

NOTES ON

PERMANENT WAY



Compiled by
YUKTI VERMA
Chief Instructor/IRTMTTC

PROMOTIONAL COURSE – PROMOTIONAL TECHNICIAN-III

Course No.CE 29

Module No.29.1

SUB: Introduction to Railway Organization, P.Way and Track Machines

Duration: = 16 Periods

Sub-discipline	Lesson	Session wise Contents	Period	Total Period
Track Technology	Introduction to Railway Organization	History of Railways, Zonal Railways, Divisions	1	2
		TT Organization, CPOH.	1	
	Railway Track	Constituents of Railway Track. Formation , Ballast	1	2
		Requirements of Good Railway Track, Classification of Routes. Different Gauges.	1	
	Rails, Sleepers and fastenings	Functions, Types & Standard Rail Section Standard length, Rolling marks & UTS Functions, Types & Sleeper Density	1	2
		Requirements of PRC sleepers-their and disadvantages. Rail to Rail fastenings Rail to Sleeper fastenings Functions & Specifications	1	
	Points & Crossings	Functions & Important terminology	1	2
		Constituents of Turnout. Switch Angle, Flange way clearance	1	
	Welding of Rails & LWR	Heel divergence, Throw of switch Types of Crossings, Crossing number & Main constituents of Built-up Crossing.	1	2
		Evil effects of Rail joints, Different types of welding.	1	
	Engineering Restrictions & Indicators	Development of Welded rails, welding Terminology	1	2
		Emergency Protection of track: Single Line& Double Line	1	
Track Machines	Curves	Detonators & Flare Signals.	1	2
		Necessity of curves: their types, TTP, CTP & Transition lengths, Radius, Degree, Versine & Field	1	
	Types of Track Machines	Measurement. Super-elevation Cant deficiency, Cant excess, Cant gradient, Equilibrium cant.	1	2
		Introduction of Track Machines in chronological order	1	
		Their functions and output.	1	
		Total	16	16

Introduction to Railway Organization

History of Railways and General Features

History of Railways:

The history of railways is closely linked with the growth of civilization of mankind. In 15th century stone slabs or wooden baulks were laid flush with the road surface for carriage of heavy goods loaded on carts and drawn by animal. These were called “Tram ways”. These Tram ways were extensively used in 16th century in mines in central Europe for carriage of coal and other minerals.

The timber bulks were replaced by iron plates to reduce wear and these were called „Plate ways“. These iron plates were also substituted in course of time by angle irons to give lateral support or better safety. The present railway track is a gradual evolution from these „Plate ways.“

The first public railway in the world was opened to traffic on 27th September, 1825, when the first train made its maiden journey between Stockton and Darlington in U.K.

The maiden trip on Indian Soil of the first train consisting of one steam engine and 4 coaches was made on 16th April 1853, when it traversed a 21 mile stretch between Bombay and Thana in 1.25 hours time. Starting from this humble beginning, the Indian railways system has grown up today into a giant network consisting of 65000 route Kms.

The Indian Railways run about 13,000 trains every day, serving about 8000 railway stations and carry about 5112 million passengers and about 581 million tonnes of goods traffic in a year. For moving this traffic, the Indian Railways deploy about 15, 40,000 (15.40lakh) employees and maintain 7,817 locomotives consisting.

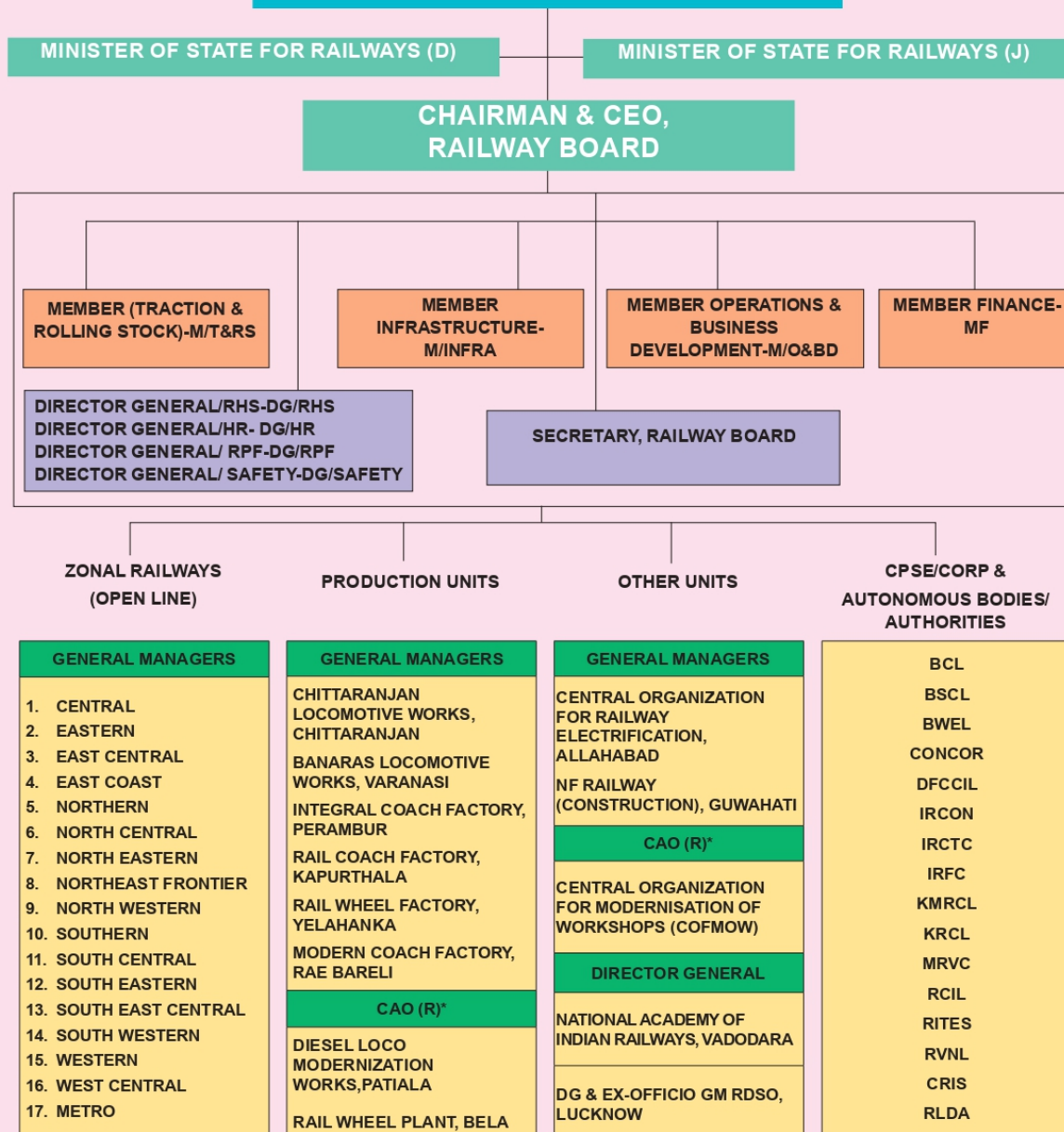
Railway Board:

The responsibility of the administration and management of the Indian Railways rests with the Railway Board under the overall supervision of the minister for railways. The Railway Board consists of Chairman, financial commissioner for railways and five other functional members.

The other members of the railway Board are separately incharge of matters relating to staff, Civil Engg., Traffic, Mechanical Engg. & Electrical Engg. They function as ex-officio secretaries to the Government of India. The board members are assisted by additional members, executive directors & directors. The organization chart is as below:

ORGANIZATION STRUCTURE OF INDIAN RAILWAYS

MINISTER OF RAILWAYS



*CHIEF ADMINISTRATIVE OFFICER (RAILWAYS)

INDIAN RAILWAYS ANNUAL REPORT AND ACCOUNTS 2020-21

Zonal Railways details & Divisions:

The entire railway system has been divided into 17 zones. Zonal Railways work on divisional system. Each division has around 800 to 1500kms of track. There are 68 divisions on Indian railways. Each division works under the overall Control of Divisional Railway Manager (DRM) who is assisted by ADRM. In Engineering the division is headed by Sr. Divisional Engineer(C) and he is assisted by Sr.DEN/DENs. Each Sr. DEN/DEN is incharge of around 1100 ITKM & has 2-3 ADENS to assist him in maintenance of P. Way & Works. The details of zones and zonewise break up of divisions over Indian Railways are listed as below:

Sl. No	Name	Abbreviation	Date Established	Headquarters	Divisions
1.	Central	CR	5 November 1951	Mumbai	Mumbai, Bhusawal,Pune, Solapur, Nagpur
2.	East Central	ECR	1 October 2002	Hajipur	Danapur, Dhanbad, Mughalsarai, Samastipur, Sonpur
3.	East Coast	ECoR	1 April 2003	Bhubaneswar	Khurda Road, Sambalpur and Waltair (Visakhapatnam)
4.	Eastern	ER	April 1952	Kolkata (Fairle Place)	Howrah, SealDAH, Asansol, Malda
5.	North Central	NCR	1 April 2003	Allahabad	Allahabad, Agra, Jhansi
6.	North Eastern	NER	1952	Gorakhpur	Izzatnagar, Lucknow, Varanasi
7.	North Western	NWR	1 October 2002	Jaipur	Jaipur, Ajmer, Bikaner, Jodhpur
8.	Northeast Frontier	NFR	15 January 1958	Guwahati	Alipurduar, Katihar, Rangia, Lumding, Tinsukia

9.	Northern	NR	14 April 1952	Delhi	Delhi, Ambala, Firozpur, Lucknow, Moradabad
10.	South Central	SCR	2 October 1966	Secunderabad	Vijayawada, Hyderabad, Guntakal, Guntur, Nanded, Secunderabad
11.	South East Central	SECR	1 April 2003	Bilaspur	Bilaspur, Raipur, Nagpur
12.	South Eastern	SER	1955	Kolkata(Garden Reach)	Adra, Chakradharpur, Kharagpur, Ranchi
13.	South Western	SWR	1 April 2003	Hubli	Hubli, Bangalore, Mysore
14.	Southern	SR	14 April 1951	Chennai	Chennai, Trichy, Madurai, Salem, Palakkad, Thiruvananthapuram
15.	West Central	WCR	1 April 2003	Jabalpur	Jabalpur, Bhopal, Kota
16.	Western	WR	5 November 1951	Mumbai	Mumbai Central, Ratlam, Ahmedabad, Rajkot, Bhavnagar, Vadodara
17.	Kolkata Metro Railway	KMR	29 December 2010	Chitpur(Kolkata)	Kolkata metropolitan area, South 24 Parganas, North 24 Parganas

Summary:

History of Railways:

Railway history is closely linked with the growth of civilization of mankind.

