# Transportation Engineering

Course Code –CE-422

Contact Hours -3+3

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# Problem

- A $6^o$ curve branches off a $3^o$ main curve in opposite direction in the layout of a BG track. If the speed on the branch track is restricted to 22 mph. Determine speed restriction on main line. Assume deficiency in super elevation is 3 inches.

# Formation

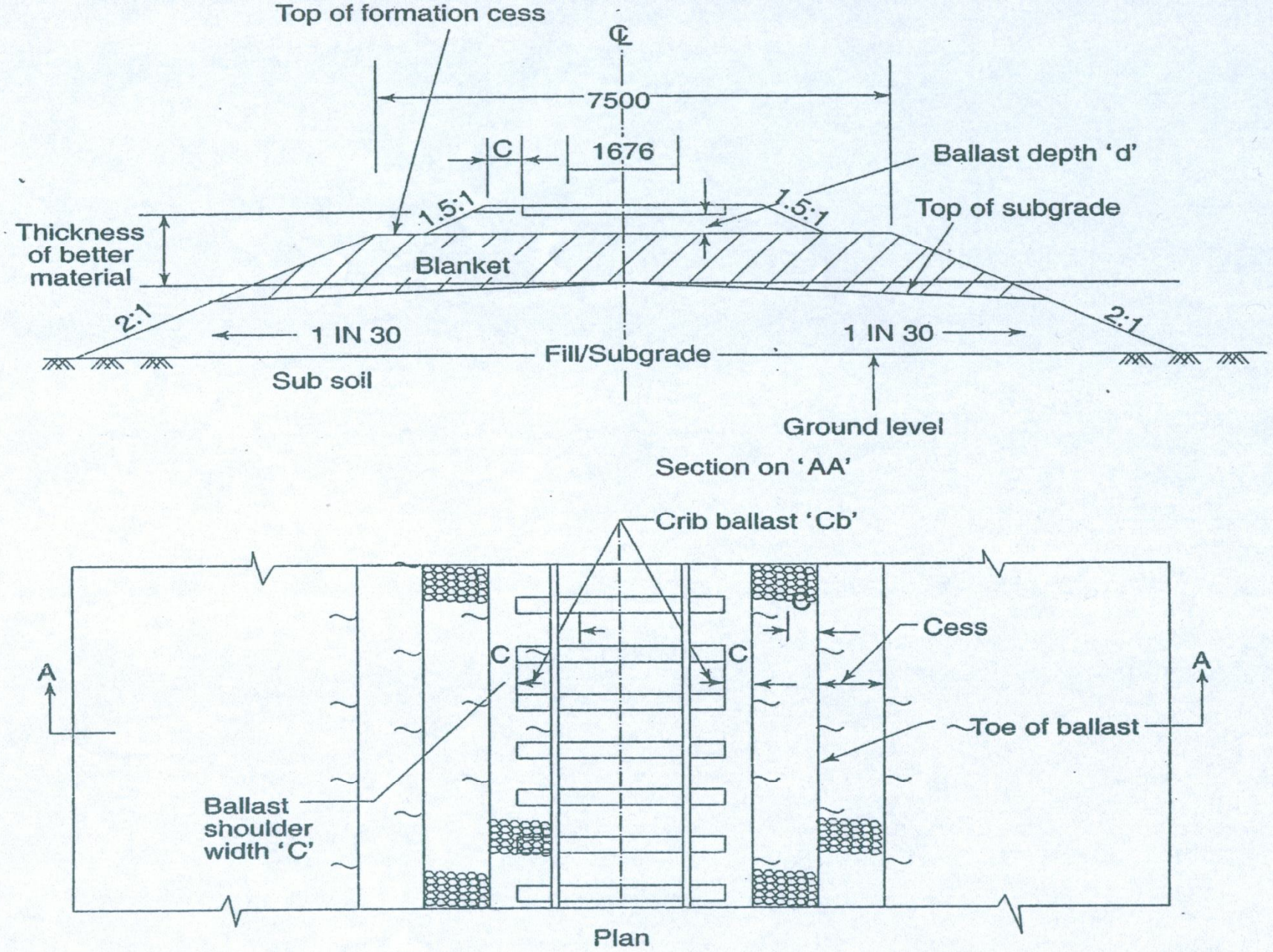
- Formation is a level surface on which the ballast is laid.
- The formation has to take all the loads coming on the track.
- The top surface of the formation is kept slightly sloping towards the sides, inorder to facilitate drainage.
- Level of the formation is the level prepared at its centre.
- Formation may be in fill or in cut or partially in fill and partially in cut. When the section is in cut the drainage becomes must.

# Function of Formation

- It distributes the load over wider area of the natural ground.
- Provides a smooth level surface for the placing of the ballast
- It facilitates the drainage
- It acts as foundation to the track and provides stability to it.

# Width of Formation

- Top width of the formation will depend upon
  - Gauge of the track
  - No of tracks
  - Centre to centre distance between the tracks
  - Width of the ballast layer
  - Width of the drain on either side if the track is in cutting
- Width of the formation for single lane BG track is 20 ft
- Width of the formation for double lane BG track is 35 ft.




*Cross-section of a railway track*

# Height of Formation

- Height of the formation depends upon the
  - Soil conditions
  - Highest flood level
  - Topography
  - Intensity of pressure transmitted to the ground.

# Side Slopes

- Side slope of the formation must be flatter than the angle of repose of the ground.
- Side slopes in case of embankment is 1 to 2
- Side slopes in case of cutting is 1 to 1.5 or even steeper
- The side is vertical when solid rock exists.

# Formation Width for Embankment

- Broad Gauge
  - Single 20 ft (6.10 m)
  - Double 35.5 ft (10.8 m)
- Meter Gauge
  - Single 16 ft (4.9 m)
  - Double 29 ft (8.8 m)
- Narrow Gauge
  - Single 12 ft (3.7 m)
  - Double 24 ft (7.3 m)

# Formation Width for Cutting

- Broad Gauge
  - Single 18  ft (5.5 m)
  - Double 35.5 ft (10.2 m)
- Meter Gauge
  - Single 14 ft (4.3 m)
  - Double 27 ft (8.3 m)
- Narrow Gauge
  - Single 11 ft (3.4 m)
  - Double 23 ft (7.0 m)

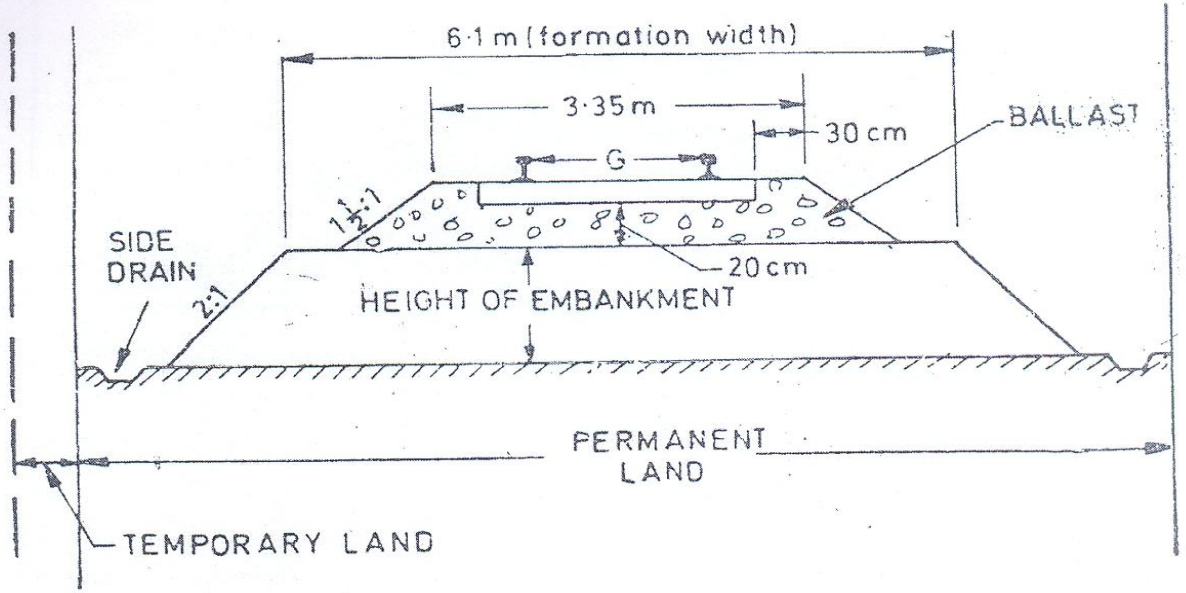
  - Note c/c distance for track is 15 ft for BG

