PART-1

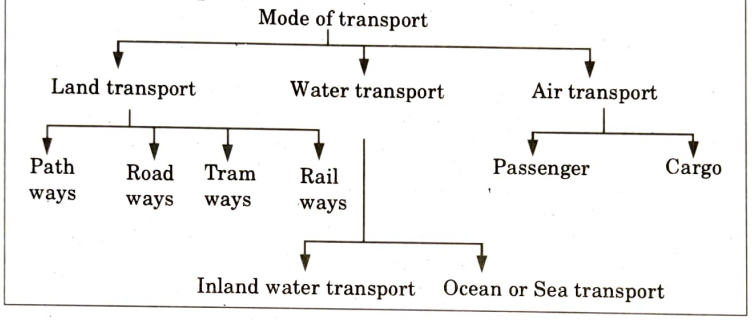
Role of Transportation, Mode of Transportation.

CONCEPT OUTLINE

Role of Transportation : Transportation plays an important role in the development of country. It plays various roles :

i. Economic role of transportation.
ii. Social role of transportation.
iii. Political role of transportation.

Mode of Transportation :



Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.1. What is the role of transportation in the development of the country ?

Answer

Following are the various role of transportation in the development of country :

1. Transport gives "place utility" to the goods.
2. Transport minimises the time for the movement of people and goods. Thus, transport gives time utility to economic activities.
3. The separation between the producer and the consumers is overcome by transport.
4. Transport enables the quick movement to preserve the quality of goods.

5. Urbanization and economic development go together. Rapid urbanization can take place only if a country has a good transport networks.
6. Industrial activity depends on a good system of transport for moving the raw materials and finished goods.
7. A good transport system results in lower transport costs and thus a lower cost of goods.
8. A good network of roads and railways facilities administration.
9. Tourism, both domestic and international, can prosper only if the country has a good transport system.

Que 1.2. What are the different modes of transportation ? Explain the specific function of each of them.

Answer

Following are the different modes of transportation :

A. Road Transport :

1. Road transport exist in all parts of the world, this involves the use of motor vehicles (cars, lorries, buses, bicycles, and trucks).
2. There are various types of roads according to size and functions, some roads are tarred while others are not.
3. The best of these roads are the modern roads which links major towns. Road transport when compared with other modes of transportation is more flexible.
4. It is relatively cheaper and faster. Road transport has a high capacity of carrying goods over short distances.
5. Maintenance is one of the major disadvantages of this mode of transport.

B. Railway Transport :

1. Railways were developed during the period of industrial revolution in the 19th century, these was partly for political reasons and for economic reasons.
2. In many countries, they were built especially to penetrate isolated regions and help promote political unity.
3. The major advantage of railway transport includes provision reliable services.
4. It has ability of conveying heavy and bulky goods; it is also very cheap, safe and comfortable for passengers over a long distance.

C. Water Transport :

1. Water transport is very important because it is the cheapest way of transporting bulky goods over a long distance.
2. In the world, there are two major types of water transport namely. Inland water transport and ocean water transport.

a. Inland water transport is the system of transport through all navigable rivers, lakes and man-made canals. Many large rivers in different parts of the world are used by ships and barges for transportation.
b. Ocean waterways carry a lot of the world's trade, majority of the bulky goods, materials and passengers pass through ocean waterways from one country to another at the cheapest cost.

D. Air Transport :

1. Air transport is the newest means of transport; it was introduced in 1903 but developed into full means of transporting people and goods in 1930s.
2. This mode of transportation can be used for both domestic and international flights.

E. Pipeline Transport :

1. This system of transportation involves the use of hollow pipes in the transportation of water, crude oil, (petroleum) and gas.
2. This mode of transportation is safer than using tankers or trailers in the transportation of these liquids.

Que 1.3. Discuss the characteristics of road transport.

Answer

Following are the characteristics of road transport :

1. Roads are used by various types of road vehicles, like passenger cars, buses, trucks, two and three wheeled automobiles, pedal cycle and animal drawn vehicles.
2. Road transport requires a relatively small investment for the government.
3. Road transport offers a complete freedom to road users to transfer the vehicle from one lane to another and from one road to another according to the need and convenience.
4. In particular for short distance travel, road transport saves time.
5. Road transport is the only means of transport that offers itself to the whole community alike.
6. Road transport is subjected to a high degree of accidents due to the flexibility of movements offered to the road users.

PART-2

History of Road Development.

CONCEPT OUTLINE

Historical Development of Roads

i. Ancient roads. ii. Roman roads.
iii. French roads. iv. British road.
v. Modern roads.

Highway Development in India : For development of highways, three 20 year road plans are generated. They are as follows :

i. Nagpur road plan (1943-61)
ii. Bombay road plan (1961-81)
iii. Lucknow road plan (1981-2001)

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.4. Briefly discuss the historical development of road construction.

OR

Discuss any three methods of historical development of road construction. **AKTU 2015-16, Marks 10**

Answer

A. Early Development :

1. The oldest mode of travel obviously was on the foot-paths.
2. Animals were also used to transport men and materials.
3. Later simple animal drawn vehicles were developed and this became a common and popular mode of transportation for very long period after the invention of wheel.
4. This brought up the necessity of providing a hard surface for these wheeled vehicles to move on.
5. Such a hard surface is believed to have existed in the period of about 3500 BC.

B. Roman Roads :

1. During the period of roman civilization many roads were built of stone blocks of considerable thickness.
2. The main features of Roman roads are :

i. They were built straight regardless of gradients.

ii They were built after the soft soil was removed and a hard stratum was reached.

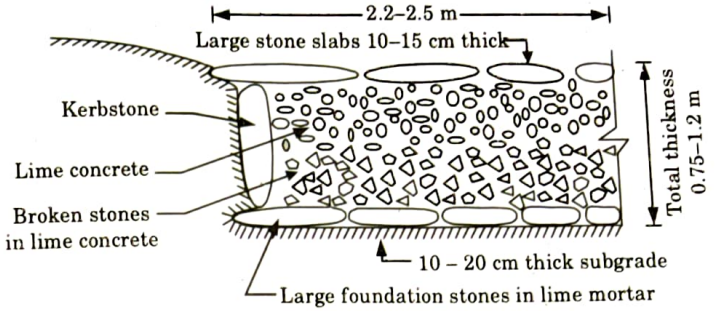


Fig. 1.4.1. Roman roads.

iii. The total thickness of the construction was as high as 0.75 to 1.2 m at some places, even though the magnitude of wheel loads of animal drawn vehicles was very low.

C. Tresaguet Construction :

1. Pierre Tresaguet developed an improved method of construction of road in France.

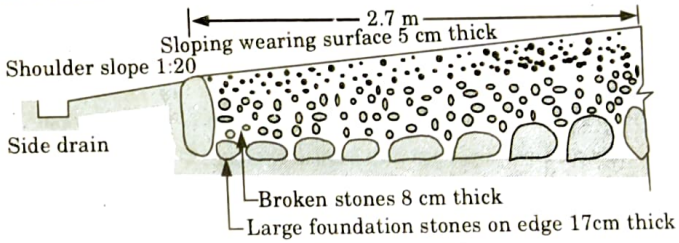


Fig. 1.4.2. French roads.

2. The main feature of Tresaguet proposal was that the thickness of construction needs to be only in the order of 30 cm.
3. Further due consideration was given by him to subgrade moisture condition and drainage of surface water.
4. A shoulders were also provided cross slope to drain the surface water to the side drain.

D. Macadam Construction :

1. The first method based on scientific thinking.
2. It was realized that the stresses due to wheel loads of traffic gets decreased to the lower layers of the pavement and therefore it is not required to provide large boulders and stones or soling course at the lower layer of the pavement.
3. The importance of subgrade draining and compaction was recognized and cross slope of 1 in 36 was proposed from subgrade level itself.
4. Compacted layer of smaller size broken stones placed at the bottom could replace the heavy foundation stones.

5. Due to better load dispersion characteristics of compacted broken stone aggregates of smaller sizes, reduced the total thickness of construction.
6. The size of broken stones for the top layer was decided based on the stability under animal drawn vehicles.

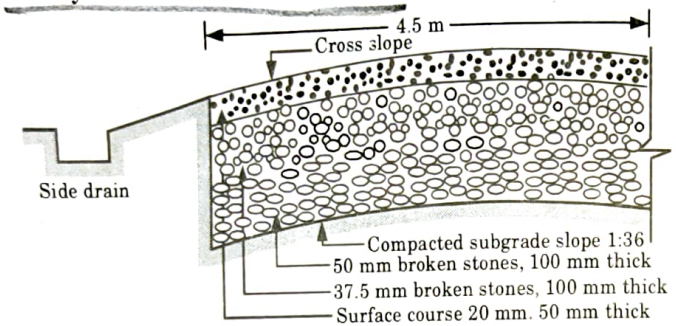


Fig. 1.4.3. British roads.

Que 1.5. **Briefly discuss the historical development of road construction. What are the salient features of early Roman Roads ? How do these differ from the present day road construction ?**

AKTU 2017-18, Marks 10

Answer

Historical Development and Features : Refer Q. 1.4, Page 1–5C, Unit-1.

Difference :

i. Early roman roads have been much stronger than what was required for the animal drawn carts in those days.
ii. The enormous cost of construction cannot be justified at all, if this technique is compared with the modern trend of pavement design based on more scientific approaches.

Que 1.6. **Briefly outline the highway development in India.**

OR

Explain briefly the role of the Jayakar commitee in road development in India. **AKTU 2013-14, Marks 2.5**

OR

Write a short note on Jayakar commitee. **AKTU 2017-18, Marks 2.5**

Answer

1. Road in Ancient India :

i. The excavations of Mohenjo-Daro and Harappa have revealed the existence of roads in India as early as 25 to 35 centuries BC.

ii. Old records reveal that in early periods the roads were considered indispensable for administrative and military purposes.
iii. Rules have been mentioned about regulating the depth of roads for various purposes and for different kinds of traffic.
iv. In the beginning of fifth century AD emperor Ashoka had improved the roads and the facilities for the travellers.

2. Roads in Mughal Period :

i. During the Pathan and Mughal periods, the roads of India were greatly improved.
ii. Roads were built running from North-West to the Eastern areas through the Gangetic plains, linking also the coastal and central parts.

3. Roads in Nineteenth Century :

i. A number of trunk roads were metalled and bridges were provided on the remains of old roads, under the supervision of the British Military Engineers.
ii. In fact these roads connected important military and business centres.
iv. In 1865 Lord Dalhousie, formed the Public Works Department in more or less the same form that exists today. The construction of the Grand Trunk Road was undertaken by this new department.

4. Jayakar Committee and the Recommendations :

i. A resolution was passed by both Chambers of the Indian Legislature 1927 for the appointment of a committee to examine and report on the question of road development in India.
ii. In response to the resolution, Indian Road Development Committee was appointed by the government with MR Jayakar as Chairman, in 1927.
iii. The most important recommendations made by the Jayakar committee are :
a. The road development in the country should be considered as a national interest as this has become beyond the capacity of provincial governments and local bodies.
b. An extra tax should be levied on petrol from the road users to develop a road development fund called Central Road Fund.
c. A semi-official technical body should be formed to pool technical knowhow from various parts of the country and to act as an advisory body on various aspects of roads.
d. A research organization should be instituted to carry out research and development work and to be available for consultations.

Que 1.7. **Write short notes on :**

AKTU 2017-18, Marks 2.5

A. Central Road Fund.
B. Indian Road Congress.
C. Central Road Research Institute.
D. National Highway Act.
E. Highway Research Board.

Answer

A. Central Road Fund :

1. The Central Road Fund (CRF) was formed on 1st march 1929.
2. The main source of income of CRF is charge an extra tax from the consumer of petrol.
3. To build up CRF, 20 % grants are to be given by the central government, and balance 80 % are to be collected from state government.
4. The whole matter related to accounts is maintained by the Accountant General of Central Revenue.
5. The administrative control over CRF is exercised by Ministry of Transport.

B. Indian Roads Congress (1934) :

1. A semi-government organization named, Indian Roads Congress was formed in the year December 1934, and was registered in the year 1937 under the registration act.
2. The main function of the IRC was to act as a forum for the regular pooling of the technical knowledge and know how, from the various parts of the country.
3. IRC performs various planning and also it has become the most important agency to provide the standards and specifications for road construction in the country.
4. The IRC publishes journals, research publications, standards specifications, guidelines and other special publications on various aspects of highway engineering.

C. Central Road Research Institute :

1. In the year 1950 the Central Road Research Institute (CRRI) was started at New Delhi for research in various aspect of highway engineering.
2. It may be indicated that one of the recommendation of Jayakar Committee report was to set up a central organization for research and dissemination of information.
3. The CRRI is one of the national laboratories of the Council of Scientific and Industrial Research; the institute is mainly engaged in applied research and offers technical advice to State Governments and the industries on various problems concerning roads.

D. National Highway Act : In 1956 the National Highway Act was Passed. The main features of the act are :

1. The responsibility of development and maintenance of the national highway (NH) to be provisionally taken by the Central Government.
2. The Central Government to be empowered to declare any other highway as NH or to omit any of the existing national highways from the list

E. Highway Research Board :

1. The Highway Research Board in the Indian Roads Congress was set up in 1973 with a view to give proper direction and guidance to road research activities in India.
2. The board is expected to act as a national body for co-ordination and promotion of highway research.
3. The objectives of Highway Research Board are :

i. To ascertain the nature and extent of research required.
ii. To correlate research information from various organizations in Indian and abroad with a view to exchange publication and information on road.
iii. To co-ordinate and conduct correlation services.
iv. To collect and disseminate result on research.
v. To channelize consultative services.

PART-3

Road Types and Pattern.

CONCEPT OUTLINE

Road Patterns : The various road patterns may be classified as follows :

i. Rectangular or block pattern.
ii. Radial or star and block pattern.
iii. Radial or star and circular pattern.
iv. Radial or star and grid pattern.
v. Hexagonal pattern.
vi. Minimum travel pattern.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.8. What are the various methods of classifying roads ?

OR

Briefly outline the classification based on location and function as suggested in the Nagpur Road Plan.

Answer

Classification of Road : Following are the various classifications of roads :

A. Based on the Weather Conditions :

1. **All-Weather Roads :** All weather roads are those which are negotiable during all weather, expect at major river crossing where interruption of traffic is permissible upto a certain extent, the road pavement should be negotiable during all weathers.
2. **Fair-Weather Roads :** On these roads, the traffic may be interrupted during monsoon season at causeways where streams may overflow across the road.

B. Based on the Type of the Carriage Way or the Road Pavement :

1. **Paved Roads :** When the roads are provided with a hard pavement course which should be at least a water bound macadam (WBM) layer are known as paved roads.
2. **Unpaved Roads :** When the roads are not provided with a hard pavement course of at least a WBM layer is known as unpaved roads, e.g. earth roads and gravel roads.

C. Based on the Type of pavement surfacing provided :

1. **Surface Roads :** These are provided with a bituminous or cement concrete surfacing these are also known as block topped roads.
2. **Unsurfaced Roads :** These are not provided with bituminous or cement concrete surfacing.

D. Based on the traffic volume : The roads are classified as heavy, medium and light traffic roads. These terms are relative and so the limits under each class should be clearly defined and expressed as vehicles per day etc.

E. Based on Load or Tonnage : This classification is also relative and the roads may be classified as class I, II etc. or class A, B etc. and the limits may be expressed as tonnes per day.

F. Based on Nagpur Road Plan : Nagpur Road Plan classified the roads in India based on location and function into following five categories.

1. **National Highways (NH) :** These are main highways running through the length and breadth of India, connecting major ports, foreign highways, capitals of large states and large industrial and tourist centres including roads required for strategic movements for the defence of India.
2. **State Highways (SH) :** These are arterial roads of a state, connecting up with the national highways of adjacent state, district head quarters and important cities within the state and serving as the main arteries for traffic to and from district roads.
3. **Major District Roads (MDR) :**

i. These are important roads within a district serving areas of production and markets and connection those with each other or with the main highways of a district.

ii. The MDR has lower speed and geometric design specifications than NH/SH.

4. **Other District Roads (ODR) :**

i. These are roads serving rural areas of production and providing them with outlet to market centres, taluk head quarters, block development head quarters or other main roads.

ii. These are of lower design specification than MDR.

5. **Village Roads (VR) :** These are roads connecting villages or group of villages with each other to the nearest road of a higher category.

Que 1.9. Briefly outline the main features of various road patterns commonly in use. **AKTU 2017-18, Marks 10**

OR

Write a short note on star and grid pattern. **AKTU 2017-18, Marks 2.5**

Answer

Following are the various types of road patterns :

1. **Rectangular or Block Pattern :**

i. In rectangular pattern all streets and roads in the form of grids or block running perpendicular with each other.

ii. In this pattern city centre is far away from some areas and takes a long time to reach the city centre.

iii. This pattern is unsafe from the road safety point of view because vehicle meets at opposite direction in any crossing or intersection.

iv. This pattern is easier to construct and maintain as well as easier to understand.

2. **Radial and Block Pattern :**

i. This pattern is fully combination of radial and block type road network.

ii. Radial from the centre outwarding with block pattern network of roads in between the radial main streets.

3. **Radial and Circular Pattern :**

i. In radial and circular pattern main road radiate from the central business area or focal point outwardly.

ii. The main radial streets are then interconnected by concentric roads.

