Transportation Engineering - II

Topics Covered: Highway Maintance Highway Drainage, Hill Roads and Brief coverage of machinery for costruction of bituminous roads: bitumen boiler, sprayer, pressure distributer, hot-mix plant, cold-mix plant, tipper trucks, mechanical paver or finisher, rollers. Mastic asphalt.

HILL ROADS

Introduction:

- Roads constructed in mountains region is called hill roads.
- There are different considerations while designing hill roads as compare to plain area roads.
- Types of curve used in hill roads is of different than plain road.
- All geometric parameters will gets changes while designing hill roads such as- Curves, Super elevation, SSD, OSD, Extra Widening, etc.

Components parts of Hill Roads

1. Road Bed
2. Side Drain
3. Parapet Drain
4. Catch Water Drains
5. Brest Wall
6. Retaining Wall
7. Cross Drains

Road Bed

- The pavement potion of hill road is called road bed.
- **Function:** To resist stresses developed due to moving traffic.

Side Drain

- Drain provided on the sides of road is called side drain.
- Side drains runs parallel to the length of road.
- **Function:** To collect and drain off rain water collected from camber of road.

Parapet Wall

- Wall which is provided above the formation level in the down side slope is called parapet well.
- **Function:** Protection to the traffic against falling down the hill slope.

Catch Water drain

- It is drain provided on higher slope running parallel to the length of road.
- **Function:** To make intercept for runoff coming from top of hill and divert water in to nearby cross drains.

Brest Wall

- The wall constructed to upside slope is called retaining wall.
- **Function:** Protect road from sliding of upside slope.

Retaining Wall

- The wall constructed to down side slope of road is called retaining wall.
- **Function:** To protect down slope from sliding.

Cross Drains

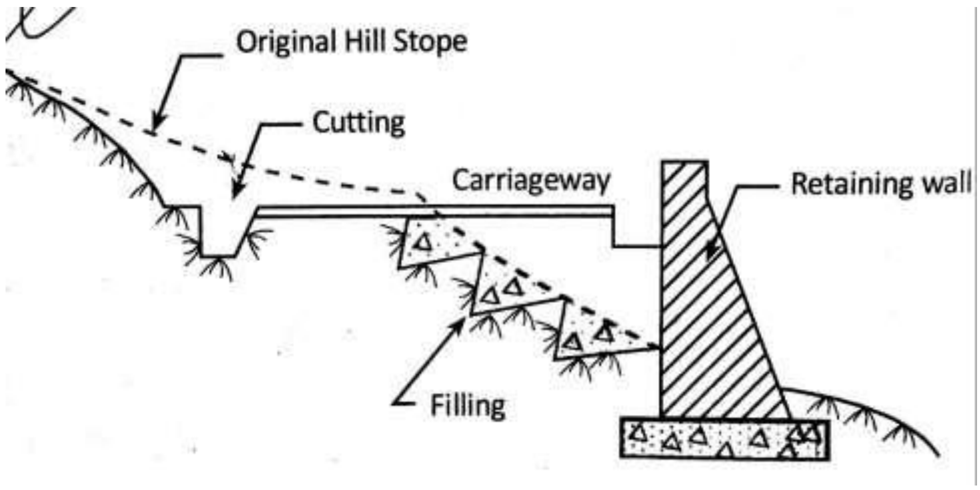
- The drain which is laid along width of road is called cross drains.
- **Function:** To drain off rain water collected in side drains and catch drains.

Image of Hill Road

Typical cross-sections hill road :-

The cross section of a road in a hilly terrain is determined by the original ground slope of the site, the slope of the road formation, width of roadway, side drain size, and shape and so on. Various types of road cross-section are:

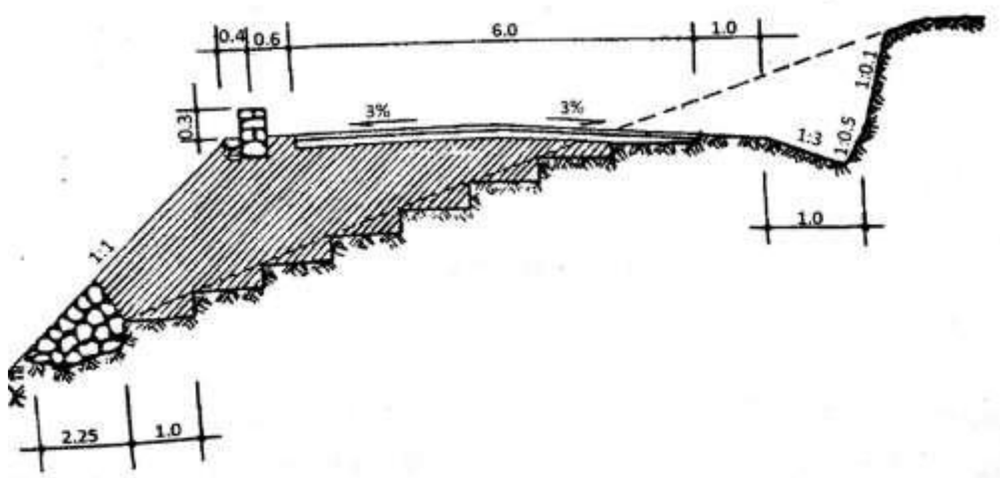
1. Cut and fill
2. Bench type
3. Box cutting
4. Embankment with retaining walls
5. Semi bridge
6. Semi tunnel
7. Platforms



Typical Cross Sections of Hill Road

Cut and fill

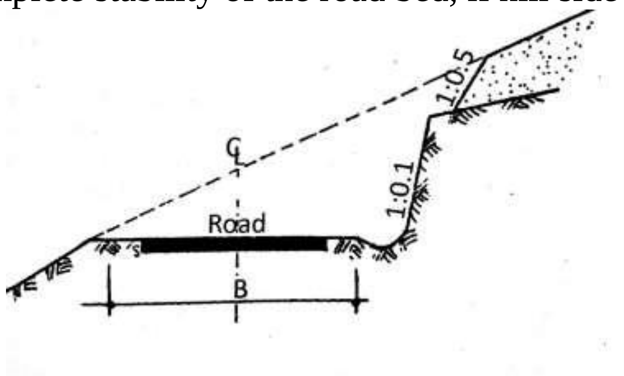
When roadbed slope has a gradient 2% or more a cut and fills road bed is cheaper and environmentally friendly as well. The fill mass is generally balanced by the cut mass. For adequate stability, benches are made on the surface of the hill side with a height of 0.5 m and length varying from 1.5 to 3.0m depending upon the slope.



Typical Cross Sections of Cut and fill

Bench type

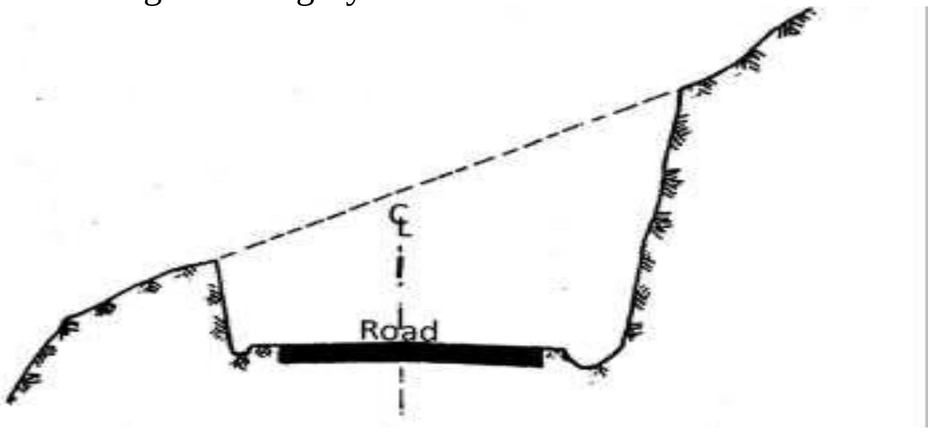
A cross section of the bench type although entails some increase in earthwork but ensures the complete stability of the road bed, if hill side is itself stable.



Typical Cross Sections of Bench type

Box cutting

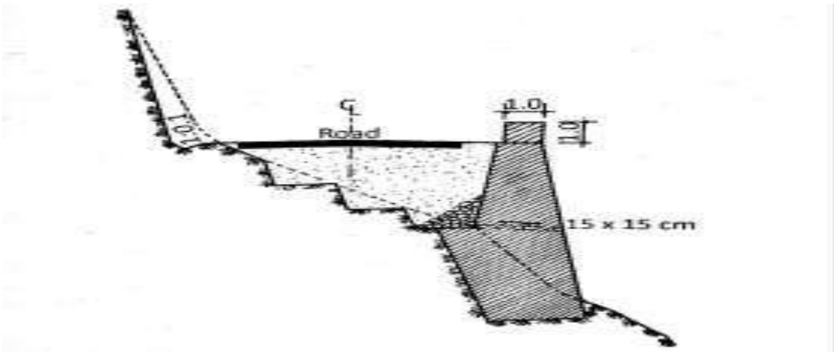
When the location of road bed is unstable or unsuitable along the hillside due to one or other reasons, the road bed is designed as trench type of cross section. It increases earthwork to a large extent. It is introduced to meet the geometric design standards for a given category road.



Typical Cross Sections of Box cutting

Embankment with retaining walls

On steep slopes of about 30-35°, the earthwork involved in constructing the embankment increases substantially. The retaining wall is sometimes provided to reduce earthwork's cost and to increase stability. Also, the retaining wall is provided when embankment soil on steep grounds itself need support. They may also be constructed on a less steep ground slope to increase the stability of road bed.



Typical Cross Sections of Embankment with retaining walls

Semi Bridge

If the road is located on a hill slope the retaining wall needs to be at a substantial height. In such cases, to reduce quantities of work, road bed with a semi-bridge type of structure may be constructed.

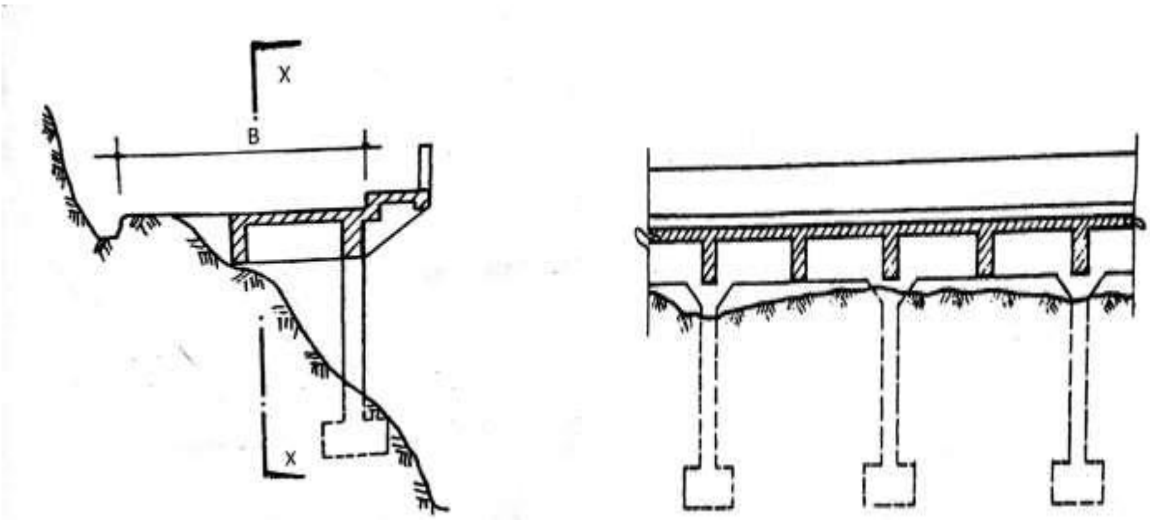


Fig: Cross Section and L-Section (X-X) of a Semi-Bridge.

Semi tunnel

When inscribing is to be cut into steep hills in stable rock faces, the rock may be permitted to overhang the road to reduce rock works. Such a cross section is called a semi-tunnel.

