CHAPTER
8

Ballast

Introduction

The ballast is a layer of broken stones, gravel, moorum, or any other granular material placed and packed below and around sleepers for distributing load from the sleepers to the formation. It provides drainage as well as longitudinal and lateral stability to the track. Different types of ballast materials and their specifications are discussed in this chapter.

8.1 Functions of Ballast

The ballast serves the following functions in a railway track.

- Provides a level and hard bed for the sleepers to rest on.
- Holds the sleepers in position during the passage of trains.
- Transfers and distributes load from the sleepers to a large area of the formation.
- Provides elasticity and resilience to the track for proper riding comfort.
- Provides the necessary resistance to the track for longitudinal and lateral stability.
- Provides effective drainage to the track.
- Provides an effective means of maintaining the level and alignment of the track.

8.2 Types of Ballast

The different types of ballast used on Indian Railways are described in the following.

Sand ballast

Sand ballast is used primarily for cast iron (CI) pots. It is also used with wooden and steel trough sleepers in areas where traffic density is very low. Coarse sand is preferred in comparison to fine sand. It has good drainage properties, but has the drawback of blowing off because of being light. It also causes excessive wear of the rail top and the moving parts of the rolling stock.

Moorum ballast

The decomposition of laterite results in the formation of moorum. It is red, and sometimes yellow, in colour. The moorum ballast is normally used as the initial ballast in new constructions and also as sub-ballast. As it prevents water from percolating into the formation, it is also used as a blanketing material for black cotton soil.

Coal ash or cinder

This type of ballast is normally used in yards and sidings or as the initial ballast in new constructions since it is very cheap and easily available. It is harmful for steel sleepers and fittings because of its corrosive action.

Broken stone ballast

This type of ballast is used the most on Indian Railways. A good stone ballast is generally procured from hard stones such as granite, quartzite, and hard trap. The quality of stone should be such that neither is it porous nor does it flake off due to the vagaries of weather. Good quality hard stone is normally used for high-speed tracks. This type of ballast works out to be economical in the long run.

Other types of ballast

There are other types of ballast also such as the brickbat ballast, gravel ballast, kankar stone ballast, and even earth ballast. These types of ballast are used only in special circumstances.

The comparative advantages, disadvantages, and suitability of different types of ballast are given in Table 8.1.

Table 8.1 Comparison of different types of ballast

Type of ballast	*Advantages*	*Disadvantages*	*Suitability*
Sand ballast	▸ Good drainage properties ▸ Cheap ▸ No noise produced on the track ▸ Good packing material for CI sleepers	▸ Causes excessive wear ▸ Blows off easily ▸ Poor retentivity of packing ▸ Track cannot be maintained to high standards	▸ Suitable for CI pot sleeper tracks ▸ Not suitable for high-speed tracks
Moorum ballast	▸ Cheap, if locally available ▸ Prevents water from percolating ▸ Provides good aesthetics	▸ Very soft and turns into dust ▸ Maintenance of track the difficult ▸ Quality of track average	▸ Used as a sub-ballast ▸ Initial ballast for new construction

(*contd*)

Table 8.1 (*contd*)

Type of ballast	*Advantages*	*Disadvantages*	*Suitability*
Coal ash or cinder	▸ Easy availability on railways ▸ Very cheap	▸ Harmful for steel sleepers ▸ Corrodes rail bottom and steel sleepers	▸ Normally used in yards and sidings ▸ Suitable for repairs of formations during floods and emergencies
	▸ Good drainage	▸ Soft and easily pulverized ▸ Maintenance is difficult	▸ Not fit for high-speed tracks
Broken stone ballast	▸ Hard and durable when procured from hard rocks	▸ Initial cost is high	▸ Suitable for packing with track machines
	▸ Good drainage properties ▸ Is stable, and resilient to the track ▸ Economical in the long run	▸ Difficulties in procurement ▸ Angular shape may injure wooden sleepers	▸ Suitable for high-speed tracks

8.3 Sizes of Ballast

Previously, 50-mm (2″) ballasts were specified for flat bottom sleepers such as concrete and wooden sleepers and 40-mm (1.5″) ballasts were specified for metal sleepers such as CST-9 and trough sleepers. Now, to ensure uniformity, 50-mm (2″) ballasts have been adopted universally for all type of sleepers.

