CE8604 **HIGHWAY ENGINEERING** **L T P C**

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OBJECTIVE:

To give an overview about the highway engineering with respect to, planning, design, construction and maintenance of highways as per IRC standards, specifications and methods.

UNIT I HIGHWAY PLANNING AND ALIGNMENT 9

Significance of highway planning – Modal limitations towards sustainability - History of road development in India – factors influencing highway alignment – Soil suitability analysis - Road ecology - Engineering surveys for alignment, objectives, conventional and modern methods - Classification of highways – Locations and functions – Typical cross sections of Urban and Rural roads

UNIT II GEOMETRIC DESIGN OF HIGHWAYS 9

Cross sectional elements - Sight distances – Horizontal curves, Super elevation, transition curves, widening at curves – Vertical curves - Gradients, Special consideration for hill roads - Hairpin bends – Lateral and vertical clearance at underpasses.

UNIT III DESIGN OF FLEXIBLE AND RIGID PAVEMENTS 9

Pavement components and their role - Design principles -Design practice for flexible and rigid Pavements (IRC methods only) – Embankments- Problems in Flexible pavement design.

UNIT IV HIGHWAY CONSTRUCTION MATERIALS AND PRACTICE 9

Highway construction materials, properties, testing methods – CBR Test for subgrade - tests on aggregate & bitumen – Test on Bituminous mixes-Construction practice including modern materials and methods, Bituminous and Concrete road construction, Polymer modified bitumen, Recycling, Different materials – Glass, Fiber, Plastic, Geo-Textiles, Geo-Membrane (problem not included) – Quality control measures - Highway drainage – Construction machineries.

UNIT V EVALUATION AND MAINTENANCE OF PAVEMENTS 9

Pavement distress in flexible and rigid pavements – Types of maintenance – Pavement Management Systems - Pavement evaluation, roughness, present serviceability index, skid resistance, structural evaluation, evaluation by deflection measurements – Strengthening of pavements –Highway Project formulation.

TOTAL: 45 PERIODS

OUTCOMES:

Students will be able to

- Get knowledge on planning and aligning of highway.
- Geometric design of highways
- Design flexible and rigid pavements.
- Gain knowledge on Highway construction materials, properties, testing methods
- Understand the concept of pavement management system, evaluation of distress and maintenance of pavements.

TEXTBOOKS:

1. Khanna.S. K., Justo.C.E.G and Veeraragavan A. "Highway Engineering", Nemchand Publishers, 2014.

2. Subramanian K.P., "Highways, Railways, Airport and Harbour Engineering", Scitech Publications (India), Chennai, 2010

3. Kadiyali. L.R. "Principles and Practice of Highway Engineering", Khanna Technical Publications, 8th edition Delhi, 2013.

REFERENCES:

1. Indian Road Congress (IRC), Guidelines for the Design of Flexible Pavements, (Third Revision), IRC: 37-2012

2. Indian Road Congress (IRC), Guidelines for the Design of Plain Jointed Rigid Pavements for Highways, (Third Revision), IRC: 58-2012

3. Yang H. Huang, "Pavement Analysis and Design", Pearson Education Inc, Nineth Impression, South Asia, 2012

4. Ian D. Walsh, "ICE manual of highway design and management", ICE Publishers, Ist Edition, USA, 2011

5. Fred L. Mannering, Scott S. Washburn and Walter P.Kilareski, "Principles of Highway Engineering and Traffic Analysis", Wiley India Pvt. Ltd., New Delhi, 2011

6. Garber and Hoel, "Principles of Traffic and Highway Engineering", CENGAGE Learning, New Delhi, 2010

7. O'Flaherty.C.A "Highways, Butterworth – Heinemann, Oxford, 2006

8. IRC-37–2012,The Indian roads Congress, Guidelines for the Design of Flexible Pavements, New Delhi

9. IRC 58-2012. The Indian Road Congress, Guideline for the Design of Rigid Pavements for Highways, New Delhi

UNIT-I

HIGHWAY PLANNING AND ALIGNMENT

PART-A

1. Write short notes on Highway Research Board. (NOV/DEC 2019), (May/June 2016)

(i) To ascertain the nature and extent of research required.
(ii) To correlative research information from various organizations in India and abroad with a view to exchanging publications and information on roads.
(iii) To sponsor basic research through universities and research organizations.
(iv) To collect and disseminate of research.
(v) To coordinate and conduct correlation services.
(vi) To involve in any other matter related to road research

2. Write the functions of Indian Road Congress (NOV/DEC 2019), (April/May 2015)

Indian Road Congress provides the following services

(i) It provides a forum for expression of collective opinion of its members for all matters affecting the construction and maintenance of roads in India.

(ii) It promotes the use of the standard specifications and practices.

(iii) It provided with the suggestions for the better methods of planning, designing, construction, administration and maintenance of roads.

(iv) It conducts periodical meetings to discuss technical problems regarding roads.

(v) It makes the laws for the development, improvement and protection of the roads.

(vi) It furnishes and maintains libraries and museums for encouraging the science of road making.

3. Write the functions of Central Road Research Institute (CRRI)

(i) To carry out the basic and applied research for investigation, design, construction and maintenance of different types of roads and runways.
(ii) To carry out research on road traffic and transportation, including traffic safety and transport economics.
(iii) To render technical advice and consultancy services to various organizations.
(iv) To arrange for utilization of results of research by extension unit, display centers etc.
(v) To conduct refresher and training courses for staff of other research Institutions, Universities and highway Departments.