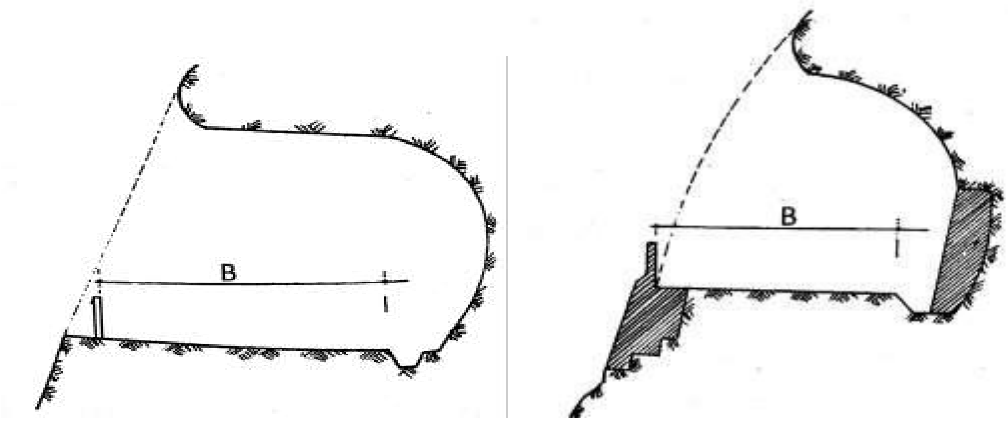
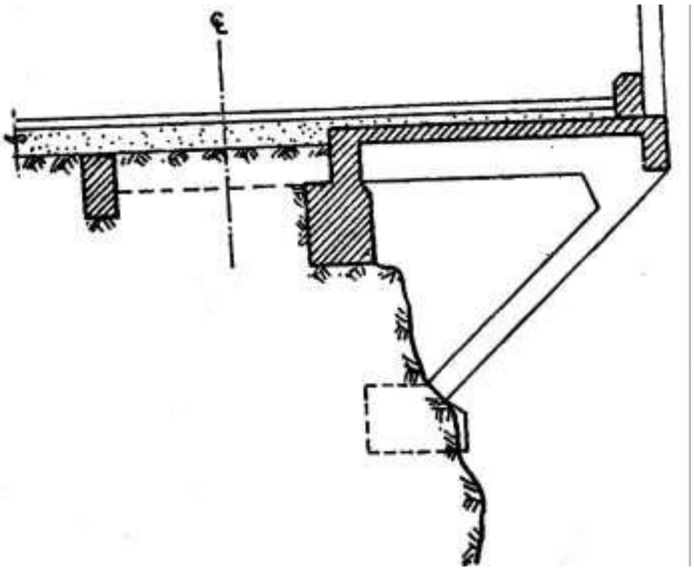


Fig: With Accommodating Road-Way Only and With Retaining and Breast Walls

Platform

On the precipitous slopes, where shifting of the route into the hillside will lead to enormous rock works which eventually increases the cost and where semi-tunnel cannot be constructed, platforms are usually cantilevered out of the rock on which road way is partially located.



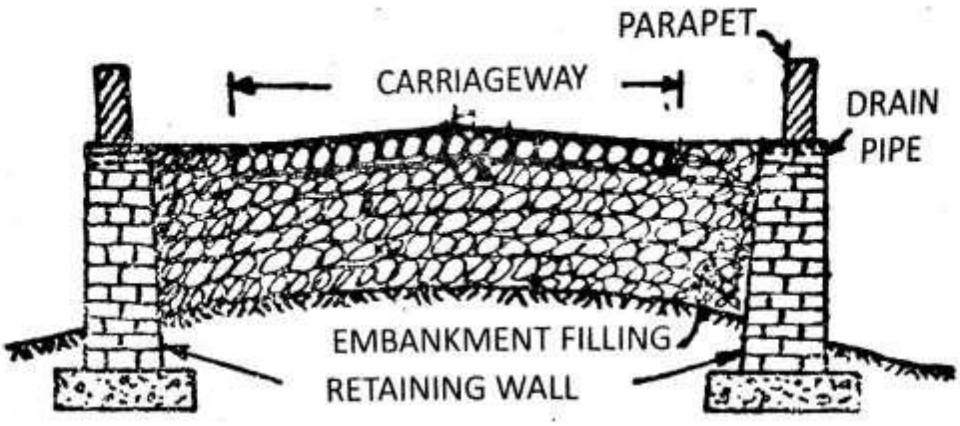


Fig: Fully In Embankment

Breast Walls

A breast wall is constructed to protect the natural sloping ground from the cutting action of natural agents. Breast walls also prevent slides of unreliable soils. The breast walls may be 0’6 m wide at the top. Weep holes should be provided at regular interval among the length of the wall to relieve the walls of saturated earth pressure. The breast wells are so designed that their line of pressure should be normal to the earth pressure or thrust.

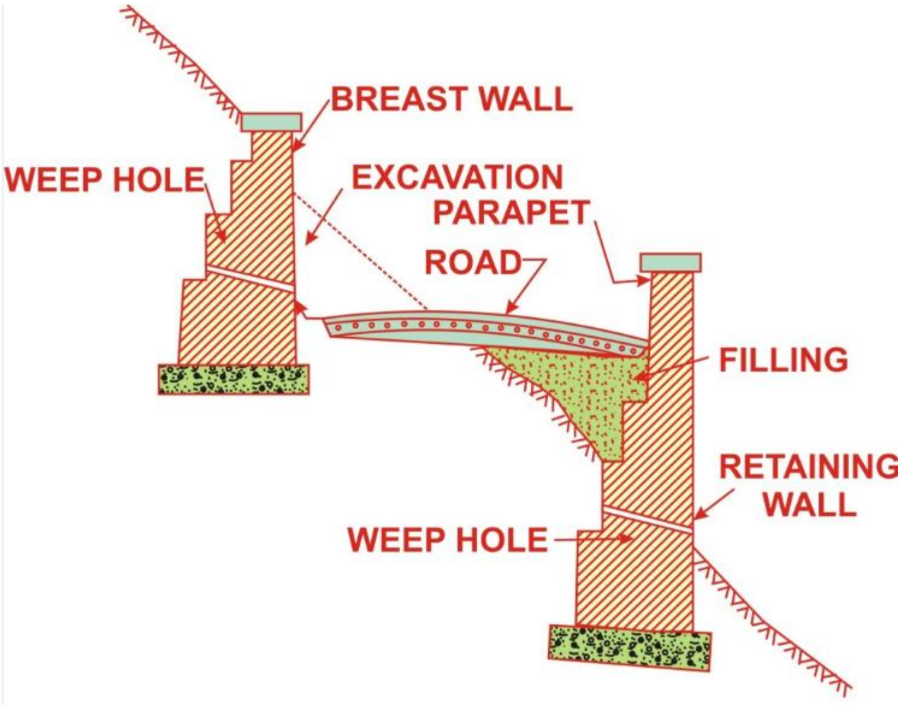


Fig. Retaining wall and breast wall

Retaining walls

The walls constructed for retaining or supporting earth against their back are called retaining walls. Earth cannot remain vertical but would be in a state of equilibrium when it assumes a natural angle which is called *angle of repose*. If it is desired to be retain the earth vertically, that portion of the earth will have to be supported by a wall called retaining wall. The back of the wall is in the form of steps and the face of the retaining wall may be either vertical or battered. The width at the base will depend upon the height of earth to be retained as the more the height, the greater will be the pressure at the base and the top can be kept 2 bricks thick .

Different between Breast walls and Retaining walls :

1. Breast wall and Retaining wall structure stand off to protect a freshly cut or old surface of a natural hill face.
2. Breast wall and Retaining wall structure prevent of hill slides under the action of weather and rain water flowing over hills slope. Retaining wall is provided to the downside of the road while breast wall uphill side of the road in hilly area.
3. Impact of snow, avalanches, landslides and surcharge are not considered in the design of Breast wall while in retaining wall all those factors are considered.
4. Height of breast wall shall not exceed 3 meter and for retaining wall we did not have such type of criteria.
5. Breast wall are not required to be constructed where back mass comprises of rocks or stable strata deposit of soil mass and for protecting the unstable soil mass we need retaining wall.

6. Retaining wall used for support artificial cutting or slope while breast wall used to support natural slope.
7. Design of retaining of wall capable to resist uplift pressure force and hydro static pressure for developed while breast wall is used to transfer the load.

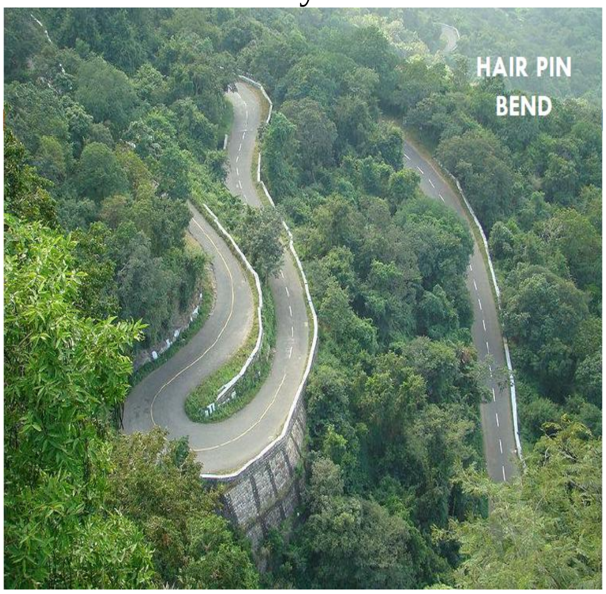
Different types of curves :

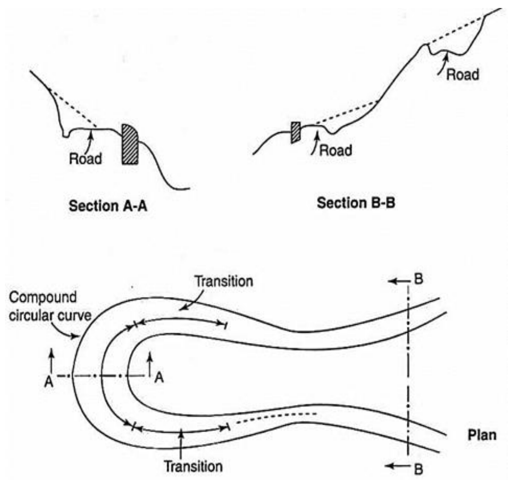
The following types of curves are mostly found on hill Roads:-

1.Hair-Pin bend curves
2.Salient Curves
3. Re-entrant Curves

1.Hair-pin curves:

- This type of curve modifies its direction via an angle of 180 degree down the hill on the similar side is defined as hair-pin curve.
- A Hair-Pin Bend: This curve is known as a hair-pin bend since it adheres to the shape of a hair-pin. If a bend is developed at the hair-pin curve in a hill road, it is called as hair-pin bend.
- This type of curve should have been situated on a hill side containing the lowest slope and highest strength. It is considered as very secure from view point of landslides and ground water. The ideal Hair-pin bends should contain long arms and farther spacing. They minimize construction issues and high-priced protective works.
- Hair-pin curves or bends with snakelike form are difficult to arrange and as a result they should not be recommended at all.



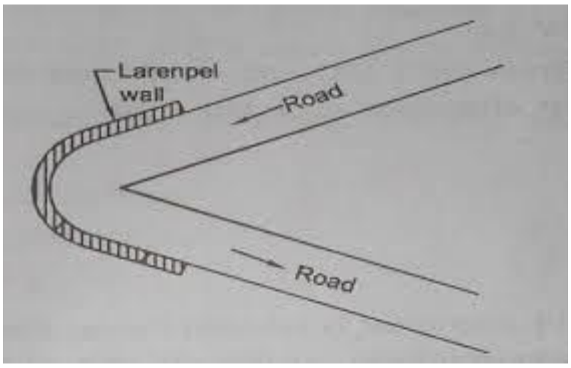


Schematic dig. of hair pin bend curve

2. Salient curves:

- The curves which contain their convexity on the exterior edges of a hill road are defined as salient curves.

