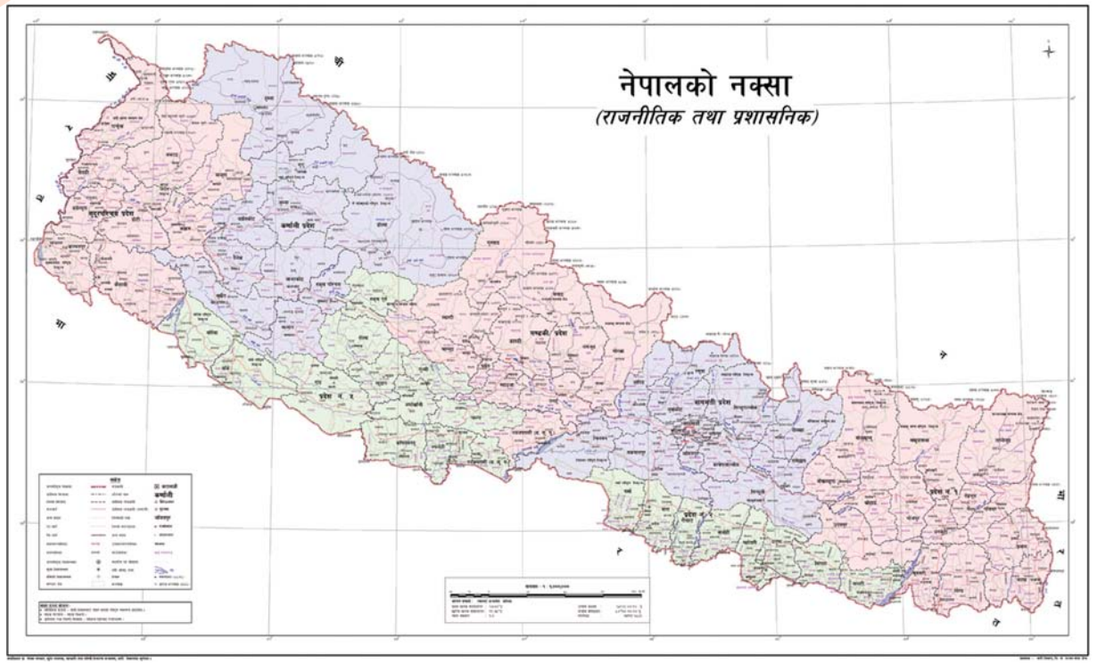

Highway Engineering

Government of Nepal
Ministry of Education, Science and Technology
Curriculum Development Centre
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Technical and Vocational Stream
Learning Resource Material

Highway Engineering

(Grade 10)

Secondary Level
Civil Engineering

Government of Nepal
Ministry of Education, Science and Technology
Curriculum Development Centre
Sanothimi, Bhaktapur

Publisher: **Government of Nepal**
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Preface

The curriculum and curricular materials have been developed and revised on a regular basis with the aim of making education objective-oriented, practical, relevant and job oriented. It is necessary to instill the feelings of nationalism, national integrity and democratic spirit in students and equip them with morality, discipline and self-reliance, creativity and thoughtfulness. It is essential to develop in them the linguistic and mathematical skills, knowledge of science, information and communication technology, environment, health and population and life skills. it is also necessary to bring in them the feeling of preserving and promoting arts and aesthetics, humanistic norms, values and ideals. It has become the need of the present time to make them aware of respect for ethnicity, gender, disabilities, languages, religions, cultures, regional diversity, human rights and social values so as to make them capable of playing the role of responsible citizens with applied technical and vocational knowledge and skills. This Learning Resource Material for Civil Engineering has been developed in line with the Secondary Level Civil Engineering Curriculum with an aim to facilitate the students in their study and learning on the subject by incorporating the recommendations and feedback obtained from various schools, workshops and seminars, interaction programs attended by teachers, students and parents.

In bringing out the learning resource material in this form, the contribution of the Director General of CDC Dr. Lekhnath Poudel, Dr. Jagatkumar Shrestha, Dr. Kamal Thapa, Dr. Bharat Mandal, Durga Bahadur Pun, Jagadishchandra Karki, Santosh Achrya, Harihar Ghimire is highly acknowledged. The book is written by Achyut Neupane and the subject matter of the book was edited by Badrinath Timalsina and Khilanath Dhamala. CDC extends sincere thanks to all those who have contributed in developing this book in this form.

This book is a supplimentary learning resource material for students and teachrs. In addition they have to make use of other relevnt materials to ensure all the learning outcomes set in the curriculum. The teachers, students and all other stakeholders are expected to make constructive comments and suggestions to make it a more useful learning resource material.

2076 BS

Ministry of Education, Science and Technology
Curriculum Development Centre

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Unit 1
Introduction

Objectives

- To give the idea about different modes of transportation
- To give the knowledge about various modes of transportation and their suitability
- To understand the classification of road according to NRS
- To gain knowledge about the history of road development

Transportation

The act or process of moving people or things from one place to another is known as transportation.

Modes of transportation

Following modes of transportation are generally used

1. Primary modes:
2. Secondary modes:

1. Primarymodes of transportation

Primary modes of transportation includes

a) Land ways: - Road, Street, highway, etc. (bus, car, truck etc.)

b) Railways: - Rails, Train, containers

c) Waterways: -River, lakes, sea, ocean (ship, boats etc.)

d) Airways: -Air routes (Aircrafts, plane, helicopters, etc.)

e) Space ways: -Space routes (Satellite, rockets etc.)

2. Secondary modes of transportation

Secondary modes of transportation include

a) Ropeways: Various types of chain and cable

b) Pipeline: water, gases, sewer pipes etc.

c) Canals: irrigation canal, Power canal etc.

d) Belt conveyers.

Advantages of road transport

Following are some important advantage of roads.

a. Wide geographical coverage

Roads can be constructed to penetrate the interior of any region and to connect remote villages. Hence, it has wide geographical coverage.

b. Large influential area

Business promotion and other commercial activities promoted along the road side, increases the life standards of many people. Development of other modes of transportation like railways and airports benefits only around the station and airport.

c. Low capital Investment

Roads can be constructed with comparatively lower initial cost than railways and airways. The cost of the roads varies with the specifications, but even the best road is cheaper than a railway line. Stage construction is feasible for roads not for railway.

d. Door to door service

Roads are only modes of transportation, which offers door-to-door service unlike railways and airways.

e. Flexibility

Road transport offer most flexible service free from fixed schedule. One can use it at any time according to his/her wish. But other services like railways and airways has fixed schedule and one can't travel according to his wish and time.

f. Highest employment potential:

Road transportation has employment potential during and after its constructions.

g. Personalized travel and service

Road transportation can be used by people according to their own wish and time. In road transporting, travel by personal car as persons in own schedule is possible. But this is not possible with airways and railways.

h. Economical

Road transportation is only economical means of travel for short distance.

i. Safety

Road accidents is less dangerous than railways or air accidents. Hence it is safer.

j. Low cost of packing

Road transportation involves very low cost of packing. This mode of transportation does notrequire any specific packing involving high cost.

k. Quick and assured deliveries

Road transport offers quick and assured deliveries. Other modes such as Plane or train transport suffers from the disadvantage that a full train load (say 2000 tonnes) has to be assembled before a train can start, where as a truck can start with just 5 to 10 tonnes.

Disadvantages of road transport

- Road transportation contributes to environmental pollution.
- It creates the problem of parking
- Road transport is economical only for short hauls. They are uneconomical for long distance
- Rate of accident is more than railways and airways
- Road transportation consume more energy.
- Loss of valuable land during construction.

History of road transportation

1. Early development

- The oldest mode of travel obviously was on the foot tracks.

- Animals were used to transport mean and material.
- Later, simple animal drawn vehicle were developed and this became a common and popular mode of transportation fora long period, which brought up the necessity of providing hard surface for this wheeled vehicle to move on.
- Such hard surface is believed to have existed in Mesopotamia in period about 3500 B.C

2. Roman Roads

- During the period of the Roman Empire, roads were constructed in large scale. Romans constructed the roads radiating in many directions from Rome, mainly for military operations.
- During roman'speriod many roads were built of stone blocks of considerable thickness.
- Appian Way was built in 312 B.C extending over 580 km.

The following are the main features of roman roads

- They were built straight regardless of gradients.
- The soft soil was excavated and removed till hard stratum was reached.
- The total thickness of construction was 0.75m to 1.2m at some places even though the magnitude of wheel load of animal drawn vehicles was very low.
- Some of these roman roads are still in existence after over 2000 years.

3. Tresaguet construction

Until the eighteen century, there is no evidence of any new road construction method except the concept used by romans. PierreTresaguet developed an improved method of construction in 1764 AD in France. His construction was much cheaper than the roman roads. The main features of his constructions are

- The thickness of construction need be only in the order of 30cm.
- Consideration was given by him to subgrade moisture condition and drainage of surface water.
- The sub-grade was prepared and a layer of foundation stones were laid on edge by hand. At two edge of pavement, large stone were embedded edge

wise to serve as submerged kerb stones.

- The corners of these heavy foundation stones were hammered and then the interstices filled with smaller stones. Broken stones were packed to a thickness of about 8 cm and compacted.
- The top wearing course was made of smaller stones and compacted to a thickness about 5 cm at the edge and gradually increased towards the centre, giving a cross slope of 1 in 45 to surface, to provide surface drainage.
- The shoulderswere also provided cross slope to drain surface water to side drain.

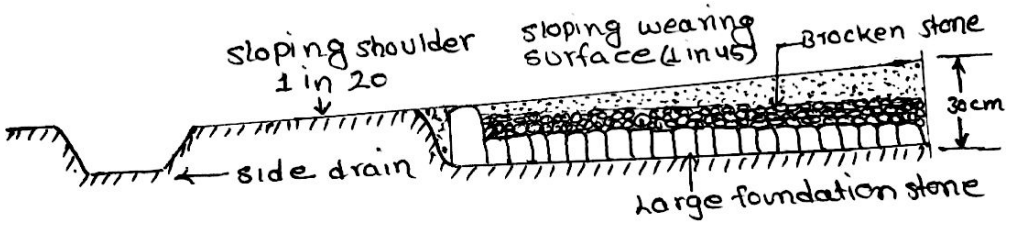


fig: Tresaguet construction

4. Telford Construction

Thomas Telford began his work in early 19th century in England. He also believed in using heavy foundation stones above soil subgrade. He insisted on providing definite cross slope for the top surface of pavement by varying the thickness of foundation stones. The main features of his construction are

- A level subgrade was prepared to design width of about 9 meters
- The stones of lesser thickness (17cm) were placed towards edge and stones of increasing thickness up to 22cm were laid towards the centre such that these stone of varying thickness provides the cross slope.
- The interstices between foundation stones were filled with smaller stone and properly beaten down.
- The central portion of about 5.5 metre width was covered with two layers of angular broken stones to compacted thickness of 10 and 5cm.
- A binding layer of wearing course 4cm thick was constructed on top using gravel. The finished surface has a cross slope of about 1 in 45.

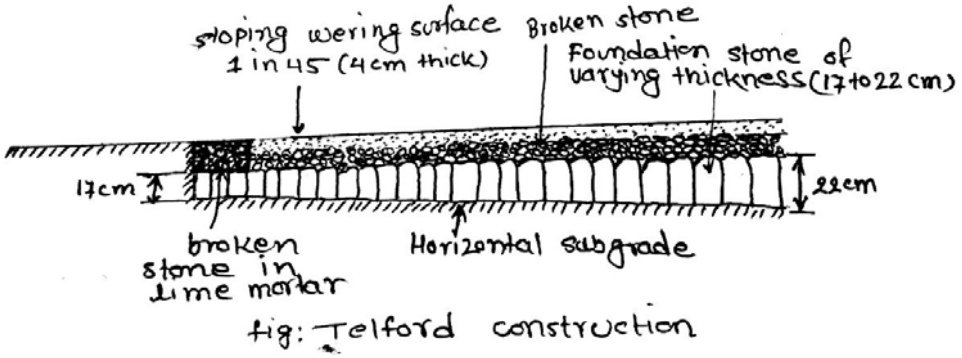


fig: Telford construction

5. Macadam construction

Johan macadam, a Scottish road builder is considered as the pioneer of modern road construction. He was the first man to realize the importance of subgrade drainage in addition to its surface drainage. He was also first person to realize the baseless use of hard and strong stones in road base. The total thickness of road pavement suggested by him is just 25 cm.

Construction steps

- Sub-grade is compacted and prepared with a cross-slope of 1 in 36 upto a desired width.
- Broken stones of strong variety, all passing through 5 cm sieve were compacted to a uniform thickness of 10cm.
- A second layer of strong broken stones of sizes 3.75cm was compacted to thickness of 10cm.
- The top layer consisted of stones of size less than 2cm compacted to a thickness of about 5cm and finished so that the cross slope of pavement was about 1 in 36.

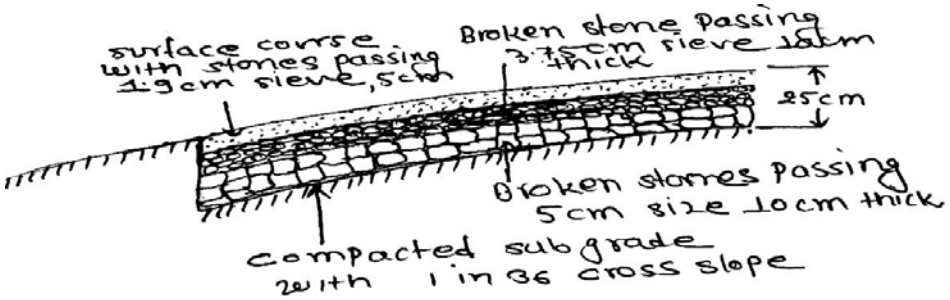


fig: macadam construction

Modern Roads

All of the modern roads are improvements over the macadam construction. Bituminous binders were made use of instead of soil binder in the surface course of road pavements. Apart from flexible pavements with bituminous layers, rigid pavements using cement concrete were also developed.

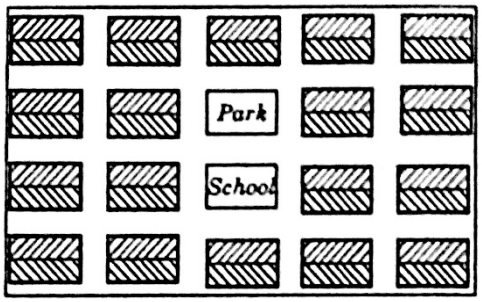
Some examples of modern roadare

- Roads with surface dressing. Surface treatments at top with various granular base below.
- Bituminous bound macadam road
- Asphalt concrete roads
- Cement concrete roads

Road patterns

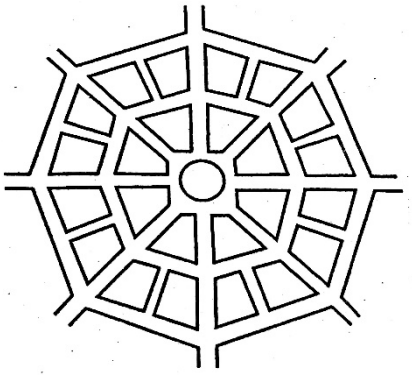
1) Rectangular or Block pattern

In this pattern, the whole area is divided into rectangular blocks of plots, with streets intersecting at right angles. The main road which passes through the centre of the area should be sufficiently wide and other branch roads may be comparatively narrow. The main road is provided a direct approach to outside the city.