Growth of Railways:

- ☞ In 15th century stone slabs or wooden baulks were laid flush with the road surface for carriage
- ☞ Of heavy goods loaded on carts and drawn by animal. These were called “Tram ways”.
- ☞ These Tram ways were extensively used in 16th century in mines in central Europe for carriage of coal and other minerals.
- ☞ The timber bulks were replaced by iron plates to reduce wear and these were called ‘Plate ways’. These iron plates were also substituted in course of time by angle irons to give lateral support or better safety.
- ☞ The present railway track is a gradual evolution from these ‘Plate ways.’

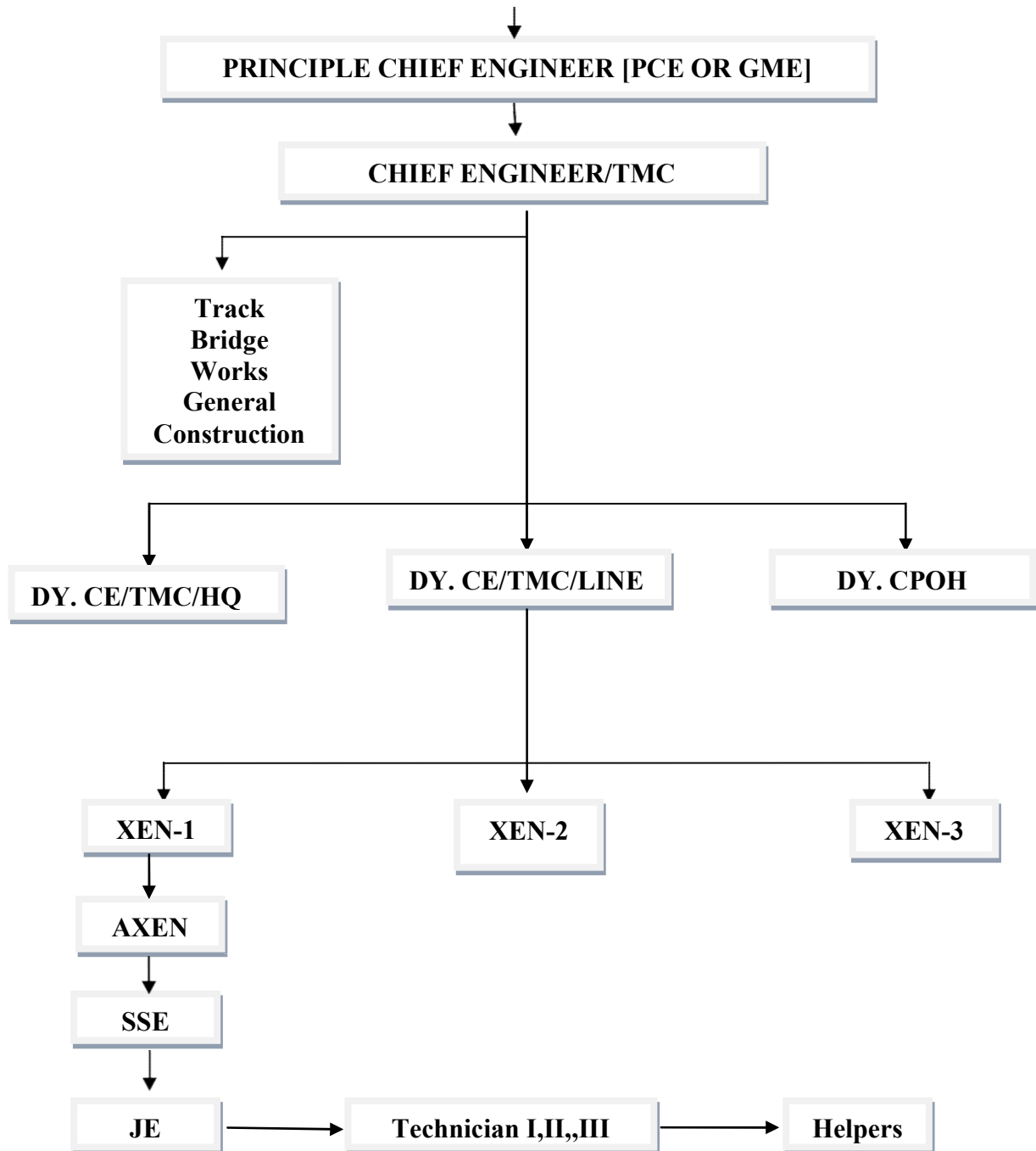
Public Railway Service

- ☞ The first public railway in the world was opened to traffic on **27th September, 1825**, when the first train made its maiden journey between **Stockton and Darlington in U.K.**

First Rail Trip in India

- ☞ The first train consisting of one steam engine and 4 coaches made its debut run on **16th April 1853**, for a Stretch of **21 miles (33.796 Kms)** between **Bombay and Thana** in **1.25 hours time**.

Zonal Railway Organization Chart for Track Machine Department:



TT Organization on Indian Railways

The organization shall be under the overall charge of Chief Track Engineer (Machines) of the Railway who shall be reporting to the Chief Engineer through Chief Track Engineer. The organization shall be responsible for the following functions:

- i. Field operation of track machines,

- ii. Repair and maintenance of machines,
- iii. Supervision and technical services including training, and
- iv. Planning and deployment of machines.

To carry out each of the above functions, chief Track Engineer (Machine) shall be assisted by one or more Deputy CE (Machine). It is already shown in the previous organizational chart.

DUTIES OF AEN:

GENERAL:

The Assistant Engineer is responsible for maintenance and efficient working of all the track machines in his charge.

IMPORTANT DUTIES:

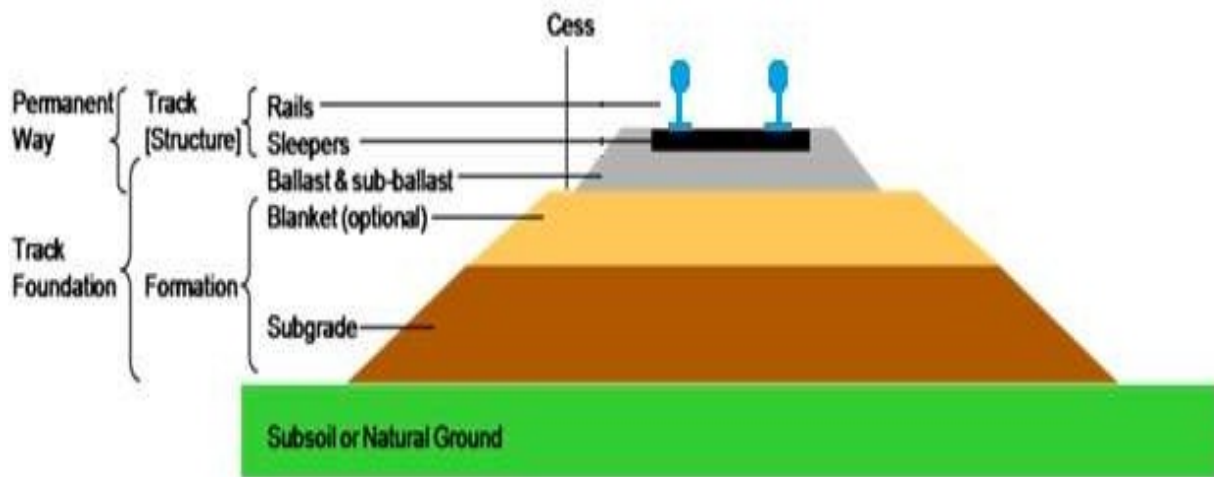
- Inspection and maintenance of all machines.
- Ensure adherence to stipulated maintenance schedules.
- Ensure availability of necessary staff for operation.
- Ensure achievement of stipulated target.
- Ensure adequate availability of consumables and spares.
- Initiate proposals and plans for major schedule of work.
- Ensure co-ordination with other units of engineering department.
- Verification of store.
- Ensure maintenance of various records.
- Ensure availability of tools.

