Section - 2

Civil Engineering (TRACK)

Lesson-I
Structure of Railway Track

1.1 Definition

Railway Track or Permanent Way is the rail-road on which trains run. It basically consists of two parallel rails having a specified distance in between and fastened to sleepers, which are embedded in a layer of ballast of specified thickness spread over the formation. The rails are joined to each other by fish plates and bolts and these are fastened to the sleepers at a specified distance and are held in position by embedding in ballast.

Each of the components of track has a basic function to perform. The rails act as girders to transmit the wheel loads of trains to the sleepers. The sleepers hold the rails in proper position and provide the correct gauge with the help of fittings and fastenings and transfer the load to the ballast. The ballast is placed on prepared ground known as formation. The sleepers are embedded in ballast, which gives a uniform level surface, provides drainage and transfers the load to larger area of formation. The formation gives a surface, where the ballast rests and transmits the total load of the track and that of the trains moving on it to the natural ground below.

Permanent Way or track, therefore, consists of (i) rails, (ii) sleepers, (iii) fittings and fastenings, (iv) ballast and (v) formation as shown in Fig.1.1. Permanent way is so called as it is not easily dividedvis a vis the roads todistinguish the final track constructed for movement of trains from the temporary track constructed to carry building materials etc. in olden times.

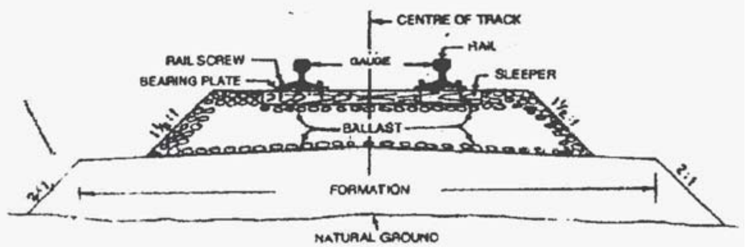


FIG. 1.1 X-SECTION OF TRACK & FORMATION

1.2 Requirements of good track

An efficient track should while serving its purpose of providing a safe and smooth ride, should be easy to maintain and economical in construction. It should have minimum number of fittings which should be of 'fit and forget' type. The performance of the track should remain unaffected from the vagaries of weather. During rainy season, the track should have good drainage so as to remain free from water logging and slush. During summer, the track should remain safe against buckling and as such should have adequate ballast section to provide the required lateral strength and stability. During winter, the rails have tendency of fractures due to tension developed on account of low temperature, The rails should, therefore, be free from internal defects and cracks, particularly in the fish plate zones (at joints).

1.3 Gauge

Gauge as used with reference to track is the minimum distance between the two gauge faces of rails. In India we have three different gauges as given below :

(a) Broad Gauge : 1676 mm

(b) Meter Gauge : 1000 mm or one metre

(c) Narrow Gauge : Three are two gauges under Narrow gauge which are 762 mm and 610 mm.

Adoption of Metre gauge and Narrow gauge is mainly based on traffic potential and geographical conditions available along the alignment. In hilly area, Metre gauge and Narrow gauge are economical as compared to Broad gauge but with the gauge being smaller, the capacity and speed go down drastically. Other problems of having a number of gauges are indicated below:-

(a) Problem of changing trains at junction points.

(b) Problem of transhipment-extra cost and theft of goods.

(c) Detention to wagons at change of gauge points.

As on 31.3.2016, the length of track (route km) with different gauges was as under:

Name of Gauge	Width (mm)	length Inkms
Broad Gauge	1676	60,510
Metre Gauge	1000	3,880
Narrow Gauge	762 or 610	2,297
Total	---	66,687

1.4 Rail

Rail is the main component of tack which provides a continuous and surface for smooth running of wheels of railway vehicles.

1.4.1 Shape of Rail (Fig.1.2)

Rail is designed as a beam supported on a number of flexible supports. For optimum design the shape of rail is such that it has maximum material at top and bottom. Mainly there are two shapes.

(a) Double headed/Bull headed : Both top and bottom are either similar or top is a little heavy.

(b) Flat footed : Bottom flange is flat.

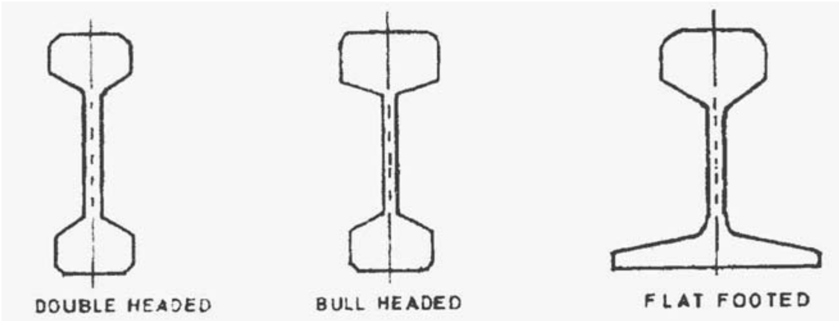


FIG. 1.2 SHAPE OF RAIL

FIG. 1.2 SHAPE OF RAIL

The top head is designed in such a manner that it takes stresses and also there is provision for wear during the service life. The bottom flange or foot is designed so that it can be fixed to the sleepers effectively. The Standard section now is flat footed as it provides a better fixing arrangement to the sleepers.

1.5 Nominal weight of rails

The rail section is known by its weight which is the nominal weight of rail per yard or metre.

The following rail sections are presently in use on Indian Railways :

Gauge		Rail Section	Types of Sections	Height Actual Weight
BG	60 KG	UIC *	172 MM	60.34 Kg/m
	52 KG	IRS*	156 MM	51.89 Kg/m
	90 R	RBS*	142.9 MM	90 Lbs/yard Or 44.61 Kg/m
MG	90 R	RBS	142.9 MM	90 Lbs/yard. Or 44.61 Kg/m
	75 R	RBS	128.6 MM	75 Lbs/yard Or 37.18 Kg/m

*UIC- International Union of Railways.

*IRS- Indian Railway Standard

*RBS-Revised British Section.

