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GEOMETRIC DESIGN OF HIGHWAYS

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Overview

- The geometric design of highways deals with the dimensions and layout of visible features of the highway.
- The features normally considered are the
  - cross section elements
  - sight distance consideration
  - horizontal curvature
  - gradients
  - intersection
- The design of these features is to a great extend influenced by driver behavior and psychology, vehicle characteristics, traffic characteristics such as speed and volume. Proper geometric design will help in the reduction of accidents and their severity.
- Therefore, the objective of geometric design is to provide optimum efficiency in traffic operation and maximum safety at reasonable cost.

Main Components Discussed

Factors affecting the geometric design,

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

Factors Affecting Geometric Design

Design speed

- Design speed is the single most important factor that affects the geometric design.
- It directly affects the sight distance, horizontal curve, and the length of vertical curves.
- Since the speed of vehicles vary with driver, terrain etc. a design speed is adopted for all the geometric design.
- Design speed is defined as the highest continuous speed at which individual vehicles can travel with safety on the highway when weather conditions are conducive.

- Design speed is different from the legal speed limit which is the speed limit imposed to curb a common tendency of drivers to travel beyond an accepted safe speed.
- Design speed is also different from the desired speed which is the maximum speed at which a driver would travel when unconstrained by either traffic or local geometry.
- Since there are wide variations in the speed adopted by different drivers, and by different types of vehicles, design speed should be selected such that it satisfy nearly all drivers.
- At the same time, a higher design speed has cascading effect in other geometric designs and thereby cost escalation.
- Therefore, an 85th percentile design speed is normally adopted. This speed is defined as that speed which is greater than the speed of 85% of drivers.

Topography

- The next important factor that affects the geometric design is the topography.
- It is easier to construct roads with required standards for a plain terrain.
- However, for a given design speed, the construction cost increases multiform with the gradient and the terrain.
- Therefore, geometric design standards are different for different terrain to keep the cost of construction and time of construction under control.
- This is characterized by sharper curves and steeper gradients.

Other factors

- Vehicle: :The dimensions, weight of the axle and operating characteristics of a vehicle influence the design aspects such as width of the pavement, radii of the curve, clearances, parking geometrics etc. A *design vehicle* which has standard weight, dimensions and operating characteristics are used to establish highway design controls to accommodate vehicles of a designated type.
- Human: The important human factors that influence geometric design are the physical, mental and psychological characteristics of the driver and pedestrians like the reaction time.
- Traffic: It will be uneconomical to design the road for peak traffic flow. Therefore a reasonable value of traffic volume is selected as the design hourly volume which is determined from the various traffic data collected. The geometric design is thus based on this design volume, capacity etc.
- Environmental: Factors like air pollution, noise pollution etc. should be given due consideration in the geometric design of roads.
- Economy: The design adopted should be economical as far as possible. It should match with the funds allotted for capital cost and maintenance cost.
- Others: Geometric design should be such that the aesthetics of the region is not affected.

Cross sectional elements

Pavement surface characteristics

For safe and comfortable driving four aspects of the pavement surface are important;

- friction between the wheels and the pavement surface,
- smoothness of the road surface,
- light reflection characteristics of the top of pavement surface,
- drainage to water.

Friction

- Friction between the wheel and the pavement surface is a crucial factor in the design of horizontal curves and thus the safe operating speed.
- Further, it also affect the acceleration and deceleration ability of vehicles.
- Lack of adequate friction can cause skidding or slipping of vehicles.
- Skidding happens when the path traveled along the road surface is more than the circumferential movement of the wheels due to friction
- Slip occurs when the wheel revolves more than the corresponding longitudinal movement along the road.

Friction

- Various factors that affect friction are:
  - Type of the pavement (like bituminous, concrete, or gravel),
  - Macro-texture of the pavement surface,
  - Condition of the pavement (dry or wet, hot or cold, etc.),
  - Condition of the tyre (new or old),
  - Speed and load of the vehicle,
  - Brake efficiency
  - Temperature of the tyre and pavement
- The frictional force that develops between the wheel and the pavement is the load acting multiplied by a factor called the coefficient of friction.
- IRC suggests the coefficient of longitudinal friction as 0.35-0.4 depending on the speed and coefficient of lateral friction as 0.15. The former is useful in sight distance calculation and the later in horizontal curve design.

Unevenness

- It is always desirable to have an even surface, but it is seldom possible to have such a one.
- Unevenness affect the vehicle operating cost, speed, riding comfort, safety, fuel consumption and wear and tear of tyres.
- Unevenness index is a measure of unevenness which is the cumulative measure of vertical undulations of the pavement surface recorded per unit horizontal length of the road.
- An unevenness index value less than 1500 mm/km is considered as good, a value less than 2500 mm/km is satisfactory up to speed of 100 kmph and values greater than 3200 mm/km is considered as uncomfortable even for 55 kmph.

Pavement Unevenness results in

1. Increase in discomfort and fatigue to road users
2. Increase in fuel consumption and tyre wear
3. Increase in vehicle maintenance cost
4. Reduction in vehicle operating speed
5. Increase in accident rate

Light reflection

- White roads have good visibility at night, but caused glare during day time.
- Black roads has no glare during day, but has poor visibility at night
- Concrete roads has better visibility and less glare
- It is necessary that the road surface should be visible at night and reflection of light is the factor that answers it.

Drainage

- The pavement surface should be absolutely impermeable to prevent seepage of water into the pavement layers.
- Further, both the geometry and texture of pavement surface should help in draining out the water from the surface in less time.

