ATME College of Engineering

13th K M Stone, Bannur Road, Mysore – 570028

ATME
College of Engineering

DEPARTMENT OF CIVIL ENGINEERING

(ACADEMIC YEAR 2024-25)

TRANSPORTATION ENGINEERING

SUB CODE: BCV403

SEMESTER: IV

INSTITUTIONAL MISSION AND VISION

Vision of the Institute

Development of academically excellent, culturally vibrant, socially responsible and globally competent human resources.

Mission of the Institute

- To keep pace with advancements in knowledge and make the students competitive and capable at the global level.
- To create an environment for the students to acquire the right physical, intellectual, emotional and moral foundations and shine as torch bearers of tomorrow's society.
- To strive to attain ever-higher benchmarks of educational excellence

DEPARTMENT VISION AND MISSION

Vision of the Department

To develop globally competent civil engineers who excel in academics, research and are ethically responsible for the development of the society.

Mission of the Department

- To provide quality education through faculty and state of art infrastructure
- To identify the current problems in society pertaining to Civil Engineering disciplines and to address them effectively and efficiently
- To inculcate the habit of research and entrepreneurship in our graduates to address current infrastructure needs of society

Program outcomes (POs)

Engineering Graduates will be able to:

PO1. **Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2. **Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO3. **Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO4. **Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5. **Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO6. **The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO7. **Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8. **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9. **Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10. **Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

PO11. **Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change

Program Specific Outcomes (PSOs)

PSO 1 – Provide the necessary infrastructure for all situations through competitive plans, maps and designs with the aid of a thorough Engineering Survey and Quantity Estimation.

PSO 2 – Assess the impact of anthropogenic activities leading to environmental imbalance on land, in water & in air and provide necessary viable solutions revamping water resources and transportation for a sustainable development

Program Educational Objectives (PEOs)

PEO 1- Engaged in professional practices, such as construction, environmental, geotechnical, structural, transportation, water resource engineering by using technical, communication and management skills.

PEO 2- Engaged in higher studies and research activities in various civil engineering fields and life time commitment to learn ever changing technologies to satisfy increasing demand of sustainable infrastructural facilities.

PEO 3- Serve in a leadership position in any professional or community organization or local or state engineering board

PEO 4- Registered as professional engineer or developed a strong ability leading to professional licensure being an entrepreneur.

Module – 1

Introduction

Structure

1.0 Introduction

1.1 Objectives

1.2 Importance of transportation

1.3 Different modes of transportation

1.4 Jayakar committee recommendations

1.5 Road types and classification

1.6 Saturation system

1.7 Present scenario of road development in India

1.8 Recommended questions

1.9 Outcomes

1.10 Further Reading

1.0 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. Transportation plays a major role in the development of the human civilization. For instance, one could easily observe the strong correlation between the evolution of human settlement and the proximity of transport facilities. Also, there is a strong correlation between the quality of transport facilities and standard of living, because of which society places a great expectation from transportation facilities. In other words, the solution to transportation problems must be analytically based, economically sound, socially credible, environmentally sensitive, practically acceptable and sustainable. Alternatively, the transportation solution should be safe, rapid, comfortable, convenient, economical, and eco-friendly for both men and material.

1.1 Objectives

Gain knowledge of different modes of transportation systems, history, development of highways and the organizations associated with research and development of the same in INDIA.

1.2 Importance of transportation:

Transportation is a toll to measure the Economic, Industrial, Social and Cultural development of any country. The world that we live in now will most likely be impossible had it not been for innovations in transportation. There would not have been any great infrastructure, industrialization, or massive production, if transportation was incompetent. Life would not have kept up with the fast changing times if there were no huge trucks, bulldozers, trailers, cargo ships, or large aircrafts to carry them to different places. In other words, the global society would not have experienced comfort and convenience had it not been for advancements in the transportation sector.

It is vital for the economic development of any region people and the communities are essentially to be transported material from one place to other. In the production stage transportation is required for carrying raw materials like seeds, manure, coal, steel etc. In the distribution stage transportation is required from the production centres viz; farms and factories to the marketing centres and later to the retailers and the consumers for distribution. The transportation has lots of advantages and even disadvantages. The more focus is on advantages as we cannot think about the life without transportation. The importance of transportation may include:

1. **Availability of raw materials:** Transportation helps in carrying the raw materials from one place to another place. Initially raw materials are made at one place and are being transported to another place for processing and for manufacturing goods.

2. **Availability of goods to the customer:** The goods are being transported from one place to another place. These goods which are produced at one place are transported to other distant places for their usage. It flexibly moves the goods from one place to another place.

3. **Enhances the Standard Of Living:** It improves the standard of living. As the transportation of each and every good is being done then the productivity increases which results in the reduced or the effective costs. Because of reduction in the cost they can use different commodities for different purposes and can lead a secure life.

4. **Helps a lot during the emergencies and even during natural disasters:** Transportation helps during the natural disturbances. It helps in quick moving from one place to another place and supplies the required operations.

5. **Helps for the employment:** Transportation provides employment for many people as drivers, captains, conductors, cabin crew and even the people are used for the construction of different types of transportation vehicles. And even by the use of transportation the remote people are being employed with the access to the urban facilities and the opportunities.

6. **Helps in mobility of the labourers:** Many people are travelling to other countries on their employment basis. Transportation plays an important role in such cases.

7.**Helps for bringing nations together:** Transportation on the whole is used for globalization i.e. it brings nations together and it creates awareness about the cultural activities and even about the industries and helps a lot for importing and exporting of different goods.

These above are some of the necessities which make us to use transportation.

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

Economic Activity: Two important factors well known in economic activity are:

1. Production or supply.
2. Consumption for human wants or demand.

Economic activity are the process by means of which the products are utilized to satisfy human demand .the role of transportation in the economic activity starts its function from production stage to the final distribution.

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

1. Sectionalism and transportation: improved transportation has important implication in reducing sectionalism with in the country and also outside the country. More frequently travels in other part of the country and outside the country tends to increases knowledge of the people from other section of society.

2.Concentration of population into urban area: the prosperity and employment opportunities of urban area attract the population from other areas resulting in enhanced the population from other areas movements to and from factories, officer, schools, hospitals and other social needs.

3. Aspect of safety, law and order: transport facilities are essential for rusting aids to areas affecting by an emergency .to maintain law and order at home it is required to have an

efficient system of transport network. to defined the territory of the country against external aggression and to guard the borders with the foreign territories transport facilities are needed.

1.3 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.

The four major modes of transportation are:

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.

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.
6. Ultimately, road network is therefore needed not only to serve as feeder system for other modes of transportation and to supplement them, but also to provide independent facility for road travel by a well-planned network of roads throughout the country.
7. Perishable commodities like vegetables, fruits and milk are transported more easily and quickly by roads than by railways.
8. It is comparatively easy and cheap to construct and maintain roads.

Pipelines

Primarily, pipeline is used for the transport of crude petroleum, refined petroleum and natural gas. Pipelines are also used for the transportation of certain types of chemicals, Pulverized dry bulk materials such as cement and flour via hydraulic suspension system, and sewage and water in cities.. E.g.: pipeline may be best suited to transport crude petroleum from the port to the refinery. But, to transport refined petrol to a gas station does not justify the use of a pipeline and this is better done by a truck. There is a talk going on between India, Iran and Pakistan regarding the transportation of crude oil from Iran to India with the help of a pipeline which will pass through Pakistan. This will reduce the cost of transporting crude oil from Iran to India.

In comparison with the other modes of transport, pipelines operate on a 24 hour basis, seven days a week. They stop functioning due to change in the commodity to be transported, or due to maintenance. Unlike other modes of transport, pipeline does not have any 'empty containers' or vehicles' which are to be returned to the origins.

Rope ways

A ropeway is a form of naval lifting device used to transport light stores and equipment across rivers or ravines. It comprises a jackstay, slung between two sheers or gyps, one at either end, from which is suspended a block and tackle, that is free to travel along the

rope and hauled back and forth by inhauls (ropes attached to the pulley from which the block and tackle are suspended).

Comparison different modes of transportation

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

The Characteristics of Road Transport are briefly listed here.

*Roads are used various types of road vehicles, like passenger cars, buses, trucks two and three wheeled automobiles, pedal cycles and animal drawn vehicles. But railway tracks are used only by rail locomotives and wagons, water ways are used by only ships and boats

*Road transport requires a relatively small investment for the government. Motor vehicles are much cheaper than carriers like rail locomotives and wagons, water and air carriers and air carriers. Construction and maintenance of roads is also cheaper than that of railway track, docks, harbours and airports.

*Road transport completely offer a freedom to road users to transfer the vehicles from one lane to another and to from one road to another according to the need and convenience. This flexibility of changes in location, direction, speed and timings of travel is not available to other modes of transport.

*In particular for short distance travel, road transport saves time. Trains stop at junctions and main stations for comparatively longer time.