DUTIES OF Master Crafts Man (MCM) and Track Machine Maintainers (TMM):

MCMs and TMMs attached with the machine(s) shall assist the SSE/JE/TM in operation and maintenance of track machines. Their main functions are:

- (1) To attend to the daily and weekly maintenance schedules of machine and record the compliance in log book. To attend and assist service checks by the service engineers.
- (2) To attend to breakdown and repairs of machines in block with due urgency.
- (3) To keep in his custody the various tools, plants and equipment necessary to attend repairs and ensure their working condition.
- (4) To attend to the repairs and maintenance of machines including during IOH and POH.
- (5) To guide and supervise the machine assistants and other staff in attending to the maintenance/repairs.
- (6) To remain vigilant during movement and working of machine and to inform the concerned SSE/JE/TM of any abnormalities.
- (7) To ensure safety of the machine and staff working at machine site.
- (8) Accompany the machines during shifting as directed, especially T-28 machine and PQRS portals.
- (9) Any other work assigned to him by the SSE/JE/TM.
- (10) MCMs and TMMs posted in depots and work areas other than machines will perform duties assigned by their controlling officials.

1. RAILWAY TRACK:

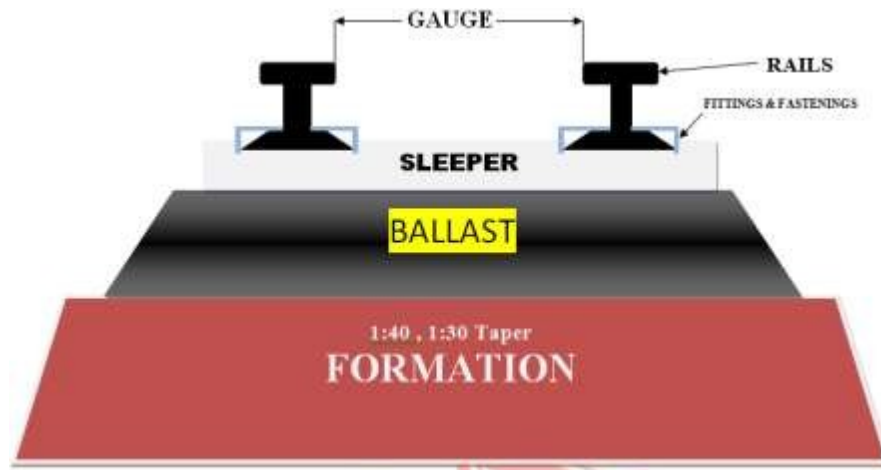


It is a rail road on which the train runs.

It is also called permanent way. It basically consists of two parallel rails having specified distance in between them and fastened to sleepers which are embedded in the layer of ballast, which is spread over formation.

Rail are joined to each other longitudinally by fish plates by end to end and fastened to sleeper by various fittings. Sleepers are placed at a specified distance and are held in position by embedding in the ballast.

Track Gauge:



The perpendicular distance between inner faces of rail is called gauge. It is measured 13mm below from rail top. The Indian Railways operate in three different gauges mainly Broad Gauge (1676mm), Meter Gauge (1000mm), and Narrow Gauge (762mm & 610mm) wide. The broad gauge accounts for nearly 94.6% followed by meter gauge 3.1% of the total route length. The gauge of track in India is measured as the minimum horizontal distance between the running or gauge faces of two rails 14mm below from top of rail. The standard gauge is 1435mm

DIFFERENT GAUGES ON INDIAN RAILWAY:

(i) B.G. (broad gauges)	:-	1676 mm
(ii) M.G.(Meter gauges)	:-	1000 mm
(iii) N.G. (Narrow gauges)	:-	762 mm
(iv) Special Narrow Gauge	:-	610 mm
(v) Standard Gauge	:-	1435 mm (Foreign Railways)

2. COMPONENTS OF TRACK:

Following are the main components of the track:-

- (1) Rails
- (2) Sleepers
- (3) Fitting & Fastenings
- (4) Ballast
- (5) Formation

3. REQUIREMENT OF GOOD TRACK:

A permanent way or track should give comfortable & safe ride at maximum permissible speed with minimum cost. For achieving the above objectives a good permanent way should have the following characteristics:-

- (i) The gauge should be correct and uniform.
- (ii) The rail should have uniform and perfect cross-level.
On curve outer rail should have proper super – elevation to take an account of the centrifugal force.
- (iii) The alignment should be straight and free of kinks. In case of curve proper transitioning should be provided between straight and curve to give smooth ride.
- (iv) The gradient should be uniform and as gentle as possible.
The change of gradient should be followed by proper vertical curve.
- (v) The track should be resilient and elastic in order to absorb shocks and vibrations of running trains.
- (vi) The track should have good drainage so that the stability of the track is not affected due to water logging.
- (vii) The track should have good lateral strength, so that it can maintain its stability due to variation of temperature and other factors.
- (viii) There should be provision for easy replacement and renewals of various track components.
- (ix) The laying & Maintenance cost of track should be low.
- (x) It should be antitheft type & shall be free from sabotage.

CLASSIFICATION OF ROUTES:

Broad Gauge Routes:

All the B.G. routes of Indian Railways have been classified based on speed criteria as given below:

(A) Group ‘A’ Lines:

These are meant for a sanctioned speed of >130 & up to 160 KMPH. In this category, the following lines fall:

1. New Delhi – Howrah – by Rajdhani Exp. Route.
2. New Delhi – Bombay – By Frontier Main or Rajdhani Route.
3. New Delhi – Chennai Central – By Grant Trunk Route.
4. Howrah – Mumbai VT - via Nagpur.

(B) Group ‘B’ Lines:

These are meant for a sanctioned speed >110 & up to 130 KMPH.

(C) Group ‘C’ Lines:

These include suburban section of Mumbai, Delhi, Chennai and Kolkata

(D) Group ‘D’ Lines:

These are meant for a sanctioned speed up to 130 KMPH

Classifications of M.G. Routes

Depending upon the importance of route, traffic carried and maximum permissible speed M.G. routes are classified in three categories as Q.R. and S. routes.

(1) ‘Q’ Routes:

These routes consist of routes where the max^m permissible speed will be more than 75 Kmph. And the traffic density will be more than 2.5 GMT. Max^m speed do not exceeds 100 Kpmh.. As Bangalore - Miraz route.

(2) ‘R’ Routes:

These routes will have a speed potential of 75 Kmph. and the traffic density will be more than 1.5 GMT. Routes have further been sub-divided into 3 categories depending upon the volume of traffic as follows:

- (a) R₁: Where the traffic density will be more than 5 GMT.
- (b) R₂: In between 2.5 GMT to 5 GMT
- (c) R₃: 1.5 GMT – 2.5 GMT

(3) ‘S’ Routes:

These routes will be the routes where speed potential will be less than 75 Kmph. and where the traffic density is less than 1.5 GMT. These will consists of other routes which are not covered in „Q“, „R₁“, „R₂“ and „R₃“ routes. S“ Routes have been further subdivided into 3 routes as S₁, S₂ and S₃ etc.

RAILS

It is a special type rolled steel bar which is placed end to end two parallel line at a fixed distance on sleeper to provide continuous, leveled and smooth surface for train to move.

Or

Rails are similar to steel girder placed end to end at gauge distance to provide continuous, leveled and smooth surface for giving path to running wheel.



FUNCTIONS OF RAILS:

Following are the main functions:-

- (i) Rails provide a continuous and leveled smooth surface for running wheels of trains.
- (ii) It provides a path way which is smooth and has very less friction like $1/6^{\text{th}}$ of road.
- (iii) The rails serve as a lateral guide for running of wheels.
- (iv) The rail wears various types of mechanical stresses such as vertical load, braking forces, and thermal stresses due to temperature etc.
- (v) Rails carry out the functions of transmitting load to a large surface area of formation through sleeper and ballast.

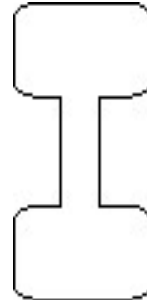
TYPES OF RAIL:

Various types of rails are:-

1. Double Headed rail (D.H. Rail)
2. Bull Headed Rail (B.H. Rail)
3. Flat Footed Rail (F.F. Rail)

(1) Double Headed Rail (D.H. Rails):

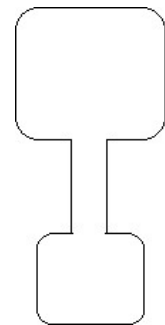
It is “I” section or “dumb-bell” section type rail having identical heads on both sides. Idea was that these rails were re-used after wear, by reversing it.



(2) Bull Headed Rail (B.H. Rails):

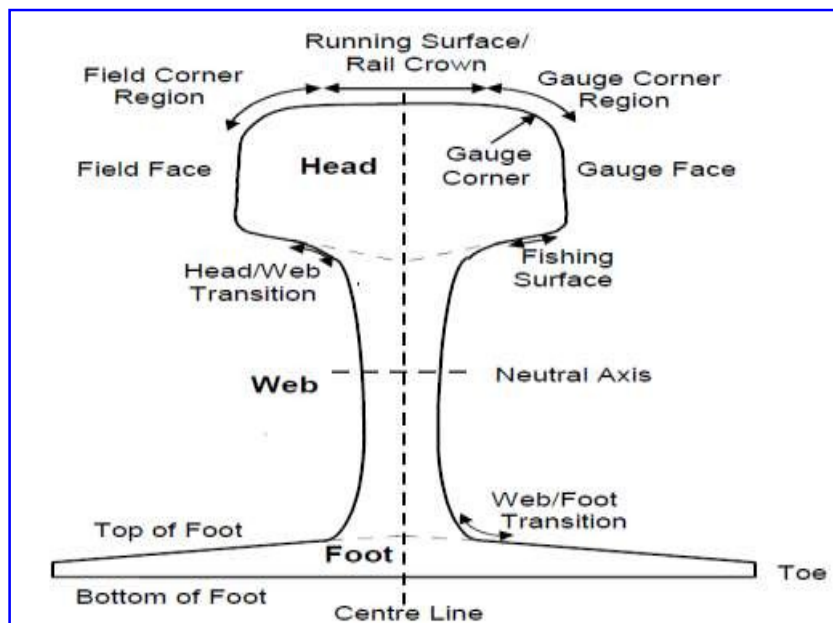
The shape of these rails is similar to D.H.R. and only difference is that its head has more metal to allow wear& tear, so that it may run for long life.

