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TRANSPORTATION ENGINEERING

By

Amit Krishna

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KCE 602 : Transportation Engineering

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Part	Topics	2017-18	2016-17	2015-16	2014-15	2013-14	Que. No.
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3.	Road Types and Pattern	2	0	0	0	0	1.9*
4.	Nagpur Road Plans	1	0	0	0	2	1.10*, 1.12
5.	Bombay Road Plans	0	1	0	1	1	1.13**
6.	3rd 20 Years Road Plan	0	0	0	0	0	0
7.	Horizontal and Vertical Profile, Factor Affecting Highway Aligment	0	0	0	0	0.	0
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* = Asked in different years

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6.	Transition Curve and Gradient	2	0	0	1	1	2.24, 2.25* 2.26
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* = Asked in different years

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4.	Traffic Capacity, Density	1	0	0	0	1	3.13*
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7.	Intersector at Grade and Grade Seperation	0	1	0	0	0	3.21
8.	Design of Roundabouts	0	0	0	1	0	3.24
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* = Asked in different years

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2.	Various Test and Specification of Aggregate and Binding Materials	0	0	1	0	0	4.6
3.	Types of Pavement and Design Factors	0	0	1	0	0	4.10
4.	Design of Bituminous Paving Mixes	0	0	0	0	0	0
5.	Design of Flexible Pavement by CBR Method (IRC : 37-2012)	1	2	1	1	0	4.12**, 4.13*
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7.	Westergaard's Theory, Load and Temperature Stresses	1	1	1	0	1	4.16, 4.17, 4.18, 4.19
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* = Asked in different years

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1.	Construction of Subgrade	0	0	0	0	0	0
2.	Water Bound Macadam	1	1	0	0	1	5.2, 5.3*
3.	Wet Mix Macadam (WMM)	0	0	0	0	0	0
4.	Granular Sub Base, Tack Coat, Prime Coat, Seal Coat, Surface Dressing	1	1	2	0	2	5.6**, 5.7**
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6.	Dry Lean Concrete, Cement Concrete (CC) Road Construction	0	1	0	1	0	5.11*
7	Roller Compacted Concrete Roads and Mixed	0	0	1	0	0	5.13
	Total Questions	3	4	3	3	4	

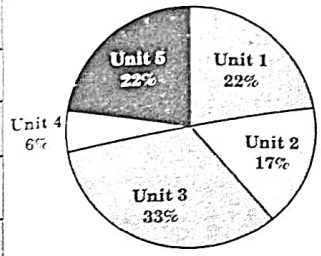
* = Asked in different years

2 Marks Questions

Units \ Year	2017-18	2016-17	2015-16	2014-15	2013-14	Total Questions
Unit-1	0	0	1	0	0	1
Unit-2	3	7	3	0	0	13
Unit-3	1	1	2	0	0	4
Unit-4	2	1	3	0	0	6
Unit-5	1	1	1	0	0	3

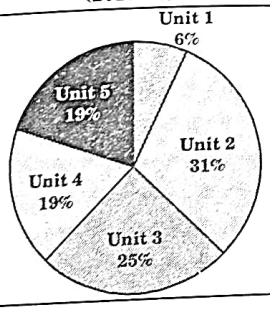
Units	Ques. Asked (2013-14)
Unit-1	4
Unit-2	3
Unit-3	6
Unit-4	1
Unit-5	4

% Weightage of Units (2013-14)



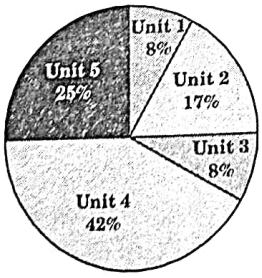
Units	Ques. Asked (2014-15)
Unit-1	1
Unit-2	5
Unit-3	4
Unit-4	3
Unit-5	3

% Weightage of Units (2014-15)



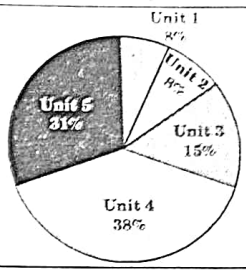
Units	Ques. Asked (2015-16)
Unit-1	1
Unit-2	2
Unit-3	1
Unit-4	5
Unit-5	3

% Weightage of Units (2015-16)



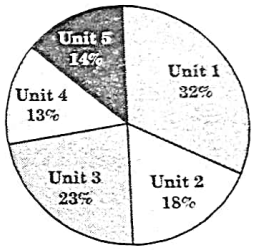
Units	Ques. Asked (2016-17)
Unit-1	1
Unit-2	1
Unit-3	2
Unit-4	5
Unit-5	4

% Weightage of Units (2016-17)



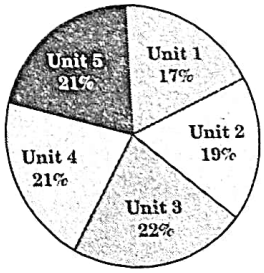
Units	Ques. Asked (2017-18)
Unit-1	7
Unit-2	4
Unit-3	5
Unit-4	3
Unit-5	3

% Weightage of Units (2017-18)



Units	Total Questions (2013-14 to 2017-18)
Unit-1	14
Unit-2	15
Unit-3	18
Unit-4	17
Unit-5	17

% Weightage of Units (2013-14 to 2017-18)



1 UNIT

Role of Transportation

CONTENTS

PART-1

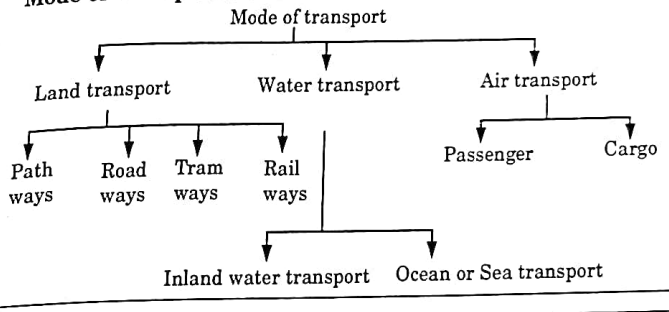
Role of Transportation, Mode of Transportation.

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.

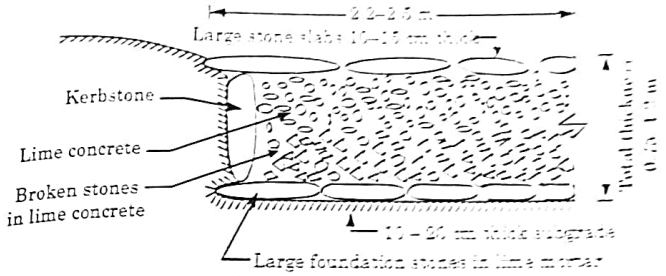


Fig. 1.4.1. Roman roads.

iii. The total thickness of the construction was as high as 1.75 to 2.0 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.

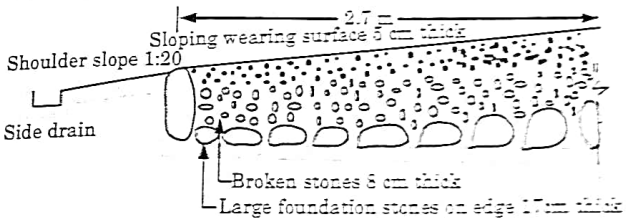


Fig. 1.4.2. French roads.

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.

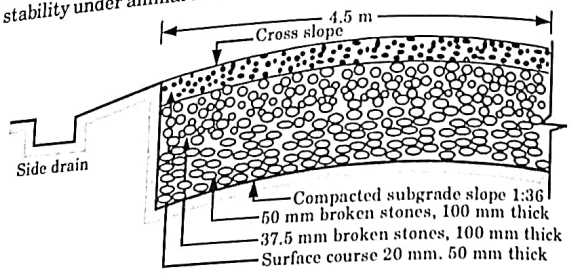


Fig. 1.4.3. British roads.

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, except 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.

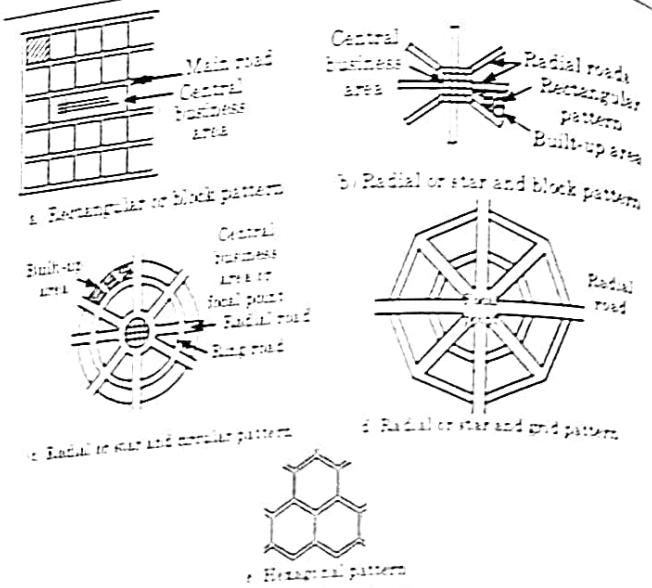


Fig. 1.9.1. Road patterns.

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, $A = 10000 - 2850 = 7150\ km^2$
2. The total length of metalled road for NH,

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

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

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

$$= 1158.8 + 173.8 - 95 = 1237.6\ km$$

3. The total length of secondary roads,

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

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

$$= 709.6 + 0.15 \times 709.6$$

$$ODR + VR = 816.04\ km$$

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 :

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

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 :

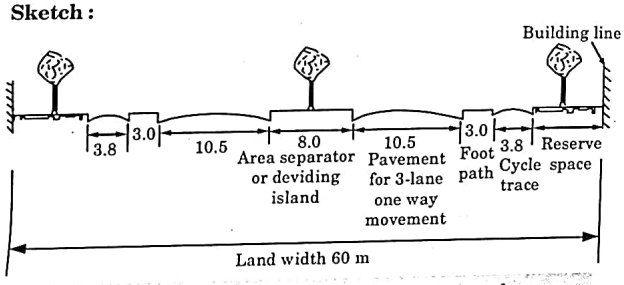


Fig. 2.2.1. Cross section of divided highway in urban area.

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.

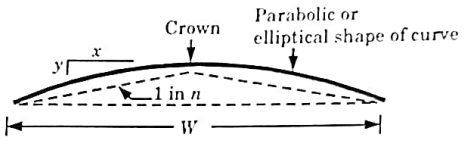


Fig. 2.5.1. Parabolic camber $y = 2x^2 / nW$.

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.

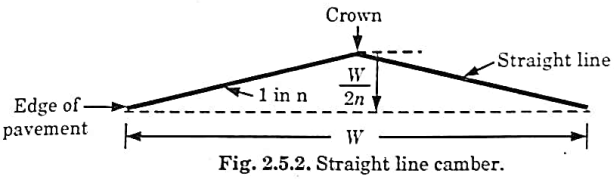


Fig. 2.5.2. Straight line camber.

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.

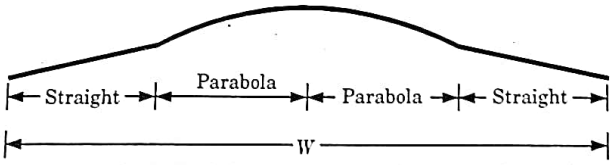


Fig. 2.5.3. Combination of straight and parabolic camber.

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.

.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

ıe 2.7. Write short note on shoulders.

ıswer

Shoulders also act as service lanes for vehicles that have broken down.

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.

The width of shoulder should be adequate to accommodate stationary vehicle fairly away from the edge of adjacent lane.

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 he 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.

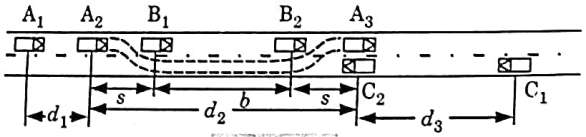


Fig. 2.12.1.

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_3 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, $v = \frac{80}{3.6} = 22.22$ 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

2. Speed of overtake vehicle, $V_b = V - 16 = 80 - 16 = 64$ kmph

3. $d_1 = 0.28\, V_b t = 0.28 \times 64 \times 2.5 = 44.8$ 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 $Wb/2$,

where, h = Height of the center of gravity of the vehicle above the road suface.

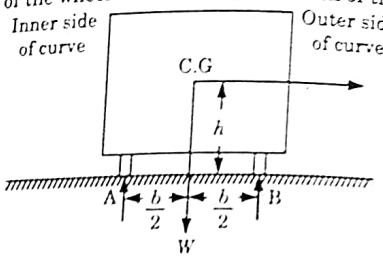


Fig. 2.15.1. Overturning due to centrifugal force.

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.

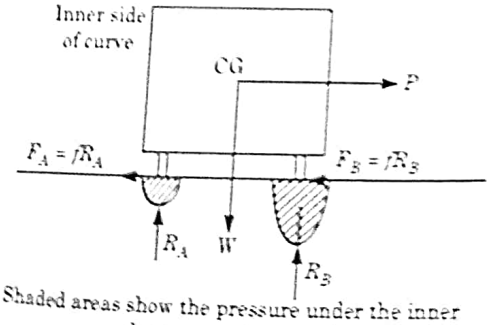
iii. From Fig. 2.15.1, the equilibrium condition for the transverse skid resistance developed is given by :

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

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,

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

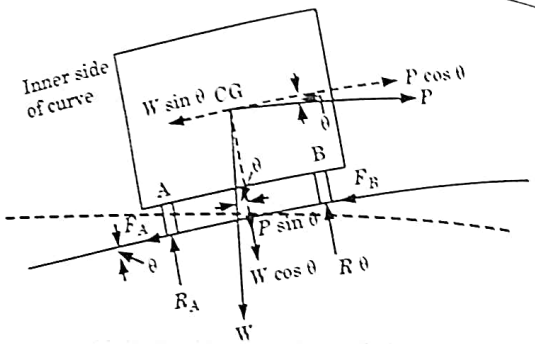


Fig. 2.16.1. Analysis of superelevation.

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

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

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

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

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

Dividing by $W\cos\theta$,

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

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

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

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

$$[\because 1 - ef = 0.99 \approx 1$$

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

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,

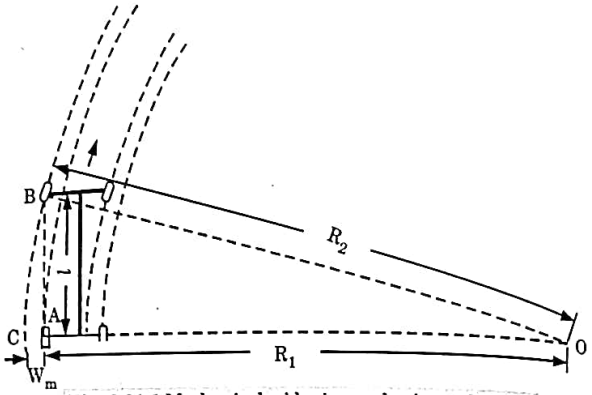


Fig. 2.21.1 Mechanical widening on horizontal curve.

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

From ΔOAB, $R_1^2 = R_2^2 - l^2$

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 7.6 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

$$L_s = \frac{eN}{2}\,(W + W_e)$$

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,

$$\Delta = 60^\circ$$

ii. Length of circular curve,

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

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)

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

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.

Limiting Gradient :

It is steeper than the rolling gradients.

This gradient is adopted when the ruling gradient results in enormous increase in cost of construction.

It may be frequently necessary to limiting gradient.

Exceptional Gradient :

Exceptional gradient are very steeper gradients given at unavoidable situations.

They should be limited for short stretches not exceeding about 100 meters at a stretch.

In mountainous and steep terrain, successive exceptional gradients must be separated by a minimum 100 meter length gentler gradient.

Minimum Gradient :

Minimum gradient is important for the longitudinal drainage along the side drains requires some slope for smooth flow of water.

It depends on the rain fall, type of soil and other site conditions.

A minimum of 1 in 500 may be sufficient for concrete drain and 1 in 200 or open soil drains are found to give satisfactory performance.

2.28. What is grade compensation ? Also give IRC specification

ver

rade Compensation : It can be defined as the reduction in gradient the horizontal curve because of the additional tractive force required e to curve resistance, which is intended to offset the extra tractive ce 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 7.5%.

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)].

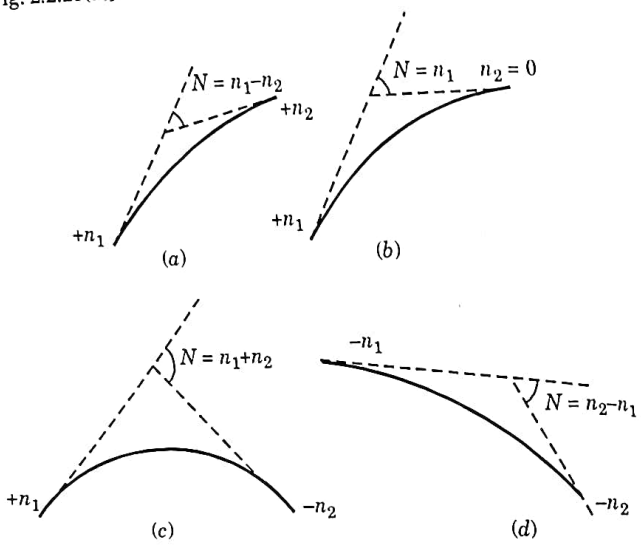
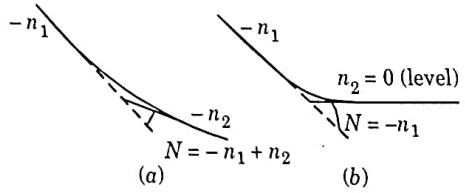


Fig. 2.29.1. Types of summit curves.

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)].



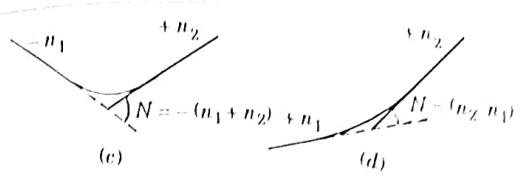


Fig. 2.29.2. Types of valley curve.

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

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

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

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

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 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 ? A ascending gradient of 1 in 50 and a descending gradient of 1 in 8 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 1

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 $L < SSD$

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

$= 120.6 = 121 \text{ m} < 128 \text{ m}$, 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. $$SSD = 0.278\ Vt + \frac{V^2}{254f}$$

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

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

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

2.

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 2-3 Unit-2.

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

Answer

A. Design Considerations for Valley Curve :

1. There is no restriction to sight distance at valley curves during day t But visibility is reduced during night.
2. In the absence or inadequacy of street light, the only source for visib is with the help of headlights. Hence valley curves are designed tak into account of headlight distance.
3. In valley curves, the centrifugal force will be acting downwards a with the weight of the vehicle, and hence impact to the vehicle w more. This will result in jerking of the vehicle and cause discomfo the passengers.
4. Thus the most important design factors considered in valley curves
   i. Impact-free movement of vehicles at design speed.
   ii. Availability of stopping sight distance under headlight of vehicle 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 10

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 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

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

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.

The vehicular characteristics are classified as :

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.

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

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

raffic 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

ue 3.2. Explain the term traffic volume.

AKTU 2013-14, 2017-18; Marks 2.5

OR

t are the objects of carrying out traffic volume studies ?

OR

e 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 30th 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 30th 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 15**

iii. Running speed.

iv. Time mean speed.

v. Average speed.

Answer

i. **Spot Speed :** It is the instantaneous speed of a vehicle at a specific 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 cross 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, thus 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.

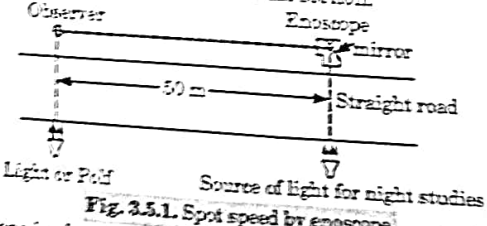


Fig. 3.5.1. Spot speed by enoscope.

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 :

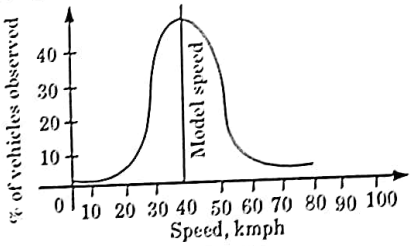


Fig. 3.6.1.

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.

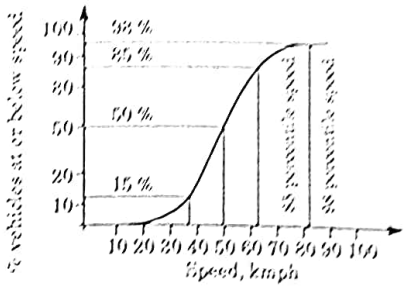


Fig. 3.6.2.

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 toward 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 no 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.

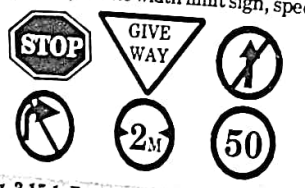


Fig. 3.15.1. Examples of regulatory signs.

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.

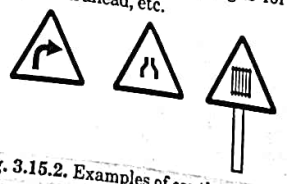


Fig. 3.15.2. Examples of cautionary signs.

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.

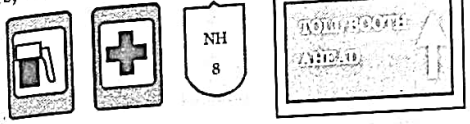


Fig. 3.15.3. Examples of informative signs.

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.

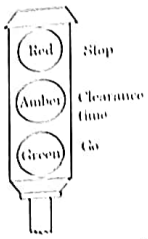


Fig. 3.16.1. Traffic signal.

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

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

$$Y = y_1 + y_2$$

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

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

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

6. $$G_2 = \frac{y_2}{Y}(C_0 - L) = \frac{0.32}{0.57}(67.5 - 16) = 29 \text{ sec}$$

7. $$G_3 = \frac{y_3}{Y}(C_0 - L) = \frac{0.25}{0.57}(67.5 - 16) = 22.5 \text{ sec}$$

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.

