TRACK STRUCTURE
CHAPTER IV
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 in para-2, the ballast should have following properties :

(i) It should be tough and wear resistant.
(ii) It should be hard 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 yr. 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 material 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, see cushion).

(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.

N.B. LWR (long welded Rails)
SWR (short welded Rails)

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	NG & MG (Other than those
	(Planned/sanctioned for conversion)	planned for conversion)
Aggregate Abrasion Value As per IS:2386 (Pt. IV)-1963	30% max*	35% max
Aggregate Impact ValueAs per IS:2386 (Pt.IV)-1963	20% max*	30% max.
*Relaxable up to 35% and 25% respectively on techno-economic grounds by CTE on open Line and CAO/C for construction projects.		
Flakiness index		
(As per IS: 2386 pt.1-1963)	Max 50%	NA
(As per IS: 2386 pt. III-1963) Water absorption	Max 1%	NA

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) In case ballast retained on 40mm square mesh sieve (machine crushed case only) exceeds 60% limit prescribed in 2.3.1 (b) above, 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)

iii) In case retention on 40mm square mesh sieve exceeds 70% the stack shall be rejected.

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

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 Plus Minus 1.5mm

40mm Square Mesh Sieve Plus Minus 1.5mm

20mm Square Mesh Sieve Plus Minus 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 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 100 cum. 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.

		Supply in stacks	
	For each stack of Volume less than 100 cum.	For each stack of volume more than 100 cum.	Supply in Wagons
Size and Gradation Test			
Testing Frequently	One for each stack	One for each stack	One for each wagon
Sample Size	**0.027 cum.	**0.027 cum. For Every 100 cum. or Part thereof	**0.027 cum
Abrasion Value Impact Value, Flakiness Index And Water Absorption Test			
Testing Frequently		One for every 2000 cum.	
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.