Terrain Classification

- Terrain is classified by the general slope of the country across the highway alignment, for which the criteria given in Table 1 should be followed
- While classifying a terrain, short isolated stretches of varying terrain should not be taken into consideration

Terrain Classification

Table 1: Terrain Classification

S. No.	Terrain Classification	Percent Cross Slope of the country
1	Plain	0-10
2	Rolling	10-25
3	Mountainous	25-60
4	Steep	Greater than 60

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Design Speed

- Choice of design speed depends on the function of the road and also terrain conditions
- Design speed for various classes of roads should be as given in Table 2 and Table 3

Design Speed

Table 2: Design Speeds

S. No.	Classification	Design Speed (Km/hr)
1	Arterial	80
2	Sub Arterial	60
3	Collector Street	50
4	Local Street	30

Design Speed

Table 3: Design Speed

S. No.	Road Classification	Design Speed, Kmph							
		Plain Terrain		Rolling Terrain		Mountainous Terrain		Steep Terrain	
		Ruling design speed	Minimum design speed	Ruling design speed	Minimum design speed	Ruling design speed	Minimum design speed	Ruling design speed	Minimum design speed
1	National and State highway	100	80	80	65	50	40	40	30
2	Major District Roads	80	65	65	50	40	30	30	20
3	Other District Roads	65	50	50	40	30	25	25	20
4	Village Roads	50	40	40	35	25	20	25	20

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Cross – Sectional Elements

1. Road Land, Building Lines and Control Lines

- Road land width (right-of-way) is the land acquired for road purposes
- Desirable land width for different classes of roads is indicated in Table 4

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.

- The right of way width is governed by: Width of formation: It depends on the category of the highway and width of roadway and road margins.
- Height of embankment or depth of cutting: It is governed by the topography and the vertical alignment.
- Side slopes of embankment or cutting: It depends on the height of the slope, soil type etc.
- Drainage system and their size which depends on rainfall, topography etc.
- Sight distance considerations : On curves etc. there is restriction to the visibility on the inner side of the curve due to the presence of some obstructions like building structures etc.
- Reserve land for future widening: Some land has to be acquired in advance anticipating future developments like widening of the road.

Table 4: Recommended land width for different class of road (meters)

S. No.	Road Classification	Plain and Rolling Terrain				Mountainous and Steep Terrain	
		Open areas		Builtup areas		Open areas	Builtup areas
		Normal	Range	Normal	Range	Normal	Normal
1	National and State highway	45	30-60	30	30-60	24	20
2	Major District Roads	25	25-30	20	15-25	18	15
3	Other District Roads	15	15-25	15	15-20	15	12
4	Village Roads	12	12-18	10	10-15	9	9

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Table 5: Recommended Land Width For road in Urban Areas

S. No.	Classification	Recommended land width in meters
1	Arterial	50-60
2	Sub-arterial	30-40
3	Collector street	20-30
4	Local Street	10-20

Note: The term "space standard" is often referred to as "right of way"

IRC:86 1983

- Building and control lines are illustrated in Fig.1 with respect to the road centre line and road boundary