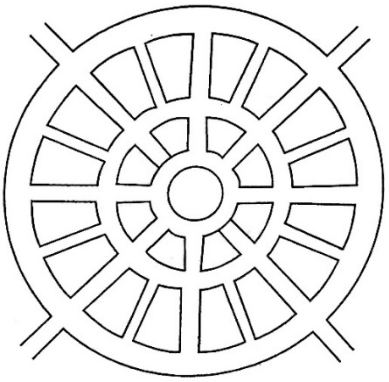


2) Radial or Star and block Pattern

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

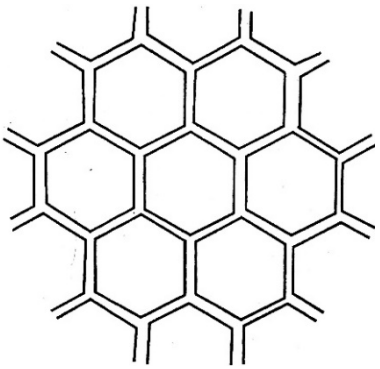


3) Radial or Star and Circular Pattern



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

4) Hexagonal Pattern



In this pattern, the entire area is provided with a network of roads formatting hexagonal figures. At each corner of the hexagon, three roads meet. The built-up area boundary by the sides of the hexagons is further divided in suitable sizes.

ROAD CLASSIFICATION

A. Based on use in different weather

- All weather road
- Fair weather road

B. Based on pavement/Carriage way

- **Paved road:** WBM, Bituminous, concrete road.
- **Unpaved road:** Earthen road, Gravel road.

C. Based on type of pavement surfacing

- **Surfaced road:** Provided with bituminous or cement concrete surfacing.
- **Unsurfaced road:** Not provided with bituminous or cement concrete surfacing.

D. Classification of urban road

- Arterial road

- Sub-arterial road
- Collector Street
- Local Street

Road Classification According to Nepal Road Standard 2070

Roads in Nepal are classified as follows

A. Administrative Classification

Administrative classification of roads is intended for assigning national importance and level of government responsible for overall management and methods of financing. According to this classification road are classified into:

1. National Highways
2. Feeder Roads
3. District Roads and
4. Urban Roads

1. National Highways

National Highways are main roads connecting East to West and North to South of the Nation. These serve directly the greater portion of the longer distance travel, provide consistently higher level of service in terms of travel speeds, and bear the inter-community mobility. These roads shall be the main arterial routes passing through the length and breadth of the country as a whole.

2. Feeder Roads

Feeder roads are important roads of localized nature. These serve the community's wide interest and connect District Headquarters, Major economic centres, Tourism centres to National Highways or other feeder roads.

3. District Roads

District Roads are important roads within a district serving areas of production and markets, and connecting with each other or with the main highways.

4. Urban Roads

Urban Roads are the roads serving within the urban municipalities.

In Nepal the overall management of National Highways and Feeder Roads comes within the responsibility of the Department of Roads (DOR). These roads are collectively called Strategic Roads Network (SRN) roads. District Roads and Urban Roads are managed by Department of Local Infrastructure Development and Agricultural Roads (DOLIDAR). These roads are collectively called Local Roads Network (LRN) roads.

Technical/Functional Classification

For assigning various geometric and technical parameters for design, roads are categorized into classes as follows:

Class I

Class I roads are the highest standard roads with divided carriageway and access control (Expressways) with ADT of 20,000 PCU or more in 20 yrs perspective period.

Design speed adopted for design of this class of roads in plain terrain is120 km/h.

Class II

Class II roads are those with ADT of 5000-20000 PCU in 20 yrs perspective period.

Design speed adopted for design of this class of roads in plain terrain is 100 km/h.

Class III

Class III roads are those with ADT of 2000-5000 PCU in 20 yrs perspective period.

Design speed adopted for design of this class of roads in plain terrain is 80 km/h

Class IV

Class IV roads are those with ADT of less than 2000 PCU in 20 yrs perspective period.

Glossary

PCU: Passenger car unit

ADT: Average daily traffic

Pavements: Any paved exterior surface, as of a road or sidewalk

Hauls: To transport something

Gradient: Rate of inclinations

Self-elevating question

1. Very short questions.

1. What do you mean by transportation?
2. Write technical classification of roads according to NRS 2070.
3. Write administrative classification of road according to NRS 2070.

2. Short answer Question.

1. Give the administrative classification of road according to NRS-2070
2. Write down the main features of romans road.
3. What are the disadvantages of road transport?
4. Describe the importance of road in development of nation.

3. Long answer questions.

1. What are the advantages and disadvantages of road?
2. What are the classification of road according NRS 2070?
3. Describe the various road patterns in brief with sketch
4. Describe the various modes of transportation with example

Unit 2
Road alignment and survey

Objective

- To explain the requirement of good alignment
- To give the knowledge of highway alignment controlling factors
- To give knowledge of various stage of engineering survey for fixing suitable highway alignment

Contents

Highway alignment

The position or layout of centre line of highway on ground is called the highway alignment. Highway alignments includes both horizontal and vertical alignment of roadway. The horizontal alignment includes straight path, horizontal deviation and curves while vertical alignment includes vertical curves gradients etc.

A new road should be aligned carefully as improper alignment would result following disadvantage.

(i) Increase in construction cost

(ii) Increase in maintenance cost

(iii) Increase in vehicle operation cost

(iv) Increase in accident rate

Requirements of good highway alignments

Short: The alignment between two terminal stations should be short and as far as possible. But due to some practical considerations deviations may be needed. Short alignment can reduce the vehicle operation cost and also save the time.

Easy: The alignment should be easy to construct and maintain. Also the alignment should be easy for the operation of vehicles with easy gradients and curves.

Safe: Alignment should be safe enough for construction and maintenance from the

viewpoint of stability of natural hill slopes, embankment and cut slopes and foundation of embankments. Except that, it should be safe for the traffic operation with safe geometric features.

Economical: Highway alignment should be economical as far as possible. Alignment could be considered economical only ,if the total cost including initial cost ,maintenance cost and vehicle operation cost is lowest.ie least earthwork, use of locally available materials, least fuel consumption, least wear and tear of vehicle parts, least maintenance cost and maximum use to the population .

Factors which controls the highway alignment

The various factors which controls the highway alignment are as follows:

1. Obligatory points
2. Traffic
3. Geometric design
4. Economics
5. Other considerations

Obligatory points

Obligatory points may be divided into two categories:

Point through which alignments has to pass

Some examples are

- Alignment along the hill side pass.
- Alignment to suit proper location of bridge.
- Alignment to connect intermediate place.
- Alignment to connect industrial area or zone

Points through which alignment should not pass

Some examples are

- Historically and archeologically important property.
- Restricted zone for defence, national security.
- Costly structural elements requiring heavy compensation.

- Densely populated areas.

Traffic

The road alignments should be decided based on the requirements of road traffic.

Geometric design

Geometric design such as gradients, radius of curve and sight distance also governs the alignment of highway.

Economics

While aligning a new highway the initial cost, cost of maintenance and vehicle operation cost should be taken into account. The initial cost of construction can be decreased if high embankments and deep cutting are avoided and alignment is chosen in manner to balance the cutting and filling.

Other consideration

Various other factors which governs the highway alignment are drainage consideration, hydrological factors, political consideration and monotony. Vertical alignment which are often guided by drainage consideration.

Engineering survey for highway alignment

The alignment of highway is finalized based on different survey. Survey should be done in right way to achieve the requirements (**SESE**) as much as possible. There are four stage of survey which decide the highway alignment. The first three stage consider all possible alternatives alignment. The fourth stage is for detailed survey of the selected alignment.

The stage of engineering survey are

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

1. Map study

If the topographic map of the area is available, it is possible to suggest the likely

routes of road. The main features like rivers, hills, valley etc. are shown on these map. By study of such map, it is possible to have an idea of several possible alternate routes, so that further details of these are studied later on site. The probable alignment can be located on map from the following details available from the map.

- Alignment avoiding valleys ponds or Lake etc.
- When the road has to cross a row of hills, possibility of crossing through mountain pass.
- Approximate location for the bridge site for crossing rivers, avoiding the bend of river if any.

Thus from map study the alternate routes can be suggested.

2. Reconnaissance

The second stage of surveys for highway location is the reconnaissance. A field survey party may fairly inspect the land along the purposed alternative routes of the map in field. All details which are not available in the topographic map are collected and noted down. It is done without accurate instruments. Clinometers are used to determine the slopes of the ground.

Details collected Reconnaissance survey are as follows.

- Village, ponds, lakes, ridge falls and other obstruction along the routes which are not available in the map.
- Number and types of cross drainage works
- Types of soil and geological features
- Sources of construction materials, water and location of stone quarries.
- Approximate values of gradients, length of gradients and radius of curves of alternate alignment.

As a result of reconnaissance a few alternatives alignment may be chosen for further study.

3. Preliminary survey

It is the large stage study of one or more feasible routes. It consists of running accurate traverse line along the routes already recommended by the reconnaissance survey in order to obtain sufficient data for final location. . It is done by using the

instruments such as chain, compass, tape, level & theodolite. The main purpose of the preliminary survey are.

- To survey the various alternate alignments purposed after the reconnaissance.
- To compare different proposal in the view of requirements of good alignment.
- To work out the probable cost of alternative alignment.
- To finalize the best alignment from all consideration.

Method of preliminary survey

- Preparation of baseline traverse.
- Levelling along base line traverse.
- Collecting topographical and other details
- Drainage study and collection of hydrological data.
- Soil survey/geological survey
- Material survey
- Determination of final centre line of road**.**

4. Final location and detail survey

The alignment finalized at the design office after preliminary survey is to be first located on field by establishing centreline and then detail survey should be carried for collecting the necessary information for preparation of plan and construction details for highway project. This is done accurately by using instruments. The final route selected after the preliminary survey is surveyed and located on the ground.

During detail survey following works are perform.

- Pegging the centre line
- Centre line levelling
- Cross section levelling up to desired width
- Fixation of property lines
- Temporary water course and stream details
- Material site survey
- Special site survey

Glossary

Clinometers: An apparatus for measuring vertical angle, a slope or the height of a large object.

Alignment: The position or layout of centre line of highway on ground is called alignment

Topographic map: The map that shows topography and features found on the earth's surface

Gradients: Rate of inclinations

Self-Evaluations

A. Very Short answer question.

1. What do you mean by highway alignment?
2. List out all the requirements of highway alignment
3. What do you mean by reconnaissance?

B. Short answer question.

1. What would be the concequenceses, if highway alignment were not properly selected?
2. Describe preliminary survey of highway alignment in short
3. Describe map study for highway alignment in short
4. What are the obligatory points related to highway alignment?
5. What are the objectives of reconnaissance in engineering surveys?

C. Long answer question.

1. What are the various requirements of ideal highway alignment? Discuss briefly
2. Explain obligatory points. With sketches, discuss how these control the alignment
3. Mention the use of map study in engineering surveys for highway location.
4. Explain how the final location and detailed survey of a highway are

carried out.

5. Briefly explain the engineering surveys needed for locating a new highway.

Unit 3

General definition of terms used in highway geometric design

Objective

- To introduce various cross section of road.
- To give knowledge about various cross sectional elements of road
- To explain the various types of sight distance and requirements

Cross section of road

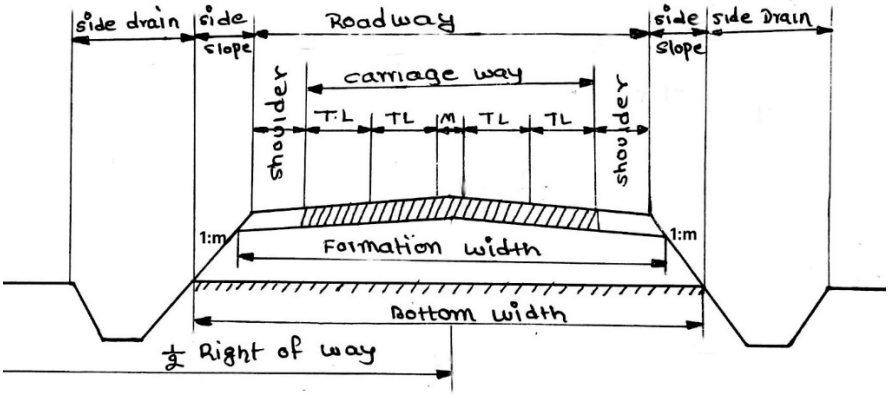


fig. : Cross section of road showing various component

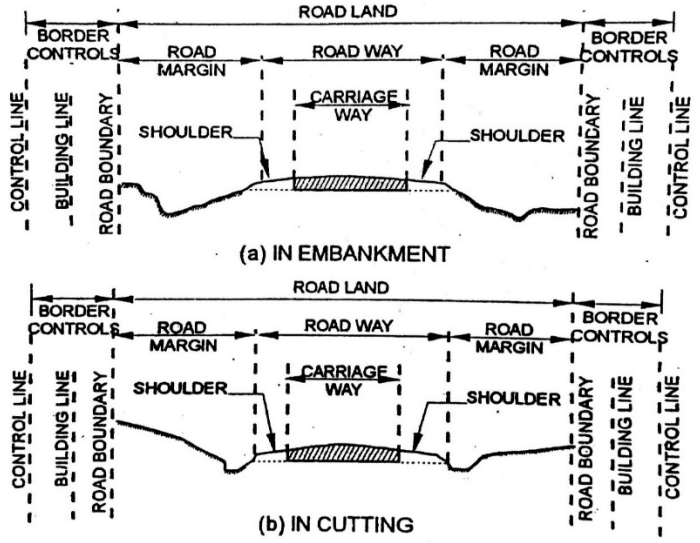


Fig. Cross section details

Element of cross section

1. Traffic lane
2. Carriage way
3. Shoulder
4. Roadway
5. Formation width
6. Side slope
7. Laybys
8. Right of way or Land width
9. Camber
10. Superelevation
11. Extra widening

In urban roads, additional elements are:

1. Sidewalk (Foot path)
2. Kerb (Curb)
3. Median Strip

Traffic lane

The strip of the carriage way occupied by vehicles moving in a single stream along the road, is referred as a traffic lane. The width of traffic lane is function of width of design vehicles and safety clearance on either sides as necessary for safe driving. The minimum required width of traffic lane is 3.75m and 3.5m for single lane roads and multiple lane roads respectively.

Carriage way

A carriage way may be defined as that strip of road which is constructed for the movement of vehicular traffic. It is also called the pavement width. Width of pavement or carriage way is sum of total of the width of traffic lane.

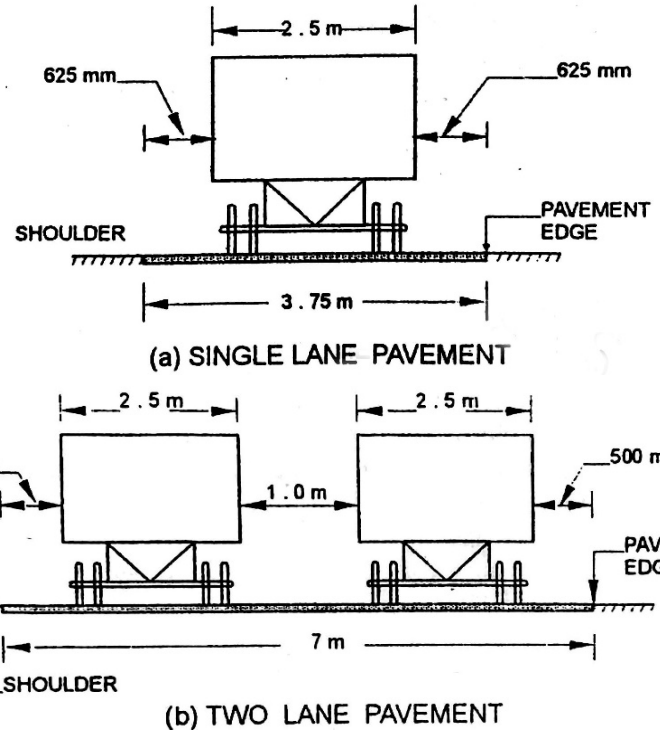
C_w = n T_w

Where,

C_w= Carriage way width

T_w = Width of lane

n = Number of lanes



Shoulder

Shoulders are the strips, provided on both the sides of carriage way. Shoulder serve as parking places for vehicles which have developed some defect and need parking. If shoulders are not provided, vehicles going out of order shall have to parked on the carriage way and thus efficiency of road is affected.