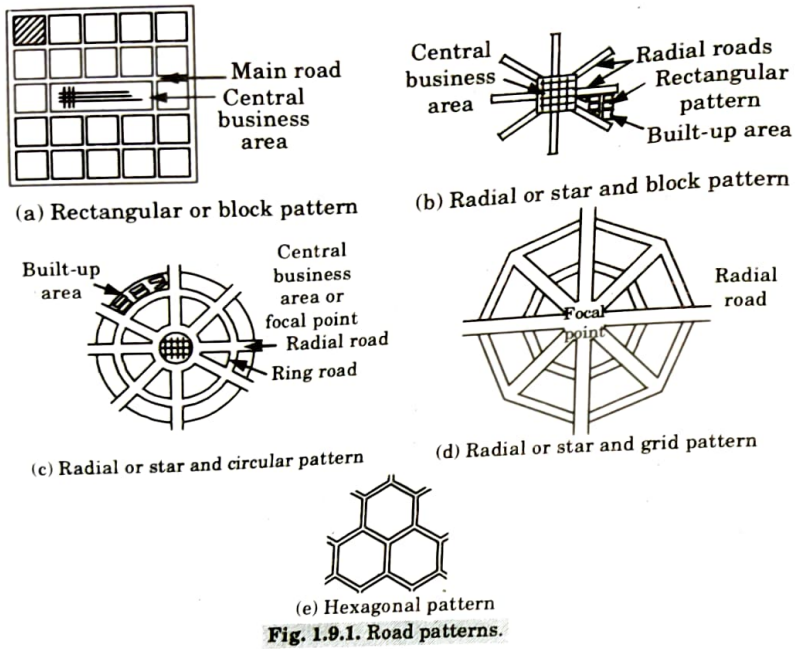
4. **Radial and Grid Pattern :**

i. This type of pattern is combination of radial and grid pattern.

ii. A network of radial roads radiate from the focal point outwardly.

iii. The main outer radial road interconnected by providing grid pattern.

5. **Hexagonal Pattern :** This type of road pattern grow in such a manner in various directions forming hexagons.



(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

Fig. 1.9.1. Road patterns.

PART-4

Nagpur Road Plan.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.10. Explain briefly the role of Nagpur road plan in road development in India. **AKTU 2013-14, Marks 2.5**

OR

Write short note on Nagpur road plan. **AKTU 2017-18, Marks 2.5**

Answer

Nagpur Road Congress 1943 :

1. *To discuss about improving the condition of roads, the government convened a conference of chief engineers of provinces at Nagpur in 1943.*

2. The result of the conference is famous as the Nagpur Plan.
3. A twenty year development programme for the period (1943-1963) was finalized. It was the first attempt to prepare a coordinated road development programme in a planned manner.
4. The roads were divided into five classes :

i. National highways.
ii. State highways.
iii. District roads.
iv. Other district roads.
v. Village roads.

5. The committee planned to construct 2 lakh kms of road across the country within 20 years.
6. They recommended the construction of star and grid pattern of roads throughout the country.
7. One of the objectives was that the road length should be increased so as to give a road density of 16 kms per 100 sq.km.

Que 1.11. How would you calculate the length of various road according to Nagpur road plan ?

Answer

1. The total length of the first category or metalled roads for National and State Highways and Major District Road in km is given by the formula :

$$NH + SH + MDR\ (km) = \left[\frac{A}{8} + \frac{B}{32} + 1.6N + 8T\right] + D - R$$

where, A = Agricultural area, km^2

B = Non-agricultural area, km^2

N = Number of towns and villages with population range 2001 – 5000.

T = Number of towns and villages with population over 5000.

D = Development allowance of 15 percent of road length calculated to be provided for agricultural and Industrial development during the next 20 years.

R = Existing length of railway track, km.

2. The total length of second category roads or other district road and village roads in km is given by the formula :

$$ODR + VR\ (km) = [0.32\ V + 0.8Q + 1.6P + 3.2S] + D$$

where, V = Number of villages with population 500 or less

Q = Number of villages with population range 501 – 1000

P = Number of villages with population range 1001 – 2000

S = Number of villages with population rang 2001 – 5000

D = Development allowance of 15 % for next 20 years.

Que 1.12. **From the following observations, compute the length of national highways and secondary roads as per Nagpur Plan. Total area 10000 km², developed non-agricultural area = 2850 km², railway track length = 95 km. Population data is given below :**

AKTU 2013-14, Marks 05

Table 1.12.1.

Population	Number of Towns or Villages
< 500	605
501 – 100	295
1001 – 2000	105
2001 – 5000	35
> 5000	15

Answer

Given : Total area = 10000 km², Developed non agricultural area, B = 2850 km², Railway track length, R = 95 km

To Find : Length of NH and secondary roads.

1. Agricultural area, $A = 10000 - 2850 = 7150$ km²
2. The total length of metalled road for NH,

$$NH + SH + MDR = \frac{A}{8} + \frac{B}{32} + 1.6N + 8T + D - R$$

$$= \frac{7150}{8} + \frac{2850}{32} + 1.6 \times 35 + 8 \times 15 + 15\% \text{ of total road length} - 95$$

$$= 893.75 + 89.0625 + 56 + 120 + \frac{15}{100} \times 1158.81 - 95$$

$$= 1158.8 + 173.8 - 95 = 1237.6 \text{ km}$$

3. The total length of secondary roads,

$$ODR + VR = [0.32V + 0.8Q + 1.6P + 3.2S] + D$$

$$= (0.32 \times 605 + 0.8 \times 295 + 1.6 \times 105 + 3.2 \times 35) + 0.15 \times \text{Road length}$$

$$= 709.6 + 0.15 \times 709.6$$

$$ODR + VR = 816.04 \text{ km}$$

PART-5

Bombay Road Plan.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.13. **Explain the Bombay Road Plan.**

AKTU 2014-15, Marks 3.5

OR

Discuss the main recommendations and road classification of Bombay Road Plan. **AKTU 2013-14, Marks 05**

OR

Discuss Bombay Road Plan. **AKTU 2016-17, Marks 10**

Answer

Bombay Road Plan :

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

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

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

iii. Rural roads were given specific attention. Scientific methods of construction were proposed for the rural roads. The necessary technical advice to the Panchayats 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 32 kms per 100 sq. km.

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

Road Classification : Road classification in Bombay Road Plan is same as Nagpur Road Plan : Refer Q. 1.8, Page 1–10C, Unit-1.

Que 1.14. **How will you determine the length of roads according to second 20 years road plan ?**

Answer

Length of roads can be calculated as :

i. National Highway (km)

$$= \left[\frac{A}{64} + \frac{B}{80} + \frac{C}{96}\right] + [32K + 8M] + D$$

ii. National Highway + State Highway (km)

$$= \left[\frac{A}{20} + \frac{B}{24} + \frac{C}{32}\right] + [48K + 24M + 11.2N + 1.6P] + D$$

iii. National Highway + State Highway + Major District Roads (km)

$$= \left[\frac{A}{8} + \frac{B}{16} + \frac{C}{24}\right] + [48K + 24M + 11.2N + 9.6P + 6.4Q + 2.4R] + D$$

iv. National Highway + State Highway + Major District Roads + Other District Roads (km)

$$= \left[\frac{3A}{16} + \frac{3B}{32} + \frac{C}{16}\right] + [48K + 24M + 11.2N + 9.6P + 12.8Q + 4R + 0.8S + 0.32T] + D$$

v. National Highways + State Highways + Major District Roads + Other District Roads + Village Roads i.e., all roads (km)

$$= \left[\frac{A}{4} + \frac{B}{8} + \frac{C}{12}\right] + [48K + 24M + 11.2N + 9.6P + 12.8Q + 5.9R + 1.6S + 0.62T + 0.2V] + D$$

where, A = Developed and agricultural areas, km^2
B = Semi-developed area, km^2
C = Undeveloped area, km^2
K = Number of towns with population over 1,00,000
M = Number of towns with population range 1,00,000 – 50,000
N = Number of towns with population range 50,000 – 20,000
P = Number of towns with population range 20,000 – 10,000
Q = Number of towns with population range 10,000 – 5,000
R = Number of towns with population range 5,000 – 2,000
S = Number of towns with population range 2,000 – 1,000
T = Number of towns with population range 1,000 – 500
V = Number of towns range below 500
D = Development allowance of 5 % of road length calculated for further development and other unforeseen factors.

PART-6

3rd 20 Year Road Plan.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.15. Explain the 3rd 20 year road plan with its salient features.

Answer

Lucknow Road Plan, 1984 : Some of the salient features of this plan are as follows :

1. This was the third 20 year road plan (1981-2001). It is also called Lucknow Road Plan.
2. It aimed at constructing a road length of 12 lakh kilometres by the year 1981 resulting in a road density of 82 kms/100 sq. km.
3. The plan has set the target length of NH to be completed by the end of seventh, eighth and ninth five year plan periods.
4. It aims at improving the transportation facilities in villages, towns etc. such that no part of country is farther than 50 km from NH.
5. One of the goals contained in the plan was that expressways should be constructed on major traffic corridors to provide speedy travel.
6. Energy conservation, environmental quality of roads and road safety measures were also given due importance in this plan.

Que 1.16. How would you calculate the length of various types of roads according to Lucknow road plan ?

Answer

Following formula give the lengths of various classes of roads :

1. Length of NH (in km) = (Area/10000) = (Area in sq. km/50)
2. Length of SH (in km) = (Area in sq. km/25)

   or Length (in km) = 62.5 × Number of towns with population above 5,000 - (Area in sq. km/50)
3. Length of MDR (in km) = (Area in sq. km/12.5)

   or Length (in km) = 90 × Number of towns with population above 5,000
4. Total road length (in km) = 4.74 × Number of villages and town
5. Rural Road Length (in km) = This can be calculated by finding the total road length and subtracting the other categories.

PART-7

Horizontal Profile and Vertical Profile, Factor Affecting Highway Alignment.

CONCEPT OUTLINE

Horizontal Profile : It includes straight path, horizontal deviation and curve.

Vertical Profile : It includes changes in gradient and vertical curve.

Factors Controlling Alignment of Roads :

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

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.17. What is alignment ? Explain the factors controlling the alignment of roads.

Answer

Highway Alignment :

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

ii. The horizontal alignment includes the straight path, the horizontal deviations and curves.

iii. Changer in gradient and vertical curves is covered under vertical alignment of roads.

Factors : Following are the various affecting factor of controlling the alignment of roads :

1. Purpose and Class of Road :

i. The alignment should be selected according to the purpose and class of road.

ii. The national highway connecting two important towns should be kept perfectly straight as far as possible.

iii. On the other hand alignment of other category of road can be deviated when straight alignment is not feasible.

2. Obligatory Points :

i. The alignment should pass through obligatory points such as intermediate important towns, group of village and area of commercial, political, military and social importance.

ii. Hence to connect obligatory points alignment may be changed.

3. Curve :

i. Curves must be as flat as possible.

ii. It may be necessary to make adjustment in the horizontal alignment of roads keeping in view the minimum radius of curve and the transition curves.

4. Gradient :

i. While aligning a new road, the gradient should be flat and less than the ruling or design gradient.

ii. Thus in order to avoid excessive fall or rise the alignment is to be changed.

5. Sight Distance :

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

ii. Also there should be enough distance visible ahead for safe overtaking operations of vehicles moving at design speed on the road.

iii. Hence the alignment should be finalised in such a way that it should provide good sight distance.

6. Number of Drainage Crossing : The alignment should have minimum number of drainage crossing.

7. Railway and River Crossing : The alignment should cross river or the railway line at right angles.

8. Obstruction :

i. Alignment should be free from obstruction.

ii. Hence alignment can be changed to avoid well, lake, pond, historical and religious buildings etc.

9. Formatting Bed : Alignment should run on good soil as far as possible.

10. Earthwork : The alignment should have less earthwork. Hence avoid excessive cutting or filling, the alignment must be changed.

Que 1.18. What are the various requirement of an ideal highway alignment ? Discuss briefly.

Answer

Following are the requirements of ideal highway alignment :

1. Short :

i. In between two terminal stations the alignment should be as short as possible.

ii. Short alignments provide economy in the cost of construction, maintenance and transportation.

iii. The alignment should be as straight as possible to meet this requirement.

2. Easy :

i. The alignment must be easy in construction, maintenance and traffic operations.

ii. The alignment should be easy for the operation of vehicles with easy gradients and curves to meet this requirement.

3. Safe :

i. The alignment should be safe for traffic operation.

ii. To fulfill this requirement, the alignment should be safe enough for construction and maintenance from the view point of stability of natural hill slopes, embankment and cut slopes and foundation of embankments.

4. Economical : The alignment should be economical in its cost of construction, maintenance and traffic operations.

5. Utility : The alignment should offer maximum utility by serving maximum population by connecting intermediate important towns and group of villages.

6. Natural Aspects : The alignment should pass through regions of natural beauty and scenery to have good natural aspects.

PART-8

Survey for Route Location.

CONCEPT OUTLINE

Survey for Route Location : Following steps are follow for survey of route location :

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

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.19. What are the various surveys to be carried out before planning a highway system for a given area ? Explain briefly.

AKTU 2017-18, Marks 10

Answer

Following are the various surveys carried out before planning a highway :

A. Map Study :

1. If the topographic map of the area is available, it will provide the possible route of the road.
2. By study of these maps, it is possible to have an idea of several possible alternate routes of highway.
3. Map study gives a rough guidance of the routes to be further surveyed in the field.

B. Reconnaissance :

1. A field survey party examines the general character of a fairly broad stretch of land between the terminal stations in the field, along the proposal alternative alignments marked on the map is known as reconnaissance survey.
2. In this survey, simple survey instruments like prismatic compass, abney level, tangent clinometers, barometer etc may be used.
3. Some of the details to be collected during this survey as given below :

i. Valleys, ponds, lake, marshy land, ridge, hills, permanent structures and other obstruction along the route which are not available in the map.

ii. Approximate value of gradient, length of gradients and radius of curve of alternate alignments.

iii. Number and types of cross drainage structures, maximum flood level and natural ground water level along the probable routes.

iv. When the road passes through hilly or mountainous terrain, additional data regarding the geological formation, type of rock, dip of strata, seepage flow etc. may be observed.

C. Preliminary Survey :

1. The art of finding the details of alternative alignments found suitable during the reconnaissance survey is known as preliminary survey.
2. In this survey chain, tape, prismatic compass, leveling instrument are used.
3. The main objectives of preliminary survey are :

i. To survey the various alternate alignments proposed after the reconnaissance.

ii. To compare the different proposals in view of the requirements of a good alignment.

iii. To estimate the quantity of earth work and other construction aspects and to work out the cost of alternate proposals.

iv. To finalize the best alignment.

D. Location and Detailed Survey :

1. The detailed examination of the field along the alignment finally recommended during the preliminary survey is called location survey.
2. Detailed survey should be carried out for calculating information necessary for the preparation of plans and construction detail for the highway project.

Que 1.20. **Explain how the find location and detailed survey of a highway are carried out.**

Answer

1. Location Survey :

i. Transferring the alignment on to ground. This is done by transit theodolite.

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

iii. Centre lines tacks are driven at suitable intervals, say 50 m interval in plane and rolling terrains and 20 m in hilly terrain.

2. Detailed Survey :

i. Temporary benchmarks are fixed at intervals of about 250 m and a tall drainage and underpass structure.

ii. Earthwork calculations and drainage details are to be work out from the level books.

iii. 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.

iv. Detail soil survey is to be carried out.

v. CBR value of the soils along the alignment may be determined for design of pavement.

vi. The data during detailed survey should be elaborate and complete for preparing detailed plans, design and estimates of project.

☺☺☺

2 UNIT

Cross Sectional Elements of Roads

CONTENTS

PART-1

Cross Sectional Element.

CONCEPT OUTLINE

Cross Sectional Elements of Road : Following are the elements of road :

i. Right of way.
ii. Width of carriageway.
iii. Kerbs.
iv. Width of roadway or formation.
v. Camber.
vi. Shoulder.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 2.1. What do you understand by highway geometric design? Discuss the objective and factors affecting of geometric design.

Answer

A. Highway Geometric Design :

1. It deals with the dimensions and layout of visible features of the highway.
2. The emphasis of the geometric design is to address the requirement of the driver and the vehicle such as safety, comfort, efficiency, etc.
3. The features normally considered are the cross section elements, sight distance consideration, horizontal curvature, gradients, and intersection.
4. The design of these features is to a great extend influenced by driver behavior and psychology, vehicle characteristics, traffic characteristics such as speed and volume.
5. Proper geometric design will help in the reduction of accidents and their severity.

B. Objective : The objective of geometric design is to provide optimum efficiency in traffic operation and maximum safety at reasonable cost.

C. Factors Affecting of Geometric Design : Following are the affecting factors of geometric design of roads :

1. **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.

2. **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.
3. **Traffic Factors :** It will be uneconomical to design the road for peak traffic flow. Therefore a reasonable value to traffic volume is selected as the design hourly volume which is determined from the various traffic data collected.
4. **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.
5. **Vehicle :** The dimensions, weight of the axle and operating characteristics of a vehicle influence the design aspect such as width of the pavement, radii of the curves, clearance, parking, etc.
6. **Environmental and Other Factors :** The environmental factors like air pollution, noise pollution, landscaping, aesthetics should be given due considerations in the geometric design of roads.
7. **Economy :** The design adopted should be economical as far as possible. It should be match with the funds allotted for capital cost and maintenance.

Que 2.2. Discuss the cross sectional elements of roads considered for design. Draw a neat sketch of cross section of two lanes road with dual carriageway and median in rural area. Also indicate proper dimension of elements on sketch. **AKTU 2013-14, Marks 05**

Answer

A. Cross-Sectional Elements of Roads : Following are the cross-sectional elements of roads :

1. Right of Way :

i. The area of land acquired for the road along road alignment is known as right of way. It is also known as land width.
ii. It depends on the importance of the road and possible future development.
iii. It is fixed by the IRC for different area and type of roads.

2. Camber :

i. Camber is the slope provided to the road surface in the transverse direction to drain off the rain water from the road surface.
ii. Camber is provided in three shapes :
   a. Straight line.
   b. Parabolic shape.
   c. Combination of parabola and straight line.

3. **Kerb :** Kerb indicates the boundary between road pavement and shoulder. Kerb may be divided into three groups.

i. Low or mountable type.

ii. Semi-barrier type.

iii. Barrier type.

4. **Road Margin :** The various elements included in the road margins are shoulder, parking lane, frontage road, driveway, cycle track, footpath, guard rail and embankment slope.

5. **Width of Carriageway :** The width of carriageway depends on the width of traffic lane and number of lanes. The minimum width of carriageway for single lane is 3.75 m.