The idea was that these rails will have long life but due to unbalanced head and problem in gauge maintenance, these rails were not successful rails.



(3) Flat Footed Rails (F.F. Rails):

These rails are having inverted “T” cross-section and can be directly fixed to the sleeper with the help of spikes. These rails have been standardized for use in Indian Railways. These rails have more economical design giving greater strength & Lateral stability.



STANDARD LENGTH OF RAIL:

The Longer rails are not only economical and gives smoother and comfortable riding of trains. The length of rails is however, restricted due to the following factors.

- Lack of facilities for transport of longer rails particularly on curves.
- Difficulties in handling of long rails.
- Uneconomical in manufacturing of very long rail.
- Difficulties in having a bigger expansion joint for long rails.
- Heavy internal thermal stresses in long rails.

However standard rail length of B.G. track is 13 meters.

Standard Gap at Fish Plate Joint

- a. Standard gap for B.G. Fish Plate joint is **6 mm**.
- b. Maximum gap can be accumulated at the rail joint in normal condition is **15mm**.

Standard Rail Section

The rails are designated with its weight per unit length. In India, initially we opted British/Revised British system in FPS system (Foot Pound Second), the rail section was designated in lbs. per yard.

For Example: 90 R lbs. rail section means weight of rail section is 90 lbs per one yard length by Revised British System.

Presently in Indian Railway Standard [I.R.S] MKS (meter /Kilogram sec] system is in co-operation in which we designate the rail system weight in kilogram / meter.

For Example: 52 kg rail section means the weight of one meter rail is 52 Kgs.

Nowadays we are manufacturing only the following two rails

- (i) 60 Kg
- (ii) 52 Kg

Note: Nowadays for laying new rails/ Gauge conversion etc only 60 Kg rail is considered as standard.

Rolling mark on rails:

Every rail rolled has a brand on its web, which is repeated at certain intervals is called rolling mark:

Details are as follows

Indian Railway Standard Rolling Mark

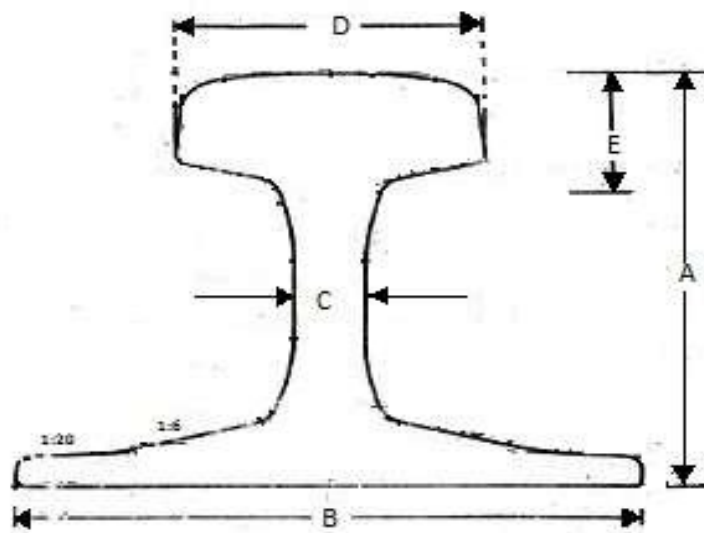
IRS-52kg-710-TISCO/SAIL-II 1997 ▼ OH

The explanation for various new abbreviations is as given below:

- IRS : Indian Railway Standard
- 52 Kg : Weight of rail section; 52 kg / meter
- 710: Grade of the rail material
- ▼ : Direction of Rolling
- TISCO/SAIL : Manufacturing Company Tata iron and Steel Company/Steel Authority Of India Ltd
- II/ 1997 : Month and year of manufacture; February 1997
- OH: Manufacturing Process Open Hearth Process

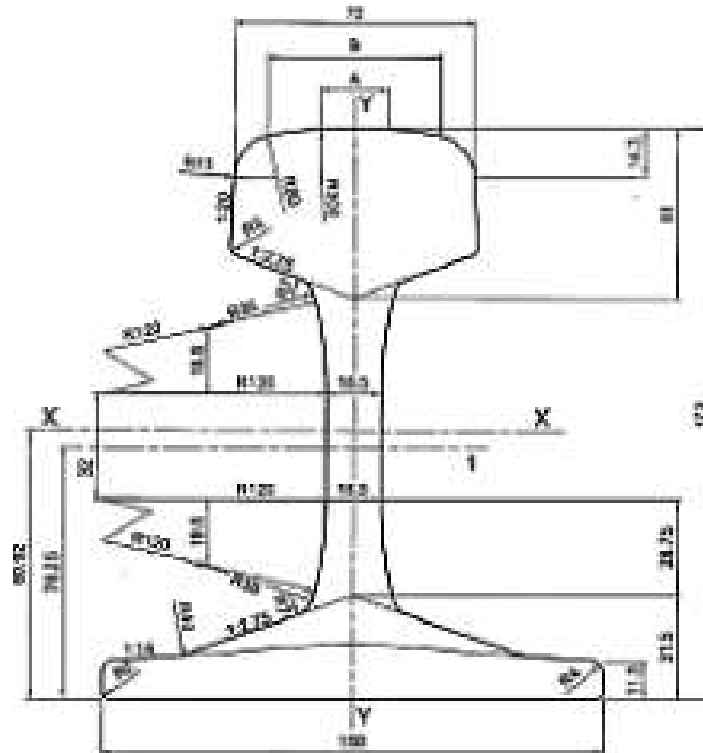
Standard Dimension of the Flat Footed Rail:

Rail Section	Height (A) in mm	Flange Width (B) in mm	Web Thickness (C) in mm	Top Width (D) in mm	Top Height (E) in mm	Actual Weight in Kg
60 Kg	172	150	16.5	74.3	51	60.34
52 Kg	156	136	15.5	67	51	52



For 60 Kg/m rail, the UIC 60 profile has been changed to 60 E1 profile, which is accurately dimensioned profile developed from the previous less accurately dimensioned profile of UIC 60. In this profile, there is a minor variation in the profile of rail head top as compared to the UIC 60 profile. There is no difference in the dimensions of Rail flange and web including the fishing planes.

60 Kg/m rail (60 E1)



Cross-Sectional Area - 76.70 cm²,
Indicative dimensions: A = 20.456mm,

Mass per metre - 60.21 Kg/m
B = 52.053mm

Relationship between Grade, Ultimate Tensile Stress (UTS) and Service Life of Rails

Grade	Ultimate Tensile Stress(UTS)	Type of Rail	Stipulated Service Life
710	72	52 Kg	350 GMT
		60 Kg	550 GMT
880	90	60 Kg	800 GMT
		52 Kg	525 GMT
1080	110	60 Kg	Under Trial

SLEEPERS

Sleepers are the components of track on which rails are fixed with the help of fittings and fastenings in correct gauge and alignment.

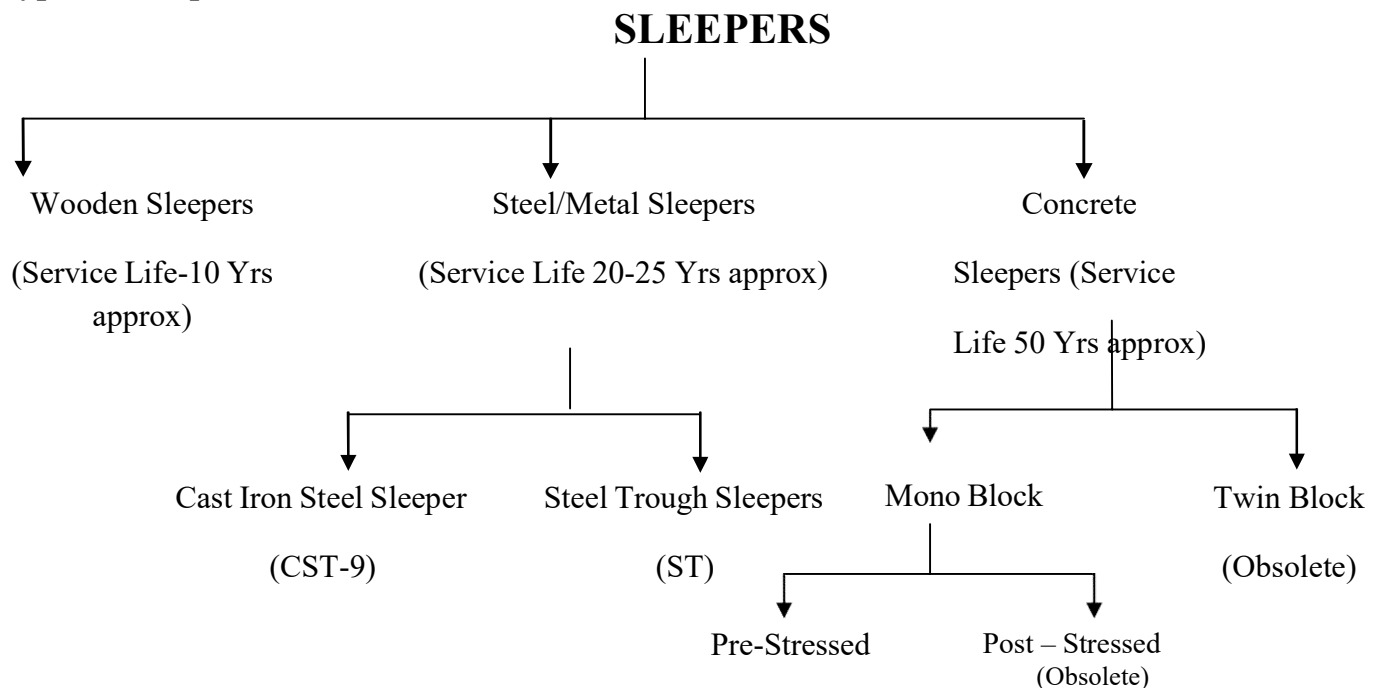
The sleepers in the initial stages were planted in the longitudinal direction of rails. These were known as Longitudinal Sleepers. These types of sleepers were not economical so they changed to transverse sleepers.