# Types of Formation

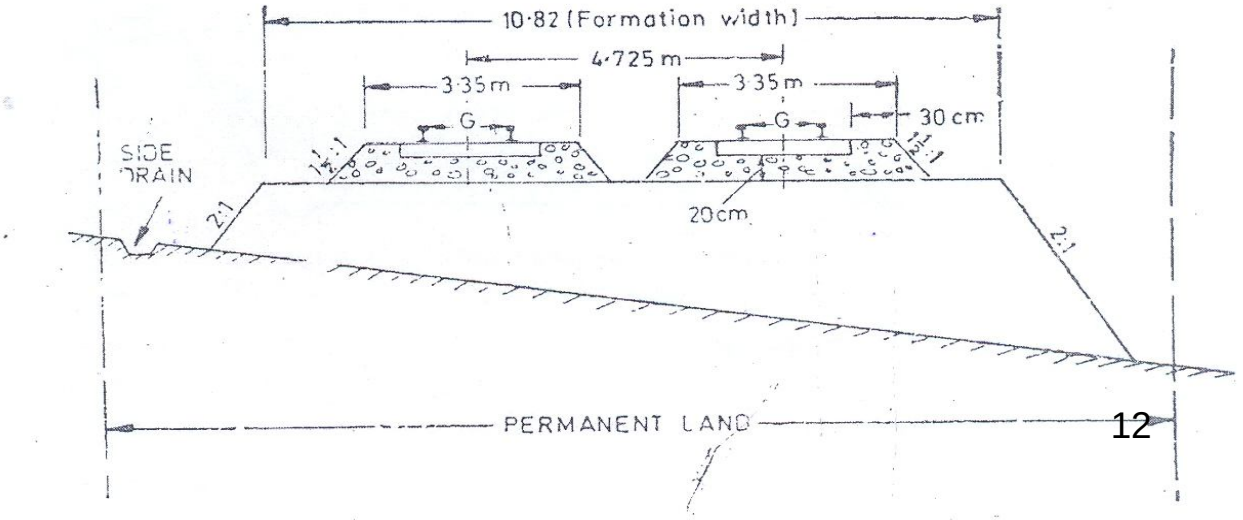
- Formation on Fill/ Embankment
  - Formation in the shape of raised bank constructed above the surface of natural ground is embankment
- Formation in Cutting
  - Formation below the level of natural ground