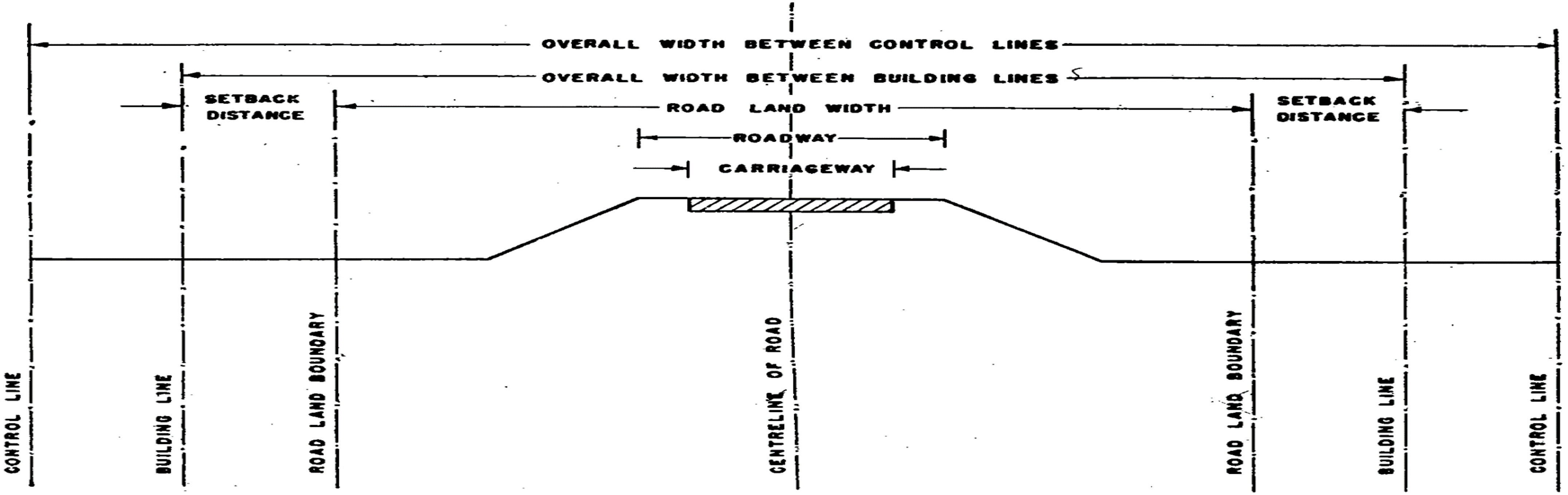

Fig. 1. Road land boundary, building lines and control lines

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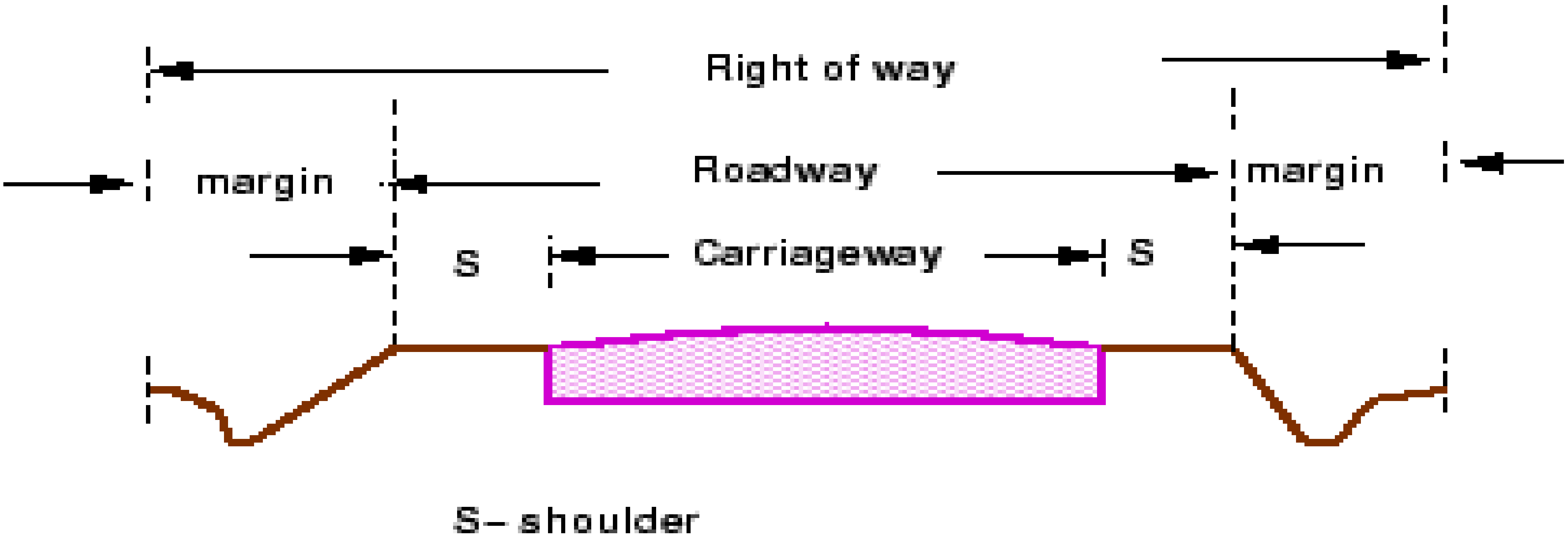

Fig. 2 Right of way

Table 6: Recommended standards for building and control line

S. No.	Road Classification	Plain and Rolling Terrain			Mountainous and Steep Terrain	
		Open areas		Builtup areas	Open areas	Builtup areas
		Overall width between building line (metres)	Overall width between control line (metres)	Distance between building line and road boundry (setback) (metres)	Distance between building line and road boundry (setback) (metres)	
	1	2	3	4	5	6
1	National and State highway	**80**	**150**	**3-6**	**3-5**	**3-5**
2	Major District Roads	**50**	**100**	**3-5**	**3-5**	**3-5**
3	Other District Roads	**25/30***	**35**	**3-5**	**3-5**	**3-5**
4	Village Roads	**25**	**30**	**3-5**	**3-5**	**3-5**

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2. Road way Width

a. The width of roadway for single and two-lane roads in plain and rolling terrain should be as given,

Table 7: Width of Road for Single Lane and Two lane Road in Plain and Rolling Terrain

S. No.	**Road Classification**	**Roadway width, metres**
		Plain and Rolling Terrain
1	National and State highway (a).Single Lane (b). Two Lane	 12 12
2	Major District Roads (a).Single Lane (b). Two Lane	 9.0 9.0
3	Other District Roads (a).Single Lane (b). Two Lane	 7.5 9.0
4	Village Roads single Lane	7.5

- The width of roadway, exclusive of side drains and parapets, for single and two-lane roads in mountainous and steep terrain should be as indicated in Table 8

Table 8: Width of Road for Single Lane and Two lane Road in Mountainous and Steep Terrain

S. No.	**Road Classification**	**Roadway width, m**
		Mountainous and Steep Terrain
1	National and State highway (a).Single Lane (b). Two Lane	 6.25 8.80
2	Major District Roads (a).Single Lane (b). Two Lane	 4.75 -
3	Other District Roads (a).Single Lane (b). Two Lane	 4.75 -
4	Village Roads single Lane	4.00

c. Passing places for roads in mountainous and steep terrain:

- The passing places/ lay-byes should be 3.75m wide, 30m long on the inside edge (i.e toward the carriageway side), and 20m long on the farther side

d. Roadway width for multi-lane highways:

- Roadway width should be adequate for the requisite number of traffic lanes
- Width of shoulders – 2.5m

3. Roadway width at Cross-Drainage Structures

a. Culverts (upto 6 m span):

- In plain and rolling terrain, the overall width on culverts should equal the normal roadway width given in Table 5
- In mountainous or steep terrain, the clear roadway width available on culverts should be as below:
  - All roads other than Village Roads

    - As given in Table 8
  - Village Roads

    Minimum - As given in Table 8

    Desirable - 4.25 m

b. Bridges (greater than 6 m span):

- At bridges, the clear width of roadway between kerbs should be as under:
  - Single-lane bridge - 4.25 m
  - Two-lane bridge - 7.5 m
  - Multi-lane bridge - 3.5 m per lane plus 0.5 m for each carriageway
- At causeways and submersible bridges, the minimum width of roadway should be 7.5 m
- Footpath for pedestrians – should not be less than 1.5 m