Functions of sleepers

The main functions of the sleepers are as follows

1. It should hold the rail in correct gauge and alignment.
2. It should give a firm and even supports to rails.
3. It should transfer the load evenly and efficiently from rails to the wider area of ballast section.
4. Act as an elastic medium between rail and ballast to absorb shocks and vibrations of moving loads.
5. It provides longitudinal and lateral stability to permanent way (Track).

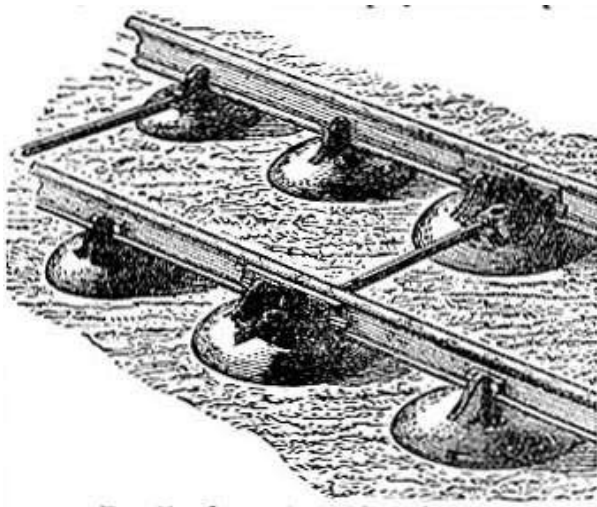
Types of Sleepers:



Note: Now-a-days in Indian Railways mono-block Pre-Stressed Concrete Sleepers (PSC)/ mono-block Pre-Reinforced Concrete Sleepers (PRC) are considered as a standard.



Wooden sleepers



Cast Iron sleepers



Steel Trough Sleepers



PRC Sleepers-Mono-block



Dual Block Concrete sleepers

Requirement of good Sleepers

The ideal sleeper should normally fulfill the following requirements:

- i) The initial cost as well as maintenance cost should be minimum (low).
- ii) The weight of sleeper should be moderate, so that it is possible to handle it easily.
- iii) The design of sleeper and fastenings should be such that it is possible to fix and remove the rails easily.
- iv) It should have sufficient bearing area
- v) It should be such that it is possible to maintain and adjust gauge properly.
- vi) It should be able to bear the load coming from rail comfortably and should not break/damage under load.
- vii) It should be „Universal Type“ and may be used in track circuiting area
- viii) It should be able to absorb the shock and vibration coming from moving train.
- ix) It should be able to provide elastic medium between rail and ballast.
- x) It should be designed in a way that quantity of loose parts and fasteners should be less.
- xi) It should have good service life.
- xii) The sleeper should have anti-sabotage and Anti-theft quality.

CONCRETE SLEEPER

Necessity of concrete sleepers:

The use of concrete sleepers in Indian Railways becomes necessary due to following reasons.

- i) Scarcity of good quality of timber.
- ii) High cost of maintenance in wooden and steel sleepers.
- iii) Introduction of high speed and heavier axle loads.

Advantages of Concrete Sleepers:

1. Concrete sleepers being heavy, gives greater strength and stability to track and are suitable especially for LWR/CWR due to great resistant to buckling.
2. Concrete sleepers with elastic fastening provide a track which can maintain better gauge, cross level and alignment and retains packing well.
3. Since Concrete sleepers have flat bottom therefore they are best suited for modern methods of tamping and maintenance (i.e. machine maintenance).
4. These can be used in track circuited areas (or) track circuited section as they are poor conductor of electricity.
5. They are neither inflammable nor subjected to be damaged by atmospheric effect (corrosion) and insects.
6. These have longer service life approx. 50 years. Compared to other type of sleepers.
7. It has anti-sabotage and anti-theft quality.
8. It is fit and forget type.
9. No chance of gauge widening.
10. Availability of PRC sleeper is easy. They can be made at the site also.
11. They can be produced on large quantities locally by installing a plant.

Disadvantages of Concrete Sleepers:

1. Due to heavy load, handling of PRC sleepers are not easy only Machine handling is recommended which is costly
2. In case of derailment, these sleepers may get heavy damage.
3. These sleepers have nil scrap value.
4. Not useful for better packing. So only machine packing is allowed.

Sleeper Density & Sleeper spacing

Sleeper Density

Sleeper Density means how many sleepers are provided in one rail length (i.e. 13 meters for B.G)

For BG sleeper density is denoted as $(M+X)$ where M = Length of rail in m

X = Variable

For example: In BG track $(M+7)$ sleeper density means $13+7=20$ sleepers per rail length. Nowadays for new laying, Doubling, Gauge renewal $(M+8)$ is considered as standard

The sleeper density depends upon the following factors:

1. Axle load and speed of trains
2. Type and strength of sleepers
3. Type of rail and its section.
4. Type of the ballast and ballast section
5. Nature of formation.

Sleeper Spacing

Sleeper spacing means center to center distance between adjacent sleepers which are provided in the rail. It depends upon the sleeper density.

Sleeper spacing is kept uniform in whole rail length but at joints it's kept close as joints are the weakest portion of track and needs more support.

Sleeper spacing at the joint is kept close in such manner so that space for packing should be available sufficiently and end of rail should be as a „bridge joint“ not supported at sleepers.

Standard Spacing for BG

Type of Sleeper	Sleeper Spacing			
	A	B	C	D
Wooden	150	610	In Between B & D is to be calculated to be equally divided in remaining length	
Metal	190	580		

Sleeper Spacing and density in LWR joint

Sleeper density in LWR track is although denoted as same as in rail length i.e (M+4),(M+7) or (M+8) but for conventional and all practical purpose it is given as number of sleeper per kilometer.

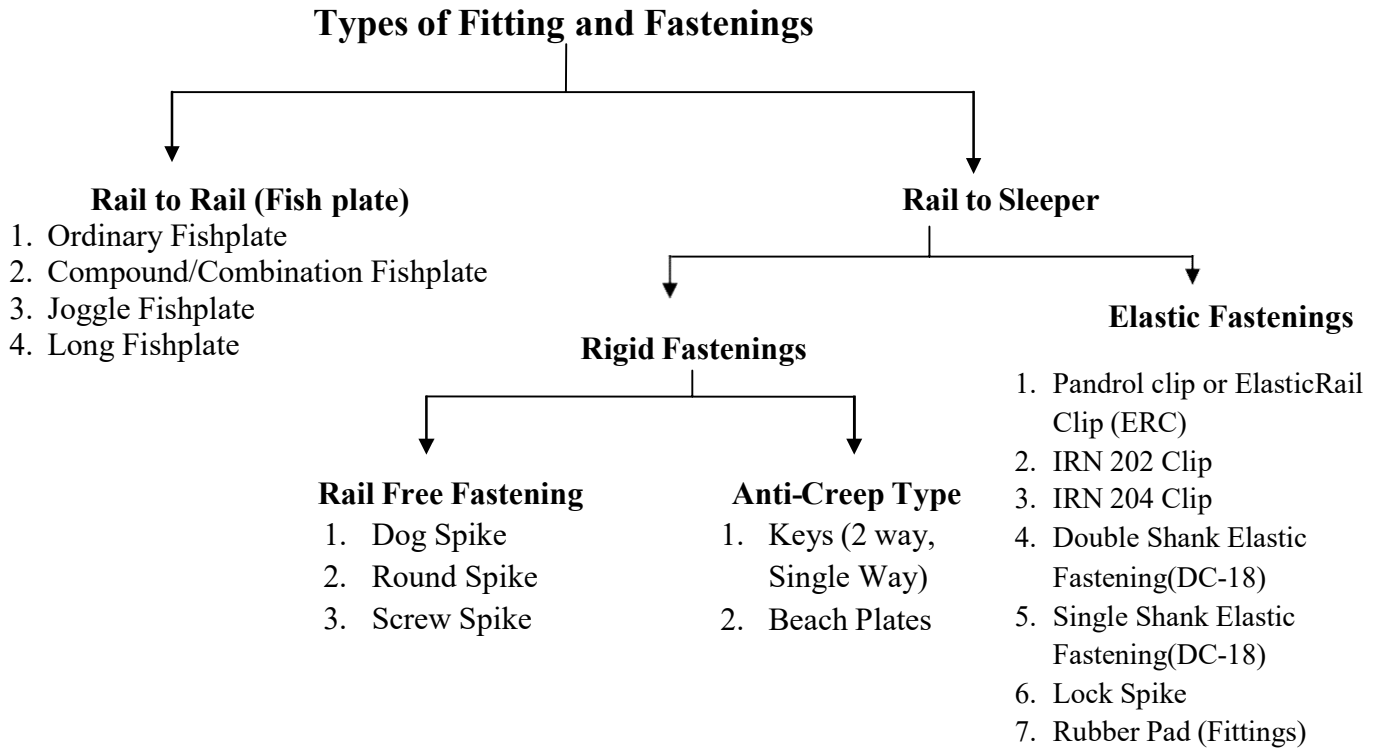
The sleeper spacing in LWR track is calculated as 1km divided by number of sleepers in one kilometer of rail.