*Speed of movement is directly related with severity of accident. The road Safety decreases with increase dispersion in speed. Road Transport is subjected to high degree of accidents due to flexibility of movements offered to the user. Derailment of railway locomotives and air planes and air crashes are not uncommon. They are in fact more disastrous.

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

*The Major defect of road is Traffic.

Traffic: It means the amount of vehicles using in given volume of road than average number of vehicles.

It causes an irritation to passengers who were travelling.

1.4 Jayakar committee recommendations

Over a period after the First World War, motor vehicles using the roads increased and this demanded a better road network which can carry mixed traffic conditions. The existing roads when not capable to withstand the mixed traffic conditions. For the improvement of roads in India government of India appointed Mr. Jayakar Committee to study the situations and to recommend suitable measures for road improvement in 1927 and a report was submitted in 1928 with following recommendations:

1. Road development in the country should be considered as a national interest. As the provincial and local government do not have the financial and technical capacity for road development.
2. Extra tax to be levied from the road users as fund to develop road.
3. A Semi-official technical body has to be formed to collect and pool technical Knowhow from various parts of the country and to act as an advisory body on various aspects of the roads.
4. A research organization should be instituted at National level to carry out research and development work and should be available for consultation.

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 build up 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.

Highway Development and Planning:

Road: A road is a thoroughfare, route or way on land between two places, which typically has been paved or otherwise improved to allow travel by some conveyance, including a horse, cart, or motor vehicle.

Highway: A highway is a public road, especially a major road connecting two or more destinations.

Traffic: The vehicles, cycles, carts, pedestrians etc. travelling together on a road constitute the traffic.

Foot way: The portion of roadway of an urban road reserved only for pedestrians are called foot path or side walk. The minimum width of side walk should be 1.5 m.

Cycle track: The portion of roadway of an urban road reserved only for bicycles is called cycle track. The minimum width of cycle track should be 2 metres.

Motor way: The portion of roadway of an urban road reserved for use only by high speed and power driven vehicles is called motor way, express way.

1.5 Classification of Roads:

Types of roads:

1. Classification based on weather:
   - All weather roads: All weather roads are those which are negotiable during all weather, expect at major river crossings where interruption to traffic is permissible up to a certain extent, the road pavement should be negotiable during all weathers.
   - Fair-weather roads: Fair weather roads are which thee traffic may be interrupted during monsoon season at causeways where streams may overflow across the road.
2. Classification based on the type of carriage way:
   - Paved roads: If they are provided with a hard pavement course which should be at least water bound macadam (WBM) layer.
   - Unpaved roads: If they are not provided with a hard pavement course which should be at least water bound macadam (WBM) layer. Thus earth roads and gravel roads may be called unpaved roads.
3. Classification based on type of pavement surface:
   - Surface roads: Which are provided with a bituminous or cement concrete surfacing.
   - Un-surfaced roads: Which are not provided with a bituminous or cement concrete surfacing.

Methods of classification of roads:

The roads are generally classified as

- Traffic volume: The roads are classified as Heavy, Medium and Light traffic roads.

- Load transported or tonnage: The roads are classified as class I, class II or class A or class B etc. And the limits may be expressed as tonnes per day.
- Location and function:

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): National Highways are main highways running through the length and breadth of India, connecting major ports, foreign highways, capitals of large state and large industrial and tourists centres including roads required for strategic movements for the defence of India.

- NH-1 Delhi-Ambala-Amritsar
- NH-3 Bombay-Agra
- NH-7 Varanasi to Kanyakumari
- NH-49 Maduri-Rameshwaram

State Highway: State Highways are arterial roads of a state, connecting up with the national highways adjacent state, district head quarters and important cities within the state and serving as the main arteries for traffic to and from district roads.

The NH and SH have the same design speed and geometric design specifications.

Major District Roads: MDR are important roads within a district serving areas of production and marketing and connecting those with each other or within the main highways of a district. The MDR has lower speed and geometric design specifications than NH/SH.

Other District Roads: ODR are serving rural areas of production and providing them with outlet to market centres, Taluk head quarters, block development head quarters or other main roads. ODR are of lower design specifications than MDR.

Village Roads: VR roads connecting villages or group of villages with each other to the nearest road of a higher category.

Modified classification of Road system by Lucknow plan:

The roads in the country are now classified into three classes, for the purpose of transport planning, functional identification, earmarking, administrative jurisdiction and assigning priorities on the road network.

1. Primary system consists of two categories:

- Expressways
- National Highways (NH)

Expressways are a separate class of highways with superior facilities and design standards and are meant as through routes having very high volume of traffic. The expressways are to be provided with divided carriage ways, controlled access, grade separations at cross roads and fencing. These highways should permit only fast moving vehicles.

2. Secondary system consists of two categories:
   - State Highways (SH)
   - Major District Roads (MDR)
3. Tertiary system consists of two categories:
   - Other District Roads (ODR)
   - Village Roads (VR)

Classification of Urban Roads:

The urban roads are

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

Arterial roads and Sub-arterial roads are streets primarily for through traffic on a continuous route, but the sub-arterials have a lower level of traffic mobility than the arterials.

Collector streets provide access to arterial streets and they collect and distribute traffic from and to local streets which provide access to abutting property.

Road patterns:

1. Rectangular or Block pattern: In this pattern, the whole area is divided into rectangular blocks of plots, with streets intersecting at right angles. The main road which passes through the centre of the area should be sufficiently wide and other branch roads may be comparatively narrow. The main road is provided a direct approach to outside the city.

Advantages:

- The rectangular plots may be further divided into small rectangular blocks for construction of buildings placed back to back, having roads on their front.
- In this pattern has been adopted for the city roads.

- The construction and maintenance of roads of this pattern is comparatively easier.

Limitations:

- This pattern is not very much convenient because at the intersections, the vehicles face each other.

Example: Chandigarh has rectangular pattern.

2. Radial or Star and block Pattern: In this pattern, the entire area is divided into a network of roads radiating from the business outwardly. In between radiating main roads, the built-up area may be planned with rectangular block.

Advantage

- Reduces level of congestion at the primary bottleneck location.
- Prevents traffic from accessing local flow routes in the direction of the event venue that operate in favour of egress traffic flow.
- If one is block then other side traffic can move.
- Vehicles face each other less than block pattern.

Limitations

- Proves particularly effective if two-lane ramp traffic does not have to merge at downstream end of ramp.
- Safety appurtenances such as guide rail transitions, crash attenuators, and post support bases have not been designed to provide adequate protection at hazardous locations from the opposite direction of travel

3. Radial or Star and Circular Pattern: In this system, the main radial roads radiating from central business area are connected together with concentric roads. In these areas, boundary by adjacent radial roads and corresponding circular roads, the built-up area is planned with a curved block system.

Advantages

- At traditional intersections with stop signs or traffic signals, some of the most common types of crashes are right-angle, left-turn, and head-on collisions. These types of collisions can be severe because vehicles may be traveling through the intersection at high speeds. With circular pattern, these types of potentially serious crashes essentially are eliminated because vehicles travel in the same direction.

- Installing circular pattern in place of traffic signals can also reduce the likelihood of rear-end crashes.
- Removing the reason for drivers to speed up as they approach green lights and by reducing abrupt stops at red lights.
- Because roundabouts improve the efficiency of traffic flow, they also reduce vehicle emissions and fuel consumption.

Limitations:

- Center lines of roads leading to circular pattern should be properly aligned with the central island.
- Approach roads should be sufficiently curved, far enough in advance of circular pattern, to reduce vehicle speeds of entering drivers.
- Islands separating the approach and exit lanes, known as splitter islands, should extend far enough to provide pedestrian refuge and to delineate the roundabout.
- Traffic signs, pavement markings, and lighting should be adequate so that drivers are aware that they are approaching a roundabout and that they should reduce their travel speed.
- For older drivers declines in vision, hearing, and cognitive functions, as well as physical impairments, may affect some older adults' driving ability. Intersections can be especially challenging for older drivers.

4. Radial or Star and Grid Pattern: Change in direction, and because street patterns are the most enduring physical element of any layout, it could potentially contribute to systematic site planning and, consequently, deserves a closer look. Though the network is entirely interconnected, north-south movement becomes circuitous, indirect, and inconvenient, making driving an unlikely choice and vividly illustrating that interconnectedness by itself is insufficient to facilitate movement.

Advantages:

- Keep vehicular traffic safe with a high proportion of 3-way intersections.
- Reduce cut-through traffic by similar or other means.
- Improve traffic flow in both directions using Savannah‟s cellular structure.
- Improve land use efficiency and unit density.

Limitations:

- Islands separating the approach and exit lanes, known as splitter islands, should extend far enough.
- Traffic signs, pavement markings, and lighting should be adequate so that drivers are aware that they should reduce their travel speed.

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

5. **Hexagonal Pattern:** In this pattern, the entire area is provided with a network of roads formatting hexagonal figures. At each corner of the hexagon, three roads meet the built-up area boundary by the sides of the hexagons is further divided in suitable sizes.