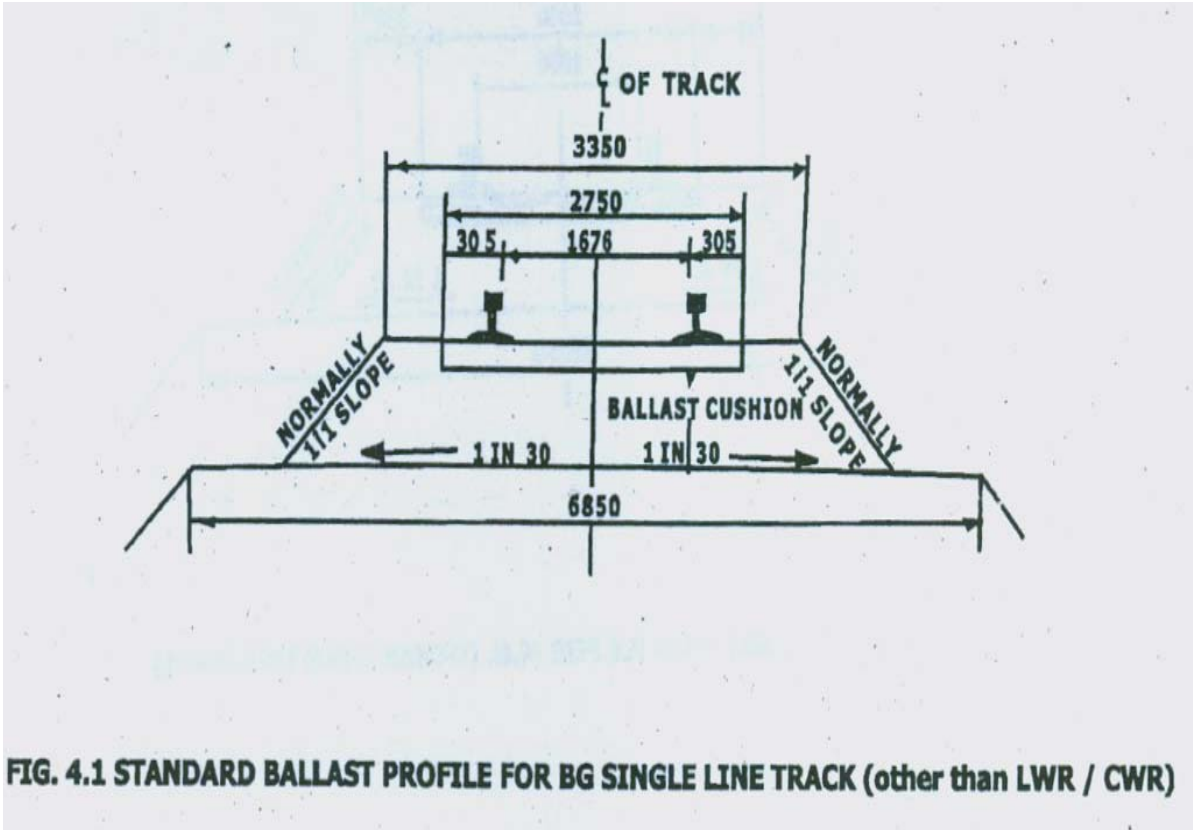

FIG. 4.1 STANDARD BALLAST PROFILE FOR BG SINGLE LINE TRACK (other than LWR / CWR)

Recommended Depths of Ballast requirements Fish plated track.

		Quantity of Ballast Required/Meter	
Group	**Recommended Depth Ballast Cushion 'Y'**	**On Straight and Curves of Radius Flatter than 600 M.**	**Curves of Radius Sharper than 600 M.**
A	300 mm.	1.588 M_3	1.636 M_3
B & C	250 mm.	1.375 M_3	1.416 M_3
D	200 mm	1.187 M_3	1.202 M_3
E	150 mm.	0.956 M_3	0.996 M_3

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. In case of S.W.R track, the minimum depth of cushion shall be 200 mm.

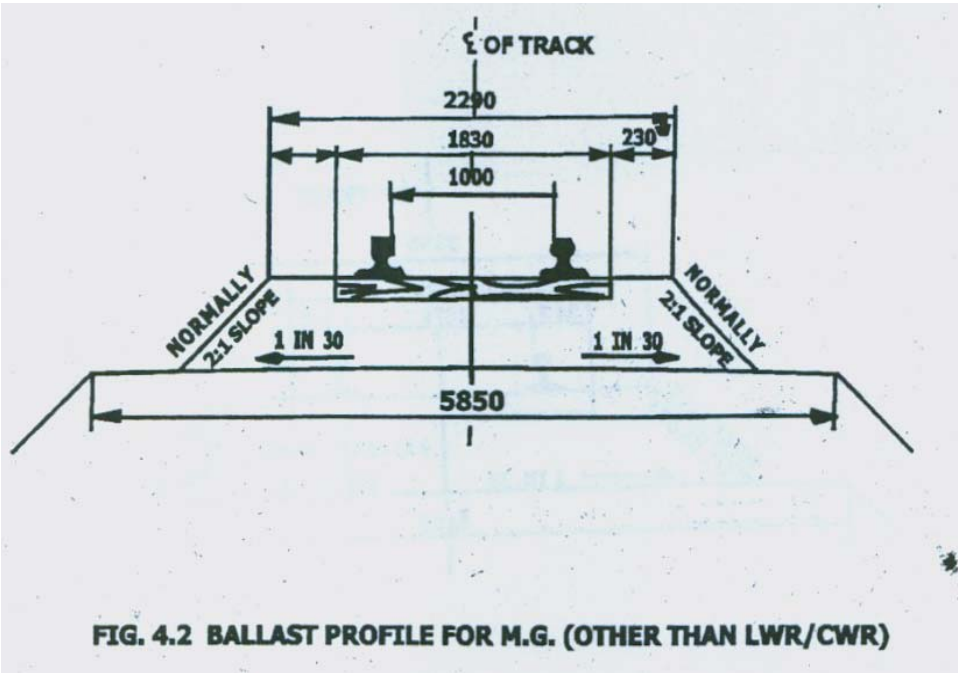

FIG. 4.2 BALLAST PROFILE FOR M.G. (OTHER THAN LWR/CWR)

Recommended Depths of ballast requirements for fish plated track

Routes	Quantity of Ballast required per Metres on		
	Recommended Depth of Ballast	Straight & Curves of Radius flatter than 600M	Curves of Radius sharper than 600M
Q Routes 100 kmph	300 mm	1.070 M_3	1.145 M_3
Q Routes of less than 100 kmph	250 mm	0.965 M_3	1.033 M_3
R-1 Routes	250 mm	0.965 M_3	1.033 M_3
R-2 Routes where LWR is contemplated	250 mm	0.965 M_3	1.033 M_3
R-2 Routes where LWR is not contemplated	200 mm	0.817 M_3	0.905 M_3
R-3 Routes	200 mm	0.817 M_3	0.905 M_3
S Routes	150 mm	0.673 M_3	0.725 M_3

Note :

1. In case of fish plated track ballast cushion to be increased on the outside of curves to 400 mm for curves sharper than 600 m Radius.

