LECTURE NOTES

ON

TRANSPORTATION ENGINEERING II

IV B.Tech Civil - I Semester

CIVIL ENGINEERING

UNIT-1

History of Indian Railways

Introduction

In the year 1832 the first Railway running on steam engine, was launched in England. Thereafter on 1st of August, 1849 the Great Indian Peninsular Railways Company was established in India. On 17th of August 1849, a contract was signed between the Great Indian Peninsular Railways Company and East India Company. As a result of the contract an experiment was made by laying a railway track between Bombay and Thane (56 Kms).

- On 16th April, 1853, the first train service was started from Bombay to Thane.
- On 15th August, 1854, the 2nd train service commenced between Howrah and Hubli.
- On the 1st July, 1856, the 3rd train service in India and first in South India commenced between Vyasarpadi and Walajah Road and on the same day the section between Vyasarpadi and Royapuram by Madras Railway Company was also opened.

Subsequently construction of this efficient transport system began simultaneously in different parts of the Country. By the end of 19th Century 24752 Kms. of rail track was laid for traffic. At this juncture the power, capital, revenue rested with the British. Revenue started flowing through passenger as well as through goods traffic.

Organizational structure

Railway zones

Indian Railways is divided into several zones, which are further sub-divided into divisions. The number of zones in Indian Railways increased from six to eight in 1951, nine in 1952 and sixteen in 2003. Each zonal railway is made up of a certain number of divisions, each having a divisional headquarters. There are a total of sixty-eight divisions. Each of the sixteen zones is headed by a general manager who reports directly to the Railway Board. The zones are further divided into divisions under the control of divisional railway managers (DRM).

Sl. No	Name	Abbreviation	Date Established	Route km	Headquarters	Divisions
1.	Central	CR	5 November 1951	3905	Mumbai	Mumbai, Bhusawal, Pune, Solapur, Nagpur
2.	East Central	ECR	1 October	3628	Hajipur	Danapur,

			2002			Dhanbad, Mughalsarai, Samastipur, sonpur
3.	East Coast	ECoR	1 April 2003	2677	Bhubaneswar	Khurda Road, Sambalpur and Waltair (Visakhapatn am)
4.	Eastern	ER	April 1952	2414	Kolkata	Howrah, Sealdah, Asansol, Malda
5.	North Central	NCR	1 April 2003	3151	Allahabad	Allahabad, Agra, Jhansi
6.	North Eastern	NER	1952	3667	Gorakhpur	Izzatnagar, Lucknow, Varanasi
7.	North Western	NWR	1 October 2002	5459	Jaipur	Jaipur, Ajmer, Bikaner, Jodhpur
8.	Northeast Frontier	NFR	15 January 1958	3907	Guwahati	Alipurduar, Katihar, Rangia, Lumding, Tinsukia
9.	Northern	NR	14 April 1952	6968	Delhi	Delhi, Ambala, Firozpur, Lucknow, Moradabad
10.	South Central	SCR	2 October 1966	5803	Secunderabad	Vijayawada, Hyderabad, Guntakal, Guntur, Nanded, Secunderabad
11.	South East Central	SECR	1 April 2003	2447	Bilaspur	Bilaspur, Raipur, Nagpur
12.	South Eastern	SER	1955	2631	Kolkata	Adra, Chakradharpu r, Kharagpur, Ranchi
13.	South Western	SWR	1 April 2003	3177	Hubli	Hubli, Bangalore, Mysore
14.	Southern	SR	14 April 1951	5098	Chennai	Chennai, Trichy, Madurai, Salem,[12] Palakkad,Thir uvananthapur am
15.	West Central	WCR	1 April 2003	2965	Jabalpur	Jabalpur,

						Bhopal, Kota
16.	Western	WR	5 November 1951	6182	Mumbai	Mumbai central, Ratlam, Ahmedabad, Rajkot, Bhavnagar, Vadodara
17	Kolkata metro rail	KNR	29 DEC 2010		Kolkata	Kolkata

Subsidiaries of Indian Railways There also exist independent organizations under the control of the Railway Board for electrification, modernization, research and design and training of officers, each of which is headed by an officer of the rank of general manager. A number of Public Sector Undertakings, which perform railway-related functions ranging from consultancy to ticketing, are also under the administrative control of the Ministry of railways.

There are fourteen public undertakings under the administrative control of the Ministry of Railways:

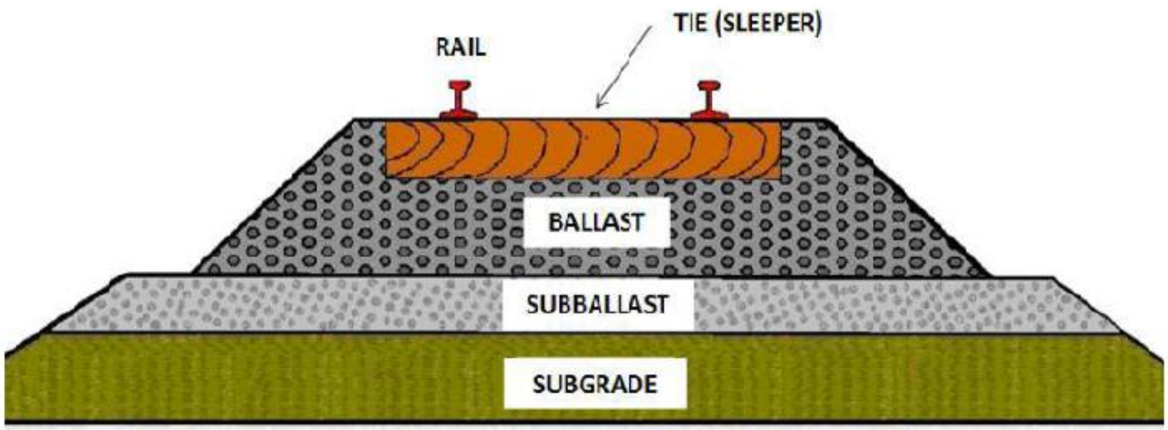
Bharat Wagon and Engineering Co. Ltd. (BWEL)

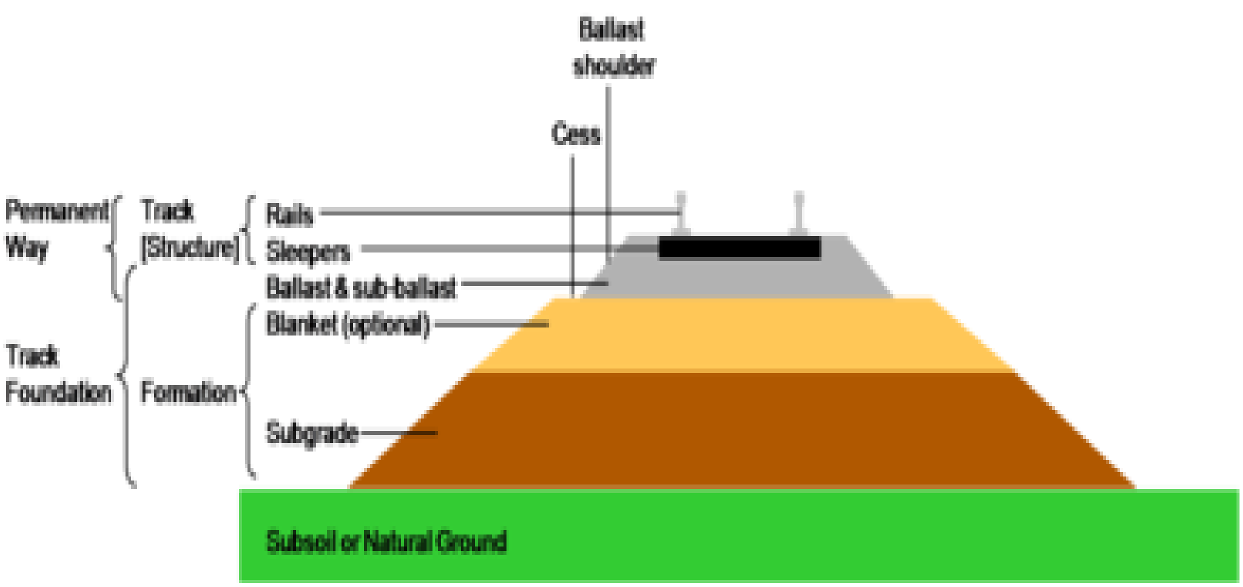
- Centre for Railway Information Systems (CRIS)[24]
- Container Corporation of India Limited (CONCOR)
- Dedicated Freight Corridor Corporation of India Limited (DFCCIL)
- Indian Railway Catering and Tourism Corporation Limited (IRCTC)
- Indian Railway Construction (IRCON) International Limited
- Indian Railway Finance Corporation Limited (IRFC)
- Konkan Railway Corporation Limited (KRCL)
- Mumbai Railway Vikas Corporation (MRVC)
- Railtel Corporation of India Limited (Rail Tel)
- Rail India Technical and Economic Services Limited (RITES)
- Rail Vikas Nigam Limited (RVNL)
- High Speed Rail Corporation of India (HSRC)
- Burn Standard Company

