GOVERNMENT POLYTECHNIC

KENDRAPARA

DEPARTMENT OF CIVIL ENGINEERING

LECTURE NOTES

Year & Semester: 2nd Year, 4th Semester

Sub- Highway Engineering (Th-4)

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CONTENTS

CHAPTER -1

INTRODUCTION

Introduction

- Highway Engineering is one of the important branches of transportation System.
- It deals with planning, design, construction and maintenance.

Importance of Highway transportation:

For rapid economic, industrial, and cultural growth of any country, a good system of transportation is very essential. Transportation system comprise of good network of roads, railways, well developed water ways and airways.

Among all the mode of transportation, road transport is the nearest to the people. The goods and passenger have to be transported by roads before reaching it to airport, harbor or railways station.

The importance of highway transportation can be easily judged from the following advantages of the roads:

i. Roads can be constructed to penetrate the interior of any region and to connect in remote villages especially in hilly region where provision of railway lines become uneconomical.
ii. Road can be constructed at comparatively lower initial cost than any other mode of transport.
iii. The cost of maintenance is also cheaper than railway track, airports and harbors.
iv. Road transport offers and quick and assume delivery.
v. Road transport provides door-to-door service.
vi. Road transport permits simpler packaging of goods to be transported.
vii. Road transport has a high employment potential.
viii. Roads help in maintaining law and order in a country.
ix. Roads have helped operations related to floor and famine relief.
x. Roads help in tourism development, some of the monuments, parks and sanctuaries are accessible only by roads.

Jayakar committee and its recommendations: –

- After the first world war motor vehicle using the roads increased and it is demanded a better road network which can capable to withstand the mixed traffic condition.

- Indian road development committee was appointed by the government with M.R Jayakar in 1927.
- It submitted its report by the year 1928.

Important Recommendations: -

- The road development in the country should be considered as a national interest.
- An extra tax should be collected on petrol from the road user to develop a road development fund called central road fund (CRF).
- A semi-official technical body (Indian road congress) should be formed to act on various accept of roads.
- A research organisation should be instituted to carry out the research & development work.
- Central road fund was developed by the year 1929.
- The semi-official technical body called IRC was formed in 1934.
- The central road research institute was started in 1950 (CRRI)

Central Road Fund (CRF): -

- The consumer of petrol was charged an extra tax of 2.64 paisa per litre of petrol to build up this road development fund.
- 20% of the annual revenue is to be retained as a central reserve, from which grants are to be given by the central government for meeting expenses on the administration of special importance.
- The balance 80% is to be allotted by the central government to the various states based on actual petrol consumers or revenue collected.
- The accounts of the central road fund are maintained by the accountant general of central revenue and the control on the expenditure is exercised by the ministry of transport.

Indian Road Congress (I.R.C):

- The Indian Road Congress was established by the Central Government in 1934 as per the recommendations of the Jayakar Committee.
- The I.R.C was constituted to provide a forum for regular pooling of experience and ideas on all matters affecting the construction and maintenance of roads in India.
- Presently the I.R.C has become the active body to recommended specification regarding design and construction of roads and bridges.
- The I.R.C works in close collaboration with road wing of ministry of surface transport, government of India.
- I.R.C publishes journals, standard specification and guidelines on various aspects of highway engineering. The technical activities of I.R.C are carried out by expects in each subject.

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Motor vehicle act: -

- 1939 the motor vehicle act was brought into effect by government of India to regulate road traffic in the form of traffic laws and regulations.
- The three phases primarily covered are control of driver, vehicle ownership and vehicle operations on road and traffic stream.
- Motor vehicle are having been revised in the year 1988.

Nagpur Road Plan: -
Or
First 20-year road development plan: -

- A conference of chief engineers of all states was held in 1943 by the government of India at Nagpur, at initiative of the Indian road congress to finalise the first road development plan for the country as a whole.
- This is a land mark in the history of road development in India.
- In this, first 20-year plan is known as Nagpur road plan.
- All roads were classified into 5 category & a 20 years development in India for the period of 1963 was finalised.
- Target road length was 16 km per 100sq.km area of the country.
- During the first and second 5 years plan period (1951-1956 & 1956-1961) the road development program was systematic.
- Hence the Nagpur plan target was achieved about 2yr ahead (1961)
- In 1961 a committee is appointed to prepare second 20yrs, road development plan.

Bombay Road Development Plan: -

Or

Second 20yr Road Development Plan: -

- 2^{nd} 20yr road development plan for the period of 1961-1981 was initiated by the Indian Road Congress.
- This road development plan is known as Bombay road plan.

the Indian Road Congress.

- This road development plan is known as Bombay road plan.
- The total road length is about 32km for 100sq km area.

Lucknow Road Development Plan: -

Or

Third 20 yr. Road Development Plan: -

- The 3rd 20 yr. road development plan for the period of 1981 to 2001 was approved by the council and also at the meeting of the chief engineers of the country in 1984.
- This road development plan is known as Lucknow road plan.
- The total road length about 82 km per 100 sq. km. area.

Ministry of Surface Transport:

- The roads wing of the ministry of surface transport handles the road matters of the central Government.
- It is headed by a director general. The director general is assisted head by two additional director generals (one for roads and one for bridges), a number of chief engineers, superintendent engineer, executive engineers and Assist. Executive engineers.
- The roads wing has a chief engineer for a north east region posted at Guwahati and a Liaison-cum-Inspectorate organization consisting of S. E's and E. E's in the various state.

The function of roads wing of ministry of surface transport are;

a) To control funds approved by central Government for the development of national highways.
b) To control the central road fund.
c) To prepare plans for development and maintenance of national highways in consultation with state PWD's.
d) To oversee technically the quality of works executed by the agencies.
e) To administer matters regarding road research.
f) To examine technically the projects of roads and bridges prepared by the PWD's.
g) To administer the central road programme other than national highways in the union territories.

