CE 308: TRANSPORTATION ENGINEERNG - I

MODULE -1

INTRODUCTION

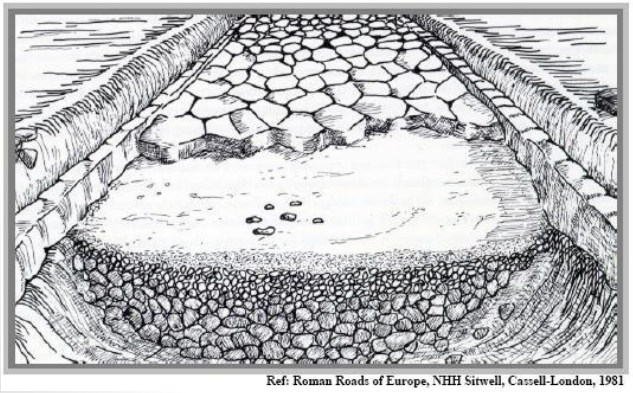
- Transportation engineering is the application of technology and scientific principles to the planning, functional design, operation and management of facilities for any mode of transportation in order to provide for the safe, efficient, rapid, comfortable, convenient, economical, and environmentally compatible movement of people and goods from one place to other.

- **MODES OF TRANSPORTATION**
  - Basic mode of transportation are
  - Land
    - Roadway
    - Railway
  - Water
  - Air

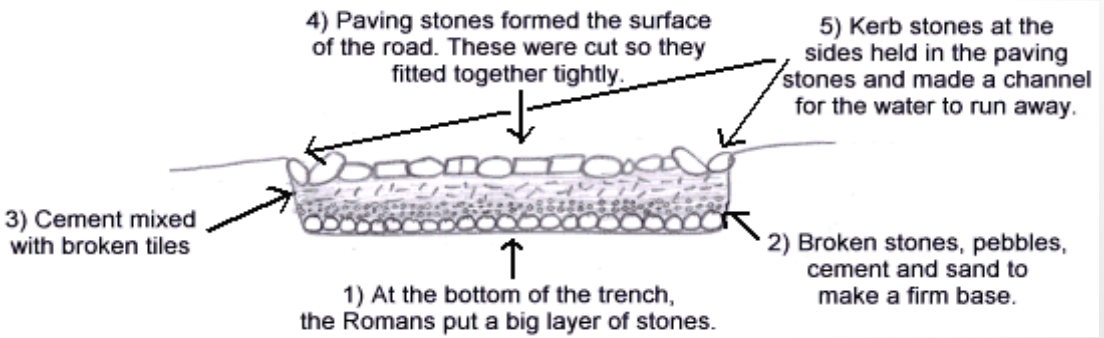
- **ROLE /IMPACT OF TRANSPORTATION**
  - Economic Development
  - Social Development
  - Spatial Development
  - Cultural Development
  - Political Development

HISTORICAL DEVELOPMENT OF ROAD CONSTRUCTION

- Oldest mode -Foot paths-animal ways, cart path etc..
- As civilization evolved the need for transportation increased
- **ROMAN ROAD-(500 B.C.)**
- They were built straight regardless of gradient
- They were built after the soft soil was removed and a hard stratum was reached.
- Thickness varies from 0.75 m to 1.2m



Ref: Roman Roads of Europe, NHH Sitwell, Cassell-London, 1981



- Other oldest road transport are
  - Tresaguet construction
  - Metcalf construction
  - Telford construction
  - Mecadam construction

Highway Development in India

- JayakarCommittee (1927)
- Central Road Fund (1929)
- Indian Roads Congress (IRC), 1934
- Central Road Research Institute (CRRI), 1950
- Motor vehicle act (1936)
- National Highway Authority of India (NHAI),1995
- First twenty year road plan (1943-61)
- Second twenty year road plan (1961-81)
- Highway Research board (1973)
- National Transport Policy committee (1978)
- Third twenty year road plan (1981-2001)

JayakarCommittee,1927

- After the first World War, motor vehicle using the roads increases, this demanded a better road network.
- In 1927,Indian road development committee was appointed by the government with M.R. Jaykar as chairman.
- Road development in the country should be made as a national interest since local govt. do not have financial and technical capacity for road development.
- An extra tax should be levied on petrol from road users to create the road development fund.
- To establish a semi-official technical institution to pool technical knowledge, sharing of ideas and to act as an advisory body.
- To create a national level institution to carry research , development works and consultation.

Central road fund

- It was formed on 1st march 1929
- The consumers of petrol were charged an extra leavy of 2.64 paisa per litre of petrol to built up this road development fund.
- From this 20% of annual revenue is to be retain as a central revenue for research and experimental work expenses..etc
- Balance 80% is allowed by central govt. to various states based on actual petrol consumption or revenue collected.

Indian Roads Congress, 1934

- Central semi official body known as IRC was formed in 1934.
- To provide national forum for regular pooling of experience and ideas on matters related to construction and maintenance of highways.
- It is a active body controlling the specification, standardization and recommendations on materials, design of roads and bridges.
- It publishes journals, research publications and standard specifications guide lines.
- To provide a platform for expression of professional opinion on matters relating to roads and road transport.