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4. Width of Carriageway

- 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 and 1.06 m in the center. Therefore, a two lane road require minimum of 3.5 meter for each lane
- The standard width of carriageway shall be indicated in Table 7.
- Where the carriageway width changes, the transition should be effected through a taper of 1 in 15 to 1 in 20

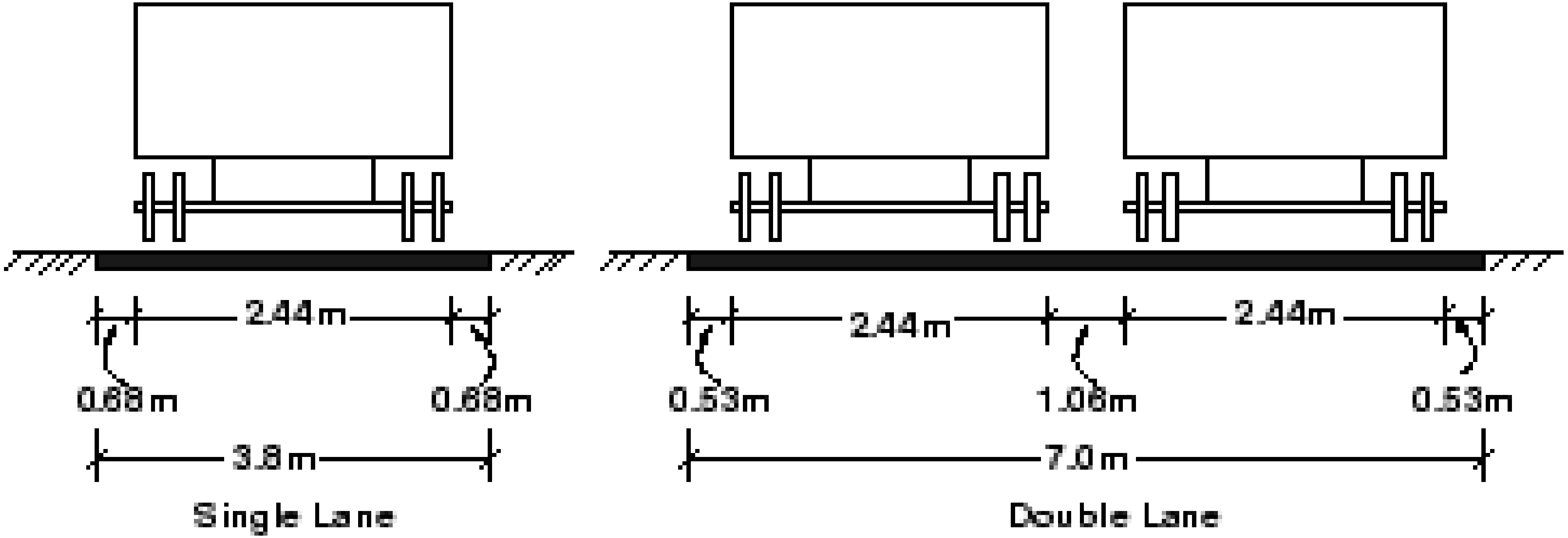

Fig. 3: Lateral Placement of Vehicle

Table 9: Width of Carriageway

S. No.	Class of road	Width of Carriageway
1	Single Lane	3.75* m
2	Two lanes, without raised kerbs	7.0 m
3	Two lanes, with raised kerbs	7.5 m
4	Intermediate carriageway (Except on important road)	5.5 m
5	Multi-lane pavements	3.5m per lane

Notes: (i). *The Width of single lane or village roads may be decreased to 3.0.

(ii). On urban roads without kerbs the single lane width may be decreased to 3.5 m and in access roads to residential areas to 3.0 m.

(iii) The minimum width recommended for kerbed urban road is 5.5 m to make allowance for stalled vehicle

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Table 10:Recommended Carriageway Width

S. No.	Description	Width of Carriageway
1	Single Lane without Kerb	3.5 m
2	2 lane without kerbs	7.0 m
3	2 lanes with kerbs	7.5 m
4	3 lane with or without kerb	10.5 /11 m
5	4 lane with or without kerb	14.0 m
6	6 lane with or without kerb	21.0 m

Note: 1. For access roads to residential area, a lower lane width of 3 m is permissible.

2. Minimum width of a kerbed urban road is 5.5 including allowance for stalled vehicle.

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5. Shoulder Width

- Shoulder width will be one-half the difference between the roadway width (Table 7 or 8) and carriageway width (Table 10)

6. Median/Traffic separator Width

- Minimum desirable width on rural highways is 5 m, but this could be reduced to 3 m where land is restricted
- On long bridges and viaducts width may be reduced to 1.5 m, but in any case it should not be less than 1.2 m

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8. Pavement Camber or Crossfall

- Camber or cant is the cross slope provided to raise middle of the road surface in the transverse direction to drain off rain water from road surface.

The objectives of providing camber 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%* (ex. 1 in 50 or 2%) and the value depends on the type of pavement surface
- The camber or crossfall on straight sections of roads as recommended in Table 11.