Shoulder provides lateral stability to the carriageway and also provide a sort of reserve lane for overtaking and crossing in the case of single lane roads. The width of shoulder on either side should be at least 0. 75m.

The surface of the shoulder may be rougher than the traffic lanes so that vehicles are discouraged to use the shoulder as a regular traffic lane.

Advantage of shoulder

- Provide space for parking vehicle
- Provide space for fixing up traffic signals
- Increase the capacity of road by providing frequent opportunities for overtaking.
- Increase the effective width of carriage way
- Improved sight distance with increased lateral clearance

Rodway

It is that portion of road which is covered by carriage way, shoulder on either side and central strip if any.

Formation width

It is the top width of the road embankment or bottom width of road cut measured at finished subgrade level over which carriage way is constructed.

Side slope

It is the slope of embankment in case of road in or slope of cutting in case of road in cutting.

Laybys

Laybys are the intermittent shoulders sufficiently wide and long provided to meet the important function of shoulder where the continuous shoulder on either side cannot be provided from economical consideration.

Right of way and land width

Right of way is the area of land acquired for the road along its alignment. The width of this acquired land is known as land width or **right of way** and it depends on the importance of road and possible future development. The right of way should be adequate to accommodate all the elements that make up the cross section of highway and may reasonably provide space for future development. The following are the purpose of right of way,

1. To accommodate drainage facilities
2. To open, side borrow pit

3. To accommodate various road ancillaries
4. To improve visibility in curves
5. To widen the road where required in future with no compensation for property.

According to NRS the right of way for various type of road is

Type of road	Right of way in m
National Highway	50m (25m on either side from center line of road)
Feeder Road	30m (15m on either side from center line of road)
District road	20m (10m on either side from center line of road)

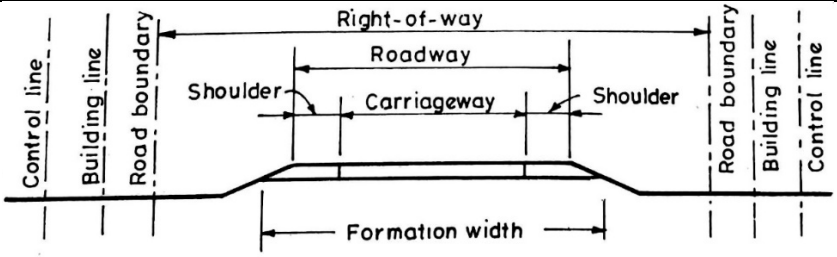


Fig. Right-of-way, building line and control line.

Camber (Cross-slope)

Cross- slope or camber is the slope provided to the road surface in transverse direction to drain off the rainwater from the road surface.

Or,

Camber is the convexity provided to the cross section of carriage way. The primary function of a camber is to provide surface drainage.

Usually the Camber is provided on straight roads by raising the center of the carriage way with respect to edges, forming crown or highest point along center line. Camber can be expressed as percentage. If camber is X %, cross slope is X m in 100 m.

Objective of providing camber

- To drain out surface water.

- To prevent infiltration of water into underlying pavement layers and soil subgrade.
- To separate the traffic in two direction
- To improve the appearance of road

Required amount of camber on road surface depends on

- Type of pavement surface
- Amount of rainfall

Camber to be provided on different road surface according to NRS 2070,

Pavement type	Cement Concrete	Bituminous	Gravel	Earthen
Camber, %	1.5 to 2.0	2.5	4.0	5.0

Types of camber

On the basis of shape following types of camber are generally used

1. Straight line camber: Adopted on flat slope with cement concrete pavement
2. Parabolic camber: Suitable for fast moving Vehicle
3. Composite Camber

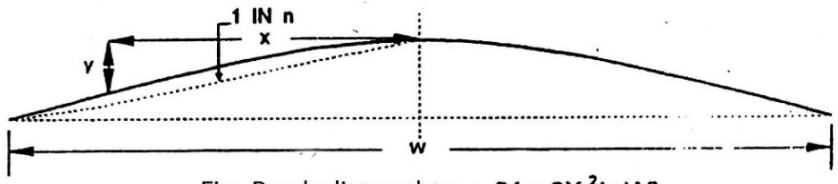


Fig : Parabolic camber $[Y = 2X^2/nW]$

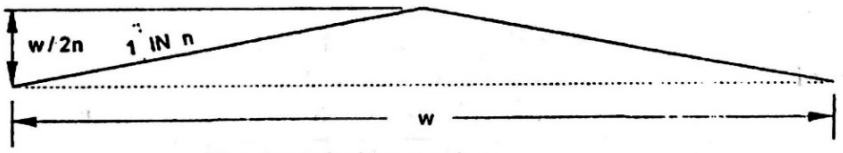


Fig : Straight line camber

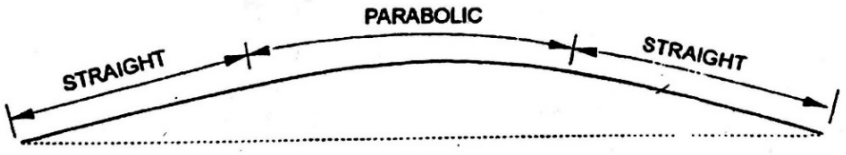


Fig : Composite camber

Super elevation

When a vehicle negotiates in a curve path, it is subjected to an outer ward force known as centrifugal force. In order to counteract the effect of this centrifugal force and to reduce tendency of vehicle to overturn or skid, the outer edge of pavement is raised with respect to inner edge, thus providing a transverse slope throughout the length of horizontal curve. This transverse inclination is calledsuperelevation.

Spperelevation is the process of raising outer edge of pavement, with respect to inner along the horizontal curve in order to counteract the effect of centrifugal force. It is also known as cant or banking.

Superelevation is expressed as the ratio between the difference of heights of outer edge and the inner edge of carriage way and the width of carriage way. Thus if the carriageway is 15m wide and the level of outer edge is 0.5m above that of inner edge, it would mean a superelevation of 1 in 30.

Following are the advantage of providing superelevation

1. Higher speed without danger of overturning.
2. Maintenance is reduced, otherwise there will be wear on the outside wheel, causing pot holes.
3. The water can be drained of easily.

- Maximum value of superelevation shouldn't exceed 7 %
- Minimum amount of superelevation is to be provided is equal to amount of camber.

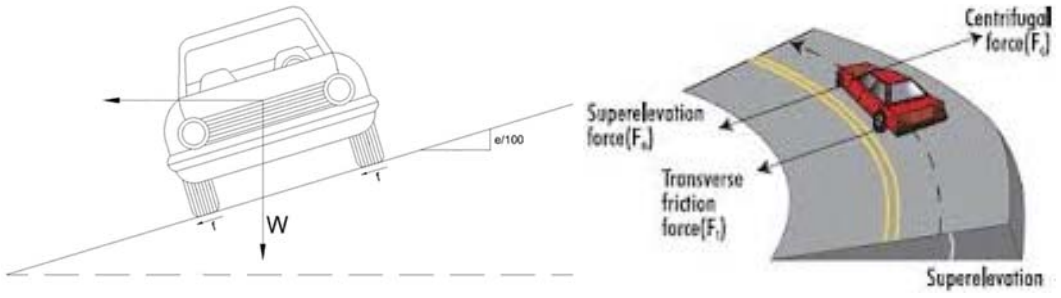


Fig: Supeerelevation on horizontal curve

Extra widening

On horizontal curves, increased carriage way width is provided than the normal width on straight reaches. The increased width of carriage way at horizontal curve is called the extra widening of the pavement. Its value depends upon the sharpness of curve.

Reasons for providing extra widening on horizontal curve

1. While travelling on a horizontal curve, rare wheels do not trace the same path as front wheel do. This is called the off tracking. In this position more with of the road is occupied by vehicle.
2. At more than designed speed if super elevation+ and lateral friction jointly cannot counteract the centrifugal force fully, outward slippage of rear wheel may occur and thus more width of road is covered.
3. There is tendency of driver to take outer path of curve to have more sight distance visible ahead.
4. The clearance between the vehicles, crossing or passing each other over horizontal curve is kept more than that on a straight road due to psychological effect

The extra widening on horizontal curve is divided into two parts

i. Mechanical widening

ii. Psychological widening

And the amount of extra widening to be provided on horizontal curve is sum of mechanical widening and psychological widening.

Mechanical Widening

The widening required to account for the off tracking is called mechanical widening. which is given by,

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

Where

n= Number of lane

l= length of wheel base of longest vehicle in m

R = Radius of horizontal curve in m

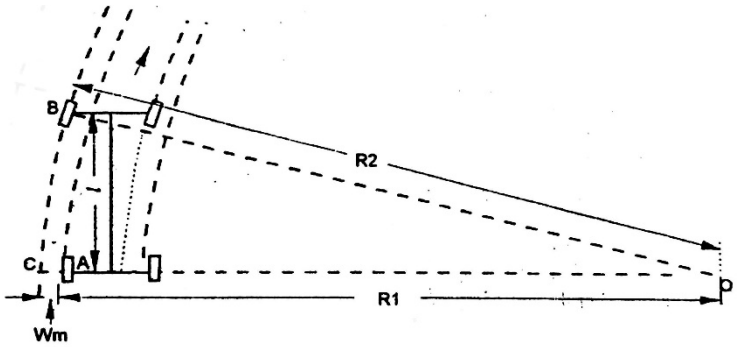


Fig. Off-tracking and mechanical widening on horizontal curve

Psychological widening

Value of psychological widening to be provided on horizontal curve is,

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

Where V is designed speed in Km/hr.

Thus total widening required on horizontal curve is

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

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

Method of introducing extra widening on horizontal curve

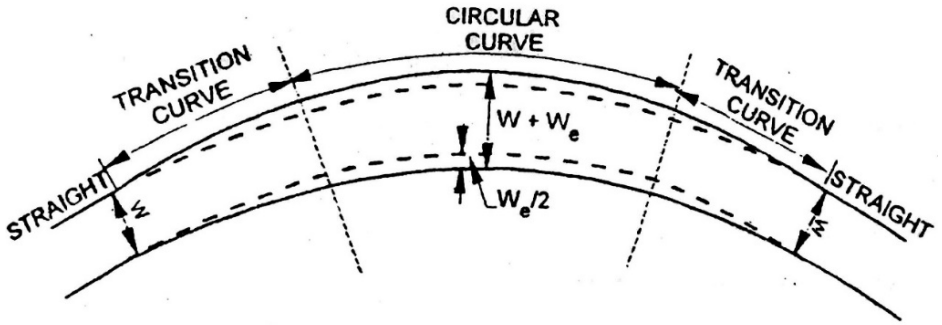


Fig. Extra widening of pavement on horizontal curve

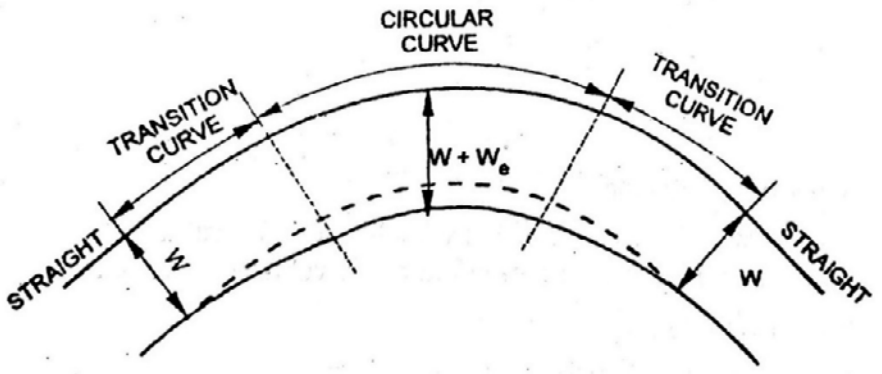


Fig. Widening of pavement on sharp curve

Side walk

It is that portion of the urban road which is provided for the movement of pedestrian traffic where their intensity is high. Sidewalks are raised to about 15 to 30 cm high from carriage way or separated by laying stone or concrete block to provide safety to pedestrian against fast moving traffic. Width of the footpath depends on the volume of anticipated pedestrian traffic. But a minimum width of 1.5 m is required.

Kerb (Curb)

It is that element of road, which separates the vehicular traffic from pedestrians by providing physical barriers between them. The face of the kerb may be vertical or slopping and height varies from 15 to 25 cm.

Function of kerb

- To facilitate and control drainage
- To strengthen and protect the pavement edge.
- To present more finished appearance
- To segregate the traffic lane

Median strip

It is the central raised strip within the roadways constructed to separate the traffic moving in one direction from the traffic in opposite direction. The main function of the median strip is to prevent head-on collision between vehicles moving in

opposite directions on adjacent lane.

- To separate the opposite streams of traffic.
- To minimize head- on collision between vehicles moving in opposite directions.
- To minimize head-light glare
- To segregate traffic lane.

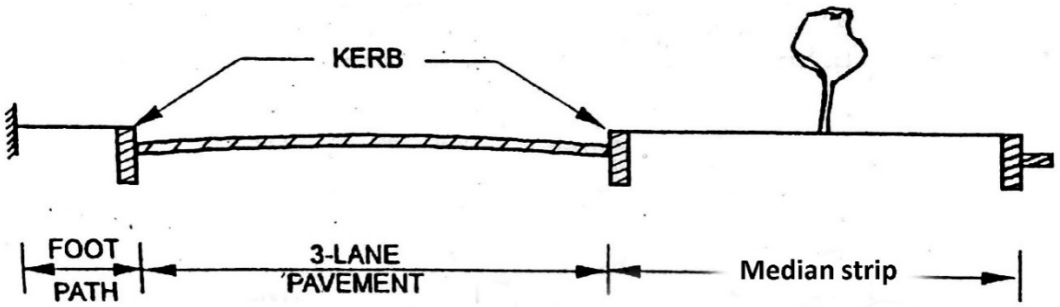


Fig.: Kerb ,foot path and Median strip

Sight distance

Sight distance is defined as the length of carriage way that is visible to the driver at any instant from the specified height of driver's eye above the road surface. The specified height of driver's eye is 1.0 and 1.2 m according to NRS and IRC respectively. The height of object is taken as 0.15m above road surface.

Restriction to sight distance

1. Restriction to sight distance at horizontal curves either due to obstruction inside curve such as building, trees etc. Or due to inability of head light to through the beam along the curve path.
2. Restriction to sight distance at vertical summit curves on the other side if the curve is not carefully selected.
3. Restriction to sight distance at vertical valley curves on the other side if the curve is not carefully selected.
4. At intersections the sight distance is reduced if an obstacle either in the form of building or greeneries comes up.

Types of sight distance

1. Stopping sight distance
2. Over taking sight distance

Stopping sight distance

Stopping sight distance is defined as the minimum sight distance required along the road for the driver in order to stop the vehicle at designed speed safely without colliding with the other vehicle. The stopping sight distance is not constant but it varies depending upon the situation.