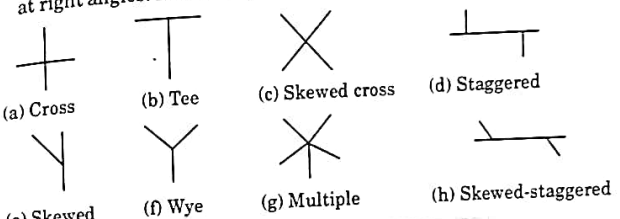


Fig. 3.23.1. Types of intersection at grade.

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.

e 3.23. **What are the relative advantages and disadvantages of pass and under pass ?**

swer

Advantages of an Over Pass :

Reduce drainage problem.

esthetic preference to main traffic.

ess feeling of restriction compared to underpass.

ture construction or expansion of separate bridge structure for divided ghway is possible.

sadvantages of an Over Pass :

olling terrain if the major road is taken above, the vertical profile will changes.

Increased grade resistance may cause speed reduction on heavy cles.

rictions to sight distance may occur.

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.

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 intersec... where all converging vehicles are forced to move round a large cen... island in one direction (clock wise direction) before they can weave ... of traffic flow into their respective directions radiating from the cen... island.
2. The main objects of providing a rotary are to eliminate the necessity ... stopping even for crossing streams of vehicles and to reduce the s... of conflict.

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

1. Traffic flow is regulated to only one direction of movement, th... eliminating severe conflicts between crossing movements.
2. All the vehicles entering the rotary are gently forced to reduce t... speed and continue to move at slower speed.
3. Because of lower speed of negotiation and elimination of seve... conflicts, accidents and their severity are much less in rotaries.
4. Rotaries are self-governing and do not need practically any control ... police or traffic signals.
5. They are ideally suited for moderate traffic, especially with irregul... 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 intersectio... Therefore the cumulative delay will be much higher than channelize... intersection.
2. Even when there is relatively low traffic, the vehicles are forced t... reduce their speed.
3. Rotaries require large area of land making them costly at urban area...
4. Since, the vehicles are not stopping, and the vehicles accelerate a... rotary exits, they are not suitable when there are high pedestria... movements.

Que 3.25. Explain briefly the various design factors that are to b... 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.

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.

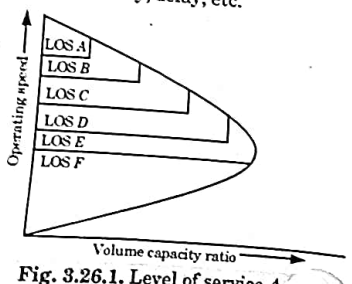


Fig. 3.26.1. Level of service A

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.

☺☺☺

4 UNIT Highway Materials

CONTENTS

PART-1

Properties of Subgrade, Aggregate and Binding Material.

CONCEPT OUTLINE

Subgrade : The top surface of the roadbed soil upon which the pavement structure and shoulders are constructed.

Aggregates : Aggregates form nearly 75 % to 90 % volume of the road structure. It bears the main stresses occurring in the road.

Type of Aggregates : Following are two types of aggregate :

i. Natural, and

ii. Artificial.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.1. What are the properties of subgrade soil in road construction ?

Answer

1. In transport engineering, subgrade is the native material underneath a constructed road, pavement or railway track.

2. Following are the desirable properties of subgrade material:

i. Stability.

ii. Incompressibility.

iii. Permanency of strength.

iv. Minimum changes in volume and stability under adverse conditions of weather and ground water.

v. Good drainage.

vi. Ease of compaction.

Que 4.2. What are the properties of good aggregate which are suitable for road construction work ?

Answer

Properties of Good Road Aggregate : Following are the properties of a good road aggregate :

1. **Hardness :**

i. The road aggregates should be sufficient hard to offer resistance to the action of abrasion and attrition.

ii. The aggregate are always subjected to constant rubbing action with the moving traffic. It is known as abrasion. It increases in the presence of abrasive material like sand.

iii. The mutual rubbing of stone is known as attrition.

2. **Strength :**

i. The road aggregate should be sufficient strong to withstand the stresses developed due to wheel load of the traffic.

ii. This property is especially desirable for the road aggregates which are to be used in top layer of pavement.

3. **Toughness :** It is the property that enables the aggregate to resist fracture when struck with a hammer and it is necessary in a road metal to withstand the impact blows caused by traffic.

4. **Shape :**

i. The shapes of aggregates may be rounded, cubical, angular, flaky or elongated.

ii. The flaky and elongated aggregate possess less strength and durability. It is not used in road construction.

iii. The rounded particles preferred in cement concrete road.

5. **Durability :**

i. The durability of an aggregate indicates its resistance to the action of weather and is largely depends upon its petrological composition.

ii. The road aggregate should possess sufficient soundness to resist the action of weather and age of the road.

6. **Cementation :** The binding quality of the road aggregate depends on its ability to form its own binding material under the traffic so as to make the rough broken stone pieces grip together to resist displacement by traffic.

7. **Adhesion with Bitumen :**

i. The aggregates which are to be used for the bituminous pavements should have less affinity with water as compared with the bituminous material.

ii. If this quality is not present in the aggregate it will lead to the separation of bituminous coating in the presence of water.

Que 4.3. **What are the different types of bituminous materials used in road construction ? Discuss the desirable properties of bitumen.**

Answer

A. Bituminous Materials :

i. Bituminous binders used in pavement construction works include both bitumen and tar.

ii. Bitumen is petroleum product obtained by the distillation of petroleum crude whereas road tar is obtained by the destructive distillation of coal or wood.

B. Types of Bituminous Materials : Following are the types of bituminous materials :

1. Bitumen :

i. It may be further divided as petroleum asphalt or bitumen and native asphalt.

ii. There are different forms in which native asphalts are available. Native asphalts are those which occur in a pure or nearly pure state in nature.

iii. Native asphalts which are associated with a large proportion of mineral matter are called rock asphalts.

iii. The viscosity of bitumen is reduced some times by a volatile diluent; this material is called cutback.

iv. When bitumen is suspended in a finely divided condition in an aqueous medium and stabilized with an emulsifier, the material is known as emulsion.

2. Tar : It is the viscous liquid obtained when natural organic materials such as wood and coal are carbonized or destructively distilled in the absence of air.

3. Properties : Following are the properties of bitumen :

1. The viscosity of the bitumen at the time of mixing and compacting should be adequate.
2. The bituminous material should not be highly temperature susceptible.
3. In presence of water the bitumen should not strip off from the aggregate.

Que 4.4. **What are difference between bitumen and tar ?**

Answer

S. No.	Property	Bitumen	Tar
1.	Colour	Dark colour with slight reddish tinge	Deep black
2.	State	Solid	Viscous liquid
3.	Carbon content	Medium	High
4.	Water resistance	More	Less
5.	Acid resistance	More	Less
6.	Adhesive power	Medium	High
7.	Setting time	Less	More

Que 4.5. **List different types of cutbacks. When are these used ? Discuss in brief the tests carried out on cutback bitumen.**

AKTU 2017-18, Marks 10

Answer

A. Cutback : Cutback bitumen is defined as the bitumen, the viscosity of which has been reduced by a volatile diluent.

B. Types of Cutbacks :

1. Rapid Curing Cutbacks :

i. These are bitumens, fluxed or cutback with a petroleum distillate such as nephta or gasoline which will rapidly evaporate after using in construction, leaving the bitumen binder.

ii. The grade of the RC cutback is governed by the proportion of the solvent used.

iii. The penetration value of residue from distillation up to 360 °C of RC cutback bitumen is 80 to 120.

2. Medium Curing Cutbacks :

i. These are bitumen fluxed to greater fluidity by blending with an intermediate-boiling-point solvent like kerosene or light diesel oil.

ii. MC cutbacks evaporate relatively at slow rate because the kerosene-range solvents will not evaporate rapidly as the gasoline-range solvents used in the manufacture of RC cutbacks.

iii. MC products have good wetting properties and so satisfactory coating of fine grain aggregate and sandy soils is possible.

3. **Slow Curing Cutbacks :**

i. These are obtained either by blending bitumen with high-boiling-point gas oil, or by controlling the rate of flow and temperature of the crude during the first cycle of refining.

ii. SC cutbacks or wood soils harden or set way slowly as it is a semi volatile material.

C. Uses : It use in surface dressings, some type of bitumen macadam and soil-bitumen stabilization.

D. Tests : Following are the test carried out on cutbacks bitumen :

i. Viscosity tests at specified temperature using specified size of orifice.

ii. Distillation test to find distillation fractions, up to specified temperature and to find the residue from distillation up to 360 °C.

iii. Penetration test, ductility test and test for matter soluble in carbon disulphide on residue from distillation up to 360 °C.

iv. Flash point test on cutback using Pensky Martens closed type apparatus.

PART-2

Various Tests and Specification of Aggregate and Binding Materials.

CONCEPT OUTLINE

Binding Material : Bitumen and tar play the role of binder material. It has adhesive property to bind the road construction materials.

Tests for Road Aggregates : Following test are carried out in laboratory on the sample of road aggregate.

i. Abrasion test.
ii. Crushing test.
iii. Impact test.
iv. Shape test.
v. Soundness test.
vi. Specific gravity and water absorption test.
vii. Stripping value test.

Test for Bituminous Material :

i. Ductility test.
ii. Flash and fire point test.
iii. Float test.
iv. Loss on heating test.
v. Penetration test.
vi. Softening point test.
vii. Solubility test.
viii. Specific gravity test.
ix. Viscosity test.
x. Water content test.
xi. Spot test.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.6. **Explain different tests of road aggregates.**

AKTU 2015-16, Marks 10

Answer

1. **Crushing Strength Test on Aggregates :**

i. Aggregate crushing value gives the crushing strength of aggregate up to which it can bear the load without fail.

ii. To conduct crushing strength test we need compression testing machine, cylindrical measure, plunger and IS sieves.

iii. First sieve the sample aggregate, aggregate passing 12.5 mm sieve and retaining 10 mm sieve is oven dries at 100-110 °C for 3-4 hrs.

iv. The cylinder is filled with aggregate in 3 layers, 25 strokes of tampering for each layer.

v. Note down its weight and insert the plunger and placed it on compression testing machine.

vi. Apply the load at uniform rate of 40 tonnes load in 10 minutes. Then stop the machine and crushed aggregate is sieved through 2.36 mm sieve and aggregate passing 2.36 mm sieve is weighed.

vii. Aggregate crushing value can be obtained as :

Aggregate crushing value = $(W_2 / W_1) \times 100$ %

2. **Abrasion Test on Aggregates :**

i. Hardness property of aggregate is determined by conducting abrasion test. Los Angeles abrasion testing machine is used to conduct this test.

ii. For this test, the sample taken should be clean and dried. The sample is weighed W_1 and placed in Los Angeles testing machine and the machine is operated.

iii. Machine should be rotated at a speed of 20-33 revolutions per minute. After 1000 revolutions the sample is taken out and sieved through 1.7 mm sieve.

iv. Sample retained on 1.7 mm is washed and dried and note down it weight W_2.

v. Aggregate abrasion value = $\{(W_1 - W_2) / W_2\} \times 100$ %

3. **Impact Test on Aggregates :**

i. Impact value of aggregate will give aggregate capability against sudde loads or forces. For this test also aggregate passing through 12.5 m and retained on 10 mm sieve is taken and oven dried.

ii. Fill the cylinder with aggregate in 3 layers, 25 strokes of tamping to each layer. Weight W_1 noted.

iii. The cylinder is placed in impact testing machine which consists a hammer. After placing the cylinder, hammer is raised to 380 mm and release freely. Then it will blow the aggregates. Repeat it for 15 such blows. After that take down the sample and aggregate passing through 2.36 mm sieve is weighed as W_2.

iv. Aggregate impact value = $(W_2/W_1) \times 100$ %

4. Soundness Test on Aggregates :

i. To determine the weathering resistance of aggregate soundness test is conducted. If the resistance against weathering is good for aggregate, then it will have high durability.

ii. For soundness test we need some chemical solutions namely sodium sulphate or magnesium sulphate.

iii. The sample of aggregate passing through 10 mm sieve and retained on 300 micron sieve is taken. Dry and weigh the sample and immerse them in the chemical solution for about 18 hours. After that, Take the sample and dried it in oven at 100-110 °C. Repeat this procedure 5 times for one sample, and weigh the aggregate finally and note down the difference in weight loss.

iv. The weight loss should be below 12 % if sodium sulphate is used, below 18 % if magnesium sulphate is used.

5. Shape test on Aggregates :

i. Shape of aggregate is also important consideration for the construction of pavement. Aggregate should not contain flaky and elongated particles in it. If they contain this type of particles, they will affect the stability of mix.

ii. The percentage by weight of aggregates whose least dimension is less the 3/5th of its mean dimension is called as flakiness index. The percentage by weight of aggregate particles whose greatest dimension is 1.8th times their mean dimension is called as elongation index.

iii. In this test shape test gauges are taken and minimum of 200 pieces containing sample is passed through respective gauges. Material retained on Thickness gauge and material retained on length gauge is weighed to an accuracy of 0.1%.

6. Bitumen Adhesion test on Aggregates :

i. Bitumen adhesion test will give the stripping of bitumen from the aggregate.

ii. To determine the stripping value of bitumen static immersion test is conducted on aggregates. In this test the aggregates are coated with bitumen and dried. After drying they are immersed in water at 40 °C for about 24 hours. Stripping value of aggregate should not exceed 5 %.

7. Water absorption test on Aggregates :

i. This test helps to determine the water absorption value of aggregate. To perform this test minimum 2 kg sample should be used.

ii. The sample should be cleaned and dried. Place the sample in wire basket and dip the basket in distilled water bath.

iii. Leave the basket for 24 hours and after that allowed it to drain for few minutes. Aggregates should be taken on dry cloth and exposed them to atmosphere sunlight. After drying, weigh the aggregates W_1.

iv. Then place the aggregate in oven at 100-110 °C for 24 hrs. After oven drying again weight the aggregate W_2.

v. The water absorption is expressed as the percent water absorbed in terms of oven dried weight of the aggregates.

Que 4.7. Describe various tests carried out on bituminous materials.

Answer

Test on Bitumen :

1. Penetration Test :

i. It measures the hardness or softness of bitumen by measuring the depth in tenths of a millimeter to which a standard loaded needle will penetrate vertically in 5 seconds.

ii. The penetrometer consists of a needle assembly with a total weight of 100 g and a device for releasing and locking in any position.

iii. The bitumen is softened to a pouring consistency, stirred thoroughly and poured into containers at a depth at least 15 mm in excess of the expected penetration. The test should be conducted at a specified temperature of 25 C.

iv. A grade of 40/50 bitumen means the penetration value is in the range 40 to 50 at standard test conditions. In hot climates, a lower penetration grade is preferred.

2. Ductility Test :

i. Ductility is the property of bitumen that permits it to undergo great deformation or elongation. Ductility is defined as the distance in cm, to which a standard sample or briquette of the material will be elongated without breaking.

ii. The dimension of the briquette thus formed is exactly 1 cm square. The bitumen sample is heated and poured in the mould assembly placed on a plate. These samples with moulds are cooled in the air and then in the water bath at 27 °C temperature.

iii. The excess bitumen is cut and the surface is leveled using a hot knife. Then the mould with the assembly containing sample is kept in the water bath of the ductility machine for about 90 minutes. The sides of the moulds are removed, the clips are hooked on the machine and the machine is operated.

iv. The distance up to the point of the breaking of thread in the ductility value which is reported in cm.

v. A minimum ductility value of 75 cm has been specified by the BIS.

3. Softening Point Test :

i. Softening point denotes the temperature at which the bitumen attains a particular degree of softening under the specifications of test.

ii. The test is conducted by using ring and ball apparatus. A brass ring containing test sample of bitumen is suspended in liquid like water or glycerin at a given temperature.

iii. A steel ball is placed upon the bitumen sample and the liquid medium is heated at a rate of 5 °C per minute.

iv. Temperature is noted when the softened bitumen touches the metal plate which is at a specified distance below.

v. Generally, higher softening point indicates lower temperature susceptibility and is preferred in hot climates.

4. Float Test :

i. Normally the consistency of bituminous material can be measured either by penetration test or viscosity test. But for certain range of consistencies, these tests are not applicable and float test is used.

ii. The apparatus consists of an aluminum float and a brass collar filled with bitumen to be tested.

iii. The specimen in the mould is cooled to a temperature of 5 °C and screwed in to float.

iv. The total test assembly is floated in the water bath at 50 °C and the time required for water to pass its way through the specimen plug is noted in seconds and is expressed as the float value.

5. Loss on heating Test :

i. When the bitumen is heated it loses the volatility and gets hardened.

ii. About 50 gm of the sample is weighed and heated to a temperature of 163 °C for 5 hours in a specified oven designed for this test.

iii. The sample specimen is weighed again after the heating period and loss in weight is expressed as the percentage by weight of the original sample.

iv. Bitumen used in pavement mixes should not indicate more than 1 % loss in weight, but for bitumen having penetration values 150-200 up to 2 % loss in weight is allowed.

PART-3

Types of Pavement and Design Factors.

CONCEPT OUTLINE

Type of Pavement : Based on structural design pavements are classified in two types :

i. Flexible pavements.

ii. Rigid Pavement.

Design Factors : Following are the factors for design of pavement :

i. Design wheel load.

ii. Subgrade soil strength.

iii. Pavement component materials.

iv. Environmental and climatic factors.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.8. What is pavement and give the requirement of good pavements.

Answer

1. **Pavement :**

A road surface or pavement is the durable surface material laid down on an area intended to sustain vehicular or foot traffic, such as a road or walkway.

2. **Requirement :** Following are the requirement of pavement :

i. Sufficient thickness to distribute the wheel load stresses to a safe value on the subgrade soil.

ii. Structurally strong to withstand all types of stresses imposed upon it.

iii. Adequate coefficient of friction to prevent skidding of vehicles.

iv. Smooth surface to provide comfort to road users even at high speed.

v. Produce least noise from moving vehicles.

vi. Dust proof surface so that traffic safety is not impaired by reducing visibility.

vii. Impervious surface, so that subgrade soil is well protected.

viii. Long design life with low maintenance cost.

Que 4.9. Compare flexible pavement with rigid pavement.

Answer

S.No.	Flexible pavement	Rigid pavement
1.	Deformation in the sub-grade is transferred to the upper layers.	Deformation in the sub-grade is not transferred to subsequent layers.
2.	Design is based on load distributing characteristics of the component layers.	Design is based on flexural strength or slab action.
3.	Have low flexural strength.	Have high flexural strength.
4.	Load is transferred by grain to grain contact.	No such phenomenon of grain to grain load transfer exists.
5.	Have low completion cost but repairing cost is high.	Have low repairing cost but completion cost is high.
6.	Have low life span.	Life span is more as compared to flexible pavement.
7.	Surfacing cannot be laid directly on the subgrade but a sub-base is needed.	Surface can directly laid on the subgrade.
8.	No thermal stresses are induced as the pavement has the ability to contract and expand freely.	Thermal stresses are more vulnerable to be induced as the ability to contract and expand is very less in concrete.
9.	Expansion joints are not needed.	Expansion joints are needed.
10.	Rolling of the surfacing is needed.	Rolling of the surfacing is not required.

Que 4.10. **What are the design factors considered in the design of pavements ?**

AKTU 2015-16, Marks 05

Answer

Following are the factors considered in design of pavement :

1. **Wheel Load Influence on Pavements :** Wheel load on pavement is an important factor to determine the pavement thickness to be adopted. By providing adequate thickness, the load coming from wheels doesn't affect the subgrade soil.
2. **Axle Configuration :** Axles are the important part of the vehicles which enables the wheels to rotate while moving. By providing multiple axles, vehicle can carry more load. So, the axle load also influences the design of pavement.
3. **Pressure :**
   i. When the vehicle is moving on pavement a pressure developed between the tire and pavement.
   ii. If the tire is low pressure tire, then contact pressure will be greater than tire pressure.
   iii. If it is high pressure tire, then contact pressure will be less than tire pressure.
4. **Vehicle Speed :** If the vehicle is moving at creep speed then also damage occurs to the pavement. If vehicle speed is gradually increased then it will cause smaller strains in the pavement.
5. **Temperature Effects on Pavements Design :**
   i. Temperature is the important environmental factor to be considered in the design of pavement.
   ii. In case of asphalt roads, temperature affects the resilient modulus of surface course.
   iii. In very hot condition asphalt layers lose their stiffness. At low temperature, asphalt layers become brittle and cracks are formed.

PART-4

Design of Bituminous Paving Mixes.

CONCEPT OUTLINE

Bituminous surface treatment (BST) or chip seal is used mainly on low-traffic roads, but also as a sealing coat to rejuvenate an asphalt concrete pavement. It generally consists of aggregate spread over sprayed-on asphalt emulsion or cut-back asphalt cement.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.11. **What are the desirable properties of bituminous mixes ? What are the steps in bituminous mix design ? Discuss briefly ?**

Answer

Properties of Bituminous Mixes : Following are the properties bituminous mixes :

1. Sufficient stability to satisfy the service requirements of the pavem and the traffic conditions, without undue displacements.
2. Sufficient bitumen to ensure a durable pavement by coating the aggrega and bonding them together and also by water proofing the mix.
3. Sufficient voids in the compacted mix as to provide a reservoir space fo a slight amount of additional compaction due to traffic and to avoi flushing, bleeding and loss of stability.
4. Sufficient flexibility even in the coldest season to prevent cracking du to repeated application of traffic loads.
5. Sufficient workability while placing and compacting the mix.
6. The mix should be the most economical one that would produce a stable durable and skid resistant pavement.

Steps of Bituminous Mix Design : Following are the steps in bitumen mix design :

1. Selection of aggregate.
2. Selection of aggregate grading.
3. Determination of specific gravity.
4. Preparation of specimen.
5. Determination of specific gravity of compacted bituminous mix.
6. Stability test on compacted bituminous mix.
7. Selection of optimum bitumen content.

