# TRANSPORTATION ENGINEERING BCV403

ATME College of Engineering

# MODULE 1

# **Introduction**

# Principles of Transportation Engineering

# Introduction

- Mobility is a basic human need. From the times immemorial, everyone travels either for food or leisure.
- A closely associated need is the transport of raw materials to a manufacturing unit or finished goods for consumption.
- Transportation fulfils these basic needs of humanity.

Basic Definition: A facility consisting of the means and equipment necessary for the movement of passengers or goods. At its most basic, the term “transportation system” is used to refer to the equipment and logistics of transporting passengers and goods.

Function:

- The purpose of a transportation system is to coordinate the movement of people, goods and vehicles in order to utilize routes most efficiently.
- When implemented, transportation systems seek to reduce transport costs and improve delivery times through effective timetabling and route management.

**Benefits:**

- The main benefit of implementing a transportation system is delivery of goods and personnel to their destinations in a timely manner.
- This in turn increases the efficiency of vehicle use, as the same vehicle can be used for "multi-drop" jobs, such as bus services or home delivery networks

**Size:**

- Transportation systems are developed in a wide variety of sizes.
- Local transport networks spanning the bus network for a city and its suburbs are common, as are wide delivery networks for haulage firms.

## Scope of transportation:

- Transportation is a non-separable part of any society.
- It exhibits a very close relation to the style of life, the range and location of activities and the goods and services which will be available for consumption.

# Different modes of transportation and comparison

- Three basic modes of transport are by land, water and air. Land has given development of road and rail transport. Water and air have developed waterways and airways respectively.
- Apart from these major modes of transportation, other modes include pipelines, elevators, belt conveyors, cable cars, aerial ropeways and monorails. Pipe lines are used for the transportation of water, other fluids and even solid particles.

## Different modes of transportation and comparison

The four major modes of transportation are:

1. Roadways or highways
2. Railways
3. Airways
4. Waterways.

**Airways:**

1. The transportation by air is the fastest among the four modes.

2. Air also provides more comfort apart from saving in transportation time for the passengers and the goods between the airports.

**Waterways:**

1. Transportation by water is the slowest among the four modes.

2. This mode needs minimum energy to haul load through unit distance

3. The transportation by water is possible between the ports on the sea routes or along the rivers or canals where inland transportation facilities are available.

**Railways:**

1. The transportation along the railway track could be advantageous by railways between the stations both for the passengers and goods, particularly for longer distances.

2. The energy requirement to haul unit load through unit distance by the railway is only a fraction (one fourth to one sixth) of the required by road.

3. Hence, full advantage of this mode of transportation should be taken for the transportation of bulk goods along land where the railway facilities are available.

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**Roadways:**

1. The transportation by road is the only mode which could give maximum service to one and all.
2. The road or highways not only include the modern highway system but also the city streets, feeder roads and village roads, catering for a wide-range of road vehicles and the pedestrians.
3. This mode has also maximum flexibility for travel with reference to route, direction, time and speed of travel etc. through any mode of road vehicle.
4. It is possible to provide door to door service by road transport.
5. The other three modes (railways; water ways; airways) has to depend on the roadway for the service.

## IMPLEMENTATIONS:

Majority of the recommendations were accepted by the government implemented by Jayakar Committee.

Some of the technical bodies were formed such as,

1. Central Road Fund (CRF) in 1929
2. Indian Roads Congress (IRC) in 1934
3. Central Road Research Institute (CRRI) in 1950.

## CENTRAL RESEARCH FUND (CRF):

1. Central Research Fund (CRF) was formed on 1st March 1929
2. The consumers of petrol were charged an extra leavy of 2.64 paisa/litre of petrol to buildup this road development fund.
3. From the fund collected 20 percent of the annual revenue is to be retained as meeting expenses on the administration of the road fund, road experiments and research on road and bridge projects of special importance.
4. The balance 80 percent of the fund to be allotted by the Central Government to the various states based on actual petrol consumption or revenue collected
5. The accounts of the CRF are maintained by the Accountant General of Central Revenues.
6. The control of the expenditure is exercised by the Roads Wings of Ministry of Transport.

# INDIAN ROAD CONGRESS (IRC):

1. It is a semi-official technical body formed in 1934.
2. It was formed to recommend standard specifications.
3. It was constituted to provide a forum of regular technical pooling of experience and ideas on all matters affecting the planning, construction and maintenance of roads in India.
4. IRC has played an important role in the formulation of the 20-year road development plans in India.
5. Now, it has become an active body of national importance controlling specifications, guidelines and other special publications on various aspects of Highway Engineering.

# CENTRAL ROAD RESEARCH INSTITUTE (CRRI):

1. CRRI was formed in the year 1950 at New Delhi
2. It was formed for research in various aspect of highway engineering
3. It is one of the National laboratories of the Council of Scientific and Industrial Research.
4. This institute is mainly engaged in applied research and offers technical advice to state governments and the industries on various problems concerning roads.

# Importance of transportation:

1. Availability of raw materials:
2. Availability of goods to the customer:
3. Enhances the Standard of Living:
4. Helps a lot during the emergencies and even during natural disasters:
5. Helps for the employment:
6. Helps in mobility of the labourers:
7. Helps for bringing nations together:

## Importance of transportation:

The importance and adequacy of transportation system of a country indicates its economic and social development.

**Economic Activity**:

1.Production or supply.

2. Consumption for human wants or demand.

# Importance of transportation:

**Social Effects**: The various social effects of transportation may be further classified into:

1. Sectionalism and transportation:

2.Concentration of population into urban area:

3. Aspect of safety, law and order:

# Different modes of transportation and comparison

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- Other modes include pipelines, elevators, belt conveyors, cable cars, aerial ropeways and monorails. Pipe lines are used for the transportation of water, other fluids and even solid particles.

# Different modes of transportation and comparison

The four major modes of transportation are:

1. Roadways or highways
2. Railways
3. Airways
4. Waterways.

| Mode | Product Options | Speed | Accessibility | Cost | Capacity | Intermodal Capability |
|---|---|---|---|---|---|---|
| **Road** | Very Broad | Moderate | High | Moderate | Low | Very High |
| **Railroad** | Broad | Slow | Moderate | Low | Moderate | Very High |
| **Air** | Narrow | Fast | Low | Very High | Very Low | Moderate |
| **Water** | Broad | Very Slow | Moderate | Very Low | Very High | Very High |
| **Pipeline** | Very Narrow | Very Slow | Low | Low | Very High | Very Low |
| **Digital** | Very Narrow | Very Fast | Very High | Very Low | Moderate | Very Low |

# Characteristics of Road Transport

*Roads are used various types of road vehicles.

*Road transport requires a relatively small investment for the government.

*Road transport completely offer a freedom to road users.

*In particular for short distance travel, road transport saves time.

# Characteristics of Road Transport

*Speed of movement is directly related with severity of accident.

*Road transport is the only means of transport offer itself to the whole community.

*The Major defect of road is Traffic.

Traffic:

# Jayakar committee recommendations

- Construction of Highways
- Fuel Tax
- Research lab

## Jayakar committee recommendations

## Implementations:

Majority of the recommendations were accepted by the government implemented by Jayakar Committee.

1. Central Road Fund (CRF) in 1929
2. Indian Roads Congress (IRC) in 1934
3. Central Road Research Institute (CRRI) in 1950.

# Highway Development and Planning:

## Meaning of Highway and Road:

- Road
- Highway
- Traffic
- Footway
- Cycle track
- Motor way

# Classification of Roads:

## Types of roads:

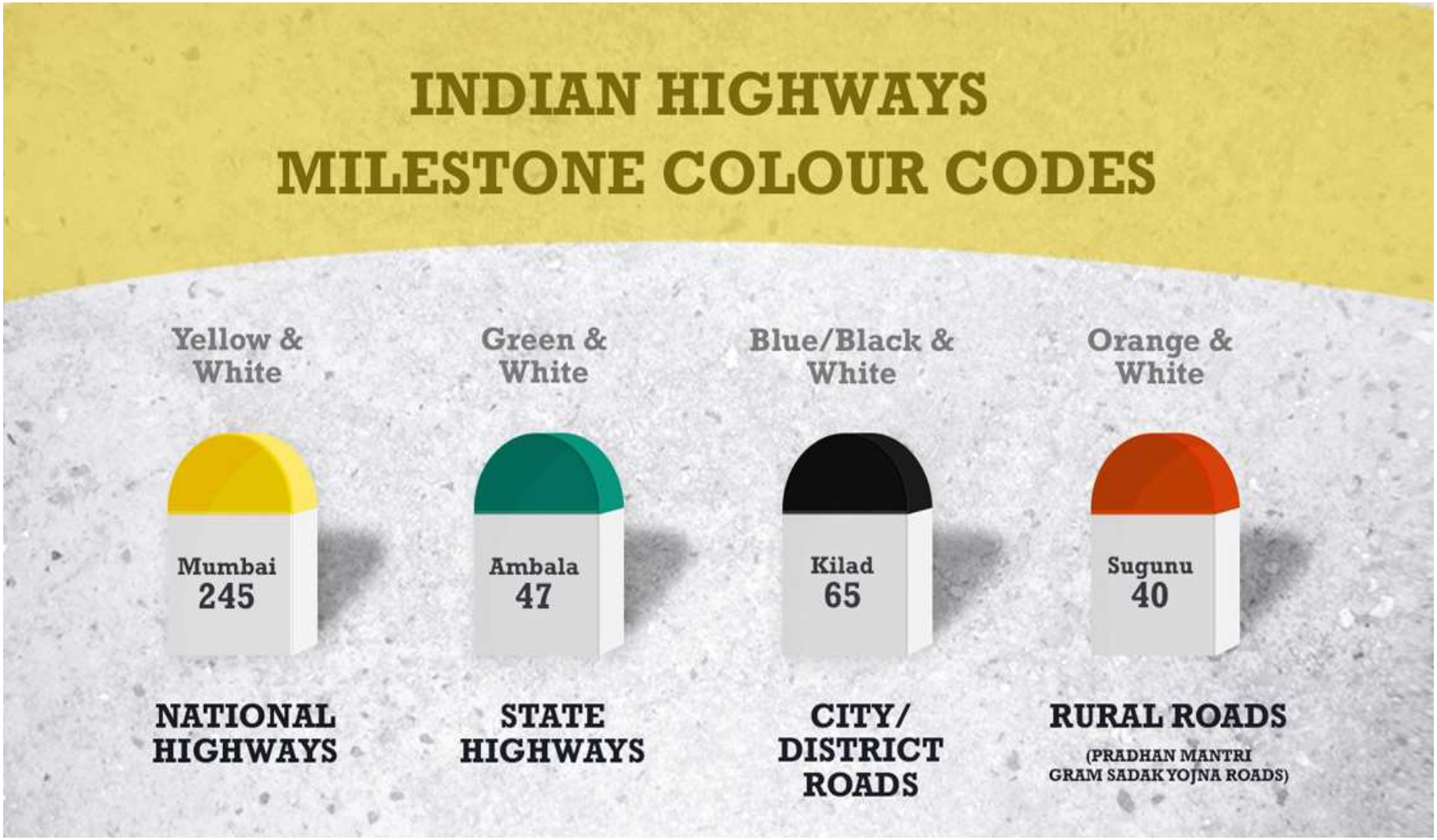
1. Classification based on weather:

- All weather roads:
- Fair-weather roads:

## Classification of Roads by Nagpur Road plan:

The Nagpur Road Plan classified the roads in India based on location and function into five categories.

