R.C.Patel College Of Engineering & Polytechnic, Shirpur

Department of Civil Engineering

Course Title- Highway Engineering **Course Code -** 313323

Programme Name -Civil Engineering **Semester-**Third

Unit	Title	COs	Learning hours	R Level	U Level	A Level	Total Marks
III	Construction of Road Pavements	CO3	15	06	08	08	22

Unit-III Construction of Road Pavements.

3.1 overview of Highway construction materials.

Road construction requires different materials that work together to provide strength, stability, smoothness, and durability. The quality of these materials directly affects the life and performance of the road.

Following are different materials:

a) Subgrade Soil

b) Aggregates

c) Binders like cement and bituminous material

d) Water

e) Reinforcement.

a) Subgrade soil.

Subgrade soil is the natural soil prepared and compacted to support the entire road pavement structure. It is the bottom most layer of a road on which all other pavement layers are constructed.

Position of subgrade in a Road.

Road surface (Bituminous/concrete layer)

Base course

Sub base course

Subgrade soil

Natural ground.

Functions of subgrade soil:

1) Supports the Pavement:
   - subgrade carries the weight of all pavement layers and traffic loads.

2) Distributes load.
   - It spreads the load received from vehicles to the ground below.

3) Provides stability
   - A strong subgrade prevents settlement and deformation of the road.

4) Reduces Pavement failure
   - Good subgrade helps avoid cracks, potholes, & uneven surfaces.

5) Acts as foundation.
   - It serves as the base on which the entire pavement structure rests.

6) Provide good drainage
   - To provide drainage in good way to the rain water, percolating through road pavement.

characteristics of Good subgrade soil.

1) High strength: Carry heavy traffic loads.
2) Good Stability: It should not move or deform easily.
3) Proper drainage: Water should not remain trapped in the soil.
4) Low compressibility: It should not settle excessively under loads.
5) Resistance to swelling and shrinkage:
   The soil should not expand when wet or shrink when dry.
6) Easy compaction: It should be compacted easily to achieve maximum density.

Soil classification systems:

- Various soil classification system in use in the field of highway engineering are:

1) Grain or particle size classification.
2) Textural classification
3) Unified Soil classification of Revised casagrande soil classification and I.S soil classification systems.
4) Burmister descriptive classification.
5) U.S public Roads Administration (PRA) classification.
6) Highway Research Board (HRB) or American Association of state Highway officials (AASHO) classification or Revised PRA classification.
7) Casagrande soil classification
8) Federal Aviation Agency (FAA) classification.
9) Civil Aeronautic Administration (CAA) classification.
10) Compaction classification.

1) Soil classification Based on Grain size.

Soil classification is based on totally on grain size.

Gravel			, values are in mm.					
Coarse	Medium	Fine	Coarse	Medium	Fine	Coarse	Medium	Fine
2.0	0.6	0.2	0.06	0.02	0.006	0.002	0.0006	0.0002

2) Textural classification

- It depends on grain size distribution.
- Chart prepared by U.S. public road administration.

3. Unified soil classification system.

- It is based on particle size and plasticity.
- The casagrande classification system which was developed in 1942 to classify soils, was later revised, modified adopted by both the U.S. Corps of Engineers and the U.S Bureau of Reclamation and was renamed as unified soil classification system.

- Major Groups:

Coarse grained Soils:
More than 50% particles are retained on a fine sieve.
Gravel (G) - High bearing capacity
- Excellent drainage.

Sand (S) - Good drainage
- Good strength.

Fine grained Soils:
More than 50% particles pass through a fine sieve.
Silt (M) - Moderate strength
- Poor drainage

Clay (C) - High plasticity
- swelling and shrinkage problems

Organic soils (O):
Contain decayed organic matter
- Very low strength
- Not suitable for subgrade.

4) I.S. soil classification:

- The Indian standard Institute (ISI) has adopted a soil classification system based on the unified soil classification system.
- There is some changes of the Subgroup & their symbols.

a) Coarse grained soil:

i) gravelly soil, more than half grains larger than I.S 4.75mm

- Well graded gravel & gravel sand mixtures with clay binder. [GB]
- Well graded gravel [GW]
- clayey gravels poorly graded gravel-sand clay mixture [GC]
- Silty gravels [GM]
- Poorly graded gravel or gravelly sand [GP]

ii) Sandy soils

smaller than IS 4.75mm of coarse grain.

- Well graded sand (SB)
- Well graded san (SW) - mixture with little or no fines.
- clayey, sand or poorly graded sand clay mixture (SC).
- Silty sand (SM)
- Poorly graded sands (SP)

b) fine grained inorganic soils.

i) Inorganic silts and clays with low or medium compressibility.

- Silt and very fine sand rock flour, [ML]
- Gravelly clays, sandy clays, silt clays, lean clays of low plasticity. [CL]
- clay of medium plasticity (CL)

ii) Inorganic silts and clays with high compressibility.

- very compressible micaceous or diatomaceous fine silty soils, silts [MH]
- clays of high plasticity (CH)

c) Silt and clay with high organic content.

i) silts, organic

- silty and silt clays of low plasticity (OL)
- clays, organic - clays of medium to high plasticity very compressible (OH)

d) Peat

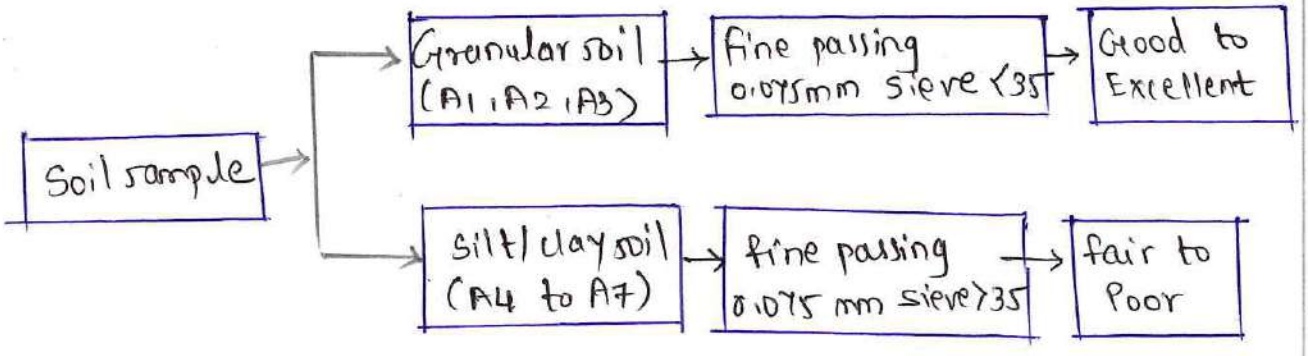
Peat - Peat & other highly organic swamp soils — Pt.

5) Highway Research Board (HRB) classification of soils.

- HRB classification is a system used to classify subgrade soils for highway and pavement design.
- According to their grain size and plasticity characteristics.

Why is HRB classification used?

- To identify the quality of soil.
- To compare different soils.
- To select suitable soil for highway construction.
- To predict the strength and performance of soil.
- In classification soils are divided into seven groups A1 to A7.



- Group index is function of percentage material passing 200mesh sieve (0.075mm), liquid limit and plasticity index of soil.

- Group Index is given by equation,

$$GI = 0.2a + 0.005ac + 0.01bd$$

a = That portion of material passing 0.075mm sieve, greater than 35 and not exceeding 75.1- expressed as whole number from 0 to 40)

b = That portion of material which passes from 0.075 mm sieve greater than 15 and not exceeding 35.1. (0 to 40)

C = value of liquid limit excess of 40 & less than 60. (0 to 20)

d = Plasticity index value → exceeding 10 & not more than 30 (0 to 20).

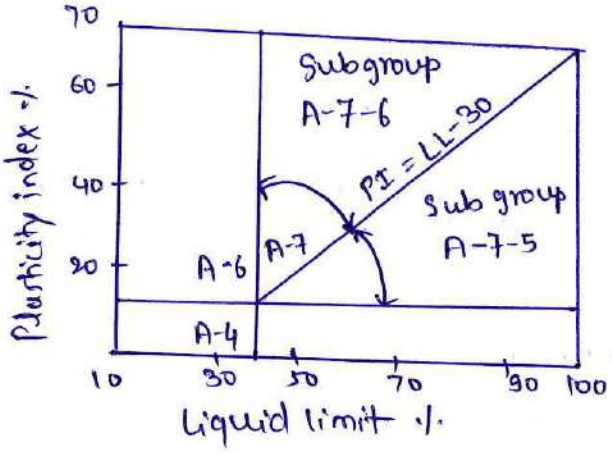


Chart for classifying fine grained soil (HRB system)

Simple Rule,

- A1 to A3 soils :- Best soils for highways.
- A4 to A5 soils :- Medium quality soils.
- A6 to A7 soils :- weak soils, not preferred for road subgrades.

Lower GI (0-4) – Better soil.

Higher GI (> 10) – Poor soil.

b) Aggregates:

- Aggregate form the major portion of pavement structure is the major component used in road construction.
- It is used in granular bases and subbases, bituminous, Constructions and in cement Concrete pavements.
- They typically constitute about 90-95% of the weight of asphalt pavements and 70-80% of the volume of concrete Pavements.

Properties of Road Aggregate:

1) strength: Ability to withstand crushing and traffic loads.
2) Hardness: Resistance to abrasion and wear.
3) Toughness: Ability to Resist impact loads.
4) Durability: Resistance to weathering, wetting, drying, and freezing effects.
5) Shape and Texture: Angular and rough textured particles provide better interlocking.
6) Specific gravity: Higher specific gravity generally indicates stronger aggregates.
7) Water absorption: Low to prevent weakening due to moisture.
8) Cleanliness: Free from clay, organic matter, and other harful impurities.

