15BECE5E04 TRANSPORTATION ENGINEERING 3 0 0 3 100

OBJECTIVE:

At the end of this course the students should have learnt the details of classification of road, Highway alignment, Highway materials, Traffic volume, Nature of Traffic problems in cities, effects of traffic on the environment, Railway lighting and drainage.

UNIT I **9**

Classification of roads-Highway alignment and surveys-Highway economics and financing. Geometric design of High way-design speed-Cross sectional elements-super elevation-sight distances-Gradients-extra widening at curves.

UNIT II **9**

Highway Materials-Aggregates and Bituminous Materials-Selection and testing-Construction methods for Earth roads,gravel,W.B.M, roads, Bituminous pavements and Cement concrete pavements

UNIT III **9**

Traffic Engineering-Traffic volume-Speed and delay studies-Parking and accident studies-Traffic signs, marking and signals-road intersections-Traffic forecasting-Need-limitation-Types of traffic-Forecasts of traffic. Traffic Compositions-Future traffic estimates-Design Vehicle-Dimensions-Types of Design Vehicles.

UNIT IV **9**

Nature of traffic problems in cities: Growth of towns-Growth of Traffic-Nature of Present Difficulties-Measures to meet problems-Need for Study-Land use and City Planning Controls-Restrain measures-Public transport-Promotion of public transport pedestriauisation-Staggy traffic hours.

Traffic and free environment-Effects of traffic on the environment-Noise-Air-Vibration-Degrading the aesthetic-Land consumption-Evaluation procedures-Environmental areas-computer application in traffic engineering-Public transport systems-Simulation, Traffic Planning and Computer application-situation in India.

UNIT V **9**

Airports-their importance-spacing and position in relation to their zone-details of their location and layout-auxiliary and terminal buildings-their location and layout.

Runway lighting and drainage-Other accessories such as hangers and repair yards-airport zoning.

TOTAL HRS : 45

TEXT BOOKS:

Sl.No	Title of Book	Author of Book	Publisher	Year of Publishing
1	Highway Engineering	C.E.G.Justo and S.K. Khanna	New Chand & Bros.,Roorkee	2000
4	Highway Engineering	Rangwala	Charotar Publications,Pune	2002

REFERENCE BOOKS:

Sl.No	Title of Book	Author of Book	Publisher	Year of Publishing
1	Highway Engineering	L.Kadiyali	Nath Market, Naisarak Delhi-110 006	2002
2	Highway Engineering	Paul K Wright and Karen K. Dixon	Replica Press Limited, Kundli, Seventh Edition	2009
3	Transportation Engineering & Planning,	C.S. Papacostas, P.D.Prevedouros	Prentice Hall of India, Third Edition, New York	2001

WEBSITES:

- http://www.icivilengineer.com
- http://www.engineeringcivil.com/
- http://www.aboutcivil.com/
- http://www.engineersdaily.com
- http://www.asce.org/
- http://www.cif.org/
- http://icevirtuallibrary.com/
- http://www.ice.org.uk/
- http://www.engineering-software.com/ce/

KARPAGAM ACADEMY OF HIGHER EDUCATION

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COIMBATORE-641 021

15BECE5E04 TransportationEngineering

Staff Name : Mr.Pa.Ganeshwaran
Semester : 5 (2018-19 EVEN)
Course Type : Core
Number of credits : 3
LTPC : 1 1 0 0

S.No	Lecture Duration (Hour)	Topics to be covered	Support Materials
		UNIT I	
1.	1	Highway development	T_1/3
2.	1	Planning	T_1/7
3.	1	Classification of roads	T_1/9
4.	1	Road development in India	T_1/12
5.	1	Current road projects in India;	T_1/15
6.	1	Highway alignment	T_1/17
7.	1	project preparation.	T_1/19
8.	1	Execution of highway work	T_1/21
9.	1	Road development in India	T_1/23
		UNIT II	
10.	1	Geometric design of highways-:	T_1/18
11.	1	Introduction;	T_1/25,26
12.	1	highway	T_1/25,29,30
13.	1	cross section elements;	T_1/28
14.	1	sight distance,	T_1/29,27
15.	1	design of horizontal alignment;	T_1/89
16.	1	design of vertical alignment;	T_1/91
17.	1	design of intersections,	T_1/97
18.	1	problems	T_1/100
		UNIT III	
19.	1	Traffic engineering & control	T_1/102
20.	1	Traffic Characteristics,	T_1/105
21.	1	traffic flow and capacity,	T_1/109
22.	1	traffic engineering studies,	T_1/111
23.	1	traffic flow and capacity,	T_1/113
24.	1	traffic regulation and control;	T_1/116
25.	1	design of road intersections;	T_1/119
26.	1	design of parking facilities; highway lighting;	T_1/121
27.	1	problems	T_1/126
		UNIT IV	
28.	1	Pavement materials-	T_1/128

29.	1	Materials used in Highway Construction-	T_1/131
30.	1	Soils, Stone aggregates,	T_1/135
31.	1	bituminous binders,	T_1/137
32.	1	bituminous paving mixes;	T_1/139
33.	1	Portland cement and cement concrete:	T_1/141
34.	1	desirable properties, tests,	T_1/143
35.	1	requirements for different types of pavements.	T_1/145
36.	1	Problems	T_1/149
UNIT V			
37.	1	Design of pavements- Introduction;	T_1/156
38.	1	Flexible pavements	T_1/158
39.	1	factors affecting design and performance;	T_1/161
40.	1	factors affecting design and performance;	T_1/163
41.	1	stresses in flexible pavements;	T_1/165
42.	1	design of flexible pavements as per IRC; rigid pavements	T_1/167
43.	1	components and functions;	T_1/169
44.	1	factors affecting design and performance of CC pavements; stresses in rigid pavements	T_1/172
45.	1	design of concrete pavements as per IRC; problems	T_1/175

Text/Reference Books:

1. Khanna, S.K., Justo, C.E.G and Veeraragavan, A, 'Highway Engineering', Revised 10th Edition, Nem Chand & Bros,2017
2. Kadiyalai, L.R., ' Traffic Engineering and Transport Planning', KhannaPublishers.
3. Partha Chakraborty, ' Principles Of Transportation Engineering, PHILearning,
4. Fred L. Mannering, Scott S. Washburn, Walter P. Kilareski,'Principles of Highway Engineering and Traffic Analysis', 4th Edition, JohnWiley
5. Srinivasa Kumar, R, Textbook of Highway Engineering, Universities Press,2011.
6. Paul H. Wright and Karen K. Dixon, Highway Engineering, 7th Edition, Wiley Student Edition,2009.

UNIT I

Significance of highway planning – Modal limitations towards sustainability - History of road development in India – Classification of highways – Locations and functions – Factors influencing highway alignment – Soil suitability analysis - Road ecology - Engineering surveys for alignment, objectives, conventional and modern methods.

PART - B

1. What is road? Write the different types of transportation.

Road:

A road is a route, or way on land between two places that has been paved or otherwise improved to allow travel by some conveyance, including a horse, cart, bicycle, or motor vehicle etc.,

Roads consist of one or two carriageways, each with one or more lanes and any associated sidewalks. Roads that are available for use by the public may be referred to as public roads or as highways.

Road transport is one of the most common mode of transport. Roads in the form of trackways, human path ways etc., were used even from the pre-historic times. Since then many experiments were going on to make the riding safe and comfort. Thus road construction became an inseparable part of many civilizations and empires.

The different means of transport that we commonly use in our life can be divided into three main categories:

1. Land transport
2. Water transport
3. Air transport

1. Land Transport: All Vehicles those move on road like scooters, cars, truck etc., included in Land Transport. But Land transport can be subdivided in two more type: Roadways and Railways

Roadways / Highways: -All states of a country are connected to each other by roads and highways. These highways are well-constructed and different types of vehicles used for different distances. Scooters, bikes and auto etc. used for short distances while cars, buses and trucks used for covering long distances. Buses is the main carrier for travellers, where as for carrying raw material and finished good from factories to market, Trucks are most useful.

Railways: In all countries of the world, all major cities are connected with railways. Even some countries are also connected by railway. Trains carry people and bulky goods over long distances. India has the second largest network of railways in the world. Metro is the latest and improved railway system which is most comfortable.

2. Water Transport: Boats, ships, steamers and submarine are included in water transport. Boats and ships are used as carriage of people and goods. In early days people used rafts and simple boats as water transport. Boats are used for short distances while ships are used for covering longer distances. Cargo ships are used to transport tones of goods like oil tankers for carrying goods, internationally.

Submarine is used for naval forces of the nations. It is mainly used for naval operation in war or for rescue operation of sinking ships in the oceans. They mostly remain submerged in water, hence fit for deep seas and oceans only.

3. Air Transport: Air Transport includes airplanes and helicopters which are very fast means of transport. Today, almost all nations of our earth are interconnected by air transport. However, air transport is more expensive as compared to other means of transport.

2.What is Highway? List its significance and objectives.

Highway:

A highway is any public road or other public way on land. It is used for major roads, but also includes other public roads and public tracks.

Highway engineering:

Highway engineering is an engineering discipline branching from civil engineering that involves the planning, design, construction, operation, and maintenance of roads, bridges, and tunnels to ensure safe and effective transportation of people and goods.

Highway planning:

Road planning is part of community planning. It is part of a planning system in which plans for traffic, land use and areas are all integrated.

SIGNIFICANCE OF HIGHWAY PLANNING:

Roads and highways have a pervasive effect on social, economic, energy, environmental and land-use issues. Planning for roads therefore begins within a broader planning and policy framework, in which the inter-connectivity between roads and other factors is established.

The importance or necessity of highway transportation can be easily judged from the following purposes or advantages of roads:-

- They facilitate conveyance of people, goods, raw-materials, manufactured articles, etc. speedily and easily in the different parts of a country.
- They act as the only source of communication in regions of high altitude i.e in mountainous regions.
- They help in growth of trade and other economy activities in and outside the villages and towns by establishing contact between towns and villages.
- They help in providing efficient distribution of agricultural products and natural resources all over the country.
- They help in price stabilization of commodities due to mobility of products all over the country.
- They help in social and cultural advancement of people and making the villagers active and alert members of the community.
- They help in promoting the cultural and social ties among people living in different part of a country and thus strengthen the national unity.
- They help in providing improved medical facilities quickly to human beings, especially to those who live in rural areas.
- They provide more employment opportunities.
- They enhance land value and thus bring better revenue.

- They serve as feeders for Airways, Waterways and Railways.
- They help in reducing distress among the people, caused due to famine, by supplying them food and clothing quickly.

Objectives of Highway Planning:

Every highway planning is done with the following objectives.

1. To establish an integrated highway network with minimum cost capable of encompassing all highway travel in a most safe, efficient, economical and orderly manner. The minimum cost should include initial cost of construction, maintenance cost, renewal cost of pavement layers and the vehicle operation costs.
2. To plan a highway system this could be constructed within the available resources during the proposed plan period with maximum utility.
3. To forecast the future requirements of road needed and improvements of roads.
4. TO phase out the entire highway development during the plan period by identifying the priorities keeping in view utility as the main criterion.
5. To workout financing system.

3. Define Modal share. Explain in detail about modal limitations towards sustainability.

MODAL LIMITATIONS TOWARDS SUSTAINABILITY:

A **Modal share** (also called mode split, mode-share, or modal split) is the percentage of travellers using a particular type of transportation or number of trips using said type. In freight transportation, this may be measured in mass.

Factors influencing the choice of mode:

The factors may be listed under three groups

1. Characteristics of the trip maker:

The following features are found to be important:

(a) Car availability and/or ownership;

(b) Possession of a driving license;

(c) Household structure (young couple, couples with children, retired people etc.);

(d) Income;

(e) Decisions made elsewhere, for example the need to use a car at work, take children to school, etc;

(f) Residential density.

2. Characteristics of the journey:

Mode choice is strongly influenced by:

(a) The trip purpose; for example, the journey to work is normally easier to undertake by public transport than other journeys because of its regularity and the adjustment possible in the long run;

(b) Time of the day when the journey is undertaken.

(c) Late trips are more difficult to accommodate by public transport.

3. Characteristics of the transport facility:

There are two types of factors. One is quantitative and the other is qualitative.

Quantitative factors are:

(a) Relative travel time: in-vehicle, waiting and walking times by each mode;

(b) Relative monetary costs (fares, fuel and direct costs);

(c) Availability and cost of parking

Qualitative factors which are less easy to measure are:

(a) Comfort and convenience

(b) Reliability and regularity

(c) Protection, security

A good mode choice should include the most important of these factors.

Towards sustainability:

In more general terms, **sustainability** is the ability to withstand the systems and processes in all situations.

The organizing principle for sustainability is sustainable development, which includes the four interconnected domains: ecology, economics, politics and culture.

Sustainable transport refers to the broad subject of transport that is sustainable in the senses of social, environmental and climate impacts and the ability to, in the global scope, supply the source energy indefinitely.

Components for evaluating sustainability include the particular vehicles used for road, water or air transport; the source of energy; and the infrastructure used to accommodate the transport (roads, railways, airways, waterways, canals and terminals).

Sustainable transport systems make a positive contribution to the environmental, social and economic sustainability of the communities they serve.

Modal share is an important component in developing sustainable transport within a city or region. In recent years, many cities have set modal share targets for balanced and sustainable transport modes, particularly 30% of non-motorized (cycling and walking) and 30% of public transport.

These goals reflect a desire for a modal shift, or a change between modes, and usually encompass an increase in the proportion of trips made using sustainable modes.

Environmentally sustainable transport

Transport systems are major emitters of greenhouse gases, responsible for 23% of world energy-related GHG emissions in 2004, with about three quarters coming from road vehicles. Currently 95% of transport energy comes from petroleum.

Energy is consumed in the manufacture as well as the use of vehicles, and is embodied in transport infrastructure including roads, bridges and railways.

The environmental impacts of transport can be reduced by improving the walking and cycling environment in cities, and by enhancing the role of public transport, especially electric rail.

4. Write in detail about the history of road development in India.

History of road development in India:

India had a network of roads in the ancient times. The development of the highways in the India, took at different times in varying speed. The road development can be discussed taking the different phases of times from the history.

Ancient Times: The excavation of the Mohn-Jodaro and Harappa civilization shows the traces of the roads in the ancient times, in a period of 35th to 25th B.C.

The Aryan Period and road construction: There are the various scriptures available to read about the road development in the India in the Aryan period.

The Indian scripture named "Arthasasthra", written by the Kautilya, prime minister of the Chandra Gupta Mourya, discusses the rules laid down for the depth of road construction for different purposes in the 4th century B.C.

There were punishments for obstruction of roads. The emperor Ashoka has improved the quality of the roads in India for the travellers, in his ruling period i.e. fifth century A.D.

Mughal period and road construction: The Mughals and Pathans improved the quality of the roads in India. Sher Shah Suri is still remembered for construction of the Grand Trunk Road (GT Road) from the Bangladesh-India to Kabul in Afghanistan.

19th Century and road construction: After the fall of the Mughal Empire in India in 19th century, the Britishers participated in the road construction for the military and administrative purposes.

The work was carried out by the British Military Engineers. Railway was introduced later but the existing roads were metalled and bridges were provided. The governor general of India i.e. Lord Dalhousie in the mid of 19th century introduced the PWD (Public works department), which still runs the various public works in India.

Later after the introduction of the railways in India the attention was shifted to the railways construction and only the feeder roads and railways got the prime importance afterwards.

Jayakar Committee: This committee was formed by the both chambers of the Indian Legislature in the 1927 to examine the roads in the India and ways to development of the roads in India. The number of the vehicles on the Indian roads increased after the First World War so it was felt necessary to develop a good network of the roads in India.

Indian Road development committee was formed in the year 1927, with M.R.Jayakar as its chairman. The committee submitted its report in the year 1928, and made some important recommendations: The road development in India should be considered a national interest, because it is out of control of the local bodies.

- An extra tax should be put on the petrol consumers to develop a road development fund, called the Central Road Fund.
- A semi-official body should be formed to pool technical ideas, knowledge from the various parts of the country and to act as an advisory body on various aspects of roads.
- A research organisation should be organised to carry out the research and development work.

As a result of these recommendations a central Road Fund was formed by the year 1929, a semi-official body called Indian Roads Congress was formed in 1934 and the Central Roads Research Institute was started in 1950.

Central Road Fund (1929): Central Road Fund was formed in the year 1929, extra money 2.64 paisa per litre of the petrol, was charged from the entire petrol buyer in the country. This fund was kept separate for the use in the road development in India.

About 20% of the fund was kept to be used for the expenses of the administrative meetings and the research work of the highways of the national importance in the country. The rest of the 80% of the

funds were distributed among the provinces at that time, according to their road users, for the development of the roads by the state governments.

Indian Roads Congress (1934): A semi-government organisation named, Indian Roads Congress was formed in the year December 1934, and was registered in the year 1937 under the registration act.

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. IRC performed the various planning, and also it has become the most important agency to provide the standards and the specifications for the road construction in the country.

Motor vehicle act (1939): The increased numbers of vehicle on the Indian roads demanded for the rules and regulations. The motor vehicle act was passed in 1939, which laid down the rules for the road users and also for the identity of the vehicles. It is still running in the country in almost same way as it was at that time.

Central Road Research Institute (1951): A series of laboratories, known as the Central Science and Industrial Research Centre situated at Delhi, contains the research centre for the research work of the road construction in India, it is known as the Central Road Research Institute

The main function of the CRRI is to do the research work for the road construction and to provide the consultation services for the state government also.

First 20-years road plan(Nagpur Road Plan-1943 to 1963): The first twenty years road network plan was prepared in the meeting of the Chief Engineers from the various parts of the country at the Nagpur, in 1943, which is also known as the Nagpur road plan.

It was the first ever major planning which contributed a lot for the development of the roads in the country. It classified the Indian roads according to their location and purpose, and also it laid down a target for a density of road network of 16 km per 100 sq. Km in the country at the end of the 20 years road network in the year 1963.

After the starting of the 5 years plans in the year 1951, the first two 5 years plans also contributed to the target set by the first 20 years plan of the Nagpur so the density of 16 km per 100 sq. Km was achieved in the year 1961, 2 years earlier to the target year.

A typical hill road (Ghaghas to Shimla- Himachal Pradesh) - in 2013

Second 20-years road plan (Bombay Road Plan- 1961 to 1981): As the earlier target was achieved before the planned year, so a need to set a new target arises and another 20 years road plan was laid down at the meeting of the various authorities from different states at Bombay. The road density target was doubled this time.

5.Discuss the twenty – year road plan and its features.

(APRIL/MAY 2010)

The first attempt for proper planning of the highway development programme in India .On a long term basis was made at the Nagpur conference in 1943.The second twenty year plan was drawn for the period 1961-81.The third twenty year road development plan for the period 1981-2001 was approved only by the year 1984.

Nagpur road plan (or) First 20-year road plan: -

The conference of civil engineer held at nagpur in 1943 finalized the first twenty year road development plan for India called Nagpur plan the period 1943-63.The road network in the country was classified into five categories.

- National highway
- State highway
- Major district road
- Other district road
- Village road

Two-plan formulas were finalized at the Nagpur conference for deciding two categories of road length for the country as a whole as well as for individual areas. The two plan formula assumed the star

and Grid pattern of road network. The total length of the first category or metalled roads for national and state Highways and Major District Roads in km is given by the formula:

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

Where

A=Agricultural area, km^2

B = Non-agricultural are, 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.

The total length of second category roads for other District road and village Roads in km is given by the formula:

$$ODR + VR\ (km) = [0.32\ V + O.8\ Q + 1.6\ P + 3.2\ S] + D$$

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 range 2001-5000

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

From the above two formulae, it may be seen that in addition to the road length based on agricultural and non-agricultural areas, specific road length were allocated for towns and villages of different population ranges.

Salient Features of Nagpur Road Plan:

1) The responsibility of construction and maintenance of national highways was assigned to the central government.

2) It was a 20-year plan intended for the period 1943-63 aiming to provide for about two-lakh km of surfaced roads and remaining unsurfaced roads.

3) The formulae were based on star and grid pattern of road network. But the existing irregular pattern of roads and obligatory points not fitting in the geometric pattern were to be given due consideration.

4) The second category roads are meant to provide internal road system linking small villages with first category roads.

5) An allowance for agricultural and industrial development during the next 20 years was estimated as 15 percent and this allowance was to be provided while calculating the road length for both the categories of roads.

Second Twenty-Year Road Plan (1961-81): -

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

Five different formulae were framed to calculate the lengths of NH, SH, MDR, ODR, VR.

These five formulae are given below:

a) National highway (km)

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

b) National Highways + State Highways (km)

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

c) National Highways + State Highways + Major district roads (km)

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

d) National Highways + State Highways + Major district roads + Other District roads (km)

$$\left[\frac{3A}{16}+\frac{3B}{32}+\frac{C}{16}\right]+[48\,k+24\,M+11.2\,N+9.6\,P+12.8Q+4\,R+0.8\,S+0.32\,T]\quad(2.6)$$

e) National Highways + State Highways + Major district roads + Other District roads +Village roads

$$\left[\frac{A}{4}+\frac{B}{8}+\frac{C}{12}\right]+[48\,k+24\,M+11.2\,N+9.6\,P+12.8Q+5.9\,R+1.6\,S+0.64\,T+0.2\,V]+D$$

Where

A= Developed and agricultural areas; km2

B = Semi-Developed area, km2

C = Undeveloped area, km2

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 5,000-2000

S = Number of towns with population range 2,000-1,000

T = Number of towns with population range 1000-500

V = Number of towns with range below 500

D = Development allowance of 5 percent of road length calculated for further development and other unforeseen factors.

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

This plan is considered to be draw more scientifically in view of development needed in under-developed areas.

Maximum distance of any place in a developed or agricultural area would be 6.4 km from a metalled road and 2.4 km from any category of roads.

The maximum distance from any place in a semi-developed area would be 12.8 km from a mettaled road and 4.8 km from any road.

Every town with population above 2000 in plains and above 1000 in semi-hill areas and above 500 in hilly areas should be connected by a metalled road.

Expressways have also been considered in this plan and 1600 km of length has been included in the proposed target of national highways

Length of railway track is considered independent of the road system and hence it is not subtracted to get the road length.

The development factor of only 5 percent is provided for future development and unforeseen factors.

Third Twenty-Year Road Development Plan 1981-2001: -

Policies and objectives:

The Third Twenty Year Road development Plan 1981-2001(also Known as Lucknow Road Plan) was finalized and the plan document was published by the year 1984.The major policies and objectives of this road plan are listed below:

a) The feature road development should be based on the revised classification of road system consisting of primary, secondary and tertiary road systems.

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

c) The overall road density in the country should be increased to 82 km per 100-sq.km areas by the year 2001.

d) The national highway network should be expanded to form square grids of 100 km sides so that no part of the country is more than 50 km away from a NH.

e) The lengths of SH and MDR required in a state or region should be decided based on both areas and number of towns with population above 5,000 in the state or region.

f) Expressways should be constructed along major traffic corridors to provide fast travel.

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

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

6. Compare the Nagpur road plan and the second twenty – year road plan. Discuss the merits of each.

S.No	Nagpur plan	Twenty year road plan
1	It gives the two formulae, one is to find the length of first category roads consisting of NH, SH, Major District roads. Second is to find the length of secondary	In the Second 20 year Road plan five different formulae have been given from which the length of each class of road (i.e.) NH, SH, MDR, ODR and VR.

	category roads are consisting of other district roads and village roads.	
2	Nagpur road plan divides the area into two parts. i) Agricultural area ii) Non Agricultural area	In Bombay road plan, the area is divided into three parts. a) Developed and agricultural area b) Semi-developed area c) Undeveloped and uncultivated area
3	It has double the Nagpur plan target.	It has a target road length of 32 km per 100-sq.km areas.
4	This formula does not take into account the towns with very large population	In this plan, towns have been divided into nine different population ranges from less than 500 for the smallest town (or) villages to above 1, 00, 000 for largest towns.
5	Nagpur road plan allowed deduction of the length of railways track in the area while calculating the length of first category roads.	In the Bombay road plan the length of railway track is not deducted.
6	Allowance for development of agriculture and industry during the next 20 years was made in nagpur plan by allowing 15 percent.	The allowance for development due to unforeseen factors according to the second plan is only 5 percent.

7. Briefly explain about the classification of highways.

(APRIL/MAY 2011)

CLASSIFICATION OF HIGHWAYS (TYPES OF ROADS IN INDIA AS PER NAGPUR PLAN):

Non-urban Roads:

Non-urban roads within the country are classified into six types:

1) Expressways:

The purpose of expressways would be to cater for motility of large volumes of motor traffic at high speeds. They connect major areas of increasing visitor count and they are

intended to serve trips of medium and long length in between prominent residential areas, industrial or business concentrations and the central business district.

They may be divided highways with high standards of geometric and full or partial control of access and provided generally with grade separation at intersections. Vehicle parking, loading and unloading of products and passengers and pedestrian traffic are not allowed on these kinds of highways.

2) National Highways:

These include main highways running throughout the distance and breadth of the country connection major parts, highways of adjoining countries, State capitals, large commercial and tourist centres etc.,

3) State Highways:

These include main arterial routes of any state connecting district headquarters and major cities in the state and connecting these with National Highways of the neighbouring states.

4) Major District Roads:

They are essential roads with a district serving parts of production and markets, and linking these together or while using the main highways.

5) Other District Roads:

They are streets serving non-urban areas of production and providing them with outlet to market centres, taluka /tehsil headquarters or other main roads.

6) Village Roads:

These are roads joining villages or group of villages with each other and also to the nearest road of any higher class.

Urban Roads:

Urban roads are classified into your following five categories:

1) Expressways:

The function of expressways is the similar regardless of if the traverse through urban areas or non-cities.

2) Arterial Streets:

This system of streets, together with expressways where they exist, serves as the key network for through traffic flows Significant intra-urban travel, for instance, among central downtown and outlying residential areas or between significant suburban ‘zones develops on this system.

These roadways may generally be spaced under 1-5 km in hugely developed central business places and at 8 km or maybe more in sparsely developed urban fringes The arterial streets are generally divided highways with full or partial access Parking, loading and unloading activities are usually restricted and regulated Pedestrians should cross only at intersections

3) Sub-arterial Streets:

These include functionally much like arterial streets but with somewhat lower level of travel mobility. Their spacing is different from about 0 – 5 km in the central downtown to three – 5 km inside the sub-urban fringes

4) Collector Streets:

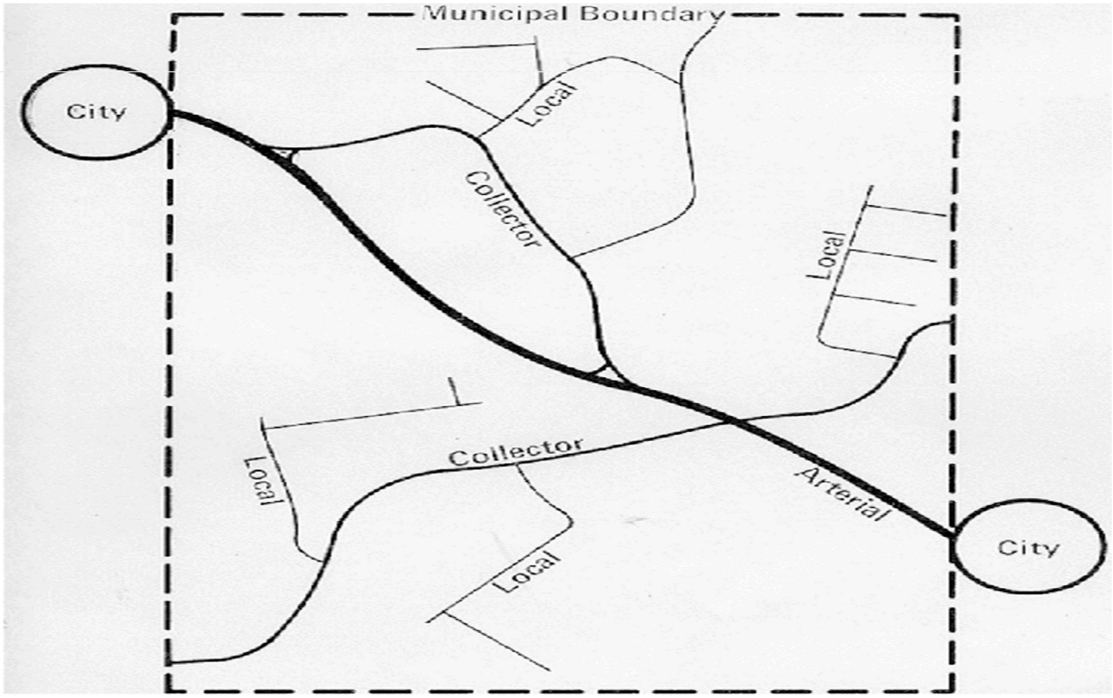
The function of collector streets should be to collect visitors from nearby streets and feed it for the arterial and sub-arterial streets or vice versa. These may be located in residential neighbour hoods, commercial areas and industrial areas.

Usually, complete approach is granted on these roadways from abutting properties. There are not car parking limitations apart from during the peak hours

5) Local Streets:

These are intended mainly to supply use of abutting properly and normally will not carry substantial amounts of traffic.

Majority of visits in urban areas originate from or terminate on these roads. Local streets could possibly be non commercial, commercial or industrial, depending on the predominant use of the nearby area. They permit unrestricted parking and pedestrian movements.



8.What are all the factors affecting the selection of highway? Write its functions.

(APRIL/MAY 2010), (NOV/DEC 2012)

LOCATIONS AND FUNCTIONS:

Factors affecting Highway location:

In general, the sequence of highway location in the urban areas is the same as in rural area i.e. reconnaissance, preliminary location and final location. The location is chiefly dictated by the desired and points of travel, topography, geology and environmental impact.

For urban highways location process, however, is more involved reflecting the complexities of urban conditions.

Among factors that affect selection of highway location are:

1. Traffic/Trip orientation and purpose
2. Land use
3. Off-street parking
4. Other transportation system
5. Topography and geology

6. Sociological conditions
7. Historical and environmental impacts.

1. Traffic/Trip orientation and purpose

Traffic planner from various studies can predict the effect of travel patterns of alternative location proposed highway. Also they analyze the probable effect of new links in highway network.

This permits the location engineer to determine how well alternative locations will fit with the existing network.

2. Land use

It is a major factor affecting the pattern of traffic generation is an urban area. For urban highway the commercial, residential and industrial areas are too considered.

Although the highway should be designed for peak hour volume and the travel patterns vary with time of day, day of weak. Season of the year also has effect in other ways.

Industries and common areas relying heavily on truck transportation need service by arterial routes. Health and safety require avoiding heavy traffic in residential areas. Aesthetic values are also considered in an urban highway.

3. Parking Facility for Vehicles

For highway location in an urban area the existing parking facility should be considered. Ideally the location should be close to existing and potential parking areas to avoiding the amount of travel on existing street.

4. Already existing Transportation System

To increase the overall level of service of transportation in an urban area interference and interaction with other transportation system should be considered.

5. Topography and Geology

It has same importance as in rural area. Due to high cost of right of way are certain areas from where the road should not pass.

6. Sociological, Historical and Environmental factors

- Proposed location should not serve residential neighbourhoods or create barriers b/w residential and other community service.
- Open public land should be retained as far as possible.
- Park and residential land should be used only if there is no alternate location can serve as stabilizing force by screening the traffic from residential communities.
- Further relocation of utilities where depressed highway and under pass are involved can add greatly to the cost.
- The procedure for locating urban highway are much less uniform and fixed e.g. there may be prior surveys and maps made for property location, street improvement or other purposes which furnish most of the information that will be gathered by reconnaissance. In many instance the data may be complete and accurate enough that no preliminary survey is required.
- Aerial photographs, the primary reconnaissance too,avoid highly developed areas of high cost.
- Just as in rural areas, location survey consists of staking and referencing the centreline, taking profile, and cross-sections, and determining the location of all cultural and property movements.
- Considerable time is needed for locating surface and underground utilities, so that construction plans can include provision for their location.
- Problems can be minimized by employing large scale vertical aerial photographs and maps made from the photographs by photogrammetric survey.

FUNCTIONS OF HIGHWAY:

A highway pavement is a structure consisting of superimposed layers of processed materials above the natural soil sub-grade, whose primary function is to distribute the applied vehicle loads to the sub-grade.

The pavement structure should be able to provide a surface of acceptable riding quality, adequate skid resistance, favourable light reflecting characteristics, and low noise pollution.

The ultimate aim is to ensure that the transmitted stresses due to wheel load are sufficiently reduced, so that they will not exceed bearing capacity of the sub-grade.

Two types of pavements are generally recognized as serving this purpose, namely flexible pavements and rigid pavements.

An ideal pavement should meet the following requirements:

- Sufficient thickness to distribute the wheel load stresses to a safe value on the sub-grade soil,
- Structurally strong to withstand all types of stresses imposed upon it,
- Adequate coefficient of friction to prevent skidding of vehicles,
- Smooth surface to provide comfort to road users even at high speed,
- Produce least noise from moving vehicles,
- Dust proof surface so that traffic safety is not impaired by reducing visibility,
- Impervious surface, so that sub-grade soil is well protected, and
- Long design life with low maintenance cost.

9. Write the factors influencing on selection of highway alignment.

(APRIL/MAY 2010)

FACTORS INFLUENCING HIGHWAY ALIGNMENT

Highway alignment

Once the necessity of the highway is assessed, the next process is deciding the alignment. The highway alignment can be either horizontal or vertical and they are described in detail in the following sections.

Alignment

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

Requirements

The requirements of an ideal alignment are

- The alignment between two terminal stations should be **short** and as far as possible be straight, but due to some practical considerations deviations may be needed.
- The alignment should be **easy** to construct and maintain. It should be easy for the operation of vehicles.So to the maximum extends easy gradients and curves should be provided.
- It should be **safe** both from the construction and operating point of view especially at slopes, embankments, and cutting. It should have safe geometric features.
- The alignment should be **economical** and it can be considered so only when the initial cost, maintenance cost, and operating cost is minimum.

Factors controlling alignment

The various factors that control the alignment are as follows:

1. Obligatory points: The points which controls the alignment of highway is called Obligatory or Controlling points. These are the control points governing the highway alignment. These points are classified into two categories. a) Points through which it should pass and b) points through which it should not pass.

Some of the examples are:

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

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

- **Intermediate town:** The alignment may be slightly deviated to connect an intermediate town or village nearby.

These were some of the obligatory points through which the alignment should pass. Coming to the second category that is the points through which the alignment should not pass are:

– **Religious places:** These have been protected by the law from being acquired for any purpose. Therefore, these points should be avoided while aligning.

– **Very costly structures:** Acquiring such structures means heavy compensation which would result in an increase in initial cost. So the alignment may be deviated not to pass through that point.

– **Lakes/ponds etc:** The presence of a lake or pond on the alignment path would also necessitate deviation of the alignment.

2. Traffic: The alignment should suit the traffic requirements. Based on the origin-destination data of the area, the desire lines should be drawn. The new alignment should be drawn keeping in view the desire lines, traffic flow pattern etc.

3. Geometric design: Geometric design factors such as gradient, radius of curve, sight distance etc., also governs the alignment of the highway. To keep the radius of curve minimum, it may be required to change the alignment of the highway. The alignments should be finalized such that the obstructions to visibility do not restrict the minimum requirements of sight distance. The design standards vary with the class of road and the terrain and accordingly the highway should be aligned.

4. Economy: The alignment finalized based on the above factors should also be economical. (High embankment, deep cut should be avoided).

5. Other Consideration

- Drainage considerations, hydro formal factors, political consideration and monotony.

- The sub surface water level, seepage flow and high flood level are the factors to be kept in view.
- Engineering feasibility
- Environmental consideration
- Social consideration
- Political Acceptability
- Monotony

10.What do you meant by soil suitability analysis? Explain in detail.

SOIL SUITABILITY ANALYSIS

Prior to commencement of any road construction project involving site formation work, site investigation is carried out to establish the geological profile along the road alignment. Very often, samples are taken by borehole drilling for tests including, particle size distribution, moisture content and tri-axial tests etc. The results are useful for engineering design e.g. slopes stability analysis. For pavement design, soil properties at sub-grade level are required.

It is recommended that samples from the designed sub-grade level should be taken for CBR evaluations. This is considered appropriate for design purpose. Other than for road construction projects, CBR tests and other associate tests are also required for the design of structural maintenance treatments for existing roads. The number of CBR tests required will very much depend on the uniformity of the sub-grade soil. Considerable Engineer input is required.

A detailed soil survey is carried out by obtaining soil samples 1.5 to 3 m below the ground level or the finished grade line whichever is lower. However, in locations where embankments are planned, sampling should be done to a depth equal to twice the height of the finished embankment. Spacing of sampling and type of sampling depends on soil type at the location.

During survey one may cross where land is loose or is subjected to slides and there may be avoid loose soils while rocky strata, all these details are to be recorded. Efforts are to be made

to avoid loose soils while rocky strata through costing very much in the initial stage of construction may be preferred.

Purposes and objectives of soil investigation:

The main purpose of soil investigation is to determine the stratigraphy of the site. In other words the determination of the sequence of different soil strata or the position of the groundwater and its fluctuation limits. Following are some of the primary objectives of the soil investigation:

- To determine the thickness of the strata, and to assess sequentially.
- To determine the quality of the bedrock and to verify the depth of the over burdening soil.
- To determine the position limit and the fluctuations of the ground water table during dry or wet seasons.
- To search the anomalies within the depth of exploration to estimate the characteristics of rock, ground water table and subsoil.

Soil Classification Tests (B.S.1377)

1. In-situ Moisture Content - This test determines the moisture content of soil as percentage of its dry mass. Test should be carried out in a Laboratory.
2. Specific gravity of soil - Specific gravity of soil measures the mass of soil per unit volume.
3. Particle Size Distribution (By wet sieving & pipette method) -This test covers the quantitative determination of the particle size distribution in soil from the coarse sand size down to clay size.
4. Compaction test - Proctor test - This test covers the determination of the mass of dry soil per cubic metre when the soil is compacted over a range of moisture contents, giving the maximum dry density at optimum moisture content. In this test, a 2.5 kg rammer falls through a height of 300 mm giving 27 blows to each of three layers.

5. California Bearing Ratio (CBR) Test - California Bearing Ratio is obtained by measuring the relationship between force and penetration when a cylindrical plunger is made to penetrate the soil at a standard rate.

11.Write in detail about road ecology.

ROAD ECOLOGY

Road ecology is a relatively new sub discipline of ecology that focuses on understanding the interactions between road systems and the natural environment.

Road ecology is an applied science, and much of the work within this field endeavours to find ways to minimize the detrimental effects that road systems can have on plant and animal populations, air and water quality, and human communities.

The knowledge generated by studies of the ecological and societal effects of road systems also informs many of the current visions of sustainable development.

Other highly visible outputs of road ecology include advances in the management of storm water runoff, transportation and land-use planning, and the development of crossing structures that allow animals' safe passage across busy roads.

Elements of road ecology

Road ecology at present is focused primarily on documenting and predicting the effects of roads on plants and animals and in understanding how roads affect the movement of water and sediments.

Effects of roads on fish and wildlife:

The potentially harmful effects that roads may have on wildlife populations have been detailed in the scientific literature since at least 1925, when an article entitled "The Toll of the Automobile" appeared in Science.

This paper provided an accounting of the number of road-killed animals observed during a car trip, and raised concerns that the increased mortality caused by collisions with motor vehicles might pose a significant problem for some populations of animals.

Understanding the effects of roads on wildlife, and more recently fish, continues as a central theme in road ecology, although current work focuses more broadly on understanding how roads constrain the movement of fish and wildlife, and what forms of mitigation can be applied to ameliorate these constraints.

Roadside vegetation

Most roadside plant communities are managed to enhance visibility for motorists, minimize risks for vehicles that leave the roadway, reduce erosion and sediment flow, and provide an aesthetically pleasing vista for travellers.

Effects of roads on the movement of water and sediments

Roads have a pronounced effect on the movement of water, acting both as conduits and barriers. For example: a road cutting across a hillside may force, surface and subsurface water to move laterally, rather than down slope.

Barrier effects such as these are even more pronounced when roads bisect wetlands. Roads, because they are generally surfaced with impervious materials, can also intercept and divert precipitation, which can result in altered hydrological patterns in natural drainages.

The effect that roads have on the movement of water also influences the movement of the material transported by water; for example, roads can accelerate scouring in natural drainages by increasing peak flows through delivery of storm water runoff (thereby increasing the ability of the water to suspend and move sediments).

Roads also influence sediment movement simply by creating areas of bare soil (for example, unvegetated cut or fill slopes or unpaved road surfaces) that are vulnerable to erosion.

The changes in water and sediment flow patterns caused by roads have potentially significant effects on aquatic ecosystems, and studies seeking to document and understand these effects comprise a large portion of the existing body of literature on road ecology.

12. Explain briefly on engineering surveys involved in alignment.

Engineering surveys for Alignment:

Before a highway alignment is finalised in highway project, the engineering surveys are to be carried out. The survey may be completed in four stages i.e.

1. Map study
2. Reconnaissance
3. Preliminary surveys
4. Final location and detailed surveys

1. Map study: With the help of topographic map it is possible to suggest the likely routes of the road. In India, topographic maps are available from the survey of India with 15 of 30 m contour interval. The main features like rivers, hills, valleys, etc., are also shown on these maps.

2. Reconnaissance: It is a rapid and rough survey. During the survey, the physical characteristics of the areal are inspected and the proposed route is thoroughly examined. It is done without accurate instruments. Clinometers are used to determine the slopes of the ground. It provides additional information not available in top sheets.

Objectives: -

i). To study the feasibility or practicability of the proposed route

ii). To reduce the number of alternative routes to the minimum to select the best two or three routes.

iii) Source of construction materials, water and location of stone quarries.

iv) Number and type of cross drainage structure, maximum flood level and natural ground water level along the probable routes.

3. Preliminary Survey: This survey can be started on the basis of reconnaissance. It consists of detailed survey of the alternative routes selected. After reconnaissance, it is done by using the instruments such as chain, compass, tape, level & theodolite.

Objectives: -

a. To select the best route.

b. To determine the centre line to be followed

c. To collect are additional information found necessary after reconnaissance.

d. To estimate quantity of earthwork materials and other construction aspects and to work out the cost of alternate proposals

4. Final Location and Detailed Survey: The alignment finalized after the preliminary survey is to be first located on the field by established the centre line.

This is done accurately by using instruments. The final route selected after the preliminary survey is surveyed and located on the ground.

Objectives:-

1. To establish temporary bench marks

2. To collect information required for,

3. The preparation of working drawings

4. The preparation of detailed estimates

5. The design of road & bridges

6. Preparing specifications

7. Land acquisition

Objectives of Engineering Surveys for Alignment:

The aim of location survey is to select a route with the following points kept in mind.

- With reasonable economy it should meet the minimum requirement regarding curvature and grades.
- To produce an easy riding (travelling), free flowing traffic artery that has a high capacity and it meets all the safety standards.
- The location survey should recognize and evaluate the routes impact on already existing industries, business, and residential values and on future development.

Before field survey for any highway location is started, tentative decision, regarding the design speed of the route, its cross-section, and the maximum grade must be made. These

decision made are based on the; Estimated of amount, character and hourly distribution of traffic, along with Knowledge of the area is traversed.

13. Describe briefly about the modern techniques involved in highway.

MODERN METHODS OF HIGHWAY ALIGNMENT:

1) Provisional alignment Identification (Map study)
2) Reconnaissance survey
3) Hand held GPS giving 3D positions to an accuracy of 10-20m
4) Preliminary Survey
    - Mapping of topography and relief
    - Use of aerial Photos
    - Airborne Laser Terrain Mapping
5) Final location and detailed survey

Modern Equipments for Surveying:

- EDM – Electronic Distance Measurement
- Auto level
- Digital level
- Total station
- GPS – global positioning system

Data from Aerial Survey:

- Mosaic for longitudinal and lateral overlaps
- Control points
- Examination of photos for spot levels and contour lines
- Topo details
- Photo interpretation for geological features, soil and drainage for the study area.

14. Write the comparison between conventional and modern method of surveying.

ELEMENTS	CONVENTIONAL	MODERN
MAPS – BASE MATERIAL	• Topo Sheet	• RS data, Aerial Photos, Satellite Imageries

INSTRUMENTS	• Chain / Tapes, Theodolite, Dumpy Levels	• Electromagnetic Distance Measurement (EDM), Total Station (TS), GPS, Auto and Digital Level, Photogrammetry
ACCURACY	• Chain / Tape 1 in 3000 to 1 in 30000 • Tachometer 1 in 1000 to 1 in 10000	• EDM / TS 1 in 10000 to 1 in 100000 • Photogrammetry 1 in 10000 to 1 in 100000
PLOTTING	• CAD Systems	• Software
ERRORS	• Human Errors	• Closing Errors hence re-measuring is required.