As far as points and crossings are concerned, these are subjected to heavy blows of moving loads and are maintained to a higher degree of precision. A small sized, 25-mm (1″) ballast is, therefore, preferable because of its fineness for slight adjustments, better compaction, and increased frictional area of the ballast.

8.4 Requirements of a Good Ballast

Ballast material should possess the following properties:

(a) It should be tough and wear resistant.
(b) It should be hard so that it does not get crushed under the moving loads.
(c) It should be generally cubical with sharp edges.
(d) It should be non-porous and should not absorb water.
(e) It should resist both attrition and abrasion.
(f) It should be durable and should not get pulverized or disintegrated under adverse weather conditions.
(g) It should allow for good drainage of water.
(h) It should be cheap and easily available.

8.5 Design of Ballast Section

The design of the ballast section includes the determination of the depth of the ballast cushion below the sleeper and its profile. These aspects are discussed below.

8.5.1 Minimum Depth of Ballast Cushion

The load on the sleeper is transferred through the medium of the ballast to the formation. The pressure distribution in the ballast section depends upon the size and shape of the ballast and the degree of consolidation. Though the lines of equal pressure are in the shape of a bulb, yet for simplicity, the dispersion of load can be assumed to be roughly 45° to the vertical. In order to ensure that the load is transferred evenly on the formation, the depth of the ballast should be such that the dispersion lines do not overlap each other.

For the even distribution of load on the formation, the depth of the ballast is determined by the following formula (refer to Fig. 8.1):

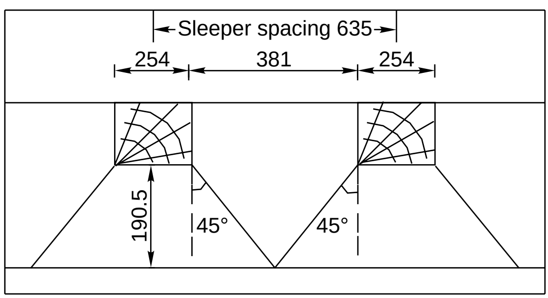

Fig. 8.1 Minimum depth of ballast cushion (dimensions in mm)

$$\text{Sleeper spacing} = \text{width of the sleeper} + 2 \times \text{depth of ballast} \tag{8.1}$$

If a BG track is laid with wooden sleepers with a sleeper density of $N + 6$, then the sleeper spacing would be 68.4 cm. If the width of the sleeper is 25.4 cm, then the depth of the ballast cushion would be

$$d = \frac{68.4 - 25.4}{2} = 21.5\,\text{cm}$$

A minimum cushion of 15–20 cm of ballast below the sleeper bed is normally prescribed on Indian Railways.

8.5.2 Ballast Profile for Fish-plated Track

The ballast profile for a fish-plated track is shown in Fig. 8.2. The requirements of ballast for different groups of railway lines as adopted by Indian Railways are given in Table 8.2.