PART-5

Design of Flexible Pavement by CBR Method (IRC 37 : 2012).

CONCEPT OUTLINE

CBR Method [IRC 37 : 2012]

$$\text{Design traffic} = N = \frac{365\left[(1+r)^n - 1\right]}{r} \times A \times D \times f$$

$r = 0.05$ (if not given)

$A = p(1+r)^x$

CBR for subgrade is given by,

$\log_{10} \text{CBR} = 2.465 - 1.12 \log_{10} N$

N = mm/blow

Thickness of pavement :

$$t = \sqrt{P}\left[\frac{1.75}{\text{CBR}} - \frac{1}{p\pi}\right]^{1/2}$$

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.12. Explain the CBR method of pavement design. How is this method useful to determine thickness of component layers ?

AKTU 2014-15, Marks 06

AKTU 2017-18, Marks 10

OR

Describe CBR method for the design of flexible pavement.

AKTU 2016-17, Marks 10

Answer

A. CBR Method :

1. CBR method also considers the characteristics of subgrade and properties of materials forming the various courses of the pavement.
2. CBR is an empirical test devised by California State Highways Department, USA, in which a property of the subgrade is measured.
3. **Procedure :**

i. CBR test is performed on a sample of the subgrade soil in a standard loading device.

ii. This device measures the load required to cause the penetration of plunger of 2.5 mm.

iii. Cross-sectional area of plunger is 1960 mm^2. Rate of penetration the sample by plunger is 1.25 mm/min.

iv. Penetration to the sample by plunger with this rate is done upto the required penetration of 2.5 mm.

v. Then pressure at the penetration of 2.5 mm is calculated and it is expressed as a percentage of unit standard pressure and this percentage of unit standard pressure is called as CBR.

vi. Test is repeated for the penetration of 5 mm and then CBR is found out. Higher value of CBR is preferably considered.

vii. The value at 2.5 mm penetration is generally higher. The unit standard load at 2.5 mm penetration is 70 kg/cm^2 or 7 N/mm^2 and the unit standard load at 5 mm is 105 kg/cm^2 or 10.5 N/mm^2.

4. IRC adopted CBR design chart is as shown in Fig. 4.12.1. There are seven curves from *A* to *G* for different volumes of traffic to be carried by the pavement as shown in CBR design chart Fig. 4.12.1.

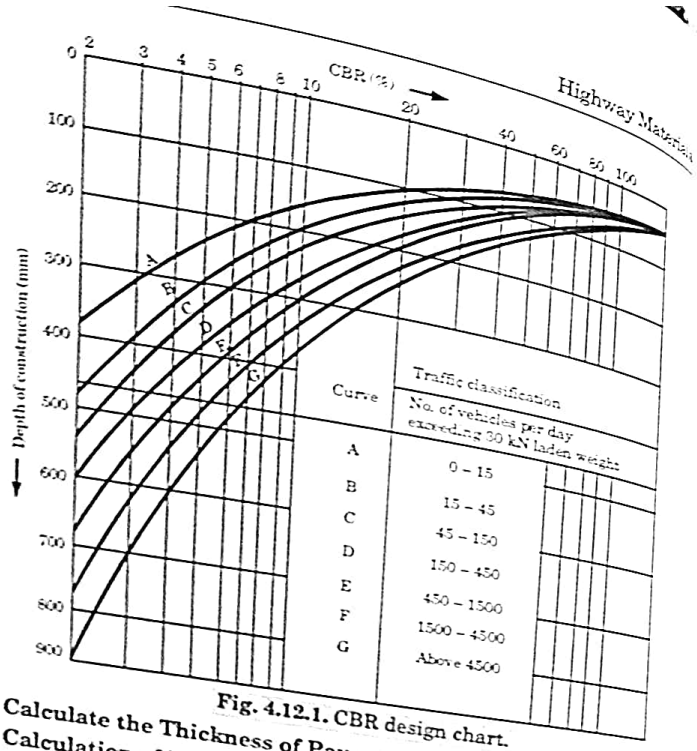


Fig. 4.12.1. CBR design chart.

B. Calculate the Thickness of Pavement :

1. Calculation of Total Thickness (T) :

a. In this step, firstly for the given value of traffic intensity select appropriate curve from classification table which is shown in Fig. 4.12.1.

b. Now, from the given CBR value of subgrade soil read the total thickness (T) with respect to selected curve.

2. Calculation of Sub Base Course Thickness (t_{sb}):

a. By using the above chart, for given CBR value of sub base course material and for traffic intensity value read the thickness of pavement which is above the soil sub base. It is denoted as (T_{sb}).

b. Thickness of sub base course,

$$t_{sb} = T - T_{sb}$$

3. Calculation of Base Course Thickness (t_b):

a. Repeat the above procedure again, from the CBR value of base course and from traffic intensity value read the value of thickness of pavement which is above the base course (t_s).

b. From this we can find out the value of t_b.

$$t_b = T_{sb} - t_s$$

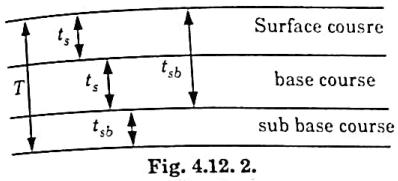


Fig. 4.12. 2.

Que 4.13. **What are the design factors considered in design of pavements ? Explain CBR method and IRC recommendations for the CBR method of design.** **AKTU 2015-16, Marks 15**

OR

Write the flexible pavement design steps and describe the procedure in brief as per IRC : 37-2012. **AKTU 2016-17, Marks 15**

Answer

A. **Design Factors :** Refer Q. 4.10, Page 4–12C, Unit-4.

B. **CBR Method :** Refer Q. 4.12, Page 4–15C, Unit-4.

C. **Design Steps :** Following are the steps should be follow in the design of flexible pavement.

Step 1 : Fix the lane distributor factor according to required number of lane in the pavement.

Step 2 : Calculate the design traffic in term of the cumulative number of standard axles to be carried during the design life of the road.

Step 3 : Determine the total pavement thickness with the help of design traffic and CBR value of components of pavements.

Step 4 : Pavement composition interpolated from various the pavement design catalogue (*i.e.*, recommended design for traffic range 1-10 msa and 10-150 msa).

D. IRC Recommendations :

1. The CBR tests should be performed on remoulded soils in the laboratory.
2. For the design of new roads, the subgrade soil sample should be compacted at OMC to proctor density.
3. If new constructions, the CBR test samples may be soaked in water for four days period before testing.
4. If the maximum variation in CBR values of the three specimens exceeds the specified limits, the design CBR should be the average of at least six samples. (The specified limits of maximum variation in CBR are 3 % for CBR values upto 10, 5 % for values 10 to 30 and 10 % for values 30 to 60 %.

5. The top 50 cm of subgrade should be compacted at least upto 95 to 100 percent of proctor density.
6. Pavements of major roads should be designed at least for 10 years life period and calculate the design traffic by given formula :

$$A = P[1 + r]^{(n + 10)}$$

where
A = Number of heavy vehicles per day for design.
P = Number of heavy vehicles per day at least count.
r = Annual rate of increase of heavy vehicles.
N = Design period.

PART-6

Design of Rigid Pavement.

CONCEPT OUTLINE

Design of Rigid Pavement : Modulus of sub-grade reaction (K),

$$K = \frac{p}{\Delta}$$

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.14. **Explain the following terms :**

1. **Modulus of subgrade reaction.**
2. **Relative stiffness of slab to subgrade.**
3. **Critical load positions.**
4. **Equivalent radius of resisting section.**

Answer

1. **Modulus of Sub-Grade Reaction :**

i. Westergaard considered the rigid pavement slab as a thin elastic plate resting on soil subgrade, which is assumed as a dense liquid.

ii. The upward reaction is assumed to be proportional to the deflection.

iii. Based on this assumption, Westergaard suggests a modulus of subgrade reaction K in kg/cm^3 and given by $K = \frac{p}{\Delta}$, where Δ is the displacement level taken as 0.125 cm and p is the pressure sustained by the rigid plate of 75 cm diameter at a deflection of 0.125 cm.

2. **Relative Stiffness of Slab to Subgrade :**

i. A certain degree of resistance to slab deflection is offered by the subgrade.

ii. The subgrade deformation is same as the slab deflection. Hence the slab deflection is direct measurement of the magnitude of the subgrade pressure.

iii. These pressure deformation characteristics of rigid pavement lead Westergaard to define the term radius of relative stiffness in cm which is given by,

$$l = \left[\frac{Eh^3}{12K(1-\mu^2)}\right]^{1/4}$$

where, E = The modulus of elasticity of cement concrete in kg/cm^2 (3.0×10^5),
μ = The Poisson's ratio if concrete (0.15).
h = The slab thickness in cm.
K = The modulus of subgrade reaction.

3. **Critical Load Positions :**

i. The intensity of maximum stress induced by the application of a given traffic load is dependent on the location of the load on the pavement surface.

ii. There are three typical locations namely the interior, edge and corner, where differing conditions of slab continuity exist. These locations are termed as critical load positions.

iii. **Interior Loading :** When load is applied in the interior of the slab surface at any place remote from all the edges.

iv. **Edge Loading :** When load is applied on an edge of the slab at any place remote from a corner.

v. **Corner Loading :** When the centre of load application is located on the bisector of the corner angle formed by two intersecting edges of the slab, and the loaded area is at the corner touching the two corner edges.

4. **Equivalent Radius of Resisting Section :**

i. When the interior point is loaded, only a small area of the pavement is resisting the bending moment of the plate.

ii. Westergaard gives a relation for equivalent radius of the resisting section in cm as

$$b = \begin{cases} \sqrt{1.6a^2 + h^2} - 0.675\,h, & \text{if } a < 1.724\,h \\ a, & \text{otherwise} \end{cases}$$

where, a = Radius of the wheel load distribution in cm.
h = Slab thickness in cm.

PART-7

Westergaards Theory.

CONCEPT OUTLINE

Westergaard developed a solution to determine distribution of stress due to point load in soils composed of thin layer of granular material that partially prevent lateral deformation of the soil.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.15. Discuss the Westergaard's concept and assumptions for analysis of rigid pavements. Also give the critical stress formulae at various positions of load.

Answer

A. Westergaard's Theory and Assumptions :

1. Cement concrete pavements represent the group of rigid pavements.
2. Here the load carrying capacity is mainly due to the rigidity and high modulus of elasticity of the slab itself *i.e.*, slab action.
3. Westergaard considered the rigid pavement slab as a thin elastic plate resting on soil subgrade, which is assumed as a dense liquid.
4. It is assumed that the upward reaction is proportional to the deflection, *i.e.*, $p = K\Delta$, where the constant K is defined as modulus of subgrade reaction in kg/cm³.

B. Critical Location of Loading : Westergaard developed relationships for the stress at interior, edge and corner regions, denoted as σ_i, σ_e and σ_c in kg/cm² respectively and given by,

i. At interior region,

$$\sigma_i = \frac{0.316P}{h^2}\left[4\log_{10}\left(\frac{l}{b}\right) + 1.069\right]$$

ii. At edge region,

$$\sigma_e = \frac{0.572P}{h^2}\left[4\log_{10}\left(\frac{l}{b}\right) + 0.359\right]$$

iii. At corner region,

$$\sigma_c = \frac{3P}{h^2}\left[1 - \left(\frac{a\sqrt{2}}{l}\right)^{0.6}\right]$$

where, h = Slab thickness in cm.
P = Wheel load in kg.
a = Radius of the wheel load distribution in cm.
l = Radius of the relative stiffness in cm.
b = Radius of the resisting section in cm.

Que 4.16. Calculate the stresses at interior, edge and corner of a cement concrete pavement by Westergaard's stress equations. Modulus of elasticity of concrete = 3.0 × 10⁵ kg/cm²
Poisson's ratio of concrete = 0.15
Pavement thickness, h = 18 cm
Modulus of subgrade reaction, K = 6.0 kg/cm³
Radius of contact area = 15 cm
Wheel load, P = 5100 kg **AKTU 2015-16, Marks 10**

Answer

Given : Modulus of elasticity, $E = 3.0 \times 10^5$ kg/cm²,
Poisson's ratio, $\mu = 0.15$, Thickness of pavement, $h = 18$ cm,
Modulus of subgrade reaction, $K = 6.0$ kg/cm³,
Wheel load, $P = 5100$ kg, Radius of loaded area, $a = 15$ cm.
To Find : Stresses at interior, edge and corner of pavement.

1. Radius of relative stiffness,

$$l = \left[\frac{Eh^3}{12K(1-\mu^2)}\right]^{1/4} = \left[\frac{3\times10^5\times18^3}{12\times6.0(1-0.15^2)}\right]^{1/4}$$

$$= 70.61 \text{ cm}$$

2. The equivalent radius of resting section is given by,

$$\frac{a}{h} = \frac{15}{18} = 0.833 < 1.724$$

Therefore, $b = \sqrt{1.6a^2 + h^2} - 0.675h$

$$= \sqrt{1.6\times15^2 + 18^2} - 0.675\times18 = 14 \text{ cm}$$

3. Stress at interior,

$$\sigma_i = \frac{0.316P}{h^2}\left[4\log\left(\frac{l}{b}\right) + 1.069\right]$$

$$= \frac{0.316\times5100}{18^2}\left[4\log\left(\frac{70.61}{14}\right) + 1.069\right]$$

$$\sigma_i = 19.3 \text{ kg/cm}^2$$

4. Stress at edge,

$$\sigma_e = \frac{0.572P}{h^2}\left[4\log\left(\frac{l}{b}\right) + 0.369\right]$$

$$= \frac{0.572 \times 5100}{18^2}\left[4 \times \log\left(\frac{70.61}{14}\right) - 0.369\right]$$

$$\sigma_e = 28.63 \text{ kg/cm}^2$$

5. Stress at corner,

$$\sigma_c = \frac{3P}{h^2}\left[1-\left(\frac{a\sqrt{2}}{l}\right)^{0.6}\right] = \frac{3 \times 5100}{18^2}\left[1-\left(\frac{15\sqrt{2}}{70.61}\right)^{0.6}\right]$$

$$\sigma_c = 24.27 \text{ kg/cm}^2$$

Que 4.17. Calculate the stresses at interior, edge and corner of a cement concrete pavement by Westergaard's stress equations: Modulus of elasticity of concrete = 3.0×10^5 kg/cm², Poisson's ratio for concrete = 0.15. Thickness of concrete pavement 18 cm, Modulus of subgrade reaction = 8.5 kg/cm², Wheel load = 5100 kg, Radius of loaded area = 15 cm, Radius of contact area = 15 cm.

AKTU 2017-18, Marks 10

Answer

Given : Modulus of elasticity, $E = 3.0 \times 10^5$ kg/cm²
Poisson's ratio, $\mu = 0.15$
Thickness of pavement, $h = 18$ cm
Modulus of subgrade reaction, $K = 8.5$ kg/cm³
Wheel load, $P = 5100$ kg
Radius of loaded area, $a = 15$ cm
To Find : Stress at edge, interior and corner points

1. Radius of relative stiffness, l

$$l = \left[\frac{Eh^3}{12K(1-\mu^2)}\right]^{1/4} = \left[\frac{3 \times 10^5 \times 18^3}{12 \times 8.5(1-0.15^2)}\right]^{1/4} = 64.72 \text{ cm}$$

2. The equivalent radius of resting section is given by,

$$\frac{a}{h} = \frac{15}{18} = 0.833 < 1.724$$

Therefore,
$$b = \sqrt{1.6a^2 + h^2} - 0.675h$$
$$= \sqrt{1.6 \times 15^2 + 18^2} - 0.675 \times 18 = 14 \text{ cm}$$

3. Stress at interior, $\sigma_i = \frac{0.316P}{h^2}\left[4\log\left(\frac{l}{b}\right) + 1.069\right]$

$$= \frac{0.316 \times 5100}{18^2}\left[4\log\left(\frac{64.72}{14}\right) + 1.069\right]$$

$$\sigma_i = 18.55 \text{ kg/cm}^2$$

4. Stress at edge, $\sigma_e = \frac{0.572P}{h^2}\left[4\log\left(\frac{l}{b}\right) - 0.369\right]$

$$= \frac{0.572 \times 5100}{18^2}\left[4 \times \log\left(\frac{64.72}{14}\right) + 0.369\right]$$

$$\sigma_e = 27.27 \text{ kg/cm}^2$$

5. Stress at corner, $\sigma_c = \frac{3P}{h^2}\left[1-\left(\frac{a\sqrt{2}}{l}\right)^{0.6}\right] = \frac{3 \times 5100}{18^2}\left[1-\left(\frac{15\sqrt{2}}{64.72}\right)^{0.6}\right]$

$$\sigma_c = 23.04 \text{ kg/cm}^2$$

Que 4.18. Calculate the stresses at interior, edge and corner of a cement concrete pavement using Westergaard stress equations, use the following data : Design wheel load = 5100 kg, pavement thickness $h = 20$ cm, modulus of elasticity concrete = 3×10^5 kg/cm², Poisson ratio of concrete is 0.15. Modulus of subgrade reaction $K = 6$ kg/cm³. Radius of contact area $a = 15$ cm.

AKTU 2013-14, Marks 10

Answer

Given : Wheel load, $P = 5100$ kg, Pavement thickness, $h = 20$ cm
Modulus of elasticity, $E = 3 \times 10^5$ kg/cm², Poisson's ratio, $\mu = 0.15$
Modulus of subgrade reaction, $K = 6$ kg/cm³, Radius of contact area, $a = 15$ cm
To Find : Stresses at interior, edge and corner.

1. Radius of relative stiffness, l

$$l = \left[\frac{Eh^3}{12K(1-\mu^2)}\right]^{1/4} = \left[\frac{3 \times 10^5 \times 20^3}{12 \times 6(1-0.15^2)}\right]^{1/4}$$

$$= 76.42 \text{ cm}$$

2. The equivalent radius of resisting section, b

$$\frac{a}{h} = \frac{15}{20} = 0.75 < 1.724$$

Therefore,
$$b = \sqrt{1.6a^2 + h^2} - 0.675h$$
$$= \sqrt{1.6 \times 15^2 + 20^2} - 0.675 \times 20 = 14.07 \text{ cm}$$

3. Stress at interior, $\sigma_i = \frac{0.316P}{h^2}\left[4\log\left(\frac{l}{b}\right) + 1.069\right]$

$$= \frac{0.316 \times 5100}{20^2}\left[4\log\left(\frac{76.42}{14.07}\right) + 1.069\right]$$

$$\sigma_i = 16.15 \text{ kg/cm}^2$$

4. Stress at edge, $$\sigma_e = \frac{0.572P}{h^2}\left[4\log\left(\frac{l}{b}\right) + 0.369\right]$$

$$= \frac{0.572 \times 5100}{20^2}\left[4\log\left(\frac{76.42}{14.07}\right) + 0.369\right]$$

$$\sigma_e = 24.13 \text{ kg/cm}^2$$

5. Stress at corner, $$\sigma_c = \frac{3P}{h^2}\left[1 - \left(\frac{a\sqrt{2}}{l}\right)^{0.6}\right] = \frac{3 \times 5100}{20^2}\left[1 - \left(\frac{15\sqrt{2}}{76.42}\right)^{0.6}\right]$$

$$\sigma_c = 20.52 \text{ kg/cm}^2$$

Que 4.19. **Discuss Westergaard's concept of temperature stresses in concrete pavements and explain warping stress and frictional stresses. What is the effect of combination of stresses ?**

OR

Discuss Westergaard's concept of temperature stresses in concrete pavement.

AKTU 2016-17, Marks 05

Answer

A. Temperature Stresses :

1. It is the property of a cement concrete slab to expand when there is a rise in temperature and contracts when there is fall in temperature.
2. If the cement concrete slab is subjected to free expansion and free contraction (*i.e.*, free deformation or natural deformation); then there will not be any changes in its length and therefore no temperature stress will be developed due to rise or fall in temperature.
3. In case of rigid pavements, the concrete slab resists the free deformation due to its own weight or due to action of frictional forces. However, the stresses are developed because of temperature variation.
4. Hence stress are so developed due to variation in temperature are classified into two types :

i. Warping Stress :

a. The stress so developed because of differential changes or variations in the top and bottom surface of the slab is termed as warping stresses.

b. There is various changes in the top and bottom surfaces and a warping or bending in the slab caused by temperature variation or difference.

c. The warping stress at the interior, edge and corner regions, denoted as σ_i, σ_e and σ_c given by the equations in kg/cm^2 respectively are,

$$\sigma_i = \frac{Eet}{2}\left(\frac{C_x + \mu C_y}{1-\mu^2}\right)$$

$$\sigma_e = \text{Max}\left(\frac{C_x Eet}{2}, \frac{C_y Eet}{2}\right)$$

$$\sigma_c = \frac{Eet}{3(1-\mu)}\sqrt{\frac{a}{l}}$$

where, E = Modulus of elasticity of concrete in kg/cm^2 (3×10^5).
e = Thermal coefficient of concrete per °C.
t = Temperature difference between the top and bottom of the slab.
C_x = Coefficient based on Lx/l in the desired direction.
C_y = Coefficient based on Ly/l in the right angle to the above direction.
μ = Poisson's ratio (0.15).
a = Radius of the contact area.
l = Radius of the relative stiffness.

ii. Frictional Stresses :

a. Temperature of the top and bottom surface is equal at such stage when temperature of the concrete remains same or constant for long period of time. Due to this constant temperature, there is uniform expansion or contraction (*i.e.*, lengthening or shortening) of the slab and at this stage warping is zero.

b. Concrete slab is in contact with the subgrade below it, hence slab movements are resisted by the friction held between the bottom surface of the slab and the subgrade.

c. The frictional stress σ_f in kg/cm^2 is given by,

$$\sigma_f = \frac{WLf}{2 \times 10^4}$$

where, W = Unit weight of concrete in kg/cm^3 (2400 kg / m^3).
f = Coefficient of subgrade friction (1.5).
L = Length of the slab in meters.

iii. Combination of Stresses : The cumulative effect of the different stresses give rise to the following three critical cases :

a. Summer, Mid-Day : The critical stress for edge region is given by,

$$\sigma_{critical} = \sigma_e + \sigma_{te} - \sigma_f$$

where, σ_e = Load stress.
σ_{te} = Warping stress.
σ_f = Frictional stress.

b. Winter, Mid-Day : The critical combination of stress for the edge region is given by,

$$\sigma_{critical} = \sigma_e + \sigma_{te} + \sigma_f$$

c. Mid-Night : The critical combination of stress for the corner region is given by,

$$\sigma_{critical} = \sigma_c + \sigma_{tc}$$

Que 4.20. A CC pavement slab of thickness 20 cm is constructed over a granular sub-base having modulus of reaction 15 kg/cm³. The maximum temperature difference between the top and bottom of the slab during summer day and night is found to be 18 °C. The spacing between the transverse contraction joints is 4.5 m and that between longitudinal joints is 3.5 m. The design wheel load is 5100 kg, radius of contact area is 15 cm, E value of CC is 3×10^5 kg/cm², Poisson's ratio is 0.15, and coefficient of thermal expansion of CC is 3×10^{-6} per °C, friction coefficient is 1.5. Using the edge and corner load stress charts given by the IRC and the chart for the warping stress coefficient, find the worst combination of stresses at the edge.