Advantages:

- Three roads meet the built-up area boundary by the sides of the hexagons.

Limitation:

- Traffic signs, pavement markings, and lighting should be adequate so that drivers are aware that they should reduce their travel speed.

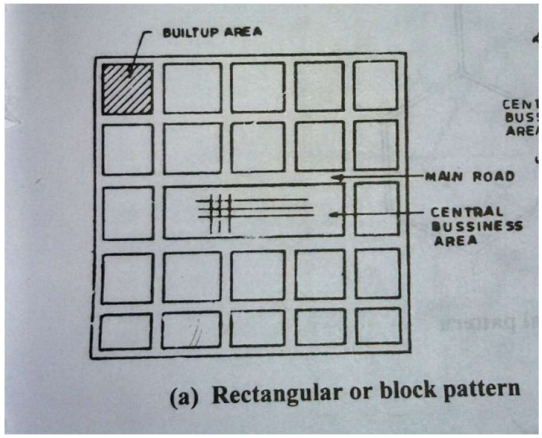
6. Minimum Travel Pattern: In this road pattern, city is contented by sector center, suburban enter and neighbourhood center by the road which required minimum to connect the city center.

Advantages:

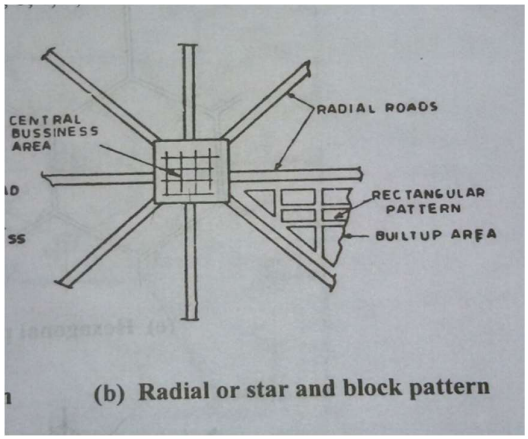
- These types of potentially serious crashes essentially are eliminated.

Limitations:

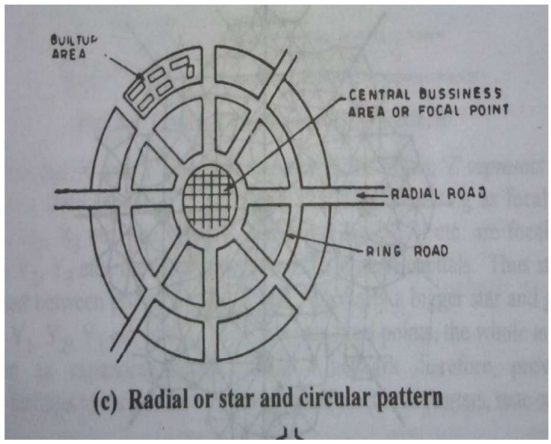
- Traffic signs, pavement markings, and lighting should be adequate so that drivers are aware that they should reduce their travel speed.
- Intersections can be especially challenging for older drivers.



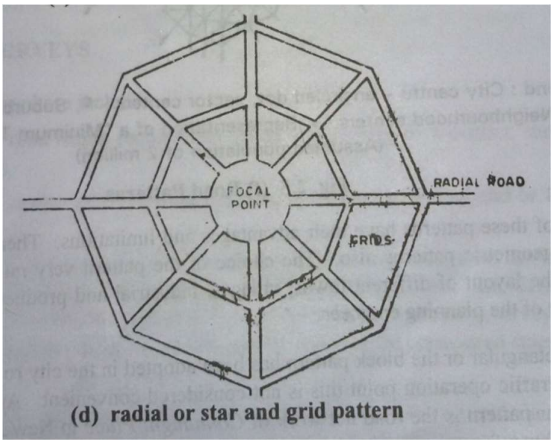
(a) Rectangular or block pattern



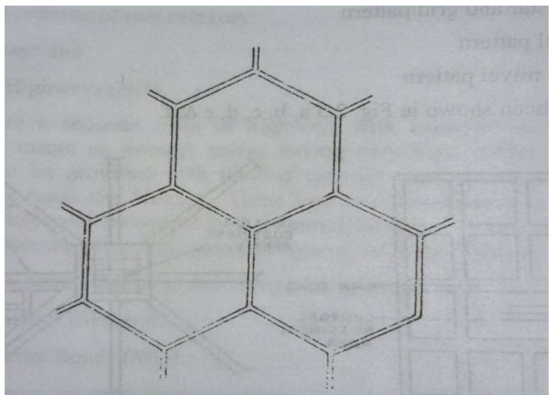
(b) Radial or star and block pattern



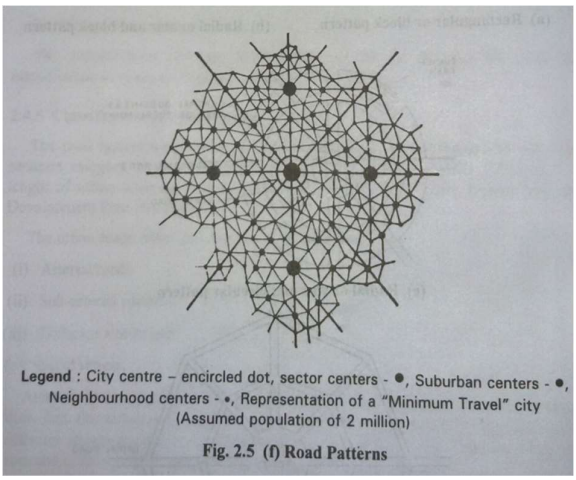
(c) Radial or star and circular pattern



(d) radial or star and grid pattern



(e) Hexagonal 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

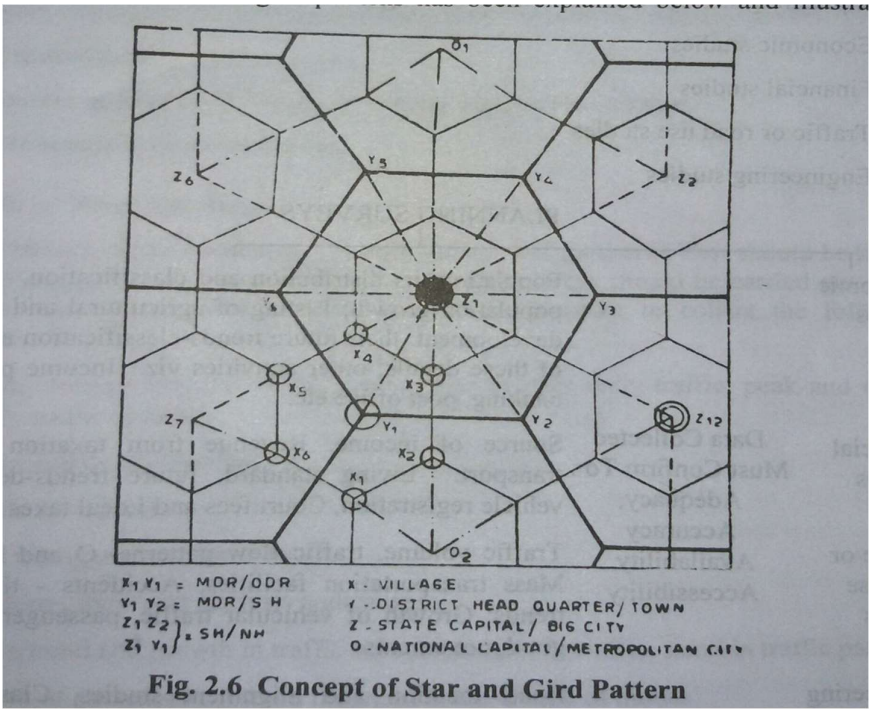


Fig. 2.6 Concept of Star and Gird Pattern

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

i) Assessment of road length requirement for an area

ii) Preparation of Master plan showing the phasing of plan in annual and or five year plans.

The planning surveys consists of the following studies

i) Economic Studies

ii) Financial studies

iii) Traffic or road use studies

iv) Engineering studies.

The planning surveys consist of the following studies:

Economic Studies: This study consists the following details:

- Total population and classified distribution of the different population groups based on occupation, income etc. In each village, town and other locality
- Trend of population growth of various population groups
- Agricultural and industrial products and their listing in classified groups, area wise

- Existing facilities with regard to communication, education, banks, hospitals, post office, recreation facilities etc
- Per Capita income

Financial Studies: This study involves collecting the details such as:

- Sources of income and estimated revenue from different types of taxation including revenue from road transport sector
- Standards of living of different population groups and the trend in changes
- Resources at local levels, toll taxes, vehicle registration and fines
- Future trends in financial aspects
- Anticipated development in the area and generated income.