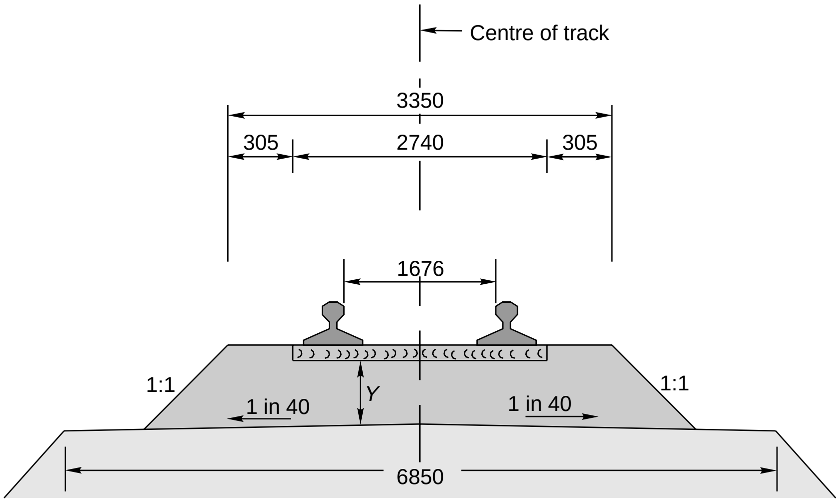

Fig. 8.2 Standard ballast profile for BG (Other than LWR/CWR)

Table 8.2 Ballast requirement for fish-plated tracks

Group	*Recommended depth of ballast cushion Y (mm)*	*Quantity of ballast required/metre*	
		On straight lines and curves of radius greater than 600 m (m^3)	*On curves of radius lower than 600 m (m^3)*
A	300*	1.588	1.634
B and C	250	1.375	1.416
D	200	1.167	1.202
E	150	0.964	0.996

* In the case of ordinary fish-plated tracks, to be increased on the outside of the curves to 400 mm in the case of sharper curves of a radius more than 600 m. In short welded panel tracks, it is to be increased to 400 mm on the outside of all curves flatter than 875 m and to 450 mm in the case of sharper curves with a radius more than 875 m. To be increased to 550 m on the outside of the turn on curves of turnouts in passenger yards. In the case of a short welded rail (SWR) track, the minimum depth of cushion should be 200 mm.

8.5.3 Ballast Profile for Long Welded Rail Tracks

The ballast profile for a long welded rail (LWR) track is shown in Fig. 8.3. The requirements of ballast for different types of sleepers on a BG railway line are given in Table 8.3.

The minimum clean stone ballast cushion below the bottom of sleeper (*A*) is 250 mm. For routes where speeds are to be more than 130 kmph, *A* is 300 mm–200 mm along with 150 mm of sub-ballast. Suitable dwarf walls should be provided in the case of cuttings, if necessary, for retaining the ballast.

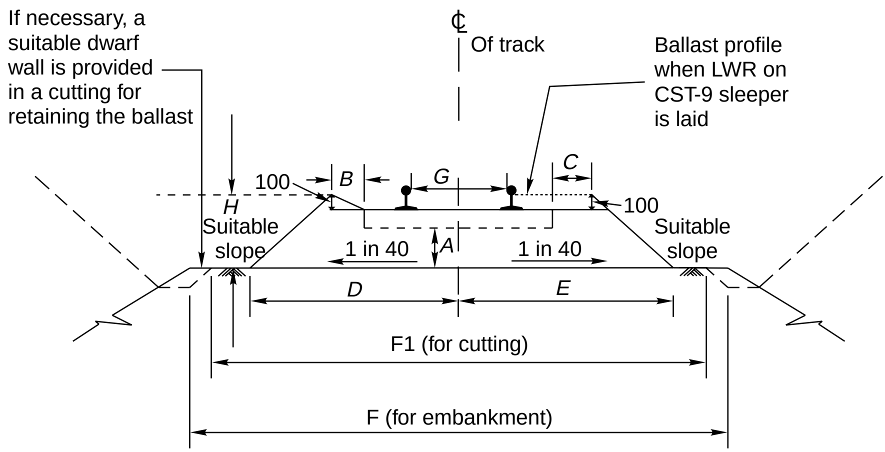

Fig. 8.3 Ballast profile for LWR track (single line BG)