- National Highways (NH)
- State Highways (SH)
- Major District Roads (MDR)
- Other District Roads (ODR)
- Village Roads (VR)


INDIAN HIGHWAYS
MILESTONE COLOUR CODES
Yellow & White
Mumbai
245
NATIONAL HIGHWAYS
Green & White
Ambala
47
STATE HIGHWAYS
Blue/Black & White
Kilad
65
CITY/ DISTRICT ROADS
Orange & White
Sugunu
40
RURAL ROADS
(PRADHAN MANTRI GRAM SADAK YOJNA ROADS)

## Modified classification of Road system by Lucknow plan:

Primary system consists of two categories:
- Expressways
- National Highways (NH)

Secondary system consists of two categories:
- State Highways (SH)
- Major District Roads (MDR)

Tertiary system consists of two categories:
- Other District Roads (ODR)
- Village Roads (VR)

# Classification of Urban Roads:

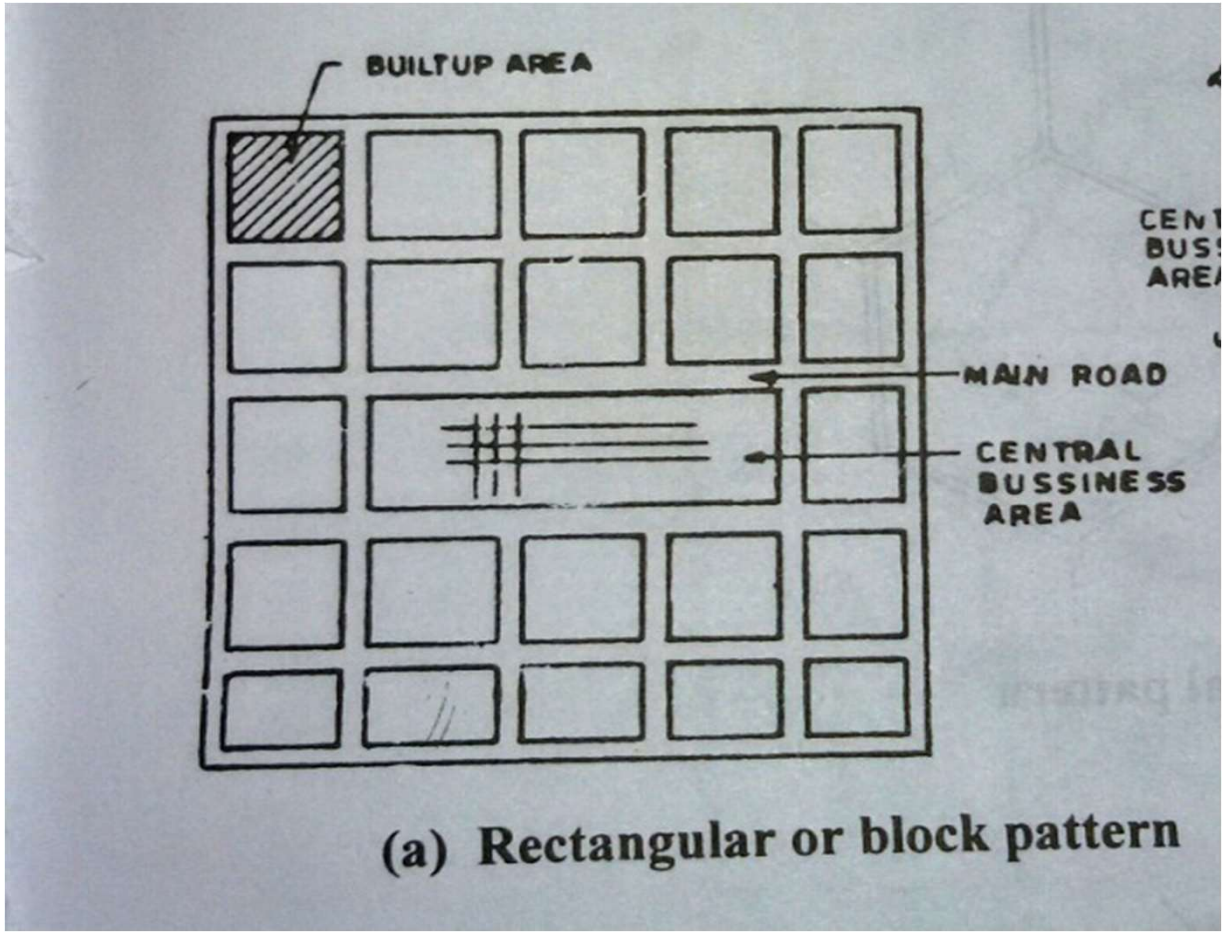
- Arterial roads
- Sub-arterial roads
- Collector streets
- Local streets

# Road patterns:

## 1. Rectangular or Block pattern:

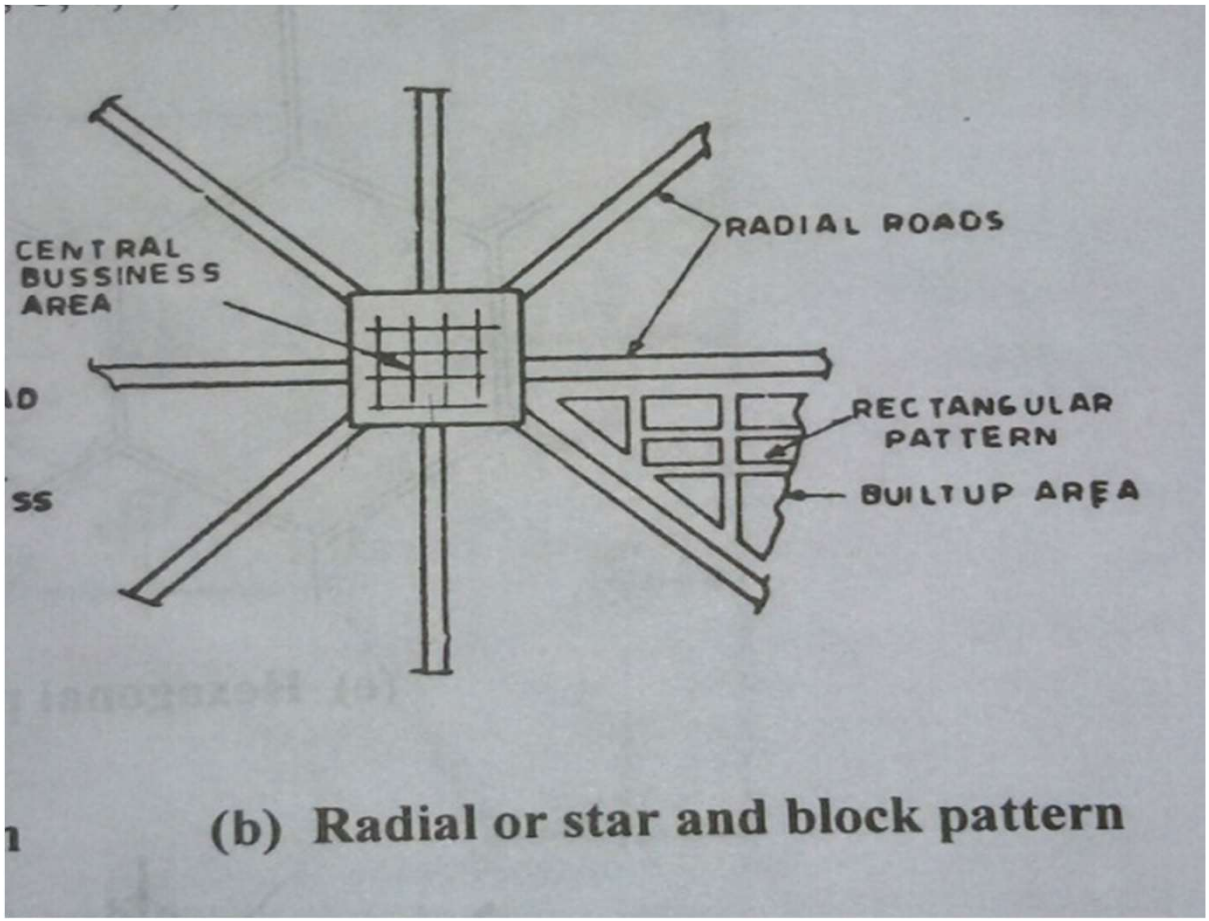
**Example:** Chandigarh has rectangular pattern.

