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**The**  
**Note's On**  
**Highway Engineering-II**

# Syllabus:

## Unit-1 Road Pavement: [2 Hours]

- 1.1 Definition, types, difference between flexible and rigid pavements
- 1.2 Different layers in pavement structures and their functions.

## Unit-2 Hill Roads: [7 Hours]

- 2.1 Definition, importance of hill roads in Nepal
- 2.2 Design and construction problems in hill roads
- 2.3 Special consideration of hill road geometric design
- 2.4 Typical cross-sections of hill roads.
- 2.5 Special structures in hill roads like retaining walls, revetment walls; toe wall, slope protection works

## Unit-3 Road Machineries: [3 Hours]

- 3.1 Methods of road construction (labor based, machine based.)
- 3.2 Different types of tools, equipments and plants
- 3.3 Different types of compacting equipments.

Apps

## Unit-4 Road Construction Technology: [18 Hours]

- 4.1 Introduction
- 4.2 Activities involved in road construction:
  - 4.2.1 - Earthwork
  - 4.2.2 - Drainage work
  - 4.2.3 - Pavement work
  - 4.2.4 - Protection works
  - 4.2.5 - Miscellaneous works
- 4.3 Earthwork:
  - 4.3.1 - Introduction
  - 4.3.2 - Purpose
  - 4.3.3 - Earthwork in embankment/excavation.
  - 4.3.4 - Relation of optimum moisture content and maximum dry density
  - 4.3.5 - Field control of compaction and test required for field control.

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- 4.4 Construction of earthen road: Introduction, materials required, equipment required, construction procedure.
- 4.5 Construction of gravel roads: Introduction, materials required, equipment required, construction procedure.
- 4.6 Construction of soil stabilized roads: Introduction to soil stabilization, types of soil stabilization, mechanical stabilization of soil (materials, equipment, construction procedure)
- 4.7 Construction of Water Bound Macadam (WBM) Roads: Introduction, materials required, equipment required, construction procedure.
- 4.8 Construction of bituminous roads: Introduction, types of bituminous surfacing, interface treatment (prime coat, tack coat), seal coat, function of each coat
- 4.9 Surface dressing: types (single, double), materials required, equipment required, construction procedure
- 4.10 Grouted macadam: types (full, semi), materials required, equipment required, construction procedure.

Apps

**Unit-5 Highway Maintenance and Repair: [9 Hours]**

- 5.1 Introduction
- 5.2 Types of maintenance activities
- 5.3 Maintenance of earth roads, gravel roads, WBM roads
- 5.4 Maintenance of bituminous roads (pot hole, patch repair works, crack sealing, edge repairing, resurfacing)
- 5.5 Maintenance of drainage structures
- 5.6 Maintenance of Miscellaneous road structures (shoulder, slope, retaining structures, road furnitures).

**Unit-6 Bridge: [6 Hours]**

- 6.1 Introduction:
  - 6.1.1 - Definition
  - 6.1.2 - Classification based on span, length, loading materials and structures.

6.2 T-beam bridge :

6.2.1 - Essential elements

6.2.2 - Detail of super-structure and sub-structure

6.3 Suspension bridge :

6.3.1 - Introduction

6.3.2 - Components and their functions

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# Unit-1 Road Pavement

## # Definition of Road Pavement:

↳ Road pavement is a specified space required for the movement of traffic/vehicle below, at or above the ground level. The space required by the road pavement is considered in longitudinal as well as transverse direction to enable the fast moving vehicles to move safely and comfortable at the design speed.

↳ The main function of pavement is to support and transfer the wheel load of vehicles over a wider area on underlying the subgrade soil.

## # Types of Road Pavement:

↳ Based on the structural behaviour, the road pavement are generally classified into following three types:

① Flexible pavement

② Rigid pavement.

③ Semi-rigid pavement

### ① Flexible Pavements:

↳ The pavement which have negligible flexural strength but flexural in their structural action under the loads are known as flexible pavements.

↳ The lower layer of flexible pavements reflect the deformations upto the surface of the layer. So, if there is undulation in sub-grade, flexible pavements also get undulated.

↳ The flexible pavement layers transmit the vertical compressive stresses to the lower layers by grain to grain transfer through the points of contact.

↳ The vertical compressive stress is maximum on the pavement surface directly under the wheel loads and decreases successively to lower layers.

↳ Therefore, quality of materials from top layer to bottom layers also decreases corresponding to resulting stress to minimize cost of road.

↳ It is made of local soil, gravel and bituminous materials.

## ① Rigid Pavements:

- ↳ 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 a cement concrete slab, below which a granular sub-base or base course over sub-grade soil.
- ↳ The rigid pavements are normally analyzed and designed based on elastic theory assuming the pavement as an elastic plate resting over an elastic or viscous foundation.
- ↳ The plain cement concrete are expected to take up above  $40 \text{ kg/cm}^2$  flexural stress.

## ② Semi-rigid Pavements:

- ↳ The pavement which have flexural strength in between rigid and flexible pavements are known as semi-rigid pavements.
- ↳ It is made of lean cement concrete, soil cement or pozzolanic concrete.
- ↳ The semi-rigid pavements have low resistance to impact and abrasion. The semi-rigid pavements can also be constructed by using intermediate class of material as sub-base or base course.

## ✓# Difference between Flexible and Rigid Pavement:

S.N.	Flexible Pavement	Rigid Pavement
1.	Initial cost is less.	→ Initial cost is more.
2.	Maintenance cost is more	→ Maintenance cost is less.
3.	The life of well designed pavement is about 20 years.	→ The life of well designed pavement is about 40 years.
4.	It can be done in stage construction.	→ It can be done at a time.
5.	The characteristics of pavement surface is worse as compared to rigid pavement.	→ The characteristics of pavement surface is good as compared to flexible pavement.
6.	Design of pavement is done with less accuracy.	→ Design of pavement is done with accuracy.

### ✓ ✕ Typical cross-section of Flexible pavement:

↳ A typical flexible pavement consists of four components

- ① Sub-grade
- ② sub-base course
- ③ Base course
- ④ Surface course (wearing course)

↳ A typical cross-section of flexible pavement is shown in figure below:

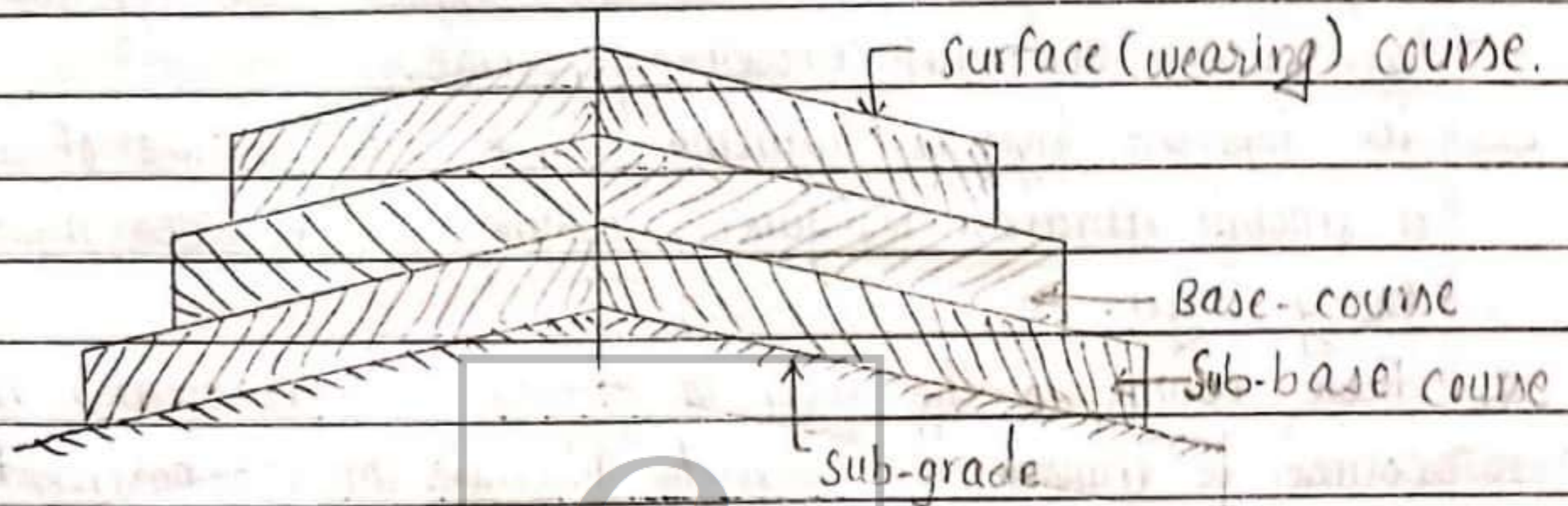


Fig:- structure of a flexible pavement.

### ✓ ✕ Typical cross-section of Rigid pavement:

↳ A typical rigid pavement consists of following three components:

- ① Sub-grade
- ② Base course
- ③ Cement-concrete slab (R.C.C. slab).

↳ A typical cross-section of rigid pavement is shown in figure below:

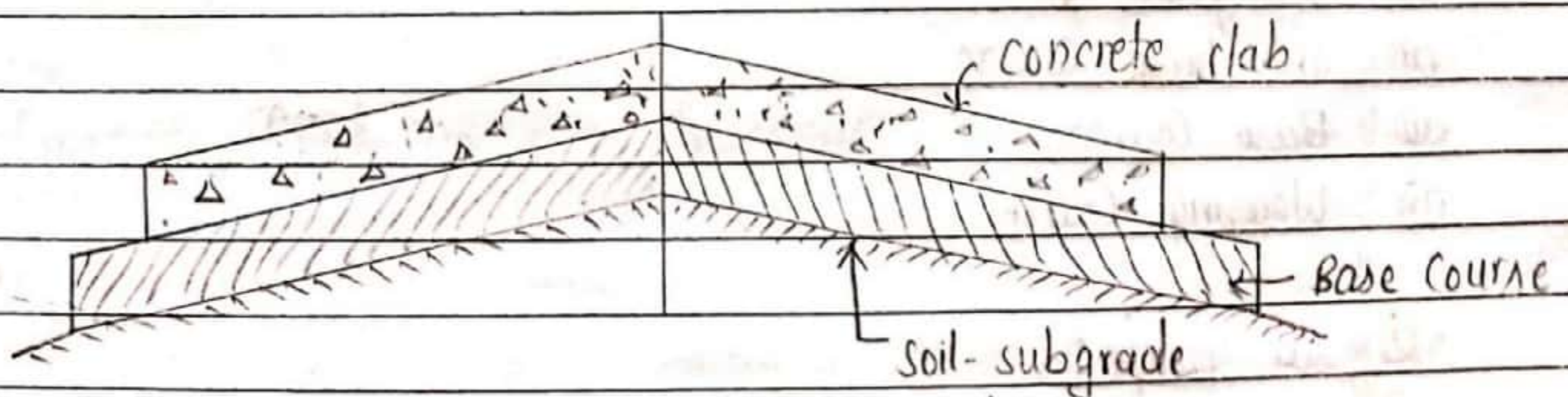


Fig:- structure of Rigid pavement.

## # Layers of pavement structures:

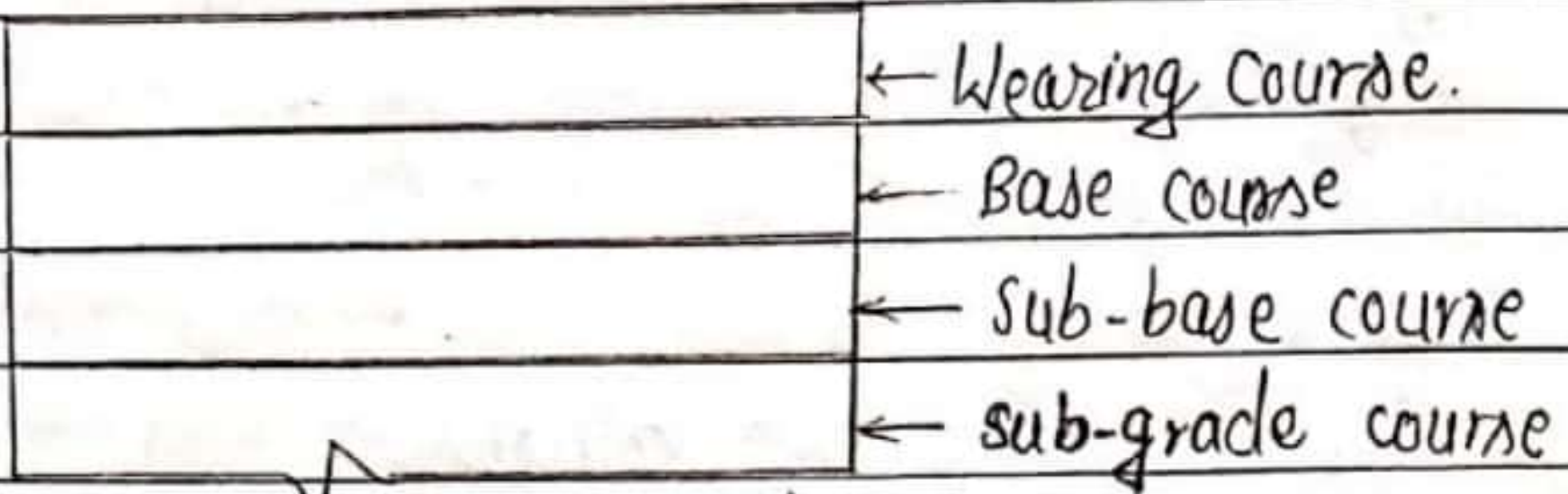


Fig:- Layers of Pavement

- ↳ A pavement consist of one or more layers normally sub-grade, sub-base, base course and surface/wearing course.
- ↳ The topmost layer is surfacing course, the purpose of which is to provide a smooth, abrasion resistance, resisting surface water infiltration and a strong layer.
- ↳ Base course is the layer of graded materials located below the wearing course to transfer the stress to subgrade through pavement sub-base.
- ↳ The aggregate or gravel located between pavement sub-grade and base course to provide additional support in the distributing stress is called sub-base.
- ↳ Sub-grade stress is an integral part of road pavement as it provide the support to the pavement from beneath.

## # Function of pavement Components / Component Parts:

↳ A road pavement consists of the following components:

- (i) Sub-grade
- (ii) Sub-base Course
- (iii) Base Course
- (iv) Wearing Course

### (i) Sub-grade:

- ↳ Sub-grade is a layer of natural soil or filled soil prepared to receive the pavement materials over it.
- ↳ Functions of sub-grade is to transfer the entire load coming to it to the earth mass and to provide a good support to the pavement structure.

- ↳ It is always essential that the stress transmitted to the top of the sub-grade should not exceed to any time beyond the allowable limit.
- ↳ To avoid any deformation of the sub-grade at least the top 50cm, layer of the soil is well compacted under controlled conditions of optimum moisture content and maximum dry density.
- ↳ The strength properties of the soil sub-grade is necessary to evaluate. The following tests on soil are carried out to findout its strength:

- CBR Test: [California Bearing Ratio]
- Triaxial Compression Test
- Plate load test
- California resistance value test.

### ① Sub-base Course:

- ↳ Sub-base course is a layer of pavement material provided between sub-grade and base course.
- ↳ It is provided as an additional layer when the sub-grade is poor quality. It consists of broken stones, slag, broken burnt bricks etc. At the sub-base course it is desirable to use small sizes aggregates for proper interlocking.
- ↳ It has following functions:
  - It improves the bearing capacity of soil sub-grade.
  - It checks the capillary rise of sub-soil water.
  - It prevents the sub-grade materials from working up into base course.
  - It eliminates ~~front~~ heave in front affected area.

### ② Base Course:

- ↳ Base course is a layer of pavement material between surface course and sub-base course. Generally large size particles like boulders, bricks etc are used as base course.
- ↳ This course is considered as the most important component of pavement structure because it has to bear the impact of traffic transferred through the wearing course.

↳ It has following functions:

- ① It acts as foundation for the road pavement and transfers the traffic load to the sub-base course.
- ② It withstands the high shearing stress imposed upon it due to impact of traffic on the wearing course.

#### (iv) Wearing Course (Surface Course):

↳ Wearing course is the topmost layer of the pavement structure. In flexible pavement normally a bituminous surfacing is used as a wearing course and in rigid pavements the cement concrete acts like a base course as well as wearing course.

↳ It has following functions:

- ① It provides smooth and dense riding surface.
- ② It resists pressure exerted by tyres.
- ③ It takes up wear and tear due to the traffic.
- ④ It provides a water tight layer against infiltration of surface water.

Apps

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# Unit-2 Hill Roads

## # Introduction:

The terrain having cross-slope of more than 25% comes under hilly terrain. The road laid in the area having cross-slope of 25% or more is called hill road.

## # Design and Construction Problem in Hill Roads:

Design and Construction of road in hill ~~and~~ mountains is more complex task than in plains. It is because the several factors associated with regions. Some of includes them:

- (i) A hilly or mountainous area is characterized by a hilly broken relief with widely differencing elevation steep slope. This may cause unnecessary increase in the length of the road.
- (ii) The formation of rock differs in a wide range. The geological condition varied from spot to spot or place to place. This will make difficult to across the foundation and find suitable one for the road embankment and other structure.
- (iii) New earth fill for road embankment may overload the relatively weak underlying soil type on hill slope.
- (iv) Due to presence of high cross slope, surface runoff reaches quickly to the road sides with high speed.
- (v) Design of hair pin bends and to gain highly.
- (vi) Frequent blasting is required due to the presence of hard rock.
- (vii) Filling may overload the weak soil underneath which may trigger new slides.

[20+3]

## # Special Considerations in geometric design of Hill roads:

↳ Special considerations in geometric design of hill road are as follows:

### (A) Route Location and Alignment Survey:

#### (a) River Route:

↳ Location of route along a river valley is called river route.

#### • Advantages:

- (i) Gentle gradient.
- (ii) Vehicle operation cost is low.
- (iii) Availability of water and other constructive materials can be used from riverside.

#### • Dis-advantages:

- (i) It involves number of curves.
- (ii) Construction of large number of bridges.
- (iii) High earthwork.
- (iv) Necessary speed structure construct.

#### (b) Ridge Route:

↳ The location of route along top of hill is called ridge route.

#### • Advantages:

- (i) Less curves.
- (ii) More service to people of hilly side.
- (iii) Short length of road.
- (iv) Less retaining structure.

#### • Dis-advantages:

- (i) Steep gradient.
- (ii) No service to people of other side of river.
- (iii) Less availability of construction materials.

2015  
2010  
2013

## ② Typical Cross-section of hill roads:

### Ⓐ Partly in cutting and partly in filling:

↳ When cross-slope of the hill is not very steep, the best selection of road shall be partly in cutting and partly in filling. Usually in this type of formation, the best selection of road shall be  $\frac{2}{3}$  in cutting and  $\frac{1}{3}$  in filling.

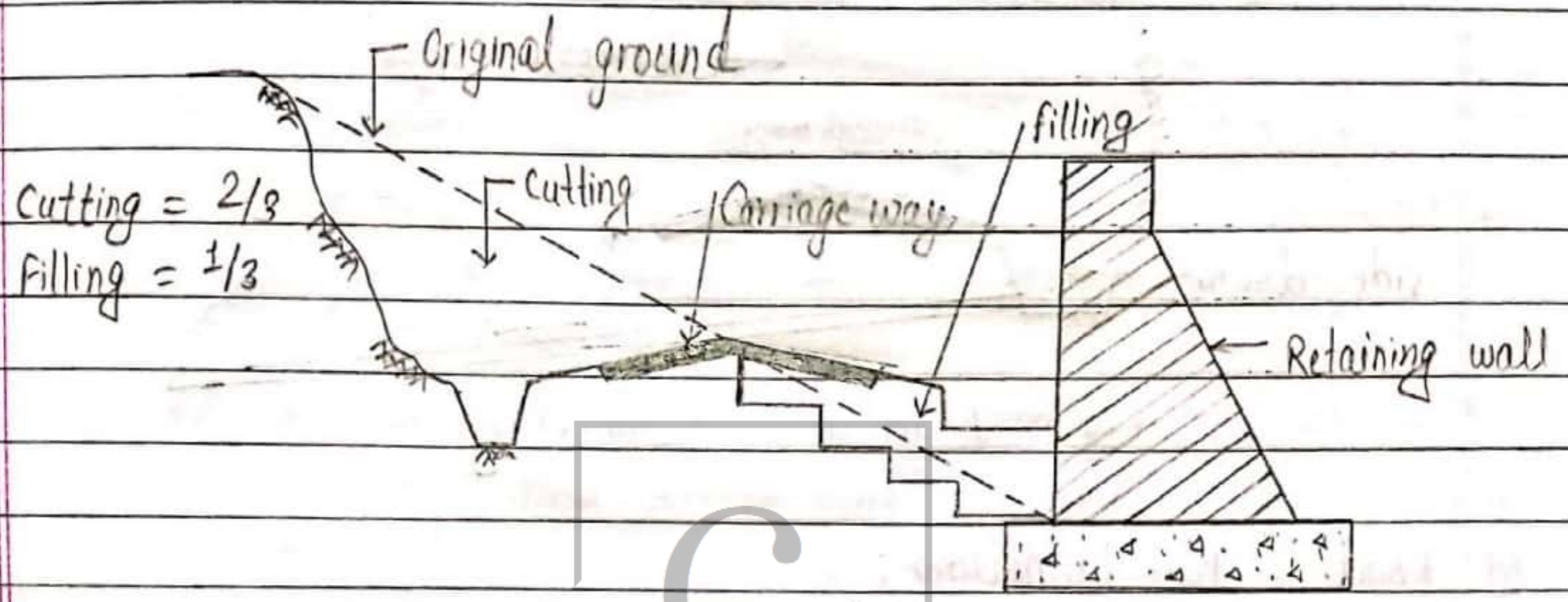


Fig: Partly in cutting and partly in filling

### Ⓑ Road Completely in Cutting:

↳ The selection of a hill road completely in cutting is shown in figure. When the cross-slope of the hill is very steep, the road is located in full cutting.