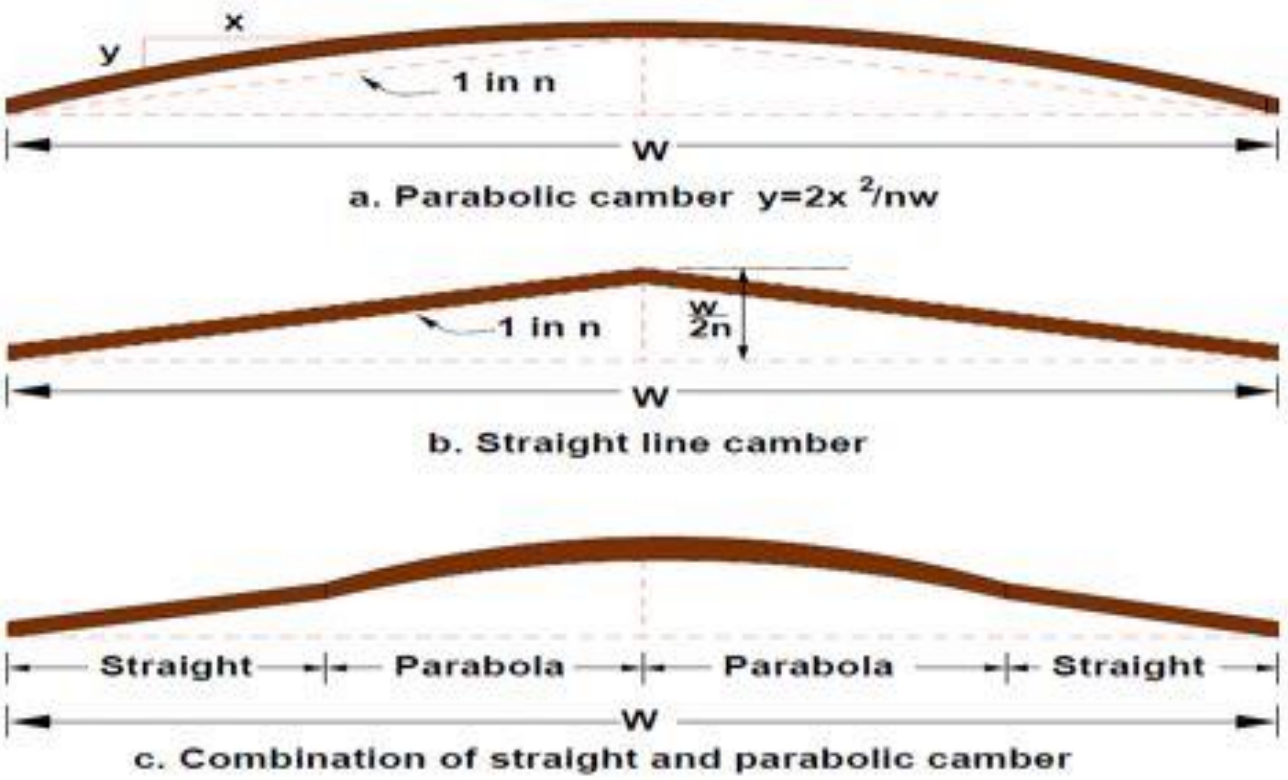

Fig. 4. Different Types of Camber

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Table11: Recommended values of camber for different types of road surfaces

S. No.	Types of road surface	Range of camber in areas of rainfall range
		Heavy to Light
1	Cement concrete and high type bituminous surface	1 in 50 (2.0%) to 1 in 60 (1.7%)
2	Thin bituminous surface	1 in 40 (2.5%) to 1 in 50 (2.0%)
3	Water bound macadam, and gravel pavement	1 in 33 (3.0%) to 1 in 40 (2.5%)
4	Earth	1 in 25 (4.0%) to 1 in 33 (3.0%)

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8. Crossfall for Shoulders

- The crossfall for earth shoulders should be at least 0.5 percent steeper than the slope of the pavement subject to a minimum of 3 percent
- If the shoulders are paved, a crossfall appropriate to the type of surface should be selected with reference to Table 11.
- Superelevated sections - shoulders should have the same crossfall as the pavement

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Functions of shoulders

- accommodation of stopped vehicles (disabled vehicles, bus stops)
- emergency use
- lateral support for the pavement
- space for roadside facilities
- space for bicycles and pedestrians
- driving comfort (freedom from strain)
- improvement in sight distance
- improvement in capacity

Kerbs

- The boundaries between pavement and shoulders or footpath are known as kerbs.

OR

- A Kerb is a vertical or sloping member along the edge of a pavement or shoulder, forming part of gutter, strengthening or protecting the edge and clearly defining the edge to vehicle operators.
- The **Functions** of Kerb are:
- To facilitate and control drainage
- To delineate roadway edge
- To strengthen and protect the pavement edge
- To delineate pedestrian walkways
- To present a more finished appearance
- To assist in the orderly development of the roadside