Motor Vehicle Act

- It was formed in 1939
- To regulate the road traffic in the form of traffic laws, ordinances and regulations.
- Three phases primarily covered are control of driver, vehicle ownership and vehicle operation
- It was revised on 1988

Central road research institute(1950)

- Engaged in carrying out research and development projects.
- Design, construction and maintenance of roads and runways, traffic and transportation planning of mega and medium cities, management of roads in different terrains,
- Improvement of marginal materials.
- Utilization of industrial waste in road construction.
- Land slide control.
- Ground improvements, environmental pollution.
- Road traffic safety.

Ministry of Road Transport & Highways

- Planning, development and maintenance of National Highways in the country.
- Extends technical and financial support to State Governments for the development of state roads and the roads of inter-state connectivity and economic importance.
- Evolves standard specifications for roads and bridges in the country.
- It stores the data related to technical knowledge on roads and bridges.

Highway Research Board

- To ascertain the nature and extent of research required
- To correlate research information from various organisation in India and abroad.
- To collect and correlation services.
- To collect result on research
- To channelise consultative services

First 20–years road plan(1943–63)

- The conference of chief engineer held at Nagpur in 1943 finalized the first 20-years road development plan for India called Nagpur road plan
- Road network was classified into five categories.
- The responsibility of construction maintenance of NH was assign to central govt.
- The target road length was 5,32,700 km at the end of 1961.
- Density of about 16 km of road length per 100 sq.km area would be available in the country by the year 1963.

- The formulae were based on standard grid pattern of road network.
- An allowance of 15% is provided for agricultural industrial development during the next20-years
- The length of railway track in the area was also consider in deciding the length of first category road. The length or railway track is directly subtracted from the estimated road length of metalledroads.

Second 20–years road plan(1961–81)

- It was initiated by the IRC and was finalised in 1959 at the meeting of chief engineers.
- It is known as the Bombay road plan.
- The target road length was almost double that of Nagpur road plan i.e. 10,57,330 km.
- Density about 32 km per 100 sq. km. and an outlay of 5200 crores
- Every town with population above 2000 in plans and above 1000 in semi hill area and above 500 in hilly area should be connected by metalled road

- The maximum distance from any place in a semi develop area would be 12.8 km from metalled road and 4.8 from any road
- Expressways have also been considered in this plan and 1600 km of length has been included in the proposed target NH
- Length of railway track is considered independent of road system
- 5% are to be provided for future development and unforeseen factor

Third twenty years road plan (1981–2001)

- The future road development should be based on the revised classification of roads system i.e. primary, secondary and tertiary
- Develop the rural economy and small towns with all essential features.
- Population over 500 should be connected by all weather roads.
- Density increases to 82 km per 100sq.km
- The NH network should be expanded to form a square grids of 100 km sides so that no part of the country is more than 50 km away from the NH

- Express way should be constructed along major traffic corridors
- All towns and villages with population over 1500 should be connected by MDR and villages with population 1000-1500 by ODR.
- Road should be built in less industrialized areas to attract the growth of industries
- The existing roads should be improved by rectifying the defects in the road geometry, widening, riding quality and strengthening the existing pavement to save vehicle operation cost and thus to conserve energy

Classification of Highways

- Depending on weather
  - All weather roads
  - Fair weather roads
- Depending the type of Carriage way
  - Paved roads(WBM)
  - Unpaved roads(earth road or gravel road)
- Depending upon the pavement surface
  - Surfaced roads(bituminous or cement concrete road)
  - Un surfaced roads

- Based on the Traffic Volume
  - Heavy
  - Medium
  - Light
- Based on Load or Tonnage
  - Class 1 or Class 2 etc or Class A , B etc Tonnes per day
- Based on location and function (Nagpur road plan)
  - National highway (NH)
  - State highway (SH)
  - Major district road (MDR)
  - Other district road (ODR)
  - Village road (VR)

Based on modified system of Highways classification

- Primary
  - Expressways
  - National Highways
- Secondary
  - Sate Highways (SH)
  - Major District Roads (MDR)
- Tertiary
  - Other District roads (ODR)
  - Village roads (VR)

- Expressways
  - Heavy traffic at high speed (120km/hr)
  - Land Width (90m)
  - Full access control
  - Connects major points of traffic generation
  - No slow moving traffic allowed
  - No loading, unloading, parking.

Mumbai –Pune
Express highway

- National Highways
- NH are the main highways running through the length and breadth of India, connecting major parts, foreign highways, capital of large states and large industrial and tourist centres including roads required for strategic movements for the defence of India.
- The national highways have a total length of 70,548kms. Indian highways cover 2% of the total road network of India and carry 40% of the total traffic.
- The highway connecting Delhi-Ambala-Amritsar is denoted as NH-1, whereas a bifurcation of this highway beyond Jalandar to Srinagar and Uri is denoted NH-1-A

- The longest highway in India is NH7 which stretches from Varansi in UttarPradesh to Kanyakumari in the southern most point of Indian main land.
- The shortest highway is NH 47 A which stretches from Ernamkulam to Kochi and covers total length of 4 Kms.
- **Golden Quadrilateral –(5,846 Kms) connecting Delhi-Kolkata-Chennai-Mumbai**
- NH-2 Delhi-Kol(1453 km)
- NH 4,7&46 Che-Mum (1290km)
- NH5&6 Kol-Che(1684 m)
- NH 8 Del-Mum (1419 km)

- State Highways
- They are the arterial roads of a state, connecting up with the national highways of adjacent states, district head quarters and important cities within the state.
- Total length of all SH in the country is 1,37,119 Kms.
- Speed 80 kmph