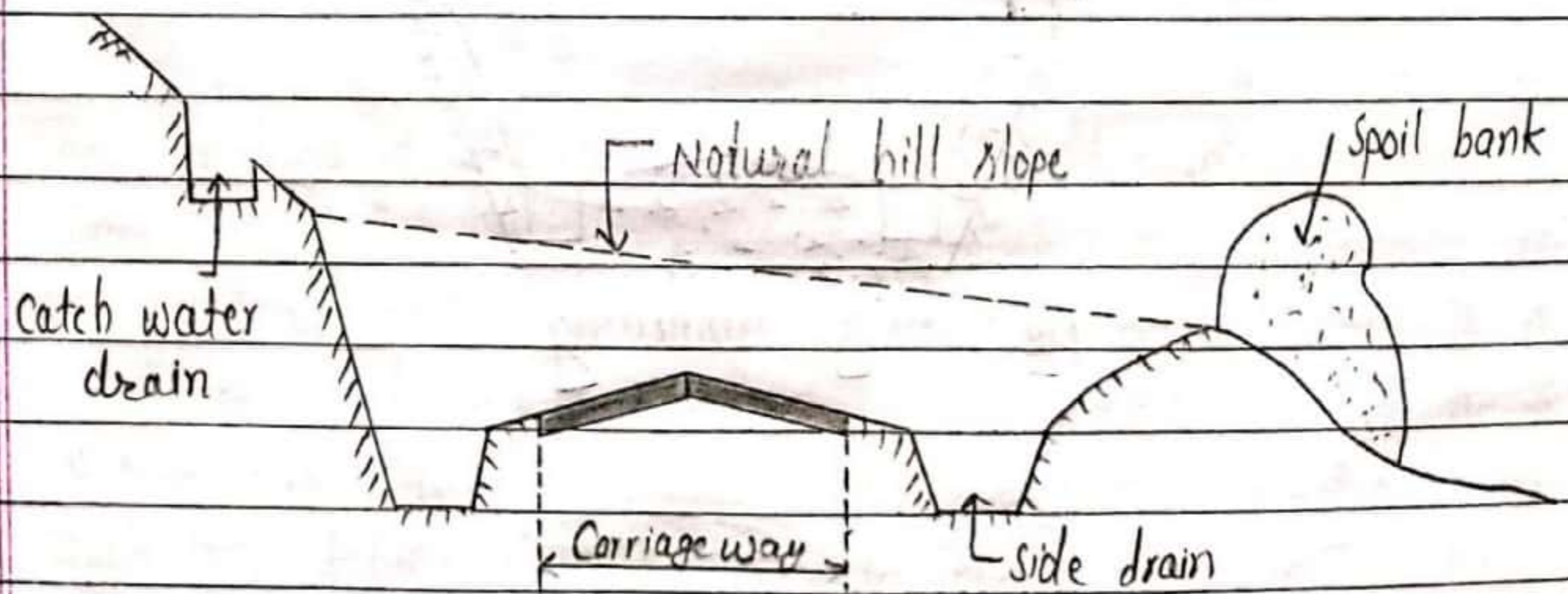


Fig: Section of hill road completely in cutting

© Road in half Tunnelling:

↳ The section of hill road in half tunnelling is shown in figure. If along with steep slope hill side is sound and solid, road can be constructed in half tunnelling.

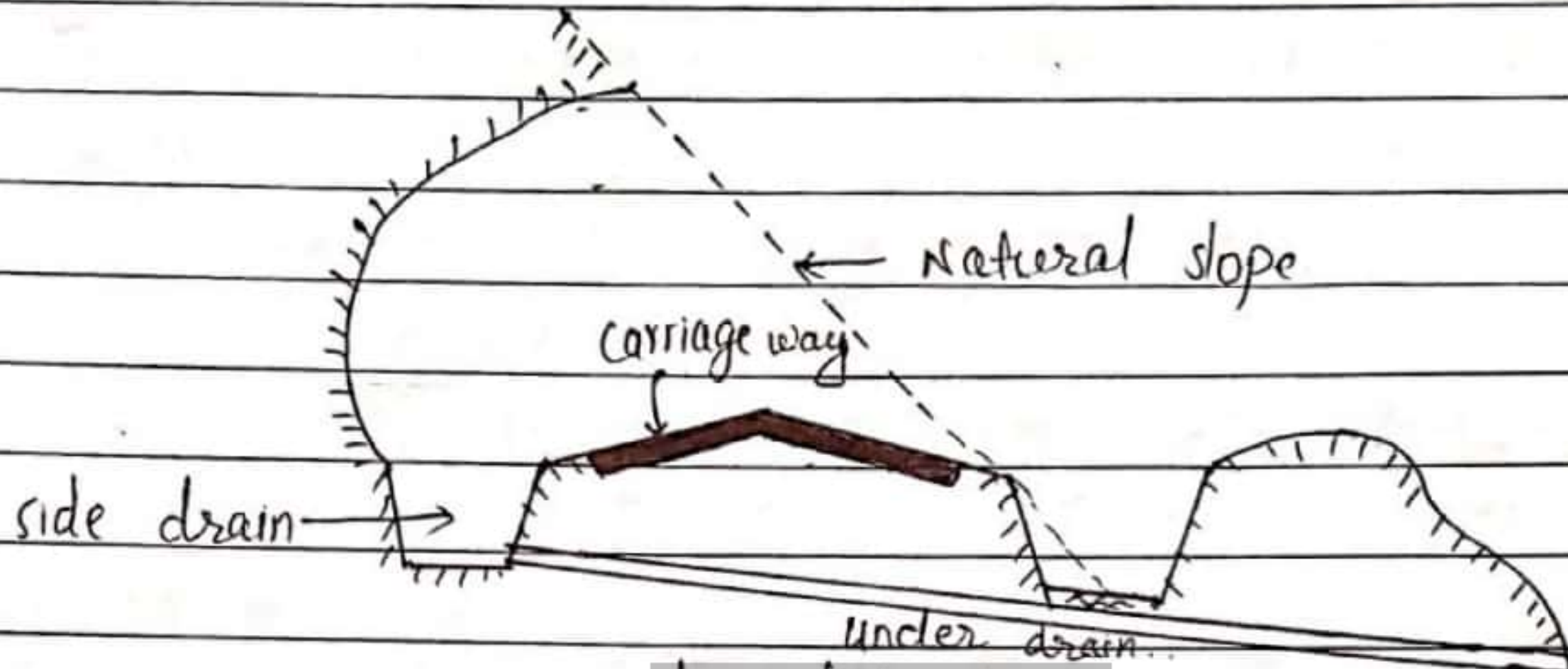


Fig: Road in half tunnelling

© Road in full Tunnelling:

↳ The section of hill road in full tunnelling is shown in figure. This is constructed when there is no other alternative for the economy of hill road project.

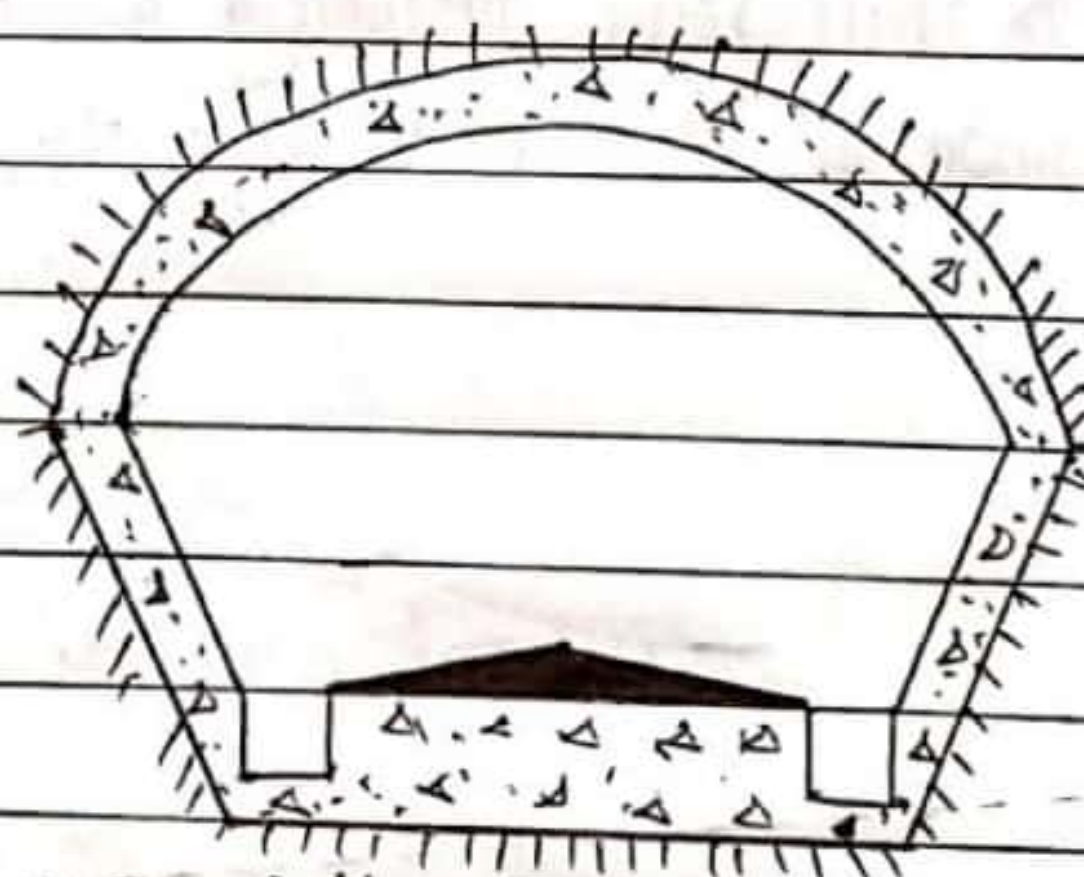


Fig: Fully Tunnelling

Text Notes

### ③ Road fully in Embankment:

↳ The road section fully in embankment is shown in figure. This type of construction is done when cross-slope of a hill is very small. In case of heavy filling retaining wall are constructed in both sides of a road.

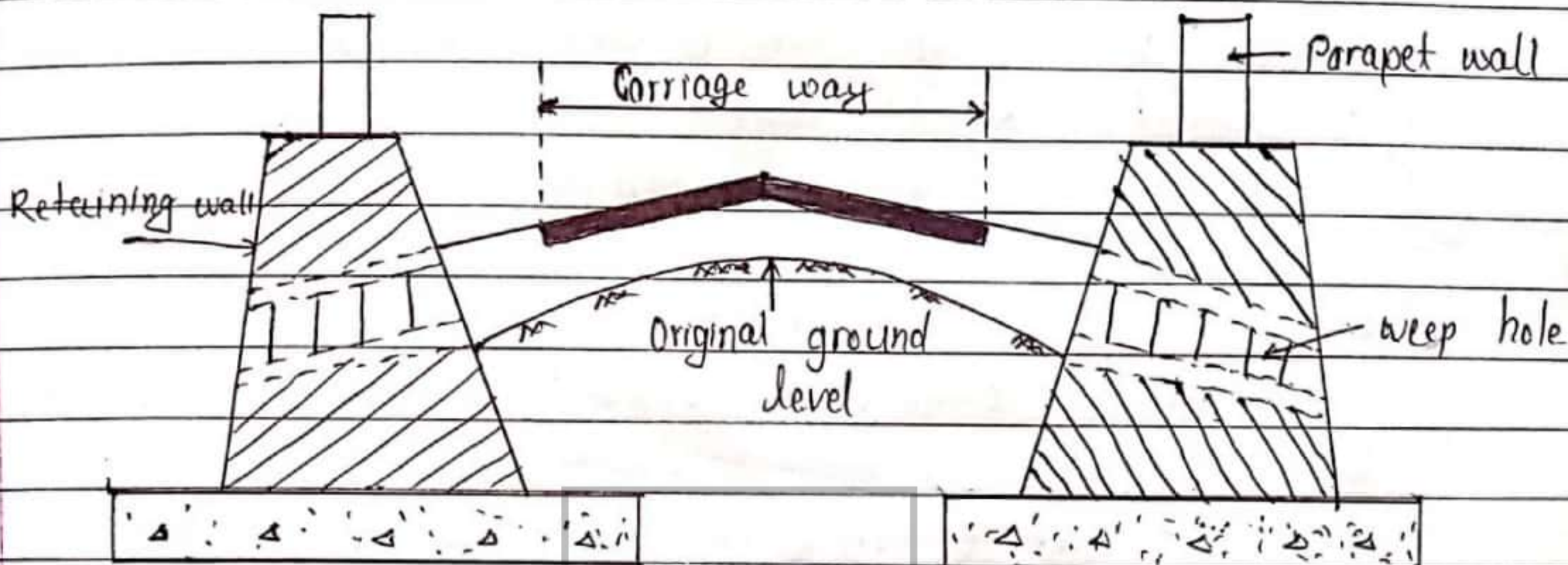


Fig.: Road section fully in cutting

### ③ Geometric Design of Hill Roads:

#### (a) Gradient:

↳ The gradient for the given section of road is normally selected maximum one in order to reduce earthwork and route length. But, the method of establishing maximum gradient according to power output is not accurate for the high altitude hill roads.

#### (b) Camber:

↳ The recommended value of camber for hill roads are given below:

S.N.	Types of Surface	Camber (%)
1	Sub-gradient, earth road and shoulders	3.0 to 4.0
2	Gradient and W.B.M surface	2.5 to 3.0
3	Bituminous Surfacing	2.5
4	High types bituminous surface and Cement Concrete	2.0

### ① Sight Distance:

↳ The sight distance is calculated from the relations

- for stopping sight distance:

$$S.S.D = 0.278 Vt + \frac{V^2}{254f} \quad \text{--- (i)}$$

Where,  $V$  = design speed of vehicle (km/hr)

$t$  = Reaction time

$f$  = Coefficient of friction (0.4 taken)

- For overtaking sight distance:

$$O.S.D = 0.556 V_b + 0.278 V_b T + 2S + 0.278 VT \quad \text{--- (ii)}$$

Where,

$V$  = Speed of overtaking vehicles (km/hr)

$V_b$  = Speed of overtaken vehicles  
=  $(V - 16)$  km/hr.

$S$  = Spacing of moving vehicles  
=  $(0.2 V_b + 6)$  m.

$T$  = Overtaking time =  $\sqrt{\frac{14.4S}{A}}$

$A$  = Acceleration in kmph/sec.

### ② Super elevation:

↳ The super elevation to be provided at horizontal curve of hill roads is calculated from the relation;

$$e = \frac{V^2}{225R} \quad \text{--- (iii)}$$

Where,

$V$  = design speed (kmph)

$R$  = Radius of curve (m)

### e) Radius of Horizontal Curves:

↳ The radius of horizontal curves in hill roads (minimum) is calculated by the formula:

$$R_{\min} = \frac{0.008 v^2}{e + f} \quad \text{--- (iv)}$$

Where,  $R$  = radius of curve (minimum) - m.

$e$  = super elevation

$v$  = design speed (kmph)

$f$  = coefficient of friction.

### f) Widening of curves:

↳ Extra width of carriage way ( $W_e$ ) at horizontal curve is calculated from the relations:

$$W_e = \frac{18n}{R} + \frac{0.1v}{\sqrt{R}} \quad \text{--- (v)}$$

Where,  $n$  = number of lanes.

Apps

### g) Set Back Distance: *Ctevt Notes*

↳ It is not possible to provided visibility corresponding to overtaking sight distance all along the hill roads; the alignment is made 30m as to provide at least the safe stopping sight distance.

### h) Transition Curves:

↳ The length of Transition curve is to be calculated from the formula:

$$L = \frac{0.0215 v^2}{CR} \quad \text{--- (vi)}$$

$$C = \frac{80}{v + 57} \quad \text{--- (vii)}$$

Where,  $L$  = length of transition curve (m)

$R$  = radius of transition curve (m)

$v$  = Design speed (kmph)

$C$  = Constant.

### ① Hairpin bends:

↳ In aligning a hill road, it becomes necessary to attain height at a particular location without substantial covering of horizontal distance. In such cases hairpin bend is provided. When developing a route in hilly areas, it is frequently necessary to insert sharp turning angle with in which very difficult and sometimes even impossible to layout curves following normal geometric standard of design.

↳ When inscribing a curve inside turning angle the length of route will be substantially reduced. Such result in steep gradient. In such circumstances it is preferable to round off the route not by inscribing but by circumscribing the curve round the turning point. Such compound curves are called hair pin bends or reverse loops.

### # Design Criteria for Hair-Pin Bends:

- ① Maximum design speed  $\rightarrow$  20 kmph.
- ② Maximum radius of inner curve  $\rightarrow$  14m
- ③ Maximum length of transition curve  $\rightarrow$  15m.
- ④ Gradient - max  $\rightarrow$  1 in 40  
- min  $\rightarrow$  1 in 200.
- ⑤ Super-elevation - 1 in 10.

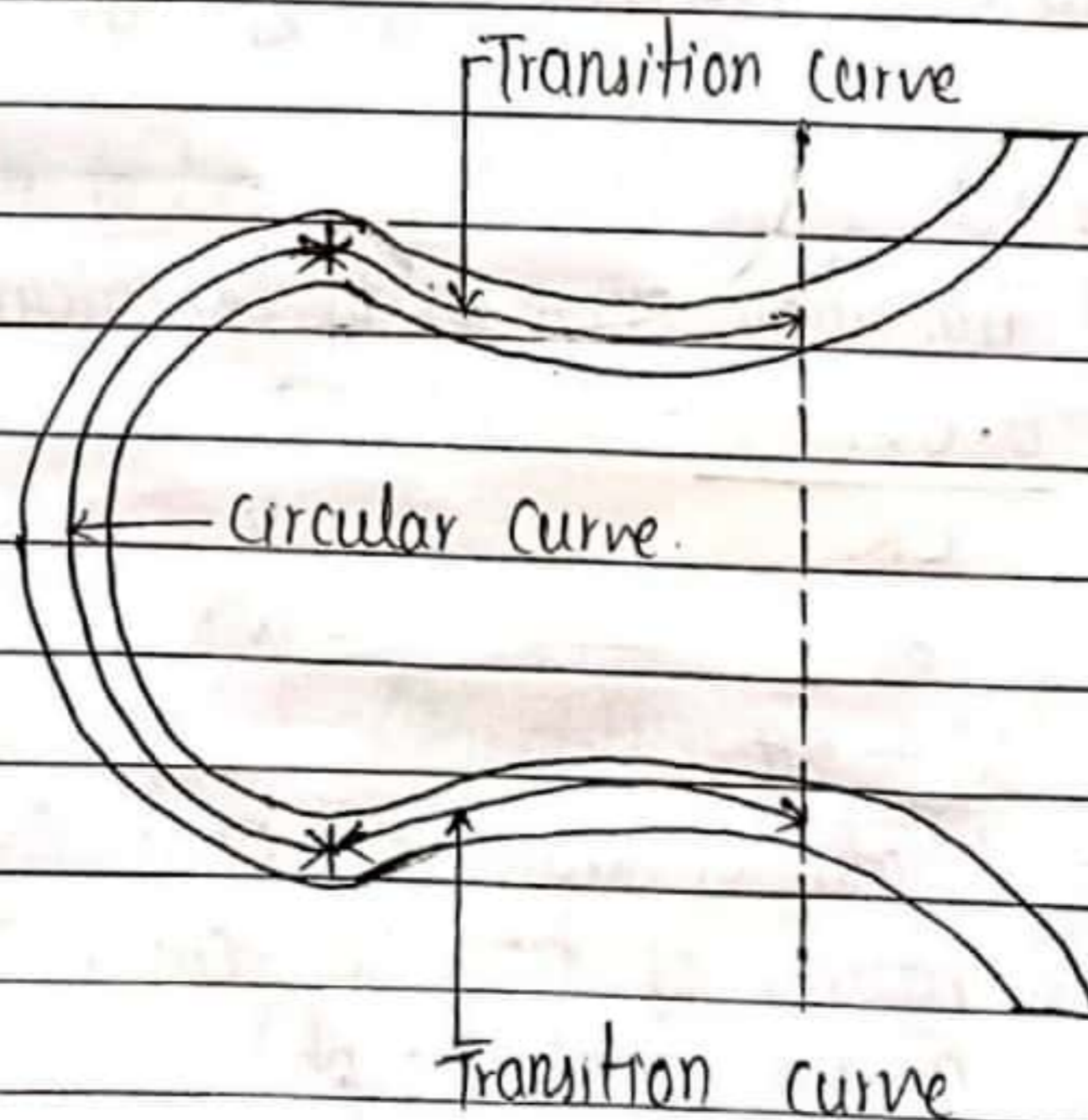


Fig: Hair pin bends

**④ Special Structures in Hill Roads:**

**Ⓐ Retaining Wall:**

- ↳ Retaining wall are needed to retain the fill portion of highway
- ↳ A retaining structure is usually a wall constructed for the purpose of supporting or retaining a vertical earth bank.
- ↳ It is constructed on the valley side of a roadway, also hill side used.
- ↳ They are also provided to retain earth for elevated and depressed road where the embankment slope cut, slope can't extant beyond the roadway.