- Braithwaite and Co. Ltd•

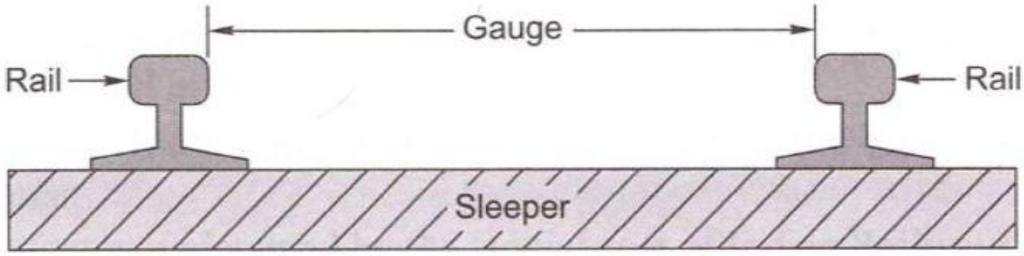
Lecture-2 Component parts of railway track

The Typical components are – Rails, – Sleepers (or ties), – Fasteners, – Ballast (or slab track), – Subgrade





GAUGE The clear minimum horizontal distance between the inner (running) faces of the two rails forming a track is known as Gauge. Indian railway followed this practice. In European countries, the gauge is measured between the inner faces of two rails at a point 14 mm below the top of the rail.



GAUGES ON WORLD RAILWAYS Various gauges have been adopted by different railways in the world due to historical and other considerations. Initially British Railways had adopted a gauge of 1525 mm (5 feet), but the wheel flanges at that time were on the outside of the rails. Subsequently, in order to guide the wheels better, the flanges were made inside the rails. The gauge then became 1435 mm (4'8.5"), as at that time the width of the rail at the top was 45 mm (1.75 "). The 1435 mm gauge became the standard on most European Railways. The various gauges on world railways are given in Table 2.1.

Type of gauge	**Gauge (mm)**	**Gauge (feet)**	**% of total length**	**Countries**
Standard gauge	1435	4'8.5"	62	England, USA, Canada, Turkey, Persia, and China
Broad gauge	1676	5 '6"	6	India, Pakistan, Sri Lanka, Brazil, Argentina
Broad gauge	1524	5'0"	9	Russia, Finland
Cape gauge	1067	3 '6"	8	Africa, Japan, Java, Australia, and New Zealand
Metre gauge	1000	3 '3.5"	9	India, France, Switzerland, and Argentina
23 various other gauges	Different gauges	Different gauges	6	Various countries

Different Gauges in Indian railways

The East India Company intended to adopt the standard gauge of 1435 mm in India also. This proposal was, however, challenged by W. Simms, Consulting Engineer to the Government of India, who recommended a wider gauge of 1676 mm (5 '6 "). The Court of Directors of the East India Company decided to adopt Simms's recommendation and 5'6 " finally became the Indian standard gauge.

Gauge Type	Width	% Route covered in India
Broad gauge	1676 mm	63
Meter gauge	1000 mm	31
Narrow gauge	762 mm	6

Broad Gauge: - When the clear horizontal distance between the inner faces of two parallel rails forming a track is 1676mm the gauge is called Broad Gauge (B.G) This gauge is also known as standard gauge of India and is the broadest gauge of the world. The Other countries using the Broad Gauge are Pakistan, Bangladesh, SriLanka, Brazil, Argentine, etc.50% India's railway tracks have been laid to this gauge.

Suitability: - Broad gauge is suitable under the following Conditions:-

(i) When sufficient funds are available for the railway project.
(ii) When the prospects of revenue are very bright.

This gauge is, therefore, used for tracks in plain areas which are densely populated i.e. for routes of maximum traffic, intensities and at places which are centers of industry and commerce.

2. **Meter Gauge**: - When the clear horizontal distance between the inner faces of two parallel rails forming a track is 1000mm, the gauge is known as Meter Gauge (M.G) The other countries using Meter gauge are France, Switzerland, Argentine, etc. 40% of India's railway tracks have been laid to this gauge.

Suitability:- Meter Gauge is suitable under the following conditions:-

(i) When the funds available for the railway project are inadequate.
(ii) When the prospects of revenue are not very bright.

This gauge is, therefore, used for tracks in under-developed areas and in interior areas, where traffic intensity is small and prospects for future development are not very bright.

3. **Narrow Gauge**:- When the clear horizontal distance between the inner faces of two parallel rails forming a track is either 762mm or 610mm, the gauge is known as Narrow gauge (N.G) The other countries using narrow gauge are Britain, South Africa, etc. 10% of India's railway tracks have been laid to this gauge.

***Suitability:* -** Narrow gauge is suitable under the following conditions:-

(i) When the construction of a track with wider gauge is prohibited due to the provision of sharp curves, steep gradients, narrow bridges and tunnels etc.
(ii) When the prospects of revenue are not very bright. This gauge is, therefore, used in hilly and very thinly populated areas. The feeder gauge is commonly used for feeding

raw materials to big government manufacturing concerns as well as to private factories such as steel plants, oil refineries, sugar factories, etc.

CHOICE OF GAUGE The choice of gauge is very limited, as each country has a fixed gauge and all new railway lines are constructed to adhere to the standard gauge. However, the following factors theoretically influence the choice of the gauge:

Cost considerations There is only a marginal increase in the cost of the track if a wider gauge is adopted. In this connection, the following points are important

(a) There is a proportional increase in the cost of acquisition of land, earthwork, rails, sleepers, ballast, and other track items when constructing a wider gauge.

(b) The cost of building bridges, culverts, and runnels increases only marginally due to a wider gauge.

(c) The cost of constructing station buildings, platforms, staff quarters, level crossings, signals, etc., associated with the railway network is more or less the same for all gauges.

(d) The cost of rolling stock is independent of the gauge of the track for carrying the same volume of traffic.

Traffic considerations The volume of traffic depends upon the size of wagons and the speed and hauling capacity of the train. Thus, the following points need to be considered.

(a) As a wider gauge can carry larger wagons and coaches, it can theoretically carry more traffic.

(b) A wider gauge has a greater potential at higher speeds, because speed is a function of the diameter of the wheel, which in turn is limited by the width of the gauge. As a thumb rule, diameter of the wheel is kept 75 per cent of gauge width.

(c) The type of traction and signalling equipment required are independent of the gauge.

Physical features of the country It is possible to adopt steeper gradients and sharper curves for a narrow gauge as compared to a wider gauge.

It was found that if we are having a steep gradients or there are very extensive curves, narrow curves have been provided then it is better to go for narrow gauge, in the state of the broad gauge or the meter gauge, but if the gradients are quite feasible or the curves are having a large radius, that is, they are much of flatter curves in that sense we can go for broad gauge constructions.

This is a example which has been given here, this hill railway like from Kalka to Shimla as you must have seen, you must have heard about or probably some of you have also gone through that experience of moving from Kalka to Shimla by a train and that is a hill railways.

Similarly, there is another railway which is being provided in the Darjeeling area. You have to go from Siliguri to Darjeeling and that is another scenic beauty area where we have the heritage rail section still working or the locomotive still working. Then, a third area in the hill railways is the Ooty area. So all these are specific area where the hill gauge or the narrow gauge

Uniformity of gauge The existence of a uniform gauge in a country enables smooth, speedy, and efficient operation of trains. Therefore, a single gauge should be adopted irrespective of the minor advantages of a wider gauge and the few limitations of a narrower gauge.

Speed In the case of the broad gauge as the size of the diameter of the wheel increases, in that case what happens is that the total circumferential area distance which can be moved by that will also increases and therefore the speed of the vehicle will increase, in the case of a higher gauge. That is why if they are interested in achieving higher speeds we can go for broad gauges instead of the narrow gauges or the meter gauges.