Test of Road Aggregate:

In compare to suitable of road stone for construction.

1. shape test.
   a) Flakiness index
   b) Elongation index
   c) Angularity number

2. Abrasion test
3. Impact test
4. Soundness or durability test
5. Crushing test
6. Cementation test
7. Bitumen adherion test
8. Water absorption test
9. Specific gravity test.

1. Shape test:

The shape of aggregate mass is determine by percentage of flaky and elongated particles contained in it and by it angularity.

a) Flakiness index:

The flakiness index of aggregate is the percentage by weight of aggregate particles whose minimum dimension is less than 3/5th or 0.6 of their mean dimension.

- This test is useable for size larger than 6.3 mm.
- If the total weight of sample taken from the different size ranges is W_T.

The flakiness index = $\frac{100 w}{W_T}$ %.

- flakiness index of aggregate used for road construction is less than 15%. & normally not exceed 25%.

b) Elongation Index

- Measures the percentage of aggregates whose length is greater than 1.8 times their mean size.
- Excessive elongated particles are undesirable.

- The elongation test is not applicable for size smaller than 6.3mm.

c) Angularity Number

- To find the angularity number of an aggregate is essentially a laboratory method intended for comparing the properties of different aggregates for mix design purpose.
- Aggregate can be estimated as angularity by properties of voids in sample of aggregate compacted in particular manner.
- Angularity number is defined as 67% solid volume.
- In constructions angularity number for aggregate varies from 0 to 11.
- Apprarus : metal cylinder of capacity 3 litre, tamping rod & metal scoop.

Process : Firstly sieved sample in range of such as, 16-20mm, 12.5-16mm etc.

- scoop full of single size aggregate placed in cylinder and by using tamping rod it tamped 100 times.
- 2 & 3rd layer similarly tamped.

so, the weight of aggregate in cylinder is found to be W_g,

Then, the cylinder is found = C_g

Specific gravity G_a also determined.

$$\text{Angularity Number} = 67 - \frac{100W}{C G_a}$$

2. Impact test:

- Measures the toughness of aggregates against sudden impact loads.
- Aggregate sample is subjected to repeated blows from a standard hammer.

The % of fines produced is determined.

$$\text{AIV}(\%) = \frac{W_2}{W_1} \times 100$$

W_1 = Total weight of sample

W_2 = weight passing 2.36 mm sieve.

3. Abrasion test

determines the resistance of aggregates to wear and surface deterioration due to traffic.

Los Angeles Abrasion test:

- Aggregates and steel balls are rotated in a drum
- The % of wear is calculated.

$$\text{Abrasion value}(\%) = \frac{W_1 - W_2}{W_1} \times 100$$

W_1 = original weight

W_2 = weight after test.

4. Soundness (durability) test:

Evaluates resistance to weathering, wetting, drying, freezing & thawing.

Aggregates is repeatedly immersed in a solution of:

- sodium sulfate (Na_2SO_4), or
- Magnesium sulfate ($MgSO_4$)
- followed by drying cycles.

- lower weight loss indicates greater durability.

5. Crushing test:

Measures resistance of aggregates to crushing under gradually applied compressive load.

Aggregate Crushing value (ACV) test.

- Aggregate is subjected to compressive load.
- Fines produced are measured.

$$ACV\ (\%) = \frac{W_2}{W_1} \times 100$$

W_1 = weight of sample

W_2 = weight of crushed material passing 2.36mm sieve.

Lower ACV indicates stronger aggregates.

6. Cementation test:

determines the binding or cementing property of aggregates with cement.

- Aggregate is mixed with cement mortar.
- Strength of the hardened specimen is measured.

7. Bitumen Adhesion Test:

Evaluates the ability of aggregates to retain bitumen coating in the presence of water.

- Aggregates are coated with bitumen.
- The sample is immersed in water.
- Percentage of stripped bitumen coating is observed.

8. Water absorption test:

determines the amount of water absorbed by aggregates

W_s = saturated surface dry weight

W_d = oven dry weight

Indicates porosity of aggregates

Lower water absorption is preferred.

9. Specific gravity test:

Measures the density of aggregates relative to water.

For Bulk sp. gr.

$$G_{Bulk} = \frac{W_1}{W_2 - W_3}$$

W_1 = weight of oven dried aggregate in air.

W_2 = weight of saturated Surface dry (SSD) aggregate in air.

W_3 = weight of saturated aggregate in water.

or,

$$\text{Specific gravity} = \frac{\text{Weight of Aggregate}}{\text{weight of Equal volume of water.}}$$

3) Bituminous Materials

The substance which contains bitumen or contain a large proportion of bitumen are known as Bituminous materials.

Types of Bituminous Materials.

Construction of road, there is bituminous road, so following types of bituminous materials are:

a) Bitumen

b) Asphalt

c) Tar

d) Bitumen emulsion

e) Cut back bitumen

f) Road oil

g) Primers

a) Bitumen

Bitumen is hydrocarbon material obtained from the refining of crude petroleum.

- Most commonly used binder in road construction.
- Thermoplastic material. (softens on heating and hardens on cooling)

Requirements of Bitumen

The desirable properties of bitumen depend on the mix type and the construction.

i) Mixing
ii) Attainment of desired stability of the mix
iii) To maintain the stability under adverse weather conditions.
iv) To maintain the stability sufficient flexibility and thus avoid cracking of bituminous surface.

Use

i) Asphalt Concrete
ii) Bituminous macadam
iii) Surface dressing
iv) Seal coats.

b) Asphat

When the bitumen contains some inert material or minerals it is called asphalt.
- can be natural or manufactured.

Uses → 1) Flexible pavements
2) Airport runways
3) parking areas.

c) Tar:

Tar is viscous liquid obtained from destructive distillation of coal, wood or shale.
- More resistant to water than bitumen.

Uses → 1) surface treatments
2) waterproofing works.

d) Bitumen emulsion:

- A bitumen emulsion is liquid product and dispersed in water with an emulsifying agent.
- Can be used without heating.

Some of the general properties of road emulsion are judged by following tests:

i) Residue on sieving: It is suitable for greater than 0.15 mm diameter and not more than 0.25 percent by weight of emulsion.

ii) Stability to mixing with coarse graded aggregate: if emulsion breaks down coats the aggregate with bitumen too early before mixing is complete.

iii) Stability to mixing with Cement: This test carried out to assess the stability of emulsion when the aggregate contains large proportions of fines.

iv) Sedimentation:-

v) Viscosity: It is enough to sprayed through jet or coat the aggregate in simple mixing.

e) Cut back bitumen:

- Bitumen diluted with volatile solvents such as kerosene or naphtha.
- Reduce viscosity for easy application at lower temperature.

Types: i) Rapid curing (RC)
ii) Medium curing (MC)
iii) Slow curing (SC)

f) Road oil

- It indicates that slow curing asphalt.
- The road oils sets very slowly, road oil ranges from less to very viscous material having less binding characteristic to excellent binding characteristics.

g) Primers

A primer may be cutback asphalt, road oil or a low viscosity road tar.

- The main function of primer is penetrate into the road surface and to coat aggregate throughly so that when bitumen is applied it can stick to the aggregate in a better way.

Test on Bitumen

Various tests on bituminous materials are:

i) Penetration test
ii) Ductility test
iii) Flash and fire point test
iv) Softening point test
v) Float test
vi) Viscosity tests
vii) Solubility test
viii) Spot test
ix) Loss on heating test
x) Water Content test.

1) Penetration test

The penetration test is used to determine the hardness or consistency of bitumen by measuring the depth to which a standard needle penetrates the bitumen sample under specified conditions.

objective: 1) To classify bitumen into different grades
2) To assess the suitability of bitumen for road construction under various climatic conditions.

Apparatus:

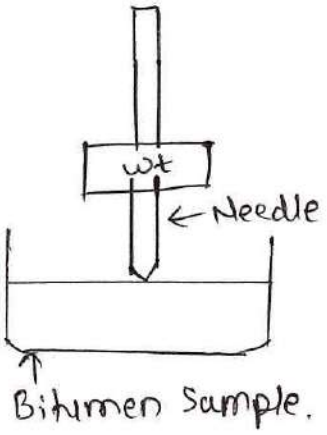
1) Penetrometer
2) standard penetration needle
3) sample container
4) water bath maintained at 25°c.
5) stopwatch.

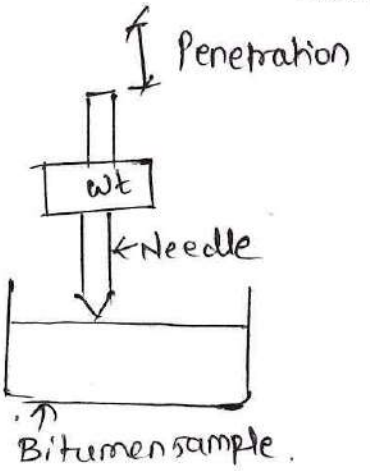
Test conditions:

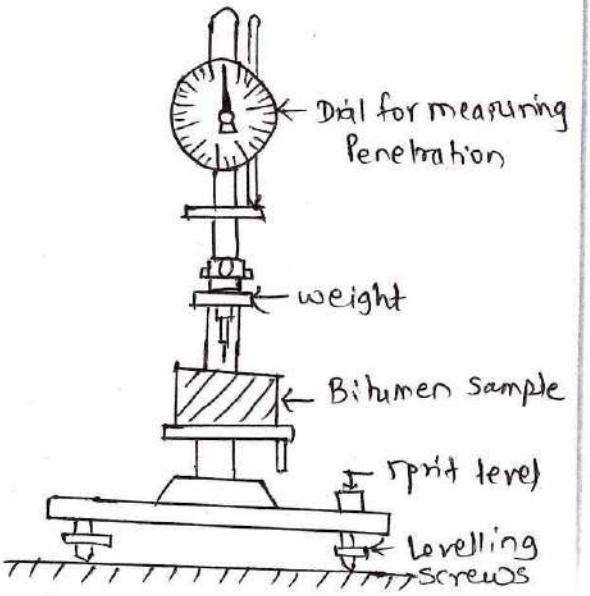
1) Temperature 25°c
2) Load on needle 100g
3) Duration of loading - 5 seconds.