Answer

Given : $h = 20$ cm, $K = 15$ kg/cm³, $t = 18$ °C, $L_y = 4.5$ m, $L_x = 3.5$ m, $P = 5100$ kg, $a = 15$ cm, $E = 3 \times 10^5$ kg/cm², $\mu = 0.15$, $\alpha = 3 \times 10^{-6}$ °C, $f = 1.5$

To Find : Worst combination of stresses at the edge.

A. **Edge region :**

Edge load stress from edge load stress chart (IRC)

For $h = 20$ cm and $K = 15$ kg/cm³, $\sigma_e = 24.0$ kg/cm²

1. **Warping stress at edge :**

2. Radius of relative stiffness,

$$l = \left[\frac{Eh^3}{12K(1-\mu^2)}\right]^{\frac{1}{4}} = \left[\frac{3\times10^5\times20^3}{12\times15(1-0.15^2)}\right]^{\frac{1}{4}} = 60.8 \text{ cm}$$

Length of slab,

$L_x = 4.5$ m $= 450$ cm

ii. Warping stress coefficient, C_x from Bradbury chart,

At $\frac{L_x}{l} = \frac{450}{60.8} = 7.4$, $C_x = 1.02$

iii. Similarly at $\frac{L_y}{l} = \frac{350}{60.8} = 5.75$, $C_y = 0.87$;

$t = 18$ °C

iv. Maximum warping stress at edge,

$$\sigma_{te} = \frac{Eet}{2} \times C_x$$

$$= \frac{1}{2} \times 3 \times 10^5 \times 10 \times 10^{-6} \times 18 \times 1.02$$

$$= 27.54 \text{ kg/cm}^2$$

2. **Frictional Stress :** (W = unit weight of concrete = 2400)

$$\sigma_e = \frac{WL_x f}{2\times10} = \frac{2400\times4.5\times1.5}{2\times10^4} = 0.81 \text{ kg/cm}^2$$

3. **Combined Stress at Edge Region :**

Critical combination of stress during summer mid-day = Load stress + Warping stress – Frictional stress

$$= 24.0 + 27.54 - 0.81 = 50.73 \text{ kg/cm}^2$$

B. **Corner Region :**

1. **Load Stress :**

From chart for $h = 20$ cm and $k = 15$,

$$\sigma_c = 28.0 \text{ kg/cm}^2$$

2. **Maximum Warping Stress :**

$$\sigma_{tc} = \frac{Eet}{3(1-\mu)}\sqrt{\frac{a}{t}} = \frac{3\times10^5\times10\times10^{-6}\times18}{3(1-0.15)}\sqrt{\frac{15}{60.8}}$$

$$= 10.51 \text{ kg/cm}^2$$

3. **Frictional Stress :** This is zero at corner region.

4. **Combined Stress at the Corner Region :** The critical combination of stress in summer mid-night

$$= \text{Load stress} + \text{Warping stress}$$

$$= 28.0 + 10.51 = 38.51 \text{ kg/cm}^2$$

Note : It may be noted that the critical combination of stresses at the edge region is higher than that at the corner under the identical condition of pavement load and temperature.

PART-8

Joints.

CONCEPT OUTLINE

Joints : Joints are provided in cement concrete pavement to reduce the temperature stress. Joints are of three types :

i. Expansion joints.
ii. Contraction joints.
iii. Warping joints.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.21. Explain different types of joints in cement concrete pavement.

AKTU 2016-17, Marks 05

OR

Write a short note on construction joint in rigid pavement.

AKTU 2015-16, Marks 10

Answer

A. **Types of Joints :** According to the direction of placement, the joints are classified in the following two categories :

1. Longitudinal joints
2. Transverse joints.

1. Longitudinal Joints :

i. When the width of concrete road exceeds 4.5 m, it has to be constructed in strips. The joints provided along the strips are known as longitudinal joints.

ii. For a two-lane road, they are also called as centre-line joints. For a multi-lane road, these joints are known as lane joints.

iii. The longitudinal joints provided between the outer edge of pavement and shoulders are known as edge joints.

iv. The longitudinal joint acts as a hinge and it help in maintaining the two portions of slab together at the same level.

v. It also takes care of the unequal settlement of the subgrade and the expansion in the transverse direction.

vi. Fig. 4.21.1 shows the general layout of joints in concrete roads.

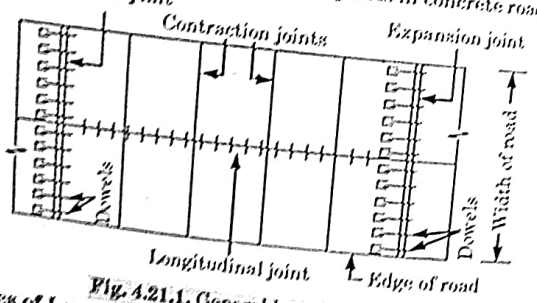


Fig. 4.21.1. General layout of joints.

i. **Types of Longitudinal Joints :**

a. **Plain Butt Joints :** This joint is the simplest longitudinal joint and it is formed by painting the joint faces with bitumen.

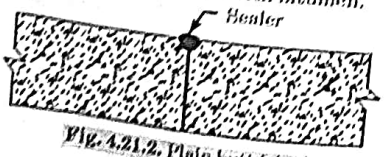


Fig. 4.21.2. Plain butt joint.

b. **Butt Joint with Tie Bars :**

i. In this type of longitudinal joint, tie bars of 12 to 15 mm diameter are provided as shown in Fig. 4.21.3.

ii. The function of providing tie bars has been recommended by IRC for their use in concrete roads slabs.

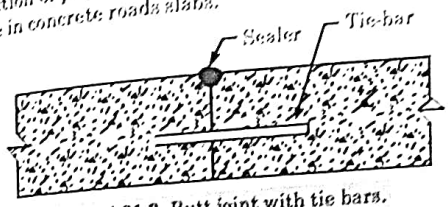


Fig. 4.21.3. Butt joint with tie bars.

iii. **Tongue and Groove Warping Joint :**

a. Fig. 4.21.4 shows the tongue and groove type of longitudinal joint.

b. It helps in controlling the differential uplift between the two adjacent edges.

c. This is a superior type of longitudinal joint and it is to be adopted when the subgrade is poor.

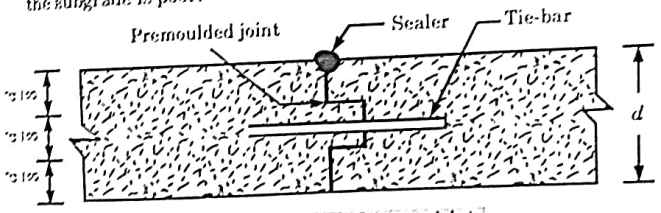


Fig. 4.21.4. Tongue and groove joint.

2. **Transverse Joints :** The joints which are provided in the transverse direction or perpendicular to the centre-line of road are known as transverse joints and according to their function, they are further classified as follows :

i. **Expansion Joints :**

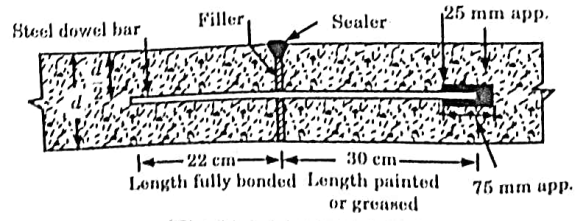


Fig. 4.21.5. Expansion joint.

a. The transverse joints constructed to allow the expansion of the road slab due to increase in temperature are known as expansion joints.

b. Expansion joints are provided at right-angles to the center line of the road at 10 to 20 m intervals.

c. This joints extend to the full width and thickness of the road slab.

ii. Contraction Joints :

a. The transverse joints constructed so as to allow the contraction of the road slab due to decreases in temperature are known as contraction joint.

b. This joints are plan butt type or dummy type joint.

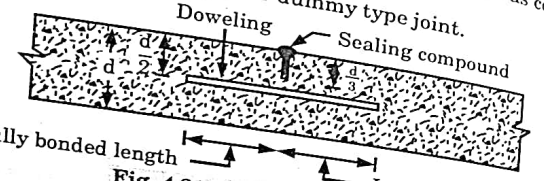


Fig. 4.21.6. Contraction joint.

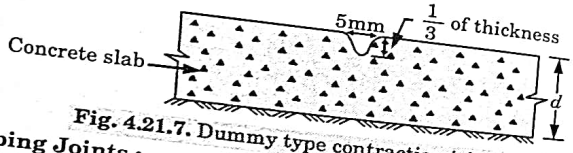


Fig. 4.21.7. Dummy type contraction joint.

iii. Warping Joints :

a. The transverse joints constructed to control the bending of a road slab due to difference in moisture content or temperature at its top and bottom are known as warping joints.

b. The joints in the form of butt joints with tie bar.

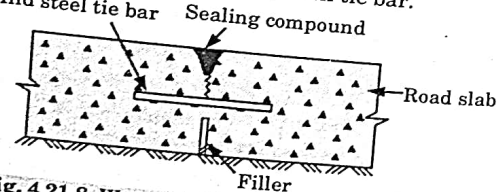


Fig. 4.21.8. Warping joint types of tranverse joints.

iv. Construction Joints : The transverse joint constructed when the construction work of the road slab is to be ended at a place other than a specified joint due to any reason is called a construction joints.

Que 4.22. Explain the design considerations for spacing of :
A. Expansion joints.
B. Contraction joints with and without reinforcement.

Answer

A. Spacing of Expansion Joint :

1. The width or the gap in expansion joint depends upon the length of slab. Greater the distance between the expansion joints, the greater is the width required of the gap for expansion.
2. It is recommended not to have a gap more than 2.5 cm in any case.
3. The IRC has recommended that the maximum spacing between expansion joints should not exceed 140 m for rough interface layer.
4. If 'δ' is the maximum expansion in a slab of length L_e with a temperature rise from T_1 to T_2.

$$\delta = L_e C (T_2 - T_1)$$

where, C = Thermal expansion of concrete per °C.

5. The joint filler may be assumed to be compressed up to 50 percent of its thickness and therefore, the expansion joint gap should be twice the allowable expansion in concrete, *i.e.*, 2δ.
6. From the relation given above, if δ is half the joint width, the spacing of expansion joint L_e is given by the equation :

$$L_e = \frac{\delta}{100C (T_2 - T_1)}$$

B. Spacing of Contraction Joints :

1. The slab contracts due to the fall in slab temperature below the construction temperature.
2. Also during the initial curing period, shrinkage occur in cement concrete. This movement is resisted by the subgrade drag or friction between the bottom fibre of the slab and the subgrade.
3. If L_c is the slab length in metre, the maximum stress occurs at half the length.

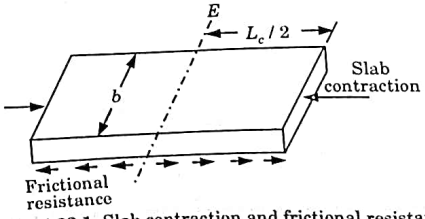


Fig. 4.22.1. Slab contraction and frictional resistance.

4. Total frictional resistance uptc distance $L_c/2$

$$= W \times b \times (L_c/2) \times (h/100) \times f$$

Allowable tension in cement concrete = $S_c \times h \times b \times 100$

Equation the above two values.

$$\frac{W b L_c h f}{200} = 100 S_c h b$$

6. Length of slab to resist the frictional drag *i.e.*, spacing of contraction joints.

$$L_c = \frac{2 S_c}{W f} \times 10^4$$

where, L_c = Slab length or spacing between contraction joints, m
h = Slab thickness, cm
f = Coefficient of friction, (maximum value is about 1.5)
W = Unit weight of cement concrete, kg/m^3 (2400 kg/m^3)
S_c = Allowable stress in tension in cement concrete, kg/cm^2 (0.8 kg/cm^2)

C. Spacing of Contraction Joints when Reinforcement is Provided:

1. It is assumed that the reinforcement takes the entire tensile force in the slab, caused by the frictional resistance of subgrade and hair cracks are allowed, then

$$W \times b \times \frac{L_c}{2} \times \frac{h}{100} \times f = S_s A_s$$

$$L_c = \frac{200 S_s A_s}{b h W f}$$

where, A_s = Total area of steel, cm^2 across the slab width (b).
S_s = Allowable tensile stress in steel, kg/cm^2 (1400).

Que 4.23. What is the purpose of dowel bars ? Discuss the design procedure of dowel bars.

Answer

A. Purpose of Dowel Bar :

1. The primary purpose of dowel bars is to transfer the shear load across the transverse joint between the two adjoining concrete slabs, by bearing against the concrete and developing contact bearing stress between the concrete and the dowel bar.
2. To increase load transfer efficiency.
3. This reduces joint deflection and stress in the approach and leave slabs.

Bradbury's Analysis : Bradbury's analysis gives load transfer capacity of single dowel bar in shear, bending and bearing as follows :

$$P_s = 0.785 d^2 F_s$$

$$P_f = \frac{2d^3 F_f}{L_d + 8.8\delta}$$

$$P_b = \frac{F_b L_d^2 d}{12.5(L_d + 1.5\delta)}$$

where, P_s, P_f and P_b = Load transfer capacity of a single dowel bar in shear s, bending f and bearing b.

d = Diameter of the bar in cm.
L_d = Length of the embedment of dowel bar in cm.
δ = Joint width in cm.
F_s, F_f and F_b = Permissible stress in shear, bending and bearing for the dowel bar in kg/cm^2.

B. Design Procedure :

Step 1 : Find the length of the dowel bar embedded in slab L_d by equating equation for P_f and P_b, *i.e.*,

$$L_d = 3\delta \sqrt{\frac{F_s}{F_b}\frac{(L_d + 1.5\delta)}{(L_d + 8.8\delta)}}$$

Step 2 : Find the load transfer capacities P_s, P_f and P_b of single dowel bar with the L_d.

Step 3 : Assume load capacity of dowel bar is 40 percent wheel load, find the load capacity factor f as

$$\max \left\{ \frac{0.4P}{P_s}, \frac{0.4P}{P_f}, \frac{0.4P}{P_b} \right\}$$

Step 4 : Spacing of the Dowel Bars :

i. Effective distance up to which effective load transfer take place is given by 1.8 l, where l is the radius of relative stiffness.
ii. Assume a linear variation of capacity factor of 1.0 under load to 0 at 1.8 l.
iii. Assume dowel spacing and find the capacity factor of the assumed spacing.
iv. Actual capacity factor should be greater than the required capacity factor.
v. If not, do one more iteration with new spacing.

Que 4.24. What is the purpose of tie bars ? Explain how the dimensions and spacing of the tie bars are designed ?

Answer

A. Purpose of Tie Bar :

1. The primary purpose of tie bars is to prevent separation of adjoining lanes of concrete pavement slabs and differential deflection between them.
2. They also help in reducing transverse cracking in concrete pavement slabs.
3. Mechanically connect slabs allowing them to expand and contract independent of each other, on account of temperature variations.

B. Diameter and Spacing : The diameter and the spacing is find out by equating the total subgrade friction to the total tensile stress for a unit length (one meter). Hence, the area of steel per one meter in cm^2 is given by

$$A_s \times \sigma_s = b \times h \times W \times f$$

$$A_s = \frac{b h W f}{100 \sigma_s}$$

where, b = Width of the pavement panel in m.
h = Depth of the pavement in cm.

σ_s = Allowable working tensile stress in steel, assume 1750 kg/cm².
Assume 0.8 to 1.5 cm ϕ diameter bars for the design.

C. **Length of the Tie Bar :** Length of the tie bar is twice the length needed to develop bond stress equal to the working tensile stress and is given by,

$$L_t = \frac{d\sigma_s}{2\sigma_b}$$

where, d = Diameter of the bar.

σ_b = Allowable bond stress and can be assumed for plain and deformed bars respectively as 17.5 and 24.6 kg/cm².

Que 4.25. **Determine the spacing between contraction joints for 3.5 meter slab width having thickness of 20 cm and f = 1.5, for the following two cases.**

i. For plain cement concrete, S_c = 0.8 kg/cm²

ii. For reinforcement cement concrete 1.0 cm. bars at 0.30 m spacing.

AKTU 2014-15, Marks 06

Answer

Given : Width = 3.5 m, Thickness = 20 cm, f = 1.5, Diameter of reinforcement = 1 cm, Spacing = 0.30 m, S_c = 0.8 kg/cm²

To Find : Spacing between contraction joints.

1. Case (i) : For Plain Cement Concrete Slab (Without Reinforcement).

i. Assume unit weight of CC, W = 2400 kg/m³

ii. Spacing between contraction joints is given by,

$$L_c = \frac{2S_c}{Wf} \times 10^4 = \frac{2 \times 0.8 \times 10^4}{2400 \times 1.5} = 4.44 \text{ m}$$

2. Case (ii) : For Reinforced Cement Concrete Slab.

i. Total cross-sectional area of steel A_s in one direction along the slab width,

$$A_s = \frac{3.5 \times \pi \times 1.0^2}{0.3 \times 4} = 9.16 \text{ cm}^2$$

ii. Spacing between contraction joints,

$$L_c = \frac{200\sigma_s A_s}{bhWf} = \frac{200 \times 1200 \times 9.16}{3.5 \times 20 \times 2400 \times 1.5} = 8.72 \text{ m}$$

PART-9

IRC Method of Rigid Pavement Design (IRC : 58-2015).

CONCEPT OUTLINE

IRC Method [IRC : 58-2011] of Rigid Pavement :

$A_g = P(1+r)^{n-2}$

P = Number of commercial vehicles per day at last count.

r = Annual rate of increase in traffic intensity.

n = Number of year.

A_g = Number of vehicles per day.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.26. **Explain IRC method of rigid pavement design.**

AKTU 2014-15, Marks 06

Answer

The following steps may be followed for design according to IRC 58 : 2015

Step 1 : Stipulate design value for the various parameters.

Step 2 : Select a trial design thickness of pavement slab.

Step 3 : Compute the repetitions of axle loads of different magnitudes and different categories during the design life.

Step 4 : Find the proportions of axle load repetitions operating during the day and night periods.

Step 5 : Estimate the axle load repetition in the six hours periods during the day time. The maximum temperature difference is constant in 6 hours for analysis of bottom-up cracking.

Step 6 : Estimate the axle load repetitions in the 6 hour period during the night time. (The maximum negative temperature differential during night is taken as half of the day time maximum temperature differential).

Step 7 : Compute the flexural stresses at the edge due to the single and tandem axle loads for the combined effects of axle loads and positive temperature differential during day time. Determine the stress ratio (Flexural stress/Modulus of rupture) and evaluate the cumulative fatigue damage for single and tandem axle loads.

Step 8 : Compute the maximum flexural stress in the top surface of the pavement slab with the front axle near the approaching transverse joint and the rear axle close to the following joint in the same panel under negative temperature differential. Determine the stress ratio and evaluate the CFD for different axle load for the analysis of top-down cracking.

Step 9 : Sum of CFD for the EUC and TDC. If the sum is less than 1.0, the pavement slab is safe against fatigue cracking.

Que 4.27. A cement concrete pavement is to be designed. Present traffic is 3000 commercial vehicles per day. Design life is 20 years and rate of traffic increase is 5.5 %. Calculate the design traffic as per IRC 58-2011.

AKTU 2016-17, Marks 10

Answer

Given : Present traffic, $A = 3000$ commercial vehicles per day
Design life, $n = 20$ years, Traffic increase rate, $r = 5.5\ \%$
To Find : Design traffic as per IRC 58-2011.

1. Assume vehicle damage factor, $V_{DF} = 2.5$

2. $$\text{Design traffic} = \frac{365A[(1+r)^n - 1]}{r} \times V_{DF}$$

$$= \frac{365 \times 3000[(1+0.055)^{20} - 1]}{0.055} \times 2.5$$

$$= 95.45 \times 10^6 = 95.45 \text{ msa}$$

☺☺☺

5 UNIT

Highway Construction Methods

CONTENTS

PART-1

Construction of Subgrade.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.1. What are the various steps for the preparation of subgrade ?

Answer

Preparation of subgrade : Following are the steps for preparation of subgrade :

1. Site should be cleared off of grass, roots and other organic matter etc.
2. Excavation or filling up to bring the subgrade to desired longitudinal grade and desired camber. It should be compacted adequately before placement of pavement layers.

i. It can be done manually or mechanically, manual work takes more time.

a. Manually, it is carried out with the help of spades, pick and hand shovels.

b. Mechanically, it is carried out by dozers, scrapers and rippers.

ii. Compaction should be done as far as possible at optimum moisture content.

iii. Special care will have to be taken for compaction of embankments during filling of road.

3. Shaping of subgrade according to longitudinal grade and camber.

PART-2

Water Bound Macadam (WBM).