Classification of Broad gauges

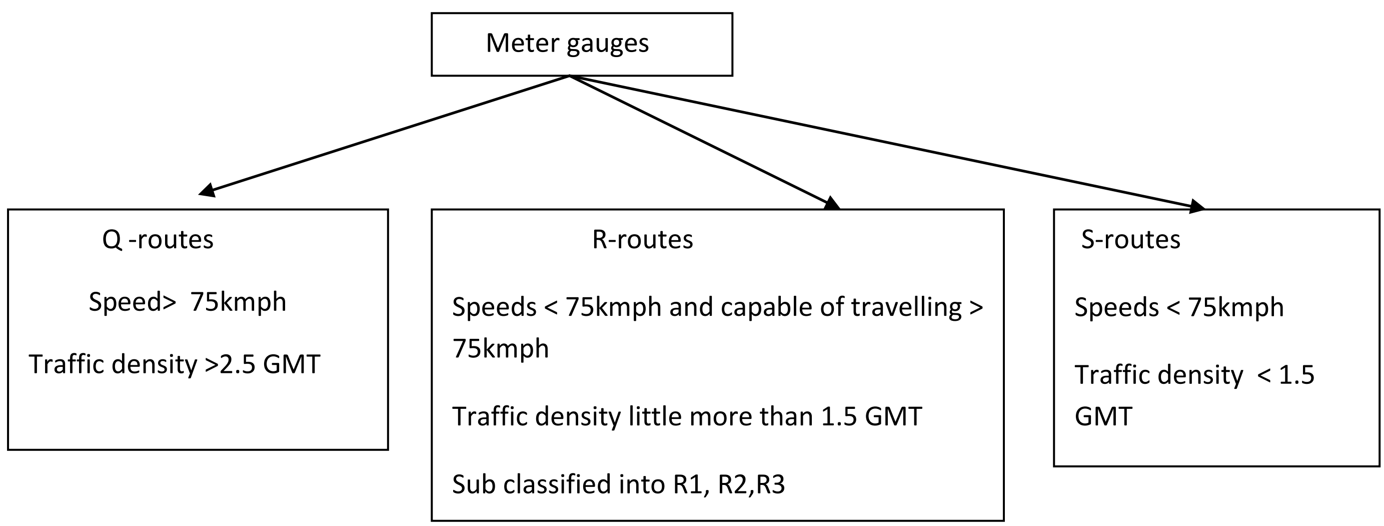
Based on speed and various other factors like traction, sleeper density etc (the action or ability of drawing or pulling something over a surface, especially a road or track.) Broad gauges are classified in to following

Type / Criteria	A	B	C	D	E
Max Speed (kmph)	160	130	Speeds are as per sub urban conditions (Metro Trains)	100	<100
Sleeper density (Sleeper/km)	1660	1660-1540	1660-1540	1660-1540	1540-1310

Example	New Delhi to Howrah ,New Delhi to Mumbai central, New Delhi to Madras central , Howrah to Mumbai	Kharagpur to Vijayawada via Waltair	local trains moving in Mumbai , Kolkata, Delhi Madras and likewise.	-	-

Classification of Meter gauges

In the case of meter gauge track classification, we have three categories of track classifications



PROBLEMS OF MULTI GAUGE SYSTEM

Introduction

The need for uniformity of gauge has been recognized by all the advanced countries of the world. A number of problems have cropped up in the operation of the Indian Railways because of the multi-gauge system (use of three gauges). The ill effects of change of gauge (more popularly known as *break of gauge)* are numerous; some of these are enumerated here.

Inconvenience to passengers Due to change of gauge, passengers have to change trains mid-journey along with their luggage, which causes inconvenience such as the following: (a) Climbing stairs and crossing bridges (b) Getting seats in the compartments of the later trains (c) Missing connections with the later trains in case the earlier train is late (d) Harassment caused by porters (e) Transporting luggage from one platform to another.

Difficulty in trans-shipment of goods: Goods have to be trans-shipped at the point where the change of gauge takes place. This causes the following problems: (a) Damage to goods during trans-shipment (b) Considerable delay in receipt of goods at the destination (c) Theft or misplacement of goods during trans-shipment and the subsequent claims (d) Non-availability of adequate and specialized trans-shipment labor and staff, particularly during strikes

Inefficient use of rolling stock As wagons have to move empty in the direction of the trans-shipment point, they are not fully utilized. Similarly, idle wagons or engines of one gauge cannot be moved on another gauge.

Hindrance to fast movement of goods and passenger traffic Due to change in the gauge, traffic cannot move fast which becomes a major problem particularly during emergencies such as war, floods, and accidents.

Additional facilities at stations and yards Costly sheds and additional facilities need to be provided for handling the large volume of goods at trans-shipment points. Further, duplicate equipment and facilities such as yards and platforms need to be provided for both gauges at trans-shipment points.

Difficulties in balanced economic growth The difference in gauge also leads to unbalanced economic growth. This happens because industries set up near MG/NG stations cannot send their goods economically and efficiently to areas being served by BG stations.

Difficulties in future gauge conversion projects Gauge conversion is quite difficult, as it requires enormous effort to widen existing tracks. Widening the gauge involves heavy civil engineering work such as widening of the embankment, bridges and tunnels, as well as tracks; additionally, a wider rolling stock is also required. During the gauge conversion period, there are operational problems as well, since the traffic has to be slowed down and even suspended for a certain period in order to execute the work.

UNI-GAUGE POLICY OF INDIAN RAILWAYS The problems caused by a multi-gauge system in a country have been discussed in the previous section. The multi-gauge system is not only costly and cumbersome but also causes serious bottlenecks in the operation of the Railways and hinders the balanced development of the country. Indian Railways therefore took the bold decision in 1992 of getting rid of the multi-gauge system and following the uni-gauge policy of adopting the broad gauge (1676 mm) uniformly.

Benefits of Adopting BG (1676 mm) as the Uniform Gauge

The uni-gauge system will be highly beneficial to rail users, the railway administration, as well as to the nation. Following are the advantages of a uni-system:

No transport bottlenecks There will be no transport bottlenecks after a uniform gauge is adopted and this will lead to improved operational efficiency resulting in fast movement of goods and passengers.

No *trans-shipment hazards* There will be no hazards of trans-shipment and as such no delays, no damage to goods, no inconvenience to passengers of transfer from one train to another train.

Provisions of alternate routes Through a uni-gauge policy, alternate routes will be available for free movement of traffic and there will be less pressure on the existing BG network. This is expected to result in long-haul road traffic reverting to the railways.

Better turnaround There will be a better turnaround of wagons and locomotives, and their usage will improve the operating ratio of the railway system as a whole. As a result the community will be benefited immensely.

Improved utilization of track There will be improved utilization of tracks and reduction in the operating expenses of the railway.

Balanced economic growth The areas currently served by the MG will receive an additional fillip, leading to the removal of regional disparities and balancing economic growth.

No multiple tracking works The uni-gauge project will eliminate the need for certain traffic facilities and multiple tracking works, which will offset the cost of gauge conversions to a certain extent.

Better transport infrastructure Some of the areas served by the MG have the potential of becoming highly industrialized; skilled manpower is also available. The uni-gauge policy will help in providing these areas a better transportation infrastructure.

Boosting investor's confidence With the liberalization of the economic policy, the uni-gauge projects of Indian Railways have come to play a significant role. This will help in boosting the investors' confidence that their goods will be distributed throughout the country in time and without any hindrance. This will also help in setting up industries in areas not yet exploited because of the lack of infrastructure facilities.

Planning of Uni-gauge Projects The gauge-conversion programme has been accelerated on Indian Railways since 1992. In the eighth Plan (1993-97) itself, the progress achieved in gauge-conversion projects in five years was more than the total progress made in the past 45 years. The progress of gauge-conversion projects is briefly given in Table below.

Year	*Progress in gauge conversion (kms)*	*Remarks*
1947-1992	2500	Approx. figure
1993-1997	6897	Actual
1998-2004	3787	Actual
2005-2011	6564	Actual

The current position is that the gauge-conversion project still pending on Indian Railways is 8855 kms which is likely to be completed in next five years. Execution of a gauge conversion project is quite a tricky job and lot of planning is to be done for the same.

Lecture-4 WHEEL AND AXIS ARRANGEMENTS AND CONING OF WHEELS

Introduction

Wheels and axles we have the different types of the locomotives under wagons which are used for the hauling of the passengers and freight. All these wagons and locomotives have different specifications depending on the gauges for which they have been used. If you look at the various locomotives from the very starting of our history, we have been using steam locomotives and then they have been replaced by diesel locomotives and finally by the electric locomotives.

In the case of the steam locomotives, the wheels and axles are classified by on the basis of **Whyte system**. Traditionally, steam locomotives have been classified using either their wheel arrangements or sometimes they are also been classified on the basis of axle arrangements. In the case of the wheel arrangements classification, they are being classified on the basis of Whyte system and other system locomotives have three different types of wheel basis. They have the wheel basis which are either coupled or which are having the driving conditions or detective power attached to them or the wheel basis on which no attractive power is attached. In Indian practice, the Indian practice has been taken from the United Kingdom because British were the persons who introduced the Indian railways in our country and in this system we count wheels and we do not count the axles as far as the steam locomotives are concerned.