Traffic or road use studies: In this details collected are

- Classified traffic volume/day, annual average daily traffic, peak and design hourly traffic volumes
- Origin and destination studies based on detailed home interview method
- Mass transportation facilities
- Accidents, cause and cost analysis
- Future trend and growth in traffic volume and goods traffic
- Growth of passenger trips and the trend in the choice of modes

Engineering studies: This involves

- Topographic surveys
- Soil surveys
- Location and classification of existing roads
- Road life studies
- Specific problems in drainage constructions & maintenance of roads

Objective of planning surveys

1. Workout, the financial system and recommended changes in tax arrangements and budget procedures, provide efficient, safe economics, comfortable and speedy movement for goods and people.
2. Plan a road network for efficient traffic operation at minimum cost.

3. Plan for future requirements and improvements of roads in view of developments and social needs.
4. Fix up data wise priorities for development of each road link based on their utilities.

Interpretation of planning surveys

i) To arrive at the road network with maximum utility among alternative proposals.
ii) To fix up the priority of the construction projects and phase the development plan
iii) To assess the actual road use by studying traffic flow patterns.
iv) Based on the studies, structural and geometric features are constructed.
v) Comparisons of the areas may be obtained on the basis of their economic activities.
vi) On statistical basic, the data obtained in fact finding surveys may be analyzed for the future trends in development of an area.

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.

It helps in controlling the industrial, commercial and agricultural and habitat growth in a systematic way of that area. It gives a perceptive picture of a fully developed area in a plan and scientific way.

Stages in the preparation of master plan

1. Data Collection: It includes data regarding existing land use, industrial and agricultural growth, population, traffic flow, topography, future trends.
2. Preparation of draft plan and invite suggestions and comments from public and experts.
3. Revision of draft plan in view of the discussions and comments from experts and public.
4. Comparison of various alternate proposals of road system and finding out the sequence in which the master plan will be implemented.

In India targeted road lengths were fixed in various road plans, based on population, area and agricultural and industrial products. The same way it may be taken as a guide to decide the total length of road system in each alternate proposal while preparing a master plan for a town or locality.

1.6 Saturation system

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

The factors which are taken for obtaining the utility per unit length of road are:

i) Population served by the road network

ii) Productivity served by the network

a. Agricultural products

b. Industrial products

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.

The various steps to be taken to obtain maximum utility per unit length are:

Population factors or units: Since, the area under consideration consists of villages and towns with different population these are grouped into some convenient population range and some reasoning values of utility units to each range of population serve are assigned.

Productivity Factors or units: The total agricultural and industrial products served by each road system are worked out and the productivity served may be assigned appropriate values of utility units per unit weight.

Optimum Road length: Based on the master plan the targeted road length is fixed for the country on the basis of area or population and production or both. And the same may be taken as a guide to decide the total length of the road system in each proposal.

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:

i) The future road development should be based on the revised classification of road system consisting of Primary, Secondary and Tertiary road system.

ii) The road network should be developed so as to preserve the rural oriented economy and to develop small towns with all the essential facilities.

iii) All the villages with population of 500 should be connected by all weather roads.

iv) The overall density of road is increased to 82km per 100 sq.km

v) 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.

vi) Expressway should be constructed along major traffic corridors to provide fast travel.

vii) Roads should also be built in less industrialized areas attract the growth of industries.

viii) Long term master plans for road development should be prepared at various levels.

ix) All towns and villages with population over 1500 should be connected by Major district Roads and villages with population 1000 to 1500 by ODR.

x) There should be improvements in environmental quality and road safety.

Formulae

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

ii) 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)

iii) 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)

iv) 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 4th twenty year road development plans and Policies - Vision: 2021

It is to be recognized that even after the habitations eligible under PMGSY are fully covered. There is still left with a large number (about 1.68 lakh) unconnected habitations of lower size population. To serve the last person and the remotest village. IRC and Ministry of Rural Development have decided to formulate a 20 year vision (May 2007) covering various

aspects related to rural areas and it's dovetailing with the higher categories of roads and the urban landscape.

Objectives

The road network as on May 2007 stands at 3.3 million km. Of this, rural roads comprise around 2.7 million km, i.e. about 85 percent. Overall village accessibility stood at 54 percent in the year 2000.

a) Emphasis is continuing in social development sectors so as to improve the quality of life and alleviate poverty
b) The objective has to be to provide full connectivity to all habitations including provision of bridges and culverts. Accordingly, the following vision for new connectivity has been recommended.
    - Habitations with population above 1000 (500 in case of hill, NE states, deserts and tribal areas) by the year 2009-10
    - Habitations with population above 500 (250 in case of hill, NE states, deserts and tribal areas) by year 2014-15
    - Habitations with population above 250 by the year 2021-22
c) The Central Government has also introduced the concept of a Core Network, which is defined as the network that is essential to provide one basic access to each habitation.
d) Proper drainage and design standards were made for rural roads .Many management rule, powers to different authorities and other standard data book was set and prepared by NRRDA (National Rural Road Development Authority).
e) Importance was given to the use of advanced and latest equipments in road constructions to facilitate the economics.
f) The Government also needs to develop independent think-tanks and academicians on various aspects of rural roads like engineering, safety, environmental issues, socio-economic impact, etc
g) Action should be taken by each state to formulate a 5-year Action Plan in the light of recommendations of the Vision document.

Salient features of vision 2021

a) The Road Development Plan Vision: 2021 was prepared with the full involvement of the highway profession both within the government and the private sector and represents an expression of the intent for highway development in the two decades from 2001.
b) 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 program me of construction of village roads and preservation of existing road assets.
c) Aspects such as road safety, social and environment concerns and energy efficiency have also been highlighted.
d) 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.
e) Target Roads Lengths by the year 2021:
    a. Expressways 10,000 km
    b. National Highways 80,000 km
    c. State Highways 160,000 km
    d. Major District Roads 320,000 km

1.7 Present scenario of various road development projects in India

Pradhan Mantri Gram Sadak Yojana (PMGSY)

i. The Government of India launched in December 2000, the programme of village connectivity known as **Pradhan Mantri Gram Sadak Yojana (PMGSY**) with the objective of connecting all unconnected habitations having a population of 500 and above with all-weather roads.
ii. 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.
iii. 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.

iv. The Ministry of Rural Development has already brought out dedicated specifications for rural roads and Standard Data Book with the support of the Indian Roads Congress. This has helped in setting national standards and specifications for rural roads at national level for uniform implementation at local level duly taking into account different terrain, soil and traffic conditions in the country.

v. As per the current guidelines, the PMGSY covers all habitations above 500 population to be provided with all-weather rural roads. In case of hills, deserts and tribal areas, the threshold is relaxed and over all habitations above 250 population.

vi. 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.

vii. 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. "

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

The National Highways have a total length of 71,772 km to serve as the arterial network of the country. The development of National Highways is the responsibility of the Government of India. The Government of India has launched major initiatives to upgrade and strengthen National Highways through various phases of National Highways Development project (NHDP), which are briefly as under:

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).

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.

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.

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.

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

MORTH

An apex organisation under the Central Government is entrusted with the task of formulating and administering, in consultation with other Central Ministries/Departments, State Governments/UT Administrations, organisations and individuals, policies for Road Transport, National Highways and Transport Research with a view to increasing the mobility and efficiency of the road transport system in the country. The Ministry has two wings: Roads wing and Transport wing.

Roads Wing

Deals with development and maintenance of National Highway in the country

Main Responsibilities:

1. Planning, development and maintenance of National Highways in the country.

2. Extends technical and financial support to State Governments for the development of state roads and the roads of inter-state connectivity and economic importance
3. Evolves standard specifications for roads and bridges in the country.
4. Serves as a repository of technical knowledge on roads and bridges.

Transport Wing

Deals with matter relating to Road Transport

Main Responsibilities:

1. Motor Vehicle legislation.
2. Administration of the Motor Vehicles Act, 1988.
3. Taxation of motor vehicles.
4. Compulsory insurance of motor vehicles.
5. Administration of the Road Transport Corporations Act, 1950.
6. Promotion of Transport co-operatives in the field of motor transport.
7. Evolves road safety standards in the form of a National Policy on Road Safety and by preparing and implementing the Annual Road Safety Plan.
8. Collects, compiles and analyses road accident statistics and takes steps for developing a Road Safety Culture in the country by involving the members of public and organising various awareness campaigns.
9. Provides grants-in-aid to Non-Governmental Organisations in accordance with the laid down guidelines

Karnataka State Highways Improvement Project (KSHIP):

It is an initiative of the Public Works Department of the Government of Karnataka for improvement of road network of the state with World Bank assistance.

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

The World Bank have extended Technical Assistance (T.A.) Loan of US $ 3.2 million for project preparation through the Department of Economic Affairs of Ministry of Finance, Government of India for taking up the Project Coordinating Consultancy (PCC) Services to

investigate and prepare detailed project report on the 2888 kms and Institutional Development Strategy (IDS) Study.

The works relating to upgrading and widening of 992 Km will be implemented in eight contract packages under International Competitive Bidding (ICB), where the contract values range from Rs.35 crores to Rs.205 crores. The work relating to rehabilitation and upgradation contracts of smaller value ranging from Rs.3 Crores to Rs.38 Crores will be procured under National Competitive Bidding (NCB).

