Lecture Note - 7
Subgrade and Formation

Subgrade

Subgrade is the naturally occuring soil which is prepared to receive the ballast.

Formation

The prepared flat surface, which is ready to receive the ballast, sleepers, and rails, is called the formation. The formation is an important constituent of the track, as it supports the entire track structure.

Functions of the formation

It has the following functions:
(a) To provide a smooth and uniform bed for laying the track.
(b) To bear the load transmitted to it from the moving load through the ballast.
(c) To facilitate drainage.
(d) To provide stability to the track.
(e) To keep the track over flood level.

The formation can be in the shape of an embankment or a cutting.

Embankment

When the formation is in the shape of a raised bank constructed above the natural ground, it is called an embankment.

The formation is prepared by providing additional earthwork over the existing ground to make an embankment.

Cutting or Excavation

The formation at a level below the natural ground is called a cutting. Normally a cutting or excavation is made through a hilly or natural ground for providing the railway line at the required level below the ground level. The formation is prepared by excavating the existing ground surface to make a cutting.

The **height of the formation** depends upon the ground contours and the gradients adopted.

The **side slope of the embankment** depends upon the shearing strength of the soil and its angle of repose.

The **width of the formation** depends upon the number of tracks to be laid, the gauge, and such other factors.

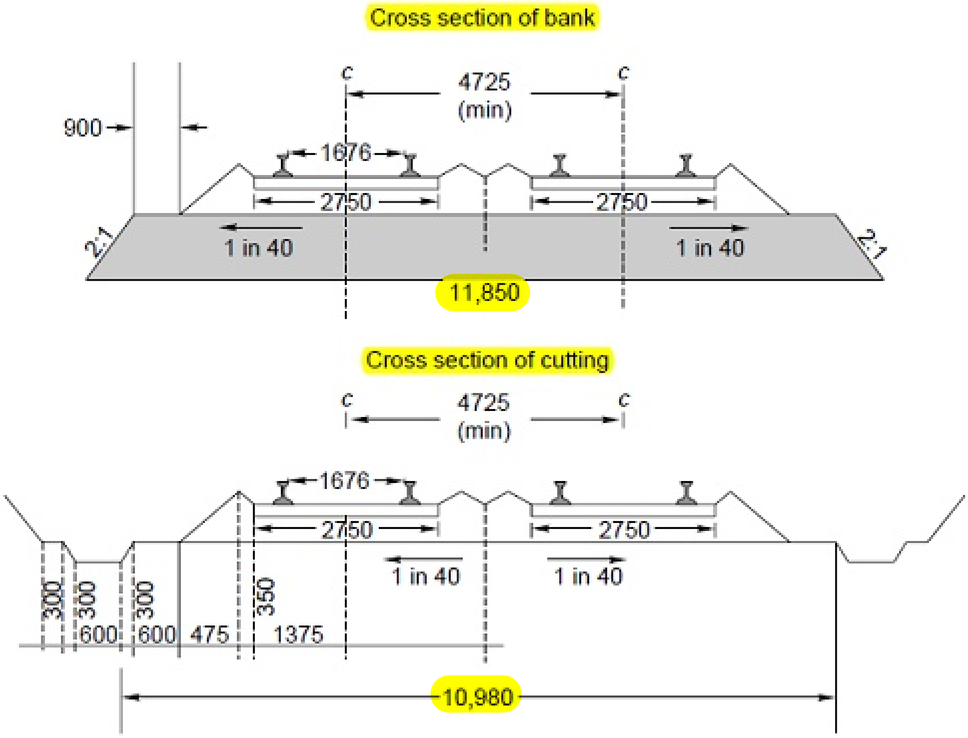

Figure: Typical cross section of bank and cutting for BG double line (dimensions in mm)

The side slopes of both the embankment and the cutting depend upon the shearing strength of the soil and its angle of repose. The stability of the slope is generally determined by the slip circle method. In actual practice, average soil such as sand or clay may require a slope of 2:1 (horizontal:vertical) for an embankment and 1:1 or 0.5:1 or even steeper particularly when rock is available for cutting.
To prevent erosion of the side slopes due to rain water, etc., the side slopes are turfed. A thin layer of cohesive soil is used for this purpose. Alternatively, the slopes are turfed with a suitable type of grass. Sometimes the bank also gets eroded due to standing water in the adjoining land. A toe and pitching are provided such cases.

