TRACK STRUCTURE
Lesson 4
BALLAST

1. INTRODUCTION

Track ballast is a granular material, usually broken stone, which is laid on the formation to form a bed for the sleepers. Importance of ballast has grown with increased axle loads and speed of trains. Use of concrete sleepers and increasing use of machines to maintain the track has brought the ballast into forefront. Life cycle economics of track is largely dependent on type, quality and quantity of ballast.

2. FUNCTIONS OF BALLAST

(a) Transfer and uniform distribution of the wheel set forces on the formation (As uniform and as low intensity of pressure as possible).

(b) Elastic behavior to reduce dynamic impact stresses.

(c) Holding the track in vertical, lateral and longitudinal direction without much of permanent deformations.

(d) Efficient drainage.

(e) Media for track geometry correction.

3. REQUIREMENTS OF GOOD BALLAST MATERIAL

To achieve the functions as described above, the ballast should have following properties:

(i) It should be hard and wear resistant.
(ii) It should be tough enough without getting crushed under the moving loads.
(iii) It should be generally cubical having sharp edges.
(iv) It should be non-porous and non-absorbent of water.
(v) It should resist attrition.
(vi) It should be durable and should not get pulverized under the weather conditions.
(vii) It should provide good drainage of water.
(viii) It should be cheap and economical in price.

3.1 Strength and durability

Ballast should have sufficient strength to resist all types of loads it receives. No single parameter can describe the strength of ballast to satisfy various types of loading patterns viz. Compression, impact, abrasion, attrition, etc. therefore, different railways use different strength parameters to specify the ballast towards strength parameters.

Durability of ballast is governed by its mineral composition and porosity. Since ballast is used in large quantities, therefore, it is always advisable to use local material, if it satisfied other requirements of the ballast. However, durability may be determined indirectly, by water absorption test and the specific gravity of ballast.

3.2 Voids

Voids in ballast plays a key role in providing elasticity to the track. Quantity of voids depends upon shape, size and grading of ballast. Cubical shape, larger size and uniform grading provides more voids to ballast. However, to achieve stability profile, slight grading of ballast is necessary. Flakiness and elongation index affects the stability of profile and wear & tear of ballast.

It is not only necessary to provide more initial voids but also it should be ensured that these voids are not reduced (ballast fouling), in service, within a reasonable time of 10-12 years by way of wear & tear of ballast or otherwise.

3.3 Surface Friction

Load distribution and holding up of the track with minimum plastic deformations are mainly facilitated by the inter-particle friction (shear strength) of the ballast. This inter-particles friction depends upon:

1. Shape of Ballast Particles (Pieces).
2. Surface Texture.
3. Conditions of Surface like Dry, Wet Etc.

4. Presence of Friction Reducing Material like Clay (Due To Mud Pumping etc.).
5. Level of Compaction and Consolidation of Ballast.
6. Quantity and Ballast Profile.

4. BALLAST CAKING

Wear and tear of ballast causes caking up of ballast there by reducing voids and inter particle friction. This further reduces the elasticity and hence more impact loads are transferred to the formation leading to mud pumping situation. Wear and tear of ballast may be due to transfer of wheel-set loads, maintenance operations and climatic disintegration.

5. SCREENING OF BALLAST

Removal of the dust or mud from ballast to restore its voids is called screening of ballast. It may be shoulder screening, shallow screening or deep screening as the case may be, as decided as per extent of ballast fouling and maintenance problems. Screening of ballast is very costly and inconvenient work. Therefore, enough preventive measures in terms of quality of ballast shall be taken to reduce the incidence of screening of ballast.

6. BALLAST PROFILE

The design of ballast profile depends upon:

(a) Length of sleeper and type of sleeper.

(b) Shoulder width (width beyond the end of sleeper).

(c) Slope of ballast (side slope).

(d) Ballast cushion (depth measured below bottom of sleeper under the rail seat).

(e) Transverse slope of formation.

(f) Type of track structure like LWR, SWR or fish plated track.

Out of above, ballast cushion and type of track structure are dependent on traffic density (GMT), speed & Axle loads.

Various ballast profiles, adopted by the Indian Railways are given in Figure-4.1 to Figure 4.6 attached in the last of this chapter.

7. SUB-BALLAST

Whenever, the requirement of ballast cushion exceeds the manageable/economical limits because of either higher traffic density or poor formation, a layer of sub-ballast (refer unit on Track Formation) is placed between ballast & formation so that the depth of ballast cushion is limited within manageable limits of 30-35 cm.

8. ASSESSMEANT OF BALLAST REQUIREMENTS

8.1 The requirement of ballast shall be assessed separately for:-

(i) Making good the deficiencies as existing in track.

(ii) Making good the deficiencies arising out of overhauling, through Packing & deep screening.

(iii) For providing adequate cushion in the case of mechanical tamping.

(iv) For providing extra cushion while converting into LWR

8.2 The ballast required for maintenance purpose shall be estimated by assessing the quantity approximately, if necessary by a survey, in every 1 kilometer. Care should be taken that the core (ballast below the sleeper) under the sleeper are not disturbed.