- **Major District Roads**
- Important roads with in a district serving areas of production and markets, connecting those with each other or with the major highways.
- India has a total of 4,70,000 kms of MDR.
- Speed 60-80kmph
- **Other district roads**
- Serving rural areas of production and providing them with outlet to market centers or other important roads like MDR or SH.
- Speed 50-60 kmph
- **Village roads**
- They are roads connecting villages or group of villages with each other or to the nearest road of a higher category like ODR or MDR.
- India has 26,50,000 kms of ODR+VR out of the total 33,15,231kms of all type of roads
- Speed-40-50kmph

Urban Road Classification

- Arterial Roads
- Sub Arterial
- Collector
- Local Street
- Cul-de-sac
- Pathway
- Driveway

- ARTERIAL
- No frontage access, no standing vehicle, very little cross traffic.
- Design Speed : 80km/hr
- Land width : 50 –60m
- Divided roads with full or partial parking
- Pedestrian allowed to walk only at intersection

- SUB ARTERIAL ROAD
- Bus stops but no standing vehicle.
- Less mobility than arterial.
- Spacing for CBD : 0.5km
- Design speed : 60 km/hr
- Land width : 30 –40 m

- **Collector Street**
- Collects and distributes traffic from local streets
- Provides access to arterial roads
- Located in residential, business and industrial areas.
- Full access allowed.
- Parking permitted.
- Design speed : 50km/hr
- Land Width : 20-30m

- **Local Street**
- Design Speed : 30km/hr.
- Land Width : 10 –20m.
- Primary access to residence, business or other abutting property
- Less volume of traffic at slow speed
- Unrestricted parking, pedestrian movements. (with frontage access, parked vehicle, bus stops and no waiting restrictions)

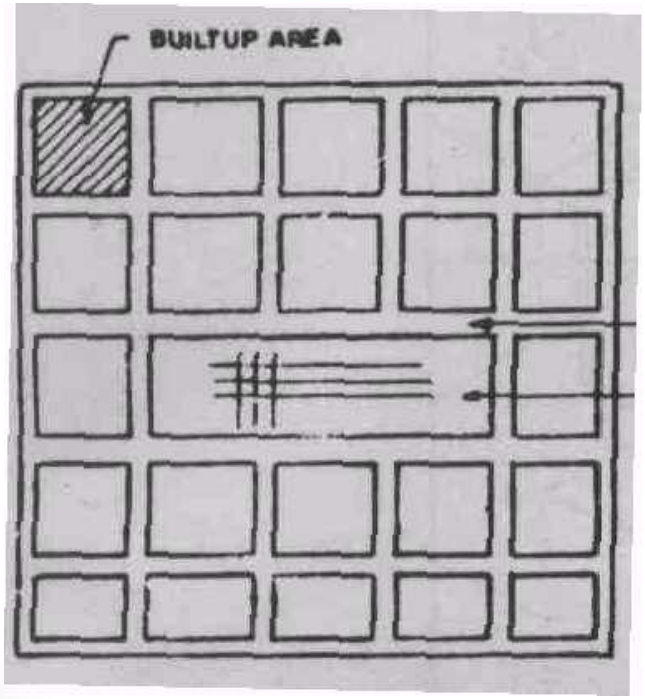
- **CUL–DE-SAC**
- Dead End Street with only one entry access for entry and exit.
- Recommended in Residential areas

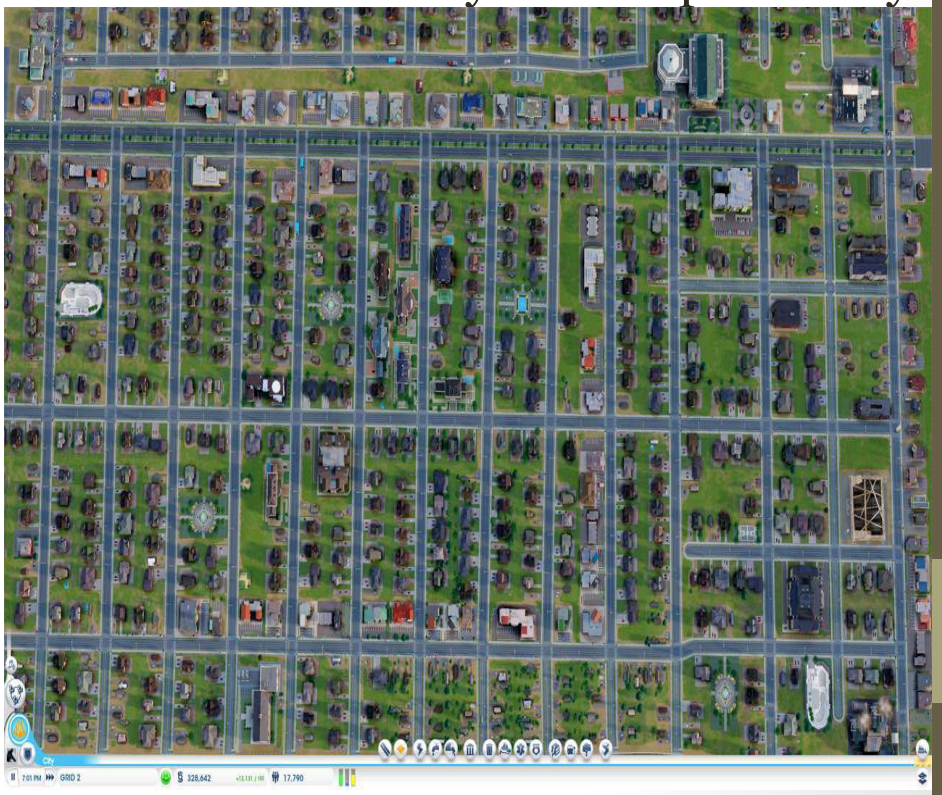
Cul de Sac

- **Driveway**
- A driveway is a type of private road for local access to one or a small group of structures, and is owned and maintained by an individual or group.
- Driveways are commonly used as paths to private garages, fuel stations, or houses