1.5.1 Quality of Steel

Three types of steel used in Rails is 72 UTS, 90 UTS and 110 UTS. 110 UTS, 90 UTS & 72

UTS have ultimate tensile strength of 110 kg/mm2, 90 kg/mm2 and 72 kg/mm2 respectively. Rails are made wear resistant by adding more Manganese. Chemical composition of rails steel of various Grades is as under:

Rail	*Carbon*	*Managenese*	*Silicon*	*Sulphur& Phoshorus*	*Aluminium*
Grade 710 (MM rails)	0.45-0.60 %	0.95-1.40 %	0.040-0.50 %	0.05 % max.	
Grade 880 (90-UTS Rails)	0.60-0.80 %	0.80-1.30 %	0.10-0.50 %	0.035 % max.	0.015%(Max)
Grade 1080	0.60-0.80	0.80-1.20%	0.5-1.10%	0.25%	0.004%(Max)

Note: Hydrogen content for 90 UTS rail should not be more than 1.6 ppm

Service Life of Rails

Total traffic which a rail can take during its primary service life is as under:

Rails Section	*UTS*	*GMT**
90R	72 UTS	250 GMT
90R	90 UTS	375 GMT
52 Kg	72 UTS	350 GMT
52 Kg	90 UTS	525 GMT
60 Kg	72 UTS	550 GMT
60 Kg	90 UTS	800 GMT

***GMT-Gross Million Tons of Traffic**

1.6 Sleepers

1.6.1 Main purpose of providing sleepers is to hold the rails so as to have correct gauge and transfer the load from rails to ballast and further to the formation. Sleeper should have the following properties:

(1) They should be strong and economical.

(2) Should be able to absorb of vibrations.

(3) Should point easy correction of gauge.

(4) Should be heavy enough to provide stability.

(5) Should be easy to pack.

(6) Should provide lateral stability.

(7) Should suffer minimum damage during derailments.

1.6.1 Types of Sleepers

The types of sleepers in use on Indian Railways are:

1.6.1.1 Wooden Sleepers : These are further classified as soft wood and hard wood sleepers.

These are very good sleepers to absorb vibrations but are not very durable and do not provide much lateral stability due to light in weight. These are good for track circuiting works.

Standard size of Wooden Sleeper : (Fig. 1.3)

Gauge	Size (Lx Bx H) in Cms
Broad Gauge	275 x 25 x 13
Metre Gauge	180 x 20 x 11.5

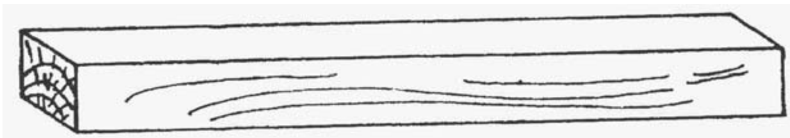


Fig. 1.3 Wooden Sleeper

However, as per Supreme Court orders now no new wooden sleepers are being procured on Indian Railway in view of the need for conservation of forests.

1.6.1.2 Steel Trough Sleepers (Fig. 1.3a) : These are made from rolled trough section of steel and then pressed hot to obtain desired shape. These sleepers are having better life, have better stability and maintain gauge properly. Service life of steel sleepers is 25 to 40 years depending upon traffic.

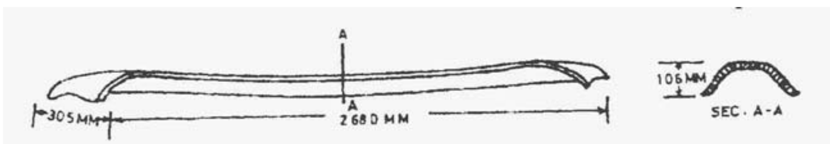


Fig. 1.3 a Wooden Sleeper

However, the holes in these sleepers have a tendency of elongating and cracks can be seen under rail seat after certain time span. They are also not fit for track circuiting. Weight of a BG sleeper is 81 Kg.

1.6.1.3 Cast Iron Sleepers (Fig. 1.4): Standard design of cast iron sleepers is CST-9. There are two parts connected with a steel tie bar. These sleepers have poor strength and is not fit for high speed or heavy traffic. There is problem of wear at rail seat & lateral stability is also not very good.

Damage to sleepers is very heavy in case of derailments. These are also not fit for welded track. C.I. Sleepers cannot absorb vibrations. There are also not fit for track circuiting. Weight of complete set is 102 Kg. for BG.

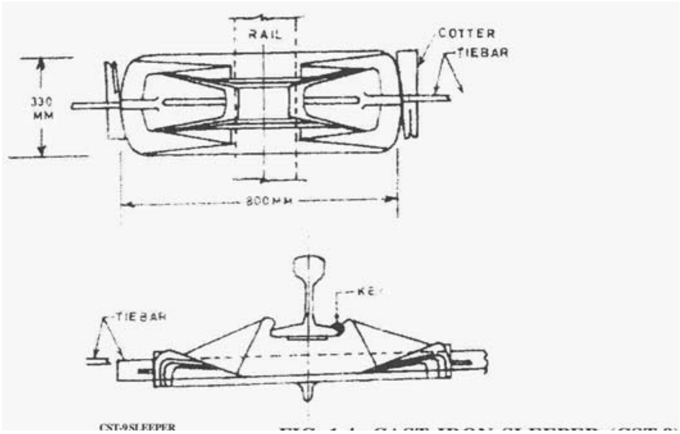


Fig. 1.4 CAST IRON SLEEPER (CST-9)

1.6.1.4 Concrete sleepers : Concrete sleepers are made of concrete, ordinary RCC or prestressed reinforced Concrete designed suitably to take the stresses safely. The concrete sleepers are much superior as compared to other types of sleepers as indicated below :

Advantages

(i) Concrete sleepers, being heavy, provide good stability to track.

(ii) This maintains gauge and cross levels very efficiently.

(iii) The sleepers can be used in track circuited area.

(iv) Life of concrete sleepers is very long, as long as 40-50 years.

(v) The concrete sleepers resist weather efficiently however, the concrete sleepers have the following disdvantages:

(a) Manual handling of sleepers is very difficult due to heavy weight.

(b) Damage to sleepers during derailment is very heavy due to brittleness.

(c) Manual maintenance is very difficult.

Concrete sleepers are of two types :

(a) **Twin Block sleeper : (Fig. 1.5)**

This is in the shape of two blocks connected bu an angle iron. This is made of ordinary RCC.