Specifications for Embankments in Good Soil

For embankments up to 6 m high

The earthwork should be carried out manually in layers not exceeding 30 cm in thickness. All clods of earth should be broken. Earthwork should be carried out in this manner for a height of up to 1 m below the formation. The earthwork is then to be exposed to rains for one season before taking up the remaining work. The remaining earthwork is carried out by mechanical compaction of the soil in layers not exceeding 30 cm at optimum moisture content in order to obtain at least 90% of the maximum dry density.

For embankments more than 6 m high

In the first working season, up to 6 m or less of earthwork should be done and exposed to the rains. In the second working season, earthwork should be progressed further up to a distance of 1 m lower than the formation level and exposed to rains. The remaining earthwork should be done in the third working season by mechanical compaction. The work can also be completed in the second working season if mechanical compaction is used. On high-speed and heavy-density routes, a blanket of suitable material or a subballast of 30 cm thickness may be provided. The formation should be given a cross slope of 1 in 40 or 1 in 30 from the center towards the cess.

Specifications for Cuttings in a Good Soil

The following guidelines are followed by Indian Railways for cuttings in good soil:

(a) If the normal dry density of the top 30 cm of soil is less than 90% of the maximum dry density, the formation should be rolled to obtain the desired density.

(b) The road bed should be given a cross slope of 1 in 40 or 1 in 30 from the centre towards the drains on either side.

Track drainage

Track drainage is defined as the interception, collection, and disposal of water from upon or under the track. It is accomplished by a surface and sub-surface drainage system. Proper drainage of the subgrade is very vital, as excess water reduces the bearing capacity of the soil as well as its resistance to shear. The full details about track drainage can be obtained from Chapter 19 where this subject is dealt with in depth.

Blanket and Blanketing Material

A blanket can be defined as an intervening layer of superior material that is provided in the body of the bank just underneath the ballast cushion. It is different from the sub-ballast, which is provided above the formation.

The functions of the blanket are twofold:
(a) to minimize the puncturing of the stone ballast into the formation soil and
(b) to reduce the ingress of rain water in to the formation soil.

The blanket should generally cover the entire width of the formation from the shoulder, except in the case of sand or similar erodable material, where it should be confined within berms of a width of 6075 cm. The depth of the blanket should normally be about 30 cm in ordinary clayey soil. However, if the formation soil is particularly weak, a thicker layer of up to 60 cm may be necessary, depending on the shear properties of the formation soil. The blanket material should have the following properties:

For sand, quarry grit, gravel, and other non-cohesive materials

(a) The blanket material should be coarse and granular.

(b) If the material contains plastic fines, the percentage of fines (particles measuring up to 75 microns) should not exceed 5. If the fines are non-plastic, then they can be allowed up to a maximum of 12%.

(c) The material should be properly graded and its particle size distribution curve should lie within the standard enveloping curves.

For Macadam

(a) The liquid limit should not exceed 35 and the plasticity index should be below 10.

(b) The uniformity coefficient should be above 4, preferably above 7. The coefficient of curvature, which is $\frac{D_{30}^2}{D_{60}} * D_{10}$, should be between 1 and 3.

(c) When macadam is used as the blanketing material, it should be compacted in a suitable number of layers at or near the optimum moisture content so as to achieve not less than 90% of the maximum dry density as determined by Proctors test using heavy compaction.

(d) If an erodible material is used as a blanket, it should be confined in a trench and sand drains should be provided across the track and the blanket. These cross sand drains with adequate slope should be 530 cm below the bottom of the blanket and spaced 24 m apart.

Failure of Railway Embankment

A railway embankment may fail due to the following causes:

(a) Failure of the natural ground

The natural ground on which the embankment is made can fail either due to shear failure or due to excessive settlement. Failure of this kind is generally associated with the upheaval of the ground beyond the toes of the embankment. Shear failure of natural ground generally takes place when construction is in progress or immediately after construction. Once the ground stabilizes, it hardly fails under existing embankments.

The following remedial measures are generally adopted to improve the load carrying capacity of natural ground and hasten the process of settlement.

(i) Provision of suitably spaced sheet or ordinary piles on either side of the embankment, which will check shear failure by obstructing the slipping mass.

