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LECTURE NOTES

ON

HIGHWAY ENGINEERING

CIVIL, 4TH SEMESTER

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1 Highway Development & Planning

I. Important events in Road development:

1. Roman's are the pioneers in road construction. At Rome 29 roads were meeting
2. Indian Roads:
   - Indus valley civilization (5000BC), towns are planned with *Grid Pattern*.
   - Mouryans (4000 to 2000 BC) Chandra Guptha Mourya constructed 2400 km long road from Pataliputra (patna) to Takshashila (now in Pakistan)
   - First British Road : GT road from Calcutta to Delhi
3. Treasagat construction (France) (1716-1796)
4. Metcalf (England) (1717-1810)
5. **Telford(1757-1834) construction:**
   - Sub grade is kept horizontal and hence sub grade drainage was not proper .
   - Heavy foundation stones, to total thickness of the order of 35 cm at edge to 41 cm at center.
6. **Macadam construction:** (1756-1856)
   - The importance of sub grade draining and compaction was recognised and cross slope of 1 in 36 was proposed from sub grade level itself.
   - *The first method based on scientific thinking.*

   It was realised that the stresses due to wheel loads of traffic gets decreased and the lower layers of the pavement and therefore it is not required to provide large boulder and stones or soiling course at the lower layer of the pavement

II. Highway development in India (Important events) :

1. **Jayakar committee (Indian road development committee)–1927 recommendations:**
   (a) Road development to be considered as a national interest.
   (b) An extra tax to be levied on petrol from the road users to develop a road developm fund called "Central Road Fund"
   (c) A semi official technical body shou formed to pool the technical know - and act as advisory body.
   (d) A research organisation should be insti
2. **Central Road Fund –(March 1929) (CR**
   - Extra leavy on petrol at the rate of 2.6 /liter in 1929
   - The levy is revised in 1998, on pet new cess is Rs.1/- on petrol and Rs. 0 diesel.
   - 20% of annual revenue is to be retain "Central reserve", and t administration, R and D on road and projects of special importance. Balan to be allotted to various states.
3. **Indian Roads Congress: (1934)(IRC):**
   - An offshoot of Jayakar Comm recommendations.
   - Publishes various codes standardizi specifications.
4. **Motor vehicle's act:** (1939) : Revised in 1977
5. **Nagpur road conference:** (1943)
   - The first attempt to prepare a coordinated road development program in a planned manner.
   - The first 20 years road development plan (1943-1963) popularly known as "Nagpur road plan"
   - All Run way roads were classified into five categories.(viz., : NH,SH,MDR, ODR and VR).
   - The target for Nagpur road development plan (1943-63) was aimed at 16 Km per 100 sq. Km area of the country.
   - Recommended gird pattern of road system is star and grid.

6. **Central Road Research Institute (CRRI) – 1950:**
   It may be in line with Jayakar Committee's recommendation. Located in New Delhi.

7. **National Highway Act – 1956 :**
   The responsibility of development and Maintenance of National Highways lies with Central Government.

8. **Second road development plan: (1961-81) (Bombay Road Plan)**
   - The target is 32 km/100sq.km area
   - Construction of 1600 km express ways.

9. **Highway research board of IRC – 1973**

10. **The third twenty year plan:**
    (1981-2001) (Lucknow plan)
    - Target 82 km/100 sq. km)
    - Expressways 2000 km
    - Length of NH = area in Km^2 / 50
    - Length of SH = area in Km^2 / 25 *or* 62.5 x no. of towns
    - Length of MDR = area in Km^2 / 12.5 *or* 90 x no. of towns

11. **National highway Authority of India(NHAI)**
    - Established in 1988, became operational only in 1995.
    - Responsibility is to develop, maintain and operate the National Highways
    - Under the control of Ministry of Road and Transport and Highways

12. **National Highway Development Program(NHDP)**
    Prime focus is on developing International standard roads with facilities for uninterrupted flow of traffic with
    - Enhanced safety features
    - Better Riding Surface.
    - Better Road Geometry
    - Better Traffic Management and Noticeable Signage.
    - Divided carriageways and Service roads
    - Grade separators
    - Over bridges and Underpasses
    - Bypasses
    - Wayside amenities