# Rectangular or Block pattern:



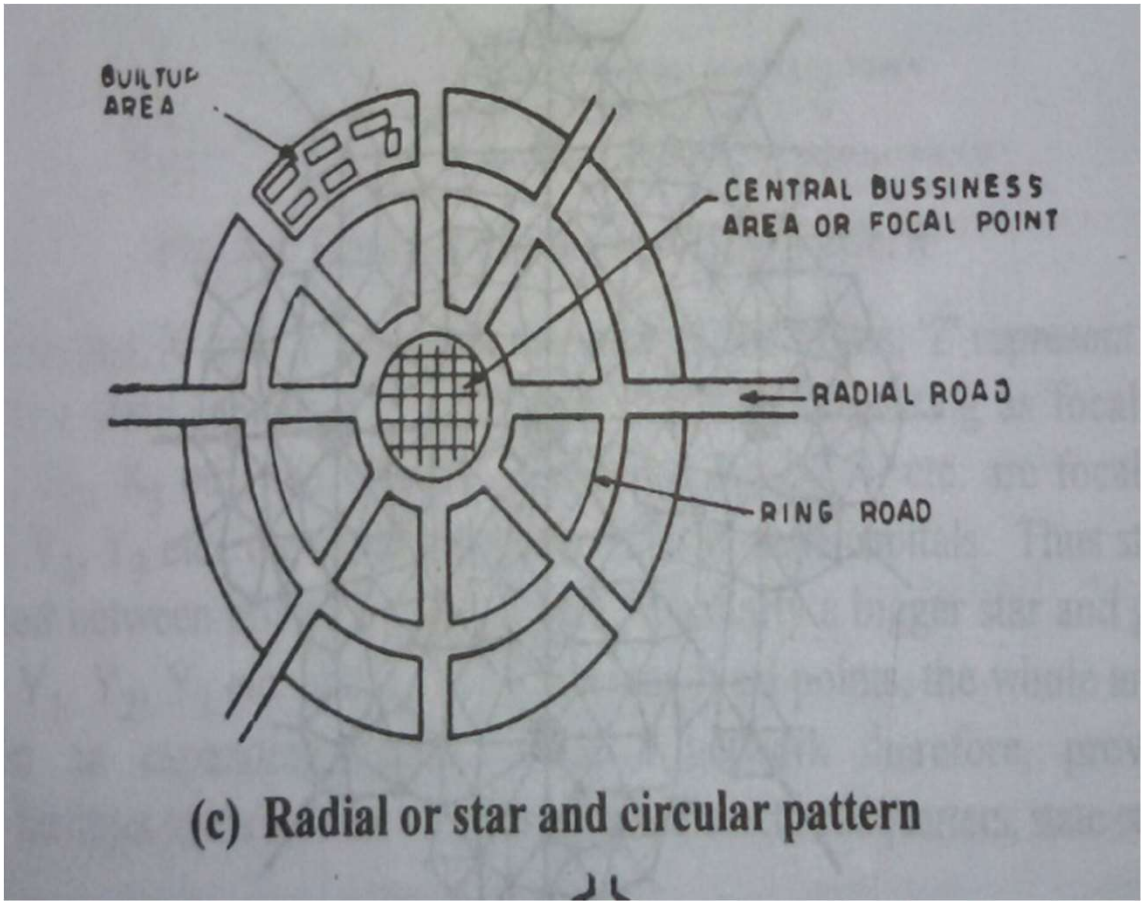

(a) Rectangular or block pattern

# Radial or Star and block Pattern:




(b) Radial or star and block pattern

# Radial or Star and Circular Pattern:

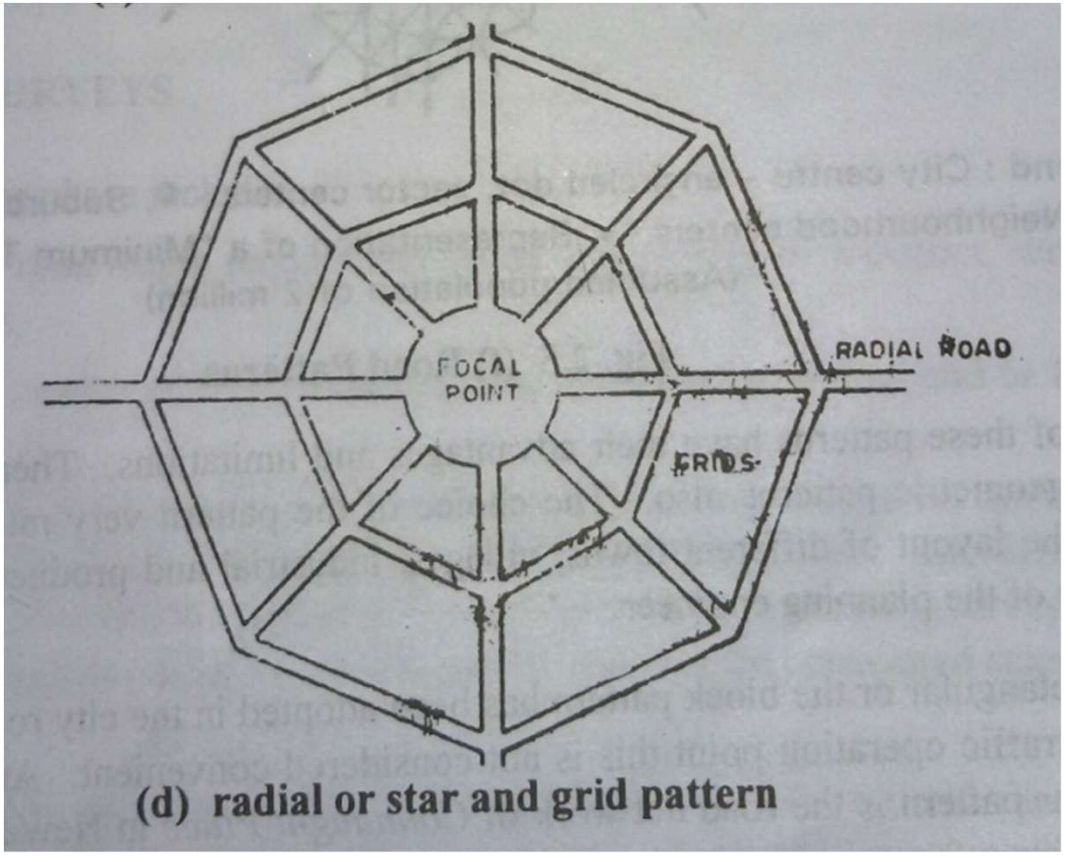



(c) Radial or star and circular pattern

## 4. Radial or Star and Grid Pattern:

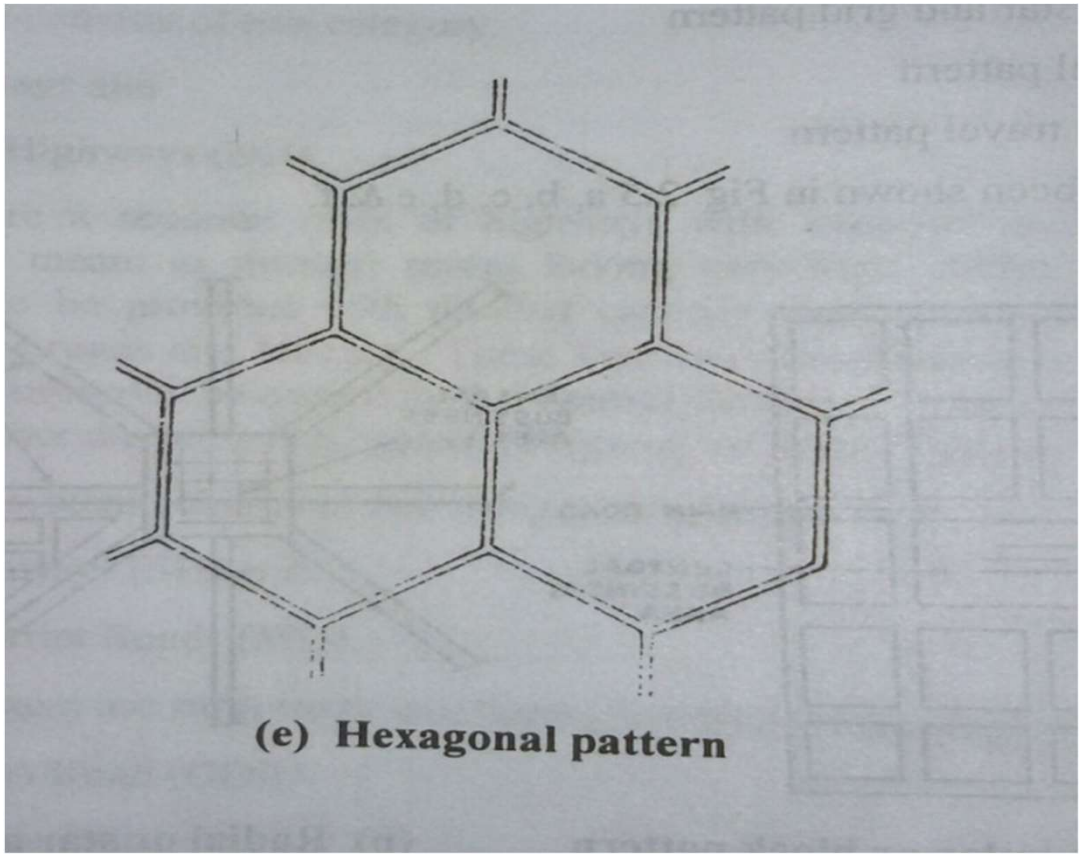
**Examples:** The Nagpur road plan formulae were prepared on the assumption of Grid pattern.

# Radial or Star and Grid Pattern:

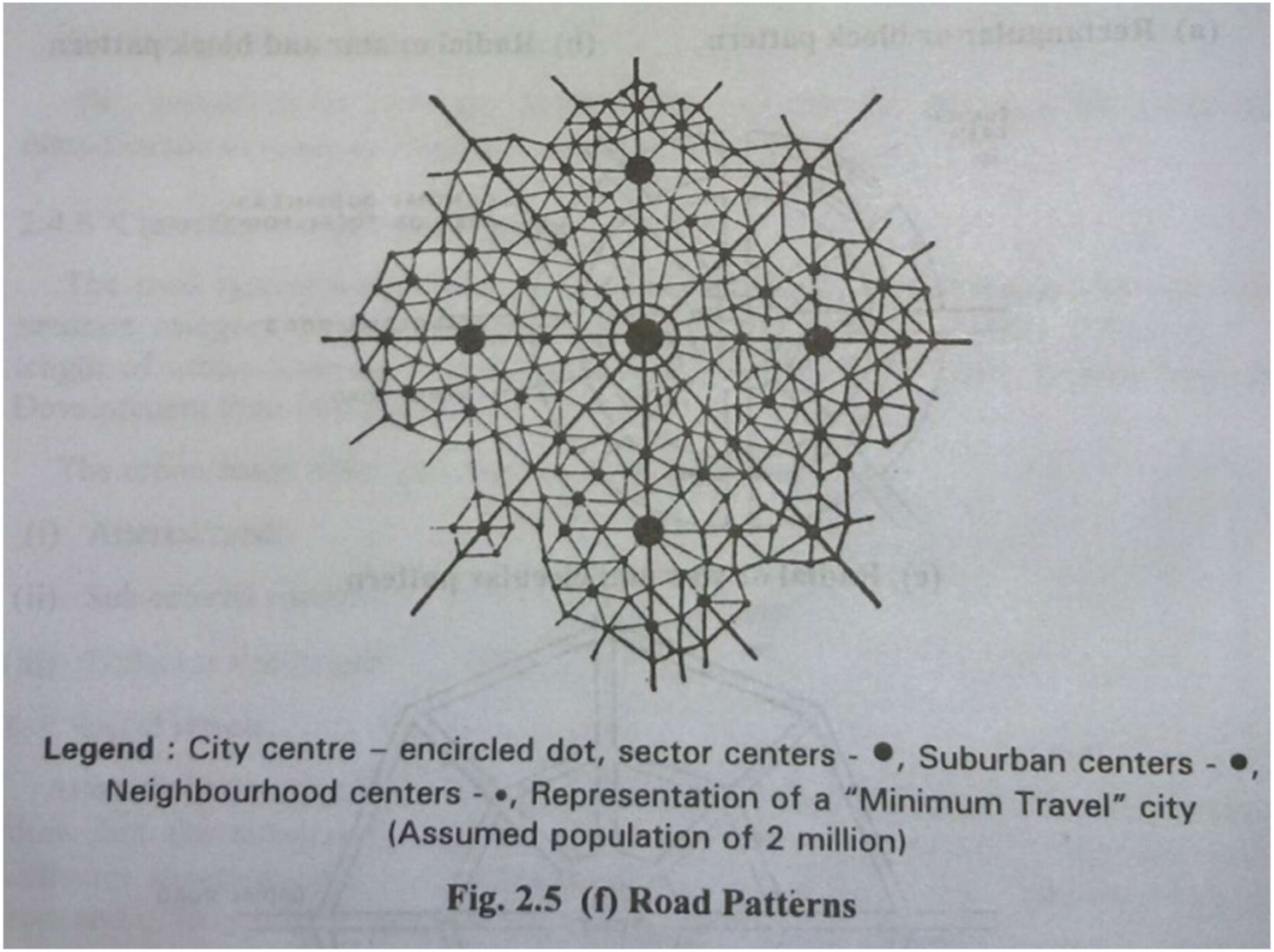



(d) radial or star and grid pattern

# Hexagonal Pattern:



# Minimum Travel Pattern:



**Legend** : City centre – encircled dot, sector centers - ●, Suburban centers - ●, Neighbourhood centers - •, Representation of a "Minimum Travel" city (Assumed population of 2 million)

**Fig. 2.5 (f) Road Patterns**

# Road patterns:

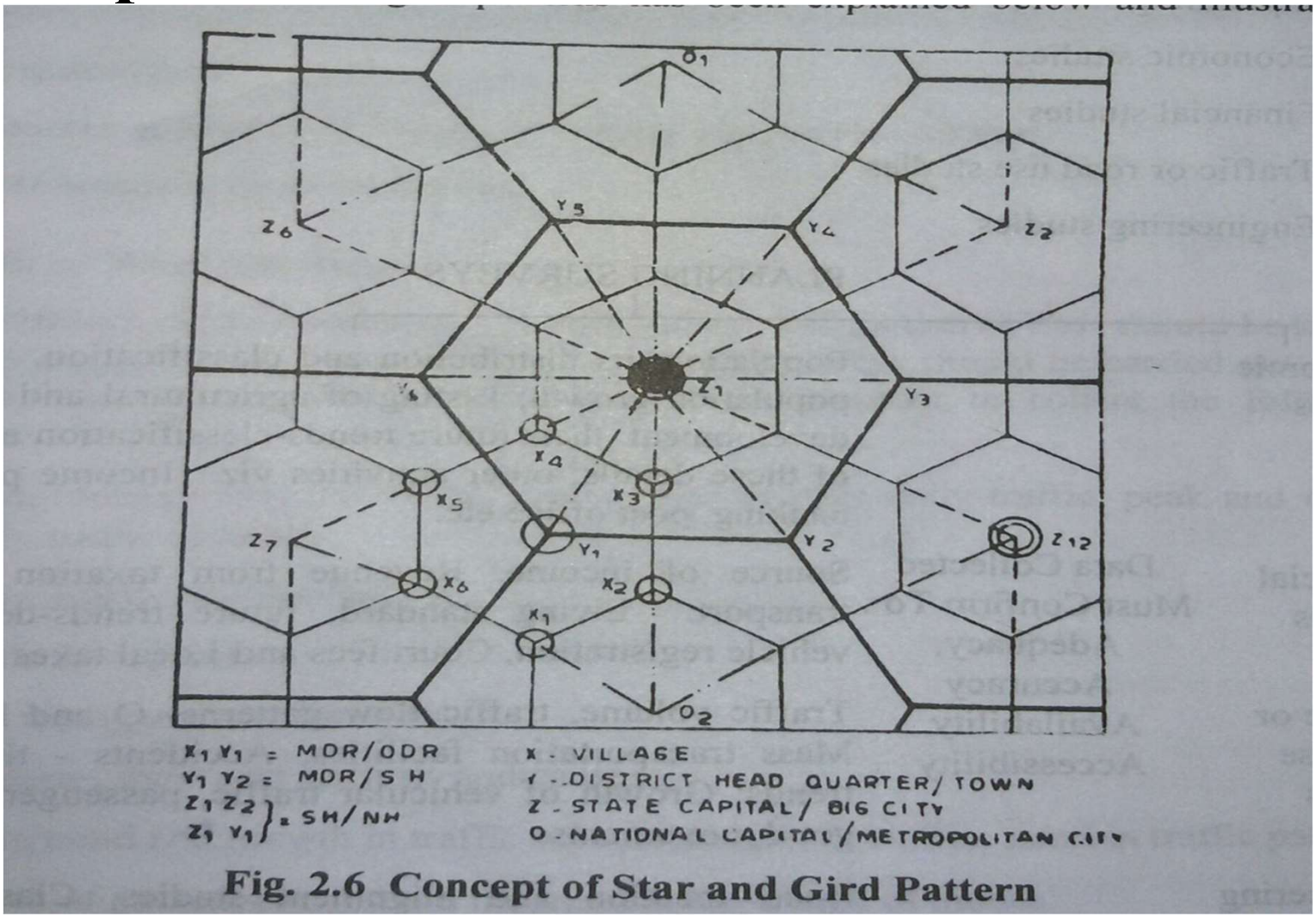



Fig. 2.6 Concept of Star and Gird Pattern

## Planning Surveys

The field surveys thus required for collecting the factual data may be called as planning survey or fact finding surveys:

Highway planning phase includes

- Assessment of road length requirement for an area
- Preparation of Master plan showing the phasing of plan in annual and or five year plans.

## Planning Surveys

The planning surveys consists of the following studies

- Economic Studies
- Financial studies
- Traffic or road use studies
- Engineering studies.

# Master plan

Master plan is referred to as road development plan of a city; district or a street or for whole country.

It is an ideal plan showing full development of the area at some future date.

It serves as the guide for the plan to improve some of the existing roads and to plan the network of new roads.