(ii) Provision of a balancing embankment to increase the load on the natural ground to check its heaving tendency.

(iii) Provision of sand drains to help quicker consolidation.

(b) Failure of the fill material in the embankment

Sometimes shear failure and excessive settlement of an embankment takes place due to the failure of the fill material of the embankment. This can easily be avoided by judicious selection of the fill material, better construction procedures, and adopting a suitably designed section for a new embankment. The main reasons for this type of failure are the following:

(i) Heavy traffic causing excessive stress in the soil, beyond its safe limit

(ii) Inadequate side slopes of the bank

(iii) Percolation of water in the embankment, thereby increasing the weight of the soil on one hand and reducing its bearing capacity and shear resistance on the other. Shear failure of existing embankments is quite common and occurs due to slips. Other causes of failure are the weights of the embankment and the moving loads on it. The forces resisting the failure are the cohesion and internal friction of the fill material.

The following types of slip failures may occur along different planes, as shown in Fig.
1. A slip passing through the toe of the bank known as toe failure.
2. A slip passing below the toe of the bank through its base known as base failure.
3. A slip passing above the toe of the bank through its slope known as slope failure.

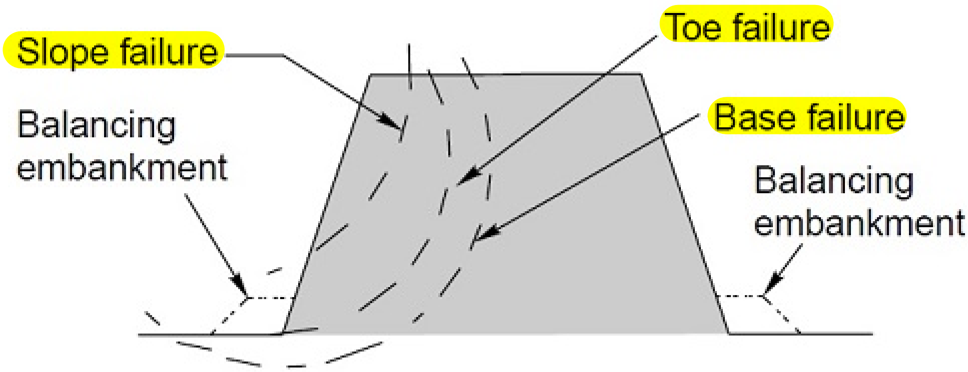

Fig: Slope failure, toe failure, and base failure

The remedies effective for such failures are listed below.

(i) Providing vertical piles on the slope on either side of the track, spaced at suitable intervals. These piles, which may be of scrap rail, bullies, etc., help check shear failure by causing an obstruction for the slip mass. This method was adopted on Ganga Bridge, Mokameh, and was found to be quite successful.

(ii) Providing balancing embankments on either side of the embankment as shown in Fig.

(iii) Flattening the side slopes.

(iv) Reducing the height of the embankment.

(v) Providing a lighter material at the top of the embankment, replacing the older material.

(vi) Providing proper surface and sub-surface drainage.

(c) Failure of the formation top

Failure of the formation top is very common in clayey soils during or just after monsoons. Some locations may trouble throughout the year. The main causes for such failures are the following.

Low bearing capacity of the soil Sinking of the ballast and the track, and the heaving up of cesses and bulging of side slopes as a consequence. The ballast punches into the formation causing ballast pockets.
Action of water and moving loads The top soil becomes soft and gets pumped up resulting in the sinking of the ballast. The ballast also gets clogged and looses its drainage property.
Effect of weather Cracks develop on the formation during the summer months and the ballast sinks through the cracks, resulting in the settlement of the track. The situation gets further worsened during the monsoons when water seeps through these cracks, turning the upper layers of the formation to slush and resulting in the formation of deeper ballast pockets.

The impact of moving loads and the development of hydrostatic pressure further deepens the ballast on the side slopes as well and can lead to slips in extreme cases. These failures present considerable problems in the maintenance of the track. Not only is the track geometry affected thereby requiring frequent attention, but also huge quantities of ballast are lost every year, making its maintenance difficult and expensive.