Projects under NHDP

1. Golden Quadrilateral – (total 5,846 km) connecting Delhi-Kolkata-Chennai-Mumbai (already constructed 99.67%) Total cost Rs. 58,000 crore
2. North - South & East - West Corridor (total 7,300 Km)
   - North-South Corridor connecting Srinagar (Kashmir) to Kanyakumari (Tamil Nadu) including Salem to Cochin (Kerala) Spur
   - East-West Corridor connecting Silchar (Assam) to Porbandar (Gujarat)
3. Port Connectivity & others 1133 km

13. **State Highway Research Laboratories:**
    1. Highway Research Station, Chennai
    2. Maharastra Engineering Institute, Nasik
    3. Gujarat Engineering Research Institute, Vadodra

14. **Highway staff Training Institute:**
    National Institute for Training of Highway Engineers (NITHE) , New Delhi.

15. **National Rural Road Development Agency (NRRDA)**
    - The programs under this agency: '*Pradhan Mantri Gram Sadak Yojana' (PMGSY)*
    - Aim of this program is to connect villages with a population over 1000 persons through good all-weather roads by 2003 (already achieved) and to connect villages with 500 population by 2007.
    - Cost of this program is 60,000 crores

III. Classification based on location and function: (Rural or non urban)

1. National Highway (NH)
2. State Highway (SH)
3. Major District Roads (MDR)
4. Other District Roads (ODR)
5. Village Roads (VR)

This classification was done in Nagpur road plan

Important National Highways:

NH-1 : Delhi-Ambala-Amritsar
NH-3 : Bombay-Agra
NH-4 : Madras-Banglore-pune
NH-5 : Madras-Calcutta
NH-7 : Varanasi- Kanyakumari :Longest National Highway
NH-9 : Bombay-Pune–Hyderabad-Vijayawada

NOTE:

Please go through the description of various types of roads and salient features of Nagpur Road Plan by following any standard textbook.

National Highways:

Main frame on which entire road communication is based, Highest specifications. A National Highway connects state capitals, Industrial tours, Places of strategic importance, neighboring countries etc…

State Highways:

Specifications similar to that of NH.

MDR: Roughly to be same specifications of SH.

ODR: Some what lower specifications. However, these roads should be maintained to function in all weathers to carry the traffic. (All weather roads).

VR : Lower specifications

Details of various Road Network in India

Indian road network of 33 lakh km. is second largest in the world and consists of

- Express ways 200 km
- National Highways 70,548 km
- State Highways 1,31,899 km
- Major District Roads 4,67,763 km
- Rural Roads and other roads 26,50,000 km

- National Highways are less than 2 % of network but carry 40% of total traffic
- Number of vehicles has been growing at an average pace of 10.16% per annum over the last five years
- Mumbai-Pune Expressway: The Mumbai-Pune Expressway was India's first limited access expressway of 93 km
- Delhi-Gurgaon Expressway: This 28 km long expressway Delhi, national Gu important satellite city of Delhi. whi of the Golden Quadrilateral.
- Delhi-Noida-Greater Noida Expressway: Two separate expressways provide high-speed connectivity between Delhi, NOIDA and Greater Noida. The DND Flyway was the first expressway built in Delhi.
- Ahmedabad-Vadodara Expressway: This 95 km long expressway connects the Ahmedabad and Baroda
- PV Narasimharao Express Flyover : A 11.46 km length, Asia's first express fly over started in Hyderabad in October 2009

Current Status of traffic:

Passenger: 85% by road, 15% by railways
Freight :70 % by road, 30% by railways

IV. Road Patterns:

1. Rectangular or Block Pattern:

- Adopted in Chandigarh, from traffic operation point this is not considered convenient.