4. **How are roads classified in Nagpur plan? (April/May 2019), (April/May 2017), (Nov/Dec 2016)**

In Nagpur road plan classified the roads in India based on location and function into the following five categories and described below.

i) National Highways (NH)

ii) State Highways (SH)

iii) Major District Roads (MDR)

iv) Other District Highways (ODR)

v) Village Roads (VR)

5. **What are the recommendations of Jayakar Committee? (April/May 2019) (April/May 2018), (April/May 2017)**

The most important recommendations made by the committee are:

i) The road development in the country should be considered as a national interest as the capacity of provincial governments and local bodies.

ii) An extra tax should be levied on petrol from the road users to develop a road development fund called central road fund in the year 1929.

iii) A semi official technical body should be formed to pool technical know-how from various parts of the country and to act as an advisory body on various aspects of roads.

iv) A research organization should be instituted to carry out research and development work pertaining to roads and to be available for consultations.

6. **Define Central Road Fund. (Nov/Dec 2016)**

The Central Road Fund (CRF) was formed on 1st march 1929.The consumers of petrol were charged an extra leavy of 2.64 paisa per liter of petrol to build up this road development fund 20 percent of the annual revenue.

The accounts of the central road fund are maintained by the Accountant General Revenue. The CRF has been revised in order to augment the revenue under this fund.

7. **What are the objective of Highway planning (April/May 2018) (Nov/Dec 2017)**

The objective of highway planning are given below

(i) To plan overall road network for efficient and safe traffic operation, but at minimum cost. Here the cost of construction, maintenance and resurfacing or strengthening of pavement layers and vehicle operation cost are to be given due consideration.

(ii) To divide the overall plan into phases and to decide priorities.

(iii) To work out suitable financing system.

8. Write the classification of roads (Nov/Dec 2018), (Nov/Dec 2017).

The classification of roads two type's urban and rural roads in India:

(I) The rural roads are as follows

a. National highways
b. State highways
c. Major district roads
d. Other district roads
e. Village roads

(II) The urban roads are as follows

The road system within urban areas is classified as urban roads. The urban roads, other than express ways are classified as:

a. Arterial roads
b. Sub-arterial roads
c. Collector roads
d. Local roads

9. Write any four model limitations highways mode towards sustainability (Nov/Dec 2018). (Nov/Dec 2015).

The four mode of transportation are

(i) Road Transportation
(ii) Rail Transportation
(iii) Air Transportation
(iv) Water transportation

The following limitations are as below

(i) Innovational Barrier
(ii) Social Barrier
(iii) Political Barrier
(iv) Economical & Financial Barrier
(v) Poor monitoring and evaluation system
(vi) Institutional Barrier

10. What are shoulders (May/June 2016)

Shoulders are provided on both sides of the pavement all along the road in the case of undivided carriageway. Shoulders are provided along the outer edge of the carriageway in the case of divided carriageway. The minimum shoulder width recommended by the IRC is 2.5m.

11. What is Right of Way (April/May 2015)

Right of way is the area 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.

11. List four parameters enumerated in traffic survey for the alignment and design of highway (April/May 2015)

Traffic surveys conducted in the region from basis for deciding the number of traffic lanes and roadway width, pavement design, thickness of pavement and economic analysis of highway project.

PART-B

1. List out the types of Highways as classified in the Indian Context starting from the Expressways upto Village/Rural Roads; for Each type, briefly state its specifications. (NOV/DEC 2019)

The Indian Highways as classified in types of roads are as follows.

(i) Expressway (E Way)
(ii) National Highways (NH)
(iii) State Highways (SH)
(iv) Major District Roads (MDR)
(v) Other District Highways (ODR)
(vi) Village Roads (VR)

(i) Express way

- For Speedy and heavy traffic
- Pedestrians not allowed
- Connect main markets, important places
- Complete separation of opposite moving traffic by a divider or median
- Level crossings, sharp curves, steep gradients avoided
- Telephone facility, Highway Police, Servicing Stations, Refreshment Facility available at regular intervals

(ii) National highways

National highways are the main highways running through the length and breath of India, connecting major parts, forgin highways, capital of large states and industrial and tourist centres including roads required for strategic movements for the defense of India.

It was agreed that a first step national trails should be constructed by the centre and that latter's these should be converted into roads to suit the traffic conditions. It was specified that national highways should be the frame on which the entire road communication should be based on that these highways may not necessarily be of same specification, but they must give an uninterrupted road communication through India and should connect the entire road network.

(iii) State highways

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

These highways are considered as main arteries of commerce by roads within a state or a similar geographical unit. In some places they may be even carry heavier traffic than some of the national highways but this will not alter their designation or function. The NH and SH have some design speed and geometric design specification.

(iv) Major district roads

Major district roads are the important roads within a district serving areas of production and markets and providing them with outlet to markets and connecting those with each other or with the main highways of a district. the MDR has lower speed and geometric design specifications than NH/SH.

(v) Other district roads

Other district roads are roads serving rural areas of production and providing them with outlet to market Centre's taluk headquarters block development headquarters or other main roads. These are of lower design specifications then MDR.

(vi) Village roads

Village roads are road connecting villages or groups of villages with each other to the nearest road of a higher category. It was specified that these villages roads should be in essence farm tracks, but it was desired that the prevalent practice of leaving such tracks to develop and maintain by themselves should be replaced by a plan for a designed and regulated system.

The Each type of roads from Expressway , National Highways (NH), State Highways (SH), Major District Roads (MDR), Other District Highways (ODR), Village Roads (VR , briefly presented its specifications in below the table.

Specifications	**Expressway**	**National Highways**	**State Highways**	**Major District Roads**	**Other District Roads**	**Village Roads**
Right of way	90-100m	45m	45m	25m	15m	12m
Carriage way	11.25m	12m	12m	9m	7.5m	7.5m
Speed	120 km/hr	100 km/hr	80 km/hr	60 km/hr	50 km/hr	40 km/hr
Horizontal curve	700-2600m	360m	360m	230m	155m	90m
Vertical curve (Minimum)	0.5 %	0.6 %	0.8 %	1.0 %	1.2 %	1.5 %
Camber	2.5%	2.5 %	2.5 %	2.5 %	2.5 %	2.5 %
Median	12-15m	4m	2m	1m	0.5m	Nil
Shoulder	2.5-3.0 m	2.5m	1m	0.5m	0.5m	Unpaved
Super elevation	7%	7%	7%	7%	7%	7%

2. ii) List the effects on Environment and Ecology of the surroundings due to a highway project. (NOV/DEC 2019).