B. Sketch :

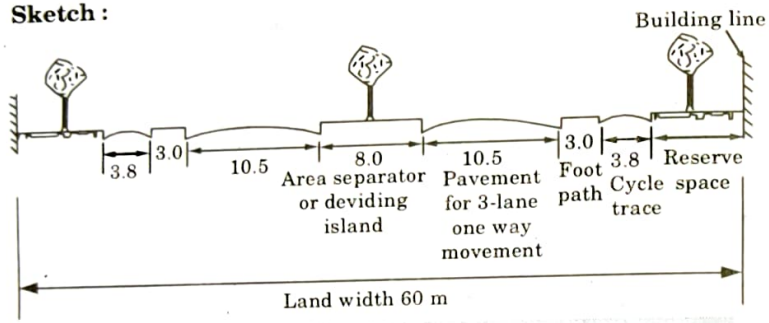


Fig. 2.2.1. Cross section of divided highway in urban area.

Que 2.3. Explain the pavement surface characteristics in highway geometric design. Also state the factors affecting friction between pavement and tyres of vehicles.

Answer

Pavement Surface Characteristics : For safe and comfortable driving four aspects of the pavement surface are important :

i. The friction between the wheels and the pavement surface.

ii. Smoothness of the road surface.

iii. The light reflection characteristics of the top of pavement surface.

iv. Drainage to water.

Following are the factors affecting friction between pavement and tyres of vehicles :

1. **Friction :**

i. Friction between the wheel and the pavement surface is a crucial factor in the design of horizontal curves and thus the safe operating speed.

ii. Further, it also affects the acceleration and deceleration ability of vehicles. Lack of adequate friction can cause skidding or slipping of vehicles.

iii. IRC suggests the coefficient of longitudinal friction as 0.35-0.4 depending on the speed and coefficient of lateral friction as 0.15.

iv. Various factors that affect friction are :

a. Type of the pavement (like bituminous, concrete, or gravel).

b. Condition of the pavement (dry or wet, hot or cold, etc).

c. Condition of the tyre (new or old).

d. Speed and load of the vehicle.

2. **Unevenness :**

i. 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.

ii. Unevenness affects the vehicle operating cost, speed, riding comfort, safety, fuel consumption and wear and tear of tyres.

3. **Light Reflection :**

i. White roads have good visibility at night, but caused glare during day time.

ii. Black roads has no glare during day, but has poor visibility at night.

iii. Concrete roads have better visibility and less glare.

iv. It is necessary that the road surface should be visible at night and reflection of light is the factor that answers it.

4. **Drainage :**

i. The pavement surface should be absolutely impermeable to prevent seepage of water into the pavement layers.

ii. Both the geometry and texture of pavement surface should help in draining out the water from the surface in less time.

PART-2

Camber, Shoulder.

CONCEPT OUTLINE

Camber : It is defined as the slope of the line joining the crown and the edge of the road surface. It is also known as transverse slope.
Shoulder : It acts as a service lane for vehicles that have broken down, The minimum shoulder width recommended by IRC is 2.5 m.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 2.4. **Explain camber. What are the objects of camber? Discuss the factors on which the amount of camber to be provided depends. Specify the recommended ranges of camber for different types of pavements surfaces.**

Answer

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

B. Objects : Following are the objectives to provide camber in roads :

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

C. Table 2.4.1. Recommended values of camber for different types of road surfaces.

S.No.	Types of Road Surface	Range of Camber in Areas of Rainfall Range	
		Heavy	Light
1.	Cement concrete and high type bituminous surface.	1 in 50 (2.0 %)	1 in 60 (1.7 %)
2.	Thin bituminous surface	1 in 40 (2.5 %)	1 in 50 (2.0 %)
3.	Water bound macadam and gravel pavement	1 in 33 (3.0 %)	1 in 40 (2.5 %)
4.	Earth	1 in 25 (4.0 %)	1 in 33 (3.0 %)

Que 2.5. **Discuss the various types of shapes of camber in road.**

Answer

Shape of Camber : Following are the various types of shapes of camber :

1. Parabolic Camber or Barrel Camber :

i. It consists of a continuous curve which may be of parabolic or elliptical shape.

ii. It gives flat profile at the middle and steep profile towards the pavement edges.

iii. It is generally preferred for fast moving vehicles. Fast moving vehicles have to cross the crown line frequently when they are to overtake other vehicles on a two-line highway.

iv. A parabolic camber is shown in Fig. 2.5.1.

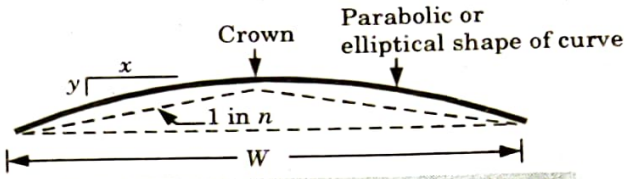


Fig. 2.5.1. Parabolic camber $y = 2x^2 / nW$.

ii. Straight Line Camber or Sloped Camber :

i. In this case, the pavement edge is joined with the edge of road in the shape of a straight line.

ii. Sloped camber is adopted when very flat camber is to be provided as in case of cement concrete roads.

iii. Steel tyred wheels while moving develop high stresses and can cause damage to the road surface. Fig. 2.5.2 shows a straight line camber.

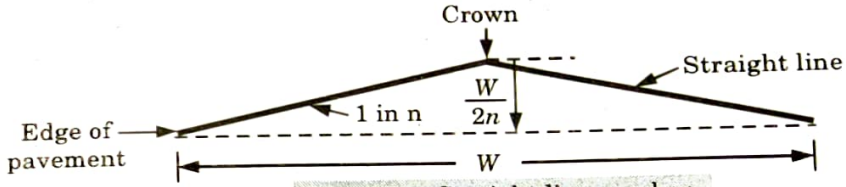


Fig. 2.5.2. Straight line camber.

iii. Combined Camber or Composite Camber :

i. In this case, straight lines are provided near the pavement edges but at the crown, parabolic shape is provided as shown in Fig. 2.5.3.

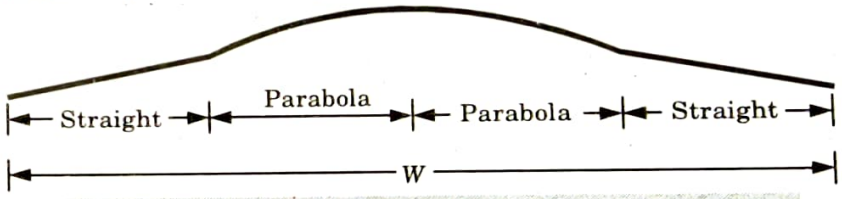


Fig. 2.5.3. Combination of straight and parabolic camber.

ii. In case of straight line camber, the board can easily be prepared with triangular shape at the bottom. But for parabolic camber, the following relation is used :

$$y = x^2 / a$$

where, $a = nW/2$ for a pavement of width W and cross slope 1 in n.

Hence, $$y = \frac{2x^2}{nW}$$

Que 2.6. **Enumerate the factors governing the width of carriage way and right of way. State the IRC specifications for width of carriageway for various classes of roads.**

Answer

A. Factors : The width of carriageway depends on the width of traffic lane and number of lanes. The lane width of road depends on width of vehicle and minimum side clearance.

B. Factor Affecting Right of Way : Following are the factors affecting right of way :

1. **Width of Formation :** It depends on the category of the highway and width of roadway and road margins.
2. **Height of Embankment or Depth of Cutting :** It is governed by the topography and the vertical alignment.
3. **Side Slopes of Embankment or Cutting :** It depends on the height of the slope, soil type etc.
4. Drainage system and their size which depends on rainfall, topography etc.
5. **Sight Distance Considerations :** On curves, there is restriction to the visibility on the inner side of the curve due to the presence of some obstructions like building structures etc.
6. **Reserve Land for Future Widening :** Some land has to be acquired in advance anticipating future developments like widening of the road.

C. IRC Specifications for Width of Carriageway :

Table 2.6.1.

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

Que 2.7. Write short note on shoulders.

Answer

1. Shoulders also act as service lanes for vehicles that have broken down.
2. Shoulders are provided along the road edge to serve as an emergency lane for vehicle compelled to be taken out of the pavement or roadway.
3. The width of shoulder should be adequate to accommodate stationary vehicle fairly away from the edge of adjacent lane.
4. It is desirable to have a minimum shoulder width of 4.6 m so that a truck stationed at the side of the shoulder would have a clearance of 1.85 m from the pavement edge.

5. The minimum shoulder width recommended by the IRC is 2.5 m.
6. The shoulders should have sufficient load bearing capacity to support loaded truck even in wet weather.
7. The surface of the shoulder should be rougher than the traffic lanes so that vehicles are discouraged to use the shoulder as a regular traffic lane.
8. The colour of the shoulder should preferably be different from that of the pavement so as to be distinct.

PART-3

Sight Distance.

CONCEPT OUTLINE

Stopping Sight Distance : The driver of vehicle should be able to see clearly at least a certain portion of road length to avoid collision or accident. The absolute minimum length of road required for this purpose is known as stopping sight distance.

SSD = Braking distance + Lag distance

$$SSD = \frac{v^2}{2gf} + vt \qquad (\because v \text{ in m/s})$$

For single lane and two way traffic = 2 × SSD

Overtaking Sight Distance (OSD) : The minimum distance able to vision of the driver of a vehicle intending to overtake slow vehicle ahead with safety against the traffic of opposite direction is known as OSD.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 2.8. Explain sight distance and what are the factors on which the stopping sight distance depends ? Explain briefly ?

Answer

Sight Distance : It is the length of road visible ahead to the driver at any instance.

Factor Affecting the SSD : Following are the affecting factors of SSD :

1. **Reaction Time of Driver :** Is the time taken from the instant the object is visible to the driver to the instant when the brakes are applied. IRC suggests a reaction time of 2.5 secs.

2. **Speed of the Vehicle :** Higher the speed, more time will be required to stop the vehicle.

3. **Efficiency of Brakes :**

i. If the brake efficiency is 100%, the vehicle will stop the moment the brakes are applied.

ii. The sight distance required will be more when the efficiency of brakes is less.

4. **Frictional Resistance Between the Tyre and the Road :**

i. When the frictional resistance is more, the vehicles stop immediately. Thus sight distance required will be less.

ii. IRC has specified the value of longitudinal friction in between 0.35 to 0.4.

5. **Gradient of the Road :**

i. While climbing up a gradient, the vehicle can stop immediately. Therefore sight distance required is less.

ii. 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 this case.

Que 2.9. Derive an expression for finding the stopping sight distance at level and at grade.

Answer

The stopping sight distance is the sum of lag distance and the braking distance.

$$SSD = \text{Lag distance} + \text{Braking distance} \quad ...(2.9.1)$$

1. **Lag Distance :** It is the distance the vehicle traveled during the reaction time t,

$$\text{Lag distance} = vt \quad ...(2.9.2)$$

where v is the velocity in m/sec.

2. **Braking Distance :**

i. It is the distance traveled by the vehicle during braking operation. For a level road this is obtained by equating the work done in stopping the vehicle and the kinetic energy of the vehicle.

ii. Work done against friction in stopping the vehicle is given by,

$$\text{Work done} = fWl, \quad ...(2.9.3)$$

where W is the total weight of the vehicle.

iii. The kinetic energy at the design speed is given by,

$$\frac{1}{2}mv^2 = \frac{1}{2}\frac{Wv^2}{g} \quad ...(2.9.4)$$

iv. From eq. (2.9.3) and eq. (2.9.4), we get

$$fWl = \frac{Wv^2}{2g}$$

Braking distance, $l = \frac{v^2}{2gf}$ ...(2.9.5)

3. From eq. (2.9.2) and eq. (2.9.5), values put in eq. (2.9.1), then

$$SSD = vt + \frac{v^2}{2gf}$$

4. When there is a ascending gradient of + n % the component of gravity adds to the braking action and hence the braking distance decreased. Equating kinetic energy and work done :

$$\left(fW + \frac{Wn}{100}\right)l = \frac{Wv^2}{2g}$$

$$l = \frac{v^2}{2g\left(f + \frac{n}{100}\right)}$$

5. Similarly the braking distance can be derived for a descending gradient. Therefore the general equation is given by,

$$SSD = vt + \frac{v^2}{2g(f \pm 0.01n)}$$

Que 2.10. Calculate the stopping sight distance for design speed of 100 kmph. Take the total reaction time 2.5 seconds and coefficient of friction = 0.35. **AKTU 2014-15, Marks 3.5**

Answer

Given : Design speed, $V = 100$ kmph
Total reaction time, $t = 2.5$ sec
Coefficient of friction, $f = 0.35$
To Find : Stopping sight distance.

1. Design speed in m/sec, $v = \frac{100}{3.6} = 27.78$ m/sec.

2. $$SSD = vt + \frac{v^2}{2gf}$$

$$SSD = 27.78 \times 2.5 + \frac{(27.78)^2}{2 \times 9.81 \times 0.35} = 181.83 \text{ m}$$

Que 2.11. What is overtaking sight distance ? State factors on which the overtaking sight distance depends.

Answer

A. **Overtaking Sight Distance :** The minimum distance able to the visible of the drive of a vehicle intending to overtake slow vehicle as head with

safety against the traffic of opposite direction is known as the minimum overtaking sight distance (OSD) or the safe passing sight distance.

B. Factor Affecting the OSD :

1. Speeds of :

i. Overtaking vehicle.

ii. Overtaken vehicle.

iii. The vehicle coming from opposite direction if any.

2. Distance between the overtaking and overtaken vehicles.

3. Skill and reaction time of the driver.

4. Rate of acceleration of overtaking vehicle.

5. Gradient of the road.

Que 2.12. Derive the expression for calculating the overtaking sight distance on a highway. **AKTU 2014-15, Marks 3.5**

OR

Derive an expression for calculating the overtaking sight distance on a highway. Calculate the stopping sight distance for design speed of 100 kmph. Take the total reaction time 2.5 seconds and coefficient of friction = 0.35. **AKTU 2017-18, Marks 10**

Answer

1. Fig. 2.12.1 shows the overtaking manoeuvre of vehicle A traveling at design speed, and another slow vehicle B on a two-lane road with two-way traffic. Third vehicle C comes from the opposite direction.

2. The overtaking manoeuvre may be split up into three operations, thus dividing the overtaking sight distance into three parts, d_1, d_2 and d_3.

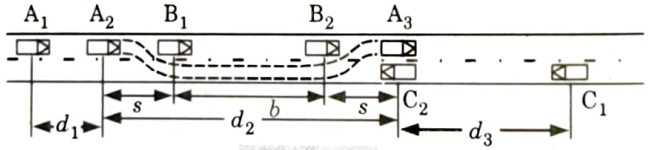


Fig. 2.12.1.

3. In Fig. 2.12.1. A is the overtaking vehicle originally traveling at design speed v m/sec, or V kmph; B is the overtaken or slow moving vehicle moving with uniform speed v_b m/sec or V_b kmph; C is a vehicle coming from opposite direction at the design speed v m/sec or V kmph.

4. Certain assumptions are made in order to calculate the values of d_1, d_2 and d_3.

i. The distance travelled by the vehicle A during the reaction time, t, $d_1 = v_b t$. This reaction time t of the driver may be taken as two seconds as an average value.

ii. From position A_2, the vehicle A starts accelerating, shifts to the adjoining lane, overtakes the vehicle B, and shifts back to its original lane ahead of B in position A_3 in time T sec.

iii. The minimum spacing between vehicles depends on their speed and is given by,

$$s = (0.7\, v_b + 6)\ \text{m}$$

iv. The distance travelled by vehicle A, from A_2 to A_3,

Hence, $d_2 = v_b T + 2s$

where, T = Time taken by A for overtaking operation.

$$T = \sqrt{\frac{4s}{a}}\ \text{sec}$$

v. The distance travelled by vehicle C moving at design speed v m/sec during the overtaking operation of vehicle A *i.e.* during time T is the distance d_2 between positions C_1 to C_2.

Hence, $d_3 = v \times T$

5. Thus the overtaking sight distance,

$$\text{OSD} = (d_1 + d_2 + d_3) = (v_b t + v_b T + 2s + vT)$$

Numerical : Refer Q. 2.10, Page 2–11C, Unit-2.

Que 2.13. Write short note on :

i. Intermediate sight distance.
ii. Head light sight distance.
iii. PIEV theory.
iv. Overtaking zone.

Answer

1. Intermediate Sight Distance :

i. This is defined as twice the stopping sight distance.

ii. When overtaking sight distance cannot be provided, intermediate sight distance is provided to give limited overtaking opportunities to fast vehicles.

2. Head Light Sight Distance :

i. This is the distance visible to a driver during night driving under the illumination of the vehicle head lights.

ii. This sight distance is critical at up-gradients and at the ascending stretch of the valley curves.

3. PIEV Theory : Total reaction time of driver is split into four parts :

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

ii. Intellection : It is the time required for understanding the situation.

iii. Emotion : It is the time elapsed during emotional sensation and disturbance such as fear, anger or any other emotional feeling such as superstition etc, with reference to the situation.

iv. **Volition :** It is the time taken for the final action.

4. Overtaking Zones :

i. It is desirable to construct highways in such a way that the length of road visible ahead at every point is sufficient for safe overtaking.

ii. This is seldom practicable and there may be stretches where the safe overtaking distance cannot be provided. But the overtaking opportunity for vehicles moving at design speed should be given at frequent intervals.

iii. These zones which are meant for overtaking are called overtaking zones.

iv. The minimum length of overtaking zone should be three time the safe overtaking distance *i.e.*, $3\ (d_1 + d_2)$ for one way roads and $3(d_1 + d_2 + d_3)$ for two-way roads.

v. Desirable length of overtaking zones is kept five times the overtaking sight distance *i.e.*, $5(d_1 + d_2)$ for one-way roads and $5(d_1 + d_2 + d_3)$ for two-way roads.

Que 2.14. Calculate the stopping sight distance and overtaking sight distance for a design speed of 80 kmph.
Take a = 2.5 kmph/sec, ascending slope of 2 %.