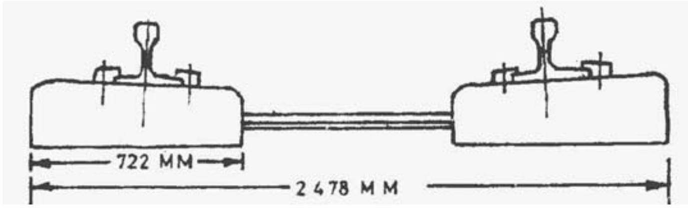


Fig. 1.5 TWIN BLOCK SLEEPER

(b) **Monoblock Sleeper : (Fig. 1.6)**

This is in the shape of a single block and is made of prestressed reinforced concrete.

Concrete sleepers require rubber pads and elastic fastenings to save the sleepers from vibrations.

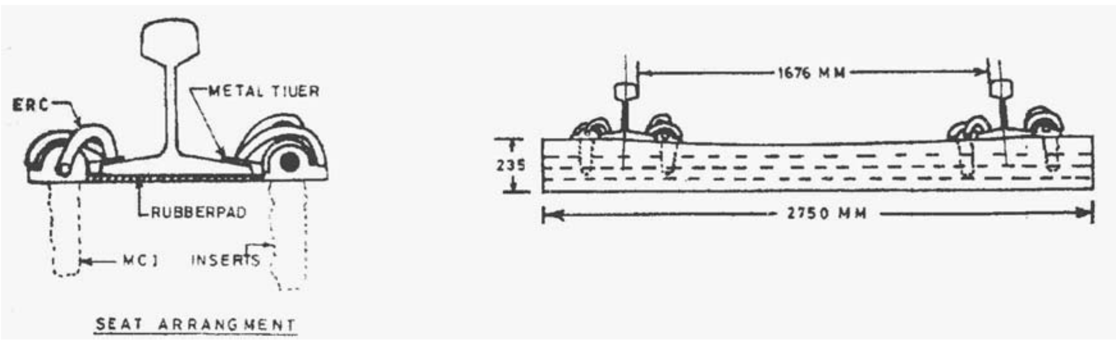


Fig. 1.6 MONOBLOCK SLEEPER

1.7 Rail Joints and Fish Plates

1.7.1 Rail joints are the weakest points in the track. The joints also cause knocking and reduce the life of rolling stock also. Due to knocking, the maintenance of joint sleepers poses special problem. Rail ends also get battered at joints which causes rough running. Incidence of rail fractures are large in fish plate zone area (joints). In view of these rail joints related problem, a good track always has least number of joints. Most of the joints can be avoided by welding the rails.

1.7.2 Fish Plates (Fig. 1.7) : These are the plates (in pairs) which are provided at joints to connect the two rails end to end, often provided with 4 Nos. bolts called as fish bolts. Since the depth of fish plates is less than rail, the strength of a pair of fish plates is about 55% of the rail in bending. To keep the stresses within limit, sleeper spacing is reduced at joints.

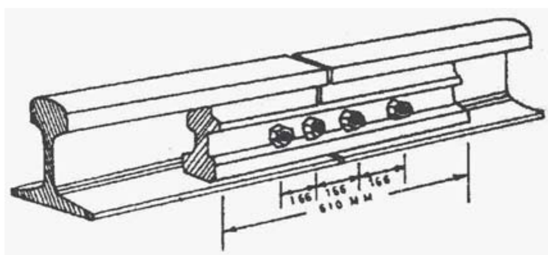


FIG. 1.7 FISH PLATE (52 KG RAIL)

1.8 Sleeper Fittings

1.8.1 Fitting which fix rails to the sleepers vary in shape and size as per the type of sleepers. Important type of fittings for different types of sleepers are described in the following paragraphs.

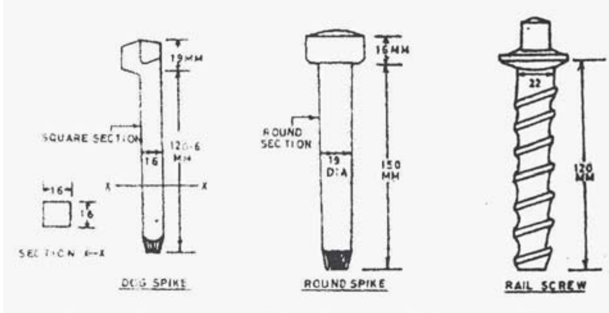


FIG. 1.8a FIG. 1.8 SPIKES (b) FIG. 1.8c

1.8.2 Fittings for Wooden Sleepers

(a) Dog Spike (Fig. 1.8a): This is one of the most basic type of fittings. Due to its shape resembling the head of a dog it is called as dog spike. It is square in cross section and does not have much holding power. A rail can be fixed directly to the sleeper

(b) Round Spike (Fig. 1.8b): It is round in section with a round head at the top. The spike is used to hold the bearing plate. Its holding power is, however, not very good.

(c) Screw Spikes (Fig. 1.8c): These are having shape like a screw and are of two types. The one used to fix the rail directly is called "Rail Screw" and the one used to fix the bearing plate is called "plate screw". Its holding power is much superior than the Round spike or Dog spike.

(d) Bearing Plates

These are of various types :

(i) Flat Bearing Plates (Fig.1.9) : These are having uniform thickness of generally 19mm and are used with points and crossing sleepers.

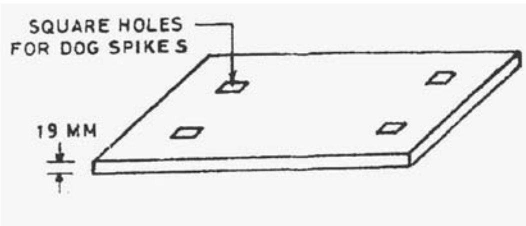


FIG. 1.9 FLAT BEARIMG PLATE

(ii) Canted Bearing Plate (fig. 1.10.) : These plates are thicker at one end than on the other, the slope being called as cant. Cant provided in the bearing plate is 1 in 20.