Factors affecting stopping sight distance

1. Total reaction time:-It is the time taken from the instant the object is visible by the driver to the instant the break is applied by the driver's feet. In average total reaction time is taken as 2.5 sec.
2. Speed of vehicle
3. Breaking efficiency
4. Coefficient of friction
5. Slope of road surface

Expression for stopping distance

Stopping distance is the sum of lagging distance and breaking distance

Lagging distance: - Distance travelled by vehicle during total reaction time. It is also known as reaction distance.

Lagging distance = vt m

Breaking Distance: -The distance travelled by the vehicle after the application of breaks to the instant the vehicle come to dead stop is known as breaking distance.

Breaking distance = $\frac{v^2}{2gf}$

We know that,

SD = Lagging Distance + Breaking distance

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

In case of slopping road with n% gradient above expression reduces to,

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

Where, v = Designed speed of vehicle in m/s

t = total reaction time in second

f = coefficient of friction

n = gradient of road in %

Note: Here + and – sign with n is applicable for ascending and descending gradient respectively.

Relationship between stopping distance and stopping sight distance

Case i: SSD= SD for one-way traffic with single lane

Case ii: SSD= SD for tow way traffic with multi-lane

Case iii: SSD = 2 SD for tow way traffic with single lane

Overtaking sight distance

It is the distance open to the vision of drivers in the vehicles intending to overtake the slow moving vehicle ahead with safety against the vehicle coming from opposite direction. This distance is also called passing sight distance.

1. Factors affecting overtaking sight distance:
2. Speed of overtaking vehicle, overtaken vehicle, and vehicle coming from opposite direction.
3. Distance between overtaking and overtaken vehicle
4. Skill and reaction time of driver

Glossary

Reaction time:time: The interval between the receptions of the stimulus and the initiations of the response

Crown: Highest point of the road surface

Subgrade: The layer of native soil on which the foundations of a road is laid

Intermittent: Stopping and starting at intervals

Accommodateto render fit, suitable or correspondent

Glare: An intense blinding light

Segregate: To separate

A. Very Short answer question.

1. What is the maximum and minimum value of super elevation that can be provided?
2. Define super elevation.
3. What do you mean by extra widening of horizontal curve?
4. What value of camber do you prefer for the concrete road and bituminous road?
5. State the factors on which the camber to be provided depends.
6. What is laybys?

B. Short answer Question.

1. Define super elevation. Where and why it is provided?
2. Why extra widening is needed at horizontal curves?
3. What do you mean by sight distance? Write an expression to calculate stopping distance of a vehicle.
4. What are the function of median strip
5. Define traffic lane and Carriageway.
6. What are the function of Kerb?
7. Explain formation width with sketch.

C. Long answer question.

1. Draw a cross section of road in filling showing various components.
2. What are the reasons for providing extra widening in horizontal curve?
3. Define shoulder. What are its advantages?
4. Define camber. What are the objects of camber? State the factors on which the amount of camber to be provided depends. Specify the recommended ranges of camber for different type of pavement surfaces.

5. Explain right of way. What are the purpose of right of way?
6. What is stopping sight distance? What are the factors on which the stopping sight distance depends?
7. Explain the sight distance and factors causing restrictions to sight distance.

Unit 4
Highway Materials

Objectives

- To sensitize various highway materials
- To explain the properties different types of road construction materials
- To have an idea about desirable properties of the stone aggregates, sub grade soils and bituminous binders.

The materials used for construction of highway is termed as highway materials. The nature quality and other some properties of these materials are differ from the building materials. Some of the materials used in highway construction are soil, stone aggregate, sand, bitumen, cement, steel etc. The materials used in the road construction can be classified into three groups.

1. Binding Materials

The materials used to unite or bind two or more materials during the construction of pavement is known as binding material. These materials are divided into three categories.

a. S**tone dust**: It produces semi rigid or semi flexible bonding between the mineral materials.

b. **Inorganic materials**: It produces rigid bond between the mineral materials. Example: - cement, lime etc.

c. **Organic materials:** it produces thin film or layer which is flexible or reversible in nature.

Example: Bitumen

2. Mineral materials

Mineral materials used for the construction of highway are soil, sand, stone chips, gravels, stone dust, brick etc. These are either naturally occurring, semi processed or fully processed. Soils are extensively used for embankment construction, while stone aggregates are used for pavement construction, back filling of retaining walls etc.

3. Other materials

The other materials used in highway construction are concrete, reinforcing steel, timber, stone, brick boulders, cobbles etc.

Subgrade soil

Soil is the deposition of the mineral matters formed by disintegrations of rocks, by the action of water, frost, temperature, pressure or by plant or animal life.

The subgrade soil is the integral part of road pavement structure as it provides the support to the pavement from beneath. The main function of the subgrade is to give adequate support to the pavement and for this subgrade, soil should possess sufficient stability under adverse climate and loading **condition.**

The formations of waves, corrugations, and rutting, in black top pavement and phenomena of pumping, blowing and consequent cracking of cement concrete pavements are generally due to poor subgrade-soil conditions.

Desirable properties of sub-grade soil

Following are the desirable properties of subgrade soil

1. Stability

The subgrade soil should be stable and strong to resist permanent deformation under loads, resistance to weathering and it should have ability to provide adequate support to the pavement.

2. Incompressibility

Soil used in the subgrade and embankment construction should be incompressible to avoid differential settlement of the pavement after its constriction.

3. Permanency of strength

Permanency of strength is the property of soil, which allows the subgrade to support pavement with same degree of strength under the varying condition of moisture and weather for long time.

4. Ease of compaction

The strength of subgrade soil depends upon its dry density .Higher the dry density, greater the strength of soil. The ease of compaction is the property of soil which, ensure the higher dry density with minimum compaction effort. Thus, if soil is easy to compact we can able to increase its strength easily in minimum effort.

5. Good drainage

Increase in moisture content of sol decreases its strength. Presence of moisture in subgrade soil, due to poor drainage characteristic reduces the strength of subgrade soil. Thus, the soil having good drainage characteristic is essential to avoid excessive moisture and frost action.

6. Minimum change in volume and stability under adverse condition of weather and ground water

It is required to ensure minimum variation in its expansion.

Stone aggregates

Aggregates are granular mineral material (such as sand, gravel, crushed stone) used with a bonding medium (such as cement or clay or bitumen) to make concrete, plaster, or terrazzo mixture.

Stone aggregates form the major portion of pavement structure and they are the prime material used in the construction of different pavement layers. The aggregate used in the various pavement layers have to sustain different magnitude of load .The aggregate of the pavement surface have to resist,

1. The wear due to abrasive action of traffic.
2. Deterioration due to weathering.
3. Highest magnitude of wheel load stress

Stone 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. Stone aggregates are used in the construction of various pavement layers such as I) Bituminous pavement layer of flexible pavement. Ii) Cement concrete mixes used for rigid pavement. III) Granular base course IV) Granular sub-base course. Thus stone aggregates form one of the important components of highway materials.

Road aggregate may be used in road pavement in single size or mixing by gradation of different size to increase density and hence strength.

Types of aggregate

Based on source of origin

(i) Natural aggregates

(ii) Crushed aggregates

Based on size

(i) Coarse aggregates

(ii) Fine aggregates

Based on types of rock

(i) Aggregate obtained from igneous rock

(ii) Aggregate obtained from sedimentary rock

(iii) Aggregate obtained from metamorphic rock

Based on strength

(i) Hard aggregates.

(ii) Soft aggregates.

Bashed on shape

(i) Rounded aggregates.

(ii) Irregular aggregates.

(iii) Flaky aggregates: Least dimension is less than 3/5 of its mean dimension.

(iv) Angular aggregates.

(v) Elongated aggregates: Greatest dimension is greater than the 9/5 times their mean dimension.

Desirable properties of stone Aggregates

1. Strength

The ability of a material to withstand various forces is called strength.

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

2. Hardness

Resistance to abrasion is known as hardness.

The aggregates used in the surface course are subjected to constant rubbing or abrasion due to moving traffic. They should be hard enough to resist the wear due to abrasive action caused by the movements of traffic. Abrasive action may be increased due to presence of abrasive material like sand between the tyres of moving vehicle and aggregates exposed at the top surface.

3. Toughness

Resistance of the aggregates to impact is termed as toughness.

Due to irregularities in the road surface impact action is developed. The constant impact of heavy traffic loads tends to break the stone aggregates into small pieces. The aggregate used in the road construction should be tough enough to resist fracture under such impact

4. Shape of aggregates

Aggregate particles may have rounded cubical, angular, flaky or elongated shapes. 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 stone. Hence too flaky and too much elongated aggregates should be avoided as far as possible. Aggregates having angular particles should be preferred

5. 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 off in presence of water.

6. 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.

7. Freedom from deleterious particles

Aggregates used in bituminous mixes usually require the aggregates to be clean, tough and durable in nature and free from excess amount of flat 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.

8. Cementation

Mixing and making unite property of stone aggregate with other material should be good.

Bitumen

Bitumen is a liquid or solid material black or dark brown in colour. It has adhesive properties consisting essentially of hydrocarbons (compound of carbon and hydrogen) which is soluble in carbon disulphide. It is non crystalline solid or viscous material derived from petroleum. Bitumen is main binders used in road construction which is obtained from petroleum.

Bitumen is manufactured by fractional distillation of crude petroleum product.

- Bitumen softens gradually when heated.
- Possesses waterproofing and adhesive properties.

- Bitumen are classified into two categories as per the source of origin. The first is petroleum bitumen and second is natural bitumen.
- Soluble in carbon disulphide, carbon tetra chloride, chloroform, benzene etc.

Petroleum bitumen

It is the product of processing crude petroleum and its resinous residue.

Natural bitumen

Bitumen is also found as a natural deposit, in which case it is known as native bitumen or natural bitumen.

Bye product of bitumen

1. **Cut back:** It is solution of bitumen in volatile or partly volatile solvent such as kerosene, creosote. Addition of solvents lowers the viscosity of bitumen.
2. **Emulsion:** Finely divided bitumen held in suspension in an aqueous medium is called bitumen emulsion. It is used in soil stabilization.
3. **Asphalt:** A mixture of bitumen and inert mineral matters. Which may occurs in natural deposit or produced by artificial means. Bitumen is binding medium in asphalt

Desirable properties of bitumen

1. The viscosity of bitumen at the time of mixing with aggregates should be adequate. This is achieved either by
    a. Heating the bitumen and aggregate prior to mixing
    b. By using in the form of cut- back.
    c. By using in the form of emulsion of suitable grade.
2. The bituminous binder should become sufficiently viscous on cooling so that compacted bituminous pavement layer can gain stability and resist deformation under traffic loads.
3. The bituminous binders used shouldn't be highly temperature susceptible. During the hottest weather bituminous surface shouldn't become too soft or unstable. During cold weather the mix shouldn't become too hard and brittle, causing cracking of surface.

4. The bitumen binder should have sufficient adhesion with aggregates in the mix in presence of water.
5. There has to be adequate affinity and adhesion between the bitumen and aggregate used in the mix. The coated binder should not strip -off from the stone aggregate under stagnant water.
6. It is desirable that bitumen binder used in bituminous mixes form ductile thin film around the aggregates to serve as satisfactory binder in improving the physical interlocking of the aggregates.

Importance of soil engineering in road construction

Soil is the cheapest and the most widely used material in any highway system. Also all road pavement structures eventually rest on soil foundation which supports load of pavements plus vehicular loads coming over it. Thus through study of engineering properties of soil is of vital in design of pavement structure.

- All road structures like bridges culverts, etc. rest in soil and hence study of soil engineering is important for foundation design of such structure.
- Retaining walls are frequently used in road construction. Soil engineering suggest design procedure of such retaining walls.
- Soil engineering helps to decide the safe side slope required for road embankments.
- Drainage requirements of subgrade is decided by study of permeability of soil in soil engineering.
- Soil engineering suggest value of bearing capacity for different soil which is needed for pavement design.
- Soil engineering suggest various method to improve the strength of subgrade soil.
- Soil stabilization technique is described in soil engineering.
- Problems of landslide and measure adopted to combat them are studied in soil mechanics which is useful in hill road construction.

A. Very Short answer question

1. Write any two binding materials used in pavement construction.

2. What do you mean by aggregates?
3. What is bitumen emulsion?
4. What is subgrade?
5. Define flaky and elongated aggregates

B. Short answer question.

1. What are the different types of Binding materials used in road construction?
2. What are the bye-product of bitumen? Discuss in short
3. Discuss the importance of soil engineering in road construction.
4. Mention the properties of bitumen

C. Long answer question.

1. What is the importance of studying behavior of soil as a highway material?
2. What are the desirable properties of subgrade soil?
3. What are the desirable properties of aggregates used in pavement construction?
4. Discuss the desirable properties of paving bitumen

Unit 5
Highway Drainage

Objectives

- To sensitize the importance of highway drainage system.
- To understand the requirements of good highway drainage system.
- To be able to describe the surface and sub-surface drainage system.
- To be familiar with the various components of highway drainage system.
- To understand the cause of moisture variation in the sub-grade soil.

Introduction

The entire serviceability of a highway is dependent upon the adequacy of measures controlling moisture content in subgrade soil. The subgrade is a soil mass, on which the entire road structure rest. Bearing capacity of soil foundation is decreased when the moisture content in it increased and is the lowest when same gets saturated. Water standing on the carriage way is danger to high-speed traffic.

Water brings about the destruction of highway by

- Softening the road surface when constructed of soil or sand- clay or gravel or water bound macadam.
- Softening the subgrade soil and decreasing its bearing capacity
- Generally softening the ground above and below the road, giving rise to landslides or slips.
- Washing out unprotected areas of the top surfaces, erosion of side slope, erosion of the side drains etc.

Highway drainage may be defined as the process of interception and removal of water from over, under and vicinity of the road surface. There are two types of highway drainage system, they are

1. Surface Drainage system
2. Sub-surface drainage system

1. Surface drainage system

Removal and diversion of surface water from highway and adjoining land is known

as surface drainage. Surface drainage of roadway is achieved with the help of well designed and constructed surface drainage system consisting of following components such as,

(i) Camber or Cross slope of pavement surface and shoulder

(ii) Road side drains

(iii) Cross drainage structures such as culverts bridge

In surface drainage system, the water from the pavement surface and shoulder is first drained off to the road side drain with the help of camber or cross slope. The collected water in the road side drain is then disposed of to the natural drain with the help of cross drainage structure.

2. Sub-surface drainage system

Removal and Diversion of excess subsoil water from the subgrade is known as sub-surface drainage system (The removal of water located below the ground level is known as sub surface drainage) system. The subsurface drainage systems,

- Enables intercepting the seepage flow of water and diverting same away from roadway to nearest water course
- Help in lowering the ground water level well below the subgrade
- Helps in controlling the capillary rise of water

Requirements of good highway drainage system

1. The surface water from the carriage way and shoulder should be effectively drained off without allowing it to percolate to subgrade.
2. The surface water from adjoining land should be prevented from entering the road way
3. The side drain should have sufficient capacity and longitudinal slope to carry away all the surface water collected
4. Flow of surface water across the raid and shoulders and along the slopes should not causes formation of cross ruts and erosion.
5. Seepage and other source of underground water should be drained off by sub-surface drainage system.

6. Highest level of water table should be kept well below the level of sub-grade, preferably by at least 1.2m.
7. In water-logged areas special precautions should be taken.