CONCEPT OUTLINE

Macadam : The term macadam is defined as the pavement base course made of crushed or broken aggregate mechanically interlocked by rolling and the voids are filled with screening and binding material with water.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.2. Explain Water Bound Macadam.

AKTU 2016-17, Marks 05

Answer

Water Bound Macadam (WBM) :

1. The Water Bound Macadam is the construction known after the name of John macadam.
2. The term macadam in the present day means, the pavement base course made of crushed or broken aggregate mechanically interlocked by rolling and the voids filled with screening and binding material with the assistance of water.
3. The WBM may be used as a sub-base, base course or surfacing course.
4. The thickness of each compacted layer of WBM ranges from 10.0 cm to 7.5 cm depending on the size and gradation of the aggregates used.
5. The number of layers and total thickness of WBM construction depends on the design details of the pavement.
6. When used as a surfacing course, WBM gets deteriorated rapidly under adverse conditions of traffic and weather.
7. Therefore it is desirable to provide a bituminous surfacing course over the WBM layer in order to prolong its life.

Que 5.3. Discuss the specification of course aggregate and binding materials required in WBM construction. Further explain how the following steps in WBM construction are carried out :

A. Spreading of course aggregates.

B. Application of binding material.

AKTU 2013-14, 2017-18; Marks 10

Answer

Material Specification :

1. **Coarse Aggregate :**

i. It should consist of hard and durable stones crushed or broken, free from flaky or elongated pieces.

ii. Soft aggregates of overburnt bricks or naturally occurring soft aggregates such as kankar or laterite may also be used.

iii. Crushed slag obtained from blast furnace may also be used.

iv. Physical requirement are as under :

Table 5.3.1.

	Test	Test Method	Requirement
a.	Los Angeles abrasion value	IS 2386 (part-4)	40 % (Max)
b.	Aggregate impact value	IS 2386 (part-4) or IS 5640	30 % (Max)
c.	Combined flakiness and elongation indices.	IS 2386 (part-1)	30 % (Max)

v. Soft aggregates which get softened in presence of water, shall be tested for impact value under wet conditions as per IS 5640.

2. Size and Grading of Coarse Aggregates :

i. For the construction of the WBM roads aggregates are used in the sub-base, base and surface course and so the aggregates are divided into 3 grades according to their size.

a. Grade 1-particles of size 90 mm to 40 mm.

b. Grade 2 - particles of size 63 to 40 mm.

c. Grade 3 - particles of size 50 to 20 mm.

ii. If we only use the WBM as the surface course, it gets deteriorated fast due to abrasion with the traffic so, bituminous surfacing over the WBM is general practice.

3. Screening : Screeners are the aggregates of the smaller sizes, generally 12.5 mm or 10 mm, for grade A and grade B. They are of the same chemical composition as of the coarse aggregates.

4. Binding Material :

i. It consisting of fine grained material is used in WBM construction to prevent raveling of the stones.

ii. Kankar dust or lime stone dust may be utilized if locally available.

iii. The binding material with plasticity index value of 4 % to 9 % is used in surface course construction, the plasticity index of binding course material should be less than 6 % in the case of the WBM layers used as base course or sub-base course, with bituminous surfacing.

iv. If the screening used consists of crushable material like moorum or soft gravel, there is no need to apply binding material, unless the plasticity index value is low.

A. Spreading of Course Aggregates :

1. Coarse aggregate shall be spread evenly upon the prepared sub-grade/ sub-base to correct profile using templates @ 6 m apart in such quantities that compacted layer is not more than 100 mm for grading 1 (45-90 mm), 75 mm for grading 2 (40-63 mm) or grading 3 (20-50 r

2. It can be spread manually or mechanically (aggregate spreader).

3. Spreading can be done from stock piles along the roads or directly from vehicles.

4. In case of lime treated sub-base, coarse aggregate lying is started after the sub-base has attained adequate strength and does not get damaged due to copious (plentiful) application of water during rolling.

B. Application of Binding Material :

1. Binding material is applied in two or more layers at a slow and uniform rate.

2. After each application, the surface shall be copiously sprinkled with water and resulting slurry swept into voids with broom to fill them properly and rolled.

3. Water is applied to the wheel of the rollers to wash down the binding material sticking to them.

Que 5.4. Write down the construction steps for water bound macadam roads.

Answer

Following are the construction steps for WBM roads :

1. Preparation of the Foundation :

i. The foundation for receiving the new layer of WBM may be either the sub grade or sub-base course.

ii. This foundation layer is prepared to the required grade and camber and the dust and other loose materials are cleaned.

iii. On existing road surface the depression and pot holes are filled and the corrugations are removed.

2. Provision of Lateral Confinement : This can be done constructing the shoulders to a thickness equal to that of the compacted WBM layer and trimming the inner sides vertically.

3. Spreading of Coarse Aggregates : The coarse aggregates are spread uniformly to the proper profile and even thickness up on the prepared foundation and checked by templates.

4. Rolling :

i. After spreading the coarse aggregates properly, compaction is done by three wheeled power roller (6 to 10 tonnes) or equivalent vibrating roller.

ii. The Rolling is started from the edges and progressed gradually towards the centre of rod road until adequate compaction is achieved.

iii. On super elevated portion, rolling it started from the inner or lower edge and progressed gradually towards the outer or upper edge of the pavement.

5. **Application of Screenings :**

i. After the coarse aggregates are rolled adequately the dry screenings are applied gradually over the surface and try rolling is continued as the screenings are being spread.

ii. Brooming operation is also carried out simultaneously.

6. **Sprinkling and Grouting :** After the application of screenings, the surface is sprinkled with water, swept and rolled.

7. **Application of Binding Material :**

i. After the application of screenings and rolling, binding materials is applied at uniform and slow rate at two or more successive thin layers.

ii. After each application of binding material, the surface is sprinkled with water and wet slurry swept with brooms to fill the voids.

8. **Setting and Drying :**

i. After final compaction, the WBM course is allowed to set over night.

ii. On the next day the hungry spots are filled with screenings or binding materials, lightly sprinkled with water if necessary and rolled.

iii. No traffic is allowed till the WBM layers sets and dries out.

PART-3

Wet Mix Macadam (WMM).

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.5. **What is WMM ? Write down its construction process.**

Answer

A. **Wet Mix Macadam :** In wet mix macadam, a well graded aggregate is mixed with water in a mechanical mixer and the prepared mixture is laid by pavers and compacted.

B. **Construction Procedure :**

1. **Preparation of Base :**

i. The surface of the sub-base/ base to receive the WMM course shall be prepared to the specified lines and camber.

ii. It is made free of dust and other extraneous matter.

iii. Any ruts and soft yielding places shall be corrected and rolled until firm surface is obtained.

2. **Provision of Lateral Confinement of Wet Mix :**

i. In this method, the shoulder and wet mix layer are provided in the sequence of operation such that the construction of the shoulder is done in layer, each matching the thickness of the adjoining pavement layer.

ii. Only after a layer of pavement and corresponding layers in shoulders have been laid and compacted, construction of the next layer of pavement and shoulder is carried out.

3. **Preparation of Mix :** WMM shall be prepared in an approved mixing plant of suitable capacity e.g., pug mill or pan type mixer. For small quantity of mix, mixing may be done in ordinary concrete mixers.

4. **Spreading of Mix :**

i. After the mixing, the mixed material shall be transported to site and spread uniformly over a prepared subgrade/sub-base in required quantities.

ii. It is spread by a paver or finisher or motor grader or a combination of both.

5. **Compaction :**

i. After the mix has been laid to the required thickness of grade and camber, it is uniformly compacted to the full depth with a suitable roller.

ii. If the thickness of the single compacted layer does not exceed 100 mm, a smooth wheel roller of 80 to 100 kN weight may be used.

iii. For thickness up to 200 mm, the vibrating roller of 80 to 100 kN weight is used such that the speed of roller should not exceed 5 km/hr.

PART-4

Granular Sub Base (GSB), Tack Coat, Prime Coat, Seal Coat Surface Dressing.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.6. **Write short note on following :**

1. **Prime coat.** **AKTU 2015-16, Marks 03**

2. **Tack coat.** **AKTU 2017-18, Marks 04**

3. **Seal coat.** **AKTU 2013-14, Marks 04**

4. **Bituminous premix carpeting.**

Answer

1. **Prime Coat :**

i. Bituminous prime coat is the first application of a low viscosity liquid bituminous material over an existing porous or absorbent pavement surface like the WBM base course.

ii. The main object of priming is to plug in the capillary voids of the porous surface and to bond the loose mineral particles on the existing surface using a binder of low viscosity which can penetrate into the voids.

iii. The bituminous primer is sprayed uniformly using a mechanical sprayer at a rate of 7.3 to 14.6 kg per 10 m^2 area depending on the porosity of the surface.

iv. The primed surface is allowed to cure for at least 24 hours, during which period no traffic allowed.

2. **Tack Coat :**

i. Bituminous tack coat is the application of bituminous material over an existing pavement surface which is relatively impervious like an existing bituminous surface or a cement concrete pavement or pervious surface like the WBM which has already been treated by a prime Coat.

ii. Tack coat is usually applied by spraying bituminous material of higher viscosity like the hot bitumen at the rate of 4.9 to 9.8 kg per 10 m^2 area depending in the type of the surface.

iii. However in some special circumstances, a tack coat of bituminous emulsion may also be applied in cold state.

3. **Seal Coat :**

i. A final coat of bituminous material provided on the top of surface for sealing the voids against entry of moisture is known as seal coat.

ii. Seal coat is also provided over and existing bituminous pavement which is worn out.

iii. The seal coat is very thin surface treatment or a single coat surface dressing which is usually applied over an existing black top surface.

iv. A premixed sand bitumen (hot mix) seal coat is also commonly used over the premixed carpet.

v. The main functions of seal coat are :
   a. To make the surface water tight.
   b. It improves the visibility at night.
   c. It develops skid resistance texture for existing roads which are very smooth and slippery.
   d. It improves the wearing resistance of an existing dry or weathered road surface.

4. **Bituminous Premix Carpeting :**

i. It consists of coarse aggregates of 12.5 and 10.0 mm sizes, premixed with bitumen or tar binder are compacted to a thickness of 20 mm to serve as a surface course of the pavement.

being a open graded construction, the PC is to be invariably covered by a suitable seal coat such as premixed sand-bitumen seal coat before opening to traffic.

ii. The PC consists of all aggregates passing 20 mm and retained on 6.3 mm sieve.

iii. When a fairly well graded material as per specification is used for the construction of the bituminous carpet of thickness 20 to 25 mm, the construction method is called semi-dense carpet.

Que 5.7. What is surface dressing ? Write the construction procedure for surface dressing. **AKTU 2016-17, Marks 10**

OR

Write a short note on surface dressing. **AKTU 2013-14, 2015-16; Marks 03**

Answer

A. **Surface dressing :**

1. The method of applying one or two coats of bituminous material, each consisting of a layer of bituminous binder sprayed on the prepared base, followed by a cover of stone chippings properly rolled to form a wearing course is known as surface dressing.
2. It is done only in dry and clear weather conditions at temperature above 16 °C.

B. **Construction Steps :** Following steps are used in BSD :

1. The existing surface is prepared to correct profile and ruts, depressions etc., are rectified.
   It is made free of dust and loose materials.
2. A prime coat is applied if the existing surface is of soil stabilize material or WBM.
3. On the prepared surface, uniform spraying of the bituminous binder is done at specified rate, avoiding excessive application which causes bleeding.
4. After it stone chippings as per requirements are spread to cover the surface uniformly.
5. Rolling is done with tandem roller of 6 to 8 tonnes capacity from edges towards the centre overlapping not less than 1/3rd of the roller tread. When rolling of the first half is completed. It is carried out on other half again starting from the edge and proceeding towards the center.
6. If second coat is to be applied, the binder is again applied over the first coat.
7. After it smaller size aggregate is applied and rolled as for first coat.
8. The surface is checked for longitudinal and cross profile using a straight edge of length 3.0 m and variations greater than 6 mm are corrected.
9. The road is opened to traffic after 24 hours.

PART-5

Semi Dense Bituminous Concrete (SDBC), Bituminous Macadam (BM) and Bituminous Concrete.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.8. **Explain bituminous macadam and asphaltic concrete.**

AKTU 2014-15, Marks 3.5

OR

Write a short note on asphaltic concrete.

AKTU 2013-14, Marks 03

OR

Explain bitumen bound macadam. **AKTU 2016-17, Marks 05**

Answer

A. Bituminous Macadam :

1. It is a course of premixed crushed aggregate with bitumen binder.
2. It is laid in compacted thickness of 75 mm or 50 mm. Three different gradations of aggregate are used to provide open graded and semi-dense constructions.
3. The BM is essentially a base course or binder course and hence should be covered by a suitable surfacing course before exposing to traffic.
4. Bituminous macadam base course is much superior to WBM in respect to load dispersion characteristics and durability.

B. Asphaltic Concrete :

1. It is a dense graded premixed bituminous mix, well compacted to form a high quality pavement surface course.
2. It consists of :

i. Mixture of course and fine aggregate.
ii. Mineral filler.
iii. Bitumen.

3. The thickness of course ranges from 40 to 75 mm.
4. IRC has provided specifications for 40 mm thick asphalt concrete surface.
5. A proportioned mixture of coarse aggregate, fine aggregate and bitumen is used.

Que 5.9. **Write short notes on the following :**

A. Sheet asphalt.

B. Mastic asphalt.

AKTU 2014-15, 2017-18; Marks 06

Answer

A. Sheet Asphalt :

1. It is a dense sand bitumen premix of 25 mm compacted thickness used as a wearing course.
2. It consists of well graded course of fine sand and suitable penetration grade bitumen.
3. It is usually laid over CC pavement to provide an excellent riding surface.
4. It causes a reduction in warping stresses of CC pavements by decreasing temperature variations between top and bottom of the concrete slab.

B. Mastic Asphalt :

1. It is a mixture of fine aggregate, filler and bitumen to yield a void less and impermeable mass.
2. These all are taken in suitable proportion, heated in sequence and cooked at 200 to 223 °C according to binder grade for over 5 hours in a special cooker.
3. At 200 °C it has a consistency that it can flow. But on cooling it gives a hard, stable and durable layer, suitable to withstand heavy traffic.
4. It should be spread at a temperature of about 200 °C in 2.50 to 5 cm thickness and forms a hard layer without compaction (rolling).
5. It has a property of self healing of cracks without bleeding.
6. It is a suitable surface material for surfacing bridge deck slabs.

PART-6

Dry Lean Concrete and Cement Concrete (CC) Road Construction.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.10. **Write a short note on dry lean concrete (DLC).**

Answer

Dry Lean Concrete (DLC) : DLC is a zero slump concrete. A sub-base of dry lean concrete is a common feature of modern highway concrete pavements. As a sub-base, it has many advantages :

i. It provides a smooth surface under the concrete pavement, permitting the free movement of slab due to temperature variations.
ii. It can permit construction traffic in a period of 7 days.
iii. It improves the load transfer at joints.
iv. It enhances the support of the subgrade and thus reduces the concrete slab thickness.
v. It prevents water through joints and cracks reaching the subgrade and lowering its supporting power.

Material Specification :

1. Coarse aggregates have a maximum size less than 25 mm.
2. The aggregate cement ratio is of order 15 : 1.
3. The average 7 days strength desired 10 MPa.
4. The minimum cement content is generally 150 kg/km.
5. The moisture content to ensure full compaction under rolling in the range of 5-7 percent.

Construction :

1. The DLC is laid by paver. Compaction is carried out by a vibratory roller to achieve 97 % of the specified density by rolling.
2. Curing is done by water ponding and curing compounds. The surface of DLC should be finished smoothly.

Que 5.11. **Enumerate the steps in the construction of cement concrete pavement.** **AKTU 2014-15, Marks 06**

OR

Write the construction procedure for cement concrete pavement. **AKTU 2016-17, Marks 10**

Answer

Construction Procedure :

1 **Preparation of Subgrade and Sub-Base :**

i. The well compacted subgrade or sub-base should extend 30 cm on either side of the width of concreting.
ii. The subgrade should be saturated with water 6 to 20 hours in advance of placement of concrete.
iii. Water proof paper should be placed over the subgrade, if concreting is done directly over the (dry) subgrade.
iv. The subgrade should be properly drained.
v. The minimum modulus of subgrade reaction in a plate bearing test should be 5.54 kg/cm².

2. **Placing of Forms :** Forms can be of steel or wooden.

i. **Steel Forms :** Steel forms are MS channel section and their depth is equal to thickness of the pavement.

ii. **Wooden Forms :**

a. Wooden forms have minimum 10 cm width for 20 cm thick slab and minimum 15 cm width for 25 cm thick slab.

b. The length of the forms is 3 m. It is shorter on curves of radius less than 45 m.

3. **Batching and Mixing :**

i. The course aggregate, fine aggregate and cement are proportioned by weight in a weight batching plant on the basis of one or whole bags of cement (50 kg – 0.03412 m^3) @ 1440 kg/m^3.
ii. Water for mixing is introduced into the drum within first 15 second and mixing commenced with 1.5 min after all the materials are placed in the mixer.

4. **Transportation and Placing of Concrete :**

i. No segregation should take place during transportation.
ii. The spreading is done uniformly to the required depth and width of pavement with the form work in continuous operation.
iii. Vibrating should be done with a needle vibrator.

5. **Compacting and Finishing :**

i. Concrete as soon as placed is struck off uniformly and screed to the crown and cross-section of the pavement to conform the grade.
ii. The tamper is placed on the side forms and is drawn ahead in combination with a series of lifts and drops to compact the concrete.
iii. It can also be compacted by power driven finishing machine.

6. **Floating and Straight Edging :** The concrete is further compacted by a longitudinal float holding it parallel to carriageway centre line and passed gradually from one side of the pavement to the other.

8. **Belting, Brooming and Edging :**

i. Just before the surface becomes hard, the surface is belted with a two-ply canvas belt.
ii. After belting, brooming is done perpendicular to the centre line of the pavement.
iii. After this the edges are rounded with an edging tool.

9. **Curing :**

i. **Initial Curing :** The pavement surface is entirely covered with very well wetted burlap, cotton or jute mats for 14 days.
ii. **Final Curing :** Edges of the slab are banked with soil and a layer of sandy soil free from stones is placed all over within. The soil thoroughly kept saturated with water for 14 days.

PART-7

Roller Compacted Concrete Roads.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.12. Write short note on roller compacted concrete roads.

Answer

Roller Compacted Concrete Road :

1. Roller Compacted Concrete pavement is best described as a zero slump concrete that is placed with standard or high-density paving equipment and consolidated/compacted using steel-drum or rubber-tired rollers to achieve a durable, wear resistant surface.
2. It has proven to be a very effective heavy duty pavement that can stand up to harsh climates, heavy wheel loads and difficult operating conditions.
3. Typically, Roller-Compacted Concrete has been used for heavy duty pavements such as log handling yards, intermodal terminals, freight depots, and other industrial applications.
4. However, more recently there has been an increase in the use of Roller-Compacted Concrete to create cost-effective pavements for many conventional highway and street applications.
5. Benefits of Roller-Compacted Concrete.
   - Speed of Construction.
   - Durability.
   - Low Maintenance.
   - Competitive Cost.
   - Sustainability.

ue 5.13. **List different methods of roads construction. Discuss ir advantages and limitations.** **AKTU 2015-16, Marks 15**

wer

ollowing are the different road construction methods :

arth Road : The road having its foundation and wearing surface onsisting of one or two compacted layers of an ordinary or stabilized d is known as earth road or kutcha road.

Advantages of Earth Road :

i. They can be constructed speedily.
ii. By proper selection of gradient, balancing of earth work can be achieved.
iii. Cheap in construction cost.

Disadvantage of Earth Road :

i. Useful only for light traffic.
ii. Wears quickly.
iii. Repair and maintenance is costly.
iv. They are useless in monsoon.

2. **Gravel Road :** It is low cost roads which consists of carriageway in which layers of gravel is compacted. Gravel is naturally occurring material with many varieties of stone.

Advantages of Gravel Road :

i. Gravel road surface is smooth and provides good appearance.
ii. It provides good traction and vehicles do not get slip when the surface is wet.
iii. It has good load taking capacity

Disadvantages of Gravel Road :

i. In dry weather, gravel road becomes dusty.
ii. For bad drainage, gravel road may become impassable.
iii. There is a frequent development of pot holes, ruts and depression and becomes more uneasy and uncomfortable to the vehicles.
iv. It has a tendency to become soft and slippery in wet weather.

3. **Water Bound Macadam Road :** The road having its wearing surface consisting of clean, crushed aggregates, mechanically interlocked by rolling and bound together with filler material (Screening) and water, laid on prepared base course is called water bound macadam road *i.e.*, WBM road.

Advantages of WBM Road :

i. Cost of construction is low.
ii. No skilled labour is required.
iii. Made from locally available material.
iv. If maintained in good condition, it can take traffic load of about 900 tonnes per lane per day.

Disadvantages of WBM Road :

i. Maintenance cost is high.
ii. Life is less.
iii. If WBM road surface is poorly maintained, it causes inconvenience and danger to the traffic.

iv. They are permeable to rain water and it leads to the softening and yielding of subsoil.

4. **Bituminous Road :** The roads having their surface consisting of bituminous materials are known as bituminous roads.

Advantages of Bituminous Road :

i. The cracks are not formed on the surface of bituminous roads.
ii. Maintenance cost is less.
iii. The surface of this roads is non slippery.
iv. Such roads are waterproof roads.

Disadvantages of Bituminous Road : In excess bituminous, it proves detrimental to the good performance of bituminous road.

5. **Cement Concrete Road :** The roads having their wearing surface consisting of cement concrete slab (plain or reinforced) are called as cement concrete road.

Advantages of Cement Concrete Road :

i. Life span of such road is more.
ii. They are strong and durable and are unaffected much by weathering agencies,
iii. Such road provides an impervious layer.
iv. They provide a dustless and sanitary surface.
Gives good visibility at night.

Disadvantages of Cement Concrete Road :

It is liable to crack, warp and twist.
Skilled supervision as well as skilled workmanship is required for their construction.
It becomes noisy under iron tyred traffic.
It is less resilient than WBM or bituminous road.