Karnataka Road Development Corporation Limited (KRDCL)

i. 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.
ii. KRDCL is a company under the Public Works, Ports & Inland Water Transport Department.
iii. 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, BOOT and BOLT.
iv. Since inception Karnataka Road Development Corporation Limited has strived to improve the road network and to establish connectivity to all the nook & corner of the State.

1.8 Recommended questions

1. Define planning survey. Explain the types of planning surveys.
2. Write a note on CRF AND CRRI.
3. Write a note on a) NHDP b) PMGSY c) KSHIP d) KRDCL
4. Explain the Jayakar committee recommendations.
5. Explain the classification of roads by Nagpur road plan.

1.9 Outcomes

Acquire the capability of proposing a new alignment or re-alignment of existing roads, conduct necessary field investigation for generation of required data.

1.10 Further Reading

1. http://nptel.ac.in/courses/105101087/downloads/Lec-1.pdf
2. http://nptel.ac.in/downloads/105101087/
3. http://omms.nic.in/

Module – 2

HIGHWAY MATERIALS AND PAVEMENTS

Structure

2.0 Introduction

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

Horizontal alignment: - straight path, horizontal deviation and curves.

Vertical alignment: - changes in gradient and vertical curve

The position or the layout of the central line of the highway on the ground is called the alignment. Horizontal alignment includes straight and curved paths. Vertical alignment includes level and gradients. Alignment decision is important because a bad alignment will enhance the construction, maintenance and vehicle operating cost. Once an alignment is fixed and constructed, it is not easy to change it due to increase in cost of adjoining land and construction of costly structures by the roadside

2.1 Objectives

1. Gain knowledge of different modes of transportation systems, history, development of highways and the organizations associated with research and development of the same in INDIA.

2. Understand Highway planning and development considering the essential criteria's (engineering and financial aspects, regulations and policies, socio economic impact).

2.2 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:** it is desirable to have a short alignment between two stations. A straight path between the two terminals would provide this.
- **Easy:** it is should be easy to construct and maintain the road with minimum problems and also the alignment should be easy for vehicle to operate with easy gradient and curves.
- **Safe:** it should be safe enough for construction and maintenance from the view point of stability of natural hill slopes, embankment and cut slopes. It should be safe for the traffic operation with safe geometric features.
- **Economical:** The road alignment could be considered economical only if the total cost including initial cost, maintenance cost and VOC is lowest.

Factors affecting alignment

The various factors which control the highway alignment are:

i. Obligatory points
ii. Traffic
iii. Geometric design
iv. Economics
v. Other considerations

Obligatory Points: there are control points governing the alignment of the highways. These control points may be divided broadly into two categories.

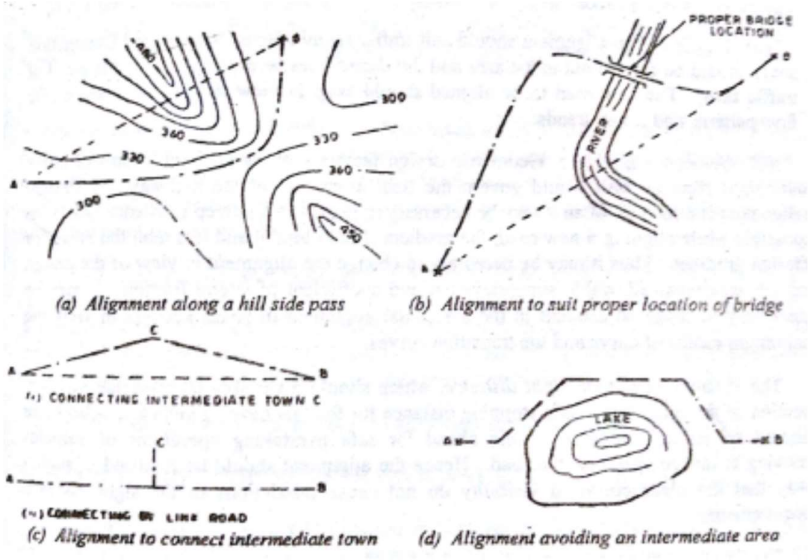
a) Points through which the alignment is to pass:

This may cause the alignment to often deviate from the shortest or easiest path. The various examples of this category may be bridge site, intermediate town, a mountain pass or quarry.

Case 1: When it is necessary to cross hill range, mountains the various alternatives are to cut a tunnel or to go around the hill. This suitability depends on many factors like site condition, topography, cost consideration etc. The figure shows how the alignment AB deviated to ACB.

Case 2: due to the position of the bridge the alignment deviated from CD to CFD. Because the bridge are constructed at narrow gap and where the intensity of water force is low.

Case 3: when connecting a road network between two station. It always beneficial to provide a link road or to connect the proposed alignment through nearby station



(a) Alignment along a hill side pass (b) Alignment to suit proper location of bridge

(c) Alignment to connect intermediate town (d) Alignment avoiding an intermediate area

b) Points through which the alignment should not pass: also make it necessary to deviate from the proposed shortest alignment. The obligatory points which includes religious places (temples church, mosque and grave), very costly structure, unsuitable land (lakes, ponds, marshy soil)

Traffic: the alignment should suit traffic requirements. Origin and destination study should be carried out in the area and the desire lines be drawn showing the traffic flow. The new alignment should keep in view of desired lines, flow patterns and future trends.

Geometric design: geometric design factors such as gradient, radius of curve and sight distance, overtaking sight distance, ruling gradient on hilly region also would govern the final alignment of the highway.

Economics: the alignment finalised based on the above factors should be economical compared to other alignment. The safety, saving and returns should be more compared to investment. It is based on the initial cost of construction and maintenance cost of the road, if it a shortest path the cost of construction will be reduced. (Decision is based on Quantity of Cutting and Filling of Earth.)

Other consideration: factors like drainage consideration, hydrological factors, water table, seepage flow, high flood level, political considerations and monotony also affect in deciding the alignment.

In hill roads additional care has to be given for:

- Stability

- Drainage
- Geometric standards of hill roads
- Resisting length.

2.3 Engineering surveys

The stages of engineering surveys for Highway locations:

i) Map study
ii) Reconnaissance
iii) Preliminary surveys
iv) Final location and detailed surveys

Map study: By careful study of topographical map, it is possible to have an idea of several possible alternate routes so that further details of these may be studied later at the site. The features like river, hills valleys, and counter intervals can be observed.

By knowing these feature it can fairly assign the alignment avoiding valleys, lakes and possible location of bridge (avoiding sharp turns etc.). It is also possible to suggest permissible gradient considering counter intervals.

Reconnaissance: it is to examine the general character of the area for deciding the most feasible routes for detailed studies. A field survey party may inspect a fairly broad stretch of land along the proposed alternative routes of the map in the field. Only few simple instruments like abney level tangent clinometers, barometer or GPS are used by the reconnaissance party to collect additional details rapidly.

Some of the following details are collected;

- Valleys, ponds, lakes, marshy land, hills, permanent structures and other obstruction along the route which are not available in the map.
- Approximate values of gradient, length of gradient and radius of curves of alternate alignments.
- Number and type of cross drainage structures, maximum flood level and natural ground water level along the probable routes.
- Sources of construction materials, water and location of stone quarries
- When the alignment passes through hill, additional details like type of rocks, dip of strata, seepage flow.

Preliminary Survey: this survey can be done either by Conventional approach or aerial survey if the area is more.

The main objectives of preliminary survey are:

- To survey the various alternate alignments proposed after the reconnaissance and to collect all the necessary physical information and details of topography, drainage and soil.
- To compare the different proposals in view of the requirements of a good alignment.
- To estimate quantity of earth work materials and other construction aspects and to work out the cost of alternate proposals.
- To finalise the best alignment from all consideration.

Final Location and Detailed survey:

- The alignment finalized at the design office after the preliminary survey is to be located on the field by establishing the centre line.
- The centre line of the road finalized is to be translated on the ground during the location survey
- The centre line stakes are driven at suitable intervals say 50 m in plain and rolling terrains and at 20 m in hilly terrain.
- Temporary bench marks are fixed at intervals of about 250 m and at all drainage and under pass structures.
- The levels are taken along longitudinal section and cross section at very 50 – 100 m intervals. The cross section should take at curves and where there is a gradient change.
- The data collected during the detailed survey should be elaborate and complete for preparation of detailed plans, design and estimate of the project.

Drawings and Reports

The following drawings are usually prepared in a highway projects

- Key map: Proposed and existing roads, important places
- Index Map : topography, size being 32 x 20 cm
- Preliminary survey plans : alternate alignment, other information
- Detailed plan : alignment, boundaries, counter intervals, A2 size sheet
- longitudinal section: Datum line, existing ground, vertical profile, scale 1 H: 10 V

- Detailed cross section: level at every 100 m interval
- Land acquisition plans; details of buildings, well, other details
- Drawing of cross drainage and other retaining structures: scale 1:1, structural details
- Drawings of road intersections: Intersection details and traffic flows
- Land plans showing quarries etc.