2. In short welded panel to be increased to 350 mm in case of all curves flatter than 600 M radius and to 380 mm in case of curves sharper than 600 M radius.

3. To be increased to 550 mm on the outside of turn in curves of turn-outs in passenger yards.

4. In the case of S.W.R. track, the minimum depth of cushion shall be 200 mm.

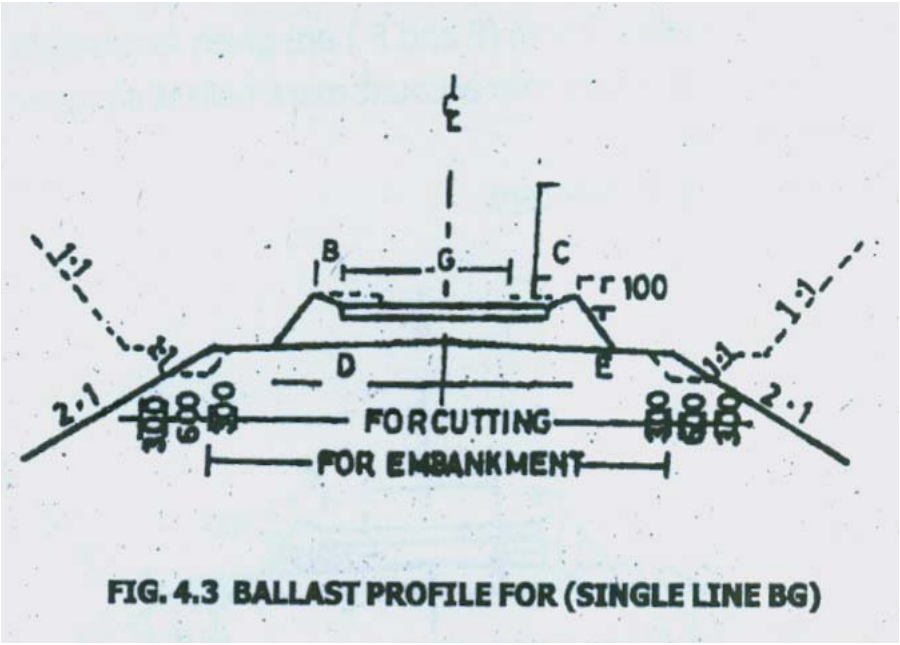

FIG. 4.3 BALLAST PROFILE FOR (SINGLE LINE BG)

Gauge	Type of Sleeper	A	B	C*	D	E*	F	F1	H
BG	Wooden	250	350	500	2270	2420	6850	6250	540
		300	350	500	2270	2420	6850	6250	590
		200 over 150 Sub-Ballast	350	500	2270	2430	6850	6250	640
1676	Steel Trough	250	350	500	2280	2430	6850	6250	550
		300	350	500	2280	2430	6850	6250	600
		200 over 150 Sub-Ballast	350	500	2220	2430	6850	6250	650
	PRC	250	350	500	2525	2675	6850	6250	640
		300	350	500	2525	2675	6850	6250	690
		200 Over 150 Sub-Ballast	350	500	2575	2675	6850	6250	740

Note :

1. The minimum clean stone ballast cushion below the bottom of sleeper is 250 mm.
2. For routes where speeds are to be more than 130 kmph ballast cushion is 350 mm or 200 mm along with 150 mm of sub-ballast.
3. *Extra ballast on outer side of curves only.
4. Suitable slope shall be given for side slope of ballast profile.
5. Dimensions for formation width (F and F_1) are given for straight portion only. This should be suitably increased taking into account extra ballast shoulder on outside of curves and for super elevation.
6. All dimensions are in millimeters.