S.NO.	Change Due to Roads	Consequence	Affected Ecosystem Good	Affected Ecosystem Service
1	**Chemical input from roads to water bodies**	Degradation of water quality, bioaccumulation	Clean water	Water purification, pollution abatement
2	**Chemical inputs to air shed**	Degradation of air quality	Clean air	Pollution abatement
3	**Chemical input to soils**	Bioaccumulation	Soil fertility	Pollution abatement
4	**Climate**	Increased temperature and rainfall	Water	Climate stability
5	**Hydrological processes**	Fluvial dynamics, sediment transport, floodplain ecology	NA	Flood and drought mitigation, nutrient cycling
6	**Modified habitat**	Plant species composition (natives and nonnatives)	Biodiversity	Nutrient cycling, soil fertility, seed dispersal
7	**Habitat quality, wildlife mortality**	Density and composition of animal species and populations	Biodiversity	Crop pollination, aesthetics, ecotourism

3. b) Illustrative with neat sketches and Explain, How obligatory points control a highway alignment. (NOV/DEC 2019), (April/May 2018), (Nov/Dec 2016)

Requirements of ideal alignment are

a)Short

It is desirable to have a short alignment between two terminal stations.

b) Easy

The alignment should be such that it is easy to construct and maintain the road with minimum problems

c)Safe

The alignment should be safe enough for construction and maintenance from the view point of stability of natural hill slopes.

d) Economical

The road alignment should be considered economical only if the total cost including initial cost, maintenance cost.

The various factors, which control the highway alignment, in general may be listed as:

- Obligatory points
- Traffic
- Geometric design
- Economics
- Other considerations

In hill roads additional care has to be given for

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

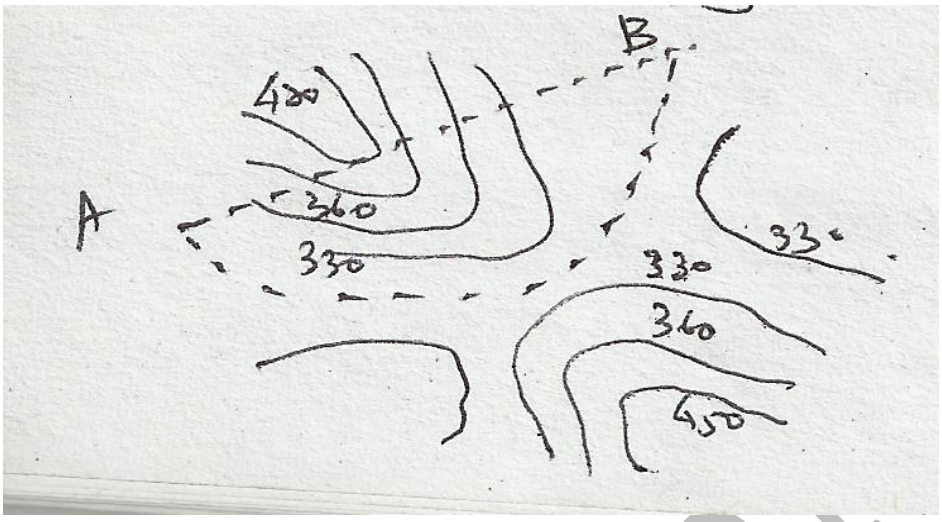
Obligatory Points: -

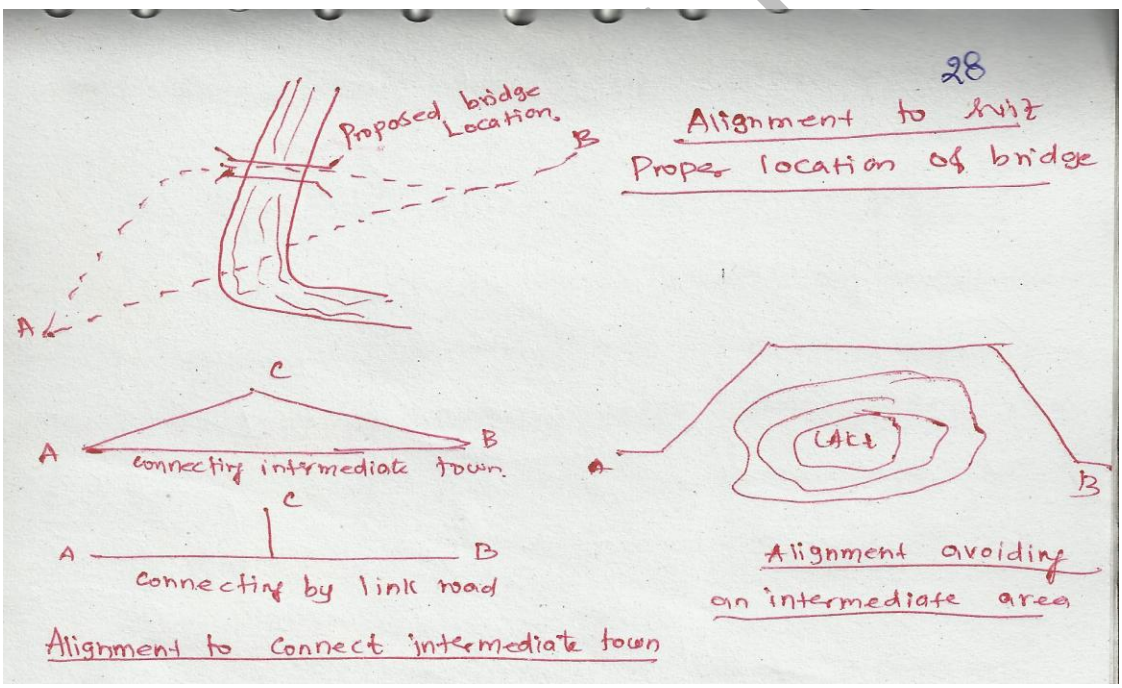
These control points may be divided in to two categories:

i) Points through which the alignment is to pass

ii) Points through which the alignment should not pass.