AKTU 2015-16, Marks 10

Answer

Given : Design speed, V = 80 kmph, a = 2.5 kmph/sec, Ascending slope = 2 %.
To Find : SSD and OSD

A. Stopping Sight Distance :

Total reaction time t may be taken as 2.5 sec and design coefficient of friction as $f = 0.35$, $g = 9.8$ m/sec^2

1. $n = 2\ \% = 0.02$

2. Velocity, $v = \dfrac{80}{3.6} = 22.22$ m/sec

3. SSD on road with gradient is given by,

$$SSD = vt + \frac{v^2}{2g(f \pm n)}$$

$$= 22.22 \times 2.5 + \frac{(22.22)^2}{2 \times 9.8\,(0.35 + 0.02)}$$

$$SSD = 124 \text{ m}$$

B. Calculation of OSD : Assume two way traffic.

1. Speed of overtaking vehicle, V = 80 kmph
Speed of overtake vehicle, V_b = V – 16 = 80 – 16 = 64 kmph

2. $d_1 = 0.28\ V_b t = 0.28 \times 64 \times 2.5 = 44.8$ m

3. $d_2 = 0.28\ V_b T + 2s$

$s = 0.2\ V_b + 6 = 0.2 \times 64 + 6 = 18.8$

$$T = \sqrt{\frac{14.4s}{a}} = \sqrt{\frac{14.4 \times 18.8}{2.5}} = 10.41 \text{ sec.}$$

$d_2 = 0.28 \times 64 \times 10.41 + 2 \times 18.8 = 224.14$ m

4. $d_3 = 0.28 \times VT = 0.28 \times 80 \times 10.41 = 233.18$ m

5. OSD $= d_1 + d_2 + d_3$
$= 44.8 + 224.14 + 233.18 = 502.12$ m

PART-4

Horizontal Curves, Superelevation.

CONCEPT OUTLINE

Horizontal Curve : A horizontal curve is a curve in plane to provide change in direction to the central line of a road.
Superelevation (e) : It is the ratio of the height of outer edge with respect to the horizontal width. It is given by,

$$e + f = \frac{v^2}{gR}$$

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 2.15. Explain the overturning effect and transverse skidding effect in design of horizontal curve for highway.

Answer

1. Overturning Effect :

i. The centrifugal force that tends the vehicle to overturn about the outer wheels B on horizontal curve without superelevation is shown in Fig. 2.15.1.

ii. The overturning moment due to centrifugal force P is $P \times h$; this is resisted by the restoring moment due to weight of the vehicle W and is equal to $W\,b/2$,
where, h = Height of the center of gravity of the vehicle above the road suface.

b = Width of the wheel base or the wheel track of the vehicle.

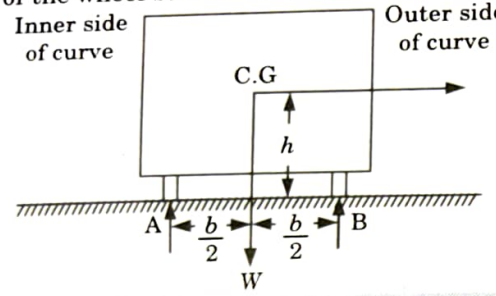


Fig. 2.15.1. Overturning due to centrifugal force.

iii. The equilibrium condition for overturning will occur when

$$Ph = Wb/2, \text{ or when } P/W = b/2h.$$

This means that there is danger of overturning when the centrifugal ratio P/W or v^2/gR attain a value of $b/2h$.

2. Transverse Skidding Effect :

i. The centrifugal force developed has also the tendency to push the vehicle outwards in the transverse direction.

ii. If the centrifugal force P developed exceeds the maximum possible transverse skid resistance due to the friction, the vehicle will start skidding in the transverse direction.

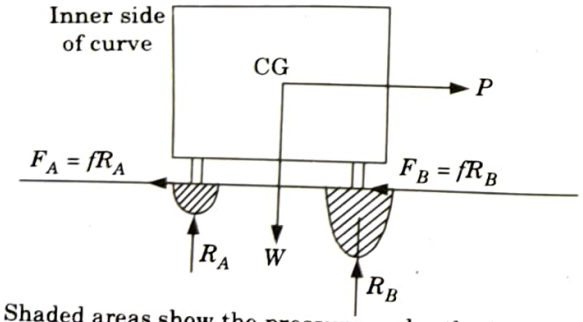
iii. From Fig. 2.15.1, the equilibrium condition for the transverse skid resistance developed is given by :

$$P = F_A + F_B = f(R_A + R_B) = fW$$

where, f = Coefficient of friction between the tyre and the pavement surface in the transverse direction.

R_A and R_B = Normal reactions at the wheels A and B

$(R_A + R_B)$ = Weight W of the vehicle, in no superelevation case.



Shaded areas show the pressure under the inner and outer wheels A and b

Fig. 2.15.2. Skidding effect due to centrifugal force.

iv. Since $P = fW$, the centrifugal ratio P/W is equal to 'f'. In other when the centrifugal ratio attains a value equal to the coefficient of lateral friction there is a danger of lateral skidding.

v. Thus to avoid overturning and lateral skidding of a horizontal curve, the centrifugal ratio should always be less than $b/2h$ and also 'f'.

Que 2.16. Explain superelevation. Derive an equation for finding the superelevation required if the design coefficient of lateral friction is 'f'.

Answer

Superelevation :

1. 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 superelevation or cant or banking.

2. The superelevation 'e' is expressed as the ratio of the height of outer edge with respect to the horizontal width. From Fig. 2.16.1 it may be see that superelevation.

$$e = \frac{NL}{ML} = \tan\theta$$

3. If e is the superelevation rate and E is the total superelevated height of outer edge, the total rise in outer edge of the pavement with respect to the inner edge = $NL = E = eB$.

Analysis of Superelevation :

1. The forces acting on the vehicle while moving on a circular curve of radius R metres, at speed of v m/sec are

i. The centrifugal force $P = Wv^2/gR$ acting horizontally outwards through the center of gravity, CG.

ii. The weight W of the vehicle acting vertically downwards through the CG.

iii. The frictional force developed between the wheels and the pavement counteractions transversely along the pavement surface towards the center of the curve.

2. From Fig. 2.16.1, for equilibrium condition,

$$P\cos\theta = W\sin\theta + F_A + F_B$$

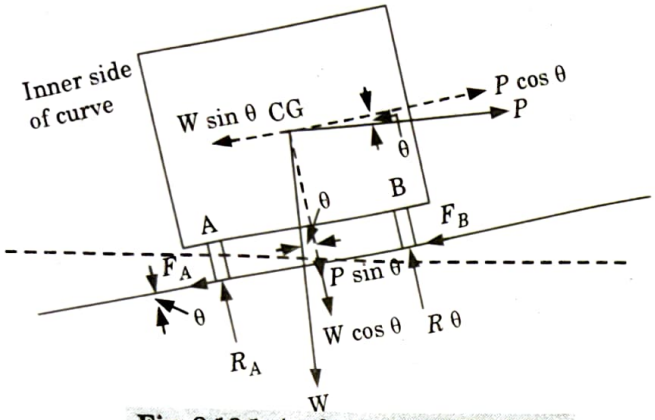


Fig. 2.16.1. Analysis of superelevation.

3. At the limiting equilibrium, $f = 0.15$

$$F_A = fR_A \quad \text{and} \quad F_B = fR_B$$

Therefore, $P \cos \theta = W \sin \theta + f(R_A + R_B)$

$$= W \sin \theta + f(W \cos \theta + P \sin \theta)$$

$$P(\cos \theta - f \sin \theta) = W \sin \theta + f W \cos \theta$$

Dividing by $W \cos \theta$,

$$\frac{P}{W}(1 - f \tan \theta) = \tan \theta + f$$

$$\frac{P}{W} = \frac{\tan \theta + f}{1 - f \tan \theta}$$

$$\tan \theta + f = \frac{v^2}{gR}(1 - f \tan \theta) \qquad \left[\because \frac{P}{W} = \frac{v^2}{gR}\right]$$

$$e + f = \frac{v^2}{gR}(1 - ef) \qquad [\because e = \tan \theta]$$

$$[\because 1 - ef = 0.99 \simeq 1]$$

Therefore, $$e + f = \frac{v^2}{gR}$$

4. when V in kmph

$$e + f = \frac{V^2}{127\,R}$$

Que 2.17. Explain maximum and minimum superelevation in brief. **AKTU 2014-15, Marks 3.5**

Answer

A. Maximum Superelevation : Following values are fixed by IRC in regards of maximum superelevation :

1. Indian Roads Congress had fixed the maximum limit of superelevation in plain and rolling terrains and in snow bound areas as 7.0 percent.
2. However, on hill roads not bound by snow a maximum superelevation upto 10 percent.
3. On urban road stretches with frequent intersection, it may be necessary to limit the maximum superelevations to 4.0 percent.

B. Minimum Superelevation :

1. From drainage considerations it is necessary to have a minimum cross slope to drain off the surface water.
2. If the calculated superelevation is equal to or less than the camber of the road surface, then the minimum superelevation to be provided on horizontal curve may be limited to the camber of the surface.
3. In very flat curves with large radius the centrifugal force developed will be very small and in such cases the normal camber may be retained on the curves.

Que 2.18. Enumerate the step for practical design of superelevation.

Answer

Steps for Superelevation Design : Following step should be follow to design of superelevation :

Step (i) : The superelevation for 75 percent of design speed (v m/sec or V kmph) is calculated neglecting the friction

$$e = \frac{(0.75\,v)^2}{gR} \text{ or } \frac{(0.75\,V)^2}{127\,R}$$

i.e., $$e \approx \frac{V^2}{225\,R} \qquad ...(2.18.1)$$

Step (ii) : If the calculated value of 'e' is less than 7 % or 0.07 the value so obtained is provided. If the value of 'e' as per eq. 2.18.1 exceeds 0.07 then provide the maximum superelevation equal to 0.07 and proceed with steps (iii) or (iv).

Step (iii) : Check the coefficient of friction developed for the maximum value of $e = 0.07$ at the full value of design speed,

$$F = \left(\frac{v^2}{gR} - 0.07\right) = \left(\frac{V^2}{127R} - 0.07\right)$$

If the value of f thus calculated is less than 0.15, the superelevation of 0.07 is safe for the design speed. If not, calculate the restricted speed as given in step (iv),

Step (iv) : As an alternative to step (iii), the allowable speed (v m/sec. or V kmph) at the curve is calculated by considering the design coefficient of lateral friction and the maximum superelevation, *i.e.*,

$$e + f = 0.07 + 0.15$$

$$= 0.22 = \frac{v^2}{gR} = \frac{V^2}{127\,R}$$

Safe allowable speed, $v = \sqrt{0.22\,gR} = \sqrt{2.156\,R}$ m/sec

or $V = \sqrt{27.94\,R}$ kmph

If the allowable speed, as calculated above is higher than the design speed, then the design is adequate and provides a superelevation of 'e' equal to 0.07. If the allowable speed is less than the design speed, the speed is limited to the allowable speed V kmph calculated above.

Que 2.19. **Design the superelevation required at a horizontal curve of radius 300 m for speed for 60 kmph. Assume suitable data.**

AKTU 2014-15, Marks 3.5

Answer

Given : Radius of horizontal curve, $R = 300$ m
Speed of vehicle, V = 60 kmph
To Find : Superelevation.

1. Superelevation is given by,

$$e = \frac{(0.75\,V)^2}{127\,R} = \frac{(0.75 \times 60)^2}{127 \times 300} = 0.0531$$

2. This value is less than 0.07
Hence, provided superelevation, $e = 0.0531$

Que 2.20. **The radius of a horizontal circular curve is 100 m. The design speed is 50 kmph and the design coefficient of lateral friction is 0.15. Calculate the superelevation required if full lateral friction is assumed to develop.**

AKTU 2016-17, Marks 10

Answer

Given : Radius of curve, $R = 100$ m, Design speed, $V = 50$ kmph
Coefficient of friction, $f = 0.15$
To Find : Superelevation.

1. Superelevation is given by,

$$e + f = \frac{V^2}{127R}$$

$$e + 0.15 = \frac{(50)^2}{127 \times 100}$$

$$e = 0.047$$

PART-5

Extra Widening.

CONCEPT OUTLINE

Extra Widening : It is the addition width of carriage way that is required on curved section of a road. It is given by,

$$W_e = W_m + W_{ps} = \frac{nl^2}{2R} + \frac{V}{9.5\sqrt{R}}$$

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 2.21. **State the objectives of widening of pavement on horizontal curves. Derive an expression for finding the extra widening required on horizontal curve.**

Answer

Objectives : Following are the objectives of widening of pavements on horizontal curve :

1. The driver experience difficulties in steering around the curve.
2. The vehicle occupies a greater width as the rear wheel doesn't track the front wheel, known as off tracking.
3. For greater visibility at curve
4. For two vehicle cross or overtake at horizontal curve safely.

Derivation of Extra Widening on Curves :

1. The extra widening of pavement on horizontal curves is divided into two parts (i) Mechanical and (ii) Psychological widening.

i. Mechanical Widening :

a. The widening required to account for the off-tracking due to the rigidity of wheel based is called mechanical widening (W_m) and may be calculated as :

From Fig. 2.21.1,

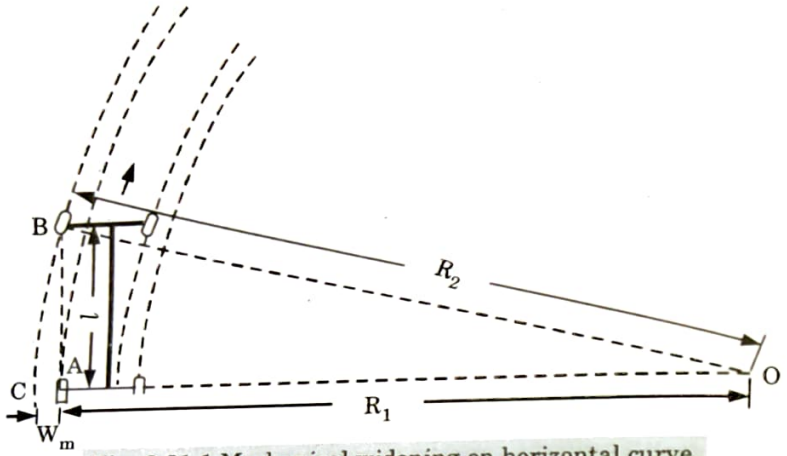


Fig. 2.21.1 Mechanical widening on horizontal curve.

$$W_m = OC - OA = OB - OA = R_2 - R_1$$

From Δ OAB, $R_1^2 = R_2^2 - l^2$

But $R_1 = R_2 - W_m$

$$(R_2 - W_m)^2 = R_2^2 - l^2$$

On solving, $$W_m = \frac{l^3}{2R_2 - W_m} = \frac{l^2}{2R} \text{ (approximately)}$$

b. In a road having 'n' traffic lanes, as 'n' vehicles can travel simultaneously, the total mechanical widening required is given by,

$$W_m = \frac{nl^2}{2R}$$

ii. Psychological Widening :

a. Extra width of pavement is also provided for psychological reasons such as, to provide for greater maneuverability 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.

b. The psychological widening is given by,

$$W_{ps} = \frac{V}{9.5\sqrt{R}}$$

2. Hence the total widening W_e required on a horizontal curve is given by,

$$W_e = W_m + W_{ps}$$

$$W_e = \frac{nl^2}{2R} + \frac{V}{9.5\sqrt{2}}$$

where, n = Number of traffic lanes.

l = Length of wheel base of longest vehicle in m. (l = 6.1 or 6 m)

V = Design speed, kmph

R = Radius of horizontal curve in, m

PART-6

Transition Curve and Gradients.

CONCEPT OUTLINE

Transition Curve : When a non circular curve is introduce between a straight and a circular curve has a varying radius which decrease from infinity at the straight end to the desired radius of the circular curve at the other end for the other end for the gradual introduction of centrifugal force is known as transition curve.

Gradient : It is the rate of rise or fall along the length of the road with respect to the horizontal.

Type of Gradients :

i. Ruling gradient. ii. Limiting gradient.

iii. Exceptional gradient. iv. Minimum gradient.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 2.22. What are the objects of providing transition curves and explain its various types.

Answer

Objective : Following are the objectives for providing transition curves on horizontal alignment of highways :

1. To introduce gradually the centrifugal force between the tangent point and the beginning of the circular curve, avoiding sudden jerk on the vehicle. This increases the comfort of passengers.

2. To enable the driver turn the steering gradually for his own comfort and security.
3. To provide gradual introduction of superelevation.
4. To provide gradual introduction of extra widening.
5. To enhance the aesthetic appearance of the road.

Types of Transition Curves : Following are the curve used as transition curve in highway alignment :

1. Spiral (also called clothoid).
2. Lemniscate.
3. Cubic parabola.

IRC recommends spiral as the transition curve because it fulfills the requirement of an ideal transition curve *i.e.*

i. Rate of change of centrifugal acceleration is consistent.

ii. Radius of the transition curve is infinity of the straight edge and changes to R at the curve point ($L_S \propto 1/R$).

Que 2.23. Derive an expression for finding length of transition curve on horizontal alignment of highways.

Answer

Length of Transition Curve : The length of the transition curve should be determined as the maximum of the following three criteria.

1. **Rate of Change of Centrifugal Acceleration :** The rate of change of centrifugal acceleration should be adopted such that the design should not cause discomfort to the drivers.

The length of the transition curve L_s (in m) is given by,

$$L_s = \frac{v^3}{CR}$$

where C is the rate of change of centrifugal acceleration given by,

$$C = \frac{80}{75 + 3.6\,v}, \quad 0.5 < C < 0.8$$

2. **Rate of Introduction of Superelevation :**

i. Raise (E) of the outer edge with respect to inner edge is given by $E = eB = e(W + W_e)$.

ii. The rate of change of this raise from 0 to E is achieved gradually with a gradient of 1 in N over the length of the transition curve (typical range of N is 60 – 150).

a. The length of the transition curve L_s is :

$$L_s = Ne\,(W + W_e)$$

b. If the pavement is rotated about the center line, then

$$L_S = \frac{e\,N}{2}\,(W + W_e)$$

3. **By Empirical Formula :**

i. IRC suggests the length of the transition curve is minimum for a plain and rolling terrain :

$$L_s = \frac{2.7\,V^2}{R}$$

ii. For steep and hilly terrain, $L_s = \frac{V^2}{R}$

4. Shift (s) is given by, $s = \frac{L_s^2}{24R}$

Que 2.24. A two lane pavement of 7.0 m width on a NH in a rolling terrain has a curve of radius 65 m. The design speed is 45 km/hr. Determine the length of transition and circular curves.