Importance of highway drainage

1. Road surface if made of soil, gravel or WBM becomes soft and loose strength.
2. The road subgrade may be softened and its bearing capacity reduced
3. Variation in moisture content in expensive soils causes variation of volume of subgrade and thus failure of road.
4. Failure of formation slopes is also attributed to poor drainage
5. If rain water is not properly drained and allowed to flow along the road side for long distances, slips and landslides may occur causing road failures.
6. Erosion of side slopes, side drains, and formation of gullies may result if proper drainage conditions are not maintained.
7. Flexible pavement's failure by formation of waves and corrugations is due to poor drainage.
8. Continuous contact of water with bituminous pavements causes failure due to stripping of bitumen from aggregate.
9. Rigid pavement's prime cause of failure in by mud pumping which.
10. Excess moisture causes increase in weight and thus increase in stresses and simultaneous reduction in strength of soil mass. This is main reason of failure of earth slopes and embankment foundation.

Surface drainage system

Removal of rain water (surface water) from road surface and road side ground is called surface drainage. The water is first collected in longitudinal drains and then the water is disposed of at the nearest stream or water course. Surface drainage consists of two operations.

1. Collection of surface water and
2. Disposal of the collected surface water

Surface drainage system may be divided into three categories.

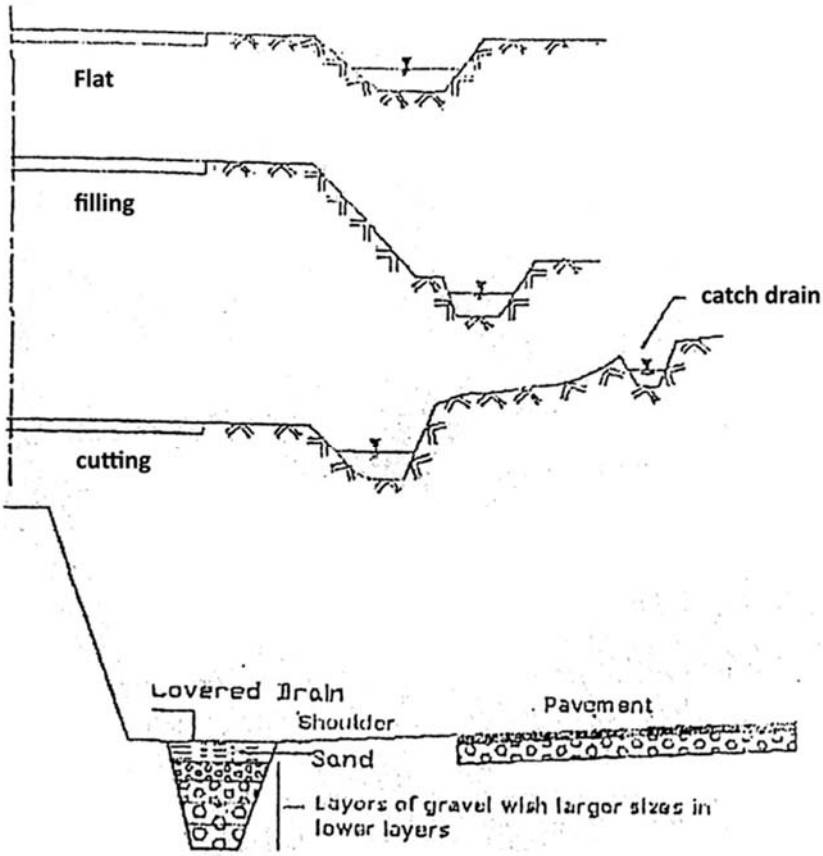
a. Drainage system in rural highway

b. Drainage system in urban road

c. Drainage system in hill road

Drainage system in rural Highway

In rural highway, the water from the pavement and shoulders is first drained off to the road side drains with the help of cross slope or camber. These side drains of rural roads are open drains of trapezoidal shape, cut to suitable cross section and longitudinal slope. In case of roads in cutting, drains are provided along the both sides of the road, just adjacent to the shoulder. In case where space is restricted in cutting, open drains are dangerous to be provided and hence covered drains or drainage trenches properly filled with layer of coarse sand and gravel may be constructed.



Drainage trench filled with filter material

Drainage system in urban road

In urban roads because of the limitation of land width and also due to presence of footpath, dividing island and other road facilities, it is necessary to provide underground longitudinal drains. Water drained from the pavement surface can be carried forward in the longitudinal direction between the kerb and the pavement for the short distance. This water may be collected in catch pits at some suitable intervals and lead to underground drainage pipes.

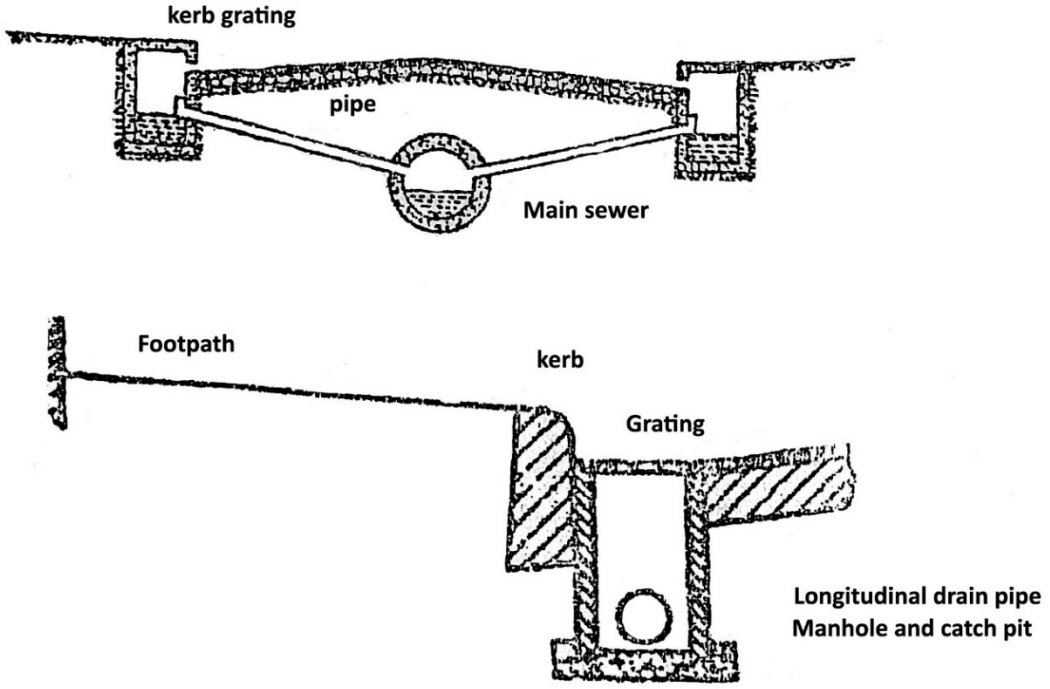


Fig. Drainage system in urban raod

Drainage system in hill road

In hill road, drainage problems are more complex. Apart from the drainage from road formation, water following down the hill also has to be efficiently intercepted and disposed off downhill side by constructing suitable cross drainage work in the form of culverts and bridges. If hills roads are not properly drained, slips and rocks slides may take place and block the road during monsoon.

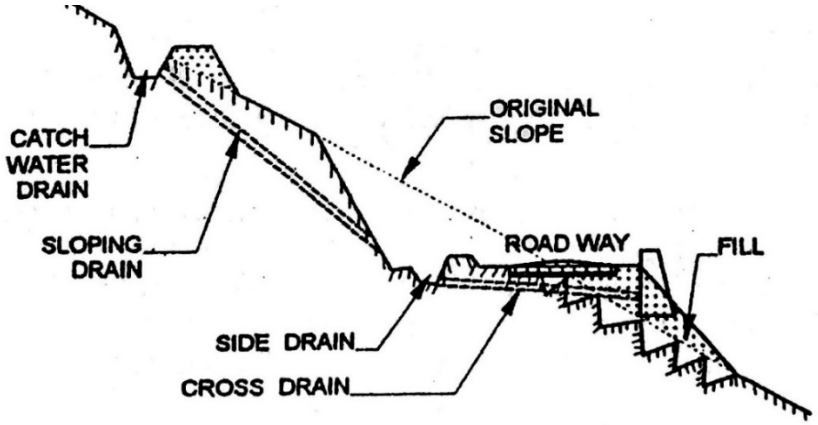


Fig. Layout of surface drainage system along hill slopes

Sub surface drainage system

Stability and strength of road surface depends upon the strength of subgrade. Subgrade is the foundation layer of the road whose strength largely depends upon its moisture content. With increase in moisture content strength of subgrade decreases. Following are the cause of moisture variation in subgrade:

Cause of moisture variation in subgrade

1. By free water

(i) Seepage of water from higher ground adjacent to the road

(ii) Penetration of water through the pavement

(iii) Transfer of moisture from shoulder and pavement edge.

2. By ground water

(i) Rise and fall of water table

(ii) Capillary rise from lower soil layer

(iii) Transfer of water vapour through soil

In case of sub surface drainage of roads, every effort should be made to reduce the change or variation in moisture content to a minimum. In sub surface drainage system of highway following methods are used to control sub soil water.

Control of sub soil water (Methods of sub-surface drainage)

1. By lowering water table
2. By control of seepage
3. By control of capillary rise

1. By lowering water table

If underground water table is more than 1.5m below the subgrade of road, it doesn't require any method for lowering water table. But if it is closer than this value the best remedy is to take the road formation on embankment of height not less than 1.2 to 1.5m above the ground level.

When the formation is to be kept at or below the general ground level at cutting, it is necessary to lower the water table

If soil is relatively permeable, it may be possible to lower the water table by construction of longitudinal drainage trenches with drain pipe and filter sand as shown in figure.

If soil is relatively less permeable, lowering of water level may not be adequate under the Centre of pavement. Hence, in addition to longitudinal drainage trenches transverse drains have to be constructed at suitable intervals as shown in figure.

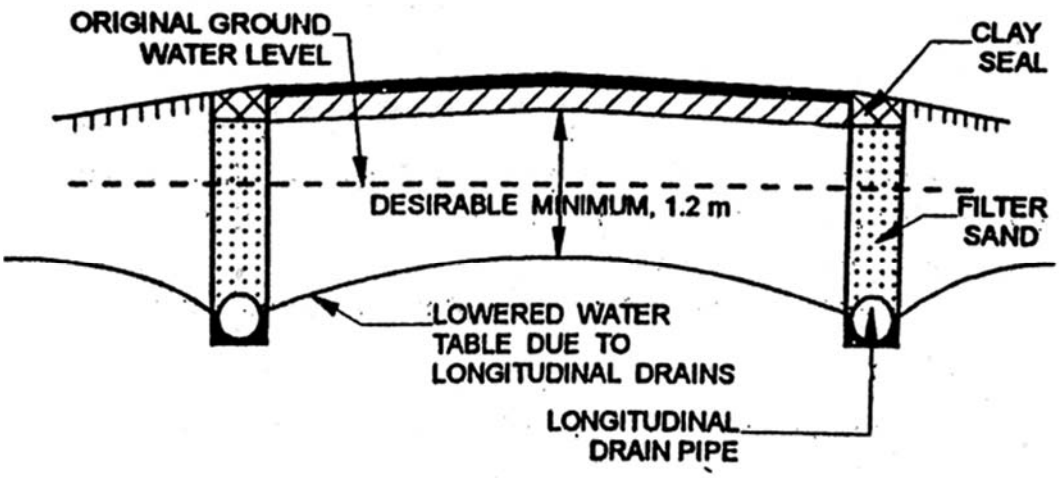


Fig. Lowering of high water table in permeable soils

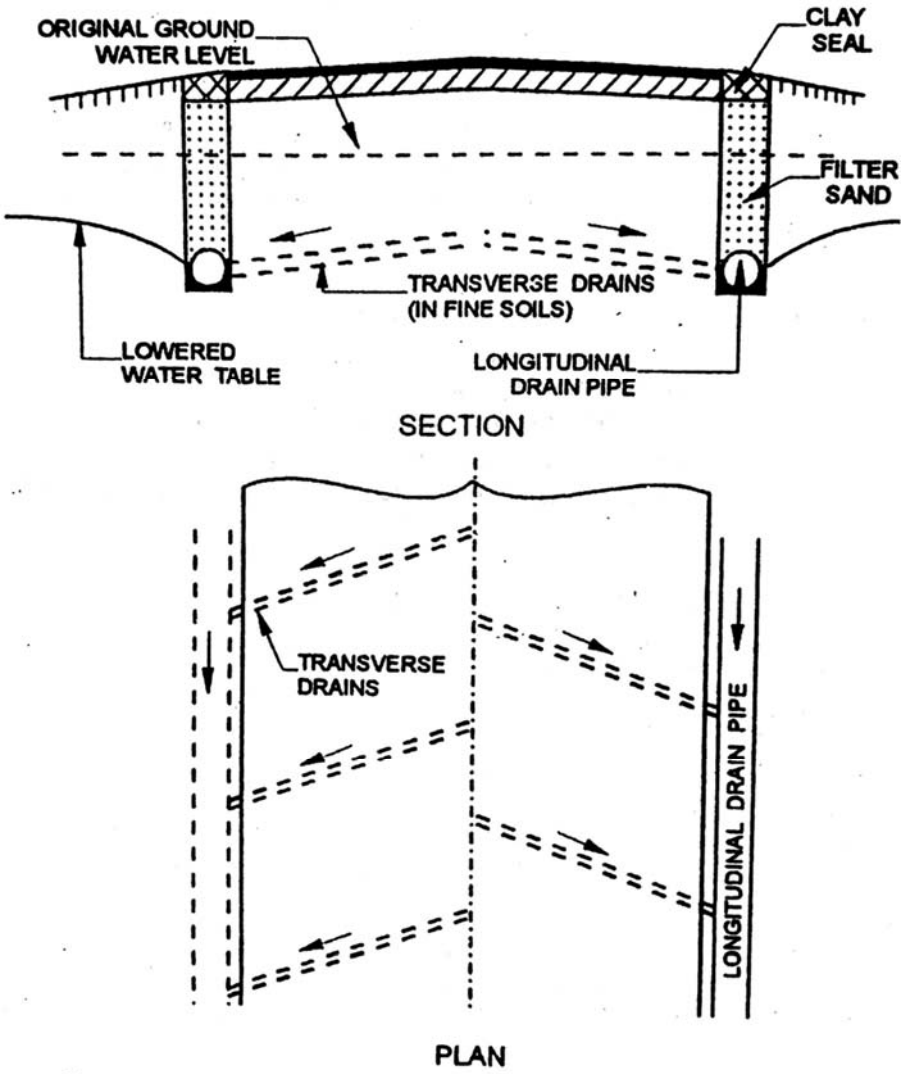


Fig. Sub-surface drainage system with transverse drains

Control of seepage flow

When surface of ground and impervious layer embedded below it are sloping towards the road, the seepage flow is likely to reach the road subgrade and affect its strength. If seepage zone is at depth less than 0.6 to 0.9 m from the subgrade level, it should be intercepted to keep seepage line at safe depth below the road subgrade. Seepage flow can be intercepted by constructing longitudinal drainage trenches with drain pipe and filter sand as shown in figure

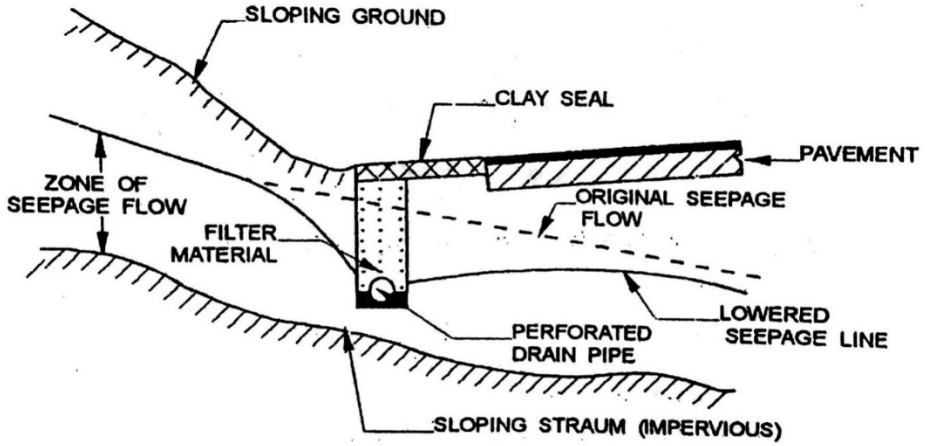


Fig. Control of seepage flow

Control of capillary rise

If the capillary rising water is very nearer to the subgrade of road and likely to affect the strength, steps should be taken to arrest the capillary rise of water. Following method can be used to control capillary rise of water.