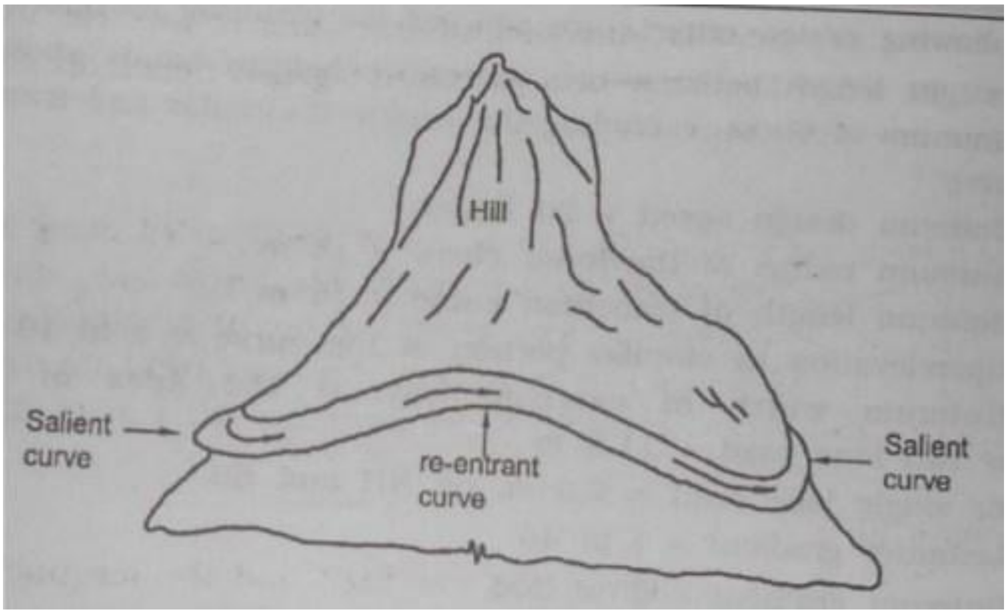
- The centre of curvature of a salient curve is located towards the hill side. This type of curve appears in the road length that is built up on the ridge of a hill. The bend that is developed at the salient curve in a hill road is called corner bend.
- Salient curves are very harmful for the traffic moving speedily. At such a curve or at corner bend, the segment of projected hill side is normally curtailed to make the perceptibility better.
- It is demonstrated in the following figure (re-entrant curve). In the exterior perimeter of the road, the curve is basically arranged with a parapet wall for safeguarding the vehicles from falling down the hill slope.



Schematic dig. of Salient curve

3. Re-entrant curves:

- The curves which contain their convexity on the inside edge of a hill road are known re-entrant curves.
- The centre of curvature of re-entrant curves is located ahead of the hill side. This type of curve appears in the road length that is built up in the valley of a hill.
- These curves are not harmful since they offer sufficient visibility to the traffic moving speedily. In such curves, the parapet wall is arranged only for protection for fast moving traffic.



Schematic dig. of Re-entrant curve

ROAD DRAINAGE

Introduction:

Highway drainage is the process of removing and controlling excess surface and sub-surface water within the right way. This includes interception and diversion of water from the road surface and sub-grade. The installation of suitable surface and sub-surface drainage system is an essential part of highway design and construction.

During rain, part of the rain water flows on surface and part of it percolates through the soil mass as gravitational water until it reaches the ground water below the water table. Removal and diversion of surface water from the roadway and adjoining land is termed as surface drainage, while the removal of excess soil-water from the sub-grade is termed as sub-surface water.

Necessity of road drainage work :

Highway drainage is important from various view points:

- Excess moisture in soil sub-grade causes instability under the road surface. The pavement may fail due to sub-grade failure. In some clayey soil variation in moisture content causes considerable variation in volume of sub-grade. This sometimes contributes to pavement failure.
- The waves and corrugations formed in case of flexible pavements also play an important role in pavement failure.
- Sustained contact of water with bituminous pavements causes failure due to stripping bitumen from the aggregates like loosening of some of the bituminous pavement layer and formation of pot holes.
- The prime cause of failures in rigid pavements by mud pumping is due to the presence of water in fine sub-grade soil.

- Excess water on shoulders and pavement edge causes considerable damage.
- Excess moisture causes increase in weight and thus increase in stress and simultaneous reduction in strength in soil mass. This is one of the main reasons of failure of earth slope and embankment foundations.
- In place where freezing temperatures are prevalent in winter, the presence of water in sub-grade and a continuous supply of water from the ground water can cause considerable damage to the pavement due to in frost action.
- Erosion of soil from top of un-surface roads and slopes of embankment, cut and hill side is also due to surface water.
- Failure due to hydraulic pressure and failure due to binder stripping can be avoided with the help of proper drainage on roads.

Cross drainage works :

For streams crossing the runways, drainage needs to be provided. Also often the water from the side drain is taken across by these cross drains in order to divert the water away from the road, to a water course or valley in the form of culverts or bridges. When a small stream crosses a road with linear water way less than amount six meter, the cross drainage structure provided is called culvert; for higher value of linear waterway, the structure is called bridge.

Types of Cross-drainage Structures:

1. Culverts (waterway less than 6 m)
2. Minor bridges (waterway from 6-30 m)
3. Medium-sized bridges (waterway from 30-100 m)
4. Major bridges (waterway more than 100 m)
5. Causeways

Categories (2) and (3) may also be clubbed and called Minor bridges. Bridges are designed such that they are not submerged even under the highest flood expected in a design period of, say 50 years or 100 years, depending upon the importance of the highway and the bridge.

From the point of view of economy, a bridge may be designed to be submerged and cause interruption of traffic a limited number of days in a year. Such bridges are called submersible bridges.

Culverts:

The popular types of culverts are:

(i) Masonry arch culverts

(ii) Slab culverts (Stone slab or R.C.C. slab with abutments and piers)

(iii) Pipe culverts (Metal pipe, Stoneware pipe, or R.C.C. Hume pipe)

(iv) R.C.C. Box culverts

Bridges:

Bridge engineering is a specialised field.

The following are types of bridges for spans in the increasing order:

(i) Masonry arch

(ii) R.C.C. slab (simply supported)

(iii) R.C.C. T-beam (simply supported)

(iv) Continuous T-beam and slab of R.C.C.

(v) R.C.C. balanced cantilever

(vi) Pre-stressed concrete

(vii) Suspension bridges.

Causeways:

Causeways allow water to flow over them when the stream or water course receives floods. These are provided on relatively unimportant roads with small volume of traffic.

The interruption to traffic on these structures should not be for more than 15 days in a year and not exceed 3 days at a stretch.

Depending upon the degree of interruption, causeways may be called low-level causeways or high-level causeways.

Surface drainage :

The surface water is to be collected and then disposed off. The water on the surface is first collected in longitudinal drains, generally in side drains and then the water is disposed off at the nearest stream, valley or water course. For the preparation of surface drainage, we should keep in mind various things like

Seeing the amount of rainfall and slope a suitable camber is to be provided for collection of surface water. The shoulders of rural roads are constructed with suitable cross slopes so that the water is drained across the shoulders to the side drains. These side drains of rural roads are generally Open (kutcha) drains of trapezoidal shape, cut to suitable cross-section and longitudinal slopes. These sides are provided parallel to the road alignment and hence these are also known as longitudinal drains. In embankments the longitudinal drains are provided on one or both sides beyond the toe; in cutting, drains are installed on either side of the formation.

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

Drainage of surface water is all the more important in hill roads. In hill roads disposal of water is also very important. Certain maintenance problems may arise due to faulty hill road construction.

Procedure for Design of Open Drains:

The following are the steps for designing open drains:

1. For the known soil conditions, calculate the Manning's rugosity coefficient, side slopes, and the maximum permissible velocity.
2. Determine the slope of the drain from the topography.
3. For the runoff or discharge expected to be drained, calculate the hydraulic mean depth using Manning's formula.
4. Calculate the cross-sectional area from the discharge and the maximum permissible velocity.
5. From the result of (3) and (4), solve the two simultaneous equations to obtain the bottom width and depth.
6. Calculate the critical depth and determine whether the flow is streamlined or turbulent. If the flow is streamlined, add a free board to the depth and finalise the cross-section. If the flow is turbulent, it may be necessary to decrease the longitudinal slope, or line the channel.

Subsurface Drainage:

Moisture changes in the subgrade occur due to percolation of rain water and seepage flow, as also due to the phenomenon of capillary rise. The aim of subsurface drainage is to keep the ground water table (GWT) sufficiently below the level of the subgrade – at least 1.2 m.

When the water table is almost at the natural ground surface, the best option is to raise the formation of the roadway on an embankment, such that it is 1.2 m above the ground. If this is not possible for the reason of unfavourable topography, the only option is to lower the ground water table by means of subsurface drainage arrangements. It must, however, be remembered that only gravitational water in the soil can be drained, but not 'held water', which is made up of the moisture film around the grains.

A few drainage arrangements for different situations are discussed below:

Subgrade Drain:

One option is to install a drain in the pervious layer besides the road to intercept the ground water before it can reach the subgrade, as shown in Fig.

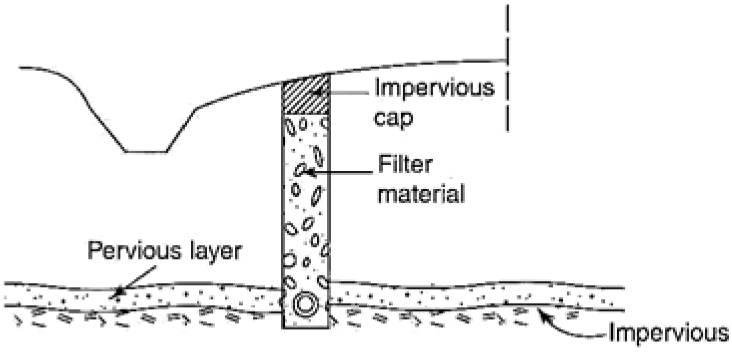


Fig. Subsurface drain to intercept drain water

Longitudinal Drain Trenches and Pipes:

If the soil is relatively pervious, longitudinal drainage trenches with drain pipe, backfilled with filter sand can be used. The depth of the trench depends on the extent of lowering required, soil type, and distance between the trenches. A typical arrangement is shown in Fig.

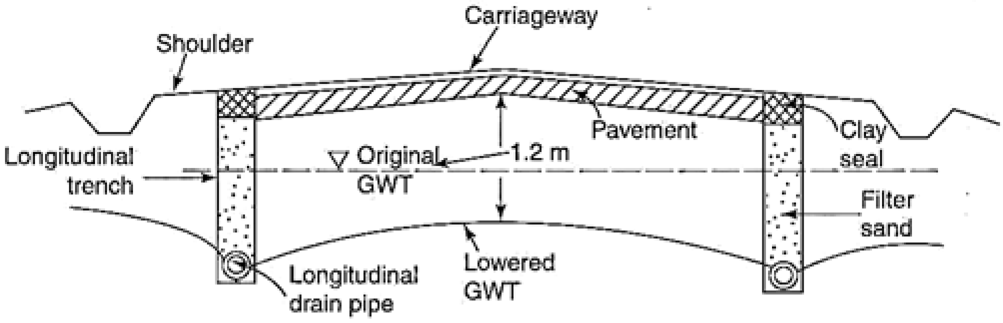


Fig. Lowering GWT in pervious soil by Subsurface drains

Longitudinal and Transverse Drains for Lowering GWT:

If the soil is relatively less permeable, longitudinal as well as transverse drains may be needed to lower the ground water table as shown in Fig.

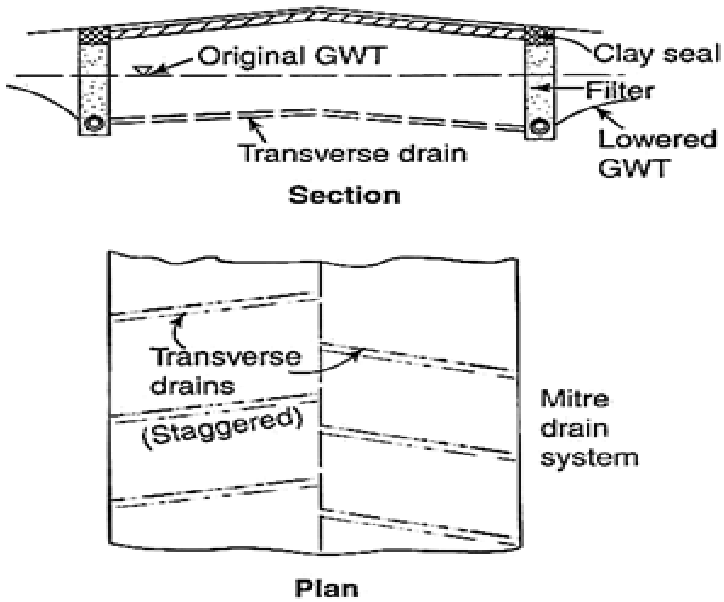


Fig. Longitudinal and transverse drain system for less permeable soil

Capillary Cut-Off for Clayey Subgrade:

If the subgrade is clayey, the system of sub-surface drains on either side will not be effective, in view of very low permeability of the subgrade. In such a case the subgrade has to be raised with a free-draining material, or a capillary cut-off has to be applied as shown in Fig.