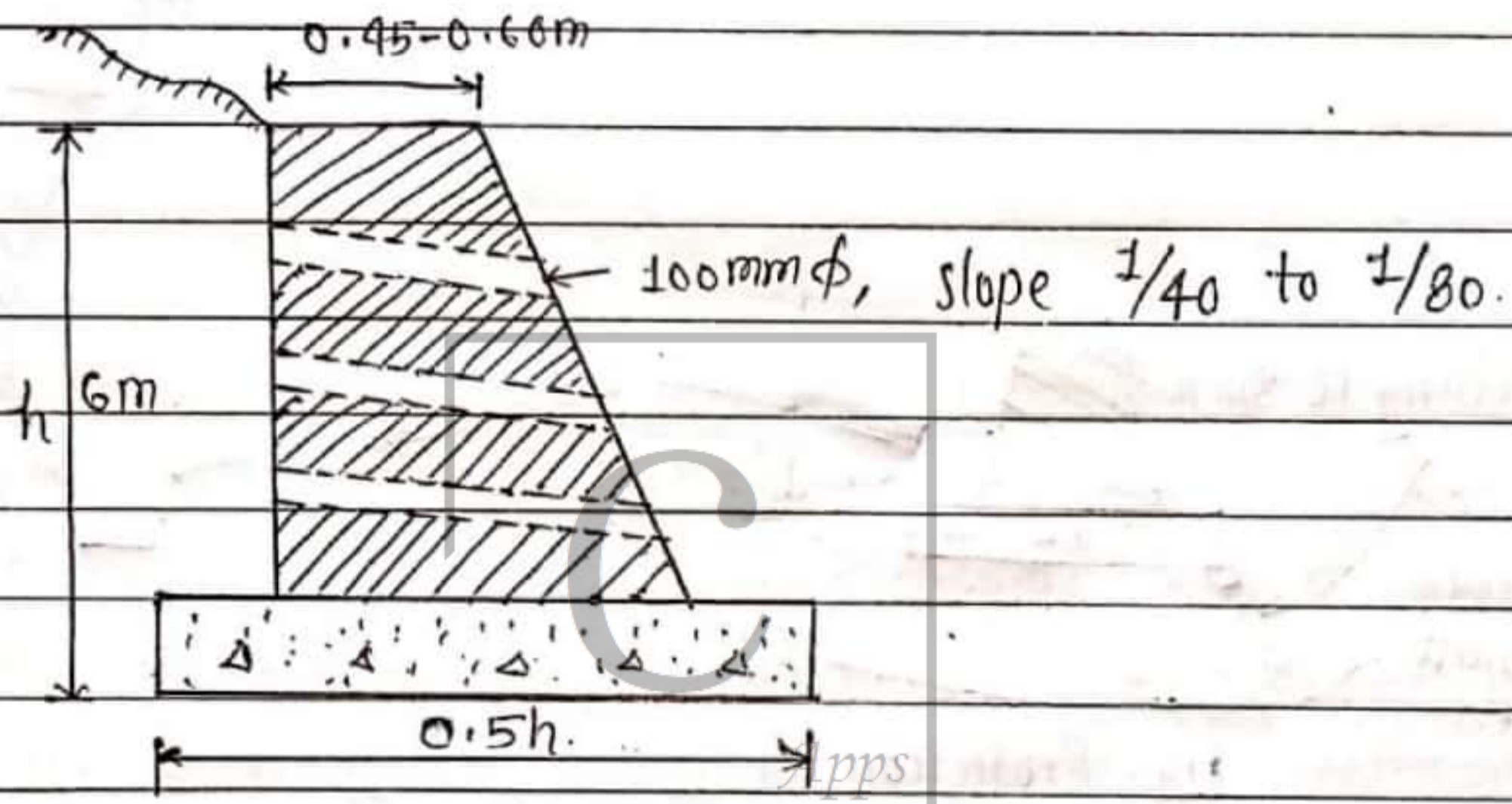
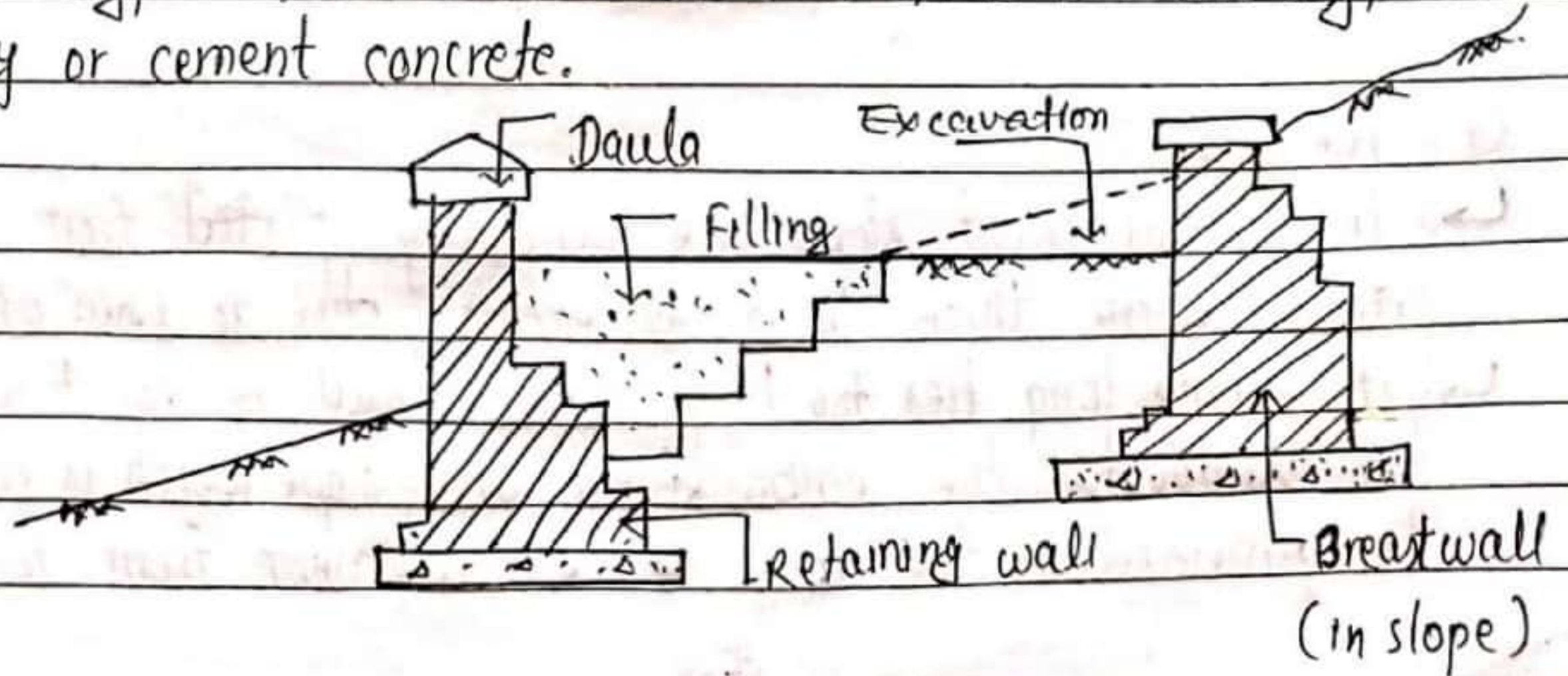


Fig: Retaining wall

**Ⓑ Breast Wall:**

- ↳ The wall constructed on the uphill side of roadway in order to retain earth from slippage is called breast wall.
- ↳ The top width of breast wall should be 600mm thick and should have number of weep holes to release the water pressure at the back of wall. This types of wall is constructed of stone masonry, brick masonry or cement concrete.



Breast wall (in slope)

[2073]

③ **Revetment Wall:**

- ↳ When the cutting slope is too steep and contain loose or scabble soils, super of slope in the form of wedge or any other form may occur. To pavement this dry masonry is constructed to retain the soil on the cutting side.
- ↳ By this slippery action of the skills on slopes is prevented. These dry masonry provided on the cutting slope is called revetment wall.

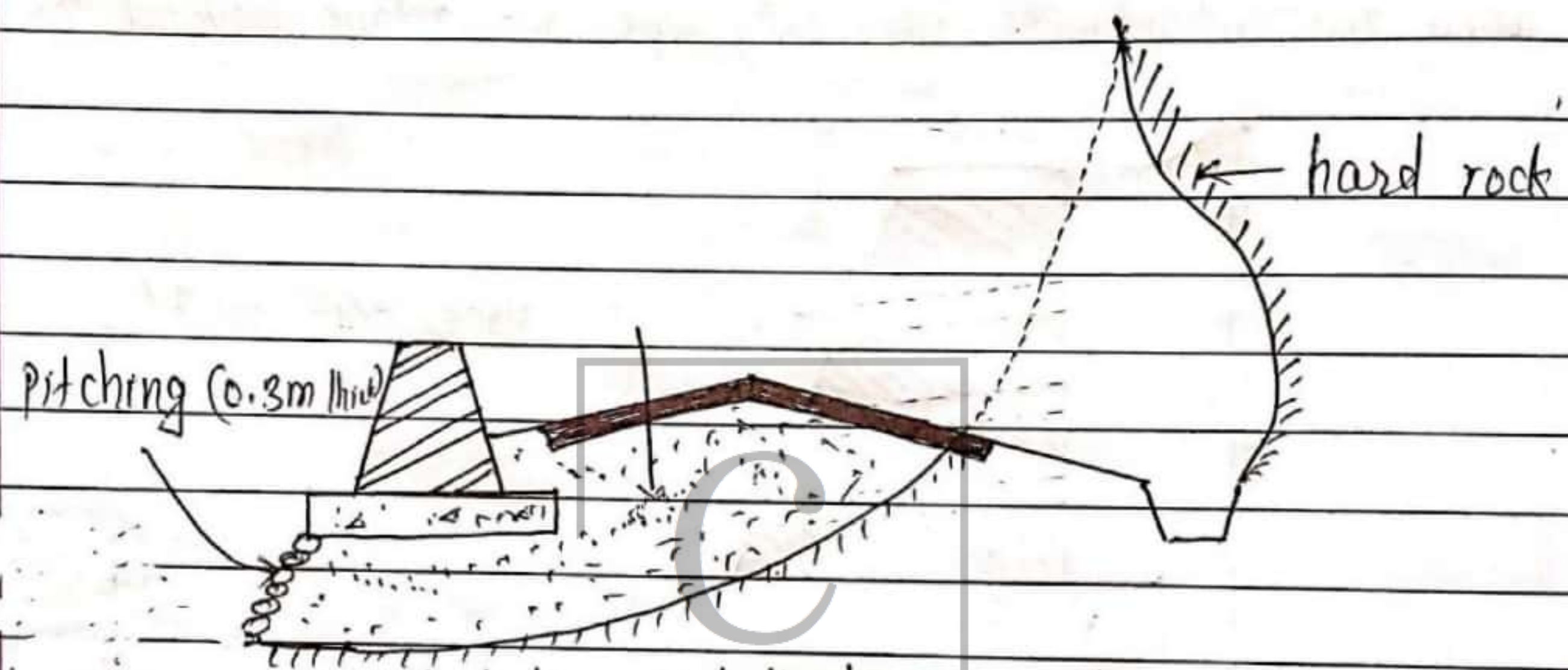


Fig: Protection of hill slope by stone pitching

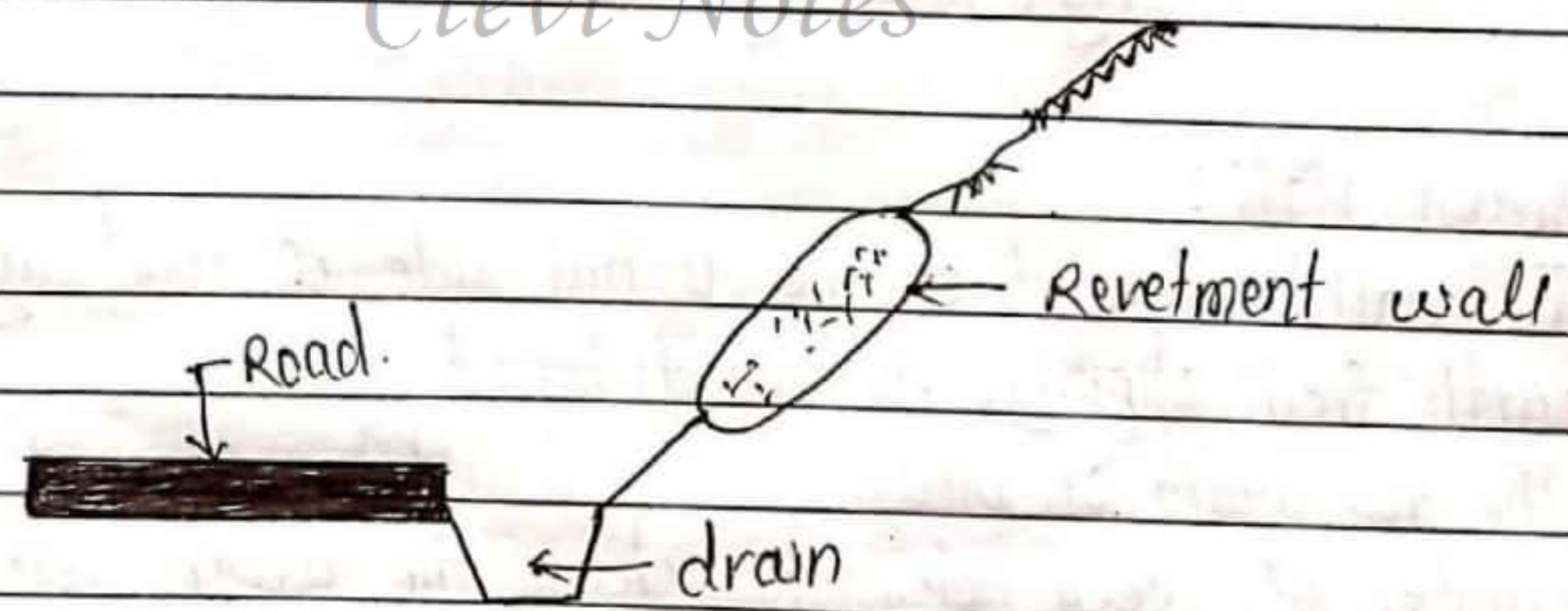
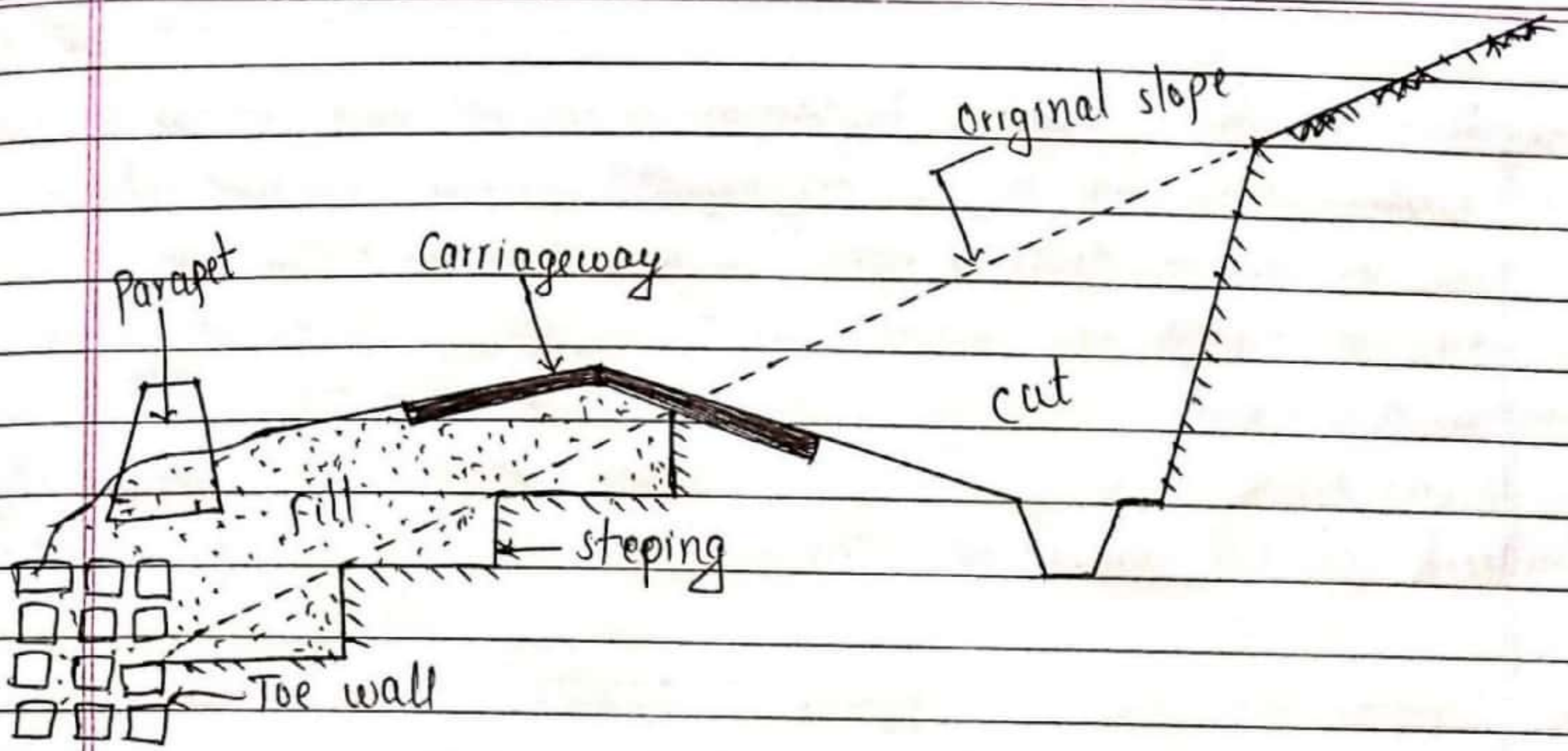


Fig: Revetment wall.

④ **Toe Wall:**

- ↳ The embankment slope are generally ported from the stone pitching above 30cm thick to avoid erosion due to flow of water.
- ↳ If sloping long ties too long than a wall is constructed from the base to support the embankment and slope which is called toe wall. It is provided in the case of embankment from toe of road.



### # Importance of Hill Road in Nepal:

- ↳ More service to people of hilly area
- ↳ Provide easy access to agriculture, industrial and other production and service centers.
- ↳ Provide support to development of other social and economic infrastructure
- ↳ For economical development of country.
- ↳ Development of tourism
- ↳ To establish other project such as hydropower, hill irrigation etc.
- ↳ In mountaineous, ferrisian, navigation and rail traffic are not possible which automatically demands hill roads.

## Unit-3 Road Machineryes

[2073] \* Definition:

↳ Highway construction can be carried out by using mechanical appliances or by manual labour. Although adoption of mechanical method involves highly initial investment but ultimately it results in economy.

↳ Road construction by mechanical methods are superior and economical than those constructed by manual labour hence adoption of mechanical means has been advocated.

[2068] [2074] ↳ Machines that can be used in road construction can be classified into following heads.

1. Earthwork Machinery
2. Water Bond Macadam (WBM) Machinery
3. Bituminous Road Machinery
4. Cement concrete Road machinery.