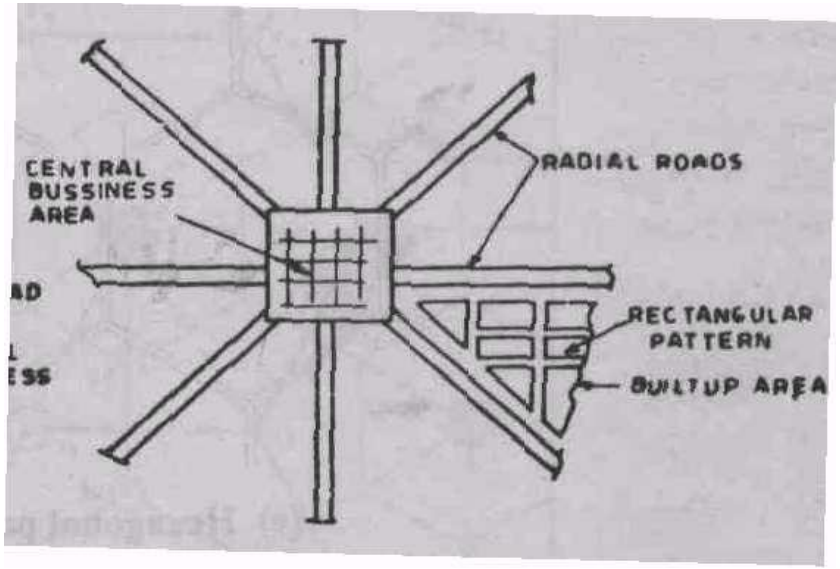
- **Road Patterns**
- Rectangular or Block patterns
- Radial or Star block pattern
- Radial or Star Circular pattern
- Radial or Star grid pattern
- Hexagonal Pattern

- Rectangular or Block patterns
- The whole area is divided into rectangular blocks of plots, with streets intersecting at right angles.
- The main road which passes through the center of the area should be sufficiently wide and other branch roads may be comparatively narrow

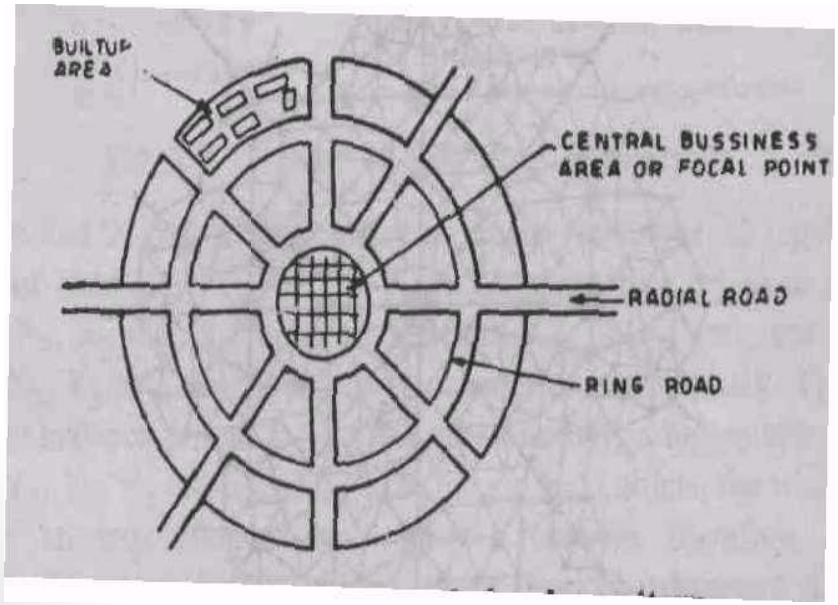




- Radial or Star block pattern
- In this pattern, the entire area is divided into a network of roads radiating from the business outwardly.
- In between radiating main roads, the built-up area may be planned with rectangular block.

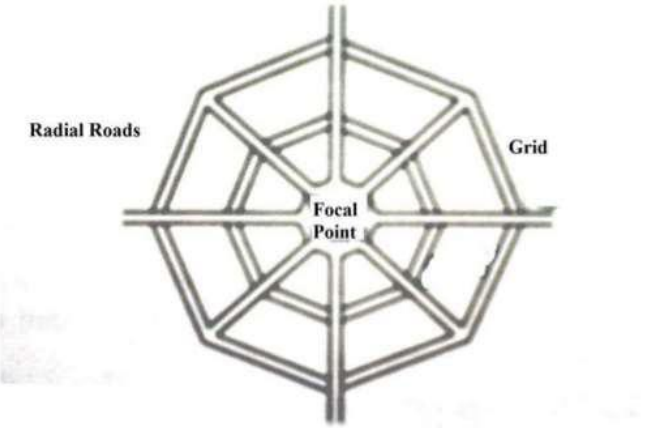


- Radial or Star Circular pattern
- In this system, the main radial roads radiating from central business area are connected together with concentric roads.
- In these areas, boundary by adjacent radial roads and corresponding circular roads, the built-up area is planned with a curved block system



- Radial or Star grid pattern
- Keep vehicular traffic safe.
- Improve traffic flow in both directions using cellular structure.
- Improve land use efficiency and unit density.
- The Nagpur road plan formulae were prepared on the assumption of Grid pattern.