Procedure:

- Heat the bitumen sample and pour it into a container.
- Allow it to cool and condition it in a water bath at 25°c.
- place the sample under the penetrometer.
- The dial is set to zero or the initial reading is taken and the needle is released for 5 seconds.
- The final reading is taken on dial gauge.
- At least 3 penetration tests are made on this sample by testing at distances at least 10 mm apart
- Measure the depth of penetration.
- 80/100 grade bitumen → 80 to 100 range at standard test condition.







ii) Ductility Test

definition → The ductility test is used to measure how much a bitumen sample can stretch before it breaks. This test shows the flexibility and adhesive property of bitumen.

Purpose of the test:

- To check the stretching ability of bitumen.
- To determine whether bitumen can withstand traffic loads and temperature changes without cracking.
- To assess the quality of bitumen for road construction.

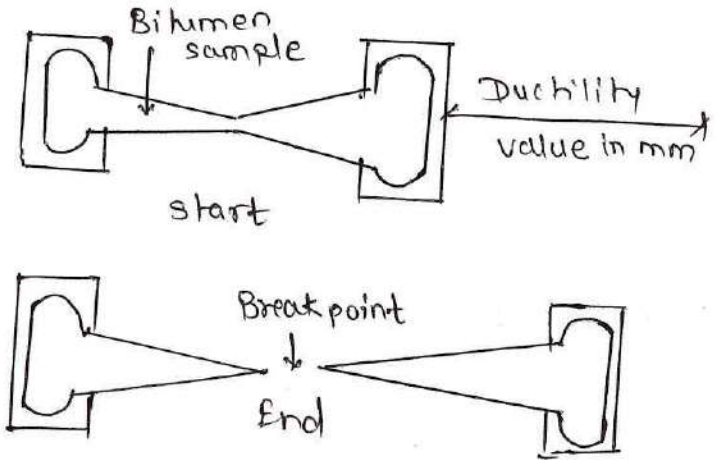
Apparatus Used.

- Ductility testing machine
- Briquette mould
- Water bath
- Thermometer

Process:

1) Heat the bitumen and pour it into a briquette mould.
2) Allow the sample to cool and become solid.
3) The test is conducted at 27°c and at a rate of pull of 50 mm per minute.
4) The excess bitumen material is cut and the surface is levelled using a hot knife.
5) The mould assembly containing sample is replaced in water bath of the ductility testing machine for 85 to 95 minute.
6) The side of the mould are removed, the clips hooked on the machine and the pointer is adjusted to zero.
7) Pull the two ends of the sample apart at a uniform speed.
8) Measure the distance stretched when the bitumen breaks.

g) A minimum ductility value of 75 cm has been specified by the IS1 for bitumen of grades 45 and above.



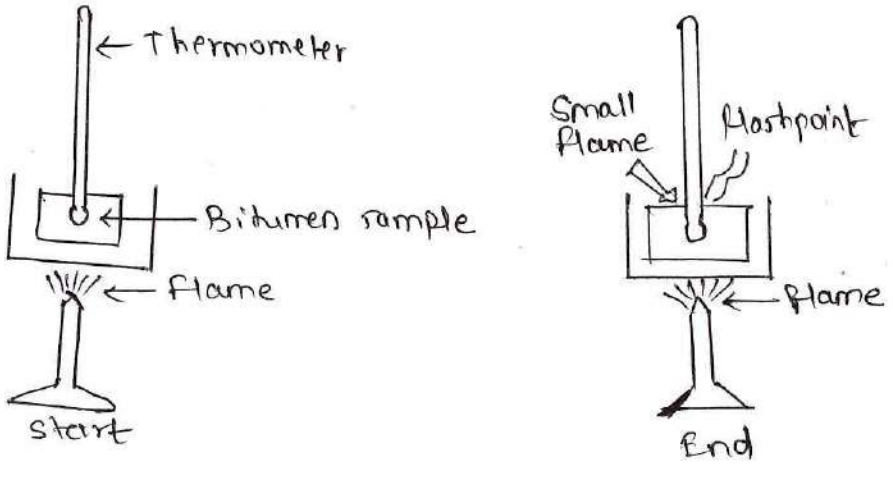
Ductility Test

iii) Flash and fire point test

The flash point test and fire point test are used to determine the temperatures at which bitumen gives off vapours that can ignite.

Flash point → The lowest temperature at which bitumen vapours catch fire momentarily when flame is brought near.

Fire point → The temperature at which bitumen vapours continue to burn for at least 5sec, after ignition.



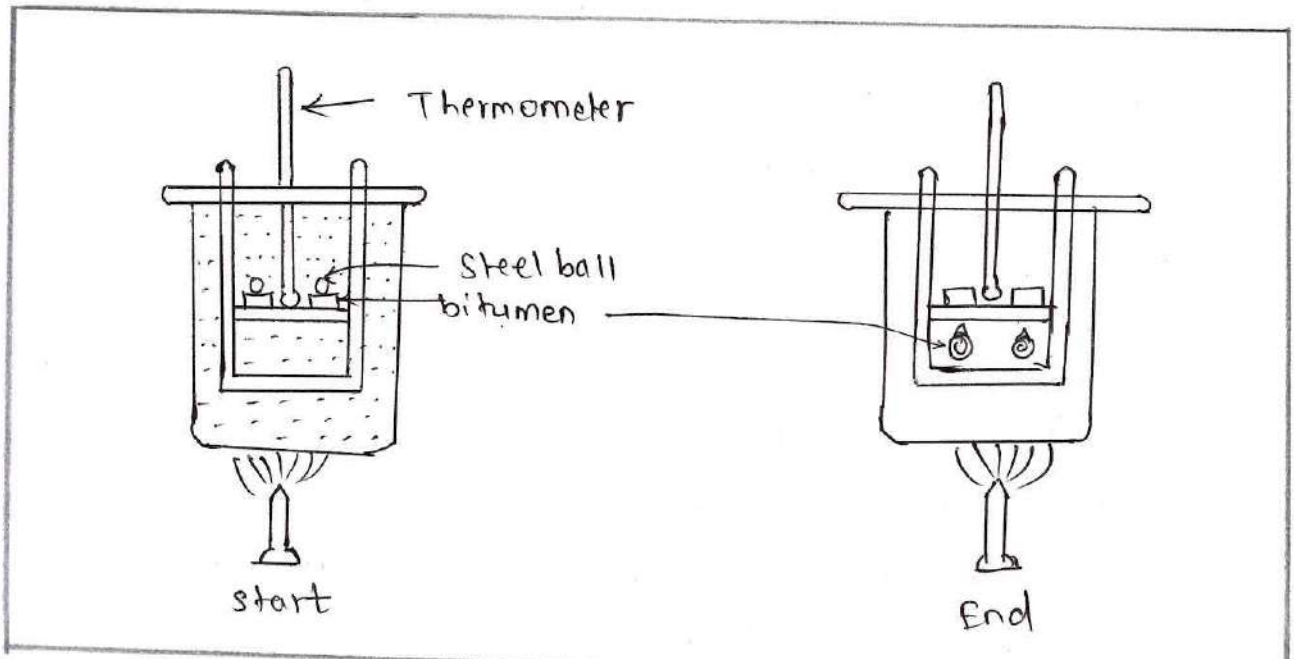
Apparatus used :-

- Pensky - Martens closed cup Apparatus
- Thermometer
- Test flame device.

Procedure :

1) Fill the test cup with bitumen.
2) The lid is placed to close the cup in closed system.
3) All accessories including thermometer of the specified range are suitably fixed.
4) The bitumen sample is then heated at the rate of 5°c to 6°c per minute, stirring the specimen.
5) The test flame is applied at intervals depending upon the expected flash and fire points.
6) First application is made at least 17°c below the actual flash point and then at every 1°c to 3°c.
7) In closed system, the flash point is taken as the temperature read on the thermometer at the time of the flame apply that causes a bright flash in the interior of the cup.
8) for open cup, it is the instance when flash appear first at any point
9) The heating is continued until the material get ignited and continues to burn for 5 sec this temperature is recorded as the fire point.
10) The minimum specified flash point of bitumen used in pavement construction in pansky Martens closed type test is 175°c.

iv) Softening point test:



Softening point test set up.

- The Softening Point test is used to find the temperature at which bitumen becomes soft enough to flow under a specified condition.
- This test tells us how much heat bitumen can withstand before it starts becoming soft.

Purpose of the test:

The test is conducted to:

1) Determine the temperature at which bitumen softens
2) Check the suitability of bitumen for hot weather conditions.
3) Compare the quality of different grades of bitumen.
4) Help engineers select the proper bitumen for road construction.

Apparatus Required

1) Brass Rings
2) Steel balls

3) Ball guide

4) Heating Container (water or glycerin bath)

5) Thermometer

6) Heating device.