Whatever may be the cause of failure, the normal symptoms are the following:

(a) Variation in cross levels
(b) Loss of ballast
(c) Upheaval of the ground beyond the toes of the embankment
(d) Slips in bank slopes

Remedial Measures
The following remedial measures can be adopted depending upon the situation.

Provision of an inverted filter
The bearing capacity of the soil is improved by the provision of a blanket of adequate thickness (inverted filter, Fig) between the ballast and the weak formation. The blanket should be of a non-cohesive material with adequate bearing capacity to withstand the load thereon. The blanketing material should conform to the following specifications.

(a) The liquid limit of the blanketing material should not be greater than 35 and the plasticity index should not be greater than 15.

(b) The blanketing material should have such a grain size that the fine soil from the bottom does not mix up with the water. The material should, therefore, conform to the specifications of an inverted filter.

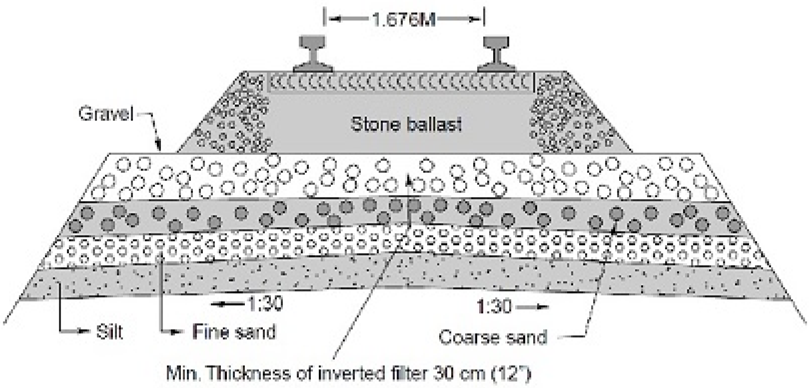

Fig: Inverted filter and underground drainage

(c) The blanketing material should be well graded, starting from a fine size to a size slightly smaller than stone ballast, the finer size lying at the bottom.

The inverted filter blanket is a very effective method of improving the bearing capacity of the soil. It serves as a barrier for the upward movement of the clay. It also provides a porous medium to drain off the surface water. The blanket also works as a capillary cut-off layer. The blanket can be inserted by imposing a traffic block of 45 hours or by temporarily operating only one line.

Improvement of surface drainage

Surface drainage can be improved by diverting ground water, providing catch water drains, etc., as well as draining the sub-surface structure.

Cement grouting

For cement grouting, a slurry or grout of cement and sand is pumped into the embankment by pneumatic injections. A 25-mm-diameter steel pipe is coupled with a rubber hose pipe of the same diameter, and through this grout of cement and sand in the ratio of 1:2 to 1:6 is injected under a pressure of 60 psi with the help of a pneumatic hammer. The injection points are kept close to both ends of the sleeper in a staggered position at an interval of 1.5 m or so. Pumping is continued till the grout appears through the ballast and reaches its top surface. Cement grouting is considered to be a very effective method of treating the subgrade. It fills the cracks, preventing the water from flowing into the subgrade, and seals off the moisture entering into it. The soil is stabilized and develops better properties and strength.

Sand piling

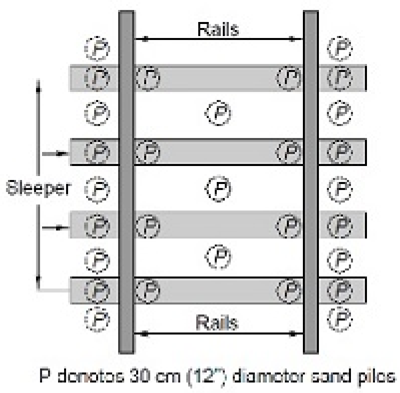

Fig: Sand piling

In sand piling, a series of 30-cm-diameter holes are drilled vertically inside and outside the rail to a depth of 23 m by means of augers or other devices. The holes are then filled up with clean sand and the track is resurfaced. The sand piles are so arranged that the cross-sectional area of the sand piles is about 20of the formation area. Sand piles compact the soil and provide mechanical support to the subgrade just like wooden piles. The drainage of the subgrade also improves, as water rises to the surface through the sand piles by capillary action and evaporates.