# Formation on Fill

Single Line
BG Track

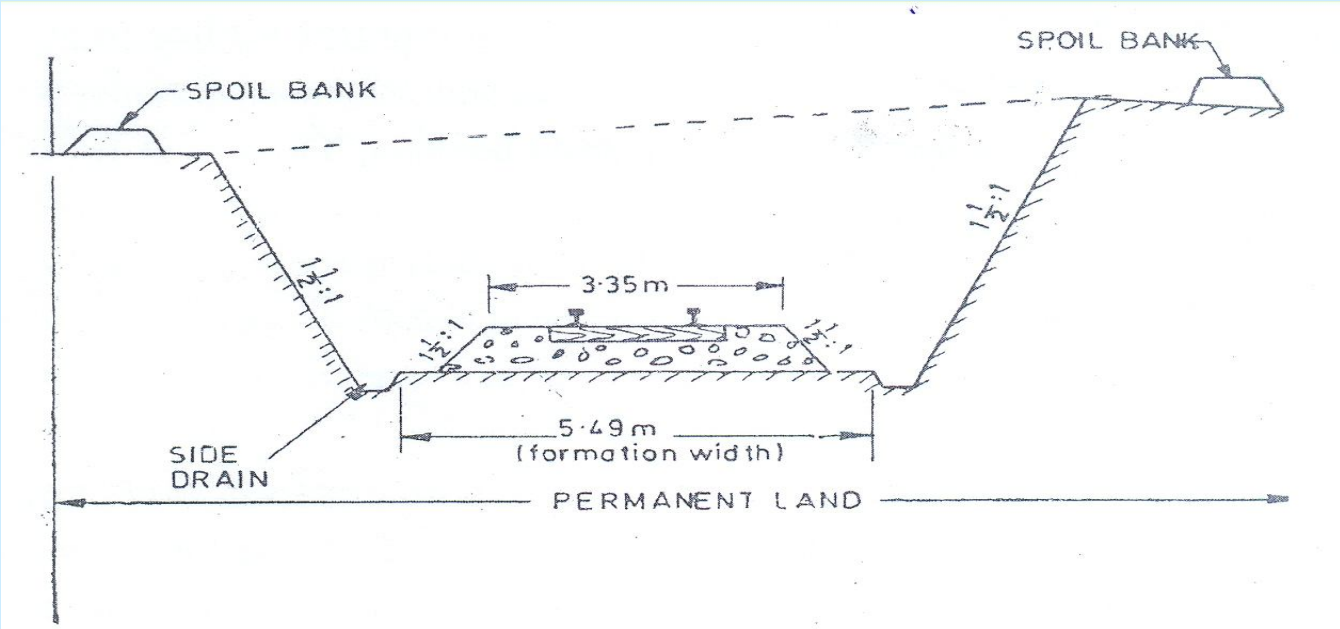



Double Line
BG Track

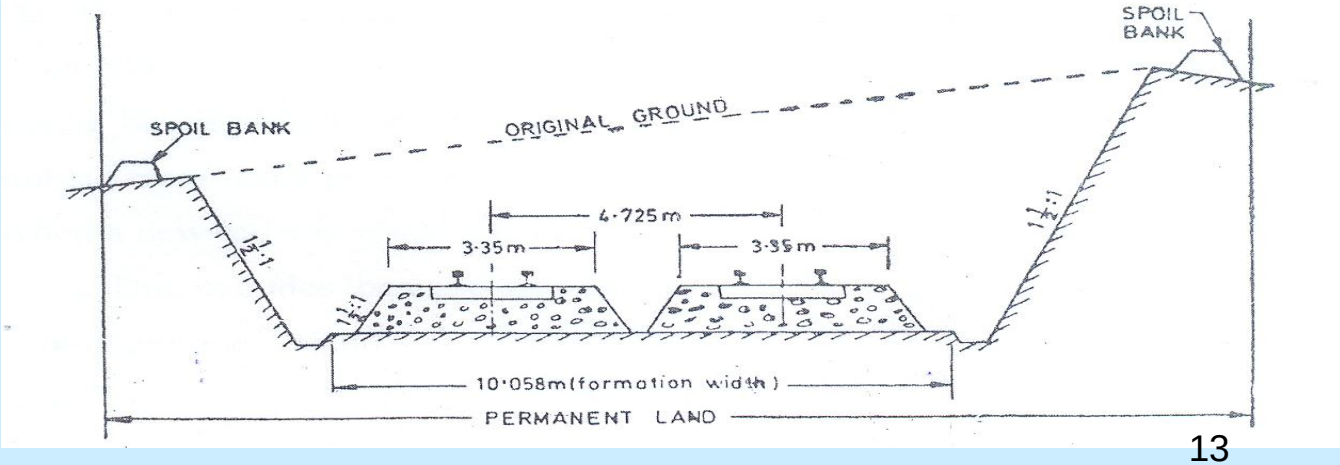


# Formation in Cutting

Single Line
BG Track



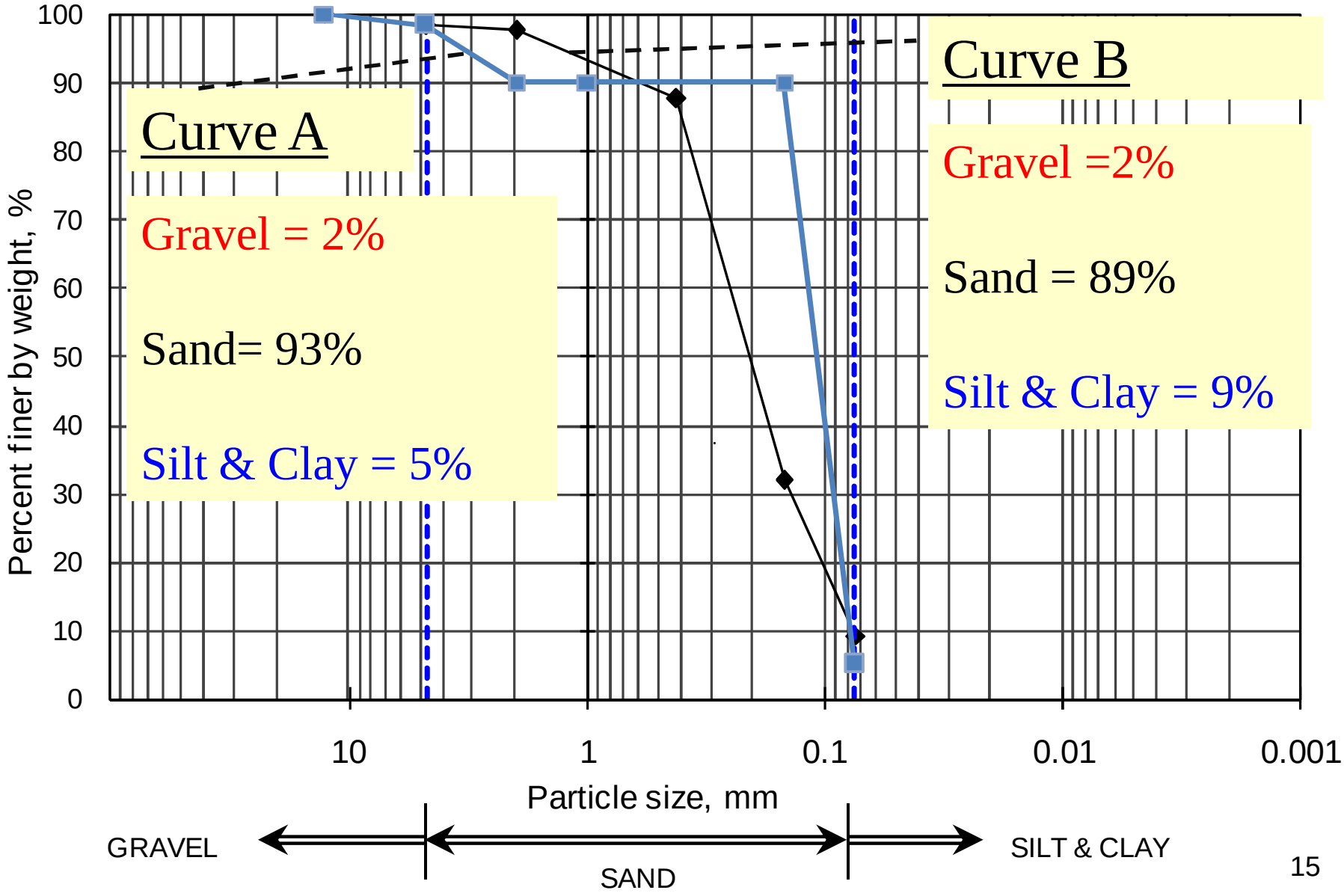

Double Line
BG Track



# Type of soil for formation

- No skip grading is allowed
- Plastic fines in the proposed formation material shall not exceed 5%
- Non-plastic can be allowed upto 12% in formation material
- Uniformity coefficient in no case less than 4 preferably more than 7
- Co-efficient of curvature between 1-3

# PARTICLE SIZE DISTRIBUTION CURVE



# Particle Size Distribution (cont'd)

- Sand
  - Passing # 4 and Retained # 200
- Gravel
  - Retained # 4
- Silt & Clay
  - Passing # 200

# Which Soil to select

- Curve A
  - gap grading
  - Fines = 5%
  - LL = -
  - PL= -
  - PI = NP
  - $C_u$ = 1.5
  - $C_c$ = 1.0
- Curve B
  - No gap grading
  - Fines = 9%
  - LL = -
  - PL= -
  - PI = NP
  - $C_u$ = 2.9
  - $C_c$ = 0.9

# Earthwork For Formation

- To keep the permitted gradient and to avoid too frequent changes of gradient it is usually necessary for the level of formation to be below or above the natural ground level in different places.
- The natural level must therefore be lowered by cutting where it is high or raised by an embankment where it is low.
- In extreme cases, where depth of cutting would be excessive, tunnels are made through the ground.
- Where an embankment is not possible, the track is supported on bridges.

# Earthwork For Formation (cont'd)

Soil exploration and feasibility study include the following

- Permanent Land
- Temporary Land
- Formation
- Slopes of cutting/ embankment
- Side drains

# Permanent Land

- When a new railway line is planned a tentative decision in respect of the proposed construction is made based on preliminary studies.
- A certain strip of land on either side of the centre line of the proposed track is acquired by the railway department.
- The strip or land thus transferred to Railway by the other department or acquired by the personal possession is termed as the permanent land.

# Permanent Land

Width of the permanent land depends upon

- Gauge of the track
- Single line track or double line track
- Formation width
- Side slopes of the formations
- Side drains
- Side slopes of cutting or embankment
- Possibilities of further extension of track.