\* Earthwork Machinery:

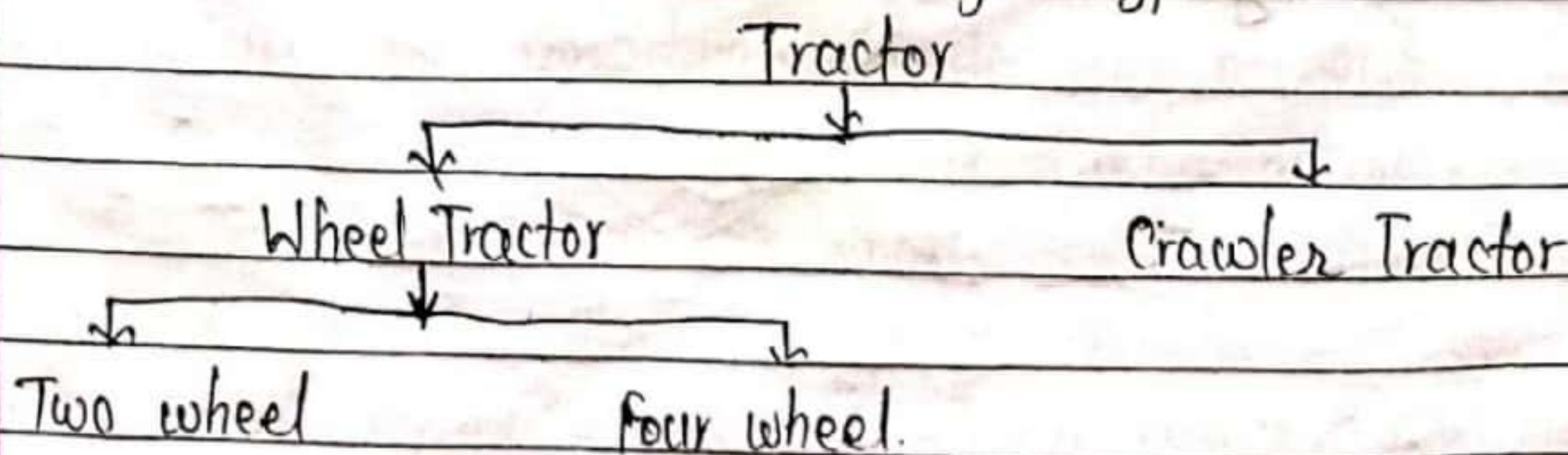
↳ Earthwork has been done to obtain necessary formation level. At some places cutting and other filling are involved. Cutting and filling both are come under earthwork.

↳ Tractor, dozer, grader, shovel, dragline, power rammers, rosters, trucks etc are the usual mechanical equipments used for earthwork. Some of the equipment in most common used are explained here.

ⓐ Tractor:

↳ Tractor is the power machine used mostly to tow the other earthwork machinery. It is a source of power.

↳ Tractors are divided into two major types:



### ① Wheel Tractor:

- ↳ The main advantages of wheel tractor over crawler tractor is higher speed. However, the pulling effort of wheel tractor is less than the crawler tractor. Because of lower coefficient of traction between rubber tyre and some soil surfaces, the wheel tractor slips - its wheel before developing its rated pull.
- ↳ Wheel tractor move on pneumatic tyres are generally used for even and smooth surface.

### ② Crawler Tractor:

- ↳ Crawler Tractor are usually rated by weight and power.
- ↳ The weight is important on many project because the maximum tractive effort that a unit can provide is limited to the product of the weight and coefficient of traction for the unit and the road surface.
- ↳ This type of tractors are widely used for most uneven and rough surfaces. It moves on an endless chain and the speed of the tractor is less than that of wheel type tractor.

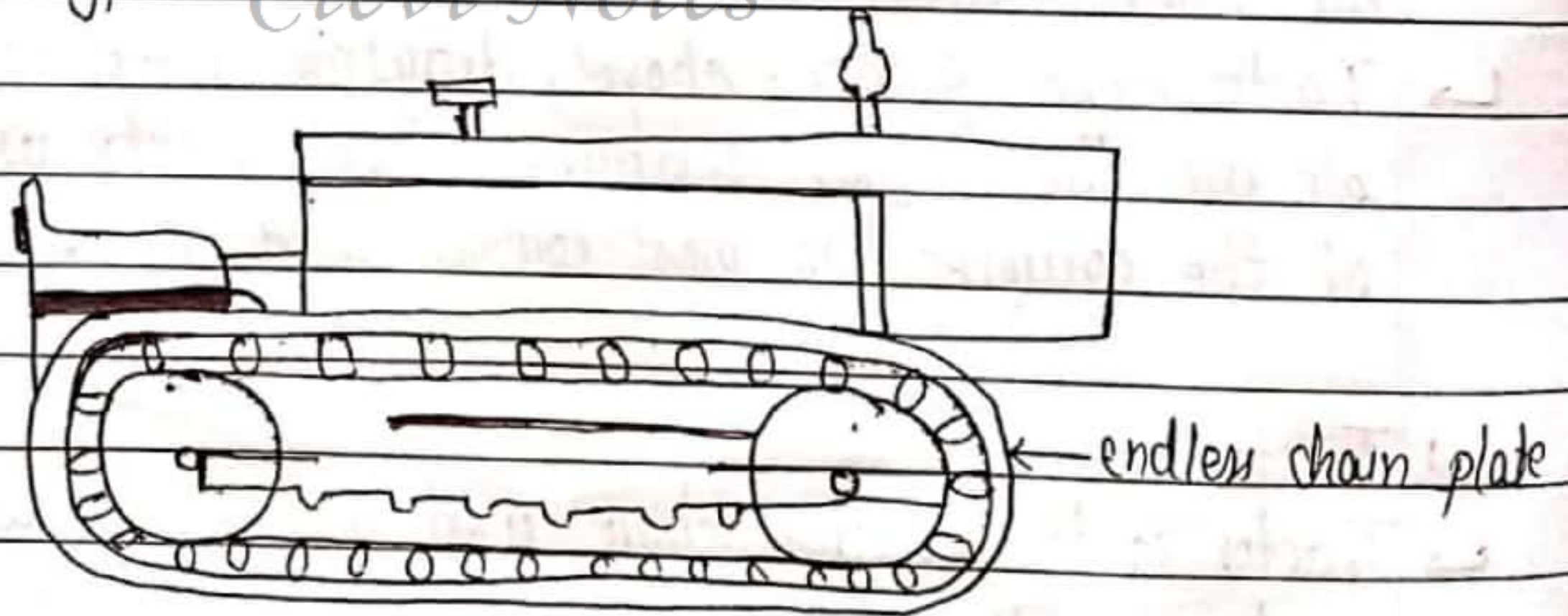
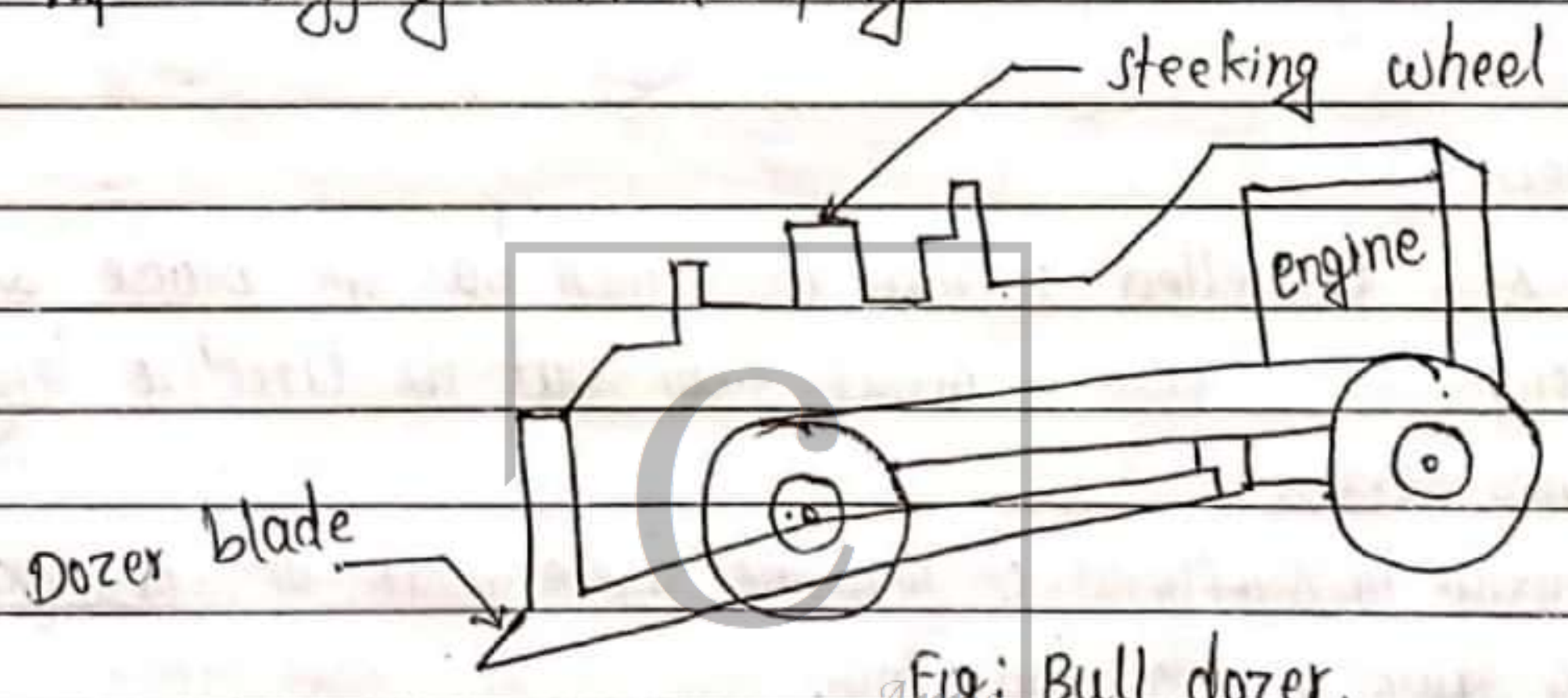


fig: Crawler Tractor.

⑥ Dozer / Bull Dozer :

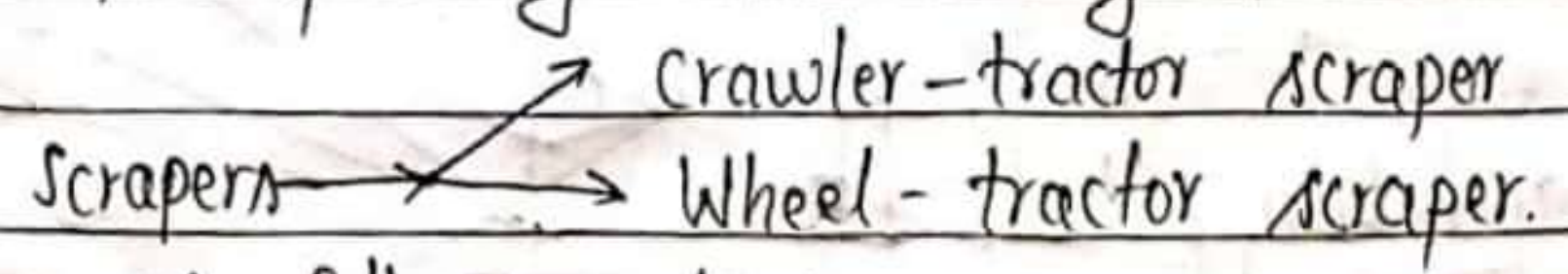
- ↳ The bull dozer often called dozer, is largely employed for excavating and moving the earth.
- ↳ It consist of a blade mounted at the front of a tractor which may either be wheel mounted or mounted on crawler tracks. The blade width may be 2m to 8.5 m and height of blade may vary from 0.6m to 2m.
- ↳ The most effective work done by a bulldozer is moving earth down hill for short hauls. The limits in grade may be such as to allow the machine to reverse and return up hill. They are also important tools in excavation plant for rapid digging and dumping.



*Text Notes*

⑦ Scrapers :

- ↳ Tractor pulled scrapers are very important equipment of earth moving field. This equipment can dig, load, haul and discharge materials independently i.e. without taking any help from other equipment.
- ↳ The scrapers have the ability to deposit their load in uniformly thick layers which facilitate the spreading operation also.
- ↳ During the return trips to borrow pits, the cutting blades of scrapers are lowered to level the freshly spreaded soil. In this way, it can be used for spreading and levelling of earth.



↳ Scrapers are of following types:

- ① Multi bowl multi engine.
- ② Elevating scrapers
- ③ Single engine
- ④ Twin engine
- ⑤ Two bowl tandem.

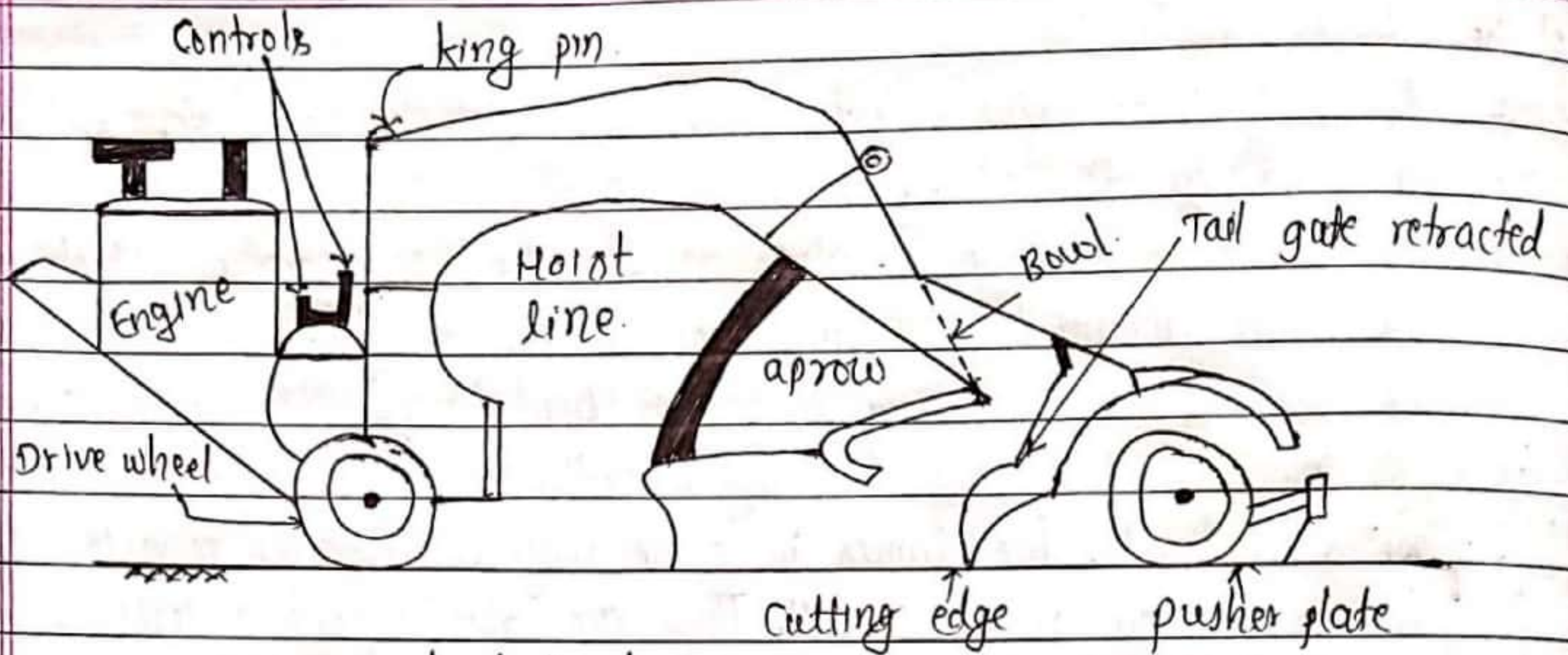


Fig:- wheel-tractor scraper

### (d) Graders:

- ↳ It is self propelled machine, which has its blade within wheel base. The length of blade is about 3.5m but its effective length during spreading becomes 2.75m.
- ↳ The blade is supported on machine frame work and is capable of turning, tilting, raising and lowering.
- ↳ The graders are used for a number of purposes:
  - (i) For spreading heaped earth into layers.
  - (ii) For maintaining cross-section of the embankment.
  - (iii) For shaping the cross-section during construction.

### (e) Drag Line:

- ↳ It is a machine most extensively used to excavate soft earth and to deposit in the nearby spoil banks or to load into wagons.
- ↳ The bucket is thrown out from the drag line on the top of the earth to be excavated and then pulled back towards the base of the machine.

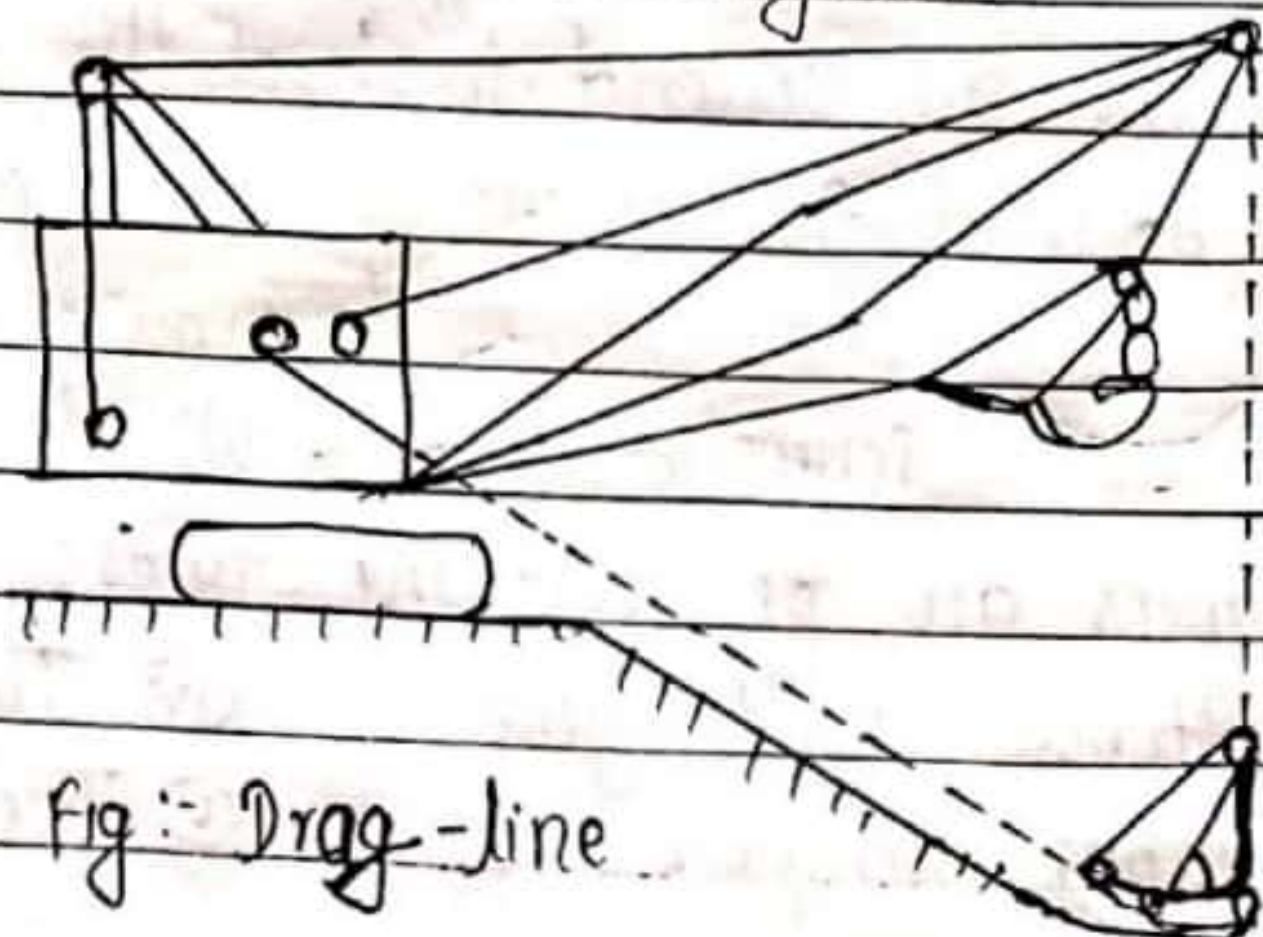


Fig:- Drag-line

④ Power shovel:

- ↳ It is used primarily to excavate earth of all classes except rock and to load it into wagons.
- ↳ It can slowly be moved forward, backward, turned with the help of diesel engine.
- ↳ The power shovel can work to excavate earth from a lower level where it stands.