AKTU 2013-14, Marks 05

Answer

Given : Width of pavement, W = 7.0 m, Radius of curve, R = 65 m, Design speed, V = 45 kmph

To Find : Length of transition and circular curves.

1. Superelevation for design speed,

$$e = \frac{(0.75\,V)^2}{127\,R} = \frac{(0.75 \times 45)^2}{127 \times 65} = 0.138 > 0.07$$

2. Check the safety against transverse skidding,

$$f = \frac{V^2}{127\,R} - e = \frac{45^2}{127 \times 65} - 0.07$$

$$= 0.175 > 0.15, \quad \text{It is not safe.}$$

3. Redesign the design speed, V

$$e + f = \frac{V^2}{127\,R}$$

$$0.07 + 0.15 = \frac{V^2}{127 \times 65}$$

$$V = 42.6 \text{ kmph}$$

4. Assume design speed for this curve is 40 kmph.

5. Length of Transition Curve :

i. By rate of change of centrifugal acceleration :

$$C = \frac{80}{75 + V} = \frac{80}{75 + 40} = 0.696 \text{ m/sec}^3$$

$$L_s = \frac{v^3}{CR} = \frac{\left(\frac{40}{3.6}\right)^3}{0.696 \times 65} = 30.32 \text{ m}$$

ii. By rate of introduction of superelevation (e),

$$e = \frac{(0.75 \times 40)^2}{127 \times 65} = 0.109 > 0.07$$

iii. Check for lateral friction, $f = \frac{V^2}{127\,R} - e$

$$= \frac{40^2}{127 \times 65} - 0.07 = 0.12 < 0.15$$

Provide superelevation, $e = 0.07$

iv. Extra widening of pavement,

$$W_e = \frac{nl^2}{2R} + \frac{V}{9.5\sqrt{R}} = \frac{2 \times 6^2}{2 \times 65} + \frac{40}{9.5\sqrt{65}} = 1.08 \text{ m.}$$

v. Total width of pavement = $W + W_e = 7 + 1.08 = 8.08$ m

Assume outer edge rise w.r.t to inner edge of pavement.

Assume rate of introduction of superelevation taken as 1 in 150

$L_s = Ne\,(W + W_e) = 150 \times 0.07 \times 8.08 = 84.84$ m

vi. By IRC formula, the minimum length,

$$L_s = \frac{2.7V^2}{R} = \frac{2.7 \times 40^2}{65} = 66.46 \text{ m}$$

vii. Adopt highest value, length of transition curve,

$$L_s = 84.84 = 85 \text{ m}$$

6. Length of Circular Curve :

i. Assume deflection angle,

$$\Delta = 60°$$

ii. Length of circular curve,

$$l = R\Delta \frac{\pi}{180°} = 65 \times 60° \frac{\pi}{180°} = 68 \text{ m}$$

Que 2.25. Calculate the length of transition curve for a design speed of 80 kmph at horizontal curve of radius 300 m in rural area. Assume suitable data.

AKTU 2014-15, Marks 06

AKTU 2017-18, Marks 05

Answer

Given : Design speed of vehicle, V = 80 kmph, Radius of horizontal curve, $R = 300$ m

To Find : Length of transition curve.

1. By rate of change of centrifugal acceleration,

Length of transition curve,

$$L_s = \frac{v^3}{CR}, C = \frac{80}{75 + V} = \frac{80}{75 + 80} = 0.516$$

$$L_s = \frac{\left(\frac{80}{3.6}\right)^3}{0.516 \times 300} = 70.89 \text{ m}$$

2. For minimum length of transition curve given by IRC,

$$L_s = \frac{2.7V^2}{R} = \frac{2.7 \times 80^2}{300} = 57.6 \text{ m}$$

3. By rate of introduction of superelevation :

Superelevation, $e = \frac{(0.75\,V)^2}{127\,R} = \frac{(0.75 \times 80)^2}{127 \times 300} = 0.094 > 0.07$

Check for lateral friction, $f = \frac{V^2}{127R} - e$

$$= \frac{80^2}{127 \times 300} - 0.07 = 0.098 < 0.15$$

Provide superelevation, $e = 0.07$

4. Assume two lane two way roads.

Width of road pavement, $W = 7.0$ m

Extra widening, $W_e = \frac{nl^2}{2R} + \frac{V}{9.5\sqrt{R}}$

$$W_e = \frac{2 \times 6^2}{2 \times 300} + \frac{80}{9.5\sqrt{300}} = 0.61$$

$$W + W_e = 7.0 + 0.61 = 7.61 \text{ m}$$

5. Assume rotation of pavement about inner edge of road

$N = 1$ in 150 (by IRC)

$L_s = Ne\,(W + W_e) = 150 \times 0.07 \times 7.61 = 79.9$ m

6. Adopt length of transition curve, $L_s = 79.9 \approx 80$ m

Que 2.26. Calculate the length of transition curve and the shift using the following data; Design speed = 65 kmph

Radius of circular curve = 220 m

Allowable rate of introduction of superelevation (pavement rotated about the centre line) = 1 in 150

Pavement width including extra widening = 7.5 m

AKTU 2017-18, Marks 10

Answer

Given : Design speed, $V = 65$ kmph, Radius of curve, $R = 220$ m

Supper elevation = 1/150, Extra widening = 7.5 m

To Find : Length of transition curve and shift.

1. Length of transition curve L_s as per allowable rate of centrifugal acceleration C.

i. Allowance rate of change of centrifugal acceleration is given by,

$$C = \frac{80}{(75 + V)} = \frac{80}{(75 + 65)} = 0.57 \text{ m/sec}^3$$

This value is between 0.5 and 0.8 and hence accepted.

ii. Length of curve, $L = \frac{0.0215\,V^3}{C\,R} = \frac{0.0215 \times 65^3}{0.57 \times 220} = 47.1$ m

2. Length L_s by allowable rate of introduction of superelevation E.

i. Superelevation rate,

$$e = \frac{V^2}{225\,R} = \frac{65^2}{225 \times 220} = 0.085$$

As this value is greater than the maximum allowable rate of 0.07, limit the value of $e = 0.07$.

ii. Check the safety against transverse skidding for the design speed of 65 kmph.

$$f = \frac{V^2}{127\,R} - e = \frac{65^2}{127 \times 220} - 0.07$$

$$= 0.15 - 0.07 = 0.08$$

As this value of f is less than the allowable value of 0.15, the superelevation rate of 0.07 is safe for the design speed of 65 kmph.

iii. The width of the pavement at the curve, $B = 7.5$ m

iv. Total raise of outer edge of pavement with respect to the centre line

$$= \frac{E}{2} = \frac{e\,B}{2} = \frac{0.07 \times 7.5}{2} = 0.26 \text{ m}$$

Rate of introduction of superelevation, 1 in N = 1 in 150

$$L_s = \frac{EN}{2} = 0.26 \times 150 = 39 \text{ m}$$

3. Minimum value of L_s as per IRC

$$= \frac{2.7\,V^2}{R} = \frac{2.7 \times 65^2}{220} = 51.9 \text{ m}$$

Adopt the highest value of the three *i.e.*, 51.9 or say 52 m as the design length of transition curve.

4. Shift, $S = \frac{L_s^2}{24\,R} = \frac{52^2}{24 \times 220} = 0.51$ m

Que 2.27. Discuss gradients and its types. Specify the values recommended by IRC for plains and hills.

Answer

Gradients : It is the rate of rise or fall along the length of the road with respect to the horizontal. It is expressed as a ratio 1 in n (1 vertical unit to n horizontal units). Sometimes the gradient is also expressed as a percentage *i.e.*, n % (n in 100)

Types of Gradients : Following are the various types of gradients :

A. Ruling Gradient :

1. The ruling gradient or the design gradient is the maximum gradient within which the designer attempts to design the vertical profile of the road.
2. This depends on the terrain, length of the grade, speed, pulling power of the vehicle and the presence of the horizontal curve.
3. In flatter terrain, it may be possible to provide at gradients, but in hilly terrain it is not economical and sometimes not possible also.
4. The IRC has recommended ruling gradient value of 1 in 30 on plain and rolling terrain, 1 in 20 on mountainous terrain and 1 in 16.7 on steep terrain.

B. Limiting Gradient :

1. It is steeper than the rolling gradients.
2. This gradient is adopted when the ruling gradient results in enormous increase in cost of construction.
3. It may be frequently necessary to limiting gradient.

C. Exceptional Gradient :

1. Exceptional gradient are very steeper gradients given at unavoidable situations.
2. They should be limited for short stretches not exceeding about 100 meters at a stretch.
3. In mountainous and steep terrain, successive exceptional gradients must be separated by a minimum 100 meter length gentler gradient.

D. Minimum Gradient :

1. Minimum gradient is important for the longitudinal drainage along the side drains requires some slope for smooth flow of water.
2. It depends on the rain fall, type of soil and other site conditions.
3. A minimum of 1 in 500 may be sufficient for concrete drain and 1 in 200 for open soil drains are found to give satisfactory performance.

Que 2.28. What is grade compensation ? Also give IRC specification for it.

Answer

Grade Compensation : It can be defined as the reduction in gradient at the horizontal curve because of the additional tractive force required due to curve resistance, which is intended to offset the extra tractive force involved at the curve.

IRC Specification : Following are specification for the grade compensation :

1. Grade compensation is not required for grades flatter than 4 % because the loss of tractive force is negligible.
2. Grade compensation is $(30 + R)/R$, where R is the radius of the horizontal curve in meters.
3. The maximum grade compensation is limited to $75/R$.

PART-7

Vertical Curves, Summit and Valley Curve.

CONCEPT OUTLINE

Vertical curves : It is of following two type :

i. Summit curve.

ii. Valley curve.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 2.29. What do you understand by vertical curve ? Also explain its types.

Answer

A. Vertical Curves :

1. Due to changes in grade in the vertical alignment of highway, it is necessary to introduce vertical curve at the intersections of different grades to smoothen out the vertical profile and thus ease off the changes in gradients for the fast moving vehicles.
2. The vertical curves used in highway may be classified into two categories :

i. Summit curves or crest curves with convexity upwards.

ii. Valley or sag curves with concavity upwards.

Type of Vertical Curve :

1. **Summit Curves :** These are vertical curves with gradient upwards. They are formed when two gradients meet as shown in Fig. 2.29.1.

i. When a positive gradient meets another positive gradient [Fig. 2.29.1(*a*)].

ii. When positive gradient meets a flat gradient [Fig. 2.29.1(*b*)].

iii. When an ascending gradient meets a descending gradient [Fig. 2.29.1(*c*)].

iv.. When a descending gradient meets another descending gradient [Fig. 2.2.29(*d*)].

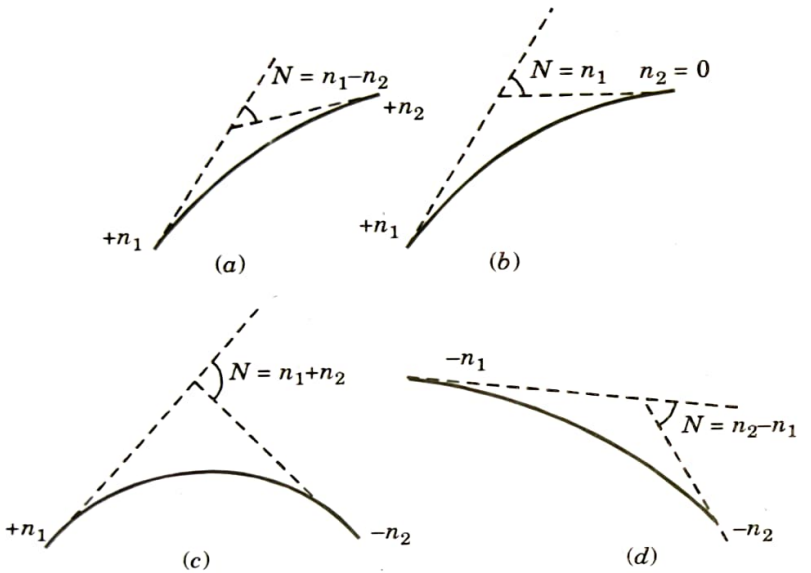
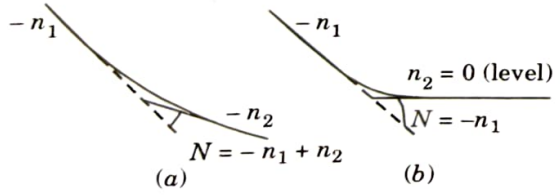


Fig. 2.29.1. Types of summit curves.

2. **Valley Curves or Sag Curves :** These are vertical curves with convexity downwards. They are formed when two gradients meet as shown in Fig. 2.29.2.

1. When a descending gradient meets another descending gradient [Fig. 2.29.2(*a*)].
2. When a descending gradient meets a flat gradient [Fig. 2.29.2(*b*)].
3. When a descending gradient meets an ascending gradient [Fig. 2.29.2(*c*)].
4. When an ascending gradient meets another ascending gradient [Fig. 2.29.2(*d*)].



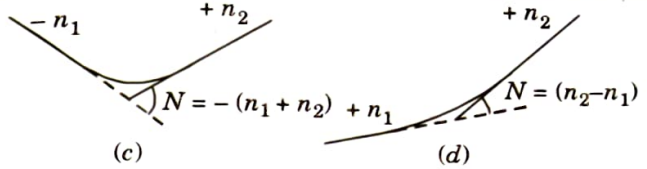


Fig. 2.29.2. Types of valley curve.

Que 2.30. Discuss the Design criteria of length of summit curve. Also give the expression of calculation of length of summit curve.

Answer

Design Criteria :

i. Design of summit curve on the basis of sight distance.

ii. On summit curves centrifugal force acting outward hence the spring of vehicle is not compressed and there force passenger comfort is not a issue.

iii. Design of summit curve as a square parabola because the rate of change of slope is decreasing always so more sight distance available at the top of curve.

Length of the Summit Curve :

1. In deriving the length of the curve, two situations can arise depending on the uphill and downhill gradients *i.e.*, when the length of the curve is greater than the sight distance and when the length of the curve is less than the sight distance.

2. Let L is the length of the summit curve, S is the SSD/ISD/OSD, N is the deviation angle, h_1 driver's eye height (1.2 m), and h_2 the height of the obstruction (0.15 m), then the length of the summit curve can be derived for the following two cases.

Case (*a*) : Length of Summit Curve Greater than Sight Distance

$$L = \frac{NS^2}{2(\sqrt{h_1} + \sqrt{h_2})^2} \qquad ...(2.30.1)$$

Case (*b*) : Length of Summit Curve Less than Sight Distance

$$L = 2S - \frac{2(\sqrt{h_1} + \sqrt{h_2})^2}{N} \qquad ...(2.30.2)$$

i. When stopping sight distance is considered, put the value of h_1 and h_2 in eq. (2.30.1) and eq. (2.30.2), then

a. $L = \frac{NS^2}{4.4}$ (for $L > S$)

b. $L = 2S - \frac{4.4}{N}$ (for $L < S$)

ii. If overtaking sight distance is considered, then the value of driver's eye height (h_1) and the height of the obstruction (h_2) are taken equal as 1.2 metres.

a. $L = \frac{NS^2}{9.6}$ (for $L > S$)

b. $L = 2S - \frac{9.6}{N}$ (for $L < S$)

Que 2.31. **What do you understand by vertical curves ? An ascending gradient of 1 in 50 and a descending gradient of 1 in 80. Determine the length of summit curve to provide**

i. SSD

ii. OSD, for design speed of 80 kmph. Assume all other data.

AKTU 2015-16, Marks 15

Answer

A. Vertical Curves : Refer Q. 2.29, Page 2–31C, Unit-2.

B. Numerical :

Given : Ascending gradient, $n_1 = 1/50$,

Descending gradient, $n_2 = -1/80$, Design speed, V = 80 kmph.

To Find : Length of summit curve.

1. Assuming $t = 2.5$ sec and $f = 0.35$ for V = 80 kmph

2. **In case of SSD :**

i. $$SSD = 0.278\ Vt + \frac{V^2}{254f}$$

$$= 0.278 \times 80 \times 2.5 + \frac{80^2}{254 \times 0.35}$$

$$SSD = 55.6 + 72.0 = 127.6 \text{ say } 128 \text{ m}$$

ii. Deviation angle, $N = n_1 - n_2 = \left(\frac{1}{50}\right) - \left(-\frac{1}{80}\right) = \frac{8+5}{400} = \frac{13}{400}$

iii. Length of summit curve :

Assuming $L > SSD$

$$L = \frac{NS^2}{4.4} = \frac{\frac{13}{400} \times 128^2}{4.4} = 121 \text{ m } (< 128 \text{ m})$$

iv. Further assume $L < SSD$

$$L = 2S - \frac{4.4}{N} = 2 \times 128 - \frac{4.4}{0.0325}$$

$$= 120.6 \simeq 121 \text{ m} < 128 \text{ m, Hence OK}$$

Therefore, length of summit curve = 121 m

3. **In case of OSD :**

i. Calculation of OSD is same as Q. 2.14, Page, Unit-2.

OSD = 502.12 m

Assume $L > OSD$

ii. Length of summit curve, $L = \frac{NS^2}{9.6} = \frac{0.0325 \times 502.12^2}{9.6} = 853.55$ m

> 502.12 m, Hence OK

iii. Therefore, the length of summit curve = 853.55 m

Que 2.32. **An ascending gradient of 1 in 50 meets a descending gradient of 1 in 80. Determine length of summit curve to provide (a) ISD (b) OSD, for design speed of 80 kmph. Assume all other data.**

AKTU 2017-18, Marks 10

Answer

Given : Ascending gradient $(n_1) = \frac{1}{50}$

Descending gradient, $(n_2) = -\frac{1}{80}$

Design speed, V = 80 kmph

To Find : Length of submit curve.