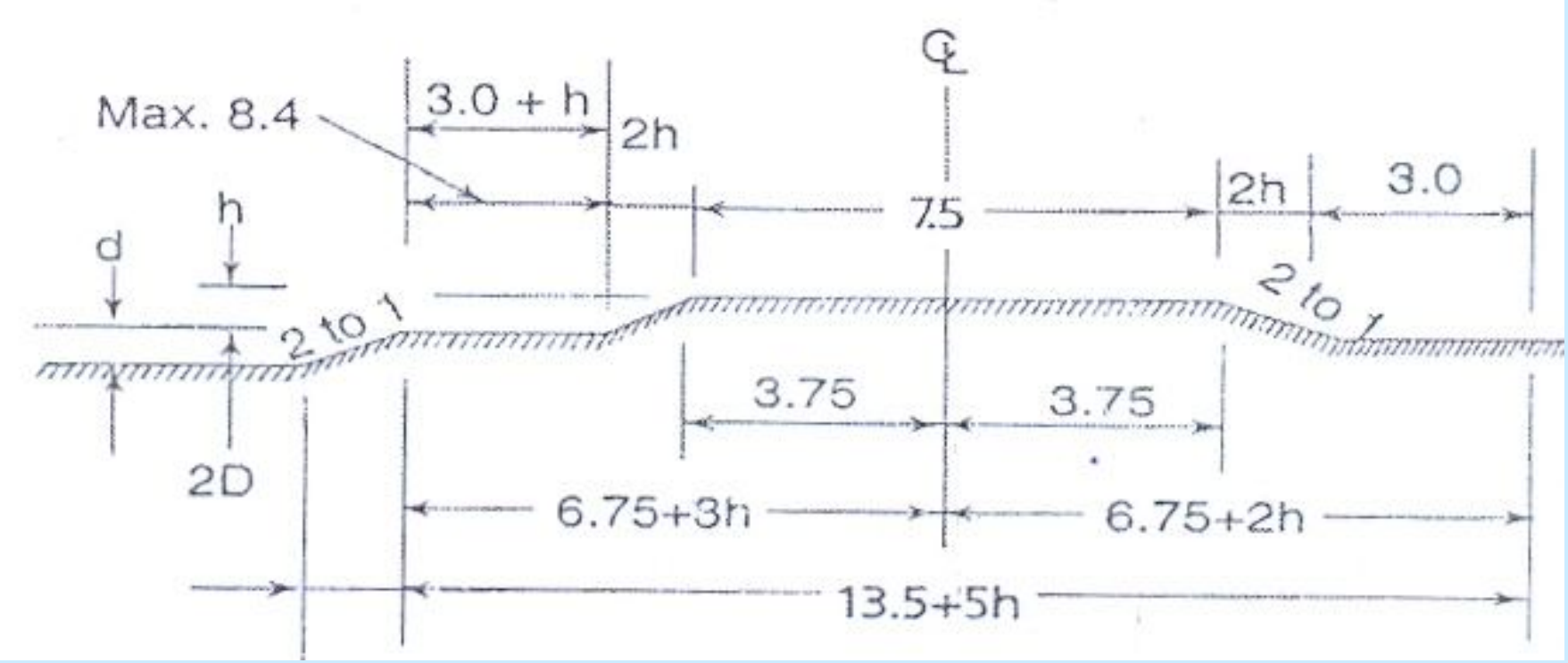
# Temporary Land

- In every rail project, the preparation of formation is the first stage of the execution work. An ideal condition is that the amount of material excavated from cutting is sufficient for embankment.

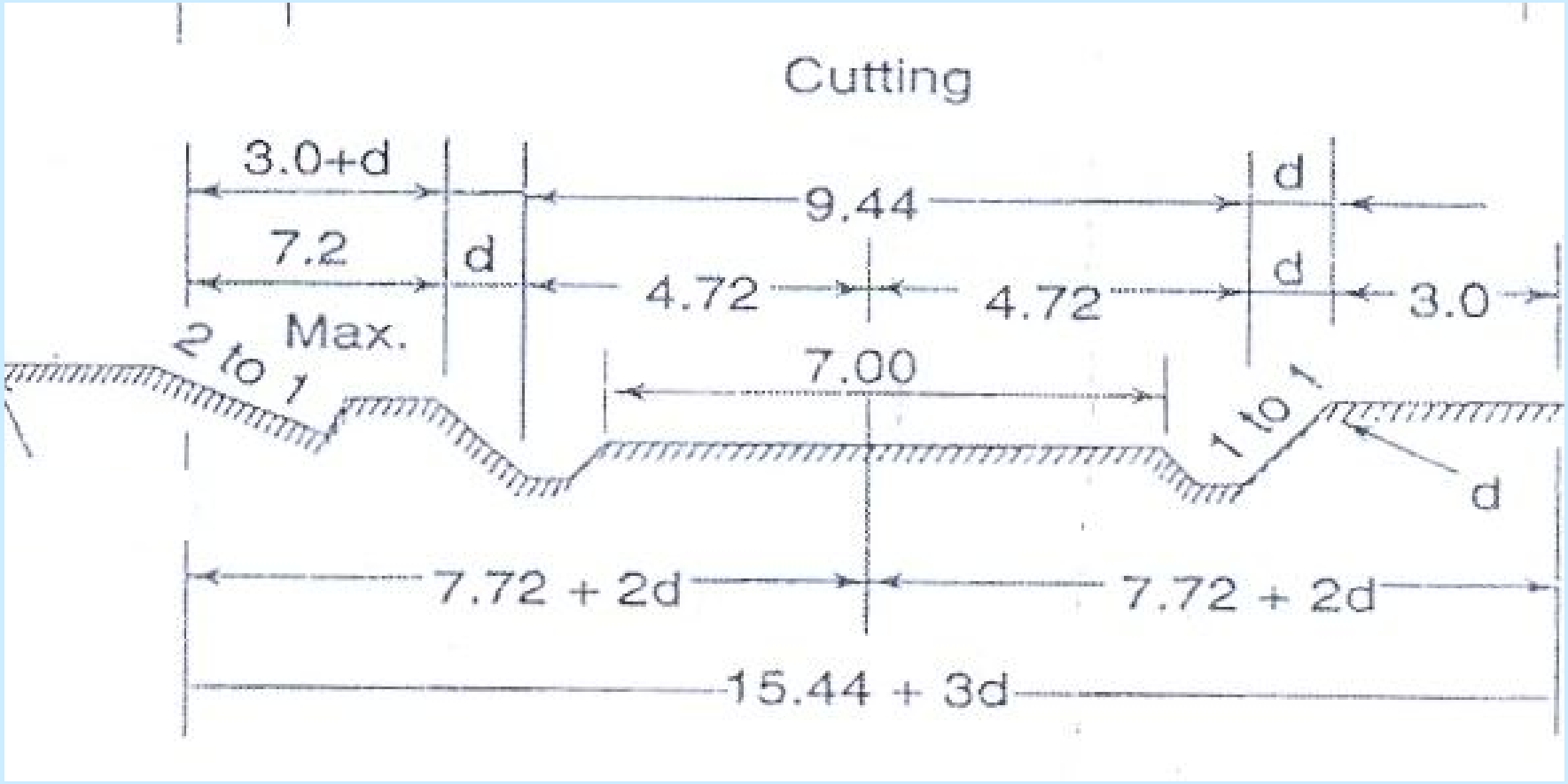
- However, when excavation and embankment do not balance it is better to temporarily acquire a strip of land adjoining the permanent land from where earth may be borrowed.

- It may be utilized as the spoil bank for the excavated earth.

# Permanent Land in Embankment



# Permanent Land in Cutting



# Guide lines for Execution of Earth Work

Control of water along with the type of sub-grade plays an important role in the construction of formation

- Non cohesive soils – Gravels and Sands
- Cohesive soils – Silt/ Clay
- Organic Soils- Peat/ organic clay/ silt
- Cemented sedimentary rocks- sand stone, limestone
- Metamorphic rocks-slate
- Igneous rocks- granite, basalt

# Soil Exploration and Surveys

- Geotechnical investigations are carried out for identification and classification of soil.
- Boring and soil sampling is carried out from the areas where borrow pits are to be located, at intervals of about 0.5 km or where change of strata occurs.
- In case sub soil problems are likely to be encountered, the spacing of bore holes should be reduced

# Soil Exploration and Surveys

- On doubling sampling should be done at locations known to be trouble-some in the existing track.

- Organic clays, silts and peat shall not be used for making of embankment. Cutting in these types of soils should be avoided.

# Design of Rail Formation

- Design should be such that the track is able to sustain track geometry under anticipated traffic densities and axle loads during service under most adverse conditions of weather. It necessitates that
- Bank/ cutting is structurally stable
- Settlement in the sub-grade supporting soil masses are within permissible limits
- There is no bearing capacity failure.
- Embankment soil shall attain moisture density equilibrium during weather cycles.

# Compaction of Earth Work

- The method of compaction should satisfy the conditions of economy and efficiency of earthwork.
- Compaction cannot guarantee the stability of formation particularly in the following cases
- Excessive creep or slipping of slopes, because long term shear strength and water contents are not governed by the compaction at the time of construction.

# Compaction of Earth Work

- Swelling and shrinkage of soils during wet and dry seasons respectively, because physiochemical properties of soil do not get altered by compaction
- Mud pumping at ballast soil interface
- Settlement due to consolidation of bank and sub-soil which can occur even for a few years after construction of bank.

# Methods of Compaction

- Sandy silty soils with moderate cohesion
- Cohesive soils
- Cohesionless soils

# Compaction of sandy Silty soils with moderate cohesion

- For such soils compaction in layers by rollers is most effective.
- Vibratory rollers have been found more effective than the static rollers
- Greater thickness of layers is allowed.

# Compaction of cohesive soils

- The main objective of compacting clayey soils is to achieve a uniform mass of soil with no voids between the chunks of clay which are placed during the earth work.
- Rollers will sink into the soil at high moisture content while chunks will not yield to rolling by rollers if moisture content is low.
- Sheep foot rollers are most effective in breaking the chunks and filling the large spaces.