Obligatory points through which the road alignment has to pass may cause the alignment to often deviate from the shortest (or) easiest path. In fig.1.shows how the straight alignment AB is deviated along the hillside pass, thus avoiding a tunnel (or) heavy cutting.





In fig.2.shows that the straight alignment between stations A and B which passes across the river band is to be deviated along the path shown in order to cross the river at a proper bridge location.

ii) Obligatory points through which the road should not pass also may make it necessary to deviate from the proposed shortest alignment.

The obligatory points, which should be avoided while aligning a road, include religious places, very costly structures.

However if there is no alternative and the alignment has to be taken across such an area, the construction and maintenance costs are likely to be very high.

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 trend of traffic flow.

Geometric design: -

- Geometric design factors such as gradient, radius of curve and sight distance also would govern the final alignment of the highway.

- The absolute minimum sight distance, which should invariably be available in every section of the road, is the safe stopping distance for the fast moving vehicles.

Economy: -

- The alignment finalized based on the above factors should also be economical.
- The initial coast of construction can be decreased if high embankments and deep cuttings are avoided and the alignment is choosing in a manner to balance the cutting and filling.

Other considerations: -

- Various other factors, which may govern the alignment, are drainage considerations, hydrological factors, political considerations and monotony.
- The vertical alignment is often guided by drainage considerations.
- In a flat terrain it is possible to have a very long stretch of road, absolutely straight without horizontal curves.

Special considerations: -

Stability: -

While aligning hill roads, special care should be taken to align the road along the side as the hill, which is stable. The cutting and filling of earth to construct roads on hillside causes steepening of existing slopes and affect its stability

Drainage: -

Numerous hillside drains should be provided for adequate drainage facility across the road. But the cross drainage structures being costly, attempts should be made to align the road.

Geometric standard of hill roads: -

Different sets of geometric standards are followed in hill roads with reference to gradient, curves and speed and they consequently influence the sight distance, and radius of curve and other related features.

Resisting length: -

The resisting length of a road may be calculated from the total work to be done to move the loads along the route taking the horizontal length. The actual difference in levels between the two stations and sum of ineffective rise and fall in excess of floating gradient.

4. Briefly explain the engineering surveys needed for locating a new highway?(April/May 2015)

The stages of the engineering surveys are:

a) Map study.

b) Reconnaissance.

c) Preliminary surveys.

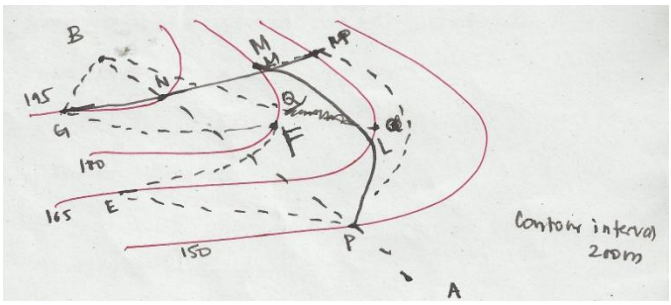
d) Final location and detailed surveys.

a) . Map study: -

In the topographic map, to suggest the likely routes of roads. In India topographic maps are available from the survey of India with 15 or 30-meter contour intervals.

The main feature like rivers, hills, and valleys etc. The probable alignment can be located on the map from the following details available on the map.

- Alignment avoiding valleys, ponds or lakes
- When the road has to cross a row of hills, possibility crossing through a mountain pass.
- Approximate location of bridge site for crossing rivers, avoiding bend of the river.
- When a road is to be connected between two stations one of the top and the other on the foot of the hill then alternate routes can be suggested keeping in view the permissible alignment.
- Suppose the scale of the contour map is known, and then the contour intervals it is possible to decide the length of road required between two consecutive contours keeping the gradient within allowable limits.
- In the fig. Let A and B be two stations to be connected by road. AB is the shortest route (Straight line) APQB is a steep route in which the gradient positively exceeds 1 in 20 as the distance between the contour intervals is only about 200 meter.



- APLMNB is a route with an approximate slope of 1 in 20 whereas APEFGB is an alternate alignment with the same gradient.
- Thus the map study also is possible to drop a certain route in view of any unavoidable obstructions (or) undesirable ground enroute.

b).Reconnaissance:-

The second stage of surveys for highway location is the reconnaissance to examine the general character of the area for deciding the most feasible routes for detailed studies.

Some of the details to be collected during reconnaissance are given below:

- Valleys, ponds, lakes, marshy, land, ridge, hills, permanent structures and other obstructions along the route, which are not available in the map.
- Approximate values of gradient, length of gradients and radius of curves of alternate alignments.
- Number and types of cross drainage structures maximum flood level and natural groundwater level along the probable routes.
- Soil type along the routes from field identification tests and observation of geological features.
- Sources of construction materials water and location of stone quarries.
- When the road passes through hilly or mountainous terrain, additional data regarding the geological formation types of rocks, dip of strata, seepage flow etc.

C). Preliminary survey: -

The main objectives of the preliminary surveys 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 earthwork materials and other construction aspects and to workout the cost of alternate proposals.
- To finalize the best alignment from all considerations.

The procedure of the conventional methods of preliminary surveys the given steps:

(i) Primary survey: -

For alternate alignments either secondary traverses (or) independent primary traverses may be necessary.

(ii) Topographical features: -

All geographical and other man made features along the traverse and for a certain width on either side surveyed and plotted.