Central Road Research Institute (CRRI): -

- 1950, CRRI was started at New Delhi for research in various aspects of highway engineering.
- The CRRI is one the national laboratories of the council of scientific & Indian research.

National Highway Act: -

In 1956, the national act was passed.

Features: -

- The responsibility of development and maintenance of national highway to be provisionally taken by the central government.
- The central government to be empower to declare any other highway as National Highway or to omit any of the existing one.

Method of Classification of Road: -

The roads are classified on the following basics: -

- Traffic volume
- Load transported
- Location and functions

The Nagpur road plan classified the roads in India based on location & function into following 5 categories.

(I) National Highway (NH)

(II) State Highway (SH)

(III) Major district road (MDR)

(IV) Another District road (ODR)

(V) Village Road (VR)

1. National highway: -

National highway are main highways running through the length & breadth of India connecting major parts foreign highways, capital of large towns and large industrial & tourist centre.

2. StateHighway: -

S.H are roads of a state connecting with the national higher of adjacent state, distinct head quarter and important cities within the state and serving as the main arteries for traffic to axis from distinct roads.

3. Major District Road: -

MDR are important road within a district serving areas of production and marketing and connecting those with each other or with the main highways of a district.

4. Other District Roads: -

ODR are road serving rural area of production and providing them outlet to market centre and these are of lower design specification there MDR.

5. VillageRoads: -

VR are roads correcting villages or groups of villages with each other to the nearest road of higher categories.

Modified classification of Road System by 3rd Road Development

(1) Primary system

(2) Secondary system

(3) Tertiary road

Primary System

*Express way

*National highways

Secondary System

*State flyways

*Major district roads

Tertiary System: -

*Other district road

*Village Road

Function of Indian Road Congress:

The I.R.C is a body of professional highway engineer, having the following functions:

i. To provide forum for expression of collective opinion of its members for all matters affecting the construction and maintenance of roads in India.
ii. To promote the use of standard specification and practices.
iii. To suggest improved method of planning, design construction, maintenance and administration of roads.
iv. To conduct periodical meeting to discuss technical questions regarding roads.
v. To make laws for the development, improvement and protection of roads.
vi. To furnish and maintain libraries and museum for encouraging the science of road making.

IRC classification of roads: -

i. National Highways (N.H)
ii. State Highways (S.H)
iii. Major District Road (M.D.R)
iv. Other District Road (O.D.R)
v. Village Roads (V.R)

(i) National Highways (N.H):

The main highways running through the length and breadth of the country connecting state capitals, ports, foreign highways, large town etc. are known as National Highways. These are of national importance for strategic administrative and other purposes. These highways constituent the main arteries of road transport in the country. All the national highways are assigned the respective numbers.

(ii) State Highways (S.H):

The highways connecting district headquarters and important cities within the state or connecting them with national highways of adjacent states are known as state highways. These highways serve as main arteries of traffic to and from district roads. These are also considered as main arteries of commerce by road within a state.

(iii) Major District Roads (M.D.R):

The important roads within the district serving areas of production and markets and connecting these with each other or with highways and railways are known as Major District Roads. These roads have roughly the same specification as the state highways.

(iv) **Other District Roads (O.D.R):**

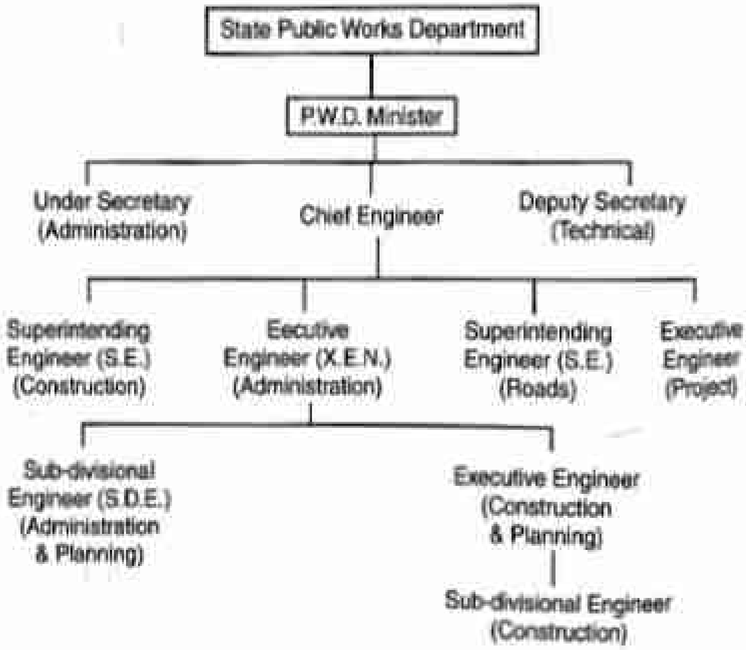
Other District Roads are the roads serving rural areas of production and providing them with outlet to Tehsil headquarters, market center, etc. These roads have somewhat lower specification than major District Roads.

(v) **Village Roads (V.R):**

Village Roads are roads connecting villages or group of villages with each other or nearest District Roads, Main Highways, Railways etc. These roads are very important from the point of view of rural area development. The construction and maintenance of these roads are the responsibility of Local District Authority.

Organization of state highway department: -

The organization chart of state highway department is given below:


State Public Works Department
P.W.D. Minister
Under Secretary (Administration)
Chief Engineer
Deputy Secretary (Technical)
Superintending Engineer (S.E.) (Construction)
Eecutive Engineer (X.E.N.) (Administration)
Superintending Engineer (S.E.) (Roads)
Executive Engineer (Project)
Sub-divisional Engineer (S.D.E.) (Administration & Planning)
Executive Engineer (Construction & Planning)
Sub-divisional Engineer (Construction)

CHAPTER-02

ROAD GEOMETRIC

The geometric design of a highway deals with the dimensions and layout of visible features of the highway such as alignment, sight distance and intersection. The geometrics of highway should be designed to provide optimum efficiency in traffic operations with maximum safety at reasonable cost.