Procedure →

1) Heat the bitumen until it becomes fluid.

2) Fill the brass rings with molten bitumen.

3) Allow the sample to cool and remove excess material.

4) Place the rings in the testing apparatus.

5) Place a steel ball on the top of each bitumen sample.

6) Fill the bath with water (or glycerin for higher temp).

7) Heat the bath at a uniform rate.

8) observe the ball carefully.

9) Record the temperature when the softened bitumen allows the ball to touch the bottom plate.

This temperature is the softening point of Bitumen.

V) Extraction test of Bitumen.

The extraction test is used to determine the amount of bitumen present in a bituminous mix (road mix).

Purpose → 1) To find percentage of bitumen in the mix.

2) To check wheather the mix contains the required quatity of binder.

3) To ensure good quality road construction.

Principle → Bitumen is dissolved using a solvent, leaving only the aggregates behind. By measuring the weight before and after extraction, the bitumen content is calculated.

Procedure → 1) Take a sample of bituminous mix
2) Weight the sample
3) Place it in the extraction apparatus.
4) Add a suitable Solvent.
5) The solvent dissolves the bitumen.
6) Collect and dry the remaining aggregates.
7) Weight the aggregate.
8) Calculate the bitumen content.

Grade of Bitumen:

The grade of bitumen indicates its hardness or softness and suitability for different climatic conditions.

Common grades:

- VG-10 ⟶ Cold climate & spray applications.
- VG-20 ⟶ Moderate climate roads.
- VG-30 → Heavy traffic roads
- VG-40 → High temperature and heavy traffic areas.

3.2 Pavement, Types, structural components of pavement and their functions:

Pavement → A pavement is a road structure made of different layers of materials placed one above another over the natural ground.

Its main purpose is to provide a smooth, safe, and durable surface for vehicle and to transfer the traffic load safely to the soil below.

- A well designed pavement improves riding comfort, reduces vehicle operating costs, and increase road life.

functions of pavement / objectives.

1) Providing a smooth surface:

- Pavement offers a level and comfortable surface for vehicles, reducing vibrations and improving ride quality.

2) Load distribution

It distributes the wheel load of vehicles to the lower layers and finally to the soil.

3) Safety

It provides adequate friction between vehicle tyres and the road surface, reducing the chances of skidding.

4) Drainage

It helps remove rainwater from the road surface and prevents water damage.

5) Durability

It withstands traffic loads and environmental effects for many years.

6) Economy

A good pavement reduces vehicle maintenance costs and fuel consumption.

Types of Pavement structure:

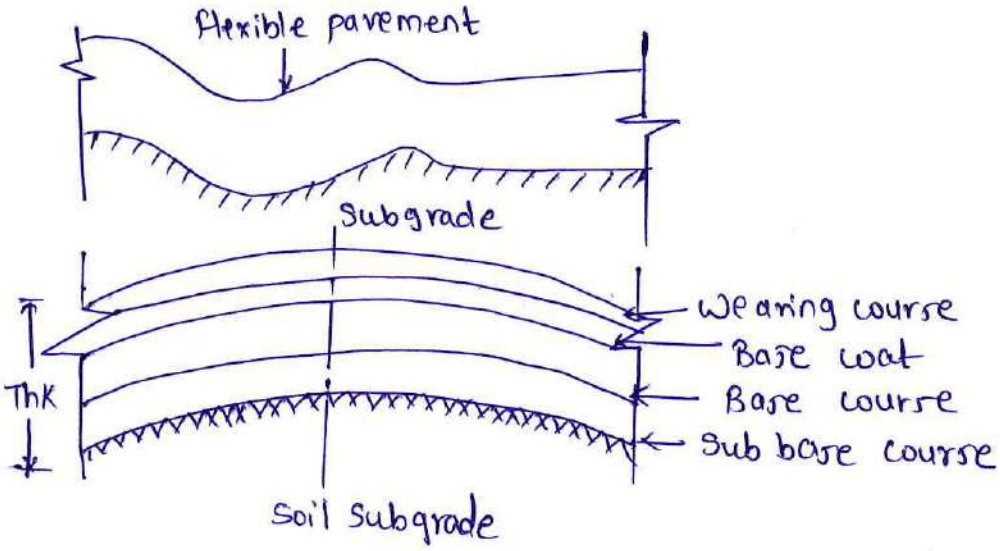
Based on the behaviour, pavements are generally classified into three categories:

i) Flexible pavements

ii) Rigid Pavements

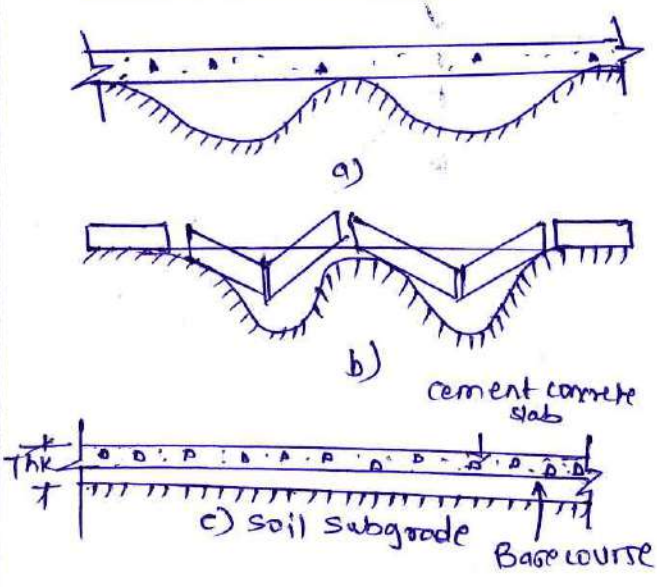
iii) Semi-rigid pavements.

i) Flexible pavement



- Flexible pavement consists of several layers of materials bound together using bitumen. The load is transferred gradually from the top layer to the lower layers.
- Construction materials →
  Bitumen, Asphalt, Crushed stone, Gravel.
- figure shows components of flexible pavement and flexible pavement redaching depression due to settlement of subgrade.
- The flexible pavement layers transmit the vertical or compressive stresses to the lower layer by grain to grain transfer through the points of contact in the granular structure.

ii) Rigid Pavement



- Rigid pavement is constructed using cement concrete slabs. The concrete slab itself acts as a structural member and distributes loads over a larger area.

Construction materials.
-Cement, sand, Aggregate, water, steel Reinforcement.

- Cement concrete slab can also be laid directly over the soil subgrade, this is not preferred when the soil condition below it is not good.
- But a Subbase course layer under the cement concrete slab, increase the pavement life. shows various components of Rigid pavement.

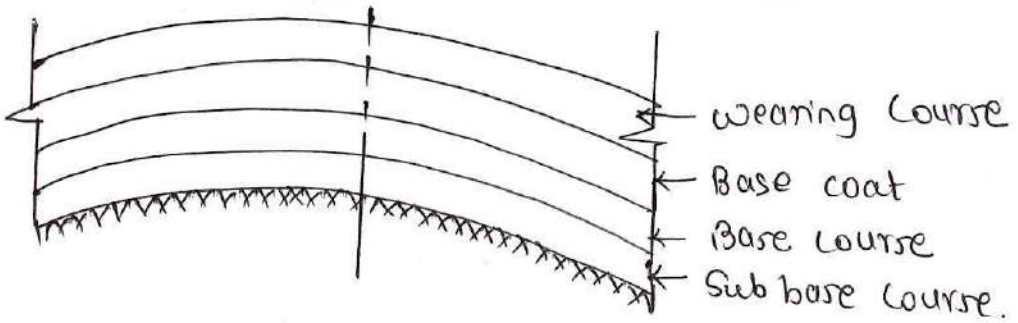
Advantages →
- long service life
- High strength
- Less maintenance
- Suitable for heavy traffic.

Disadvantages →
- Higher intial cost.
- Longer construction period.
- Difficult repairs.

iii) Semi-rigid pavement

- Generally pavement having 3 or 4 layers wearing course, Base coat, Base course, Sub base course, when bonded materials like pozzolanic concrete, lean cement concrete or soil, cement are used in base course or sub base course layer has considerably higher flexural strength than the common flexible pavement layer.
- However these bonded materials do not possess as much flexural strength as the cement concrete pavements.
- Therefore, when this intermediate class of materials are used in the base or sub base course layer of the pavements, they are called semi rigid pavement.

Components of Pavement and their functions.



i) Soil subgrade:

The subgrade is the lowest layer and consists of compacted natural soil.

Functions: Supports all upper pavement layers.
- Transfers loads safely to the ground.
- Maintains overall pavement stability.

ii) Sub-base course:

The sub base course is provided between the base course and subgrade. It is the layer of broken stones bounded or unbounded aggregates.

functions: - Provides additional load distribution
- Improves drainage of the pavement structure.
- Improve bearing capacity of subgrade.

iii) Base course:

A layer of boulder stone or bricks provided in double layer over the sub base course or over the subgrade in road pavement is known as Base course.

functions: - Supports the surface layer.
- Distributes traffic loads to lower layers.
- Base course acts as foundation to the road pavement.

iv) Base coat:

The layer of hard stone provided in between the base course and wearing course is known as Base coat.

functions:- It act as layer of transmission material.
- It transfers the vehicular load over large area of base course.

v) Wearing Course:

The top most smooth riding surface road pavement exposed to traffic is called as wearing course.

functions:- It provide smooth riding surface.
- It resists pressure exerted by tyres and takes up wear and tear due to traffic.
- this course also offers water tight layer against the surface water infiltration.