Table 8.3 Ballast requirement (mm) for single-line BG LWR tracks

Type of sleeper	*A*	*B*	*C**	*D*	*E**	*F*	*F1*	*H*	*Quantity of ballast per metre* (m^3)	
									Straight track	*Curved track*
Wooden	250	350	500	2270	2420	6850	6250	540	1.682	1.646
	300	350	500	2270	2420	6850	6250	590	1.782	1.853
	†	350	500	2270	2420	6850	6250	640	1.982	2.060
Steel trough	250	350	500	2270	2430	6850	6250	550	1.762	1.827
	300	350	500	2270	2440	6850	6250	600	1.962	2.035
	†	350	500	2270	2430	6850	6250	650	2.162	2.242
Prestressed concrete	250	350	500	2270	2510	6850	6250	630	1.954	2.032
	300	350	500	2270	2510	6850	6250	680	2.158	2.243
	†	350	500	2270	2510	6850	6250	730	2.362	2.455
Two-block	250	350	500	2270	2510	6850	6250	630	2.110	2.193
	300	350	500	2270	2510	6850	6250	680	2.314	2.405
	†	350	500	2270	2510	6850	6250	730	2.518	2.616

* On the outer side of the curves only. Cess may be widened where required depending on local conditions and the outer ends of the curves.
† 200 mm over 150 mm sub-ballast.

8.6 Specifications for Track Ballast

The following specifications of ballast, which have recently been revised (June 2004), are followed on Indian Railways. These specifications are applicable for the stone ballast to be used for all types of sleepers on normal tracks, turnouts, tunnels, and deck slabs on all routes.

8.6.1 General Qualities

The ballast material should possess the general qualities described below.

Basic quality The ballast should be hard, durable, as far as possible angular along edges/corners, and free from weathered portions of parent rock, organic impurities, and inorganic residues.

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

Mode of manufacture Ballasts for all BG main lines and running lines, except on E routes, but including E special routes, should be machine crushed. For other BG lines and MG/NG routes planned or sanctioned for conversion, the ballast should preferably be machine crushed. Hand broken ballast can be used in exceptional cases with the prior approval of the chief track engineer or the CAO (chief administrative officer). Such approval should be obtained prior to the invitation of tenders. Hand broken ballasts can be used without any formal approval on MG and NG routes not planned or sanctioned for conversion.

8.6.2 Physical Properties

All ballast samples should possess the physical properties given in Table 8.4 when tested in accordance with IS:2386 (IV)–1963.

Table 8.4 Physical requirements of ballast

Characteristics	*BG, MG, and NG (planned/sanctioned for conversion)*	*NG and MG (other than those planned for conversion)*
Aggregate abrasion	30% maximum*	35% maximum
Aggregate impact	20% maximum*	30% maximum
Water absorption	1%	–

* In exceptional cases, relaxable on technical and/or economic grounds up to 35% and 25%, respectively, by the chief track engineer (CTE) in open lines and the chief administration officer (construction) (CAO/C) for construction projects. Relaxation in abrasion and impact values is given prior to the invitation of tender and should be incorporated in the tender document.

8.6.3 Size and Gradation

The ballast should satisfy the size and gradation requirements given in Table 8.5.

Table 8.5 Ballast gradation

Size of sieve	*% retained*
65 mm	5% maximum
40 mm	40% to 60%
20 mm	Not less than 98% for machine crushed and not less than 95% for hand broken

8.6.4 Oversized Ballast

(a) *Retention on 65-mm square mesh sieve* A maximum of 5% ballast retained on a 65-mm sieve is allowed without deduction in payment. In case the ballast retained on a 65-mm sieve exceeds 5% but is less than 10%, payment at a 5% reduction of 5% in the contracted rate is made for the full stack. Stacks retaining more than 10% of ballast on a 65-mm sieve are rejected.

(b) *Retention on 40-mm square mesh sieve* In case the ballast retained on a 40-mm square mesh sieve (machine crushed only) exceeds the 60% limit prescribed above, payment at the following reduced rates is made for the full stack in addition to the reduction as worked out above.

  (i) 5% reduction in contracted rates if the retention on a 40-mm square mesh sieve is between 60% (excluding) and 65% (including).

  (ii) 10% reduction in contracted rates if retention on a 40-mm square mesh sieve is between 65% (excluding) and 70% (including).

  (iii) In case the retention on a 40-mm square mesh sieve exceeds 70%, the stack is rejected.