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1 UNIT

Role of Transportation (2 Marks Questions)

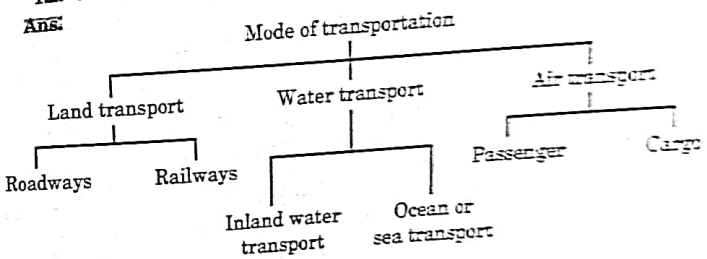
1.1. What is the role of transportation in the development of country ?

Ans: 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.

1.2. Describe the modes of transportation.

Ans:



1.3. Discuss the historical development of road.

Ans: Following are the sequence of historical development of road :

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

1.4. Enumerate the various road plans for the development of highways in India.

Ans: Following are the three 20 year road plans for development of highways in India :

i. Nagpur road plan (1943-63).
ii. Bombay road plan (1961-81).
iii. Lucknow road plan (1981-2001).

1.5. Explain different types of roads in third twenty year road plan. **AKTU 2015-16, Marks 02**

Ans. Following are the road in third 20 year road plan :

1 Primary roads :
- i. Expressways.
- ii. National highways.

2. Secondary roads :
- i. State highways.
- ii. Major district roads.

3. Tertiary roads :
- i. Other district roads.
- ii. Village roads.

1.6. Enlist the different road patterns.

Ans. Following are the various road patterns :
- 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.

1.7. Write down the disadvantages of transportation system.

Ans. Following are the disadvantages of transportation :
- i. Chances of accidents.
- ii. Air pollution.
- iii. Noise pollution.
- iv. Energy consumption.
- v. Land consumption, etc.

1.8. Write down the various features of the Roman roads.

Ans. Following are the features of the Roman roads :
- i. They were built straight regardless of gradients.
- ii. They were built after the soft soil was removed and a hard stratum was reached.
- iii. Total thickness of the construction was as high as 0.75 m to 1.2 m at some places, even though the magnitude of wheel loads of animal drawn vehicles was very low.

1.9. What do you mean by urban roads ?

Ans. The road systems within urban areas are known as urban roads and will form a separate category of roads to be taken care by the respective urban authorities.

1.10. Classify the urban roads.

Ans. Following are the classification of urban roads :
- i. Arterial roads.
- ii. Sub-arterial roads.
- iii. Collector streets.
- iv. Local streets.

1.11. Define arterial roads.

Ans. The streets primarily for through traffic on a continuous route, but with high level of traffic mobility are known as arterial roads.

1.12. Describe sub-arterial roads.

Ans. The streets primarily for through traffic on a continuous route but have lower level of traffic mobility than the arterials are known as sub-arterial roads.

1.13. Discuss collector streets.

Ans. The street which provides access to arterial streets and they collect and distribute traffic from and to local streets is known as collector streets.

1.14. What do you mean by local street ?

Ans. The street which provides access to abutting streets are known as local streets.

1.15. Discuss the objectives of IRC Highway Research Board.

Ans. Following are the objectives of highway research board :
- i. To ascertain the nature and extent of research required.
- ii. To coordinate and conduct correlation services.
- iii. To collect and disseminate results on research.
- iv. To channelize consultative services.

1.16. What are the objects of highway planning ?

Ans. Following are the main objects of highway planning :
- i. To plan a road network for efficient and safe traffic operation, but at minimum cost.
- ii. To fix up datewise priorities for development of each road link based on utility as the main criterion for phasing the road development programme.
- iii. To plan for future requirements and improvements of roads in view of anticipated development.
- iv. To work out financing system.

1.17. What are the objectives of NHAI ?

Ans. Following are the various objectives of National Highway Authority of India :
- i. To manage the NH network in a manner that provides safety and comfort to those who use it.
- ii. To improve and extend the NH network in an efficient and environmentally sensitive manner.
- iii. To improve road safety including road geometries.
- iv. To provide on-route facilities for road users, etc.

☺☺☺

2 UNIT

Cross Sectional Elements of Roads (2 Marks Questions)

2.1. Define the highway alignment.

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

2.2. Enumerate the factors which control the highway alignment.

Ans: Following are the factors controlling highway alignment :

i. Obligatory points. ii. Traffic.
iii. Geometric design. iv. Economics, etc.

2.3. Define the term right of way and width of carriageways.

Ans: **Right of Way :** The area of land acquired along the road alignment by highway organization is called right of way.
Width of Carriageway : The number of traffic lanes will decide the width of carriageway or pavements.

2.4. Define kerb.

Ans: Kerb indicates the boundary between the pavement and shoulder or sometimes islands or footpath or kerb parking space.

2.5. What is kerb marking and object marking ?

AKTU 2017-18, Marks 02

Ans: **Kerb Marking :** These may indicate certain regulations like parking regulations. Also the markings on the kerb and edges of islands with alternate black and white line increase the visibility from a long distance.
Object Marking : Physical obstruction on or near the roadway are hazardous and hence should be properly marked. Typical obstructions are supports for bridge, signs and signals, level crossing gates, traffic islands, narrow bridges, culvert, head walls etc.

2.6. What is kerbed stone ?

AKTU 2016-17, Marks 02

Ans: Kerb stone that is manufactural using a slip casting machine. Typically made from concrete, these serve as an edge where a raised pavement or footpath road median, or road shoulder meets an unraised street or other roadway.

2.7. What is width of roadway or formation ?

Ans: The top width of the embankment or bottom of cutting is known as roadway width or formation width.
Width of formation = Width of pavement + Width of shoulder.

2.8. What do you understand by shoulder ?

Ans: Shoulder acts as a service lane for vehicles. It is generally used as a temporary line and is rougher than the pavement surface. The minimum shoulder width recommended by IRC in 2.5 m.

2.9. What is camber ? What are the different shapes of camber used ?

AKTU 2015-16, Marks 02

OR

Define camber with shapes.

AKTU 2016-17, Marks 02

Ans: **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.
Shapes : Following are shapes of camber :

i. Parabolic camber. ii. Straight line camber.
iii. Combined camber.

2.10. Give the factors on which the camber of pavement depends.

Ans: Following are the factors on which camber of a pavement depends :

i. The type of pavement surface.
ii. The amount of rainfall.

2.11. Describe the parabolic camber or barrel camber.

Ans: Parabolic camber consists of a continuous curve which may be of parabolic or elliptical shape. It gives flat profile at the middle and steep profile towards the pavement edges. It is generally preferred for fast moving vehicles.

2.12. What are the different objects of camber ?

Ans: Following are objective of camber :

i. Surface protection especially for gravel and bituminous roads.
ii. Subgrade protection by proper drainage.
iii. Quick drying of pavement which in turn increases safety.
iv. On account of transverse tilt of vehicles, wear of tyres will not be uniform.

2.13. What is superelevation (e) ?

AKTU 2016-17, Marks 02

Ans: Superelevation is the ratio of the height of outer edge with respect to the horizontal width. It is given by,

$$e = \frac{v^2}{gR} \qquad [\because f = 0]$$

2.14. What is horizontal curve ?

Ans: A horizontal curve is a curve in plane to provide change in direction to the central line of a road.

2.15. Define impact factor.

Ans: Impact factor is the ratio of the centrifugal force to the weight of the vehicle.

Impact factor is given by,

$$\frac{P}{W} = \frac{v^2}{gR}$$

when, $\frac{P}{W} = \frac{b}{2h}$ (Overturning occurs)

when, $\frac{P}{W} = f$ (Transverse skidding occurs)

2.16. Define and give the expression for extra widening of pavement.

Ans: It is the additional width of carriage way that is required on curved section of a road. It is calculated as :

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

2.17. Enlist the objectives for providing transition curve.

Ans: Following are the objectives for providing transition curve :

i. To provide gradual introduction of superelevation.
ii. To provide gradual introduction of extra widening.
iii. To enhance the aesthetic appearance of the road.
iv. To provide comfort for passengers.

2.18. Define SSD. **AKTU 2016-17, Marks 02**

Ans: 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

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

2.19. What is OSD ? **AKTU 2016-17, Marks 02**

Ans: The minimum distance open 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 overtaking sight distance (OSD).

2.20. Write down the formula for overtaking sight distance and explain each term. **AKTU 2015-16, Marks 02**

Ans: Overtaking sight distance is given by,

$$OSD = 0.28\,Vt + 0.28\,VT + 2s + 0.28\,V_bT$$

where, V = Speed of overtaken vehicle, kmph
t = Reaction time of driver = 2 sec
V_b = Speed of overtaking vehicle, kmph

$$T = \sqrt{\frac{14.4s}{A}}, \quad s = (0.2\,V_b + 6)$$

A = Acceleration in kmph/sec

2.21. Write down the factors affecting OSD.

Ans: Following are the factors that affect the OSD :

i. Velocity of the overtaking vehicle.
ii. Spacing between vehicles, which in-turn depends on the speed.
iii. Skill and reaction time of the driver.
iv. Rate of acceleration of overtaking vehicle.
v. Gradient of the road.

2.22. Define and classify the gradients.

OR

Define the term gradients. **AKTU 2016-17, Marks 02**

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

Types of Gradient :

i. Ruling gradient. ii. Limiting gradient.
iii. Exceptional gradient. iv. Minimum gradient.

2.23. What are the recommendations of IRC for grade compensation ?

Ans: These are the following recommendation of IRC for grade compensation :

i. Grade compensation is not required for grade flatter than 4 %.

ii. Grade compensation = $\frac{30 + R}{R}$,

where, R = Radius of horizontal curve.

iii. Maximum grade compensation = $\frac{75}{R}$

2.24. Classify the vertical curves.

Ans: Following are the two types of vertical curves :

i. Summit curve. ii. Valley curve.

2.25. What are the special considerations to be taken for aligning roads on hilly areas ?

Ans: Following are the special consideration for aligning roads on hilly areas :

i. Stability.
ii. Drainage.
iii. Geometric standards of hill roads.
iv. Resisting length.

2.26. What do you understand by setback distance ?

AKTU 2017-18, Marks 02

Ans: It is the distance between the centre line of a horizontal curve to an obstruction on the inner side of the curve.

2.27. What are the stages of the engineering survey for highway location ?

AKTU 2015-16, Marks 02

Ans: Following are the stages of the engineering survey for highway location :

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

2.28. What is design speed ?

AKTU 2016-17, Marks 02

Ans: It is the maximum safe speed that can be maintained over a specified section of a highway when conditions are so favourable that the design features of the highway govern.

☺☺☺

3
UNIT

Traffic Engineering (2 Marks Questions)

3.1. Define the term traffic engineering.

Ans: Traffic engineering is that branch of engineering which deals with the improvement of traffic performance of road network and terminals.

3.2. What are different objectives of traffic engineering ?

Ans: Following are objectives of traffic engineering :

i. To achieve easy and smooth flow of traffic at intersection.
ii. To improve the speed of vehicles.
iii. To increase traffic carrying capacity of road.
iv. To reduce delays in road journeys.

3.3. Write down the characteristics of traffic.

Ans: Following are the characteristics of traffic :

1. Traffic Characteristics :

i. Physical.
ii. Mental.
iii. Psychological.
iv. Environmental.

2. Vehicular Characteristics :

i. Vehicle dimension.
ii. Weight of loaded vehicles.
iii. Power of vehicles.
iv. Speed of vehicles.
v. Braking characteristics.
vi. Off tracking.

3.4. Explain traffic volume.

Ans: Traffic volume 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.

3.5. How can we count traffic volume ?

AKTU 2015-16, Marks 02

Ans: Following are the types of volume measurements :
i. Average annual daily traffic (AADT).
ii. Average annual weekday traffic (AAWT).
iii. Average daily traffic (ADT).
iv. Average weekday traffic (AWT).

3.6. Describe the term traffic capacity.

Ans: Traffic capacity is expressed as the maximum number of vehicles in a lane or a road that can pass a given point in unit time.

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

where, V = Speed in kmph.
S = c/c spacing of vehicles.

3.7. What do you understand by traffic density ?

Ans: Traffic density is the number of vehicles occupying a unit length of lane of roadway at a given instant. It is expressed as vehicle/km.

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

3.8. What are the different factors on which PCU values depends?

Ans: Following are factors on which PCU value depends :
i. Vehicles characteristics such as dimensions, power, speed, acceleration and braking characteristics.
ii. Roadway characteristics such as road geometries including gradients, curves etc.
iii. Environmental and climatic conditions.

3.9. Define and classify the traffic control devices.

Ans: The various aids and devices used to control, regulate and guide traffic is called traffic control device.
Following are the traffic control device :
i. Signs.
ii. Signals.
iii. Markings.
iv. Islands.

3.10. Classify the traffic sign.

Ans: According to Indian Motor Vehicles Act, traffic sign is divided into three categories :
i. Regulatory signs.
ii. Warning signs.
iii. Informatory signs.

3.11. What are the different regulatory signs ? Explain with neat sketch.

AKTU 2015-16, Marks 02

Ans: Regulatory or mandatory signs are meant to inform the road users of certain laws, regulations and prohibitions. The regulatory signs are classified as :
i. Stop and Give-way signs.
ii. No parking and No stopping signs.
iii. Speed limits and Vehicle control signs.
iv. Restriction ends signs and other signs.
Sketch : Refer Q. 3.15, Page 3–16C, Unit-3.

3.12. Describe the traffic signal.

Ans: Traffic signals are controlled devices which could alternately direct the traffic to stop and proceed at intersection using red and green traffic light signal automatically.

3.13. Enumerate the types of signal.

Ans: Following are the various types of signal used on roads :
i. Traffic Control Signals :
a. Fixed-time signals.
b. Manually operated signals.
c. Traffic actuated signals.
ii. Pedestrian signals.
iii. Special traffic signals.

3.14. Enlist the advantages of traffic signal.

Ans: Following are the advantages of traffic signal :
i. They reduce the certain type of accidents e.g., right angle collision.
ii. They provide sequence and more reliable movement of traffic.
iii. They increase the traffic handling capacity.
iv. They prevent the road jam and congestion.

3.15. Write any two advantages and disadvantages of traffic signals.

AKTU 2017-18, Marks 02

Ans: **Advantages :** Refer Q. 3.14, 2 Marks Questions, Page SQ–11C, Unit-3.
Disadvantages : Following are the disadvantages of traffic signal :
i. The rear-end collision may increase.
ii. Improper design and location of signals may lead to violation of the control system.

iii. Failure of electric power and any other defect takes place, traffic signal do not work.

3.16. What are the various methods used to design the signal system ?

Ans: These are some methods used to design the signal system :

i. Trial cycle method.

ii. Webster's method.

iii. Approximate method.

3.17. Define traffic islands.

Ans: Traffic islands are raised areas constructed within the roadway to establish physical channels through which the vehicular traffic may be guided.

3.18. Classify the traffic islands.

Ans: Following are the classification of traffic islands :

i. Divisional islands.

ii. Pedestrian loading islands.

iii. Channelizing islands.

iv. Rotary.

3.19. What are the uses of channelizing islands ?

Ans:

i. These islands are used to guide the traffic into proper channel through the intersection area.

ii. Channelizing islands are very useful as traffic control devices for intersection at grade, particularly when the area is large.

3.20. Define rotary intersection. **AKTU 2016-17, Marks 02**

Ans: Rotary is the large central island of a rotary intersection. This island is much larger than the central islands of channelized intersection.

3.21. What are the different advantages of rotary intersection ?

Ans: Following are the advantages of rotary intersection :

i. Traffic flow is regulated to only one direction of movement, thus eliminating severe conflict between crossing movements.

ii. Rotaries are self-governing and do not need practically any control by police or traffic signals.

iii. They are ideally suited for moderate traffic, especially with irregular

3.22. Write down the various disadvantages of rotary intersection.

Ans: Following are the disadvantages of rotary intersection :

i. All the vehicles are forced to slow down and negotiate the intersection.

ii. Even when there is relatively low traffic, the vehicles are forced to reduce their speed.

iii. Rotaries require large area of land making them costly in urban areas, etc.

3.23. Name the design elements of rotary.

Ans: The design elements include design speed, radius at entry, exit and the central island, weaving length and width, entry and exit width.

3.24. What do you mean by the intersection at grade ?

Ans: All road intersection which meets at about the same level allowing traffic manoeuvres like merging, diverging, crossings and weaving are called intersection at grade.

3.25. What are the different requirements of intersection at grade ?

Ans: The basic requirements of intersection at grade are :

i. At the intersection, the area of conflict should be as small as possible.

ii. The relative speed and particularly the angle of approach of vehicle should be small.

iii. Sudden change of path should be avoided.

iv. Good lighting at night is desirable, etc.

4 UNIT

Highway Materials (2 Marks Questions)

4.1. What are the different types of materials required for the construction of highway ?

Ans: Following are the materials required for the construction of highway :

i. Aggregates.
ii. Bituminous materials.
iii. Cement.

4.2. Enumerate the different types of aggregates.

Ans: Following are of two types of aggregates :

i. Natural aggregate.
ii. Artificial aggregate.

4.3. Define binding material.

Ans: Binding materials are those materials which are used to bind the materials which may be two or more. Bitumen and tar play role of binder material. It has adhesive property to bind the road construction materials.

4.4. What are the different bituminous materials ?

AKTU 2015-16, Marks 02

Ans: Following are the bituminous materials used in highway construction :

i. Bitumen.
ii. Tar.

Bitumen may be further divided as petroleum asphalt or bitumen and native asphalt.

4.5. What are the different laboratory tests used for road aggregates ?

OR

List out the various tests on road materials.

AKTU 2015-16, Marks 02

Ans: Following tests are carried out in laboratory on the sample of road aggregate :

i. Abrasion test.
ii. Crushing test.
iii. Impact test.
iv. Shape test.
v. Soundness test.
vi. Specific gravity and water absorption test.
vii. Stripping value test.

4.6. Write down the tests for bituminous materials.

Ans: Following are the test conducted on bituminous materials :

i. Ductility test.
ii. Flash and fire point test.
iii. Float test.
iv. Loss on heating test.
v. Penetration test, etc.

4.7. Explain Flash and fire point in bitumen.

AKTU 2017-18, Marks 02

Ans: **Flash Point :** It is the lowest temperature at which the vapour of a substance momentarily takes fire in the form of a flash under specified condition of test.

Fire Point : It is the lowest temperature at which the material gets ignited and burns under specified conditions of test.

4.8. Define Equivalent single wheel load (ESWL).

AKTU 2017-18, Marks 02

Ans: As per deflection criterion the ESWL is that single wheel load having the same contact pressure which produces the same value of maximum deflection at the depth Z. Similarly by stress criterion, the ESWL is the single wheel load producing the same value of maximum stress at the desired depth Z as the dual.

4.9. Classify the pavement.

Ans: Based on structural design, pavements are classified into two types :

i. Flexible pavement.
ii. Rigid pavement.

4.10. What are the factors considered for design of pavement ?

Ans: For design of pavement, following factors are considered :

i. Design wheel load.
ii. Subgrade soil strength.
iii. Pavement component materials.
iv. Environmental and climatic factors.

4.11. What are the design parameters for rigid pavement ?

AKTU 2015-16, Marks 02

Ans: Following are the design parameters for rigid pavement :

i. Modulus of subgrade reaction.
ii. Relative stiffness of slab.
iii. Stress acting on a rigid pavement :
a. Wheel load stresses. b. Temperature stresses.
iv. Critical load position.

4.12. Define temperature stresses in concrete pavement.

AKTU 2016-17, Marks 02

Ans: Temperature stresses are developed in cement concrete pavement due to variation in slab temperature. This is caused by,

i. Daily variation resulting in a temperature gradient across the thickness of the slab, and
ii. Seasonal variation resulting in an overall change in the slab temperature.

The former results in warping stresses and the later in frictional stresses.

4.13. What is the critical combination of stresses during summer season ?

Ans: The critical stresses occur at edge region = Load stress + Warping stress – Frictional stress.

4.14. Write down the critical combination of stresses during winter season.

Ans: The critical stress combination occurs at edge region = Load stress + Warping stress + Frictional stress.

4.15. Discuss the critical stress combination at corner region.

Ans: The critical stress combination = Load stress + Warping stress.

4.16. Why the joints are provided in pavement ?

Ans: Joints are provided in cement concrete pavement to reduce the temperature stresses and to maintain the continuity of the pavement.

4.17. What are the different types of joints provided in cement concrete pavement ?

Ans: Following are the two types of joints :

i. Longitudinal joints, and
ii. Transverse joints.

4.18. Describe the longitudinal joint.

Ans: The two lanes are jointed together by a joint known as longitudinal joint. It is provided in the longitudinal direction of road.

4.19. Discuss the transverse joints.

Ans: These joints are provided in the transverse direction of the road. These joints minimize the temperature stresses in the pavement slab.

4.20. Classify the transverse joint.

Ans: Following are the classification of transverse joint :

i. Expansion joint.
ii. Contraction joint.
iii. Warping joint.
iv. Construction joint.

4.21. Explain the expansion joint.

Ans: An expansion joint or movement joint is an assembly designed to safely absorb the temperature-induced expansion and contraction of construction materials, to absorb vibration, to hold parts together, or to allow movement due to ground settlement or earthquakes.

4.22. Discuss expansion and contraction joints.

AKTU 2017-18, Marks 02

Ans: **Expansion Joints :** Refer Q. 4.21, 2 Marks Questions, Page SQ–17C, Unit-4.

Contraction Joints : These are provided along the transverse direction to take care of the contraction of concrete slab due to its natural shrinkage

4.23. What do you understand by construction joint ?

Ans: Construction joints are provided whenever the construction work stops temporarily. The joint direction could be either along the transverse or longitudinal direction.

4.24. Define warping joint.

Ans: These are known as hinged joints. These are provided to relieve stresses included due to warping. These joints are rarely needed. These are provided in longitudinal direction.