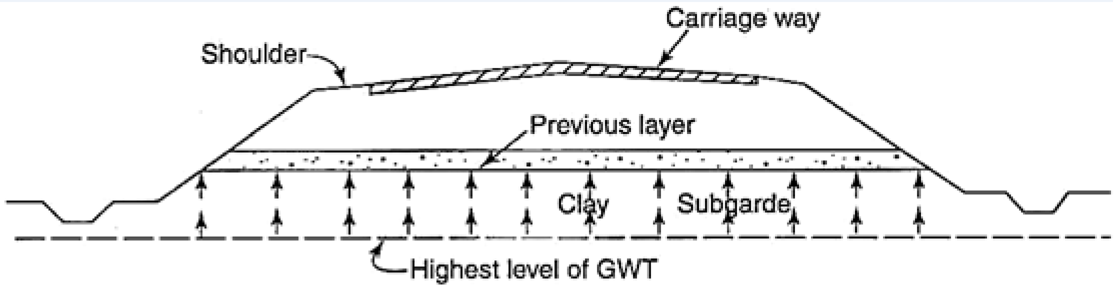


Fig. Capillary cut-off for a clayey subgrade

The capillary cut-off may even be an impermeable bituminous layer.

The location of the cut-off should be above the level of capillary rise expected for the clayey subgrade.

Sub-Surface Drains to Control Seepage in Cut Slopes:

Sometimes, seepage water renders cut slopes unstable by reaching the face of the slope. This can be prevented by lowering the seepage line by providing a sub-surface longitudinal drain installed to a depth below the pervious layer as shown in Fig.

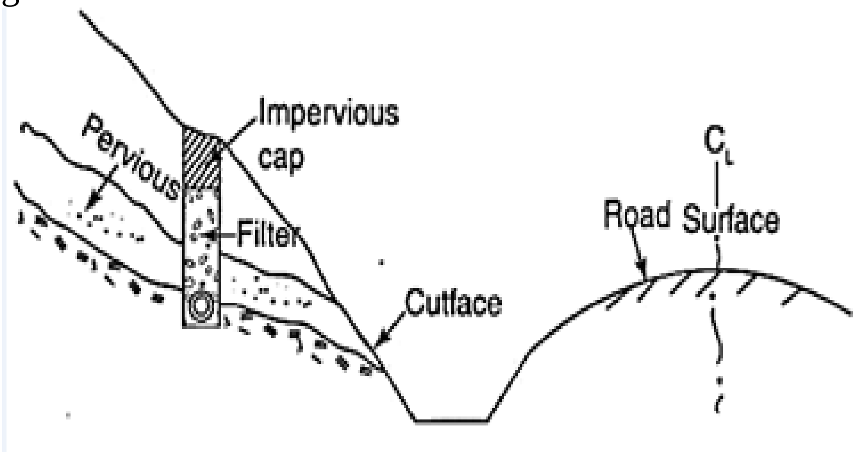


Fig. Subsurface drains at cut slope to control seepage

If the depth of pervious layer is more, horizontal drains comprising perforated metallic pipes or PVC pipes installed at a suitable slope may be provided to serve the same purpose.

Drain Pipes and Filter Media:

A subsurface drain may comprise of perforated pipe, a porous concrete pipe or solid pipe laid with open joints. Alternatively, a trench filled with a free draining material may be used to serve the purpose of a drain.

A perforated pipe or a porous pipe (of no fines concrete) with an impervious cap at the top, laid in a trench and backfilled with a granular, free-draining material top is considered to be a good choice.
If granular filter material with appropriate gradation has to be used, it has to be designed to satisfy certain criteria.

Design of a Filter Material:

The gradation requirements of the filter material are based on three criteria:

(i) Permeability of filter
(ii) Prevention of Piping (because of high seepage velocity)
(iii) Prevention of clogging of the drain pipe.

These requirements are:

(i) ***Permeability ratio***: $\frac{D_{15}(\text{filter})}{D_{15}(\text{soil to be drained})} > 5$

(ii) ***Piping ratio***: $\frac{D_{15}(\text{filter})}{D_{85}(\text{soil to be drained})} < 5$

(iii) $\frac{D_{85}(\text{filter})}{(d_p\text{: diameter of the perforation in the drain pipe.})} > 2d_p$

Fig. shows an example of the selection of a suitable filter material based on the gradation of the soil to be drained.

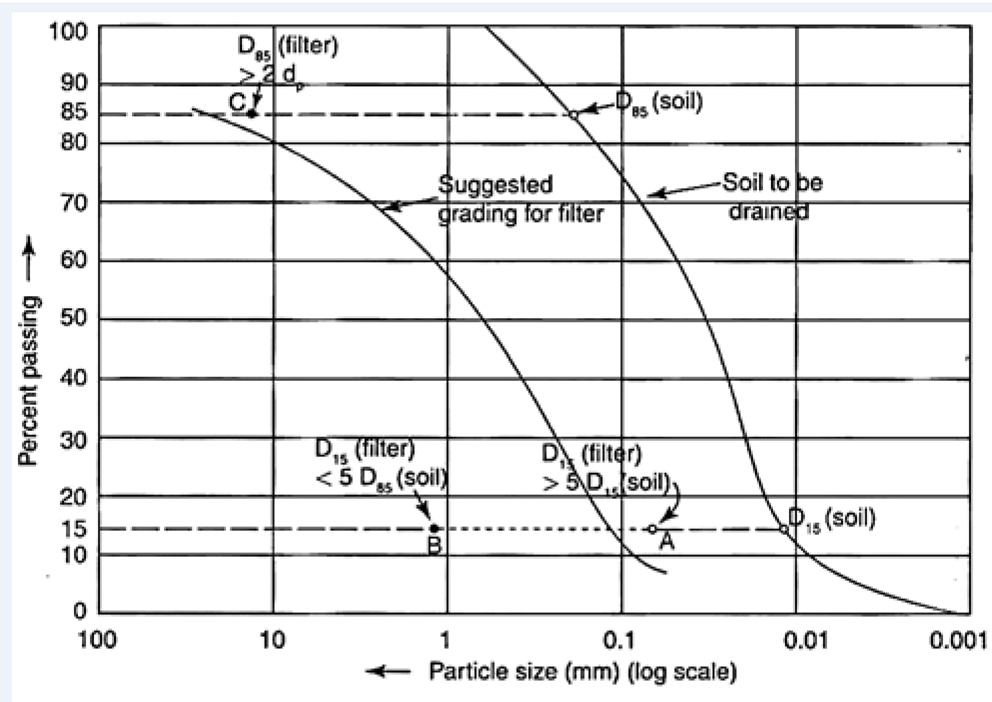


Fig. Filter design for subsurface drains

Set the grading of the soil to be drained be plotted as shown. Mark the D_{15} and D_{85} of the soil. From permeability criterion, mark D_{15} of filter ($>5D_{15}$ of soil) as A.

From piping criterion, mark D_{15} of filter ($<5D_{85}$ of soil) as B.
On D_{85} line, mark point C, such that D_{85} (filter) is greater than $2d_p$ (d_p being the diameter of the perforation of the drain pipe).
A suggested grading of filter may be drawn smoothly such that it lies to the left of C and lies between A and B as shown.
The perforated pipe is usually 100 to 150 mm in diameter with holes in two or more lines towards the bottom of the pipe. The collector pipes of porous concrete, metal or PVC should be laid with a minimum of 100 mm of filter sand around them.
Usually 5 mm diameter holes are considered adequate, if restricted to the lower 60° arc of the pipe. Solid pipes with open joints may be used, but care should be taken to see that silt and fine sand do not enter the pipe.
When the flow of water takes place through porous backfill of graded sand, it is likely to be clogged after some time. Hence, this involves maintenance, washing of the clogged backfill .

Geosynthetics in Subsurface Drains:

Geosynthetics or geotextiles are becoming popular as substitutes or alternatives to graded filters. They have high retention fine particles and permeability similar to graded material and good tensile strength. Installation is also easy.
Geosynthetic products perform the functions of a filter as well as that of a separator.
Fig. shows an aggregate drain with a pipe encased in a geosynthetic.

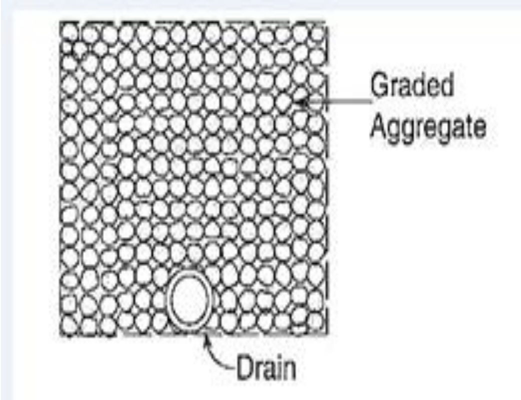


Fig. Geosynthetic-encased aggregate drain with a pipe

Shoulder Drainage:

For quick drainage of water from the roadway, the shoulder surface has to be properly sloped. A continuous drainage layer, 75 to 100 mm thick, can be laid under the shoulder at the bottom level of the sub-base or the bottom-most granular sub-base layer and extended up to the edge. A paved shoulder, if provided, should have a cross- slope of at least 0.5% more than the camber; the unpaved shoulder beyond this should be a further 0.5% steeper as shown in Fig.

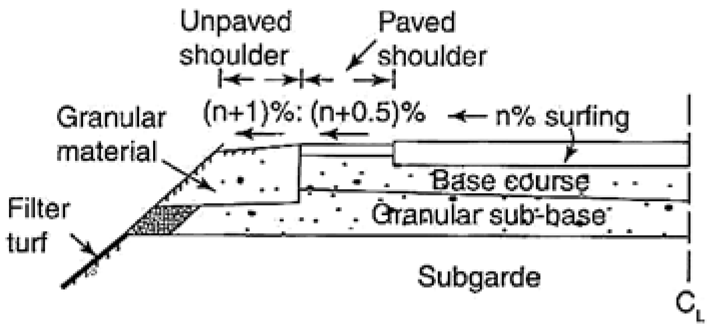


Fig.Shoulder Drainage

Median Drainage:

Narrow medians may be drained towards the pavement. Medians with a width of up to 1.8 m can be provided with kerbs and paved; those with width ranging from 1.8 to 5 m are usually turfed and crowned for the surface water to run towards the pavement (which may be with or without kerbs). For medians that are more than 5 m wide, there are no kerbs at the edge.

If the carriageway drains towards the median, central drain may be made to carry the run off. At intervals, the drain may also be made to lead water to an outlet.

Drainage of High Embankment:

In the case of high embankments (more than 8 metres high) as with bridge approaches, slopes and shoulders may be eroded by surface run-off. To prevent or minimise this, longitudinal drains are to be provided at the edges of the roadway, from which the water may be led down the slopes by means of lined chutes with energy dissipation basins at the toe.

The water thus collected at the toe can be led in an open toe drain at the bottom parallel to the road, and led to a natural outlet at an appropriate point. In between the chutes, the slope is to be turfed to protect it from surface erosion .

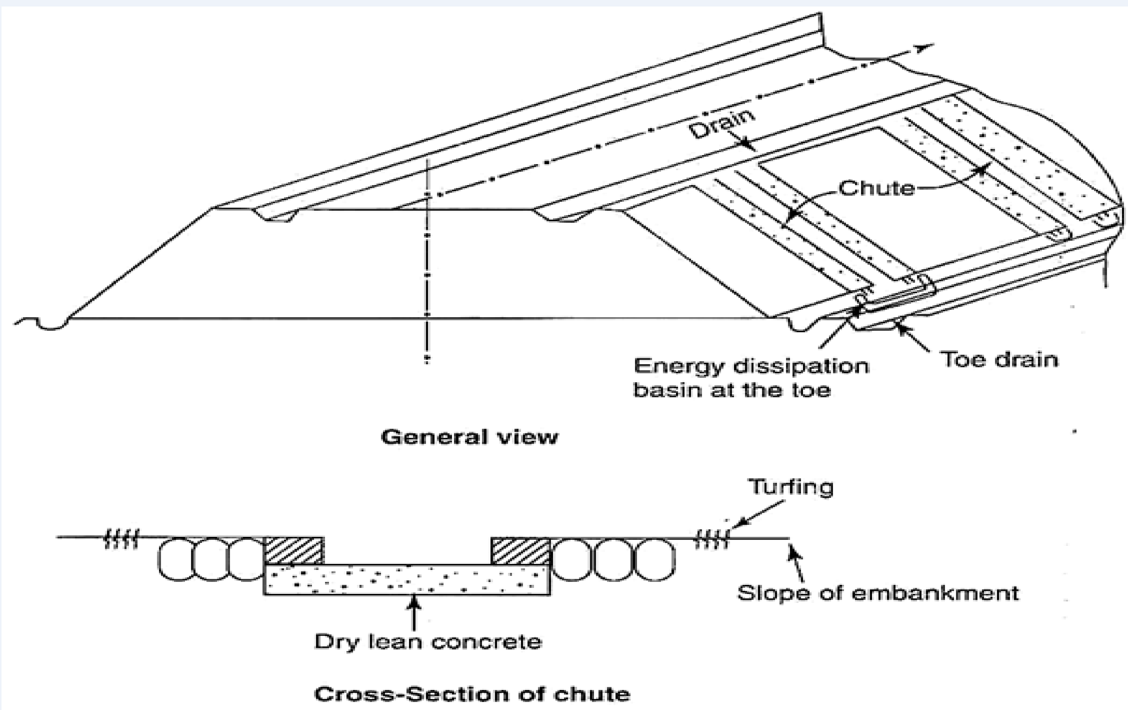


Fig. Drainage system for high Embankment

Drainage of Rotaries:

Water, from the large area around a rotary, flows towards the centre of the rotary, because of the super-elevated pavements. This has to be collected and led into the overall drainage system. A typical arrangement is shown in Fig.