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, labour 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: preparation of sub grade, Construction of sub base, surface courses.
- Construction control: quality check during construction and test on pavement like unevenness, camber, super elevation, extra widening.

Necessity of Re-Alignment:

- Improvement of horizontal alignment design elements, such as radius, superelevation, transition curve, clearance on inner side of the curve of shifting the curve to provide adequate sight distance, elimination of reverse curve and undesirable zigzag.
- Improvement of vertical alignment design elements like steep gradients, changes in summit curves to increase sight distance, correction of undesirable undulations like humps.
- Raising the level of a portion of a road which is subjected to flooding, sub mergence or water-logging during monsoons.
- Re-construction of weak and narrow bridges and culverts and changes in water way at locations slightly away from the existing site.
- Construction of over bridges or under bridges at suitable locations across a railway line in place of level crossing or across another road to provide grade separated intersection.
- Re-alignment required due to a portion of road being submerged under water at the reservoir area on account of construction of a new dam.
- Construction of a bypass to avoid the road running through a town or city
- Defence requirement.

Steps in Re Alignment

- Reconnaissance of the stretch of road to be re-aligned, study of the deficiency and possible changes in alignment.
- Survey of existing road recording the topographic features and all other existing features including drainage conditions along a strip of land on either side of the road.
- Observation of spot level along the centre line of the road and cross section levels at suitable intervals.
- Soil survey along the stretches of land through which the re-aligned road may possibly pass.
- Comparison of economics and feasibility of alternate proposal of realignment.
- 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

2.4 Cross sectional elements

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:** 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.
- **Topography:** It is easier to construct roads with required standards for a plain terrain. However, for a given design speed, the construction cost increases multi form with the gradient and the terrain.
- **Traffic factors:** It is of crucial importance in highway design, is the traffic data both current and future estimates. Traffic volume indicates the level of services (LOS) for which the highway is being planned and directly affects the geometric features such as width, alignment, grades etc., without traffic data it is very difficult to design any highway.
- **Design Hourly Volume and Capacity:** The general unit for measuring traffic on highway is the Annual Average Daily Traffic volume, abbreviated as AADT. The traffic flow (or) volume keeps fluctuating with time, from a low value during off peak hours to the highest value during the peak hour. It will be uneconomical to design the roadway facilities for the peak traffic flow.
- **Environmental and other factors:** The environmental factors like air pollution, noise pollution, landscaping, aesthetics and other global conditions should be given due considerations in the geometric design of roads.

Highway cross section elements:

Unevenness:

It is always desirable to have an even surface, but it is seldom possible to have such a one. Even if a road is constructed with high quality pavers, it is possible to develop

unevenness due to pavement failures. It affects the vehicle operating cost, speed, riding comfort, safety, fuel consumption and wear and tear of tires.

Unevenness index is a measure of unevenness which is the cumulative measure of vertical undulation of the pavement surface recorded per unit horizontal length of the road. An unevenness index value less than 1500mm/km is considered as good, a value less than 2500 mm/km is satisfactory up to speed of 100 kmph and values greater than 3500 mm/km is considered as uncomfortable even for 50 kmph.

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 affects the acceleration and deceleration ability of vehicles. Lack of adequate friction can cause skidding or slipping of vehicles.

Factors affecting friction or skid resistance:

The maximum friction offered by pavement surface or the skid resistance depends upon the following factors,

- Types of surface namely cement concrete, bituminous, WBM, earth surface.
- Condition of pavement namely wet or dry, smoothened or rough, mud or dry sand on pavement.
- Type and condition of tyre i.e. new with good treads or smoothened and worn out 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. The width of this acquired land is known as land width and it depends on the importance of the road and possible future development.

- 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.

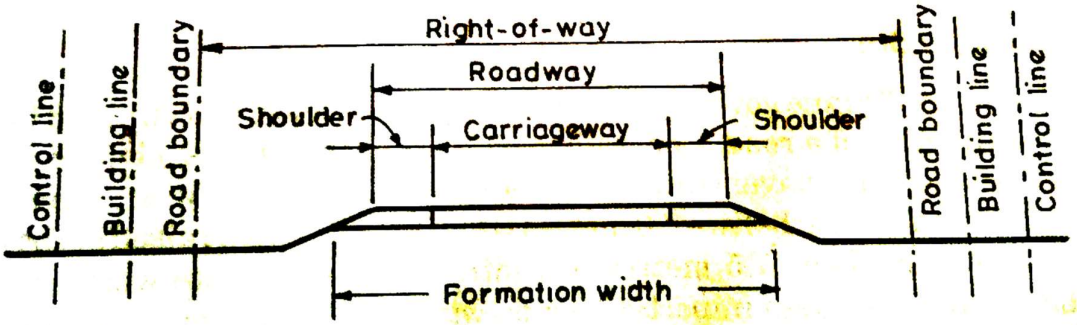


Fig. 6.18. Right-of-way, building line and control line.

The right of way for various roads according to IRC are given below

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:

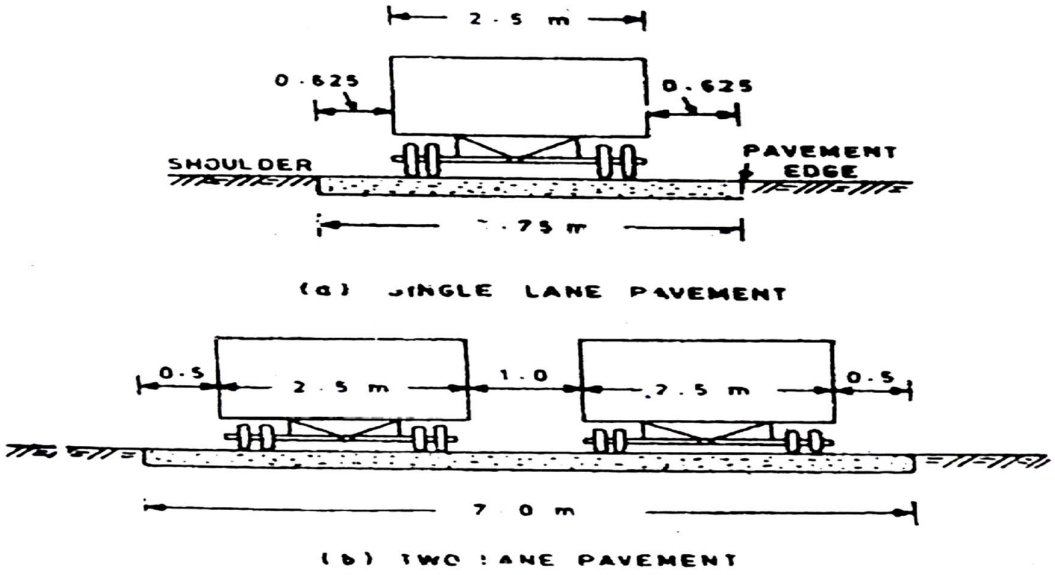
Carriage way or the width of the pavement depends on the width of the traffic lane and number of lanes. Width of a traffic lane depends on the width of the vehicle and the clearance. Side clearance improves operating speed and safety. The maximum permissible width of a vehicle is 2.50 and the desirable side clearance or single lane traffic is 0.625 m.

The number of lanes required in a highway depends on the predicted traffic or the design traffic volume and the desired level of service.

The width of carriageway for various roads according to IRC are given below

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



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. 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% (Eg. 1 in 50 or2%) and the value depends on the type of pavement surface.

Recommended values of camber for different types of road surface by IRC are as follows

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. Formation or roadway width is the top width of the highway embankment or the bottom width of highway cutting excluding the side drains. Recommended values of roadway or formation for different types of road surface by IRC are as follows

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

Typical cross-sections:

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

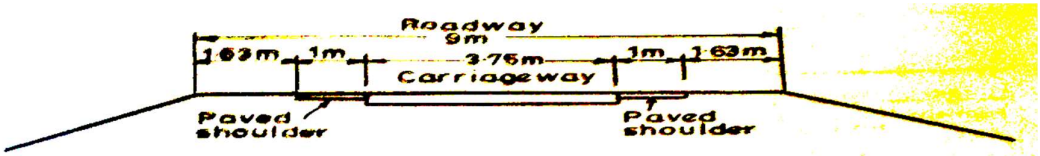


Fig. 6.23. Typical single lane road with paved shoulders. (Major District Road or Other Dist. Road)

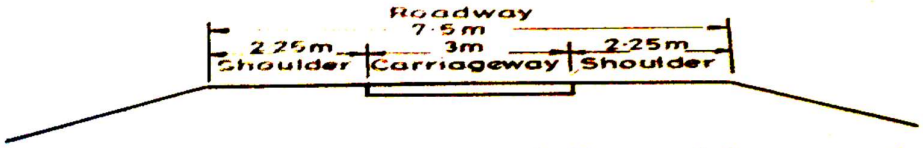


Fig. 6.24. Typical village road.