4.25. What are the design considerations of expansion joints ?

Ans: Following are the design considerations :

i. Provide along the longitudinal direction.

ii. Design involves finding the joint spacing for a given expansion joint thickness (say 2.5 cm specified by IRC) subject to some maximum spacing (say 140 as per IRC).

4.26. Write down the design considerations of construction joints.

Ans: Following are the design considerations :

i. The movement is restricted by the subgrade friction.

ii. Design involves the length of the slab given by,

$$L_c = \frac{2 \times 10^4 \sigma_c}{Wf}$$

iii. Steel reinforcement can be use, however with a maximum spacing of 4.5 m as per IRC.

5 UNIT

Highway Construction Methods (2 Marks Questions)

5.1. Classify the highway roads.

Ans: The highway roads are classified as follows :

i. Earth roads and gravel roads.

ii. Soil stabilized roads.

iii. Water bound macadam (WBM) road.

iv. Cement concrete roads.

5.2. Define the term 'macadam'.

Ans: The term 'macadam' is defined as the pavement base course made of crushed or broken aggregate mechanically interlocked by rolling and the voids are filled with screening and binding materials with water.

5.3 Draw typical cross section of macadam's construction.

AKTU 2017-18, Marks 02

Ans:

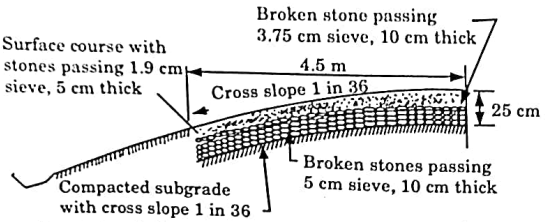


Fig. 1. Typical cross section of macadam's construction.

5.4. What do you understand by surface dressing ?

AKTU 2015-16, Marks 02

Ans: Surface dressing is the process by which a thin film of bituminous binder is sprayed on the road surface covered by a coat of mineral aggregates and after coating, road surface is well rolled.

5.5. Describe bituminous macadam.

Ans. Bituminous macadam is a premixed construction method consisting of one or more coarse of compacted and crushed aggregates premixed with bituminous binder and laid immediately after mixing.

5.6. What are the various steps for preparation of subgrade ?

Ans. Following are the steps for preparation of subgrade :

i. Site should be cleared off from grass, roots and other organic matter etc.

ii. Excavation or filling up to bring the subgrade to desired longitudinal grade and desired camber. It should be compacted adequately before placement of pavement layers.

iii. Shaping of subgrade according to longitudinal grade and camber.

5.7. What is wet mix macadam ?

Ans. In wet mix macadam, a well graded aggregate is mixed with water in a mechanical mixer and the prepared mixture is laid by pavers and compacted.

5.8. Write down the advantages of wet mix macadam.

Ans. Following are the advantages of wet mix macadam :

i. Superior gradation of aggregates.

ii. Faster rate of construction.

iii. Higher standard of densification.

iv. Less consumption of water.

v. Strict standards of quality achieved.

5.9. Write down the steps for the construction of wet mix macadam.

Ans. Following are constructional steps for wet mix macadam :

i. Preparation of base.

ii. Provision of lateral confinement of wet mix.

iii. Preparation of mix.

iv. Spreading of mix.

v. Compaction.

5.10. Give the different methods of bituminous construction.

Ans. Following are the different methods of bituminous construction :

i. Interface treatment like prime coat and tack coat.

ii. Surface dressing and seal coat.

iii. Grouted or penetration type constructions.

iv. Sheet asphalt or rolled asphalt.

v. Mastic asphalt, etc.

5.11. Explain dry lean concrete (DLC).

Ans. DLC is a zero slump concrete. A sub-base of dry lean concrete is a common feature of modern highway concrete pavement.

5.12. What are the advantages of dry lean concrete ?

Ans. Following are the advantages of dry lean concrete :

i. It provides a smooth surface under the concrete pavement, permitting the free movement of slab due to temperature variations.

ii. It can permit construction traffic in a period of 7 days.

iii. It improves the load transfer at joints.

iv. It prevents water through joints and cracks reaching the subgrade and lowering its supporting power.

5.13. Give the merits of cement concrete pavement.

Ans. Following are the merits of cement concrete pavement :

i. Give excellent riding surface.

ii. Their life is much more than any other type of road pavement.

iii. Their design is more rationalized, etc.

5.14. What are the demerits of cement concrete pavement ?

Ans. Following are demerits of cement concrete pavement :

i. Very high initial cost.

ii. Transverse and longitudinal joints are points of weakness. Repairs are mostly associated with joints.

iii. A minimum of 28 days curing is required before opening to traffic.

5.15. Discuss rolled cement concrete.

Ans. Lean mix of cement concrete is laid on prepared subgrade or sub-base and rolled like WBM to 80 % thickness. Rolling operation should be completed within final setting time of cement.

5.16. Describe the seal coat.

Ans. Seal coat is usually recommended as a top coat over certain bituminous pavements which are not impervious, such as open graded bituminous constructions like premixed carpet and grouted macadam.

5.17. Differentiate between prime coat and tack coat.

AKTU 2016-17, Marks 02

Ans.

S. No.	Prime coat	Tack Coat
1.	It is first application of low viscosity liquid bitumen over an existing WBM base course.	It is an application of bituminous material over a relatively impervious existing pavement e.g., an existing bituminous surface or CC pavement or a WBM treated by a prime coat.
2.	The main objective is to plug in the capillary voids of existing surface by penetrating into the voids.	In tack coat, bituminous material of higher viscosity like the hot bitumen is applied.

5.18. Discuss the penetration macadam.

Ans. Bituminous penetration macadam or grouted macadam is used as a base or binder course. The coarse aggregates are first spread and compacted well in dry state and after that hot bituminous binder of relatively high viscosity is sprayed in fairly large quantity at the top.

5.19. What do you understand by built-up spray grout?

Ans. Built-up spray grout (BSG) consists of two layer composite construction of compacted crushed aggregates with application of bituminous binder after each layer for bonding and finished with key aggregates at the top to provide a total compacted thickness of 75 mm.

5.20. Describe the bituminous concrete or asphalt concrete.

Ans. Bituminous concrete or asphalt concrete (AC) is a dense graded premixed bituminous mix which is well compacted to form a high quality pavement surface course. The thickness of bituminous concrete surface course layer usually ranges from 40 to 75 mm.

5.21. Discuss about the sheet asphalt.

Ans. Sheet asphalt or rolled asphalt is a dense sand-bitumen premix of compacted thickness 25 mm, used as a wearing course. The sheet asphalt consists of well graded course to fine and suitable penetration grade bitumen to form a dense and impervious layer. This is usually laid over cement concrete pavement to provide an excellent riding surface.

5.22. Explain the mastic asphalt.

Ans. Mastic asphalt is a mixture of bitumen, fine aggregates and filler in suitable proportions which yields a voidless and impermeable mass.

5.23. What are the purpose of the sub-base course beneath the cement concrete pavement?

Ans. Following are the purpose of sub-base course beneath the cement concrete pavement :

i. To provide a strong supporting layer.
ii. To reduce the thickness requirement of cement concrete slab and lower the cost of construction.
iii. To increase the service life of the cement concrete pavement.

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B. Tech.
(SEM. V) ODD SEMESTER THEORY EXAMINATION, 2013-14
TRANSPORTATION ENGINEERING-I

Time : 2 Hours **Max. Marks : 50**

Note : Attempt **all** the questions.

1. Attempt any **two** parts of the following : (2 × 5 = 10)

a. Explain briefly the role of the following in road development in India :

i. Jayakar Committee.

Ans. Refer Q. 1.6, Page 1–7C, Unit-1.

ii. Nagpur Plan.

Ans. Refer Q. 1.10, Page 1–13C, Unit-1

b. Discuss the main recommendations and road classification of Bombay Road Plan.

Ans. Refer Q. 1.13, Page 1–16C, Unit-1.

c. 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 :

Table 1.

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

Ans. Refer Q. 1.12, Page 1–15C, Unit-1.

2. Attempt any two parts of the following : (2 × 5 =10)

a. 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.

Ans. Refer Q. 2.2, Page 2–3C, Unit-2.

b. 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.

Ans. Refer Q. 2.24, Page 2–25C, Unit-2.

c. 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.

Ans. Refer Q. 2.34, Page 2–38C, Unit-2.

3. Attempt any two parts of the following : (2 × 5 =10)

a. 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 2, calculate upper and lower speed limit regulation as well as speed for design.

Table 2. 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

Ans. **Methods :** Refer Q. 3.5, Page 3–6C, Unit-3.
Numerical : Refer Q. 3.7, Page 3–8C, Unit-3.

b. Explain the following terms :

i. Volume.

Ans. Refer Q. 3.2, Page 3–3C, Unit-3.

ii. Density.

Ans. Refer Q. 3.13, Page 3–13C, Unit-3.

iii. Space mean speed.

Ans. Refer Q. 3.4, Page 3–5C, Unit-3.

iv. Passenger car units.

Ans. Refer Q. 3.9, Page 3–10C, Unit-3.

c. Explain the various types of traffic signs and their functions. Also draw the basic layout of type of regulatory and informative signs.

Ans. Refer Q. 3.15, Page 3–16C, Unit-3.

4. Attempt any two parts of the following : (2 × 10 =20)

a. Calculate the stresses at interior, edge and corner of a cement concrete pavement using Westergaard stress equations, use the following data : Design wheel load = 5100 kg, pavement thickness h = 20 cm, modulus of elasticity concrete = 3×10^5 kg/cm^2, Poisson ratio of concrete is 0.15. Modulus of subgrade reaction K = 6 kg/cm^3. Radius of contact area a = 15 cm.

Ans. Refer Q. 4.18, Page 4–23C, Unit-4.

b. Discuss the specification of course aggregate and binding materials required in WBM construction. Further explain how the following steps in WBM construction are carried out :

i. Spreading of course aggregates.

ii. Application of binding material.

Ans. Refer Q. 5.3, Page 5–3C, Unit-5.

c. Write short notes on any two of the following :

i. Bituminous carpeting.

Ans. Refer Q. 5.6, Page 5–7C, Unit-5.

ii. Asphaltic concrete.

Ans. Refer Q. 5.8, Page 5–10C, Unit-5.

iii. Surface dressing.

Ans. Refer Q. 5.7, Page 5–9C, Unit-5.

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B. Tech.
(SEM. V) ODD SEMESTER THEORY EXAMINATION, 2014-15
TRANSPORTATION ENGINEERING-I

Time : 2 Hours Max. Marks : 50

Note :
1. Attempt all the questions.
2. All questions carry equal marks.
3. If required any missing data, then choose suitably.

1. Attempt any four parts : (4 × 3.5 = 14)

a. Explain Bombay road plan.

Ans: Refer Q. 1.13, Page 1–16C, Unit-1.

b. Explain maximum and minimum superelevation in brief.

Ans: Refer Q. 2.17, Page 2–18C, Unit-2.

c. 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.

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

d. Explain bituminous macadam and asphaltic concrete.

Ans: Refer Q. 5.8, Page 5–10C, Unit-5.

e. Derive the expression for calculating the overtaking sight distance on a highway.

Ans: Refer Q. 2.12, Page 2–12C, Unit-2.

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

Ans: Refer Q. 2.19, Page 2–20C, Unit-2.

2. Attempt any two parts : (2 × 6 = 12)

a. Write the short notes on

i. Thirtieth highest hourly traffic volume.

Ans: Refer Q. 3.3, Page 3–4C, Unit-3.

ii. Traffic volume study.

Ans: Refer Q. 3.2, Page 3–3C, Unit-3.

b. Enumerate the steps in the construction of cement concrete pavement.

Ans: Refer Q. 5.11, Page 5–12C, Unit-5.

c. Determine the spacing between contraction joints for 3.5 meter slab width having thickness of 20 cm and $f = 1.5$, for the following two cases.

i. For plain cement concrete, $S_c = 0.8$ kg/cm^2

ii. For reinforcement cement concrete 1.0 cm, bars at 0.30 m spacing.

Ans: Refer Q. 4.25, Page 4–34C, Unit-4.

3. Attempt any two parts : (2 × 6 = 12)

a. 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.

Ans: Refer Q. 2.25, Page 2–27C, Unit-2.

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

Ans: Refer Q. 3.24, Page 3–26C, Unit-3.

c. Explain IRC method of rigid pavement design.

Ans: Refer Q. 4.26, Page 4–35C, Unit-4.

4. Attempt any two parts : (2 × 6 = 12)

a. Explain the CBR method of pavement design. How is this method useful to determine thickness of component layers ?

Ans: Refer Q. 4.12, Page 4–15C, Unit-4.

b. Discuss the various types of traffic signals.

Ans: Refer Q. 3.16, Page 3–18C, Unit-3.

c. Write short notes on the following :

i. Sheet asphalt.

Ans: Refer Q. 5.8, Page 5–11C, Unit-5.

ii. Mastic asphalt.

Ans: Refer Q. 5.8, Page 5–11C, Unit-5.

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B. Tech.
(SEM. V) ODD SEMESTER THEORY EXAMINATION, 2015-16
TRANSPORTATION ENGINEERING-I

Time : 3 Hours **Max. Marks : 100**

Section-A

Attempt all questions. (10 × 2 = 20)

1. a. Explain different types of roads in third twenty year road plan.

Ans: Refer Q. 1.5, 2 Marks Questions, Page SQ–1C, Unit-1.

b. What are the stages of engineering survey for highway locations ?

Ans: Refer Q. 2.27, 2 Marks Questions, Page SQ–8C, Unit-2.

c. What is camber ? What are the different shapes of camber used ?

Ans: Refer Q. 2.9, 2 Marks Questions, Page SQ–5C, Unit-2.

d. Write down the formula for overtaking sight distance and explain each term.

Ans: Refer Q. 2.20, 2 Marks Questions, Page SQ–6C, Unit-2.

e. How can we count traffic volume ?

Ans: Refer Q. 3.5, 2 Marks Questions, Page SQ–10C, Unit-3.

f. What are the different regulatory signs ? Explain with neat sketch.

Ans: Refer Q. 3.11, 2 Marks Questions, Page SQ–11C, Unit-3.

g. List out the various tests on road materials.

Ans: Refer Q. 4.5, 2 Marks Questions, Page SQ–14C, Unit-4.

h. What are the different bituminous materials ?

Ans: Refer Q. 4.4, 2 Marks Questions, Page SQ–14C, Unit-4.

i. What are the design parameters for rigid pavements ?

Ans: Refer Q. 4.11, 2 Marks Questions, Page SQ–16C, Unit-4.

j. What do you understand by surface dressing ?

Ans: Refer Q. 5.4, 2 Marks Questions, Page SQ–19C, Unit-5.

Section-B

Attempt any five questions. (5 × 10 = 50)

2. Discuss any three methods of historical development of road construction.

Ans: Refer Q. 1.4, Page 1–5C, Unit-1.

3. Explain the procedure for preparation of detailed project report.

Ans: This question is out of syllabus from sessions 2018-19.

4. 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 %.

Ans: Refer Q. 2.14, Page 2–14C, Unit-2.

5. Explain origin and destination study. What are the various uses of O and D studies ?

Ans: Refer Q. 3.8, Page 3–9C, Unit-3.

6. Explain different tests of road aggregates.

Ans: Refer Q. 4.6, Page 4–7C, Unit-4.

7. Calculate the stresses at interior, edge and corner of a cement concrete pavement by Westergaard's stress equations.
Modulus of elasticity of concrete = 3.0×10^5 kg/cm^2
Poisson's ratio of concrete = 0.15
Pavement thickness, h = 18 cm
Modulus of subgrade reaction, K = 6.0 kg/cm^3
Radius of contact area = 15 cm
Wheel load, P = 5100 kg

Ans: Refer Q. 4.16, Page 4–21C, Unit-4.

8. Write short notes on - Prime Coat, Bituminous Surface Dressings, Construction Joints in rigid pavement.

Ans: **Prime Coat :** Refer Q. 5.6, Page 5–7C, Unit-5.
Bituminous Surface Dressing : Refer Q. 5.7, Page 5–9C, Unit-5.
Construction Joints in Rigid Pavement : Refer Q. 4.21, Page, 4–27C, Unit-4.

9. List different methods of roads construction. Discuss their advantages and limitations.

Ans: Refer Q. 5.13, Page 5–14C, Unit-5.

Section-C

Attempt any two. (2 × 15 = 30)

10. **Write the notes on :**
    i. **NHAI Act (1988).**
    ii. **Expressway master plan, and**
    iii. **PMGSY.**

Ans: This question is out of syllabus from sessions 2018-19.

11. **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.**

Ans: **Vertical Curve :** Refer Q. 2.29, Page 2–31C, Unit-2.
Numerical : Refer Q. 2.31, Page 2–34C, Unit-2.

12. **What are the design factors considered in design of pavements ? Explain CBR method & IRC recommendations for the CBR method of design.**

Ans: **Design Factors :** Refer Q. 4.10, Page 4–12C, Unit-4.
CBR Method : Refer Q. 4.12, Page 4–15C, Unit-4.
IRC Recommendations : Refer Q. 4.13C, Page 4–17C, Unit-4.

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B. Tech.
(SEM. V) ODD SEMESTER THEORY EXAMINATION, 2016-17
TRANSPORTATION ENGINEERING-I

Time : 3 Hours | Max. Marks : 100

Note : Attempt all questions. (10 × 2 = 20)

1. Attempt all parts. Each part carries equal marks.

a. **What is superelevation ?**
Ans: Refer Q. 2.13, 2 Marks Questions, Page SQ–5C, Unit-2.

b. **Differentiate between prime coat and tack coat.**
Ans: Refer Q. 5.17, 2 Marks Questions, Page SQ–21C, Unit-5.

c. **Define SSD.**
Ans: Refer Q. 2.18, 2 Marks Questions, Page SQ–6C, Unit-2.

d. **Define temperature stresses in concrete pavement.**
Ans: Refer Q. 4.12, 2 Marks Questions, Page SQ–16C, Unit-4.

e. **What is design speed ?**
Ans: Refer Q. 2.28, 2 Marks Questions, Page SQ–8C, Unit-2.

f. **What is OSD ?**
Ans: Refer Q. 2.19, 2 Marks Questions, Page SQ–6C, Unit-2.

g. **Define rotary intersection.**
Ans: Refer Q. 3.20, 2 Marks Questions, Page SQ–12C, Unit-3.

h. **What is kerbed stone ?**
Ans: Refer Q. 2.6, 2 Marks Questions, Page SQ–4C, Unit-2.

i. **Define the term gradients.**
Ans: Refer Q. 2.22, 2 Marks Questions, Page SQ–7C, Unit-2.

j. **Define camber with shapes.**
Ans: Refer Q. 2.9, 2 Marks Questions, Page SQ–5C, Unit-2.

2. Attempt any **five** questions : (5 × 10 = 50)

a. **Explain water bound macadam and bitumen bound macadam.**
Ans: **Water Bound Macadam :** Refer Q. 5.2, Page 5–3C, Unit-5.
Bitumen Bound Macadam : Refer Q. 5.8, Page 5–10C, Unit-5.

b. What is surface dressing ? Write the construction procedure for surface dressing.

Ans. Refer Q. 5.7, Page 5–9C, Unit-5.

c. A cement concrete pavement is to be designed. Present traffic is 3000 commercial vehicles per day. Design life is 20 years and rate of traffic increase is 5.5 %. Calculate the design traffic as per IRC 58-2011.

Ans. Refer Q. 4.27, Page 4–36C, Unit-4.

d. What are the various types of traffic control devices ? Discuss.

Ans. Refer Q. 3.14, Page 3–15C, Unit-3.

e. Describe CBR method for the design of flexible pavement.

Ans. Refer Q. 4.12, Page 4–15C, Unit-4.

f. 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.

Ans. Refer Q. 2.20, Page 2–20C, Unit-2.

g. Discuss the Bombay road plan.

Ans. Refer Q. 1.13, Page 1–16C, Unit-1.

h. Enumerate the various types of intersection and the basic principles involved.

Ans. Refer Q. 3.22, Page 3–23C, Unit-3.

3. Attempt any **two** parts of the following : (2 × 15 = 30)

a. Discuss Westergaard's concept of temperature stresses in concrete pavement.

Ans. Refer Q. 4.19, Page 4–24C, Unit-4.

b. Write the construction procedure for cement concrete pavement and explain different types of joints in cement concrete pavement.

Ans. **Construction Procedure of Cement Concrete Pavement :** Refer Q. 5.11, Page 5–12C, Unit-5.
Types of Joint : Refer Q. 4.21, Page 4–27C, Unit-4.

c. Write the flexible pavement design steps and describe the procedure in brief as per IRC : 37-2012.

Ans. Refer Q. 4.13, Page 4–17C, Unit-4.

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B.Tech.

(SEM. V) ODD SEMESTER THEORY EXAMINATION, 2017-18

TRANSPORTATION ENGINEERING-I

Time : 3 Hours **Max. Marks : 100**

Note : Attempt **all** sections. If any missing data required, then choose suitably.

Section – A

1. Attempt all questions in brief. (2 × 10 = 20)

a. Draw typical cross section of Macadam's construction.

Ans. Refer Q. 5.3, 2 Marks Questions, Page SQ–19C, Unit-5.

b. Write short note on IRC.

Ans. Refer Q. 1.7(B), Page 1–8C, Unit-1.

c. Define Kerbs and shoulders.

Ans. **Kerbs :** Refer Q. 2.4, 2 Marks Questions, Page SQ–4C, Unit-2.
Shoulders : Refer Q. 2.8, 2 Marks Questions, Page SQ–5C, Unit-2.

d. What do you understand by setback distance ?

Ans. Refer Q. 2.26, 2 Marks Questions, Page SQ–8C, Unit-2.

e. Explain passenger car unit (PCU).

Ans. Refer Q. 3.9, Page 3–10C, Unit-3.

f. Write any two advantage and disadvantage of traffic signals.