3.3 Construction of WBM road, flexible pavement / Bituminous Road.

Construction of Water Bound Macadam Road

A water bound macadam road is a road in which crushed stone aggregates are spread and compacted, and the voids between stones are filled with screening material and water.

The binding action of water helps the materials lock together to form a strong road layer.

Construction Procedure of WBM road as per IRC.

i) Preparation of foundation for receiving the WBM course:
- The foundation for WBM road is either the subgrade or sub base or base course.
- The foundation layer is prepared for required grade and camber and the dust and loose materials are cleaned.

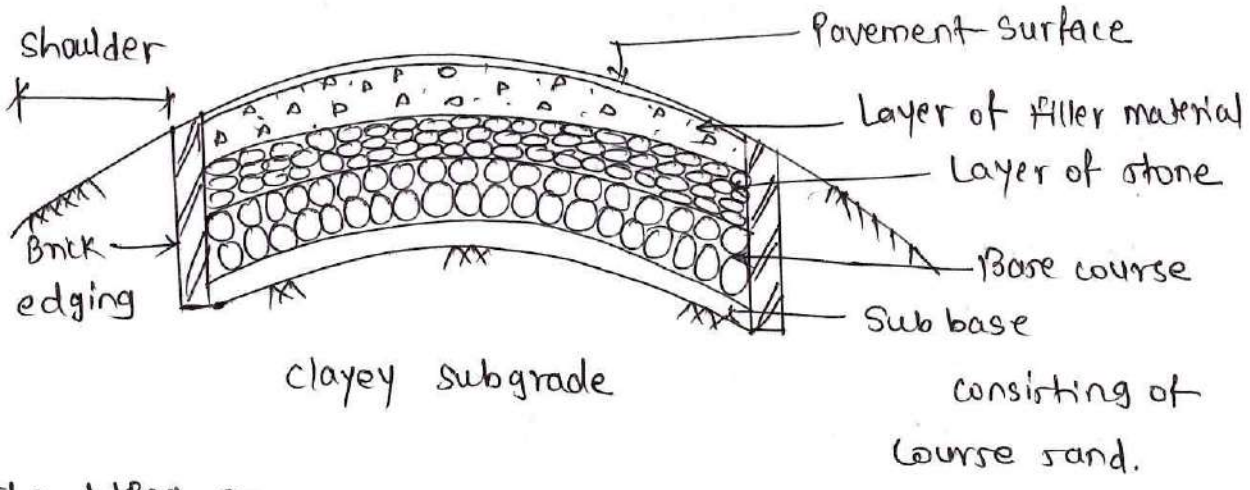
- The firstly ground cleaned and leveled.
- soft spots are removed
- The soil is compacted properly.
- proper drainage provided.

ii) Provision of lateral confinement.

- Lateral confinement is to be provided before starting WBM construction.
- This may be done by constructing the shoulders to advance to a thickness equal to that of the compacted WBM layer and by trimming the inner sides vertically.

iii) Spreading of coarse Aggregates:

- crushed stones of specified size are spread uniformly.
- The thickness of the layer is maintained as per design.
- To form the main load carrying layer.



The WBM course → thickness 7.5cm.
When course using coarse aggregate grading no 1.
which is of 10cm of compacted thickness.

iv) ~~Rolling~~ Rolling

- The aggregate layer is compacted using a road roller.
- Rolling starts from the edges and moves toward the center.
- To make the layer dense and otable.

v) Application of Screening

- smaller stone particles are spread over the surface.
- They fill the spaces between larger stones.
- To reduce voids in the aggregate layer.

vi) Sprinkling and grouting

- Water is sprinkled uniformly over the surface.
- To help screenings fill the voids and bind the materials together.

vii) Application of Binding Material

- After the application of screening and rolling binding material is applied at uniform and slow rate at two or more successive thin layer.
- This is followed by rolling with 6 to 10 tonnes roller and water is applied to the wheels to wash down the binding materials that stick to the roller wheels.

Merits and Demerits of WBM Road

i) Merits:

- Construction cost of WBM road is low.
- Locally available material and labour can be used.
- The WBM may be used base course or surfacing course.

ii) Demerits:

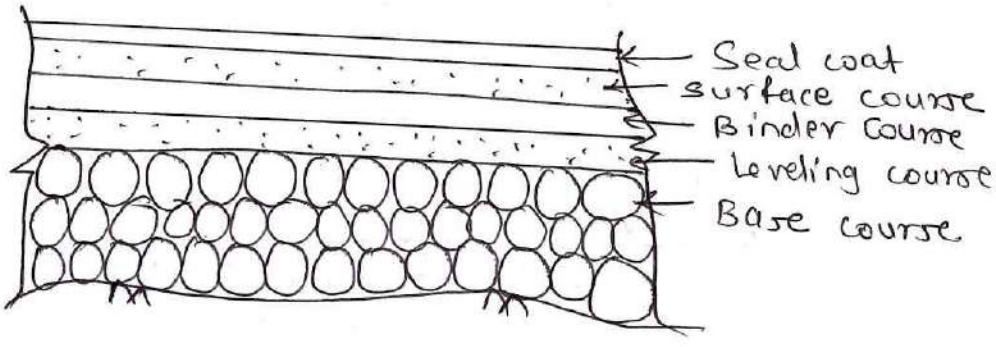
- WBM gets deteriorated rapidly under adverse conditions of traffic and weather.
- Maintenance cost is high.
- Life is less.
- Permeable to rain water thus may lead to softening and yielding of subsoil.

Construction of Bituminous Pavements

A bituminous pavement is a road in which bitumen is used as the binding material. It consists of several layers placed over the prepared soil.

- Number of types and methods are in use for bituminous Pavement Construction. they are as follow:

i) Interface treatments like prime coat and tack coat.
ii) Surface dressing and Seal coat
iii) Grouted or penetration type constructions
   a) Penetration Macadam
   b) Built up spray Grout
iv) Premix which may be ony of the following.
   a) Bituminous bound macadam
   b) Carpet
   c) Bituminous Concrete
   d) Sheet asphalt or rolled asphalt
   e) Mastic asphalt.



Components of bituminous surface.

Terms used in Bituminous Road

i) Interface Treatment

- firstly existing pavement layer is to be cleaned to remove dust & dirt.
- This treatment of spraying a bituminous binder is called interface treatment which is necessary to provide the necessary bond between the old & new layers.

- The interface treatment may either be a prime coat or a tack coat and in some cases the prime coat followed by a tack coat.

a) Prime coat →

Prime coat is a thin layer of low-viscosity bitumen applied on a granular base before laying the bituminous layer.

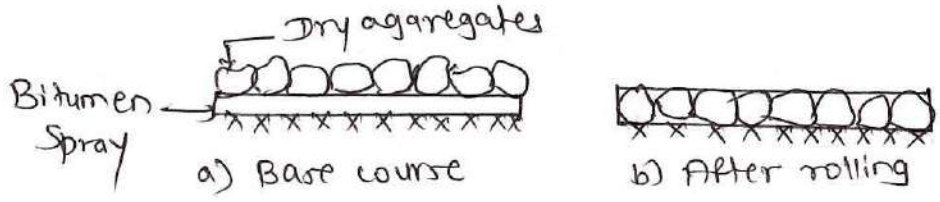
function: - Binds loose particles
- Improves adhesion between base and surface layers.
- Reduces dust.

b) Tack coat →

Tack coat is a light spray of bitumen applied betn two bituminous layers.

functions: - creates a strong bond between layers.
- Prevents separation of layers.

ii) Bituminous Surface dressing



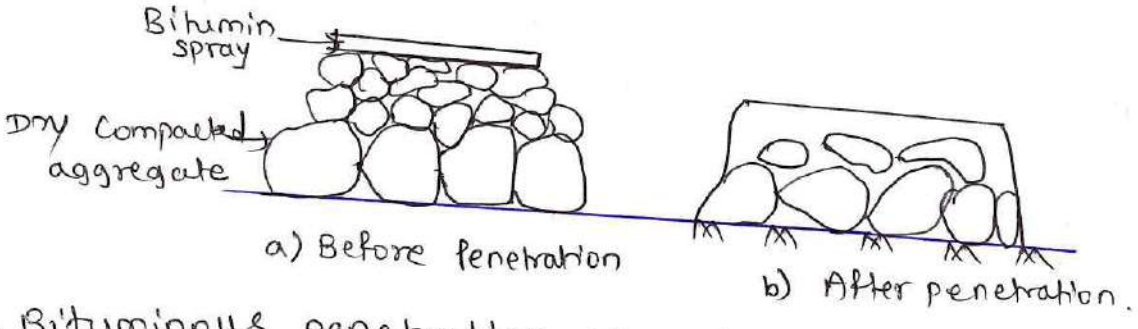
- Bituminous surface dressing is provided over an existing pavement to serve as thin wearing coat.
- The single coat surface dressing consists of a single application of bituminous binder material followed by spreading of aggregate cover and rolling.
- When the surface dressing is similarly done in two layers. It is called two coat bituminous surface dressing.

iii) Seal coat →

Seal coat is a thin layer protective layer placed on the top of a bituminous surface.

functions: seals small cracks
- Prevents water entry
- Improves surface life.

iv) Penetration Macadam



- Bituminous penetration macadam or grouted macadam is used as a base or binder course.
- The coarse aggregates are first spread and compacted well in dry state and after that hot bituminous binder of relatively high viscosity is sprayed in fairly large quantity at the top.
- Bitumen penetrate into the voids from the surface of the compacted aggregates, filling the voids and binding some stone aggregates together.
- When bitumen penetrates to full depth of compacted aggregates it is called full grout.
- When bitumen half depth of compacted aggregate called as Semi grout.

v) Built-up spray Grout

- This method is used for strengthening existing bituminous pavements.
- Built up spray grout two layer composite construction of compacted crushed aggregate with bituminous binder thickness 75 mm

vi) Premix methods.