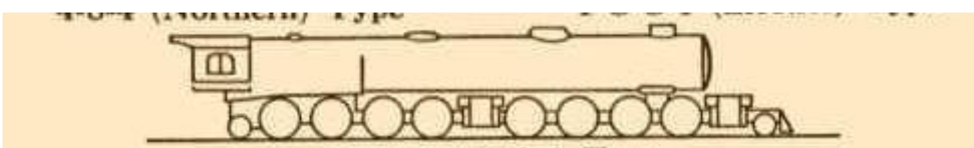
In the case of steam locomotives, one examples is been taken here where it is been shown as **2-4-2**. Now this 2-4-2 has the significance in terms of the wheel basis as been defined earlier. The first 2 is the front wheels or the 2 number of wheels have been placed or what we can say is that there is one axle which is being placed in the front condition. Then the 4 part is to the 4 number of wheels which have been placed in the central condition where they are the powered wheels or the driving wheels and therefore they transforms into the 2 axles condition and then there are trailing wheels where we have 2 wheels at the back and again, if it transform them into the actual condition, it will be working to one axle. Now when we are talking about the steam locomotives; the steam locomotives require a certain storage area or the tank where the coal can be stored because this is the prime condition which is required for the movement of the steam locomotives. In such cases, a suffix is also used to indicate the type of the tank which is provided on the steam engine

In the case, the tank engine is being provided, then it is indicated using the alphabet T. If it is a saddle tank then it is denoted as ST, if it is well tank then it is denoted as WT and if it is pannier tank then it is denoted as PT.

Compound locomotive

The compound locomotive is a condition where there is a more attractive power which is required to haul the passenger or the freight. The heavy amount of the freight which is to be transported and the trailing conditions governs the conditions where we require to provide two locomotives together so as to haul them. Here, this is an example of compound locomotive where two locomotive of condition 2-8-2 and 2-8-4 have been joined together so as to haul the traffic or the passengers or the freight. This is represented as 2-8-2+2-8-4 Again, if we go by the Whyte condition, Whyte system of classification of the locomotives of the wheel configuration then 2-8-2 means they have 2 front wheels, 8 medium or central wheels and 2 trailer wheels, in case of the first locomotives whereas in the case of the second locomotives we have 2 front wheels, 8 central condition wheels which are electrically driven, which are driven for the movement of the locomotives and then in this case we have 4 trailing wheels.

Locomotives may have two or three sets of coupled power driving axles



2-8-8-2 (Mallet) Type

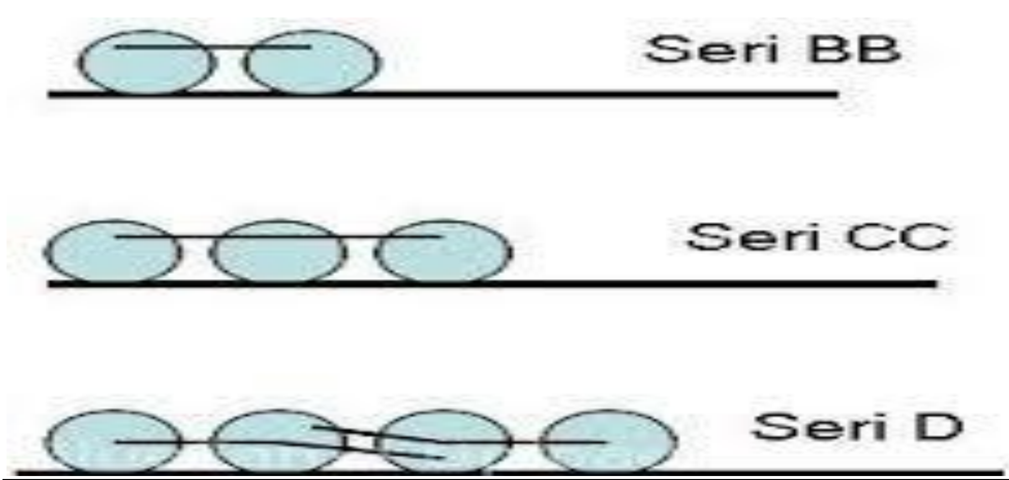
Here the examples have been taken is 2-8-8-2. This 2-8-8-2 indicates that there are 2 sets of 4 driving axles. When we say there are 2 sets of 4 driving axles, it means we are having 8 wheels in one set and 8 wheels again in another set. That is why in the central location we are having 8 and 8, still we have 2 trailing and 2 front wheels been provided which are not being given any driving conditions or they are not been coupled together. Similarly, there is an example of 2-6-6-6-2, and in this case there are 3 sets of 3 driving axles each.

European arrangement

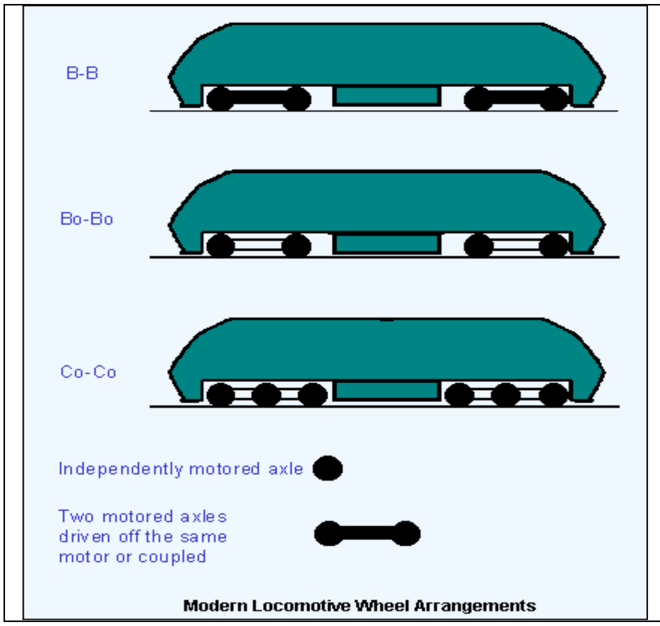
The European arrangement says that they count the axles then the wheels. As we have taken the example previously, here it was 2-4-2 condition where the wheels were counted with 2 front, 4 central and 2 trailing wheels. Here in this case, it will be transformed into 1-2-1 where there is 1 axle in the front condition, 1 axle in the trailing condition and there are 2 axles which have been connected to the power. So, that is why it is 1-2-1 or 1 dash 2 dash 1.

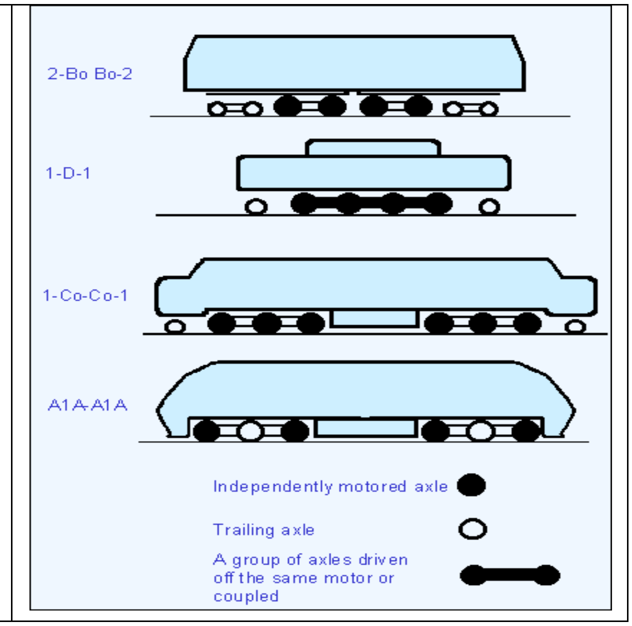
Electric and diesel locomotives wheel arrangement

In the case of diesel and electric locomotives, the wheel arrangements are more or less similar in nature. In these cases the powered axles are described using letters and unpowered axles if any there are indicated by the digits. Now in this case, the various digits we are using have been shown here. We can use A, B, C and D depending on the type of the conditions for which the vehicle or the locomotives or the wheel arrangements has to be identified. In case we are using A, it means it is single powered axle on a bogie. A bogie is a base which is provided at the base of the locomotives, which provides the motive power to the locomotive. Therefore, the locomotive has two structures; one is the upper structure on which the rest of the things have been placed and there is a bogie which is a supporting structure which has a powered axle and through which it will be moving.



Similarly, there is another case which is termed as ‘Bo’. ‘Bo’ means there are set of two independently powered axles on a bogie. These two independently powered axles on a bogie, they are a not a coupled condition. In the case of the coupled conditions the power will be use to transfer the traction to the axles which has been attached to it whereas in this case the power will be given separately to the different axles. Similarly, the third condition is 'Co'. In case of the 'Co', the set of three independently powered axles are placed in the same bogie. Then 'Do' or 'D', it denotes a set of four powered axles. So, this is a case where we are having a single bogie condition and in that single bogie condition these abbreviation have to be used. In case we are having more than one bogie system, there are two set bogie or three bogies being placed for the C locomotives, then the combination of all these alphabets can be used. The representations are understood by seeing the figures below





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Track capacity

- Track capacity is defined as the number of trains that can be handled or run safely on a track per hour.
- It is the number of trains which can move per direction per track.