Ans. **Advantage :** Refer Q. 3.14, 2 Marks Questions, Page SQ–11C, Unit-3.
Disadvantage : Refer Q. 3.15, 2 Marks Questions, Page SQ–11C, Unit-3.

g. What is kerb marking and object marking ?

Ans. Refer Q. 2.5, 2 Marks Questions, Page SQ–4C, Unit-2.

h. Explain Flash and fire point in bitumen.

Ans. Refer Q. 4.7, 2 Marks Questions, Page SQ–15C, Unit-4.

i. Discuss Expansion and Contraction joint.

Ans. **Expansion :** Refer Q. 4.21, 2 Marks Questions, Page SQ–15C, Unit-4.
Contraction : Refer Q. 4.22, 2 Marks Questions, Page SQ–15C, Unit-4.

j. Define Equivalent single wheel load (ESWL).

Ans. Refer Q. 4.8, 2 Marks Questions, Page SQ–15C, Unit-4.

Section-B

2. Attempt any three of the following : (10 × 3 = 30)

a. 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

Ans. Refer Q. 2.26, Page 2–28C, Unit-2.

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

Ans. Refer Q. 1.19, Page 1–21C, Unit-1.

c. Calculate the stresses at interior, edge and corner of a cement concrete pavement by Westergaard's stress equations : Modulus of elasticity of concrete = 3.0×10^5 kg/cm², Poisson's ratio for concrete = 0.15. Thickness of concrete pavement 18 cm, Modulus of subgrade reaction = 8.5 kg/cm², Wheel load = 5100 kg, Radius of loaded area = 15 cm, Radius of contact area = 15 cm.

Ans. Refer Q. 4.17, Page 4–22C, Unit-4.

d. Briefly outline the main features of various road patterns commonly in use.

Ans. Refer Q. 1.9, Page 1–12C, Unit-1.

e. 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.

Ans. (a) Refer Q. 2.32, Page 2–35C, Unit-2.
(b) Refer Q. 2.31, Page 2–34C, Unit-2.

Section-C

Attempt any one part of the following : (10 × 1 = 10)

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

Ans. **Historical Development and Features :** Refer Q. 1.4, Page 1–5C, Unit-1.
Difference : Refer Q. 1.5, Page 1–7C, Unit-1.

b. Write a short notes on :

i. Central road fund.

Ans. Refer Q. 1.7(A), Page 1–8C, Unit-1.

ii. Nagpur road plan.

Ans. Refer Q. 1.10, Page, 1–13C, Unit-1.

iii. Star and Grid pattern.

Ans. Refer Q. 1.9, Page 1–12C, Unit-1.

iv. Jayakar Committee.

Ans. Refer Q. 1.6, Page 1–7C, Unit-1.

4. Attempt any one part of the following : (10 × 1 = 10)

a. Explain the factors based on which the length of valley curve is designed. 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.

Ans. **Factors :** Refer Q. 2.33, Page 2–36C, Unit-2.
Numerical : Refer Q. 2.25, Page 2–27C, Unit-2.

b. 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.

Ans. **Expression :** Refer Q. 2.12, Page 2–12C, Unit-2.
Numerical : Refer Q. 2.10, Page 2–11C, Unit-2.

5. Attempt any one part of the following : (10 × 1 = 10)

a. Explain the following terms :

i. Traffic Volume.

Ans. Refer Q. 3.2, Page 3–3C, Unit-3.

ii. Traffic Density.

Ans. Refer Q. 3.13, Page 3–13C, Unit-3.

iii. Space Mean Speed.

Ans. Refer Q. 3.4, Page 3–5C, Unit-3.

iv. Passenger Car Units.

Ans. Refer Q. 3.9, Page 3–10C, Unit-3.

b. With neat sketches show various types of traffic signs and signals classifying them in proper groups.

Ans: Refer Q. 3.15, Page 3–16C, Unit-3.

6. Attempt any **one** part of the following : **(10 × 1 = 10)**

a. Explain the CBR method of pavement design. How is this method useful to determine thickness of component layers ?

Ans: Refer Q. 4.12, Page 4–15C, Unit-4.

b. List different types of cutbacks. When are these used ? Discuss in brief the tests carried out on cutback bitumen.

Ans: Refer Q. 4.5, Page 4–5C, Unit-4.

7. Attempt any **one** part of the following : **(10 × 1 = 10)**

a. Write short notes on :

i. Seal coat.

ii. Sheet asphalt.

iii. Mastic asphalt.

Ans:

i. Seal Coat : Refer Q. 5.6, Page 5–7C, Unit-5.

ii. Sheet Asphalt and Mastic Asphalt : Refer Q. 5.9, Page 5–11C, Unit-5.

b. Discuss the specification of course aggregate and binding materials required in WBM construction. Further explain how the following steps in WBM Construction are carried out :

i. Spreading of course aggregates.

ii. Application of binding material.

Ans: Refer Q. 5.3, Page 5–3C, Unit-5.

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B. Tech.

(SEM. VI) EVEN SEMESTER THEORY EXAMINATION, 2018-19

TRANSPORTATION ENGINEERING

Time : 3 Hours **Max. Marks : 70**

Note : 1. Attempt **all** section.
2. Any data if missing may be suitably assumed.

SECTION-A

1. Attempt **all** questions in brief : **(2 × 7 = 14)**

a. Define bump integrator.

Ans: Bump integrator also known as roughometer or automatic road unevenness recorder gives quantitative integrated evaluation of surface irregularities on a digital counter LCD screen.

b. Differentiate between skid and slip in highway engineering.

Ans:

S. No.	Slip	Skid
1.	When vehicle travels less than the circumference distance of wheel.	When vehicle travels more than the circumference distance of wheel. It happens when driver applies brake but, vehicle still moves.
2.	In this case only rotational-motion of wheel occur.	In this case only translation-motion of wheel occurs.

c. Enlist various road patterns.

Ans: Refer Q. 1.6, 2 Marks Questions, Page SQ–2C, Unit-1.

d. List the conditions under which summit curve is used.

Ans: Refer Q. 2.29, Page 2–31C, Unit-2.

e. Define possible capacity and basic capacity.

Ans: Refer Q. 3.13, Page 3–13C, Unit-3.

f. What do you understand by warping stresses and temperature stresses ?

Ans: **Temperature Stresses :** Refer Q. 4.12, 2 Marks Questions, Page SQ–16C, Unit-4.

Warping Stresses : Warping stresses are due to temperature differential between the top and bottom of the pavement as a result of daily variation in temperature of the location.

g. Differentiate between tack coat and prime coat.

Ans. Refer Q. 5.17, 2 Marks Questions, Page SQ–21C, Unit-5.

SECTION-B

2. Attempt any **three** of the following : **(7 × 3 = 21)**

a. Write salient features of first twenty year road development plan.

Ans. Refer Q. 1.10, Page 1–13C, Unit-1.

b. A vehicle moving at 40 km/h speed was stopped by applying brake and the length of the skid mark was 12.2 m. If the average skid resistance of the pavement is 0.70, the brake efficiency of the test vehicle will be nearly ?

Ans.

Given : Speed of vehicle, V = 40 kmph, Skid distance, l = 12.2 m
Average skid resistance = 0.7
To Find : Brake efficiency of vehicle.

1. Braking distance is given by, $l = v^2 / 2gf = (0.278\ V)^2 / 2gf$

$$12.2 = (0.278 \times 40)^2 / 2 \times 9.81 \times f$$

$$f = 0.5166$$

2. Brake efficiency = 0.5166 × 100 / 0.7 = 73.8 %.

c. What is the extra widening required (as nearest magnitude) for a pavement of 7 m width on a horizontal curve of radius 200 m, if the longest wheel of vehicle expected on the road is 6.5 m and the design speed is 65 km/h ?

Ans.

Given : Width of pavement, W = 7 m, Radius of horizontal curve, R = 200 m, Design speed, V = 65 km/h, Wheel base of vehicle, l = 6.5 m
To Find : Required extra width of pavement, w_e

Extra widening is given by, $W_e = W_n + W_{ps} = \dfrac{nl^2}{2R} + \dfrac{V}{9.5\sqrt{R}}$

Hence, n = 2 (two lanes for pavement width of 7.0 m)

$$W_e = \frac{2 \times 6.5^2}{2 \times 200} - \frac{65}{9.5\sqrt{200}}$$

$$W_e = 0.21125 + 0.48381 = 0.69506 = 0.7 \text{ m}$$

d. Consider the following data with respect to the design of flexible pavement :
Design wheel load = 4200 kg
Tyre pressure = 6.0 kg/cm²
Elastic modulus = 150 kg/cm²
Permissible deflection = 0.25 cm
(Take $\pi^{1/2}$ = 1.77, $\pi^{-1/2}$ = 0.564, $1/\pi$ = 0.318, and π^2 = 9.87)
The total thickness of flexible pavement for a single layer elastic theory will be nearly ?

Ans.

Given : Wheel load, P = 4200 kg, Tyre pressure, p = 6 kg/cm², Elastic modulus, E = 150 kg/cm², Deflection, Δ = 0.25 cm.
To Find : Total thickness of flexible pavement, T.

1. Tyre pressure is given by, $p = P / \pi a^2$

$$a = \sqrt{\frac{P}{\pi p}} = \sqrt{\frac{4200}{3.14 \times 6}} = 14.93 \text{ cm}$$

2. The total thickness of pavement for a single layer elastic theory is given by,

$$T = \sqrt{\left(\frac{3P}{2\pi E_s \Delta}\right)^2 - a^2} = \sqrt{\left(\frac{3 \times 4200}{2\pi \times 150 \times 0.25}\right)^2 - 14.93^2}$$

$$T = 51.35 \text{ cm}$$

e. Write short notes on :
i. Sheet asphalt. ii. Mastic asphalt.
iii. Bituminous carpeting.

Ans. Sheet Asphalt and Mastic Asphalt : Refer Q. 5.8, Page 5–11C, Unit-5.
Bituminous Carpeting : Refer Q. 5.6, Page 5–7C, Unit-5.

SECTION-C

3. Attempt any **one** part of the following : **(7 × 1 = 7)**

a. Discuss the cross sectional elements of the roads considered for design. Draw a neat sketch of cross section of 2 lane road with dual carriageway and median in rural area.

Ans. Refer Q. 2.2, Page 2–3C, Unit-2.

b. Determine the length of transition and circular curves for the following data : 2 lane pavement of width 7 m on NH on a rolling terrain having radius 65 m. Design speed is 45 km/hr.

Ans. Refer Q. 2.24, Page 2–25C, Unit-2.

4. Attempt any **one** part of the following : **(7 × 1 = 7)**

a. What are the objectives of highway research board ? Briefly explain the role of MORTH and IRC in highway development.

Ans.

A. Objectives of Highway Research Board : Refer Q. 1.7(E), Page 1–8C, Unit-1.

B. Role of MORTH :

i. To administer funds approved by centre for the development of National Highways.

ii. To formulate plans for development and maintenance of National Highways in consultation with the executing agencies (State PWDs).

iii. To oversee technically the quality of works executed by the agencies.
iv. To administer the Central Road Fund.
v. To administer the Central Road Programme other than National Highways in the Union Territories.
vi. To administer the Indian Roads Construction Corporation, a public sector undertaking.
vii. To evolve standards and specifications for road and bridge works.

C. Role of IRC : Refer Q. 1.7, Page 1–18C, Unit-1.

b. Write brief notes on :
i. Central road fund. ii. Indian road congress.
iii. Central road research institute.

Ans. Refer Q. 1.7, Page 1–8C, Unit-1.

5. Attempt any **one** part of the following : (7 × 1 = 7)

a What is mean by minimum gradient in highway ? Why it is provided ? A valley curve is formed due to two gradients + 3.5 % and – 2.75 %. If the design speed of this highway is 80 kmph, determine the stopping sight distance and design the valley curve to fulfill both comfort and head light distance conditions.

Ans. Minimum Gradient : Refer Q. 2.27, Page 2–29C, Unit-2.
Numerical :

Given : $n_1 = +3.5\ \%$, $n_2 = -2.75\ \%$, Design speed, V = 80 kmph.
To Find : Stopping sight distance, SSD and total length of valley curve.
Assume : i. Total reaction time, $t = 2.5$ sec
ii. Longitudinal co-efficient of friction, $f = 0.35$

1. As there is ascending gradient on one side of the crest and descending gradient on the other side, the effect of gradients on the SSD is assumed to get compensated and hence ignored in the calculations.

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

3. Deviation angle, $N = 3.5 - (-2.75) = 6.25\ \%$

4. **Comfort Condition :**
Allowable rate of change of centrifugal acceleration,
$$C = 80/75 + 80 = 0.52 \text{ m/sec}^3$$
Length of valley curve,
$$L = 2\left[\frac{Nv^3}{C}\right]^{\frac{1}{2}} = 2\left[\frac{6.25}{100} \times \frac{(80/3.6)^3}{0.52}\right]^{\frac{1}{2}} = 72.636 \text{ m}$$

5. **Head Light Sight Distance :**
Assume $L >$ SSD
$$L = \frac{NS^2}{1.5 + 0.035S} = \frac{0.0625 \times 127.45^2}{1.5 + 0.035 \times 127.45} = 170.32 \text{ m}$$

where, S = Stopping sight distance, (SSD).

6. Design length of valley curve = 170.32 m

b. State the limitations of CBR method of pavement design & also enlist the different tests on road aggregates.

Ans. Limitation of CBR Method : It may be seen that the total thickness of construction remains same though the pavement component layers are of different material with different CBR values.
Tests : Refer Q. 4.6, Page 4–7C, Unit-4.

6. Attempt any **one** part of the following : (7 × 1 = 7)

a. Calculate the stresses at interior and edge of a cement concrete pavement by Westergaard's equation:
μ of concrete = 0.15, h =18 cm, K = 6.0 kg/cm³,
Radius of contact area =15 cm, wheel load P = 5500 kg,
Modulus of elasticity of concrete = 3 × 10⁵ kg/cm². Where dowels bars are used ?

Ans.

Given : Modulus of elasticity, $E = 3.0 \times 10^5$ kg/cm²,
Poisson's ratio, $\mu = 0.15$, Thickness of pavement, $h = 18$ cm,
Modulus of subgrade reaction, $K = 6.0$ kg/cm³,
Wheel load, $P = 5500$ kg, Radius of loaded area, $a = 15$ cm.
To Find : Stresses at interior and edge of pavement.

1. Radius of relative stiffness,
$$l = \left[\frac{Eh^3}{12K(1-\mu^2)}\right]^{1/4} = \left[\frac{3 \times 10^5 \times 18^3}{12 \times 6.0(1-0.15^2)}\right]^{1/4} = 70.61 \text{ cm}$$

2. The equivalent radius of resting section is given by,
$a/h = 15/18 = 0.833 < 1.724$
Therefore, $b = \sqrt{1.6a^2 + h^2} - 0.675h$
$= \sqrt{1.6 \times 15^2 + 18^2} - 0.675 \times 18 = 14$ cm

3. Stress at interior,
$$\sigma_i = \frac{0.316P}{h^2}\left[4\log\left(\frac{l}{b}\right) + 1.069\right]$$
$$= \frac{0.316 \times 5500}{18^2}\left[4\log\left(\frac{70.61}{14}\right) + 1.069\right] = 20.813 \text{ kg/cm}^2$$

4. Stress at edge, $\sigma_e = \frac{0.572P}{h^2}\left[4\log\left(\frac{l}{b}\right) + 0.369\right]$
$$= \frac{0.572 \times 5500}{18^2}\left[4 \times \log\left(\frac{70.61}{14}\right) + 0.369\right] = 30.877 \text{ kg/cm}^2$$

Use of Dowels Bars :
i. It transfer load from one slab to another without preventing the joint form opening.
2. To reduce joint faulting and corner cracking.

b. Write short notes on: Bituminous macadam (BM), Semi dense bituminous concrete (SDBC) and Bituminous concrete, Dry lean concrete (DLC), Cement Concrete (CC) road construction, Roller Compacted Concrete Roads.

Ans. **Bituminous Macadam (BM) :** Refer Q. 5.8, Page 5–10C, Unit-5.

Semi Dense Bituminous Concrete (SDBC) : It consists of coarse aggregates of size 12.5 and 10.0 mm, premixed with bitumen or tar binder which are compacted to a thickness of 20 mm to serve as a surface course of the pavement.

Bituminous Concrete : Refer Q. 5.10, Page 5–11C, Unit-5.

Cement Concrete Road Construction : Refer Q. 5.13, Page 5–14C, Unit-5.

Roller Compacted Concrete Road : Refer Q. 5.12, Page 5–14C, Unit-5.

7. Attempt any **one** part of the following : **(7 × 1 = 7)**

a. Explain 30th highest hourly traffic volume with neat graph. The width of a carriage way approaching an intellection is given as 15 m. The entry and exit width at the rotary is 10 m. The traffic approaching the intersection from the four sides is shown in the figure below. Find the capacity of the rotary using the given data :

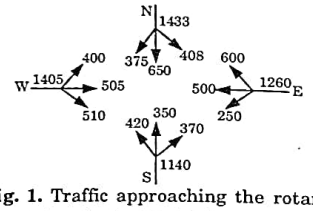

Fig. 1. Traffic approaching the rotary.

Ans. **30th Highest Hourly Traffic Volume :** Refer Q. 3.3, Page 3–4C, Unit-3.

Graph :

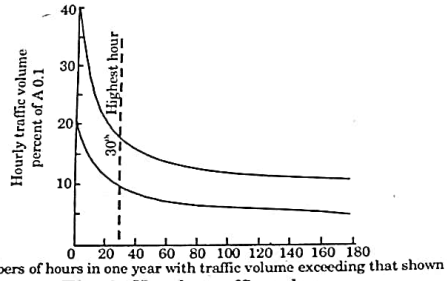

Fig. 2. Hourly traffic volume.

Numerical :

Given : $w = 15$ m, $e_1 = e_2 = 10$ m

To Find : Capacity of rotary.

1. The traffic from the four approaches negotiating through the roundabout is illustrated in Fig. 3.
2. Weaving width is calculated as,
$$w = (e_1 + e_2)/2 + 3.5 = 10 + 3.5 = 13.5 \text{ m}$$
3. Weaving length, $l = 4 \times w = 4 \times 13.5 = 54$ m

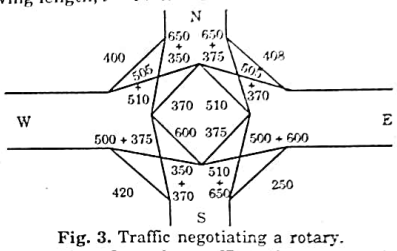

Fig. 3. Traffic negotiating a rotary.

4. The proportion of weaving traffic to the non-weaving traffic in all the four approaches is found out first.
5. Let the proportion of weaving traffic to the non-weaving traffic in West-North direction be denoted as p_{WN}, in North-East direction as p_{NE}, in the East-South direction as p_{ES}, and finally in the South-West direction as p_{SW}.

$$p_{WN} = \frac{505+510+350+600}{505+510+350+600+400+370} = \frac{1965}{2735} = 0.718$$

$$p_{NE} = \frac{650+375+505+370}{650+375+505+370+510+408} = \frac{1900}{2818} = 0.674$$

$$p_{ES} = \frac{510+650+500+600}{510+650+500+600+250+375} = \frac{2260}{2885} = 0.783$$

$$p_{SW} = \frac{350+370+500+375}{350+370+500+375+420+600} = \frac{1595}{2615} = 0.6099$$

6. Thus the proportion of weaving traffic to non-weaving traffic is more in the east-south direction.

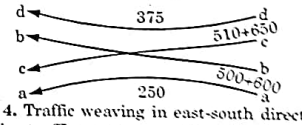

Fig. 4. Traffic weaving in east-south direction.

7. The weaving traffic movement in the East-South direction is shown in Fig. 4.
8. Therefore, the capacity of rotary will be capacity of this wearing section.

Capacity of weaving section is given by,

$$Q = \frac{280w\,[1 + (e/w)]\,[1 - (p/3)]}{[1 + (w/l)]}$$

$$Q_{ES} = \frac{280 \times 13.5\,[1 + (10/13.5)]\,[1 - (0.783/3)]}{[1 + (13.5/54)]} = 3890 \text{ vehicle/hour}$$

b. A national highway passing through a rolling terrain has two horizontal curves of radius 450 m and 150 m. Design the required super elevation for the curves as per IRC guidelines.

Ans.

Given : Radius of horizontal curve, $R = 450$ m, Radius of another horizontal curves, $R = 150$ m

To Find : Super elevation.

Assume : The ruling design period for NH passing through a rolling terrain is 80 kmph. The co-efficient of lateral friction, $f = 0.15$. The maximum permissible super elevation, $e = 0.07$.

1. Case-1 : Radius = 450 m

i. Find e for 75 percent of design speed, neglecting f, *i.e.*,

$$e = \frac{(0.75\,v)^2}{gR} \qquad \text{(v in m/sec)}$$

$$v = \frac{V}{3.6} = \frac{80}{3.6} = 22.22 \text{ m/sec} \qquad \text{(V in km/h)}$$

$$e = \frac{(0.75 \times 22.22)^2}{9.81 \times 450} = 0.0629 = 0.063$$

ii. $e \leq 0.07$. Therefore, the design is sufficient.

iii. Hence, the designed super elevation is 0.063.

2. Case-2 : Radius = 150 m

i. Find e for 75 percent of design speed, neglecting f, *i.e.*,

i.e., $$e = \frac{(0.75\,v)^2}{gR} = \frac{(0.75 \times 22.22)^2}{9.81 \times 150} = 0.188 > 0.07$$

ii. Maximum e to be provided = 0.07.

iii. Find f for the design speed and maximum e,
Friction coefficient,

$$f = \frac{v^2}{gR} - e = \frac{22.22^2}{9.81 \times 150} - 0.07 = 0.265 \not< 0.15$$

iv. Find the allowable speed v_a for the maximum $e = 0.07$ and $f = 0.15$.

$$v_a = \sqrt{0.22gR} = \sqrt{0.22 \times 9.81 \times 150} = 17.99 \text{ m/sec}$$
$$= 17.99 \times 3.6 = 64.76 \text{ kmph}$$

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