In method aggregates and the bituminous binder are mixed thoroughly before spreading and compacting.

- Premixed bituminous constructions are bituminous macadam, bituminous carpet & bituminous concrete.

vii) Bituminous Macadam.

After mixing immediately laid bituminous macadam or Bitumen bound is a premixed construction method of one or more courses of compacted crushed aggregates Premixed with bituminous binder.

Bituminous Road Construction Procedure

1) Site Preparation

- Remove grass, roots, loose soil, and unwanted materials
- Mark the road alignment and levels.
- Provide proper drainage arrangements.

Purpose – To prepare the area for road construction.
- To prevent future settlement and water damage.

2) Preparation of Subgrade.

The subgrade is the compacted natural soil forming the foundation of the road.

- Level the soil surface
- Adjust moisture content if required
- Compact the soil using rollers
- Check density & strength

Purpose – To provide a stable foundation.
- To support all pavement layers.

3) Construction of sub base course

- spread granular material such as gravel or crushed stone.
- Maintain the required thickness.

- Water the surface if necessary.
- compact using rollers.

Purpose → To improve drainage.
To distribute traffic loads
To protect the subgrade.

4) Construction of Base course
- Spread crushed aggregate uniformly.
- Grade the surface properly.
- Compact throughly with rollers.

5) Application of Prime coat:
- clean the base course surface
- Spray a thin layer of liquid bitumen evenly.

Purpose → - To bind loose particles
- To improve bonding between base and bituminous layers.
- To make the surface waterproof.

6) Application of Tack coat:
- Apply a light spray of bitumen over the primed surface or existing bituminous layer.

Purpose → To create a strong bond between layers.
- To prevent layer separation.

7) Preparation of Bituminous mix.
- Heat aggregate and bitumen separately.
- mix them a hot mix plant.
- Ensure all aggregates are coated with bitumen.

8) Transportation of Mix.
- Transport the hot mix to be construction site using trucks.
- Cover the mix to maintain temperature.

9) Laying of Bituminous mix
- Spread the hot mix using a paver machine.
- Maintain the required thickness, width & level.

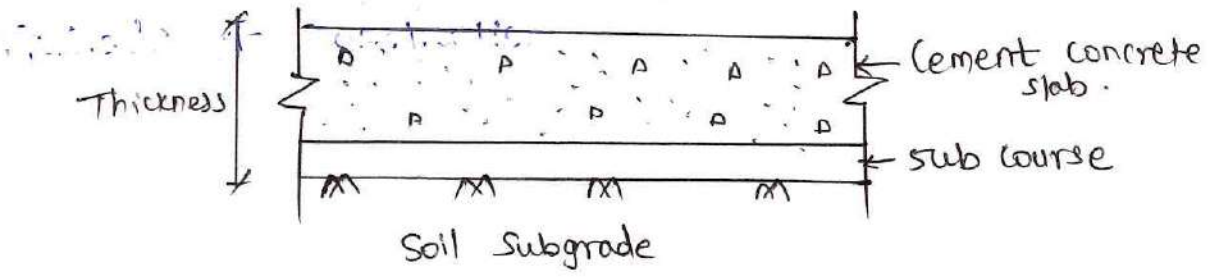
10) Rolling and compaction.
- Compact the freshly laid mix using rollers.
- Rolling begins from the edges and moves toward the center.
- Continue until the required density is achieved.

11) Surface finishing and Inspection.
- check surface smoothness.
- Inspect thickness and levels.
- Correct any defects.

12) opening to traffic.
- Allow the pavement to cool.
- Conduct final inspection.
- Open the road for vehicles.

3.4 Construction of Rigid Pavement (cement Concrete): methods of construction, Alternate and continuous Bay method, construction joints, Filler and Sealers.

Rigid pavement:
- A rigid pavement is a road made of cement concrete slabs. It is called rigid because the concrete slab is strong and does not bend much under traffic loads.



Methods of Construction of Cement Concrete Road :

There are two methods :

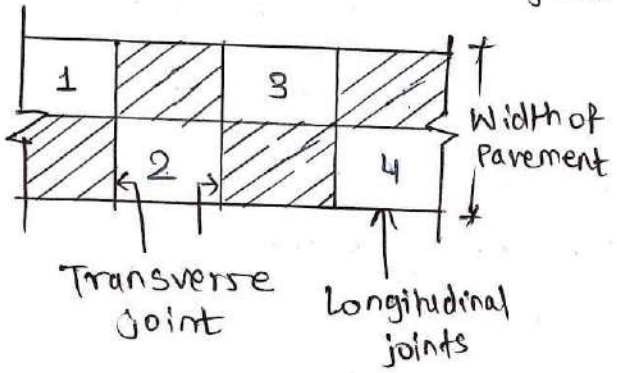
a) Alternate bay method

b) Continuous bay method

So,

a) Alternate bay method :

- In this method, alternate slabs are constructed first.
- Construct slab No, 1, 3, 5 etc
- Leave gaps between them.
- After these slabs gain strength, construct slab No, 2, 4, 6 etc.



Advantages :

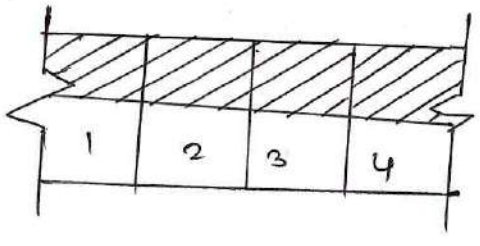
1. Provides additional working convience for laying slab.
2. The construction of joints is easier.

Disadvantages →

1. Large number of transverse joint are form from which construction cost will be maximum and reduce smooth riding.
2. More time required to complete work.

b) Continuous bay method

- In this method, concrete laid continuosly without leaving alternate gaps.
- Joints are provided at specified intervals.



Advantages →

1. Faster construction
2. Suitable for large projects.

Construction steps for cement concrete Pavement slab.

a) Preparation of sub grade and Sub base:

The sub grade or sub base for laying the concrete slab should comply with the following requirement.

- The natural soil is cleaned and leveled.
- Soft and weak soil is removed.
- The soil is compacted properly.
- The minimum modulus of subgrade reaction obtained with a plate bearing test is 5.54 kg/cm.

b) Placing of forms

Steel or wooden forms are used for this purpose,

c) Batching of Material and mixing.

- fine aggregates and coarse aggregates are proportioned by weight in a weight-batching plants.
- cement is measured by bags.
- mixing of concrete is done in batch mixer.

d) Transporting and placing of concrete

- The cement concrete is mixed in quantities requires immediate use and is deposited to subgrade or subbase.
- care is taken to see that nosegregation of materials.
- spreading will be uniformly.

e) Compaction and finishing

- concrete is compacted using vibrators
- Air voids are removed for increase strength & durability.

f) Floating and straight edging.

- floating will be longitudinal in which position parallel to carriageway centreline and passed gradually from one side of the pavement to the other.
- After floating - slab surface tested for its grade and level with straight edge.

g) Belting, Brooming - Edging:

- Just before the concrete become hard, the surface is belted with two-ply canvas belt.
- After belting, the pavement is given a broom finish with fibre broom brush, brooming is done perpendicular to the centre line of the pavement.

h) Curing of cement concrete:

The concrete surface is kept moist for about 14 days.

i) Open to traffic

When the concrete attain the required strength or after 28 days of 28 days of curing the road is opened to traffic.

Construction of Joints in cement concrete Road

Construction joints are provided when concreting work is stopped and resumed later.

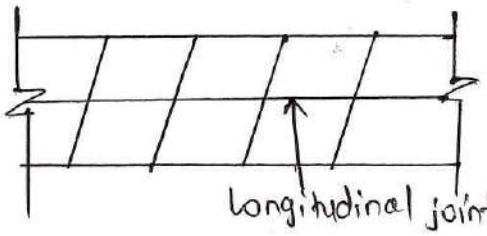
- To connect old and new concrete
- To maintain continuity of pavement.

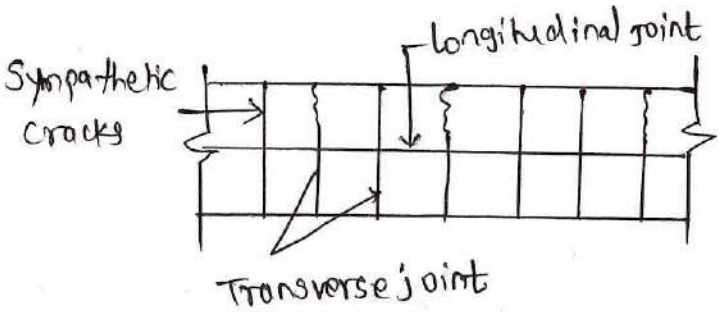
Types of Joints:

The various joints in concrete roads are classified as:

I. Transverse Joints: These are further classified as:
   a) Expansion Joint
   b) Contraction Joint
   c) Warping Joint
   d) Construction Joint.