UNIT II

PART – A

1. **What are the elements of geometric design?(May /June 2016)**
   - i. Cross section elements
   - ii. Sight distance considerations
   - iii. Horizontal alignment details
   - iv. Vertical alignment details
2. **What are the factors which controls the geometric elements?**
   - i. Design speed
   - ii. Topography
   - iii. Traffic factors
   - iv. Design hourly volume and capacity
   - v. Environmental and other factors

3. What are the factors affecting friction?

i. type of pavement surface

ii. macro-texture or relative roughness of pavement

iii. type and condition of tyre

iv. speed of vehicle

v. brake efficiency

4. Define sight distance.(Nov/Dec 2015)

Sight distance in the actual length of road over which a driver sitting at a specified height in a vehicle can see objects either moving (or) stationary on the road surface.

5. What are classifications of sight distance depending upon the situation?

1. Stopping sight distance

2. Safe overtaking sight distance

3. Sight distance at intersection

6. Define intermediate sight distance.

This is defined as twice the stopping sight distance. When overtaking sight distance cannot be provided intermediate sight distance is provided for purpose of overtaking.

7. Define Head light sight distance.

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

8. Define S.S.D.

Stopping sight distance is the minimum distance required with in which a vehicle moving at designed speed can be stopped without colliding with any other obstructions.

9. What are the factors influencing the sight distance?

i. Feature of the road ahead

ii. Height of the drivers eye above the road surface

iii. Height of object above road surface.

10. What is the height of driver eye above the road surface?

IRC recommended height of driver eye is 1.2m.

11. Define total reaction time.

It is the time in seconds from which a driver can taken from the instant the objects is visible to him to the instant the brakes are effectively applied.

12. Define perception period.

Perception period is the time taken by an average driver to realize a danger a head before actually trying to apply the breaker

13. Define PIEV Theory. (May /June 2013,2014,2015)

According to this theory the total reaction time of the driver is split into four parts, viz, time taken by the driver for

(1)Perception

(2)Intellection

(3)Emotion, and

(4)Volition

14. Define perception time

Perception time 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 chord in other words, it is the time required to perceive an object or situation.

15. Define intellection time.

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

16. Define emotion time.

Emotion time 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.

Therefore the emotion time of a driver is likely to vary considerably depending upon the

problems involved

17. Define volition.

Volition time is the time taken for the final action.

19. Define lag distance.

The distance travelled by the vehicle during the total reaction time know as lag distance

20. Define breaking distance.

The distance travelled by the vehicle after the application of the brakes, to a dead stop position which is known as the braking distance.

21. What is the formula for SSD in level surface?

When 'v' in m/sec SSD in m = $vt + (v^2/2gf)$

When 'V' in kmph SSD in m = $0.278Vt + (V^2/254f)$

22. What is the formula for SSD in slopes?

When 'v' in m/sec SSD in m = $vt + \{v^2/2g(f\pm0.01n)\}$

When 'V' in kmph SSD = $0.278Vt + \{ V^2/254(f\pm0.01)n\}$

23. Define OSD

The minimum distance open to the vision of the driver of a vehicle intending to overtake slow vehicle ahead with safety against the traffic of opposite direction is known as the minimum overtaking sight distance (OSD) or the safe passing sight distance

24. Write down the important factors on which the minimum overtaking sight distance required for the safe overtaking maneuver?

(a) Speeds of the vehicle

(b) Distance between the overtaking and overtaken vehicles;

(c) Skill and reaction time of the driver

(d) Rate of acceleration of overtaking vehicle

(e) Gradient of the road, if any

25. What is the formula to find OSD?

$OSD = d_1 + d_2 + d_3$ $d_1 = .28\ V_b\ t$

$d_2 = .28\ V_b\ T + 2$ $d_3 = 28\ V\ T$

$s = (.2\ V_b + 6)$ $T = \sqrt{14.4S/A}$

26. Define overtaking zone.

- Sign posts should be installed at sufficient distance in advance to indicate the start and end of the overtaking zones; this distance may be equal.
- Minimum length of overtaking zone - three time the safe overtaking distance for two-way roads.

27. Write about Sight Distance at Intersections?

- It is important that on all approaches of intersecting roads, there is a clear view across the corners from a sufficient distance so as to avoid collision of vehicles.

- This is all the more important at uncontrolled intersections.
- The area of unobstructed sight formed by the lines of vision is called the sight triangle

28. Define Horizontal Curves

A horizontal highway curve is a curve in plan to provide change in direction to the central line of a road. When a vehicle traverses a horizontal curve, the centrifugal force acts horizontally outwards through the centre of gravity of the vehicle.

29. Define transverse skidding effect.

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

30. Define super elevation.(May /June 2013,2014,2015)

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 thinner edge, thus providing a transverse slope throughout the length of the horizontal curve, this transverse inclination to the pavement surface is known as Super elevation or cant or banking

31. What is the reason for providing extra widening of pavement on horizontal curves?(May /June 2016)

i. In the turning rear wheels do not follow front wheel.

ii. To overcome the skidding effect.

iii. To have greater visibility.

iv. To maintain greater clearance between the vehicles in curves.

32. What is the reason for providing transition curves?

a. to introduce gradually the centrifugal force between the tangents point and the

beginning of the circular curve.

b. to enable the driver to turn the steering gradually.

c. to improve the aesthetic appearance of road**.**

33. What are the different types of transition curves?

i. spiral

ii. Lemniscates

iii. Cubic parabola.

34. Define gradient.

The maximum length of the ascending gradient which a loaded truck can operate without undue reduction in speed is called critical length of the grade. A speed of 25 kmph is a reasonable value. This value depends on the size, power, load, grad-ability of the truck, initial speed, final desirable minimum speed etc

35. What are the different types of gradients?

a. ruling gradient

b. limiting gradient

c. exceptional gradient

d. minimum gradient

36. What is the purpose of providing vertical curves?

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

40. What are the types of vertical curves?

a. summit curves- is also known as crest curves with convexity upwards.

b. valley curves- is also known as sag curves with concavity upwards.

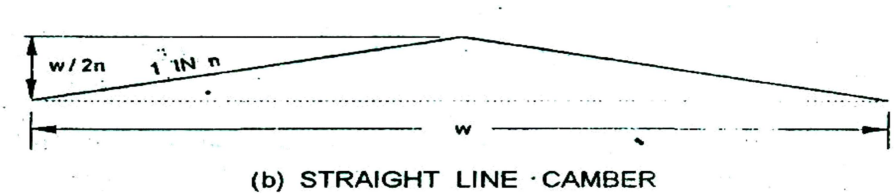
41. What is meant by off tracking?

In any vehicle where the rear axle cannot steer during a turn, the rear tires will follow a different path than the steering tires is known as off tracking

42. Define Camber (or) What is meant by cross slope?

Camber is provided on the straight roads by raising the centre of the carriageway with respect to the edges, forming a crown or highest point

along the centre line.



(b) STRAIGHT LINE · CAMBER

43. What is carriage way? (or) What is mean by width of pavement?

- It is way to carry the vehicles on roads is called carriageway.
- The width of the traffic lane should also be such that there is sufficient lateral clearance on either side of the moving vehicle.
- Width of 3.5 m per lane: One or two lanes generally in India.

44. What is right of way (or) Land width?

Right of way is the area of land acquired for the road, along its alignment.

The width of the acquired land for right of way is known as 'land width' and it depends on the importance of the road and possible future development.

45. Differentiate intermediate sight distance and illumination sight distance (or) Head-light sight distance.(Apr/May 2015)

Intermediate sight distance	Illumination sight distance (or)

	Head-light sight distance
This is defined as twice the stopping sight distance. When overtaking sight distance cannot be provided, intermediate sight distance (ISD) is provided to give limited overtaking opportunities to fast vehicles.	This is the distance visible to a driver during night driving under the illumination of the vehicle head lights. This sight distance is critical at up-gradients and at the ascending stretch of the valley curves.

46. What are Shoulders? (or) What you understand about shoulder and why it is provided in highways?

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

47. Define sag curves (or) Write about the Valley curve.(Apr/May 2015)

- Valley curves or sag curves with convexity downwards are formed.
- The deviation angle, N between the two intersecting gradients is equal to the algebraic difference between them.
- Among all the cases the maximum possible deviation angle is obtained when a descending gradient (- n1) meets with an ascending gradient (+ n2).
- Therefore deviation angle, N = - n1 - (+ n2) = - (n1 + n2).

48. Briefly explain illumination Sight distance (or) Define Head-light sight distance.

This is the distance visible to a driver during night driving under the illumination of the vehicle head lights. This sight distance is critical at up-gradients and at the ascending stretch of the valley curves.

49. What are the elements involved in Highway Geometric design? (May/June-2016)

The following elements are involved in Highway Geometric design

- Design speed
- Topography or terrain
- Traffic factors
- Design hourly volume and capacity
- Environmental and other factors

50. Differentiate 'lag distance' and 'breaking distance(Nov/Dec 2014)

Lag distance	Breaking distance
During the total reaction time, 't' seconds the vehicle may be assumed to move forward with a uniform speed at which the vehicle has been moving and this speed may be taken as the design speed.	The coefficient of friction 'f' depends on several factors such as the type and condition of the pavement surface and tyres.
If 'v' is the design speed in m/sec and 't' is the total reaction time, of the driver in seconds, then Lag distance = v t m	Also the value of f decreases with increase in speed, for the determination of braking distance as part of the stopping sight distance, the driver is expected to apply the brakes such that skidding does not take place and also the retardation is not too uncomfortable to the passengers.

51. What is meant by extra widening at curves? (May/June-2016)(Nov/Dec 2010)

On the horizontal curves, especially when they are not of very large radii; it is a common practice to widen the pavement slightly more than the normal width it is called extra widening.

52. What are the three types of sight distance situations are consider in the design?

(a) Stopping sight distance (SSD) or absolute minimum sight distance

(b) Safe overtaking sight distance (OSD) or passing sight distance

(c) Safe sight distance for entering into uncontrolled intersections

Apart from the three situations mentioned above, the following sight distances are considered by the **IRC** in highway design:

(i) Intermediate sight distance

(ii) Head-light sight distance

53. What are the factors influencing in vertical alignment of highway?

The vertical alignment of a highway influences:

(i) vehicle speed

(ii) acceleration and deceleration

(iii) slopping distance

(iv) sight distance

(v) Comfort while travelling at high speeds and vehicle operation cost.

54. What do you understand by 'curve resistance'? (Nov/Dec 2014)

- The automobiles are steered by turning the front wheels, but the rear wheels do not turn.
- When a vehicle driven by rear wheels moves on a horizontal curve, the direction of rotation of rear and front wheels are different, so there is some loss in the tractive force.
- Thus the loss of tractive force due to turning of a vehicle on a horizontal cure, which is termed as curve resistance.

PART - B

1. Draw the various components of Overtaking Sight Distance on a straight stretch of a highway and explain each zone. (Nov/Dec-2015)

1. Vehicle A travelling at the design speed v m/sec or, V kmph desires to overtake another slower vehicle B moving at a speed of V_b m/sec or V_b kmph.

2. The vehicle A has to accelerate, shift to the adjacent right side lane, complete the overtaking manoeuvre and return to the left lane, before the on-corning vehicle C approaches the overtaking stretch as shown in Fig.

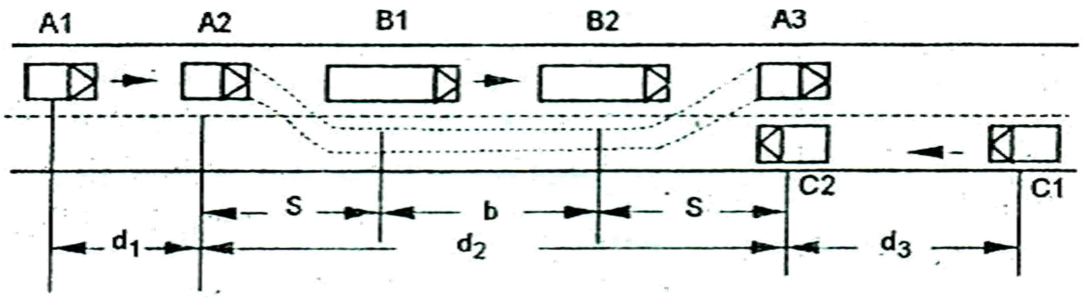


Fig. 4.14 Overtaking manoeuvre

3. The overtaking manoeuvre may be split up into three operations, thus dividing the overtaking sight distance, OSD into three parts, d_1, d_2 and d_3.
4. d_1 is the distance (m) travelled by the overtaking vehicle A during the reaction time t (secs) of the driver, from position $A_1$to A_2 before starting to overtake the slow vehicle B.
5. d_2 is the distance (m) travelled by the vehicle A during the actual overtaking operation during T (secs) from position A_2 to A_3 .
6. d_3 is the distance (m) travelled by on-coming vehicle C during the actual overtaking operation of A during T (secs) from position C_1 to C_2.
7. Thus on a 2-lane road with 2-way traffic the overtaking sight distance, OSD = $d_1+d_2+d_3$ (m).

2. List and Draw the various Vertical Curves adopted in Highways. (Nov/Dec 2015)

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

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

Summit curves (or) Crest curve:

- Summit curves with convexity upwards are formed in any one of the cases illustrated in Fig. 4.34 - (a), (b), (c) or (d).
- The deviation angle, N between the two intersecting gradients is equal to the algebraic difference between them. Of all the cases, the deviation angle will be maximum when an ascending gradient, (+ n_1) meets with a descending gradient, (n_2).
- Therefore deviation angle, N= n_1 - (- n_2) = (n_1 + n_2)

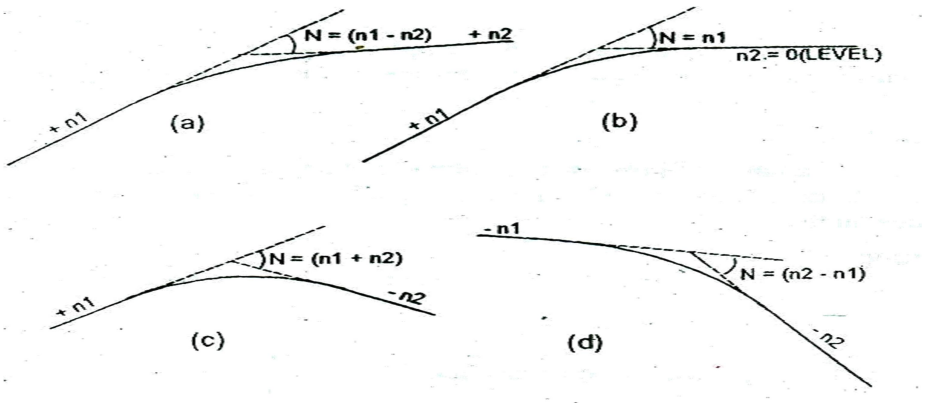


Fig. 4.34 Types of summit curves

Valley curves (or) Sag curves:

- Valley curves or sag curves with convexity downwards are formed in anyone of the cases illustrated in Fig. 4.36 - (a), (b), (c) or (d).

- The deviation angle, N between the two intersecting gradients is equal to the algebraic difference between them.
- Among all the cases the maximum possible deviation angle is obtained when a descending gradient (- n_1) meets with an ascending gradient (+ n_2).
- Therefore deviation angle, N = - n_1 - (+ n_2) = - (n_1 + n_2).

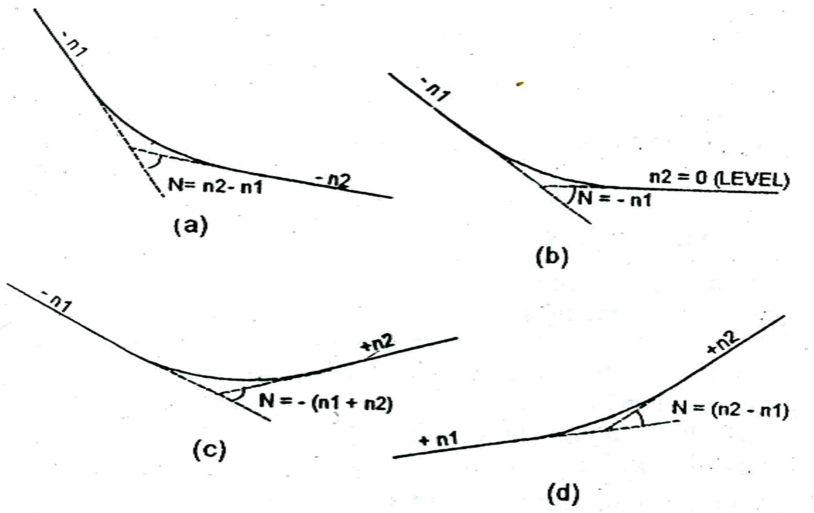


Fig. 4.36 Types of valley curves

3. Explain the factors influencing overtaking sight distance. Or Explain factors influencing sight distance. (May/June 2011, 2012, 2016)(Apr/May 2015)

- The most important consideration in all these is that at all times the driver travelling at the design speed of the highway must have sufficient carriageway distance within his line of vision to allow him to stop his vehicle before colliding lane. The computation of sight distance depends on:

Reaction time of the driver

- Reaction time of a driver is the time taken from the instant the object is visible to the driver to the instant when the brakes are applied.
- The total reaction time may be split up into four components based on PIEV theory.
  - In practice, all these times are usually combined into a total perception-reaction time suitable for design purposes as well as for easy measurement. Many of the Studies show that drivers require about 1.5 to 2 sec under normal conditions.
- However, taking into consideration the variability of driver characteristics, a higher value is normally used in design. For example, IRC suggests a reaction time of 2.5 sec.

Speed of the vehicle

- The speed of the vehicle very much affects the sight distance. Higher the speed, more time will be required to stop the vehicle.
- Hence it is evident that, as the speed increases, sight distance also increases.

Efficiency of brakes

- The efficiency of the brakes depends upon the age of the vehicle, vehicle characteristics.
- If the brake efficiency is 100%, the vehicle will stop the moment the brakes are applied. But practically, it is not possible to achieve 100% brake efficiency.
- Therefore the sight distance required will be more when the Efficiency of brakes is less.

  Also for safe geometric design, we assume that the vehicles have only 50% brake efficiency.

Frictional resistance between the tyre and the road

- The frictional resistance between the tyre and road plays an important role to bring the vehicle to stop.
- When the frictional resistance is more, the vehicles stop immediately. Thus sight required will be less.

No separate provision for brake efficiency is provided while computing the sight distance.

- This is taken into account along with the factor of longitudinal friction. IRC has specified the value of longitudinal friction in between 0.35 to 0.4.

Gradient of the road

- Gradient of the road also affects the sight distance. While climbing up a gradient, the vehicle can stop immediately.
- Therefore sight distance required is less. While descending a gradient, gravity also comes into action and more time will be required to stop the vehicle.
- Sight distance required will be more in this case.

The following factors affecting the overtaking sight distance (OSD)

Some of the important factors on which the minimum overtaking sight distance

required for the safe overtaking manoeuvre depends are:

(a) Speeds of vehicle.

(i) Overtaking vehicle

(ii) Overtaken vehicle and

(iii) The vehicle coming from opposite direction, if any

(b) Distance between the overtaking and overtaken vehicles; the minimum spacing between vehicles depends on the speeds.

(c) Skill and reaction time of the driver

(d) Rate of acceleration of overtaking vehicle

(e) Gradient of the road, if any

1. Skill and reaction time of driver:

Reaction time of the driver is the time taken from the instant the object is visible to the driver to the instant the brakes are effectively applied. The actual time gap or the reaction time of the driver depends on several factors.

2. Speed of the vehicle:

The stopping distance depends very much on the speed of the vehicle. First, during the total reaction time of the driver the distance moved by the vehicle will depend on the speed.

4. Explain the steps involved in the geometric design of hill road (Apr/May 2015)

Hair-pin Bends:

In hill roads it is often needed to provide hair-pin bends depending on the topography. The geometric standards adopted for the conventional roads cannot be adopted for hairpin bends. Design of such hair-pin bends needs special consideration.

The Indian Standard Practice (1944) for the design of hair-pin bends are given below:

- Minimum design speed 20 km/hr.
- Minimum width at apex.
    - (i) National and state Highways.
        - (a) Double lane 11.5 m.
        - (b) Single lane 9.0 m.
    - (ii) Major District Roads and Other District Roads 7.5 m
    - (iii)Village Roads 6.5 m
    - Minimum radius of inner curve 14.0 m
    - Minimum length of transition 15.0 m
    - Gradient
        a) Maximum 1 in 40

b) Minimum 1 in 200

Super elevation 1 in 10

Distance between two consecutive hair-pin bends should be a minimum of 60 m. Approach gradient should not be steeper than 5%. Straight length (60 m), if possible, should be introduced between two successive hair-pin bends. A typical hair-pin bend is shown in figure.

Typical Hair-Pin Bend

The minimum norms which may be adopted in the design of hair-pin bends are as follows:

1) Minimum radius = 14 m.
2) Design speed at the curve = 20 km/hr.
3) Maximum super elevation = 1 in 10 and for light traffic 1 in 15.
4) Width of carriage way at the apex of the curve should be 11.5 m for two-lane and 9 m for single lane National Highway and State Highway and for District Roads 7.5 m.
5) Maximum and minimum gradients are 1 in 40 and 1 in 200 respectively at curves.
6) Approach gradient should not be steeper than 5 % for 40 metre (60 m).
7) Straight length (60 m) roads should be introduced between two successive hair-pin bends.

5. Explain the general principles to be followed in the design of vertical alignments.

General principles:

1) The natural ground or the topography may be level at some places, but may have slopes of varying magnitudes at other locations.
2) While aligning a highway it is the common practice to follow the general topography or profile of the land, keeping in view the drainage and other requirements on each stretch.
3) Hence the vertical profile of a road would have level stretches as well as slopes or grades. In order to have smooth vehicle movements on the roads, the changes in the gradient should be smoothened out by the vertical curves.

4) The vertical alignment is the elevation or profile of the centre line of the road.

5) The vertical alignment consists of grades and vertical curves.

6) The vertical alignment of a highway influences: (i) vehicle speed (ii) acceleration' and 'deceleration (iii) slopping distance (iv) sight distance (v) comfort while travelling at high speeds and vehicle operation cost.

Gradient:

- ***Longitudinal gradient or slopes on roads:***

  Gradient is the rate of rise or fall along the length of the road with respect to the horizontal. It is expressed as a ratio of 1 in x (1 vertical unit to x horizontal units).

- The gradient is also expressed as a percentage, such as n %, the slope being n vertical units to 100 horizontal units.
- If the gradient is 1 in x and the angle of the gradient or slope angle is a, (see Fig. 4.33a) the gradient may also be expressed as, 'tan '.
- When the slope angle is small, tan is approximately equal to the circular measure or in radians (α^o).
- All angles within the practical range of gradients on roads may be treated as small.
- Hence gradients which are generally represented as 'n' percent, would mean that this is the value of the tangent of the angle made by the gradient with horizontal, i.e., a gradient of n % = tan α^o.
- The ascending gradients are given positive signs and are denoted as + n_1, + n_2 etc., and descending gradients are given negative si~ and are denoted as –n_3..j, - n_4, etc.

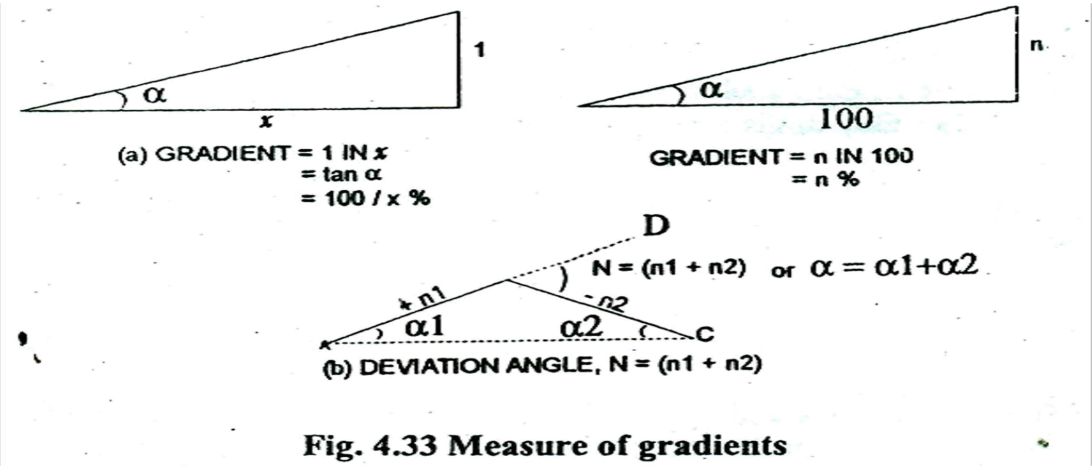


Fig. 4.33 Measure of gradients

The angle which measures the change of direction at the intersection of two grades is called the 'deviation angle' N which is equal to the algebraic difference between the two grades. In Fig. 4.33-b the deviation angle,

$$N = \angle DBC = \angle BAC + \angle BCA$$

$$= \quad +n_1 - (-n_2) = (n_1 + n_2)$$

Vertical Curves

- 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.

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

(a) Summit curves or crest curve with convexity upwards

(b) Valley curves or sag curves with concavity upwards

Summit curves:

- Summit curves with convexity upwards are formed.
- The deviation angle, N between the two intersecting gradients is equal to the algebraic difference between them. Of all the cases, the deviation angle will be maximum when an

ascending gradient, (+ n_1) meets with a descending gradient, (-n_2).

Therefore deviation angle, N= n_1 - (- n_2) = (n_1 + n_2)

- When a fast moving vehicle travels along a summit curve, the centrifugal force will act upwards, against gravity and hence a part of the self weight of the vehicle is relieved resulting in reduction in pressure on the tyres and on the suspension springs of the vehicle suspensions.
- So there is no problem of discomfort to passengers on summit .curves, particularly because the deviation angles on roads are quite small.
- Also if the summit curve is designed to have adequate sight distance, the length of the summit curve would be long enough to ease the shock due to change in gradient

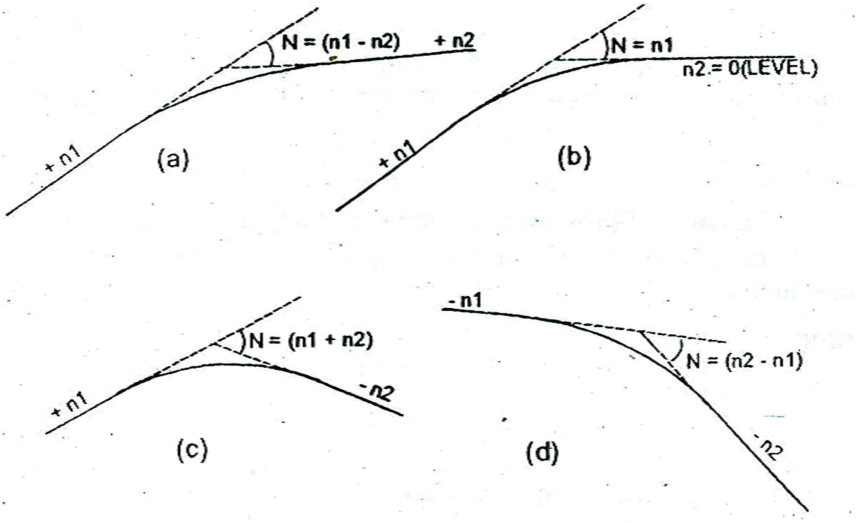


Fig. 4.34 Types of summit curves

Valley curves:

- Valley curves or sag curves with convexity downwards are formed in anyone of the cases illustrated in Fig. 4.36 - (a), (b), (c) or (d).
- The deviation angle, N between the two intersecting gradients is equal to the algebraic difference between them. Among all the cases the maximum possible deviation angle is obtained when a descending gradient (- n_1) meets with an ascending gradient (+ n_2). Therefore deviation angle, N = - n_1 - (+ n_2) = - (n_1 + n_2).
- As fast moving vehicles negotiate valley curves, the centrifugal force developed acts down ward in addition to the self weight, thus adding additional pressure on the suspension system of the vehicle and discomfort to passengers due to impact, unless the valley curve is properly designed and laid.

- There is no problem of restriction to sight distance in valley curves during day light. However, during night driving under head lights of vehicles, the sight distance available at valley curve is restricted.

Therefore the important factors to be considered in valley curve design are:

- Impact-free movement of vehicles at design speed or the comfort to the passengers
- Providing adequate sight distance under head lights of vehicles for night driving.

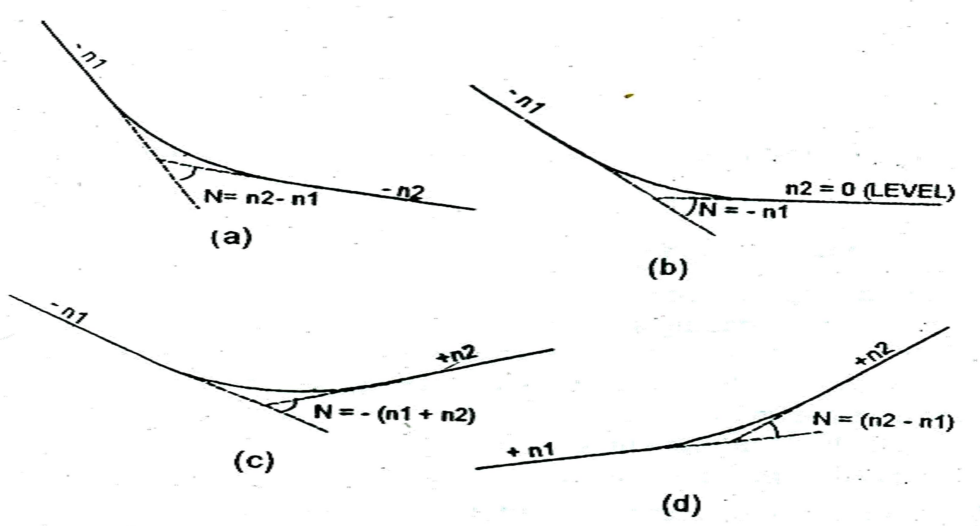


Fig. 4.36 Types of valley curves

- Locating lowest point of the valley curve for providing suitable cross drainage facilities so as to prevent stagnation of water during rains.

6. Explain the factors governing (control) geometric design of highway elements.

The geometric design of highways depends on several design factors. The important factors which control the geometric elements are:

(a) Design speed

(b) Topography or terrain

(c) Traffic factors

(d) Design hourly volume and capacity

(e) Environmental and other factors

Design speed:

- The design speed is the most important 'factor controlling the geometric design elements of highways.
- The design speed is decided taking into account the overall requirements of the highway.
- In India, different speed standards have been assigned depending upon the importance or the class of the road such as National/State Highways, Major/Other District Roads and Village Roads.
- Further the design speed standards are modified depending upon the terrain or topography. Similarly urban roads have a different set of design speeds.
- Design of almost every geometric design element of a road is dependent on the design speed.
- For example, the requirements of the pavement surface characteristics, the cross section element of the road such as, width and clearance requirements, the sight distance requirements are decided based on the design speed of the road.
- Also the horizontal alignment elements such us radius of curve, super elevation, transition curve length and the vertical alignment elements such as gradient, length of summit and valley curves depend mainly on- the design speed of the road.

Topography:

- The topography or the terrain conditions influence the geometric design of highway significantly.
- The terrains are classified based on the general slope of the country across the alignment, as plain, rolling, mountainous and steep terrains.
- The design standards specified for different classes of roads arc different depending on the terrain classification.
- As the speed standards affect every geometric design element, topography also affects the geometric design of roads.
- Further in hilly terrain, it is necessary to allow for steeper gradients and sharper horizontal curves due to the construction problems.

Traffic factors:

- This is a complex problem. The different vehicle classes such as passenger cars, buses, trucks, motor cycles, and various other types of non-motorized vehicles have different speed and acceleration characteristics, apart from having different dimensions and weights.
- However, it is often necessary to consider some standard vehicle as the 'design vehicle'.
- The important human factors which affect traffic behaviour include the physical, mental and psychological characteristics of drivers and pedestrians.

Design hourly volume and capacity:

- The traffic flow or volume keeps fluctuating with time, from a low value during certain off-peak hours to the higher flow during the peak hours.
- Therefore a reasonable value of traffic volume is decided for the design and this is called the 'design hourly volume.
- The ratio of volume to capacity affects the 'level of service' of the road.

Environmental and other factors:

- The environmental factors such as aesthetics, landscaping, air pollution, noise pollution

and other local conditions should be given due consideration in the design of road geometries.

- Some of the arterial high speed highways and expressways are designed for higher speed standards and uninterrupted flow of vehicles by providing controlled access and grade separated intersections

7. Explain the highway cross section elements.

The following are the elements of highways:

1. Cross Slope or Camber
2. Width of Pavement or Carriageway:
3. Medians/Traffic separators:
4. Kerbs:
5. Road Margins:
    - Shoulders
    - Guard rails
    - Drive way
    - Cycle tracks
    - Parking lanes

- Bus bays
- Lay-byes
- Frontage roads
- Embankment slopes

6. Width of Formation or Roadway:

7. Right of Way and Land Width:

Typical Cross Sections of Roads:

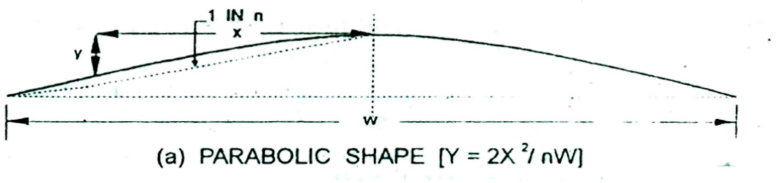
Some of the typical cross sections of different categories of highways in rural areas and a typical urban arterial road are shown in Fig.

1. Cross slope or chamber

Cross slope or camber is the slope provided to the road surface in the transverse direction to drain off the rain water from the road surface. Drainage and quick disposal of water from the pavement surface by providing cross slope is considered important because of the following reasons

i. To prevent the entry of surface water into the pavement layers and the sub-grade soil through pavement; the stability, surface condition and the life of the pavement get adversely affected if the water enters in to the sub-grade and the soil gets soaked.
ii. To prevent the entry of water into the bituminous pavement layers, as continued contact with water causes stripping of bitumen from the aggregates and results in deterioration of the pavement layer.

Shape of cross slope:



(a) PARABOLIC SHAPE [Y = 2X ²/ nW]

2. Width of pavement or carriageway:

The width of the pavement or carriage way depends upon

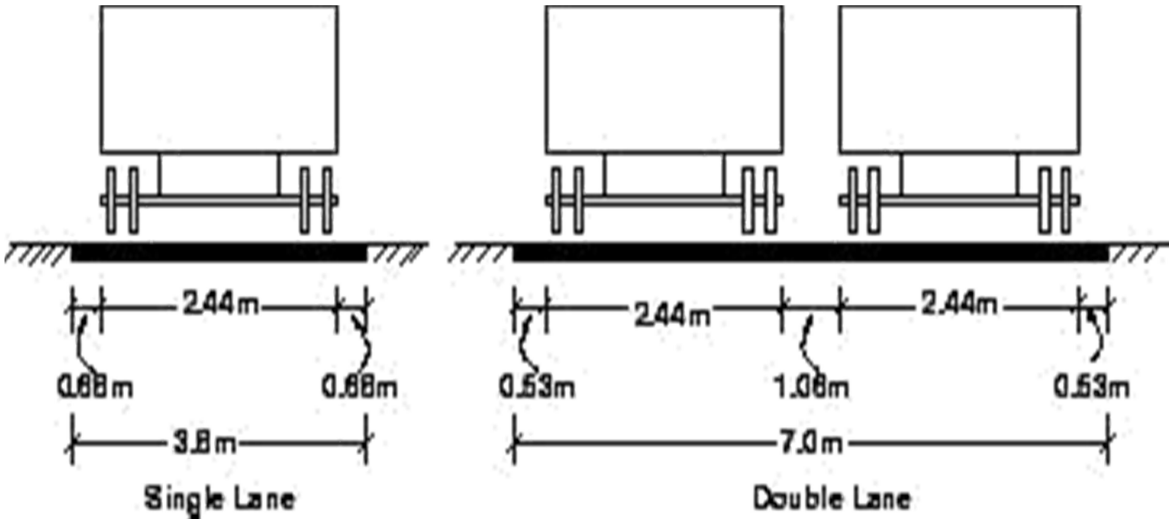
i. Width of the traffic lane

ii. Number of lanes

The portion of carriage width that is intended for one line for traffic movement is called a traffic lane.

As different classes of vehicles travel along the same roadway generally the lane width is decided based on a standard vehicle, such as the passenger car. However it is also necessary to consider the maximum width of the larges

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



3. Medians /Traffic separators

In highways with divided carriageway, a median is provided between two sets of traffic lanes intended to divide the traffic moving in opposite directions on adjacent lanes is called traffic separators

The main function of the median is to prevent head on collision between vehicles moving on opposite direction

The medians/traffic separators may also serve the following functions:

a. To channelize traffic into streams at intersections
b. To shadow the crossing and turning traffic
c. To segregate slow traffic
d. To protect pedestrians

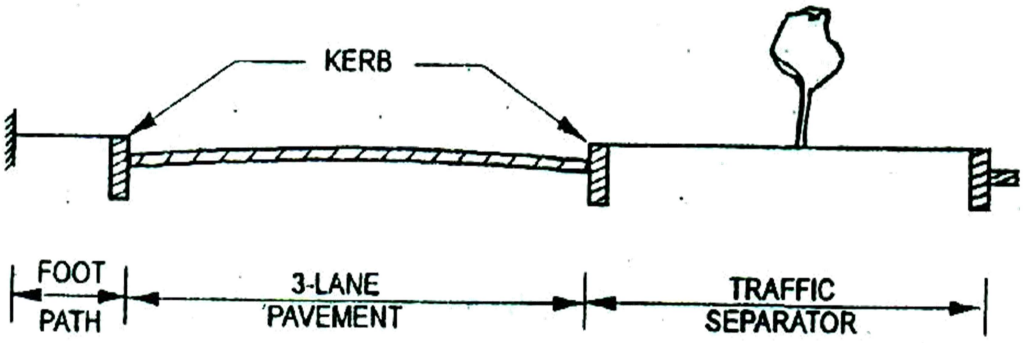


Fig. 4.3 Kerb and traffic separator

4. Kerbs:

- Kerb indicates the boundary between the pavement and median or foot path or island or shoulder . It is desirable to provide kerbs on urban roads. There are a variety of kerb designs. Kerbs may be mainly divided into three groups based on their functions.

(a) Low kerb or mountable type kerb'

(b) Semi-barrier type kerb

(c) Submerged kerb

5. Road Margins:

- The various elements included in the road margins are shoulder, guard rail, foot path, and drive way, cycle track, parking lane, bus bay, lay-bye, frontage road and embankment slope. Shoulders are provided on both sides of the pavement all along the road in the case of undivided carriageway.

- Shoulders are provided along the outer edge of the carriageway in the case of divided carriageway.

- The earth shoulders should have sufficient stability to support even a loaded truck and therefore they are constructed using good quality material.

Guard rails:

- Guard rails are provided at the edge of the shoulder when the road is constructed on a fill so that vehicles are prevented from running off the embankment, especially when the height of the fill exceeds 3 m.

Driveway:

- Drive ways connect the highway with commercial establishment like fuel-stations, service-stations etc.

- Drive ways should be properly designed and located, fairly away from an intersection.

- The radius of the drive way curve should be kept as large as possible, but the

width of the drive way should be minimised to reduce the crossing distance for the pedestrians.

Cycle tracks:

- Cycle tracks are provided in urban areas where the volume of cycle traffic on the road is very high. Refer Fig. 4.10.
- A minimum width of 2 m is provided for the cycle track and the width may be increased by 1.0 m for each additional cycle lane.
- The layout of the cycle tracks should be carefully decided in large highway intersections and traffic rotaries.

Parking lanes:

- Parking lanes are provided on urban roads to allow kerb parking. As far as possible only 'parallel parking' should be allowed as it is safer for moving vehicles.
- Also the clearance available between the parked vehicles and the edge of adjacent lane is more in the case of parallel parking than in angle parking..For parallel parking, the minimum lane width should be 3.0 m.

Bus bays:

- Bus bays may be provided by recessing the kerb to avoid conflict with moving traffic.

Bus bays should be located at least 75 m away from the intersections.

Lay bays:

- Lay-byes arc provided near public conveniences with guide maps to enable drivers to stop clear off the carriageway.
- Lay-byes should normally be of 3.0 width and at least 30 m length with 15 m end tapers on both sides.

Frontage roads:

- Frontage roads arc provided to' give access to properties along an important highway with controlled access to express way or free way.
- The frontage roads may run parallel to the highway and are isolated by a separator, with approaches of the through facility only at selected points, preferably with grade separations.

Embankment

- Embankment slopes should be as flat as possible for the purpose of safe traffic movement and also for aesthetic reasons.
- Though from the slope stability point, a steeper slope may be possible, the slope may be kept as flat as permitted by financial considerations.

For safety considerations, the desirable slope for the embankment is 1 in 3.

6. Width of formation or road way

- Width of formation or roadway is the sum of widths of pavement or carriageway including separators, if any and the shoulders.

Formation or roadway width is the top width or the highway embankment or the bottom width of highway cutting excluding the side drains,

7. Right of way

- Right of way is the area of land acquired for the road, along its alignment.
- The width of the acquired land for right of way is known as 'land width' and it depends on the importance of the road and possible future development.
- A minimum land width has been prescribed for each category of road.

A desirable range of land width has also been suggested for each category of road.

8. Explain about sight distance and give their importance and also explain the limitation of sight distance or visibility.

- One of the important factors on which safe and efficient operation of vehicle on roads depends is the road length when an obstruction, if any, becomes visible to the driver in the direction of travel.
- In other words the distance visible ahead to the driver is very important for safe vehicle operation on a highway.
- 'Sight distance' is the length of road visible ahead to the driver at any instance.
- Sight distance available at any location of the carriageway is the actual distance a driver with his eye level at a specified height above the pavement surface has visibility of any stationary or moving object of specified height which is on the carriageway ahead.
- The sight distance between the driver and the object is measured along the road surface.

Restrictions to sight distance:

Restrictions to visibility or sight distance may be caused in the following circumstances:

Horizontal curves:

At the horizontal curves when the line of sight is obstructed by objects at the inner side of the curve, Here the sight distance is measured along the centre line of the horizontal curve when the vehicle driver is able to see another vehicle or object on the carriageway.

Vertical curves: (Summit curves)

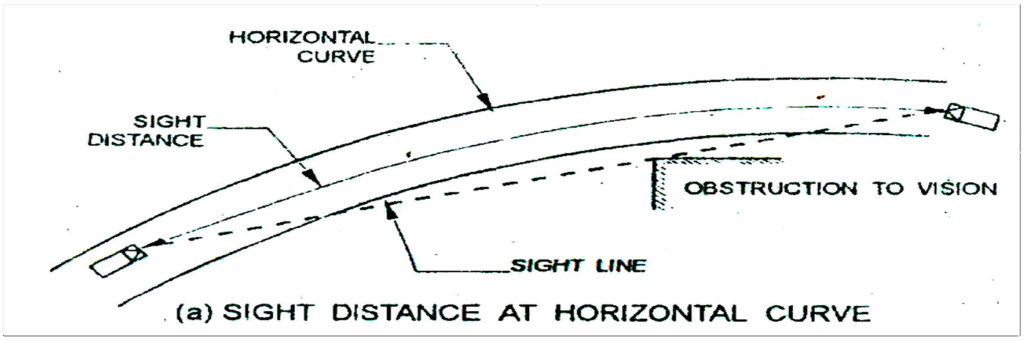
At the vertical curves the line of sight is obstructed by the road surface of the summit curve (i.e., a vertical curve of the road with convexity upwards), as shown in Fig. 4.11.

- In this case also the sight distance is measured along the centre line of the vertical curve when the vehicle driver is able to see another vehicle or object on the road

Uncontrolled intersection:

- At an uncontrolled intersection when a driver from one of the approach roads is able to sight a vehicle from another approach road proceeding towards the intersection, as shown in Fig. 4

Here the sight distance for each vehicle drivel is the distance from the position when the two can see each other up to the intersection point of the two roads as shown.