## Stages in the preparation of master plan

1. Data Collection:
2. Preparation of draft plan
3. Revision of draft plan
4. Comparison of various alternate proposals

## Saturation system

It is one of the methods to determine the best alternative based on maximum utility of road network.

- Population served by the road network
- Productivity served by the network

a. Agricultural products

b. Industrial products

**Saturation system**

Since the area under consideration may consist of villages and towns with different populations, it grouped into some ranges and assigned utility units.

Population less than 500, utility unit = 0.25

501-1000, utility unit = 0.50

1001- 2000, utility unit = 1.00

2001 – 5000, utility unit = 2.00 etc..

Similarly the agriculture products for tonnes productivity, utility units = 1

Industrial products for tonnes productivity, utility units =10 etc.

## Example 2.1

An imaginary area with existing roads is shown in Fig. 2.4. There are four alternate plan proposals P, Q, R and S with different road length by adding extra road links to the existing roads in the area and the details of the population and products served are given below:

| Proposal | Total road length, km | Number of towns and villages served with population range | | | | Total agriculture & industrial products served, thousand |
|---|---|---|---|---|---|---|
| | | 1001 – 2000 | 2001 – 5000 | 5001 – 10000 | > 10000 | |
| P | 300 | 160 | 80 | 30 | 6 | 200 |
| Q | 400 | 200 | 90 | 60 | 8 | 270 |
| R | 500 | 240 | 110 | 70 | 10 | 315 |
| S | 550 | 248 | 112 | 73 | 12 | 335 |

Work out the utility per unit length of each system and indicate which system is considered to be optimum with maximum utility per unit length. Assume utility units of 0.25, 0.5, 1.0 and 2.5 respectively for villages served with population ranges (1001 – 2000), (2001 – 5000), (5001 – 10,000) and higher than 10,001.

**Solution**

| Road plan proposal | Road length, km | No. of towns & villages served with population served in thousand | | | | Total units | | Utility per unit length | Priority based on utility |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 – 2 | 2 – 5 | 5 – 10 | > 10 | Population | Productivity | | |
| P | 300 | 160 × 0.25 | 80 × 0.5 | 30 × 1 | 6 × 2.5 | 125 | 200 | 325/300 = 1.083 | II |
| Q | 400 | 200 × 0.25 | 90 × 0.5 | 60 × 1 | 8 × 2.5 | 175 | 270 | 445/400 = 1.112 | I |
| R | 500 | 240 × 0.25 | 110 ×0.5 | 70 × 1 | 10 × 2.5 | 210 | 315 | 525/500 = 1.050 | III |
| S | 550 | 248 × 0.25 | 112 ×0.5 | 73 × 1 | 12 × 2.5 | 221 | 335 | 556/550 = 1.010 | IV |

From the above table it is seen that the plan proposal Q with total road length of 400 km has maximum utility per unit length of road = 1.112 (based on population and productivity). Therefore the optimum road length in this area is 400 km.

Three new roads A, B and C are to be completed in a district during a five year plan period. Using the data given below work out the order of priority for phasing the plan programme by the principle of maximum utility per unit length. Adopt utility unit of 1.0 for serving a village with population range 2000 to 5000, or for catering for 1000 t of agricultural products or 100 t of industrial products. Assume other data suitably.

| Road | Length km | No. of villages served population | | | Productivity, 1000 tonnes | |
|---|---|---|---|---|---|---|
| | | < 2000 | 2000 – 5000 | > 5000 | Agricultural | Industrial |
| A | 15 | 10 | 8 | 3 | 15 | 1.2 |
| B | 12 | 16 | 3 | 1 | 11 | 0.0 |
| C | 18 | 20 | 10 | 2 | 20 | 0.8 |

## Solution

The following utility units are assumed:

0.5, 1.0 and 2.0 units for villages served with population < 2000, 2000 – 5000 and > 5000 respectively. 1.0 unit for 1,000 t of agricultural products and 10 units for 1000 of industrial products served.

| Road | Length, km | Total utility units served by the road | Utility per unit length | Priority |
|---|---|---|---|---|
| A | 15 | $10 \times 0.5 + 8 \times 1 + 3 \times 2 + 15 \times 1 + 1.2 \times 10 = 46$ | 46/15 = 3.07 | I |
| B | 12 | $16 \times 0.5 + 3 \times 1 + 1 \times 2 + 11 \times 1 + 0 = 24$ | 24/12 = 2.0 | III |
| C | 18 | $20 \times 0.5 + 10 \times 1 + 2 \times 2 + 20 \times 1 + 0.8 \times 10 = 52$ | 52/18 = 2.89 | II |

Therefore order of priority is A, C and B.

## Salient Features of 3rd 20-year road development plan – 1981-2001 (Lucknow Plan)

It was finalized and the plan document was published by the year 1984. The major objectives are:

- The future road development should be based on the revised classification of road system consisting of Primary, Secondary and Tertiary road system.
- The road network should be developed so as to preserve the rural oriented economy and to develop small towns with all the essential facilities.
- All the villages with population of 500 should be connected by all weather roads.

- The NH network should be expanded to form square grids of 100 km sides so that no part of the country is more than 50 km away from NH.
- Expressway should be constructed along major traffic corridors to provide fast travel.
- Roads should also be built in less industrialized areas attract the growth of industries.

- Long term master plans for road development should be prepared at various levels.
- All towns and villages with population over 1500 should be connected by Major district Roads and villages with population 1000 to 1500 by ODR.
- There should be improvements in environmental quality and road safety.

**Formulae**

- Length of NH (km) = area of the region/ 50
- Length of SH (km)

By area, SH (km) = area of the region/ 25

Based on no. of towns, SH (km) = 62.5 x no. of towns – NH

Adopt length of SH (higher of the two criteria)

Length of MDR, in the District

- Based on area, MDR (km) = area of the region/12.5
- Based on number of towns, MDR(km) = 90 x number of towns
- Provide length of MDR (higher of the two criteria)

## Formulae

- Total length of all categories of roads may be assumed to provide an overall density of road length equal to 82km per 100 sq.km area by the year 2001.
- NH + SH + MDR + ODR + VR (km) = area of the region x (82/100)

Therefore length of ODR + VR (km) = Total Length – (NH + SH + MDR)

## Salient features of vision 2021

The Road Development Plan Vision:

This Vision addressed concerns such as the need for mobilization of financial resources including augmentation of road fund, toll financing, private sector participation, capacity augmentation of main highways, strengthening of pavement to cope with movement of heavy commercial vehicles, undertaking massive programme of construction of village roads and preservation of existing road assets.

Aspects such as road safety, social and environment concerns and energy efficiency have also been highlighted.

## Salient features of vision 2021

The vision document laid down targets for main roads but did not specify the length of the rural road network. Instead, stress was laid on preparation of proper district level master plans to optimize the network.

Target Roads Lengths by the year 2021:

Expressways 10,000 km

National Highways 80,000 km

State Highways 160,000 km

Major District Roads 320,000 km

# Present scenario of various road development projects in India

## Pradhan Mantri Gram Sadak Yojana (PMGSY)

The Government of India launched in December 2000, objective of connecting all unconnected habitations having a population of 500 and above with all-weather roads.

The population threshold is relaxed to 250 in case of hill, tribal and desert areas. In departure from the earlier programmes of rural road development, the PMGSY is a hundred percent funded programme of the central government.

The **Ministry of Rural Development (MoRD)** has been entrusted with the task of implementing this programme. The **National Rural Development Agency (NRRDA)** – an arm of the Ministry provides management and technical support to this programme.

It is estimated that about 1.79 lakh unconnected habitations need to be taken up under the PMGSY programme. This would involve new construction in a length of about 375,000 km at an estimated cost of Rs. 78,000 crore and improvements of 372,000 km at an estimated cost of Rs. 59,000 crore.

Up to the end of December, 2006, a total of about 83,000 habitations have been covered and rural road works for an amount of Rs.38,387 crore have been sanctioned.

**NHAI:**

"The **National Highways Authority of India** was constituted by an act of Parliament, the National Highways Authority of India Act, 1988.

It is responsible for the development, maintenance and management of National Highways entrusted to it and for matters connected or incidental thereto.

The Authority was operationalized in February, 1995 with the appointment of full time Chairman and other Members. “

**NHAI:**

National Highways Authority of India (NHAI) is mandated to implement **National Highways Development Project (NHDP)** which is

1. India's Largest ever highways project
2. World class roads with uninterrupted traffic flow

## National Highways Development Project (NHDP)

NHDP Phase I : NHDP Phase I was approved by Cabinet Committee on Economic Affairs (CCEA) in December 2000 at an estimated cost of Rs.30,000 crore comprises mostly of GQ (5,846 km) and NS-EW Corridor (981km), port connectivity (356 km) and others (315 km).

# National Highways Development Project (NHDP)

NHDP Phase II : NHDP Phase II was approved by CCEA in December 2003 at an estimated cost of Rs.34,339 crore (2002 prices) comprises mostly NS-EW Corridor (6,161 km) and other National Highways of 486 km length, the total length being 6,647 km. The total length of Phase II is 6,647 km.

## National Highways Development Project (NHDP)

NHDP Phase-III: Government approved on 5.3.2005 up gradation and 4 laning of 4,035 km of National Highways on BOT basis at an estimated cost of Rs. 22,207 crores (2004 prices). Government approved in April 2007 up gradation and 4 laning at 8074 km at an estimated cost of Rs. 54,339 crore.

## National Highways Development Project (NHDP)

NHDP Phase IV: CCEA has approved on 5.10.2006 six laning of 6,500 km of existing 4 lane highways under NHDP Phase V (on DBFO basis). Six laning of 6,500 km includes 5,700 km of GQ and other stretches.

## National Highways Development Project (NHDP)

NHDP Phase V: CCEA has approved on November 2006 for 1000 km of expressways at an estimated cost of Rs. 16680 crs .

NHDP Phase VI: CCEA has approved on December 2007 for 700 km of Ring Roads, Bypasses and flyovers and selected stretches at an estimated cost of Rs. 16680 crores

**Karnataka State Highways Improvement Project (KSHIP)**:

The Public Works Department carried out Strategic Option Study (SOS) during 1996 on a road network of 13,362 kms comprising SH and MDR and the study identified 2888 kms of roads for prioritized improvements.

## Karnataka Road Development Corporation Limited (KRDCL)

It was incorporated on 21st of July 1999 as a wholly owned Government of Karnataka Company as per the Provisions of the Company's Act, 1956.

KRDCL is a company under the Public Works, Ports & Inland Water Transport Department.

## Karnataka Road Development Corporation Limited (KRDCL)

This Company was established to promote surface infrastructure by taking up Road Works, Bridges etc., and to improve road network by taking up construction widening and strengthening of roads, construction of bridges, maintenance of roads etc., and to take up projects on

BOT (build, own, transfer)

BOOT(build, own, operate and transfer)

BOLT(build, own, lease, transfer)

ATME College of Engineering

# Module – 2
# Highway Alignment and Surveys

# Introduction

The position or the layout of the centre line of the highway on the ground is called the alignment.

It includes,

Horizontal alignment: Horizontal alignment includes straight and curved paths.

Vertical alignment: Vertical alignment includes level and gradients.

# Ideal alignment

An ideal alignment between two stations should offer maximum utility by serving maximum population and products and also should possess following requirements:

**Short:**

**Easy:**

**Safe:**

**Economical:**

## Factors affecting alignment

The various factors which control the highway alignment are:

- Obligatory points
  - ✓Points through which the alignment is to pass:
    - ❑Alignment along hill side pass
    - ❑Alignment to suit proper bridge location
    - ❑Alignment to connect intermediate area
    - ❑Alignment avoiding intermediate area
  - ✓Points through which the alignment should not pass:

# Factors affecting alignment

- Traffic
- Geometric design
- Economics
- Other considerations

# Engineering surveys

The stages of engineering surveys for Highway locations:

- Map study
- Reconnaissance
- Preliminary surveys
- Final location and detailed surveys

## Drawings and Reports

The following drawings are usually prepared in a highway projects

- Key map:
- Index Map :
- Preliminary survey plans :
- Detailed plan :
- longitudinal section:
- Detailed cross section:
- Land acquisition plans:
- Drawing of cross drainage and other retaining structures:
- Drawings of road intersections:

## Project Report:

The project report forms an important part of the project document. It should contain information such as

- General details of the project and its importance
- Feature of the road including selection of the route, alignment, traffic etc.
- Road design and specifications
- Drainage facilities and cross drainage structures
- Materials, labours and equipments
- Rates
- Construction programming
- Other miscellaneous items like diversion of traffic, road side amenities, rest houses etc.