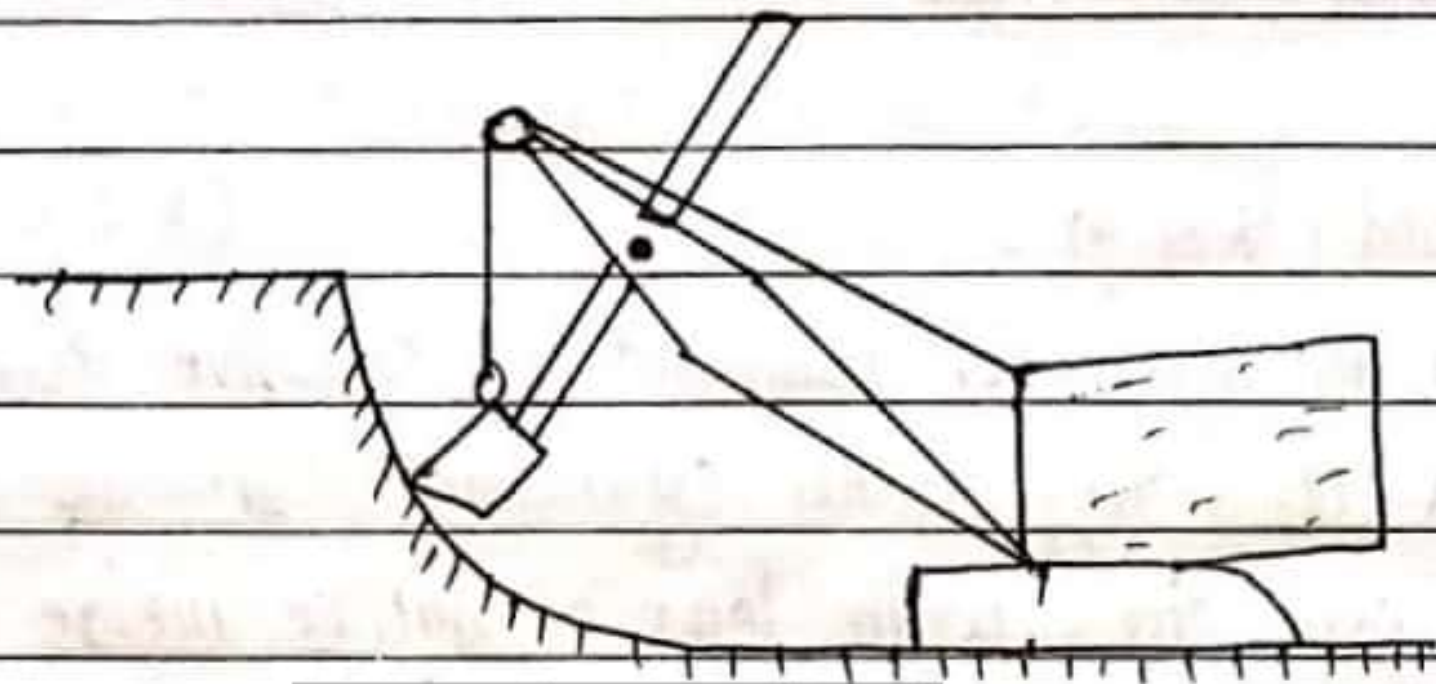


Fig: Power shovel

⑧ Hoe:

- ↳ It is an excavating machine of the family of the power shovel. Hoe is used to excavate earth below the natural surface where the machine is stationed.
- ↳ It can excavate stiff material which normally can not be excavated by drag line.

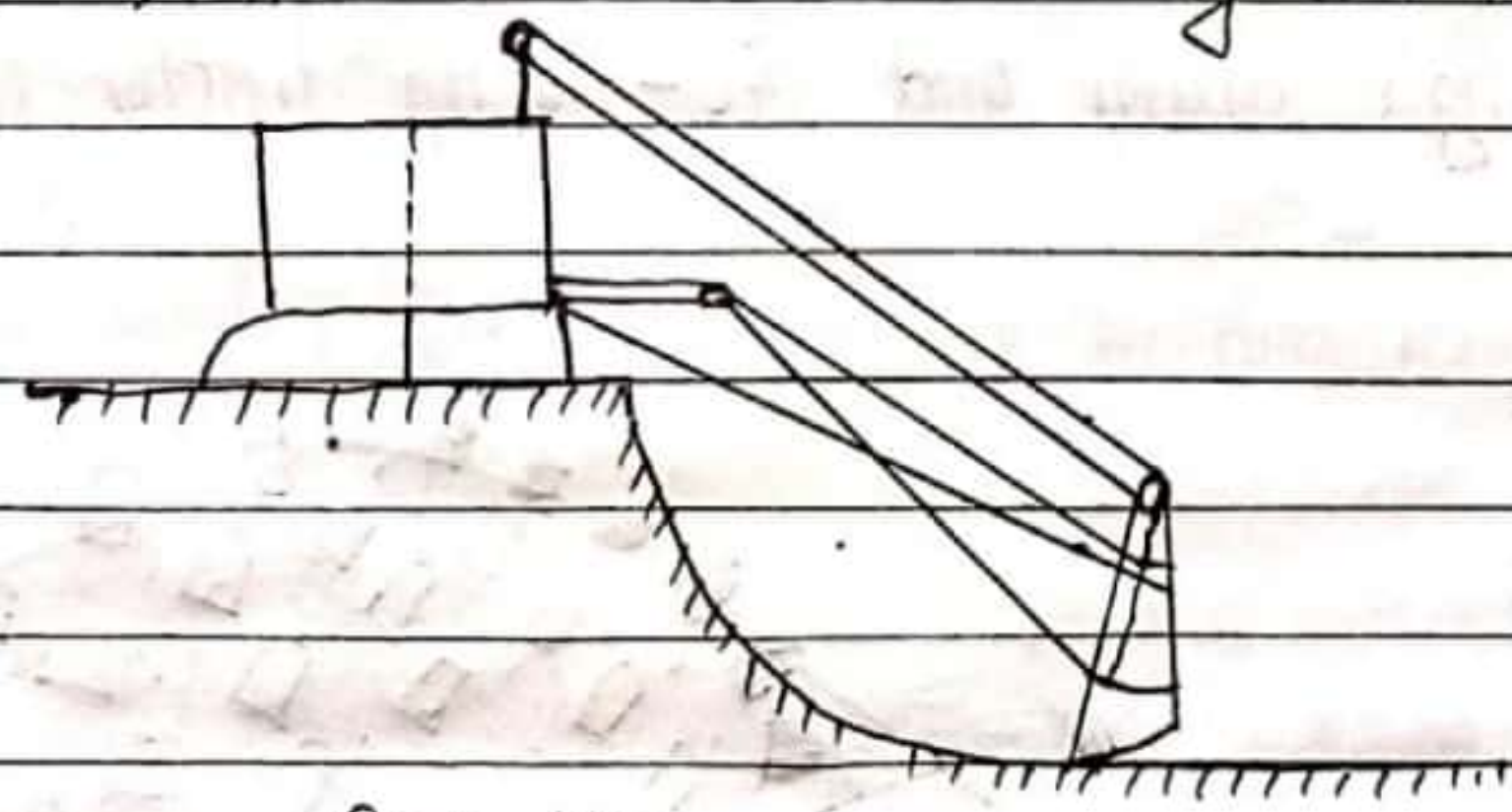


Fig: Hoe.

## # Compacting Equipments:

### (a) Rollers:

↳ Roller is a machine used for compaction of soils and road macadam.

Rollers can be of following three types:

- (i) Sheep foot roller
- (ii) Pneumatic tyred roller
- (iii) Smooth wheeled roller

### (i) Sheep's foot Roller:

↳ This roller is used for compacting cohesive soils of large fills.

↳ It consists of heavy metal cylinders 1m to 1.5m long and 0.9m to 1.2m in diameter, with legs on square metre area.

↳ It has steel projections in the form of sheep's foot. These projections are called tamping feet. The tamping feet on the drums are staggered in rows.

↳ The length of the feet should be at least sufficient to pass through three-fourth ( $\frac{3}{4}$ ) of the thickness of the loose layer and is usually 150mm to 200mm.

↳ They are generally towed by tractors. A tractor of 45 Hp can pull a single drum and 70-90 Hp tractor can pull double drum.

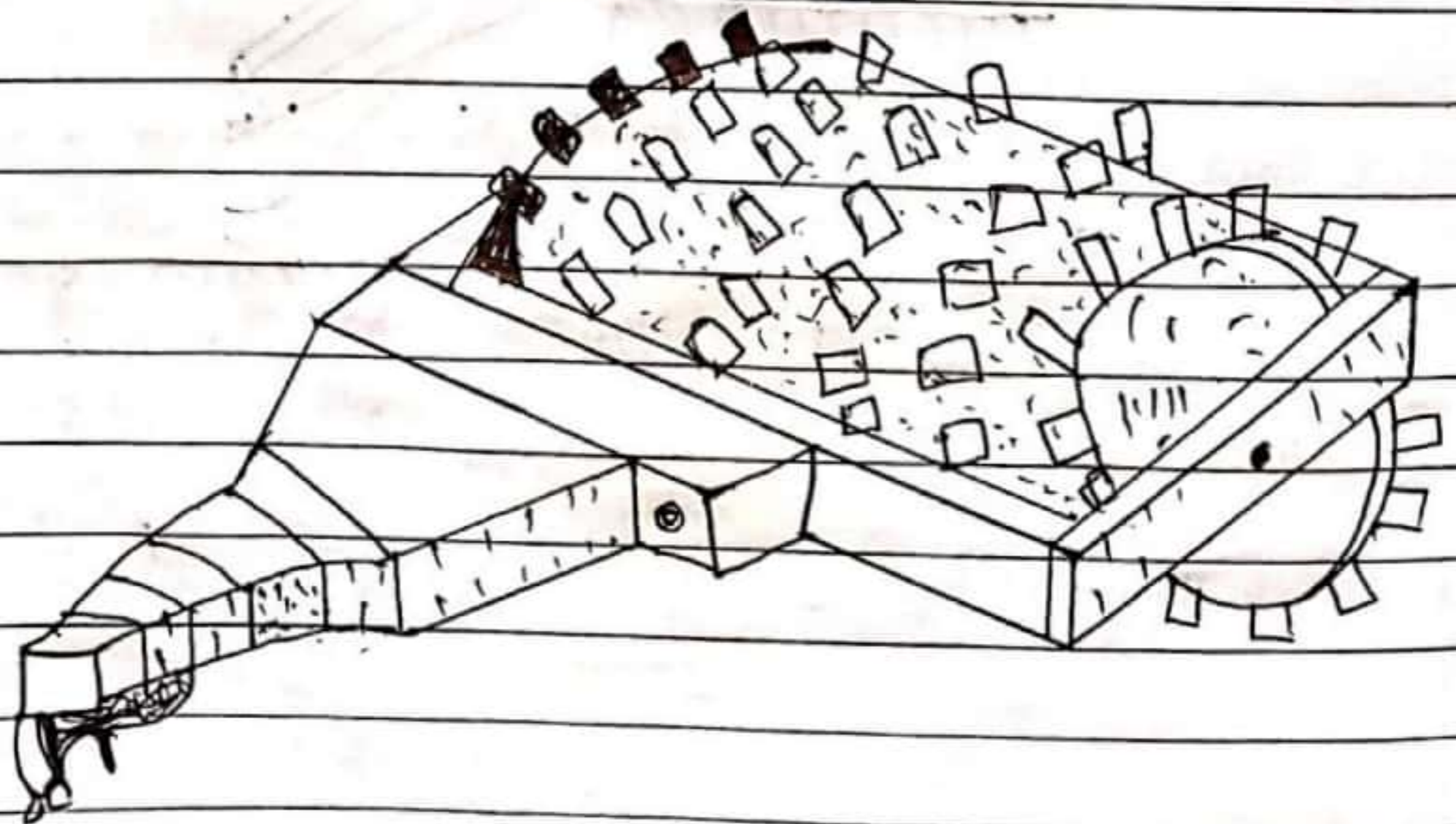


Fig: sheep's foot Roller

### (ii) Pneumatic Tyred Roller:

- ↳ This roller consists of one or two axles on which a number of rubber-tyred wheels are fitted. These wheels carry a platform over which sand bags or other weight may be placed to provide the effective compaction.
- ↳ These rollers are useful for compacting sandy soil and also the final rolling operations in bituminous surface dressing of roads.
- ↳ The weight of such a roller may be as large as 50 tones and two to four (2-4) passes are generally sufficient to achieve compaction of 60cm thick soil layer.
- ↳ These rollers compact the soil by kneading action.

### (iii) Smooth Wheeled Roller:

- ↳ Smooth wheeled rollers may have either two axles or three axles. Three axles rollers are very heavy and are useful for heavy rolling.
- ↳ Two axle roller may be two wheels or three wheels. Two wheels rollers are called tandem roller. Three wheels rollers are having weight 8-10 tones are most common rolling equipment used in road construction.
- ↳ The diameter and width of front roll is around 105cm and 100cm respectively. The diameter and width of rear wheel (roll) is 145cm and 50cm respectively. The rolling width is around 2m.
- ↳ The smooth wheeled rollers are effective in compacting granular soils such as sand, gravel and crushed stone.
- ↳ The compacting efficiency of smooth wheeled rollers depend upon the weight, width and diameter of wheels.

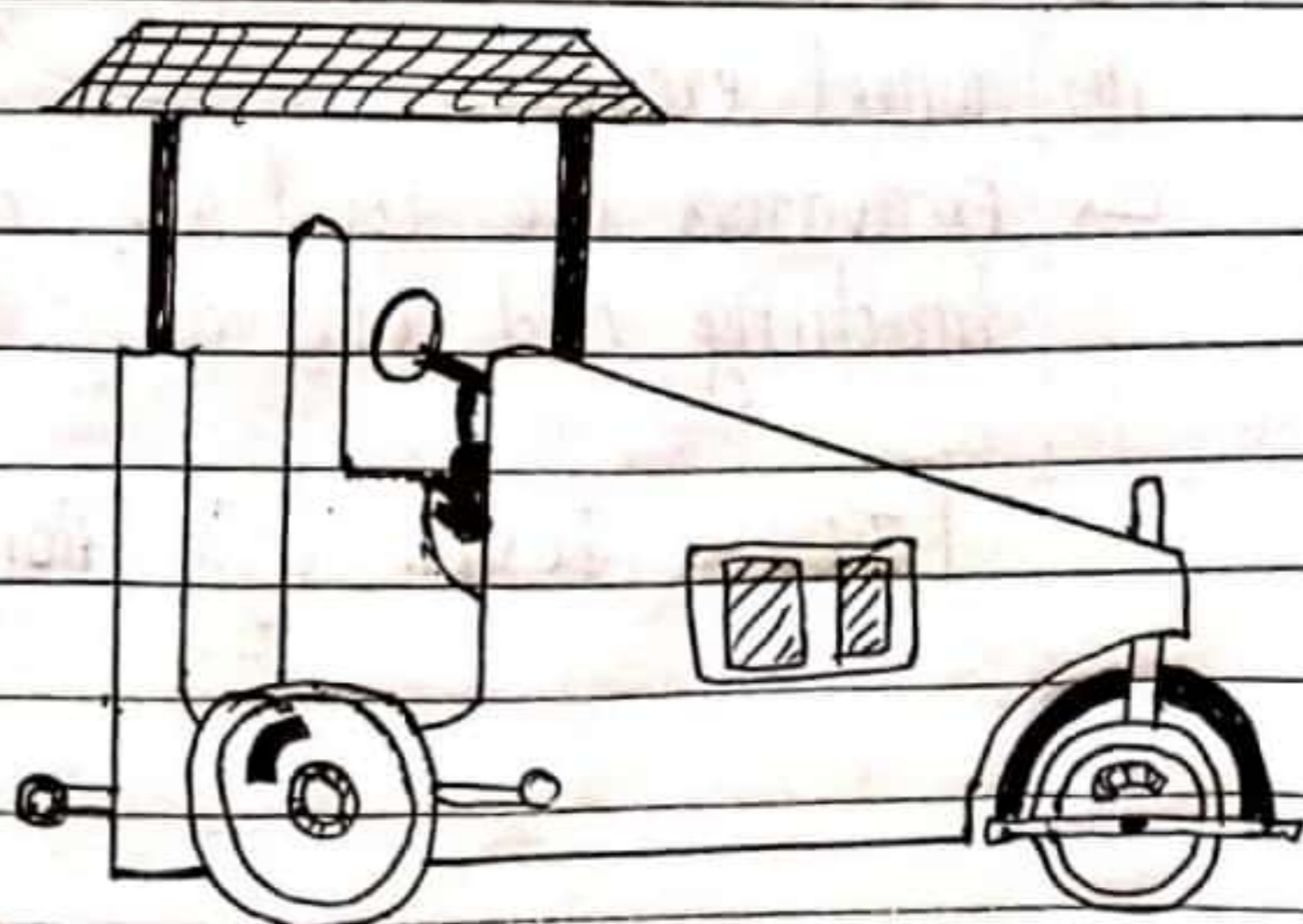


Fig:- Smooth wheeled Roller

### (b) Vibratory Roller: [W.B.M. Road Machinery] →

- ↳ This roller vibrates while travelling. It is useful in compaction of W.B.M roads and deep compaction of granular soils.
- ↳ This roller is not as heavy as smooth wheeled roller.
- ↳ Vibrators are provided mechanically.

### (c) Impact Rammer:

- ↳ Impact rammers are used for compacting small areas by providing impact load to the soil.
- ↳ This equipment is light and can be hand or machine operated. The base size of rammer can be 15cm \* 15cm or 20cm \* 20cm or more.
- ↳ These rammers are suitable for compacting cohesive soil as well as other soils.

### # Excavator: [Earthwork Machinery] →

- ↳ Excavator is the machine that can excavate the soil of various types forcefully and then using hydraulic system, a hydraulic force is generated and utilizing this force bucket is pull back towards the machine.
- ↳ Bucket of excavator is replaceable.
- ↳ Excavators are mostly used for digging of soils and for loading dump trucks.
- ↳ There are two types of excavator:
  - (i) Crawler excavator (chain wheel system).
  - (ii) wheel excavator
- ↳ Excavators are used for digging of earth, loading and dumping, trenching and excavating under water.

[JCB - Joseph Cyril Bamford] - (Japan Credit Bureau.)

## # Loader:

↳ A loader is a type of tractor, usually wheeled, that has a front-mounted square wide bucket connected to the end of two arms to scoop up loose material from the ground such as dirt, sand or gravel, and move it from one place to another without pushing the material across the ground.

## # Road Metal Machinery:

↳ Small sized crushed stone is called road metal.

↳ Road metal machinery are:

- (a) Jaw crushers
  - (b) Gyratory crushers
  - (c) Hammer mill crushers
  - (d) Roller crushers
  - (e) Rod or ball mill crushers
- Primary crushers
- Secondary crushers (Tertiary crushers)
- 

## # Bituminous Road Machinery:

↳ Bituminous roads are constructed by a mixture of bitumen and aggregate.

↳ Bituminous road machineries are:

- (a) Bitumen boiler
- (b) Bitumen sprayer
- (c) Bitumen mixer and spreader.
- (d) Gritting machine
- (e) Hot mix plant
- (f) Bitumen pavers.

## # Cement Concrete Road Machinery:

↳ Machinery required for cement concrete road construction are as follows:

- (a) Concrete mixer
- (b) Concrete paver
- (c) Concrete screeds
- (d) Concrete vibrator
- (e) Concrete finisher.

# Unit-4 Road Construction Technology

## # Introduction:

↳ Road construction is a tedious work. It starts from planning to finally construction. In between both geometric, materials, structural design, protection works etc. occurs. As per the network and type of works and elements of road to be constructed various activities can broadly divided into several works which are maintained below:

### ① Earthwork and site Clearance:

- ① Site clearance.
- ② Earthwork in filling for embankment.
- ③ Excavation for cutting.
- ④ Excavation for borrow pit.
- ⑤ Excavation for structural foundations.
- ⑥ Disposal of surplus earth.

### ② Drainage Works:

- |                 |               |
|-----------------|---------------|
| ① Minor bridges | ⑩ Side drains |
| ② Causeways     | ⑪ Culverts.   |

### ③ Pavement Works:

- ① Sub-grade works
- ② Sub-base works
- ③ Base works
- ④ Surface works.

### ④ Protection Works:

- |                              |                             |
|------------------------------|-----------------------------|
| ① Earth retaining structure  | ⑩ Land slide stabilization. |
| ② Slope protection structure | ⑪ Bridge protection works.  |
| ③ Gully control works        |                             |

### ⑤ Miscellaneous works:

- |                    |                          |
|--------------------|--------------------------|
| ① Road ancillaries | ⑩ Bio-engineering works. |
| ② Traffic works    |                          |

## ✓ # Earthwork:

- ↳ Subgrade is the lowermost portion of the highway construction. It may be situated on embankment or excavation or at the existing ground surfaces.
- ↳ In all the cases site should be cleaned off and top soil consisting of grass, roots, rubbish and other organic matters are to be removed.
- ↳ Grading operation is necessary to bring the vertical profile of the sub-grade to designed grade and camber.
- ↳ It is most essential to compact the top of subgrade adequately before placing the pavement layer.

## ✓ \* Earthwork in Excavation:

- ↳ It is the process of cutting or loosening and removing earth including rocks from its original position, transporting and dumping it as a fill or spoil bank.
- ↳ The excavation may be needed in soil, soft rock or even in hard rock before preparing the sub-grade.
- ↳ The selection of excavation equipment and cost analysis is based on the stiffness of the materials to be excavated.
- ↳ Following are the design elements in highway excavation work in road construction:

- ① Depth of excavation
- ② Stability of foundation
- ③ Stability of slopes
- ④ Accommodation of road side drain.
- ⑤ fill material.