9. What are the requirements should be taken into account during the design of road geometries?

The following requirements should be taken into account during the design of road geometries:

(a) Safe stopping:

Driver travelling at the design speed has sufficient sight distance or length of road visible ahead to stop the vehicle without collision, in case of any obstruction on the road ahead, As safe stopping is most essential requirement to avoid collision, this requirement has to be invariably fulfilled all along the road.

(b)Safe overtaking

Driver travelling at the design speed should be able to safely overtake the slower vehicles without causing obstruction or hazard to traffic of opposite direction, at reasonable intervals.

(c) Safety at an uncontrolled intersection:

Driver entering an uncontrolled intersection has sufficient visibility to enable him to take control of his vehicle and to avoid collision with another vehicle.

10. Explain briefly about PIEV theory:

According to 'PIEV' theory, the total reaction time of the driver is split into four parts, viz., and time taken by the driver for:

(i) Perception,

(ii) Intellection

(iii) Emotion

(iv) Volition

Perception time:

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

  In other words, it is the time required to perceive an object or situation.

Intellection time

- It is the time required for the driver to understand the situation. It is also the time required for comparing the different thoughts, regrouping and registering

new sensations.

Emotion time

- It is the time elapsed during emotional sensations and other mental disturbance such as fear, anger or any other emotional feelings like superstition etc. with reference to the situation.

The emotion time varies for different drivers, but even for a particular driver the emotion time is likely to vary considerably depending upon the situation or the actual problem involved.

Volition time

- It is the time taken by the driver for the final action, such as brake application
- It is also possible that the driver may apply brakes or take any other avoiding action like turning, by the ***'reflex action'***, without the normal thinking process, which is probably the minimum time for taking a prevent action like brake application.

The PIEV time of a driver also depends on several factors such as physical and psychological characteristics of the driver, type of the problem involved, environmental conditions and temporary factors (e.g., motive of the trip, travel speed, fatigue, consumption of alcohol, etc.).

The total reaction time of an average driver may vary from 0.5 second for simple situations to as much as 3 to 4 seconds or even more in complex problems.

11. Explain the various types transition curve in horizontal alignment.

The following types of transition curves commonly adopted m horizontal alignment of highways are:

(a) Spiral

(b) Lemniscate

(c) Cubic parabola

- The general shapes of these three curves are shown in Fig.4.29
- All the three curves follow almost the same path up to deflection angle of 4°, and practically there is no significant difference even up to 9°.
- In all these curves, the radius decreases as the length increases. But the rate of change of radius and hence the rate of change of centrifugal acceleration is not constant in the case of lemniscates and cubic parabola, especially at deflection angles higher than 4°.

In spiral curve the radius is inversely proportional to the length and the late of change of centrifugal acceleration is uniform throughout the length of the curve. Thus the spiral fulfils the condition of an ideal transition curve.

The Indian Roads Congress recommends the use of the spiral as transition curve in the horizontal alignment of highways due to the following reasons:

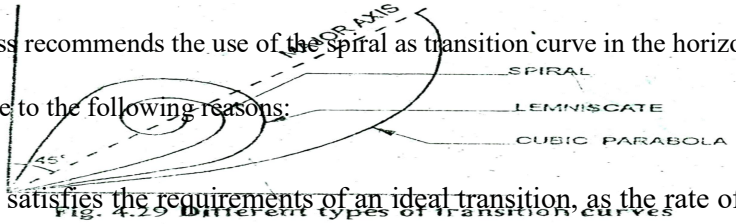


Fig. 4.29 Different types of transition curves

- The spiral curve satisfies the requirements of an ideal transition, as the rate of change of centrifugal acceleration is uniform throughout the length.
- The geometric property of spiral is such that the calculations and setting out the curve in the field is simple and easy.

The equation of the spiral may be written as:

$$L\,R = L_S\,R_C = \text{Constant}$$

Therefore,

Here, m is a constant equal to $2RL_S$ and θ is the tangent deflection angle in radian.

12. Draw the typical cross sections of different categories of highways in rural areas and a typical urban arterial road.

Some of the typical cross sections of different categories of highways in rural areas and a typical urban arterial road are shown in Fig.

1. Cross section of National or State Highway:

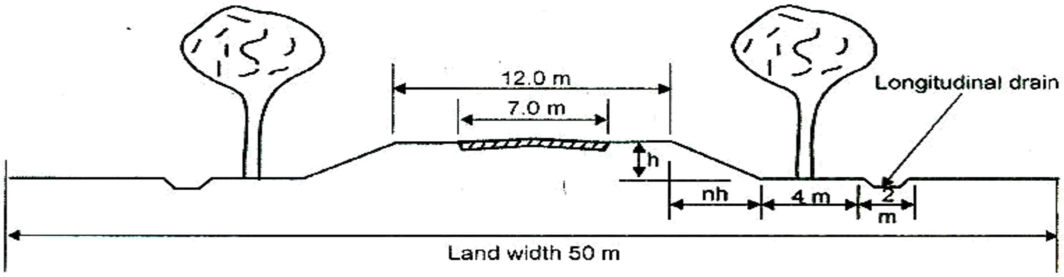


Figure 4.8: Cross-section of National Highway or State Highway in rural area

2. Cross section of major district road:

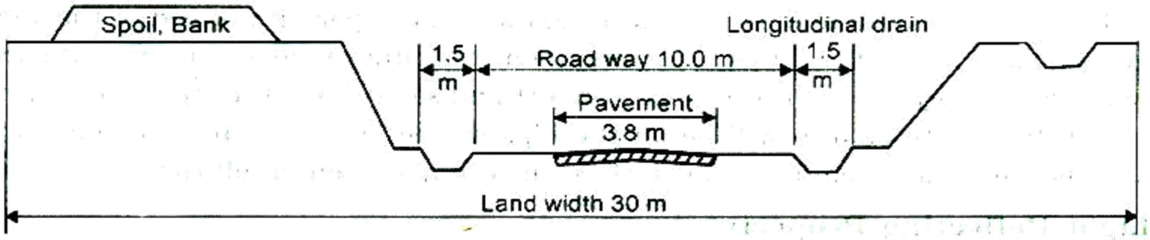


Figure 4.7: Cross-section of Major District Road in cutting

3. Cross section of village road or other district road::

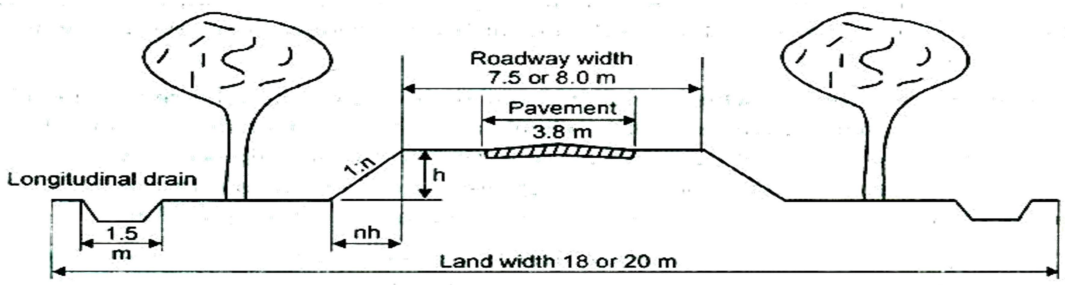


Figure 4.6: Cross-section of Village Road or Other District Road in embankment

4. Cross section of Two lane city road in built up area:

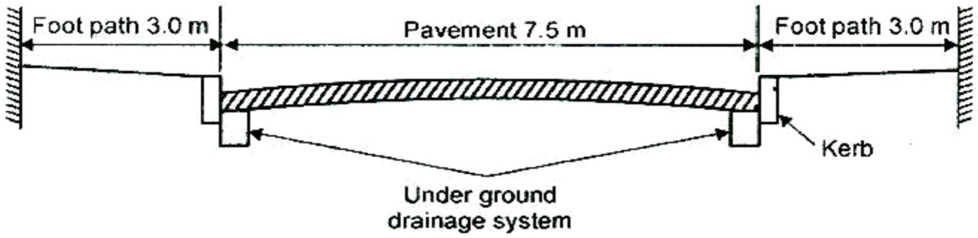


Figure 4.9: Cross-section of two-lane city road in built-up area

5.Cross section of roads in Urban area:

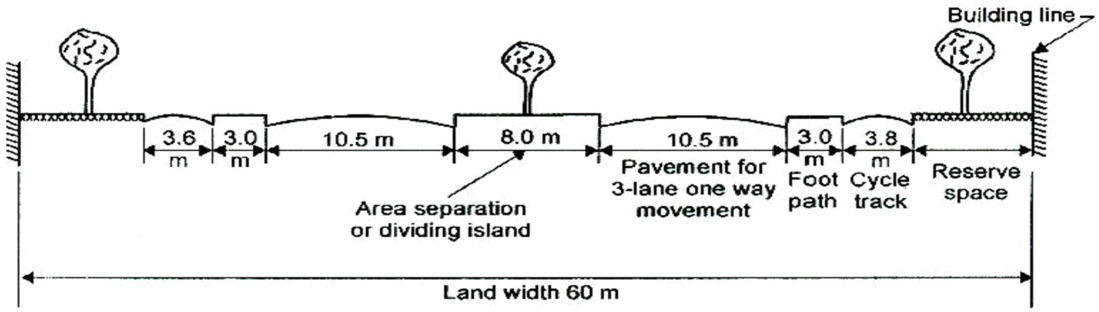


Figure 4.10: Cross-section of divided highway in urban area

13. Discuss the special care to be taken while aligning hill roads.

Special Considerations while Aligning Roads on Hilly Areas

During alignment of hill roads, special care should be taken on the following points which pertain to the hill roads:

a. Stability of hill side slopes
b. Drainage of surface and subsurface water flowing from the hill side
c. Special geometric standards for hill roads, and

Resisting length

Stability:

- While aligning hill roads, special care should be taken to align the road along the side of the hill which is stable.

  A common problem in hill roads is that of landslides.

  The cutting and filling of earth to construct wads on hill-side causes steepening of existing slopes and this affect its stability of the hill slopes.

Drainage:

- Numerous hill-side drains should be provided for adequate drainage facility across the road.

  But the cross drainage structure being costly, attempts should be made to align the road in such a way that the number of, very expensive cross drainage structures are kept minimum.

Geometric standard of hill roads:

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

  The route should enable the ruling gradient to be attained in most of the length, minimizing steep gradients, hair pin bands and needless rise and fall.

Resisting length

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

  In brief, the resisting length of the alignment should keep as low as possible. Thus the ineffective rise and excessive fall should be kept minimum.

14.(i) Explain about Lateral and vertical clearance. (ii) What are the advantage and disadvantages of underpass?

Highways may have to cross a roadway or railway. At this junction grade separation structures are constructed.

Structures may be T-beam Bridge, arch bridge, prestressed concrete bridge, etc. For conventional vehicles, there should be vertical clearance of atleast 4.3 m. For double-decker vehicles the vertical clearance should be 5.2.m.

Grade separated intersections are classified as:

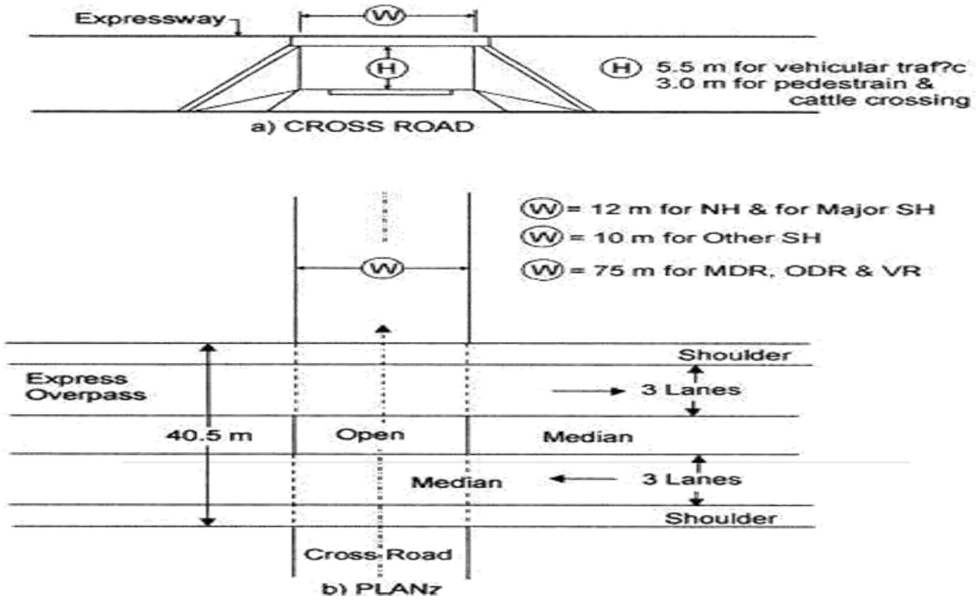
Over-pass

Under-pass

- When the major highway is taken above by raising its profile above the general ground level by embankments and an over-bridge across another highway or railway, it is called as over-pass. If

the highway is taken by depressing it below the ground level to cross another road or railway by means of an under bridge, it is known as under-pass.

- The choice of an over-pass or an under-pass depends on various conditions such as topography, vertical alignment, drainage, economy, aesthetic features and preferential aspects for one of the highways



Underpass for cross-roads in an Express way

Merits and Demerits of Under-pass:

Merits:

- Adequate warning is provided to the traffic in advance due to the presence of an under-pass which can be seen from distance.
- Useful for the turning traffic.

Demerits:

- Possibility of drainage problem at the under-pass where the ground water level rises high.

- During water-logging problem in monsoons, continuous pumping of water may be needed.

- There is some restriction of the vertical sight distance even at the valley curve near the under-pass.

- Unless the clearance is sufficiently large, there is a feeling of restriction to the traffic.

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

15. Explain about extra widening of Pavement on Horizontal Curves.

Widening of Pavement on Horizontal Curves:

Objects:

On horizontal curves, especially when they are not of very large radii, it is a common practice to widen the pavement slightly more than the normal width. The objects of providing extra widening of pavements on horizontal curves are due to the following reasons:

(1) An automobile such as car, bus or truck has a rigid wheel base and only the front wheels can be turned. When the vehicle takes a turn to negotiate a horizontal curve, the rear wheels do not follow the same path as that of the front wheels.

(2) This phenomenon is called 'off tracking'. Normally at low speeds and up to the design speed when no lateral slipping of rear wheels take place, the rear wheels follow the inner path on the curve as compared with those of the corresponding front wheels. This means that if inner front wheel takes a path on the inner edge of a pavement at a horizontal curve, inner rear wheel will be off the pavement on the inner shoulder.

The off-tracking depends on

(i) the length of the wheel base of the vehicle and

(ii) the turning angle or the radius of the horizontal curve negotiated.

(3) At speeds higher than the design speeds when the super elevation and lateral friction developed are not fully able to counteract the outwards thrust due to the centrifugal force, some

transverse skidding may occur 'and the rear wheels may take paths on the outside of those traced by the front wheels on the horizontal curves. However this occurs only at excessively high speeds.

(4) The path traced by the wheels of a trailer in the case of trailer units, is also likely to be on either side of the central path of the towing vehicle, depending on the speed; rigidity of the universal joints and pavement roughness.

(5) In order to take curved path with larger radius and to have greater visibility at curve, the drivers have tendency not to follow the central path of the lane, but to use the outer side at the beginning of a curve.

(6) While two' vehicles cross or overtake at horizontal curve there' is a psychological tendency to maintain a greater clearance between the vehicles, than on straights for increase safety.

Thus the required extra widening of the pavement at the horizontal curves,We depends on (i) the length of wheel based of the vehicle l, radius of the curve negotiated R and

(ii) the psychological factor which is' a function of the speed of the vehicle and the radius of the curve. It has been a practice therefore to provide extra width of pavement on horizontal curves when the radius is less than about 300 m.

16. Explain the types of gradients

Gradients are divided into four categories:

- Ruling gradient
- Limiting gradient
- Exceptional gradient and

- Minimum gradient.

Ruling gradient:

- Ruling gradient is the maximum gradient within which the designer attempts to design the vertical profile of a road.

- Alignment and accordingly the quantities of cut and fill are decided. Hence ruling gradient is also known as *'design gradient'*.

- Therefore different values of 'ruling gradient' are specified on different terrains. A vehicle which travels with a certain speed on a level ground, with the same tractive effort put in, would lose speed at grades; the speed would steadily decrease with increase in length of grade.

- With the maximum pulling power, the vehicle would be able to sustain the same speed even on long stretches only up to a certain gradient.

- This is when the maximum power developed by the engine is equal to the power required to overcome the resistances to motion on the grade at this speed. Therefore this gradient is the one which should be adopted as 'ruling gradient' by the designer for this vehicle and the design speed. But the problem is not as simple as different vehicles have different values of hauling power and varying tractive resistances.

- The commercial vehicles in particular have to carry different amounts of load. Further in India due consideration is to be given to the pulling power of-animal drawn-vehicles like the bullock carts also.
- The maximum length of ascending gradient which a loaded truck can operate without undue reduction in speed is called 'critical length of grade' for a design. A reduction in speed of about 25 kmph may be considered reasonable limit.
- The critical length for design depends on several factors" such as size, power, load and grade ability data of the truck, its initial speed at the beginning of the ascending grade and the desirable limit of the minimum speed at the end of the grade so as to avoid unreasonable interference with the movement of other vehicles.

- The critical length of ascending gradients should therefore be limited to lower values at steeper gradients.

Thus it is not possible to Jay down precise standards of ruling gradient applicable for the mixed traffic and for the country as a whole.

The IRC -has recommended ruling gradient values of:

(a) 1 in 30 on plain and rolling terrain

(b) 1 in 20 on mountainous terrain and

(c) 1 in 16.7 on steep terrain,

Limiting gradient:

- Where topography of a place compels adopting steeper gradient than the ruling gradient, 'limiting gradient' is used in view of enormous increase in cost in constructing roads with gentler gradients:

- However the length of continuous grade line steeper than ruling gradient should be limited.

- On rolling terrain and on hill roads, it may be frequently necessary to exceed ruling gradient and adopt limiting gradient; but care should be taken to separate such stretches of steep gradients by providing either a level road or a road with easier grade.

Gradients for roads in different terrains

Type of terrain	Ruling gradient	Limiting gradient	Exceptional gradient
Plain or rolling	3.3%(1 in 30)	5%(1 in 20)	6.7%(1 in 15)
Mountainous terrain,steep terrain having elevation more than 3,000 m above	5%(1 in 20)	6%(1 in 16.7)	7%(1 in 14.3)

the mean sea level Steep terrain up to 3,000 m height above mean sea Level	6%(1 in 16.7)	7%(1 in 14.3)	8%(1 in 12.5)

Exceptional gradient

- In some extra ordinary situations it may be unavoidable to provide still steeper gradients than limiting gradient at least for short stretches and in such cases the steeper gradient up to exceptional gradient' may be provided.

- However the exceptional gradient should be strictly limited only for short stretches not exceeding about 100 m at a stretch.

- The maximum values of ruling, limiting and exceptional gradients recommended by the IRC in different terrains are given in Table 4.16.

Minimum gradient:

- The road can be level, with little or no gradient. In' such cases, there will be problems of drainage.

- Though the surface water can be drained off to the side drains by-providing proper camber on the pavement surface and cross slope on the shoulders, a certain longitudinal slope is essential, to drain the water along the side drains depending on the surface of the drains.

- Suppose the road is with zero gradient passing through level land and opel1 side drains are provided with a gradient of say 1 in 400.

- It may then be necessary to deepen the downstream end of the drain by about 2.5 m for one km length of road. This is not possible from practical considerations. Hence from drainage point of view, it is desirable to 'have a certain 'minimum gradient' on roads provided topography favours this.

- The minimum gradient would depend on the amount of rain fall, type of soil, runoff, topography and other site conditions.

- A minimum gradient of about 1 in 500 may be sufficient to drain water in concrete drains-or gutter; but on inferior surfaces of drains a slope of 1 in 200 or 0.5 percent may be needed where as on kutcha open drains or soil drains, steeper slopes up to 1 in 100 or 1.0 percent may be needed depending on the soil type.

17. Explain the general principles to be followed in the design of Horizontal alignments.

While designing the horizontal alignment, the following general principles shall be kept in view:

1. Alignment should be fluent and it should blend well with the surrounding topography.
2. On new roads, the curves should be designed to have largest practical radius, but in no case less than ruling value corresponding to ruling design speed.
3. As a normal rule, sharp curves should not be introduced at the end of long
4. The curves should be sufficiently long and they should have suitable transitions to provide pleasing appearance.
5. Reverse curves shall be avoided as far as possible. Where unavoidable, sufficient length between two curves shall be provided for introduction of requisite transition curves.
6. Curves in the same direction, separated by short tangents known as broken back curves, should be avoided as far as possible.
7. To avoid distortion in appearance, the horizontal alignment should be coordinated carefully with the longitudinal profile.
8. Hairpin bends on hilly terrain should be avoided as far as possible.

Horizontal Curves:

- A horizontal highway curve is a curve in plan to provide change in direction to the centre line of a road.

- A simple circular curve may be designated by either the radius, R of the curve in metres or the degree, D of the curve.

- The degree of the curve (D) is the central angle subtended by an arc of length 30 m and is given by the relation, **R x D x (π/180) = 30.**

Therefore the relation between the radius and degree of the circular curve is given by,

R = 1720 / D

- When a vehicle traverses a horizontal curve, the centrifugal force acts horizontally outwards through the centre of gravity of the vehicle.

  The centrifugal force developed depends on the radius of the horizontal curve and the speed of the vehicle negotiating the curve.

- This centrifugal force is counteracted by the transverse frictional resistance developed between the tyres and the pavement which enables the vehicle to change the direction along the curve and to maintain the stability of the vehicle. Centrifugal force P is given by the equation:

$$P = \frac{WV^2}{gR}$$

P - Centrifugal force, kg

W - Weight of the vehicle, kg

R - Radius of the circular curve, m

V - Speed of vehicle, m/sec

G - Acceleration due to gravity = 9.8 m/sec^2

The ratio of the centrifugal force to the weight of the vehicle, P/w is known as the centrifugal ratio' or *the **'impact factor'***. Therefore centrifugal ratio"

$$\frac{P}{W} \quad \frac{V^2}{gR}$$

The centrifugal force acting on a vehicle negotiating a horizontal curve has the following two effects:

(i) Tendency to overturn the vehicle outwards about the outer wheels and

(ii) Tendency to skid the vehicle laterally, outwards

The analysis of stability of those two conditions against overturning and transverse skidding of the vehicles negotiating horizontal curves without super elevation are given below:

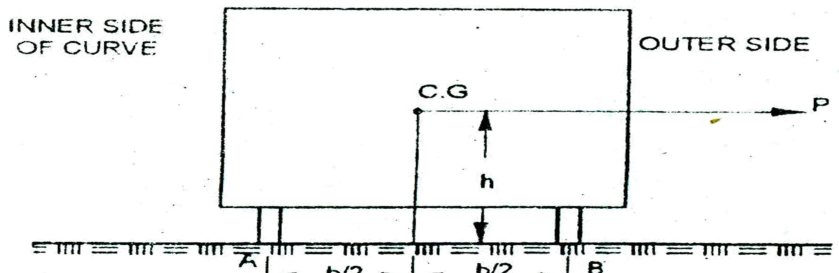
Overturning effect:

The centrifugal force that tends the vehicle to overturn about the outer wheels B on horizontal curve without super elevation is illustrated in below Fig. Let h be the height of the centre of gravity of the vehicle above the road surface and b be the width of the wheel base or the wheel track of the vehicle.

The overturning moment due to centrifugal force, P = P x h

This is resisted by the restoring moment due to weight of the vehicle Wand is equal to (W x b/ 2).

The equilibrium condition for overturning will occur when Ph = Wb/2 or when P/W = (b /2h). This means that there is danger of overturning when the centrifugal ratio P/W or V^2/gR attains a values of' b/2h.



Transverse skidding effect:

The centrifugal force developed has also the tendency to push the vehicle outwards in the transverse direction. The forces developed under this condition are shown in below Fig. If the centrifugal force developed exceeds the maximum transverse friction force or transverse skid resistance counteracting the centrifugal force, the vehicle will start skidding in the transverse direction.

The equilibrium condition for the transverse skid resistance developed is given by:

$$P = F_A+F_B=f\,(R_A+R_B) = f\,W$$

In the above relation, f is the coefficient of friction between the tyre and the pavement surface in the transverse direction, R_A and R_B are normal reactions at the wheels A and B such that (K_A+R_B) is equal to the weight W of' the vehicle, as no Super elevation has been provided in this case.

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

Thus to avoid both overturning and lateral skidding on a horizontal curve, the centrifugal ratio should always be less than (b/2h) and also transverse friction coefficient, f.

Super elevation:

In order to counteract the effect of centrifugal force and to reduce the tendency of the vehicle to overturn 01 skid, the outer edge of the pavement is raised with respect to the inner edge, thus providing a transverse slope throughout the length of the horizontal curve.

- ✓ This transverse inclination to the pavement surface is known as ***'super elevation' or cant or banking***. The rate of super elevation "e ' is expressed as the ratio of the height of outer edge with respect to the horizontal width From below Fig., it may be seen that the outer edge of the pavement is raised by NL = E and the rate of super elevation ***e*** may be expressed as:

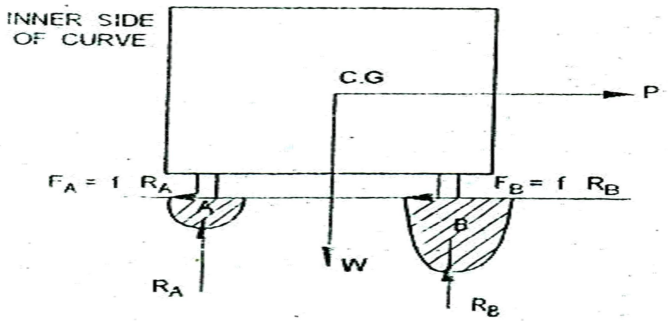


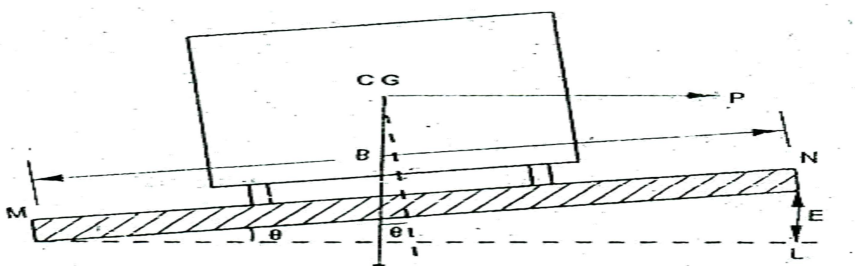
Fig. 4.19 Transverse skidding effect due to centrifugal force

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

In practice the inclination θ with the horizontal is very small and the value of tan θ seldom exceeds 0.07. Therefore the value of than θ is practically equal to sinθ

This is measured as the ratio of the relative elevation of the outer edge, E to width of pavement, B. This is more convenient to measure in the fig:

If e is the super elevation rate and E is the total super elevated height of outer edge, the total rise in outer edge of the pavement with respect to the inner edge = 0 NL =E- e B.



Analysis of super elevation:

The forces acting on the vehicle while moving on a circular curve of radius I metres at speed of v m/sec are shown in below Fig. These forces are:

(a) The centrifugal force P = (Wv2/gR) acting horizontally outwards through the centre of gravity, CG

(b) The weight W of the vehicle acting vertically downwards through the CG

(c) The frictional force developed between the wheels and the pavement counteraction transversely along the pavement surface towards the centre of the curve

Widening of Pavement on Horizontal Curves:

(1) An automobile such as car, bus or truck has a rigid wheel base and only the front wheels can be turned. When the vehicle takes a turn to negotiate a horizontal curve, the rear wheels do not follow the same path as that of the front wheels.

(2) This phenomenon is called 'off tracking'. Normally at low speeds and up to the design speed when no lateral slipping of rear wheels take place, the rear wheels follow the inner path on the curve as compared with those of the corresponding front wheels.

(3) This means that if inner front wheel takes a path on the inner edge of a pavement at a horizontal curve, inner rear wheel will be off the pavement on the inner shoulder.

(4) The off-tracking depends on (i) the length of the wheel base of the vehicle and (ii) the turning angle or the radius of the horizontal curve negotiated. This is illustrated in Fig. 4.25

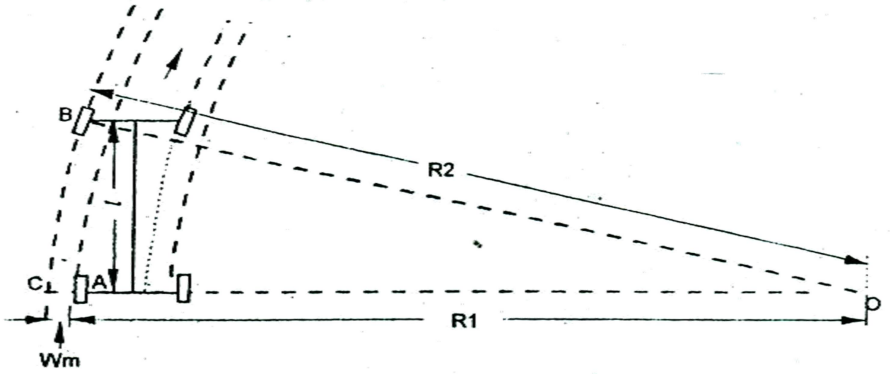


Fig. 4.25 Off-tracking and mechanical widening on horizontal curve

(5) At speeds higher than the design speeds when the super elevation and lateral friction developed are not fully able to counteract the outwards thrust due to the centrifugal force, some transverse skidding may occur 'and the rear wheels may take paths on the outside of those traced by the front wheels on the horizontal curves. However this occurs only at excessively high speeds.

(6) The path traced by the wheels of a trailer in the case of trailer units, is also likely to be on either side of the central path of the towing vehicle, depending on the speed; rigidity of the universal joints and pavement roughness.

Horizontal Transition Curves:

- A transition curve has a radius which decreases from infinity at the tangent point to a designed radius of the circular curve.

- When a transition curve is introduced between a straight and circular curve, the radius of the transition curve-decreases and becomes minimum at the beginning of the circularcurve

- The rate of change of radius of the transition curve will depend on the shape of the curve adopted-and the equation of the curve.

18. List the various technical guidelines recommended for safe, comfort in case of Highway horizontal Curves. *(Nov/Dec-2015)*

- ✓ Alignment should be fluent and it should blend well with the surrounding topography.

- ✓ On new roads, the curves should be designed to have largest practical radius, but in no case less than ruling value corresponding to ruling design speed.
- ✓ As a normal rule, sharp curves should not be introduced at the end of long tangent since these can be extremely hazardous.
- ✓ The curves should be sufficiently long and they should have suitable transitions to provide pleasing appearance.
- ✓ Reverse curves shall be avoided as far as possible. Where unavoidable, sufficient length between two curves shall be provided for introduction of requisite
- ✓ transition curves.
- ✓ Curves in the same direction, separated by short tangents known as broken back curves, should be avoided as far as possible.
- ✓ To avoid distortion in appearance, the horizontal alignment should be coordinated carefully with the longitudinal profile.
- ✓ Hairpin bends on hilly terrain should be avoided as far as possible.
- ✓ All horizontal curves shall consist of circular portion flanked by spiral transitions at both ends.

Super elevation:

- ✓ Super elevation shall be provided on curves as per details given in IRC:73 corresponding to the design speed adopted.
- ✓ Super elevation shall be limited to 7 per cent.
- ✓ Super elevation shall not be less than the minimum specified cross fall/camber.

Radii of Horizontal Curves

The radius of horizontal curves for various terrain conditions shall not be less than the desirable values given in below Table except where site conditions are restrictive and adequate land is not available.

Where such restrictions exist, the radius of curve shall not be less than the specified absolute minimum value.

Nature of terrain	Desirable minimum	Absolute minimum
Plain	360 m	230 m
Rolling	230 m	155 m
Mountainous	90 m	60 m
Steep	60 m	30 m

Transition Curves:

Minimum length of transition curve shall be determined from the following two considerations and the larger of the two values adopted for design:

(i) The rate of change of centrifugal acceleration should not cause discomfort to drivers. From this consideration, the length of transition curve is given by:

$$Ls = 0.0215\ V^3/CR,$$

Where,

Ls = Length of transition curve in metres, V

= Speed in km/hr,

R = Radius of circular curve in metres,

C = 80/(75 + V) (subject to a maximum of 0.8 and minimum of 0.5) The rate of change of super elevation should be such as not to cause discomfort to travelers. Further, rate of change should not be steeper than 1 in 150 for roads in plain/rolling terrain, and 1 in 60 in mountainous/steep terrain. The formula for minimum

length of transition on this basis is:

$$Ls = 2.7\ V2/R$$

UNIT III

General

In order to provide, safe and comfortable journey of the vehicles on road, it is necessary to provide stable, strength and smooth road surface.

The requirements of a road user or any road surface will be,

- The vehicle should operate with a defined speed range.
- The roughness of the pavement surface should not generate any vibration above the tolerance level.
- The safe operation of the vehicle should be compromised.

1. EXPLAIN IN DETAIL ABOUT PAVEMENT COMPONENTS AND THEIR ROLE..

PAVEMENT

In highway engineering, the term 'pavement' means that the layers which are included to form a highway or road.

Purpose of Highway Pavement and Pavement Design

Highway design is very important for the following purposes.

- ✓ To keep the elastic deformation of the pavement within the permissible limits.
- ✓ To provide the safe, smooth and comfortable journey for the road – users.
- ✓ To reduce the operating and maintenance cost of both vehicle and road construction.

PAVEMENT COMPONENTS AND THEIR ROLE

WEARING (OR) SURFACE COURSE

This is uppermost layer of the highway. Its thickness is very low, when compared to outer layers. It resists the abrasion of the wheel on vehicle, impacts caused by the wheel loads and weather effects on road surface.

The various purposes of providing the wearing surface are:

a. To provide smooth surface fro comfortable journey
b. To resist the pressure of tyres.
c. To withstand the abrasion due to traffic.
d. To protect the bottom layers from action of rain and provides a water tight barrier against water infiltration.

In bituminous pavement, the wearing surface will be of bituminous surfacing and for rigid pavements; the wearing course may be cement concrete.

The type of the wearing surface depends on the following factors:

a. Availability of material
b. Availability of plants and equipments
c. Magnitude of surface loads

There is no specific test for evaluation of structural stability of the wearing surface and however **Marshall Stability Test** is used to calculate the strength of bitumen binder and **Plate Bearing Teat**, **Benkelman beam test** are some of the methods used to evaluate the wearing course and the pavement as a whole.

BASE COURSE

It is the layer of selected material, above the sub base (or) sometimes sub grade to support the surface of the highway. It is designed to distribute the wheel loads over the sub base or road bed.

SUB-BASE

It is also the layer of selected material placed between the sub grade and base course to support the base course.

This is the layer of pavement made of broken stones, bound or unbound aggregates. In some cases, the sub base may be of stabilized earth or some selected granular soil.

When sub grade consists of fine grained soil and carries heavy loads, from undulations and unevenness of pavement surface. Sub base is having the same function of base course and they are used to distribute the load to the soil sub grade in flexible pavements.

Base course are used for rigid pavements. They are,

- ✓ Prevention of pumping
- ✓ Prediction of sub grade against frost action

Hence the basic purpose of providing the base course and sub base is to distribute the compressive stress and to prevent the shear deformation and consolidation deformations.

SUB-GRADE

It is the layer on the road bed, on which the pavement structure and shoulders are constructed.

It is a layer of natural soil prepared to receive the layers of pavement materials placed over it. The loads on the pavement are finally received by the sub-grade for distribution to the earth mass.

The top 500 mm thickness layer of the sub grade soil is well compacted under the conditions of maximum moisture content with maximum dry density.

It is important to evaluate the soil strength of the sub-grade and numerous testing methods are available for measuring the strength properties of the sub-grade soil.

- CBR Test (California Bearing Ratio Test)
- CRV Test (California Resisting Test)
- Tri-axial compression test
- Plate- bearing test

ROAD BED

Road bed is defined as the graded portion of a highway within top and side slopes prepared as foundation for the pavement structure.

Functions of Pavement Components

The general functions of a pavement component is given as

- ✓ Traction
- ✓ Protection
- ✓ Distribution

2. WRITE THE CLASSIFICATION OF PAVEMENT STRUCTURE.

Classification of Pavement Structure

Based on the structural behaviour, the highway pavements are classified as,

1. Flexible pavement
2. Rigid Pavement
3. Semi-flexible pavement
4. Semi-rigid pavement
5. Composite pavement

Flexible Pavement

Flexible pavements are defined as the highway pavements with low flexural strength against the action of loads. For undulated lower layer of the flexible pavement makes the undulated surface of the pavement. A typical flexible pavement consists of the following components:

a. Soil sub-grade
b. Sub base course
c. Base course
d. Surface course

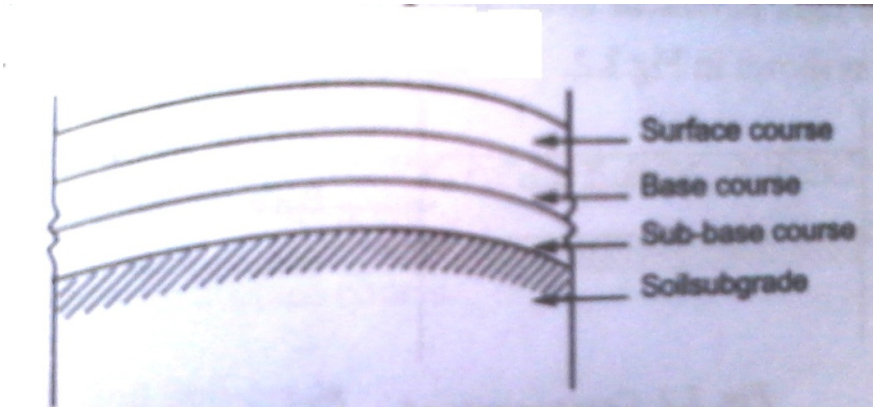
A layers of this flexible pavements, transmits the compressive loads to the lower layer by grain to grain transfer.

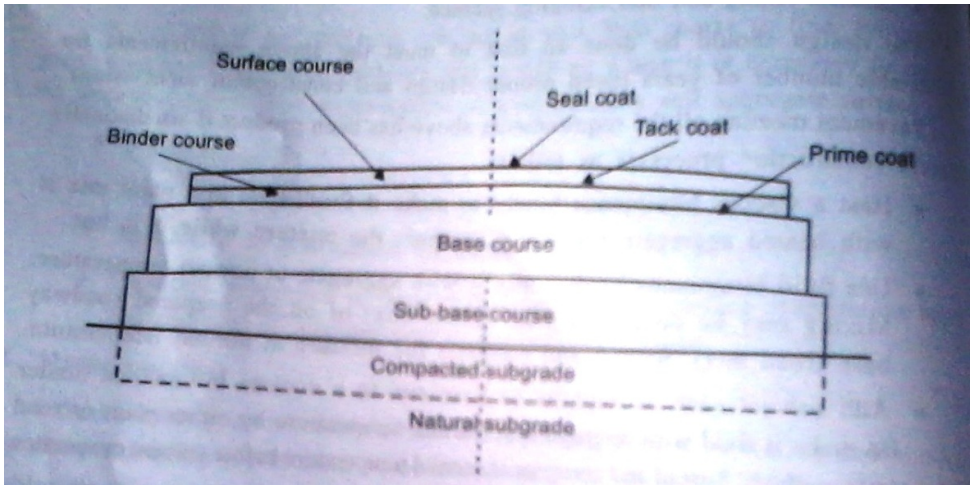
On the pavement surface, the compressive stress will be maximum due to the direct contact of wheel loads on the surface.

Due to this ability of distributing the pressure, to a larger area, the stresses get decreased at the lower layers. For taking the complete advantages of stress distribution from top to bottom, the layer system phenomena have been adopted in flexible pavement.

In case of flexible pavement, the top layer takes the maximum compressive loads and only the top layer is subjected to high rate of wear and tear and impact. The lower layers take minimized or reduced stress intensities and hence the top layer should be constructed by superior materials and the lower layers may be of inferior materials with lower cost.

Flexible pavements are designed by using empirical design charts or equations by considering some design factors.





Rigid Pavements

The Rigid pavements are defined as the Highway pavements with high flexural strength, against the action of loads.

The stresses are not transferred from grain to grain to the lower layers, as in the case of flexible pavements.

The rigid pavements are made of cement concrete (with or without steel reinforcement) are pre-stressed concrete slabs. The P.C.C slabs are expected to take up about 3500 to 4500 kN/m^2 flexural stress.

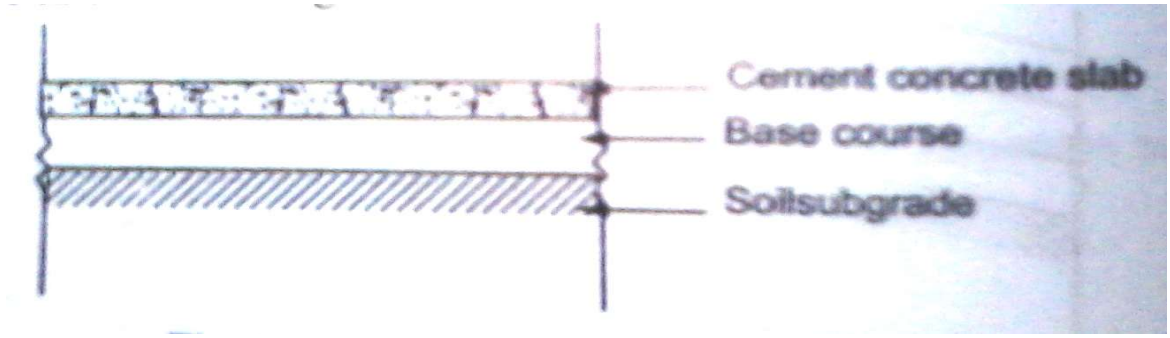
Due to the larger area of the concrete slab, the wheel load will be transferred through the slabs (due to slab action) below.

When bending of the slabs and temperature variations occur in the rigid pavement, the tensile stress also produced in the pavement.

In general, the rigid pavement structure consists of a C.C slab, over the granular base or sub base as shown in figure.

Sometimes, the concrete slab may directly be laid over the soil sub grade (without sub base course) and which is not suitable for the sub grade consists of fine grained soil. Providing a good sub base course under the CC slab will increase the life of the pavement structure.

Rigid pavements are designed and the stresses are analysed by using the elastic theory. The elastic theory is based on the assumption that, the pavement is an elastic plate, resting over an elastic (or viscous) foundation.



Semi-Rigid Pavements

In the flexible pavements, if the base course layer of some standard material is replaced by the soil cement mixture or lime- fly ash aggregate mix is called semi rigid pavements.

The semi rigid pavements are designed as either flexible pavement design method (with some corrections) or by using new design methods.

These pavements are provided with surface course as in the case of flexible pavement, in order to withstand the action of impact loads and wear and tear.

3. DIFFERENTIATE BETWEEN FLEXIBLE AND RIGID PAVEMENTS.

Difference between Flexible and Rigid Pavements

S.No	Parameter	Flexible Pavements	Rigid Pavements
1	Flexural Strength	Low or negligible	High strength
2	Layers	Consists of series of layers with high quality material	Consists of one course cement concrete slab of high bending resistance
3	Stability	Depends on the aggregate interlock - particles friction and cohesion	Depends on pavement slab by beam action
4	Design parameters	Layering system concept	Beam action concept
5	Stress (or) load	Compressive load	Both compressive and tensile stress
6	Designing system	Based on empirical charts or equation	Based on elastic theory
7	Stress distribution	Compressive stress distributed to the soil sub grade by grain to grain transfer	No such grain to grain transfer of load or stress
8	Material	Granular material	Portland cement concrete slab of strength 3500 to 4500 kN/m^2

4. EXPLAIN IN DETAIL ABOUT DESIGN OF PAVEMENT.

DESIGN PRINCIPLES

The various factors to be considered for the design of pavements are:

1. Design wheel load
2. Sub-grade soil
3. Climatic factors
4. Pavement component materials
5. Environmental factors
6. Special factors, etc.,

The above factors are considered, based on the pavement type to be chosen.