2. Star and Grid Pattern : Nagpur road plan formulae were prepared assuming star and Grid pattern

- Provides inter communication facilities to each of the villages, towns, district Head Quarters, State Capitals etc…
- The best example of grid pattern is Chandigarh (Chandigarh is the 1st planned modern city of India designed by the French architect *Le Corbusier*)

3. Radial and circular pattern: Connaught place, New Delhi

V. Master Plan: It is the final road development plan for the area under study which may be a district, state or the whole country.

Features of Nagpur Plan

- In the Nagpur plan, roads were divided into four classes:
  - (i) **National Highways**, which would traverse several provinces or states and would be of national importance for strategic, administrative and other purposes.
  - (ii) **Provincial and State Highways** which would be the other main roads of a province or state.
  - (iii) **District Roads**, which would take traffic from the main roads to the interior of each district or similar units. According to their importance, some of these are to be considered Major **District Roads** and the remaining **as Other District Roads**.
  - (iv) **Village Roads**, which would link the villages to the road system and would be designed, constructed and maintained under the authority of the provincial or state highway departments.
- National Highway would be the framework within which the road system of the country should be developed and the financial responsibility of the Centre will have an effective say in the use and control of these roads.
- National and Provincial Highways and Major District Roads would be provided with a hard durable crust.
- The committee planned to construct 2 lakh kms of road across the country within 20 years. They recommended the construction of star and grid pattern of roads throughout the country.
- They recommended that road length should be increased so as to give a road density of 16 kms per 100 sq.km.
- The Nagpur Plan laid down the following formulae for road length of different classes, considering the geographical, agricultural and population conditions:

  (I) Length of National and Provincial Highway and Major District Roads, (in miles)

  $$= \frac{A}{5} + \frac{B}{20} + N + 5T + D + R$$

  where,

  A = Agricultural area of province in sq. miles.

  B = Non-agricultural area in sq. miles

  N = Number of towns and villages having a population of 2,000-5,000

  T = Number of towns and villages having a population of over 5,000,

  D = An allowance for agricultural and industrial development (about 15%)

  R = Railway mileage in the area under consideration.

  (II) Length of other District and Village Roads, (in miles)

  $$= \frac{V}{5} + \frac{Q}{2} + R + 2S + D$$

  where,

  Q = Number of villages with population 501-1000,

  R = Number of villages with population 1,001-2,000,

  S = Number of villages with population 2,001-5,000, and

  D = An allowance for agricultural and industrial development during the next 20 years.

THE BOMBAY PLAN (1961-81)

- By the end of the Nagpur plan, the length of roads envisaged under it was achieved, but the road system was deficient in many respects. The changed economic, industrial and agricultural conditions in the country in that period needed a review of the Nagpur plan.
- Hence, a second long-term plan of 20-year was drafted by the Roads wing of Government of India, which is popularly known as the Bombay plan.

Features of Bombay Plan

- The total road length targeted to construct was about 10 lakhs km which will give a road density of 32 km per 100 sq. km. 40 percent of the length would be surfaced.
- The construction of 1600 km of expressways was also included in the plan.
- Funds for highway financing should come not only from direct beneficiaries (motor vehicles), but also from those on whom indirect benefits accrue. Sources which may be tapped are betterment levy, cess on land revenue, toll projects and tax on diesel oil used for motor vehicles.
- The question of vesting authority with road engineers to remove encroachments needs to be examined.
- Traffic engineering cells should be established in each State.

THE LUCKNOW PLAN (1981-2001)

Earlier two road development plans led to 2 shortcomings: (i) Ist two plans were not conceived to meet the needs of freight & passenger movement by road (ii) The plans were not part of the total transportation plan of the country.