Sleeper density	No. of sleeper per kilometer	Exact c/c spacing required as per calculation in cm	C/c spacing to be provided in the filed (cm)	
			L.W.R.	S.W.R.
M + 8	1660	60.24	60	-
M + 7	1540	64.93	65	66
M + 4	1310	76.33	76	78

Note: Normally M+4 density is only used in SWR tracks.

1. The above rail spacing (M+X) will be applied only on curve up to 4° in BG and 6° in MG.
2. Curve more than 4° in BG and 6° in MG, mid slaggery if joints are provided.
3. Outer rail of curve will be reference line for all practical purpose related to spacing.
4. In LWR track since there is no joints hence spacing will be as usual. Also there are restrictions to lay the LWR on curve for more than 4° in BG.

FITTING AND FASTENINGS



RAIL TO RAIL FITTINGS:

These fittings are used for tying one rail to another longitudinally in same horizontal and vertical plane. One of the main fittings of such types of rail is fishplate. Fishplate is called, so as its section looks like a fish.

TYPE OF FISHPLATE:

Fishplates are of following four types:

- i. Ordinary fishplate
- ii. Combination fishplate.
- iii. Joggle Fishplate
- iv. Long Fish Plate

(i) Ordinary Fishplate:

These plates are having I-section. These are used to connect similar line section together, such as 90R rail to 90R rail and 60 Kg rail to 60 Kg rail.



(ii) Combination Fishplate:

These are used for connecting the rail length of two different rail sections. Such as 90R rail to 52 Kg rail, 52 Kg rail to 60 Kg rail. The combination fishplates are designed so as to

Suit the two rail sections. No expansion gap is kept at such joints so as to give more strength. A common top table and gauge face of the two rail section is available with the help of the Junction fish

Plates or combination fish plates in spite of varying depth & thickness of the section.



(iii) Joggle Fishplate:

These fishplates are very similar to ordinary fishplate for particular rail section with only difference its mid portion is projected outside to accommodate weld material at welded joints. Hence it is used only at welded joints.

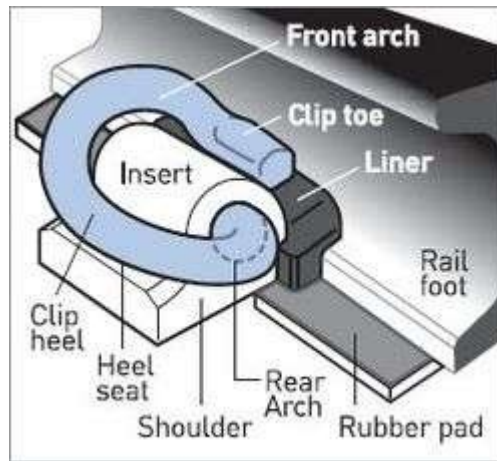


(iv) Long Fishplate:

These fishplates are very similar to ordinary fishplate for particular rail section but longer in length exactly 1 meter. These fishplates are used at the location where the higher joint strength is required. (with 6 bolts). **For Example:** near to LWR territory or at glued joint etc.



Elastic fastenings



The Primary function of the fastenings is to connect the rail with the sleepers. The Elastic fastenings serve this and in addition to that it has an additional property of elasticity after fixation (Toe Load and deflection etc.). So that it is very useful to absorb the vibration, shocks and jerks etc. coming from moving train by this additional property. These fittings are very useful for modern high speed track because these fastenings do not loosen and get off due to vibration and load effect. Hence it may be fit & forget type.

Requirement of Elastic Fastenings:

An idle elastic fastening should be able to meet the following requirement

1. It should hold gauge well
2. It should have adequate “toe load” which should not reduce under service.
3. It should provide sufficient elasticity to absorb the shocks and vibrations coming from moving train
4. It should keep the track parameter well maintained
5. It should offer adequate resistance to lateral and longitudinal track for maintaining the stability of track.
6. It should be anti-creep type.
7. It should be reusable type
8. It should be fit and forget type
9. It should have minimum loose parts so that its fixation and maintenance should be easy
10. It should be free from sabotage and anti-theft type
11. It should be cheap and have long life
12. It should be universal type so it can be used with any type of sleeper.

Type of Elastic Fasteners

1. Pandrol clip or Elastic Rail Clip (ERC)
2. IRN 202 Clip
3. IRN 204 Clip
4. Double Shank Elastic Fastening(DC-18)
5. Single Shank Elastic Fastening(DC-18)
6. Lock Spike
7. Rubber Pad (Fittings)

Pandrol Clip/ Elastic Rail Clip (ERC)



Types of Elastic Rail Clips (in Use):

1. Elastic Rail Clip- Mark-I
2. Elastic Rail Clip- Mark-II
3. Elastic Rail Clip- Mark-III
4. Elastic Rail Clip- Mark-IV
5. Elastic Rail Clip- Mark-V

Note: Material of Pandrol Clip:
Silico Manganese Spring Steel (SMSS)

All the ERCs are of two types they are

1. Flat Type-used at joint of track circuited areas.
2. Round type-normal use.

Type	Toe Load (Kg)	Toe Deflection (mm)	Bar Diameter(BD) (mm)	Weight (gm)
MARK-I	645-800	11.4	20.64	1000
MARK-II	700-900	11.2	18	800
MARK-III	850-1100	13.5	20.64	910
MARK-IV	1100-1300	13.5	20.64	855
MARK-V	1300-1500	15.5	22	1000

Note: Now a day ERC Mark-III is widely used in Indian Railway Compared to other.

Rubber Pad



It is an integral part of the elastic fastenings. It is provided between Rail and Sleepers to Perform following duties

- i. To absorb the shocks
- ii. It dampens and absorb the vibration
- iii. It resists the longitudinal movement of rail
- iv. It prevents the abrasion of rail sleeper
- v. It provides electrical insulation between rail and sleepers in the electrified areas

Note: (a) Normally in Indian Railway groove Rubber Pad of 6mm is used with PRC Sleepers
(b) But with PRC Wider Sleepers groove Rubber Pad of 10mm is used

Liners:



Liners are used with pandrol clips on PRC sleepers to prevent „dent, mark on rails produced due to toe load. In Indian Railways normally insulating composite liners are used. There are three types as follows

- i. Composite liner with Mild steel and nylon Component
- ii. Composite liner with Mild steel and nylon Component/ P.V.C Liners
- iii. Composite liner with Mild steel and Glass Filled Nylon(GFN)

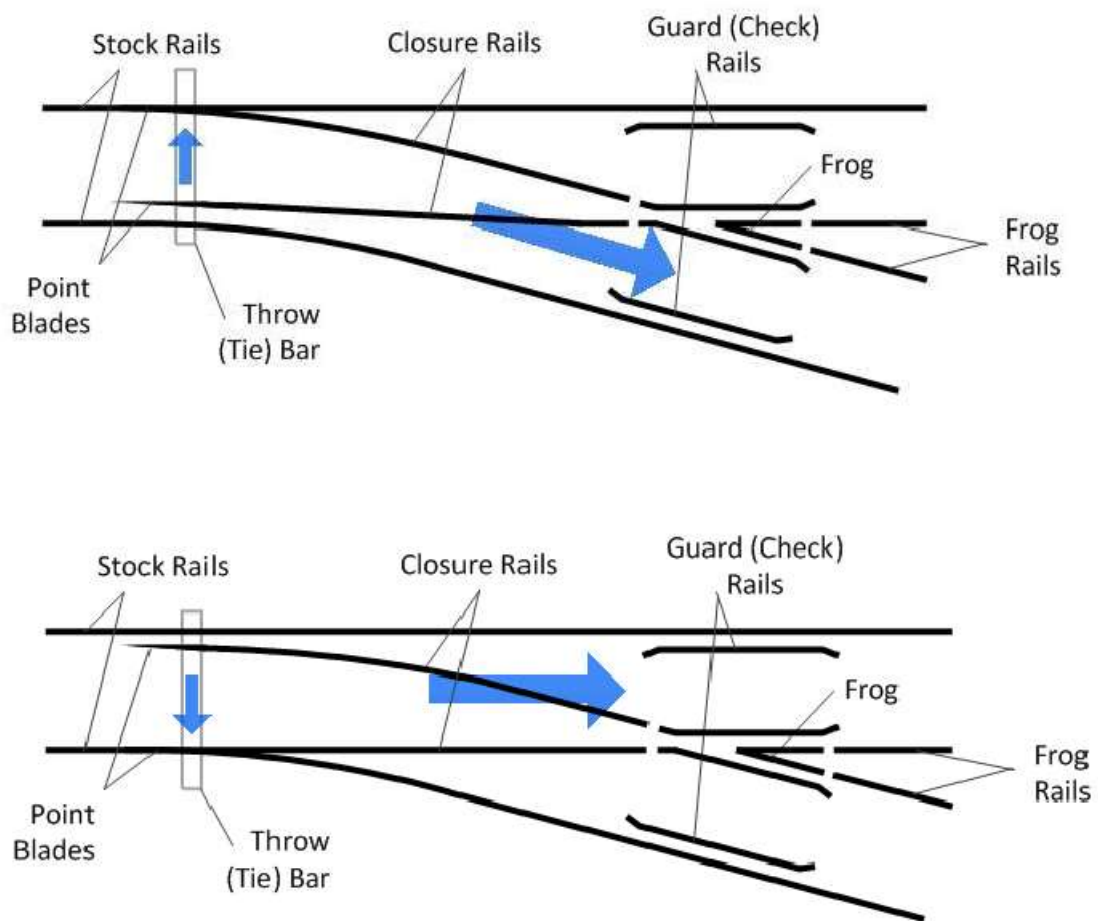
Note: Nowadays in Indian Railways Liners with GFN are considered as standard liners.