(i) Granular capillary cut off

(ii) Impermeable capillary cut off

Granular capillary cut off

A layer of granular materials of suitable thickness is provided during the construction of embankment between the subgrade and highest level of sub surface

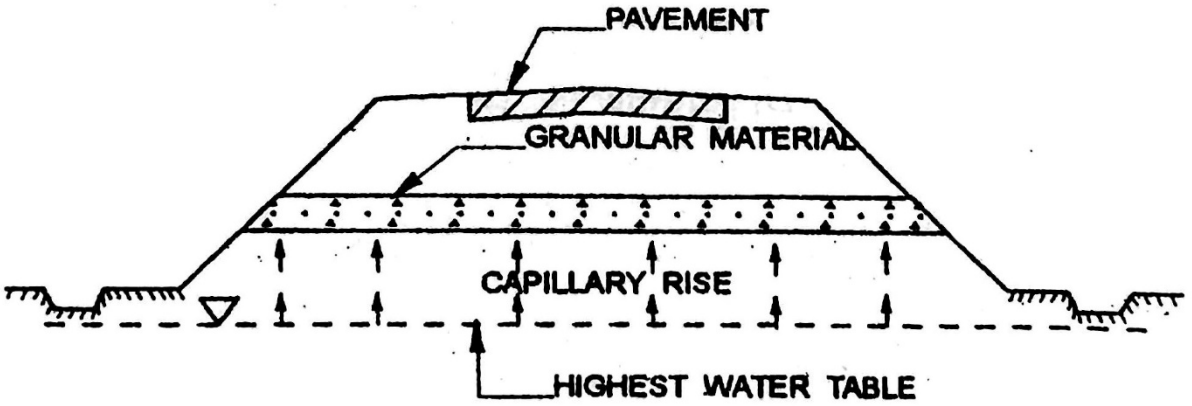


Fig. Granular capillary cut-off

water table as shown in figure.

Impermeable capillary cut -off

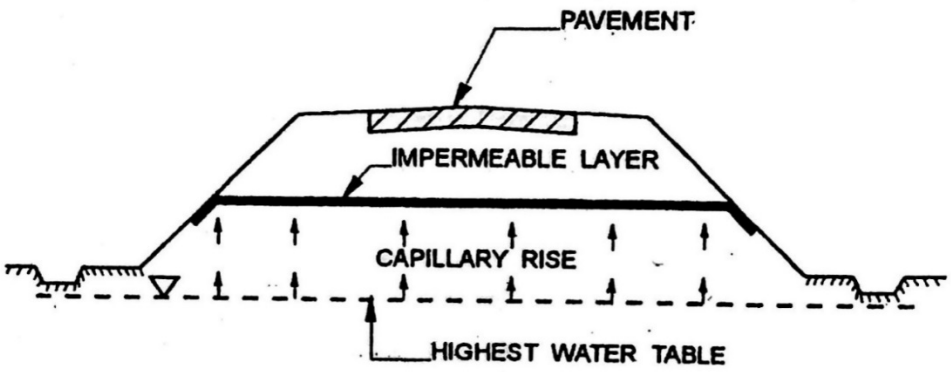


Fig. Impermeable capillary cut-off

In this method, an impermeable or bituminous layer is inserted in the place of granular blanket as shown in figure.

Glossary

Bearing capacity: Supporting power of a soil

Capillary: The drawing of a liquid into or up narrow interstices due to surface tension

Percolate: To pass a liquid through a porous substance.

Gullies: A trench, ravine or narrow channel, which was worn by water flow, especially on a hillside.

Culverts: A transverse channel under a road or railway for the draining of water.

Embedded: Partially buried in concrete or planted in earth.

A. Very short answer question.

1. Define highway drainage
2. What do you mean by surface drainage system?
3. What do you mean by sub surface drainage system?
4. How do you control capillary water in highway?

B. Short answer question.

1. Explain with sketch the methods of controlling seepage flow
2. Explain with sketch method of providing capillary cut off to control capillary rise of water
3. List out all of the components of surface drainage system
4. What are the special problems in drainage of surface water on hill roads?
5. Mention the cause of moisture variation in the subgrade soil
6. Explain how excess water can destruct the highway.

C. Long answer Question.

1. Discuss the importance of highway drainage
2. What are the requirements of good highway drainage system?
3. Explain how the surface water is collected and disposed of in the rural roads and urban roads
4. Write an explanatory note on cross drainage and drainage structure

Unit 6
Road Pavement

Objective

- To sensitize the different component of highway pavement
- To describe the specific function of the different component layer of the highway pavement
- To describe different types of highway pavement
- To explain the difference between the rigid and flexible pavement

Introduction

The surface of road should be stable and non-yielding to allow the heavy vehicles to move over it. The road surface should also be even along the longitudinal profile to enable fast moving vehicle to move safely and comfortably at design speed. At high moisture contents, the soils becomes weaker and soft and starts yielding under heavy wheel loads. The earth road may not be able to full fill the any of the above requirements, especially during the varying conditions of traffic and weather changes.

- Therefore, pavement consists of superior or stronger materials laid over the prepared earth surface, which could full fill the above requirements.
- Road surface or pavement is the layers of durable materials, laid down on the area intended to sustain vehicular traffic.
- It is the actual travel surface, specially made durable and serviceable to withstand the traffic load coming upon it.

Requirement of highway pavement

- Sufficient thickness to distribute the wheel load stress to safe value on the subgrade soil.
- Structurally strong to withstand all type of stress imposed on it
- Adequate coefficient of friction to prevent skidding of the vehicle
- Smooth surface to provide comfort to the road user even at high speed.
- Provide least noise

- Dust proof surface so that safety is not impaired by reducing visibility.
- Impervious surface so that subgrade soil is well protected
- Long design life with least maintenance

Types of pavement

Based on structural behavior road pavements are generally classified into two categories, namely

1. Flexible pavement
2. Rigid Pavement
3. Sami rigid Pavement

1. Flexible pavement

The pavements, which have negligible flexural strength but flexible in their structural actions under the loads, are known as flexible pavements. Because of the low flexural strength, the pavements deflects normally under load but rebounds to its original level on removal of load. Flexible pavements are constructed using local soils, bituminous materials; gravel etc. The lower layer of flexible pavements reflects the deformation up to the surface layer. Therefore, if there is undulation in subgrade, flexible pavements also gets undulated. The vertical compressive stress is maximum on the pavement surface directly below the wheel loads and decreased successively to the lower layers, therefore quality of materials from top layers to bottom layers decreases to minimize the cost of road.

2. Rigid Pavement

The pavements, which have worthy flexural strength, are known as rigid pavements. The rigid pavements are made of plain, reinforced or pre-stressed concrete. Rigid pavement structure consists of cement concrete slab over a granular sub-base or base course over sub-grade soil. The rigid pavement does not get deformed to the shape of supporting layer below, as the pavement slab can bridge the gap or minor iregulatries of the supporting layer below.

3. Semi Rigid pavement

The pavement, which have flexural strength in between rigid and flexible

pavements, are known as semi-rigid pavement. It is made of lean cement concrete or soil cement.

Difference between Flexible and rigid pavement

Flexible Pavement	Rigid Pavement
1. Deformation in the subgrade is transferred to the upper layers.	1. Deformation in the sub-grade is not transferred to the subsequent layer
2. Design is based on load distributing characteristics of components layers.	2. Design is based on flexural strength or slab action
3. Have low flexural strength	3. Have high flexural strength
4. Load is transferred by grain to grain contact	4. No such phenomenon of grain to grain contact
5. Have low life span	5. Life span is more in comparison to flexible pavement
6. 5.High maintenance cost	6. 9. Have low mentainence cost
7. Rolling of surface is needed	7. Rolling of surface is not needed
8. Damaged by oil and certain chemical	8. No damage by oil and grease
9. Strength of pavement is highly dependent on the strength of subgrade	9. Strength of subgrade is less dependent on the strength of subgrade
10. Initial cost of construction is less	10. Initial cost of construction is more
11. Road can be used for traffic within 24 hours	11. Road cannot be used until 14 days of curing

Components of flexible pavements

A flexible pavement structure consists of a number of layers normally,

1. Wearing course / Surface course
2. Base course

3. Sub-Base course
4. Sub-grade

1. Wearing course/ surface course

It is the topmost layer of the pavement, the purpose of which is to provide smooth, abrasion resistant, dust free, reasonably waterproof and strong layer. It is made up of various selected aggregates bound together with bituminous binders.

Function of wearing course

- To prevents penetration of surface water to lower layer
- To resist abrasive forces of traffic
- To provide skid resistance surface
- To provide smooth and uniform riding surface
- To perform as structural portion of pavement

Base course

Base course is the layer of graded materials located below the wearing course. The granular base course is considered as the most important component of flexible pavement layer, which sustain the wheel load stresses and disperse through larger area on the granular sub –base layer below. Good quality coarse aggregates are generally used on the base course of the flexible pavement.

Function of base course

- To acts as structural portion of pavement and thus distributes the load to the sub-base course and lower layer i.e. sub-grade soil.

Sub- Base course

It is the layer of aggregates materials laid on the subgrade on which base course is located. Sub –base course helps to provide additional support to base course in distributing the loads and acts as effective drainage layer of pavement. A sub –base is not always needed. This layer is used in the areas where frost action is severe or subgrade soil is extremely weak. The materials requirements of sub-base course are not strict as those of the base course, since sub-base is subjected to lower value of wheel load stress.

Function of sub-base course

- To provide additional helps to the base and surface course in distributing the load
- To prevent intrusion of the fine grain road bed soils into the base course
- To minimize the damaging effect of frost action
- To facilitate the drainage of free water , that might get accumulated

Sub- grade soil

The sub-grade is the compacted soil layer that forms foundations of pavements system. The sub-grade is the lowest layer of the pavement, which ultimately supports all other pavement component layer and traffic load.

Glossary

Yielding: Produce or provide agricultural or industrial product

Stress: Force per unit area

Impaired: To weaken, to affect negatively

A. Very short answer question.

1. What do you mean by rigid and flexible pavement .Define in one sentence
2. Define rigid pavement.
3. Define flexible pavement
4. Define highway pavement

B. Short answer question

1. Explain about general structures or layers of pavement.
2. What are the different types of pavement?
3. Explain the function of wearing course.
4. Define sub grade, sub base, base and surface course
5. Write importance of sub-grade soil

C. Very short answer question

1. Write down eight differences between rigid and flexible pavements.

2. What are the functions of wearing course?
3. Differentiate between sub-base and base course of pavement. Write the uses of different pavement layers.

Unit 7
Road Making Machinery and Its Uses

Objective

- To provide general knowledge various tools and equipment used in the road construction.
- To knew the function various equipment used in road construction.
- To choose the suitable construction equipment according to the field conditions.
- To describe various plants and tools required for road construction

Road construction work may be labour intensive or equipment or capital intensive.

Labour Intensive method

Labour intensive method of road construction is method of road construction in which human resources are used instead of equipment. It takes long time and stepwise construction is followed. In Nepal labour intensive work is mostly used in the hilly or mountainous reason.

Capital intensive method

In capital intensive work for road construction, equipment is mostly used instead of human labour. It takes short time for construction of road.

Role of labour vs machinery in road construction

Role of machinery in road construction

- Machinery is useful where a large quantity of work is to be done in concentrated area in limited time. For example urban streets etc.
- Machinery is useful for working in remote and inaccessible area where labour is scarce.
- Control over the quality is assured, if machinery is used.
- Certain specifications such as bituminous macadam and asphaltic concrete are possible only with machinery.

- Vibration caused by use of heavy equipment can make the slope unstable in mountainous areas.
- Operating heavy machinery may not be possible everywhere due to space limitation and other safety factors.

Role of labour in road construction

- Use of labour in road construction provides the employment generation for the unskilled labour.
- Road construction schemes are popular measure of affording relief to the flood and drought affected persons.
- If stage wise construction of road is needed due to scarcity of resource then, labour use is best methods.
- For low cost roads using the local material and resource, labour intensive road construction is suitable.
- Use of labour in road construction is environmental friendly.
- Some condition dose not permits the use of heavy equipment in road construction, in that case labour are used for work.

Tools, Equipments and Plants Used in Road Construction

S.N	Tool /equipment/Plant	Suitability/ Function
A.	**For excavation in soft soil**	
	1. Hand shovel, spade	For excavation in soft soil
	2. Peak	For excavation in hard soil
	3. Chisel	For excavation in hard soil or to disintegrate rocks
	4. Hand rammer	For small compaction work
	5. Wheel barrow	To carry material over short distance
	6. Trowel	To mix mortar
B.	**Construction equipment**	
	Earth work equipment	
	7. Bull dozer, scraper	Shallow excavation/To move piles of soil

	8. Backhoe	
	9. Dragline	Excavation and movement of soft soil
	10. Excavator	For excavation/ material handling/trench excavation etc.
	11. Trench digger	For deep trench excavation
	12. Dump trucks	To move soil and stone from one place to another
	Compaction equipment	
	13. Vibrating roller	For compaction of cohesion less soil.
	14. Pneumatic roller	For compaction of cohesive and cohesion less soil
	15. Ship foot roller	For compaction of cohesive soil
	16. Smooth wheel roller	For compaction of granular soil like crust, gravel soil etc.
	17. Impact rammer	For compacting small area where large roller can't be used
C.	**leveling equipment**	
	18. Grader	To make or create flat surface
D.	**Paving equipment**	
	19. Binder spreader	To spread bitumen
	20. Aggregate spreader	To spread aggregate
	21. Cement concrete mixer	To mix cement aggregate and sand
	22. Bituminous paver	
	23. Cement concrete pavers	
E.	**Lifting equipment**	
	1. Backhoe, Excavators	To lift construction material up to certain limit.