## Steps in new highway project

- Map Study:
- Reconnaissance survey:
- Preliminary survey
- Location of final alignment
- Detailed survey
- Material survey
- Design
- Earthwork
- Pavement construction:
- Construction control:

**Necessity of Re-Alignment:**

- Improvement of horizontal alignment design elements
- Improvement of vertical alignment design elements
- Raising the level of a portion of a road
- Re-construction of weak and narrow bridges and culverts
- Construction of over bridges or under bridges
- Re-alignment required due to a portion of road being submerged under water
- Construction of a bypass
- Defence requirement.

## Steps in Re Alignment

- Reconnaissance of the stretch of road to be re-aligned
- Survey of existing road recording the topographic features
- Observation of spot level along the centre line of the road and cross section levels at suitable intervals.
- Soil survey
- Comparison of economics and feasibility of alternate proposal of realignment.

# Steps in Re Alignment

- Finalization of the design features and realigned road stretch
- Preparation of drawings.
- Marking out centre line
- Earthwork and preparation of sub grade
- Checking of geometric design elements
- Design and construction of new pavement

**Cross-section elements:** It includes cross slope, various widths of road (i.e., width of pavement, formation width and road land width), surface characteristics and features in the road margins.

**Design Control and Criteria:**

Factors affecting geometric design are as follows

- Design speed:
- Topography:
- Traffic factors:
- Design Hourly Volume and Capacity:
- Environmental and other factors:

# Highway cross section elements:

## Unevenness:

# Highway cross section elements:

## Unevenness:

## Friction:

## Factors affecting friction or skid resistance:

- Types of surface
- Condition of pavement
- Type and condition of tyre
- Speed of vehicle.
- Extent of brake application or brake efficiency.
- Load and tyre pressure.
- Temperature of tyre and pavements.

## Right of way:

Right of way (ROW) or land width is the width of land acquired for the road, along its alignment.

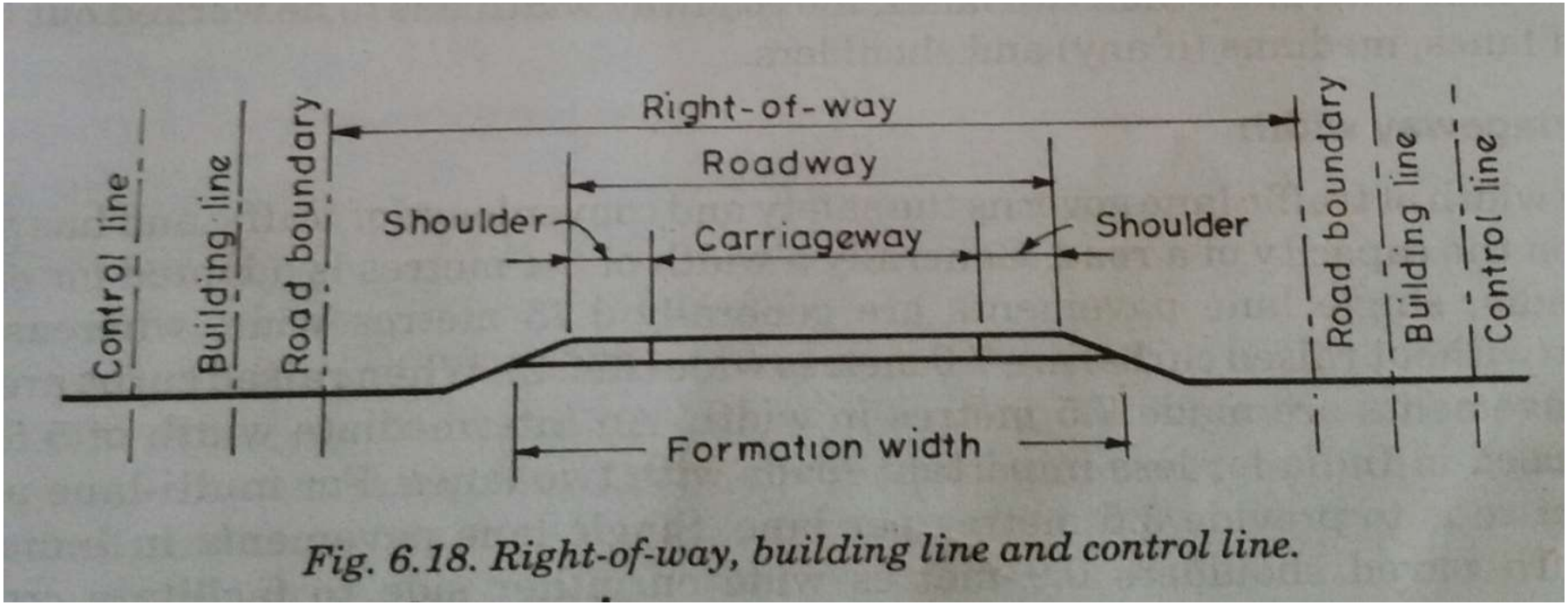
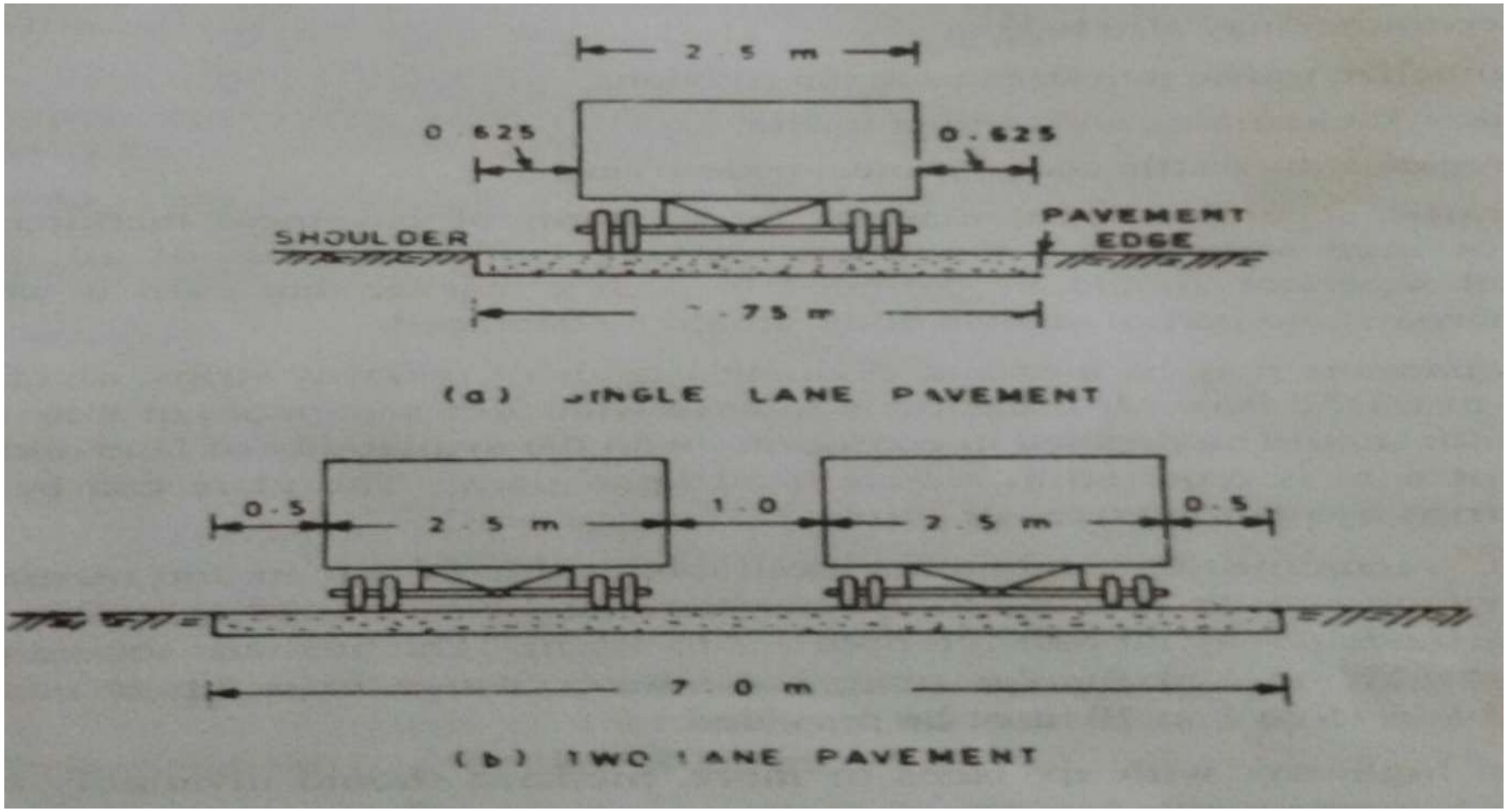



*Fig. 6.18. Right-of-way, building line and control line.*

| Sl no. | Road classification | Plain and rolling terrain | | | | Mountainous and steep terrain | |
|---|---|---|---|---|---|---|---|
| | | Open area | | Built-up area | | Open area | Built-up area |
| | | Normal | Range | Normal | Range | Normal | Normal |
| 1 | NH & SH | 45 | 30-60 | 30 | 30-60 | 24 | 20 |
| 2 | MDR | 25 | 25-30 | 20 | 15-25 | 18 | 15 |
| 3 | ODR | 15 | 15-25 | 15 | 15-20 | 15 | 12 |
| 4 | VR | 12 | 12-18 | 10 | 10-15 | 9 | 9 |

# Width of carriageway or pavement:



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

# Typical cross-sections:

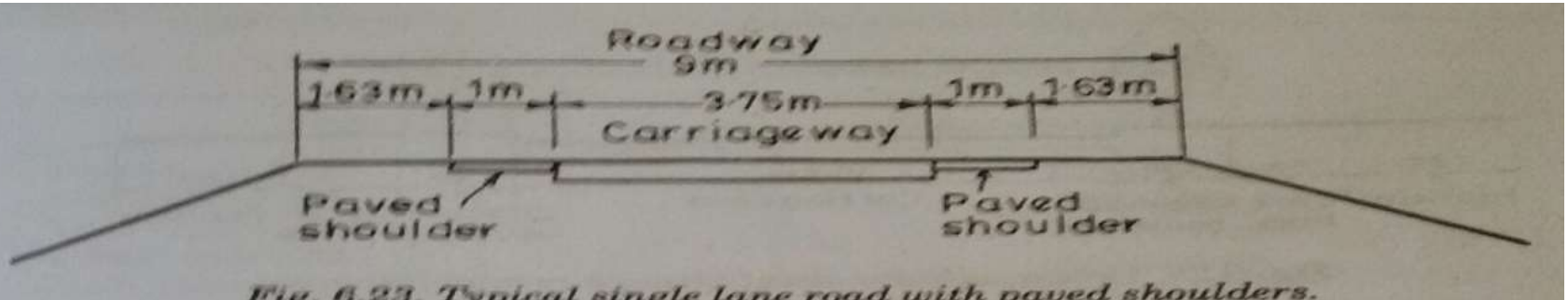



*Fig. 6.23. Typical single lane road with paved shoulders. (Major District Road or Other Dist. Road)*