## ✓ \* Earthwork in Embankment:

- ↳ When it is required to raise the grade line of highway above the existing ground level, it becomes necessary to construct embankments.
  - ↳ The design elements in highway embankment are as follows:
- |                        |                           |
|------------------------|---------------------------|
| ① Height of embankment | ④ Stability of foundation |
| ② fill material        | ⑤ stability of slopes.    |
| ③ settlement           |                           |

### ✓ • Fill:

- ↳ When the existing level of ground on the alignment of highway is higher than the bed level of sub-grade then excavation is required.
- ↳ If the same level is lower than the bed level of sub-grade, then filling is required. Before filling the top soil consisting of grass, root of plants and other organic materials should be removed.
- ↳ Granular soil is generally preferred as highway filling material.

### ✓ # Construction of Embankment:

- ↳ The embankment may be constructed either by rolling in relatively thin layers or by hydraulic fills. The former is called rolled earth method and is preferred in highway embankments.
- ↳ Each layer is compacted by rolling to a satisfactory degree or to a desired density before the next layer is placed.
- ↳ Compaction is carried out at optimum moisture content so as to take advantages of maximum dry density using a specified compacting effort and equipment.
- ↳ The thickness of the layers may vary between 10 and 30cm depending on various factors such as soil type, equipment, specifications etc.

### ✓ # Compaction:

- ↳ It is a mechanical process by which air is expelled out from soil mass to reduce the void and increases the density of soil.
- ↳ It increases density and stability, reduces settlement and lowers the adverse effects of moisture, hence proper compaction of fills, sub-grade, sub-base, and base course are considered essential for proper highway construction.
- ↳ Rolling, ramming and vibration are the method used for the compaction of soil.

### • Factors affecting Compaction:

- (i) Water content
- (ii) Amount of compaction
- (iii) Types of compaction.
- (iv) Types of soil
- (v) Addition of admixtures.

## ✓ # Relation of optimum moisture content and maximum dry density :

↳ Mr. R.R. Proctor deeply studied the soil with respect to moisture in 1933 A.D. He found that density of soil increases with increase in water content upto certain limit. The limit is known as optimum moisture content (OMC).

↳ As the water content is further increase beyond this limit the density of soil starts decrease. Hence it is desirable to compact the soil at the OMC in highway construction.

↳ Mr. R.R. Proctor also plotted on graph between the moisture content and density of the soil. The graph thus obtained is called compaction curve which is shown in figure below:

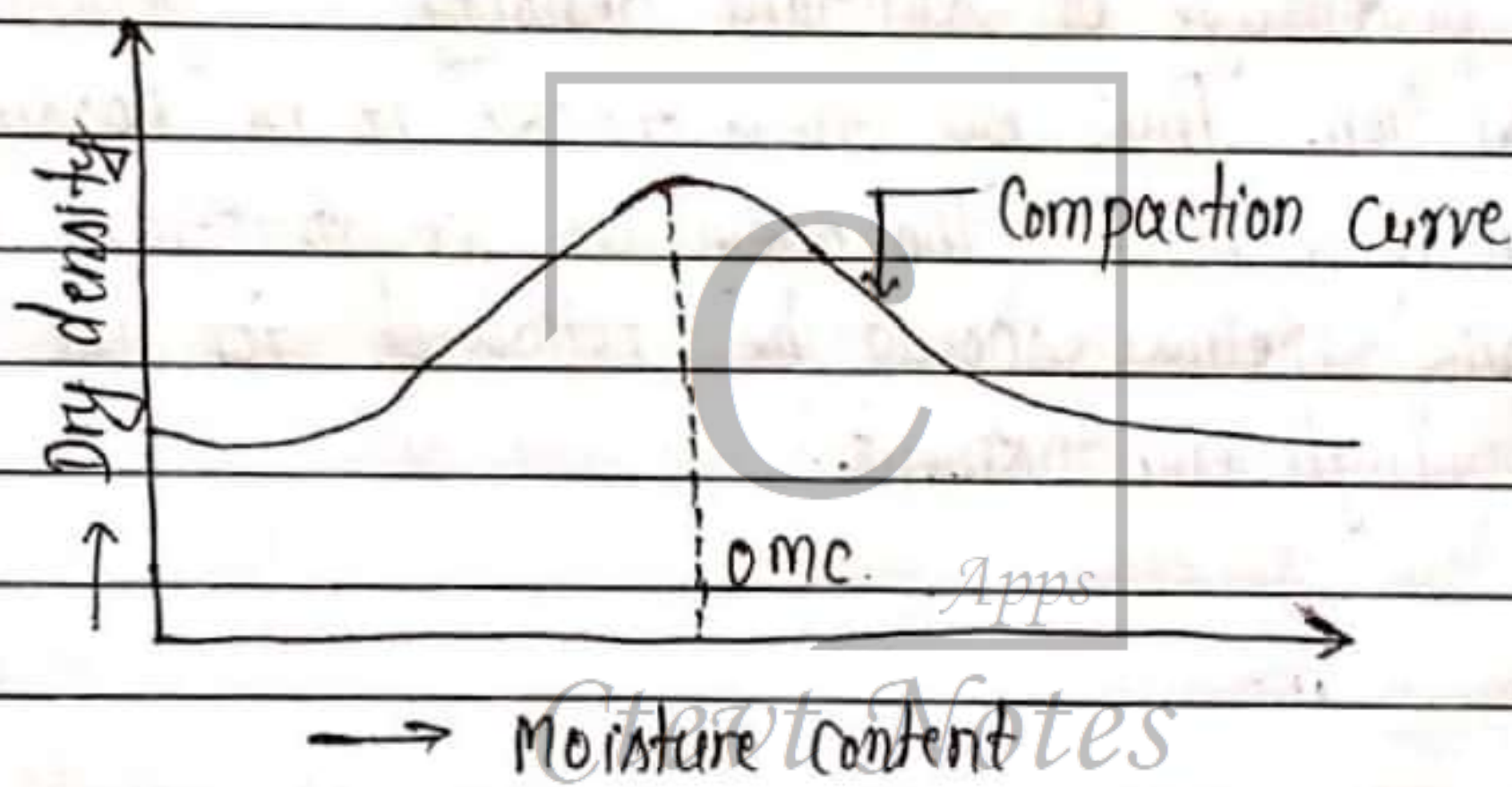


Fig: Moisture density relationship.

The theoretical relationship between moisture content and dry density is given below:

$$\gamma_d = \frac{\gamma}{1+w}$$

Where,

$\gamma_d$  = dry unit weight of soil

$\gamma$  = unit weight of soil

$w$  = water content.

#.

## ✓ # Field Control of Compaction and Tests required for field control:

↳ For adequate quality control in construction, it is essential to have proper field control in compaction. The two tests for field control are:

- ① Measurement of water content (moisture content)
- ② Measurement of dry density.

↳ The moisture content of the soil may be found before compaction by any one of the rapid methods suitable at the site. If the moisture is controlled at the OMC, then the next control needed is the dry density, the desired value of which may be achieved by increasing the number of passes for the selected equipment and the thickness of each layer.

↳ A certain percentage of standard density is generally aimed at the field compaction. Thus, by field checks it is possible to control the construction to achieve the adequate construction. However, statistical quality control method should be followed for the compaction in construction high embankment.

Apps

Text Notes

## V. imp # Construction of Roads :

- 1- Construction of Earthen Roads
- 2- Construction of Gravel Roads
- 3- Construction of Soil Stabilized Roads
- 4- Construction of Water Bound Macadam [WBM] Roads
- 5- Construction of Bituminous Roads

### 1- Construction of Earth Road / Earthen Road :

#### # Introduction:

- ↳ It is cheapest road and less advanced.
- ↳ Type of construction depends on the types of soil available at site or near by borrow pits.

#### # Materials Required :

- ↳ It contains natural soil due to which cheapest type road prepared. It may contain clay, silt, sand etc. The liquid limit of a soil should be less than 35% for a base course as well as wearing course. The plasticity index of a base course should be less than 6% and 4-10% for wearing course.

#### # Equipments Required :

- ↳ Spade, shovel, pick axe, bucket, wheel barrow etc.

#### # Construction Procedure :

##### (i) Soil Survey:

- ↳ The soil survey is carried out and suitable borrow pits are located within economical haulage distances.

##### (ii) Location:

- ↳ Centre-line and road edges are marked on the ground along the alignment with wooden pegs.

continue. . .

### iii) Preparation of sub-grade:

↳ cleaning of site, grading to desired shape, shaping of a sub-grade with proper compaction.

### iv) Pavement Construction:

↳ The borrowed soils are dumped on the prepared sub-grade and pulverized. The field moisture content is checked and additional water mixed if necessary to bring it upto OMC.

### v) Opening to Traffic:

↳ The compacted earth road is allowed to dryout for a few days before opening to traffic.

## 2- Construction of Gravel Roads:

### # Introduction:

↳ It is considered superior to earth roads as they can carry heavier traffic. The road consists of a carriageway constructed using the gravel.

↳ The camber may be between 1 in 25 and 1 in 30. It may be feather edge type and the trench type.

### # Materials Required:

↳ Hard, durable and strong varieties of crushed stone or gravel of specified gradation is used.

↳ In practice, softer varieties are also used. Rounded stone or gravel are not preferable as they have poor interlocking. Proper gradation is chosen to have maximum density.

### # Equipment Required:

↳ Manually with hand tools and compaction is done by the equipment, eg: dozer, roller, tractor etc.

## # Construction Procedures:

### (i) Materials:

- ↳ Adequate and perfect materials source is chosen.
- ↳ Gravel to be used for construction.

### (ii) Location:

- ↳ Wooden pegs are used for fixing centreline and road edges are marked on the ground along the alignment.

### (iii) Preparation of sub-grade:

- ↳ Cleaning of site, grading by cut or fill, trench excavation to desired depth and width and finally compaction is done before spreading the gravels.

### (iv) Pavement Construction:

- ↳ Gravel are placed carefully in the trench so as to avoid segregation.
- ↳ Gravel spread with greater thickness at center and less towards edges so as to obtain the designed camber.
- ↳ Rolling with smooth wheel roller or vibrated. It starts in edges and towards center with  $\frac{1}{2}$  width of roller overlapping.
- ↳ Control of field moisture and density add water or corrected.

### (v) Open to Traffic:

- ↳ After a few days of completion of final rolling and the traffic is opened.

### 3. Construction of Soil Stabilized Roads:

#### # Definition of Soil Stabilization:

- ↳ Soil stabilization is a method of improving the qualities of inferior soil with respect to strength, stability, density, bearing capacity etc.
- ↳ Soil improves the improvement of the stable or bearing power of the soil by the <sup>use</sup> of controlled compaction proportionally or the addition of suitable admixtures.
- ↳ After stabilization it may result in any one or more following changes:
  - (i) Increase the stability, change in physical properties density, swelling.
  - (ii) Change in chemical properties.
  - (iii) Retaining the desired minimum strength by water proofing.

#### # Principle of soil stabilization:

- ↳ The main principles of soil stabilization are:
  - (i) Evaluation the properties of given soil i.e. bearing index etc.
  - (ii) Designing the effective technique for stabilization.
  - (iii) Compacting to stabilized soil layer.

#### # Techniques of Soil Stabilization:

- ↳ Following techniques are used for the soil stabilization:
  - (a) **Proportioning Technique:**
    - ↳ Various locally available soils and aggregates are mixed in suitable proportions and compacted to serve the desired objectives.
  - (b) **Cementing Agents:**
    - ↳ The strength of the stabilized soil can considerably be increased by the addition of cementing agents like portland cement, lime mortar etc.
  - (c) **Modifying Agents:**
    - ↳ If the stabilizer added in small proportions could modify the undesirable properties of certain soils making them more useful as construction material.

### ① Water proofing Agents :

↳ Water absorption properties of water is related by means of some water proofing agent such as bituminous materials.

### ② Water Repelling Agents :

↳ Use of vassel resin or other water repelling agents.

### ③ Heat Treatment :

↳ Used to reduce swelling properties.

### ④ Chemical stabilization :

↳ Used the chemical agents or chemical procedure.

### # Methods of Soil Stabilization :

↳ There are four methods for soil stabilization :

① Mechanical soil stabilization.

② Soil - Cement stabilization.

③ Soil - Lime stabilization.

④ Soil - bitumen stabilization.

### ① Mechanical Soil Stabilization :

↳ Correctly proportioned material (aggregate and soil) when adequately compacted to get a mechanically stable layer, the method is known as mechanical stabilization. Thus, the two basic principle for the mechanical stabilization of soil are :

① Proportioning

② Compaction.

↳ Granular with less fine when combined with soil increase stabilization. Stability also can be increase in fine grain size by mixing suitable Proportion of granular materials.

continue ---

↳ There is a typical stage in which compacted soil aggregate mix could be found.

① **Compacted aggregate with no fine:**

↳ Stable only in confirmed condition.

↳ Very high promotable.

↳ No variation in strength due to moisture.

↳ Not easy to compact.

② **Compacted aggregate with compacted fines:**

↳ Used for fine aggregate for just filling voids.

↳ Land permeability.

↳ Depend upon moisture variation.

↳ Depend volume change.

③ **Aggregate with excess fines:**

↳ stability decrease due to excess fine.

Apps

# **Factors affecting the mechanical stabilization:**

① Mechanical strength of aggregate.

② eradation well graded aggregate soil mix for better stability max. density

③ Properties of soil.

④ Presence of soil and mica etc → their presence reduce stability.

⑤ Compaction.

# **Road Construction Procedures:**

• **Materials Required:**

↳ Stacked along the side of road is desired properties.

• **Equipment Required:**

↳ Machinery or manual labour may be used for excavation or haulage compaction equipment is necessary.

### • Construction Steps:

- ① Preparation of subgrade
- ② Mixing of materials to a desired proportion per design.
- ③ Checking of moisture if require addition of water and remix.
- ④ Wet mix spreading and compaction.
- ⑤ Field control test:
  - ↳ Determination of moisture contents of the mix before compaction.
  - ↳ Determination of dry density.
- ⑥ Open to traffic after the carpeted layer get hardness.

[2074, 2073,  
2070, 2063]

### 4. Construction of Water Bound Macadam [WBM] Roads:

- ↳ Water Bound Macadam road is named in the honour of John Macadam.
- ↳ The principle of construction of this type of road is "crushed or broken aggregate are bounded together by the action of rolling and traffic".
- ↳ Thickness of pavement is 8 to 30cm and each layer is 7.5 to 15cm while compacting.
- ↳ Camber is provided with slope 1 in 36 to 1 in 48.
- ↳ Materials comprise of coarse aggregate, softening materials and filter materials.
- ↳ Stone dust is used as filter materials.
- ↳ The WBM roads are made either of following:
  - ① WBM made with gravel including crushed gravel.
  - ② WBM made with hard broken stones.
  - ③ WBM made with soft broken like brick blast, kankar.

### # Materials Required:

- ↳ Materials should be broken crushed stone hard, durable strong and free from excess flakey, elongation, soft and dust free.
- Materials used such as:
  - ① Coarse aggregate
  - ② Screening materials
  - ③ Filter materials or binding materials.

## # Equipments Required:

- (i) Manually or water tamer (trailer).
- (ii) Grader.
- (iii) Compacting equipment etc.

## # Construction Procedure:

↳ The following procedure is applied on construction of WBM road materials survey:

### (i) Layout and Site clearance:

- ↳ fixed centerline and make the construction width.
- ↳ Site clearance consist of grouping of sapling, bushes, trees and organic materials.

### (ii) Sub-grade Preparation:

- ↳ Excavation or embankment.
- ↳ Bring vertical profile to designer grade and cross-section to design camber.
- ↳ Rolling should start from edge to center.
- ↳ Compaction is done by rolling in layers not less than 15cm.

### (iii) Pavement Construction:

#### (a) Provision of Lateral Confinement:

- ↳ Provision of lateral confinement by digging trenches. If the trenches are not made, this is 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.

#### (b) Spreading coarse aggregates:

- ↳ It is to be spread uniformly over the constructed width.

#### (c) Dry rolling with roller of weight 6 tonnes to 10 tonnes

- (v) Application of screening
- (vi) Wet rolling to fill about 50% of total voids
- (vii) Application of filler
- (viii) Finishing of surface with 6mm thick sand or earth is spread sprinkled with water and rolled.
- (ix) Making shoulder
- (x) Opening traffic after few days of construction.

### 5- Construction of Bituminous Roads :

- ↳ It is possible to construct relatively thin bitumen layer over an existing pavement. Therefore, these are commonly adopted as wearing course.
- ↳ Flexible pavement called base strength stages by construction bituminous pavement layer.

### # Types of Bituminous Construction :

↳ Number of types and methods are in use for bituminous pavement construction. It is attempted to broadly classify them here based on the methods of construction. The following construction techniques are in use :

- (a) Interface treatments like prime coat and tack coat.
- (b) Surface dressing and seal coat.
- (c) Grouted or penetration type constructions:
  - (i) Penetration Macadam.
  - (ii) Built-up spray grout
- (d) Premix which may be any of the following
  - (i) Bituminous Bound Macadam

continue - - - -

- Date \_\_\_\_\_  
Page \_\_\_\_\_
- ⑫ Carpet
  - ⑬ Bituminous Concrete
  - ⑭ sheet asphalt or rolled asphalt
  - ⑮ mastic asphalt.

## # Explanatory Notes on Bituminous Construction:

### ① Interface Treatment:

↳ The surface of the existing pavement layer is to be cleaned to remove dust and dirt and a thin layer of bituminous binder is to be sprayed before the construction of any type of bituminous layer over this surface. This treatment with bituminous material is called interface treatment which is necessary to provide the necessary bond between the old and the new layers.

↳ One interface treatment may either be a prime coat or a tack coat and in some cases, the prime coat followed by a tack coat.

### ② Prime Coat:

↳ Prime coat is the first application of low viscosity liquid bituminous material over an existing porous pavement surface.

↳ The main objective of prime coat is to plug capillary voids of porous surface and to bond the loose mineral particles on the existing surface.

↳ The bituminous primer is sprayed uniformly using mechanical sprayer at a rate of 7.30 to 14.60 kg per  $10m^2$ .

### • Functions of Prime Coat:

- ① It develops adhesion or bond between base and wearing surface.
- ② It seals the pores and capillary voids thus making it water proofing.
- ③ It binds together any loose aggregates on the existing surface.

### ① Tack Coat:

- ↳ Tack coat is the application of bituminous material over an existing pavement surface which is relatively impervious.
- ↳ Tack coat is usually applied by a mechanical sprayer of higher viscosity like the hot bitumen at the rate of 4.90 to 9.80 kg per  $10\text{m}^2$  area depending upon the type of the surface.

#### • Function of Tack Coat:

- ① It ensures adhesion between the existing surface and the new bituminous surface.

### # Seal Coat:

- ↳ Seal coat is usually recommended as a top coat over certain bituminous pavements which are not impervious. It is also provided over an existing bituminous pavement which is worn out.

↳ The seal coat is a very thin surface treatment which is usually applied over an existing black top surface.

- ↳ It consists of aggregates and binder. The quantity of binder and aggregates can be as follows:

- Binder: 9.8 - 12 kg /  $10\text{m}^2$  area.

- Aggregates: 0.09  $\text{m}^3$  /  $10\text{m}^2$  area.

#### • Functions of Seal Coat:

- ① To seal the surface against infiltration of water.
- ② To make the road surface smooth, even and skid resistant.
- ③ To increase the strength and bearing capacity of existing surface.

## # Surface Dressing:

### # Introduction:

↳ Surface dressing is a process whereby a thin film of bituminous binder is sprayed on the road surface, covered by a coat of mineral aggregates and well rolled.

### # Importance of Surface Dressing:

↳ Surface dressing refers to the thin surface coverings of bituminous layers and mineral aggregates. The stability of WBM road depends upon the gradation, shape of aggregate and binders, which keeps the stone pieces together. Since, the binder in WBM road is soil slurry (semi-liquid mixture), it is easily removed by fast moving vehicles and causes the failure of WBM road. Bituminous surface dressing prevents the removal of binding materials from WBM course.

### # Function of WBM Course:

↳ The main functions of WBM course are as follows:

- ① To provide a dust free pavement surface over a base course.
- ② To provide a water proof layer and to prevent the infiltration of surface water.
- ③ To prevent the base course from raveling and abrasion action of traffic.

### # Types of Surface Dressing:

① Single Bituminous Surface Dressing

② Double Bituminous Surface Dressing

#### ① Single Bituminous Surface Dressing:

↳ A single surface treatment is a wearing course of bituminous material and aggregate in which the aggregate is placed uniformly over the applied bituminous materials in a single layer. The thickness of which approximates the normal maximum size of the aggregate used.

## \* Construction of single Bituminous surface Dressing:

↳ The construction of single bituminous surface dressing involves:

### • Materials Required:

#### ① Bitumen:

↳ Having grade between  $\frac{80}{100}$  ~~or~~  $\frac{180}{200}$ .

#### ② Coarse aggregate:

↳ Preferable crushed stone, clean, strong, durable.

#### ③ For first coat:

↳ Passing through 18mm sieve and retained at 9mm sieve. Thickness of first coat 12mm @  $0.14 - 15 \text{ m}^3$  per  $10 \text{ m}^2$  area.