Assuming $t = 2.5$ sec and $f = 0.35$ for V = 80 kmph

1. $$SSD = 0.278\ Vt + \frac{V^2}{254f}$$

$$= 0.278 \times 80 \times 2.5 + \frac{80^2}{254 \times 0.35}$$

$$SSD = 55.6 + 72.0 = 127.6 \text{ say } 128 \text{ m}$$

2. $$ISD = 2 \times SSD = 2 \times 128 = 256 \text{ m}$$

3. Deviation angle, $N = n_1 - n_2 = \left(\frac{1}{50}\right) - \left(-\frac{1}{80}\right) = \frac{8+5}{400} = \frac{13}{400} = 0.0325$

A. Length of Summit Curve in case of ISD :

1. Assuming $L > ISD$

$$L = \frac{NS^2}{9.6} = \frac{\frac{13}{400} \times 256^2}{9.6} = 221.86 \text{ m } (< 256 \text{ m})$$

2. Further assume $L < ISD$

$$L = 2S - \frac{9.6}{N} = 2 \times 256 - \frac{9.6}{0.0325}$$

$$= 216.6 \simeq 217 \text{ m} < 256 \text{ m OK}$$

3. Therefore, length of summit curve = 217 m

B. Length of Summit Curve in case of OSD : Refer Q. 2.31, Page 2–34C, Unit-2.

Que 2.33. Describe the design consideration of length of valley curve. Also write down the formulae for determining the length of valley curve.

Answer

A. Design Considerations for Valley Curve :

1. There is no restriction to sight distance at valley curves during day time. But visibility is reduced during night.
2. In the absence or inadequacy of street light, the only source for visibility is with the help of headlights. Hence valley curves are designed taking into account of headlight distance.
3. In valley curves, the centrifugal force will be acting downwards along with the weight of the vehicle, and hence impact to the vehicle will be more. This will result in jerking of the vehicle and cause discomfort to the passengers.
4. Thus the most important design factors considered in valley curves are :

i. Impact-free movement of vehicles at design speed.

ii. Availability of stopping sight distance under headlight of vehicles for night driving.

5. For gradually introducing and increasing the centrifugal force acting downwards, the best shape that could be given for a valley curve is a transition curve. Cubic parabola is generally preferred in vertical valley curves.
6. During night, under headlight driving condition, sight distance reduces and availability of stopping sight distance under head light is very important. The head light sight distance should be at least equal to the stopping sight distance.
7. There is no problem of overtaking sight distance at night since the other vehicles with headlights could be seen from a considerable distance.

B. Length of the Valley Curve : The length of the valley transition curve is designed based on two criteria :

1. Comfort criteria; that is allowable rate of change of centrifugal acceleration is limited to a comfortable level of about 0.6 m/sec^3.
2. Safety criteria; the driver should have adequate headlight sight distance at any part of the country.

Comfort Criteria : The length of the valley curve based on the rate of change of centrifugal acceleration that will ensure comfort :

Length of valley curve, $L_s = \sqrt{\frac{Nv^3}{C}}$

$$L = 2\sqrt{\frac{Nv^3}{C}} \qquad (\because \ L = 2L_s)$$

where, L = Total length of valley curve.

N = Deviation angle.

C = Allowable rate of change of centrifugal acceleration which may be taken as 0.6 m/sec^3.

C. Safety Criteria : Length of the valley curve for headlight distance may be determined for two conditions :

Case (1) : Length of Valley Curve Greater than Stopping Sight Distance ($L > S$)

$$L = \frac{NS^2}{2h_1 + 2S\tan\alpha}$$

where, $h_1 = 1.5$ m, Height of headlight beam, α = Head beam inclination S = Sight distance. The inclination α is $\approx 1°$.

$$L = \frac{NS^2}{(1.5 + 0.035S)}$$

Case (2) : Length of Valley Curve Less than Stopping Sight Distance ($L < S$)

$$L = 2S - \frac{(1.5 + 0.035S)}{N}$$

Que 2.34. **A valley curve is formed by a descending gradient of 1 in 20 which meets an ascending gradient of 1 in 25 :**

i. **Design the total length of valley curve if the design speed is 80 kmph so as to fulfill both comfort condition and head light sight distance for night driving, after calculating the SSD required.**

ii. **Find the position of the lowest point of the valley curve to locate a under passing culvert.**

AKTU 2013-14, Marks 05

Answer

Given : $n_1 = -1/20$, $n_2 = 1/25$, Design speed, V = 80 kmph

To Find : Total length of valley curve and the position of lowest point of the valley curve.

Assume : Total reaction time, $t = 2.5$ sec

Longitudinal co-efficient of friction, $f = 0.35$

1. $$SSD = vt + \frac{v^2}{2gf} = \frac{80}{3.6} \times 2.5 + \frac{\left(\frac{80}{3.6}\right)^2}{2 \times 9.81 \times 0.35} = 127.45 \text{ m}$$

2. $$N = -\frac{1}{20} - \frac{1}{25} = \frac{-5-4}{100} = \frac{-9}{100}$$

3. **Comfort Condition :**

$$C = \frac{80}{75 + 80} = 0.52 \text{ m/sec}^3$$

$$L = 2\left[\frac{Nv^3}{C}\right]^{\frac{1}{2}} = 2\left[\frac{9}{100} \times \frac{\left(\frac{80}{3.6}\right)^3}{0.52}\right]^{\frac{1}{2}} = 87.15 \text{ m}$$

4. **Head Light Sight Distance :**

Assume $L > SSD$

$$L = \frac{NS^2}{1.5 + 0.035S} = \frac{0.09 \times 127.45^2}{1.5 + 0.035 \times 127.45} = 245.26 \text{ m}$$

Design length of valley curve = 245.26 m

B. Position of Lowest Point of the Valley Curve :

1. When a valley curve is included between descending and ascending grades, it is necessary to know the lowest point on the curve for fixing the positions of culverts, drain outputs, etc.

2. When the two grades are unequal, the lowest point occurs on the side of the flatter gradient.

3. The lowest point will be at a distance of $\frac{n_1}{n_1 - n_2} L$ from starting point of valley curve.

4. Distance, $$x = \frac{n_1}{n_1 - n_2} L$$

$$= \frac{-1/20}{-1/20 - 1/25} \times 245.26$$

$$x = 136.25 \text{ m}$$

☺☺☺

3 UNIT

Traffic Engineering

CONTENTS

PART-1

Traffic Characteristics.

CONCEPT OUTLINE

Traffic Characteristics : These are of two types :

i. Traffic characteristics
- Physical.
- Mental.
- Psychological.
- Environmental.

ii. Vehicular characteristics
- Vehicle dimension.
- Weight of loaded vehicles.
- Power of vehicles.
- Speed of vehicles.
- Braking characteristics.
- Off tracking.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 3.1. Discuss the various types of traffic characteristics in traffic engineering.

Answer

Following are the types of traffic characteristics in traffic engineering :

A. Road User Characteristics :

1. Human beings performing different roles in the traffic are most important elements of the traffic and so we have to study their characteristics and behavior. Various roles of human are such as driver, pedestrians, cyclists etc.
2. The physical, mental and emotional characteristics of human beings affect their ability to operate motor vehicle safely or to service as a pedestrian.
3. Broadly classified under four heads :

i. **Physical Characteristics :** Vision, hearing, strength and reaction to traffic situation.

ii. **Mental Characteristics :** Knowledge, skill, intelligence, experience, literacy.

iii. **Psychological Characteristics :** Emotional factors such as fear, anger, anxiety, etc.

iv. **Environmental Factors :** Traffic stream conditions, atmospheric conditions, facilities to the traffic locality, etc.

B. Vehicular Characteristics :

1. It is quite important to study the important vehicular characteristics which affect the design and traffic performance. For economic feasibility the standards of vehicles should be kept uniform.

2. The vehicular characteristics are classified as :

i. **Static Characteristics :** It involves dimensions of vehicles (length, width and height, wheel base, departure and ramp angles, the front, rear and centre clearances), weight, maximum turning angle.

ii. **Dynamic Characteristics :** It includes speed, acceleration, power and breaking characteristics.

iii. **Braking Characteristics :** The deceleration and braking characteristics of vehicles depend on design and type of braking system and its efficiency. The safety of vehicle operation, stopping distance, and the spacing between two consecutive vehicles in a traffic stream is affected by the braking capacity.

PART-2

Traffic Studies on Flow, Speed, Travel Time-delay and O-D Study.

CONCEPT OUTLINE

Traffic Volume : It is the number of vehicles moving in a specified direction on a given lane or roadway that pass a given point or cross section in specified unit of time. It is expressed as vehicle/hr or vehicle/day.

Traffic Capacity : It is expressed as the maximum number of vehicles in a lane or a road that can pass a given point in unit time. It is given by,

$$C = \frac{1000\ V}{S}$$

where, C = Capacity of a single lane vehicles/hr.
V = Speed in kmph.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 3.2. **Explain the term traffic volume.**

AKTU 2013-14, 2017-18; Marks 2.5

OR

What are the objects of carrying out traffic volume studies ?

OR

Write short note on traffic volume study.

AKTU 2014-15, Marks 03

Answer

A. Traffic Volume Study :

1. The number of vehicles that pass a point on a highway or a given lane or direction of a highway during a specific time interval.
2. The measurement is carried out by counting the number of vehicles (n_t) passing a particular point in one lane in a defined period t.
3. Then the flow (q) expressed in vehicles/hour is given by,

$$q = \frac{n_t}{t}$$

B. Objects : Following are the objectives of traffic volume study :

i. Traffic volume is generally accepted as a true measure of the relative importance of roads and in deciding the priority for improvement and expansion.

ii. Traffic volume study is used in planning, traffic operation and control of existing facilities and also for planning and designing the new facilities.

iii. This study is used in the analysis of traffic patterns and trends.

iv. Classified volume study is useful in structural design of pavements, in geometric design and in computing roadway capacity.

v. Volume distribution study is used in planning one-way streets and other regulatory measures.

vi. Turning movement study is used in the design of intersections, in planning signal timings, channelization and other control devices.

vii. Pedestrian traffic volume study is used for planning side walks, cross walks subways and pedestrian signals.

Que 3.3. **How the traffic volume data are presented in traffic engineering ?**

OR

Write short note on thirtieth highest hourly traffic volume.

AKTU 2014-15, Marks 03

Answer

Presentation of Traffic Volume Data : Following forms in which traffic volume data are represented :

1. Annual average daily traffic (AADT or ADT) of the total traffic as well as classified traffic are calculated. This helps in deciding the relative importance of a route and in phasing the road development programme. In order to convert the different vehicle classes to one class such as passenger car, conversion factors known as passenger car unit (PCU) are used.
2. Trend charts showing volume trends over period of years are prepared. These data are useful for planning future expansion, design and regulation.

3. Variation charts showing hourly, daily and seasonal variations are also prepared. These help in deciding the facilities and regulation needed during peak traffic periods.
4. Traffic flow maps along the routes, (the thickness of the lines representing the traffic volume to any desired scale), are drawn. These help to find the traffic volume distribution at a glance.
5. Volume flow diagram at intersections either drawn to a certain scale or indicating traffic volume is prepared, thus showing the details of crossing and turning traffic. These data are needed for intersection design.

6. Thirtieth Highest Hourly Traffic Volume :

i. Thirtieth highest hourly volume or the design hourly volume is found from the plot between hourly volume and the number of hours in a year that the traffic volume is exceeded.

ii. The 30^{th} highest hourly volume is the hourly volume that will be exceeded only 29 times in a year and all other hourly volumes of the year will be less than this value.

iii. The highest or peak hourly volume of the year will be too high that it will not be economical to design the facilities according to this volume.

iv. The annual average hourly volume (AAHV) found from AADT will not be sufficient during considerable period of a year.

v. The high facilities designed with capacity for 30^{th} highest hourly traffic volume in the assumed year is found to be satisfactory from both facility and economic considerations.

Que 3.4. Explain the following terms :

i. Spot speed.

ii. Space mean speed. **AKTU 2013-14, 2017-18; Marks 2.5**

iii. Running speed.

iv. Time mean speed.

v. Average speed.

Answer

i. Spot Speed : It is the instantaneous speed of a vehicle at a specified section or location.

ii. Space Mean Speed : It represents the average speed of vehicles in a certain road length at any time. This is obtained from the observed travel time of the vehicles over a relatively long stretch of the road. Space-mean speed is calculated from,

$$V_s = \frac{3.6\, dn}{\sum_{i=1}^{n} t_i}$$

where, V_s = Space-mean speed, kmph
d = Length of road considered, m
n = Number of individual vehicle observations.
t_i = Observed travel time (sec) for i^{th} vehicle to travel distance d, m

iii. Running Speed : It is the average speed maintained by a vehicle over a particular stretch of road, while the vehicle is in motion; this is obtained by dividing the distance covered by the time during which the vehicle is actually in motion.

iv. Time Mean Speed : It represents the speed distribution of vehicles at a point on the roadway and it is the average of instantaneous speeds of observed vehicles at the spot. Time-mean speed is calculated form,

$$V_t = \frac{\sum_{i=1}^{n} V_i}{n}$$

where, V_t = Time-mean speed, kmph
V_i = Observed instantaneous speed of i^{th} vehicles, kmph
n = Number of vehicles observed.

v. Average Speed : It is the average of the spot speeds of all vehicles passing a given point on the highway.

Que 3.5. Discuss in detail any one methods of spot speed studies. Also give the application of spot speed studies.

Answer

A. Various Methods of Spot Speed Study : There are following method which are used in spot speed studies :

1. Graphical recorder method.
2. Electronic meter.
3. Photoelectric meter.
4. Radar.
5. Speed meter or enoscope studies.
6. Photographic method.

B. Spot Speed by Enoscope :

1. It is the simplest method of finding spot speed.
2. In this method enoscope is used. It is a mirror box supported on a tripod stand.
3. In this method observer stand on one side of the road and start a stopwatch when a vehicle crosses that section.

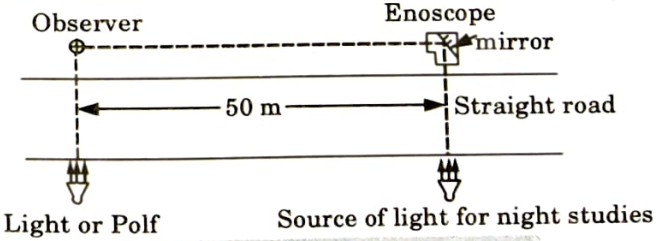


Fig. 3.5.1. Spot speed by enoscope.

4. Enoscope is placed at a distance 50 m in such a way that the image of

the vehicle is seen by observer when vehicle crosses an enoscope, at this instant the stop watch is stopped.

5. Thus the time required for the vehicle to cross the known length is found and the speed is calculated in kmph.
6. It is very simple and cheap method but it is very slow and there is possibility of human error.

C. Application of Spot Speed Data : Following are the applications of spot speed data :

i. To use in planning traffic control and in traffic regulations.
ii. To use in geometric design-for redesigning existing highways or for deciding design speed for new facilities.
iii. To use in accident studies.
iv. To study the traffic capacity.
v. To decide the speed trends.
vi. To compare diverse types of derivers and vehicles under specified conditions.

Que 3.6. Explain any one method for presentation of spot data in speed study.

Answer

Presentation of spot speed data by two methods :

1. Model Average :

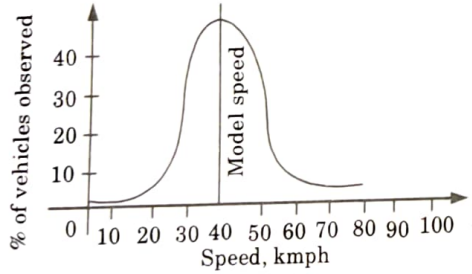


Fig. 3.6.1.

i. A frequency distribution curve of spot speeds is plotted with speed of vehicles or average values of each speed group of vehicles on the X-axis and the percentage of vehicles in that group on the Y-axis.
ii. This curve will have a definite peak value of travel speed across the section and this speed is denoted as model speed.
iii. The speed distribution curve is helpful in determining the speed at which the greatest proportion of vehicles move given by the model speed.

2. Cumulative Speed of Vehicles :

i. A graph is plotted with the average values of each speed group on the X-axis and the cumulative percent of vehicles travelled at or below the different speed on the Y-axis.

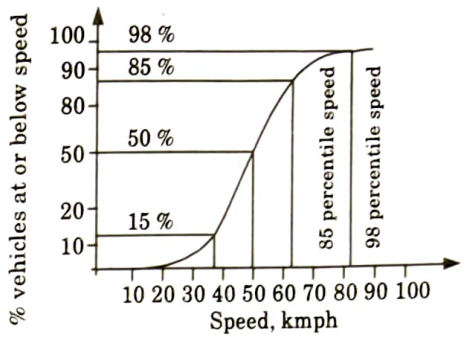


Fig. 3.6.2.

ii. From this graph, the 85th percentile speed is found out which gives that speed at or below 85 percent of the vehicles are passing the point on the highway or only 15 per cent of the vehicles exceed the speed at the spot.
iii. This speed is adopted for the safe speed limit at this zone.
iv. For the purpose of highway geometric design, the 98th percentile speed is taken.
v. The 15th percentile speed represents the lower speed limit if it is desired to prohibit slow moving vehicles to decrease delay and congestion.

Que 3.7. List down the various methods for spot speed studies that are carried out. Discuss in detail any one of them. On the basis of data for spot studies given in Table 3.7.1, calculate upper and lower speed limit regulation as well as speed for design.

Table 3.7.1. Spot speed study data

Speed Range (kmph)	Number of Vehicles
0-10	12
10-20	18
20-30	68
30-40	90
40-50	207
50-60	252
60-70	21
70-80	44
80-90	32
90-100	9

AKTU 2013-14, Marks 10

Answer

Methods : Refer Q. 3.5, Page 3–6C, Unit-3.

C. Numerical :

To Find : Upper and lower speed limit.

