Transportation Engineering II: Highway Design & Railways

Lecture 7

BALLAST & SUBGRADE

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Ballast

- Functions
  - Provide a hard and level bed for sleepers
  - Hold sleepers in place during passage of trains
  - Transfers and distributes load from sleepers to larger area
  - Provides effective drainage and keep sleeper dry
  - Prevent vegetation growth
  - Prevents water from percolating (capillary rise)
  - Provide track stability
- Design of ballast
  - Choose material
  - Determine depth

Desirable Properties of Ballast

- Good bearing capacity and crushing value
- Tough and wear resistant
- Good drainage property
- Non porous
- Should resist attrition and abrasion
  - Attrition: getting carried/ rubbed away by means of friction
  - Abrasion: wearing down by means of friction
- Weather resistant
- Low lifecycle cost

Materials Used for Ballast

1. Broken stone
2. Gravel
3. Coarse sand
4. Brick bats
5. Selected earth

1. Broken Stone

- Mechanically broken large stones
- Best material for ballast
- Advantages
  - Excellent bearing capacity
    - Controlled gradation and uniform strength
  - Excellent drainage
  - Keeps track in better position, specially under heavy traffic
- Disadvantages
  - High initial cost

2. Gravel/Shingles

- Naturally available fragmented rocks (e.g. from river beds)
- Advantages
  - Cheaper than broken stone
  - Excellent drainage property
- Disadvantages
  - Size variation can cause strength non-uniformity
    - Requires screening
  - High vibration can cause significant loss of packing

3. Coarse Sand

- Suitable for temporary or low quality track
- Advantages
  - Cheaper than broken stone and gravel
  - Excellent drainage property
  - Provides silent track
- Disadvantages
  - Requires frequent renewal as sand can easily get washed or blown away
  - Maintenance is difficult as easily disturbed by vibration
  - Can cause problems by adhering to moving parts of the trains

4. Brickbat/ Khoa/Moorum

- Over-burnt/ Vitrified brick bats (*Jhama*)
- Usually used a sub-ballast material in high standard tracks
- Advantages
  - Useful in places where stones are not available
  - Fairly good drainage property
- Disadvantages
  - Fragile and turns into powder easily
    - Difficult to maintain track

5. Selected Earth

- Compacted to get desirable bearing capacity
- Used in tracks where trains move in low speed/ remain stationary
  - Yards
  - Sick yards

Required Properties

- Basic properties
  - Hard, durable, edges as angular as possible
  - Free from organic and inorganic residues
- Physical properties

Type of test	Recommended Value
Aggregate Abrasion values	Maximum 30%
Aggregate Impact test	Maximum 20%.
Soundness	Maximum 10%
Elongation Index	Maximum 50%
Flakiness Index	Maximum 50%.
Specific gravity	Minimum 2.65
Water absorption	Maximum 1%

Required Properties (2)

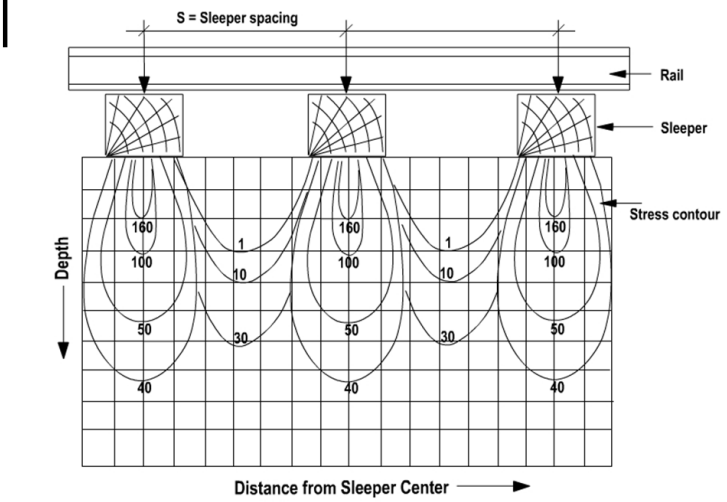
- Size and gradation:

Retained on 65 mm square mesh:Nil
Retained on 40 mm square mesh: 55% to 70%
Retained on 20 mm square mesh: Not less than 100%