Features of Lucknow Plan

- Roads should be classified for India as follows:
  (a) Primary system : (i) Expressways (ii) National Highways
  (b) Secondary system : (i) State highways (ii) Major District Roads
  (c) Tertiary system (Rural Roads) : (i) Other District Roads (ii) Village Roads
- Road length for the year 2001 should be 27,00,000 km giving a density of 82 km/100 sq. km.
- An all-weather road should connect all villages or groups of villages with a population of 500 and above by 2001. For villages less than a population of 500, the road network shall be so planned as to result in an all-weather road being available at a distance of less than 3 km in plain areas and 5 km in hilly terrain.
- *Expressways* should be constructed on major traffic corridors to provide speedy travel.
- National Highways should form a square grid of 100 km × 100 km.
- State Highways should be extended to serve district headquarters, sub-divisional (taluka) headquarters, major industrial centres, places of commercial interest, places of tourist attraction, major agricultural market centres and ports.
- The Major District Roads should serve and connect all towns and villages with a population of 1,500 and above.
- The other District Roads should serve and connect villages with a population of 1,000-1,500.
- Energy conservation, environmental quality of roads and road safety measures were also given due importance in this plan.
- Selection of specifications should be done on the basis of (i) their amenability to stage construction

(ii) the need to adopt appropriate technology (iii) the use of local materials (iv) the use of soil-stabilization techniques (v) the use of alternate binders (vi) the use of cement concrete pavements wherever economically feasible and (vii) the need to conserve bitumen.

Following formulae give the lengths of various classes of roads as per the above guidelines:

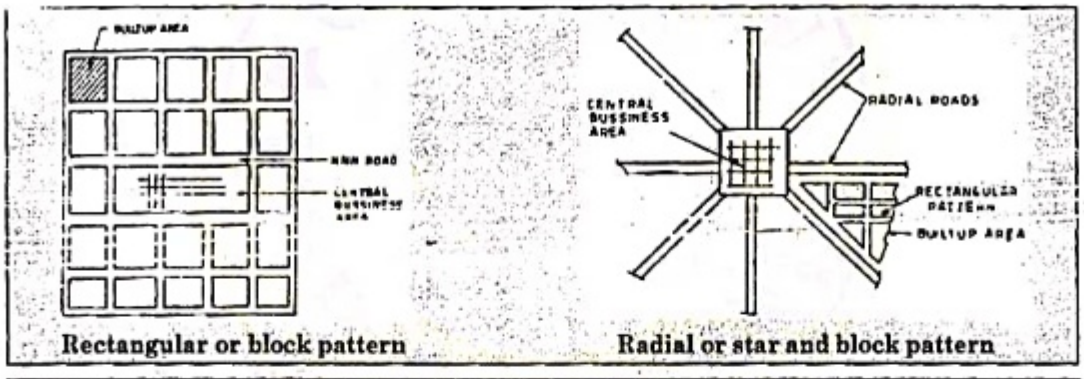
1. Length of NH (in km) = $\frac{\text{Area}}{10{,}000} = \frac{\text{Area(insq.km)}}{50}$
2. Length of SH (in km) = $\frac{\text{Area(in sq.km)}}{25}$;

   or Length (in km) = 62.5 × Number of towns with population above 5,000 – $\frac{\text{Area(insq.km)}}{50}$
3. Length of MDR (in km) = $\frac{\text{Area(in sq.km)}}{12.5}$

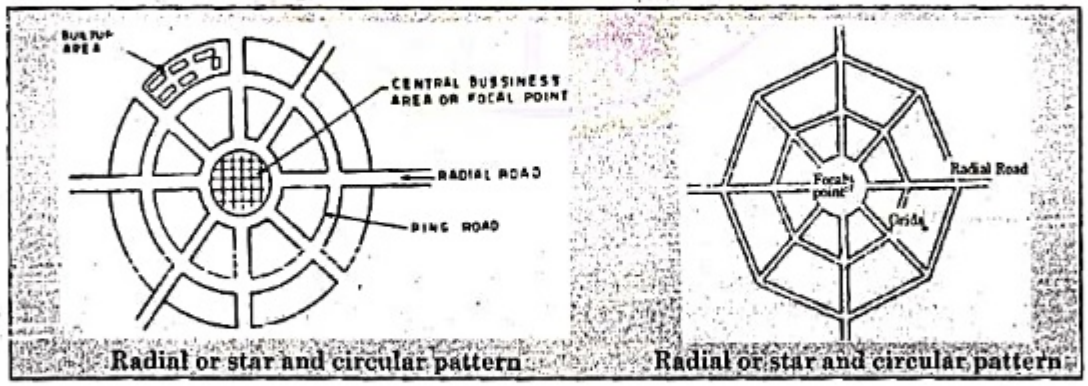
   or Length (in km) = 90 × Number of towns with population above 5,000
4. Total road length (in km) =4.74 × Number of villages and town
5. Rural Road Length (in km) ⇒ This can be calculated by finding the total road length and subtracting the other categories.