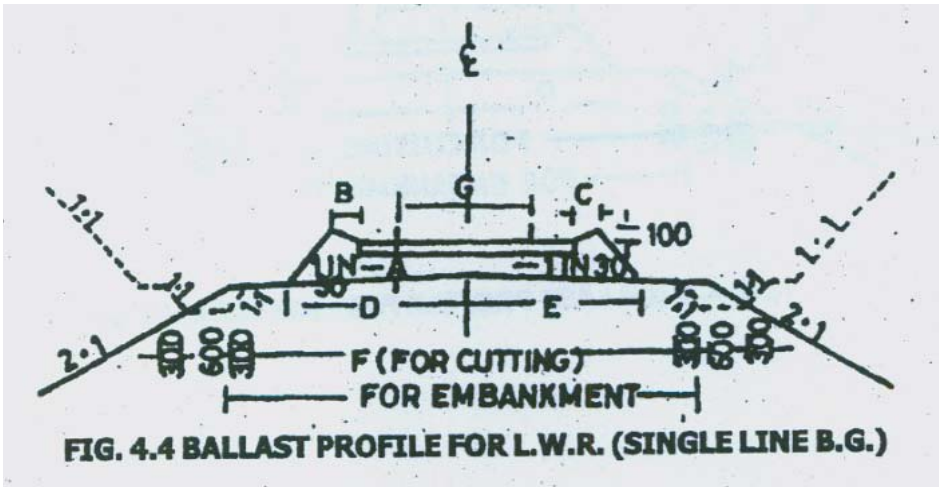

FIG. 4.4 BALLAST PROFILE FOR L.W.R. (SINGLE LINE B.G.)

Gauge	Type of Sleeper	A	B	C*	D	E*	F	F_1	H
MG 1000	Wooden	250	350	500	1760	1930	5850	5250	510
		300	350	500	1760	1930	5850	5250	560
		200Over 150 Sub-Ballast	350	500	1760	1930	5850	5250	670
	Steel Trough	250	350	500	1790	1940	5850	5250	520
		300	350	500	1790	1940	5850	5250	570
		200 Over 150 Sub-Ballast	350	500	1790	1940	5850	5250	620
	PRC	250	350	500	2025	2175	5850	5250	510
		300	350	500	2025	2175	5850	5250	560
		200Over 150 Sub-Ballast	350	500	2025	2175	5850	5250	610
	CST-9	250	350	500	1730	1860	4880	4270	510
		300	350	500	1730	1880	4880	4270	560
		200Over 150 Sub-Ballast	350	500	1730	1880	4880	4270	610

Note :

1. The minimum clean stone ballast cushion below the bottom of sleeper to A-250 mm.
2. For routes where speeds are to be more than 100 kmph. A-300 mm or 200 mm along with 150mm of sub ballast.
3. *Extra ballast On outer side of curves only.
4. Suitable slope shall be given for side slope of ballast profile.
5. Dimensions for formation width (F and F_1) are given for straight portion only. This should be suitably increased taking into account extra ballast shoulder on outside of curves and on super elevation.
6. All dimensions are in millimeters

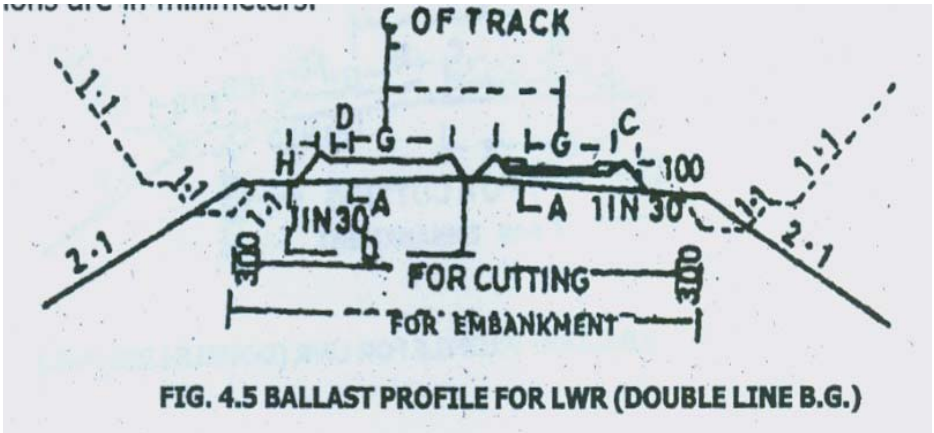

FIG. 4.5 BALLAST PROFILE FOR LWR (DOUBLE LINE B.G.)