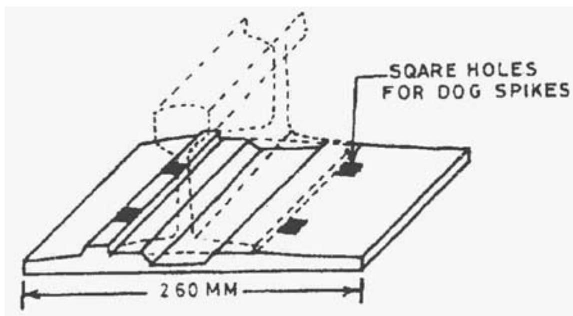


FIG. 1.10 CANTED M.S. BEARING PLATE

(e) Cast Iron Anti Creep Bearing plate (Fig.1.11): These plates are made of cast iron and are used to fix the rail tight with the help of keys.

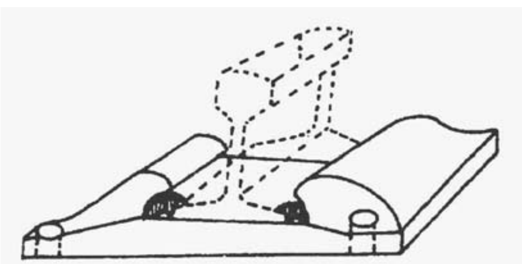


FIG. 1.11 ANTI CREEP BEARING PLATE

1.8.3 Fittings for Steel Trough Sleeper and CST- 9 Sleepers :

(a) Loose Jaws (Fig. 1.12) : Loose jaws are used to fix the rail to the Steel Trough Sleeper with the help of keys.

There is another type of jaw called Modified Loose Jaws which is specially designed to fix Pandrol clips instead of keys.

FIG. 1.12 LOOSE JAW

(b) Keys (Fig.1.13) : These are mild steel keys which are tapered in shape and are used with steel trough sleepers as well as CST-9 sleepers.

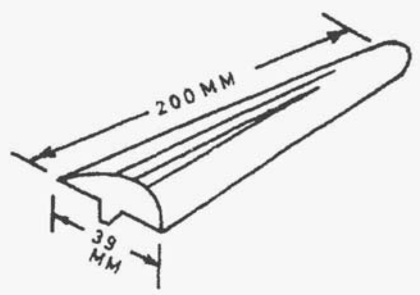


FIG. 1.13 TWO WAY KEY

These keys are known as two way keys as the same can be driven both ways left to right or right to left.

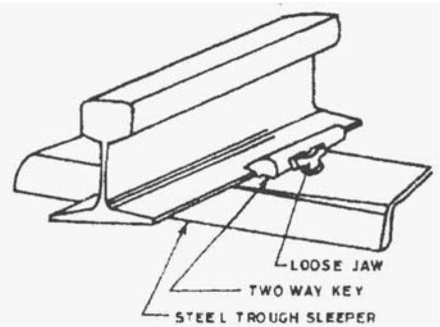


FIG. 1.14 RAIL FIXED WITH LOOSE JAWS & TWO WAY KEY

1.8.4 Fittings for Concrete Sleepers

(a) Elastic Rail Clips (ERC) or Pandrol Clips (Fig.1.15): These clips are widely used with concrete sleepers and also with steel trough sleepers. These are elastic in nature made from silicon steel rod of 20.6 mm diameter. Each sleeper needs 4 clips. These clips are excellent in function as the rails are always kept pressed under toe load of 710 kg by each clipfor a normal deflection of 11.4 mm. The clips are able to adsorb vibrations due to elastic in nature and do not fall out. ERC clip mark IV gives higher toe load of 1000 Kgs.

The clips are generally used alongwith rubber pad and liners (mild steel or nylon).

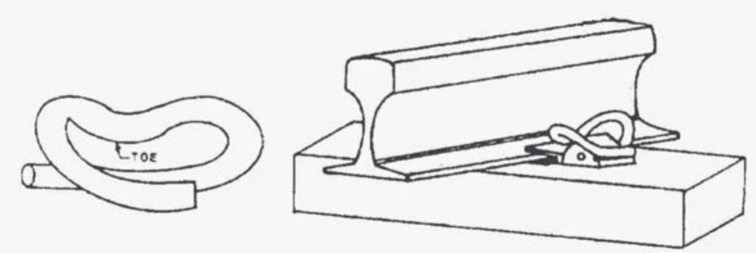


FIG. 1.15 ELASTIC RAIL CLIP OR PANDROL CLIP

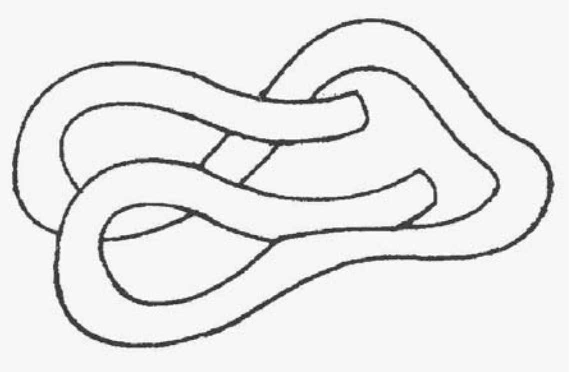


FIG. 1.16 IRN 202 CLIP

(c) IRN-202 Clip (Fig.1.16) : This clip has been designed by RDSO mainly for two block RCC sleepers. This gives a toe load of 1000 Kgs. Per clip. The clip holds the track gauge.

(d) H.M. Fastening (Fig. 1.17) : This fastening has also been used in a limited number on Indian Railways. It consists of 4 coach screws (or plate screws) and two W-shape clips. Each clip gives a toe load of about 1000 kgs. Gauge is maintained with the help of angled guide plates.

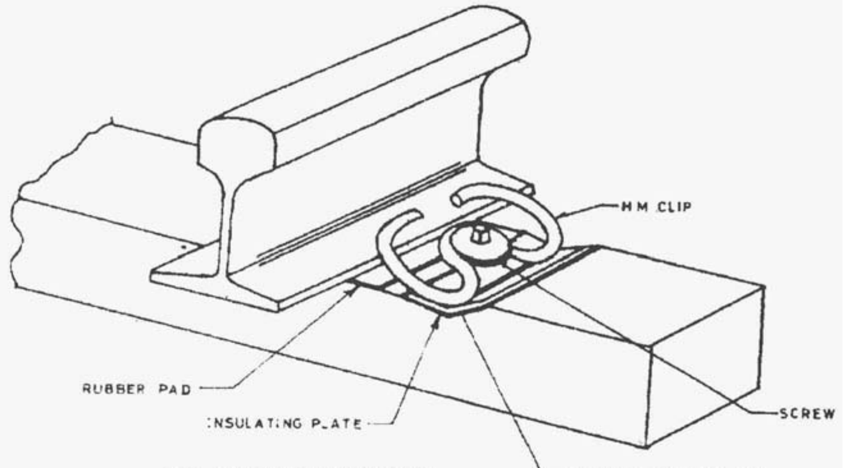


FIG. 1.17 H.M FASTENING

1.9 Ballast

Ballast is a layer of broken stone, gravel, moorum or any other gritty material placed and packed below and around sleepers for distributing the load from sleeper to formation and for providing drainage as well as giving longitudinal stability to the track. On Indian Railways 65mm Size stone ballast is being used.