(iii) Leveling work: -

Levelling work is also carried out side by side to give the centerline profiles and typical cross sections. The leveling work in the preliminary survey is kept to a minimum just sufficient to obtain the approximate earthwork in the alternate alignments.

(iv) Drainage studies: -

Drainage investigations and hydrological data are collected so as to estimate the type, number and approximate size of cross and drainage structures.

(v) Soil survey: -

The soil survey conducted at this stage helps to working out details of earthwork, slopes, suitability of materials, subsoil and surface drainage requirements and pavement type and the approximate thickness requirements.

(vi) Material survey: -

The survey for naturally occurring materials like stone aggregates, soft aggregates etc and identification of suitable quarries should be made.

(vii) Traffic survey: -

Traffic surveys conducted in the region from basis for deciding the number of traffic lanes and roadway width, pavement design and economic analysis of highway project.

(viii) Final location and detailed survey: -

The alignment finalized at the design office after the preliminary survey is to be first located on the field by establishing the centerline. The detailed survey should be carried out for collecting the information technology for the preparation of plans and construction details.

(ix) Location: -

- The centerline of the road finalized in the drawings to be translated on the ground during the location survey.

- Major and minor control points are established on the ground and center pegs are driven, checking the geometric design, requirements.

(x) Detailed survey: -

- Levels along his final centerline should be taken at all staked points. Levelling work is to great importance as the vertical alignment.
- A detailed soil survey is carried out to enable drawing of the soil profile.
- The data during the detailed survey should be elaborate and complete for preparing detailed plans, design and estimates of the project.

4. Write shortly the significance of Soil suitability analysis and road Ecology in highway planning (April/May 2019), (Nov/Dec 2018), (Nov/Dec 2015)

a) Detailed explain the soil suitability analysis

It is the process of understanding existing site qualities and factors which will determine the locating of a particular highway. The following parameters can be considered for the analysis:

1. Land use/ land cover.

2. Proximity to major road.

3. Proximity to city/ urban built-up land.

4. Soil salinity.

5. Ground water table depth

6. Ground water quality.

7. Slope of the terrain.

Areas with less fertile soil and poor quality of groundwater offer a good choice for the highway development.

b) Procedure to carry out the analysis

i. A detailed soil survey is carried out by groundwater obtaining soil samples 1.5-3m below the ground level.

ii. Sampling should be done to a depth equal to the twice of the height of final embankment.

iii. Spacing of sampling and type of sampling depends on the soil type or location.

iv. During survey one may cross areas where land is loose or is subjected to slides or may be stretches of rocky strata, all these details are to be recorded.

v. Preparation of highway formation, the primary operation involves excavation and embankments.

vi. Formation of pavements involves construction of embankments.

vii. Soil is obtained from the adjoining areas of the highway within the highway land itself.

viii. For this additional land may be acquired temporarily and after completion of the project, it may be handed over.

c) Explain the Road ecology

1. Road ecology focuses on understanding the interactions between load system and natural environment.
2. Road ecology find ways to minimize the detrimental effects that roads systems can have on plant and animal populations, air and water quality and human communities.
3. Outputs of road ecology includes advances in the management of storm water runoff, transportation and land use planning, and the development of crossing structures that animals use for safe passage across busy roads.
4. The science of road ecology is concerned with understanding how road affect ecological processes, often with the goal of developing strategies for controlling any negative effects that roads may have on the environment.

d) History of road ecology

1. For more than a century, we have allowed expressway, arterials and rural roads to define our landscapes without seriously considering how we might redefine the road. Engineers rarely attempted to incorporate ecological functions.
2. Studies of the impact of roads have existed as long as roads themselves.
3. Early work focused on the threat that motor vehicles posed to wildlife.
4. Broader consideration of the role that roads can have on ecological process was largely ignored until the latter half of the 20^{th} century.
5. Researchers also began presenting result that suggested traffic noise might have profound and far reaching effects on bird population.

e) Elements of road ecology

1. Road ecologists investigate the complex interactions between road and the natural environment how roads act as barriers inhibiting the movement of plans and, animals.

2. They also help develop emissions and test solutions to these pervasive problems.
3. Highway design process environmental factors in the earliest phases of project design and make extensive use of wildlife crossings and other ecological mitigation infrastructure.

4. Write in brief the history of road development in India after independence (April/May 2019), (Nov/Dec 2018)(April/May 2015)

The following road developments are after independence in India

(i) Central Road Research Institute (CRRI, 1950)
(ii) National Highway Act, (1956)
(iii) National Highways Authority of India (NHAI, 1995)
(iv) Second Twenty Year Road Development Plan, (1961-1981)
(v) Third Twenty Year Road Development Plan, (1981-2001)
(vi) Pradhan Mantri Gram Sadak Yojana (PMGSY,2000)
(vii) Road Development Plan: Vision 2021
(viii) Rural Road Development Plan: Vision 2025

(i) Central Road Research Institute (CRRI, 1950)

The main objectives are:

- To carry out the basic and applied research for investigation, design, construction and maintenance of different types of roads and runways.
- To carry out research on road traffic and transportation, including traffic safety and transport economics.
- To render technical advice and consultancy services to various organizations.
- To arrange for utilization of results of research by extension unit, display centers etc.
- To conduct refresher and training courses for staff of other research Institutions, Universities and highway Departments.

(ii) National Highway Act, (1956)

In 1956 the National Highway act was passed

The main features of the act are:

- The responsibility of developing and maintenance of the national highway (NH) to be provisionally taken by the central government.
- The Central Government to be empowered to declare any other highway as NH or to omit any of the existing highway from the list.

(iii) National Highways Authority of India (NHAI, 1995)

The NHAI was established under the national highway authority of India act 1988.

The objectives are:

- Take responsibility of development and maintenance
- Improve and extend the NH network in an efficient
- Improve road safety including road geometric
- Provide on route facilities for road users.
- To promote the scheme of three plantations along the roads as well as beautify all major intersections and junctions.