# Compaction of Cohesionless soils

- An effective method to compact cohesionless soils is to use vibratory rollers.
- Moisture content control is not necessary.
- Poorly graded sands and gravels with uniformity co-efficient less than 2 should not be used in earth work for banks, to safeguard against liquefaction under moving loads or due to an earthquake.

# Cuttings

- If the subgrade soil is not fit to absorb stresses of traffic, the cutting will be made deeper to place a layer of blanket or sub-ballast of adequate thickness.

- In cutting of slope, softening of the soil occurs with the passage of time, therefore, long term stability is vital for designing of cutting.

# Unstable Formations

- Variation in the track level particularly during extreme hot or wet season, causing the need for speed restriction or increased maintenance.
- Loss of ballast which sinks into the formation
- Instability of bank slopes resulting in slips and consequent disruption of traffic.

# Causes of Formation Troubles

- If any formation is suspected of giving any trouble, the first step should be to identify the cause of the trouble.

- To do so, the data regarding the ballast penetration profiles along with the history of the section and the trouble should be obtained and analyzed.

# Causes of Formation Troubles

- Following are the most common causes
  - Instability problems due to railway cutting or embankment not being stable, resulting in excessive deformation.
  - Excessive swelling and shrinking of bank soil causing large volumetric changes and thus unequal settlement and heaving of the formation, disrupting the track levels and alignment

# Causes of Formation Troubles

- Bearing capacity failure due to
  - Inadequate formation width or bank slopes
  - Inadequate thickness of the ballast and the blanket
- Other causes such as loss of formation soil caused by porcupines, ants, rats, seepage

# Formation Failures

The failure of the formation is due to

- Failure of the natural ground under the formation
- Failure of the fill material in the formation
- Failure of the top of formation

# Failure of Natural Ground (causes)

- The failure of the natural ground takes place due to excessive settlement or the shear failure.
- The failure due to excessive settlement is generally associated with the upheaval of the ground beyond the toe of embankment.
- The shear failure normally takes place during the construction or immediately after the construction.

# Failure of Natural Ground

b) Remedial Measures

- Use of sand piles by the wooden logs
- Counter weight at the toe
- By providing sand drains which help in quicker consolidation

# Failure of Fill Material (causes)

- Excessive loading which produces excessive shear stresses in soil
- Steepness of the slopes
- Percolation of rain water

# Percolation of rain water

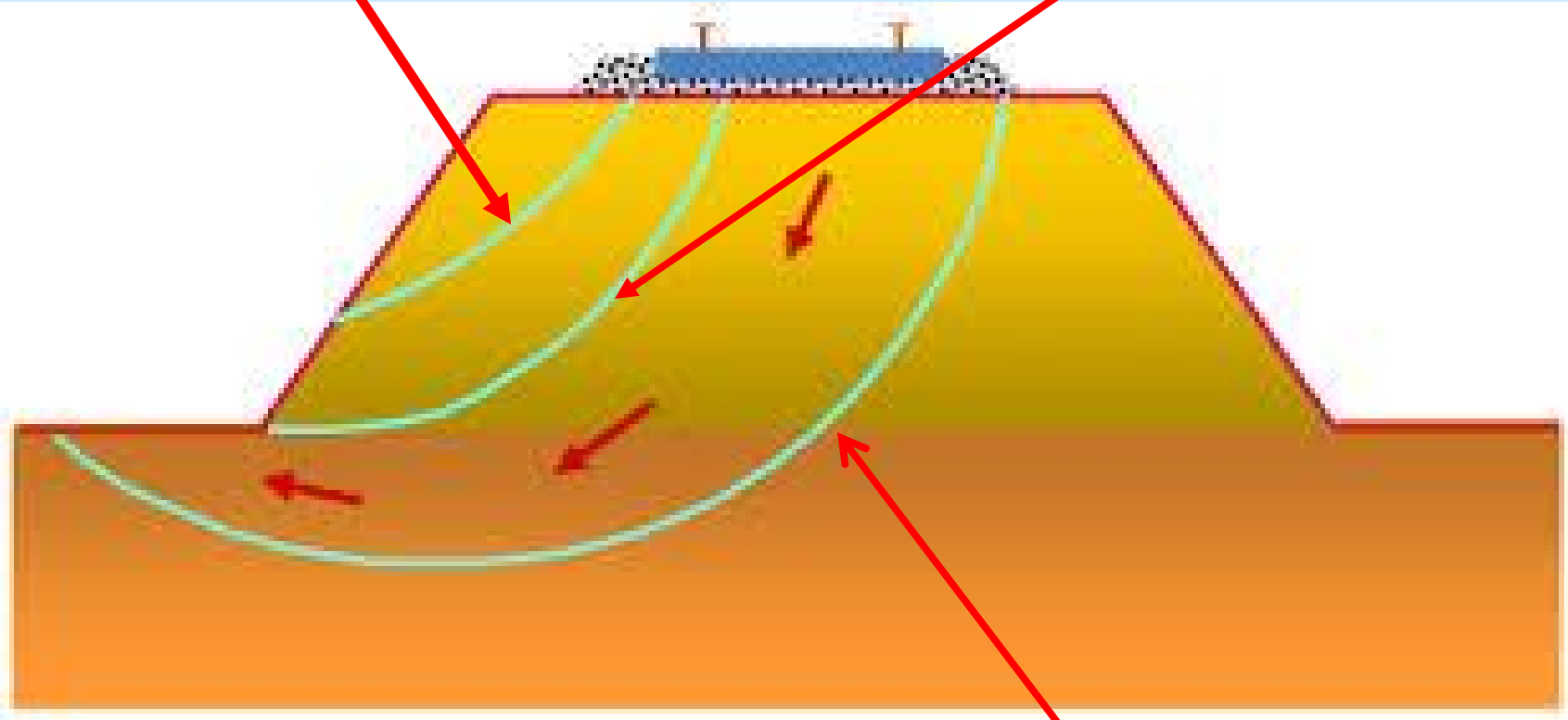
- Percolation of rainwater in the embankment increases the weight of the soil on one hand and reduces its bearing capacity and resistance to shear on the other hand.
- Shear failures of the existing embankment are quite common and occur by slips.
- The forces causing the failure are weight of the embankment and weight of the rolling stock.

# Percolation of rain water (cont'd)

- The forces which resist this failure are internal friction and cohesion of soil.
- Failure are
  - Toe failure
  - Base failure
  - Slope failure