Ballast is used in the track under the sleepers and performs the following functions:-

(i) Ballast provides resistance to the track which gives good running.

(ii) It provides good drainge.

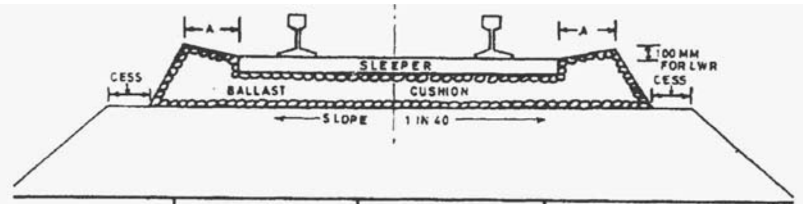
(iii) It helps in transferring the load from sleepers to the formation.

(iv) It provides lateral resistance against buckling of track.

1.9.1 Requirement of good ballast

1. It should be hard, durable and wear resistant.
2. It should be angular to provide good interlocking.
3. It should resist weathering effects.
4. It should be strong and should not get crushed under load and vibrations.
5. It should provide good drainage of water.
6. It should be cheap & economical in price.

1.9.2 Ballast Profile (Fig.1.18)



GROUP	CUSHION	"A'	"A" FOR LWR
A	300 mm	300mm	350 mm
B&C	250 mm	300mm	350 mm
D	200 mm	300mm	350 mm
E	150 mm	350mm	

Note : For outside of curves on LWR A=500mm

FIG. 1.18 BALLAST PROFILE

1.10 Formation

1.10.1 Purpose of Formation (Fig.1.19) :

(i) To provide an even and regular surface to lay ballast and track.

(ii) To ensure laying of track well above the high flood level.

(iii) To distribute the load over a wide area on natural ground.

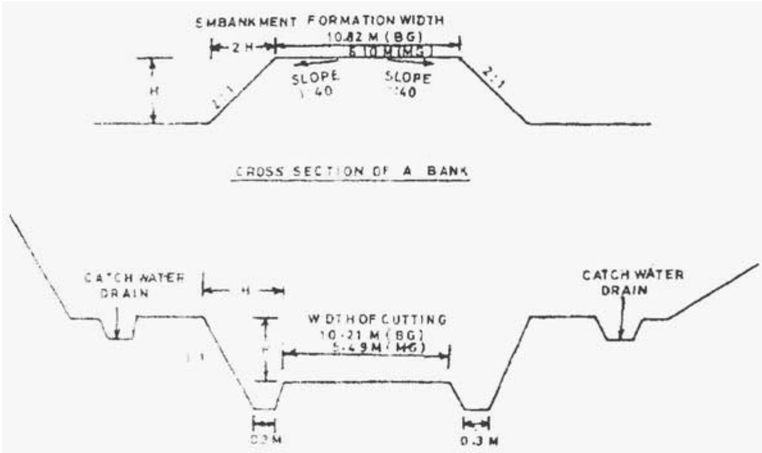


FIG. 1.19 CROSS SECTION OF FORMATION

Gauge	Line	Width of Embankment	Width of Cutting (for LWR Track)
B.G.	Single Line	7850 mm	7850 mm
	Double Line	13160 mm	13160 mm
M.G	Single Line	5850 mm	5250 mm
	Double Line	9810 mm	9210 mm

1.10.2 Mechanical Compaction

To ensure good quality of embankment, mechanical compaction of soil is preferred. This ensures stability of bank even during rainy season. The objective of compaction is to achieve 95% to 98% of maximum dry density of the top layer the soil. This is achieved by adding controlled quantity of water to the soil and compacting in layers not exceeding 250-300 mm in depth at a time.

The compaction should be done preferably using vibratory rollers.

1.10.3 Blanketting

It is essential that the Formation be provided with a strong foundation. To improve the bearing capacity the bank, it is necessary to provide top layer of the bank using coarse sand or other harder material like quarry dust, moorum, except where the natural soil is grandeur and strong. Blanket is usually of one metre depth but can vary as per actual sight condition. Geo-Grid is also used as blanket.

1.11 Coning Of Wheels

Unlike the arrangement of wheels and axles in road vehicles, the Railway vehicles have fixed wheels on axles. The 2 wheels and axle form a rigid arrangement where the wheels and axle rotate together.

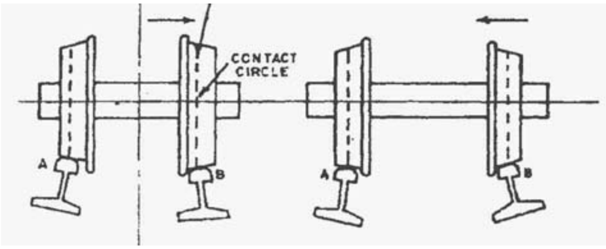


FIG. 1.20 CONING OF WHEEL

The movement of wheels is guided by flange on the wheels provided on the inside which prevents derailment of vehicles. The tread of wheel is provided with a slope of 1: 20, the main function of which is to keep the vehicle centrally.

As the axle and wheels move to the right, the diameter of contact surface on the right side wheel increases and the same on the left side wheel decreases. Because of this wheels and axle have a tendency to move in a circular path and move to the left. Thus coning of wheels helps in neutralizing the sidewise movement of wheels and keeps them centrally, reducing the side wear on rails and wheels.

1.12 Canting of Rails (Fig.1.21)

To match the coning of wheels and to ensure proper contact of wheels and rails, the rails are also provided at a slope of 1 in 20 from the vertical. This is done by providing the slope of 1 in 20 in the rail seat in the sleeper as shown below.