ROAD PATTERNS

The various road patterns may be classified as follows:



Rectangular or block pattern — Radial or star and block pattern



Radial or star and circular pattern — Radial or star and circular pattern

HIGHWAY CROSS SECTIONAL ELEMENTS :-

* CROSS SLOPE OR CAMBER :-

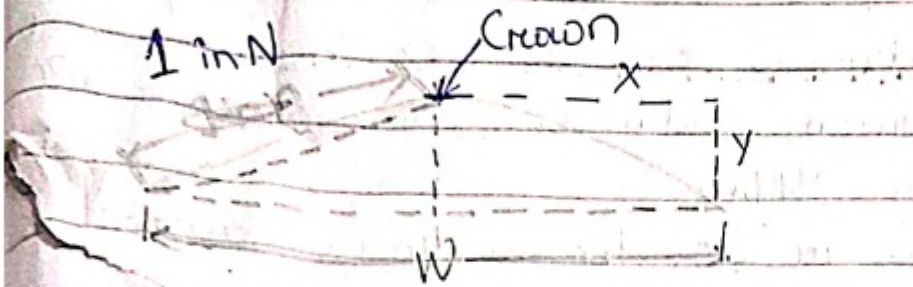
Cross slope or cambere is the slope provided to the road surface in the transverse directions to drain off the rain watere from the road surface. Drainage & quick disposal of watere from the pavement surface by providing cross slope.

The amount of cambere for the roads is decided according to the road surface & the amount of rainfall.

Crown- The highest point on the road surface.

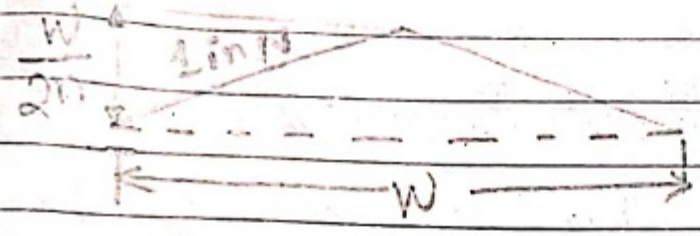
The shape of cross slope are

① Parabolic shape.