Geometric design of highways deals with the following elements:

1. Cross section elements
2. Sight distance consideration
3. Horizontal alignment details
4. Vertical alignment details
5. Intersection elements

HIGHWAY CROSS SECTION ELEMENTS

Camber

Camber or cant is the cross slope provided to raise middle of the road surface in the
Transverse direction to drain of rain water from road surface. The objectives of providing
Cambers are:

- Surface protection especially for gravel and bituminous roads
- Sub-grade protection by proper drainage
- Quick drying of pavement which in turn increases safety.
- Too steep slope is undesirable for it will erode the surface.

Camber is measured in 1 in n or n% (E.g. 1 in 50 or 2%) and the value depends on the type of pavement surface.

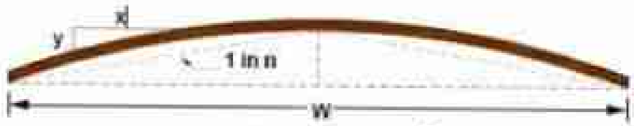
The values suggested by IRC for various categories of pavement is given in table below.

IRC VALUES FOR CAMBER

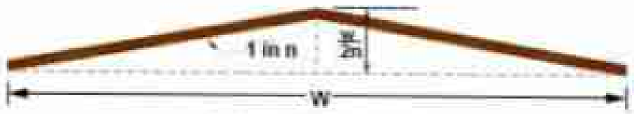
Surface type	Heavy rain	Light rain
Concrete/Bituminous	2 %	1.7 %
Gravel/WBM	3 %	2.5 %
Earthen	4 %	3.0 %

Types of cambers:

The common types of camber are parabolic, straight, or combination of them.



a. Parabolic camber $y=2x^2/nw$



b. Straight line camber

c. Combination of straight and parabolic camber

Width of carriage way

- Width of the carriage way or the width of the pavement depends on the width of the traffic lane and number of lanes.

- Width of a traffic lane depends on the width of the vehicle and the clearance. Side clearance improves operating speed and safety.

- The maximum permissible width of a vehicle is 2.44 and the desirable side clearance for single lane traffic is 0.68 m. This require minimum of lane width of 3.75 m for a single lane road .

- However, the side clearance required is about 0.53 m, on either side or 1.06 m in the center.

Table 12:1: IRC Values for camber

Surface type	Heavy rain	Light rain
Concrete/Bituminous	2 %	1.7 %
Gravel/WBM	3 %	2.5 %
Earthen	4 %	3.0 %

- Therefore, a two lane road require minimum of 3.5 meter for each lane. The desirable carriage way width recommended by IRC is given in table below

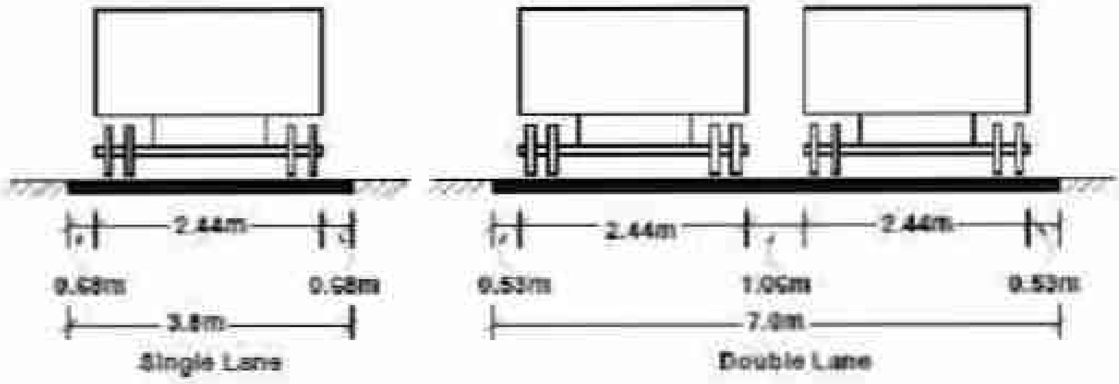
IRC specification for carriageway width:

Single lane	3.75
Two lane, no kerbs	7.0
Two lane, raised kerbs	7.5

- Therefore, a two lane road require minimum of 3.5 meter for each lane. The desirable carriage way width recommended by IRC is given in table below

IRC specification for carriageway width:

Single lane	3.75
Two lane, no kerbs	7.0
Two lane, raised kerbs	7.5
Intermediate carriage	5.5
Multi-lane	3.5



(WIDTH OF LANE FOR SINGLE LANE AND DOUBLE LANE)

Kerbs

Kerbs indicate the boundary between the carriage way and the shoulder or islands or footpaths. It is desirable to provide kerbs on urban roads.

Different types of kerbs are:

Low or mountable kerbs :

- This type of kerbs are provided such that they encourage the traffic to remain in the through traffic lanes and also allow the driver to enter the shoulder area with little difficulty.
- The height of this kerb is about 10 cm above the pavement edge with a slope which allows the vehicle to climb easily.

Semi-barrier type kerbs :

- When the pedestrian traffic is high, these kerbs are provided.

- Their height is 15 cm above the pavement edge.