II. Longitudinal Joints.

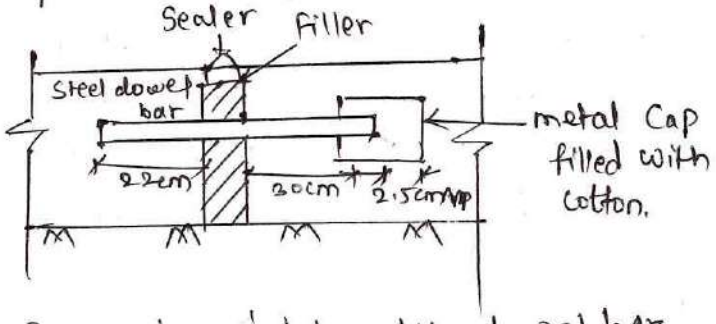




I. Transverse joints

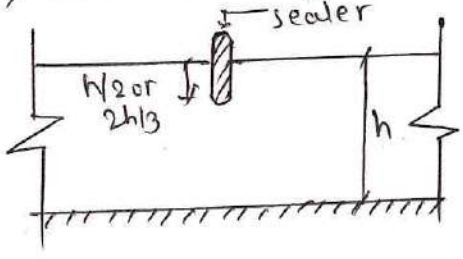
a) Expansion joints.

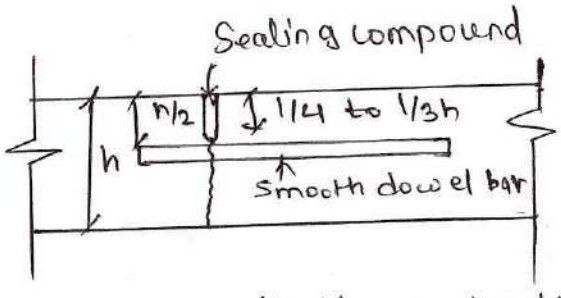
- These joint provided to allow for expansion of the slab due to rise temperature above construction temperature.
- This joints provided at interval 50 to 60m, in winter 90 to 120m for smooth interface laid in summer.
- load transference is affected through a system of dowel bars.
- Dowel bars are provided for expand pumpose it connected one end and other end is kept free.
- Metal cap is provided at this end to offer a space of about 2.5 cm of moremenets during expansion.
- In the design 40% of wheel load is expected to be taken up by the group of dowel bars.



Expansion joint with dowel bar.

b) Contraction joints



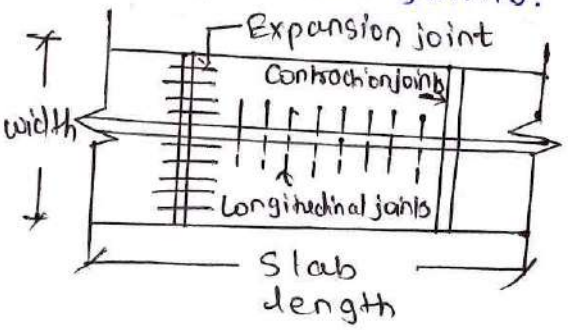


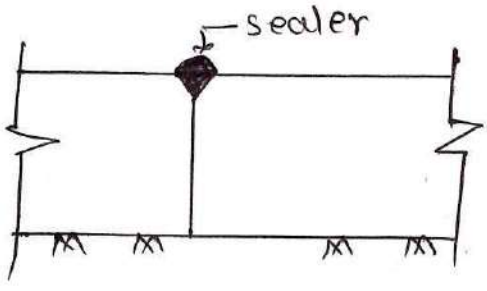
- Contraction joints are provided to permit the contraction of the slab.
- This are spaced closer than expansion joints.
- As per IRC Specification, the maximum spacing of contraction joints is unreinforced cement concrete slabs is 4.5 m and reinforced slab of thickness 20 cm is 14m.

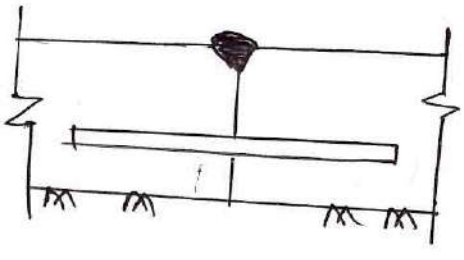
c) Warping joints.

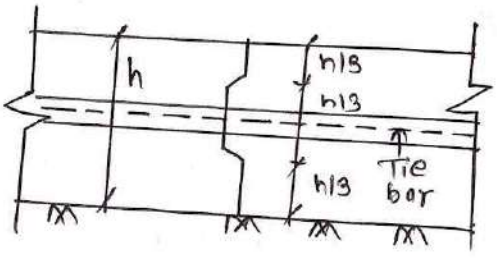
The warping joints are provided to relieve stresses included due to warping, this are known as hinged joints, longitudinal joints with the bars falls in this class of joint.

II. Longitudinal joints.









- Provided parallel to the center line of the road.
- Used when the pavement width is large.
- Prevent longitudinal cracking.
- A butt joint is the simplest longitudinal joint and is formed by painting the joint faces with bitumen.

Joint Filler and Sealer

- Joints forms the break in cement concrete pavement and these can allow the infiltration of water and ingress of stone grits.
- If grits enters into the joint space, effective width get reduced and faults like spalling of joint edges take place.
- Thus the joint spaces are first filled with compressible filler materials & Top of joint are sealed using a sealer.

1) Joint filler

The joint spaces are first filled with compressible filler materials called joint filler.

Joint filler should possess the following properties:

a) Compressibility

b) Elasticity

c) Durability

The filler material should be compressible and elastic it should be able to get compressed and release of the compression, should be able to regain its shape and be elastic.

Types of joint filler:

a) Softwood

b) Impregnated fibreboard

c) Cork or cork bounded with bitumen.

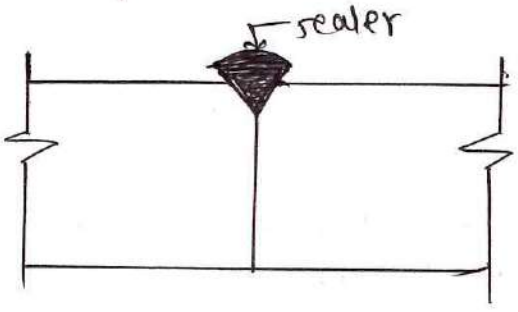
- The pressure required to compress the specimen to 50% of its original thickness should be between 7 to 53 kg/cm^2
- Materials should not show loss of its original weight by more than 3%.
- Specimen should recovery at least 70% of original thickness
- Extrusion of one edge should not be more than 6.5 mm when the specimen is compressed to 50% of its thickness with three edges restrained.

Joint Sealer

A joint sealer is a waterproof material placed at the top of the joint above the filler material.

- It seals the joint and prevents water and dirt from entering.

- Example of sealer material are bitumen & Rubber bitumen.



i) Adhesion to cement concrete slab.
ii) Extensibility without fracture
iii) Resistance to ingress of grit.
iv) Durability.

3.5 Components, Functions of Hill roads

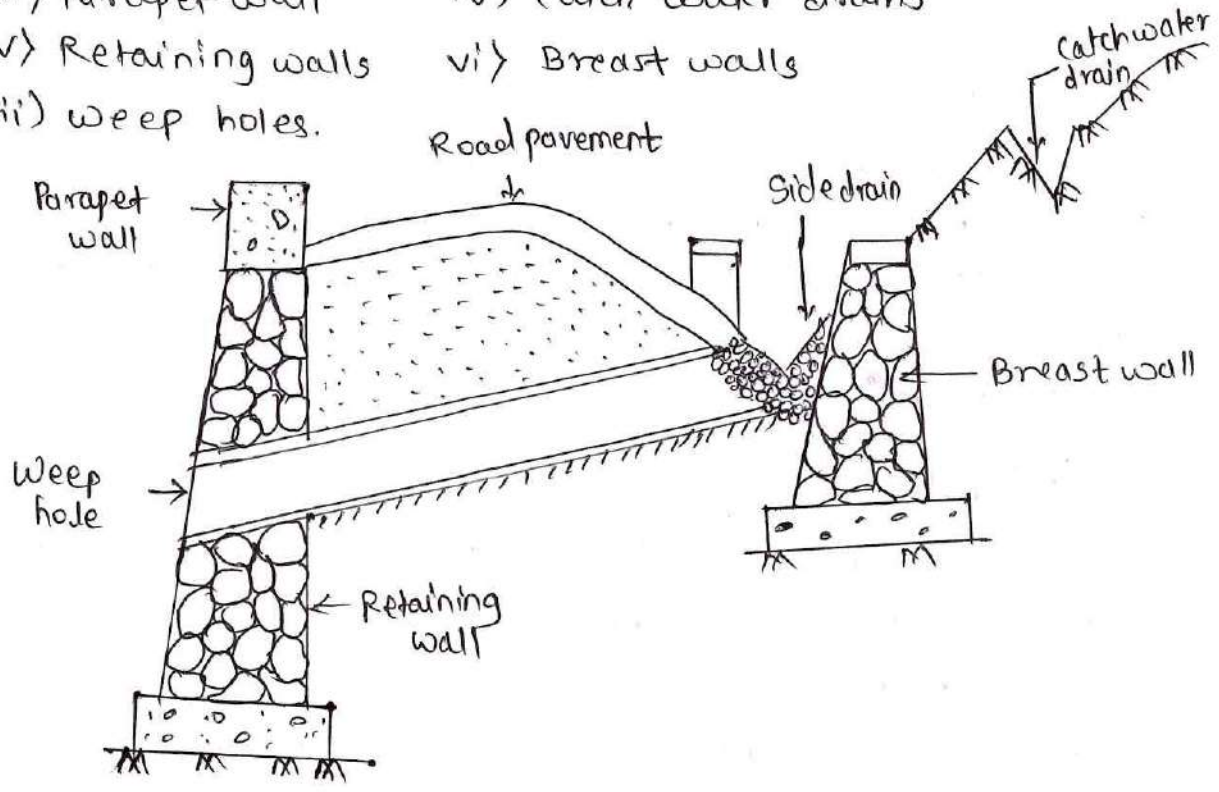
Hill Road →

A road which passes through a terrain with a cross slope of 25% or more is known as hill Road.