Radial (Star) and Grid Pattern



- Hexagonal Pattern

Typical Cross Section Of Roads

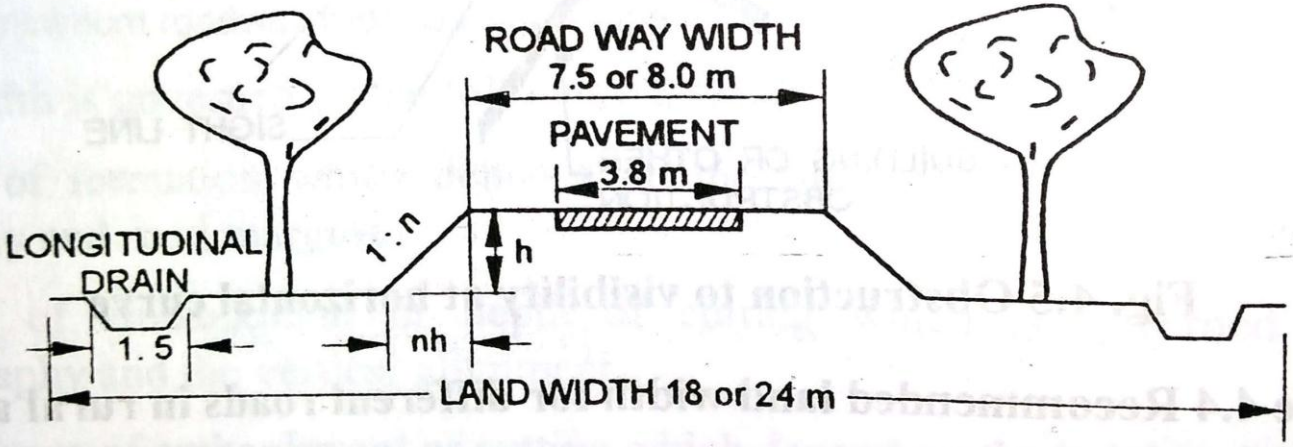


Fig. 4.6 Cross section of VR or ODR in embankment in rural area

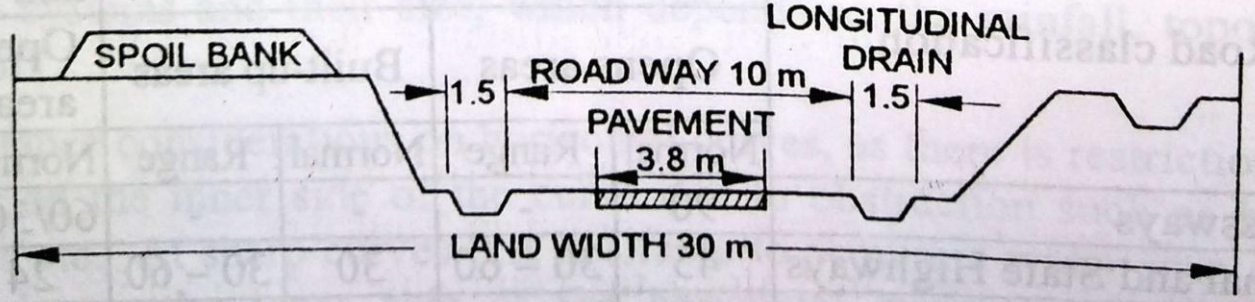


Fig. 4.7 Cross section of MDR in cutting in rural area

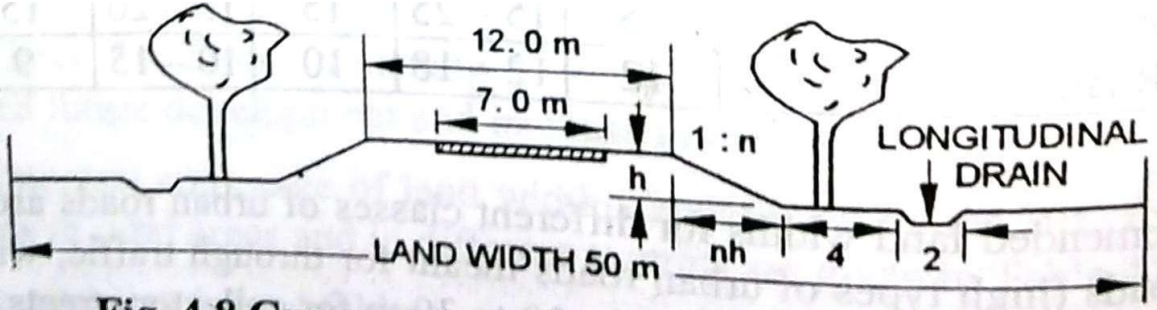