Slope Failure

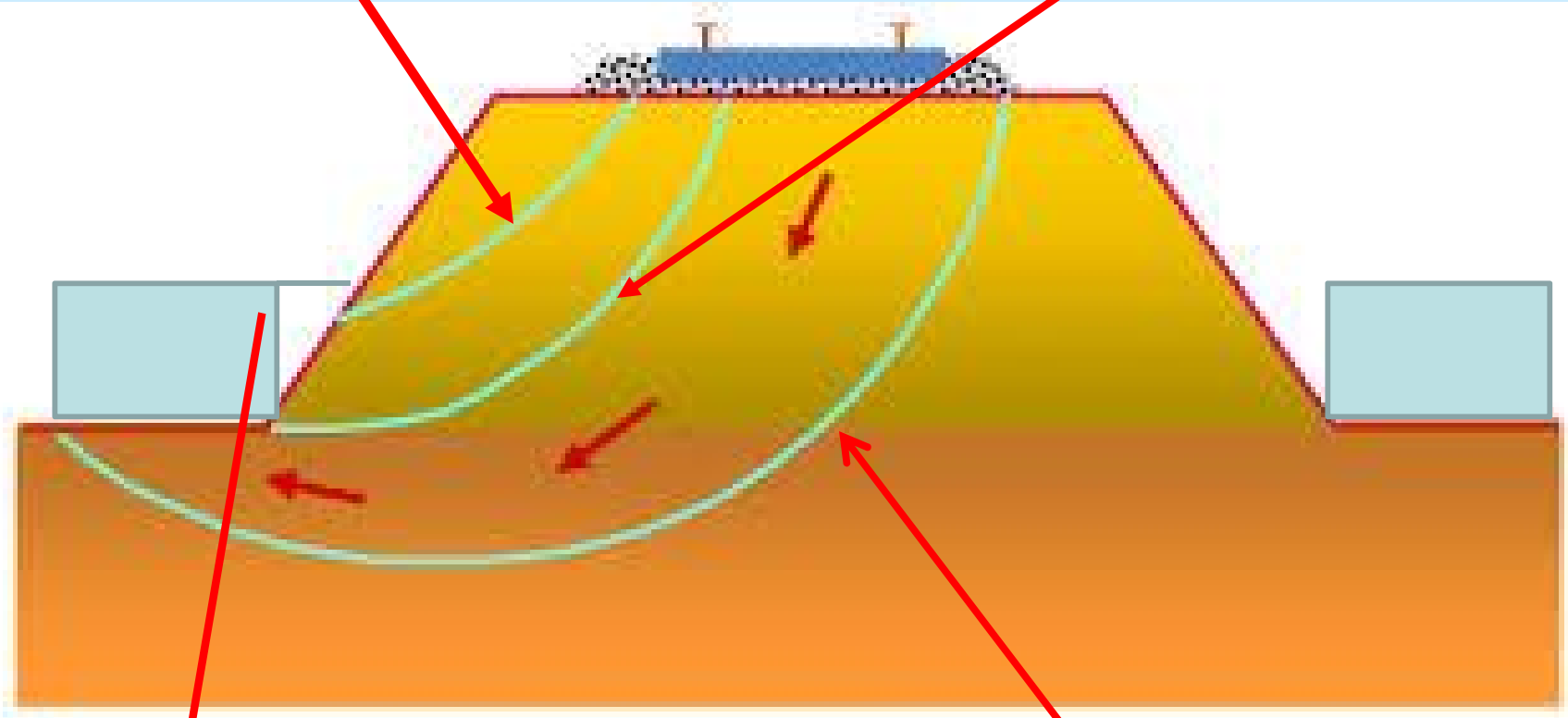
Toe Failure



Base Failure

Slope Failure

Toe Failure



Balancing Embankment

Base Failure

# Failure of Fill Material (Remedial )

- By flattening the slopes
- By providing steps in the foundations
- By providing stone pitching on the sides
- Providing proper surface and sub-surface drainage.
- Height of the embankment may be reduced

# Failure of Top of Formation

Causes

- Low bearing capacity of the soil
- Pumping action
- Weather effects

# Failure of Top of Formation

Remedial Measures

- Use good blanket material or sub-ballast at the top of formation
- Use of geotextile fabrics.
  - It will act as a separator between the top layer and the ballast. Secondly, it will act as reinforcement to the soil and will help better drainage.

# Formation treatment methods

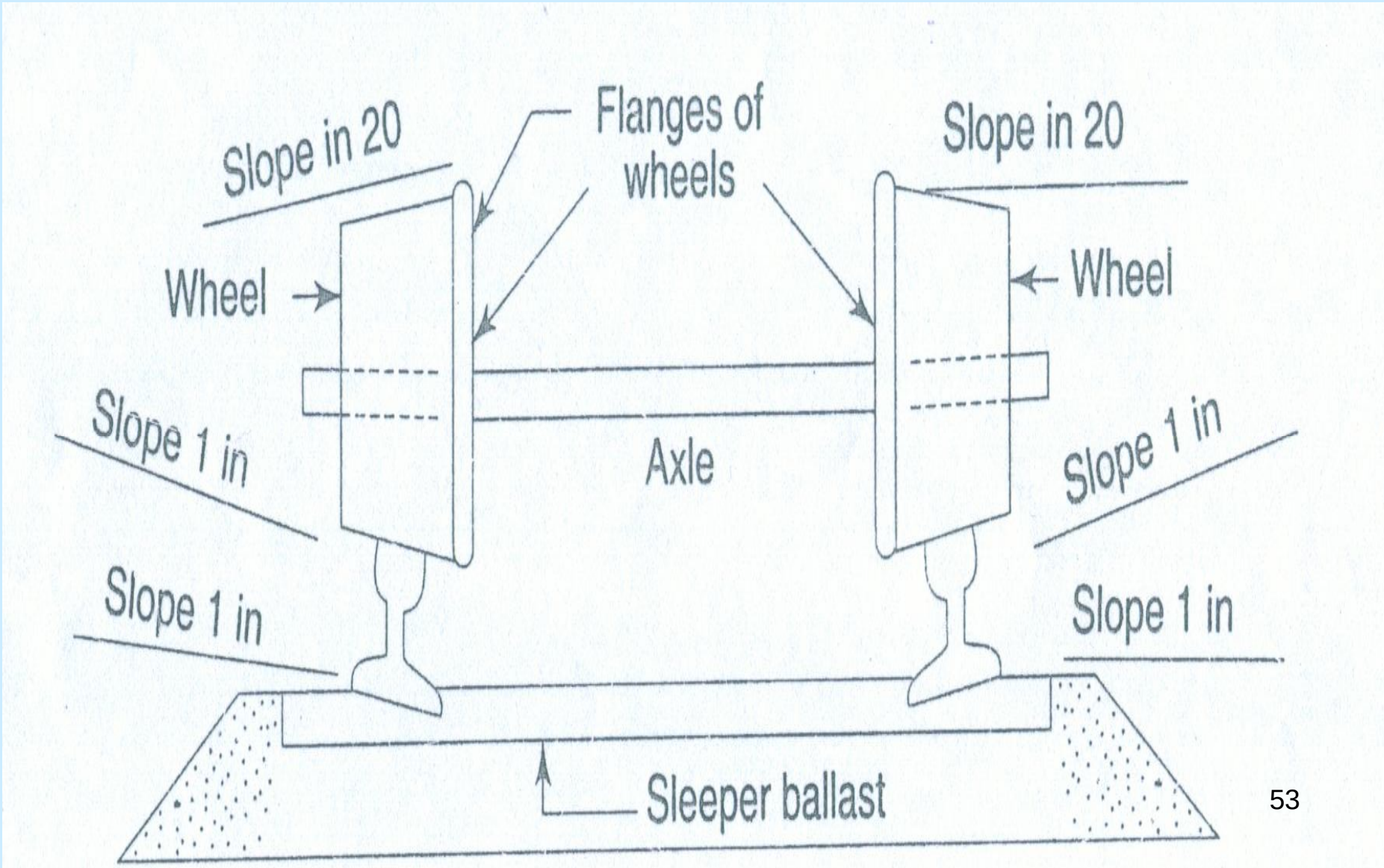
Various methods are used to stabilize soil embankments

- Stabilization by driving piles, poles or scrap rails into the embankment of medium height
- By driving sand piles in the embankment
- Stabilization by pressure grouting
- Stabilization of the embankment soil by chemicals
- Stabilization by use of geo-textiles
- Providing an inverted filter