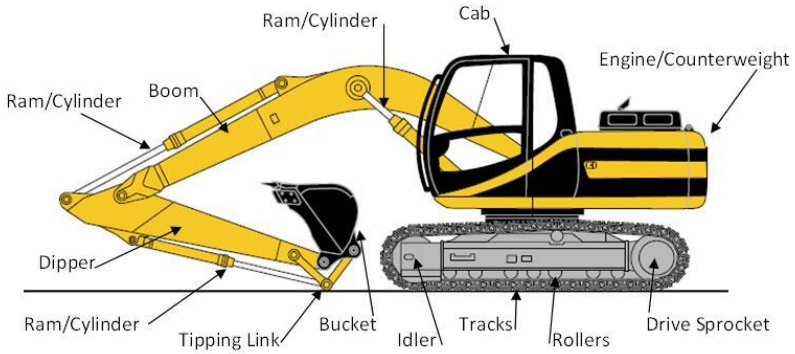
	2. Crane	To lift construction materials and equipment
F.	**Transportation equipment**	
	3. Dumping truck	To shift the material
	4. Trucks	To shift the construction material in large quantity
	5. Mini dumpers	To shift construction material in small quantity
G.	**Plant**	
	6. Cement concrete plant	Mixing cement sand and aggregates
	7. Asphalt concrete plant	To mix fine aggregate coarse aggregate and binders.
	8. Aggregate crusher plant	To break the stone as per site
	9. Washing plant	To wash the aggregates
	10. Screening plant	To screen the aggregates
	11. Sand blowing unit	To heat sand

Earthwork machinery

1. Excavators

Excavators are large earth moving equipment that can be available over wheels or tracks. Excavators are commonly used for digging rocks and soil, but with its many attachments, it can also be used for cutting steel, breaking concrete, drilling holes in earth, crushing rocks, and moving earth. The most common uses of an excavator are:

- Material handling
- Digging of trenches, holes and foundations
- Brush cutting with hydraulic attachments.
- Lifting



2. Backhoe

Backhoe loaders are very similar to tractors with a slight difference that they contain an adjustable, shovel in front of the equipment and a small bucket in the back of the loader, used for digging. It is used to excavate below the natural surface on which it rest. They can move dirt, backfill, dig trenches and place smaller pipes into place.

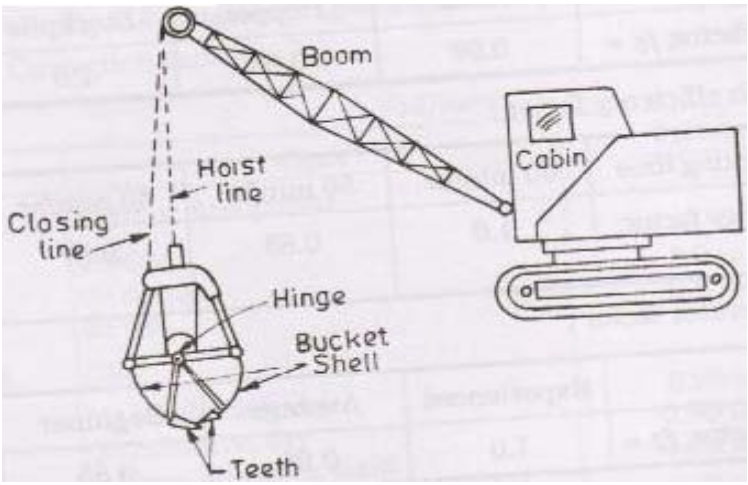
3. Front shovel

A front shovel (also stripping shovel or power shovel) is a bucket-equipped machine, usually electrically powered, used for digging and loading earth or fragmented rocks.

- They are mounted on crawler tracks or wheel.
- To excavate the earth and to load the trucks
- It is used to excavate earth of all classes except hard rock and load it into wagons.

4. Clam shell

- It consists of a hydraulically controlled bucket suspended from a lifting arm. It is mainly used for deep confined cutting in pits and trenches.
- It is having bucket of two halves which are hinged together at top. It is used to excavate soft to medium materials and loose materials.



5. Bulldozers

Bulldozers are considered one of the strongest and toughest heavy equipment used in the construction industry. Bulldozer is a tractor equipped with a front pusher blade, which can be raised and lowered by hydraulic rams. They are normally used to push piles of earth. Bulldozers have a wide variety of roles including excavating soils and weak rocks, moving excavated material over short distances, spreading materials, and trimming earthworks.

6. Trenchers

A trencher is heavy equipment used to dig trenches on which pipes can be laid down.

7. Scraper

Scraper is another type of construction equipment, which is used to scrap a thin layer of soil, and then carry it meters away as desired. They are commonly used in big project sites.

8. Motor Graders

Graders are used to spread fill and finely trim the subgrade. They have a long blade that can be adjusted to meet certain angles to create a flat surface. The blade is used to trim and redistribute soil and therefore graders usually operate in the forward direction.

9. Dump Trucks

They are used to move excavated soil from one place to other .They have ability to unload the soil mechanically by tilting of its bucket with powerful hydraulic system.

Drag line

- They are used to excavate soft earth from below ground and to deposit or to load in wagons. Output of dragline is measured in Cubic Meters per hour.

- They are used for bulk excavation below its track level in loose soils, marshy land and areas containing water.

Compaction equipment

Following are the mostly compaction equipment used in road construction:

1. Vibrating Roller

Vibratory type rollers have two smooth wheels/ drums plus the vibrators. One vibrator is fixed at the front and the other one is on the rear side of vibratory roller.

Both wheels/drums are of the same diameter, length and also of same weight. The compaction is achieved by vibration produced by its vibrator on vibrating drums. Compacting the subgrade with high densities by static rollers is very difficult and costly. Both cohesive and non-cohesive soil can be compacted using vibratory roller.

- Compacting sand and cohesion less soil
- Compacting granular base and sub bases to obtain high density
- Compacting all type of soil to high density

2. **Pneumatic roller:** It consist of a box mounted over two axle, the rear axle having one more wheel than the front and wheel of front axle is so arranged that they are located in plan in between rear wheel. Generally, there are four wheels in the front and five on back.

- This roller is suitable for compacting non-plastic silts and silty soils.

3. Sheep foot roller/ tamping roller

Sheep foot roller also named tamping roller. Front steel drum of sheep foot roller consists of many rectangular shaped boots of equal sizes fixed in a hexagonal pattern. Sheep foot roller done compaction by static weight and kneading of respective layer.

- Suitable for clayey and cohesive soil

4. Smooth wheel roller

Smooth wheel roller and vibratory rollers are the same. Both have the same characteristics. Only the difference in both is vibratory equipment. Smooth wheel roller has no vibrator attached with the drum. This makes smooth wheel roller best suited for rolling of weaker aggregates, proof rolling of subgrades and in compacting asphalt pavements.

5. The plate compacter

The plate compactor (vibratory rammer) has a large vibrating baseplate. These compactors are very popular tools for compaction in small works, such as pot hole patching. The plate compacter is normally provided with a long steel handle so that the operator can walk behind it and control the operation.

6. Frog rammer

Frog rammers are used for cohesionless soil and soils in inaccessible and restricted location where ordinary roller cannot work. The weight varies from 30kg to 1 tones.

Transporting equipment

Following transporting equipment are used in road construction

- Dump Trucks

- Mini Trucks
- Wheel barrow
- Scraper
- Dumper

Watering equipment

1. Water tankers

   Water tankers of 4000-5000 capacity are generally used for watering earthwork and water bound macadam work. A sprinkler attachments provides uniform distribution at any desired speed

2. Water pumps

   Small pumps of 2.5 to 5 H.P, diesel driven, are extremely useful for conveying water for roadway work.

Rock Excavation MachinerY

Rock excavation is achieved by drilling and Blasting.

1. Drilling

Drilling into rock is accomplished by jack hammers or wagon drills.

2. Blasting

Blasting is done by explosives. The normal explosive used is dynamite, gun powder, gun cotton etc.

Production of aggregates

Aggregate production consists of two stages, collection of large – sized stones (by blasting or from natural deposits) and processing.

- Basic material, such as stone, collected from a rock quarry or from the river bed and processing is done which consists of crushing, grading, washing and stock piling of aggregate.
- Crushers are used mainly to reduce the size of large stone or rock to smaller uniform sized aggregates required for concrete mix.

Crushing consists of,

- Pressure

- Impact
- Attrition
- A combination of these operations.

Following type of crusher are used for crushing stones,

1. Jaw crushers
2. Gyratory crushers
3. Cone crushers
4. Roll crushers
5. Impact or hammer mills
6. Road and ball mills

Glossary

Specification: An explicit set of requirements to be satisfied by a material, product or service

Asphaltic: Resembling, containing or relating to asphalt

Mortar: A mixture of cement, sand and water

Bitumen:

Crawler tracks:

Wagons: A four-wheeled cart for hauling loads

Pot hole:

Patching

Gun powder: A material for projecting a hard object very force fully

Quarry: A site for mining stone

Attrition: Wearing or grinding down by friction

Self- Evaluation

A. Very short answer question.

1. What are the uses of motor grader?
2. Mention the uses of Scrapper
3. Mention the uses of dragline
4. Which type of compacting equipment is suitable for compaction of cohesion less soil?
5. In which situation plate compactor are suitable

B. Short answer question.

1. Mention the various plants used in road construction.
2. What are the various transporting method.
3. What are the various compacting equipment used in road construction
4. What do you mean by compaction? Why it is necessary?

C. Long answer question.

1. Discuss the role of labor vs machinery in road construction
2. Illustrate the role of labor vs. machinery in road construction. Which one is best for Nepal? Give reasons.
3. Make a list of various tools and equipment used in road construction

Unit 8
Road Construction Technology

Objectives

- To be familiar with various road construction activities.
- Sensitize the construction techniques and construction equipment.
- To be able to supervise the work and determine the mistakes and connection during construction
- To learn the construction procedure for Various type of pavements
- To learn the construction technique of otta seal and surface dressing

Road construction technology is the branch of highway engineering which deals with all kinds of activities and technology or operations for changing existing ground to desired shape, slope and to provide all necessary facilities for smooth, safe and efficient traffic operation. It also includes reconstruction of existing roads. Various activities used in road construction can broadly classified as

1. Earthwork ● Site clearance. ● Earthwork in filling for embankment ● Excavation for cutting ● Excavation for borrow pits ● Excavation for structure foundation ● Disposal of surplus earth	**2. Drainage works** ● Side drains ● Culverts ● Sub-surface drain ● Causeways ● Minors bridges ● Other water management structures
3. Structural works ● Earth retaining structures ● Gully control works ● Landslide stabilization works ● River training works	**4. Pavement works** ● Sub- grade preparation ● Sub-base course preparation ● Base course preparation ● Wearing course preparation.

● Bridge protection works	
5. Miscellaneous Works ● Road furniture ● Traffic sign/signal/marking etc. ● Bio-engineering works	

Construction of highway embankment

The material suitable for construction of embankment are soil, moorum, gravel and mixture of these which are free from organic matters such as stumps, roots, or such organic ingredients likely to decay or deteriorate. The maximum permissible size of coarse aggregates for embankment construction is 75mm.

Generally, the embankments are constructed using locally available soils whichfulfill the specified requirements mentioned under "materials" for highway construction. The embankment is constructed by spreading the loose soil and compacting the same at OMC to obtain maximum density. The embankment is constructed in layers. The compacted thickness of each layer varies from 100 to 300mm, depending upon types of soil and compacting equipment.

The procedure of embankment construction

1. The selected soil is spread to uniform thickness using appropriate equipment over the prepared ground surface.
2. Additional water, as required is sprayed as to obtain OMC of soil.
3. The soil layer is compacted by rolling, using roller so as to obtain the specified dry density.
4. After ensuring the layer has been compacted to desired density, the next layer of soil is spread over the already compacted layer, and above procedure is repeated. Until the desired height of embankment is achieved.

Preparation of the sub-grade

The material suitable for construction of embankment are selected soil, moorum, gravel and mixture of these which are free from organic matters such as stumps, roots, or organic ingredients likely to decay or deteriorate. The maximum

permissible size of coarse aggregates for embankment construction is 50mm.

The highway subgrade is generally constructed using suitable soil fulfilling the requirements or specified properties that are transported from identified borrow pits. The efforts are made to select borrow pits which are not too far away from the construction site.

Following steps are necessary for the preparation of the sub-grade;

1. First the ground should have prepared level and smooth, byremoving top lose and weak soil for sub-grade preparation.
2. The material considered suitable for sub grade preparation is the selected soil, moorum and mixture of these which are free from organic matters that are likely to be decay or deteriorate. The maximum size of coarse aggregate in subgrade is 50mm.
3. Soils having specified properties are transported from the identified borrow pits to the construction site. The effort is made to select borrow pits, which are not too far away from the construction site.
4. The selected soil in lose condition is speared to required grade and cross slope in layers of desired thickness using equipment like grader, over the prepared surface.
5. Additional water as required is sprayed so as to obtain OMC of soil.
6. The soil layer is compacted by rolling using roller to obtain specified density. The compaction is started from outer edge to center on straight section and from inner edge to outer on super elevated section.
7. After ensuring that the layer is compacted to the desired density, the next layer is spread over it and above process is repeated until desired compacted thickness of subgrade is achieved.
8. The compacted subgrade should be checked for camber and grade.

Earthen road construction

The earthen road may be constructed in two layers, a base course of thickness about 100mm laid over prepared subgrade and surface course of thickness about 100 mm

laid over this base course. Earthen roads are the cheapest type of road pavement. The camber normally provided in the earthen road is 4-5%. Steep camber helps to keep the pavement surface free from standing water.

Material needed: Good quality soil having specified properties.

Equipment needed: Grader, tipper, water tanker etc.

Construction steps

1. The soil survey is done, to find the suitable borrow pits for extraction of soil having specified properties free from organic matters. The borrow peat is selected nearer to the purposed road, to minimize transportation cost.
2. The soil having specified properties to be used for construction, is stacked along the side of purposed road.
3. The center lines and reference points are fixed with wooden pegs at suitable interval.
4. Sub- grade of total thickness of 300 mm is constructed by compacting the soil in two or three layers to achieve maximum dry density. The thickness of each layer not exceeding 100 mm.
5. After the subgrade gets sufficiently dry, base course of earth road is constructed using selected soil. The selected soil is speared at greater thickness at center and less towards outer edge so as to obtain desired camber. Layer wise construction of base course is done. The compacted thickness of each layer is 100mm.
6. After the base course is adequately dried, surface course layer is constructed using selected soil. The layer is compacted to maximum dry density to thickness of 100mm.
7. The cross slope and surface are checked and rectified where necessary.

Gravel road construction

The gravel road is the cheapest types of road and comes under the categories of 'un-surfaced roads'. Gravel roads are constructed using soil – aggregate mixes having specified properties. It is superior to earth road and can carry heavy traffic. The

camber normally provided in earthen road is 3-4 %.

Material needed

Clean, hard, strong tough and durable verities of crushed stone, or gravel of specified gradation is used. Rounded and river aggregates are not preferable as they have poor interlocking properties. Proper gradation is chosen to have maximum density.

Equipment needed: Grader, tipper and water tanker or manually for small project.

Construction procedure

1. The gravel and the crushed stone to be used for construction is stacked along the side of purposed road.
2. Wooden pegs are driven for center lines and boundaries of pavement.
3. Subgrade of total thickness 300mm is constructed, by compacting the soil in suitable layer to obtain maximum density.
4. After the subgrade gets sufficiently dry, base course of gravel or crushed stone is spread to greater thickness at center and less towards outer edge so as to obtain desired camber. Layer wise construction of base course is done. The compacted thickness of each layer should be in between 100 to 200mm, depending upon type of roller used.
5. The surface course layer is laid using selected gravel; and this layer is compacted to obtain maximum density.
6. The cross slope and surface are checked and rectified where necessary.
7. Opening to traffic.

WBM road construction

Water bound macadam is known after the name of John macadam. The main principle of this pavement structure is that, the crushed or broken stone aggregates are bound together by action of rolling or traffic. The binding of aggregate is achieved by stone dust used as filler material in presence of water. Normally cross slope of 2.5-3.5% is provided.

The material used: Coarse aggregate, screening aggregates and filler material

(binding material).

Equipment needed: Grader, roller, tipper, water tanker and aggregates spreader.