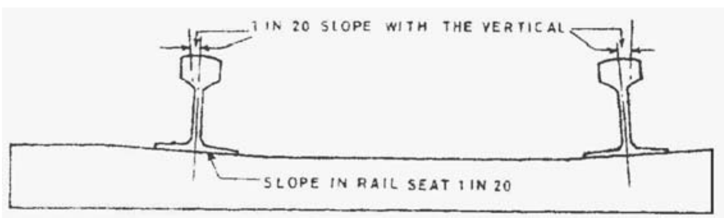


FIG. 1.21 CANTING OF RAIL

1.13 Main Components of a Turn-out are :

(i) Switches (Points) (ii) Lead rails (iii) Crossing

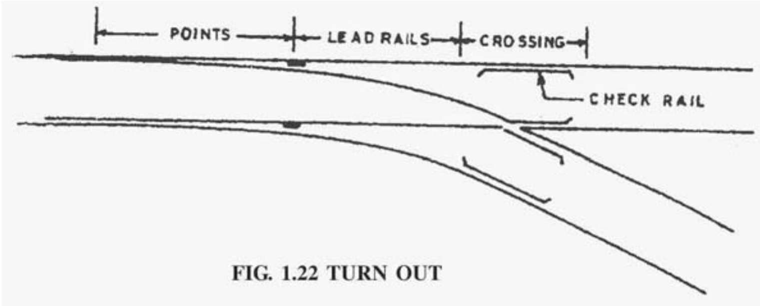


FIG. 1.22 TURN OUT

(a) Switch: A Switch is composed of a stock rail and a tongue rail. A set of two switches is called as point. Tongue rail is a piece of rail, one end of which is tapered (called toe) and the other end is fixed to the lead rail (called heel). The tapered end is pushed or pulled to set the routes as indicated below.

The two tongue rails are joined together with the help of 2 or 3 stretcher bars. The rear end of the tongue rail is joined with the stock rail with the help of heel blocks. If the tongue rail has a joint at the heel block, it is called a loose heel and if the joint in tongue rail is ahead of the heal block, it is called as fixed heel type. Recently form shape Switches have been introduced an Indian Railway.

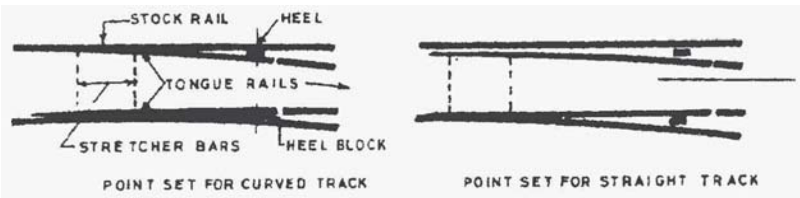


FIG. 1.23 DETAILS OF SWITCH

(a) The Tongue Rails are of two types.

(i) *Straight tongue rail :* The rail is straight upto the heel block.

(ii) *Curved tongue rail :*The tongue rail is in the shape of a curve. This ensures smooth entry of the trains into the curved track.

(b) **Lead rails :** Lead rails serve to join the switches to the crossing. These rails are ordinary rails and fixed to the sleepers rigidly.

(c) **Crossings (Fig. 1.24) :** This is a built up assembly and provide necessary gap for the passage of wheel-flange to either direction. The nose assembly is made up of a point rail and a splice rail. There are two wing rails attached to the nose assembly. The minimum distance between the wing rail is called throat.

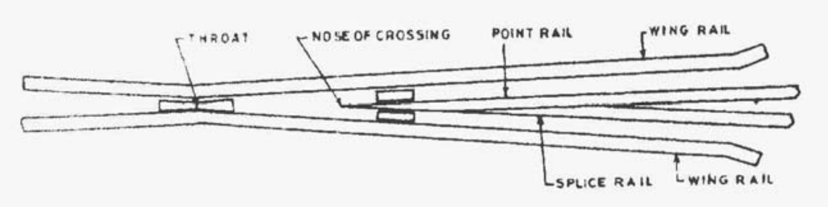


FIG. 1.24 DETAILS OF A CROSSING

Opposite to the crossing, a check rail is provided on both sides which avoids hitting of wheels against the nose of crossing.

Angle of crossing (Fig.1.25) : The angle made at crossing between the two tracks is known as angle of crossing, There are various standard angles of crossings. (i) 1 in 8½ (ii) 1 in 12 (iii) 1 in 16 (iv) 1 in 20

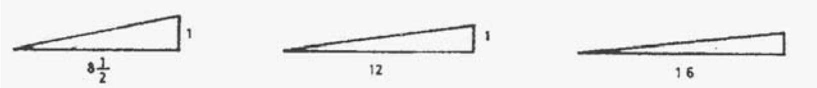


FIG. 1.25 ANGLE OF CROSSING

A flat crossing angle provides higher speed but the length of turn out becomes more. 1 in 8½ crossings are not normally permitted for passenger lines.

1.13.1 Classification of Crossings

Crossings are classified as under :

(a) Built up Crossing

(b) CMS Crossing

(a) *Built up Crossing :*This is the type of Crossing in which two wing rails and 'V' which consist of splice and point rails are assembled together by means of bolts & distance blocks to form a crossing.

(b) *CMS Crossing :*This type is one piece Cast manganese Crossings with no bolts and therefore needs less maintenance. It is more rigid crossing being one complete mass.

1.13.2 Permissible speeds on turn outs

The speeds of passengertrains negotiating a crossing and entering the curved side are regulated as under:

Type of Crossing	Straight Switch or Curved Switch	Speed
1 in 8½	Straight Curved	10kmph. 15kmph

	Symmetrical split	30 kmph
1 in 12	Straight	15kmph.
	Curved	30kmph.
1 in 16	Curved	50 kmph.
1 in 20	Curved	50 kmph.

1.13.3 Various Layouts

(a) Diamond crossings (Fig.1.26) : When two tracks with same or different gauges cross each other.