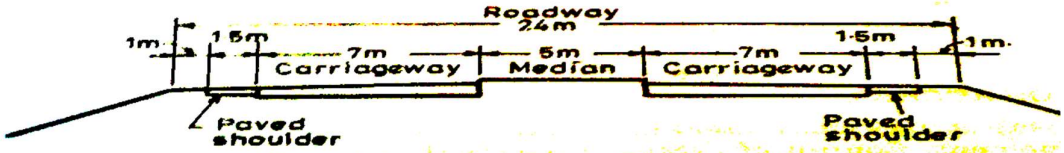


Fig. 6.25. Typical dual carriageway (2 lane each) in rural areas.

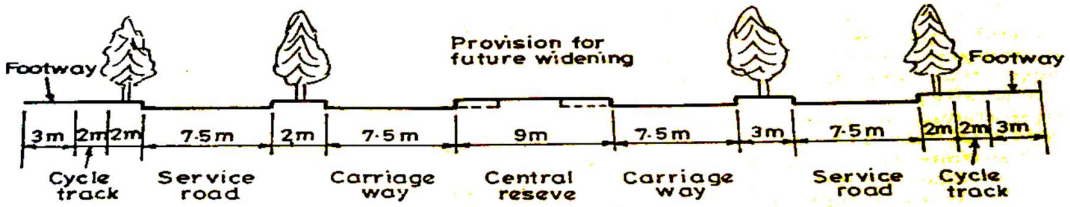


Fig. 6.26. Urban arterial street.

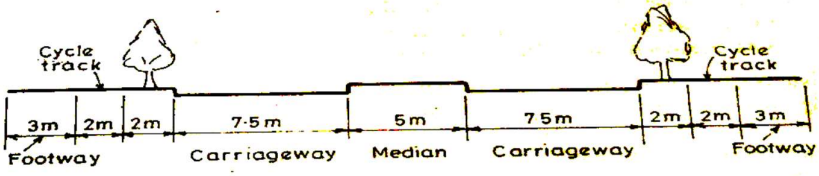


Fig. 6.27. Urban sub-arterial street through open area.

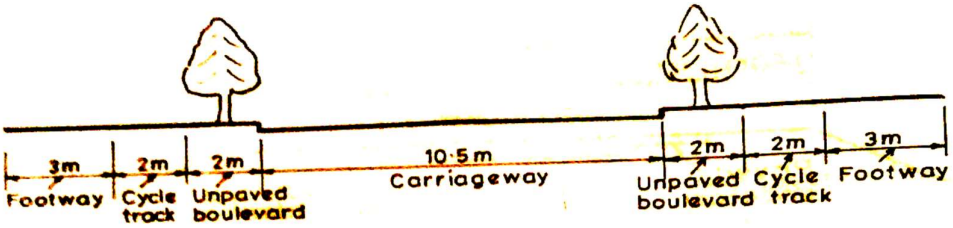


Fig. 6.28. Urban collector street through residential area.

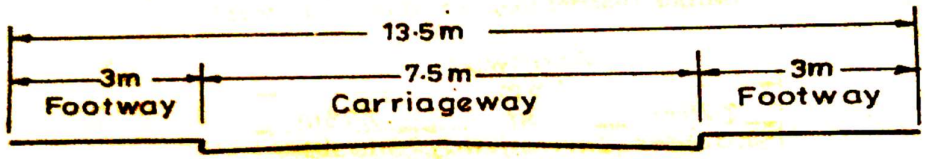


Fig. 6.29. Urban residential street.

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

- **Low or mountable kerbs:** These types 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. This is usually provided at medians and channelization schemes and also helps in longitudinal drainage.
- **Semi-barrier type kerbs**: When the pedestrian traffic is high, these kerbs are provided. Their height is 15 cm above the pavement edge. This type of kerb prevents encroachment of parking vehicles, but at acute emergency it is possible to drive over this kerb with some difficulty.
- **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.

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**: Shoulders are provided along the road edge and is intended for accommodation of stopped vehicles, serve as an emergency lane for vehicles and provide lateral support for base and surface courses. The shoulder should be strong enough to bear the weight of a fully loaded truck even in wet conditions. The shoulder width should be adequate for giving working space around a stopped vehicle. It is desirable to have a width of 4.6 m for the shoulders. A minimum shoulder width recommended by the IRC is 2.5 m.
- **Parking lanes:** Parking lanes are provided in urban lanes for side parking. Parallel parking is preferred because it is safe for the vehicles moving on the road. The parking lane should have a minimum of 3.0 m width in the case of parallel parking.
- **Bus-bays:** Bus bays are provided by recessing the kerbs for bus stops. They are provided so that they do not obstruct the movement of vehicles in the carriage way. They should be at least 75 meters away from the intersection.
- **Service roads:** Service roads or frontage roads give access to access controlled highways like freeways and expressways. They run parallel to the highway and will be usually isolated by a separator and access to the highway will be provided only at selected points. These roads are provided to avoid congestion in the expressways and also the speed of the track in those lanes is not reduced.
- **Cycle track:** Cycle tracks are provided in urban areas when the volume of cycle track is high Minimum width of 2 meter is required, which may be increased by 1 meter for every additional track.
- **Footpath:** Footpaths are exclusive right of way to pedestrians, especially in urban areas. They are provided for the safety of the pedestrians when both the pedestrian track and vehicular track is high. Minimum width is 1.5 meter and may be increased based on the track. The footpath should be either as smooth as the pavement or smoother than that to induce the pedestrian to use the footpath.
- **Guard rails:** They are provided at the edge of the shoulder usually when the road is on an embankment. They serve to prevent the vehicles from running o the embankment, especially when the height of the fill exceeds 3 m. various designs of guard rails are there. Guard stones painted in alternate black and white are usually used. They also give better visibility of curves at night under headlights of vehicles.

2.5 Sight distances

Visibility is very important for safe vehicle operation on a highway. Restrictions to sight distance may be caused at horizontal curves, by objects obstructing vision at the inner side of the road or at vertical summit curves or at intersections.

Three sight distance situations are considered in the design,

1. Stopping or absolute minimum sight distance
2. Safe overtaking or passing sight distance
3. 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.

Factors affecting sight distance:

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 it could be understood that 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 tire and the road: The frictional resistance between the tire 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 that case.

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.

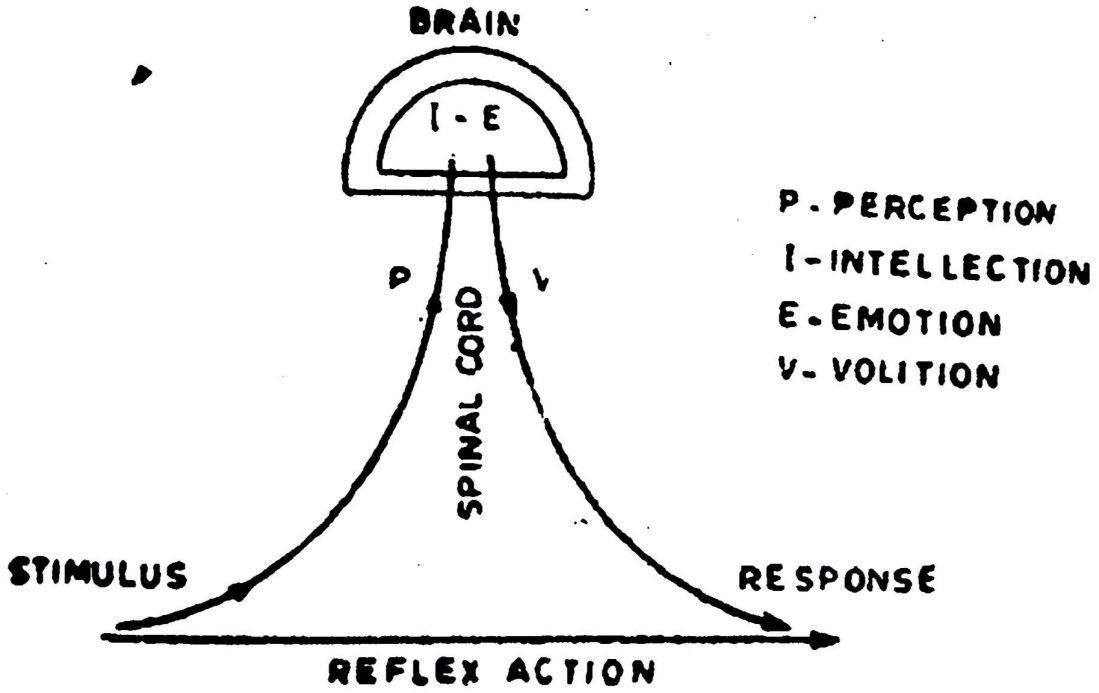
- Perception
- Intellection
- Emotion
- Volition (final action)

Perception time is the time required for the sensations received by eyes or ears to be transmitted to the brain through nervous system and the spinal cord.