Deep screening of ballast and drainage of water pockets

The problem of ballast pockets can be tackled by assessing the depth of the penetration of the ballast in the bank. For this purpose, about five vertical trial bores are drilled to get a complete picture of the drainage condition of the subsurface structure. Water pockets can then be removed by any of the following methods, depending upon the situation.

(a) If the problem has just started, it can be remedied by deep screening and the provision of a pervious layer of 3060 cm on the cess. If necessary, the water pockets can be drained using a perforated pipe drain inserted with the help of a jack, as shown in Fig

(b) Cement grouting can also be done to seal the water pockets in case the problem is in a very small stretch. This method is, however, very expensive.

(c) If the problem is extensive, a geological survey should be done to assess the type of soil strata available. In case there is impervious soil under the water pocket, it can be drained out using a perforated pipe deep screening of the ballast is done, the water pockets are drained out using a perforated pipe, and then an inverted filter of about 30 cm thickness is provided.

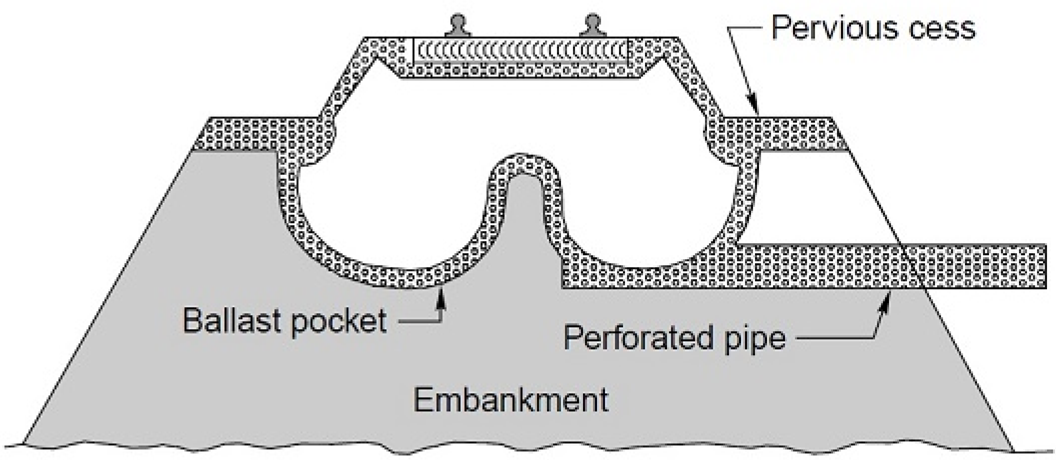

Fig: Drainage of Ballast Pockets

(d) Counterfeit drains are sometimes provided to drain the water pockets. Such drains are generally 60 cm wide and spaced at intervals of 10 m or so, depending upon the extent of the problem.

(e) Water may also be held up in the ballast pockets by an impervious layer of soil over a good pervious layer of soil of fissured strata. In this case the remedy lies in drilling a tap hole in the thin impervious strata, allowing the water to go into the pervious subsoil, where it gets drained automatically.

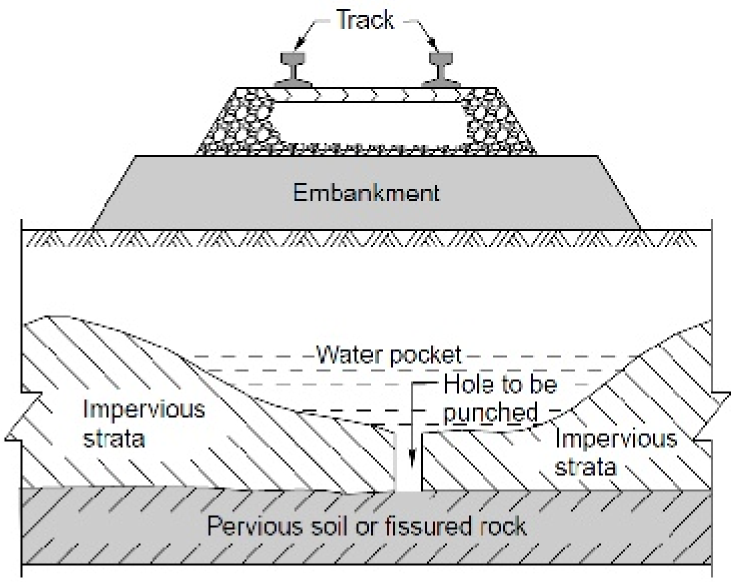

Fig: Drainage of water pocket by puncturing holes through impervious strata

Soil Stabilization by Geotextiles

A new method of stabilization of soil using geotextiles has recently been developed in many countries. Geotextiles are made up of polymers and have the unique property of allowing water, but not soil fines, to pass through. Geotextiles not only work as separators and filters but also help drain the water and provide reinforcement to the soil bed.