Table 3.7.2. Frequency distribution of spot speed data.

Speed Range, kmph	Mid Speed, kmph	Frequency, f	Frequency, $\frac{f}{\Sigma f}$ %	Cumulative Frequency, %
0 – 10	5	12	1.59	1.59
10 – 20	15	18	2.39	3.98
20 – 30	25	68	9.03	13.01
30 – 40	35	90	11.95	24.96
40 – 50	45	207	27.5	52.46
50 – 60	55	252	33.46	85.92
60 – 70	65	21	2.79	88.72
70 – 80	75	44	5.84	94.56
80 – 90	85	32	4.25	98.81
90 – 100	95	9	1.2	100.00
	Total	753	100.00	

1. Upper speed limit for regulation = 85^{th} percentile speed = 55 kmph
2. Lower speed limit for regulation = 15^{th} percentile speed = 30 kmph
3. Speed for design = 98^{th} percentile speed = 85 kmph

Que 3.8. **Explain origin and destination study. What are the various uses of O and D studies ?** **AKTU 2015-16, Marks 10**

Answer

A. Origin and Destination Studies :

1. The origin and destination (O and D) study is carried out mainly to :

i. Plan the road network and other facilities for vehicular traffic.

ii. Plan the schedule of different modes of transportation for the trip demand of commuters.

2. The O and D studies of vehicular traffic determines their number, their origin and destination in each zone under study.

3. Origin and destination study gives information like the actual direction of travel, selection of routes and length of the trip.
4. These studies are most essential in planning new highway facilities and in improving some of the existing systems.
5. As an example, there can be a high percentage of through traffic which may be diverted by providing a by-pass and thus considerable saving in distance and time can be made.
6. O and D study provides the basic data for determining the desired directions of flow or the desire lines.
7. Scientific planning of transportation system and mass transit facilities in cities should be based on O and D data of passenger trips.
8. Also, future traffic needs may be estimated by extrapolating the data from O and D study, together with socio-economic studies.

B. Uses : The various applications of O and D studies may be as follows :

1. To judge the adequacy of existing routes and to use in planning new network of roads.
2. To plan transportation system and mass transit facilities in cities including routes and schedules of operation.
3. To locate expressway or major routes along the desire lines.
4. To establish preferential routes for various categories of vehicle including by-pass.
5. To locate terminals and to plan terminal facilities.
6. To locate new bridge as per traffic demands.
7. To locate intermediate stops of public transport.
8. To establish design standards for the road, bridges and culverts along the route.

Que 3.9. **Explain the term passenger car units.** **AKTU 2013-14, 2017-18; Marks 2.5**

Answer

1. It is a common practice to consider the passenger car as the standard vehicle unit to convert the other vehicle classes and this unit is called Passenger Car Unit or PCU.
2. Thus in mixed traffic flow, the traffic volume and capacity are generally expressed as PCU per hour or PCU/lane/hour and the traffic density as PCU per kilometre length of lane.
3. The PCU may be considered as a measure of the relative space requirement of a vehicle class compared to that of a passenger car under a specified set of roadway, traffic and other conditions.
4. If the addition of one vehicle of a particular class in the traffic stream produces the same effect as that due to the addition of one passenger car, then that vehicle class is considered equivalent to the passenger car with a PCU value equal to 1.0.

5. The PCU value of a vehicle class may be considered as the ratio of the capacity of a roadway when there are passenger cars only to the capacity of the same roadway when there are vehicles of that class only.

PART-3

Peak Hour Factor, Parking Study.

CONCEPT OUTLINE

Parking Studies : The demand by automobile users of parking space is one of the major problems of highway transportation in metropolitan cities. It includes :

i. Parking demand.
ii. Parking characteristics.
iii. Parking space inventory.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 3.10. Explain briefly the various aspects to be investigated during parking studies. What are the uses of these studies ?

Answer

Following are the various aspects to be investigated during parking studies :

1. **Parking Demand :** The parking demand may be evaluate by different methods :

i. One of the methods is by making cordon counts of the selected area and recording accumulation of vehicles during the peak hours by subtracting the outgoing traffic from the traffic volume entering the cordoned area.

ii. One other method is by counting the number of vehicles parked in the area under study during different periods of the day; this method is useful when the parking demand is less than the space available for parking.

iii. Another useful method of field study is by interviewing the drivers of parked vehicles, shop owners and other vehicle owners in the locality. This method is very useful when the parking demand in the study area is higher than the parking space available.

2. **Parking Characteristics :**

i. The study is directed to note the present parking practices prevalent in the area under consideration and the general problems in parking.

ii. In case of kerb parking, it is also necessary to study the parking pattern, interference to smooth flow of traffic and the accidents involved during parking and unparking operations.

3. **Parking Space Inventory :**

i. The area under study is fully surveyed and a map is prepared showing all places where kerb parking and off-street parking facilities can be provided to meet the parking demands.

ii. The traffic engineer has to strike a balance between capacity and parking demands and to design proper facilities for parking.

Que 3.11. What are the different causes of traffic accidents ? Discuss the objectives of accident studies.

Answer

A. Causes : Following are the causes of road accidents :

1. **Drivers :** Excessive speed and rash driving, carelessness, violation of rules and regulations, failure to see or understand the traffic situation, sign or signal, temporary effects due to fatigue, sleep or alcohol.
2. **Pedestrians :** Violating regulations, carelessness in using the carriageway meant for vehicular traffic.
3. **Passengers :** Alighting from or getting into moving vehicles.
4. **Vehicle Defects :** Failure of brakes, steering system, or lighting system, tyre burst and any other defects in the vehicles.
5. **Road Condition :** Slippery or skidding road surface, pot holes, ruts and other damaged conditions of the road surface.
6. **Road Design :** Defective geometric design like inadequate sight distance, inadequate width of shoulders, improper curve design, improper lighting and improper traffic control devices.
7. **Weather :** Unfavourable weather condition like mist, fog, snow, dust, smoke or heavy rainfall which restricts normal visibility and renders driving unsafe.
8. **Animals :** Stray animals on the road.

B. Objective : Following are the objective of this study :

1. To study the causes of accidents and to suggest corrective treatment at potential location.
2. To evaluate existing designs.
3. To support proposed designs.
4. To carry out before and after studies and to demonstrate the improvement in the problem.
5. To make computations of financial loss.
6. To give economic justification for the improvements suggested by the traffic engineer.

Que 3.12. Explain various measures that may be taken to prevent accidents.

Answer

Following are the measures to be taken to prevent accidents :

1. Well-maintained vehicles with good brakes, lighting, tyres etc. will reduce accidents.
2. Vehicles should be provided with seat belts and airbags.
3. Roads should be well maintained with frequent relaying of road surfaces and markings of road safety signs.
4. Provide separate lanes for slow-moving and fast-moving vehicles.
5. Strict punishment should be enforced by government, if a person drives in over speed.
6. Tamper proof speed controllers should be installed in all vehicles.
7. Driving tests for issue of driving license is to be made more stringent and foolproof.
8. Raising of lower age limit for two wheeler and heavy vehicle license to 21.
9. Helmet should be made compulsory by law in all states, or impose a lower speed limit for those who do not use helmet.
10. Footpaths and medians should be made mandatory for important roads.
11. Zebra crossings should be provided for pedestrians for safe road crossings at appropriate places.
12. Signals for road crossings at important busy places where a large number of people have to cross the road every day.
13. Roads should be properly marked. Proper sign boards should be installed.

PART-4

Traffic Capacity, Density.

CONCEPT OUTLINE

Traffic Density : It is the number of vehicles occupying a unit length of lane of roadway at a given instant, it is expressed as vehicle/km

$$\text{Traffic density} = \frac{\text{Traffic volume}}{\text{Traffic speed}}$$

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 3.13. Explain the following term :

i. **Traffic capacity,**
ii. **Basic capacity,**
iii. **Possible capacity,**

iv. **Practical capacity and**
v. **Traffic density.**

AKTU 2013-14, 2017-18; Marks 2.5

Answer

1. **Traffic Capacity :**
   i. It is the ability of a roadway to accommodate traffic volume.
   ii. It is expressed as the maximum number of vehicle in a lane or a road that can pass a given point in unit time, usually an hour, *i.e.*, vehicles per hour per lane or roadway.
   iii. Capacity and volume are measures of traffic flow and have the same unit.
2. **Basic Capacity :** It is the maximum number of passenger cars that can pass a given point on a lane or roadway during one hour under the most nearly ideal roadway and traffic conditions which can possibly be attained.
3. **Possible Capacity :**
   i. It is the maximum number of vehicles that can pass a given point on a lane or roadway during one hour under prevailing roadway and traffic conditions.
   ii. The possible capacity of a road is generally much lower than the basic capacity as the prevailing roadway and traffic conditions are seldom ideal.
4. **Practical Capacity :** It is the maximum number of vehicle that can pass a given point on a lane or roadway during one hour, without traffic density being so great as to cause unreasonable delay, hazard or restriction to the driver's freedom to manoeuvre under the prevailing roadway and traffic conditions.
5. **Traffic Density :**
   i. It is the number of vehicles occupying a unit length of lane of roadway at a given instant, usually expressed as vehicles per kilometre.
   ii. The highest traffic density will occur when the vehicles are practically at a stand still on a given route, and in this case traffic volume will approach zero.

PART-5

Traffic Control Devices : Signs, Island.

CONCEPT OUTLINE

Traffic Control Device : The various aids and devices used to control, regulate and guide traffic is called traffic control device e.g.,
i. Signs, ii. Signals, iii. Markings, and iv. Islands.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 3.14. What are the various types of traffic control devices ? Discuss. **AKTU 2016-17, Marks 10**

Answer

Traffic control device is the medium used for communicating between traffic engineer and road users. Following are the major types of traffic control devices :

1. **Traffic Signs :** These are signs which use symbols and/or words to convey information to road users. These devices are made with retroreflective materials that reflect light from headlights back towards the driver's eyes. This is to achieve maximum visibility especially at night.
2. **Variable Message Signs :** These are traffic control devices which can exhibit different traffic messages according to the needs of a specific road.
3. **High-Level Warning Devices :**
   i. These are traffic control devices that are high enough to see over other vehicles, but not limited to vehicle top, poles and other places not lower than 8 feet.
   ii. These devices are also called flag tree because they feature two or three square fluorescent orange flags and sometimes a flashing warning light.
   iii. This type of traffic control devices are used in work zones in high traffic density urban areas.
4. **Channelizing Devices :**
   i. These are used to warn drivers and pedestrians and to guide them through a work zone.
   ii. Common channelizing devices are traffic cones and drums.
   iii. This type of traffic control device is usually placed between traffic and road construction sites, or between opposing traffic streams.
5. **Road Surface Markings :**
   i. These are traffic control devices that are applied directly to the road surfaces.
   ii. They are used to guide and channel traffic by designating lanes and indicating stopping points at intersections.
   iii. Pavement markings may be permanent or removable.
6. **Traffic Lights :**
   i. These are traffic control devices used for alternately assign right-of-way to traffic moving in conflicting directions at an intersection.

   ii. Traffic lights feature three different lights that convey different meanings.
   iii. The red light means that the vehicle facing the traffic light must come to a complete stop.
   iv. A green light means that the vehicle facing the traffic light may proceed when it is safe to do so.
   v. A yellow light indicates that a red light will follow, and vehicle drivers must stop if it is safe to do so.
7. **Rumble Strips :**
   i. These are roughened surfaces that are either embossed or recessed.
   ii. When a vehicle drives over them, they make a loud rumbling sound and vibration.
   iii. They can be placed across traffic lanes to alert drivers that they are approaching a potentially hazardous location, such as a work zone or an isolated intersection.
   iv. They are used along the shoulders or centerlines of highways to alert drivers that they are leaving their traffic lane.

Que 3.15. Explain the various types of traffic signs and their functions. Also draw the basic layout of type of regulatory and informative signs. **AKTU 2013-14, Marks 05**

OR

With neat sketches show various types of traffic signs and signals classifying them in proper groups. **AKTU 2017-18, Marks 10**

Answer

Types of Traffic Signs : Following are the various types of traffic signs :

A. Regulatory Signs :

1. These signs are also called mandatory signs because it is mandatory that the drivers must obey these signs.
2. If the driver fails to obey them, the control agency has the right to take legal action against the driver.
3. These signs are primarily meant for the safety of other road users.
4. These signs have generally black legend on a white background.
5. They are circular in shape with red borders.
6. The regulatory signs can be further classified into :

   i. **Right of Way Series :** These include two unique signs that assign the right of way to the selected approaches of an intersection. They are the STOP sign and GIVE WAY sign.

   ii. **Speed Series :** Number of speed signs may be used to limit the speed of the vehicle on the road. They include typical speed limit signs, truck speed, minimum speed signs, etc.

iii. **Movement Series :** They contain a number of signs that affect specific vehicle maneuvers. These include turn signs, alignment signs, exclusion signs, one-way signs, etc.

iv. **Parking Series :** They include parking signs which indicate not only parking prohibitions or restrictions, but also indicate places where parking is permitted, the type of vehicle to be parked, duration for parking, etc.

v. **Pedestrian Series :** They include both legend and symbol signs. These signs are meant for the safety of pedestrians and include signs indicating pedestrian only roads, pedestrian crossing sites, etc.

vi. **Miscellaneous :** Wide variety of signs that are included in this category are : a "KEEP OF MEDIAN" sign, signs indicating road closures, signs restricting vehicles carrying hazardous cargo or substances, signs indicating vehicle weight limitations, etc.

7. Some examples of the regulatory signs are shown in Fig. 3.15.1. They include a stop sign, give way sign, signs for no entry, sign indicating prohibition for right turn, vehicle width limit sign, speed limit sign, etc.

Fig. 3.15.1. Examples of regulatory signs.

B. Warning Signs :

1. Warning signs or cautionary signs give information to the driver about the impending road condition.
2. These signs are meant for the own safety of drivers.
3. They call for extra vigilance from the part of drivers.
4. The colour convention used for this type of signs is that the legend will be black in colour with a white background.
5. The shape used is upward triangular or diamond shape with red borders.
6. Some of the examples for this type of signs are shown in Fig. 3.15.2, and includes right hand curve sign board, signs for narrow road, sign indicating railway track ahead, etc.

Fig. 3.15.2. Examples of cautionary signs.

C. Informative Signs :

1. Informative signs also called guide signs are provided to assist the drivers to reach their desired destinations.

2. These are predominantly meant for the drivers who are unfamiliar to the place. The guide signs are redundant for the users who are accustomed to the location.
3. Some of the examples for these types of signs are route markers, destination signs, mile posts, service information, recreational and cultural interest area signing, etc.
4. Fig. 3.15.3 shows examples for informative signs which include route markers, destination signs, mile posts, service centre information, etc.

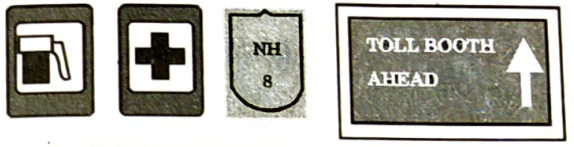


Fig. 3.15.3. Examples of informative signs.

Que 3.16. Discuss the various types of traffic signals.

AKTU 2014-15, Marks 06

Answer

A. Classification of Signal : Following are the various types of traffic signals :

1. Traffic Control Signal :

i. Traffic control signal is used to control the movement of the vehicles at the crossings.

ii. The traffic control signals consists of three coloured light, the red light meant for stop, the green light meant for go and the amber light allows the clearance time for vehicles.

iii. It is also categorized into three types :

a. **Fixed Time Signals :** These types of signals are set to repeat regularly in a cycle of red, amber and green lights. The timing of each phase of the cycle is predetermined based on the traffic volume.

b. **Manually Operated Signals :** These signals are operated manually and not commonly used.

c. **Traffic Actuated Signals :** This is a type of signal in which the timing of phase and cycle are changed according to traffic demand. In this signal detectors and computers assigns the right of way for various traffic movements on the basis of demand. It is very costly.

2. Pedestrian Signal : It is the signal which give the right of way to pedestrian to cross a road during the walk periods when the vehicular traffic shall be stopped by red right.

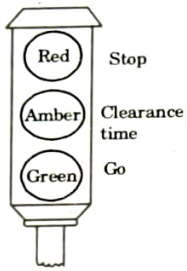


Fig. 3.16.1. Traffic signal.

3. Specific Traffic Signal :

i. Special traffic signals such as 'flashing beacons' may be installed at certain location in order to warn the traffic of certain situations.

ii. At flashing red signals, the drivers of vehicles shall stop before entering the nearest cross walk at an intersection or at a stop line.

iii. Flashing yellow signals are cautionary signals meant to signify that drivers may proceed with caution.

PART-6

Signal Design by Webster's and IRC Method.

CONCEPT OUTLINE

According to Webster's method :

Optimum signal cycle, $C_0 = \dfrac{1.5\,L + 5}{1 - Y}$

Total lost time, $L = 2n + R$, n = Number of phase and R = Total red time.

$$Y = y_1 + y_2$$

$$G_1 = \frac{y_1}{Y}(C_0 - L) \text{ and } G_2 = \frac{y_2}{Y}(C_0 - L)$$

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 3.17. Explain the Webster's method of traffic signal design.

Answer

Webster's Method :

1. In this method, the optimum signal cycle C_o corresponding to least total delay to the vehicles at the signalized intersection has been worked out.

This is a rational approach.

2. The field work consists of finding :

i. The saturation flow S per unit time on each approach of the water section.

ii. The normal flow q on each approach during the design hour.

3. Based on the higher value of normal flow, the ratio $y_1 = q_1/S_1$ and $y_2 = q_2/S_2$ are determined on the approach road 1 and 2.

4. The optimum signal cycle is given by,

$$C_o = \frac{1.5\,L + 5}{1 - Y}$$

Total lost time per cycle in sec, $L = 2n + R$

where, n = Number of phase.

R = All red-time.