Fig. 4.8 Cross section of NH or SH in rural area

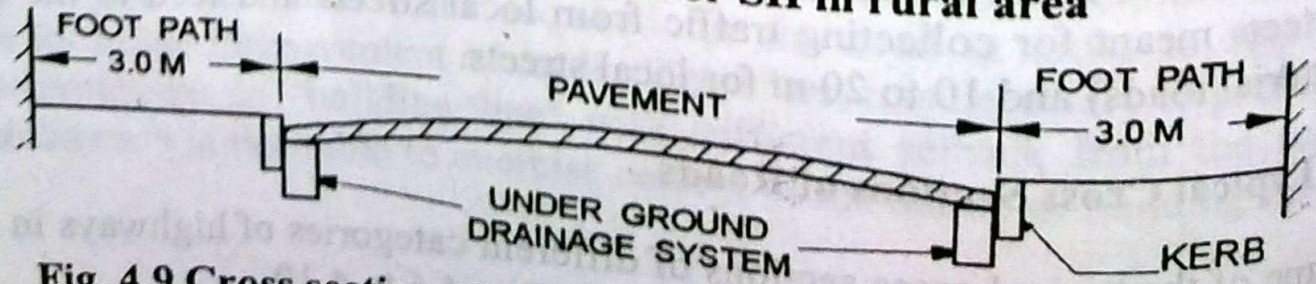


Fig. 4.9 Cross section of two-lane city road in built-up area

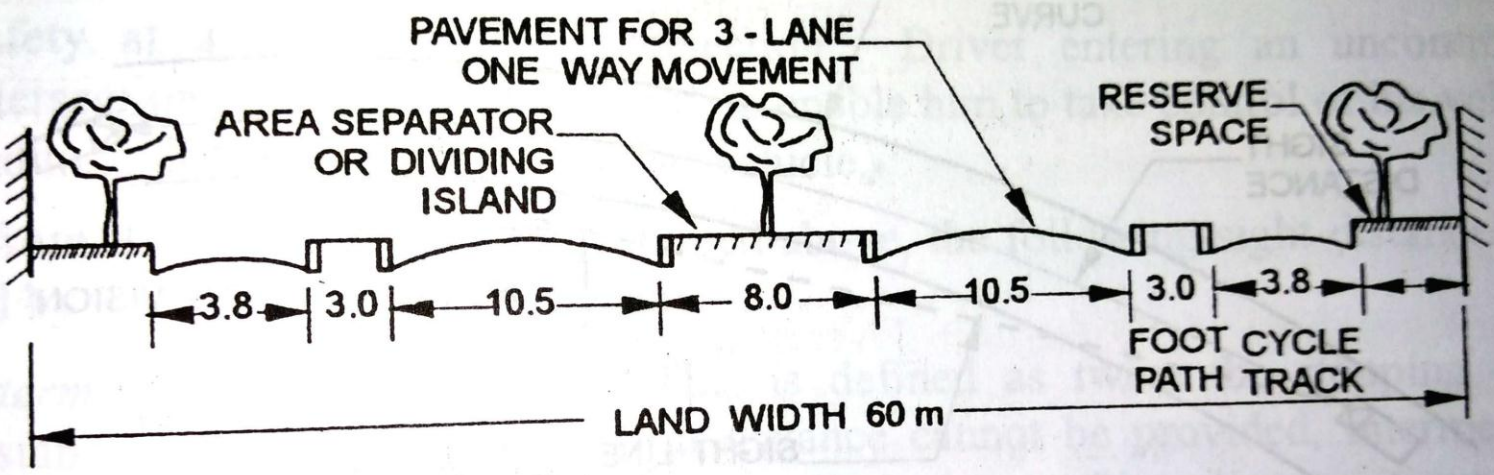


Fig. 4.10 Cross section of divided highway in urban area

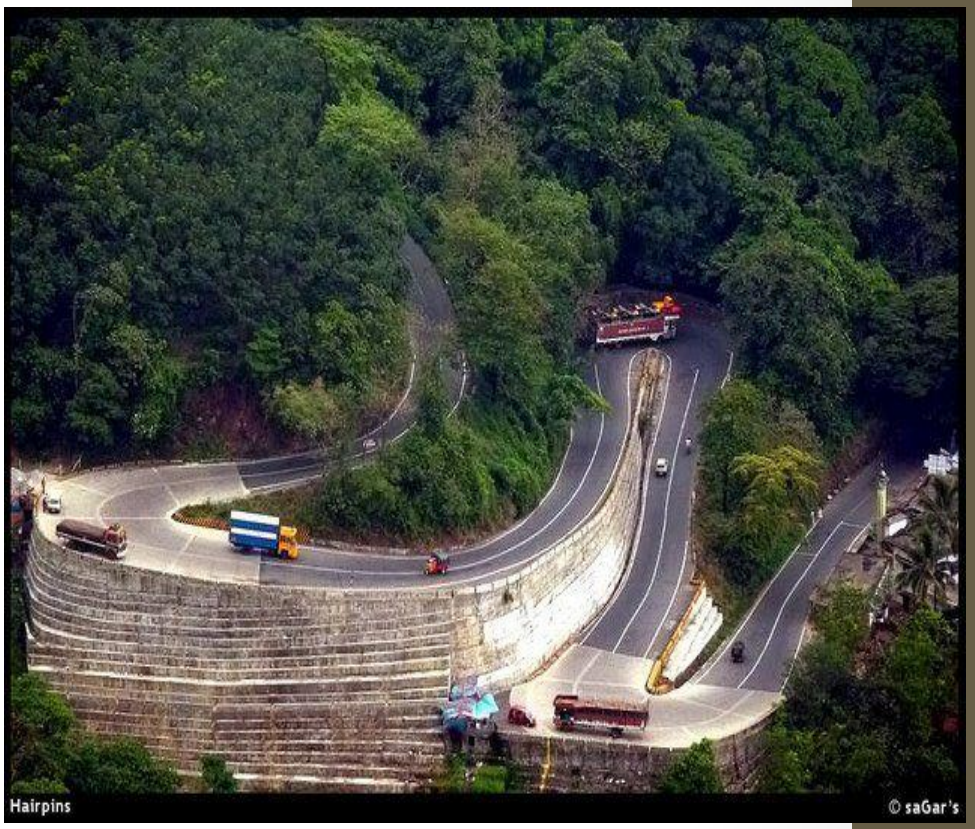
Table 4.5 Recommended standards for building lines and control lines