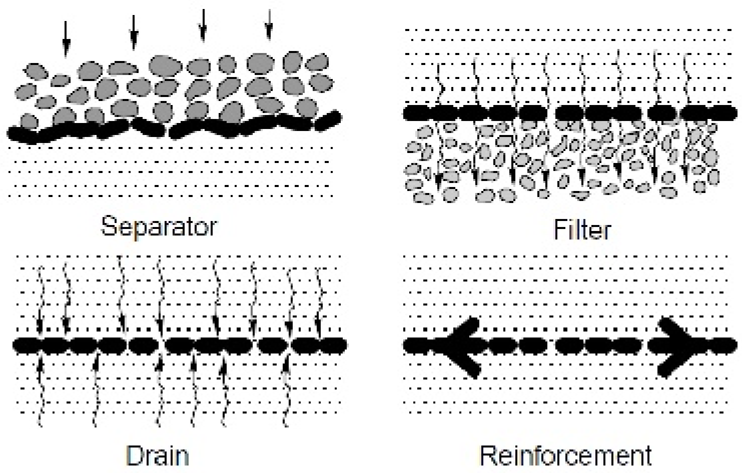

Fig: How geotextiles are laid

A layer of geotextile is normally either laid directly below the ballast or sandwiched between layers of sand. On Indian Railways, the geotextile is proposed to be sandwiched between a 50-mm layer of sand on top and a 25-mm layer of sand below so that the ballast does not rest directly on the geotextile and incidences of tear and puncture are reduced.

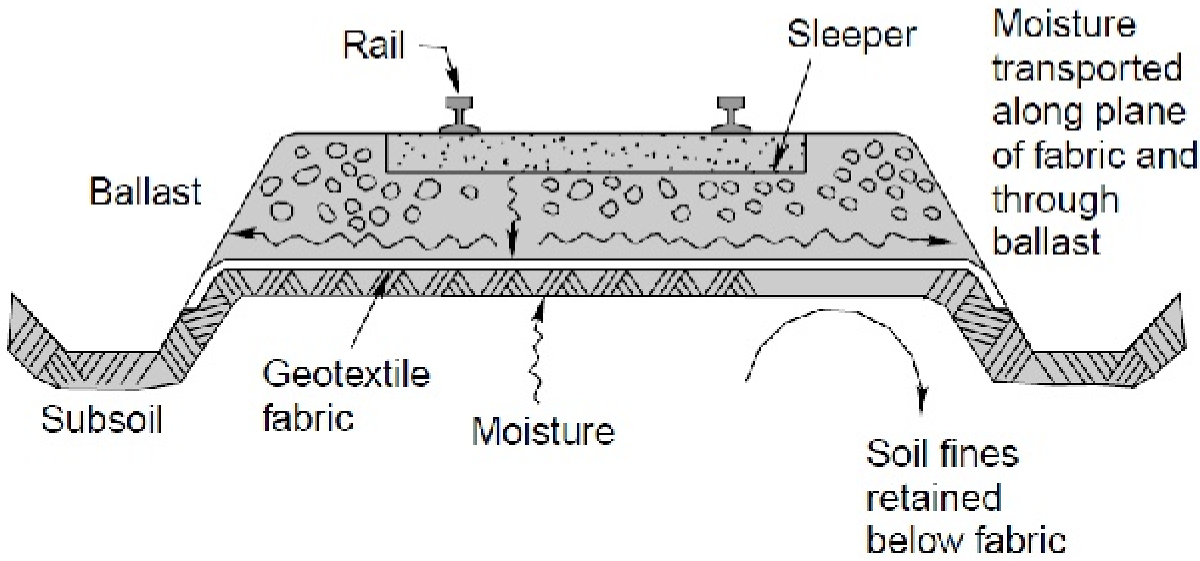

Fig: Laying of geotextiles