### • Equipments Required:

① Bitumen heating device and sprayers

② Mechanical sweeper or hand brush.

③ Aggregate spreader.

④ Pneumatic roller etc.

### • Construction Procedures:

#### ① Preparation of existing surface:

↳ Ruts and depressions are rectified and prepared to proper profile before the treatment is done. All the dust particles or loose materials are removed and prime coat is applied if the existing base course has previous surface.

#### ② Application of binder:

↳ Uniform spraying of bituminous binder is done at the specified rate on a prepared surface using mechanical sprayer. Care is taken not to apply excessive binder at localized area as it would result bleeding.

Continue - - -

### (iii) Application of Stone chippings:

↳ Cover material is spread as per the requirement to cover the space uniformly.

### (iv) Rolling of first coat:

↳ Rolling is done with tandem roller (6 to 8 tonnes) starting from the edge and proceeding towards the centre longitudinally. Rolling is continued until the particles are firmly inter-locked.

### (v) Finishing and Opening to Traffic:

↳ The surface is checked for longitudinal and cross profile. The road surface is opened to traffic after 24 hours.

## (2) Double Bituminous Surface Dressing:

↳ A double surface treatment is a wearing course composed of bituminous material and aggregate in which the coarser aggregate is placed over an initial application of bituminous material and followed by subsequent application of bituminous material and smaller aggregate.

### # Construction of Double Bituminous Surface Dressing:

↳ The construction of double bituminous surface dressing involves:

#### ● Materials Required:

##### (i) Bitumen:

↳ Having grade between  $\frac{80}{100}$  or  $\frac{180}{200}$ .

##### (ii) Coarse aggregate:

↳ Preferable crushed stone, clean, strong, durable.

##### (iii) For First Coat:

↳ Passing through 18mm sieve and retained on 9mm sieve. Thickness

Continue---

of first coat 12mm @ 0.14 - 15 m<sup>3</sup> per 10 m<sup>2</sup> area.

(iv) For second coat:

- ↳ Passes through 12mm sieve and retained in 6mm sieve.
- ↳ Thickness - 9mm
- ↳ Spreading rate → [0.09 - 0.1 / m<sup>3</sup> / 10 m<sup>2</sup> area]

• Equipments Required:

- (i) Bitumen heating device and sprayers
- (ii) Mechanical sweeper or hand brush
- (iii) Aggregate spreader
- (iv) Pneumatic roller etc.

• Construction Procedures:

(i) Preparation of existing surface:

↳ Ruts and depressions are rectified and prepared to proper profile before the treatment is done. All the dust particles or loose materials are removed and prime coat is applied if the existing base course has pervious surface.

(ii) Application of binder:

↳ Uniform spraying of bituminous binder is done at the specified rate on a prepared surface using mechanical sprayer. Care is taken not to apply excessive binder at localized area as it would result bleeding.

(iii) Application of stone chippings:

↳ Cover material is spread as per the requirement to cover the space uniformly.

(iv) Rolling of first coat:

↳ Rolling is done with tandem roller (6 to 8 tonnes) starting

continue....

from the edge and proceeding towards the centre longitudinally. Rolling is continued until the particles are firmly inter-locked.

(v) Application of binder and stone-chippings for second coat:

↳ Immediately after applying the binder to the prepared surface as per the requirement, cover materials are spread as before.

(vi) Rolling of Second coat:

↳ Rolling is done with tandem roller (6 to 8 tones) starting from the edge and proceeding towards the centre longitudinally. Rolling is continued until the particles are firmly inter-locked.

(vii) Finishing and Opening to Traffic:

↳ The surface is checked for longitudinal and cross profile. The road surface is opened to traffic after 24 hours.

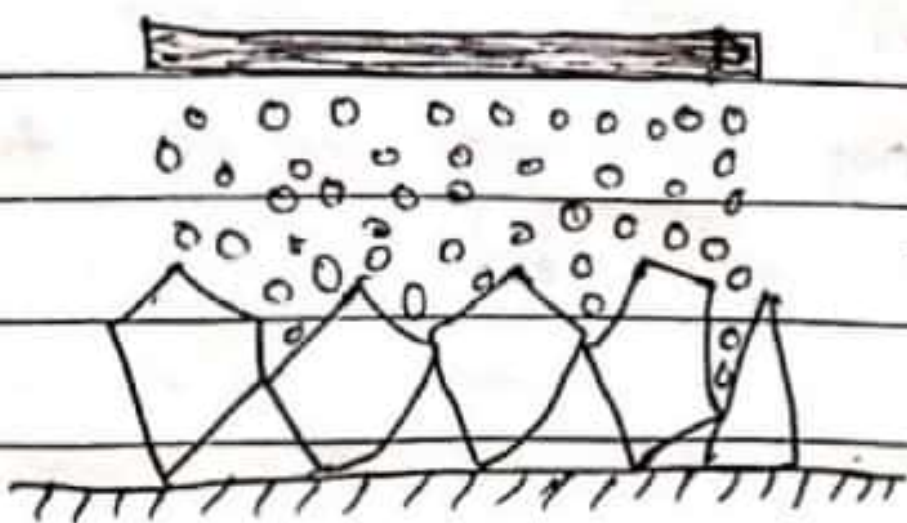
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# Grouted Macadam [Penetration Macadam] Construction:

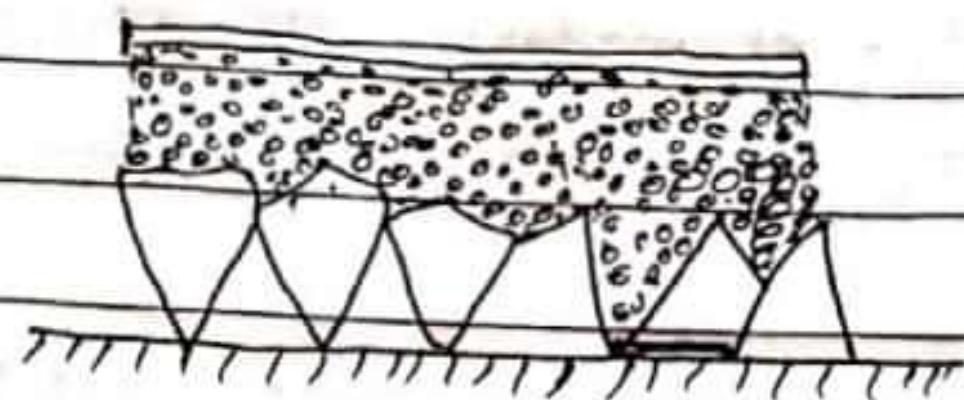
# Introduction:

↳ It is used as base or binder course. The coarse aggregate are first spread and compacted well in dry state and after that hot bituminous binder of relatively high viscosity is sprayed in large quantity.

↳ The bitumen penetrates into the voids from the surface of the compacted aggregates. Thus filling some part of the voids and binding some stone aggregates together.



(a) Before Compaction



(b) After Compaction.

Fig: Grouted [Penetration] Compaction

## # Types of Grouded [Penetration] Macadam:

↳ Depending upon the quantity of bitumen spread and the extent of penetration, it is classified as:

(a) Full Groud

(b) Semi Groud

### (a) Full Groud:

↳ When bitumen penetrates to the full depth of compacted aggregates, it is called full groud. It is adopted in regions of heavy rainfall.

### (b) Semi Groud:

↳ When bitumen penetrates up to about half of the depth, it is called semi groud. It is adopted in regions of moderate rainfall.

## # Construction of Grouded [Penetration] Macadam:

• Thickness: Thickness varies from 5 to 7.5 cm.

### • Materials Required:

#### (i) Bitumen:

↳ Bitumens having grade;  $\frac{80}{100}$ ,  $\frac{60}{70}$ ,  $\frac{30}{40}$ .

#### (ii) Aggregate:

↳ Aggregate should be hard, durable, strong, clean etc.

↳ Test Values:

• Los Angeles abrasion value — 35% (maximum).

• Water absorption — 1% maximum.

• Maximum size of aggregates.

Thickness of layer

Coarse aggregate

key aggregate

75mm thick

63mm down

5mm down

50mm thick

50mm down

19mm down.

continue ---

• **Plants and Equipments :**

- ① Bitumen heating device
- ② Bitumen sprayer.
- ③ Aggregate spreader
- ④ Pneumatic roller

• **Construction Procedures (steps) :**

① **Penetration of existing surface :**

↳ The under laying course is prepared and conditioned to a uniform grade. The surface is lightly scarifier and brushed prime coat may be applied on porous surface.

② **Spreading of coarse aggregate (edge protection) :**

↳ The coarse aggregates are spread either by mechanical spreader or by hand. A template cut to camber profile is used to achieve the desired profile in cross-section.

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③ **Rolling (Dry rolled with 10 tonne roller) :**

↳ Rolling is commenced from side and proceeded to the centre the overlap recommended being 30cm. Rolling of crushing or when the internal movement of aggregate are stopped.

④ **Bitumen Application :**

↳ 50 and 68 kg for 5 and 7.5cm thick for  $10\text{m}^2$  area are used.  
↳ The binder is applied over dry compacted aggregate with mechanical sprayer.

⑤ **Spreading of key aggregate :**

↳ After the application of bitumen, the key aggregates are spread and rolled them and at last checked profile on cross-section.

Continue - - - -

### (VI) Seal coat:

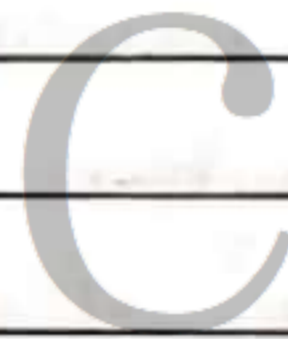
- ↳ Seal coat is applied if another surfacing course is constructed immediately and traffic has to be allowed.
- ↳ The pavement section is rolled again but excessing rolling should be avoided.

### (VII) Finishing:

- ↳ The constructed pavement is checked for its cross profile with templates long it national profile by straight edge.

### (VIII) Opening to Traffic:

- ↳ The road is opened to traffic after 24 hours.



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## Unit-5 Highway Maintenance & Repair

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### # Introduction to Highway Maintenance:

- ↳ Road maintenance is one of the important components of the entire road system. The maintenance operations involve the assessment of road condition, diagnosis of the problem and adopting the most appropriate maintenance steps.
- ↳ The process of preserving the serviceable condition of road or highway as normal as possible is called highway maintenance.

### # Causes of Pavement failures:

- ↳ Some of the general causes of pavement failures needing maintenance measures may be classified as given below:
  - (i) Defects in the quality of materials used.
  - (ii) Defects in the construction methods and quality control during construction.
  - (iii) Inadequate surface or sub-surface drainage in the locality resulting in the stagnation (circulation) of water in the subgrade or in any of the pavement layers.
  - (iv) Increase the magnitude of wheel loads and the number of loads — repetitions due to increase in traffic volume.
  - (v) Settlement of foundation of embankment of the fill materials itself.
  - (vi) Environmental factors including heavy rainfall, soil erosion, high water table, snow fall, frost action etc.

### # Types of Maintenance Works:

- ↳ The various items of highway maintenance works may be broadly classified under three heads:

#### (I) Routine Maintenance:

- ↳ This type of maintenance may be termed as the repair. Generally this type of maintenance is repair continuously formed by road called routine maintenance.
- ↳ This include filling up of pot holes, and patch repairs, maintenance of shoulders and the cross slope, up-keep of the road side drains and clearing chocked culverts, maintenance of miscellaneous items like road signs, arboriculture, inspection bungalows.

## ② Periodic Maintenance :

↳ It is the maintenance operation of large quantity required fixed interval of time. This maintenance includes of :

- ① Renewal of wearing course.
- ② Surface Treatment.
- ③ Preventive maintenance of various items.

## ③ Special Maintenance :

↳ These include strengthening of pavement structure or overlay construction, reconstruction of pavement, widening of roads, repair of damages caused by floods, providing additional safety measures like islands, signs etc.

## # Maintenance and Repair Works in Low-cost Surfaces :

↳ Low cost surfaces includes the surface of earthen road, gravel road and WBM road which are described below:

### ① Maintenance of Earthen Roads :

↳ Earthen road is spread used in case of Nepal. So the great maintenance is necessary of these roads.

↳ The usual damages caused in the earth roads needing frequent maintenance are:

- ① Formation of dust in dry weather
- ② Formation of longitudinal ruts along wheel path or vehicles.
- ③ Formation of cross ruts along the surface after monsoons due to surface water.

### • Maintenance :

① Dust nuisance may be remedial by:

- frequent sprinkling of water.
- Treatment with calcium chloride.
- Use of other dust.

② By adopting oiled earthen roads.

③ By spreading moist soil along ruts.

continue-----

- (iv) By reshaping of camber properly.
- (v) Providing appropriate drainage facilities.
- (vi) By providing stabilized layer on top.

### ② Maintenance of Gravel Roads:

↳ Maintenance of gravel roads includes the following operations:

- (i) Filling the local depressions with fresh materials.
- (ii) Grading is done to restore them to original condition for this matter grader is used.
- (iii) Dragging or corrugation that arise within pavement can be rectified by dragging.
- (iv) Re-gravelling if this occurs the pot holes or holes with 25 mm thickness.
- (v) By frequent sprinkling water.

### ③ Maintenance of WBM Roads:

↳ Defects that occurs in the WBM roads are as follows:

- (i) Formation of ruts.
- (ii) Formation of pot holes.
- (iii) Formation of corrugation.
- (iv) Dust in the dry weather.
- (v) Revelling of coarse aggregate.
- (vi) Damage edges.

#### • Maintenance:

↳ All these problems can be remedies by following maintenance activities:

- (i) frequent sprinkling of water in surface.
- (ii) Spreading practically, it is really in monsoon season.
- (iii) Using calcium - chlorides.
- (iv) Providing bituminous surface dressing over WBM.
- (v) Patch repair works on ruts and pot holes.
- (vi) Re-surface after period of useful life.

## \* Maintenance and Repair Works in Bituminous Surface Roads:

↳ Mainly the maintenance works of bituminous surfacing consists of:

- (i) Patch repairs
- (ii) Pot hole repair works
- (iii) Surface treatments
- (iv) Re-surfacing.

### (i) Patch Repairs:

↳ Patch repairs are carried out on the damaged or improper road surface. Localized depression and pot holes may be formed in the surface layers - due to defects in materials and construction.

### (ii) Pot-holes repair work:

- ↳ Pot holes are cut to rectangular shape and the affected materials in the section is removed until the sound materials are encountered.
- ↳ The excavated patches are cleaned and painted with bituminous binder.
- ↳ A premixed material is then placed in the sections. Generally, cutback or emulsion is used as binder.
- ↳ Compaction with properly.

### (iii) Surface Treatments:

- ↳ Excess of bitumen in the surface materials bleeds and the pavement becomes patchy and slippery. Corrugations or rutting or shoving develop in such pavement surfaces.
- ↳ It is customary to spread blotting materials such as aggregate chips of maximum size of about 10mm or coarse sand during summer.
- ↳ Necessary rolling is done to develop permanent bond between the existing surface and the new materials after heating the surface if necessary.

continue - - -

### (iv) Re-surfacing :

- ↳ Re-surfacing is carried out only, when the existing pavement surface is totally worn out and develops a poor riding surface. It may be more economical to provide an additional surface course on the existing surface.
- ↳ In case of pavement is of inadequate thickness due to increase in traffic loads and strengthening is necessary, then an overlay of adequate thickness should be designed and constructed.

### # Maintenance and Repair Works in Drainage Structures :

- ↳ Proper drainage maintenance requires, that all of structured pavement to removal water from drainage structure. The following problems are formed in drainage works:

- (i) Growing of vegetation inside to the drainage.
- (ii) Formation of gulling in side slopes.
- (iii) Damage of drainage structure and outlet due to flood and other external factor.
- (iv) Blocking of drainage.
- (v) Outflow of drainage structure.

- ↳ The maintenance operations are followed under the following unit of drainage.

1. Surface drainage
2. Ditches
3. Sub-surface drainage.

#### 1. Surface Drainage Maintenance :

- (i) Silt cleaning side drain and construction of new drains when necessary.
- (ii) Cross result may be repaired after necessary stabilized layer is provided.
- (iii) Removal of vegetations.
- (iv) Regular inspection, routine maintenance.
- (v) First of all detailed inspection of culvert and bridge and finding the problems.

## 2- Ditches Maintenance:

- ① The collected water is drain off by pumping agent or removed from surface regularly.
- ② The slope of ditches should be properly maintained.
- ③ Remove the blocked pavement from ditches.

## 3- Sub-Surface Drainage Maintenance:

- ① Sub-surface drainage such as catch basin, manholes, culverts, storm sewer etc are inspected regularly.
- ② Used filter media on inlet of sub-surface clearing.
- ③ Clear the drain regularly and maintain the wall of drainage on new construct.
- ④ Remove the silts on pipe of drainage.

## # Maintenance of Miscellaneous Road Structures:

### ● Shoulder Maintenance:

↳ Shoulder gives the lateral support to the pavement and also provides rooms for wheel when crossing and overtaking on narrow pavement. So, proper maintenance is done on shoulder which may be done following:

#### ① Turfing:

↳ Turfing is done to increase stability of shoulder. Light cutting of grass should be done for good performance. The turfed shoulder should be immediate require.

#### ② Soil stabilization:

↳ Shoulder may be prevented from damage by its stabilization materials. Bituminous treatment used on shoulder.

• **Slope Maintenance:**

↳ Slope may be the cutting slope or banking slope and should be kept in the well condition. Failure of any slope may cause damage in the pavement. Slope can be kept in well condition by:

- ① Riprap work on slope.
- ② Turfing
- ③ Different bio-engineering techniques.

• **Maintenance of Retaining structures:**

↳ Proper maintenance of retaining wall should be done. Retaining wall may be of cement concrete, plain or reinforced. Maintenance of these surface required regular inspection to added defects. Weepholes are checked regularly. Otherwise retaining wall collapse due to water presence.

- ① Disintegration of complete wall should be repaired by pressure grouting methods.
- ② Mortar joint in masonry should be defilled.
- ③ If required new masonry structure should be construct.

• **Maintenance / Painting of the Road Furnitures:**

↳ Painting is done in guard-rail (horizontal bar), timber posts, metal posts etc. Generally maintenance work in the steel bridge is painting. Before new painting the surface of metal to be painted should be cleaned, having more dirt and dust.

↳ The painting through single coat and double coat on steel surface. Re-painting of sign-post in the highway should be done periodically.

## Unit-6 Bridge

### # Introduction:

↳ A bridge is a structure providing a passage over an obstacle without closing the way beneath. The passage may be for a road, pedestrians, railways, etc. The obstacle may be a river, a road, railways etc.

### # Characteristics of Ideal Bridge:

- (i) Bridge should be designed to carry standard load or other equipment load with factor of safety.
- (ii) Foundation of bridge should be constructed over the hard rock.
- (iii) Foundation of deep enough to reduce the scouring effect.
- (iv) Camber should be provided throughout the length of bridge.
- (v) Bridge should not produce obstruction to flow of water even in highly water flow.
- (vi) The line of bridge should not deviate from the line of approach roads on either side.
- (vii) The bridge should be in level. It has to be provided of gradient. It should be confirmed to that roadway on the both side.
- (viii) The width of the road should be adequate to enter the traffic of design speed.
- (ix) Overall structure should fit into the surrounding landscape.
- (x) The bridge should be economical in construction and maintenance.

### # Ideal Location of Bridge Site:

- (i) Straight edges of river.
- (ii) Narrow and well define channel.
- (iii) Steady regime of the river without serious cross-current.
- (iv) Strong foundation layer.
- (v) straight approach road.
- (vi) No erosionable banks.
- (vii) Economical in term of construction and other expenses.
- (viii) Absence costly drainage works in the river.

## # Factors Affecting Choice of Bridge Site:

- (i) Climatic and environmental condition unsuitable for bridge.
- (ii) Topographic and soil condition.
- (iii) Traffic type load etc.
- (iv) Ability of found materials and manpower.
- (v) To reduce no. of piers, special type of bridge.

## # Classification of Bridge:

↳ Bridges can be classified into various types according to:

### (1) Based on Inter-Span:

- (a) Simple Bridge
- (b) Continuous Bridge
- (c) Cantilever Bridge

### (2) Based on Length [According to NRS]:

- (a) Minor Bridge - Length more than 6m and upto 20m.
- (b) Medium Bridge - Length above 20m and span less than 20m.
- (c) Major Bridge - Length above 120m and span more than 20m.

### (3) Based on structure:

- (a) RCC or simply supported bridges.
- (b) Cantilever bridge.
- (c) Double-cantilever bridge.
- (d) Arch bridge
- (e) steel bridge
- (f) Suspension / suspended bridge
- (g) Cable stayed bridge.
- (h) Movable bridge.

continue-----

#### ④ Based on Loading:

##### ① IRC class-AA Loading:

↳ Individual axial load maximum 20 tonne and boggies axial load of 40 tonne.

##### ② IRC Class-A Loading:

↳ Axial load maximum 11.4 tonne.