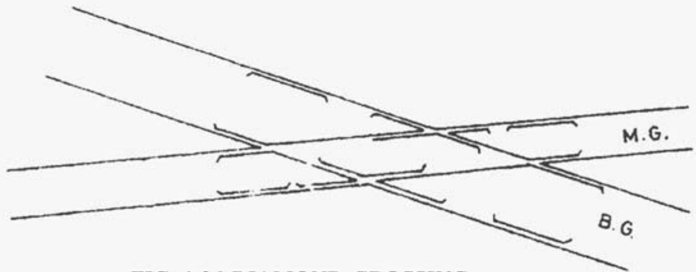


FIG. 1.26 DIAMOND CROSSING

(b) Cross Over (Fig.1.27) : A set or two turnouts is called a cross over.

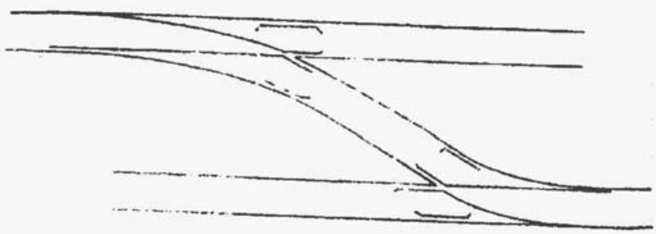


FIG. 1.27 CROSS OVER

FIG. 1.27 CROSS OVER

(c) Ladder (Fig.1.28) : When a number of parallel tracks are joined to main line, the arrangement is known as a ladder

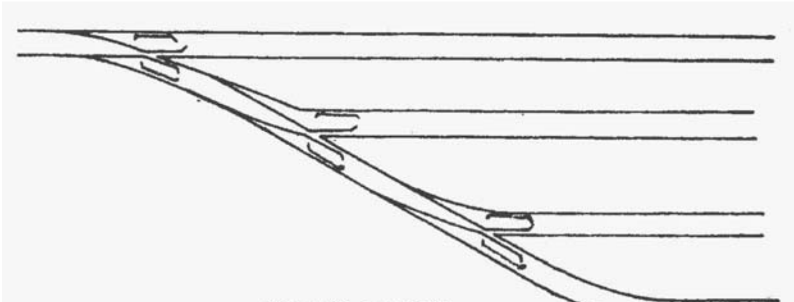


FIG. 1.28 LADDER

(d) Symmetrical Split (Fig.1.29) : When the two directions are making equal angle with the main line, it is called a symmetrical split.

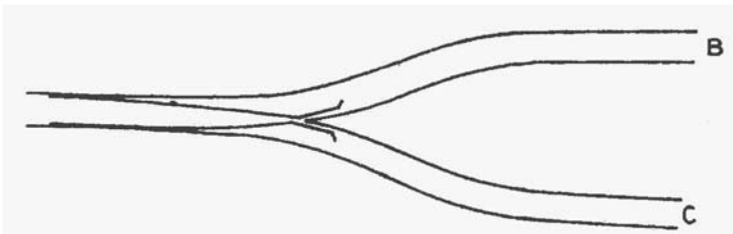


FIG. 1.29 SYMMETRICAL SPLIT

(e) Single and Double Slips (Fig.1.30) : It is a combination of diamond crossing and turnouts so that there is facility available from either track on one side to go to either track on the other side.

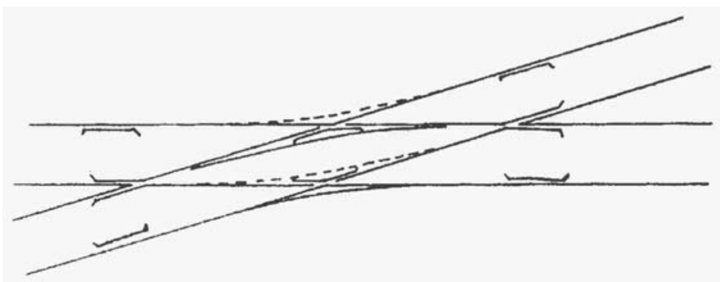


FIG. 1.30 DIAMOND CROSSING WITH SINGLE/DOUBLE SLIP

FIG. 1.30 DIAMOND CROSSING WITH SINGLE / DOUBLE SLIP

1.14 Curves

11.1 Curves are a necessary evil. We cannot avoid provision of curves in Railway alignment as it is not possible to have the entire alignment in a straight line due to

(a) The necessity of avoiding natural obstructions.

(ii) To connect several important cities which are not on a straight line.

(iii) To provide extra length to regulate the gradient.

1.14.1 Defining Curvature

One of the important parameter of a curve is its curvature. It is defined either by radius or degree of curvature. The angle subtended by 30.5 meter chord at the centre is called the Degree of Curve. (Fig. 1.31)

One degree curvature is equivalent of 1750 m radius. Thus 20 curve means 875 m radius.\

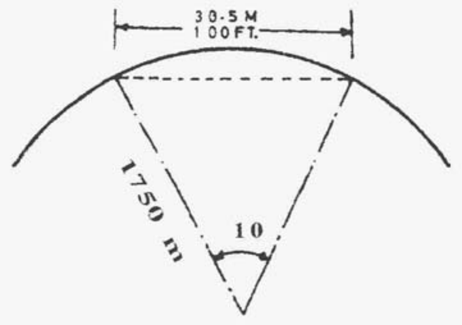


FIG. 1.31 DIGREE OF A CURVE

(1) Cant or superelevation is the amount by which one rail is raised above the other rail. It is positive when the outer rail on a curved track is raised above inner rail and is negative whenthe inner rail on a curved track is raised above the outer rail.

(2) Equilibrium speed is the speed at which the centrifugal force developed during the movement of the vehicle on a curved track is exactly balanced by the cant provided.

(3) Cant deficiency – Cant deficiency occurs when a train travels around a curve at a speed higher than the equilibrium speed. It is the difference between the theoretical cant required for such higher speed and actual cant provided.

(4) Cant excess – Cant excess occurs when a train travels around a curve at a speed lower than the equilibrium speed. It is the difference between the actual cant and the theoretical cant required for such a lower speed.

(5) Maximum permissible speed of the curve–

It is the highest speed which may be permitted on a curve taking into consideration the radius of the curvature, actual cant, cant deficiency, cant excess and the length of transition. When the maximum permissible speed on a curve is less than the maximum sectional speed of the section of a line,permanent speed restriction becomes necessary.

(6) Cant gradient and cant deficiency gradient indicate the amount by which cant or deficiency of cant is increased or reduced in a given length of transition e.g., 1 in 1000 means that cant or deficiency of cant of 1mm. is gained or lost in every 1000mm.