Kerbs

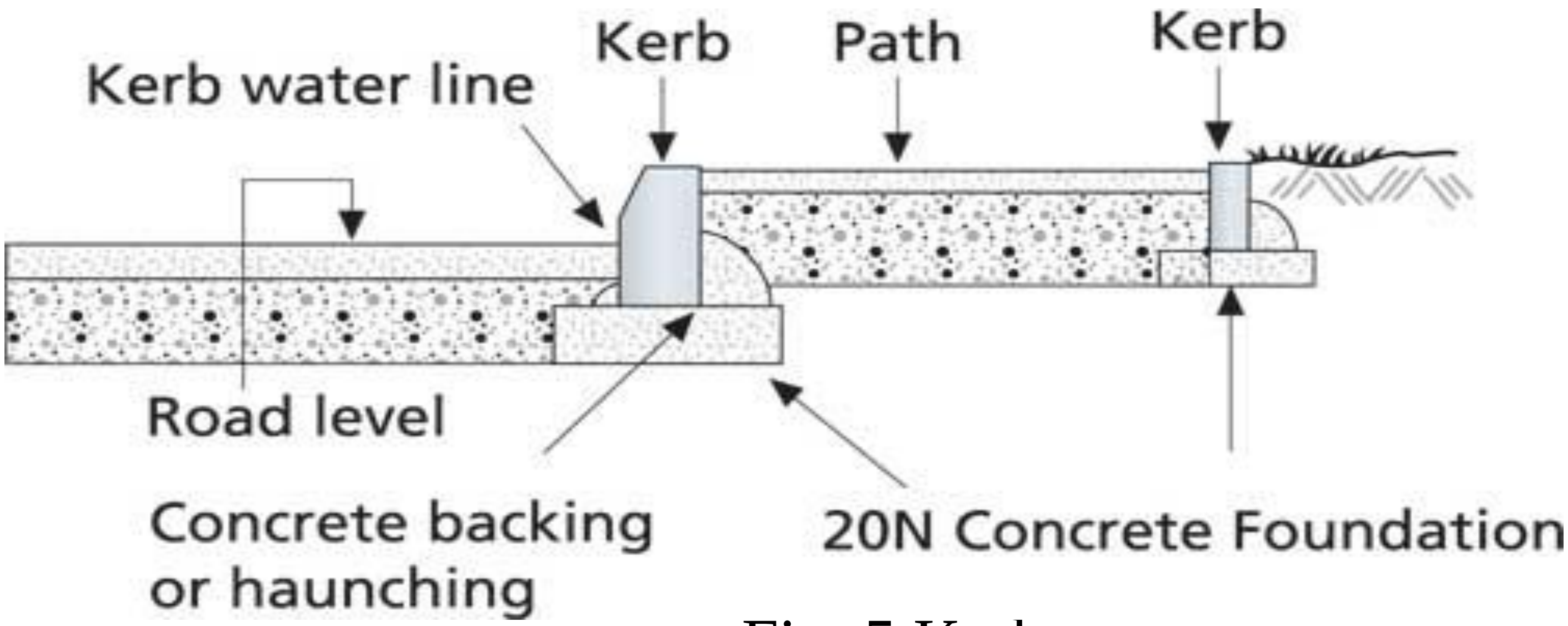

Fig. 5 Kerb

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Mountable kerbs :

- These kerbs are indicator between the boundary of a road and shoulder.
- The height of the kerb is such that driver find no difficulty in crossing these kerbs and use the shoulder incase of emergency.
- Its height is kept as 10cm above the pavement edge.

Semi-barrier kerbs :

- It prevents encrouchment of slow speed or parking vehicles to the footpath
- But at emergency vehicle can climb over and can be parked on footpath or shoulder.
- Its height is 15 to 20cm

Barrier kerbs

- They are mainly provided to cause obstruction to the vehicles leaving the carriage way under emergency.
- Its height is 23 to 45cm
- Generally, such kerbs are provided on hills bridges etc.