8.3 In case of deep screening, assessment of ballast required for recoupment and providing standard section should be made by Deep Screening the ballast section to the full depth in a rail length for 2-3 sleepers at every ½ to 1 km.

9. BALLAST SPECIFICATINS

9.1 Basic Quality: Ballast should be hard, durable and as far as possible angular along edges/corners, free from weathered portion of parent rock, organic impurities and inorganic residues.

9.2 Particle Shape: Ballast should be cubical in shape as far as possible. Individual pieces should not be flaky and should have generally flat faces with not more than two rounded/sub rounded faces.

9.3 Physical Properties: Following physical properties as determined in accordance with Indian standard codes as specified by Indian Railways are shown in Table below

Specifications for Physical properties of Ballast

Specification	**BG, MG & NG** (Planned/sanctioned for conversion)
Aggregate Abrasion Value As per IS:2386 (Pt. IV)-1963	30% max*
Aggregate Impact ValueAs per IS:2386 (Pt.IV)-1963	20% max*
*Relaxable up to 35% and 25% respectively on techno-economic grounds by CTE on open Line and CAO/C for construction projects prior to the invitation of tender.	
Water absorption (As per IS: 2386 pt. III-1963)	Max 1%*
*Relaxable up to 2.5% on techno-economic grounds by CTE on open Line and CAO/C for construction projects prior to the invitation of tender.	

9.4 Size and Gradation

9.4.1 Ballast should satisfy the following size and gradation

(a)	Retained on 65mm Sq. mesh sieve	5% Maximum
(b)	Retained on 40mm Sq. mesh sieve*	40%-60%.
(c)	Retained on 20mm Sq. mesh sieve	Not less than 98% for machine crushed Not less than 95% for hand broken

* For machine crushed ballast only.

9.4.2 Oversize ballast

i) Retention on 65mm square mesh sieve.
A maximum of 5% ballast retained on 65mm sieve shall be allowed without deduction in payment.

- In case ballast retained on 65mm sieve exceeds 5% but does not exceed 10% payment at 5% reduction in contracted rate shall be made for the full stack.
- Stacks having more than 10% retention of ballast on 65mm sieve shall be rejected.

ii) Retention on 40mm square mesh sieve.
In case ballast retained on 40mm square mesh sieve (only in case of machine crushed ballast) exceeds 60% limit prescribed in payment at the following reduced rates shall be for the full stack in addition to the reduction worked out at i) above.

- 5% reduction in contracted rates if retention on 40mm square mesh sieve is between 60% (excluding) and 65% (including).
- 10% reduction in contracted rates if retention on 40mm square mesh sieve is between 65% (excluding) and 70% (including).
- In case retention on 40mm square mesh sieve exceeds 70% the stack shall be rejected.

9.4.3 Under size ballast

The Ballast shall be treated as undersize and shall be rejected if-

(a) Retention on 40mm sq. Mesh sieve is less than 40%.

(b) Retention on 20mm sq. Mesh sieve is less than 98% (for machine crushed) or 95% (for hand broken)

9.4.4 Method of Sieve Analysis

i) Sieve size mentioned in this specification are nominal sizes. The following tolerances in the size of holes for 65, 40 and 20mm nominal sieves size shall be permitted.

65mm Square Mesh Sieve ± 1.5mm

40mm Square Mesh Sieve ± 1.5mm

20mm Square Mesh Sieve ± 1.0mm

Mesh sizes of the sieves should be checked before actual measurement. The screen for sieving the ballast shall be of square mesh and shall not be less than 100cm in length, 70cm in breadth and 10cm in height on sides.

ii) While carrying out sieve analysis, the screen shall not be kept inclined, but held horizontally and shaken vigorously. The pieces of ballast retained on the screen can be turned with hand to see if they pass through but should not be pushed through the sieve.

iii) The percentage passing through or retained on the sieve shall be determined by weight.

9.5 METHODS OF BALLAST MEASUREMENT

9.5.1 Stack Measurement

Ballast stack shall be made neat, plane, well drained and firm ground at a site prespecified by accepting authorities. Edges of stack shall be uniform and the minimum height of stack shall be 1 m except in hilly areas where it may be 0.5 m. The maximum height of the stack shall not be more than 2 m.The side slopes of stack shall not be flatter than 1.5:1(H:V), the cubical content of stack shall not be less than 30m^3 in plain area and 15m^3 in hilly areas, Stack measurement may be recorded in ballast depot or along the side of railway track as the case may be.

9.5.2 Wagon Measurement

Ballast can also be measured after it is directly loaded into the wagons provided the cubical content are determined and recorded and top fill line is marked over the wagon.

9.5.3 No shrinkage allowance for voids is to be provided for while recording measurements.

9.6 SAMPLING AND TESTING

9.6.1 Acceptance

Fulfillment of size, gradation, and physical properties shall be the criteria for acceptance of supply in the field.

9.6.2 Norms for supply of ballast.

On supply of the first 100m^3. The test for size, gradation, abrasion value, impact value, flakiness index and water absorption shall be carried out by accepting authority. Further supply shall be carried out only after this ballast satisfies the specification for these tests.