  (iv) In the case of hand broken ballast supply, 40-mm-sieve analysis may not be carried out. The executive may, however, ensure that the ballast is well graded between 65 mm and 20 mm.

8.6.5 Undersized Ballast

The ballast is treated as undersized and rejected if

(a) retention on a 40-mm sieve is less than 40% and

(b) retention on a 20-mm sieve is less than 98% (for machine crushed ballast) or 95% (for hand broken ballast).

8.6.6 Shrinkage Allowance

Payment is made for the gross measurements either in stacks or in wagons without any deduction for shrinkage/voids. However, when ballast is supplied in wagons, up to 8% shrinkage is permitted at the destination by the consignee verifying the booked quantities.

8.6.7 Sampling and Testing

The following procedure is specified for the sampling and testing of the ballast.

(a) A minimum of three samples of ballast should be taken for sieve analysis for measurement done on any particular date, even if the number of stacks to be measured is less than three.

(b) The tests for abrasion value, impact value, and water absorption should be done in approved laboratories or in the Railways' own laboratories (A list of these laboratories should be given in the tender document).

(c) In order to ensure the supply of a uniform quality of ballast, the specifications given in Table 8.6 should be followed with respect to sampling, testing, and acceptance of the ballast. The tests given in this table may be carried out more frequently if warranted at the discretion of the Railways.

(d) On supply of the first 100 m^3, tests for size gradation, abrasion value, impact value, and water absorption (if prescribed) should be carried out by the Railways. Further supply should be accepted only after the first batch satisfies these tests. The Railways reserves the right to terminate the contract as per the general conditions of contract (GCC) at this stage itself in case the ballast supply fails to meet any of these specifications.

Table 8.6 Frequency of tests for ballast supply

Item	*Supply in stacks*		*Supply in wagons*
	For a stack of volumne less than 100 m^3	*For a stack of volume more than 100 m^3*	
Number of size and gradation tests	One for each stack	One for each stack	One for each wagon
Size of one sample* (m^3)	0.027	0.027 for every 100 m^3 or part thereof	0.027
Abrasion value, impact value, and water absorption test†	One test for every 2000 m^3 of ballast		

* This sample should be collected using a wooden box of internal dimensions 0.3 m × 0.3 m × 0.3 m from different parts of the stack/wagon.

† These tests should be done for the purpose of monitoring the quality during supply. In case the test results are not as per the prescribed specifications at any stage, further supplies should be suspended till suitable corrective action is taken and supply as per specifications is ensured.

8.7 Collection and Transportation of Ballasts

The collection and transportation of ballasts can be done by either of the following methods.

- Collecting the ballast at ballast depots and transporting it to the site in ballast trains.
- Collecting the ballast along the cess and putting the same on the track directly.

The mode of collection is decided taking into account the proximity of the quarry, availability of good stone ballast, serving roads along side the railway line for the carriage of ballast, availability of ballast trains, turnround of ballast trains, and availability of traffic blocks for unloading.

8.7.1 Collection at Ballast Depots

The following procedure is adopted when ballasts are being collected at ballast depots.

(a) The space along side the railway line meant for stacking is divided into a convenient number of zones and demarcated.

(b) For each depot, a diagram indicating the site details of all the measured stacks is maintained.

(c) Each stack in each zone is serially numbered.
(d) Operations of collecting and training out materials should not be carried out at the same time in any zone.
(e) The ground on which the stacks are made should be selected and levelled.
(f) Measurements should be taken for complete stacks. The measured stack should be identified suitably by lime sprinkling or any other method.
(g) As soon as a stack is lifted, it should be recorded on the depot diagram, which should always be kept up-to-date. Challans should be prepared after loading the ballast into wagons.

8.7.2 Collection of Ballast Along the Cess

In case the ballast is collected along the side of the cess, the inspector in charge should maintain a separate register showing the measurement of stacks as well as its disposition (from km to km). The stacks should be serially numbered between successive posts. Entries should be made in a register whenever stacks are removed and ballast is put onto the track. The record should state the place where the removed ballast has been used as well as the date of removal of the stack. Materials passing through a 6-mm square mesh are classified as 'dust' (limited to 1%).