(iv) Second Twenty Year Road Development Plan, (1961-1981)

Second Twenty-Year Road Plan (1961-81)

The Nagpur road plan was intended for the period 1943-63,but the target road length was nearly completed earlier in 1961. Hence the next long term plan for the twenty year period commencing from 1961 was initiated by the IRC and was finalized by the subcommittee and this was approved by the Chief Engineers. The Second Twenty Year Road Development plan 1961-81 is also Called Bombay Road Plan.

Salient features of the second 20-year plan (1961-81):-

- This plan is considered to be draw more scientifically in view of development needed in under-developed areas.
- Maximum distance of any place in a developed or agricultural area would be 6.4 km from a metalled road and 2.4 km from any category of roads.
- The maximum distance from any place in a semi-developed area would be 12.8 km from a mettaled road and 4.8 km from any road.
- Every town with population above 2000 in plains and above 1000 in semi-hill areas and above 500 in hilly areas should be connected by a metalled road.
- Expressways have also been considered in this plan and 1600 km of length has been included in the proposed target of national highways
- Length of railway track is considered independent of the road system and hence it is not subtracted to get the road length.
- The development factor of only 5 percent is provided for future development and unforeseen factors.

(v) Third Twenty Year Road Development Plan, (1981-2001)

Policies and objectives:

a) The Third Twenty Year Road development Plan 1981-2001(also Known as Lucknow Road Plan) was finalized and the plan document was published by the year 1984.The major policies and objectives of this road plan are listed below:
b) The feature road development should be based on the revised classification of road system consisting of primary, secondary and tertiary road systems.
c) The road network should be developed so as to preserve the rural oriented economy and to develop small towns with all the essential facilities.
d) The overall road density in the country should be increased to 82 km per 100-sq.km areas by the year 2001.
e) The national highway 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 a NH.
f) The lengths of SH and MDR required in a state or region should be decided based on both areas and number of towns with population above 5,000 in the state or region.
g) Expressways should be constructed along major traffic corridors to provide fast travel.
h) Roads should also be built in less industrialized areas to attract the growth of industries.
i) There should be improvements in environmental quality and road safety.

(vi) Pradhan Mantri Gram Sadak Yojana (PMGSY,2000)

- Pradhan Mantri Gram Sadak Yojana (PMGSY) was launched on 25th December, 2000 as a Centrally Sponsored Scheme to provide road connectivity in rural areas of the country.
- The programme envisages connecting all habitations with a population of 500 persons and above in plain areas and 250 persons and above in Hill States.

(vii) Road Development Plan: Vision 2021

The Indian Roads Congress Have Prepared a Rural Road Development Plan, Vision 2025 The salient features of the Plan

Master Plans should be prepared for Rural Roads showing the core Network which gives accessibility to each village. All future programmes should strictly conform to this network All habitations with a population of above 100 will be connected by all weather roads.

(viii) Rural Road Development Plan: Vision 2025

- Rural Road Development Plan: Vision 2025 has been prepared for the 20 year period 2005-2025.
- Rural Road Development Plan was initiative of the Ministry of Rural Development, Government of India.
- District wise rural road development plan have been prepared.
- The vision document targets to provide connectivity to all unconnected habitations of the country in a phase manner, beyond the norms laid down in the PMGSY.
- Lower population limits were fixed for under development limits were fixed for under development regions including hills, deserts and tribal areas.

5. Describe the classification of Highways based on location and function (April/May 2018)

(Refer Part B. Question 1.)

6. Write shorts notes on i) Indian Road Congress ii) Central Road Research Institute (CRRI), and iii) Highway Research Board (April/May 2018)

(Refer Part A- Question no. 1,2 and 3)

7. Explain the Bombay road congress 1961(May/June 2016)

The length of roads envisaged under the Nagpur plan was achieved by the end of it, but the road system was deficient in many respects. The changed economic, industrial and agricultural conditions in the country warranted a review of the Nagpur plan. Accordingly a 20-year plan was drafted by the Roads wing of Government of India, which is popularly known as the Bombay plan. The highlights of the plan were:

i) It was the second 20 year road plan (1961-1981)

ii) The total road length targeted to construct was about 10 lakhs.

iii) Rural roads were given specific attention. Scientific methods of construction were proposed for the rural roads. The necessary technical advice to the Panchayaths should be given by State PWD's.

iv) They suggested that the length of the road should be increased so as to give a road density of 32kms/100 sq.km

v) The construction of 1600 km of expressways was also then included in the plan.

8. Explain the Jayakar Committee Recommendation (Nov/Dec 2016)

In 1927 Jayakar committee for Indian road development was appointed. The major recommendations and the resulting implementations were:

i) Committee found that the road development of the country has become beyond the capacity of local governments and suggested that Central government should take the proper charge considering it as a matter of national interest.

ii) They gave more stress on long term planning programme, for a period of 20 years (hence called twenty year plan) that is to formulate plans and implement those plans with in the next 20 years.

iii) One of the recommendations was the holding of periodic road conferences to discuss about road construction and development. This paved the way for the establishment of a semi-official technical body called Indian Road Congress (IRC) in 1934

iv) The committee suggested imposition of additional taxation on motor transport which includes duty on motor spirit, vehicle taxation, license fees for vehicles plying for hire. This led to the introduction of a development fund called Central road fund in 1929. This fund was intended for road development.

v) A dedicated research organization should be constituted to carry out research and development work. This resulted in the formation of Central Road Research Institute (CRRI) in 1950.