Track capacity can be enhanced by

i. Achieving faster movement of trains on tracks
ii. Decreasing the distance between trains

Some more measures include

Improving the existing track

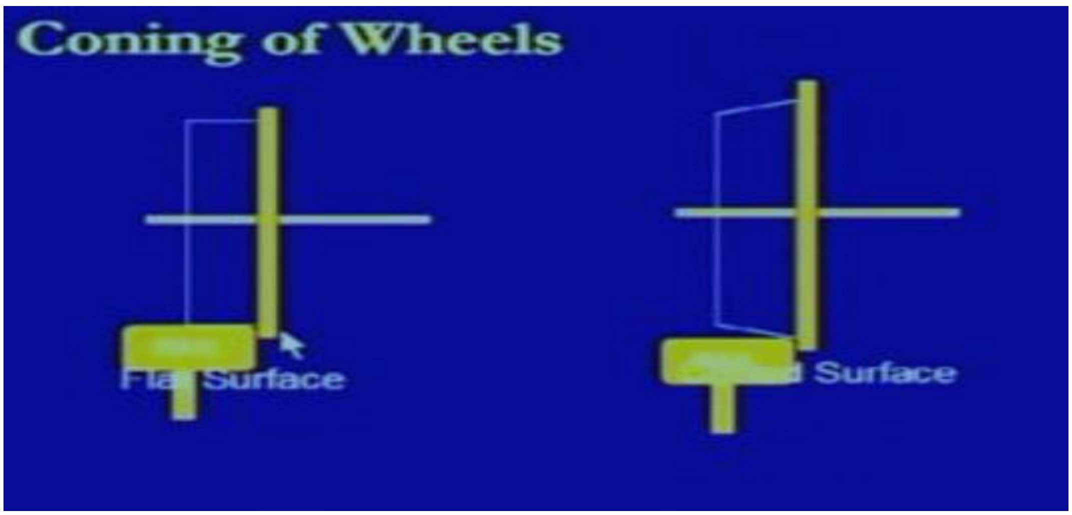
Electronic control and signalized arrangements

Use centralized monitoring control systems for monitoring safety

Availability of relief mechanisms in case of mis happenings

Coning of Wheels

It is provision of conical surface or slopped surface to the wheel to overcome various disadvantages like sway, wear and tear which occur during the movement of locomotives and transfer their load to rails.



<u>Advantages of coning of wheels</u>

<u>Reduces effect of lateral sway</u> when you have been moving on any train it can be sometimes noticed that the train compartment vibrates in the sideward directions. When that compartment is moving in the sideward directions, that is, what is the lateral sway which is coming. As soon as there is a lateral sway, what happens is that it will create a condition of wearing of the flanges, at the same time it will also create the wearing of the side of the rail head. So, this is the one of the drawbacks of the flat wheels.

<u>Smooth movement on curved sections</u> Another condition which we can look at is in terms of the curved sections of the tracks. In the case of the curved sections of the tracks, if we take the radius of the curves of the wo rail sections which have been placed parallel to each other on the curved section then what we found is that the radius of the inner condition is smaller than the radius of the outer condition and therefore when it transforms into the circumference there is a more distance which needs to be moved on the outer rail condition as compared to the inner rail condition.

CONING OF WHEELS & TILTING OF RAILS

- Disadvantages.
  - more tendencies to wear at inner edges.
  - Gauge tends to widen out.
  - If no base plates are provided, sleepers under outer edge get damaged.
- Tilting of Rails. To reduce the damaging effects, rails are tilted inwards with 1:20 slope. Sleepers are cut inwards to achieve tilt of rails, and this is called 'adzing' of wooden sleepers. The advantages are: -
  - Gauge remains maintained.
  - Wear of head is uniform.
  - Increased life of sleepers and rails.

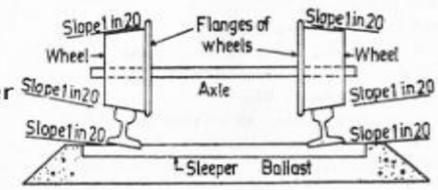


Fig. 1.2 *Coning of wheels on level track*

Permanent way

it is defined as rail road's on which the train runs or in a more detailed form, we can define it in the form of it consists of two parallel rails which are placed at a specified distance in between them and which are fastened to the sleepers, which are embedded in a layer of ballast of specified thickness is spread over the formation.

It means any permanent way consists of certain components and those components are the rails, the sleepers, the fastenings, the ballast and the formation level.

RAILS

Rails are the members of the track laid in two parallel lines to provide an unchanging, continuous, and level surface for the movement of trains. To be able to withstand stresses, they are made of high-carbon steel.

FUNCTION OF RAILS

Rails are similar to steel girders. They perform the following functions in a track:

(a) Rails provide a continuous and level surface for the movement of trains.

(b) They provide a pathway which is smooth and has very little friction. The friction between the steel wheel and the steel rail is about one-fifth of the friction between the pneumatic tire and a metal road.

(c) They serve as a lateral guide for the wheels.

(d) They bear the stresses developed due to vertical loads transmitted to them through axles and wheels of rolling stock as well as due to braking and thermal forces.

(e) They carry out the function of transmitting the load to a large area of the formation through sleepers and the ballast.

TYPES OF RAILS

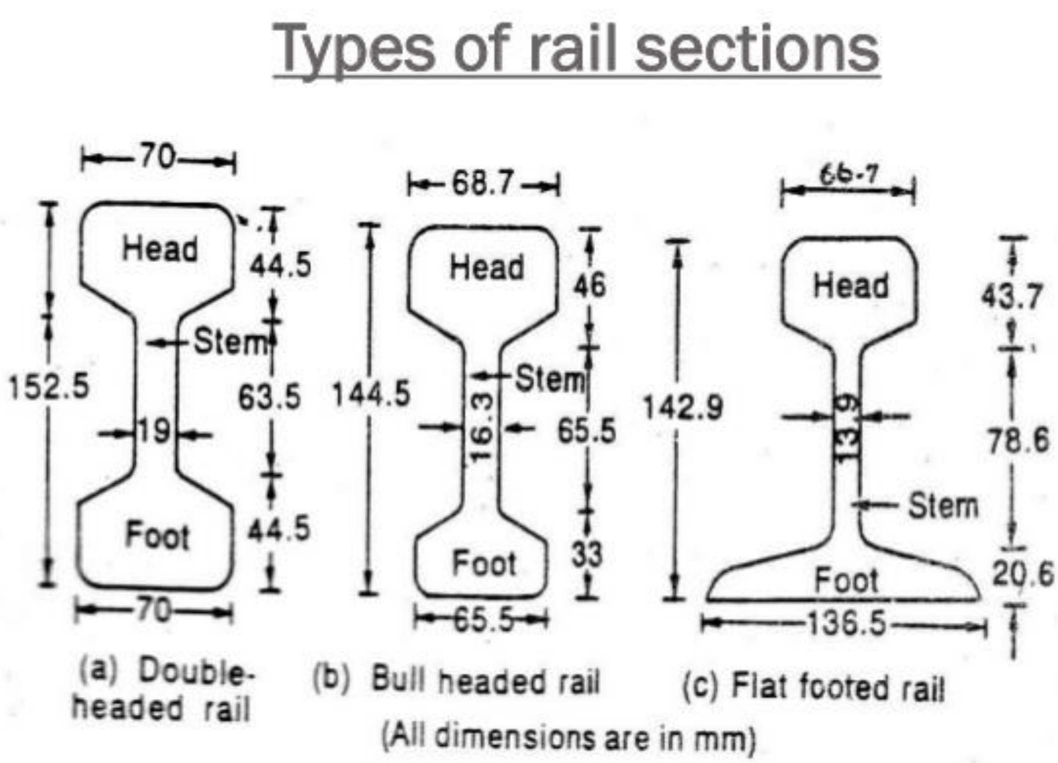


Fig.2.1 Rail Sections

REQUREMENTS OF AN IDEAL RAIL SECTION

The requirements of an ideal rail section are as follows:

(a) The rail should have the most economical section consistent with strength, stiffness, and durability.

(b) The centre of gravity of the rail section should preferably be very close to the mid-height of the rail so that the maximum tensile and compressive stresses are equal.

(c) A rail primarily consists of a head, a web, and a foot, and there should be an economical and balanced distribution of metal in its various components so that each of them can fulfill its requirements properly. The requirements, as well as the main considerations, for the design of these rail components are as follows:

Head: The head of the rail should have adequate depth to allow for vertical wear. The rail head should also be sufficiently wide so that not only is a wider running surface available, but also the rail has the desired lateral stiffness.

Web: The web should be sufficiently thick so as to withstand the stresses arising due to the loads bore by it, after allowing for normal corrosion.

Foot The foot should be of sufficient thickness to be able to withstand vertical and horizontal forces after allowing for loss due to corrosion. The foot should be wide enough for stability against overturning. The design of the foot should be such that it can be economically and efficiently rolled.