It is important to choose the type of pavement, before the pavement is to be designed and various factors to be considered for the selection of pavement are:

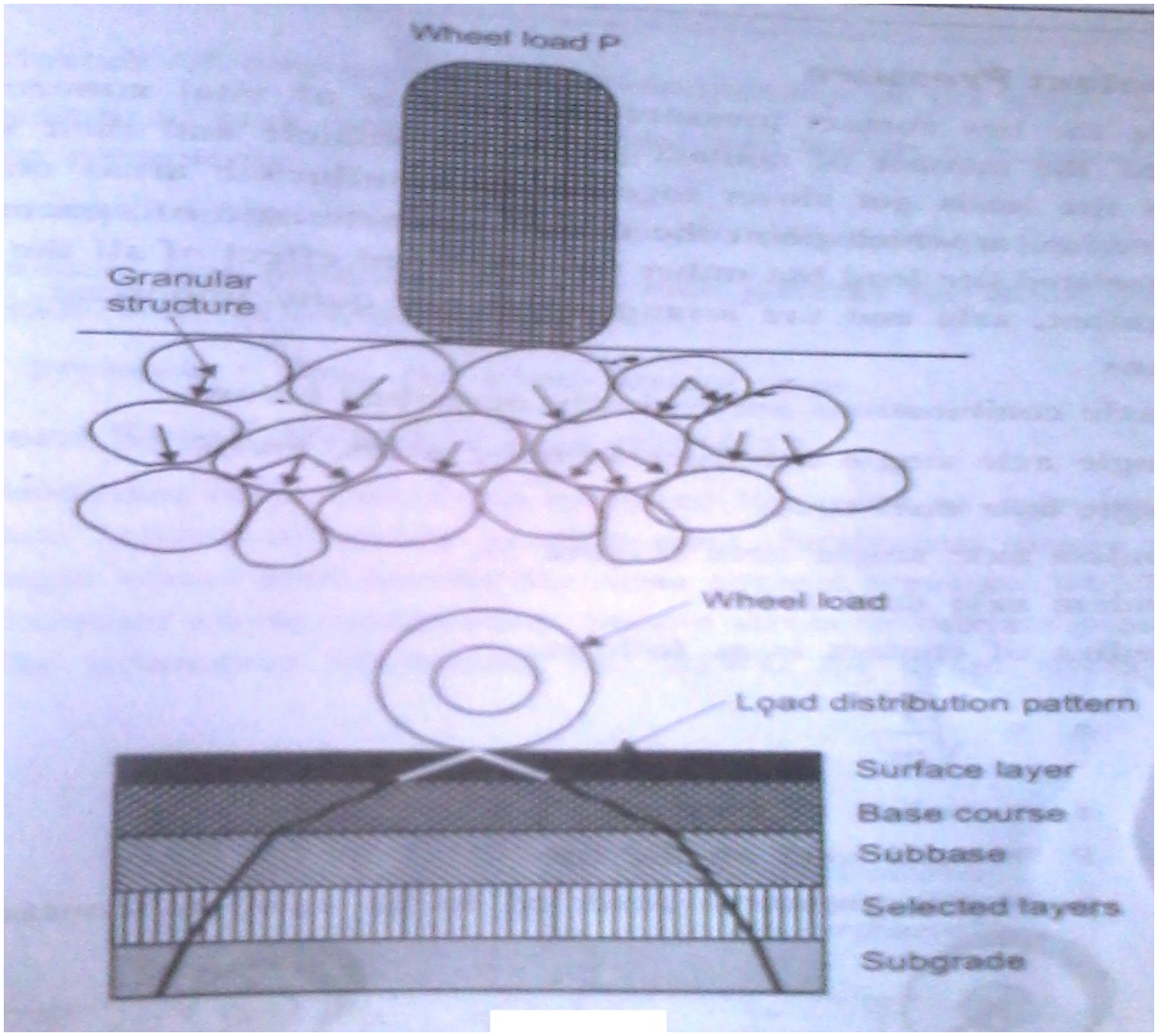
- Amount and type of traffic
- Sub-grade soil conditions
- Cost of materials, construction, etc
- Expected life of the pavement structure
- Available of financial sources.

Design Consideration

1. Design Wheel load

The thickness of the pavement and various layers thickness depend on the wheel load considerations. In design load considerations, the following parameters are included,

- Maximum wheel load
- Contact pressure
- Load repetition and ESWL
- Dynamic effects of transient loads



- **Maximum wheel load**

Indian Road Congress has specified for highways, the maximum legal axle load of 8200 kg and tandem axle load of 14500 kg. Load on the one set of dual tyres is one half of the axle, i.e., 4100 kg.

The maximum safe laden weight of the vehicle or combination should not exceed the limit and the limit is given by,

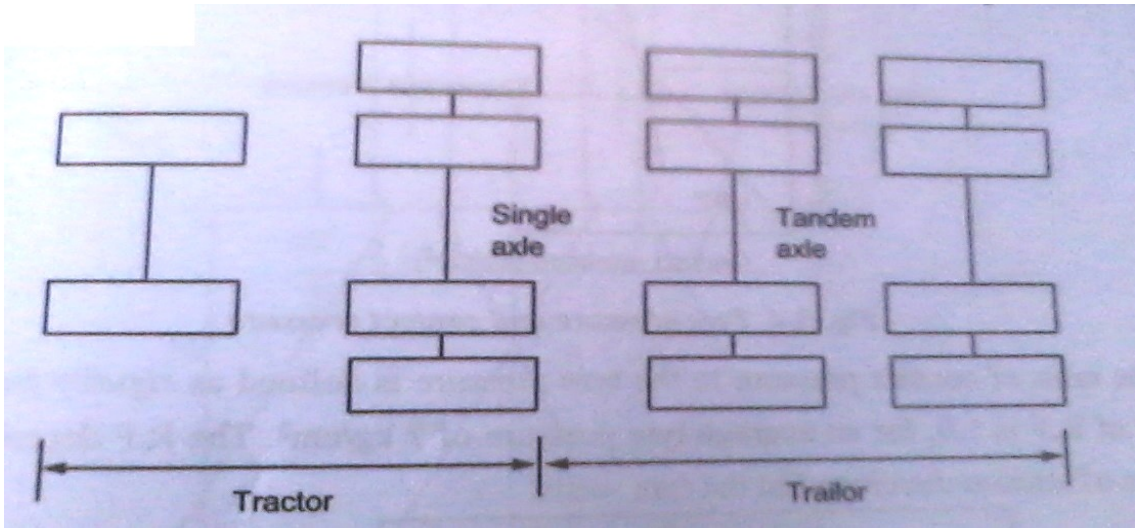
$$W = 465\ (24 + 3.28L) - 14.6\ L^2$$

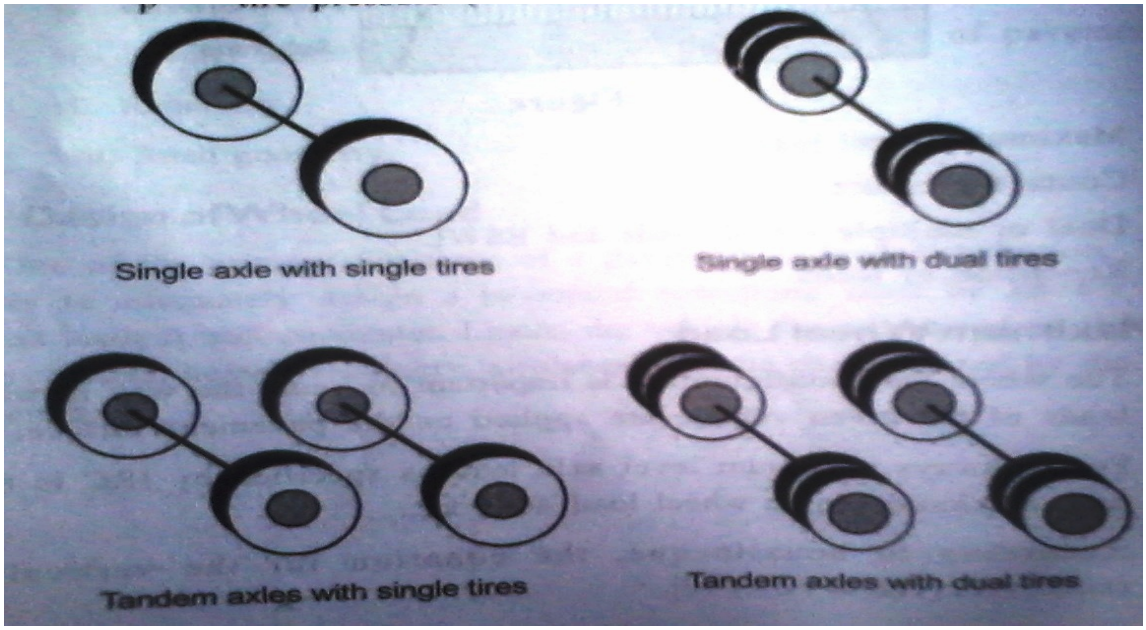
Where,

W = Maximum safe laden weight in kg

L = Distance between extreme axles in metres

The wheel load configuration of a tractor trailer unit of heavy duty vehicles is as shown in figure.





Total load of the wheels influences, the thickness of the each layer of the pavement and tyre pressure influences the quality of the wearing surface.

Based on Boussineq's theory, the vertical stress at any depth 'd' will be,

$$\sigma_{d=} p \{ 1 - \frac{d^3}{(x^2 + d^2)3/2} \}$$

where, p = surface pressure in kg/m^2

x = radius of the loaded area in m

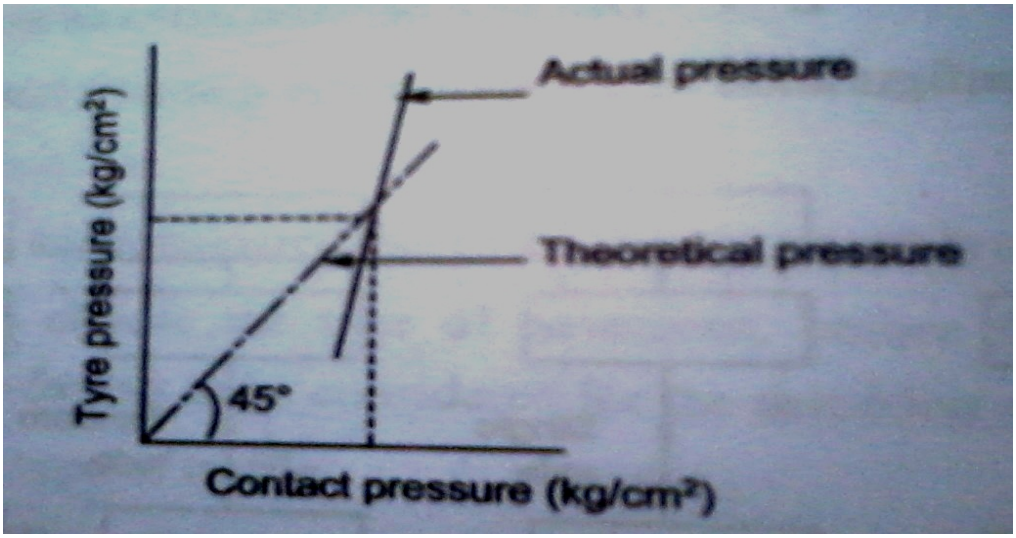
- **Contact Pressure**

Tyre pressure is an important factor of deciding the wearing surface. Tyre pressure is predominating in the upper layers and at a greater depth; the effect of tyre pressure is almost zero. The total depth (or) thickness of the pavement is not decided by tyre pressure, whereas tyre pressure only influences the material used for top surface.

The contact pressure may be calculated from the following formula

$$Contact\ Pressure = \frac{Load\ on\ wheel}{Contact\ area\ (area\ of\ imprint)}$$

The general variation between the tyre pressure and contact pressure is shown in figure.



The ratio of contact pressure to the tyre pressure is defined as **rigidity factor**. The value of R.F is 1.0, for an average tyre pressure.

$$Rigidity\ Factor = \frac{Contact\ Pressure}{Tyre\ Pressure}$$

- **Equivalent Single Wheel Load (ESWL)**

In order to determine the concept, impact of loads on the pavement, the wheel configurations is used. Mostly commercial vehicles are having dual rear wheels and the wheel configurations have considerable influence on the stress distribution and deflection.

It is necessary to provide dual wheel to the rear axles of vehicles, to maintain the maximum wheel load within the specified limit. But, the effect of dual carriage way on the pavement is not equal to two times the effect of the load on any one wheel.

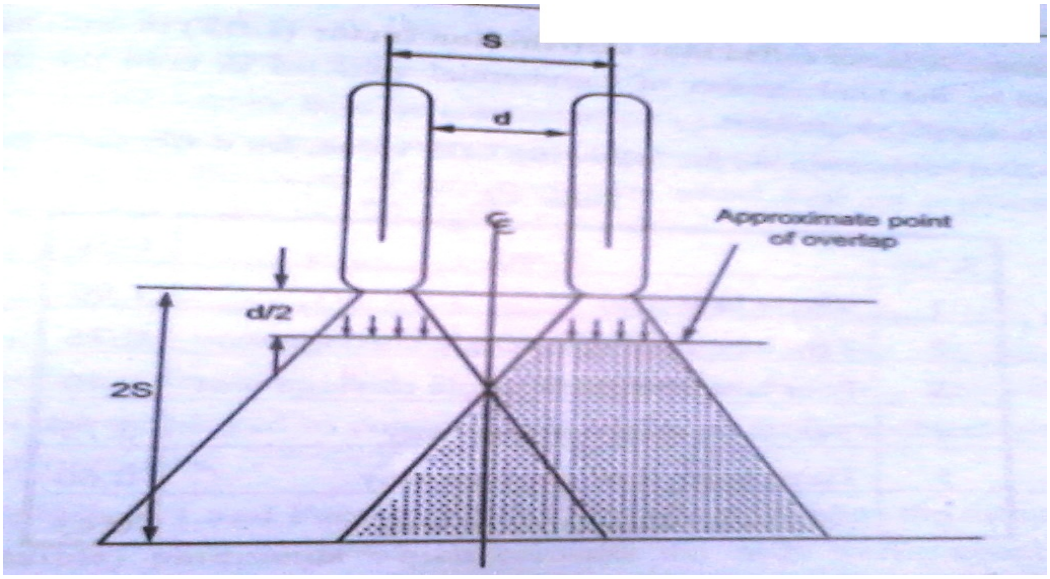
The following figure, explains the concept of the effect between the load carried by a single wheel and a dual wheel.

In order to simplify the analysis the load and stress distribution is assumed to be at an angle of 45^0. In the dual wheel assembly, 'd' will be the clear horizontal distance between two wheels, as shown figure, and 'S' will be the spacing between the centres of the wheel. In this concept, if 'x' be the radius of the circular contact area of each wheel, the spacing is

$$S = d + 2x$$

At any depth greater than 2S, the stress due to the dual wheels is considered to be equivalent to a single wheel load of magnitude 2W.

Stress Overlap Concept of ESWL



Equivalent Single Wheel Load (ESWL) may be calculated based on either equivalent deflection or equivalent stress concept. Multiple wheel loads are converted into ESWL and this value is used in pavement design.

As per the deflection concept, the ESWL is the single wheel load, having the same contact pressure which produces the same value of maximum deflection (Δ) at the depth (d), equal to the thickness of the pavement.

As per the stress distribution concept, the ESWL is the single wheel load producing the same value of maximum stress at desired depth (d) as the dual. Generally, ESWL is determined by this method, using a simple graphical representation.

- **Lane Distribution Factor (LDF)**

Traffic surveys report that, the average total traffic has been counted in both the direction. However for design purposes, the traffic along a particular lane needs to be only considered.

A factor called Lane Distribution Factor (**LDF**) is introduced, which is multiplied by the total number of commercial vehicles in both the direction to obtain traffic along a single lane.

IRC 37-2001 recommended the following LDF value, for different types of roads.

S.No	Road	LDF
1	Single lane road	1.00
2	Two lane road with single carriage way	0.75
3	Four lane road with single carriage way	0.40
4	Two lanes dual carriage way	0.75
5	Three lanes dual carriage way	0.60
6	Four lanes dual carriage way	0.45

- **Vehicle Damage Factor (F)**

Vehicle damage factor is defined as the conversion factor, used in the design of pavement, which converts the commercial vehicles of different axle loads to the number of standard axle load repetitions. It is equivalent to the number of standard axles per commercial vehicles on the road.

IRC recommended the following vehicle damage factor values.

S.No	Range of Commercial Vehicles	Terrain	
		Rolling / Plain	Hill
1	0 to 150	1.5	0.5
2	150 to 1500	3.5	1.5
3	More than 1500	4.5	2.5

- **Repetition of Loads**

Very small deformation of pavement may occur due to the single application of wheel loads. But due to the repeated application of load, there elastic and also plastic deformations will be increased. Due to this, a permanent deformation will occur and results in failure of the pavement.

A detailed traffic survey is to be conducted for calculating the factor of repetitions for wheel loads in the design of pavement. Equivalent Wheel Load is a single load equivalent to

the applications of any particular wheel load on a pavement which requires the same thickness and strength of pavements.

Equivalent Wheel Load Factor (EWLF)

If the failure of a pavement is due to the n1 number of repetitions of P1 kg wheel load and the n2 number of repetitions of P2 kg of wheel load can also cause failure of the same pavement structure, then P1n1 is equivalent to P2n2. Equivalent Wheel Load Factors are employed to convert daily traffic count for each category of wheel load for design purposes.

Equivalent Wheel Load Factor (EWLF) may be defined as the factor used in the design of (flexible) pavements which converts the daily traffic count into single standard wheel load, to the repeated applications of any particular wheel load on a pavement.

2. Pavement Component Materials

The strength behaviour of various pavement materials are analysed for the design purpose. The strength parameters, which are essentially used for design purposes are,

a. California Bearing Ratio (CBR) Value
b. Elastic Constants

a. California Bearing Ratio (CBR) Value

The California Bearing Ratio (CBR) Value is defined as the ratio of force per unit area required to penetrate a soil mass with a circular plunger of 50 mm diameter at the rate of 1.25 mm / minute to that required for corresponding penetration of a standard material.

Various methods are available to design the flexible pavement and IRC recommends that, CBR method if the most commonly adopted method.

b. Elastic Constants

The elastic moduli of different pavement materials are evaluated for the design of pavements, and plate bearing test is employed for this purpose. The modulus of elasticity can be determined by,

Tri-axial Compression Test

The plate bearing test is used to determine the

- ✓ Sub- grade modulus
- ✓ Elastic modulus of base course
- ✓ Elastic modulus of sub-base course

3. Climatic Variations

The pavement performance is very much affected by the variation of climatic conditions due to the variation in stability and the volume of the sub grade soil.

Following are the causes of climatic variations

- Variation in moisture condition
- Frost action
- Variation in temperature

Variation in temperature generally affects the pavement materials like bituminous mixes and cement concrete.

5. WRITE IN DETAIL ABOUT DESIGN OF FLEXIBLE PAVEMENT.

DESIGN OF FLEXIBLE PAVEMENT

The flexible pavements are constructed by number of layers. For designing the thickness of these various layer, various methods are available.

Various procedures for flexible pavement design based on the followed three major concepts,

- Design based on empirical formulas
- Design based on semi empirical formulas
- Design based on theoretical considerations

Empirical methods are based on either physical properties or strength parameters of the soil sub grade.

When the design is based on the stress-strain function and if the design can be modified based on the experience consideration, then it is called semi empirical or semi theoretical approach.

Some designs are based on the theoretical analysis and mathematical applications and it is called theoretical designs.

Out of the various approaches, the following are the available methods for flexible pavement design.

1. G.I Method (Group Index Method)
2. CBR Method (California Bearing Ratio Method)
3. CRV Method (California Resistance Value Method)
4. Mc Leod Method
5. Tri-axial Test Method
6. Burmister Method

In the above methods, G.I Method, CBR Method, CRV Method and Mc Leod methods are **empirical methods.**

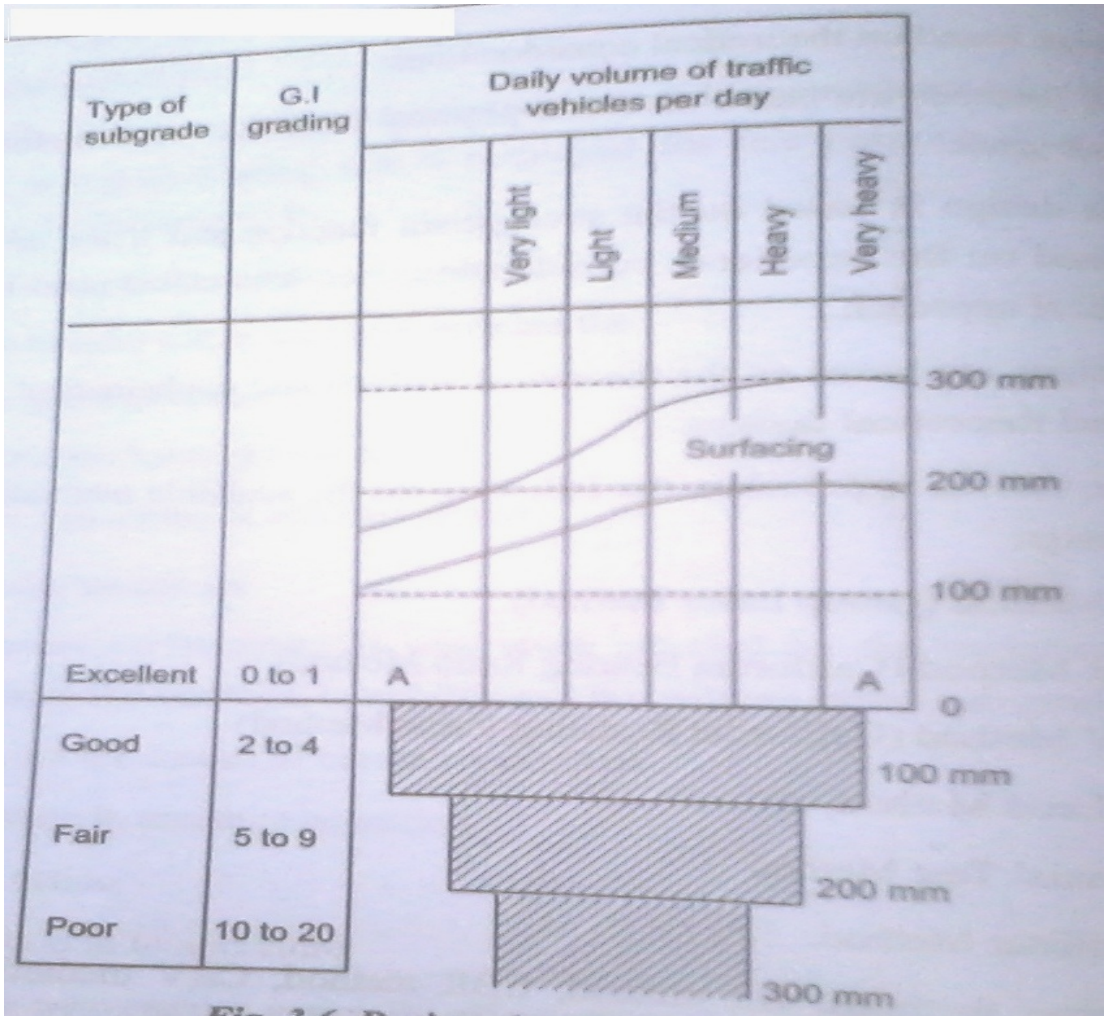
The triaxial method is a **theoretical method** using **empirical modifications (semi empirical method).**

Burmister method is a **theoretical method** using **elastic two layer theory**.

1. G.I Method (Group Index Method)

The Group Index (G.I) is an arbitrary index, given to the type of soil and it is based on percentage of fines, liquid limit and plasticity index.

The G.I value varies from 0 to 20, and the greater the value, the poorer the soil.



For the purpose of design, the volume of daily traffic is divided into the following five categories.

S.No	Traffic Volume (Commercial Vehicles)	Number of Vehicles per day
1	Very Light	Less than 50
2	Light	50 to 250
3	Medium	250 to 500
4	Heavy	500 to 750
5	Very Heavy	750 to 1000

Depending upon the G.I. grading of soil and daily volume of traffic, the thickness of surface base and sub base are designed from the chart as shown in fig.3.6.While designing the flexible pavement by G.I. method, the following points should be considered.

1. The thickness of the sub base depends on the G.I. grading of soil.
2. The thickness of the surface and base depend on the value of traffic, minimum of 100 mm thickness being provided for base.
3. The method as such is essentially an empirical method based on the physical properties of the sub grade soil and it does not consider the strength characteristics of the sub grade soil.

2. California Bearing Ratio Method (CBR Method)

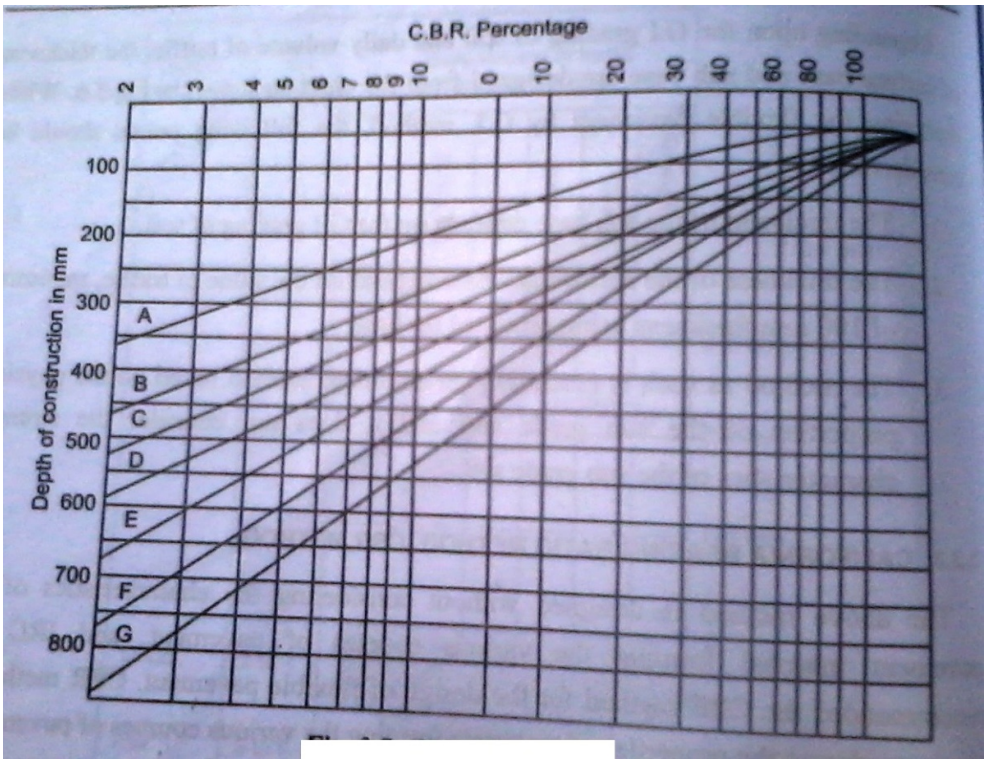
The above method is designed without considering the characteristics of the pavement material forming the various courses of pavement, and IRC has recommended the CBR method for the design of flexible pavement.CBR method is also considering the properties of materials forming the various courses of pavement.

The CBR is a property of the sub grade soil, and the CBR is measured by an empirical method developed by California State Highway Department, USA.

The test is made on a sample of the sub grade soil in a standard loading device which measures the load required to cause 2.5 mm penetration of a plunger having cross sectional area 1960 mm^2.

The plunger is made to penetrate the sample, at the rate of 1.25 mm per minute until the required penetration of 2.5 mm obtained. The pressure at 2.5mm penetration is worked out and it is expressed as a percentage of unit standard pressure. The percentage of this unit standard pressure is known as CBR.

The test is repeated for 5 mm penetration and the CBR is worked out. The higher value of CBR is adopted. Generally the value of CBR at 2.5 mm penetration is higher. The unit standard loads at 2.5 mm and 5 mm penetrations are 70 kg/cm^2 and 105 kg/cm^2 respectively.



Figure, shows the CBR design chart adopted by IRC. The seven curves A to G are for different volumes of traffic likely to be carried by the pavement as shown in the following table.

The traffic is considered in units of heavy vehicles per day in both directions. The term heavy vehicle is meant to apply to any vehicle with a laden weight of 3 tonnes or more.

S.No	CBR Design Curve	Traffic units per day
1	A	Less than 15
2	B	15 to 45
3	C	45 to 150
4	D	150 to 450
5	E	450 to 1500
6	F	1500 to 4500
7	G	More than 4500

If the component layers of pavement consist of materials with different CBR, they can be suitably split up the use of same curves as shown in Figure.This is the serious disadvantage of this method.

The total thickness of the pavement above a sub grade will remain the same irrespective of the quality of materials used in its component layers.

Drawbacks of CBR –Design Method

The following are the some of the demerits in CBR Design method.

- Same design procedure is used for dual carriageway and multi-lane single carriageway and there is no difference in design procedure for them.
- The design curve provides only the total thickness of the pavement and did not specify the thickness of sub-base, base and surface separately.
- The design permits the equivalency factor of upto 2 for flexible pavement. It is not the suitable design of various bases and each one need to be evaluated under different traffic and environmental conditions.
- It did not take into account, the damaging effects of heavier wheel loads completely.

Pavement thickness by wheel load

The pavement thickness 't' can also be determined from the wheel load, tyre pressure and CBR value (within a range of 10 to 12 %).

The thickness of the pavement't' is

$$t = \{\frac{1.75P}{CBR} - \frac{A}{\pi}\}^{1/2} \quad \text{in m}$$

Where, P – Wheel load in kg

CBR - California Bearing Ratio in %

A - Area of contact in cm^2

IRC has recommended the CBR design chart for tentative use in India (as shown in figure). This chart is similar to the chart followed in U.K.

As per the IRC recommendation, the pavements of major traffic roads should be designed at least for 10 years life period and the following formula may be used. The number of heavy vehicles per day 'N' is

$$N = P(1 + \gamma\}^n$$

Where, P - Number of heavy vehicles / day at last count

γ - Annual rate of increase count in heavy vehicles

n - Number of years between the last count and year of completion of construction

In the above formula, the value of 'P' should be taken at least for seven day average of heavy vehicles from 24 hours count. If the suitable value of 'r' is not obtained, the value of 7.5% may be assumed for roads in rural areas.

CBR Method for Cumulative Standard Axle Load

The mixed commercial vehicles with various axle loads are converted into cumulative number of standard axle load for the pavement design.

Cumulative number of standard axle load Ns,

$$N_S = \frac{365\ N\ [\ (1+r)^n\ -1]}{r}\ X\ F\ X\ D$$

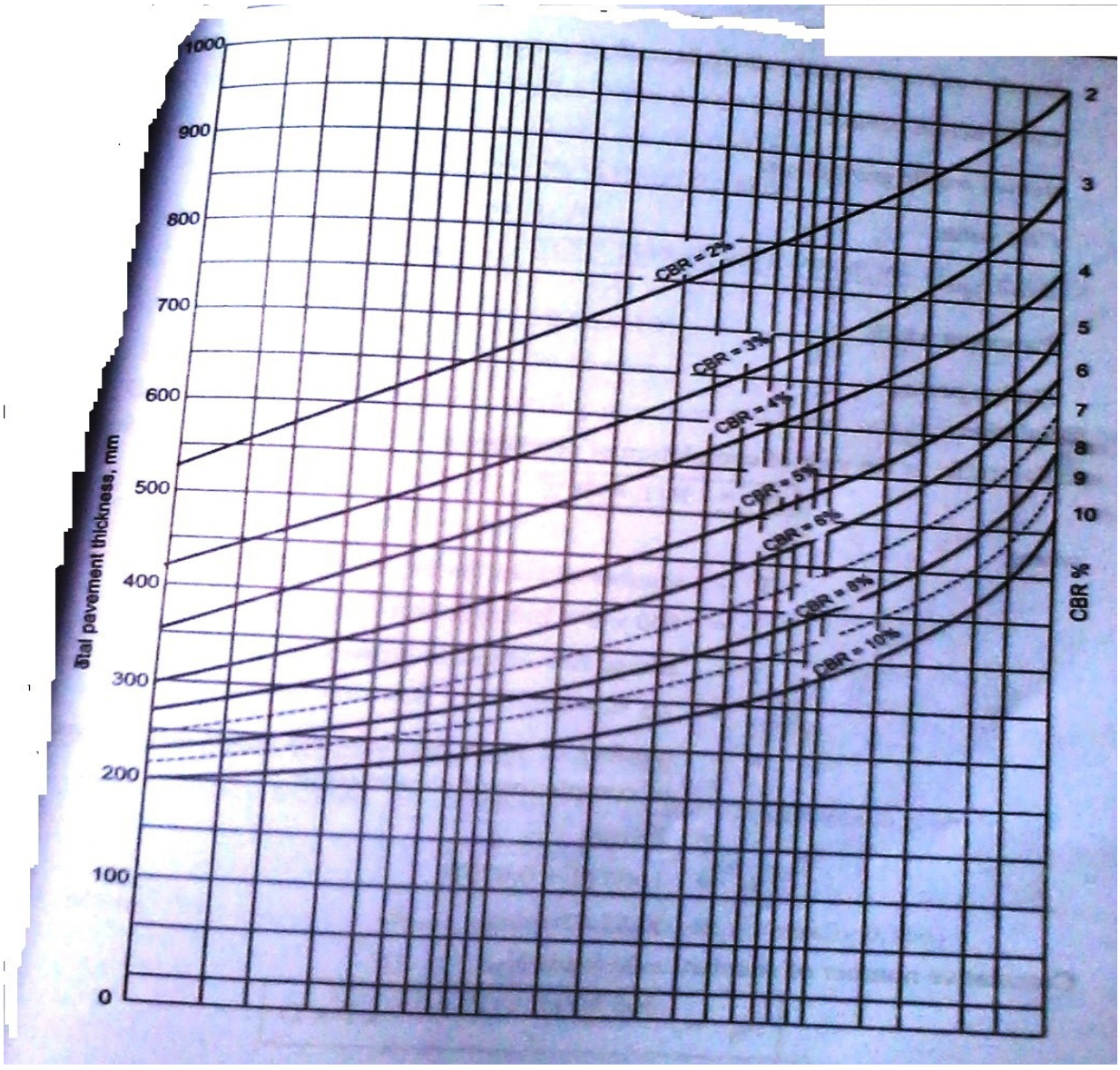
Where, N - Number of commercial vehicles per day considering the number of lanes

r – Annual growth rate

n – Design life of the pavement (generally 10 to 15 years)

F – Vehicle Damage Factor

The total pavement thickness required is determined by using the design chart as shown in figure.



3. California Resistance Value (CRV) Method

Based on CRV method, the expression for pavement thickness is given by,

$$T = \frac{K\,(TI)(90-R)}{C^{1/5}} \quad \text{in cm}$$

Where, K - Numerical constant (generally 0.166)

TI - Traffic Index = 1.35 (EWL) $^{0.11}$

R - Stabilometer resistance value

C - Cohesiometer value

The annual value of equivalent wheel load (EWL) is the accumulated sum of the products of the constants and the number of axle loads.

EWL = Σ (Constant **X** Axle loads)

Number of axles	**EWL Constants**
2	330
3	1070
4	2460
5	4620
6	3040

The cohesiometer value 'C' is obtained for each layer of pavement material separately from tests. Typical C- value for some pavement materials are given below,

Material	**C-Value**
Soil –cement base course	120 - 130
Bituminous concrete	60 - 62
Open graded bituminous mix	22 - 30
Gravel base course	15

Tri –axle Method

Based on this method, the pavement thickness T, is given by

$$T = \sqrt{\frac{3P}{2\pi\,\Delta\,E_s} - a^2} \quad \text{in cm}$$

Where, P - Wheel load in kg

Es - Modulus of elasticity of sub grade from tri-axial test (in kg/cm^2)

a - Radius of the contact area, in cm

Δ - Design deflection (generally 0.25 cm)

Mc Leod Method

Mc Leod Method is based on the plate load experiments and the thickness of the gravel base is given by,

$$t = K\ log_{10}(\frac{P}{S}) \quad \text{in cm}$$

Where, P - Gross wheel load (in kg)

K - Base course constant

S - Total sub grade support (in kg)

DESIGN OF FLEXIBLE PAVEMENTS AS PER CBR METHOD

- Wheel load 3175 kg light traffic
- Wheel load 5443 kg heavy traffic
- Wheel load 4082 kg light traffic
- Pavement thickness, wheel load, tyre pressure and CBR within range of 10 to 12% CBR Design curve for various loading condition.

$$\boldsymbol{T = \sqrt{P}\ [\left(\frac{1.75}{CBR}\right) - \left(\frac{1}{P\pi}\right)]^{\frac{1}{2}}}$$

$$\boldsymbol{T = \ [\left(\frac{1.75 * P}{CBR}\right) - \left(\frac{A}{\pi}\right)]^{\frac{1}{2}}}$$

Where, T = Pavement thickness, cm

P = Wheel load, kg

CBR = California Bearing Ratio, %

P = Tyre Pressure, kg/cm^2

A = Area of contact, cm^2

- The IRC has recommended a CBR design chart for tentative use in India, different curve A,B,C,D,E,F &G

6. DESCRIBE IN DETAIL ABOUT DESIGN OF FLEXIBLE PAVEMENT AS PER IRC RECOMMENDATION.

DESIGN OF FLEXIBLE PAVEMENTS AS PER IRC RECOMMENDATION

- The CBR test to be conducted on remoulded soil in the lab specimen should be prepared by static compaction (or) dynamic compaction.
- For the design of new road, the sub-grade soil sample should be compacted at OMC to proctor density.
- For new construction the CBR test sample may be soaked in water for 4 days period sector testing.

- At least 3 samples should be test on each type of the soil at the same density and moisture content. The top 50cm sub-grade should be compacted at least up to 95 to 100% proctor density. Life period = 10 years.
- To estimate design traffic

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

A = No. of heavy vehicles/day of design

P = No. of heavy vehicles/day at least count

r = Annual rate of increase of heavy vehicles

N = No. of years between the least count and the year of completion of construction

- The design thickness is considered applicable for single axle loads up to 8200 kg and hardens axle up to 14500 kg.
- When sub base course materials contain sustainable proportion of aggregate of size above 20 mm.

7. DESCRIBE IN DETAIL ABOUT DESIGN OF RIGID PAVEMENT AS PER IRC RECOMMENDATION.

DESIGN OF RIGID PAVEMENTS AS PER IRC RECOMMENDATION

Design Parameters

The design wheel load is 5100 kg with equivalent circular area of 15 cm^2. The Tyre pressure ranging from 6.3 to 7.3 kg/cm^2. The traffic volume is projected for 20 years.

$$A_d = P[1 + r]^{(n+20)}$$

Where, Ad = No. of commercial vehicles/day of design

P = No. of commercial vehicles/day at least count

r = Annual rate of increase in commercial vehicles

N = No. of years between the least count and the year of completion of construction

Calculation of Stresses

- The wheel load stresses at edge region is calculated for the designed slab thick westergaared analysis.
- Temperature stresses at edge region is calculated as per westergaared analysis.
- Wheel load stress at corner is calculated.

Design steps for slab thickness

- The width of the slab is decided based on the joint spacing and lane width.
- The length of the cement concrete slab is equal to spacing of contraction joint.
- A trial thickness value of the slab is assumed for calculating the stresses. The warping stress at the edge region is calculated.
- The load stress in edge region is found using stress chart.
- The total stress at the corner due to wheel load and warping is checked using chart.
- The design thickness is adjusted for the traffic intensity.

Spacing of Joints

- The maximum spacing recommended for 25 mm wide expansion joints, is 140m. When the foundation is rough, all slab thickness.
- When the foundation is smooth spacing 90 m for slab thickness upto 20cm and spacing of 120m for slab thickness 25 cm.
- The maximum spacing may be kept 4.5m in unreinforced slab.
- In a reinforced slab the contraction joint spacing 13m for 15cm steel reinforcement of 2.7kg/m^2 and 14cm spacing for 20cm thick with steel reinforcement of 3.8 kg/cm^2.

Design of Dowel Bars

- The dowel bar system may be designed on the basis of brad burry's analysis for load transfer capacity.
- The load capacity of the dowel system is assumed to be 40% of the design wheel load.
- The distance on either side of the load position up to which the dowel bars are effective in load transfer is taken as 1.8 times the radius of relative stiffness.

Design of Tie Bars

Permissible bond stress for deformed bars is 24.6 kg/cm^2 and that in plain tie bars is 17.5 kg/cm^2.

Design of Reinforcement

It is provided to prevent detoriation of cracks and not to increase the flexural strength of un-cracked slab.

The area of longitudinal and transverse steel required per meter width $A = L f_S / 2S$

Where, A = Area of steel required per meter width (or) length.

L = Distance between free transverse joint

F = Co-efficient of friction between pavement and sub-grade

S = Spacing of main reinforcement.

8. WHAT IS MEANT BY EMBANKMENT? EXPLAIN IN DETAIL.

EMBANKMENTS

A bank of earth or stone built to carry a road or railway over an area of low ground.

A raised structure (as of earth or gravel) used especially to hold back water or to carry a roadway

A road, railway line or canal is normally raised onto an embankment, made of compacted soil (typically clay or rock-based) to avoid a change in level required by the terrain.

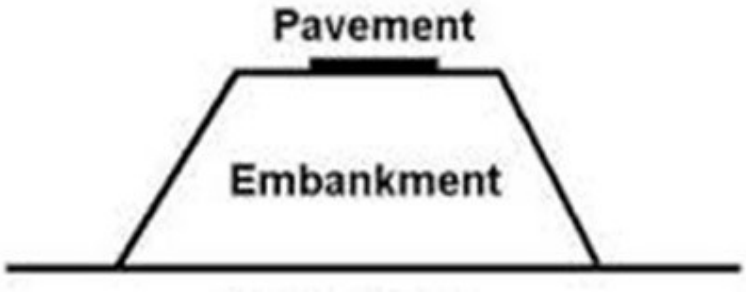
A cutting is used for the same purpose where the land is originally higher than required.

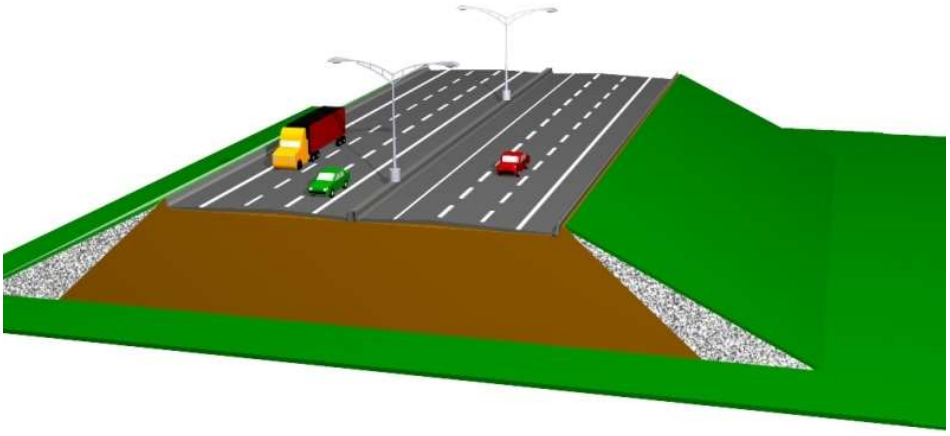
Materials

Embankments are often constructed using material obtained from a cutting. An embankment needs to be constructed using non-aerated and waterproofed, compacted (or entirely non-porous) material to provide adequate support to the formation and a long-term level surface with stability.

Intersection of embankments

To intersect an embankment without a high flyover, a series of tunnels can consist of a section of high tensile strength viaduct (typically built of brick and/or metal) or pair of facing abutments for a bridge.





UNIT IV

INTRODUCTION

The durability and performance of a highway are mainly depending on the quality of materials used for highway construction. The main functions of a pavement are,

- To distribute the traffic load over the sub-grade soil.
- To provide good riding surface.
- To protect the sub grade from climatic effects.

In order to attain the above objectives, the construction materials used for highway pavement should have some specific properties.

The important highway materials used for flexible and rigid pavements are soil, gravel, aggregates, cement, bitumen etc.,

1. BRIEFLY DISCUSS ABOUT SOIL AND ITS PROPERTIES.

SUB – GRADE SOIL AND DESIRABLE PROPERTIES

Sub-grade is an integral complex material produced by the weathering of the rock and provides the support to the pavement. The important function of the sub grade is to give the adequate support to the pavement and for this; the sub grade should possess sufficient stability under and loading conditions.