5. $Y = y_1 + y_2$

6. Then, $G_1 = \dfrac{y_1}{Y}(C_o - L)$ and $G_2 = \dfrac{y_2}{Y}(C_o - L)$

7. Similar procedure is followed when there is more number of signal phases.

Que 3.18. The average normal flow of traffic on cross roads A and B during design period are 400 and 250 PCU per hour; the saturations flow values on these roads are estimated as 1250 and 1000 PCU per hour respectively. The all-red time required for pedestrian crossing is 12 secs. Design two phase traffic signal by Webster's method.

Answer

Given : Traffic flow on road A and B = 400 and 250 PCU/hr, Saturated flow on road A and B = 1250 and 1000 PCU/hr, Pedestrian time = 12 sec

To Find : Time for red, yellow and green light.

1. $$y_a = \frac{q_a}{S_a} = \frac{400}{1250} = 0.32$$

2. $$y_b = \frac{q_b}{S_b} = \frac{250}{1000} = 0.25$$

3. $$Y = y_a + y_b = 0.32 + 0.25 = 0.57$$

4. $$L = 2n + R = 2 \times 2 + 12 = 16 \text{ sec}$$

5. $$C_0 = \frac{1.5\,L + 5}{1 - Y} = \frac{1.5 \times 16 + 5}{1 - 0.57}$$

$$= \frac{29}{0.43} \approx 67.5 \text{ sec}$$

6. $$G_a = \frac{y_a}{Y}(C_0 - L) = \frac{0.32}{0.57}(67.5 - 16) = 29 \text{ sec}$$

7. $$G_b = \frac{y_b}{Y}(C_0 - L) = \frac{0.25}{0.57}(67.5 - 16) = 22.5 \text{ sec}$$

8. All red time for pedestrian crossing = 12 sec
9. Providing amber times of 2.0 sec. each for clearance, total cycle time = 29 + 22.5 + 12 + 4 = 67.5 sec

Que 3.19. **Discuss the IRC guidelines for the design of traffic signals.**

Answer

Design Method as Per IRC Guideline :

1. The pedestrian green time required for the major and minor roads are calculated based on walking speed of 1.2 m/sec and initial walking time of 7.0 sec. These are the minimum green time required for the vehicular traffic on the minor and major roads respectively.
2. The green time required for the vehicular traffic on the major road is increased in proportion to the traffic on the two approach roads.
3. The cycle time is calculated after allowing amber time of 2.0 sec each.
4. The minimum green time required for clearing vehicles arriving during a cycle is determined for each lane of the approach road assuming that the first vehicle will take 6.0 sec. And the subsequent vehicles (PCU) of the queue will be cleared at a rate of 2.0 sec. The minimum green time required for the vehicular traffic on any of the approaches is limited to 16 sec.
5. The optimum signal cycle time is calculated using Webster's formula. The lost time is calculated from the amber time, inter-green time and the initial delay of 4.0 sec for the first vehicle, on each leg.
6. The signal cycle time and the phases may be revised keeping in view the green time required for clearing the vehicles and the optimum cycle length determined it steps (4) and (5) above.

Que 3.20. **At a right angled intersection of two roads, Road 1 has four lanes with a total width of 12.0 m and Road 2 has two lanes with a total width of 6.6 m. The volume of traffic approaching the intersections during design hour are 900 and 743 PCU/hour on the two approaches of Road 1 and 278 and 180 PCU/hour on the two approaches of Road 2. Design the signal timings as per IRC guidelines.**

Answer

Given : Width of road 1 and road 2 = 12 m and 6.6 m respectively, Traffic flow on road 1 and road 2 = 900 and 743 PCU/hr, Traffic flow on road 2 = 278 and 180 PCU/hr.

To Find : Signal timing.

1. Design traffic on road 1 = Higher of the two approach volume per lane = 900/2 = 450 PCU/hr.
2. Design traffic on road 2 = 278 PCU/hr
3. Pedestrian green time for road 1 = $\frac{12.0}{1.2} + 7.0 = 17$ sec
4. Pedestrian green time for road 2 = $\frac{6.6}{1.2} + 7.0 = 12.5$ sec
5. Green time for vehicles on road 2, $G_2 = 17.0$ sec
6. Green time for road 1, $G_1 = 17 \times \frac{450}{278} = 27.5$ sec
7. Adding 2.0 sec, each towards clearance amber and 2.0 sec, inter-green period for each phase, total cycle time required = (2 + 17 + 2) + (2 + 27.5 + 2) = 52.2 sec.
8. Signal cycle time may be conveniently set in multiples of five sec, and so the cycle time = 55 sec.
9. The extra 2.5 sec, per cycle may be apportioned to the green times of roads 1 and 2 as 1.5 and 1.0 sec and so $G_1 = 27.5 + 1.5 = 29.0$ sec and $G_2 = 17.0 + 1.0 = 18.0$ sec.
10. Vehicle arrivals per lane cycle on Road 1
    = 450/55 = 8.2 PCU
11. Minimum green time for clearing vehicles on Road 1
    = 6 + (8.2 – 1.0)2 = 20.4 sec
12. Vehicle arrivals per cycle on Road 2
    = 278/55 = 5.1 PCU
13. Minimum green time for clearing vehicles on Road 2
    = 6 + (5.1 – 1.0) 2 = 14.2 sec
14. Lost time per cycle = (Amber time + Inter-green time + Time lost for initial delay of first vehicle) for two phases
    = (2 + 2 + 4) × 2 = 16 sec
15. Saturation flow for Road 1 = 525 × 6 = 3150 PCU/hr
16. Saturation flow for Road 2 = $1850 + \frac{40 \times 3}{5} = 1874$ PCU/hr

17. $y_1 = \frac{900}{3150} = 0.286$ and $y_2 = \frac{278}{1874} = 0.148$

18. $Y = 0.286 + 0.148 = 0.434$

19. Optimum cycle time,

$$C_0 = \frac{1.5L + 5}{1 - Y} = \frac{1.5 \times 16 + 5}{1 - 0.434} = 51.2 \text{ sec.}$$

Therefore the cycle time of 55 sec designed earlier is acceptable.

20. The details of the signal timings are given in Table. 3.20.1.

Table. 3.20.1.

Road	Green	Amber	Red	Cycle
Road 1	29	2	(22 + 2)	55
Road 2	18	2	(33 + 2)	55

PART-7

Intersection at Grade and Grade Separated Intersections.

CONCEPT OUTLINE

Intersection : Following are the types of intersection :

i. Intersection at grade.

ii. Grade separated Intersection.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 3.21. **Enumerate the various types of intersection and the basic principles involved.** **AKTU 2016-17, Marks 10**

Answer

Types of Intersection : Following are the types of intersection :

A. At grade intersections.

B. Grade separated intersections.

A. **Types of Intersection at Grade :** All road intersection which meet at about the same level allowing traffic monoeuvers like merging, diverging, crossings and weaving are called intersection at grade.

There are many types of intersection at grade and are described below :

i. **Tee Intersection :** It is one of the common type of intersection at grade. It is provided at the time when two road meet each other at right angles (*i.e.*, 90°).

ii. **Y-Intersection :** It is fit for three roads joint at a place at different angles. It is also named as three way or fork intersection. Precautions should be taken while designing such intersections to avoid accidents.

iii. **Cross Intersection :** It is provided when two roads cross each other at right angles. It is also called as square intersection.

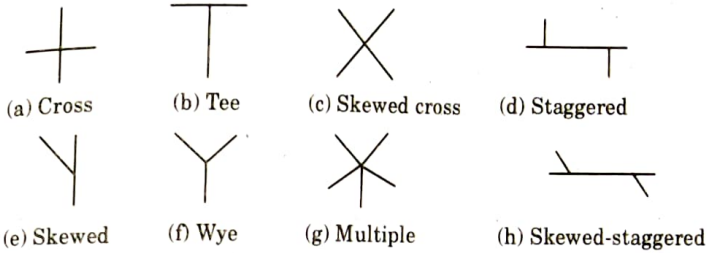


Fig. 3.23.1. Types of intersection at grade.

iv. **Multiple Intersection :** This type of intersection should be provided in case when more than three roads join at a place in different angles. A high precaution is needed in such intersection to avoid accidents.

v. **Skewed Intersection :** Skewed intersection is to be provided when two roads meet each other at an angle expect the right angle. It should be used or preferred only in case when there is no alternative.

vi. **Skewed Cross Intersection :** Skewed cross intersection is provided when two roads cross each other at angles other than right angle. This is also named as acute intersection.

B. **Grade Separated Intersections :**

1. When the two or more roads intersect at different levels then such intersections are known as grade separated intersections.

2. Types of grade separated intersection are as follows :

i. **Over Passes or Fly Over :** In this type of intersection, major highway is taken above in embankment across the other highway by creating an over bridge. Over pass is also called as fly over.

ii. **Under Passes :**

a. This is the type of grade separated intersection in which one highway (minor one) is taken by pressing it below ground level across the highway by constructing as under bridge.

b. The under pass is always advantageous when the main highway is taken along the existing grade without alteration of its vertical alignment and the cross road a depressed and taken underneath by constructing an under bridge.

Que 3.22. What are the advantages of channelized intersection ?

Answer

Following are the advantages of channelized intersection :

1. By channelization vehicles can be confined to definite paths.
2. Angle of merging streams can be forced to be at flat angles so as to cause minimum disruption.
3. Both the major and minor conflict areas within the intersection can considerably be decreased.
4. Angle between intersecting streams of traffic may be kept as desired in a favourable way.
5. Speed control can be established over vehicles entering the intersection.
6. Refuse islands can be provided for pedestrians within the intersection area.
7. Points of conflicts can be separated.
8. The channelizing islands provide proper place for installation of signs and traffic control devices.

Que 3.23. What are the relative advantages and disadvantages of over pass and under pass ?

Answer

1. Advantages of an Over Pass :

i. Reduce drainage problem.

ii. Aesthetic preference to main traffic.

iii. Less feeling of restriction compared to underpass.

iv. Future construction or expansion of separate bridge structure for divided highway is possible.

2. Disadvantages of an Over Pass :

i. In rolling terrain if the major road is taken above, the vertical profile will also changes.

ii. The increased grade resistance may cause speed reduction on heavy vehicles.

iii. Restrictions to sight distance may occur.

3. Advantages of an Under Pass :

i. Provide warning to traffic in advance due to the presence of an under pass which can be seen from distance.

ii. When the major highway is taken below, it is advantageous to the turning traffic because the traffic from the cross road can accelerate while descending the ramp to the major highway.

iii. Traffic from the major highway can decelerate while ascending the ramp to the cross roads.

iv. The under-pass may be of advantage when the main highway is taken along the existing grade without alteration of its vertical alignment and cross road is depressed.

4. Disadvantages of an Under Pass :

i. Drainage problem during rainy season when under pass is depressed upto 5–7 m below ground level.

ii. Necessity of pump to discharge water.

iii. Feeling of restriction to the traffic at the sides while passing along the under pass.

iv. No possibility of stage construction for the bridge structure at the under pass.

PART-8

Design of Roundabouts as per latest IRC 65-2017.

CONCEPT OUTLINE

Rotary : A rotary is a type of circular intersection or junction in which road traffic flows almost continuously in one direction around a central island.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 3.24. What is traffic rotary ? What are its advantages and limitations in particular reference to Indian conditions ?

AKTU 2014-15, Marks 06

Answer

A. Traffic Rotary :

1. A rotary intersections or traffic rotary is an enlarged road intersection where all converging vehicles are forced to move round a large central island in one direction (clock wise direction) before they can weave out of traffic flow into their respective directions radiating from the central island.
2. The main objects of providing a rotary are to eliminate the necessity of stopping even for crossing streams of vehicles and to reduce the area of conflict.

B. Advantages : Following are the advantages of the rotary intersection :

1. Traffic flow is regulated to only one direction of movement, thus eliminating severe conflicts between crossing movements.
2. All the vehicles entering the rotary are gently forced to reduce the speed and continue to move at slower speed.
3. Because of lower speed of negotiation and elimination of severe conflicts, accidents and their severity are much less in rotaries.
4. Rotaries are self-governing and do not need practically any control by police or traffic signals.
5. They are ideally suited for moderate traffic, especially with irregular geometry, or intersections with more than three or four approaches.

C. Limitations : Following are the limitations of rotaries :

1. All the vehicles are forced to slow down and negotiate the intersection. Therefore the cumulative delay will be much higher than channelized intersection.
2. Even when there is relatively low traffic, the vehicles are forced to reduce their speed.
3. Rotaries require large area of land making them costly at urban areas.
4. Since, the vehicles are not stopping, and the vehicles accelerate at rotary exits, they are not suitable when there are high pedestrian movements.

Que 3.25. Explain briefly the various design factors that are to be considered in rotary intersection design.

Answer

Following are the factors considered in designing the rotary :

1. **Design Speed :** Vehicles approaching intersection have to reduce speed, than the design speed of road.

30 km/h — urban
Upto 40 km/h — rural

2. **Shape of Central Island :**
   i. It depends on number and layout of intersecting roads.
   ii. The various shapes considered are circular, elliptical, turbine and tangent shapes.
3. **Radius of Rotary Roadway :**
   i. Rotary around the central island and different radii at different points depending on shapes of central island.
   ii. Recommended minimum radii of central island is 1.33 times the radius of entry curve.
   iii. Radius at entry is 25–35 m.
4. **Width of the Rotary Roadway :**
   i. The minimum width of carriage way at entrance and exit should be 5 m.
   ii. All the traffic rotary has to go round the one-way rotary roadway at least a short distance.
   iii. The minimum width of rotary roadway between the edge of central island and adjoining kerb is effective width of rotary.
5. **Weaving Angle and Weaving Distance :**
   i. The angle between path of vehicle entering the rotary and that of another vehicle leaving the rotary is called weaving angle.
   ii. The length between 2 channelizing island of adjacent roads where operating takes place is called weaving length.
   iii. Recommended value of this 45–90 m for 40 kmph design speed.
6. **Width of Carriageway at Entry and Exit :**
   i. The carriageway width at the entrance and exit of a rotary is governed by the amount of traffic entering the rotary.
   ii. The minimum width of carriageway at the entrance and exit should be 0.5 m.
7. **Capacity of the Rotary :** The practical capacity of the rotary is dependent on the minimum capacity of the individual weaving section. The capacity is calculate from the formula :

$$Q_p = \frac{280\, W(1 + e/W)(1 - p/3)}{(1 + W/L)}$$

where,

Q_p = Practical capacity of the weaving section of a rotary in PCU per hour.

W = Width of weaving section (6 to 18 m).

e = Average width of entry e_1 and width of non-weaving section e_2 for the range $e/W = 0.4$ to 1.0

L = Length of weaving section between the ends of channelizing islands in metre for the range of $W/L = 0.12$ to 0.4

p = Proportion of weaving traffic given by

$$p = \frac{b+c}{a+b+c+d}$$ in the range 0.4 to 1.0

a = Left turning traffic moving along left extreme lane.

d = Right turning traffic moving along right extreme lane.

b = Crossing/weaving traffic turning towards right while entering the rotary.

c = Crossing/weaving traffic turning towards left while leaving to rotary.

PART-9

Highway Capacity and Level of Service of Rural Highway and Urban Roads as per Latest IRC Recommendation.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 3.26. Describe the level of service of rural and urban highway. Gives its classification.

Answer

A. Level of Service (LOS) : It is a qualitative measure used to relate the quality of traffic service LOS is used to analyze highways by categorizing traffic flow and assigning quality levels of traffic based on performance measure like speed, density, delay, etc.

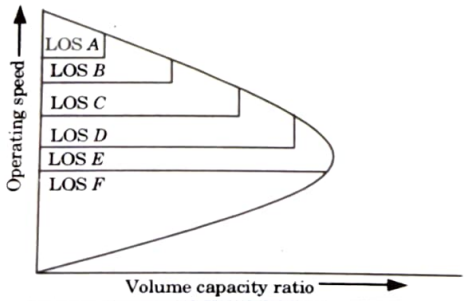


Fig. 3.26.1. Level of service *A* to *F*.

B. Classification of Level of Service :

1. LOS *A* :

i. Traffic flows at or above the posted speed.

ii. Complete mobility between lanes.

iii. Average spacing between vehicles is about 550 ft (167 m) or 27 car lengths.

iv. Motorists have a high-level of physical and psychological comfort.

2. LOS *B* :

i. Reasonably free flow.

ii. Traffic stream is slightly restricted than LOS *A*.

iii. The lowest average vehicle spacing is about 330 ft (100 m) 16 car lengths.

iv. Motorists still have a high level of physical and psychological comfort.

3. LOS *C* :

i. Stable flow, at or near free flow.

ii. Lane changes require more driver awareness.

iii. Minimum vehicle spacing is about 220 ft (67 m) or 11 car lengths.

iv. Most experienced drivers are comfortable.

4. LOS *D* :

i. Approaching unstable flow.

ii. Freedom to maneuver within the traffic stream is much more limited.

iii. Driver comfort levels decrease.

iv. Vehicles are spaced about 160 ft (50 m) or 8 car lengths.

5. LOS *E* :

i. Unstable flow, operating at capacity.

ii. Flow becomes irregular and speed varies rapidly.

iii. Speeds rarely reach the posted limit.

iv. Vehicle spacing is about 6 car lengths, but speeds are still at or above 80 km/h.

7. LOS *F* :

i. Forced or breakdown flow. Every vehicle moves in lockstep with the vehicle in front of it.

ii. Travel time cannot be predicted.

iii. A road in a constant traffic jam is at this LOS.

Que 3.27. Discuss the highway capacity and its affecting factors.

Answer

A. Highway Capacity : It is defined as the maximum hourly rate at which persons or vehicles can be reasonably expected to traverse a point or a uniform segment of a lane or roadway during a given time period under prevailing roadway, traffic and control conditions.

B. Factors : Following are the affecting factors of highway capacity :

1. Traffic Conditions :

i. It refers to the traffic composition in the road such as the mix of cars, trucks, buses etc in the stream.

ii. It also includes peaking characteristics, proportions of turning movements at intersections, etc.

2. Roadway Characteristics:

i. This points out to the geometric characteristics of the road.

ii. These include lane width, shoulder width, lane configuration, horizontal alignment and vertical alignment.

3. Control Conditions : This primarily applies to surface facilities and often refer to the signals at intersections, etc.