Fishing angles These must ensure proper transmission of loads from the rails to the fish plates. The fishing angles should be such that the tightening of the plate does not produce any excessive stress on the web of the rail.

Height of the rail The height should be adequate so that the rail has sufficient vertical stiffness and strength as a beam.

Weight of rails Though the weights of a rail and its section depend upon various considerations, the heaviest axle load that the rail has to carry olavs the most important role. The following is the thumb rule for denning the maximum axle load with relation to the rail section:

Maximum axle load = 560 x sectional weight of rail in Ibs per yard or kg per meter

• For rails of 90 Ibs per yard,

Maximum axle load = 560 x 90 Ibs = 50,400 Ibs or 22.5 tones

• For rails of 52 kg per m,

Maximum axle load = 560 x 52 kg = 29.12 tones

• For rail of 60 kg per m,

Max. axle load for 60 kg/m rail = 560 x 60 kg = 33.60 tones

LENGTH OF RAILS

Theoretically, the longer is the rail, the lesser would be the number of joints and fittings required and the lesser the cost of construction and maintenance. Longer rails are economical and provide smooth and comfortable rides. The length of a rail is, however, restricted due to the following factors:

(a) Lack of facilities for transport of longer rails, particularly on curves

(b) Difficulties in manufacturing very long rails

(c) Difficulties in acquiring bigger expansion joints for long rails

(d) Heavy internal thermal stresses in long rails

Taking the above factors into consideration, Indian Railways has standardized a rail length of 13 m (previously 42 ft) for broad gauge and 12 m (previously 39 ft) for MG and NG tracks. Indian Railways is also planning to use 39 m, and even longer rails in its track system. Now 65 m/78 m long rails are being produced at SAIL, Bhilai and it is planned to manufacture 130 m long rails.

SLEEPERS

Introduction

Sleepers are the transverse ties that are laid to support the rails. They have an important role in the track as they transmit the wheel load from the rails to the ballast. Several types of sleepers are used on Indian Railways.

FUNCTIONS OF SLEEPERS

The main functions of sleepers are as follows:

(a) Holding the rails in their correct gauge and alignment

(b) Giving a firm and even support to the rails

(c) Transferring the load evenly from the rails to a wider area of the ballast

(d) Acting as an elastic medium between the rails and the ballast to absorb the blows and vibrations caused by moving loads

(e) Providing longitudinal and lateral stability to the permanent way

(f) Providing the means to rectify the track geometry during their service life

REQUIREMENTS OF IDEAL SLEEPERS

Apart from performing these functions the ideal sleeper should normally fulfill the following requirements.

a) The initial as well as maintenance cost should be minimum.

b) The weight of the sleeper should be moderate so that it is convenient to handle.

c) The designs of the sleeper and the fastenings should be such that it is possible to fix and remove the rails easily.

d) The sleeper should have sufficient bearing area so that the ballast under it is not crushed.

e) The sleeper should be such that it is possible to maintain and adjust the gauge properly

f) The material of the sleeper and its design should be such that it does not break or get damaged during packing.

g) The design of the sleeper should be such that it is possible to have track circuiting.

h) The sleeper should be capable of resisting vibrations and shocks caused by the passage of fast moving trains,

i) The sleeper should have anti-sabotage and anti-theft features.

SLEEPER DENSITY AND SPACING OF SLEEPERS

Sleeper density is the number of sleepers per rail length. It is specified as ($M + x$) or ($N + x$), where M or N is the length of the rail in meters and x is a number that varies according to factors such as

(a) axle load and speed,

(b) type and section of rails,

(c) Type and strength of the sleepers,

(d) Type of ballast and depth of ballast cushion, and

(e) Nature of formation.

If the sleeper density is M+ 7 on a broad gauge route and the length of the rail is 13 m, it implies that 13 + 7 = 20 sleepers will be used per rail length of the track on that route. The spacing of sleepers is fixed depending upon the sleeper density. Spacing is not kept uniform throughout the rail length. It is closer near the joints because of the weakness of the joints and impact of moving loads on them. There is, however, a limitation to the close spacing of the sleepers, as enough space is required for working the beaters that are used to pack the joint sleepers.

Types of sleepers and comparison

Characteristics	**Type of sleeper**			
	Wooden	**Steel**	**'CI**	**Concrete**
Service life (years)	12-15	40-50	40-50	50-60
Weight of sleeper for BG (kg)	83	79	87	267

Cost of maintenance	High	Medium	Medium	Low
Damage by white ants and corrosion	Can be damaged by white ants	No damage by white ants but corrosion is possible	Can be damaged by corrosion	No damage by white ants or corrosion
Scrap value	Low	Higher than wooden	High	None

Wooden sleepers and classification

The wooden sleeper is the most ideal type of sleeper, and its utility has not decreased with the passage of time

Durable and Non-durable Types of Sleepers

Wooden sleepers may be classified into two categories, durable and non-durable.

Durable type

Durable sleepers do not require any treatment and can be laid directly on the track. The Indian Railway Board has classified particular categories of sleepers as the durable type. These are sleepers produced from timbers such as teak, sal, nahor,rosewood, anjan, kongu, crumbogam kong, vengai, padauk, lakooch, wonta, milla, and crul.

Non-durable

If a non-durable type of sleeper is put onto the track directly without any preservative treatment, the sleeper will decay in a very short time. If, however, such sleepers are treated before use, they last longer and their life is comparable to that of durable sleepers. Fir sleepers, however, have not provided good service and
their use has been restricted to only those trunk routes and main lines where traffic density is not more than 10 GMT [gross million tonne(s) per km/annum]. The primary service life of a wooden sleeper is approximately as follows:

TYPE	BG	MG
Durable	19 years	31 years
Non-durable	12.5 years	15.5 years

Seasoning of sleepers

Wooden sleepers are seasoned to reduce the moisture content so that their treatment is effective. The Indian Standard code of practice for preservation of timber lays down that the moisture content in the case of sleepers to be treated by pressure treatment should not be more than 25%.

Steel sleepers and classification

All steel sleepers conforming to Indian Railways specifications T-9 are classified as first quality sleepers. The sleepers not accepted as first quality but free from the following defects are termed second quality steel trough sleepers.

(a) Inward tilt at rail seat beyond the limits of 1 in 15 to 1 in 25

(b) Sleepers with a twist

(c) Heavy scale fitting or deep grooves or cuts

(d) Deep guide marks at heads, blisters, etc.

Adzing of Wooden Sleepers

In order to enable the rails to be slightly tilted inwards at a cant of 1 in 20, wooden sleepers are required to be cut to this slope at the rail seat before laying. This process of cutting the wooden sleeper at a slope of 1 in 20 is known as ‘adzing of the wooden sleeper’.

It may be pointed out that adzing or cutting of a wooden sleeper at a slope of 1in 20 is done with great care, otherwise the slope will vary from sleeper to sleeper resulting in a rough ride. The adzed surface of a wooden sleeper is treated with coal tar or creosote to ensure proper protection of the surface. Normally, adzing ofa wooden sleeper is done only when bearing plates are not provided.

BALLAST AND BALLAST REQUIREMENTS

Introduction

Ballast is a layer of broken stones, gravel, rnorrum, 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.

FUNCTIONS OF BALLAST

The ballast serves the following functions in a railway track

. • It provides a level and hard bed for the sleepers to rest on.

• It holds the sleepers in position during the passage of trains

. • It transfers and distributes load from the sleepers to a large area of the formation.

• It provides elasticity and resilience to the track for proper riding comfort.

• It provides the necessary resistance to the track for longitudinal and lateral stability.

• It provides effective drainage to the track.

• It provides an effective means of maintaining the level and alignment of the track.

TYPES OF BALLAST The different types of ballast used on Indian Railways are described here.

Sand ballast Sand ballast is used primarily for cast iron (CI) pots. It is also used with wooden 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. 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 it should be porous nor it flake off due to the weathering. 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.

SIZES OF BALLAST

Previously different sizes of ballast are used for various conditions and are as listed below

Condition	**Size**
Flat-bottom sleepers such as concrete and wooden sleepers	50 mm (2")
for metal sleepers such as CST-9 and trough sleepers.	40 mm (1.5")
Points and crossings (They are subjected to heavy blows of moving loads)	25 mm (1")

Now, to ensure uniformity, 50 mm (2") ballasts have been adopted universally for all types of sleepers.

REQUIREMENTS OF 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 economical.

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.

For the even distribution of load on the formation, the depth of the ballast is determined by the following formula:

Sleeper spacing = width of the sleeper + 2 x depth of ballast

FORMATION

Introduction

Sub grade is the naturally occurring soil which is prepared to receive the ballast. The prepared flat surface, which is ready to receive the ballast, along with sleeps and rails, is called the formation. The formation is an important constituent of the track, as it supports the entire track structure. It has the following functions:

(a) It provides a smooth and uniform bed for laying the track.