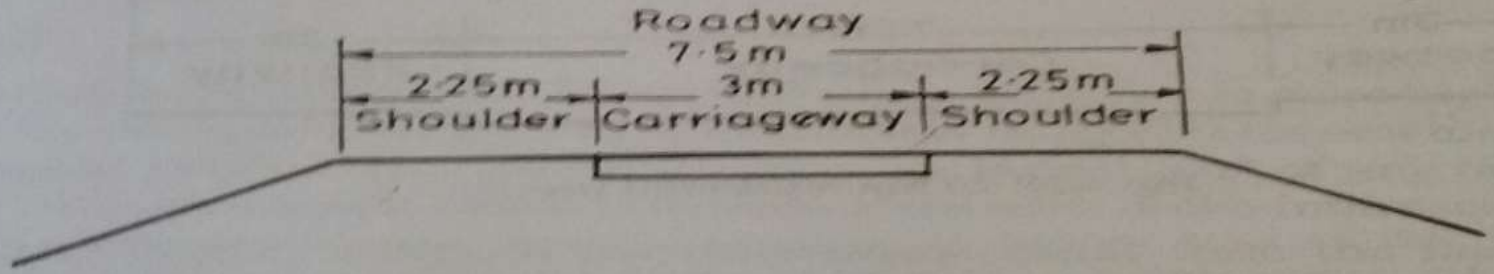



*Fig. 6.24. Typical village road.*

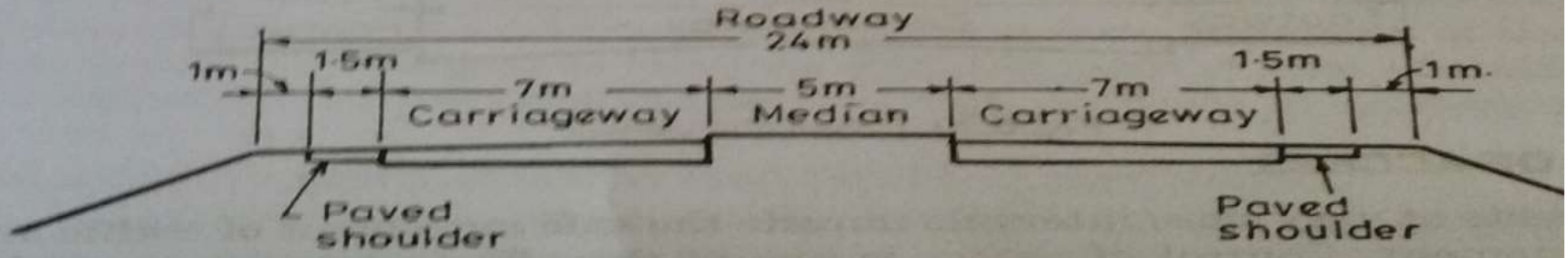



*Fig. 6.25. Typical dual carriageway (2 lane each) in rural areas.*

# Typical cross-sections:

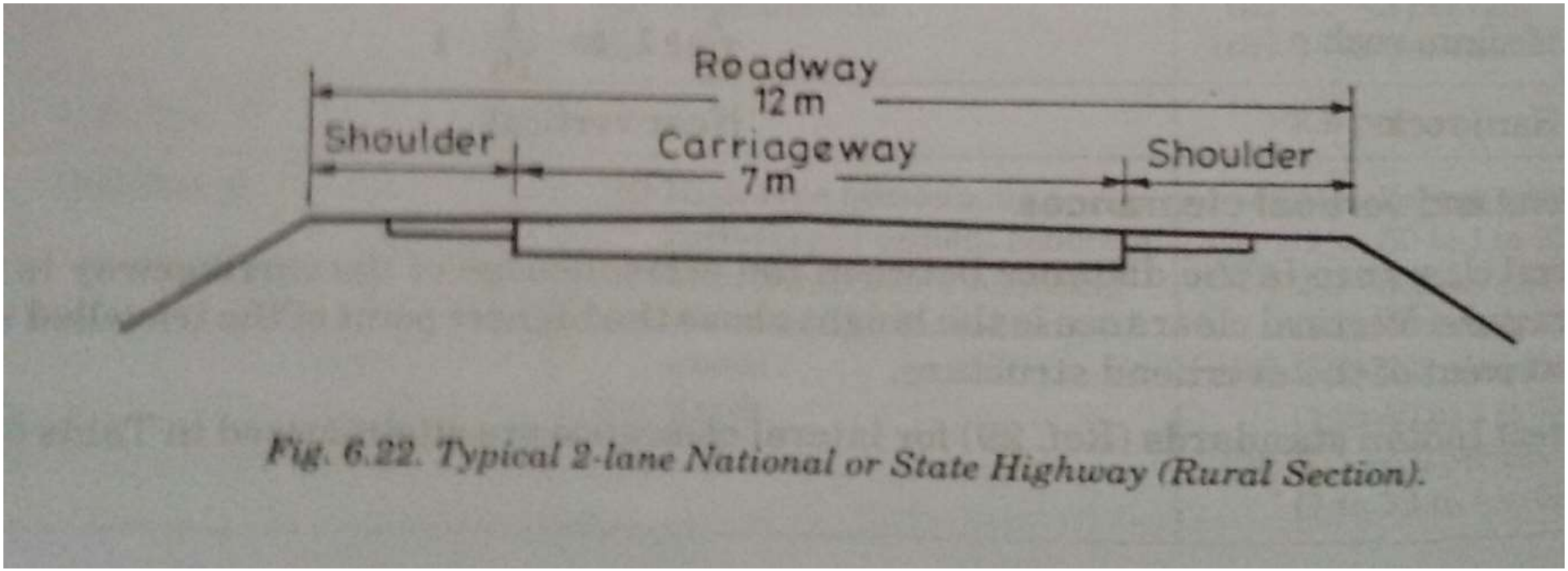



*Fig. 6.22. Typical 2-lane National or State Highway (Rural Section).*

# Typical cross-sections:

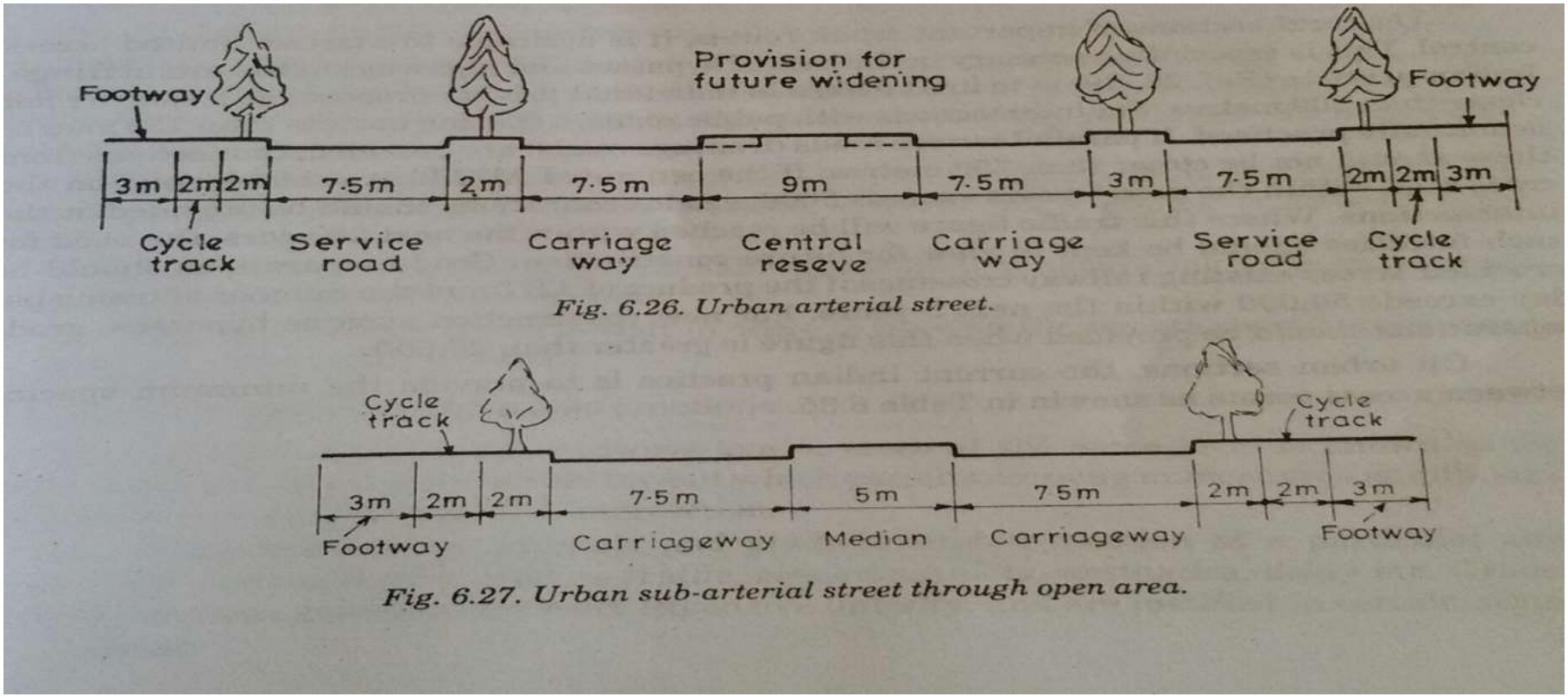



*Fig. 6.26. Urban arterial street.*




*Fig. 6.27. Urban sub-arterial street through open area.*

# Camber or cross slope or Cant:

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.

**Objectives:**

- Surface protection especially for gravel and bituminous roads
- Sub-grade protection by proper drainage
- Quick drying of pavement which in turn increases safety

| Sl no | Types of road surface | Range of camber in areas of | |
|---|---|---|---|
| | | Heavy rainfall | Low rainfall |
| 1 | CC and high type bituminous surface | 1 in 50 or 2.0% | 1 in 60 or 1.7% |
| 2 | Thin bituminous surface | 1 in 40 or 2.5% | 1 in 50 or 2.0% |
| 3 | WBM and gravel pavement | 1 in 33 or 3.0% | 1 in 40 or 2.5% |
| 4 | Earth road | 1 in 25 or 4.0% | 1 in 33 or 3.0% |

## Width of roadway or formation:

Width of roadway or formation is the sum of widths of pavement or carriageway including separators and the shoulders.

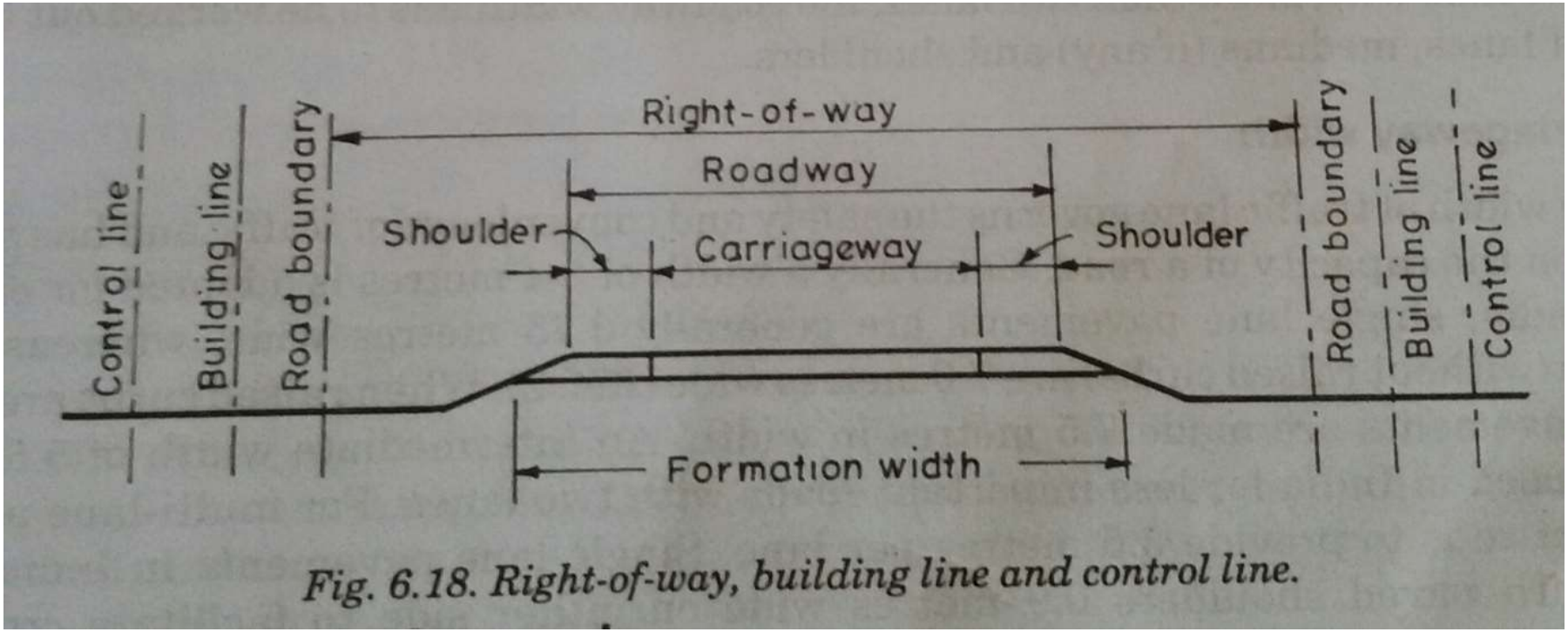



*Fig. 6.18. Right-of-way, building line and control line.*

| Sl no. | Road classification | Road way width, m | |
|---|---|---|---|
| | | Plain & Rolling terrain | Mountainous & steep terrain |
| 1 | **NH & SH** | | |
| | Single lane | 12.0 | 6.25 |
| | Double lane | 12.0 | 8.80 |
| 2 | **MDR** | | |
| | Single lane | 9.0 | 4.75 |
| | Double lane | 9.0 | - |
| 3 | **ODR** | | |
| | Single lane | 7.5 | 4.75 |
| | Double lane | 9.0 | - |
| 4 | **Village roads** | 7.5 | 4.0 |

**Kerbs:** Kerbs indicate the boundary between the carriage way and the shoulder or islands or footpaths. Different types of kerbs are

# Types:

## Low or mountable kerbs:

# Types:

## Semi-barrier type kerbs:

# Types:

## Barrier type kerbs:

# Types:

## Submerged kerbs:

## Road margins

The portion of the road beyond the carriageway and on the roadway can be generally called road margin. Various elements that form the road margins are given below.