Based on the individual grain size of the soil particles, soil have been classified as gravel, sand and clay. The characteristics of soil grains depend on the shape, size, chemical composition and surface texture.

The desirable properties of sub grade soil as a highway material are

- Stability
- Incompressibility

- Permanency of strength
- Minimum changes in volume and stability under adverse conditions of weather and ground water
- Good drainage, and
- Ease of compaction

INDEX PROPERTIES OF SOIL

Index properties are soil properties, on which the soil identification and classification are based. In order to facilitate and construction of good roads, it is essential to identify and classify the soil systematically.

A soil description is a catalogue of what the soil is. A simple scheme for soil description is as given below.

1. **The nature of the grains**

   The most important features of soil grains are their size and the grading (grading-proportions of different sizes) together with the shape and surface texture and minorology.

2. **The current state of the soil**

   The current state of the soils is current stresses, current water content and history of loading and unloading. These are reflected by the relative strengths and stiffness of the soil sample.

3. **The structure of the fabric**

   Natural soils are of rare in uniformity and structure of soil includes layering (or) bedding, jointing and cementing.

4. **The formation of the soil**

   The formation of the soil may differ and it may be formed by natural deposition of water (wind), sometimes the soil may be the residual products of rock weathering and they may be formed by the compaction of machines in embankments and fills.

   All of these properties of soil used for identification and classification are called index properties. Following are the some of the index properties.

   (i) Water content
   (ii) Specific gravity
   (iii) Grain size distribution
   (iv) Field density
   (v) Compacted dry density

SOIL PROPERTIES –IMPORTANT DEFINITIONS

Sub-grade: It is defined as the natural fill (or) natural foundation of the pavement, which directly receives the load from pavement the material.

Moisture Content: It is the loss in weight (expressed in %) of the dry material when a soil is dried to constant weight at 100^0C to 110^0C.

Bulk Density: This is the ratio of total weight of the soil to its total volume.

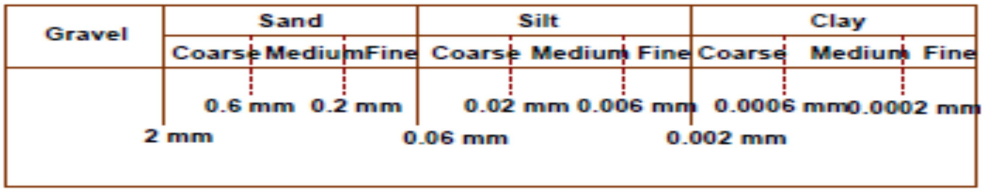
Void Ratio: It is the ratio of volume of voids to the volume of soil solids.

Dry Density: It is the ratio of weight of the soil solids to the volume of the soil.

Specific Gravity: It is the ratio of bulk density of soil to the bulk density of water at constant temperature.

SOIL TYPES

The wide range of soil types available as highway construction materials have made it obligatory on the part of the highway engineer to identify and classify different soils. A survey of locally available materials and soil types conducted in India revealed wide variety of soil types, gravel, moorum and naturally occurring soft aggregates, which can be used in road construction. Broadly, the soil types can be categorized as Laterite soil, Moorum / red soil, Desert sands, Alluvial soil, Clay including Black cotton soil.



Gravel: These are coarse materials with particle size under 2.36 mm with little or no fines contributing to cohesion of materials.

Moorum: These are products of decomposition and weathering of the pavement rock. Visually these are similar to gravel except presence of higher content of fines.

Silts: These are finer than sand, brighter in color as compared to clay, and exhibit little cohesion. When a lump of silty soil mixed with water, alternately squeezed and tapped a shiny surface makes its appearance, thus dilatancy is a specific property of such soil.

Clays: These are finer than silts. Clayey soils exhibit stickiness, high strength when dry, and show no

dilatancy. Black cotton soil and other expansive clays exhibit swelling and shrinkage properties.

Paste of clay with water when rubbed in between fingers leaves stain, which is not observed for silts.

TESTS ON SOIL

Sub grade soil is an integral part of the road pavement structure as it provides the support to the pavement from beneath. The sub grade soil and its properties are important in the design of pavement structure. The main function of the sub grade is to give adequate

support to the pavement and for this the sub grade should possess sufficient stability under adverse climatic and loading conditions. Therefore, it is very essential to evaluate the sub grade by conducting tests.

- Determination of Water Content
  - Oven Drying Method (IS 2720 -1964)
  - Sand bath method (B.S 1377 - 1961)
  - Alcohol method
  - Calcium Carbide method
  - Pycnometer Method
- Determination of Specific Gravity
  - 50 ml Density Bottle method
  - 500 ml flask method
  - Pycnometer Method
- Determination of Consistency Limits (Empirical test)
  - The liquid limit test
  - The Plastic limit test
  - The shrinkage limit test
- Determination of field density
  - Sand replacement method
  - Core cutter method
  - Rubber balloon method
  - Water displacement method
- Dry density and moisture content method
  - Standard proctor test
  - Modified proctor test

The tests used to evaluate the strength properties of soils may be broadly divided into three groups:

_ Shear tests

_ Bearing tests

_ Penetration tests

Shear tests are usually carried out on relatively small soil samples in the laboratory. In order to find out the strength properties of soil, a number of representative samples from different locations are tested. Some of the commonly known shear tests are direct shear test, triaxial compression test, and unconfined compression test.

Bearing tests are loading tests carried out on sub grade soils in-situ with a load bearing area. The results of the bearing tests are influenced by variations in the soil properties within the stressed soil mass underneath and hence the overall stability of the part of the soil mass stressed could be studied.

Penetration tests may be considered as small scale bearing tests in which the size of the loaded area is relatively much smaller and ratio of the penetration to the size of the loaded area is much greater than the ratios in bearing tests. The penetration tests are carried out in the field or in the laboratory. CBR Test is the one of the penetration test for determination of strength.

2. EXPLAIN IN DETAIL ABOUT CBR TEST WITH NEAT SKETCH.

CALIFORNIA BEARING RATIO TEST

California Bearing Ratio (CBR) test was developed by the California Division of Highway as a method of classifying and evaluating soil-sub grade and base course materials for flexible pavements. CBR test, an empirical test, has been used to determine the material properties for pavement design. Empirical tests measure the strength of the material and are not a true representation of the resilient modulus. It is a penetration test wherein a standard piston, having an area of 3 in2 (or 50 mm diameter), is used to penetrate the soil at a standard rate of 1.25 mm/minute. The pressure up to a penetration of 12.5 mm and it's ratio to the bearing value of a standard crushed rock is termed as the CBR.

In most cases, CBR decreases as the penetration increases. The ratio at 2.5 mm penetration is used as the CBR. In some case, the ratio at 5 mm may be greater than that at 2.5 mm. If this occurs, the ratio at 5 mm should be used. The CBR is a measure of resistance of a material to penetration of standard plunger under controlled density and moisture conditions. The test procedure should be strictly adhered if high degree of reproducibility is desired. The CBR test may be conducted in re-moulded or undisturbed specimen in the laboratory. The test is simple and has been extensively investigated for field correlations of flexible pavement thickness requirement.

TEST PROCEDURE

The laboratory CBR apparatus consists of a mould 150 mm diameter with a base plate and a collar, a loading frame and dial gauges for measuring the penetration values and the expansion on soaking.

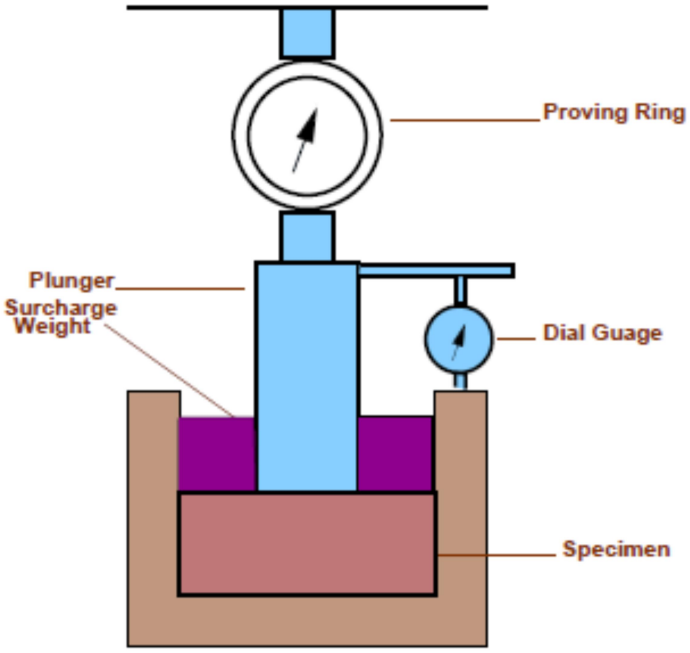
The specimen in the mould is soaked in water for four days and the swelling and water absorption values are noted. The surcharge weight is placed on the top of the specimen in the mould and the assembly is placed under the plunger of the loading frame.

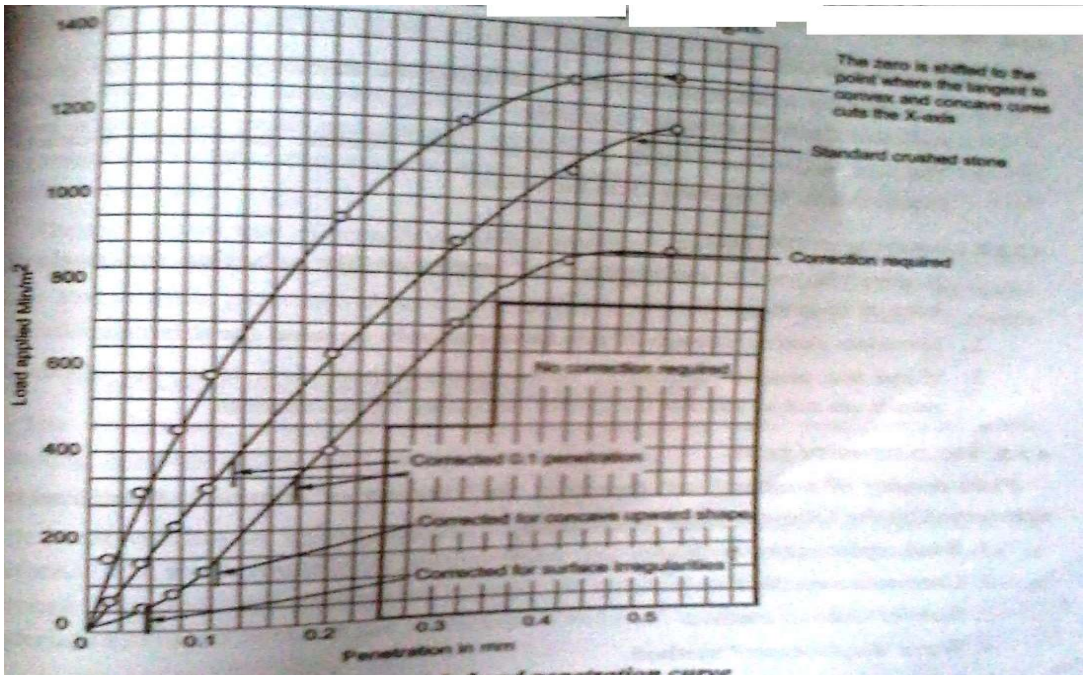
Load is applied on the sample by a standard plunger with dia of 50 mm at the rate of 1.25 mm/min. A load penetration curve is drawn. The load values on standard crushed stones are 1370 kg and 2055 kg at 2.5 mm and 5.0 mm penetrations respectively.

CBR value is expressed as a percentage of the actual load causing the penetrations of 2.5 mm or 5.0 mm to the standard loads mentioned above. Therefore,

$$CBR = \frac{\text{load carries by specimen}}{\text{load carries by standard specimen}} \times 100$$

Two values of CBR will be obtained. If the value of 2.5 mm is greater than that of 5.0 mm penetration, the former is adopted. If the CBR value obtained from test at 5.0 mm penetration is higher than that at 2.5 mm, then the test is to be repeated for checking. If the check test again gives similar results, then higher value obtained at 5.0 mm penetration is reported as the CBR value. The average CBR value of three test specimens is reported as the CBR value of the sample.





IMPORTANCE OF CBR TEST:

1. It is the best suitable method for evaluating the stability of soil sub grade and other flexible pavement materials.
2. The test results have been correlated with flexible pavement thickness requirements, for highways and air fields.

LIMITATIONS OF CBR TEST

1. It cannot be used to evaluate the soil properties like cohesion (or) angle of internal friction (or) shearing resistance.
2. Materials passing through 20 mm sieve can only be used for this test.
3. If the test sample consists of coarse grained particles, then they obtained results are not so suitable for proper designing of pavements.

3. WRITE BRIEF NOTE ON AGGREGATE AND ITS TESTING. NOV/DEC 2011

April / may 2011

AGGREGATE

Aggregate is a collective term for the mineral materials such as sand, gravel, and crushed stone that are used with a binding medium (such as water, bitumen, Portland cement, lime, etc.) to form compound materials (such as bituminous concrete and Portland cement concrete). By volume, aggregate generally accounts for 92 to 96 percent of Bituminous concrete and about 70 to 80 percent of Portland cement concrete. Aggregate is also used for base and sub-base courses for both flexible and rigid pavements. Aggregates can either be

natural or manufactured. Natural aggregates are generally extracted from larger rock formations through an open excavation (quarry). Extracted rock is typically reduced to usable sizes by mechanical crushing. Manufactured aggregate is often a bye product of other manufacturing industries.

DESIRABLE PROPERTIES

Strength

The aggregates used in top layers are subjected to (i) Stress action due to traffic wheel load, (ii) Wear and tear, (iii) crushing. For a high quality pavement, the aggregates should posses high resistance to crushing, and to withstand the stresses due to traffic wheel load.

Hardness

The aggregates used in the surface course are subjected to constant rubbing or abrasion due to moving traffic. The aggregates should be hard enough to resist the abrasive action caused by the movements of traffic. The abrasive action is severe when steel tyred vehicles moves over the aggregates exposed at the top surface.

Toughness

Resistance of the aggregates to impact is termed as toughness. Aggregates used in the pavement should be able to resist the effect caused by the jumping of the steel tyred wheels from one particle to another at different levels causes' severe impact on the aggregates.

Shape of aggregates

Aggregates which happen to fall in a particular size range may have rounded, cubical, angular, flaky or elongated particles. It is evident that the flaky and elongated particles will have less strength and durability when compared with cubical, angular or rounded particles of the same aggregate. Hence too flaky and too much elongated aggregates should be avoided as far as possible.

Adhesion with bitumen

The aggregates used in bituminous pavements should have less affinity with water when compared with bituminous materials; otherwise the bituminous coating on the aggregate will be stripped o_ in presence of water.

Durability

The property of aggregates to withstand adverse action of weather is called soundness. The aggregates are subjected to the physical and chemical action of rain and bottom water, impurities there-in and that of atmosphere, hence it is desirable that the road aggregates used in the construction should be sound enough to withstand the weathering action.

Freedom from deleterious particles

Specifications for aggregates used in bituminous mixes usually require the aggregates to be clean, tough and durable in nature and free from excess amount of at or elongated pieces, dust, clay balls and other objectionable material. Similarly aggregates used in Portland cement concrete mixes must be clean and free from deleterious substances such as clay lumps, silt and other organic impurities.

Specific Gravity

It is the ratio of bulk density of aggregate to the bulk density of water at the constant temperature.

Texture

It is the measure of degree of roughness or smoothness of stone. It can be glossy, smooth, rough or crystalline.

Cementation

It is the ability of the road stone to form its own binding property under traffic so as to make the rough broken stone pieces, grip together imparting resistance to displacement.

Hydrophobic Characteristics

It is the property by virtue of which, the stone aggregate resists stripping off of the bitumen in the presence of water.

TEST FOR AGGREGATE

In order to decide the suitability of the aggregate for use in pavement construction, following tests are carried out:

1. Crushing test
2. Abrasion test
3. Impact test
4. Soundness test
5. Shape test
6. Specific gravity and water absorption test
7. Bitumen adhesion test

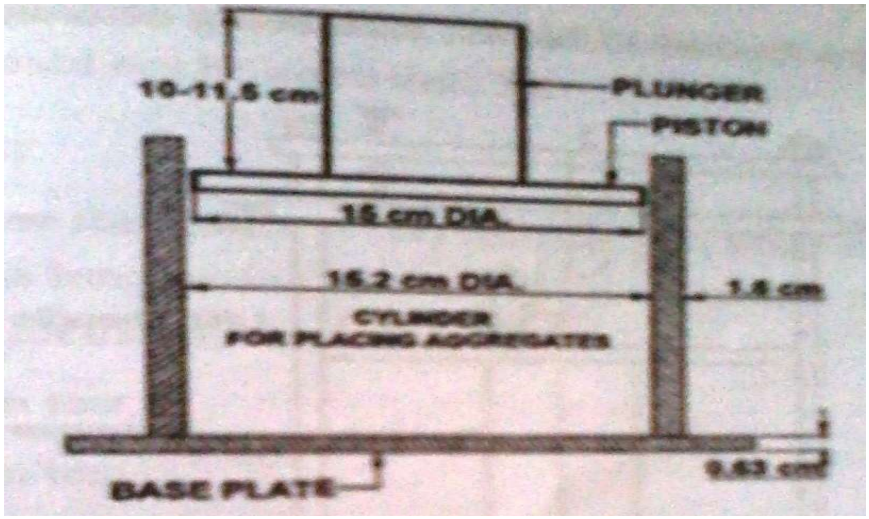
1. Crushing Test

One of the model in which pavement material can fail is by crushing under compressive stress. A test is standardized by IS:2386 part-IV and used to determine the crushing strength of aggregates. The aggregate crushing value provides a relative measure of resistance to crushing under gradually applied crushing load. The test consists of subjecting the specimen of aggregate in standard mould to a compression test under standard load conditions (Figure 22:1). Dry aggregates passing through 12.5 mm sieves and retained 10

mm sieves are filled in a cylindrical measure of 11.5 mm diameter and 18 cm height in three layers. Each layer is tampered 25 times with at standard tamping rod. The test sample is weighed and placed in the test cylinder in three layers each layer being tampered again. The specimen is subjected to a compressive load of 40 tonnes gradually, applied at the rate of 4 tonnes per minute. Then crushed aggregates are then sieved through 2.36 mm sieve and weight of passing material (W2) is expressed as percentage of the weight of the total sample (W1) which is the aggregate crushing value.

$$\text{Aggregate crushing value} = \frac{W_1}{W_2} \times 100$$

A value less than 10 signifies an exceptionally strong aggregate while above 35 would normally be regarded as weak aggregates. A good quality aggregate to be used in base course and surfacing course should not have crushing value more than 45 % and 30% respectively.



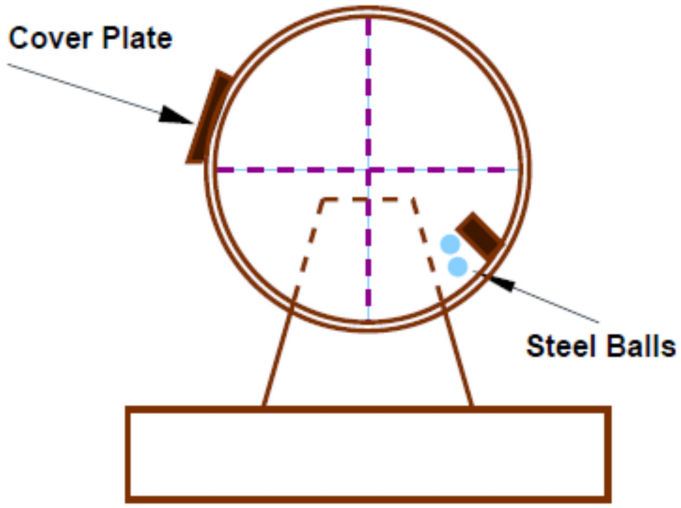
2. Abrasion Test

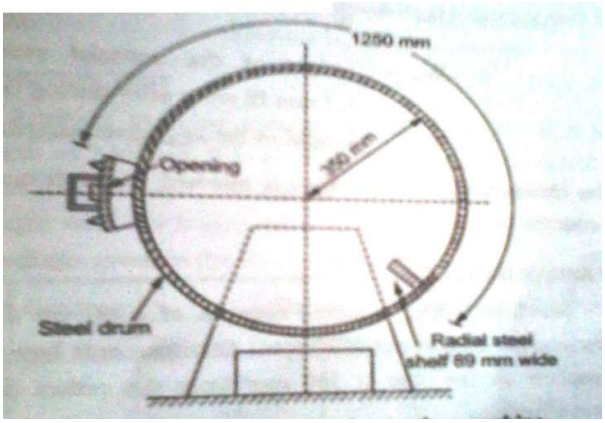
Abrasion test is carried out to test the hardness (or) resistance to wear and to study the abrasive effects of traffic over a long period of time, the abrasion test is carried out by anyone of the following three methods.

a. Deval abrasion test
b. Dorry abrasion test
c. Los Angeles abrasion test

Los Angeles abrasion test is a preferred one for carrying out the hardness property and has been standardized in India (IS:2386 part-IV). The principle of Los Angeles abrasion test is to find the percentage wear due to relative rubbing action between the aggregate and steel balls used as abrasive charge.

Los Angeles machine consists of circular drum of internal diameter 700 mm and length 520 mm mounted on horizontal axis enabling it to be rotated. An abrasive charge consisting of cast iron spherical balls of 48 mm diameters and weight 340-445 g is placed in the cylinder along with the aggregates. The number of the abrasive spheres varies according to the grading of the sample. The quantity of aggregates to be used depends upon the gradation and usually ranges from 5-10 kg. The cylinder is then locked and rotated at the speed of 30-33 rpm for a total of 500 -1000 revolutions depending upon the gradation of aggregates. After specified revolutions, the material is sieved through 1.7 mm sieve and passed fraction is expressed as percentage total weight of the sample. This value is called Los Angeles abrasion value. A maximum value of 40 percent is allowed for WBM base course in Indian conditions. For bituminous concrete, a maximum value of 35 is specified.





$$Abrasion\ Value = \frac{W_2}{W_1} * 100$$

Where,

W_2 - Weight of the material passed through the 1.7 mm sieve after testing (kg)

W_1 - Weight of the aggregate sample (kg)

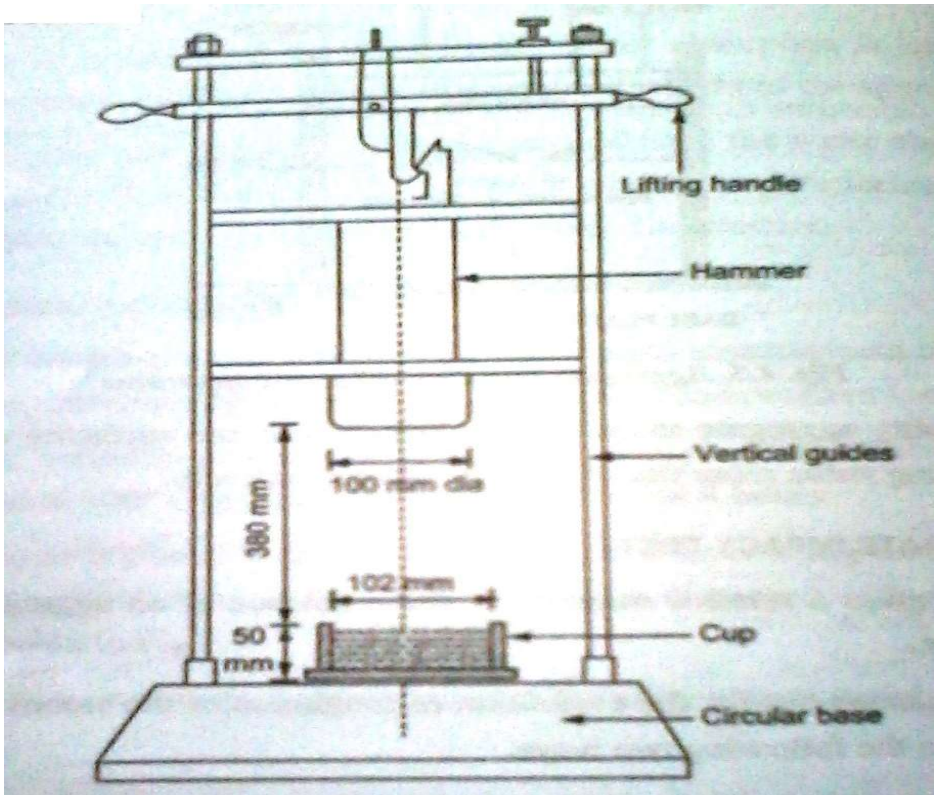
Los angeles abrasion value up to 30% is allowed high quality surfaces and 50% for base courses.

3. Impact Test

The aggregate impact test is carried out to evaluate the resistance to impact of aggregates. Aggregates passing 12.5 mm sieve and retained on 10 mm sieve is filled in a cylindrical steel cup of internal dia 10.2 mm and depth 5 cm which is attached to a metal base of impact testing machine. The material is filled in 3 layers where each layer is tamped for 25 number of blows. Metal hammer of weight 13.5 to 14 Kg is arranged to drop with a free fall of 38.0 cm by vertical guides and the test specimen is subjected to 15 number of blows. The crushed aggregate is allowed to pass through 2.36 mm IS sieve. And the impact value is measured as percentage of aggregates passing sieve (W2) to the total weight of the sample (W1).

$$\text{Aggregate impact value} = \frac{W_1}{W_2} \times 100$$

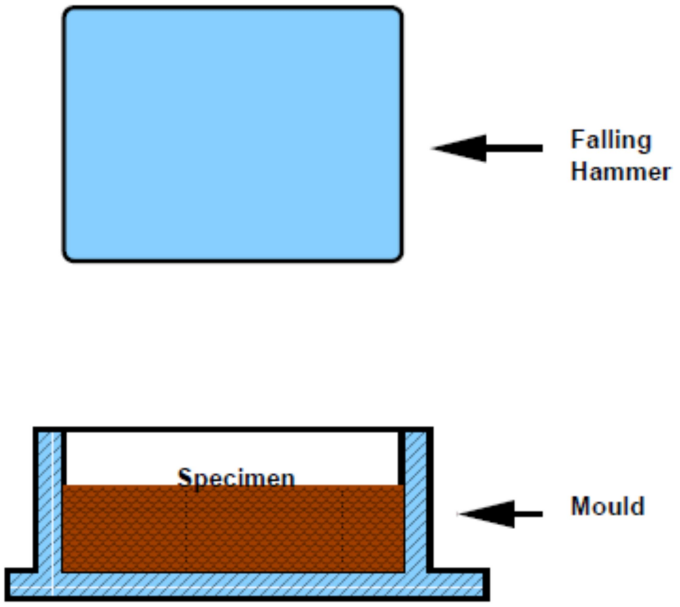
Aggregates to be used for wearing course, the impact value shouldn't exceed 30 percent. For bituminous macadam the maximum permissible value is 35 percent. For Water bound macadam base courses the maximum permissible value defined by IRC is 40 percent.



4. Soundness Test

Soundness test is intended to study the resistance of aggregates to weathering action, by conducting accelerated weathering test cycles. The Porous aggregates subjected to

freezing and thawing are likely to disintegrate prematurely. To ascertain the durability of such aggregates, they are subjected to an accelerated soundness test as specified in IS:2386 part-V. Aggregates of specified size are subjected to cycles of alternate wetting in a saturated solution of either sodium sulphate or magnesium sulphate for 16 - 18 hours and then dried in oven at 105^0 to 110^0 C to a constant weight. After five cycles, the loss in weight of aggregates is determined by sieving out all undersized particles and weighing. And the loss in weight should not exceed 12 percent when tested with sodium sulphate and 18 percent with magnesium sulphate solution.

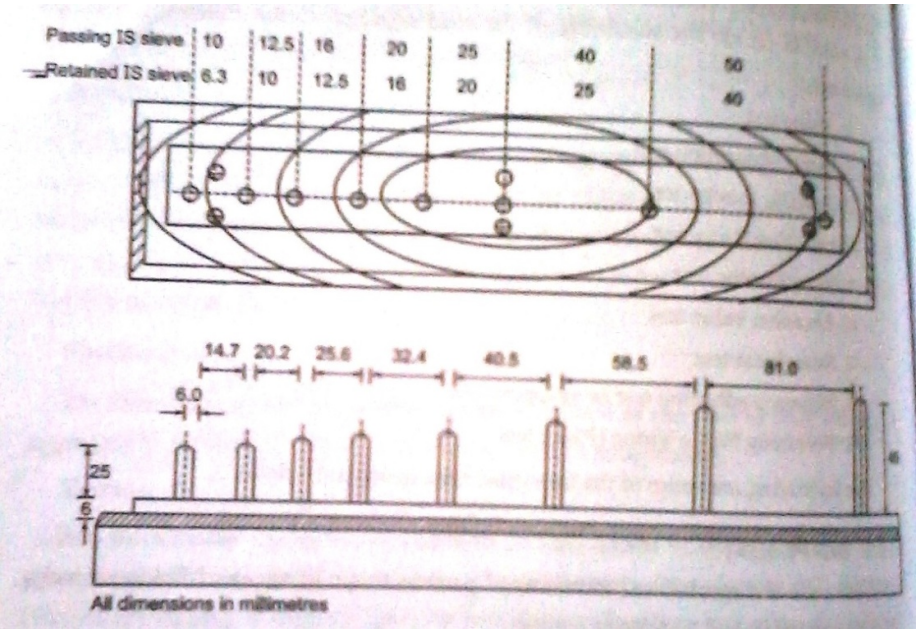


5. Shape Tests

The particle shape of the aggregate mass is determined by the percentage of flaky and elongated particles in it. Aggregates which are flaky or elongated are detrimental to higher workability and stability of mixes.

a) Flakiness Index

The **flakiness index** is defined as the percentage by weight of aggregate particles whose least dimension is less than 0.6 times their mean size. Test procedure had been standardized in India (IS:2386 part-I). The flakiness test is not applicable to particle smaller than 6mm. the test is carried out by first separating the aggregate into individual percentages retained on specified sieve size and then passing at least 200 particles from the individual percentages through the sieve. It is having elongated slots whose widths are 3/5 times of the individual mean dimension. The flakiness index is calculated as the total weight of the material passing the various sieves, expressed as percentage of total weight of the sample taken. From the practical consideration, the flakiness index of the aggregates suitable for road construction should not be less than 15% and should not be greater than 25%.



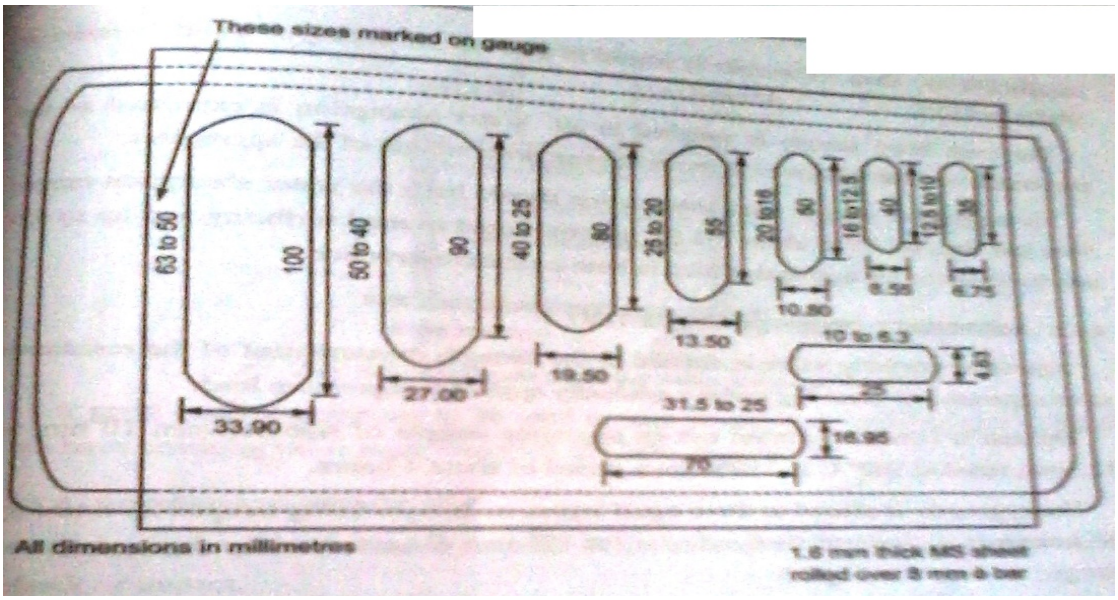
b) Elongation Index

The **elongation index** of an aggregate is defined as the percentage by weight of particles whose greatest dimension (length) is 1.8 times their mean dimension. This test is applicable to aggregates larger than 6.3 mm. This test is also specified in (IS:2386 Part-I). However there are no recognized limits for the elongation index.

The sample of aggregates to be tested is sieved through a set of sieves and then the individual particles from the fractions are passed through opening on metal length gauge.

The elongation index is calculated as the total weight of the material retained on the length gauge, expressed as a percentage of the total weight of the sample taken.

Generally, aggregates used in road construction should have elongation value less than 15%. The gauges used for flakiness index and elongation index are shown in figure.



c) Angularity Number

It is the amount to the nearest whole number by which the percentage voids exceeds 33%, when an aggregate is compacted in a specified manner in a standardized metal cylinder. It can be worked out by the following simple equation. Generally, aggregates used in road construction should have the angularity number from 0 to 11.

$$\textbf{\textit{Angularity Number} = 67 - \textit{Percent Soild Volume}}$$

6. Water absorption Test

The specific gravity and water absorption of aggregates are important properties that are required for the design of concrete and bituminous mixes. The specific gravity of a solid is the ratio of its mass to that of an equal volume of distilled water at a specified temperature.

In this test, the aggregate sample is soaked in distilled water for 24 hours. After this time, the aggregate sample is taken back from water, it is surface dried and weighted in air. Then the sample is placed in an oven for drying of about 24 hours at 100^0C to 110^0C.

The oven dried sample is weighted in air. Water absorption is expressed as the percentage of water observed in terms of oven dried weight of the aggregates.

The aggregates used in road construction should have the water absorption ranges from less than 0.1% to about 2% for materials used in road surfacing and up to 4% may be accepted for aggregates used in base course construction.

Property of aggregate	Type of Test	Test Method
Crushing strength	Crushing test	IS : 2386 (part 4) -1963
Hardness	Los Angeles abrasion test	IS : 2386 (Part 5)-1963
Toughness	Aggregate impact test	IS : 2386 (Part 4)-1963
Durability	Soundness test- accelerated durability test	IS : 2386 (Part 5)-1963
Shape factors	Shape test	IS : 2386 (Part 1)-1963
Specific gravity and porosity	Specific gravity test and water absorption test	IS : 2386 (Part 3)-1963
Adhesion to bitumen	Stripping value of aggregate	IS : 6241-1971

7. Polishing Stone Value Test

It is used to determine the aggregate skid resistance value. Aggregates are embedded in a curved mould in cement sand motor. The sample is then subjected to accelerate polishing, caused by a rotating pneumatic wheel. The specimens, which are 45mm X 90.5mm, are mounted on a circular frame of 400 mm dia.

A portable tester which consists of a rubber sliding shoe mounted at the end of a pendulum, when released brushes past the specimen and comes to a halt. It directly measures polishing stone value (PSV) on a graduated scale.

Sand stone have higher PSV Value of more than 55 and granites have the range of 40 to 48, lime stone have low PSV values of about 35 to 40.

4. WRITE IN DETAIL ABOUT BITUMINOUS MATERIAL AND ITS TYPES.

BITUMINOUS MATERIAL

Bituminous materials are also called binders and they are used in combination with minerals aggregate. Various objectives for using bituminous binder are,

1. **Binding effect**

   The bitumen works as a binding material for the surface particles together.

2. **Cushion**

   It acts as a cushioning material on the surface and absorbs the impact, friction, etc, due to the movements of wheels of vehicles on road. Hence bituminous material increases the life of the pavement structure.

3. **Resistance to weathering actions**

   The weathering actions like wind and sun etc, can affect the surface of the pavement and hence a properly selected bituminous material can resist (or) withstand such actions.

4. **Sealing of Surface**

   Bitumen, when used with the dense graded granular material, it seals the surface of the road against rain water.

Bituminous materials or asphalts are extensively used for roadway construction, primarily because of their excellent binding characteristics and water proofing properties and relatively low cost. Bituminous materials consists of bitumen which is a black or dark colored solid or viscous cementations substances consists chiefly high molecular weight hydrocarbons derived from distillation of petroleum or natural asphalt, has adhesive properties, and is soluble in carbon disulphide. Tars are residues from the destructive distillation of organic substances such as coal, wood, or petroleum and are temperature sensitive than bitumen. Bitumen will be dissolved in petroleum oils where unlike tar.

PRODUCTION OF BITUMEN

Bitumen is the residue or by-product when the crude petroleum is refined. A wide variety of refinery processes, such as the straight distillation process, solvent extraction process etc. may be used to produce bitumen of different consistency and other desirable properties. Depending on the sources and characteristics of the crude oils and on the properties of bitumen required, more than one processing method may be employed.

Vacuum steam distillation of petroleum oils

In the vacuum-steam distillation process the crude oil is heated and is introduced into a large cylindrical still. Steam is introduced into the still to aid in the vaporization of the more volatile constituents of the petroleum and to minimize decomposition of the distillates and residues. The volatile constituents are collected, condensed, and the various fractions stored for further refining, if

needed. The residues from this distillation are then fed into a vacuum distillation unit, where residue pressure and steam will further separate out heavier gas oils. The bottom fraction from this unit is the vacuum-steam-refined asphalt cement. The consistency of asphalt cement from this process can be controlled by the amount of heavy gas oil removed. Normally, asphalt produced by this process is softer. As the asphalt cools down to room temperature, it becomes a semi solid viscous material.

DIFFERENT FORMS OF BITUMEN

1. Bitumen
   a) Cutback bitumen
   b) Bitumen emulsion
   c) Rubber Bitumen
2. Tar
3. Tar-Bitumen

Cutback bitumen

Normal practice is to heat bitumen to reduce its viscosity. In some situations preference is given to use liquid binders such as cutback bitumen. In cutback bitumen suitable solvent is used to lower the viscosity of the bitumen. From the environmental point of view also cutback bitumen is preferred. The solvent from the bituminous material will evaporate and the bitumen will bind the aggregate. Cutback bitumen is used for cold weather bituminous road construction and maintenance. The distillates used for preparation of cutback bitumen are naphtha, kerosene, diesel oil, and furnace oil. There are different types of cutback bitumen like rapid curing (RC), medium curing (MC), and slow curing (SC). RC is recommended for surface dressing and patchwork. MC is recommended for premix with less quantity of _ne aggregates. SC is used for premix with appreciable quantity of _ne aggregates.

Bitumen Emulsion

Bitumen emulsion is a liquid product in which bitumen is suspended in a finely divided condition in an aqueous medium and stabilized by suitable material. Normally cationic type emulsions are used in India. The bitumen content in the emulsion is around 60% and the remaining is water. When the emulsion is applied on the road it breaks down resulting in release of water and the mix starts to set. The time of setting depends upon the grade of bitumen. The viscosity of bituminous emulsions can be measured as per IS: 8887-1995. Three types of bituminous emulsions are available, which are Rapid setting (RS), Medium setting (MS), and Slow setting (SC).

Bitumen emulsions are ideal binders for hill road construction. Where heating of bitumen or aggregates are difficult. Rapid setting emulsions are used for surface dressing

work. Medium setting emulsions are preferred for premix jobs and patch repairs work. Slow setting emulsions are preferred in rainy season.

Bituminous primers

In bituminous primer the distillate is absorbed by the road surface on which it is spread. The absorption therefore depends on the porosity of the surface. Bitumen primers are useful on the stabilized surfaces and water bound macadam base courses. Bituminous primers are generally prepared on road sites by mixing penetration bitumen with petroleum distillate.

Road Tar

It is a viscous liquid, black in color with adhesive properties, obtained by destructive distillation of organic matters such as wood, coal, shale etc., In the destructive distillation process, the material is subjected to heat alone, in the absence of air.

The first step for the production of tar is the carbonization of coal to produce crude tar. In the second stage crude tar is refined by distillation process.

Modified Bitumen

Certain additives or blend of additives called as bitumen modifiers can improve properties of Bitumen and bituminous mixes. Bitumen treated with these modifiers is known as modified bitumen. Polymer modified bitumen (PMB)/ crumb rubber modified bitumen (CRMB) should be used only in wearing course depending upon the requirements of extreme climatic variations. The detailed specifications for modified bitumen have been issued by IRC: SP: 53-1999. It must be noted that the performance of PMB and CRMB is dependent on strict control on temperature during construction.

The advantages of using modified bitumen are as follows,

- Lower susceptibility to daily and seasonal temperature variations
- Higher resistance to deformation at high pavement temperature
- Better age resistance properties
- Higher fatigue life for mixes
- Better adhesion between aggregates and binder
- Prevention of cracking and reflective cracking

Comparison of Bitumen with Tar

S.No	Parameter	Bitumen	Tar
1	Colour	Black or blackish brown	Black
2	Source	Derived from petroleum occurring naturally	Obtained from the destructive distillation of coal or wood
3	Solubility	Soluble in carbon-tetra sulphide	
4	Temperature Effects	Less temperature resistance	More temperature resistance
5	Setting behaviour	Takes lesser time to set	Takes more time to set
6	Free Carbon Content	Contains lesser % of carbon	Contains more % of carbon
7	Weathering Action	Good	Poor
8	Durability	More	Less
9	Presence of Water	It does not coat aggregates	It coats aggregates more easily in the presence of water

REQUIREMENTS OF BITUMEN

The desirable properties of bitumen depend on the mix type and construction. In general, Bitumen should posses following desirable properties.

- The bitumen should not be highly temperature susceptible: during the hottest weather the mix should not become too soft or unstable, and during cold weather the mix should not become too brittle causing cracks.
- The viscosity of the bitumen at the time of mixing and compaction should be adequate. This can be achieved by use of cutbacks or emulsions of suitable grades or by heating the bitumen and aggregates prior to mixing.
- There should be adequate affinity and adhesion between the bitumen and aggregates used in the mix.

5. DESCRIBE IN DETAIL ABOUT TESTS TO BE CARRIED OUT ON BITUMEN.

May/June 2012, Nov/dec 2012, May/june 2013

TESTS ON BITUMEN

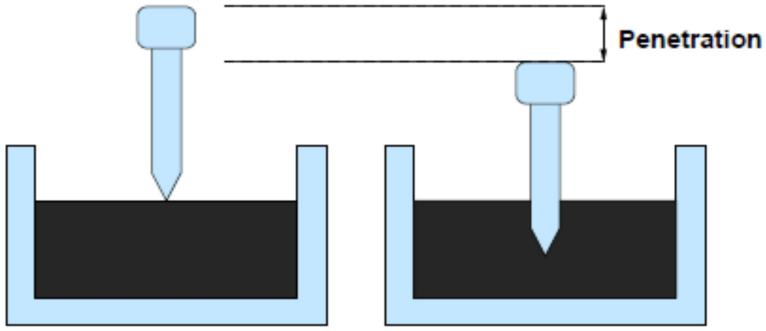
There are a number of tests to assess the properties of bituminous materials. The following tests are usually conducted to evaluate different properties of bituminous materials.