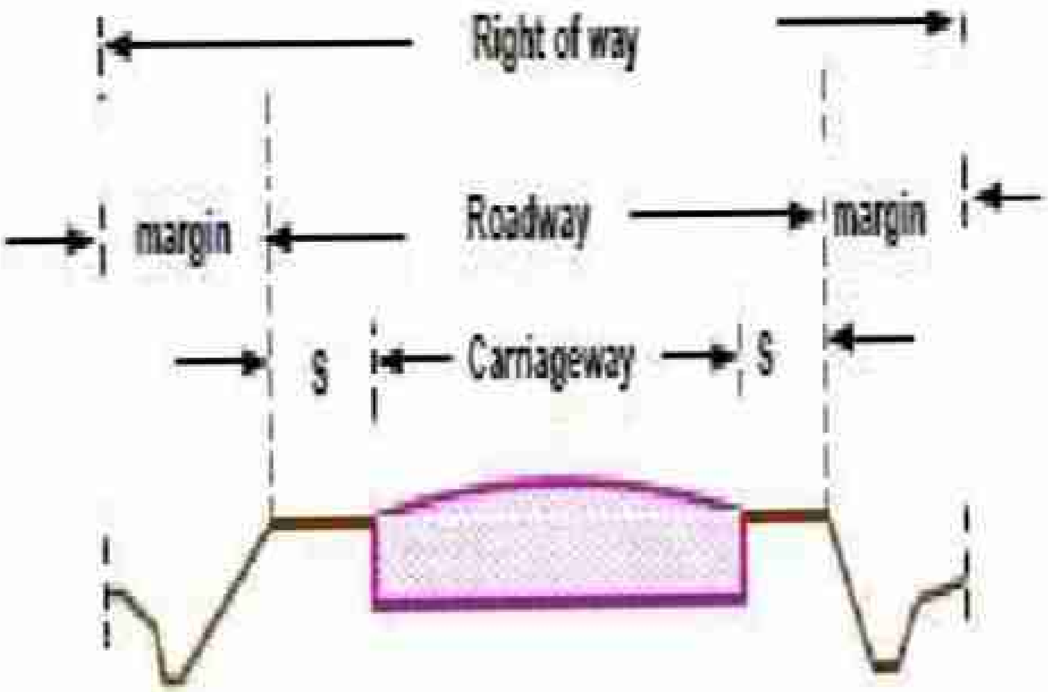
Barrier type kerbs :

They are designed to discourage vehicles from leaving the pavement. They are provided when there is considerable amount of pedestrian traffic they are placed at a height of 20 cm above the pavement edge with a steep batter.

Submerged kerbs: They are used in rural roads. The kerbs are provided at pavement edges between the pavement edge and shoulders. They provide lateral confinement and stability to the pavement.

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.



S- shoulder

NORMAL RIGHT OF WAY FOR OPEN AREAS

Road classification	Roadway width in m	
	Plain and rolling terrain	Mountainous and steep terrain
Open areas		
NH/SH	45	24
MDR	25	18
ODR	15	15
VR	12	9
Built-up areas		
NH/SH	30	20
MDR	20	15
ODR	15	12
VR	10	9

Formation Width or Roadway width

- Formation width is the sum of widths of carriageway or pavement, shoulders and separators and if any.
- It is the top width of the highway embankment or the bottom width of the highway cutting excluding the side drains.

Road Margins:

- Road margins are the portions of land on either side of roadway of a road.
- The various elements included in the road margins are parking lane, frontage road, driveway, cycle track, footpath, guard rail and embankment.

Formation Level

- Formation level is the reduced level of the finished surface of earthwork for a road in cutting or in embankment.
- In a road project the formation level of a road is decided in such a manner so as to give economical earthwork.
- The formation level of a road in embankment should be kept above the highest flood level of the area, whereas in case of road in cutting formation level should be kept sufficiently above the sub-soil water table.

Shoulder:

- Shoulders are the portions of the road way between the outer edges of the carriageway and edges of the top surface of embankment or inner edges of the side drains in cutting.
- These are provided along the road edge to serve as an emergency lane for vehicle required to be taken out of the pavement or roadway.
- Shoulders also act as service lanes for breakdown vehicles.
- Minimum shoulder width of 4.6m is desirable so that a vehicle stationed at the side of the shoulder would have a clearance of 1.85m from the pavement edge.
- The minimum shoulder width recommended by I.R.C. is 2.5m.

Gradient:

- Gradient is the rate of rise or fall of road surface along its length with respect to horizontal. It is longitudinal slope provided to the road surface along its length.
- Gradients in the road should not be very steep. Steep grade are not only difficult to climb, but also the vehicle operation cost is increased.

Types of Gradients:

Gradients are of following types:

- Ruling gradients
- Limiting gradients
- Exceptional gradients
- Minimum gradients

Ruling gradient: -

- It is the maximum gradient within which designer attempts to fix the vertical profile of the road.
- Ruling gradient is also known as design gradient. Ruling gradient values of 1 in 30 on plain and rolling terrain, 1 in 20 on mountainous and 1 in 16.7 on steep terrain has been recommended by I.R.C.

Limiting gradient: -

It is steeper than ruling gradient and is provided at places where topography compels to adopt steeper gradient to avoid enormous increase in cost in gentler gradients.

Exceptional gradients: -

Exceptional gradient is steeper than ruling gradient and may be provided in short lengths of the road in some extra ordinary situations. It should not exceed 60m in one kilometer of road length.

Minimum gradient: -

- It is the minimum desirable slope essential for effective drainage of rain water from the road surface.
- A gradient of about 1 in 500 may be sufficient to drain water in concrete drains while kutcha open drain may require 1 in 250 slope or even more.

Design Speed:

The design speed, as noted earlier, is the single most important factor in the design of horizontal alignment.
The design speed also depends on the type of the road. For e.g, the design speed expected from a National highway will be much higher than a village road, and hence the curve geometry will vary significantly.

The design speed also depends on the type of terrain. A plain terrain can afford to have any geometry, but for the same standard in a hilly terrain requires substantial cutting and filling implying exorbitant costs as well as safety concern due to unstable slopes. Therefore, the design speed is normally reduced for terrains with steep slopes.

Average running speed:

Average running speed is the speed maintained by vehicles over a particular section of a road. This is calculated by dividing the distance travelled by a vehicle with actual running time. The relationship between design speed and average running speed is very important as most of the vehicles travel at speeds very close to the average running speed.

Sight Distance

Sight distance is the actual distance along the road at which a driver has visibility of stationary or moving objects from a specified height above the carriageway.

Factors affecting Sight distance

The most important consideration in all these is that at all times the driver traveling at the design speed of the highway must have sufficient carriageway distance within his line of vision to allow him to stop his vehicle before colliding with a slowly moving or stationary object appearing suddenly in his own traffic lane.