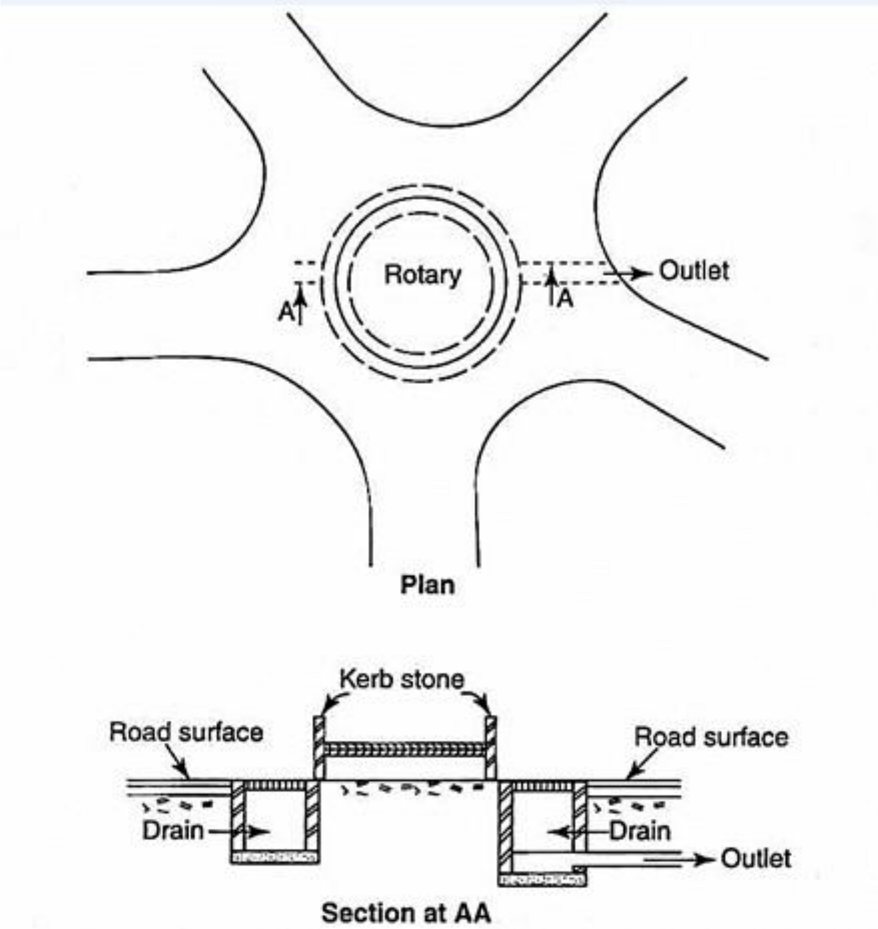


Fig. Typical drainage arrangement at a Rotary

Similar arrangements can be made at an intersection.

At a flyover, the water collected in longitudinal drains on either side of the pavements can be led thorough the hollows of pillars of the supporting structure like a bridge and led away through a storm water drainage system.

ROAD MAINTENANCE

Introduction

Road maintenance is essential in order to (1) preserve the road in its originally constructed condition, (2) protect adjacent resources and user safety, and (3) provide efficient, convenient travel along the route. Unfortunately, maintenance is often neglected or improperly performed resulting in rapid deterioration of the road and eventual failure from both climatic and vehicle use impacts. It follows that it is impossible to build and use a road that requires no maintenance.

Preserving and keeping each type of roadway, roadside, structures as nearly as possible in its original condition as constructed or as subsequently improved and the operation of highway facilities and services to provide satisfactory and safe transportation, is called **Road Maintenance** or **maintenance of highways**.

Fig. Roads Maintenance / Highways Maintenance Definition

Road Maintenance Components

The various road maintenance function includes:

1. Surface maintenance
2. Roadside and drainage maintenance
3. Shoulder and approaches maintenance
4. Snow and ice control
5. Bridges maintenance
6. Traffic service

Highway maintenance is closely related to the quality of construction of original road. Insufficient pavement or base thickness or improper construction of these elements soon results in expensive patching or surface repair. Shoulder care becomes a serious problem where narrow lanes force heavy vehicle to travel with one set of wheels off the pavement.

Improperly designed drainage facilities, mean erosion or deposition of material and costly cleaning operation or other corrective measures. For regular highways maintenance and repair sharp ditches and steep slopes require manual maintenance as compare to cheap repair of flatter ditch and soil by machine.

In snowy country, improper location extremely low fills and narrow cuts leave no room for snow storage, creating extremely difficult snow removal problems.

COMMON TYPES OF ROAD FAILURES – THEIR CAUSES AND REMEDIES

Failures may be:-

Failure in sub grade

- Inadequate Stability
- Excessive application of stresses
- Plastic deformation

Failures in sub base or Base course

- Inadequate stability
- Loss of binding action
- Loss of bearing course materials
- Inadequate wearing course

4.3 Causes of premature failures:-

- Rutting due to high variation in ambient temperature.
- Uncontrolled heavy axle loads.
- Limitation of pavement design procedures to meet local environmental conditions.

Common Flexible Pavement Failure/ Distresses:-

- Cracking
- Deformation
- Deterioration
- Mat problems
- Problems associated with seal coats

Category	**Distress type**
1. Cracking	Longitudinal, Fatigue, Transverse, reflective, block, edge
2.Deformation	Rutting, Corrugation, Shoving, depression, overlay bumps
3. Deterioration	Delamination, Potholes, Patching, raveling, stripping, Polished aggregate, Pumping
4.Mat Problems	Segregation, Checking, Bleeding
5.Seal coats	Rock loss, Segregation, bleeding/fat spots, Delamination

Types of Distresses/Failures and Definitions:-

Alligator Cracking

Alligator cracking is a load associated structural failure. The failure can be due to weakness in the surface, base or sub grade; a surface or base that is too thin; poor drainage or the combination of all three. It often starts in the wheel path as longitudinal cracking and ends up as alligator cracking after severe distress.

FIX: Because a structural failure is taking place the only possible solution to alligatoring is to perform a full-depth patch.

Fig. Alligator Cracking

Block Cracking

Block cracks look like large interconnected rectangles (roughly). Block cracking is not load-associated, but generally caused by shrinkage of the asphalt pavement due to an inability of asphalt binder to expand and contract with temperature cycles. This can be because the mix was mixed and placed too dry; Fine aggregate mix with low penetration asphalt & absorptive aggregates; poor choice of asphalt binder in the mix design; or aging dried out asphalt.

FIX: Less severe cracks measuring 1/2 inch or less can be sealed to prevent moisture from entering into the sub grade. More severe cracks should be fixed by removing the cracked pavement layer and replacing it with an overlay.

Fig. Block Cracking

Longitudinal (Linear) Cracking

Longitudinal cracking are cracks that are parallel to the pavements centerline or laydown direction. These can be a result of both pavement fatigue, reflective cracking, and/or poor joint construction. Joints are generally the least dense areas of a pavement.

FIX: Less severe cracks measuring 1/2 inch or less can be sealed to prevent moisture from entering into the sub grade. More severe cracks should be fixed by removing the cracked pavement layer and replacing it with an overlay.

Longitudinal (Linear) Cracking

Transverse Cracking

Transverse cracks are single cracks perpendicular to the pavement's centerline or laydown direction. Transverse cracks can be caused by reflective cracks from an underlying layer, daily temperature cycles, and poor construction due to improper operation of the paver.

FIX: Less severe cracks measuring 1/2 inch or less can be sealed to prevent moisture from entering into the sub grade. More severe cracks should be fixed by removing the cracked pavement layer and replacing it with an overlay.

Fig**.** Transverse Cracking

Edge Cracks

Edge Cracks travel along the inside edge of a pavement surface within one or two feet. The most common cause for this type of crack is poor drainage conditions and lack of support at the pavement edge. As a result underlying base materials settle and become weakened. Heavy vegetation along the pavement edge and heavy traffic can also be the instigator of edge cracking.

FIX: The first stepin correcting the problem is to remove any existing vegetation close to the edge of the pavement and fix any drainage problems. Crack seal/fill the cracks to prevent further deterioration or remove and reconstruct to full depth fixing any support issues.

Fig**.** Edge Cracks

Joint Reflection Cracks

These are cracks in a flexible pavement overlay of a rigid pavement (i.e., asphalt over concrete). They occur directly over the underlying rigid pavement joints. Joint reflection cracking does not include reflection cracks that occur away from an underlying joint or from any other type of base (e.g., cement or lime stabilized).

FIX: For less severe cracks (less than 1/2 inch) crack sealing will prevent the further entry of moisture into the subgrade. If the cracks are more severe the removal of the cracked pavement layer followed by an overlay may be required.

Fig**.** Joint Reflection Cracks

Slippage Cracks
Slippage cracks are crescent-shaped cracks or tears in the surface layer(s) of asphalt where the new material has slipped over the underlying course. This problem is caused by a lack of bonding between layers. This is often because a tack coat was not used to develop a bond between the asphalt layers or because a prime coat was not used to bond the asphalt to the underlying stone base course. The lack of bond can be also caused by dirt, oil, or other contaminants preventing adhesion between the layers.
FIX: All of the areas exhibiting the "stretch marks" will need to be removed and will require a partial or full depth patch.

Fig. Slippage Cracks

Pot Holes
Small, bowl-shaped depressions in the pavement surface that penetrate all the way through the asphalt layer down to the base course. They generally have sharp edges and vertical sides near the top of the hole. Potholes are the result of moisture infiltration and usually the end result of untreated alligator cracking. As alligator cracking becomes severe, the interconnected cracks create small chunks of pavement, which can be dislodged as vehicles drive over them. The remaining hole after the pavement chunk is dislodged is called a pothole.

FIX: Full depth replacement patch.

Fig. Pot Holes

Depressions (bird baths)

Depressions are localized pavement surface areas with slightly lower elevations than the surrounding pavement. Depressions are very noticeable after a rain when they fill with water.

FIX: Depending on the severity of the depression the asphalt may have to be removed and replaced (severe). Less severe depressions can be fixed by applying a thin surface patch or infrared patch.

Fig.Depressions (bird baths)

Rutting

Ruts in asphalt pavements are channelized depressions in the wheel-tracks. Rutting results from consolidation or lateral movement of any of the pavement layers or the subgrade under traffic. It is caused by insufficient pavement thickness; lack of compaction of the asphalt, stone base or soil; weak asphalt mixes; or moisture infiltration.

FIX: If rutting is minor or if it has stabilized, the depressions can be filled and overlaid. If the deformations are severe, the rutted area should be removed and replaced with suitable material.

Fig. Rutting

Shoving

Shoving is the formation of ripples across a pavement. This characteristic shape is why this type of distress is sometimes called wash-boarding. Shoving occurs at locations having severe horizontal stresses, such as intersections. It is typically caused by: excess asphalt; too much fine aggregate; rounded aggregate; too soft an asphalt; or a weak granular base.

FIX: Partial or full depth patch

Fig. Shoving

Upheaval

Upheaval is a localized upward movement in a pavement due to swelling of the subgrade. This can be due to expansive soils that swell due to moisture or frost heave (ice under the pavement).