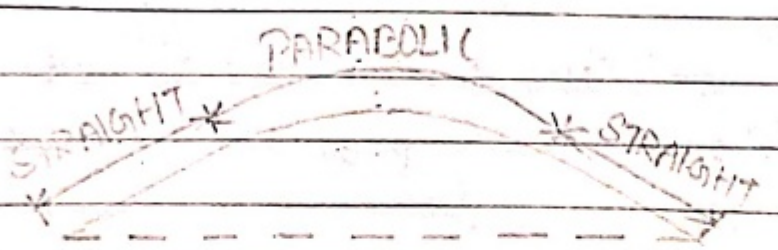


$$y = \frac{2x^2}{nW}$$

② Straight line Camber:-



③ Combination of Straight & Parabolic Shape



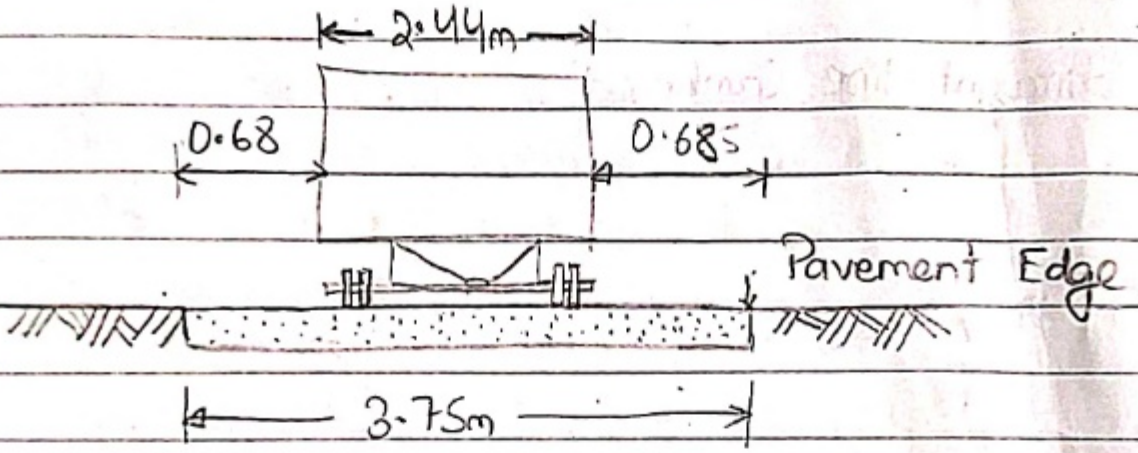
Sl. No.	Types of Road Surface	Range of Camber in areas of rainfall range Heavy to light	
1.	Cement concrete & high type bituminous	1 in 50 (2%)	1 in 60 (1.7%)
2.	Thin bituminous surface	1 in 40 (2.5%)	1 in 50 (2%)
3.	Water bound macadam & gravel	1 in 33 (3%)	1 in 40 (2.5%)
4.	Earth	1 in 25 (4%)	1 in 33 (3%)

WIDTH OF PAVEMENT / CARRIAGEWAY :

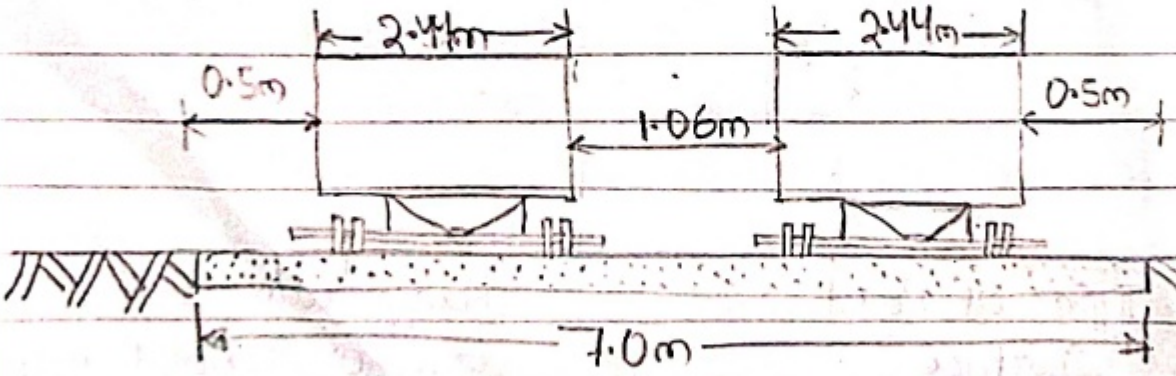
The portion of the road surface which is used for vehicular traffic is known as carriageway or pavement. The width of carriage way depends upon the width & number of lanes.

The maximum width of vehicle as per IRC specifications is 2.44m.

For single lane roads, the width of pavement is generally kept 3.75m



Single Lane Pavement



TWO LANE PAVEMENT

Class of Road	Width of Carriageway
① Single Lane	3.75m
② Two lanes, without raised kerbs	7.0m
③ Two lanes. with raised kerbs	7.5m
④ Intermediate carriageway	5.5m
⑤ Multi lane pavements	3.5m per lane

TRAFFIC SEPARATOR OR MEDIAN:-

The narrow continuous structure provided for dividing the two directions of traffic flow, is known as separator or divider.