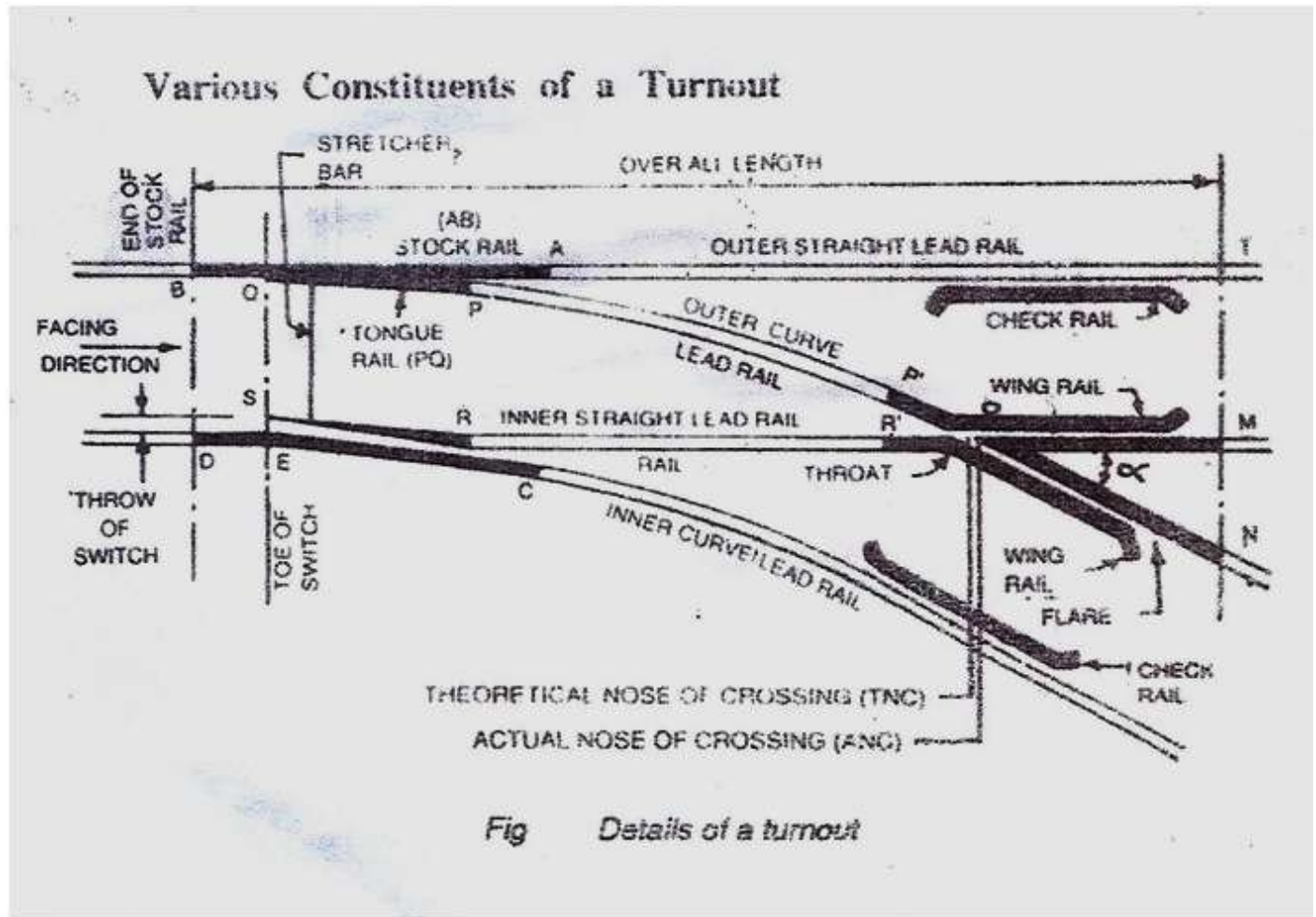
POINTS & CROSSING

Necessity of Point & Crossing

Point & Crossing i.e. turnout are necessary due to following reasons:

1. On single line track to give path to trains coming from both directions.
2. In double line, to give path to faster train against slow train coming from same direction.
3. To connect the places which are not lying on main line.
4. To place/direct the passenger train to platform line (or) goods train to yard line for stay.





SOME IMPORTANT DEFINITIONS OF POINTS AND CORSSING:

Tongue Rail:

It is the tapered movable rail made of high carbon and manganese steel to withstand wear whose thicker end is connected with running rail/ lead rail. Some time it is also known as Switch Rail.

Stock Rail:

It is the running rail in which the tongue rail is housed.

Switch:

A pair of tongue e rail with necessary connections and fittings forms a switch.

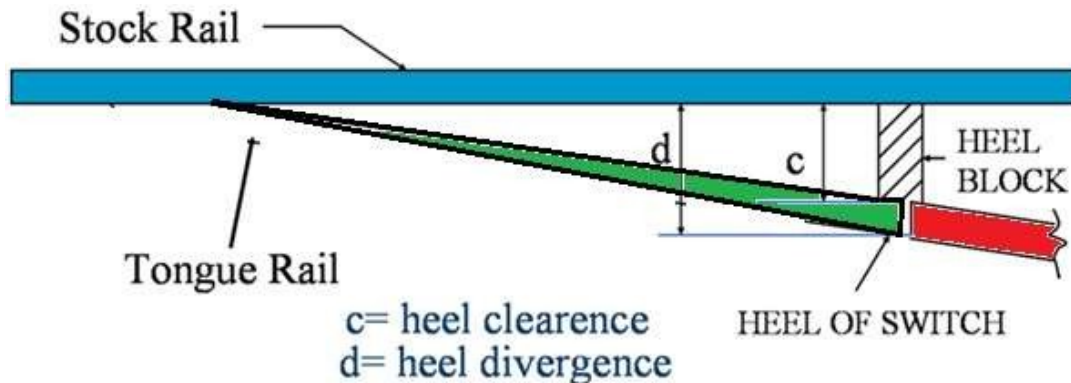
Point:

A pair of tongue rails and a pair of stock rails with necessary connections form a point.

Heel of Switch:

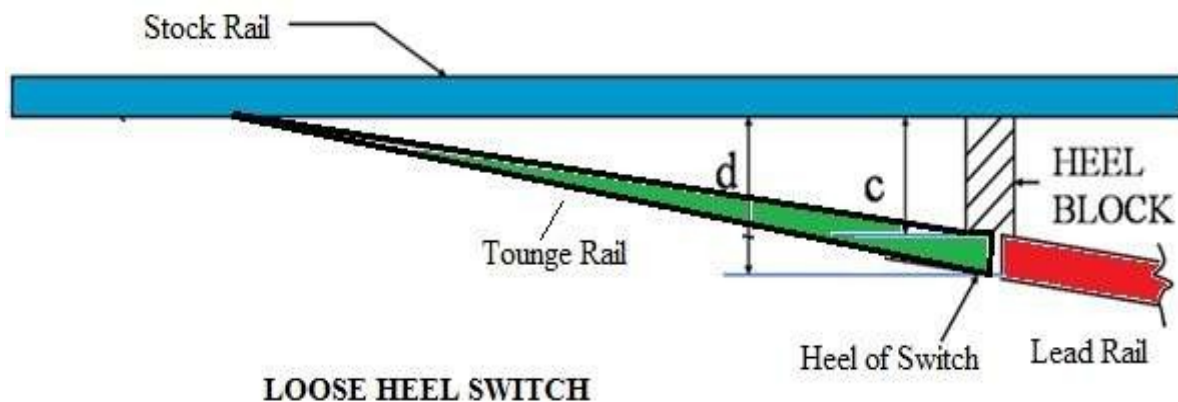
Heel of Switch is an imaginary point midway between the end of the lead rail and tongue rail in case of “loose heel switch.”