FIX: Full depth patch

Fig. Upheaval

Raveling (very porous asphalt)

Raveling is the on-going separation of aggregate particles in a pavement from the surface downward or from the edges inward. Usually, the fine aggregate wears away first and then leaves little "pock marks" on the pavement surface. As the erosion continues, larger and larger particles are broken free and the pavement soon has the rough and jagged appearance typical of surface erosion.

There are many reasons why raveling can occur, but one common cause is placing asphalt too late in the season. This is because the mixture usually lacks warm weather traffic which reduces pavement surface voids, further densification, and kneading of the asphalt mat. For this reason raveling is more common in the more northern regions(snow belt).

FIX: Apply a thin hot-mix overlay. Other solutions could include: sand seal, chip seal, slurry seal or micro-surfacing.

Fig. Raveling (very porous asphalt)

Other issues that need treatment before maintenance:

Oil Spots – oil spots are a common problem in parking lots and driveways. These areas must be treated before sealcoating or the oil and chemicals will seep up through the newly applied material and render your sealed surface ineffective. There are number of great products for treating these types of issues. Ask your material supplier what they offer.

Grass – Poorly maintained parking lots will often have grass growing up through the cracks. Cleaning the cracks should be standard practice before sealing them. Use a heat lance to burn out the crack and/or blow out the cracks depending on the severity of the problem.

Mud, tree sap, berry stains, etc – Anything that would sit between the asphalt and the sealer must be removed. Without removing it the sealer can not properly adhere to the asphalt and will eventually (sooner than later most likely) peel off. Blowers, push brooms, pressure washers, and gas powered brooms are all tools you should have in your pavement maintenance arsenal.

Maintenance of bituminous road such as patch work and resurfacing

In addition to standard causes such as traffic, weather and ingress of water for the deterioration of earth, gravel and WBM roads, loss of volatiles, oxidation of the binder material and inadequacy of the specification and construction standards also could be the reasons for distress and disintegration of bituminous pavements.

Depending upon the degree of deterioration of the highway facility, the nature of the maintenance operations for bituminous pavements could be:

(a) Patch repair

(b) Surface treatment

(c) Resurfacing

(a) Patch Repair:

This consists of patching up of pot-holes and localised failures, and may be up to about 25 per cent of the surface area annually. For patching, sand premix, open-grade premix, dense-graded premix, or penetration patching may be adopted.

(b) Surface Treatment:

The aim of surface treatment may be renewal of the surface course when patch repair becomes uneconomical; it may also be to improve skid resistance when the surface is worn out badly. Standard specifications for tack coat, prime coat and seal coat, along with surface dressing/premix carpet should be used.

(c) Resurfacing:

This is taken up when the pavement has deteriorated badly. When the pavement is of inadequate thickness, an ‘overlay’ of adequate thickness should be designed and provided.

A brief description of the defects, symptoms, probable causes, and possible treatment is given in the Table 10.3, extracted from “IRC; 82-1982: ‘Code of Practice for maintenance of bituminous surfaces’, Indian Roads Congress, New Delhi, 1982”: Defects, Symptoms, Causes and Treatment of Defects in Bituminous Surfacings.

Table 10.3 Defects, symptoms, causes and treatment of defects in bituminous surfacings

Type of defect	Symptoms	Probable causes	Possible treatment
A. Surface defect 1. Fatty surface	Collection of binder on the surface	Excessive binder; loss of cover aggregates excessively heavy axle load.	Sand-blinding; open-graded premix; liquid seal coat; removal of affected area.
2. Smooth surface	Slippery	Polishing of aggregates under traffic; or excessive binder	Resurfacing with surface dressing or premix carpet.
B. Cracks 1. Alligator cracks	Interconnected cracks forming a series of small blocks	Weak pavement, poor subgrade, excessive loads, or brittle binder	The treatment depends on whether the pavement is structurally sound or unsound. For structurally sound condition, cracks are to be filled with low viscosity binder. Unsound cracked pavement need strengthening or rehabilitation treatment.
2. Longitudinal cracks	Cracks on a straight line along the road.	Poor drainage, shoulder settlement, or differential frost-heave	
3. Shrinkage cracks	Cracks in transverse direction or interconnected cracks forming large blocks	Shrinkage of bituminous layer with age.	
C. Deformation 1. Rutting	Longitudinal depression in the wheel tracks	Heavy channelized traffic inadequate compaction or heavy steel-tyred traffic	Filling the depressions with premix material
2. Corrugations	Formation of regular undulations	Lack of mix stability, oscillations from vehicle spring, faulty laying of surface course	Scarification and relaying of surface.
3. Settlement	Large deformation of pavement	Poor compaction of fills, poor drainage, inadequate pavement or frost heave	Where fill is weak, it should be replaced. If pavement is inadequate, it should be strengthened.
D. Disintegration 1. Stripping	Separation of bitumen from aggregates in the presence of moisture	Use of hydrophilic aggregate, poor mix, continuous contact with water	Spreading and compacting heated sand, replacement with fresh bituminous mix
2. Loss of aggregate	Rough surface with loss of aggregate in some portions	Ageing and hardening of binder, poor bond between aggregate and binder, poor compaction	Application of liquid seal, fog seal or slurry seal depending upon the extent of damage.
3. Ravelling	Failure of binder to hold the aggregates with small eroded areas on the surface.	All the above and insufficient binder, and brittleness of binder	Application of cutback covered with coarse sand, or a premix renewal coat.
4. Pot-holes	Appearance of bowl-shaped holes, usually after rain.	Ingress of water into the pavement, lack of bond between WBM base and surfacing, insufficient bitumen content.	Filling pot-holes with premix material or penetration patching.

Renewal of surface is needed every 4 to 5 years for national and state highways.
The renewal can be with metal (75 mm), surfacing dressing, premix chipping carpet with seal coat, semi-dense bituminous concrete, or bituminous concrete.

Maintenance of concrete roads – filling cracks, repairing joints, maintenance of shoulders (berm), maintenance of traffic control devices

A cement concrete pavement needs very little maintenance if it is well-designed and properly constructed. In fact, this is considered to be the most important advantage which offsets the high initial cost. However, defects are likely to occur due to ingress of water, especially through ill-maintained joints and cracks, inadequate pavement thickness and poor workmanship.

Cracks:

Appearance of cracks, which may be shrinkage cracks or warping cracks due to temperature changes.

Cracks which appear in the corner and edge regions are called 'structural cracks' as they are due to the excessive stresses caused by wheel loads. They indicate inadequacy of the pavement thickness and should be viewed seriously and treated differently.

Hair cracks are not harmful, but medium and wide cracks allow water to seep through and cause progressive loss of subgrade support. Such cracks should be filled up with low-viscosity epoxy grout, after cleaning the cracks of dust. Compressed air is used for effective cleaning. The material is topped up with sand or fine aggregate chips to prevent the disturbance of the material under traffic.

Joints:

Joint maintenance consists of replenishing lost sealant, removal of deteriorated joint filler, and introduction of fresh filler material. The sealant is then poured to an excess height of about 3 mm and sand sprinkled for it to be compressed by the traffic to the level of the pavement surface.

Patch Repair of Slabs:

Sealing, spalling, depressions and irregularities can occur in a slab locally. Immediate patching up of such defective slabs can arrest further deterioration.

Premix bituminous materials are commonly used for this purpose, but they do not provide a satisfactory result. The best materials are epoxy resin mortars and concrete for such patch repair work. The sides of the area of the slab to be patched are trimmed, made vertical, and fresh concrete is laid and tamped; the areas are usually made of regular geometrical shapes like rectangles.

Mud-Pumping:

When water gets collected in the subgrade, heavy axle loads cause ejection of mud through joints, cracks and edges. This phenomenon is commonly known as mud-pumping and blowing. When this is observed, defective joints and wide cracks should be refilled and sealed.

To prevent further damage and recurrence, grouting of the slab is done through holes drilled in it; the grout can be of cement mortar (1:3.5 mix) or of bituminous material (the latter is preferred since it is effective in filling the void spaces between the slab and the subgrade), and raising the slab to the desired level. This process is called mud-jacking and is popularly used in advanced countries.

Restoration of Anti-Skid Surface:

When the surface becomes smooth and slippery, anti-skid surface can be restored by cutting grooves by grooving machines or by grinding machines.

Crack Repair:

A patching mix of epoxy mortar can be filled and compacted after chipping off the area and cleaning it thoroughly by using compressed air. This is adequate only when the crack depth is not more than one-third of the depth of the slab.

However, when the crack extends almost to the entire depth of the slab, cross-stitching with inclined tie-bars or stapling with U-bars may be adopted; the former is shown schematically in Fig. 10.9.

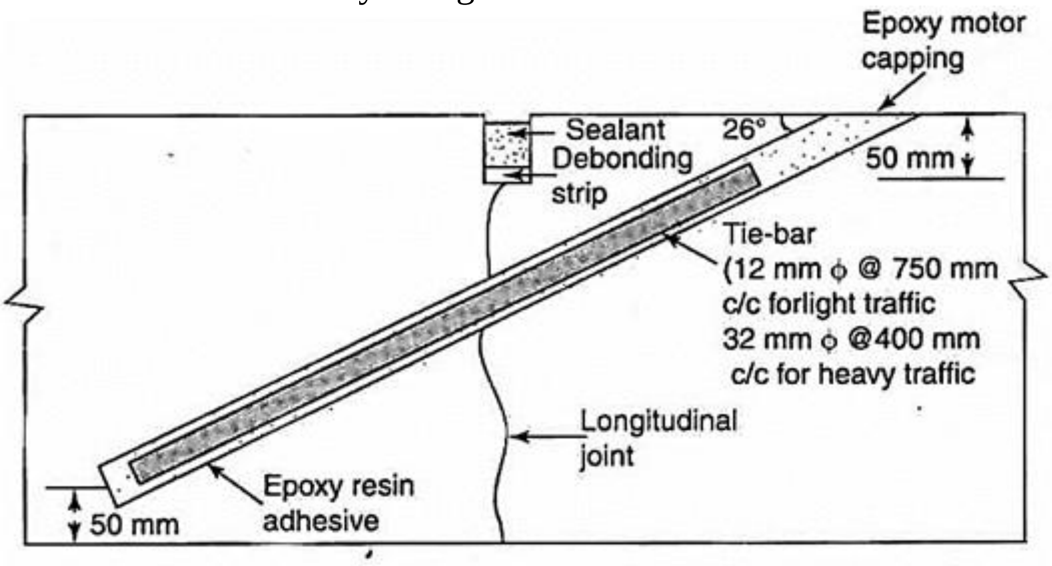


FIG. 10.9 *Crack repair by cross-stitching*

Mechanised Maintenance of Roads:

In India, road maintenance is mostly labour-oriented; however, mechanical maintenance of roads also can be practised with indigenous equipment for speedy implementation and better quality control.

Maintenance Management System (MMS):

In view of the several steps and factors involved in the maintenance operations of highways, systems approach is considered desirable to evolve an efficient maintenance programme for any highway network.

A computer package known as 'Pavement Management System' has been formulated to facilitate optimal resource allocation for maintenance.

The elements in this are:

a. Basic road data bank
b. Pavement performance model
c. Selection of maintenance levels
d. Evolving priorities for maintenance (renewal and overlay) for a given budget.

Several organisations have developed their own MMS packages and implemented them in their respective countries.

HIGHWAY CONSTRUCTION EQUIPMENTS

CONSTRUCTION EQUIPMENTS

Preliminary ideas of the following plant and equipment:

Hot mixing plant :

Asphaltic concrete is a mixture of asphalt, coarse aggregates, fine aggregates & filler material. After mixing, we are heating them up to final product called "HOT MIX".

There are two basic types of plants used to manufacture hot mix asphalt:

- Batch type plant
- Drum(continuous) type plant

The various parts of Batch mix plant are given below as per flow of material:

1. Cold aggregate four-bin feeder.
2. Cold conveyor.
3. Aggregate dryer.
4. Mixing Chamber
5. Asphalt tank.
6. Mineral filler unit.
7. Load-out conveyor.
8. Centralized control panel.