The main function of traffic separator is to prevent head on collision between vehicles moving in opposite directions on adjecent lanes.

The disirable wide area separators of 8 to 14m width.

A minimum 6m is required to reduce head light glare.

The IRC recommends a minimum disirable width of 5.0m for medians of rural highway which may be reduced to 3.0m where land is restricted.

On long bridge the width of median may be reduced upto 1.2 to 1.5m.

Where change in width is unavoidable, a transition of 1 in 15 to 1 in 20 must be provided.

KERBS:-

The boundaries between the pavement & shoulder or footpath are known as kerb. These are also provided between the pavement & the traffic separator or divider. It is disirable to provide kerbs on urban roads.

Width of Roadway OR FORMATION WIDTH:

The top width of the highway embankment or the bottom width of highway cutting excluding the side drains, is called formation width or road way.

The formation width is the sum of widths of pavements or carriage way including the separators & width of the shoulders on either side of the carriage way.

RIGHT OF WAY:

The area of land acquired for construction & future development of a road symmetrically about the central alignment is called right of way.

The width of these acquired land is known as land width & it depends upon the importance of the road & possible future development.

ROAD MARGINS:

The various elements included in the road margins are shoulder, parking lane, frontage road, driveway, cycle track, footpath, guard rail & embankment slope.

SHOULDER:

The portions of the roadway bet^n the outer edge of the carriage way & edges of the top surface of the embankment or inner edges of the side drains in cuttings of the roads are called shoulders. The shoulders are generally in level with road surface, having a slope towards drain side. The shoulders & foot paths prevent the edges of the road from wear & tear. The minimum shoulder width recommended by IRC is 2.5m.

Side Slopes :-
The slopes of the sides of earth work of pavements & cutting to ensure their stability are called side slopes. The embankments are generally given a side slope of 1 in 1:5.

SIGHT DISTANCE :-
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.
In other words, sight distance is the length of road visible ahead to the driver at any instance.
The standard height of the line of sight of the driver above the road surface is taken as 1.2m.
3 sight distance situations are considered in the design-
(i) Stopping or absolute minimum sight distance
(ii) Safe overtaking or passing sight distance.
(iii) Safe sight distance for entering into uncontrolled intersections.

STOPPING SIGHT DISTANCE (SSD)
The minimum sight distance available on a highway at any spot should be of sufficient length to stop a vehicle travelling at design speed, safely without collision with any other obstruction.
The stopping sight distance is also called the non-passing sight distance.

The distance within which a motor vehicle can be stopped depends upon the following factors:

(I) Total reaction time of the driver
(II) Speed of Vehicle
(III) Efficiency of brakes.
(IV) Frictional resistance bet^n the road & the tyres.
(V) Gradient of the road

Total Reaction Time:

Reaction time of the driver is the time taken from the instant the object is visible to the driver to the instant the brakes are effectively applied.

Total reaction time may be split up into 2 ways
(i) Perception time
(II) brake reaction time.

The stopping distance of a vehicle is the sum of

SSD = Lag distance + Breaking distance

Lag distance:

The distance travelled by the vehicle during the total reaction time is known as lag distance.

Lag distance = $V \cdot t$ in m/s
= $0.278\ V.t$ in Kmph.

Where t = total reaction time of driver is 2.5sec

Breaking distance:

Breaking distance obtained by equating the work done in stopping the vehicle & the kinetic energy

The minimum SSD should be equal to to the stopping distance in one-way traffic lanes & also in 2-way traffic roads when there are 2 or more traffic lanes.

On a 2 way traffic road with single lane, the minimum stopping sight distance is equal to twice the SSD.

Intermediate sight distance = 2 SSD

Overtaking Sight distance (OSD) :

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 safe passing sight distance available.