The computation of sight distance depends on:

Reaction time of the driver

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

- The total reaction time may be split up into four components based on PIEV theory.
- In practice, all these times are usually combined into a total perception reaction time suitable for design purposes as well as for easy measurement.
- Many of the studies show that drivers require about 1.5 to 2 secs under normal conditions. However, taking intoconsideration the variability of driver characteristics, a higher value is normally used in design. For example, IRC suggests a reaction time of 2.5 secs.

Speed of the vehicle

The speed of the vehicle very much affects the sight distance. Higher the speed, more time will be required to stop the vehicle. Hence it is evident that, as the speed increases, sight distance also increases.

Efficiency of brakes

The efficiency of the brakes depends upon the age of the vehicle, vehicle characteristics etc. If the brake efficiency is 100%, the vehicle will stop the moment the brakes are applied. But practically, it is not possible to achieve 100% brake efficiency. Therefore the sight distance required will be more when the efficiency of brakes are less. Also for safe geometric design, we assume that the vehicles have only **50%** brake efficiency.

Frictional resistance between the tyre and the road

The frictional resistance between the tyre and road plays an important role to bring the vehicle to stop. When the frictional resistance is more, the vehicles stop immediately. Thus sight required will be less. No separate provision for brake efficiency is provided while computing the sight distance. This is taken into account along with the factor of longitudinal friction. IRC has specified the value of longitudinal friction in between **0.35 to 0.4.**

Gradient of the road.

Gradient of the road also affects the sight distance. While climbing up a gradient, the vehicle can stop immediately. Therefore sight distance required is less. While descending a gradient, gravity also comes into action and more time will be required to stop the vehicle. Sight distance required will be more in this case.

Stopping sight distance

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.

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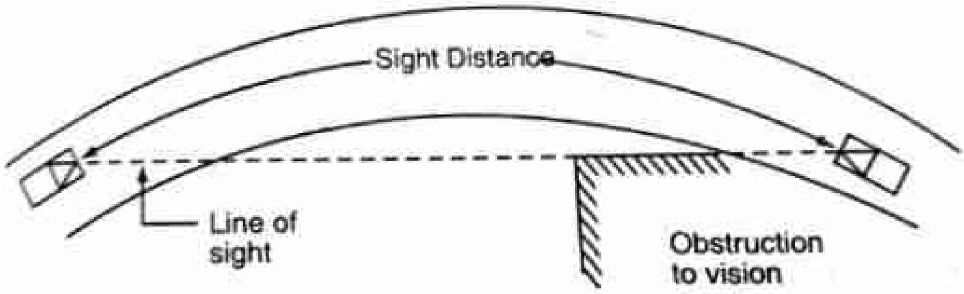
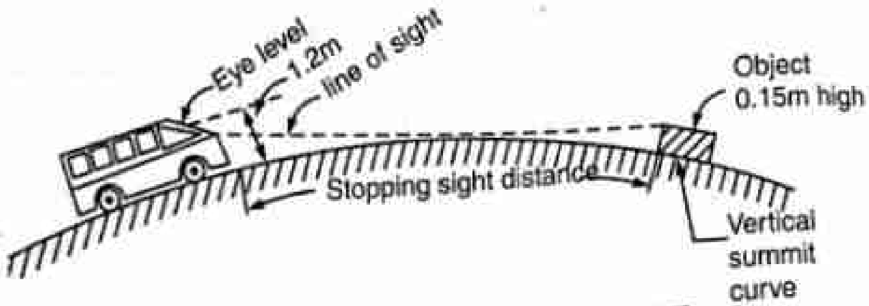
Stopping sight distance (SSD) is the minimum sight distance available on a highway at any spot having sufficient length to enable the driver to stop a vehicle traveling at design speed, safely without collision with any other obstruction.

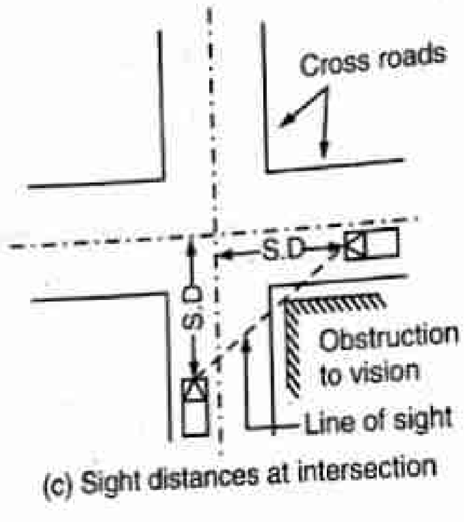
Drivers must have adequate time if they are to suddenly respond to a situation. Thus in highway design, sight distance at least equal to the safe stopping distance should be provided. The stopping sight distance is the sum of lag distance and the braking distance.



(a) Sight distance at horizontal curve



(b) Sight distance at vertical summit curve



(c) Sight distances at intersection

∴ Stopping Distance (S.D) = *Lag distance + **braking distance

∴ $$S.D. = \left[vt + \frac{v^2}{2gf}\right] m$$

where v = Speed of vehicle in m/sec

t = Reaction time in secs.

f = Design co-efficient of friction

= 0.4 to 0.35 for 20 to 100 kmph speed.

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

If speed is V kmph, then stopping distance

$$S.D. = \left[0.278\,Vt + \frac{V^2}{254f}\right] \text{ m for level road}$$

Stopping distance at slopes is calculated by using the formula

$$S.D. = \left[Vt + \frac{V^2}{2g(f \pm 0.01n)}\right] m$$

where n = Gradient in % and V in m/s.

If speed is V kmph,

then $$S.D. = \left[0.278\,Vt + \frac{V^2}{254(f \pm 0.01n)}\right] m$$

Overtaking sight distance

- The overtaking sight distance is the minimum distance open to the vision of the driver of a vehicle intending to overtake the slow vehicle ahead safely against the traffic in the opposite direction.
- The overtaking sight distance or passing sight distance is measured along the center line of
- the road over which a driver with his eye level 1.2 m above the road surface can see the top of an object 1.2 m above the road surface.