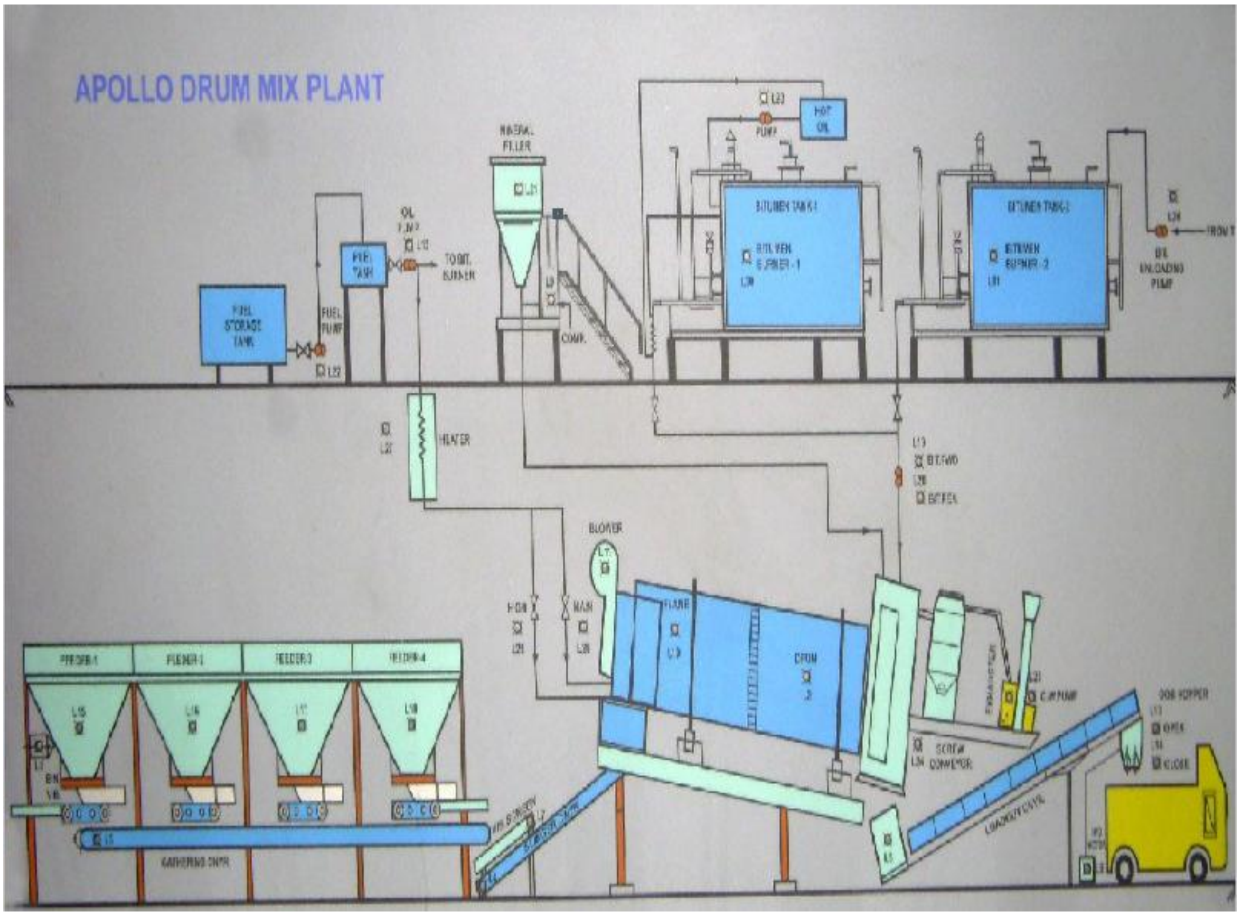


Fig. Schematic Diagram of Drum Mix Plant

Cold aggregates four – bin feeder: -

1. It consists of FOUR independent top open type bins having being fabricated from MS plate mounted on rigid Channel supported on channel. Each bin consists of an independent and synchronized variable speeds D.C. motor for feeding the aggregates at a predetermined rate through a precisely adjustable bin quadrant gate.
2. Gathering conveyor belt equipped with an electronic weigh bridge and driven by electric motor.
3. Single deck screen provided at the discharge end of the gathering conveyor for rejection of any paver size material above permissible limit.
4. Single main transfer conveyor to receive the aggregates from the gathering conveyor and discharge it into the dryer under the combustion zone driven by electric motor and reduction gear

Separate detachable slinger conveyor is provided to transfer the aggregates received from the vibratory screen to feed into the thermo- drum. Slinger conveyor is driven by constant speed electric motor coupled with reduction gearbox.

The rigid frame of conveyor is fabricated from appropriate channel sections and the conveyor belt is supported by uniformly spaced roller stands. Any sagging on the return travel of the belt is also taken care of by roller.

Fig. Aggregate Dryer

From the cold aggregates conveyor, aggregates are delivered to the dryer. The dryer removes moisture from the aggregates and rises temperature to the desired level.

The dryer has an oil or gas burner with a blower fan to provide the primary air for combustion of the fuel, and an exhaust fan to create a draft through the dryer.

Proper aggregate temperature is essential. Aggregates that are heated to an excessive temperature can harden the binder during mixing. Under heated aggregates are difficult to coat thoroughly with binder and the resulting mix is difficult to place on the roadway.

Fig. Mixing Chamber

In this chamber the binder & aggregates are mixed. It consists of a lined mixing chamber with horizontal shaft about which the drum rotates. The chamber is so designed that there are no dead areas formed. The temperature of the mix shall be maintained properly so as to have homogeneous mix.

The whole assembly of Chamber is supported over prefabricated steel sections preferably of channel or I-sections.

Fig. Asphalt Tank

The bitumen section of batch mix plant mainly consists of bitumen tank, bitumen heating burner, bitumen pumping & metering unit and hot oil system.

The tank is fully insulated to minimize heat losses and is of 15,000 liters. capacity. The bitumen inside the tank is heated by U-shaped heating tube fitted with automatic burner of adequate capacity. A jacketed bitumen pump driven by variable speed motor through reduction gearbox is provided to pump the bitumen to the drum. The bitumen flow rate is controlled by varying the RPM of motor.

Hot mix storage silos can be offered with options to store different types of mix Designs to meet varied site demands.

Fig.Hot mix storage silo

Mineral filler unit:

The Filler hopper is provided to add mineral filler from a separate hopper, in the mix to the extent pre-selectable in percentage by weight of the maximum plant output.

The unit is fabricated from 5 m thick steel plate and mounted on steel structure.

The system is powered by a variable speed motor coupled with gearbox to rotary valve and also synchronized with aggregate & bitumen output.

The filler material from this unit is conveyed automatically up to coated zone in the pug-mill.

Fig. Mineral filler unit

Fig. Load Out Conveyor

Hot mix material discharged from the pugmill is carried by inclined hot conveyor belt and discharged into the tipper / truck through hydraulically operated surge storage hopper.

Hydraulically operated storage hopper is provided at the discharge end of the conveyor which stores the hot mix and allows it to fall as mass in the batches and thus avoids segregation and spillage during out cycle.

CONTROL SYSTEM

The plant is supplied with centralized control panel. All controls, including the motor control, center circuit breakers are provided in the control panel. The control panel controls feeder bin controls and electric switchgear. All the parameters like, temperature of bitumen-hot mix materialexhaust gases and aggregate weight, asphalt percentage, hot mix material weight etc. are displayed on the control panel.

Fig. Control Panel

Tipper, tractors (wheel and crawler) scraper, bulldozer, dumpers, shovels, graders, roller dragline

Tipper

A truck or lorry the rear platform of which can be raised at the front end to enable the load to be discharged by gravity also called tip truck.

Tippers are suited for the rough and tumble of mining & quarrying operations, as well as for carrying bulk loads in construction and infrastructure industries. Complete manoeuvrability, high performance and long-term endurance are common to all trucks, resulting in lower operating costs.

Fig. Tipper Truck

Tractors (Wheel And Crawler)

Multi-purpose machines used mainly for pulling and pushing the other equipment.

• Tractors may be classified as

a) Crawler type tractor- Used to move bull dozers, scrapers. The crawler has a chain by which these tractors can be very effective even in the case of loose or muddy soils. The speed of this type dose not exceed 12 kmph normally.
b) Wheel type tractor- The engine is mounted on four wheels. The main advantage is higher speed, sometimes exceeding 50 kmph it is used for long-distance hauling and good roads.


Fig. Crawler type tractor and Wheel type tractor

Comparison between crawler and wheeled tractors

Crawler type	Wheeled type
1. Slow speed	1. Greater speed
2. More compact and powerful and can handle heavier jobs	2. Con handle only lighter jobs
3. costly	3. cheaper
4. Cost of operation and maintenance is high	4. Operational and maintenance cost is less
5. Stick control for steering	5. Wheel steering control
6. Moves on rough roads only	6. Moves on rough as well as good roads
7. Used for short distances	7.Used for longer distances
8. Requires skillful operation, maintenance and repairs	8. Lesser skills required for operations, maintenance and repairs

Scraper

- In civil engineering, a wheel tractor-scraper is a piece of heavy equipment used for earthmoving.
- The rear part has a vertically moveable hopper (also known as the bowl) with a sharp horizontal front edge. The hopper can be hydraulically lowered and raised. When the hopper is lowered, the front edge cuts into the soil or clay like a plane and fills the hopper.
- When the hopper is full it is raised, and closed with a vertical blade (known as the apron). The scraper can transport its load to the fill area where the blade is raised, the back panel of the hopper, or the ejector, is hydraulically pushed forward and the load tumbles out. Then the empty scraper returns to the cut site and repeats the cycle.

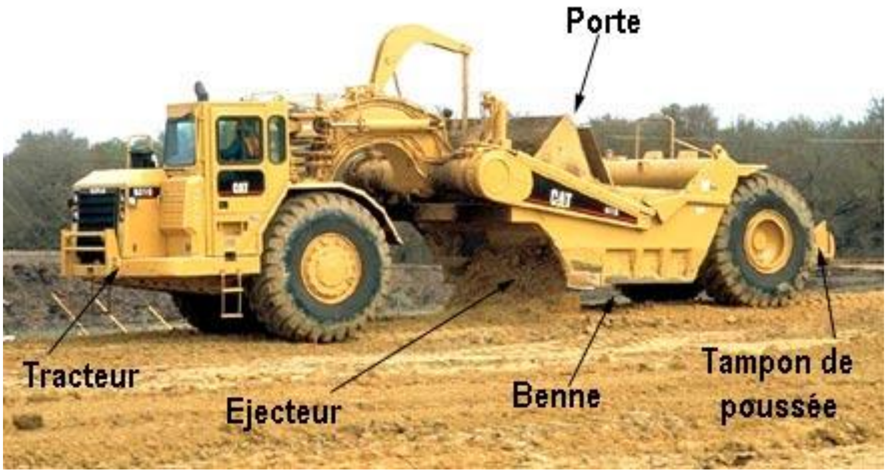


Fig. Scraper

Bulldozer

A bulldozer is a crawler (continuous tracked tractor) equipped with a substantial metal plate (known as a blade) used to push large quantities of soil, sand, rubble, or other such material during construction or conversion work and typically equipped at the rear with a claw-like device (known as a ripper) to loosen densely-compacted materials.

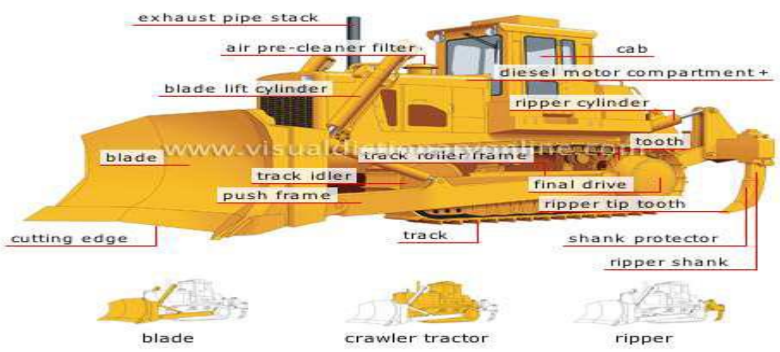
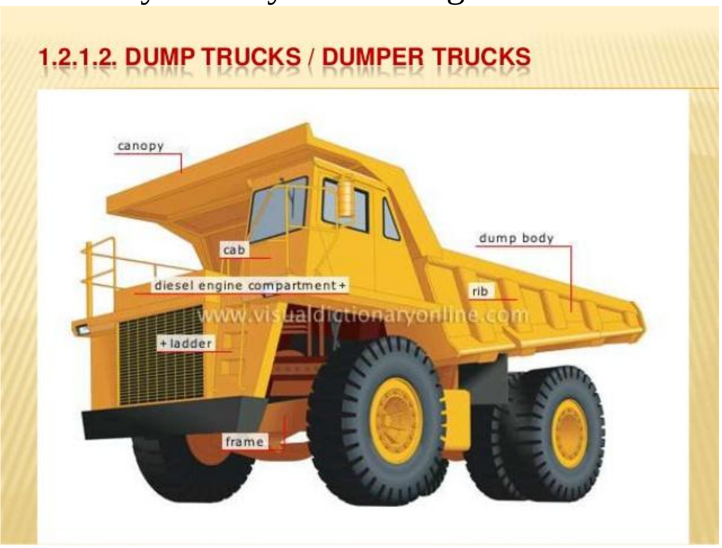


Fig. Bulldozer

Dumpers

- A dumper is a vehicle designed for carrying bulk material, often on building sites. Dumpers are distinguished from dump trucks by configuration: a dumper is usually an open 4-wheeled vehicle with the load skip in front of the driver, while a dump truck has its cab in front of the load.
- The skip can tip to dump the load; this is where the name "dumper" comes from. They are normally diesel powered. A towing eye is fitted for secondary use as a site tractor. Modern dumpers have payloads of up to 10 tones and usually steer by articulating at the middle of the chassis.