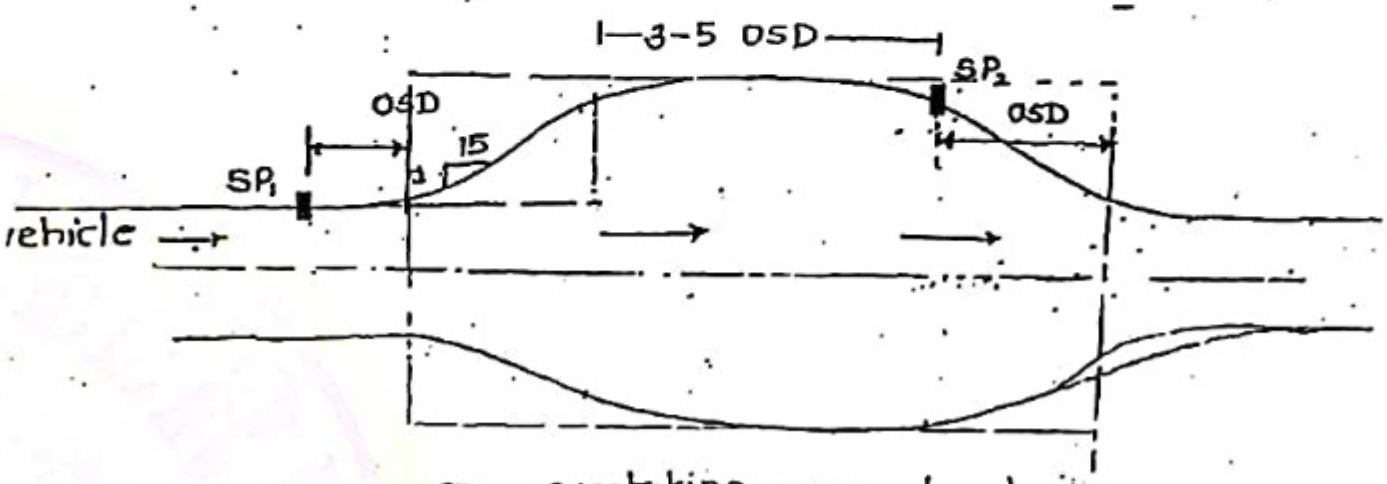
The minimum OSD should be $(d_1 + d_2 + d_3)$ when 2-way traffic exists. On divide highways and on roads with one-way traffic regulation the OSD is $(d_1 + d_2)$.

According to IRC.

Minimum OSD provided = 3 x OSD

Desirable OSD = 5 x OSD

Overtaking Zone:



SP_1 - overtaking zone ahead

SP_2 - overtaking zone ends

Effect of gradient on OSSD:

OSD will increase for both upgradient and downgradient.

Intermediate sight distance

ISD is provided only when it is difficult to provide OSD

ISD = 2 x SSD

Sight distance	Height of driver	Height of object
SSD	1.2 m	0.15 m
OSD	1.2 m	1.2 m
ISD	1.2 m	1.2 m

SSD at sloping road:

$$\text{SSD} = vt + \frac{v^2}{2g(f \pm 0.01n)} \quad (v \text{ in m/s})$$

or $$\text{SSD} = 0.278Vt + \frac{V^2}{254(f \pm 0.01n)} \quad (\text{V in km/h})$$

'+' for ascending slope and '–' for descending slope.
'n' is gradient percentage.

SSD at level surface with braking efficiency, η:

$$\text{SSD} = Vt + \frac{V^2}{2gf\eta} \text{ or } 0.278Vt + \frac{V^2}{254f\eta}$$

Overtaking Sight Distance (OSD):

It is the minimum sight distance visible to a driver intending to overtake a slow moving vehicle with safety against collision with traffic from opposite direction.

A → Overtaking vehicle

B → Overtaken vehicle

C → Oncoming vehicle

d_1 → distance travelled by A during reaction time

d_2 → distance travelled by A during overtaking

d_3 → distance travelled by C during overtaking

$d_1 = v_B t$

t → reaction time (2.5 seconds)

$d_2 = b + 2s = v_B T + 2s$

T → time for overtaking

$d_3 = vT.$ $\quad T = \sqrt{\frac{4s}{a}}$ sec (a → acceleration in m/s)

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