Types of kerbs

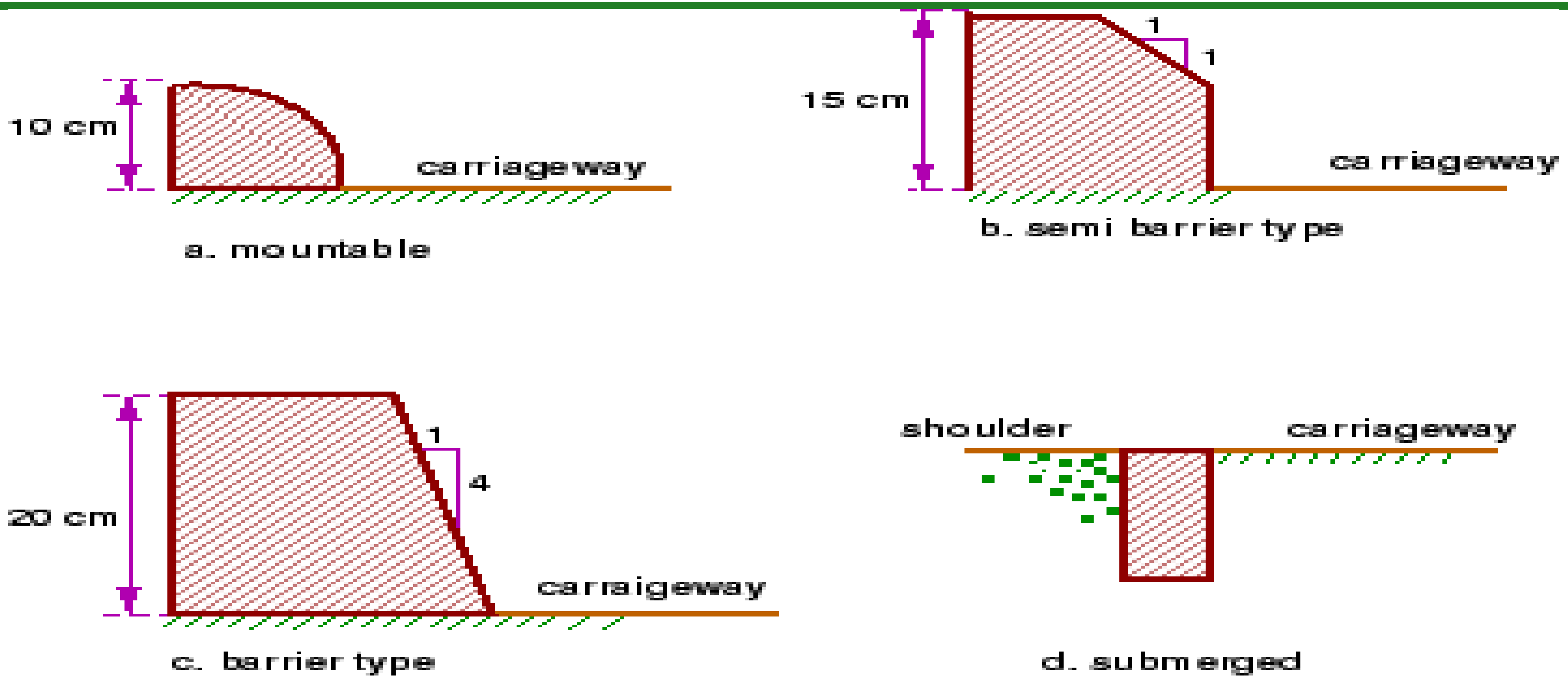

Fig. 6 Types of Kerbs

Fig. 7 Kerb on the road

Road Margins

The various elements include in the road margins are,

- Shoulder
- Guard Rail
- Foot path
- Drive way
- Cycle Track
- Parking Lane
- Bus bay
- Lay-bye
- Frontage road
- Embankment Slope

Shoulder

- Shoulder are provided on both sides of the pavement all along the road in the case of undivided carriageway.
- Shoulder are provided along the outer edge of the carriageway in the case of divided carriageway.
- The earth shoulders should have sufficient stability to support even a loaded truck and therefore they are constructed using good quality material.
- In order to increase the capacity of the roadway paved road are also laid down on roads with high traffic flow.
- The minimum shoulder width recommended by the IRC is 2.5 m
- The surface of the shoulder may be rougher than the traffic lanes so that vehicles are discouraged to use the shoulder as a regular traffic lane.
- The colour of the shoulder should preferably be different from that of the pavement so as to distinct.

Guard Rail

- They are provided at the edge of the shoulder usually when the road is on an embankment.
- They serve to prevent the vehicle from running off the embankment, especially when the height of the fill exceeds 3m.
- They also give better visibility of curves at night under headlights of vehicles.

Footpath or side walk

- Footpath are exclusive right of way to pedestrians, especially in urban area.
- They are provided for the safety of the pedestrians when both the pedestrian and vehicular traffic is high.
- The footpath should be either as smooth as the pavement or more smoother than that to induce the pedestrian to use the footpath.
- The absolute minimum width of footpath is 1.5 m and desirable minimum width is 2 m.

Drive ways

- Drive way connect the highway with commercial establishment like fuel-stations service stations etc.
- Drive way should be properly designed and located, fairly away from an intersection.
- The radius of the drive way curve should be kept as large as possible, but the width of dive way should be minimised to reduce the crossing distance for the pedestrians.

Cycle Track

- Cycle track are provided in urban areas when the volume of cycle traffic is high.
- Minimum width of 2 m is required, which may be increased by 1 m for every additional tracks

Parking lanes

- Parking lanes are provided in urban lanes for side parking
- Parallel parking is preferred because it is safe for the vehicle moving on the road.
- The parallel parking lane should have a minimum of 3 m width.
- The clearance available between the parked vehicle and the edge of the adjacent lane is more in the case of parallel parking than in angle parking

Bus bays

- Bus ways are provided by recessing the kerb for stops.
- They are provided so that they do not obstruct the movement of vehicles in the carriage way.
- They should be at least 75 m away from the instruction so that the traffic near the intersection is not affected by the bus bay.

Lay byes

- Lay byes are provided near public conveniences with guide maps to enable drivers to stop clear off the carriageway.
- Lay byes should normally be of 3 m width and at least 30 m length with 15 m end tapers on both sides.

Frontage roads

- Frontage roads are provided to give access to properties along an important highway with controlled access to express way or free way.
- The frontage roads may run parallel to the highway and are isolated by a separator, which approaches to the through facility only at selected points, preferably with grade separations.

Embankment slopes

- Embankment slope should be as flat as possible for the purpose of safe traffic movement and also for aesthetic reasons.
- Road side landscaping can improve the aesthetic features of road, making road travel more pleasant.
- For safety consideration, the desirable slope for the embankment is 1 in 3.