Intellection time is the time required for understanding the situation. It is also the time required for comparing the different thoughts, regrouping and registering new sensations.

Emotion time is the time elapsed during emotional sensations and disturbance such as fear, anger or any other emotional feelings such as superstition etc.

Volition time is the time taken for the final action.



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 sec under normal conditions. However taking into consideration the variability of driver characteristics, a higher value is normally used in design. For example, IRC suggests a reaction time of 2.5 sec.

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.

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;

Speed, kmph	Maximum overtaking acceleration	
	A, kmph / sec	a, m/s^2
25	5.00	1.41
30	4.80	1.30
40	4.45	1.24
50	4.00	1.11
65	3.28	0.92
80	2.56	0.72
100	1.92	0.53

Horizontal alignment:

Design speed: The design speed is the main factor on which geometric elements depends. 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. This transverse inclination to the pavement surface is known as super elevation or cant or banking.

Widening of pavement on horizontal curve:

On horizontal curves, especially when they are not of very large radii, it is common to widen the pavement slightly more than the normal width. The extra widening of pavement on horizontal curves is divided into two parts,

Mechanical widening: The widening required to account for the off-tracking due to the rigidity of wheel based is called mechanical widening.

Psychological widening: Extra width of pavement is also provided for psychological reasons such as, to provide for greater manoeuvrability of steering at higher speeds, to allow for the extra space requirements for the overhangs of vehicles and to provide greater clearance for crossing and overtaking vehicles on the curves. Psychological widening is therefore important in pavements with more than one lane.

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

Ruling gradient:

The ruling gradient or the design gradient is the maximum gradient with which the designer attempts to design the vertical profile of the road. This depends on the terrain, length of the grade, speed, pulling power of the vehicle and the presence of the horizontal

curve. The ruling gradient is adopted by the designer by considering a particular speed as the design speed and for a design vehicle with standard dimensions.

The IRC recommended ruling gradient vales of 1 in 30 0n plain and rolling terrain, 1 in 20 on mountainous terrain and 1 in 16.7 on steep terrain.

Limiting gradient:

This gradient is adopted when the ruling gradient results in enormous increase in cost of construction. On rolling terrain and hilly terrain it may be frequently necessary to adopt limiting gradient. But the length of the limiting gradient stretches should be limited and must be sandwiched by either straight roads or easier grades.

Exceptional gradient:

Exceptional gradient are very steeper gradients given at unavoidable situations. They should be limited for short stretches not exceeding about 100 meters at a stretch. In mountainous and steep terrain, successive exceptional gradients must be separated by a minimum 100 metre length gentler gradient. At hairpin bends, the gradient is restricted to 2.5%.

Minimum gradient:

This is important only at locations where surface drainage is important. Camber will take care of the lateral drainage. But the longitudinal drainage along the side drains requires some slope for smooth flow of water. Therefore minimum gradient is provided for drainage purpose and it depends on the rain fall, type of soil and other site conditions. A minimum of 1 in 500 may be sufficient for concrete drain and 1 in 200 for open soil drains is found to give satisfactory.

Vertical curves:

Due to changes in grade in the vertical alignment of highway, it is necessary to introduce vertical curve at the intersection of different grades to smoothen out the vertical profile and thus ease off the changes in gradients for the fast moving vehicles.

The vertical curves used in highway may be classified into two categories

1. Summit curves or crest curves with convexity upwards
2. Valley or sag curves with concavity upwards

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. $N = n_1 - (-n_2) = (n_1 + n_2)$

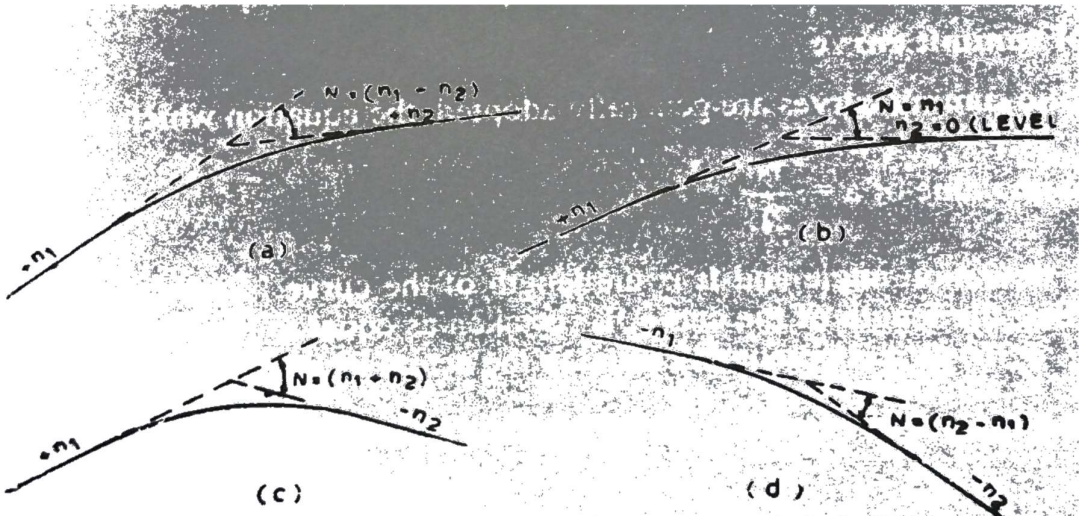


Fig. 4.35 Summit Curves

Valley curve:

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

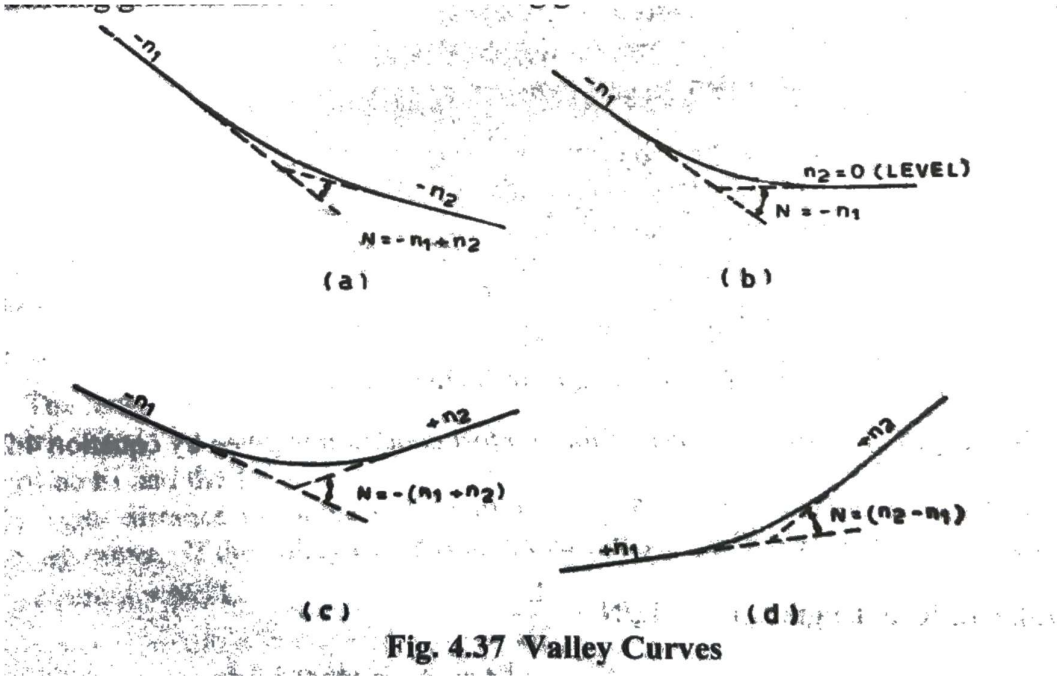


Fig. 4.37 Valley Curves

2.6 Recommended questions

1. Write a note on carriage way, right of way and camber with sketches.
2. Calculate the SSD on a level road stretch for design speed of 50kmph for (a) 2-way traffic on 2-lane road (b) 2-way traffic on a single lane road. Values of f = 0.37 and t = 2.5 sec
3. Write a note on skid, road margins and roadway.
4. The area of a certain district in India 80000 sq. km and there are 86 towns as per 1981 census. Determine length of different categories of roads consisting of ODR and VR to be achieved by the year 2001

2.7 Outcomes

Acquire the capability of proposing a new alignment or re-alignment of existing roads, conduct necessary field investigation for generation of required data.

2.8 Further Reading

1. http://nptel.ac.in/courses/105101087/downloads/Lec-13.pdf
2. http://transportationengineering2012onwards.blogspot.in/2013/09/engineering-surveys-and-location-of.html
3. http://nptel.ac.in/courses/105101087/downloads/Lec-12.pdf
4. https://www.civilengineeringnews.tk/2014/09/highway-alignment.html