9. Explain in detail the reconnaissance survey for highway location in rural area (April/May 2017)

(Refer Part B Question No.4)

10. Explain the classification of urban roads with neat sketches (Nov/Dec 2015)

Classification of urban roads

(i) Arterial roads

(ii) Sub-arterial roads

(iii) Collector Street

(iv) Local Street

(i) Arterials

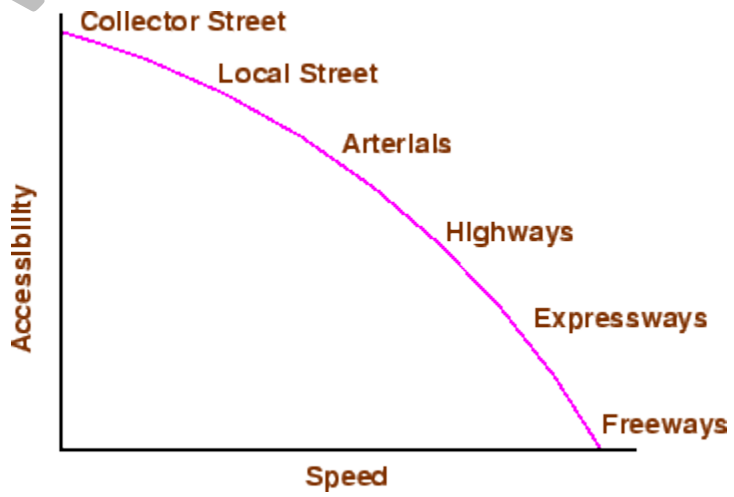
It is a general term denoting a street primarily meant for through traffic usually on a continuous route. They are generally divided highways with fully or partially controlled access. Parking, loading and unloading activities are usually restricted and regulated. Pedestrians are allowed to cross only at intersections/designated pedestrian crossings.

(ii) Local streets

A local street is the one which is primarily intended for access to residence, business or abutting property. It does not normally carry large volume of traffic and also it allows unrestricted parking and pedestrian movements.

(iii) Collector streets

These are streets intended for collecting and distributing traffic to and from local streets and also for providing access to arterial streets. Normally full access is provided on these streets. There are few parking restrictions except during peak hours.



11. Elaborate the factors affecting the geometric design of highways (Nov/Dec 2017)

(i) Design speed

Design speed is the single most important factor that affects the geometric design. It directly affects the sight distance, horizontal curve, and the length of vertical curves. Since the speed of vehicles vary with driver, terrain etc, a design speed is adopted for all the geometric design.

Design speed is defined as the highest continuous speed at which individual vehicles can travel with safety on the highway when weather conditions are conducive. Design speed is different from the legal speed limit which is the speed limit imposed to curb a common tendency of drivers to travel beyond an accepted safe speed. Design speed is also different from the desired speed which is the maximum speed at which a driver would travel when unconstrained by either traffic or local geometry.

Since there are wide variations in the speed adopted by different drivers, and by different types of vehicles, design speed should be selected such that it satisfy nearly all drivers. At the same time, a higher design speed has cascading effect in other geometric designs and thereby cost escalation. Therefore, an 85th percentile design speed is normally adopted. This speed is defined as that speed which is greater than the speed of 85% of drivers. In some countries this is as high as 95 to 98 percentile speed.

(ii) Topography

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

(iii) Other factors

In addition to design speed and topography, there are various other factors that affect the geometric design and they are briefly discussed below:

- **Vehicle:** :The dimensions, weight of the axle and operating characteristics of a vehicle influence the design aspects such as width of the pavement, radii of the curve, clearances, parking geometrics etc. A *design vehicle* which has standard

weight, dimensions and operating characteristics are used to establish highway design controls to accommodate vehicles of a designated type.

- **Human:** The important human factors that influence geometric design are the physical, mental and psychological characteristics of the driver and pedestrians like the reaction time.
- **Traffic:** It will be uneconomical to design the road for peak traffic flow. Therefore a reasonable value of traffic volume is selected as the design hourly volume which is determined from the various traffic data collected. The geometric design is thus based on this design volume, capacity etc.
- **Environmental:** Factors like air pollution, noise pollution etc. should be given due consideration in the geometric design of roads.
- **Economy:** The design adopted should be economical as far as possible. It should match with the funds allotted for capital cost and maintenance cost.
- **Others:** Geometric design should be such that the aesthetics of the region is not affected.

12. (i) For a highway alignment, to cross a river, what are the various obligatory and other technical and economical considerations in aligning the highway across the river (Nov/Dec 2015)

The various factors that control the alignment are as follows:

Obligatory points:

These are the control points governing the highway alignment. These points are classified into two categories. Points through which it should pass and points through which it should not pass. Some of the examples are:

Bridge site:

The bridge can be located only where the river has straight and permanent path and also where the abutment and pier can be strongly founded. The road approach to the bridge should not be curved and skew crossing should be avoided as possible. Thus to locate a bridge the highway alignment may be changed.

Mountain:

While the alignment passes through a mountain, the various alternatives are to either construct a tunnel or to go round the hills. The suitability of the alternative depends on factors like topography, site conditions and construction and operation cost.

Intermediate town:

The alignment may be slightly deviated to connect an intermediate town or village nearby. The location should avoid obstructions such as places of cemeteries, archeological, historical monument, public facilities like schools and hospitals, utility services.

Geometric design features

- Facilitate easy grade and curvature
- Enable ruling gradient in most sections
- Void sudden changes in sight distance, especially near crossings
- Avoid sharp horizontal curves
- Avoid road intersections near bend or at the top or bottom of a hill
- Precautions at river and railway crossings
- Bridges should be preferably be located at right angles to the river flow, not located on a horizontal curve
- Crossing railway lines should avoid intersections at gradient, frequent crossing and re crossing

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
• Avalanche prone areas
– Flat terrain-below 3%
– Rolling terrain -3 to 25%
– Mountainous terrain – above 25%
– A location on high ground should be preferred rather than valley to avoid cross drainage works

Economics

The total cost Construction cost+ maintenance cost+ operation cost) should be kept minimum.