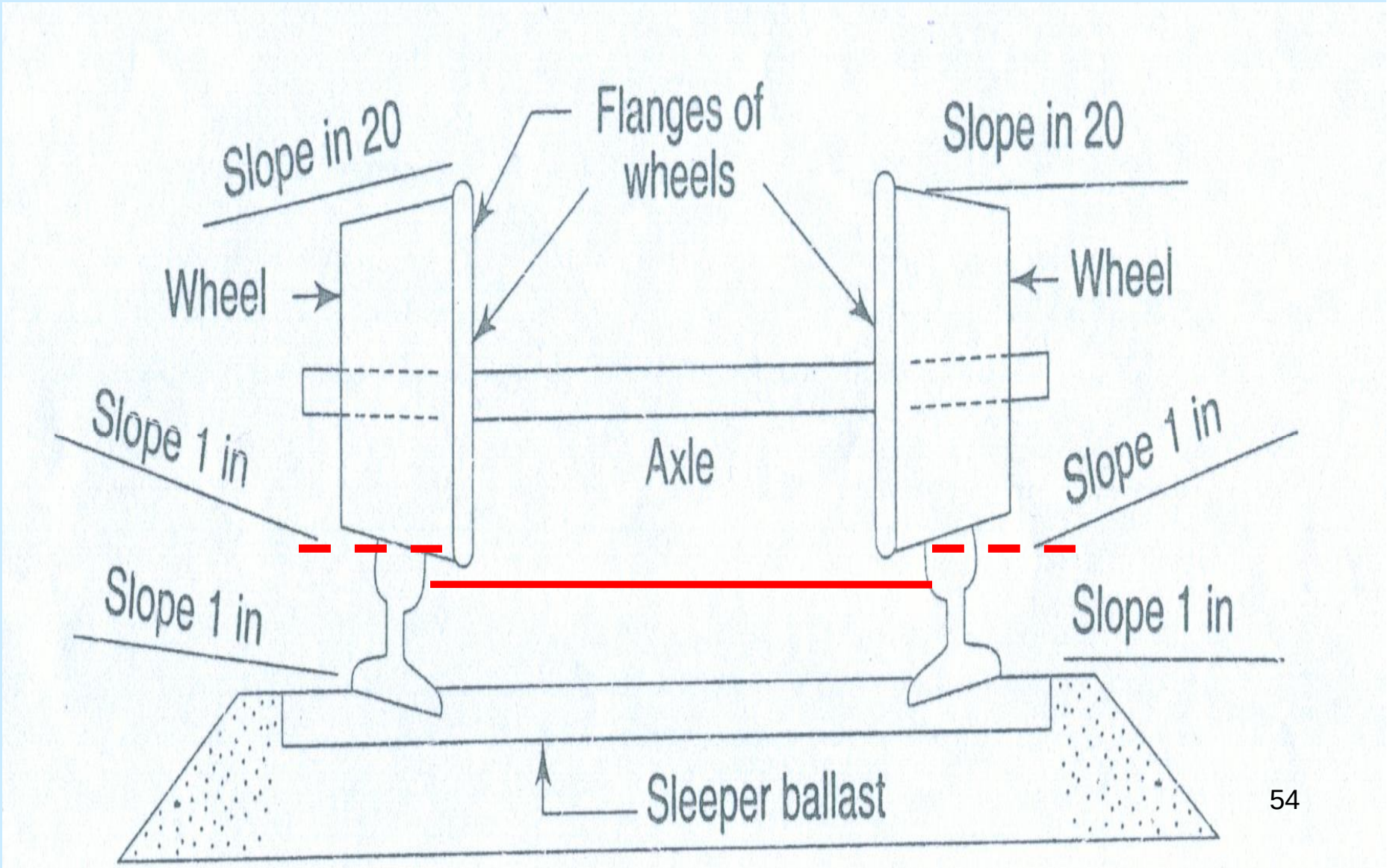
# Coning of Wheels and SE of Rails

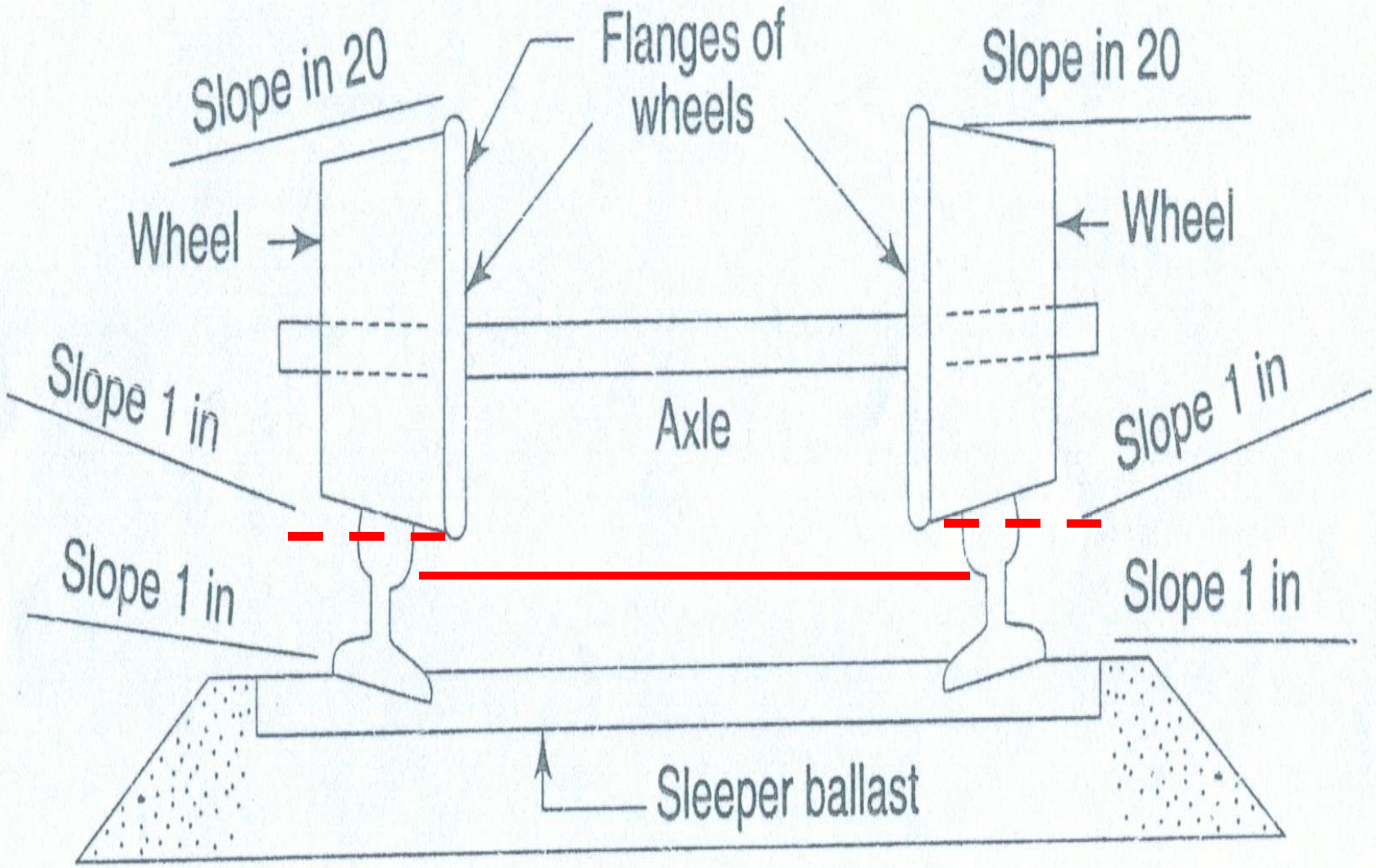
- If the distance between the inside flanges is kept equal to the gauge distance, the flanges of the wheel would rub against the inside face of the rail.
- To prevent this, the distance between the inside edge of the flanges is kept less than the gauge distance