8.8 Methods of Measurement

The quantity of the ballast can be measured either in a stack or in a wagon. Both methods are described below.

8.8.1 Stack Measurement

Stacking should be done on an almost plane and firm ground with good drainage. The height of the stack should not be less than 1 m except in hilly areas, where it may be 0.5 m. The top width of the stack should not be less than 1 m and should be kept parallel to the ground plane. The side slopes of the stack should not be flatter than 1.5:1 (horizontal:vertical). The volume of each stack should normally not be less than 30 m^3 in plain areas and 15 m^3 in hilly areas.

8.8.2 Wagon Measurement

In the case of the ballast supply being directly loaded into wagons, a continuous white line should be painted inside the wagon to indicate the level up to which the ballast can be loaded. The volume in cubic metres corresponding to white line should also be painted outside the wagon on both sides. In addition to the painted line mentioned above, short pieces of flats (cut pieces of tie bars or otherwise) punched with the volume should be welded in the centre of all the four sides of the wagon.

8.9 Laboratory Tests for Physical Properties of Ballast

The following tests are recommended to judge the suitability of the ballast material for a railway track.

8.9.1 Aggregate Abrasion Value

To check for aggregate abrasion, a test sample of 10 kg of clean ballast conforming to the following grading is taken

Passing the 50-mm sieve and retained on the 40-mm square mesh sieve: 5000 g
Passing the 40-mm and retained on the 25-mm square mesh sieve: 5000 g

The sample, along with the abrasive charge, is placed in the Los Angeles machine, which is rotated at a speed of 30–33 rpm for 1000 revolutions. The sample is sieved and material coarser than the 1.70-mm sieve is washed, dried, and weighed. The difference between the original weight (*A*) and the final weight of the sample (*B*) is expressed as a percentage of the original weight of the test sample. This value is reported as the abrasion value.

$$\text{Aggregate abrasion value} = \frac{A - B}{A} \times 100 \tag{8.2}$$

8.9.2 Aggregate Impact Value

To check for aggregate impact, the test sample is prepared out of the track ballast in such a way that it has a grading that passes the 12.5-mm sieve and is retained on the 10-mm sieve. The ballast sample is oven dried and placed duly tamped in the different stages in a cylindrical metal container with 75 mm diameter. and 50 mm depth (weight *A*). The cup of the impact testing machine is fixed firmly in position on the base of the machine and entire test sample is placed in it and compacted by 25 strokes of the tamping rod. The test hammer weighing about 14 kg is raised 380 mm above the upper surface of the cup and dropped. The test sample is subjected to a total of 15 such blows. The sample is then removed and sieved using a 2.36-mm sieve and the weight of quantity retained is measured (weight *B*):

$$\text{Aggregate impact value} = \frac{A - B}{A} \times 100 \tag{8.3}$$

8.9.3 Flakiness Index

The flakiness index of an aggregate is the percentage by weight of the particles with a least dimension (thickness) less than three-fifths of their mean dimension. The test is not applicable to sizes smaller than 6.3 mm.

Track ballast sample of sufficient quantity is taken to provide a minimum of 200 pieces, which is weighed (weight *A*). The sample consisting of aggregates is sieved as per the prescribed procedure in a series of sieves. The flaky material is separated and weighed (weight *B*). The flakiness index is then determined by the total weight of the material passing the various sieves, expressed as a percentage of the total weight of the sample gauged.

$$\text{Flakiness index} = \frac{B}{A} \times 100 \tag{8.4}$$

8.9.4 Specific Gravity and Water Absorption Test

A sample consisting of at least 2000 g of aggregate is washed thoroughly to remove finer particles and dust. The whole material is then drained, placed in a wire basket, and immersed in distilled water at a temperature between 22°C and 32°C. The sample is shaken, jolted, and dried as per specific procedure. The sample is finally placed in an oven in a shallow tray at a temperature of 100°C to 110°C. It is then removed from the oven, cooled in the container, and weighed (weight *C*). The specific gravity and water absorption is calculated as follows:

$$\text{Specific gravity} = \frac{C}{B - A} \tag{8.5}$$

$$\text{Water absorption (\% by weight)} = \frac{100\,(B - C)}{C} \tag{8.6}$$

where A = weight in grams of saturated aggregate in water, B = weight in grams of saturated dry aggregate in air, and C = weight in grams of oven-dried aggregate in air.