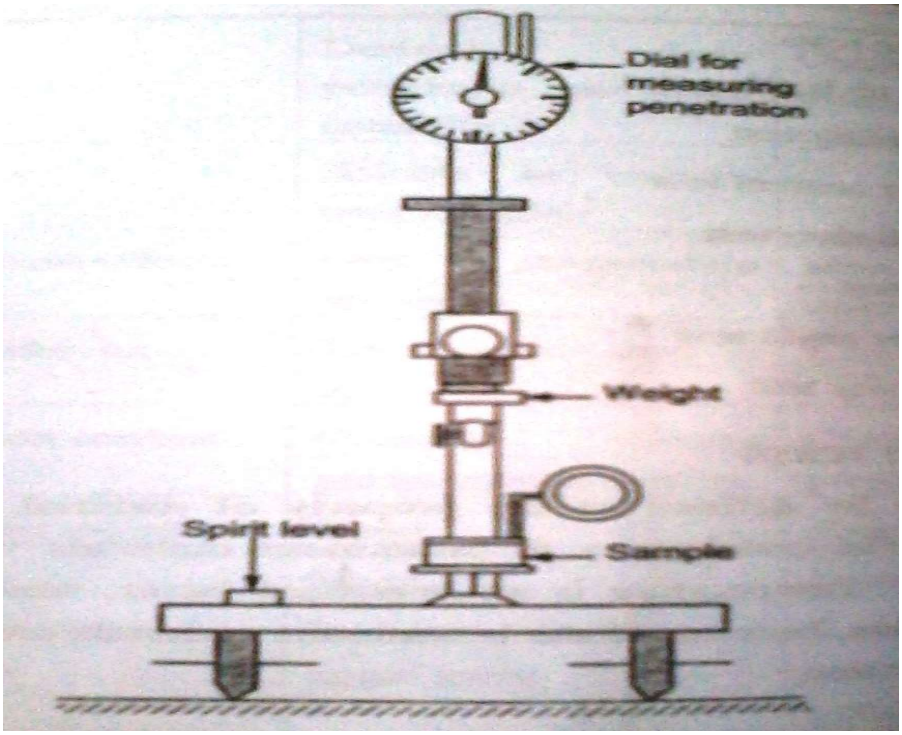
1. Penetration test
2. Ductility test
3. Softening point test
4. Specific gravity test
5. Viscosity test
6. Flash and Fire point test
7. Float test
8. Water content test
9. Loss on heating test

1. Penetration test

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. BIS had standardized the equipment and test procedure. The penetrometer consists of a needle assembly with a total weight of 100g and a device for releasing and locking in any position. 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 25o C. It may be noted that penetration value is largely influenced by any inaccuracy with regards to pouring temperature, size of the needle, weight placed on the needle and the test temperature. 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. The Figure shows a schematic Penetration Test setup.

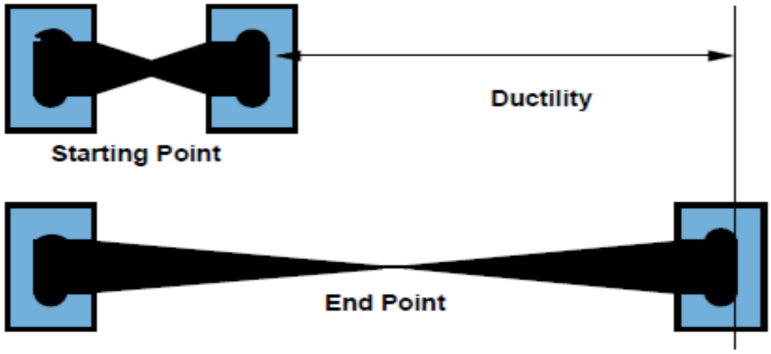




2. Ductility Test

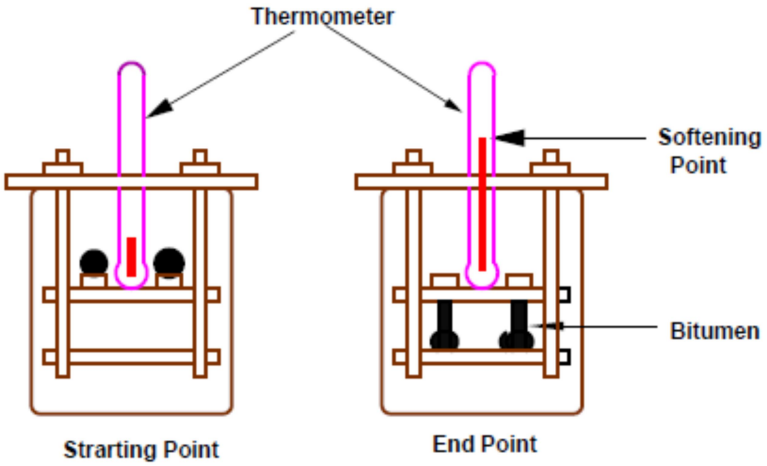
Ductility is the property of bitumen that permits it to undergo great deformation or elongation. Ductility is defined as the distance in cm, to which a standard sample or briquette of the material will be elongated without breaking. Dimension of the briquette thus formed is exactly 1 cm square. The bitumen 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 water bath at 27o C temperature. The excess bitumen is cut and the surface is leveled using a hot knife. Then the mould with assembly containing sample is kept in 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. The distance up to the point of breaking of thread is the ductility value which is reported in cm. The ductility value gets affected by factors such as

pouring temperature, test temperature, rate of pulling etc. A minimum ductility value of 75 cm has been specified by the BIS. Figure shows ductility moulds to be filled with bitumen.



3. Softening point test

Softening point denotes the temperature at which the bitumen attains a particular degree of softening under the specifications of test. 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. A steel ball is placed upon the bitumen sample and the liquid medium is heated at a rate of 5o C per minute. Temperature is noted when the softened bitumen touches the metal plate which is at a specified distance below. Generally, higher softening point indicates lower temperature susceptibility and is preferred in hot climates. Figure shows Softening Point test setup.



4. Specific gravity test

In paving jobs, to classify a binder, density property is of great use. In most cases bitumen is weighed, but when used with aggregates, the bitumen is converted to volume using density values. The density of bitumen is greatly influenced by its chemical composition. Increase in aromatic type mineral impurities cause an increase in specific gravity.

The specific gravity of bitumen is defined as the ratio of mass of given volume of bitumen of known content to the mass of equal volume of water at 27o C. The specific gravity can be measured using either pycnometer or preparing a cube specimen of bitumen in semi solid or solid state. The specific gravity of bitumen varies from 0.97 to 1.02.

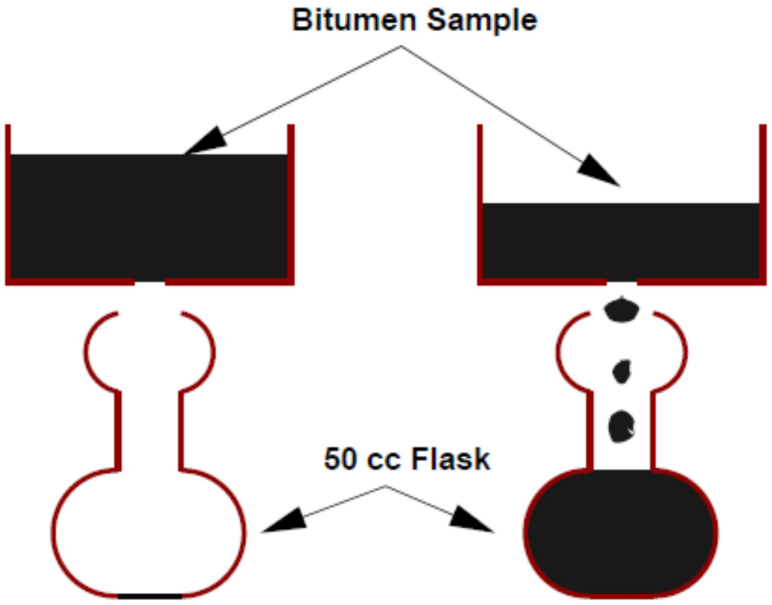
5. Viscosity test

Viscosity denotes the fluid property of bituminous material and it is a measure of resistance to flow. At the application temperature, this characteristic greatly influences the strength of resulting paving mixes. Low or high viscosity during compaction or mixing has been observed to result in lower stability values. At high viscosity, it resists the compactive effort and thereby resulting mix is heterogeneous, hence low stability values. And at low viscosity instead of providing a uniform film over aggregates, it will lubricate the aggregate particles.

Orifice type viscometers are used to indirectly find the viscosity of liquid binders like cutbacks and emulsions. The viscosity expressed in seconds is the time taken by the 50 ml bitumen material to pass through the orifice of a cup, under standard test conditions and specified temperature. Viscosity of a cutback can be measured with either 4.0 mm orifice at 25^{o} C or 10 mm orifice at 25 or 40^{o} C.

6. Flash and fire point test

At high temperatures depending upon the grades of bitumen materials leave out volatiles. And these volatiles catch fire which is very hazardous and therefore it is essential to qualify this temperature for each bitumen grade. BIS defined the ash point as the temperature at which the vapor of bitumen momentarily catches fire in the form of ash under specified test conditions. The fire point is defined as the lowest temperature under specified test conditions at which the bituminous material gets ignited and burns.



Type of test	Test Method
Penetration Test	IS: 1203-1978
Ductility test	IS: 1208-1978
Softening Point test	IS: 1205-1978
Specific gravity test	IS: 1202-1978
Viscosity test	IS: 1206-1978
Flash and Fire Point test	IS: 1209-1978
Float Test	IS: 1210-1978
Determination of water content	IS: 1211-1978
Determination of Loss on heating	IS:1212-1978

6. EXPLAIN IN DETAIL ABOUT WBM ROAD AND THE MATERIALS FOR CONSTRUCTION.

CONSTRUCTION PRACTICE OF ROADS

WATER BOUND MACADAM (WBM) ROADS

Water Bound Macadam (WBM) Roads are the low cost roads, having dense and compact road surface made of crushed or broken aggregates. The aggregates are interlocked by rolling and the voids may be filled up with screening material and binding material with the help of water.

Following three materials are required for the construction of WBM Roads:

1. Coarse aggregate (any one of the following)
   a) Broken stones
   b) Crushed stone

c) Crushed slag
d) Over burnt brick aggregate
e) Natural aggregate (kankar, laterite, etc.,)

2. Screenings
3. Binding material

Coarse Aggregate

The coarse aggregate used for WBM road construction should be durable, hard and free from flaky and elongated particles. The IRC recommended the test values of coarse aggregate ranges in the following table.

S.No	Property	Requirements for pavement layers (max %)		
		Sub-base	Base Course	Surface Course
1	Los Angeless Abrasion Value	60	50	40
2	Aggregate Impact Value	50	40	30
3	Flakiness Index	-	15	15

The thickness of the aggregate is depending upon the following factors:

- Intensity of traffic
- Weight of commercial vehicles using the road
- Bearing capacity of the soil
- Hardness of the stone used

Screenings

The screenings are used to fill up the voids in the compacted layer of coarse aggregates and they usually consist of aggregates of small size of the same material as that of coarse aggregates. In order to reduce the construction cost, the IRC has recommended that the use of predominantly non plastic material such as kankar modules, moorum or gravel provided such material satisfies the following requirements.

- The liquid limit is less than 20 %
- The plastic index is less than 6 %
- The portion of fines passing 0.075 mm sieve is less than 10 %

For crushable type aggregates such as bricks, kankar and laterite, there is no need of using screenings for filling up the voids in coarse aggregates.

Binding Materials

In WBM road construction, binders or binding material (in the form of fine grained material) is used to prevent the wearing action by rubbing of aggregates.

The material having 4% to 9% plasticity index is used for the surfacing course. If kankar or limestones are locally available, their dust can be used as binding material. For crushable type screenings like moorum or gravel, there is no need for applying binders, unless the plasticity index is very low.

7. WRITE THE CONSTRUCTION PROCEDURE FOR WBM ROAD.

METHOD OF CONSTRUCTION FOR WBM ROAD

1. The sub grade (or base course) is prepared to the required grade and camber
2. For providing lateral confinements of aggregates, the shoulders (having thickness equal to compacted WBM layers) should be constructed in advance, with good earth or moorum. The shoulders are prepared and rolled so as to retain the road structure between them
3. The coarse aggregate spread uniformly on the prepared base course in required quantities. The number of layers and thickness of the pavement will depend on the design of pavement.
    - For ordinary roads - Compacted thickness of 75 mm
    - For important roads - Compacted thickness of 150 mm of two layers
4. After spreading of aggregate, the rolling is carried out for compaction. It may be done with the help of a three wheeled power roller of 6 to 10 tonnes capacity or an equivalent vibratory roller. The roller should pass equally over the entire surface and its speed should be slow and uniform.
5. After compaction by rollers, the screenings are applied to fill up the voids. The screenings are applied to fill up the voids in three or more layers and each layer is compacted by dry rolling.
6. The surface of the road is then sprinkled with plenty of water after the application of screenings. Then it is swept and rolled. The hand brooms are used to sweep and additional screenings may be applied.
7. The binding material is then applied at a uniform and slow rate in two or more successive thin layers. After each application of binding material, the surface is sprinked with excessive water and the wet slurry formed is swept with the help of hand brooms or mechanical brooms to fill up the voids.
8. The road surface is then allowed to cure or set over night after final rolling. If any depressions are present on the nest day, they are filled up with screenings or binding material.

9. The road is then opened to traffic. If the road surface is to be coated with bituminous dressing, the WBM layer should be allowed to dry completely before laying the bituminous surfacing over it.

Advantages of WBM Roads

- For good conditioned WBM roads can take rubber tyre traffic of 450 tonnes and about 450 tonnes of iron tyre traffic.
- If the maintenance work is properly done means, WBM road provides best service for a long time.
- The initial cost is low.
- The construction process is very simple and locally available material can be used.

Disadvantages of WBM Roads

- Due to depressions on road surface, small water pools are formed.
- Improper maintenance of WBM road causes inconvenience and dangerous to the traffic.
- They are permeable to rain water and it leads to the softening and yielding of sub soil.

8. WRITE BRIEF NOTE ON BITUMINOUS ROAD.

BITUMINOUS ROADS

Bituminous roads are defined as the pavements (or) roads, composed of a mixture of bitumen and / or tar with coarse aggregate. Bitumen or tar are used as a binding material and due to black appearance of the surface of the pavement, these roads are also termed as black top roads.

Nowadays bitumen and bituminous materials are one of the major highway construction materials due to the following advantages and functions.

1. It provides smooth and comfortable riding surface.
2. It also provides high resistance to surface wear and deformation.
3. Bitumen provides skid resistance surface.
4. It distributes the wheel loads evenly, without overstressing the lower layers.
5. It protects the sub base and soil grade against the action of rain water and climatic changes considerably.

Types of Bituminous Pavement

Based on the methods of construction bituminous pavements can be classified under the following categories.

1. Surface Treatments

- Prime Coat
- Tack Coat
- Surface Dressing
- Seal Coat

2. Grouted or Penetration Macadam
    a. Semi – grouted macadam
    b. Fully – grouted macadam
3. Road mix surfaces
    a. Open graded mixes
    b. Dense grade mixes
    c. Sand asphalt
4. High type bituminous pavements
    a. Bituminous macadam
    b. Bituminous concrete (or) asphalt concrete
    c. Sheet asphalt (or) rolled asphalt concrete
    d. Sand asphalt
    e. Mastic asphalt
    f. Tar concrete

Bituminous pavements can also be classified based on the basis of mixing and as follows:

1. Road Mix
2. Central Plant Mix

SURFACE TREATMENTS

Surface Treatments are the process carried out to alter the qualities of a wearing surface. The different types of surface treatments are briefly explained below:

Prime Coat:

Prime coat consists of application of low viscosity cut back (E.g.RC-0 MC-1 or SC-1) as primers on an existing base of previous texture. Various functions of a prime coat are

1. It plugs capillary voids and act as a water proofing agent for the existing base.
2. It provides best bonding between old and new surface.
3. It serves as a mixing table for road mix paving jobs.

Prime coat is applied by spraying at a uniform rate by using a mechanical sprayer, and the rate of spraying may vary from 7.3 kg to 14.6 kg per 10 m^2 area. The rate of spraying depends on the porosity of the surface in case of prime coat.

Tack Coat

Where new wearing surface is to be provided over an old bituminous surfacing (or) a new coat of old concrete pavement (or) on a brick, stone and block pavement (or) on a primed granular base course, a tack coat is provided.

Before application of tack coat, the surface is cleaned and a bitumen run surface layer at the rate of 5 kg/10 m^2 over an existing surface (or) 10 kg/10m^2 over an untreated WBM surface.

The materials used for tack coat are, RC – 2, RC – 3, RC – 4, Emulsified asphalt, asphalt cement of 150 – 200 penetration value, RT – 4 to RT – 9.

Seal Coat

Seal coat is required for bituminous wearing surface and serves as,

- Bituminous coat
- Developing non skid structure
- Sealing exterior surface
- Demarcation of traffic between shoulder of the road and the carriageway

Seal coat consists of bituminous material with covering of stone, sand or gravel passing 12.5 mm sieve and retained on 6.3 mm sieve. The construction process is similar to single coat surface dressing. The quantity of materials for seal coat is given in the following table.

Material	**Size**	**Quantity per 10 m^3**
Chippings	9 mm, passing 12 mm and retained in 6 mm square mesh	0.09 to 0.11 m^3
Binder	Road tar of suitable grade	9.8 to 12 kg

9. WRITE THE CONSTRUCTION PROCEDURE FOR SURFACE DRESSING.

April / may 2011, Nov/dec 2011

SURFACE DRESSING

Generally surface dressing consists of a layer of small aggregates such as chippings of stone, slag or gravel on a thin layer of binder, which is freshly applied to an existing road surface.

A surface dressing provided on earth or gravel of WBM road provides non-skid surface improves the night visibility, arrests disintegration and provides a clear demarcation between the carriageway and shoulders. It does not increasing the load carrying capacity but provides a dust free surface and water proof surface. Generally specifications suggested that the

surface dressing for use in single coat surface dressing, double coat surface dressing, open graded premix carpet and mix seal surfacing.

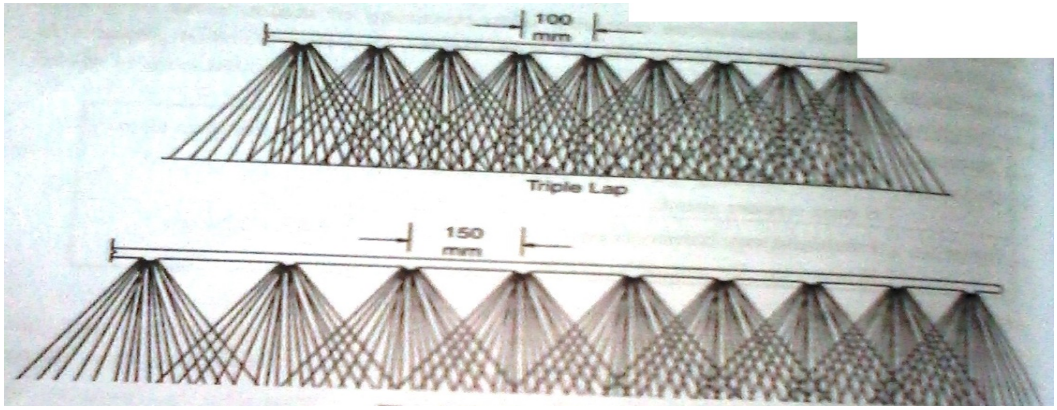
MATERIAL AND CONSTRUCTION OPERATION

MATERIALS

Bitumen – Depending upon the climatic conditions of the locality, the grade of the straight run bitumen is selected, and mostly 80/100 and 180/200 grade are utilized for surface dressing.

For single surfaced dressing on WBM base course, the quantity of bitumen needed ranges from 17 to 19.5 kg / 10 m^2 area and 10 to 12 kg / 10 m^2 area.

For second coat of surface dressing, the quantity of bitumen needed ranges from 10 to 12 kg / 10 m^2 area.



Aggregates – the stone chippings should consist of clean, durable and uniform quality aggregates of following properties.

The aggregates should also be free from soft pieces, salt, alkali, vegetable matters, elongated, flaky pieces and dust coating.

The quantity of aggregates used in first coat of surface dressing should be 0.15 m^3 per 10 m^2 area of 12 mm normal size. On the other hand, the quantity of aggregates used in second coat of surface dressing should be 0.10 m^3 / 10 m^2 area and of 10 mm size.

EQUIPMENTS USED FOR CONSTRUCTION

The equipments used for construction of surface dressing are: bitumen boiler, spraying unit, spraying cans, road roller (8 to 10 tonnes), buckets, Wire brushes, Coir Brushes, Gunny bags, Baskets lined with gunny clothes, Empty drums, Road Barriers, Diversion Boards, Thermometers, Tractor, Hammer, Spades, Measuring tapes, Spades, Measuring tapes, Camber board, Straight edges etc.,

CONSTRUCTION PROCEDURE

1. **Preparation of Base**

   Before laying the surface dressing, the base should be prepared with grade and cross section. The prepared surface should be completely cleaned by hard and soft brushes and finally by blowing with gunny bags.

2. **Application of Binder**

   Bitumen heated at 163^0C to 177^0C is uniformly sprayed with the help of a mechanical sprayer. The binder is to be sprayed longitudinally along the length of the road and not transversely, so as to prevent corrugations.

3. **Application of Stone Chippings**

   After the application of binder, over the cleaned surface, the stone chippings are uniformly spread with mechanically or manually.

4. **Rolling**

   After the stone chipping, the rolling process is to be carried out by using a 8 to 10 tonnes roller, till the entire surface is firmly bedded.

5. **Application of Second Coat**

   The second coat should be applied immediately after laying the first coat, by the similar procedure of first coat. The road should not be opened for traffic before 24 hours.

10. WRITE THE CONSTRUCTION PROCEDURE FOR PENETRATION MACADAM AND ROAD MIX SURFACES.

GROUTED OR PENETRATION MACADAM

It is a type of highway construction in which a bituminous binder is applied in a fluid state to partially compacted aggregate layer. When binder is allowed to penetrate to full depth, it is known as full grouted macadam and when binder is allowed to penetrate half the depth, it is called semi – grouted macadam.

Full grouted macadam is used in heavy rainfall areas on having a thickness of 5 to 8 cm thickness. Semi grouted macadam is used in the average rainfall areas and medium traffic locations with about 5 cm thickness.

MATERIALS

The binder is straight run bitumen of grade 80 / 100 or 60/70 or 30/40. The required quantity for 5 cm thickness is about 58 kg / 10 m^2 area and 68 kg / 10 m^2 area for 7.5 cm thickness.

Crushed stone or crushed gravel may be used as coarse aggregate and they should be clean cubical in shape and free from organic, hydrophobic matters. Is should also have less porosity.

The coarse aggregate and key aggregates required for 5 cm compacted thickness should be 0.6 m^3 and 0.15 m^3 per 10 m^2 area respectively.

EQUIPMENTS AND ACCESSORIES

Equipments used for spray grout macadam is same as that of equipment and accessories used for surface dressing.

CONSTRUCTION PROCEDURE

The various construction procedures and operations are similar to that of the previous methods. Heated binder should be sprayed on aggregate layer at the rate of 12.5 kg / 10 m^2 area, in a uniform manner with the help of mechanical sprayers.

Immediately after the first application of binder, the second layer of coarse aggregates should be spread and rolled. Heated binder at the rate of 12.5 kg/ 10 m^2 area is spreaded and over which key aggregates should be spread uniformly at the rate of 0.13 m^3 / 10 m^2. The top surface should be rolled with 8 to 10 tonnes smooth wheeled roller till the key aggregates are firmly in position. The road surface should be open to traffic after 24 hours.

ROAD MIX SURFACE

In this type of construction, the binder and aggregate are mixed, on the top of an existing surface or a base. If the aggregates used are of uniform size, then the road mix is known as open grade mix. In dense graded mix, the aggregates used are well graded.

In case of mix in place, sand asphalt construction the naturally occurring sand is mixed with liquid asphalt to form the weathering surface. The road mix surfaces are suitable for light to moderate traffic conditions on old or new bases.

Road mixes have the following advantages over penetration macadam

- Saving in quantity of bitumen
- Better coating of aggregates
- Increased stability.

HIGH PERFORMANCE PAVEMENTS

These types of pavements use central plant mix for its construction. The various high types of bituminous pavements using premixed aggregates described below.

1. **Bituminous Macadam**

This is the type of construction of 5 cm to 7.5 cm thickness and in this, the compacted crushed aggregates premixed with the bituminous binder.

Bituminous macadams are suitable for areas in snow bound hilly terrain, regions of high ground water table and in areas where medium type of aggregates are available in plenty.

Construction materials

The various binders used for bituminous macadam are, straight run bitumen, road tar, cut back or emulsion.

The bitumen grade 30/40, 60/70 or 80/100 is chosen depending upon the climatic conditions. The quantity of the bitumen needed depends upon the grading adopted in the design.

The crushed aggregates should be used. Is should be clean, strong, durable, cubical in shape.

Construction Procedure

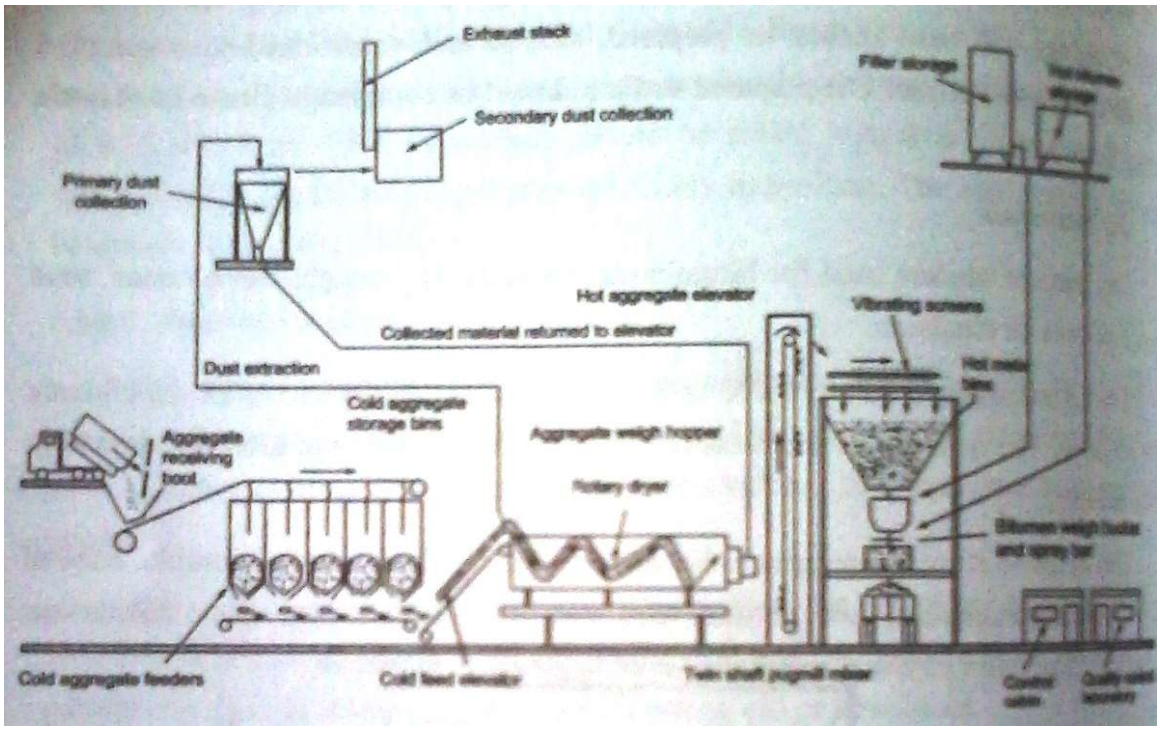
It is essential to lay tack coat over the base before laying bitumen bound macadam construction. The quantity of binder for tack should be 5 kg to 7.5 kg per 10 m^2 for bitumen base and 7.5 kg to 10 kg / 10 m^2 for untreated Water Bound Macadam layer.

Mix Preparation: the bitumen and aggregates heated to a temperature range of 155^0C to 163^0C and 155^0C to 177^0C respectively. The difference in temperature between aggregate and bitumen should not exceed 14^0C.

The mixer should be a completed one in which all parts of aggregate should be coated uniformly by the bitumen. The figure shows the typical layout of batch plant. The mixture is carried out to the site through a wheel barrow or vehicle.

Equipments and Accessories: Drying and mixing unit, Bitumen boiler, chain pulley arrangement for lifting of drums, Road roller of 8 to 10 tonnes capacity, Bitumen Sprayer, Spring Balance, Buckets, Baskets, Wire brushes, Coir brushes, Gunny bags, Spades, Thermometer, Wheel barrow etc.,

Layout of Batch Plant



Spreading: The mix should be spread immediately after mixing by means of a self propelled mechanical paver with suitable screeds capable of spreading, tamping and finishing the mix. The temperature of the mix at the time of laying should be maintained in the range of about 120 to 165^0 C.

Rolling: After spreading, the rolling is to be done with the help of 8 to 10 tonnes tandem roller. The rolling is commenced from edge to the centre of the pavement and uniform overlapping is carried out.

11. WRITE BRIEF NOTE ON CEMENT CONCRETE ROAD. MAY/JUNE 2013

CEMENT CONCRETE PAVEMENT:

Cement concrete roads are very high standard. They are costliest than all other types of roads. These roads provide excellent riding surface and pleasing appearance. They are called rigid pavements because they do not allow any flexibility. These roads although require initial heavy expenditure but because of their long span of life, excellent riding surface and negligible maintenance cost, they prove cheaper than bitumen roads. Moreover engineers have more confidence in cement concrete material and they also like to construct these roads.

The cement concrete roads are monolithic slabs f cement concrete, and it serves two main functions simultaneously.

1. Load carrying base
2. Wearing Surface.

In order to provide, high rigid surface to the pavement, the C.C road should satisfy the following two conditions.

1. It should rest on non- rigid surface having uniform bearing capacity
2. The combined thickness or depth of the concrete pavement should be sufficient to distribute the wheel load.

ADVANTAGES AND DISADVANTAGES OF CONCRETE ROADS

The following are some of the advantages and disadvantages of cement concrete roads:

Advantages

- They provide excellent smooth surface for driving.
- They can deal with very heavy traffic
- Considering their life span, maintenance cost etc, cement concrete roads prove cheaper than bituminous roads.
- Maintenance cost is negligible.
- Their life span is very large
- Even after their span of life, they can be used as base course and surfacing can be provided of bituminous materials.
- Heating of aggregates and cement is not to be done
- They provide better visibility.
- Working with cement concrete is much easier and safer than with bituminous materials.
- Cement concrete roads offer comparatively less attractive resistance.
- In high class cement concrete roads heavy rollers are not required for compaction.
- Handling of cement is easier than bitumen.
- They perform quite satisfactorily when laid on poor types of sub - grades.

Disadvantages

- They involve heavy initial investment.
- Lots of joints are to provide which prove additional places of weakness.
- 28 days curing is required after completion before they can be opened to traffic.
- It is not possible to adopt stage construction programmed in these roads.
- Cement concrete road surface after some time of use becomes very smooth and slippery
- It is a noisy road, as bullock carts or steel tyred vehicles cause lot of noise while moving on them.

CLASSIFICATION OF CEMENT CONCRETE ROADS

Cement concrete roads can be of following types. Out of all these types, cement concrete slab roads, are most commonly used,

- Cement concrete slab pavements
- Cement grouted macadam pavement
- Roller concrete layer pavements
- Cement-bound macadam sandwich type
- Crete-ways

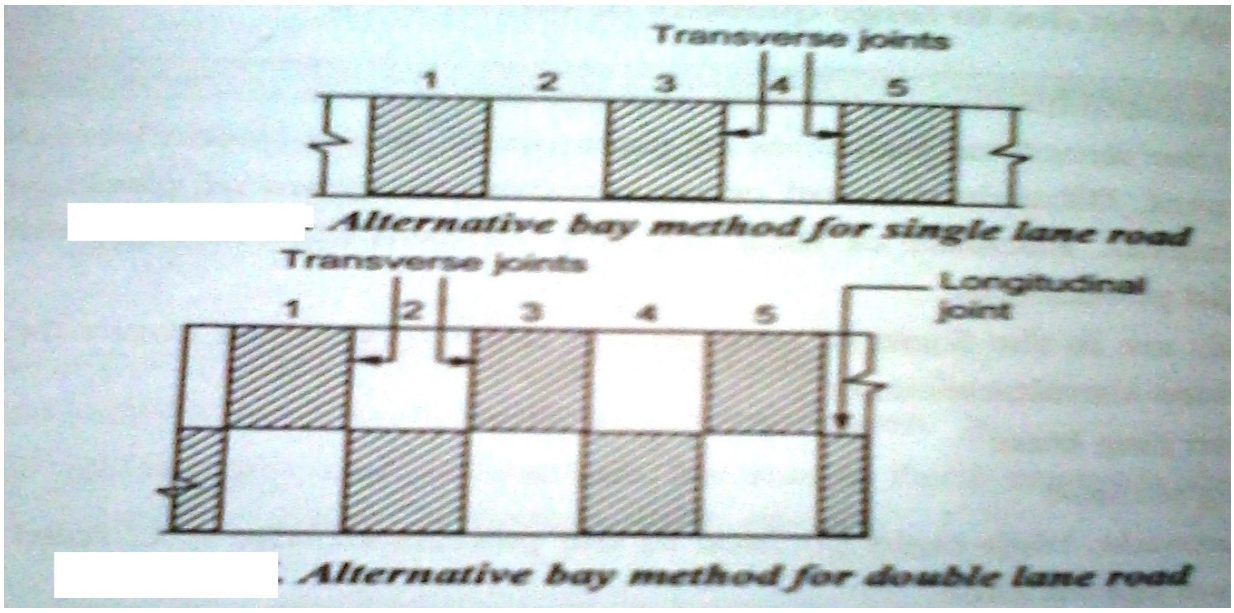
Method of Construction of C.C Road

a. Alternative bay Method
b. Continuous Bay Method
c. Expansion Joint and Strip Method

a) Alternative Bay Method

In this method of laying concrete, width of the road is divided into longitudinal strips. The longitudinal strips are further sub-divided into panels by providing transverse formwork. If the width of the road is just one lane, full width is adopted as one longitudinal strip, but in the case of more than one lane width, each lane is adopted as one longitudinal strip. In short, the road surface is divided into panels. After this cement concrete is filled in alternative panels or bays both longitudinally and transversely. Size of the bay may be anything like 4 X 4 m, 3.6 X 4.6 m or so.

After a lapse of about one week, remaining left out bays are also filled with cement concrete. The object of adopting alternate bay system of construction is to allow sufficient time to settle and shrink before adjoining bays are filled. The method reduces the possibilities of developing shrinkage base cracks.



Alternative bay method for single lane road

Alternative bay method for double lane road

This system of construction suffers from following draw backs:

1. A large number of joints are developed which increase the labour cost and also reduce the smooth riding qualities of the resulting surface.
2. During rain, water gets collected in the unfilled bays.
3. Works are not finished at a stretch but a large length of the road remains occupied at any moment. If full width is involved, diversions for traffic will have to be provided, thus causing difficulties to traffic and increase in the cost over of all construction.
4. Fully mechanized construction is not possible.v.Progress of the work is very slow.

The only advantage of this method of construction is that joints can be easily constructed. Figure shows formation of bays on the surface of the road. A, B, C bays are filled first and A', B', C' bays subsequently after a laps of about one week.

b) Continuous Bay Method

In this system of construction, continuous longitudinal strips are constructed without any break. Width of the strip is generally kept one lane. This method also helps in marking the traffic lanes after completion, since longitudinal joints will demarcate the limit of each lane. The construction joints are provided at the end of the day's work.

This method of construction is preferred because of the following reasons:

i. Very few joints will be formed
ii. In case of roads having more than one lane width, no diversion is required to be constructed. One lane may be adopted for construction at a time and remaining lanes may continue to be used by the traffic. Although traffic will face difficulties but there is no need diversion.

c) Expansion Joint and Strip Method

In this method, the road is divided into longitudinal strips and transverse bays by means of framework as shown in figure. The joints are then suitably filled up with fillers like asphalt and finished so as to provide for the expansion of the concrete slab.

By this method, any width of road can be constructed at ease and it gives better alignment and finish. It also carries the traffic during construction and hence no temporary diversion road is necessary. There has been considerable improvement in the technology of joints in concrete roads and hence most of the modern concrete roads are constructed by this method.

12. WRITE DOWN THE STEP BY STEP PROCEDURE FOR CONSTRUCTION OF CEMENT CONCRETE ROAD. NOV/DEC 2012

CONSTRUCTION STEPS OF CEMENT CONCRETE SLAB PAVEMENTS

Construction of cement concrete pavement involves following stages:

1. Preparation of sub grade.
2. Preparation of sub base.
3. Fixing of farm.
4. Batching of materials and mixing.
5. Carrying and placing concrete.
6. Compaction and finishing.
7. Floating and edging.
8. Belting and edging.
9. Curing
10. Final Surface Check
11. Removing the Forms
12. Sealing of the Joints

1. Preparation of Sub Grade:

Where formation soil is of very good quality, cement slab may directly be laid over the prepared sub grade. The top 15 cm layer of the sub grade should be compacted and checked for trueness by mean of scratch template. Unevenness of the surface should not exceed 12 mm in3 m length. Sub grade should be prepared and checked at least two days in advance of concreting. It is

desirable to lay a layer of water proofing paper then even concrete can be laid directly over the soil sub grade .Prepared sub grade should complete the following requirements:

- There should not be any soft patches on the prepared sub grade.
- Sub grade should present the uniform support to the concrete slab.
- Should be properly drained.
- Minimum modulus of sub grade reaction obtained with plate bearing test should be 5.5 kg / cm^2
- If water proof paper is to be laid directly over the sub-grade, moistening of sub grade prior to placing of the concrete over it, is not required. Moistening is essential in case water proof papers are not used.

2. Preparation of Sub Base

When formation soil is very poor quality, or traffic load expected on the pavement is very heavy, a 15 cm thick sub base layer may be used over the prepared sub grade before lying of cement concrete slab. The sub base slab may consist of:

i. One layer of flat brick soling below one layer of Water Bound Macadam.
ii. Two layers of Water Bound Macadam may consists of stone, hard rock, dense blast furnace slag, brick aggregate or any other granular material which is not likely to soften under action of water.
iii. Well graded soil gravel mixture.
iv. Soil stabilized with 3 – 4 % lime or cement.
v. Lime concrete or lean concrete giving 28 days compressive strength in the field as 40 – 60 kg / cm^2
vi. Existing macadam sub base
vii. Existing black top surface sub base.

From i to v, all the points are for new constructions and can be adopted as per design requirements. But vi and vii points are for existing sub base and thus have been given in details

Existing Macadam Sub Base: In case concrete slabs are to be laid on existing Water Bound Macadam roads, it should be seen that Water Bound Macadam should extend at least 30 cm beyond the proposed concrete slab edges. Water Bound Macadam should be at least15 cm thick. If Water Bound Macadam surface is smaller in width than the proposed width of the concrete slab up to 30 cm on either side, the extra width may be developed by placing 10 cm of 1: 4: 8 lean cement concrete.

Black Topped Surface: Here concrete slab is to be laid over existing black – topped surface no special treatment is necessary. Concrete should not be laid on black topped surfaces having soft spots caused by excessive bitumen or where thick premixed carpets have been rutted badly under traffic. In

such cases entire surfacing material should be removed up to the top of compacted macadam and the surface should be prepared as explained in existing Water Bound Macadam surfaces.

3. Fixing of Forms.

Forms may be made from mild steel channel sections or wooden planks. Depth of the forms should be equal to the thickness of the slab to be provided. Length of the section for side forms is kept at least 3 m except on curves of less than 45 m radius where shorter lengths Wooden forms should be dress on one side and should have a minimum base width of 10 mm for slab thickness of 20 cm and have a minimum base width of 15 mm for slabs over 20 cm thickness. Deviation of more than 3mm in a length of 3 m should not occur when forms are filled with concrete. Sufficient number of stakes or pins should be put at the back of the form to impart sufficient support to it.

4. Batching of Materials and Mixing:

Cement is measured in number of bags. If cement stored in silos is used, its weight is taken as 1440 kg / m^3. Course aggregate and fine aggregates are batched in weigh batching plant and put into the hopper of the mixer along with required quantity of cement. Water is measured by volume. The mixing of each batch should be at least for 1 ½ minutes counted after all the materials have been put into the mixer.

5. Carrying and Placing of Concrete

Prepared premix is carried immediately to the place of actual use by filling into wheel barrows, hand carts or baskets. While concreting, it should be ensured that there is on segregation in the concrete. Concrete put at site is spread uniformly as per requirements of the thickness of the slab. While being placed, the concrete should be rodded so that the formations of voids or honey comb pockets are prevented. The concrete should be particularly well placed and tapped against the forms and along all the joints.

6. Compaction and Finishing

After having uniformly spread, the concrete is compacted either with the help of power-driven finishing machine or by vibrating screed. For constrained areas like corners and junctions, hand compaction can be done using tampers. Hand tamper is also known as hand tamping beam. It consists of a wooden beam 10 cm wide and 25 cm depth. Length of the tamping beam should be equal to the width of the slab plus 30 cm. A steel plate is fixed at the underside of this beam. Tamper is used by placing it on the side forms. Tampers are lifted and dropped to affect compaction. Tamper beam is provided with handles to lift and drop.

7. Floating and Edging

After compaction, with vibrating screed or tamper, the concrete is further compacted and smoothened by means of longitudinal floats. The float is worked longitudinally with sawing motion from one edge of the pavement to the other edge. After this operation, excess water gets disappeared but while concrete is still plastic; the surface of the slab should be tested for trueness with the help of 3 m straight edge.

8. Belting and Edging

Just before the concrete becomes non-plastic, the surface should be belted with the help of a two-ply canvas belt which is usually 20 cm wide and at least 1 m longer than the width of the slab. The belt is worked on the surface in transverse direction in short forward and back ward strokes. After belting and as soon as surplus water disappears from the surface, the pavement is given a broomed finish with an approved steel or fibre broom not less than 45 cm wide. The broom should be pulled gently over the surface of the pavement from edge with each stroke slightly over lapping the adjacent one. After belting and brooming and before the concrete has taken initial set, the edges of the slab should be carefully finished with an edger of 6mm radius.

9. Curing

Immediately after finishing, the entire surface of the newly laid concrete should be covered against rapid drying with wetted burlap, cotton or jute mat. Covering operation with wet burlap is known as initial curing. Burlap curing is carried out for at least two days. After this, wet burlaps are removed and surface is covered either with damp saturated sand or with free water. Final curing can also be done by applying an impervious membrane which does not impart slipperiness to the pavement. Impervious membrane which is in form of liquid is applied under pressure, covering the entire surface uniformly. The liquid may be applied immediately after finishing of the surface and before the set of the cement has taken place. If the pavement is first covered with burlap it may be applied upon removal of the burlap. This method of curing can be adopted at places where there is scarcity of water.

10. Final Surface Check

This check is done after curing period when curing sand has been removed from the surface. Undulations in the surface should not exceed 6mm in length of 3 m.

11. Removing the Forms

Forms should be removed after a lapse of about 12 hour’s from placing of concrete. Forms should be removed carefully avoiding any damage to the pavement edges.

12. Sealing of the Joints

After curing period, and before the pavement is opened to traffic, all the joints should be cleared of intruded materials and suitable sealing material put into them.

13. DESCRIBE IN DETAIL ABOUT JOINTS IN CEMENT CONCRETE ROAD.

JOINTS IN CEMENT CONCRETE ROADS

Effective system of joints is essential feature in the successful functioning of the cement concrete roads. Tie bars and dowel bars are provided to maintain the strength of the pavement at the joints and also to act as load transfer devices. Joints in cement concrete pavements can be classified under three headings:

a. Expansion joints

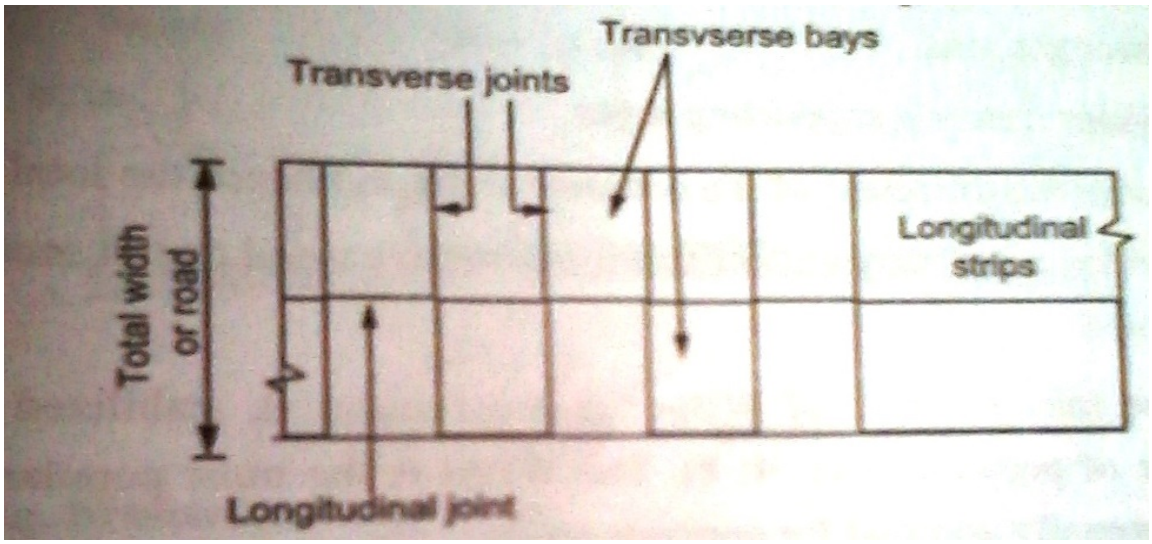
b. Contraction joints

c. Warping or hinged joints

Expansion joints provide space into which pavement can expand. These joints release compressive stresses developed in the concrete slab. Expansion joints also relieve stresses caused by construction and warping.