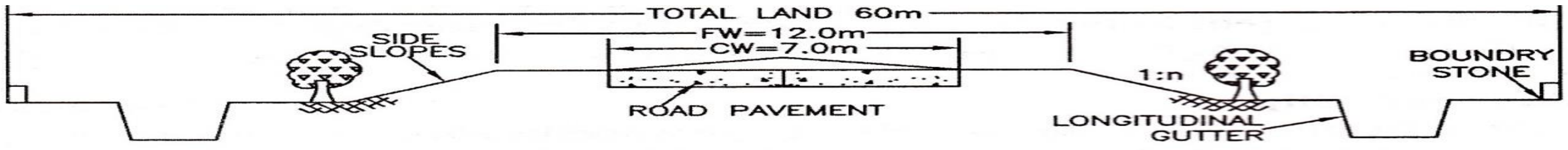

FIG. 3.4 CROSS-SECTION OF NH OR SH IN RURAL AREA IN EMBANKMENT

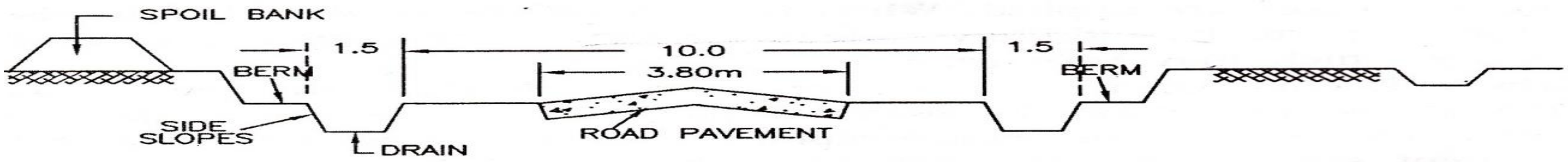

FIG. 3.5 CROSS-SECTION OF MDR IN CUTTING IN RURAL AREA

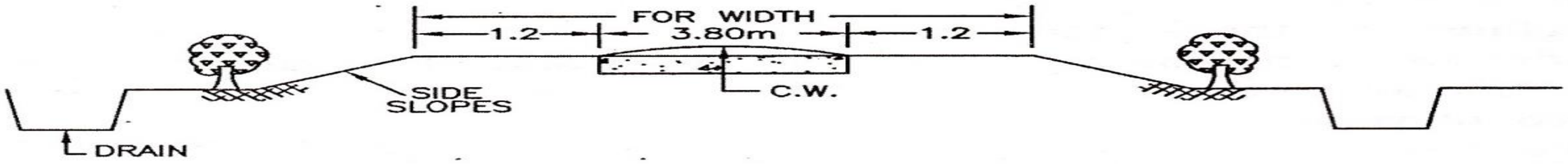

FIG. 3.6 CROSS-SECTION OF VR OR ODR IN EMBANKMENT IN RURAL AREA

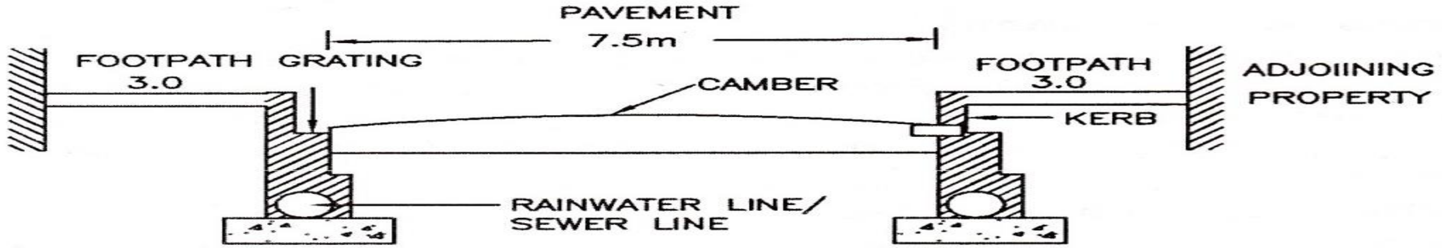

FIG. 3.7 CROSS-SECTION OF TWO-LANE CITY ROAD IN BUILT UP AREA

Curtesy: Justo and Khanna

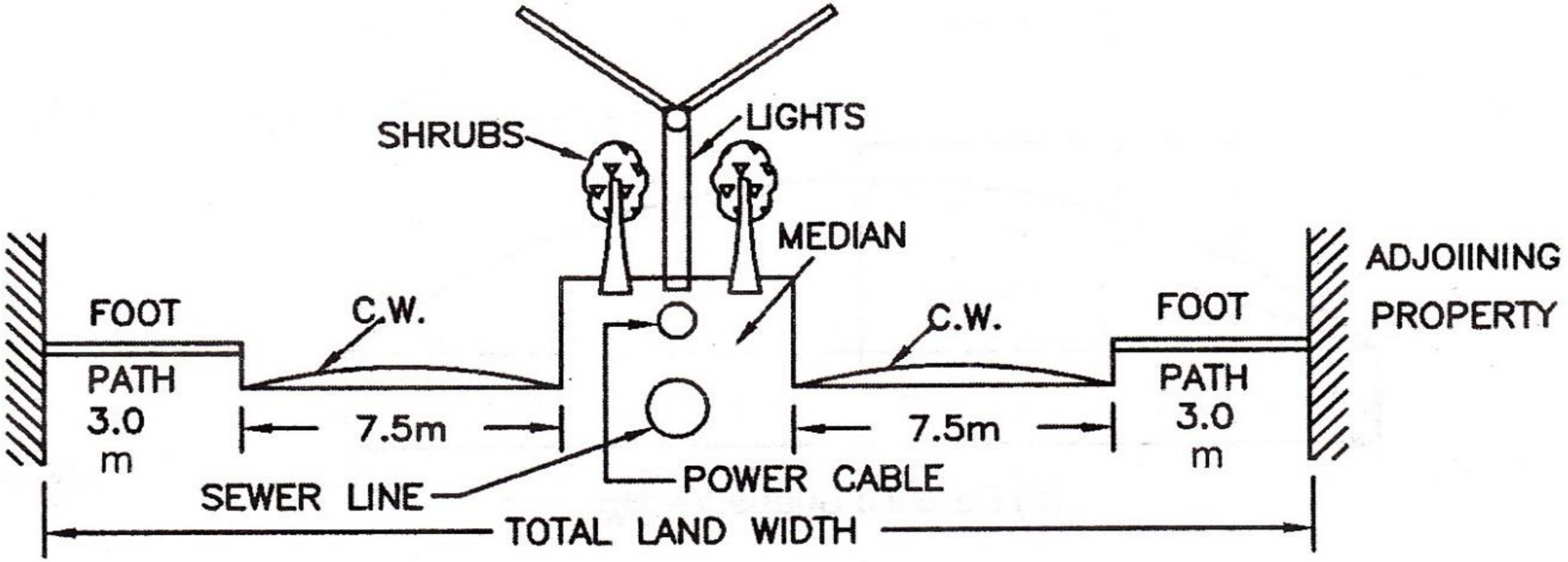

FIG. 3.8 CROSS-SECTION OF DIVIDED HIGHWAY IN URBAN AREA

Curtesy: Justo and Khanna

THANK YOU

FOR

YOUR TIME & ATTENTION