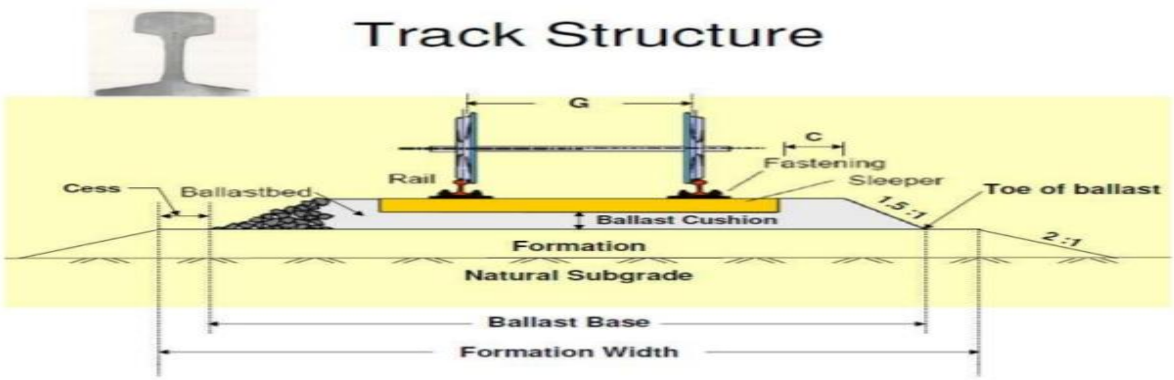
(b) It bears the load transmitted to it from the moving load through the ballast

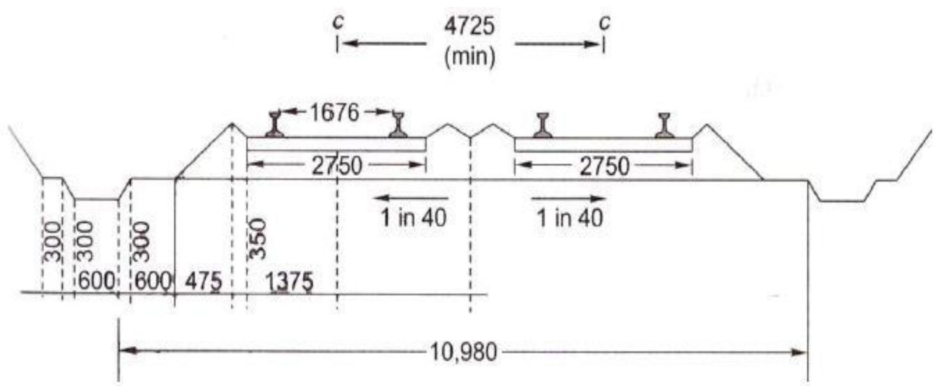
(c) It facilitates drainage.

(d) It provides stability to the track.

GENERAL DESCRIPTION OF FORMATION

The formation can be in the shape of an embankment or a cutting. When formation is in the shape of a raised bank constructed above the natural ground, it is called an *embankment.* The formation at a level below the natural ground is called a *cutting.* Normally, a cutting or an excavation is made through a hilly or natural ground for providing the railway line at the required level below the ground level. The formation (Fig. below) is prepared either by providing additional earthwork over the existing ground to make an embankment or by excavating the existing ground surface to make a cutting. The formation can thus be in the shape of either an embankment or a cutting. The height of the formation depends upon the ground contours and the gradients adopted. The side slope of the embankment depends upon the shearing strength of the soil and its angle of repose. The width of the formation depends upon the number of tracks to be laid, the gauge, and such other factors.





(b) Cross section of cutting

Typical cross section of bank and cutting for BG double line (dimensions in mm)

Slopes of Formation The side slopes of both the embankment and the cutting depend upon the shearing strength of the soil and its angle of repose. The stability of the slope is generally determined by the *slip circle method.* In actual practice, average soil such as sand or clay may require a slope of 2:1 (horizontal: vertical) for an embankment and 1:1 or 0.5:1 or even steeper particularly when rock is available for cutting.

To prevent erosion of the side slopes due to rain water, etc., the side slopes are turfed. A thin layer of cohesive soil is used for this purpose. Alternatively, the slopes are turfed with a suitable type of grass. Sometimes the bank also gets eroded due to standing water in the adjoining land. A toe and pitching are provided in such cases.

- **Requirement of Good Track** A permanent way or track should provide comfortable and safe ride at the maximum permissible speed with minimum maintenance cost. To achieve these objectives, a sound permanent way should have the following characteristics:
- The gauge should be correct and uniform.
- The rail should have perfect cross levels. In curves, the outer rail should have proper super elevation to take into account the centrifugal force.
- The alignment should be straight and free of kinks. In the case of curves, a proper transition should be provided between the straight track and the curve.
- The gradient should be uniform and as gentle as possible. The change of gradient should be followed by a proper vertical curve to provide a smooth ride.
- The track should be resilient and elastic in order to absorb the shocks and vibration of running trains.
- The track should have a good drainage system so that the stability of the track is not effected by water logging.
- The track should have good lateral strength so that it can maintain its stability despite variations in temperature and other such factors.
- There should be provisions for easy replacement and renewal of the various track components.
- The track should have such a structure that not only is its initial cost low, but also its maintenance cost is minimum.

REQUIREMENTS OF AN IDEAL PERMANENT WAY

The following are the principal requirements of an ideal permanent way or of a good railway track :-

i. The gauge of the permanent way should be uniform, correct and it should not get altered.

ii. Both the rails should be at the same level on tangent (straight) portion of the track.

iii. Proper amount of *superelevation* should be provided to the outer rail above the inner rail on curved portion of the track.

iv. The permanent way should be sufficiently strong against lateral forces.

v. The curves, provided in the track, should be properly designed.

vi. An even and uniform gradient should be provided through out the length of the track.

vii. The *tractive resistance* of the track should be minimum.

viii. The design of the permanent way should be such that the load of the train is uniformly distributed on both the rails so as to prevent unequal settlement of the track.

ix. It Should provide adequate elasticity in order to prevent the harshness of impacts between the rails and the moving wheel loads of a train.

x. It should be free from excessive rail joints and all the joining should be properly designed and constructed.

xi. All the components parts such as *rails, sleepers, ballast, fixtures* and *fastenings,* etc. should satisfy the design requirements.

xii. All the fixtures and fastenings such as *chairs, bearing plates, fish plates, fish bolts, spikes* etc. should be strong enough to withstand the stresses occurring in the track.

xiii. All the **points and crossings,* laid in the permanent way, should be properly designed and carefully constructed.

xiv. It should be provided with fence near *level crossings* and also in urban areas.

xv. It should be provided with proper drainage facilities so as to drain off the rain water quickly away from the track.

xvi. It should be provided with safe and strong bridges coming in the alignment of the track.

xvii. It should be provided with safe and strong bridges coming in the alignment of the track.

xviii. It should be so constructed that repairs and renewals of any of its portion can be carried out without any difficulty.

CREEP

The creep can be defined as the longitudinal movement of rails in a track

Creep is location specific. We may not found a creep that is the longitudinal movement of the rails happening along whole of the length of the railway track. It is mostly being found only at a certain specific location

The magnitude of the creep at one point is not necessarily is the same at the other point.

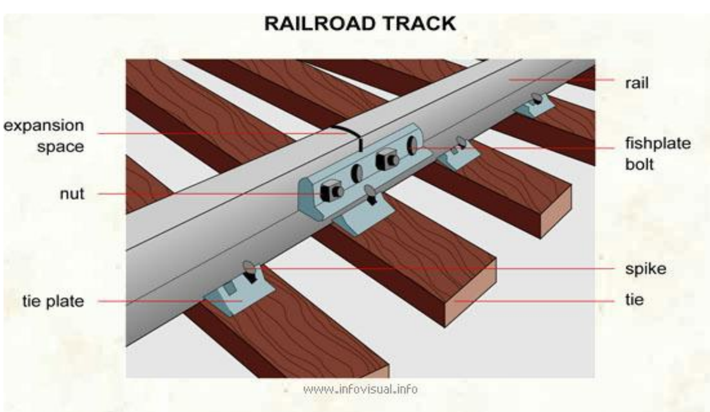
Creep Indicators

The following symptoms indicate creep over a rail section

Closing of joints in the direction of creep In the creep effected location the first rail is trying to move in to that gap which is being provided at this joint and that is how the closing of the joint will happen in the direction of creep.

Opening of joint at point from where the creep starts It is another end of rail section which is moving. At one end of rail section it is trying to close the joint at which it is being jointed with the other rail section whereas when it is trying to move in one direction obviously on the other end of that rail section it will try to open out.

Note: Expansion joints are as shown in below figure



Scrapping or scratching marks on the rail flanges or the webs due to spike head.