**Shoulders**:

**Parking lanes:**

**Bus-bays:**

**Service roads:**

**Cycle track:**

**Footpath:**

**Guard rails:**

**Lay-byes:**

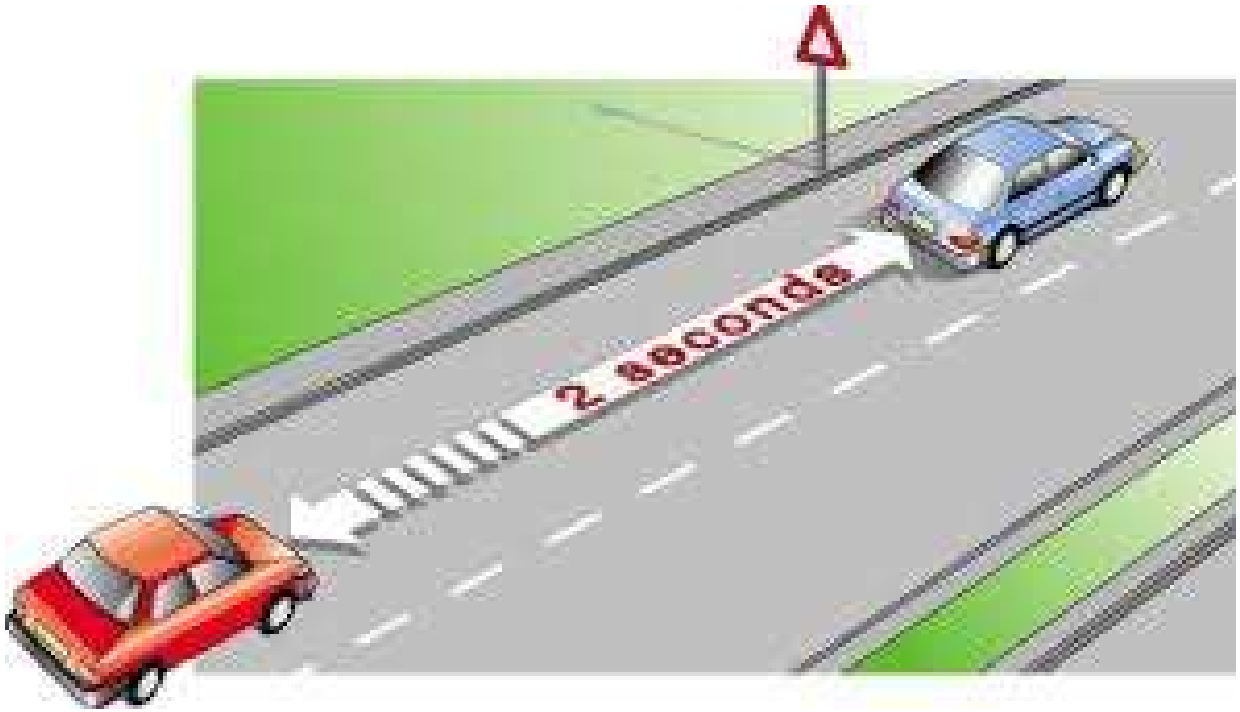
**Drive ways:**

## Sight distance:

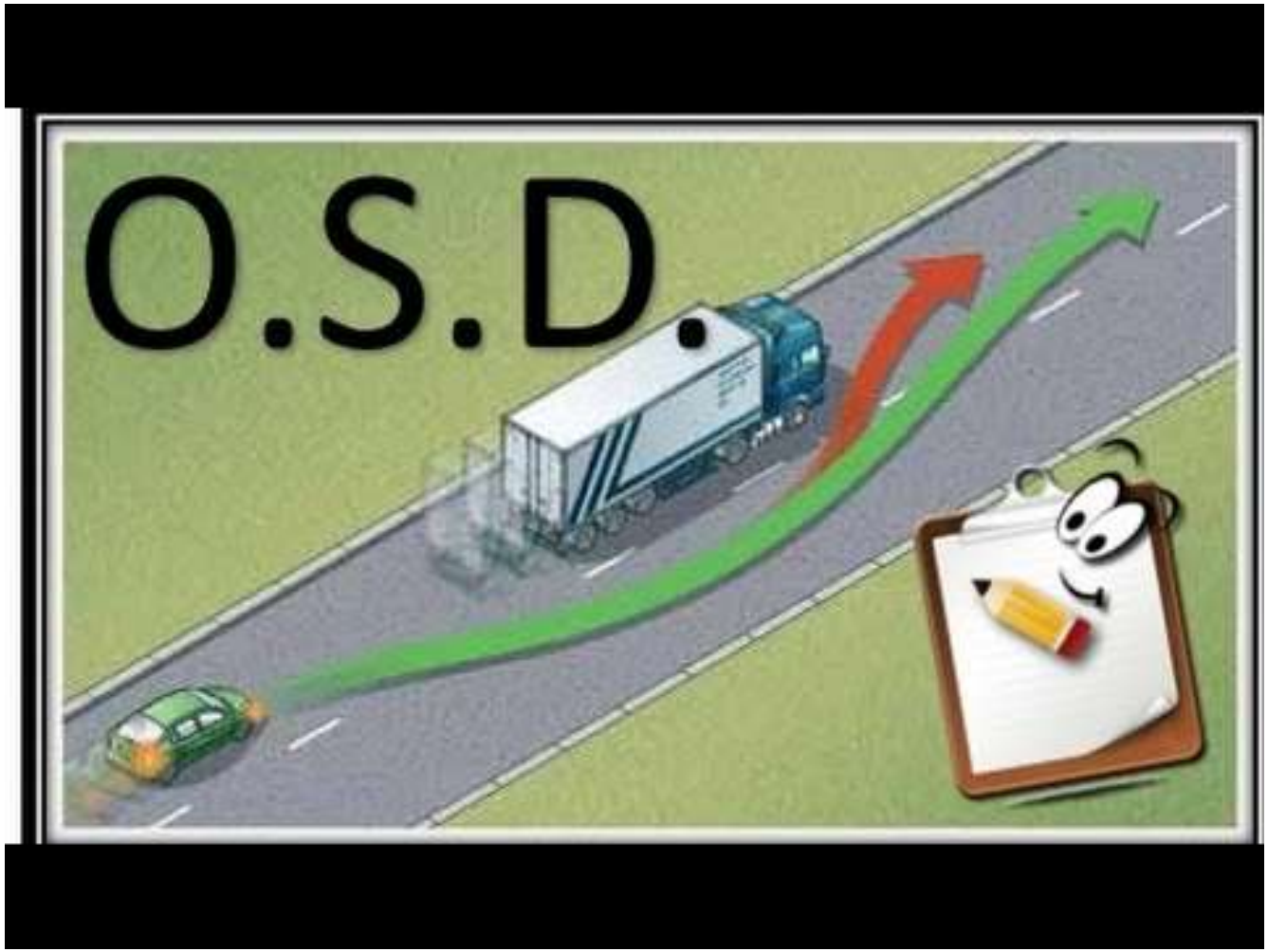
Visibility is very important for safe vehicle operation on a highway.

Three sight distance situations are considered in the design,

- Stopping or absolute minimum sight distance



- Safe overtaking or passing sight distance



- Safe sight distance for entering into uncontrolled intersections

## 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 travelling at design speed, safely without collision with any other obstruction.

# Stopping sight distance:

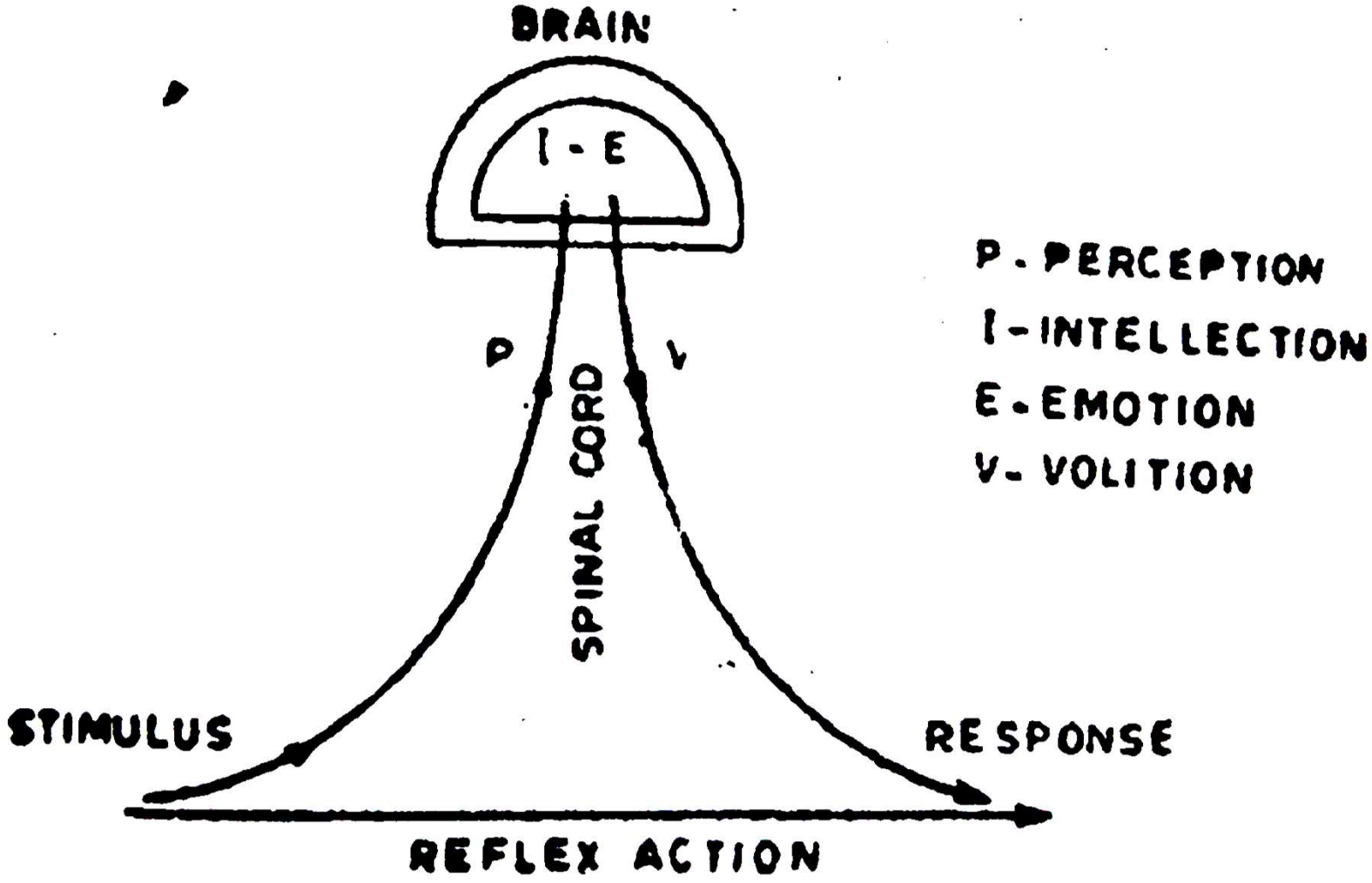
Factors affecting sight distance

- Speed of the vehicle:
- Efficiency of brakes:
- Frictional resistance between the tire and the road:
- Gradient of the road:

## Reaction time of the driver:

The total reaction time may be split up into four components based on PIEV theory.

- Perception
- Intellection
- Emotion
- Volition (final action)


BRAIN
I - E
P
V
SPINAL CORD
STIMULUS
RESPONSE
REFLEX ACTION
P - PERCEPTION
I - INTELLECTION
E - EMOTION
V - VOLITION

## Overtaking Sight Distance (OSD):

The minimum distance to open the vision of the driver of a vehicle intending to overtake slow vehicle ahead with safety against the traffic of opposite direction.

## Overtaking Sight Distance (OSD):

Factors required for the safe overtaking manoeuvre depends, are

- Speed of (i) overtaking vehicle (ii) overtaken vehicle (iii) the vehicle coming from opposite direction
- Distance between the overtaking and overtaken vehicle: the minimum spacing depends on the speeds
- Skill and reaction time of driver
- Rate of acceleration of overtaking vehicle
- Gradient of the road
- Minimum overtaking acceleration at different speeds;

# Horizontal alignment:

**Design speed:** The sight distances, radius of horizontal curve, super elevation, extra widening of pavement, length of horizontal curve are all dependent on speed.

## Super elevation:

In order to counteract the effect of centrifugal force and to reduce the tendency of the vehicle to overturn or skid, the outer edge of the pavement is raised with respect to the inner edge, thus providing a transverse slope throughout the length of the horizontal curve.