The factors that affect the OSD are:

1. Speed of the overtaking vehicle, overtaken vehicle and of the vehicle coming in the oppositedirection.

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.

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5. Gradient of the road.

Analysis of Overtaking sight Distance

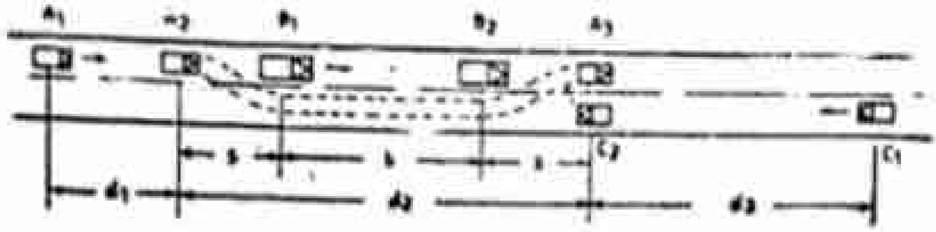
Let A is the overtaking vehicle travelling at design speed V kmph and vehicle B is the overtaken vehicle moving with uniform speed V_b m/sec on a two lane road with two way traffic.

Vehicle C comes from opposite direction at a design speed of v m/sec or V kmph

Let d_1 is the distance travelled by overtaking vehicle A during the reaction time t sec of the driver from position A_1 to A_2

d_2 is the distance travelled by overtaking vehicle A during the actual overtaking operation time T sec of the driver from position A_2 to A_3

d_3 is the distance travelled by overcoming vehicle C from C_1 to C_2 during the actual overtaking operation of A i.e T secs.



OVERTAKING MANOEUVRE

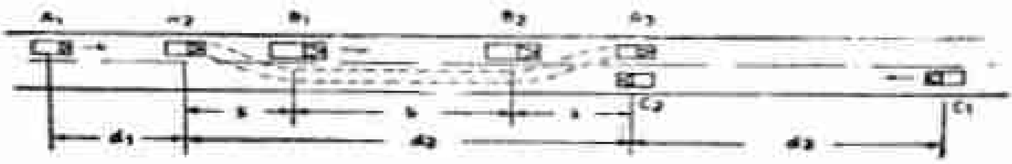
(i) d_1 is the distance travelled by overtaking vehicle A during the reaction time t sec of the driver from position A_1 to A_2.

(ii) d_2 is the distance travelled by the vehicle A from A_2 to A_3 during the actual overtaking operation, in time T sec.

(iii) d_3 is the distance travelled by on-coming vehicle C from C_1 to C_2 during the overtaking operation of A, i.e. T secs.

Certain assumptions are made in order to calculate the values of d_1, d_2 and d_3.

In Fig. 4.14, A is the overtaking vehicle originally traveling at design speed v m/sec, or V kmph; B is the overtaken or slow moving vehicle moving with uniform speed v_b m/sec or V_b kmph; C is a vehicle coming from opposite direction at the design speed v m/sec or V kmph. In a two-lane road the opportunity to overtake depends on the frequency of vehicles from the direction and the overtaking sight distance available at any instant.



(i) It may be assumed that the vehicle A is forced to reduce its speed to the speed v_b of till there is an the slow vehicle B and moves behind it allowing a space s, opportunity for safe overtaking operation. The distance travelled by the vehicle A during this reaction time is d_1 and is between the positions A_1 and A_2. This distance will be equal to $v_b \times t$ metre where 't' is the reaction time of the driver in second. This reaction time 't' of the driver may be taken as two seconds as an average value, as the aim of the driver is only to find an opportunity to overtake. Thus,

$$d_1 = v_b t = 2 v_b, m$$

(ii) From position A_2, the vehicle A starts accelerating, shifts to the adjoining lane, overtakes the vehicle B, and shifts back to it original lane ahead of B in position A_3 in time T sec. The straight distance between position A_2 and A_3 is taken as d_2. The minimum distance between position A_2 and B_1 may be taken as the minimum spacing 's' of the two vehicles while moving with the speed v_b m/sec. The minimum spacing between vehicles depends on their speed and is given by empirical formula :

$$s = (0.7 v_b + 6), m$$

The minimum distance between B_2 and A_3 may also be assumed equal to s as mentioned above. If the time taken by vehicle A for the overtaking operation from position A_2 to A_3 is T second, the distance covered by the slow vehicle B traveling at a speed of v_b m/sec = b = v_b/T m.

Thus the distance d_2 = (b + 2s), m

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Thus the distance $d_2 = (b + 2s)$, m

Now the time T depends on speed of overtaken vehicle B and the acceleration of overtaking vehicle A. This time T may be calculated by equating the distance d_2 to $(v_b T + \frac{1}{2} a T^2)$, using the general formula for the distance travelled by an uniformly accelerating body with initial speed v_b m/sec and 'a' is the acceleration in m/sec^2.

$$d_2 = (b + 2s) = \left(v_b T + \frac{aT^2}{2}\right)$$

$$b = vb.T, \text{ and therefore } 2s = \frac{aT^2}{2}$$

Therefore, $$T = \sqrt{\frac{4s}{a}} \text{ sec, where } s = (0.7\, v_b + 6)$$

Hence, $$d_2 = (v_b T + 2s), \text{ m}$$

(iii) The distance travelled by vehicle C moving at design speed v m/sec during the overtaking operation of vehicle A i.e. during time T is the distance d_3 between positions C_1 to C_2.

Hence, $$d_3 = v \times T$$

Thus the overtaking sight distance

$$OSD = (d_1 + d_2 + d_3)$$

$$= (v_b t + v_b T + 2s + vT) \quad (4.5)$$

In kmph units, equations (4.5) worksout as :

$$OSD = 0.28\, V_b t + 0.28\, V_b T + 2s + 0.28\, V.T \quad (4.6)$$

Here V_b = speed of overtaking vehicle, kmph

t = reaction time of driver = 2 secs.