The rail sections are being fastened to sleepers and the spike head is one of the fastener which tries to fix the rail section to the sleeper. Now if there is any movement in the rail section the spike head tries to remain in its position and because it is abetting with the flange or the web of the rail section it will start putting the scrapping or the scratching mark on that section because of the movement of the rail

CAUSES OF CREEP

The main factors responsible for the development of creep are as follows.

Ironing effect of the wheel The ironing effect of moving wheels on the waves formed in the rail tends to cause the rail to move in the direction of traffic, resulting in creep.

Starting and stopping operations When a train starts or accelerates, the backward thrust of its wheels tends to push the rail backwards. Similarly, when the train slows down or comes to a halt, the effect of the applied brakes tends to push the rail forward. This in turn causes creep in one direction or the other.

Changes in temperature Creep can also develop due to variations in temperature resulting in the expansion and contraction of the rail. Creep occurs frequently during hot weather conditions. **Unbalanced traffic** In a double-line section, trains move only in one direction, i.e., each track is unidirectional. Creep, therefore, develops in the direction of traffic. In a single-line section, even though traffic moves in both directions, the volume of traffic in each direction is normally variable. Creep, therefore, develops in the direction of predominant traffic.

Poor maintenance of track Some minor factors, mostly relating to poor maintenance of the track, also contribute to the development of creep.

These are as follows:

• Improper securing of rails to sleepers

• Limited quantities of ballast resulting in inadequate ballast resistance to the movement of sleepers

• Improper expansion gaps

• Badly maintained rail joints

• Rail seat wear in metal sleeper track

• Rails too light for the traffic carried on them

• Yielding formations that result in uneven cross levels

• Other miscellaneous factors such as lack of drainage, and loose packing, uneven spacing of sleepers

Ill effects of creep

- Opening or jamming of joints
- Kink formation at joints
- Sleepers get out of position-It affects gauge and alignment
- Bucking of trains- It can derail the train
- Points, crossing, switches, interlocking gets distorted

Theories related to creep

There are different theories which have been postulated by different researchers.

They found there are three major theories which are best among them.

- Wave theory
- Percussion theory
- Drag theory

Wave Theory

The wave theory says that there are certain moving wheels and these loads set a wave motion in the rails. Now whatever wheels are moving on the rail section obviously they are putting the load, they are transferring loads from the top to the rail section. Now when this load is being transferred to the rail section it says that some sort of a wave motion will get induced because of this loading coming from the top. Now what happens is a vertical reverse curve is formed ahead of wheels in the rails. At the point of location application of the load the rails will get depressed or deformed or deflected in the downward direction. When this are getting deflected or deformed in the downward direction, that is, deflection is there then what will happen is a vertical reverse curve will get formed. So if we take this rail section in a continuous form, it will be acting as a vertical reverse curve. We were looking at this aspect in the diagrammatic form also and then as the wheel moves this reverse curve will be moving which is there in the front of the moving load, it will be carried forward. Now when this reverse curve is being carried forward it will cause the creep of the rail because the rail will start trying to move in the forward direction.

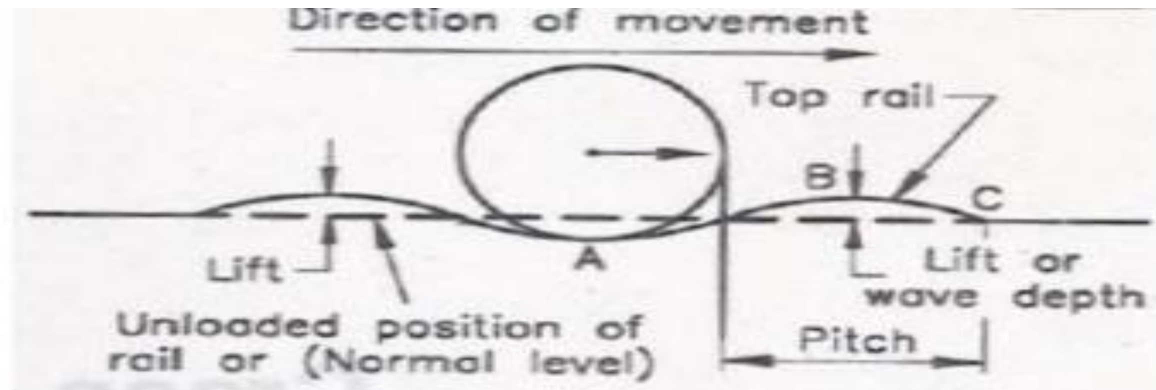


Fig. 8.2. Wave Theory of Creep (Formation of Wave)

This is how wave theory is explains creep in rails. It can be understood by above diagramThis is the normal rail level at this point. The dotted line is showing the normal level of the rail at which this wheel was placed. Now because of the loading condition there is this much deflection being caused in the rail section. So the rail section has gone down like this at point A that is the point of application of the loading. Now when this has gone down in this form what is going to happen is a reverse curve gets formed like this. This is a reverse curve; it is having a reverse curvature on this side as well as on this side. This curvature is having a point of center on this direction whereas this curvature is having a point of center in this direction, that is why this is a reverse curve condition. So we have a reverse curve here and in this reverse curve just before this wheel section, that is, at this location and just as well as in the front of this wheel at this location what we are finding is that the this rail section is going above the normal level of the rail. Now when this rail section is going above the normal level of the rail then this is what is the amount of lift which will be there with respect to the normal rail section whereas this is the amount of depression which will be there at this location because of the loading condition due to this wheel. So the distance between this point and this one is termed as the pitch whereas this is the total overall depth is taken from this point to this point so that will be the depth of total by which this rail section is going to be deflected and we have to look at this wave depth

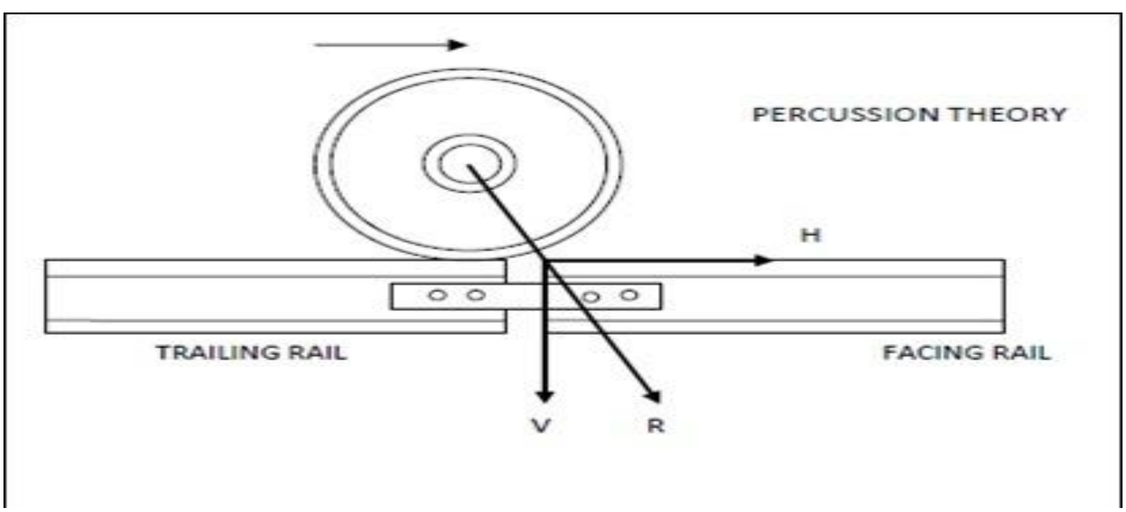
Wave action is controlled by pitch and depth of wave

Pitch and depth of wave depends on track modulus, track stiffness and track stability

percussion theory

The percussion theory states that the creep is due to impact of wheels at the rail end ahead at joints.

Let us say there are 2 rail sections which have been jointed together using fish plates and fish bolts. At this location as soon as any wheel comes it will strike on the rail section which is placed in the forward direction. So if it is going to strike at the rail end of the rail which is provided in the forward direction then that rail will move in the forward direction because of a horizontal component of the thrust and this is the reason due to which the creep will get induced in the rail section. So at the rail joint the wheel load presses the trailing rail down thus causing an impact of wheel with the forward rail. So this is the reason which will be causing the creep in the rail section.



Drag Theory

According to drag theory, the backward thrust of the driving wheels of a locomotive has the tendency to push the rail backwards, while the thrust of the other wheels of the locomotive pushes the rail in the direction in which the locomotive is moving. This results in the longitudinal movement of the rail in the direction of traffic, Thereby causing creep.

Portions of Track Susceptible to Creep

The following locations of a track are normally more susceptible to creep.

(a) The point where a steel sleeper track or CST-9 sleeper track meets a wooden sleeper track

(b) Dips in stretches with long gradients

(c) Approaches to major girder bridges or other stable structures

(d) Approaches to level crossings and points and crossings