Gauge	Type of Sleeper	A	B	C*	D	E*	F	F_1	H	J
BG 1676	Wooden	250	350	500	2300	2340	12155	11535	570	5300
		300	350	500	2300	2340	12155	11535	620	5300
		200Over 150 Sub-Ballast	350	500	2300	2340	12155	1535	670	5300
	Steel	250	350	500	2320	2350	12155	11535	580	5300
		300	350	500	2310	2350	12155	11535	630	5300
		200Over 150 Sub-Ballast	350	500	2310	2350	12155	11535	680	5300
	PRC	250	350	500	2525	2450	12155	11535	700	5300
		300	350	500	2525	2460	12155	11535	750	5300
		200Over 150 Sub-Ballast	350	500	2525	2460	12155	11535	800	5300

Note :

1. The minimum clean stone ballast cushion below the bottom of sleeper IS 250 mm.
2. For routes where speed are to be more than 130 kmph. Ballast Cushion is 300mm or 200mm along with 150 mm of sub-ballast.
3. *Extra ballast on outer side of curves only.
4. Suitable slope shall be given for side slope of ballast profile.
5. Dimensions for formation width (F and F_1) are given for straight portion only. This should be suitably increased taking into account extra ballast shoulder on outside of curves and on super elevation.
6. All dimensions are in millimeters.

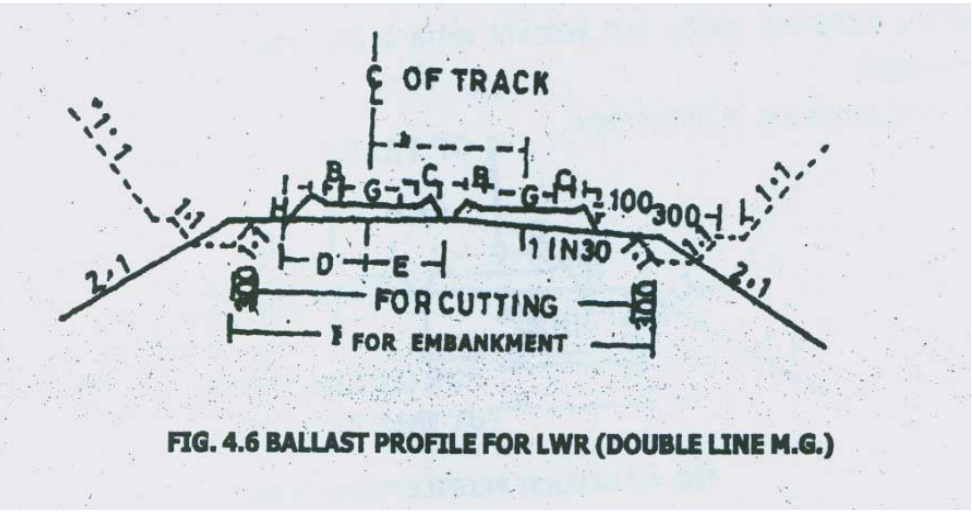

FIG. 4.6 BALLAST PROFILE FOR LWR (DOUBLE LINE M.G.)

Gauge	Type Sleeper	A	B	C*	D	E*	F	F_1	H	J
MG 1000	Wooden	250	350	500	1790	1850	9810	9210	535	3960
		300	350	500	1790	1850	9810	9210	585	3960
		200 Over 150 Sub-Ballast	350	500	1790	1550	9810	9210	635	3960
	Steel Trough	250	350	500	1810	1960	9810	9210	540	3960
		3 00	350	500	1810	1960	9810	9210	590	3960
		200 Over 150 Sub-Ballast	350	500	1810	1860	9810	9210	640	3960
	PRC	250	350	500	2025	1970	9810	9210	595	3960
		300	350	500	2025	1970	9810	9210	645	3960
		200 over 150 Sub-Ballast	350	500	2025	1970	9810	9210	695	3960
	CST-9	250	350	500	1750	1810	9810	9210	535	3960
		300	350	500	1750	1810	9810	9210	585	3960
		200 Over 150 Sub-Ballast	350	500	1750	1810	9810	9210	635	3960

Note :

1. The minimum clean stone ballast cushion below the bottom of sleeper 250 mm.
2. For routes where speeds are to be more than 100 kmph. Ballast cushion 300 mm or 200 mm along with 150 mm of sub-ballast.
3. *Extra ballast On outer side of curves only.
4. Suitable slope shall be given for side slope of ballast profile.
5. Dimensions for formation width (F and F_1) are given for straight portion only. This should be suitably increased taking into account extra ballast shoulder on outside of curves and on super elevation.
6. All dimensions are in millimeters.