V = speed of overtaking vehicle or design speed, kmph

$$T = \sqrt{\frac{4 \times 3.6 s}{A}} = \sqrt{\frac{14.4 s}{A}}$$

s = spacing of vehicles = $(0.2\, V_b + 6)$

A = acceleration, kmph/sec.

In case the speed of overtaken vehicle V_b is not given, the same may be assumed as (V – 16) kmph where V is the design speed in kmph or $v_b = (v - 4.5)$ m/sec and v is the design speed in m/sec.

CURVE

Curves are the geometrical arcs provided at the change in gradient or alignment of the road.

Necessity of providing Curves

Curves are provided at the change in the alignment or gradient of a road due to the following reason:-

1. To lay the road according to the topography of the country
2. To avoid costly land
3. To avoid excessive cutting and filling
4. To avoid certain important structures
5. To make use of the existing roads, bridges, etc.

Types of curves

Curves on highways have been divided into following classes

i. Horizontal curve
ii. Vertical curve

Horizontal Curve

The presence of horizontal curve imparts centrifugal force which is 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. For proper design of the curve, an understanding of the forces acting on a vehicle taking a horizontal curve is necessary.

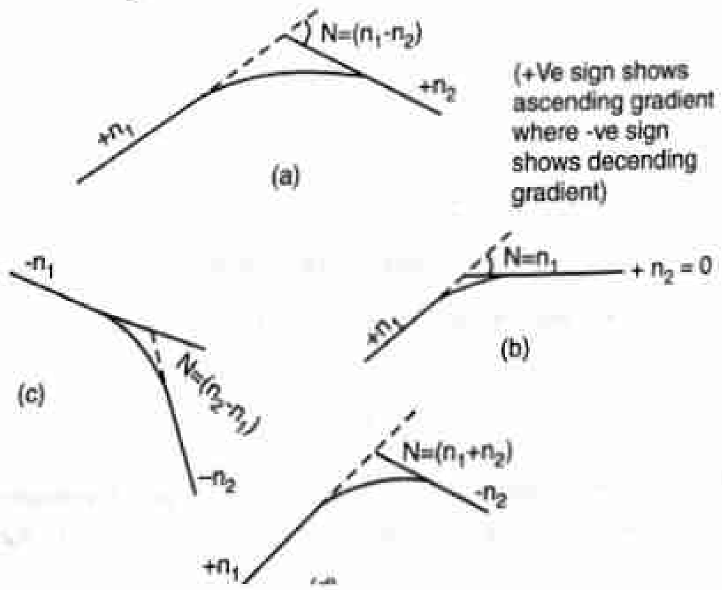
Vertical curve

Due to changes in grade in the vertical alignment of highway it is necessary to introduce vertical curve at the intersections of different grade to smoothen out the vertical profile and thus each of changes in gradient for the fast moving vehicles. The vertical curves may be classified into two categories:

1. Summit curves
2. Valley curves

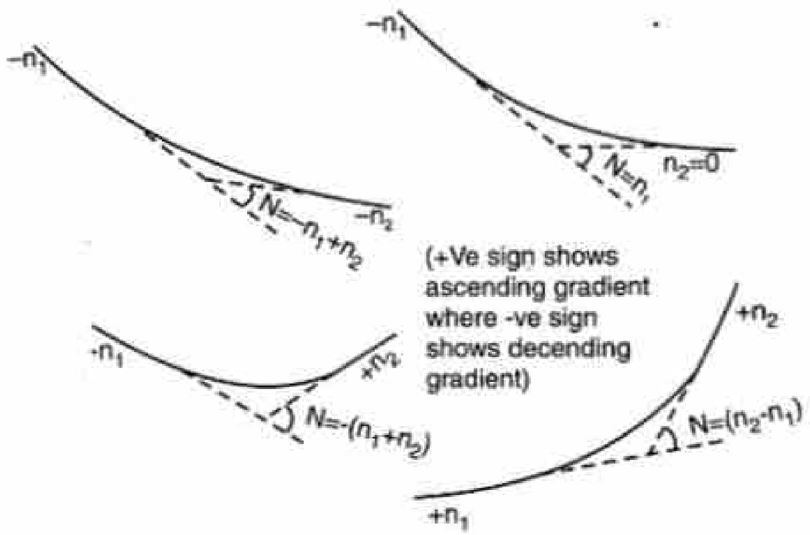
Summit curves:

Summit curves are vertical curves with gradient upwards. The centrifugal force will acts upwards against gravity when a fast moving vehicle travels along a summit curve and there will be no problem of discomfort to the passengers. At the time of designing the length of summit curve and there will be no problem of discomfort to the passengers.at the time of designing the length of summit curve the stopping sight distance and overtaking sight distance are considered separately.



Valley curves:

Valley curve are vertical curves having their convexity downward. This is also called sag curves. At the valley curve the centrifugal force acts downward adding to the pressure on the suspension in addition to the self weight of a vechile moving on the curve . hence the design of valley cuvre is goverened by the allowable rate of change centrifugal acceleration.



Transition Curve:

A transition curve is the curve having a radius which decreases from infinity at the tangent point to a designed radius of the circular curve. This type of curve is generally introduced on highways between a straight and circular curve to provide ease and gradual change in direction of road alignment.