9.6.3 Subsequent test shall be carried out as follows:-

Table 2: Frequency of Sampling and sample size for Acceptance of Ballast.

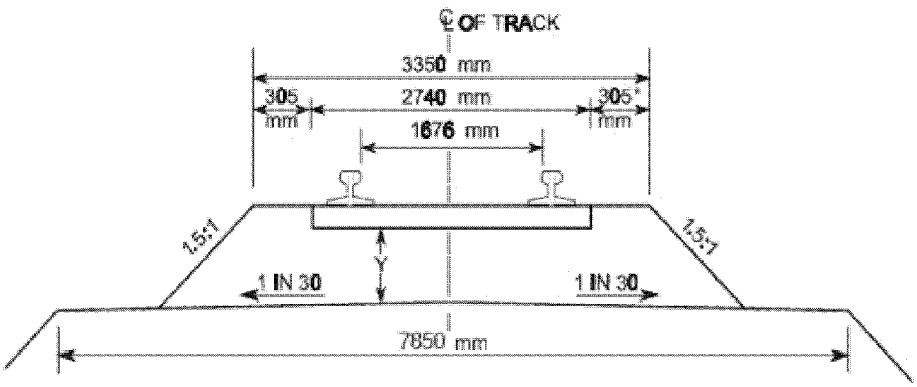
Test	Supply in Stacks		Supply in Wagons
	For each stack of volume less than 100 m^3	For each stack of volume more than 100 m^3	
Size and Gradation Test			
Testing Frequently	One for each stack	One for each stack	One for each wagon

Sample Size	**0.027m^3	**0.027m^3 for every 100 m^3 or part there of	**0.027m^3
Abrasion Value, Impact Value and Water Absorption Test			
Testing Frequently	One for every 2000 m^3		
Sample Size	45 kg		

** Sample should be collected from different part of the stack/wagon using a wooden box of internal dimension 0.3x0.3x0.3m.

Standard Ballast Profile for BG

(Other than LWR/CWR)



S. No.	Depth of Ballast Cushion	Quantity of Ballast per Meter	
		On Straight and Curves of Radius flatter than 600 M	Curves of Radius sharper than 600 M
1	250 mm	1.769 M^3	1.820 M^3
2	300 mm	2.022 M^3	2.078 M^3
3	350 mm	2.282 M^3	2.344 M^3

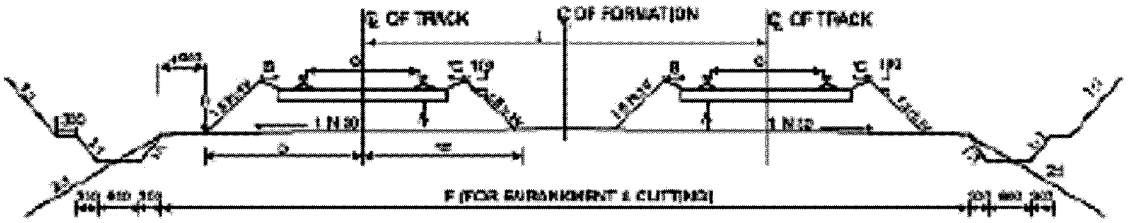
Recommended Depths of Ballast requirements Fish plated track in BG.

Note

1. In the case of ordinary fish-plated track ballast cushion to be increased to 400 mm. on outside of curves sharper than 600 M. Radius.
2. In short welded panel track ballast cushion to be increased to 400 mm on outside of all curves flatter than 875 Radius and to 450 mm in the case of curves sharper than 875 M. radius.
3. To be increased to 550 mm on the outside of turn in curves of turnouts in passenger yards.
4. Minimum Formation width of 7850 mm shall be ensured for new works in both embankment and in cuttings (excluding side drains).
5. Super elevation has not been considered in calculation of ballast quantity for curved track.
6. The cess width on existing track is to be increased on programmed basis wherever required so that minimum cess width as per side slope given above is ensured

Ballast Profile for LWR Track

(Double Line BG)



Gauge	Type of Sleeper	A	B	C*	D	E*	F	H	J
1676 mm	PRC	250	350	500	2785	2943	13160	707	5300
		300	350	500	2864	3022	13160	760	5300
		350	350	500	2943	3101	13160	812	5300

Note:

1. Cross-Slope of 1 in 30 shall be provided for New Works.
2. Minimum Formation width of 13160 mm shall be ensured for New works in both embankment and in cuttings (excluding side drains).
3. In doubling work of existing lines, cross-slope of 1 in 40 in existing old formation need not be disturbed. However, the cross slope of 1 in 30 shall be provided in widened formation width, newly constructed for doubling.
4. Suitable dwarf walls shall be provided in case of cuttings, if necessary, for retaining ballast.
5. *On outer side of curves only.
6. Super elevation has not been considered in calculating various dimensions.
7. The cess width on existing track is to be increased on programmed basis wherever required so that minimum cess width as per side slope given above is ensured.
8. All dimensions are in mm.