##### ③ IRC Class B Loading:

↳ Axial load maximum 60 tonne.

#### ⑤ Based on Material:

① Timber bridge

② RCC bridge

③ steel bridge

④ Pre-stressed bridge etc.



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#### # T-Beam Bridge:

↳ T-beam bridge is suitable for a span range in 10 to 25m.

↳ The main longitudinal girders are designed as T-beams, integral with part of the deck slab, which is cast-monolithically with the girders.

↳ There are following points to T-beam bridges.

##### ① Super-structure:

↳ Super structure defines the component above the level of bearing, which consists of:

##### ① Decking:

↳ It consists of:

• Slab

• Girder beam

• Trusses

• Railing parapet etc.

##### ② Bearing of decking

**⑥ Sub-structure:**

↳ Parts of the bridge below bearing level is called sub-structure parts. It consists of:

- ① Abutments and piers.
- ② Foundation of pier and abutment.
- ③ River training work.
- ④ Approaches of bridges to connect bridge to road.

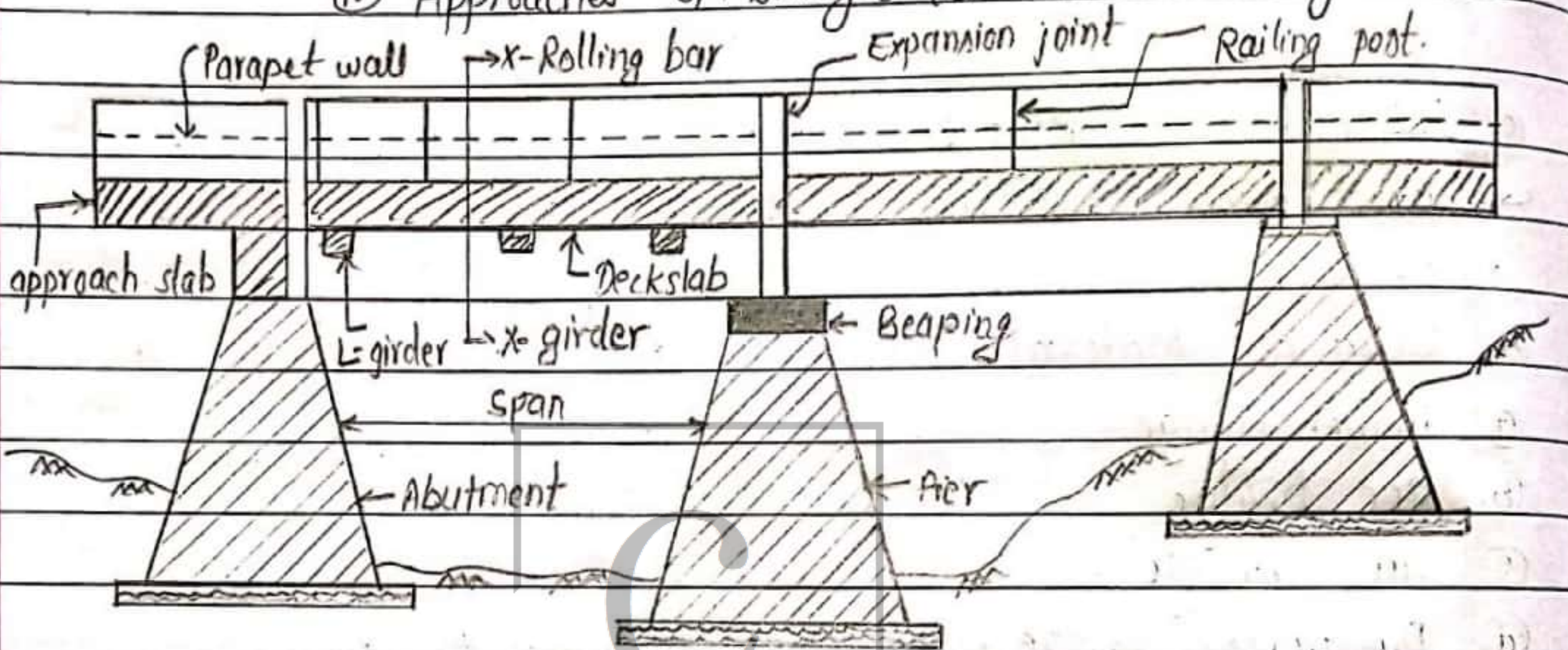
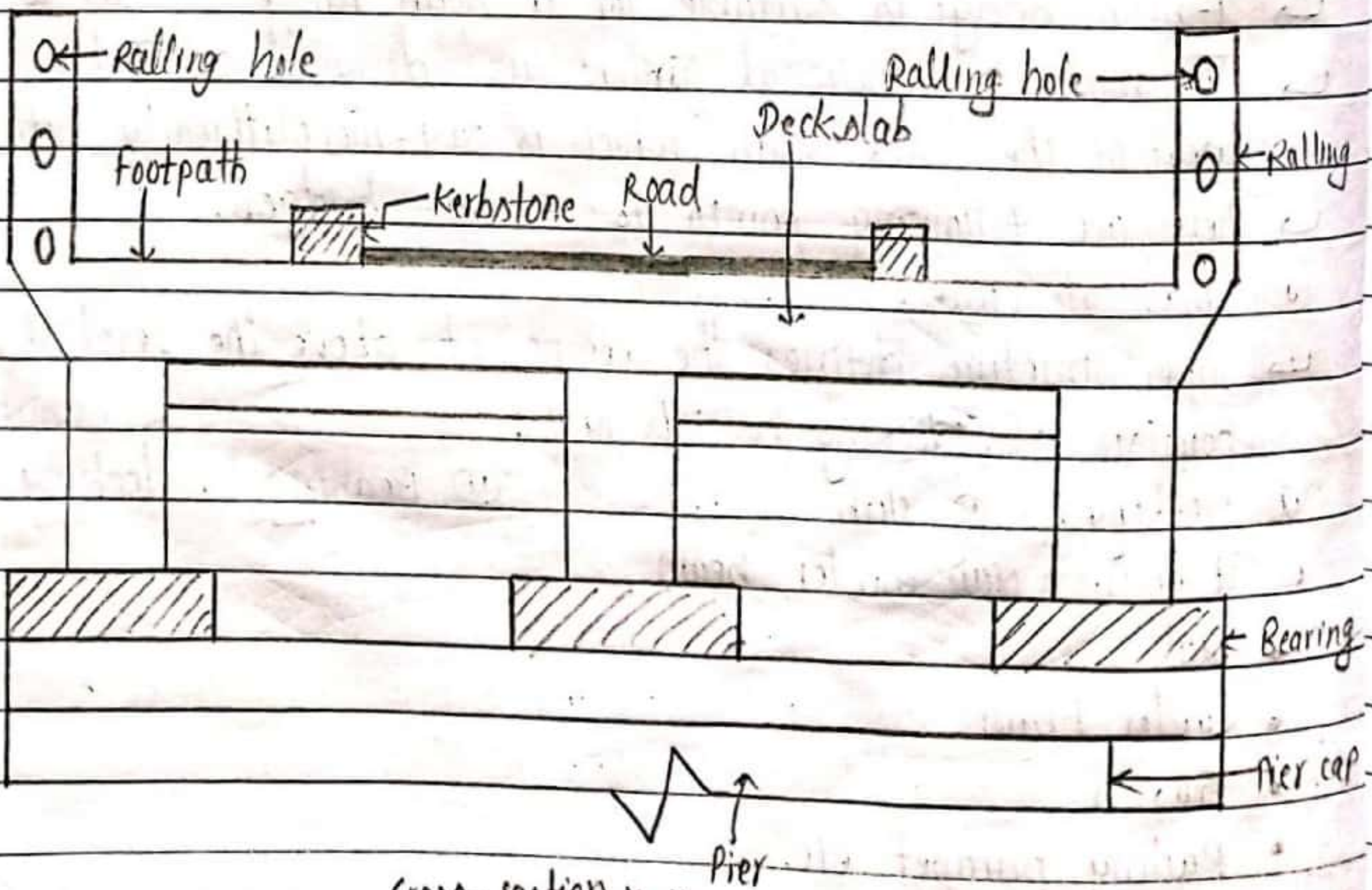


Fig:- L-section of bridge.

*Ctevt Notes*



Cross-section x-x  
Fig:- T-beam with components.

## # Trail Bridge:

- (i) Suspended bridge (D-type)
- (ii) Suspension bridge (N-type)
- (iii) Longspan trail bridge.
- (iv) short span trail bridge
- (v) Twin bridge
- (vi) steel-truss bridge.
- (vii) Cable stayed bridge.

## # Suspension Bridge:

### # Introduction:

- ↳ A Suspension bridge is a type of bridge in which the deck (load bearing portion) is hung below the suspension cable on vertical suspenders.
- ↳ This type of bridge has cable suspended between the towers plus vertical suspenders that carry the weight of the deck below.
- ↳ The suspension cable must be anchored at each end of bridge load transfer by tension on main cable.
- ↳ The advantages of such bridge are longer main spans, low construction cost and can withstand earthquake movements that heavier and more rigid bridges.

### # Components of Suspension Bridge and their Functions:

↳ The following components are adopted on suspension bridge:

#### 1. Tower:

↳ Take the load within the main cable and transport to the tower foundations. Take tension load in the main cable.

#### 2. Main Cable:

↳ Always is in tension. Take up the load within the bridge. It is the main component of the bridge.

Continue - - -

### 3. Suspenders:

↳ Join main cable and spanning cable hence transfer all the loads in the walkway deck to the main cable through it.

### 4. Handrail Cable:

↳ Generally provided for the effective walkway provide the stability to the pedestrian over it.

### 5. Walkway deck:

↳ Provide the effective walkway to the pedestrian, generally walkway deck are of steel materials.

### 6. Main Cable of drum anchorage:

↳ Generally provided over the rocky start and is made stiff through steel rods under it.

### 7. Windgye Cable:

↳ Prevent the swing of suspension bridge due to the effect of wind.

### 8. Dead-man anchorage:

↳ Provide transfer load of main cable to the ground.

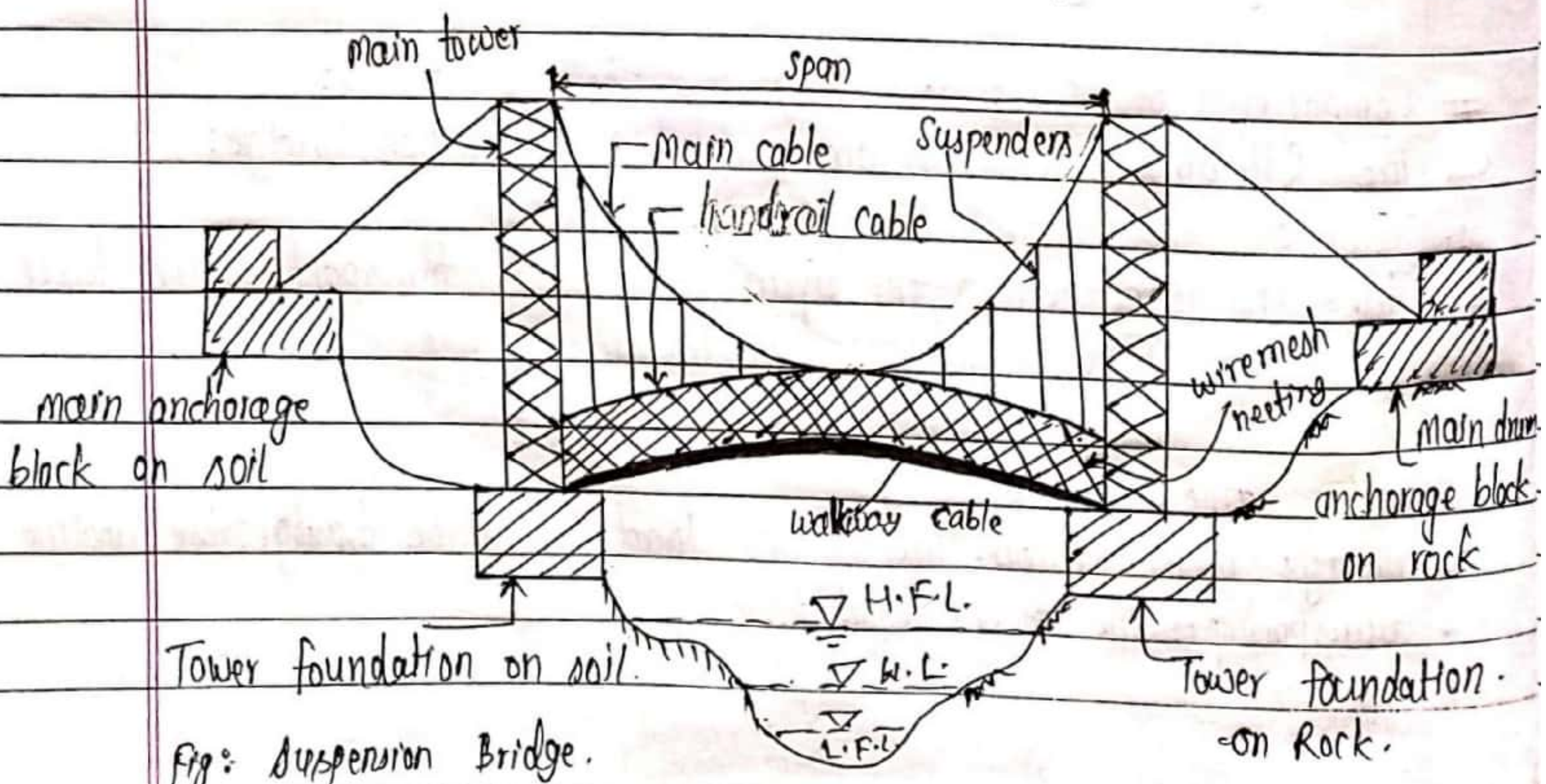


Fig: Suspension Bridge.

## # Suspended Bridge:

- ↳ This type of bridge has downward walkway. Sagging walkway cables are suspended below, their anchorage cable are anchored into the main anchorage foundation at both bank.
- ↳ This type of bridge is selected where the bridge foundation can be placed at sufficiently high position giving required free board from highest flood level. Suspended type is more economical, simple to design and construct than suspension type bridge.

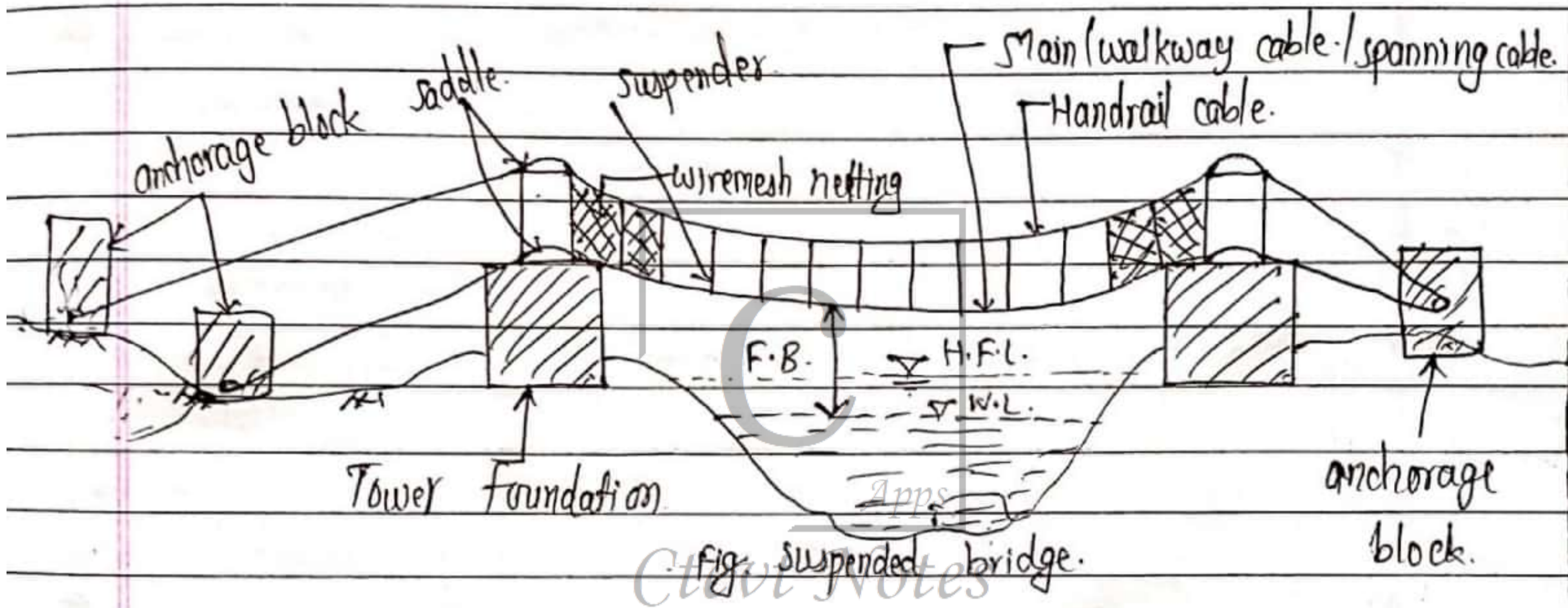


Fig. Suspended bridge.

## # Difference between Suspension and Suspended Bridge:

S.N.	Suspension Bridge	Suspended Bridge
1.	Tower taking load exists in this type. Cables are above the tower.	No tower exists in this type and walkway cables carry load bearing
2.	walkway width is 706 cm	walkway width is of two types i.e. 70cm and 100cm.
3.	Both banks should be equal levelled in this type.	Both banks may or may not be levelled in this type.
4.	It is too expensive (20-25% more than suspended bridge).	It is less expensive as compared to suspension bridge.
5.	It is ancient one and was used in 18 <sup>th</sup> century in Europe.	It is less ancient one and was used later on.
6.	walkway deck is hogging type.	walkway deck is sagging type.

#

Council for Technical Education and Vocational Training  
Office of the Controller of Examinations  
Sanothimi, Bhaktapur

Regular/Back Exam-2076, Shrawan/Bhadra

Program: Diploma in Civil Engineering Full Marks: 80  
Year/Part: III / II (2013) Pass Marks: 32  
Subject: Highway Engineering II Time: 3 hrs

-Candidates are required to give their answers in their own words as far as practicable. The figures in the margin indicate full marks.

Attempt Any Five questions.

- 1.a) What do you mean by road pavement? Discuss about different layers in pavement structure and their function. [2+6]
- b) Define compaction. Explain different types of compacting equipment used during road construction. [2+6]
- 2.a) Explain with neat sketches different typical cross-sections of hill road. [8]
- b) Define hill road. What are the specific considerations in the geometric design of hill road? [2+6]
- 3.a) What do you mean by road construction technology? Explain the construction procedure of Gravel roads. [2+6]
- b) What do you mean by surface dressing? Explain the construction procedure of double coat surface dressing. [2+6]
- 4.a) Define soil stabilization. Explain mechanical stabilization of soil in brief. [2+6]
- b) Define highway maintenance. How maintenance and repair works are carried out in bituminous road? [2+6]
- 5.a) What are the major problems in WBM road and describe the remedial measures for maintenance? [8]
- b) Define bridge. List out its components. Explain the characteristics of an ideal bridge. [2+2+4]
6. Write short notes on: (Any Four) [4x4=16]
- Interface treatment
  - Suspension bridge
  - Maintenance of road furniture's
  - Protection work in road construction.
  - Patch repair works.

**Good Luck!**

Council for Technical Education and Vocational Training  
Office of the Controller of Examinations  
Sanothimi, Bhaktapur  
Regular/Back Exam- 2077, Chaitra

80  
80

Program: Diploma in Civil Engineering

Full Mark:80

Year/Part: III/II (2013)

Pass Mark:32

Subject: Highway Engineering II

Time: 3 hrs.

Candidates are required to give their answers in their own words as far as practicable. The figures in the margin indicate full marks.

Attempt Any Five questions.

1. a) Define Road pavements. Distinguish between flexible pavement & rigid pavements. [2+6]
- b) List down the different types of tools, equipments & plants used in road construction. [8]
2. a) Define hill Road & Hair pin bends used in hill road. Explain the special structures used in hill road. [3+5]
- b) Define highway maintenance. Explain the various types of maintenance that is carryout in a highway. [2+6]
3. a) Introduce the WBM road. Write down its construction procedures. [8]
- b) What do you mean by soil stabilized road? Discuss on purpose & techniques of soil stabilization. [2+6]
4. a) Explain briefly the various activities involved in road construction [8]
- b) Discuss on maintenance & repair of drainage structures & shoulders. [8]
5. a) Classify the bridges according to span, length, loading, materials & structures. [8]
- b) Define suspension bridge draw a labeled diagram of suspension bridge along its components & functions. [2+6]
6. Write short notes on: (Any Four) [4x4=16]
- a) Gravity road
- b) Prime coat & Tackcoat
- c) Relation of OMC & Maximum dry density
- d) Maintenance of bituminous roads
- e) Types of surface dressing
- f) Road protection works.

Good Luck!