# Widening of pavement on horizontal curve:

- **Mechanical widening:**
- **Psychological widening:**

## Vertical alignment:

## Gradient:

Gradient is the rate of rise or fall along the length of the road with respect to the horizontal. It is expressed as a ratio of 1 in x (1 vertical to x horizontal units). It is also expressed as a percentage n i.e. n in 100.

Gradients are divided into the following categories:

- Ruling gradient
- Limiting gradient
- Exceptional gradient
- Minimum gradient

## Vertical curves:

## Summit curves:

The deviation angle between the two interacting gradients is equal to the algebraic difference between them. Of all the cases, the deviation angle will be maximum when an ascending gradient meets with a descending gradient i.e. $N = n_1 - (-n_2) = (n_1 + n_2)$

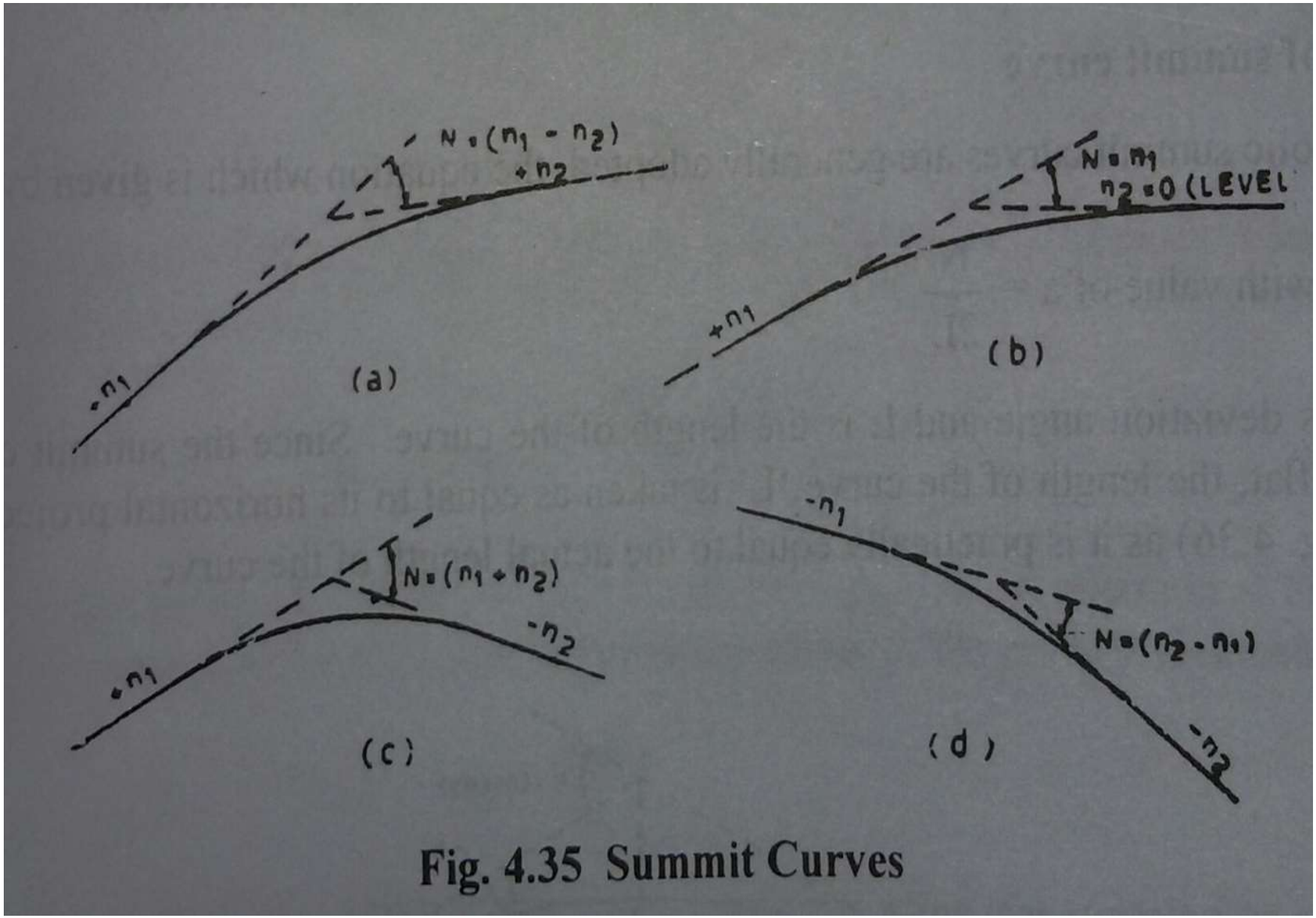



Fig. 4.35 Summit Curves

**Valley curve:**

In all the cases the maximum possible deviation angle is obtained when a descending gradients meets with an ascending gradient.

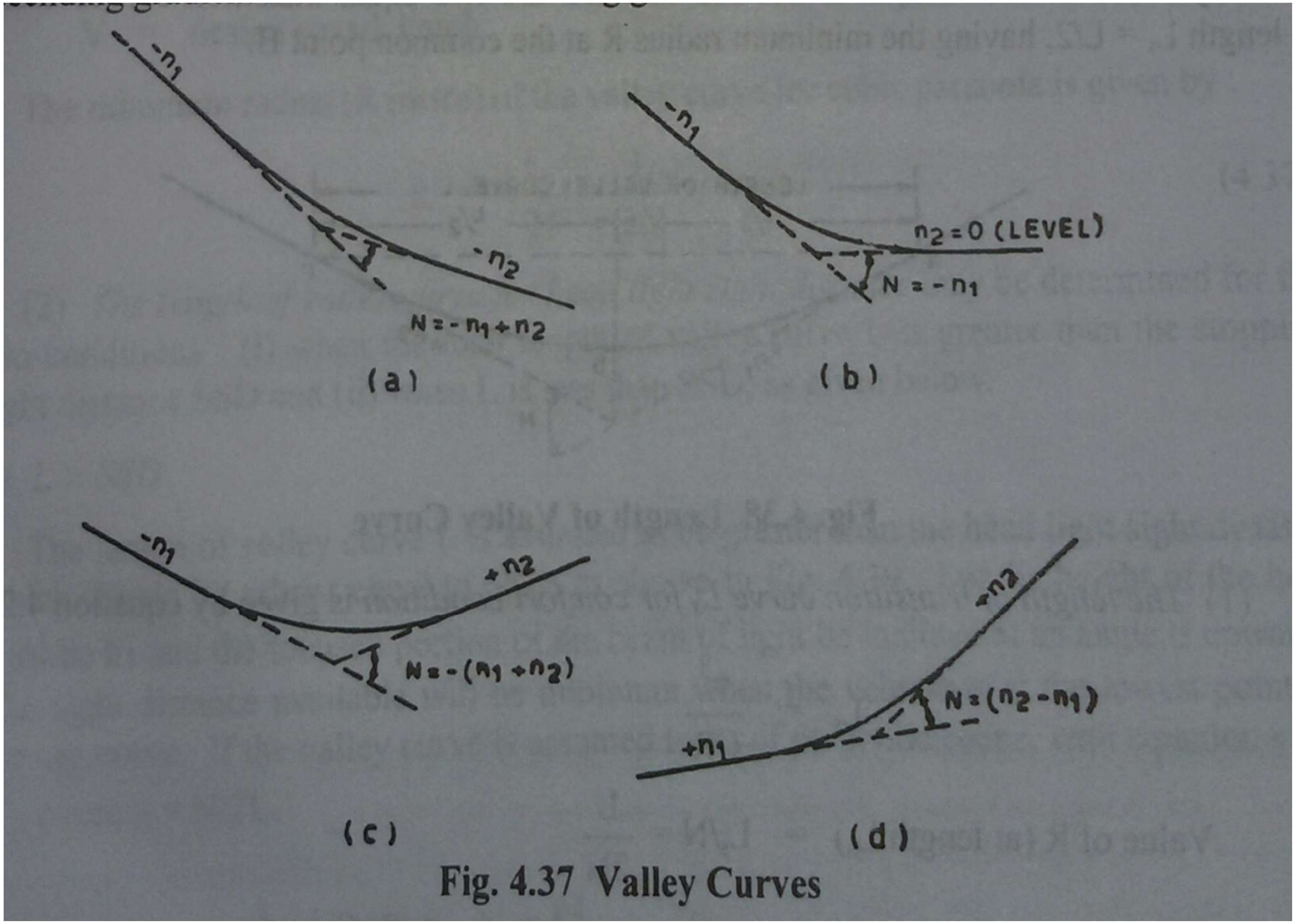



Fig. 4.37 Valley Curves

**Example 4.2**

Calculate the safe stopping sight distance on a level road stretch for design speed of 50 kmph for (a) two-way traffic on a two lane road (b) two way traffic on a single lane road.

Assume coefficient of friction as 0.37 and reaction time of driver as 2.5 seconds.

**Solution**

Given data: $V = 50$ kmph or $v = \frac{50}{3.6} = 13.9$ m/sec, $t = 2.5$ sec, $f = 0.37$

Assume $g = 9.8$

Stopping distance, SD on level road stretch (Eq. 4.3)

$$= vt + \frac{v^2}{2gf} = 13.9 \times 2.5 + \frac{13.9^2}{2 \times 9.8 \times 0.37} = 34.8 + 26.6$$

$$= 61.4 \text{ m}$$

Alternatively, stopping distance may also be calculated from Eq. 4.4 as follows:

$$SD = 0.278\, V_t + V^2/254f = 0.278 \times 50 \times 2.5 + \frac{50^2}{254 \times 0.37} = 61.4 \text{ m}$$

(a) Stopping sight distance, SSD when there are two lanes = stopping distance = 61.4 m.

(b) Stopping sight distance, SSD on single lane road with two-way traffic = 2 [SD] = 2 × 61.4 = 122.8 m.

Calculate the minimum sight distance required to avoid a head-on collision of two cars approaching from the opposite directions at 90 and 60 kmph. Assume a reaction time of 2.5 seconds, coefficient of friction of 0.7 and a brake efficiency of 50 percent, in both the cases.

**Solution**

Given data:

Reaction time, $t = 2.5$ sec,

Effective friction coefficient, f with 50 % brake efficiency during stopping
$= 0.5 \times 0.7 = 0.35.$

Speed of Car – 1, $V_1 = 90$ kmph, $v_1 = \frac{90}{3.6} = 25$ m/sec

Speed of Car – 2, $V_2 = 60$ kmph, $v_2 = \frac{60}{3.6} = 16.67$ m/sec

$SD_1$ of Car – 1 $= v_1 t + v_1^2/2gf = 25 \times 2.5 + \frac{25^2}{2 \times 9.8 \times 0.35} = 153.6$ m

$SD_2$ of Car – 2 $= 16.67 \times 2.5 + \frac{16.67^2}{2 \times 9.8 \times 0.35} = 82.2$ m

Total sight distance required to avoid head-on collision of the two approaching cars
$= SD_1 + SD_2 = 153.6 + 82.2 = 235.8$ m, say 236 m.

Calculate the stopping sight distance on a highway at a descending gradient of 2% for a design speed of 80 kmph. Assume other data as per IRC recommendations.

**Solution**

Given data: total reaction time, t = 2.5 sec, design coefficient of friction as f = 0.35, V = 80 kmph; n = – 2% = – 0.02, g = 9.8 m/sec$^2$, $v = \frac{80}{3.6} = 22.2$ m/sec.

SSD on road with gradient is given in Eq. 4.5 and Eq 4.6.

From Eq. 4.5, $$SSD = vt + \frac{v^2}{2g(f \pm n\%)} = 2.2 \times 2.5 + \frac{22.2^2}{2 \times 9.8(0.35 - 0.02)}$$

$$= 55.5 + 76.2 = 131.7 \text{ m say } 132 \text{ m}$$



Alternatively, using Eq. 4.6

$$SSD = 0.278\,Vt + \frac{V^2}{254(f \pm 0.01n)}$$

$$= 0.278 \times 80 \times 2.5 + \frac{80^2}{254(0.35 - 0.02)} = 55.6 + 76.4$$

$$= 132 \text{ m}$$

**Example 4.5**

The design speed of a road is 65 kmph, the friction coefficient is 0.36 and reaction time of driver is 2.5 sec. Calculate the values of (a) Head light sight distance and (b) Intermediate sight distance required for the road.

**Solution**

Given: V = 65 kmph, f = 0.36, reaction time, t = 2.5 sec

$$\text{Stopping sight distance, SSD} = 0.278\,Vt + \frac{V^2}{254f}$$

$$= 0.278 \times 65 \times 2.5 + \frac{65^2}{254 \times 0.36} = 91.4 \text{ m}$$

(i) Head light sight distance = SSD = 91.4 m

(ii) Intermediate sight distance, ISD = 2 SSD = 2 × 91.4 = 182.8 m, say 183 m