Construction Procedure

1. The coarse aggregate, screening and binding materials are stacked along the side of purposed road.
2. The center lines and reference points are fixed with wooden pegs at suitable interval.
3. Sub- grade of total thickness of 300mm is constructed by compacting the soil in two or three layers to achieve maximum dry density.
4. Lateral confinement is to be provided before construction of WBM. This can be done by constructing the shoulder to a thickness equal to that of compacted WBM layer to be laid.
5. Coarse aggregates are spread with compacted thickness 8-15 cm. with more thickness at center and less towards outer edge to provide camber specified.
6. The coarse aggregates, as provided are compacted with smooth wheel roller and vibratory roller of 6 to 10 ton. Compaction is started from outer edge to center on straight section and from inner edge to outer on super elevated section. If required, slight sprinkling of water may be done during rolling.
7. After compaction of coarse aggregate, the dry screening aggregates material is applied gradually over the surface to fill the voids in there.
8. After application of screening, the surface is sprinkled with water and rolled until coarse aggregate are well bounded and firmly set.
9. Binding material (usually stone dust) is applied at a uniform and slow rate at two or more successive thin layers. The surface is finished with 6 cm thick sand or earth rolled properly.
10. After the WBM layer is fully dry, steps are taken to lay next layer or it can be opened for traffic.

Surface dressing

Surface dressing consists of applications of suitable grade of bitumen or emulsion

by spraying over the prepared base course or existing pavement surface followed by spreading specified size of hard stone aggregate at recommended rate and rolling.

The surface dressing doesn't add to the structural stability or strength of pavement, nor will it increase the existing riding quality of pavement surface. The surface dressing is the cost effective surface –treatment to provide dust free and impervious pavement surface. It also provides non skidding riding surface.

Functions of surface dressing

- To provide dust free surface over the base course.
- To provide water proof layer of pavement.
- To protect base course material.
- To increase skid resistance of smooth surfaces.

Constructions step for surface dressing

Material required

Normally 80/100 grade straight run bitumen,

Clean, strong, and durable stone aggregate.

Equipment required Storage tanks with bitumen heating system

- Mechanical broom or hand brushes
- Air compressor
- Bitumen spreader
- Aggregates spreader
- Pneumatic roller

Construction steps

1. The receiving surface on which surface dressing is to be laid is prepared by patching pot holes, filling up the depressions, correcting cross slope etc. and compacting well.
2. The surface is cleaned with a mechanical broom to remove loose particles and dust.

(Note: If receiving surface is granular base course, prime coat is applied as specified and allowed to cure fully and if surface dressing is being laid over an existing bituminous surface neither tack coat nor prime coat is to be applied.)

3. Bituminous binder is heated to specified temperature and is uniformly spread over the prepared clean dust free surface.
4. Immediately after spreading bituminous binder, the selected aggregates for surface dressing is spread uniformly using spreader.
5. After spreading of aggregates, the entire surface is rolled using pneumatic tyred roller or 6 to 8 tonne smooth wheeled roller. Rolling is done starting from edge and proceeding towards the Centre. Rolling is continued till the aggregates are embedded firmly in bituminous binder layers.
6. When paving bitumen is used as binder, the finished surface can be opened to traffic the next day. when emulsion binder is used the traffic are allowed after 24 hours only.

Otta seal

Otta seal is the bituminous surfacing consisting of graded aggregates ranging from natural gravel to crushed rock in combination with relatively soft (less viscous) binders. In comparison to other surface treatments, material and construction specifications are not strict. Local aggregates that would not meet the requirements for high quality paving aggregate are often used in Otta seals. Otta seal is formed by adding graded aggregate to a soft bituminous binding agent. The agent is usually emulsified asphalt. The largest aggregate size used is between 13 and 25mm.

Otta seal is primarily used in places that do not have strict requirements for strength, grading, particle shape, binder adhesion, and dust content, which have low capital and expect relatively low traffic (up to 500 vehicles per day).

Construction steps

1. The base course or the surface, where the otta seal is to be laid, is prepared and cleaned by mechanical broom or hand brushes or air compressor.
2. Prime coat is applied over prepared surface, if necessary.

3. After application of prime coat, binders are spread in required thickness and quantity uniformly.
4. Aggregates of specified grading are spread over the binders that are previously spread.
5. The new surface is rolled with two pneumatic rollers at minimum weight of 12 KN or more at day of construction. A minimum of 15 passes is required with pneumatic roller.
6. Traffic must be restricted to speed of no more than 30km per hours for two to three week after construction.
7. During this initial period, aggregates displaced by the action of traffic should back into the wheel path and should be rolled again.
8. If second layer is to be applied to create double otta seal, then minimum of 2 to 3 month should be passed before application of second layer.

Bituminous concrete road

Bituminous concrete is a dance graded premixed bituminous mix which is well compacted to from a high quality pavement surface course. It consists of mixture of graded mineral aggregate, mineral filler and bitumen in suitable proportion. It is hot mixed and hot laid. The thickness of bituminous concrete surface course varies from 40 to 75 mm. its life varies from 10 to 15 years.

Construction procedure

1. **Thickness:** As per design based on traffic intensity and quality of base course.
2. **Materials**

   Bitumen: 80/100 grade straight run bitumen.

   Coarse aggregate: The coarse aggregate should be entirely crushed and should be clean, hard, strong and durable.

   Fine aggregate: It should be free from clay, silt, organic and other deleterious matter

   Mineral filler: Mineral filler shall consist of finely ground particles of lime stone.

3. Tool plant

- Storage tanks with bitumen heating system
- Mechanical broom or hand brushes
- Air compressor
- Bitumen Distributor
- Aggregates spreader
- Pneumatic roller/smooth wheel roller
- Hot mix plant
- Mechanical paver
- Tippers

Construction step

1. Preparation and of existing base course layer by removing the pot hole or dust if any.
2. Application of tack coat layer.
3. Preparation and placing of premix
4. Rolling with roller of 8 to 12 tonnes having speed not more than 5km/hr.
5. Quality control of bituminous concrete construction.
6. **Opening to traffic:** The road section is opened to the traffic after 24 hours.

Prime Coat

Spraying of liquid bituminous binder of low viscosity over a granular or nun bituminous surface is called application of prime coat or 'priming'. The objectives of priming are,

1. Penetrate deep into the surface and plug or seal the void in the surface
2. Coat and bond the loose particle in the surface
3. Render the surface of the base course water resistant

Tack coat

Tack coat is application of a small quantity of liquid bituminous binder of low viscosity over either a primed granular surface or over an existing bituminous

cement concrete surface. Application of tack coat is important part of preparation before laying a bituminous layer over an existing pavement layer. The main objective of tack coat is to provide adequate interface bond between the receiving pavement surface and new bituminous layer being overlaid.

Glossary

Embankment: A long artificial mound of earth and stone built to support a road

Stump:

OMC: Optimum moisture content

Stacked:

Rectified: To restore to its proper conditions

Viscosity: A quantity expressing the magnitude of internal friction in a fluid.

Adhesion: The ability of substance to stick to an unlike substance

Impervious:

Self-evaluation

A. Very short answer question.

1. What is WBM road?
2. What is prime coat?
3. Define tack coat
4. In which conditionsurface dressing is done.

B. Short answer question.

1. Define the terms: a) Surface dressing b) Otta seal
2. Write the construction process of WBM road.
3. What is surface dressing? Explain.
4. Differentiate between gravel road and bituminous road.
5. Write in short otta seal construction procedure. (Only procedures)
6. Define prime coat and tack coat.

7. Write functions of surface dressing.

C. Long answer question

1. Describe the bituminous road construction procedures.
2. Explain about the general structure of pavement with figure.
3. What is surface dressing? Describe the construction procedure of earthen road.
4. Write down the bituminous road construction procedures.
5. Describe the construction procedure of otta seal
6. Make a list of different activities conducted during a construction of road.

Unit 9
Low Cost Road

Objectives

- To have an idea about various types of low cost road
- To learn the construction technique of low cost road
- To sensitize the importance of stage construction of road.
- To explain the advantage of stage construction of road

Introduction

The low cost road can be defined as those roads whose cost of construction and maintenance is less. Therefore, such roads should as far as possible be constructed from locally available road construction materials using local manpower, and initially constructed in such a way that step by step improvement of road is possible without incurring any extra expenditure.

Such low cost road should have potentiality of subsequently being improved to higher specification as traffic intensity of highway increases. Therefore, geometric standards of village roads should be chosen in such a way that no alternation in vertical and horizontal alignment might be required when these are to be upgraded. Further, with the increase in traffic it should be possible to strengthen the pavement in stages utilizing the existing pavement layers.

A typical example of stage construction is as below

Stage-1: Land acquisition and road embankment or cutting (Formation)

The road may at the first stage be thrown open to the traffic which may be of the order of 500 tonnes/day. The advantage of keeping road formation open for few season before upgrading is that the formation gets stabilized and chance of settlement of the soil due to subsequent heavier traffic loads are reduced. The formation width should however be for a fully developed road in view.

Stage-2: Pavement

The thickness of pavement may initially be to cater to the intermediate traffic needs, which at latter stage may form sub base for the main travelling surface

Stage-3: The strips of pavement provided under stage-2 may be widened.

Stage-4: The existing pavement may be improved by providing additional layer of pavement so that larger traffic can be taken care of or the existing layer of pavement may form the base/sub base for a rigid pavement or a bituminous carpet may be laid over this layer to upgrade road classification

Low costs roads may broadly classified into the following categories.

1. Earth roads
2. Kankar roads
3. Gravel roads
4. Traffic bound macadam roads
5. Water bound macadam roads

The following construction practices should be reviewed for low cost road construction

1. Construction of roads should be done on balance approach following mass curve instead of cut and spoils.
2. Construction of road should be done in stage wise in different years instead of one years instead of one year. By this way dispute raised at the site is managed.

year	1st Yr.	2nd Yr.	3rd Yr.
Width	1.5	3	4.5

3. The planning of road should be done based on decentralization without any political interference.
4. During construction local materials should be utilized
5. During construction local manpower should be utilized
6. For stabilizing the slope bio-engineering technique is used instead of civil engineering structures.
7. In combination of bio engineering technique gabion is used instead of retaining wall.

8. Soil stabilization technique should be used.
9. In case of natural water courses, causeway should be preferred instead of bridge.
10. The slope of road should be outward which avoid the provision of longitudinal side drain.
11. Water discharging from hill-side to valley side is collected by the provision of catch drain with proper water management.

Advantages of stage construction

1. The formation width is stabilized and chance of settlement of the soil due to subsequent heavier traffic loads are reduced.
2. Easy for construction of first stage as well as next stage
3. Local people gets maximum engaged in construction
4. Dispute arise at site can easily be managed
5. Locally available materials are used which reduce cost of construction

Glossary

Dispute: A condition of disagreement

Expenditure: Act of expending or paying out

Subsequently: Following, afterwards in either time or place

Cater: To serve

Causeway: A type of cross drainage structure in sroad.

A. Very short answer question .

1. What is low cost road?
2. What do u mean by stage construction?
3. Write any three example of low cost road

B. Short answer question.

1. Write a typical example of low cost road
2. Write importance of low cost road in context of Nepal

3. What are the advantages of stage construction?

C. Long answer questions.

1. Write the field construction procedures of low cost roads
2. Write advantages of stage construction of road? What general practices is followed for construction of low cost road?
3. Describe the types and field construction technology of low cost road.

Unit 10
Hill Road

The road lying in the hill or mountain is known as hill road. But the definition is not clear since hill is not defined So first of all we have to defined terrain based on the cross slope perpendicular to the center line of the road.

Classification of the terrain

Types of terrain	Cross -slope
Level or plain(L)	0-10
Rolling (R)	10-25
Mountainous(M)	25-60
Steep(S)	>60

Terrain: Area of land or particular feature of it.

A hill road is defined as one, which passes through with cross slope of 25% or more i.e. mountainous or steep. However, there are section along hill roads with cross slope less than 25% also.

Hill road alignment

The following are the certain special points, which should be considered in design of hill road alignment.

1. Deep cutting should be avoid as they are very difficult and costly
2. Rise and fall in the hill roads should be as easy as possible. Very steep grades should be avoided and if provided in the certain reaches of the road, they should not be continued for a long stretches
3. For safety of the traffic , parapet wall should be constructed on outer edge of the horizontal curve
4. Road alignment should be on that side of hill which is sound and stable
5. There should be proper arrangement for surface drainage and drainage from the up hill side.

6. As far as possible the cross – section of hill road should be kept fully in cutting
7. Road should be aligned on that side of hill which remains exposed to sun for most of the time
8. Hill road should be aligned in such a way that it lies on the side against the direction of wind
9. Sight distance should be at least equal to stopping sight distance at all points of road
10. Wider stretches of the roads should be planned at suitable intervals to provide facilities of parking the vehicles in case of any vehicular trouble or any reasons or for overtaking purpose.

Importance of hill road

Special structure in hill roads

The following types of special structures are most frequently used in hill roads in Nepal.

1. Retaining structure
2. Drainage structure
3. Slope protection structure

Retaining structures

A retaining structure is usually a wall constructed for the purpose of retaining a vertical or nearly vertical earth bank which in turns supports vertical loads. Retaining walls are most important structure in hill road construction.it provides adequate stability to the roadway and to the slope. Retaining walls are constructed on the valley side of the roadway and on the cut hill side to prevent slide towards the roadway.

They are also provided to retain the earth mass for elevated and depressed where embankment slope or cut slope cannot be extend beyond roadway due to private land or existing building.

Classification of retaining wall

Based on materials used

1. Dry stone masonry retaining wall
2. Stone filled gabion wire crates
3. Stone masonry with cement and mortar
4. PCC retaining wall
5. RCC retaining wall

Based on location of wall

Hill or valley side
Toe wall
Revement wall or breast wall
Cut –off wall
Check wall

Revement or breast wall

Revement or breast walls are the retaining wall constructed to buttress the up hill slope of the road cross section. This wall is constructed on the inner side of road to give support to the loose and unreliable soil of the cut in hillside

Where cutting slope is steep and contain loose and scourablesoils,slips are likely to occur . In such locations , revetments wall of dry stone masonry are constructed to retain the soil on cutting side to prevent occurance of any slide on such soil.

Toe wall

The toe walls are the low walls constructed at the bottom of an embankment to prevent slippage of filled portion. If sloping length of filled portion is too long it is perferable to construct the toe wall as shown in figure to support the embankment.

Check wall

checks walls are small retaining walls(structures) constructed on series on sloping hill face to check the slides and to generally add overall stability of the hill face.

Parapet wall

Parapet walls are needed to give protection physiologically and physically to the motorist, while travelling along the road with steep valley slope. They need not be made continuously

Drainage structure

Some special feature of hill road drainage are described below

Drainage of water from hill side slope

Road side surface drainage

Drainage of water from hill slope

Surface water from the hill slope towards the road way is one of the main problems in drainage of hill road. It is not desirable to let the surface water from the large area uphill to flown into the side drains , since this call for large section. In order to intercept and divert water from hillslope catch water drains are provided running parallel to roadway.Wataer intercepted by catch water drain is diverted by sloping drains at suitable intervals and carried across the roadway through suitable cross drainage structure such as culverts.

Note : catch water drains should be given a gradient of 1 in 50 to 1 in 33 to avoid high velocity of water and possible wash out

Road side surface drainage:og

In hill raods, road side drains is provided only on the hill side and and not on the both side. Due to limitations of foundation width, sides drains are constructed to such a shape that at emergency the vehicles could utilize the part of the side drain for crossing another vehicle at low speed or for parking.