Contraction joints relieve tension developed in the concrete due to contraction. They prevent formation of irregular cracks contraction joints also relieve stresses due to warping.

Warping joints relieve stresses due to warping effect develops in the slab. These joints are commonly used for longitudinal joints dividing the pavement into lanes. Warping tendencies are set up in the concrete slab due to temperature difference between top and bottom of the slab. At 12 noon the temperature at the top surface of the slab will be higher than that at the bottom. This causes top fibers of the slab to expand by larger amount than the bottom fibers and slab warps down wards at the edges. Similarly at 12 pm the temperature of the bottom of the slab is higher than the temperature at the top of the slab and slab warps upwards at the edges. Weight of the slab tries to prevent this warping of the slab and thus warping stresses are set up. Intensity of warping stress is maximum at the interior and minimum at the edges.



Reason for Providing Joints

- To absorb the expansion and contraction due to the change of temperature.
- To avoid the warping of concrete slab at edges.
- To provide the continuity of concrete laying.

Requirements of Good Joints

- Easy to maintain
- Moves freely without developing stresses
- Not allows the infiltration and rain water
- Should not make inconvenience to the road users
- Should maintain the level of surface

Joints in concrete slab pavement can also be classified according to their direction in relation to the road alignment. Joints constructed in the direction, perpendicular to the alignment of the road are termed as transverse joints. Joints constructed in the direction of alignment known as longitudinal joints.

1. Transverse Joints

Arrangements of transverse joints may be staggered, square or skew. All these arrangements are shown in figure below. Out of these arrangements, square arrangement is the best.

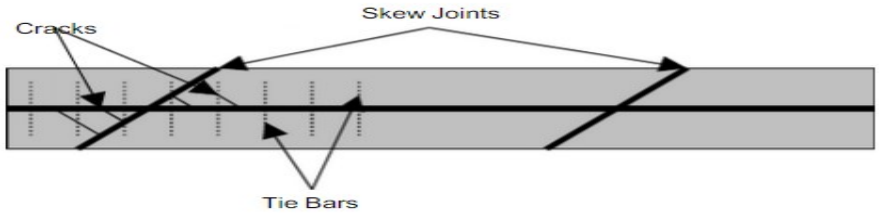


Figure : Skew System Of Joints

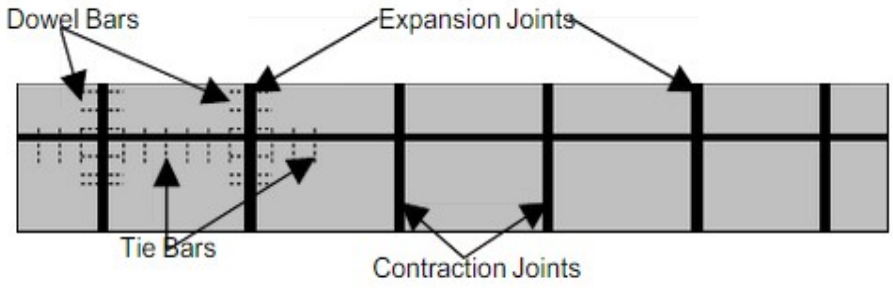


Figure : Square System Of Joints

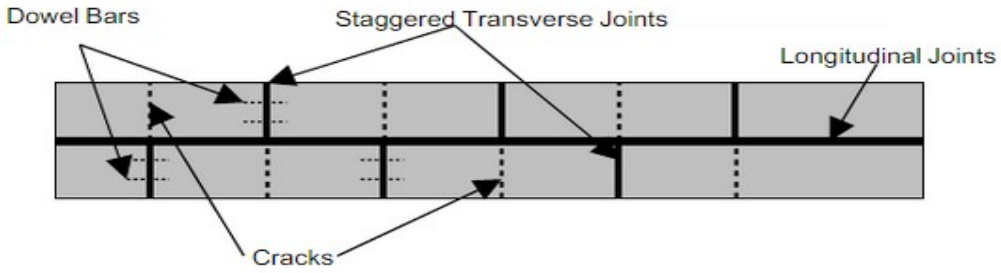


Figure : Staggered System Of Joints

In case of staggered arrangement, it is seen that cracks known as sympathetic cracks are developed in the adjoining longitudinal strip just in front of transverse joints already provided skew arrangement should not be adopted because in this case acute corners generally get crushed away. Transverse joints can be further classified as follows:

- Expansion joints
- Contraction joints
- Warping joints
- Construction joints

2. Longitudinal Joints.

Spacing of longitudinal joints is determined by the lane widths. If during construction of the slab, hand tamping or vibrating hand screeds have been used, the spacing should be limited to 4 m. Where machines have been used for all the process involved in concreting and at the time, more than 6 m width is being laid, an intermediate longitudinal joints should be provided either by sawing a dummy joint or inserting a mild steel T-iron to the depth varying from 1/3 to 1/6 of the depth of the slab. These joints may be plain butt type or butt with tie bars in them. Tie bars should be bonded in the slabs across longitudinal joints and whilst casting the first slabs they may be bent so that one end of them lies along the forms. After removal of the forms, bars should be straightened so that they may extend into the concrete placed on the other side of the joint. Tongued and grooved joints are also sometimes used as the longitudinal joints.

14. BRIEFLY DISCUSS ABOUT HIGHWAY DRAINAGE. MAY/JUNE 2012

HIGHWAY DRAINAGE

Drainage is defined as the interception and removal of water from an area (or) over an area (or) under an area. Highway drainage is defined as the process of removal of water from road surface and also from sub-grade.

Sources of Water –Entering the Road Structure:

- Capillary action of water
- Floods due to heavy rains
- Direct falling of rain water on the road surface
- Rain water from nearby area through sub – grade

REQUIREMENTS OF GOOD DRAINAGE SYSTEM

Adjoining Land: the surface water from the land should be prevented from entering the roadway.

Camber: the road surface should be provided with suitable camber, so as to drain the water quickly without allowing it to percolate.

Cross – drainage Works: The design of cross drainage works overflowing water on the road surface.

Gradient: The roads passing through zones of heavy rainfall should be provided with minimum gradient even if it is not theoretically required.

Highest flood level: The carriageway should be provided at least 600 mm higher than the H.F.L of the surrounding locality.

Intercepting Drains: Where the topography of the area is such that the water flows towards the roadway itself, it becomes important to construct intercepting drains parallel to the road.

Side Drains: It is necessary to construct sufficiently wide and deep side drains with suitable longitudinal slope to carry

Underground Sources of Water: All springs and underground sources of water should be tapped and the water should be drained off by the sub surface drainage system.

Water – logged areas: It is important to take special precautions in case of water – logged areas.

Water table: The sub-surface drainage system should aim at keeping the highest level of ground water table well below the level of sub grade, preferably by at least 1.2 m.

Surface Drainage: the main objective of surface drainage system is to remove the rain water from the carriageway. The provision of surface drainage is one of the essential considerations for the location of a highway and it is seen that all the streams flow away from the highway.

The longitudinal side drains or ditches are laid and the water is then disposed off to the nearest stream, valley or water course. The side drains are usually, V – Shaped or trapezoidal. The capacity of trapezoidal shape is greater. They should be preferably lined, with rubble masonry work.

SIDE DRAINS FOR ROAD IN EMBANKMENT

For roads in embankment, the side drains are provided on one or both sides of the road beyond the shoulder as shown in figure. The side drains are constructed at a minimum distance of about 2 m from the edge of embankment, so that the water flowing in the drains does not enter in to the earth work.

These drains are also helpful for arresting the rain water falling on the adjacent land parallel to the road and it is not allowed to reach the embankment. The water flowing in the side drains can then be suitably disposed off without causing any harm to the roadway.

SIDE DRAINS FOR ROAD IN CUTTING

For roads in cutting, the side drains are provided on either side of the formation, as shown in figure. These drains are carefully designed and it is to be seen that they do not overflow under any circumstances and making the roadway submerged in water.

The open deep side drains may prove to be dangerous and unsightly especially in cases where there is restriction of space. In such circumstances, the covered drains or pipe drains or ditches filled properly with suitable materials like coarse sand and gravel may be provided.

SUB-SURFACE DRAINAGE

The increase in the moisture content of the soil beyond a certain limit leads to the decreases in the strength of soil. It is therefore necessary to have an efficient sub-surfacing drainage system for keeping the road surface in good order.

Methods of Sub-surface Drainage

The main objective if sub- surface drainage is to keep the highest water table level below the level of sub-grade so that the sub-grade and pavement layers not subjected to excessive moisture. The methods adopted for sub-surface drainage can be grouped in the following three methods:

- Methods to control capillary rise
- Methods to control seepage flow
- Methods to lower water table

14. WRITE NOTE ON DIFFERENT MATERIALS GLASS, FIBER, PLASTIC, GEO TEXTILE, GEO MEMBRANE WITH QC MEASURES.

GLASS

Glass is an amorphous (non-crystalline) solid which is often transparent and has widespread practical, technological, and decorative usage in things like window panes, tableware, and optoelectronics. The most familiar, and historically the oldest, types of glass are based on the chemical compound silica (silicon dioxide), the primary constituent of sand. The term *glass*, in popular usage, is often used to refer only to this type of material, which is familiar from use as window glass and in glass bottles.

FIBER

Fiber or fibre is a natural or synthetic string used as a component of composite materials, or, when matted into sheets, used to make products such as paper, papyrus, or felt. Fibers are often used in the manufacture of other materials.

The strongest engineering materials often incorporate fibers, for example carbon fiber and ultra-high-molecular-weight polyethylene.

Synthetic fibers can often be produced very cheaply and in large amounts compared to natural fibers, but for clothing natural fibers can give some benefits, such as comfort, over their synthetic counterparts.

PLASTIC

Plastic is a material consisting of any of a wide range of synthetic or semi-synthetic organics that are malleable and can be molded into solid objects of diverse shapes. Plastics are typically organic polymers of high molecular mass, but they often contain other substances. They are usually synthetic, most commonly derived from petrochemicals, but many are partially natural. Plasticity is the general property of all materials that are able to irreversibly deform without breaking, but this occurs to such a degree with this class of moldable polymers that their name is an emphasis on this ability.

GEO - TEXTILES

Geo - textiles are permeable fabrics which, when used in association with soil, have the ability to separate, filter, reinforce, protect, or drain.

Typically made from polypropylene or polyester, geo-textile fabrics come in three basic forms: woven (resembling mail bag sacking), needle punched (resembling felt), or heat bonded (resembling ironed felt).

Geo-textile composites have been introduced and products such as geo-grids and meshes have been developed. Overall, these materials are referred to as geo-synthetics and each configuration: geo-nets, geo-grids, geo-tubes (such as TITAN Tubes) and others can yield benefits in geotechnical and environmental engineering design

GEO-MEMBRANE

Geo-membrane is very low permeability synthetic membrane liner or barrier used with any geotechnical engineering related material so as to control fluid (or gas) migration in a human-made project, structure, or system. Geo-membranes are made from relatively thin continuous polymeric sheets, but they can also be made from the impregnation of geotextiles with asphalt, elastomer or polymer sprays, or as multilayered bitumen geo-composites. Continuous polymer sheet geo-membranes are, by far, the most common.

QUALITY CONTROL MEASURES

Quality control (QC) is a procedure or set of procedures intended to ensure that a manufactured product or performed service adheres to a defined set of **quality** criteria or meets the

requirements of the client or customer. QC is similar to, but not identical with, **quality assurance** (QA).

Quality control, or **QC** for short, is a process by which entities review the quality of all factors involved in production. ISO 9000 defines quality control as "A part of quality management focused on fulfilling quality requirements".

This approach places an emphasis on three aspects:

1. Elements such as controls, job management, defined and well managed processes, performance and integrity criteria, and identification of records
2. Competence, such as knowledge, skills, experience, and qualifications
3. Soft elements, such as personnel, integrity, confidence, organizational culture, motivation, team spirit, and quality relationships.

Controls include product inspection, where every product is examined visually, and often using a stereo microscope for fine detail before the product is sold into the external market. Inspectors will be provided with lists and descriptions of unacceptable product defects such as cracks or surface blemishes for example.

The quality of the outputs is at risk if any of these three aspects is deficient in any way.

Quality control emphasizes testing of products to uncover defects and reporting to management who make the decision to allow or deny product release, whereas quality assurance attempts to improve and stabilize production (and associated processes) to avoid, or at least minimize, issues which led to the defect(s) in the first place. For contract work, particularly work awarded by government agencies, quality control issues are among the top reasons for not renewing a contract.

1. List the main functions of Pavement.

- To distribute the traffic load over the sub-grade soil.
- To provide good riding surface.
- To protect the sub grade from climatic effects.

2. Mention a few desirable properties of highway materials. (MAY/JUNE 2013)

Strength, Stability, Incompressible nature, Compactibility and Permissible Chemical contents etc.,

3. Enumerate the desirable properties of sub grade soil.

- Stability
- Incompressibility
- Permanency of strength

- Minimum changes in volume and stability under adverse conditions of weather and ground water
- Good drainage, and
- Ease of compaction

4. Define Index Properties of Soil.

Index properties are soil properties, on which the soil identification and classification are based. In order to facilitate and construction of good roads, it is essential to identify and classify the soil systematically.

5. List the various types of test to be carried out in Soil.

- Determination of Water Content
- Determination of Specific Gravity
- Determination of Consistency Limits (Empirical test)
- Determination of field density
- Dry density and moisture content method

6. Write the importance of CBR test.

(MAY/JUNE 2013)

- It is the best suitable method for evaluating the stability of soil sub grade and other flexible pavement materials.
- The test results have been correlated with flexible pavement thickness requirements, for highways and air fields.

7. List the limitations of CBR test.

- It cannot be used to evaluate the soil properties like cohesion (or) angle of internal friction (or) shearing resistance.
- Materials passing through 20 mm sieve can only be used for this test.
- If the test sample consists of coarse grained particles, then they obtained results are not so suitable for proper designing of pavements.

8. State the Desirable Properties of Aggregates. (MAY/JUNE 2012)

Strength, Hardness, Toughness, Shape of aggregates, Adhesion with bitumen, Durability, Freedom from deleterious particles, Specific Gravity, Texture, Cementation and Hydrophobic Characteristics

9. What are the requirements of good aggregates? (NOV/DEC 2012)

High hardness value, More toughness to load action, High durability, Easy availability and High strength etc.,

10. Enlist the different types of tests for aggregate. (NOV/DEC 2011)

1. Crushing test

2. Abrasion test
3. Impact test
4. Soundness test
5. Shape test
6. Specific gravity and water absorption test
7. Bitumen adhesion test

11. Enumerate the different methods for Abrasion test.

- Deval abrasion test
- Dorry abrasion test
- Los Angeles abrasion test

12. Define Flakiness index. (NOV/DEC 2011), (APRIL/MAY 2011)

The flakiness index is defined as the percentage by weight of aggregate particles whose least dimension is less than 0.6 times their mean size.

13. What is Flaky Aggregate? (APRIL/MAY 2010)

Flaky aggregates have small thickness when compared to their width or lengths are called flaky aggregate.

14. What is Elongation index?

The elongation index of an aggregate is defined as the percentage by weight of particles whose greatest dimension (length) is 1.8 times their mean dimension.

15. What do you meant by Angularity Number?

It is the amount to the nearest whole number by which the percentage voids exceeds 33%, when an aggregate is compacted in a specified manner in a standardized metal cylinder.

16. What are the various objectives of bituminous binder?

Binding effect, Cushion, Resistance to weathering actions and Sealing of Surface

17. What are different forms of Bituminous Material?

1. Bitumen
   a) Cutback bitumen
   b) Bitumen emulsion
   c) Rubber Bitumen
2. Tar
3. Tar-Bitumen

18. Compare Bitumen with Tar.

S.No	Parameter	Bitumen	Tar
1	Colour	Black or blackish brown	Black
2	Source	Derived from petroleum occurring	Obtained from the destructive

		naturally	distillation of coal or wood
3	Solubility	Soluble in carbon-tetra sulphide	
4	Temperature Effects	Less temperature resistance	More temperature resistance
5	Setting behaviour	Takes lesser time to set	Takes more time to set
6	Free Carbon Content	Contains lesser % of carbon	Contains more % of carbon
7	Weathering Action	Good	Poor
8	Durability	More	Less
9	Presence of Water	It does not coat aggregates	It coats aggregates more easily in the presence of water

19. What are the laboratory tests to be carried out for Bitumen?

1. Penetration test
2. Ductility test
3. Softening point test
4. Specific gravity test
5. Viscosity test
6. Flash and Fire point test
7. Float test
8. Water content test
9. Loss on heating test

20. Define Softening Point of Bitumen. (MAY/JUNE 2012)

Softening Point of a bitumen material is defined as the temperature, at which it gradually changes from semi-solid state to liquid state on the application of heat. The softening point test is carried out by Ring and Ball test.

21. What do you understand the term Screenings?

The screenings are used to fill up the voids in the compacted layer of coarse aggregates and they usually consist of aggregates of small size of the same material as that of coarse aggregates.

22. Write the Advantages of WBM Roads.

- For good conditioned WBM roads can take rubber tyre traffic of 450 tonnes and about 450 tonnes of iron tyre traffic.
- If the maintenance work is properly done means, WBM road provides best service for a long time.

- The initial cost is low.
- The construction process is very simple and locally available material can be used.

23. Write the Disadvantages of WBM Roads.

- Due to depressions on road surface, small water pools are formed.
- Improper maintenance of WBM road causes inconvenience and dangerous to the traffic.
- They are permeable to rain water and it leads to the softening and yielding of sub soil.

24. What are the types of Bituminous Pavement?

1. Surface Treatments
   - Prime Coat
   - Tack Coat
   - Surface Dressing
   - Seal Coat
2. Grouted or Penetration Macadam
   - Semi – grouted macadam
   - Fully – grouted macadam
3. Road mix surfaces
   - Open graded mixes
   - Dense grade mixes
   - Sand asphalt
4. High type bituminous pavements
   - Bituminous macadam
   - Bituminous concrete (or) asphalt concrete
   - Sheet asphalt (or) rolled asphalt concrete
   - Sand asphalt
   - Mastic asphalt
   - Tar concrete

25. List the Various functions of a prime coat.

1. It plugs capillary voids and act as a water proofing agent for the existing base.
2. It provides best bonding between old and new surface.
3. It serves as a mixing table for road mix paving jobs

26. What are the functions of a tack coat in bituminous construction?

(APRIL/MAY 2010), (NOV/DEC 2012)

Where new wearing surface is to be provided over an old bituminous surfacing (or) a new coat of old concrete pavement (or) on a brick, stone and block pavement (or) on a primed granular base course, a tack coat is provided.

27. Write any four advantages of CC Road.

- They provide excellent smooth surface for driving.
- They can deal with very heavy traffic
- Considering their life span, maintenance cost etc, cement concrete roads prove cheaper than bituminous roads.
- Maintenance cost is negligible.

28. What are the methods available for Construction of C.C Road?

d. Alternative bay Method

e. Continuous Bay Method

f. Expansion Joint and Strip Method

29. Write the Joints in C.C Road.

Joints in cement concrete pavements can be classified under three headings:

a. Expansion joints

b. Contraction joints

c. Warping or hinged joints

30. Write the Reason for Providing Joints.

- To absorb the expansion and contraction due to the change of temperature.
- To avoid the warping of concrete slab at edges.
- To provide the continuity of concrete laying.

31. What are the basic Requirements of Good Joints?

- Easy to maintain
- Moves freely without developing stresses
- Not allows the infiltration and rain water
- Should not make inconvenience to the road users
- Should maintain the level of surface

32. Write note on Highway Drainage.

Drainage is defined as the interception and removal of water from an area (or) over an area (or) under an area. Highway drainage is defined as the process of removal of water from road surface and also from sub-grade.

33. State any two techniques for protecting the sub-grade from moisture due to capillary rise? (APRIL/MAY 2011)

- Inserting an impermeable or a bituminous layer.
- Providing a layer of granular material of suitable thickness.

UNIT V

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

1. WHAT DO YOU MEANT BY HIGHWAY MAINTENANCE? WRITE NOTE ON IT.

HIGHWAY MAINTENANCE

Highway Maintenance is the process of correcting the deficiencies in the highway which have developed due to years, weather and damages. There are two types of maintenance, namely preventive and break down.

Causes of Pavement Defects

- Increase in traffic
- Environmental Changes
- Design and Construction Deficiencies
- Maintenance Deficiencies

Various Terms Used To Express Different Types of Pavement Defects

Distortion

Any deviation in the pavement surface, from its original shape is called distortion.

Distress

Any indication of poor or unfavourable pavement performance or signs of impending failure is called Distress.

Roughness

Irregularities in the pavement surface that affect the riding quality of the vehicle.

Stripping

It is Separation of bituminous film from aggregate particle in the presence of moisture.

Failure

Failure is an unsatisfactory performance of a pavement or portion of the pavement.

Polished aggregate

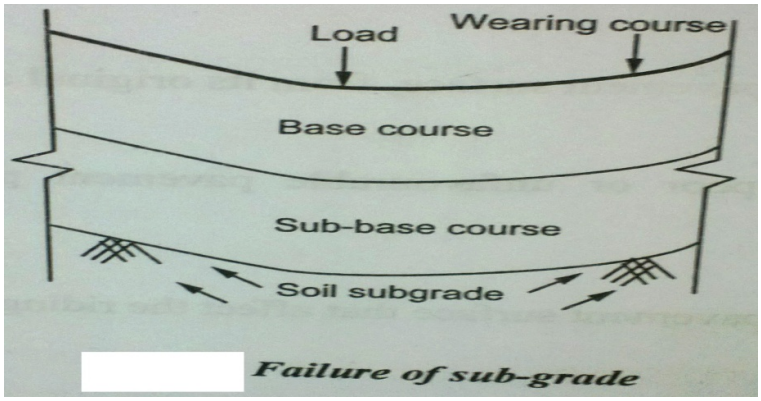
Aggregate that has a low coefficient of friction as a result of traffic action or natural causes.

2. DISCUSS IN DETAIL ABOUT FAILURES IN FLEXIBLE PAVEMENTS.

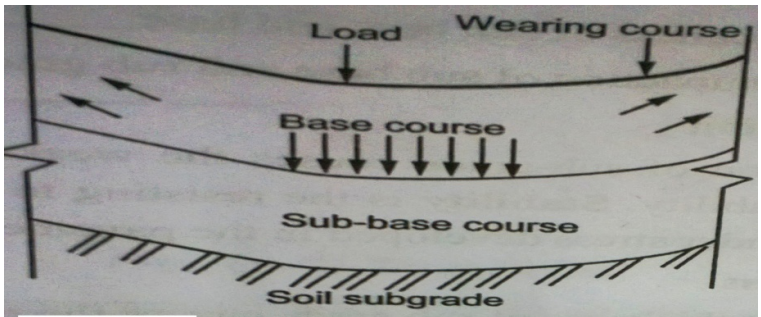
FAILURES IN FLEXIBLE PAVEMENTS

Flexible pavement failure is defined as the localized depressions or settlements. The failure of the pavement is due to the failure of any component layer of the flexible pavement structure.

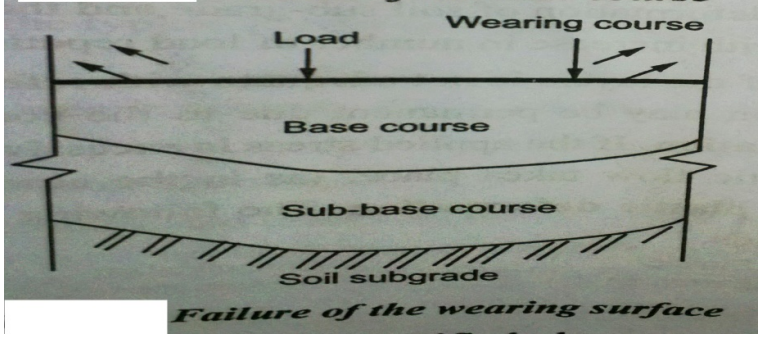
Following figures shows the failure of pavement due to the failure of sub grade, base course and wearing course respectively.



Failure of sub-grade



Failure of the base course



Failure of the wearing surface

Flexible pavement failures may be classified depending upon the **Sources of Failures.**

- Failure due to surface
    - Scaling
    - Stripping
    - Ravelling
    - Disintegration
    - Cracking
    - Plastic Distortion

- Failures due to slippage due to lack of bond with the base
- Failures due to deficiencies of base, sub base and sub grade due to,
    - Inadequate thickness of sub base and base.
    - Inadequate compaction of sub base and sub grade

Inadequate Compaction

Inadequate Compaction of sub-grade causes the weakness of the pavement and results in inadequate stability. Stability is the resisting to the deformation under the application of load or under stress developed in the pavement.

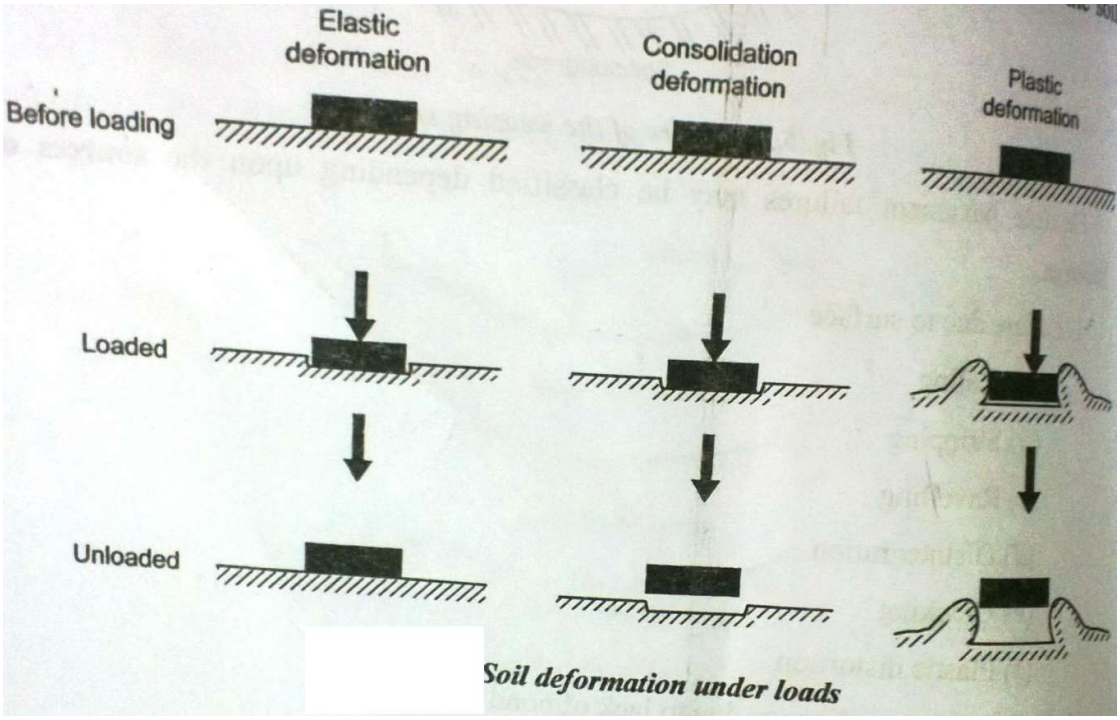
Inadequate Thickness

Inadequate pavement thickness of sub grade causes the excessive stress application on the pavement. The deformation of soil sub-grade and the other pavement, materials are found to increase with increase in number of load repetitions.

If the compaction of the layers is not adequate with reference subsequent loading, part of the deformation may be permanent due to the compaction of soil is called **Consolidation Deformation.**

If the applied stress is excessive than the stability of sub-grade and if the plastic flow takes place, (as in the case of wet clayey soil) this deformation is called **Plastic Deformation.**

The following figure shows the soil deformation under loads,



Soil deformation under loads

3. DESCRIBE IN DETAIL ABOUT TYPICAL FLEXIBLE PAVEMENT FAILURES.

TYPICAL FLEXIBLE PAVEMENT FAILURES

ABRASION

It is the scuttling (spoil) of the wearing course. It is due to the equipment blades, dragging chains etc.,

BLAST EROSION

It is the deep erosion or scouring of a pavement, in which a portion of a structure is lost. It is due to continued jet blast impinging on the pavement.

BUMP OR BUMPING

It is the upward movement or displacement due to the frost action.

CHAR OR BURN

It is charred surface, in which the bitumen has lost or carbonized.

SHRINKAGE CRACKING

It is the horizontal separation of a pavement overlay. It is due to the shrinkage of the surface course with possible loss of flexibility of the surface course.

EDGE CRACKING

It is the linear cracking near the edge of the surface of the pavement. It is due to either lateral displacement of embankment (or) inadequate thickness of the pavement (or) both.

IMPRINT

It is the impression in the surface of the pavement. It is due to the standing or moving of times and vehicles on the soft pavement surface.

INDENTATION AND SCARRING

It is the shearing of the surface and it is due to wheel rims of blown tyres, etc.

STREAKING

Streaking are alternate lean and heavy lines of bitumen running parallel to the alignment. It is due to the improperly adjusted nozzles of spray bar, during seal coating.

UNEVENNESS OF PAVEMENT

Unevenness of the pavement are caused to the various reasons such as repeated action of load on damaged surfaces, improper compaction, poor mix design and infiltration etc. Pavement unevenness creates uncomfortable movement on surface and also affects the operation cost. It also increases the fatigue and accidents.

The pavement unevenness can be measured by using a **Bump integrator**, in terms of unevenness index. **Unevenness index** of a pavement surface is defined as the cumulate

measure of vertical undulations of the pavement surface recorded per unit horizontal length of the road.

WAVES

These are longitudinal and transverse undulations in the surface of the pavement, consisting of alternative valleys and crests approximately 0.6 m or more apart. It is due to the contour of the road bed or base.

WEATHERING

It is the gradual disintegration of the pavement wearing surface and exposing the aggregates to view.

Generally flexible pavement failures involve both **compaction** and **shear deformation**. **Shear deformation** may be defined as the change in shape with no change in volume. Shear deformation in a particular layer may be determined by the following measurements.

1. Deflection measurement
2. In-place CBR and other strength tests
3. Cracking of the pavement
4. Upheaval of the surface
5. Position of the layers

ALLIGATOR CRACKING (OR) MAP CRACKING

Description: A series of interconnected cracks caused by fatigue failure of the surface under repeated traffic loading. As the number and magnitude of loads becomes too great, longitudinal cracks begin to form (usually in the wheel paths). After repeated loading, these longitudinal cracks connect forming many-sided sharp-angled pieces that develop into a pattern resembling the back of an alligator or crocodile.

Problem: Roughness, indicator of structural failure, cracks allows moisture infiltration into the base and sub grade, eventually results in potholes and pavement disintegration if not treated.

Possible Causes: Inadequate structural support for the given loading, which can be caused by a many things.

BLEEDING OR FLUSHING

Description: A film of asphalt binder on the pavement surface. It usually creates a shiny, glass-like reflecting surface that can become sticky when dry and slippery when wet.

Problem: Loss of skid resistance when pavement is wet.

Possible Causes: Bleeding occurs when asphalt binder fills the aggregate voids during hot weather or traffic compaction, and then expands onto the pavement surface. Since bleeding is not reversible during cold weather or periods of low loading, asphalt binder will accumulate on the pavement surface over time.

BLOCK CRACKING

Description: Interconnected cracks that divide the pavement up into rectangular pieces. Blocks range in size from approximately 1 ft^2 to 100 ft^2. Larger blocks are generally classified as longitudinal and transverse cracking. Block cracking normally occurs over a large portion of pavement area but sometimes will occur only in non-traffic areas.

Problem: Allows moisture infiltration, roughness

Possible Causes: HMA shrinkage and daily temperature cycling. Typically caused by an inability of asphalt binder to expand and contract with temperature cycles because of:

- Asphalt binder aging
- Poor choice of asphalt binder in the mix design

CORRUGATION AND SHOVING

Description: A form of plastic movement typified by ripples (corrugation) or an abrupt wave (shoving) across the pavement surface. The distortion is perpendicular to the traffic direction. Usually occurs at points where traffic starts and stops (corrugation) or areas where layer is adjacent to a rigid object (shoving).

Problem: Roughness

Possible Causes: Usually caused by traffic action (starting and stopping) combined with:

- An unstable (i.e. low stiffness) layer (caused by mix contamination, poor mix design, poor surface manufacturing, or lack of aeration of liquid asphalt emulsions)
- Excessive moisture in the sub-grade

DEPRESSION

Description: Localized pavement surface areas with slightly lower elevations than the surrounding pavement. Depressions are very noticeable after a rain when they fill with water.

Problem: Roughness, depressions filled with substantial water can cause vehicle hydroplaning

Possible Causes: Sub-grade settlement resulting from inadequate compaction during construction.

JOINT REFLECTION CRACKING

Description: Cracks in a flexible overlay of a rigid pavement. The cracks occur directly over the underlying rigid pavement joints. Joint reflection cracking does not include reflection cracks that occur away from an underlying joint or from any other type of base (e.g., cement or lime stabilized).

Problem: Allows moisture infiltration, roughness

Possible Causes: Movement of the rigid pavement slab beneath the surface because of thermal and moisture changes. Generally not load initiated, however loading can hasten deterioration.

LONGITUDINAL CRACKING

Description: Cracks parallel to the pavement's centerline or lay down direction. It is a type of fatigue cracking.

Problem: Allows moisture infiltration, roughness, indicates possible onset of fatigue cracking and structural failure.

Possible Causes:

- Poor joint construction or location. Joints are generally the least dense areas of a pavement. Therefore, they should be constructed outside of the wheelpath so that they are only infrequently loaded. Joints in the wheelpath will general fail prematurely.
- A reflective crack from an underlying layer (not including joint reflection cracking)
- Top-down cracking

PATCHING

Description: An area of pavement that has been replaced with new material to repair the existing pavement. A patch is considered a defect no matter how well it performs.

Problem: Roughness

Possible Causes:

- Previous localized pavement deterioration that has been removed and patched
- Utility cuts

POLISHED AGGREGATE

Description: Areas of HMA pavement where the portion of aggregate extending above the asphalt binder is either very small or there are no rough or angular aggregate particles.

Problem: Decreased skid resistance

Possible Causes: Repeated traffic applications. Generally, as a pavement ages the protruding rough, angular particles become polished. This can occur quicker if the aggregate is susceptible to abrasion.

POTHOLES

Description: Small, bowl-shaped depressions in the pavement surface that penetrate all the way through the surface layer down to the base course. They generally have sharp edges and vertical sides near the top of the hole. Potholes are most likely to occur on roads with thin surfaces (1 to 2 inches) and seldom occur on roads with 4 inch or deeper surfaces.

Problem: Roughness (serious vehicular damage can result from driving across potholes at higher speeds), moisture infiltration

Possible Causes: Generally, potholes are the end result of fatigue cracking. As fatigue cracking becomes severe, the interconnected cracks create small chunks of pavement, which can be dislodged as vehicles drive over them. The remaining hole after the pavement chunk is dislodged is called a pothole.

RAVELLING

Description: It is the developing disintegrations from the surface, downward by the non positioning of aggregates. This is due to the uneven distribution of bitumen from the sprayer bar.

Problem: Loose debris on the pavement, roughness, water collecting in the raveled locations resulting in vehicle hydroplaning, loss of skid resistance

Possible Causes:

- Loss of bond between aggregate particles and the asphalt binder.
- Mechanical dislodging by certain types of traffic (studded tires, snowplow blades or tracked vehicles).

RUTTING

Description: Surface depression in the wheel path. Pavement uplift (shearing) may occur along the sides of the rut. Ruts are particularly evident after a rain when they are filled with water.

There are two basic types of rutting: mix rutting and sub-grade rutting.

Mix rutting occurs when the sub-grade does not rut yet the pavement surface exhibits wheel path depressions as a result of compaction/mix design problems.

Sub-grade rutting occurs when the sub-grade exhibits wheel path depressions due to loading.

Problem: Ruts filled with water can cause vehicle hydroplaning, can be hazardous because ruts tend to pull a vehicle towards the rut path as it is steered across the rut.

Possible Causes: Permanent deformation in any of a pavement's layers or sub-grade usually caused by consolidation or lateral movement of the materials due to traffic loading.

SLIPPAGE CRACKING

Description: Crescent or half-moon shaped cracks generally having two ends pointed into the direction of traffic.

Problem: Allows moisture infiltration, roughness

Possible Causes: Braking or turning wheels causes the pavement surface to slide and deform. The resulting sliding and deformation is caused by a low-strength surface mix or poor bonding between the surface layer and the next underlying layer in the pavement structure.

STRIPPING

Description: The loss of bond between aggregates and asphalt binder that typically begins at the bottom of the surface layer and progresses upward. When stripping begins at the surface and progresses downward it is usually called raveling.

Problem: Decreased structural support, rutting, shoving/corrugations, raveling, or cracking (fatigue and longitudinal)

Possible Causes: Bottom-up stripping is very difficult to recognize because it manifests itself on the pavement surface as other forms of distress including rutting, shoving/corrugations, raveling, or cracking. Typically, a core must be taken to positively identify stripping as a pavement distress.

TRANSVERSE (THERMAL) CRACKING

Description: Cracks perpendicular to the pavement's centerline or lay down direction. It is a type of thermal cracking.

Problem: Allows moisture infiltration, roughness

Possible Causes:

- Shrinkage of the surface due to low temperatures or asphalt binder hardening.
- Reflective crack caused by cracks beneath the surface layer
- Top-down cracking

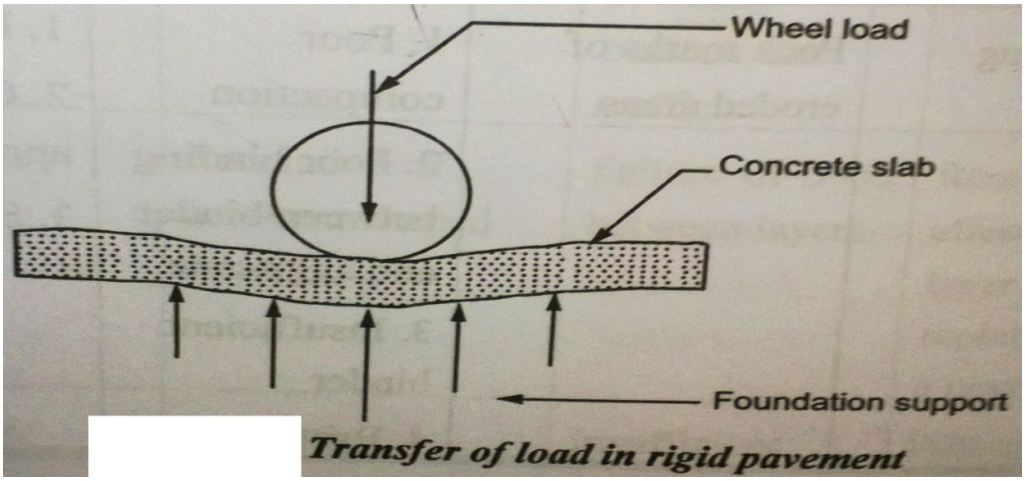
4. WHAT ARE THE DEFICIENCIES OCCURRED IN RIGID PAVEMENT?

RIGID PAVEMENT DEFICIENCIES

Following are the some of the typical rigid pavement failures:

- Water Bleeding and Mud Pumping
- Structured Cracks
- Scaling
- Spalling of Joints
- Warping (or) curling (or) bending

Following figure shows the transfer of load in rigid pavement.



Transfer of load in rigid pavement

WATER BLEEDING AND MUD PUMPING

Description: Water bleeding occurs when water seeps out of joints or cracks or through an excessively porous layer. Pumping occurs when water and fine material is ejected from underlying layers through cracks in the surface layer or out the sides of the surface layer under moving loads.

The infiltration of water through the cracks, joints and edges of the rigid pavement and forms the soil slurry called mud, and when heavy load passes over the pavement. The mud is ejected out through these joints and cracks and thus mud pumping happens.

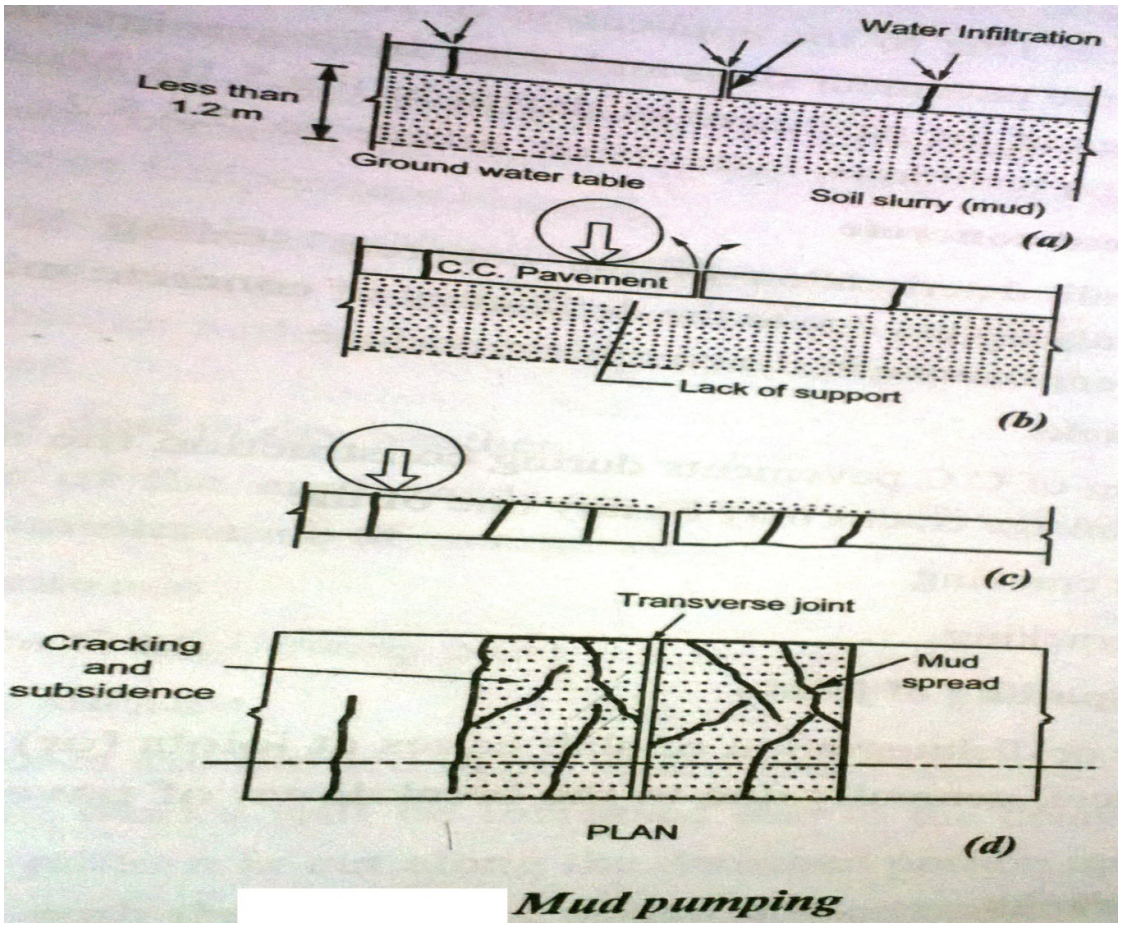
Mud pumping is mainly due to the insufficient support from water saturated bases (or) from under saturated road beds, and the other factors are,

- Type of sub-grade soil
- Extent of slab deflection
- Amount of free water

When a load is imposed on the rigid pavement slabs, it is depressed on the saturated material, squeezing the water and fine out through the cracks and joints.

Due to the repeated happenings of mud pumping, there is considerable loss of fine grained soil, from the sub grade and due to this lack of support at these joints.

In C.C pavements, mud pumping is exposed to view after the rains that are placed on clayey soil sub-grade. Due to the application of repeated loads initial spaces are developed underneath the pavement slabs and water infiltrates into the spaces through the joints, cracks and edges of the pavement shown in figure.



