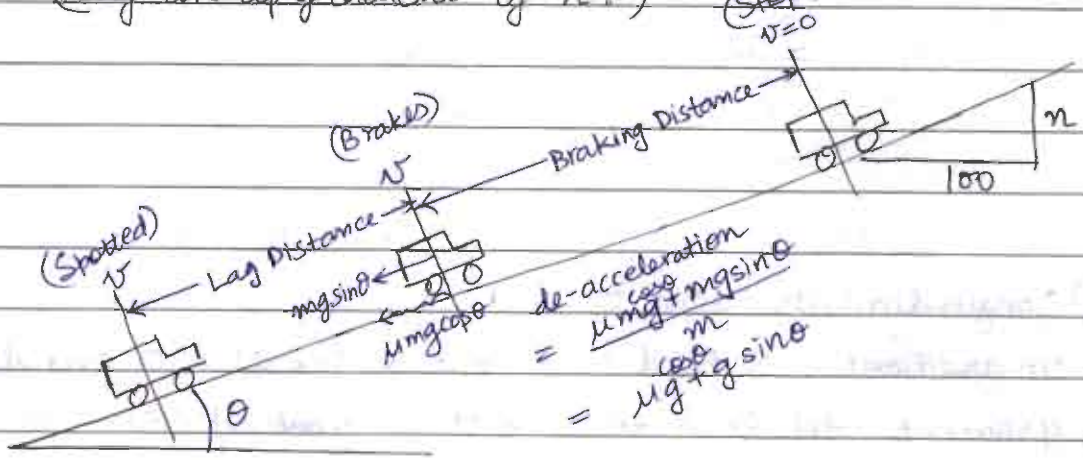
SSD = Lag Distance + Braking distance

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

$v \rightarrow m/s$

$V \rightarrow kmph$

Case II – When the vehicle is moving on a longitudinal gradient (Say an up gradient of n%)



$$\text{Lag Distance} = v t_r$$

$$v^2 = u^2 + 2as$$

$$0^2 = v^2 - 2(\mu g \cos\theta + g \sin\theta) l \Rightarrow l = \frac{v^2}{2(\mu g \cos\theta + g \sin\theta)}$$

$$l = \frac{v^2}{2g\cos\theta(\mu + \tan\theta)}$$