OR → The road constructed in mountainous regions of a country is known as hill roads.

components parts of hill Road

i) Road bed
ii) side drain
iii) Parapet wall
iv) Catch water drains
v) Retaining walls
vi) Breast walls
vii) weep holes.



i) Road bed →

Pavement and carriage way portion of hill road bed function, to resist the load safely, cause due to moving vehicles.

ii) Side drains →

The drains provided on the sides of the hill road is known as side drain.

iii) Parapet Wall →

Parapet wall provides protection of traffic against falling down the hill slope.

The wall provided above the formation level of hill road usually towards the down slope side.

iv) Catch water drain →

A drain provided higher up on the hill slope side, running parallel to the alignments of road are Catch water drain.

v) Retaining Walls. →

A walls which are constructed on the valley side of hill road is known as Retaining walls.

- It provides adequate stability to the hill road way and to the slope.

vi) Breast Wall →

Walls constructed to support the uphill slope of the road cross section is known as Breast walls.

- When the hill side is steep and there is tendency of its sliding down towards the road breast walls are constructed.

vii) Weep holes →

- The holes provided in a retaining wall, breast wall etc, to drain off the seepage flow are known as weep holes.
- To drain off the seepage flow.

Functions →

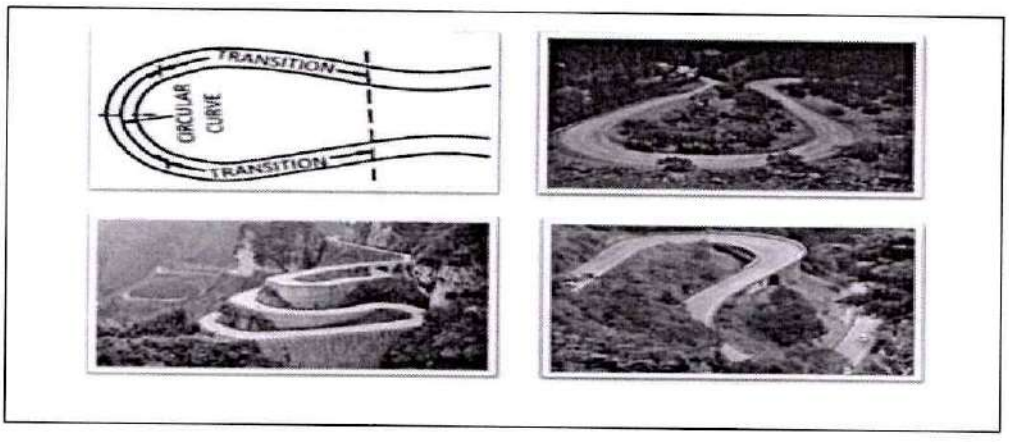
1. Transportation: Provide connectivity between villages, towns, and cities in hilly areas.
2. Economic development: Help in transporting agricultural products, goods & tourists.
3. Tourism development: Provide access to tourist destinations and hill stations.
4. Emergency Services: Enable movement of ambulances, fire services & rescue teams.
5. Social Connectivity: Connect remote areas with schools, hospitals & markets.

- **TYPES OF HILL ROAD CURVE**

1) Hair pin curve

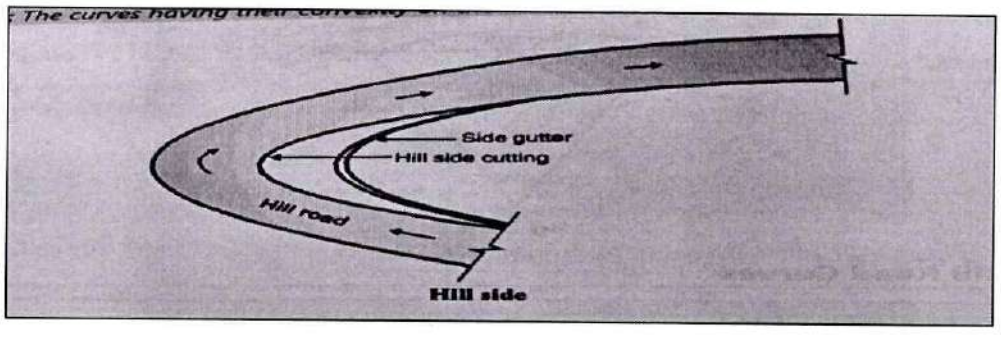
A **hairpin curve** or **hairpin bend** is a very sharp turn provided on a hill road where the road changes direction by nearly **180°**. It is used to help vehicles climb or descend steep slopes safely.

In simple words, a hairpin bend is a U-shaped curve on a mountain road that allows the road to gain height gradually instead of going straight up the hill.



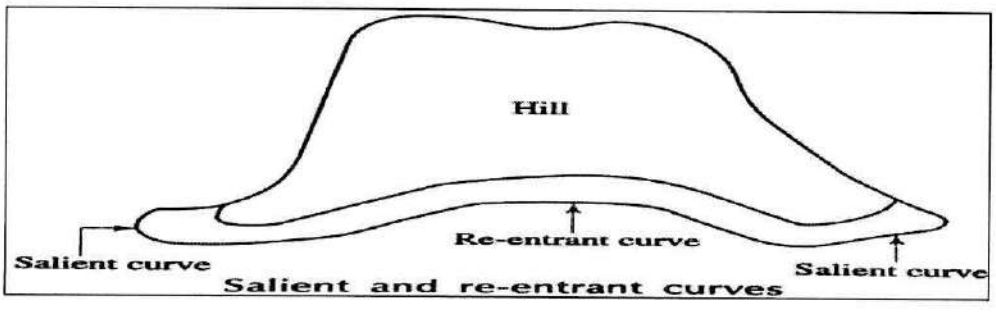
2) Salient Curve

The word **salient** means **projecting outward or prominent.** In general geometry or surveying, a salient point is a point that sticks outward from a boundary.



3) Re-entrant curve

A re-entrant curve is an **inward or concave curve** that looks like a valley.



Salient and re-entrant curves

3.6 Landslides: define, causes, Types, Preventation of landslides.

Landslides → The downward or upward movement of slope-forming materials such as natural rocks, soils, artificial fills etc. known as landslides.

Types of Landslides →

1) **Fall** → When there is free fall and rolling of rocks and debris down the hill a slope then called Fall.

2) **Slide** → A mass ~~or single~~ of soil or rock moves downward along a definite surface.

3) **Flow** → When there is the movement of the slope forming materials within the displaced mass then it is called flow.

4) **Complex landslides** →

When there is movement due to the combined effect of two or more types of landslides.

Causes of Landslides:

1) Heavy Rainfall:
- Rainwater enters the soil and reduces its strength.
- The soil becomes heavy and starts sliding.

2) Earthquakes:
- Ground vibrations loosen soil and rocks
- Slopes become unstable and collapse.

3) Deforestation
- Cutting trees removes root support
- Soil becomes loose & easily slides.

4) steep slopes
- very steep slopes are naturally less stable.
- Gravity pulls soil & rocks downward.

5) Mining & Excavation
- Cutting hills for roads, tunnels, or mining weakens slopes.

6) Poor drainage
- Accumulation of water increases soil weight
- Excess water reduces soil strength.

7) Weathering of Rocks
- Rocks breaks into smaller pieces over time.
- Weak rocks cannot support the slope properly.

Prevention and control of land slides.

1) Afforestation
- Planting trees and vegetation on slopes.
- Roots hold the soil together
- Reduces soil erosion

2) Proper drainage
construct drains to remove excess water.
- Prevents water accumulation.
- Maintains soil strength.

3) Retaining Walls.
Walls built to support on slopes.
- Prevents soil movement
- Increases slope stability.

4) Slope stabilization.
Reduce steepness of slopes by proper cutting & grading
- decreases the chance of slope failure.

5) Rock bolts & Wire mesh.
steel bolts and wire mesh are used on rocky slopes.
- Hold loose rocks in place.
- Prevent rock falls.

6) Controlled Construction Activities.
Avoid excessive excavation and blasting.
- Maintains natural slope stability.

Unit - III Construction of Road Pavements

1. State the components of hill road.
2. State causes of landslide.
3. Write the names of road construction material and their sources and use.
4. State the different types of tests carried on an aggregates which are used for pavement construction.
5. Differentiate Rigid and flexible pavement. (Minimum 08 point of difference)
6. Draw a neat labelled cross-section of a hill road.
7. State the causes of failure of flexible road pavement with sketch.
8. Expain Flash point and Fire point of bitumen and draw neat sketch of penetrometer used in bitumen testing.
9. Define Land Slides, Explain causes of landslides and preventive measure of landslides.
10. State any four failures in rigid pavements.
11. Enlist any six situations where flexible pavement is adopted.
12. Explain construction of WBM road.
13. Illustrate the construction methods of Cement concrete road in respect to :
    (i)Alternate Bay Method (ii) Continuous Bay Method
14. Explain components parts of road pavement with respect to :
    (i)Wearing course (ii) Base Coat (iii) Base Course (iv) Sub-base course
15. Draw a neat sketch of cross section of Hill Road and label the following components : (i)Breast wall (ii) Parapet wall (iii) Retaining wall (iv) Catch water drain (v) Road pavement (vi) Side drain
16. Explain cement concrete road joints with necessary sketch in respect to : (i) Expansion joints (ii) Contraction joints (iii) Warping joints (iv) Construction joints (v) Longitudinal joints (vi) Dowel bar