Depth of Ballast Cushion

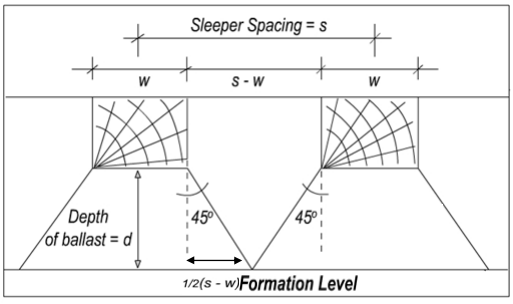
- Influencing factors
  - Size and shape of ballast
  - Degree of consolidation
- Depth of ballast should be such that the *dispersion lines* of the load from the sleeper do not cross each other

Load Dispersion Lines



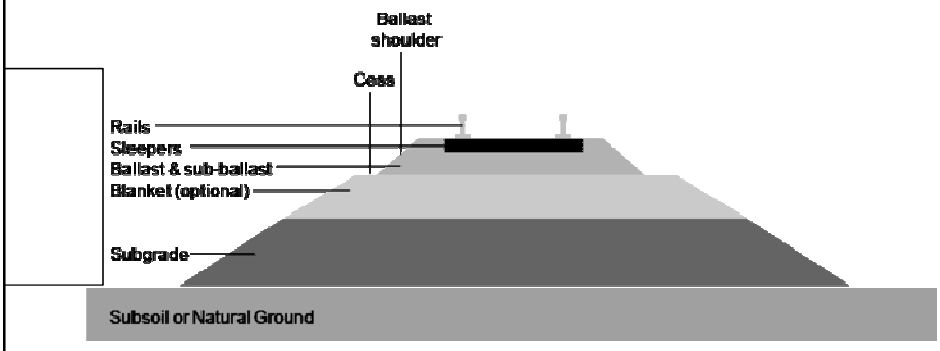
Depth of Ballast Cushion

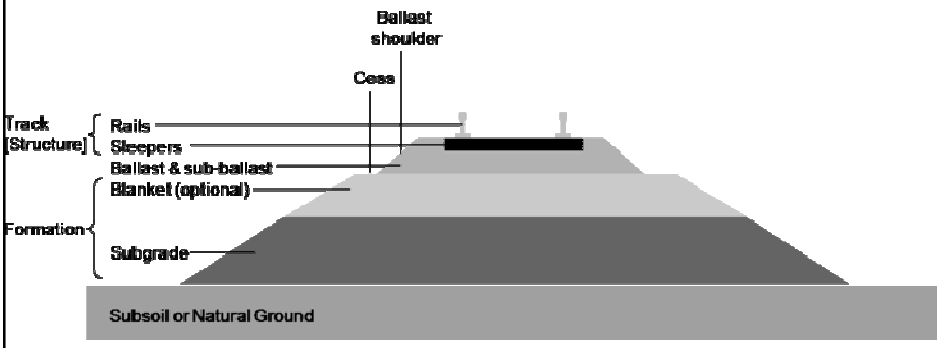
- Depth of ballast d= (s-w)/2
  s= sleeper spacing, w= width of sleeper



Example

- Calculate the minimum depth of ballast for a BG track with wooden sleepers with sleeper spacing =38.1cm and width of sleeper=25.4cm
- Calculate the minimum depth of ballast for a BG track with wooden sleepers with sleeper *clear* spacing =38.1cm and width of sleeper=25.4cm





Formation

- Prepared level surface above which sleepers lie
- Ballast
  - Granular material
- Subgrade
  - Naturally occurring soil or ground
- Improved subgrade (ISG)
  - Natural subgrade which can be further prepared to receive the ballast i.e. prepared ground

Embankment

- Types
  - Fill
  - Cut

Embankment Geometry

- Height
  - Ground contour
  - Highest flood level
  - Gradient of track
- Width
  - Number of tracks
  - Gauge
  - Future expansion plans
- Side slope
  - Shearing strength
  - Bearing capacity
  - Angle of repose

Failure of Embankment

- Causes
  - Failure of natural ground
  - Failure of fill-material
  - Failure of formation top
- Typical symptoms
  - Variation in cross sections
  - Loss of ballast
  - Upheaval of the ground beyond the toes of the embankment
  - Slips in bank slopes

Techniques to Improve Embankment Stability

- Improve bearing capacity, shear strength and drainage
  - Use flat slopes
  - Provision of inverted filter (or blanket)
    - Blanket is made of a non-cohesive material (e.g. sand) with adequate bearing capacity to withstand load
    - Provides drainage of excess water and prevents upward movement of clay layer
  - Cement grouting
    - Grout of cement/ slurry injected to soil
    - Fills cracks, prevents water from entering subgrade, improves bearing capacity
  - Sand piling
    - Bore vertical holes and inject sand
  - Sheet piling
  - Geotextile layer