Length of transition curve:

The length of transition curve is determined from the following:

(a)Rate of change of centrifugal acceleration:

$$L_s = 0.0215V^3/CR$$

Where L_s=Length of transition curve

V=design speed in km/hr

R= radius of circular curve

C=allowable rate of change of centrifugal acceleration ($0.5<C<0.8$)

(b) By empirical formula:

(i) for plain and rolling terrain:

$L_s=2.7V^2/R$

(ii) For mountainous and steep terrain:

$L_s=V^2/R$

(c) Rate of introduction of super elevation:

$L_s=eN(W+W_e)$

Where, e=rate of super elevation

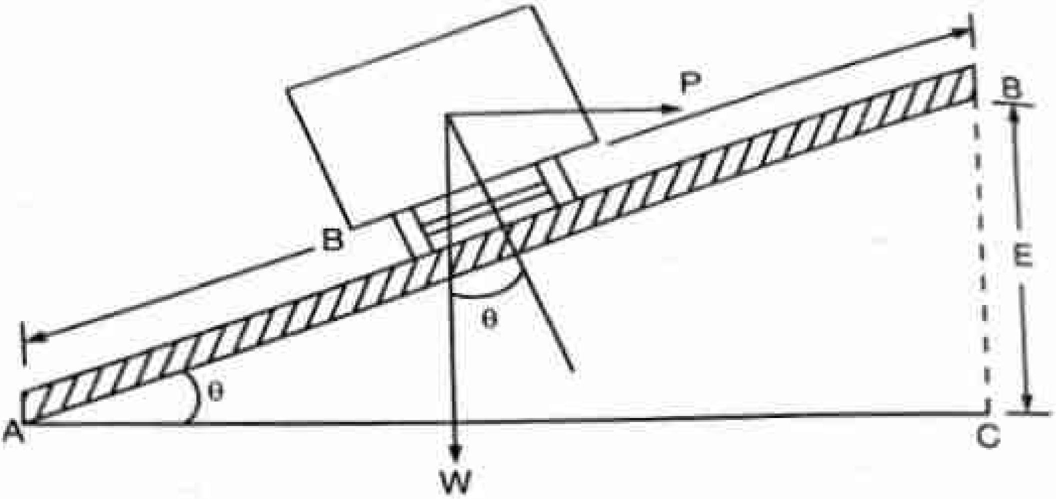
W=Normal width of pavement

W_e=Extra widening provided

1 in N=Rate of change of super elevation

Super-elevation

Super-elevation or cant or banking 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.



$$e = \tan\theta = \sin\theta = \frac{BC}{AB} = \frac{E}{B}$$

Analysis of super elevation

When a vehicle (Refer Fig. 2.15) is moving on a circular curve of radius 'R' at a

When a vehicle (Refer Fig. 2.15) is moving on a circular curve of radius 'R' at a speed V, then the forces acting on the vehicle are :

(i) Weight 'W' of vehicle acting vertically downward.

(ii) Frictional force F_A and F_B acting along the pavement surface towards the centre of the curve.

(iii) The centrifugal force $\left(P = \frac{WV^2}{gR}\right)$ acting horizontally outwards as shown in Fig. 2.15.

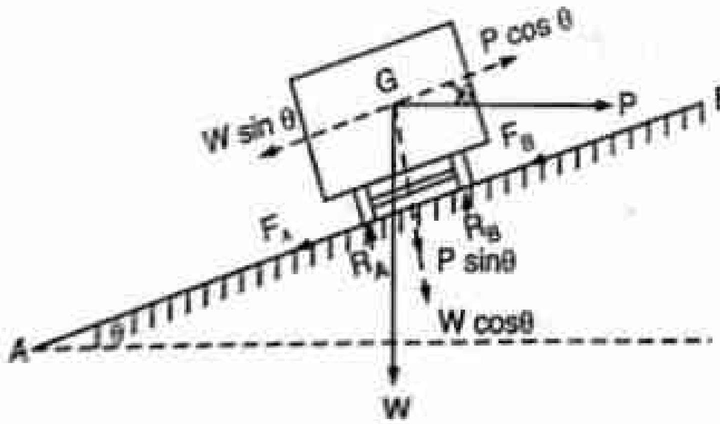
Resolving the forces along the pavement AB and for equilibrium condition.

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

$$= W \sin\theta + f.R_A + f.R_B$$

$$[\because F_A = f.R_A \ \& \ F_B = f.R_B]$$

$$= W \sin\theta + f(R_A + R_B) \quad ...(i)$$



Now, resolving the forces perpendicular to the pavement AB and for equilibrium condition.

$$R_A + R_B = (P \sin\theta + W \cos\theta) \quad ...(ii)$$

Putting the value of $(R_A + R_B)$ from eqn. (ii) to eqn. (i), we get

$$P \cos \theta = W \sin \theta + f \, . \, (P \sin \theta + W \cos \theta)$$

or $$P \cos \theta = W \sin \theta + f \, . \, P \sin \theta + f \, . \, W \cos \theta$$

or $$P(\cos \theta - f \, . \, \sin \theta) = W(\sin \theta + f \, . \, \cos \theta) \qquad \text{... (iii)}$$

Dividing eqn. (iii) by W cos θ, we get

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

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

As the value of co-efficient of friction, f and angle θ is small, the value of f tan θ may be neglected and hence the value of $(1 - f \tan \theta) = 1$.

∴ $$\frac{P}{W} = \tan \theta + f$$

$$= e + f \qquad [\because e = \tan \theta] \quad \text{... (iv)}$$

Again $$P = \frac{WV^2}{gR}$$

∴ $$\frac{P}{W} = \frac{V^2}{gR} \qquad \text{... (v)}$$

Putting the value of P/W from eqn. (v) to eqn. (iv), we get

$$e + f = \frac{V^2}{gR} \qquad \text{... (vi)}$$

where e = Rate of superelevation = tan θ

V = Speed of vehicle in m/sec.

R = Radius of horizontal curve in m

f = Co-efficient of lateral friction = 0.15

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

If the speed of vehicle is V Kmph then eqn. (vi) becomes

$$e + f = \frac{(0.278V)^2}{gR} = \frac{(0.278V)^2}{9.8R} = \frac{V^2}{127R}$$

∴ $$e + f = \frac{V^2}{127R} \text{ when V is in Kmph} \qquad \text{... (vii)}$$

If f = 0, then equilibrium superelevation is given by

$$e = \frac{V^2}{127R} \qquad \text{... (viii)}$$