Shovels

- A power shovel (also stripping shovel or front shovel or electric mining shovel) is a bucket equipped machine, usually electrically powered, used for digging and loading earth or fragmented rock and for mineral extraction.
- Power shovels are used principally for excavation and removal of overburden in open-cut mining operations, though it may include loading of minerals, such as coal. They are the modern equivalent of steam shovels, and operate in a similar fashion.
- A shovel's work cycle, or digging cycle, consists of four phases:

- Digging
- Swinging
- Dumping
- Returning

Fig. Old Power Shovel

Fig. New Power Shovel

Graders

- A grader, also commonly referred to as a road grader, a blade, a maintainer, or a motor grader, is a construction machine with a long blade used to create a flat surface.
- Typical models have three axles, with the engine and cab situated above the rear axles at one end of the vehicle and a third axle at the front end of the vehicle, with the blade in between.
- In civil engineering, the grader's purpose is to "finish grade" (refine, set precisely) the "rough grading" performed by heavy equipment or engineering vehicles such as scrapers and bulldozers.
- Graders are commonly used in the construction and maintenance of dirt roads and gravel roads.
- In the construction of paved roads they are used to prepare the base course to create a wide flat surface for the asphalt to be placed on. Graders are also used to set native soil foundation pads to finish grade prior to the construction of large buildings.

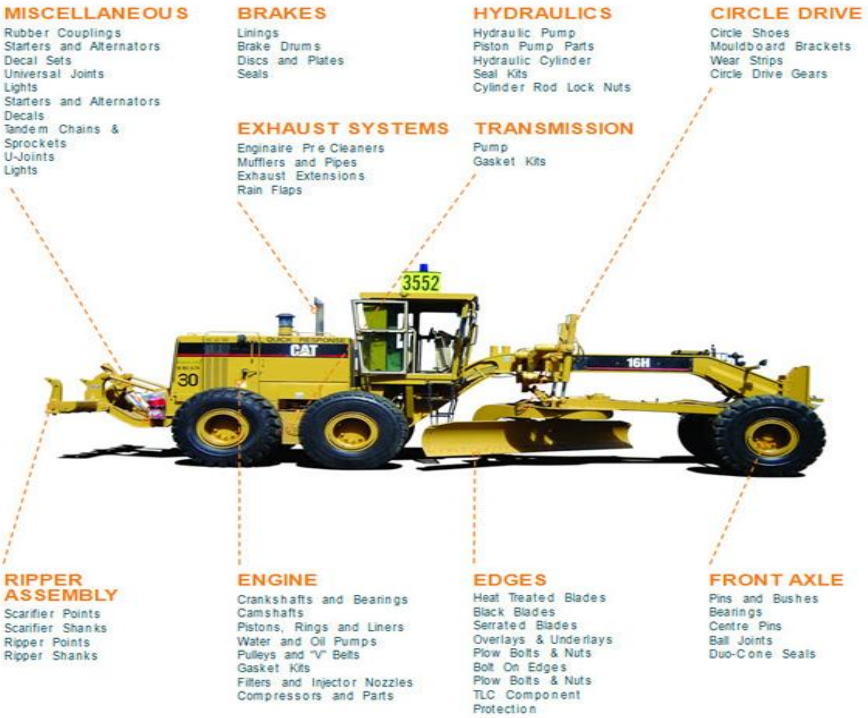


Fig. Grader

Roller

A road roller (sometimes called a *roller-compactor*, or just *roller*) is a compactor type engineering vehicle used to compact soil, gravel, concrete, or asphalt in the construction of roads and foundations, similar rollers are used also at landfills or in agriculture.

Fig. Roller

Dragline

- ➢ The drag line is so name because of its prominent operation of dragging the bucket against the material to be dug.
- ➢ Unlike the shovel, it has a long light crane boom and the bucket is loosely attached to the boom through cables.
- ➢ Because of this construction, a dragline can dig and dump over larger distances than a shovel can do.
- ➢ Drag lines are useful for digging below its track level and handling softer materials.

- The basic parts of a drag line including the boom, hoist cable, drag cable, hoist chain, drag chain and bucket.

Application

- It is the most suitable machine for dragging softer material and below its track level
- It is very useful for excavating trenches when the sides are permitted to establish their angle of repose without shoring.
- It has long reaches.
- It is mostly used in the excavation for canals and depositing on the embankment without hauling units
- It is the most suitable machine for dragging softer material and below its track level
- It is very useful for excavating trenches when the sides are permitted to establish their angle of repose without shoring.
- It has long reaches.
- It is mostly used in the excavation for canals and depositing on the embankment without hauling units.

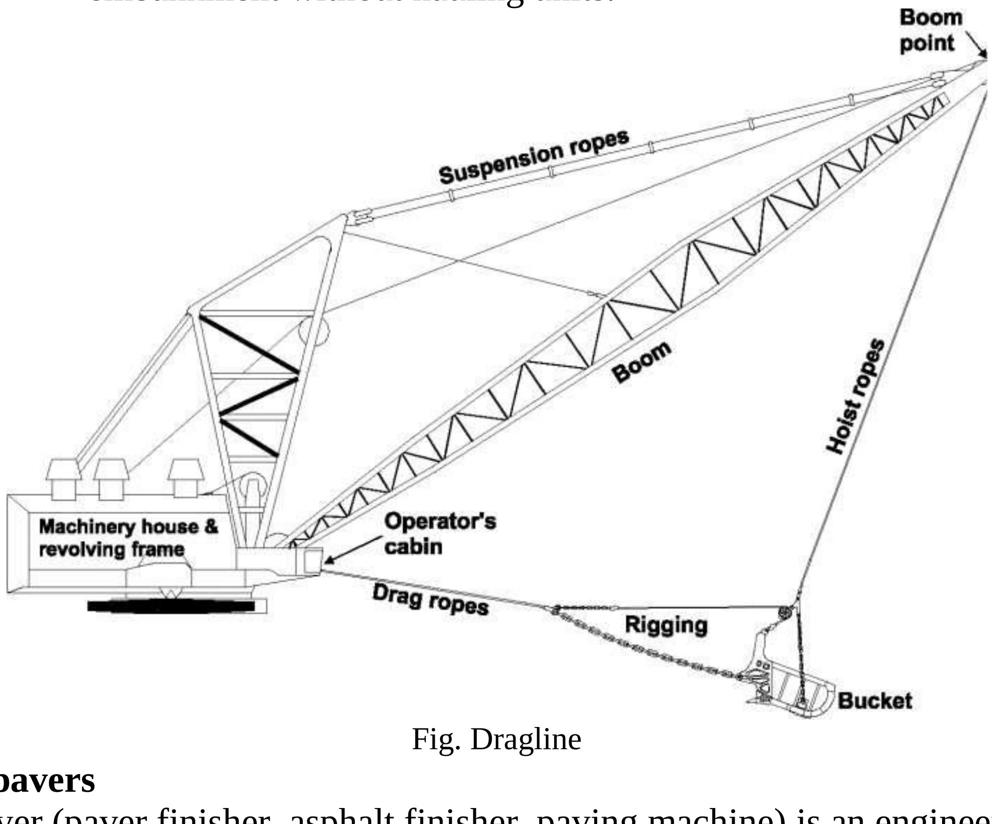


Fig. Dragline

Road pavers

A paver (paver finisher, asphalt finisher, paving machine) is an engineering vehicle used to lay asphalt on roadways. It is normally fed by a dump truck. A separate machine, a roller, is then used to press the hot asphalt mix, resulting a smooth, even surface. The sub-base being prepared by use of a grader to trim crushed stone to profile after rolling.

Fig. Road Paver

Modern construction equipments for roads

Excavators

Excavators are heavy construction equipment consisting of a boom, stick, bucket and cab on a rotating platform (known as the "house").

- The house sits a top an undercarriage with tracks or wheels.
- Excavators are also called diggers
- Excavators are used in many ways:
    - Digging of trenches, holes, foundations
    - Material handling
    - Brush cutting with hydraulic attachments
    - Forestry work
    - Demolition
    - General grading/landscaping
    - Heavy lift, e.g. lifting and placing of pipes
    - Mining, especially, but not only open-pit mining
    - River dredging
    - Driving piles, in conjunction with a pile driver

Fig. Excavator

Loaders

A loader is a heavy equipment machine often used in construction, primarily used to Load material (such as asphalt, demolition debris, dirt, snow, feed, gravel, logs, raw minerals, recycled material, rock, sand, and woodchips) into or onto another type of machinery (such as a dump truck, conveyor belt, feed hopper, or railcar).

Fig. Loader

Skid steer loaders

- A skid loader or skid-steer loader is a small rigid frame, engine-powered machine with lift arms used to attach a wide variety of labour-saving tools or attachments.
- Though sometimes they are equipped with tracks, skid steer loaders are typically four wheel vehicles with the wheels mechanically locked in synchronization on each side, and the left-side drive wheels can be driven independently of the right-side drive wheels.

Fig. Skid steer loader

BACKHOE

- A backhoe, also called a rear actor or back actor, is a piece of excavating equipment or digger consisting of a digging bucket on the end of a two part articulated arm. They are typically mounted on the back of a tractor or front loader.
- The section of the arm closest to the vehicle is known as the boom, and the section which carries the bucket is known as the dipper or dipper stick (the terms "boom" and "dipper" having been used previously on steam shovels). The boom is attached to the vehicle through a pivot known as the kingpost, which allows the arm to slew left and right, usually through a total of around 200 degrees. Modern backhoes are powered by hydraulics.

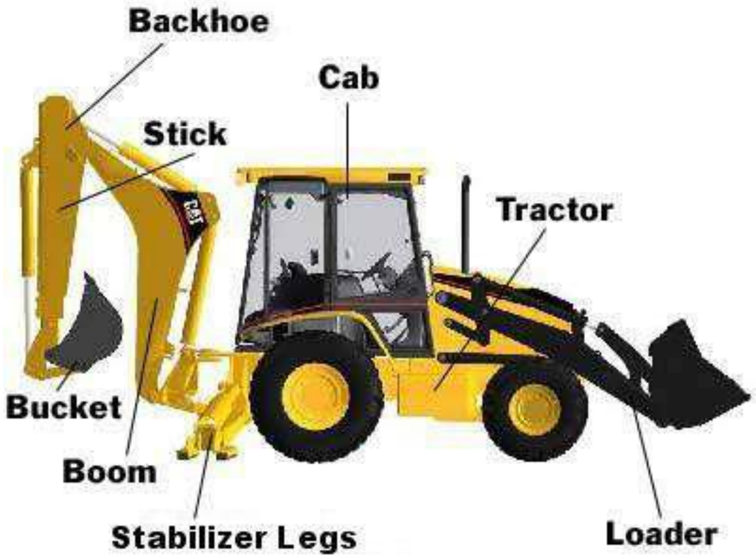


Fig. Backhoe

Compactors

- A compactor is a machine or mechanism used to reduce the size of waste material or soil through compaction.
- In construction, there are three main types of compactor: the plate compactor, the "Jumping Jack" and the road roller. The roller type compactors are used for compacting crushed rock as the base layer underneath concrete or stone foundations or slabs.
- The plate compactor has a large vibrating base plate and is suited for creating a level grade, while the jumping jack compactor has a smaller foot. The jumping jack type is mainly used to compact the backfill in narrow trenches for water or gas supply pipes etc. Road rollers may also have vibrating rollers.

Fig. Compactor