Problem: Decreased skid resistance, an indication of high pavement porosity (water bleeding), decreased structural support (pumping)

Possible Causes:

- Porous pavement as a result of inadequate compaction during construction or poor mix design
- High water table
- Poor drainage

SCALLING OF CEMENT CONCRETE

Due to the overall deterioration of the concrete scaling is observed in C.C pavement and it mainly occurs due to the deficiency of concrete mix. It is appeared as a rough and shabby appearance in the pavement surface.

SHRINKAGE CRACKS

During the curing of C.C pavements during construction, the shrinkage cracks are developed. The shrinkage cracks may be any one of the,

- Longitudinal Cracking
- Transverse Cracking

SPALLING OR SPALLING OF JOINTS

It is breakdown or disintegration of slab edges at joints (or) at cracks (or) directly over reinforcing steel, generally due to the breakdown of pavement joint edges from traffic action.

STRUCTURAL CRACKS

Structural cracks are occurring, when the pavement thickness is in adequate to withstand the traffic loads, and generally the pavements are found to crack at the corners and edges. The structural cracks may occur, both in longitudinal and transverse directions.

WARPING (OR) CURLING

It is bending of the concrete slab due to the uneven expansion or contraction of top and bottom slab surfaces. It is caused by differences in temperature above and below the slab (or) caused by differences in moisture conditions.

5. EXPLAIN IN DETAIL ABOUT PAVEMENT MANAGEMENT SYSTEM.

PAVEMENT MANAGEMENT SYSTEMS

Pavement management is the process of planning the maintenance and repair of a network of roadways or other paved facilities in order to optimize pavement conditions over the entire network. Pavement management brings more science into this process

A **Pavement Management System (PMS)** is a planning tool used to aid pavement management decisions. PMS software programs model future pavement deterioration due to traffic and weather, and recommend maintenance and repairs to the road's pavement based on the type and age of the pavement and various measures of existing pavement quality.

Measurements can be made by persons on the ground, visually from a moving vehicle, or using automated sensors mounted to a vehicle. PMS software often helps the user create composite pavement quality rankings based on pavement quality measures on roads or road sections. Recommendations are usually biased towards preventive maintenance, rather than allowing a road to deteriorate until it needs more extensive reconstruction.

Typical tasks performed by pavement management systems include:

1. Inventory pavement conditions, identifying good, fair and poor pavements.
2. Assign importance ratings for road segments, based on traffic volumes, road functional class, and community demand.
3. Schedule maintenance of good roads to keep them in good condition.
4. Schedule repairs of poor and fair pavements as remaining available funding allows.

Research has shown that it is far less expensive to keep a road in good condition than it is to repair it once it has deteriorated. This is why pavement management systems place the priority on preventive maintenance of roads in good condition, rather than reconstructing roads in poor condition.

In terms of lifetime cost and long term pavement conditions, this will result in better system performance. Agencies that concentrate on restoring their bad roads often find that by the time they've repaired them all, the roads that were in good condition have deteriorated.

The State of California was among the first to adopt a (PMS) in 1979. Like others of its era, the first PMS was based in a mainframe computer and contained provisions for an extensive database. It can be used to determine long-term maintenance funding requirements and to examine the consequences on network condition if insufficient funding is available.

A pavement management system consists of three major components:

- A system to regularly collect highway condition data
- A computer database to sort and store the collected data
- An analysis program to evaluate repair or preservation strategies and suggest cost effective projects to maintain highway conditions

In most agencies, these components are then combined with planning needs and political considerations to develop annual highway repair/preservation programs.

Management Approach

The pavement management process has been incorporated into several pavement management systems. The following management approach evolved over the last 30 years as part of the development of the PAVER management system (U.S. Army COE, Construction Engineering Research Laboratory and Micro PAVER 2004).

The approach is a process that consists of the following steps:

1. Inventory Definition
2. Pavement Inspection
3. Condition Assessment
4. Condition Prediction
5. Condition Analysis
6. Work Planning

6. WRITE BRIEF NOTE ON PAVEMENT EVALUATION.

PAVEMENT EVALUATION

Pavement evaluation is defined as the study of various factors such as sub-grade support, pavement composition and its thickness, traffic loading and environmental conditions.

Method of Pavement Evaluation

In order to assess the condition of the pavement, pavement evaluation is carried out for the maintenance and strengthening is planned at time. Strengthening of pavement is decided by the data collected by the pavement evaluation and various methods used for the evaluation is,

- Methods based on deflection criteria
- Methods based on serviceability

RE-BOUND DEFLECTION TEST

The performance of a flexible pavement is related to its rebound deflection. The rebound deflection tests are based on the concept that the pavement structure deforms elastically under the design test load. The **Benkelman Beam** designed by **A.C. Benkelman** is being used extensively for measuring the deflection of flexible pavements under the action of moving loads.

The instrument was first used in WASHO roads tests and later in AASHO road test. If the rebound deflection value of any highway section is high, then the section gives poor performance and has shorter life. The sections which show low rebound deflection may need little maintenance and possess longer life.

Based on experience and performance study correlations, the rebound deflection data have been employed to indicate the present and future structural performance of highway. Non destructive testing methods can also be used to assess the load carrying capacity of the pavements.

VISUAL METHOD

This method is one of the most widespread methods, was initially developed at the Texas A and M university and is commonly Deduct values or deduct point method. In this method, some deduct points are associated with specific values of various distress type. These deduct points are then subtracted from an established perfect score (generally 100) to arrive at overall rating score of the pavement. The following table gives the deduct points for various level of distress.

METHODS BASED ON SERVICEABILITY RATING

This method, takes into account the physical measurement like longitudinal and transverse profile of the pavement surface extent of unevenness, patching and cracking etc., These physical measurements are related to a predetermined scale. This concept was extended based on the performance studies at AASHO road tests for determining the **Present Serviceability Index (PSI)** of pavements.

The AASHO road test, introduced a user based evaluation method (also called functional evaluation), in which the serviceability of a pavement section is determined from subjective evaluations of the riding quality.

For various pavement sections, the subjective ratings are correlated with objective measurements of the surface characteristics. The correlated results are termed the Present Serviceability Index.

Mathematical models are evolved for determining serviceability indices for predicting the road user serviceability rating of pavement, on physical measurements.

The following equations give the value of PSI for flexible and rigid pavements.

For Flexible pavements,

$$PSI = 5.03 - 1.91\log(1 + SV) - 1.38^2\ (RD)^2 - 0.01\sqrt{C + P}$$

For Rigid pavements,

$$PSI = 5.41 - 1.80\log(1 + SV) - 0.09\sqrt{C + P}$$

Where,

SV - Slope Variance giving an Index of the longitudinal profile

RD - Rut Depth under a 4 feet straight edge

C - Distress in terms of linear feet of cracks per 1000 sqft area (in inches)

P - Patched area in sqft (per 1000 sqft area)

The SI has been used to serve as a measure of a pavement ability to serve high speed high volume mixed traffic, as indicated on a scale of 0 to 5. On this scale, the values from 0 to 5 are,

From 0 to 1	Very Poor
From 1 to 2	Poor
From 2 to 3	Fair
From 3 to 4	Good
From 4 to 5	Very Good

In this test, the new pavement had an average index value of about 4 or more. Testing was discontinued on a pavement section, when its index dropped to 1.5.

7. WHAT IS ROUGHNESS? EXPLAIN THE MEASUREMENT TECHNIQUES.

ROUGHNESS

Pavement roughness is generally defined as an expression of irregularities in the pavement surface that adversely affect the ride quality of a vehicle (and thus the user).

Roughness is an important pavement characteristic because it affects not only ride quality but also vehicle delay costs, fuel consumption and maintenance costs.

The World Bank found road roughness to be a primary factor in the analyses and trade-offs involving road quality vs. user cost.

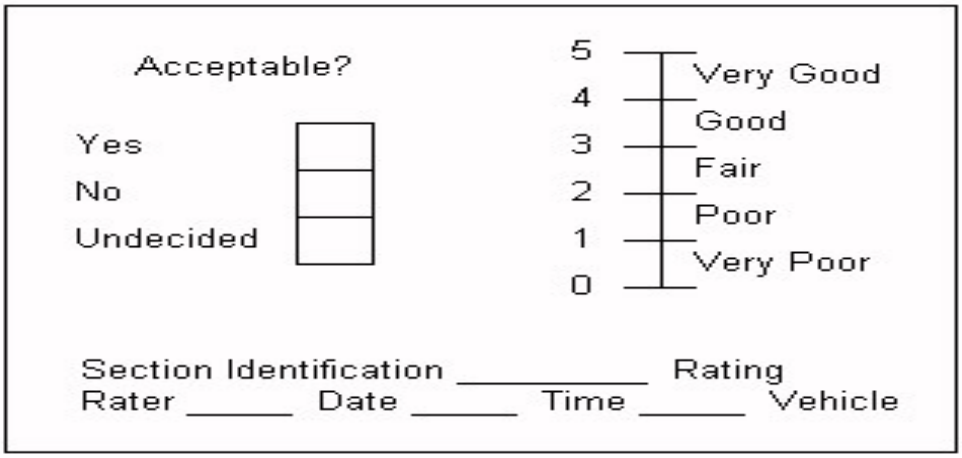
Roughness is also referred to as "smoothness" although both terms refer to the same pavement qualities.

Measurement

Today, roughness is typically quantified using some form of either present serviceability rating (PSR), international roughness index (IRI) or other index with IRI being most prevalent.

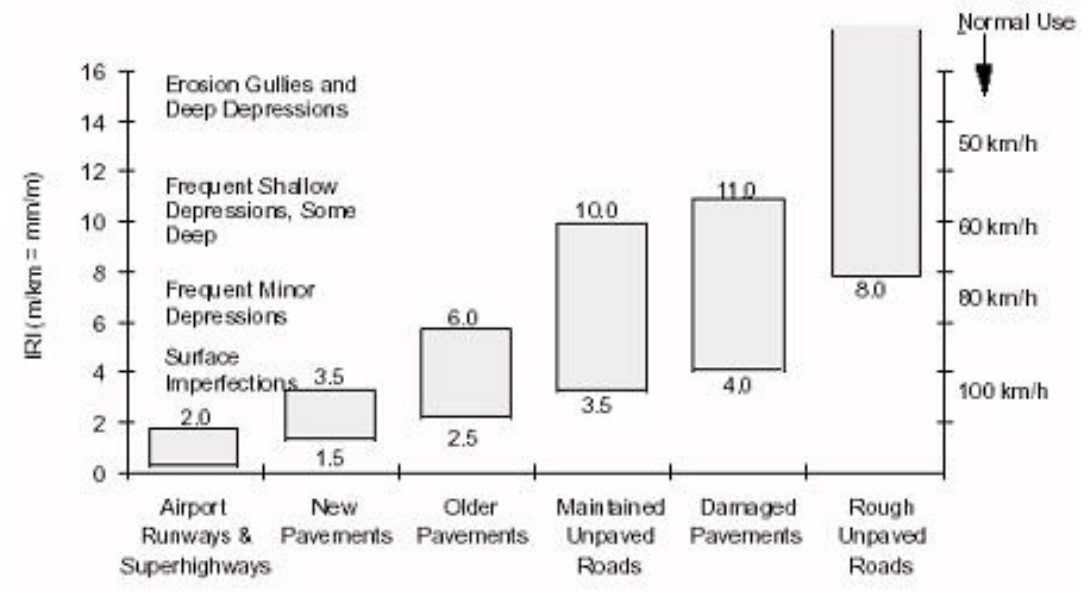
Present Serviceability Rating (PSR)

The AASHO Road Test (Highway Research Board, 1972) developed a definition of pavement serviceability, the present serviceability rating (PSR) that is based on individual observation. PSR is defined as "The judgment of an observer as to the current ability of a pavement to serve the traffic it is meant to serve" (Highway Research Board, 1972). To generate the original AASHO Road Test PSR scores, observers rode around the test tracks and rated their ride using the quantitative scale shown in Figure. This subjective scale ranges from 5 (excellent) to 0 (essentially impassable). Since PSR is based on passenger interpretations of ride quality, it generally reflects road roughness because roughness largely determines ride quality.



International Roughness Index (IRI)

The international roughness index (IRI) was developed by the World Bank in the 1980s. IRI is used to define a characteristic of the longitudinal profile of a traveled wheel track and constitutes a standardized roughness measurement. The commonly recommended units are meters per kilometer (m/km) or millimeters per meter (mm/m). The IRI is based on the average rectified slope (ARS), which is a filtered ratio of a standard vehicle's accumulated suspension motion (in mm, inches, etc.) divided by the distance traveled by the vehicle during the measurement (km, mi, etc.). IRI is then equal to ARS multiplied by 1,000. The open-ended IRI scale is shown in Figure.



Measurement Techniques

The equipment for roughness survey data collection can be categorized into the four broad categories shown in Table.

Roughness Measuring Equipment

Equipment / Technique	**Complexity**
Rod and level survey	most simple
Dipstick profiler	simple
Profilographs	simple
Response type road roughness meters (RTRRMs)	complex
Profiling devices	more complex

8. WTITE BRIEF NOTW ON PRESENT SERVICEABILITY INDEX.

PRESENT SERVICEABILITY INDEX

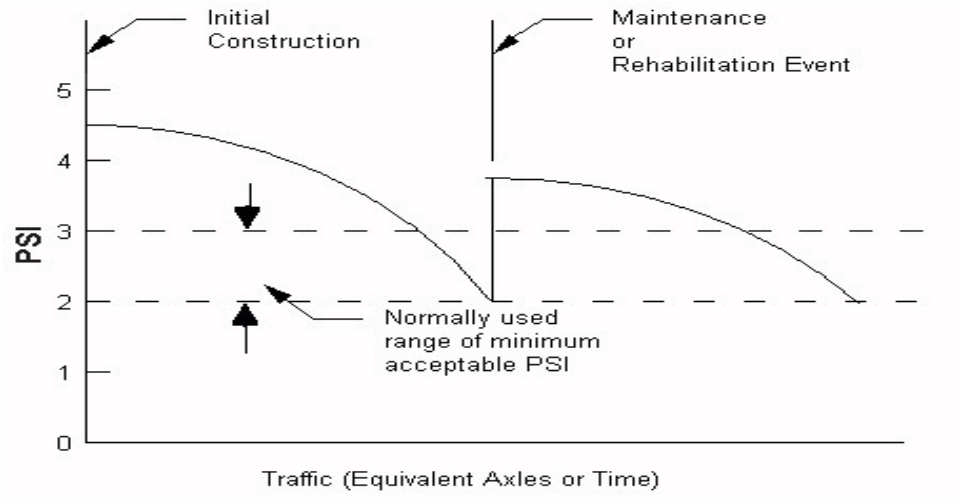
The present serviceability index (PSI) is based on the original AASHO Road Test PSR. Basically, the PSR was a ride quality rating that required a panel of observers to actually ride in an automobile over the pavement in question. Since this type of rating is not practical for large-scale pavement networks, a transition to a non-panel based system was needed.

To transition from a PSR serviceability measure (panel developed) to a PSI serviceability measure (no panel required), a panel of raters during 1958 to 1960 rated various roads in the states of Illinois, Minnesota, and Indiana for PSR. This information was then correlated to various pavement measurements (such as slope variance (profile), cracking, etc.) to develop PSI equations.

Further, the raters were asked to provide an opinion as to whether a specific pavement assessed for PSR was "acceptable" or "unacceptable" as a primary highway. Thus, although PSI is based on the same 5-point rating system as PSR it goes beyond a simple assessment of ride quality. About one-half of the panel of raters found a PSR of 3.0 acceptable and a PSR of 2.5 unacceptable. Such information was useful in selecting "terminal" or failure serviceability (PSI) design input for empirical structural design equations.

It is interesting to note that the original AASHO Road Test rater opinions are based on car ride dynamics; it is unclear whether such levels are acceptable for trucks.

Pavement performance can then be defined as "The serviceability trend of a (pavement segment) with increasing number of axle applications". Figure further demonstrates this concept.



9. EXPLAIN IN DETAIL ABOUT SKID RESISTANCE AND ITS TESTING METHOD.

SKID RESISTANCE

Skidding, i.e. loss of adhesion between a vehicle's tyres and the road surface occurs in many road accidents whether or not it is the actual cause of the accident.

Skid resistance is the force developed when a tire that is prevented from rotating slides along the pavement surface. Skid resistance is an important parameter of pavement evaluation because of the following factors.

- Inadequate skid resistance will lead to high accidents rate.
- Skid resistance measurements can be used to evaluate various types of materials and construction practices.

Skid resistance depends on a pavement surface's micro-texture and macro-texture. Micro-texture refers to the small-scale texture of the pavement aggregate component (which controls contact between the tire rubber and the pavement surface) while macro-texture refers to the large-scale texture of the pavement as a whole due to the aggregate particle arrangement (which controls the escape of water from under the tire and hence the loss of skid resistance with increased speed).

Skid resistance changes over time. Typically it increases in the first two years following construction as the roadway is worn away by traffic and rough aggregate surfaces become exposed and then decreases over the remaining pavement life as aggregates become more polished. Skid resistance is also typically higher in the fall and winter and lower in the spring and summer.

Measurement of Skid Resistance

Skid resistance is generally quantified using some form of friction measurement such as a friction factor or skid number.

Friction factor (like a coefficient of friction): $f = F/L$

Skid number: $SN = 100(f)$

where: F = frictional resistance to motion in plane of interface

L = load perpendicular to interface

It is not correct to say a pavement has a certain friction factor because friction involves two bodies, the tires and the pavement, which are extremely variable due to

pavement wetness, vehicle speed, temperature, tire wear, tire type, etc. Typical friction tests specify standard tires and environmental conditions to overcome this.

In general, the friction resistance of most dry pavements is relatively high; wet pavements are the problem. The number of accidents on wet pavements is twice as high as dry pavements (but other factors such as visibility are involved in addition to skid resistance). Table shows some typical Skid Numbers (the higher the SN, the better).

Typical Skid Numbers

Skid Number	Comments
<30	Take measures to correct
≥30	Acceptable for low volume roads
31 – 34	Monitor pavement frequently
≥35	Acceptable for heavily traveled roads

Skid Resistance Test

Polishing Stone Value Test and Pendulum Skid Resistance Test are used to determine the skid resistance value for aggregate and surface.

PENDULUM SKID RESISTANCE TEST

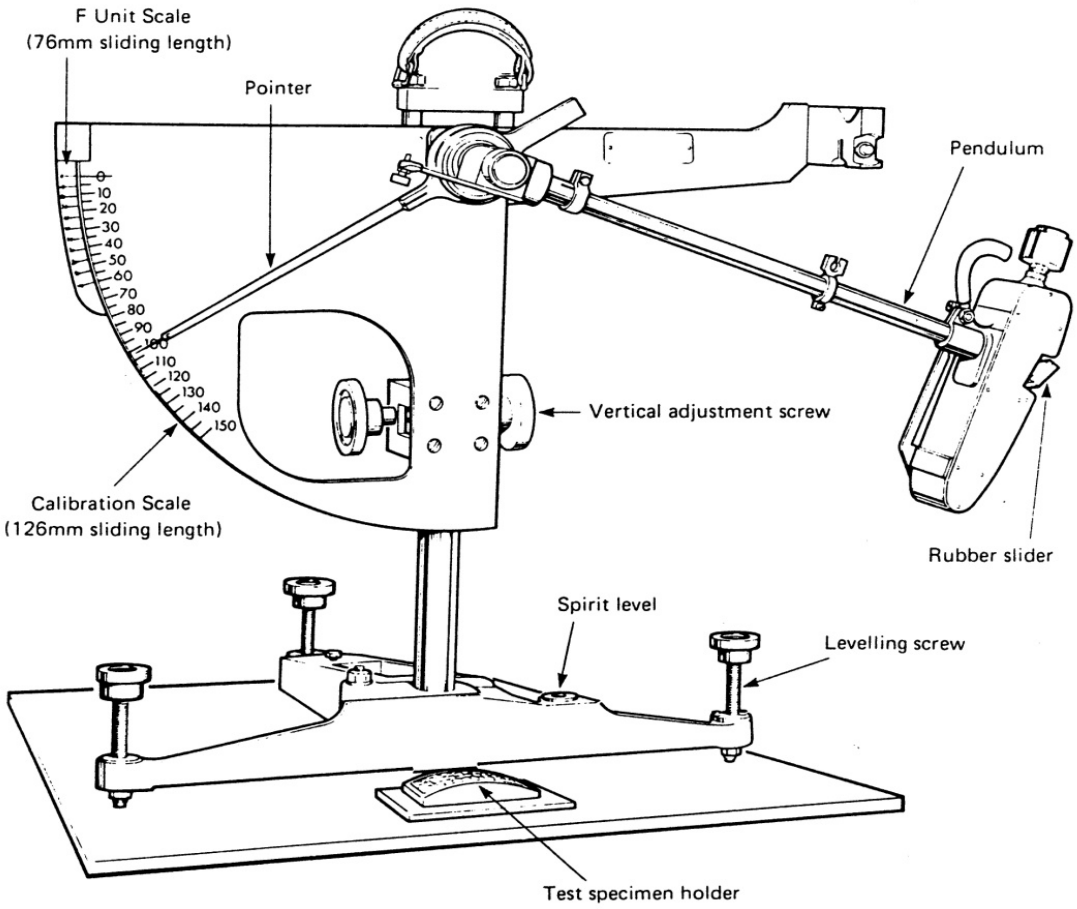
Pendulum Skid Resistance Tester is used to measure the texture depth and skid resistance of a road surface, recommended by Transport and Road Research Laboratory (TRRL), UK. This device simulates the skid resistance offered by a road surface to a motor car travelling at 50km/h. it gives a number, in percentage related to a coefficient of friction.

Test Procedure

1. Select the spot in which the texture depth has been measured.
2. Set the apparatus (Figure 2) on the road so that the slider will swing in the direction of traffic flow and level the base screws.
3. Raise the swinging arm clear of the road and clamp in the horizontal position. Release the arm and check that the pointer reads zero.
4. With the pendulum arm free and hanging vertically, place the spacer, attached to a chain on the base of the column, under the lifting handle setting screw to raise the slider. Lower the head of the tester so that the slider just touches the road surface and clamp in position. Remove the spacer.
5. Check the sliding length of the rubber slider over the road surface by gently lowering the

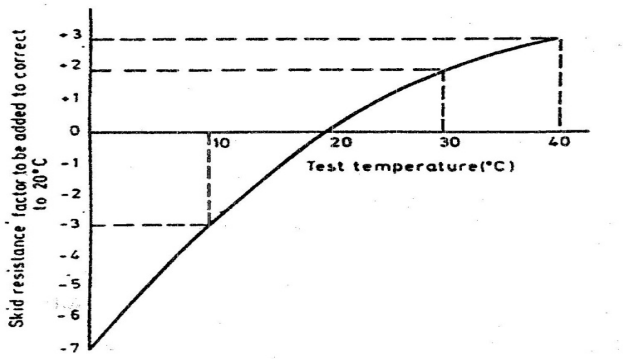
pendulum arm until the slider just touches the surface first on one side of the vertical and then on the other. When passing the arm through the vertical, use the lifting handle so that the slider does not touch the road. The sliding length should be between 125 and 127 mm. If not, adjust by raising or lowering the head.

6. Place the pendulum arm in the horizontal and clamp in position.
7. Wet the road surface and slider with water.
8. Bring the pointer to its stop then release the pendulum by pressing the button. Take care to catch the arm on its return swing before it hits the ground.
9. Return the arm and pointer to the release position keeping the slider off the road surface by means of the lifting handle. Repeat the test, wetting the surface between swings. Record the mean of five successive readings, provided they do not differ by more than three units. If the range is greater than this, repeat swings until three successive readings are constant; record this value.
10. Record the temperature of the water on the road surface.



Results

The skid resistance value (SRV) is the mean of five readings or the constant of three readings as stated above. As the stiffness of the rubber slider will vary with temperature a correction has to be made if the temperature is not 20°C. Use the temperature curve (Following Figure) for this purpose.



Discussion – Texture depth and SRV

(a) Describe the site and the nature of the road surface, i.e. material state of wear, etc.

(b) Describe the average texture depth and texture classification.

(c) Report the temperature-corrected skid resistance value (SRV) and comment on suitability of this value for the current use of the road (see below Table). Compare results obtained by other group(s).

Suggested minimum values of 'skid resistance' (measured with the portable tester) (TRRL, 1969)

Category	Type of site	Minimum skid resistance (surface wet)
A	Difficult sites such as: 1. Roundabouts 2. Bends with radius less than 150 m on unrestricted roads 3. Gradients 1 in 20 or steeper of lengths greater than 100 m 4. Approaches to traffic lights on unrestricted roads	**65**
B	Motorways, trunk and class 1 roads and heavily trafficked roads in urban areas (carrying more than 2000 vehicles per day)	**55**
C	All other sites	**45**

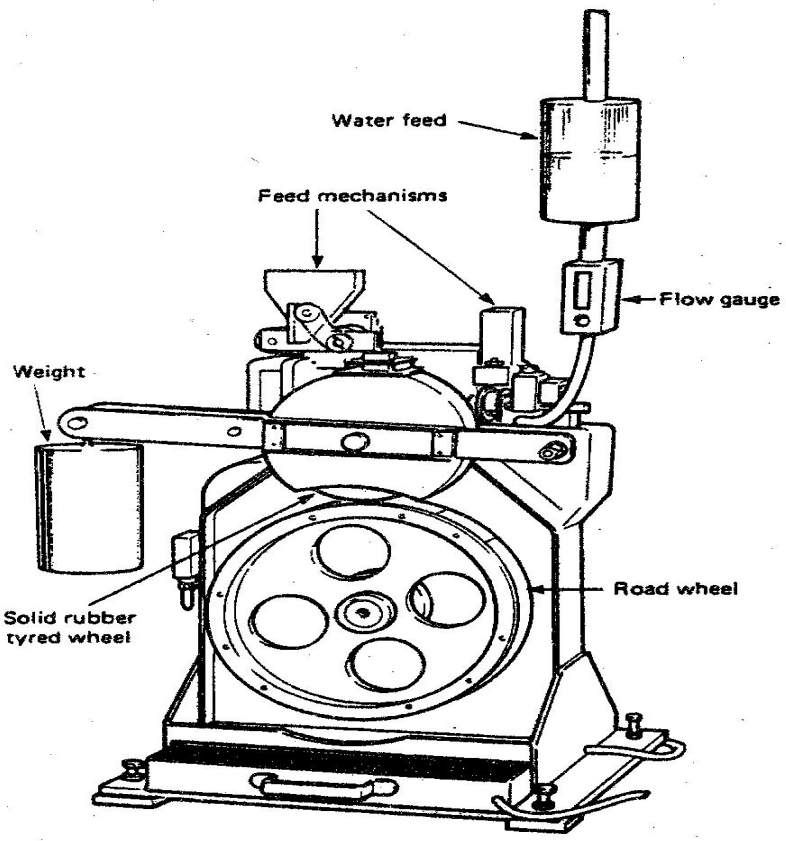
POLISHED STONE VALUE

Accelerated Polishing Machine is used to evaluate the PSV (Polished Stone Value), recommended by British Standards Institution, London and the test procedure is given below,

Procedure (BSI 1990)

1. As the preparation of specimens and the polishing process (using accelerated polishing machine, as shown in Figure) takes many hours, this will have been done, in accordance with BS 812, in advance of the laboratory session.
2. The specimen is clamped into the holder in such a way that the slider of the pendulum traverses it in the same direction as it has been trafficked in the polishing machine. The height of the suspension axis of the pendulum is then adjusted, as described for the road test, so that the slider traverses a length of 76 ± 0.5 mm.
3. The specimen and the slider are then thoroughly wetted and five readings (F scale unit x 100) are taken as described for the road test. The specimen and slider are thoroughly wetted before each reading. The mean of the last three readings is then recorded.
4. The mean value as determined is reported as the PSV.

Accelerated Polishing Machine



Discussion - PSV

a) Report the geological name, source quarry and description of the rock.

b) Recommend the type of road and traffic volume for which the aggregate is a suitable surfacing material (see following Table). Use only the polished stone value (PSV) in your discussion.

Site	Definition	Traffic in commercial vehicles (CV) per lane per day	Min. PSV (%)
A1	(i) Approaches to traffic signals on roads with a speed limit greater than 64 km/h	Less than 250 cv/lane/day	60
(very		250 to 1000 cv/lane/day	70
	(ii) Approaches to traffic signals, pedestrian		
difficult)		1000 to 1750 cv/lane/day	70
	crossings and similar hazards on main urban		
		More than 1750 cv/lane/day	75
	roads		
A2	(i) Approaches to major junctions on roads carrying more than 250 commercial vehicles per lane per day	Less than 1750 cv/lane/day	
(difficult)		1750 to 2500 cv/lane/day	60
			70
	(ii) Roundabouts and their approaches		70
		2500 to 3250 cv/lane/day	
	(iii) Bends with a radius less than 150 m on roads		75
		More than 3250 cv/lane/day	
	with a speed limit greater than 64 km/h		
	(iv) Gradients of 5% or steeper, longer than 100 m		
B	Generally straight sections of and large		
(average)	radius curves on	Less than 1750 cv/lane/day	55

	(i) Motorways	1750 to 4000 cv/lane/day	60
	(ii) Trunk and principal	More than 4000 cv/lane/day	65
	(iii) Other roads carrying more than 250 commercial vehicles per lane per day		
C	(i) Generally straight sections of lightly trafficked roads	…	45
(easy)	(ii) Other roads where wet accidents are unlikely to be a problem		

9. BRIEFLY DISCUSS ABOUT STRENGTHENING OF PAVEMENT.

STRENGTHENING OF PAVEMENT

Strengthening of Pavement is defined as the process of giving the additional strength to the pavement, in order to increase the utility of the pavement, based on the pavement evaluation and it can be both remedial and preventive step. The preventive strengthening can be carried out through the regular observation and study of pavement performance.

For effective and economical strengthening of pavement, the following factors are considered.

- The field study, to know the types of prevailing distress and its distribution.
- The general appraisal of the sub grade and the environmental conditions.
- Detailed pit examination on a comprehensive basis with regards to sub grade condition and strength, composition of crust, quality of the various constructions, interaction of various layers and the sub surface distribution of distress, etc.
- Determination of design requirements for preventive and remedial measures, based on the collected data.

The process of strengthening the pavement, by increasing the thickness of the pavement is called ***overlay.*** The following are the four combinations of possible overlays,

1. Flexible overlay over Flexible Pavement
2. Flexible overlay over Rigid Pavement
3. Rigid overlay over Flexible Pavement
4. Rigid overlay over Rigid Pavement

1. Flexible overlay over Flexible Pavement

For the design of this combination the existing flexible pavement sub grade is evaluated by any one of the suitable method. The overlay design thickness is defined as the difference between the calculated design thickness and the thickness of existing pavement.

$$\textit{Overlay Design Thickness} = \textit{Design Thickness Calculated} - \textit{Thickness of Existing Pavement}$$

Benkelman Beam Method

Benkelman Beam Method is used to calculate the overlay thickness, by using empirical formula.

$$h_0 = \frac{R}{0.434} \log_{10} \frac{\Delta_c}{\Delta_a}$$

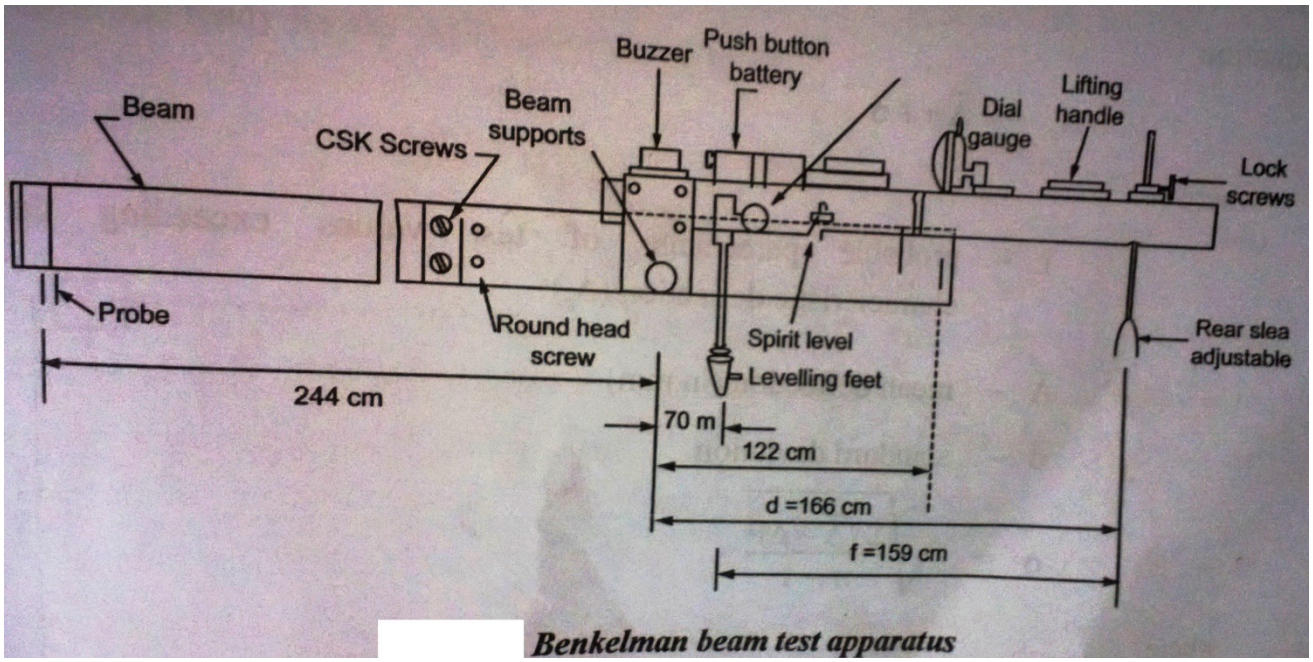
Where, h_0 - Overlay Thickness

Δ_c - Characteristic deflection of existing pavement (in 0.01 mm units)

Δ_a - Allowable deflection on pavement section (in 0.01 mm units)

- Normally 0.75 mm (depends on the type of pavement, climatic conditions and traffic conditions)

R - Deflection reduction factor



Benkelman beam test apparatus

Deflectograph in Benkelman Test

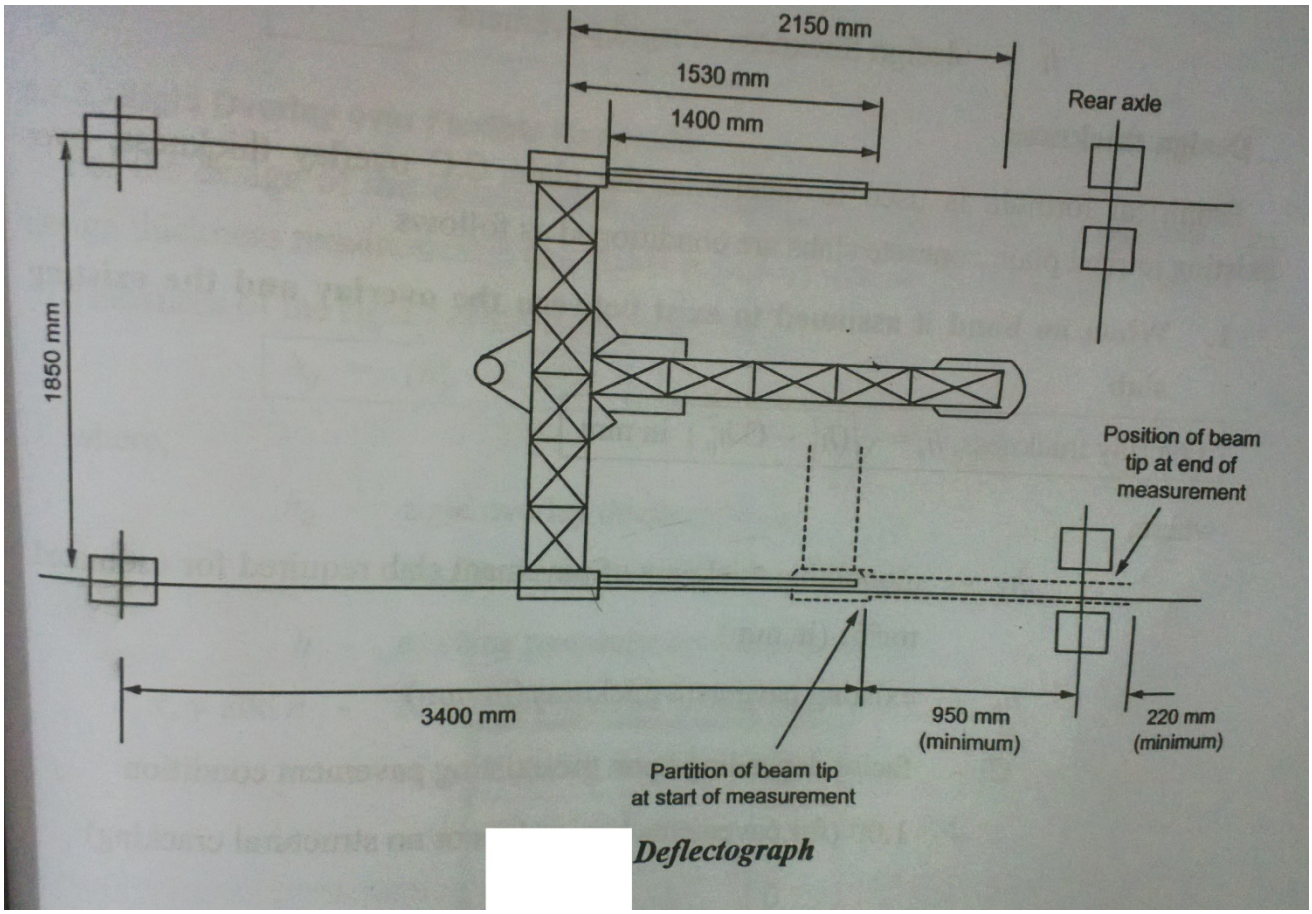
In recent years, there were a modification applied to Benkalman beam rebound deflection and the deflection data are normally provided by a Deflectograph. Deflectograph is equipment, used to take the deflection measurements over about 20 kms of carriageway per day.

The Deflectograph equipment consists of a special lorry, a deflection beam assembly located beneath its body and an associated automatic recording system.

When measurements are taken, the beam assembly rests on the carriageway. It is suitably aligned between the front and rear axles of the vehicles. Deflections are measured, as the rear wheel assemblies approach the tip of the beam. During this time, the two tips of the beam are at rest in contact with the road surface. The rear wheel assembly is loaded with 3175 kg of weight approaching the beam tip.

When the maximum deflection has been recorded by electrical transducers located near the beam pivots the beam assembly is pulled forward at about twice the speed of the vehicle. The forward pulling of beam assembly is carried out by an electromagnetic clutch and winch assembly, until it is at its initial position on the vehicle and ready for the nest measurement cycle.

An arrangement of guides ensures that the beams are aimed at the centre of the space between two types of the rear twin wheel assembly, even when the vehicle is negotiating bends. The deflectograph measures automatically, the deflections at 3.8 m intervals at a velocity of 2 kmph.



Deflectograph

2. Flexible overlay over Rigid Pavement

For the design of this combination, the following relationships are used

$$h_f = 2.5\,(F_h - h_e)$$

$$h_b = 1.66\,(F_h - h_e)$$

where,

h_f - flexible overlay thickness

h_b - bitumen overlay thickness

F - factor and it is a function of the modules of sub grade reaction

h_e - existing rigid pavement thickness

h - design thickness of rigid pavement

3. Rigid overlay over Flexible Pavement

For the design of this combination, the existing rigid pavement is evaluated. The design thickness requirement is calculated as per any one of the design method.

$$h_0 = (h_d^x - C\,h^y)^n$$

where,

h_0 - rigid overlay thickness (cm)

h_d - design thickness (cm)

h - existing pavement thickness (cm)

C, x, y, n - factors

4. Rigid overlay over Rigid Pavement

The modulus of sub grade reaction of the existing flexible pavement is determined for the design of rigid overlay over rigid pavement. Based on this value and the design wheel load, the thickness of rigid overlay is calculated by using the standard methods.

Widening and strengthening have often to be carried out as a simultaneous process.

Widening is done by water bound macadam construction on each side in layers of 75 mm thickness. This is the first step of operation.

The second stage consists in laying a strengthening layer over the whole width.

Strengthening the layer – A bituminous strengthening layer over a tack coat would be ideal. With the high cost of bitumen a bituminous macadam layer costs, little more than the normal WBM costs. The old black top surface should be peeled off the thin bituminous layer which is normally carried out by pick axes then the laying of WBM, strengthening the layers.

11. WHAT ARE THE METHODS AVAILABLE FOR STRENGTHENING OF PAVEMENT?

TYPES OF MAINTENANCE

Maintenance of Earth Roads

Frequent and regular maintenance is to be carried out for the earth roads than other type of roads, because, the surface of the earth roads get easily disrupted by traffic and climatic or temperature changes.

Following are the regular problems in earth roads,

- Formation of ruts in longitudinal direction along the wheel path of slow moving vehicles and in perpendicular direction in rainy seasons due to the surface water.
- Formation of dust in dry weather.

The maintenance of the earth roads are done as normal maintenance of regular interval preventive maintenance of emergencies.

1. **Normal Maintenance**

In this maintenance the following points are carried out,

a) **Repairing of Surface** – The roots, pot holes etc formed in the road surface should be repaired as soon as possible and the repair works will be increased due to the delayed maintenance or patchworks. A regular pattern is cut along the damaged portion up to the depth of pot hole and it is filled up with the same type of soil and compacted

properly. If a large portion of road surface is damaged, the entire portion is resurfaces with the help of mechanical equipment.

b) **Checking of camber and side slope –** During this normal maintenance work, the side slope and camber should be checked. If there is any damage or detects present means, they should be completed rectified.

c) **Maintenance of Side Drains –** The side drains of earth roads are not lined and hence it is essential to clean them frequently during the process of normal maintenance.

d) **Removal of Stumps and Rocks –** Harder material such as boulders, bricks, timber pieces or stones are sometimes mixed with earth and from part of the pavement during compaction. If such materials are found during normal maintenance they should be removed.

2. **Preventive Maintenance**

The purpose of preventive maintenance of earth road is to rectify the defects and repairs during emergencies such as flood, rain etc., Following are the two ways of in which preventive actions are carried out.

a) **Control of Moisture Content** – The increase or decrease of moisture content affects the stability of the earth roads. Depending upon the climatic conditions, suitable preventive measures should be taken to maintain the desired degree of moisture in the pavement. It will also help in controlling the dust nuisance.

b) **Restricting traffic after rains** – the road barriers may be used at either end of the earth roads to restrict the movement of vehicles (traffic) for few hours after rains.

Maintenance of Gravel Roads

(i) Normal repairs

a. Repairs of Pot Holes

b. Upkeep of the surface

(ii) Periodical Repairs

A fairly long stretch of road, (may be for 1 km) may be renewed and such operation may be carried out after providing suitable diversion of the road traffic.

Maintenance of WBM Roads

(i) Normal repairs

a. Cleaning of surface

b. Repairs of pot holes and Ruts

c. Replacement of binding

(ii) Surface renewal – The WBM wearing course shall be renewed when the surface is worn out, is corrugated and badly raveled or has a profusion of pot holes and depression which cannot be treated economically with patching or blinding operations. For surface renewal, the existing surface shall be scarified to a depth of 50mm to 75 mm and the resulting material removed to beam for screening to salvage and usable course aggregates. The exposed pavements shall be scarified again at high spots so as to ensure proper grade and camber.

Maintenance of Bituminous Roads

The pot holes defective area is cut out to a rectangular shape and then cleaned. Then the portion is applied with primer. The coated excavated area is then filled with a premixed material using cut back or emulsions and compacted.

Corrugations (or) rutting (or) shoving developed during summer on bituminous pavements due to bleeding are remedied by application of blotting material such as coarse stone chips. The surface is then rolled and applied with a heat treatment, if necessary.

The bituminous surface with minute cracks due to oxidation, ageing or volatization of binders is remedied by surface treatments. If the pavement surface gets severely cracked then an additional surface should be provided on the existing surface.

The waviness and corrugations developed on the bituminous surfaces are remedied using different methods depending upon the basic cause for the failure.

If the waves and corrugations distress are due to the excessive moisture conditions, then the suitable sub surface drainage system is provided. If this distress is due to improper compaction, then the entire road system needs reconstruction. If it is due to highly expensive plastic sub grade soil, then the sub grade soil is modified stabilization.

The polished aggregates distress causes loss in skid resistance which in turn results in pavement slipperiness. These surfaces are modified by application of renewed surface course.

The following flow chart represents a sequential process of structural examination for a bituminous pavement.