8.10 Assessment of Ballast Requirements

The requirements of the ballast should be assessed separately for

(a) correcting the deficiencies existing in the track as well as those arising out of overhauling, through packing and deep screening,
(b) providing adequate cushion for mechanical tamping, and
(c) providing extra cushion while converting into LWR.

The ballast required for maintenance purposes is estimated by assessing the quantity approximately, if necessary by a survey, over every 1 km of rail length. Care should be taken to ensure that the cores under the sleepers are not disturbed.

In the case of deep screening, the ballast required for recoupment and providing a standard section should be assessed by deep screening the ballast on a trial basis. For this, full depth screening is done for a length of 2–3 sleepers at every 0.5 to 1 km interval. In this case, the screening is done under the sleepers as well. The quantity of ballast required for deep screening is roughly taken as 1.5% of the existing quantity of ballast based on field trials.

The quantities assessed above will be the net quantities of ballast required to recoup the deficiencies or to provide required profiles/sections. These net quantities of ballast may be enhanced suitably (say by 8%) to arrive at the gross quantities of ballast needed for the purpose of procurement in case the measurements are proposed to be taken in stacks or wagons at the originating station.

8.11 Guidelines for Provision of Sub-ballast

The sub-ballast is normally made of granular material and is provided between the formation and the ballast in order to distribute the load evenly over the formation. The following points should be kept in mind while selecting a material for sub-ballasts.

(a) The material should consist of coarse granular substance such as river gravel, stone chips, quarry grit, and predominantly coarse sand. Ash, cinder, and slag containing predominantly fine and medium sand should not be used.
(b) The material should be non-cohesive and graded. The uniformity coefficient should be more than 4 to ensure that the sub-ballast is well graded.
(c) The material should not contain more than 15% of fines that measure less than 75 microns.
(d) The thickness of the sub-ballast should not be less than 150 mm.

Summary

The ballast is a layer of granular material provided below and around sleepers to distribute load from the sleepers over a larger area of the formation. Any granular material can be used as ballast if it satisfies certain requirements of strength, size, and gradation. The ballast gets crushed because of the dynamic action of the wheel load and, therefore, requires regular maintenance. The thickness of the ballast cushion under the sleepers depends upon the axle load, type of sleepers, sleeper density, and other related factors.

Review Questions

1. Mention the properties required of a good ballast for a railway track.
2. Explain briefly how the pressure created by wheel loads is transmitted through the ballast. What factors of the ballast influence the intensity of the pressure on the formation?
3. (a) What are the functions of the ballast in a railway track?
   (b) Explain the elastic-cum-frictional behaviour of ballast under passing wheel loads.
   (c) What types and sizes of ballast are required for measured shovel packing?
4. What is the ballast? Why is it used in the railway track? Briefly describe the various types of ballasts used.
5. Explain the following with respect to the ballast used on Indian Railways.
   (i) Functions
   (ii) Requirements of ideal ballast material
   (iii) Different materials used for ballast and their relative merits
6. Name six materials commonly used as ballast on Indian Railways. Write down the specifications of an ideal stone ballast.
7. Determine the optimum thickness of the stone ballast required below sleepers of density $M + 7$ on a BG track. (***Ans***: 19.8 cm)
8. Sketch a typical section of an MG line on wooden sleepers and show the ballast cushion and side slopes for a sleeper density of $M + 3$.
9. What size of ballast is used for the main line, and points and crossings on Indian Railways?
10. Write short notes on the following.
    (a) Abrasion test

(b) Impact test
(c) Oversized ballast
(d) Sub-ballast