Road classification	Plain and rolling terrain			Mountainous and steep terrain	
	Open area		Built-up	Distance between building line and road boundary (set back), m	
	Overall width between building lines, m	Overall width between control lines, m	Distance between building line and road boundary (set-back), m	Open areas	Built-up areas
Expressways	110	130	5	5	5
N.H. & S.H.	80	150	3 to 6	3 to 5	3 to 5
M.D.R.	50	100	3 to 5	3 to 5	3 to 5
O.D.R.	25/30*	35	3 to 5	3 to 5	3 to 5
V.R.	25	30	3 to 5	3 to 5	3 to 5

Note: *If the land width is equal to the width between building lines indicated in this column, the building lines should be set back 2.5 m from the road land boundary.

Highway alignment

- The position or lay out of centre line of the highway on the ground is called the alignment.
- It includes straight path, horizontal deviation and curves.
- Due to improper alignment ,the disadvantages are,
  - Increase in construction
  - Increase in maintenance cost
  - Increase in vehicle operation cost
  - Increase in accident cost
- Once the road is aligned and constructed, it is not easy to change the alignment due to increase in cost of adjoining land and construction of costly structure.


Hairpins
© saGar's

Requirements

- Short - Desirable to have a short alignment between two terminal stations.
- Easy – Easy to construct and maintain the road with minimum problem also easy for operation of vehicle.
- Safe - Safe enough for construction and maintenance from the view point of stability of natural hill slope, embankment and cut slope also safe for traffic operation.
- Economical - Total cost including initial cost, maintenance cost and vehicle operation cost should be minimum.

Factors controlling alignment

- Obligatory points
- Traffic
- Geometric design
- Economics
- Other considerations
- **Additional care in hill roads**
  - Stability
  - Drainage
  - Geometric standards of hill roads
  - Resisting length

- Obligatory points
- These are control points governing the alignment of highways. These may be divided into 2 categories:
- ***Obligatory points through which alignment has to pass***
- Examples:-bridge site, intermediate town , Mountain pass etc…
- **Obligatory points through which alignment should not pass**.
- Examples:-religious places, costly structure, unsuitable land etc…
- Traffic
- Road alignment should be decided based on the requirements of road traffic.
- Origin and destination survey should be carried out in the area and the desire lines be drawn showing the trend of traffic flow.
- New road to be aligned should keep in view the desired lines, traffic flow patterns and future trends.

- Geometric design
- Design factors such as gradient ,radius of curve and sight distance also govern the final alignment of the highway.
- Gradient should be flat and less than the ruling gradient or design gradient.
- Avoid sudden changes in sight distance, especially near crossings
- Avoid sharp horizontal curves
- Avoid road intersections near bend
- Economy
- Alignment finalised based on total cost including initial cost, maintenance cost and vehicle operation cost.

- Other consideration
- Drainage consideration, political consideration
- Surface water level, high flood level
- Environmental consideration
- **Topographical control points**
- The alignment, where possible should avoid passing through
  - Marshy and low lying land with poor drainage
  - Flood prone areas
  - Unstable hilly features

- Materials and constructional features
- Deep cutting should be avoided
- Earth work is to be balanced; quantities for filling and excavation
- Alignment should preferably be through better soil area to minimize pavement thickness
- Location may be near sources of embankment and pavement materials

Special Considerations

- **Stability**
- A common problem in hilly roads is land sliding
- The cutting and filling of the earth to construct the roads on hilly sides causes steepening of existing slope and affect its stability.
- **Drainage**
- Avoid the cross drainage structure
- The number of cross drainage structure should be minimum.
- **Geometric standard of hilly road**
- Gradient, curve and speed
- Sight distance, radius of curve
- **Resisting length**
- The total work to be done to move the loads along the route taking horizontal length, the actual difference in level between two stations and the sum of the ineffective rise and fall in excess of floating gradient. Should kept as low as possible.

Engineering Surveys for Highway locations

- Before a highway alignment is finalised in highway project, the engineering survey are to be carried out.
- The various stages of engineering surveys are
- Map study (Provisional alignment Identification)
- Reconnaissance survey
- Preliminary survey
- Final location and detailed surveys

- **MAP STUDY**
- From the map likely and alternative routes can be suggested from the office, if the topographic map of that area is available.
- The probable alignment can be located on the map from the following details available on the map.
  - Avoiding valleys, ponds or lake
  - Avoiding bend of river
  - If road has to cross a row of hills, possibility of crossing through mountain pass.
  - The design or ruling gradient and the maximum permissible gradient has to be considered while connecting between top and foot of hill stations.
- •Map study gives a rough guidance of the routes to be further surveyed in the field

- **RECONNAISSANCE SURVEY**
- To confirm features indicated on map.
- To examine the general character of the area in field for deciding the most feasible routes for detailed studies.
- A survey party may inspect along the proposed alternative routes of the map in the field with very simple instrument like abney level, tangent clinometer, barometer etc. To collect additional details.