Initial cost-by avoiding high embankments and deep cutting

Maintenance cost-by avoiding unsuitable land Operation cost- by avoiding steep gradient and curves

Other considerations

• Environmental considerations
• Engineering feasibility

• Social considerations
• Drainage and Hydrological factors
• Political considerations- avoiding into foreign territory
• Monotony- long stretch of straight road leads to driving discomfort

(ii) **Construction of route:**

In roadways, these routes consist of suitable pavement of specified width provided usually with shoulders on either side. In railways, the routes consist of pair of steel rails which are laid parallel to each other on sleepers at fixed distance apart.

Suitability to traffic:

In roadways, routes are meant for movement of different types, of traffic such as buses, trucks, scooters, rickshaws, cycles, pedestrians etc. The railway routes are meant only for movement of trains.

Width of right-of-way:

The roadway routes require more width of right-of-way. The railway routes require less width of right-of-way. Starting and destinations: In roadways, starting and destination points of traffic are not fixed. In railways, starting and destination points of trains are always fixed.

Right of entry:

In roadways, the right of entry is free to all vehicles because their movements are not according to any schedule. In railways, the right of entry is not free to all railway vehicles because their movements are always according to schedule. Strength of route: The required strength of roadways is less. The required strength of railway tracks is more.

Elasticity:

The roadway routes do not require an elastic structure since they are not to withstand impacts of heavy wheel loads. The railway routes require an elastic structure to withstand impact of heavy wheel loads.

Gradients and curves:

In roadways, the routes can be constructed with steep gradients and sharp curves. Thus, route length in their case is less. In railways, these routes cannot be constructed with steep gradients and flat curves. Thus, route length in their case is more.

Load handling capacity:
The load handling capacity of road vehicles is less and that too at low speeds. Load handling capacity of railway vehicles is more and that too at high speeds.

Requirement of turning devices:
In roadways, no special turning devices are constructed for turning vehicles on these routes. In railways, special turning devices in the form of points and crossings are constructed for turning vehicles on these routes.
Operational control devices:

In roadways, no special operational control devices in the form of signaling and interlocking are required on these routes for safe and efficient movement of vehicles. In railways, special operational control devices in the form of signaling and interlocking are required on these routes for safe and efficient movements of trains as per schedule.

Suitability to transportation of people and goods:

Transportation of people and light goods for short distances (upto 500 km) is convenient and cheap by roadway routes. Transport of people and heavy goods like raw materials, coal, ores, etc. for long distance or manufacturing concerns is convenient and cheap by railway routes.
Adaptability to type and size of goods:

All types and sizes of goods cannot be handled by road vehicles. Almost all types and sizes of goods can be handled by the trains.
Suitability for hilly area:
Roadway vehicles are more suitable for hilly area. Railway vehicles are less suitable for hilly area.

Construction and maintenance cost:
The construction and maintenance cost of roadway vehicles is less. In case of railway vehicles, the cost is more.

(ii) Compare two modes of Transportation –Railways and Highways (Nov/Dec 2015)

(Refer Part –C , Question No.3)

PART C

1. **Explain the process of engineering survey for a highway alignment through conventional method. (Nov/Dec 2019), (April/May 2018)**

   (Refer Part b- Question no. 4)

2. **Explain PIEV Theory with neat sketch (Nov/Dec 2019)**

   1) Perception

   2) Intellection

   3) Emotion

   4) Violation

   1) Perception

   Time required for the sensations received by the eyes or ears of the driver to be transmitted to the brain through the nervous system & spinal cord or it is the time required to perceive an object or situation.

   2) Intellection

   Time require for the driver to understand the situation it is also the time required for comparing the different thoughts.

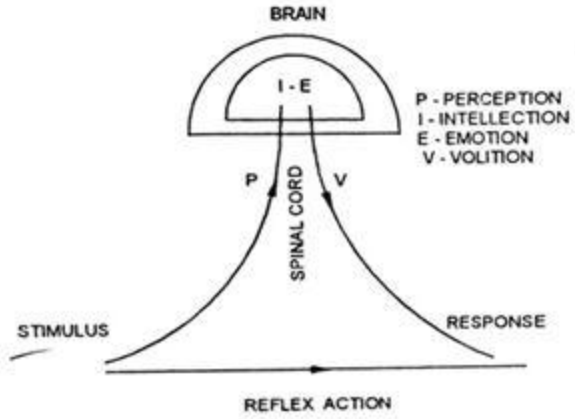
   3) Emotion

   Time elapsed during emotional sensational and other mental disturbance such as fear, anger or any other emotional feeling superstition etc

   4) Volition

   Time taken by the driver for the final action such as brake application.

   The total reaction time t=2.5 Second



3. **Compare two modes of Transportation –Railways and Highways (Nov/Dec 2019), (Nov/Dec 2015)**

(A) Road Transport

Advantages	Disadvantages
1. Less Capital Outlay 2. Door to Door Service 3. Service in Rural Areas 4. Flexible Service 5. Suitable for Short Distance 6. Lesser Risk of Damage in Transit 7. Saving in Packing Cost 8. Rapid Speed 9. Less Cost	1. Seasonal Nature 2. Accidents and Breakdowns 3. Unsuitable for Long Distance and Bulky Traffic 4. Slow Speed 5. Lack of Organisation

(B) **Railway Transport**

Advantages	Disadvantages
1. Dependable 2. Better Organised 3. High Speed over Long Distances 4. Suitable for Bulky and Heavy Goods 5. Cheaper Transport 6. Safety 7. Larger Capacity 8. Public Welfare 9. Administrative Facilities of Government 10. Employment Opportunities	1. Huge Capital Outlay 2. Lack of Flexibility 3. Lack of Door to Door Service 4. Monopoly 5. Unsuitable for Short Distance and Small Loads 6. Booking Formalities 7. No Rural Service 8. Under-utilised Capacity 9. Centralised Administration

4. **Explain in brief the modern methods of laying highway alignment being adopted at present with its merit and demerits.(April/May 2019), (April/May 2018)**

(Refer Part B- Question no. 4)