# Coning of Wheel and Canting of Rails

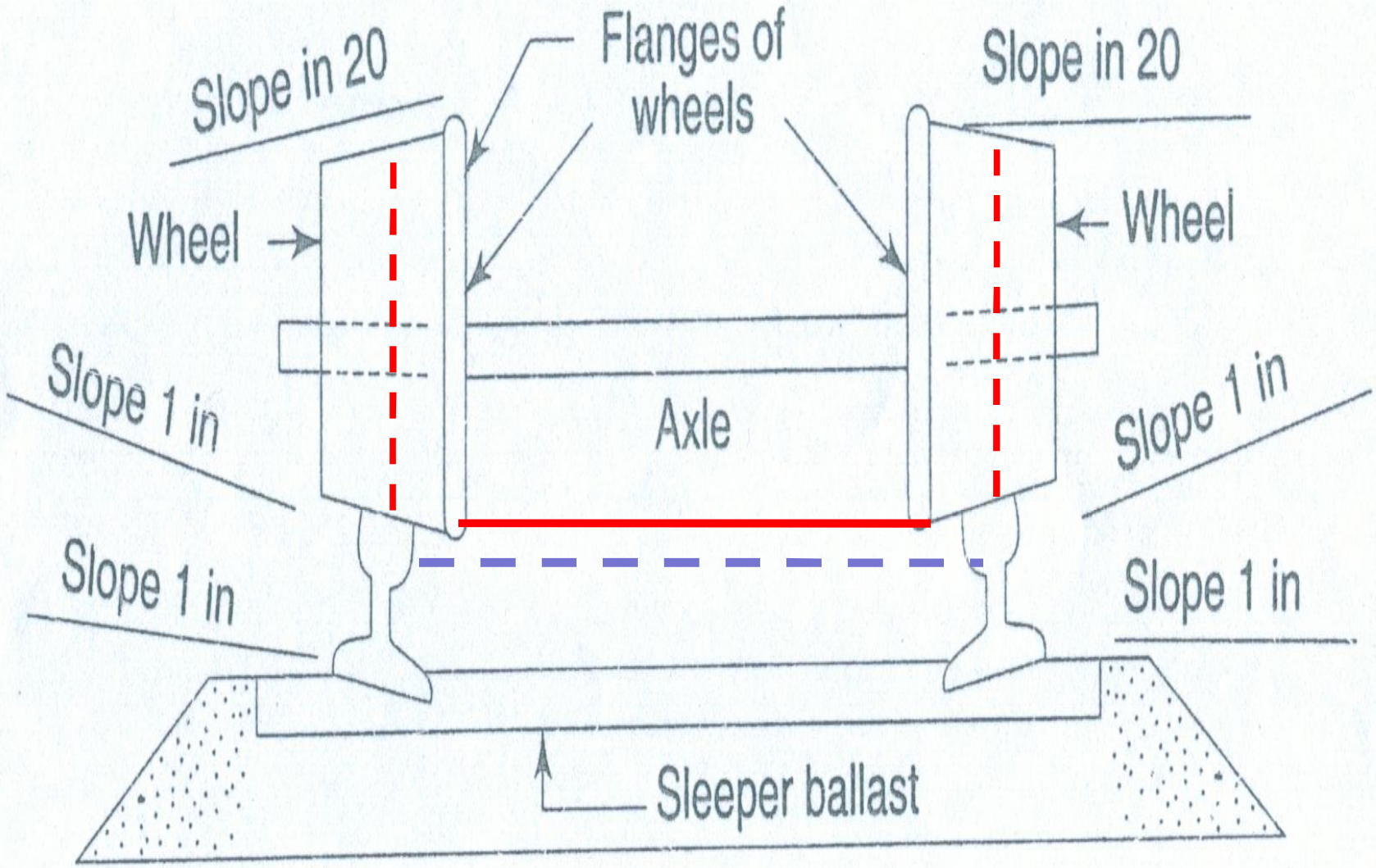


# Coning of Wheel and Canting of Rails





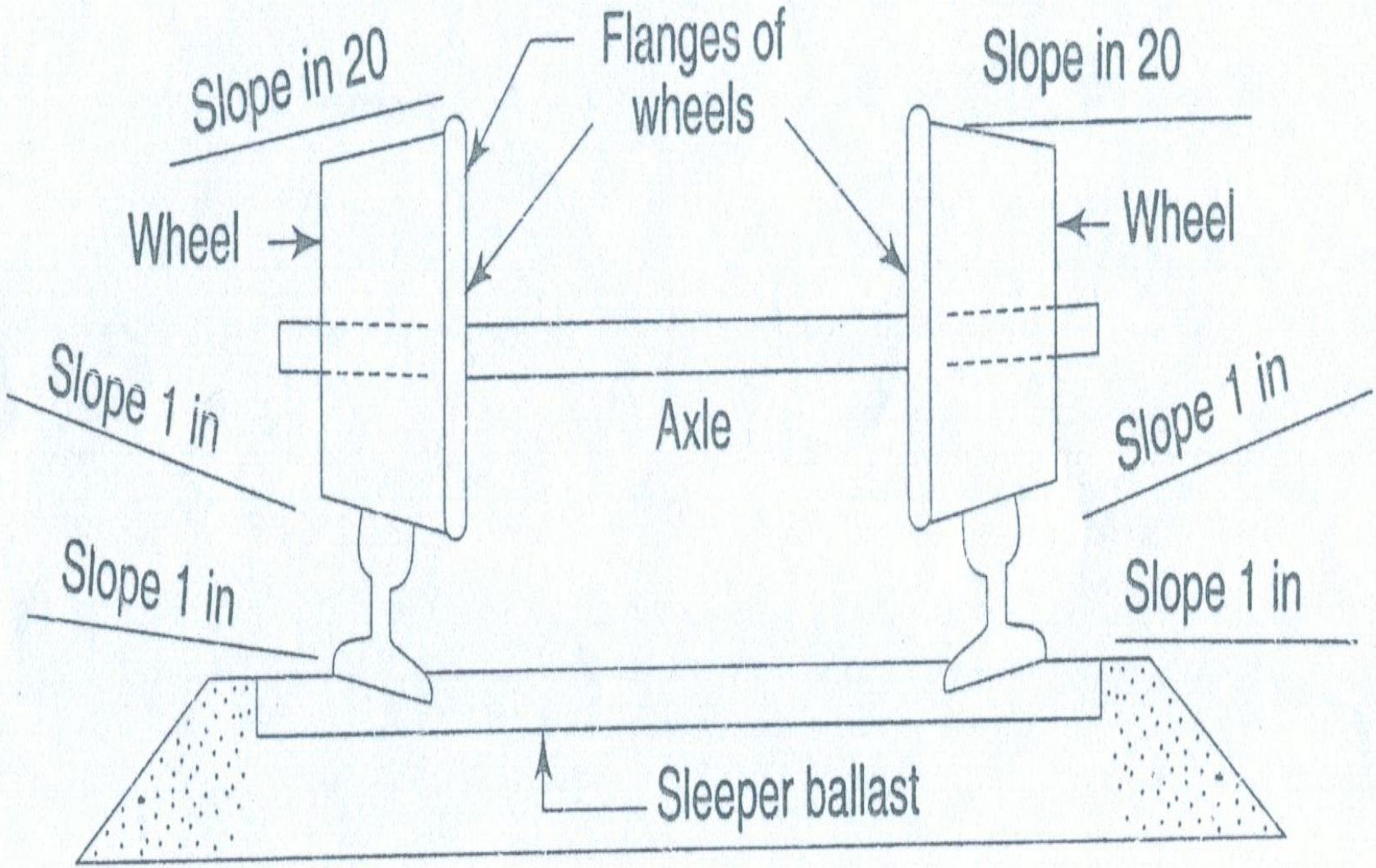

# CONING OF WHEEL AND CANTING OF RAILS




# CONING OF WHEEL AND CANTING OF RAILS

# Coning of Wheels and SE of Rails

- The wheels of the railway vehicle are not made flat but sloped like a cone in order to facilitate the wheel to move smoothly over the curve and also on the straight path.
- On straight track coning of the wheels keeps them central, thereby reducing the wear of flanges.
- If the wheels goes out of their central position they have to cover unequal distances, thus one wheel start sliding and they retreat to the central position
- This helps in smooth riding




# CONING OF WHEEL AND CANTING OF RAILS

# Curves and Coning of Wheels

- On curves, outer wheel has to cover more distance as compared to inner wheel.
- Due to centrifugal force the vehicle tends to move outwards
- To avoid this circumference of the outer wheel is made great with respect to the inner wheel by providing coning.
- Coning of the wheels causes wear and tear due to slipping action

# Coning

- Coning is useful
  - Helps the vehicle to negotiate curve smoothly
  - It provides smooth rides
  - Reduces wear and tear of wheel flanges

# Coning (cont'd)

- If the rails are laid flat, due to coning of wheel they will be subjected to eccentric loading.
- This would create problem both in rail design and maintenance
- This will also cause unequal loading of sleepers
- To avoid wear and tear, slope of 1 in 20 is provided.