- Details to be collected from alternative routes during this survey are,
  - Valleys, ponds, lakes, marshy land, hill, permanent structure and other obstruction.
  - Value of gradient, length of gradient and radius of curve.
  - Number and type of cross drainage structures.
  - High Flood Level(HFL)
  - Soil Characteristics.
  - Geological features.
  - Source of construction materials-stone quarries, water sources.
- Prepare report on merits and demerits of different alternative routes.
- As a result a few alternate alignments may be chosen for further study based on practical considerations observed at the site.

- **Preliminary survey**
- Objective of preliminary survey are:
- To survey the various alternative alignments proposed after the reconnaissance and to collect all the necessary physical information and detail of topography, drainage and soil.
- To compare the different proposals in view of the requirements of the good alignment.
- To estimate quantity of earthwork materials and other construction aspect and to workout the cost of the alternate proposals.
- To finalise the best alignment from all considerations

- Methods of preliminary survey:
- **a)Conventional approach**-survey party carries out surveys using the required field equipment, taking measurement, collecting topographical and other data and carrying out soil survey.
- Longitudinal and cross sectional profile.
- PlainTerrain`:100–200 m
- RollingTerrain:50 m
- HillyTerrain:30 m
- Other studies
- Drainage, Hydrological survey, soil survey, Traffic and Material survey.

- **b)Modern rapid approach-** By Aerial survey taking the required aerial photographs for obtaining the necessary topographic and other maps including details of soil and geology
- Finalise the best alignment from all considerations by comparative analysis of alternative routes.
- **c)Modern technique – GPS**
- The procedure of conventional methods of preliminary survey is given in following steps:
  - Primary traverse
  - Topographical features
  - Levelling work
  - Drainage studies and hydrological data
  - Soil survey
  - Material survey
  - Traffic studies

- **Final location and detailed survey**
- The alignment finalised at the design office after the preliminary survey is to be first located on the field by establishing the centre line.
- **Location survey:**
- Transferring the alignment on the ground.
- This is done by transit theodolite.
- Major and minor control points are established on the ground and centre pegs are driven, checking the geometric design requirements.
- Centre line stacks are driven at suitable intervals, say 50m interval in plane and rolling terrains and 20 m in hilly terrain.

- **Detailed survey:**
- Temporary benchmarks are fixed at intervals of about 250 m and at all drainage and under pass structure.
- Earthwork calculations and drainage details are to be workout from the level books.
- Cross sectional levels are taken at intervals of
  - 50-100 m in Plane terrain,
  - 50-75 m in Rolling terrain,
  - 50 m in built-up area,
  - 20 m in Hill terrain.
- Detail soil survey is to be carried out.
- CBR value of the soils along the alignment may be determined for design of pavement.
- The data during detailed survey should be elaborate and complete for preparing detailed plans, design and estimates of project.

- **Drawing and Report**
  - Key map
  - Index map
  - Preliminary survey plans
  - Detailed plan and longitudinal section
  - Detailed cross section
  - Land acquisition plans
  - Drawings of cross drainage and other retaining structures
  - Drawings of road intersections
  - Land plans showing quarries etc

New highway project

- Map study
- Reconnaissance survey
- Preliminary survey
- Location of final alignment
- Detailed survey
- Material survey
- Geometric and structural design
- Earth work
- Pavement construction
- Construction controls

GEOMETRIC DESIGN OF HIGHWAYS

- The geometric design of a highway deals with the dimensions and layout of visible features of the highway such as alignment, sight distance and intersection.
- The main objective of highway design is to provide optimum efficiency in traffic operation with maximum safety at reasonable cost.
- Geometric design of highways deals with following elements :
  - Cross section elements
  - Sight distance considerations
  - Horizontal alignment details
  - Vertical alignment details
  - Intersection elements

Design Controls and Criteria

- The important factors which control geometric elements are
  - Design speed
  - Topography
  - Traffic factors
  - Design hourly volume and capacity
  - Environmental and other factors

- Design speed
- In India different speed standards have been assigned for different class of road
- Design speed may be modified depending upon the terrain conditions.
- Topography
- Classified based on the general slope of the country.
  - Plane terrain-<10%
  - Rolling terrain-10-25%
  - Mountainous terrain-25-60%
  - Steep terrain->60%
- Traffic factor
- Vehicular characteristics and human characteristics of road users.
- Different vehicle classes have different speed and acceleration characteristics, different dimensions and weight .
- Human factor includes the physical, mental and psychological characteristics of driver and pedestrian.

- Design hourly volume and capacity
- Traffic flow fluctuating with time
- Low value during off-peak hours to the highest value during the peak hour.
- It is uneconomical to design the roadway for peak traffic flow.
- Environmental factors
- Aesthetics
- Landscaping
- Air pollution
- Noise pollution

Highway Cross section Elements

- Pavement Surface Characteristics
- Cross slope or Camber
- Width of Pavement or Carriageway
- Medians / Traffic Separators
- Kerbs
- Road margins
- Width of Formation or Roadway
- Right of way and Land width