1.14.2 Maximum Permissible Curvatureon plain track -

Gauge	Maximum Degree	Curvature Radius permitted
BG	100	175 m
MG	160	109 m
NG	400	44 m

1.14.3 (a) : Length of Curve (Fig.1.32)

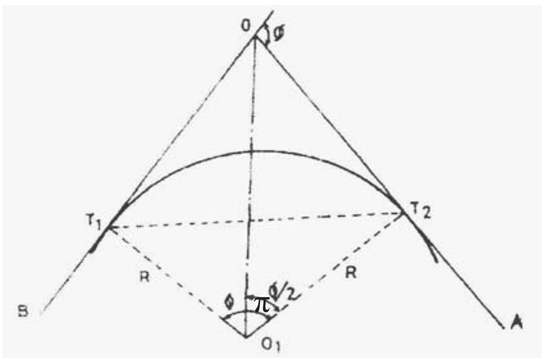


Fig.1.32 DEGREE OF A CURVE

Straights BT_1 and AT_2

Tangent points T_1 and T_2

O is the point of intersection of the tangents.

OT_1 and OT_2 are called tangent lengths.

T_1T_2 is the long chord.

O_1 is centre of curve.

ø is the angle of deflection.

$O_1T_1 = O_1T_2$ = Radius of curve

Tangent length $O_1T_1 = O_1T_2 = R \tan (ø/2)$….(i)

T_1T_2= Long Chord = $2R \sin (ø/2)$,….(ii)

Length of curve = $2\pi R \times ø/360$ = R ø/180 …..(iii)

1.14.4 Super Elevation on curves or Cant

Whenever a vehicle moves in a circular path, a radial force called centrifugal force is applied on it. This is because the natural tendency of the vehicle being to move always in a straight line. This causes extra vertical load on the other wheel. To neutralize the effect of centrifugal force, the outer rail is raised by certain amount which is called super elevation or cant.

1.14.5 Maximum Value of Super Elevation

Maximum value of super elevation on curves shall be as under :

Gauge	Group	Normal Value	With special permission of Chief Engineer
BG	A	165 mm	185* mm
	B & C	165 mm	_____
	D &E	140 mm	______
MG	___	90 mm	100 mm
NG	___	65 mm	75 mm

** Note: maximum cant of 185 mm may be assumed for the purpose of locating all permanent structures etc. by the side of curve on new construction and doubling of A route having potential for increase in future. The transition length should also be provided on the basis of 185 mm cant for the purpose of planning and layout of the curve.*

1.14.6 Cant Deficiency

The actual cant provided is always less than the equilibrium cant required as per calculations, Maximum cant deficiency allowed is as under :

Gauge	Cant Deficiency (max. value)
BG	75 mm*
MG	50 mm
NG	40 mm

*Note : * (can be allowed as 100 mm on routes of BG with track maintained with C&M -1 Vol. 1standard for nominated rollingstock with permission of Principal Chief Engineer)*

1.14.7 Cant Excess

Maximum value of cant excess on BG is 75 mm and on MG 65 mm for all rolling stock. The cant excess should be worked out taking into consideration the booked speed of a goods train on a particular section.

1.15 Train Resistance and Hauling Capacity of a Locomotive

1.12.1 When a train is moving at a certain speed, it offers various types of resistance against movement. Locomotive power has to be more than the sum total of maximum resistance it has to overcome. Even when the train is at standstill and when the locomotive is about to start, there are various types of resistances which resist the movement of the train. These are due to friction in the bearings of wheel axles, unevenness of rail surface, dip at the joints, curvature of track, gradient wind etc. These are discussed in detail in the following paragraphs :-

(i) Resistance due to wind and speed (Rw) : This resistance is proportionate to the square of speed of the train. This is equal to :

Rw = $0.00156V^2$ W (in kg)

V = speed in kmph

W = weight of train in tones

Value of Rw is zero at start

(ii) Resistance due to friction in bearings and wave action of rails (Rf)

The resistance due to friction (Rf) caused by bearings and wave action of rails including unevenness of rail surface is generally taken as 0.0025 pf weight of the train while the train is in movement and double of this value when the train is about to start. Hence it can be expressed as :

Rf = 0.0025 W in motion

Rf = 0.005 W at start

(iii) Resistance due to Gradient (Rg) :

Value of resistance due to gradient is proportional to the gradient of track. If the gradient is G in 100 (G%), the value of Rg can be expressed as :

Rg = G x W/100

In case of a falling gradient, the value of G will be negative, so will be the value of Rg i.e. we will get support from the falling gradient. But since trains move both in up or down directions, the value of Rg is always taken as positive.

(iv) Resistance due to Curves (Rc)

As per Newton's law of motion, a body always keeps on moving in straight direction. Hence, when a train moves on a curved track, the outer wheels always rub against the inner face of the outer rail creating lot of resistance to train movement. The amount of resistance is expressed as function of curvature and is different for different gauge as shown below :

for BG Rc = 0.0004 degree of curvature

for MG Rc = 0.0003 degree of curvature

for NG Rc = 0.0002 degree of curvature

1.15.1 Solved Example

Find out the maximum permissible load of a goods train when hauled with a locomotive of 30 tonne tractive effort (pulling power), over a gradient of 0.75% grade and 20 sharpest curvature when the maximum speed is 75 kmph.

Assuming the total weight of train is W tones

(i) Resistance due to wind and speed = Rw = 0.00156x75x75xW

(ii) Resistance due to friction, Rf = 0.0025 W (in motion) and = 0.005 W at start

(iii) Resistance due to gradient, Rg = 0.75 x W/100

(iv) Resistance due to curvature, Rc = 0.004 x 2 x W

Hence

30 = 0.00156/1000 x 75 x 75 x W + 0.0025W +0.75/100 x W + 0.004 x 1 xW

30 = 0.008775 W + 0.0025 W + 0.0075 W + 0.008 W

30 = 0.026775 W

W = 30/0.026775 tonnes .... (a)

W = 1120 tonnes (including the weight of locomotive)

Checking at start

30 = 0 + 0.005 W + 0.0075 + 0.008 W ∴

30 = 0.0205 W

W = 30/0.0205 = 1460 tonnes (OK)

However, the maximum weight should be limited to 1120 tonnes due to ‘a’ above.

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