In case of fixed heel switches it is the point at the center of the heel block itself



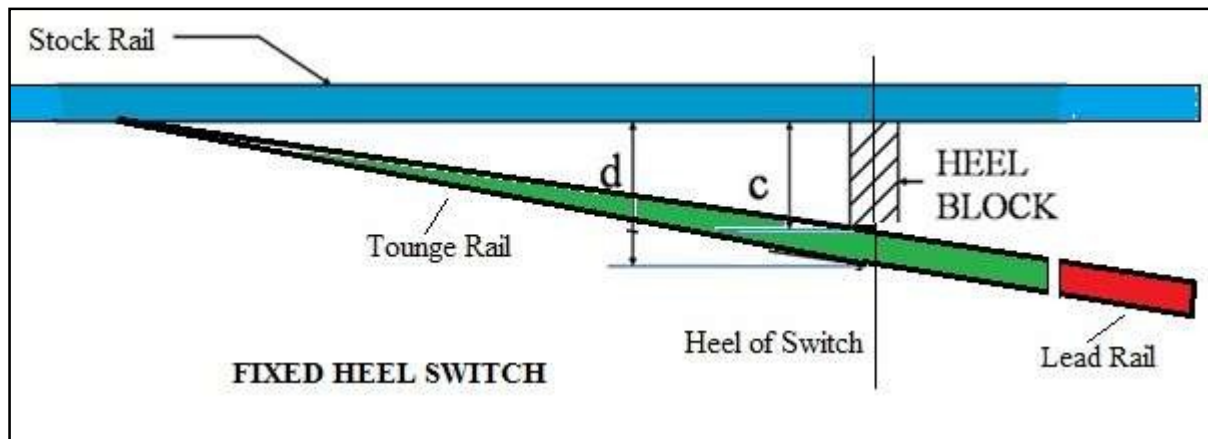
Loose Heel Type:

In this type, the switch rail or tongue rail finishes at the heel of the switch. In order to enable the free end of the tongue rail to be moved, two front bolts of the heel block are kept loose.



Fixed Heel Type:

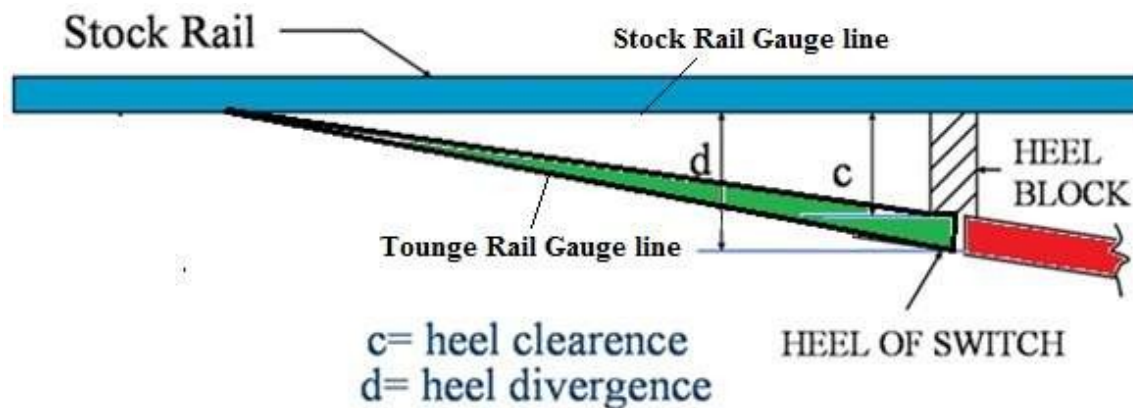
In this type of switch, tongue rail does not end at heel of the switch, but it extends further. The movement of the tongue rail is made on account of the flexibility of tongue rail by increasing its length.



Heel Divergence:

The minimum distance between gauge line of stock rail and gauge line of tongue rail at heel of switch is called Heel Divergence.

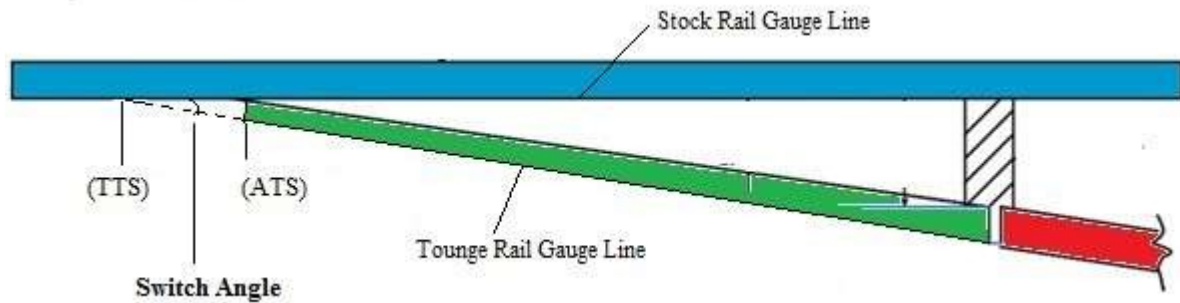
In other words it is the clearance between stock rail and running rail at HOS plus head width of tongue rail



Switch Angle:

It is the angle between the gauge lines of stock rail and tongue rail at theoretical toe of switch (TTS) in close position. This angle depends upon heel divergence and length of tongue.

In case of curved switches it is called as “**Entry Angle**”.

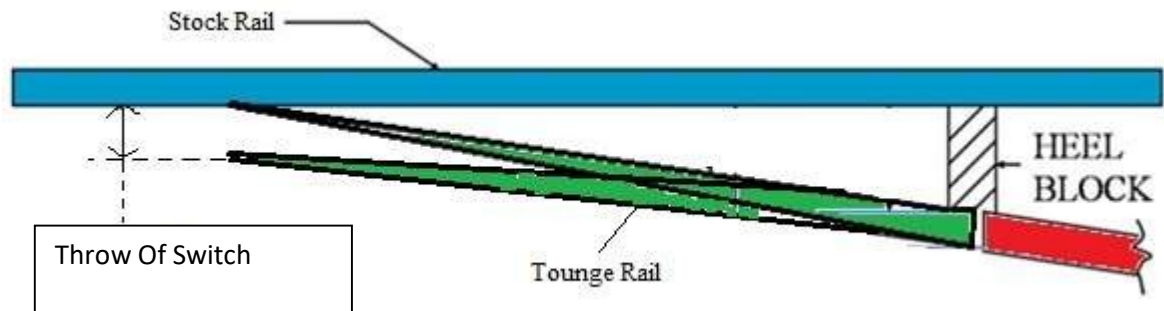


Note: In case of curved switches it is the angle between gauge lines of stock rail and tangent drawn at actual toe of gauge line of tongue rail. Hence it is called “**Entry Angle**”.

The various switch angles in BG Track are as given below:

1 in 8 ½	Straight Switch	1°-34'-27"
1 in 12	Straight Switch	1°-8'-0"
1 in 8 ½	Curved Switch	0°-47'-27"
1 in 12	Curved Switch	0°-27'-35"

Throw of switch:



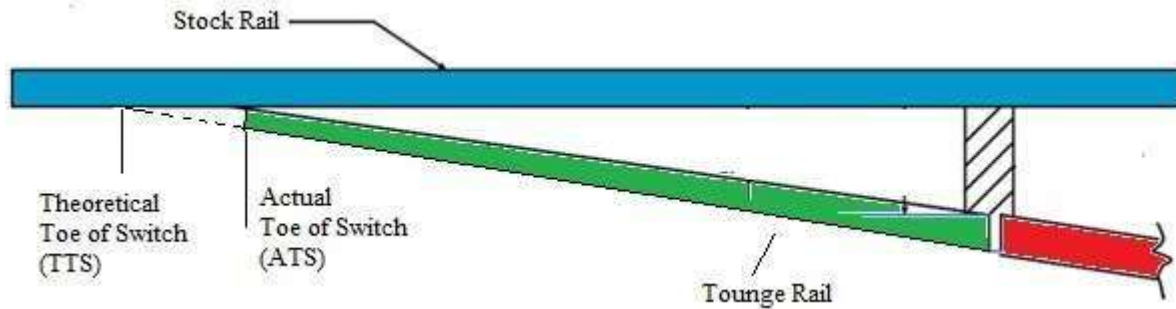
It is the distance moved by a tongue rail against stock rail at Actual Toe of Switch (ATS) at the time of making path to either side.

As per Schedule for Dimension (SOD) the maximum and minimum value of switch is as under following.

Track	Maximum Value in mm	Minimum value in mm
Broad Gauge	115	95
Meter Gauge	100	89

Toe of Switch or Actual Toe of Switch (ATS):

Thin tapered end of tongue rail is called Toe of Switch or Actual Toe of Switch (ATS).

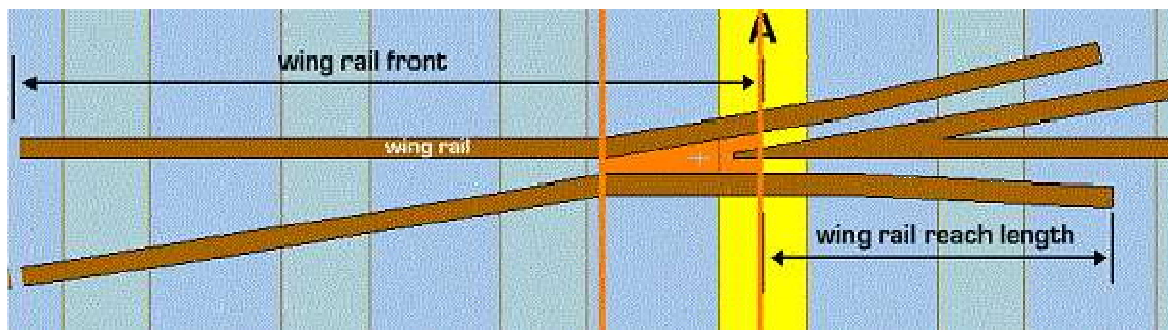


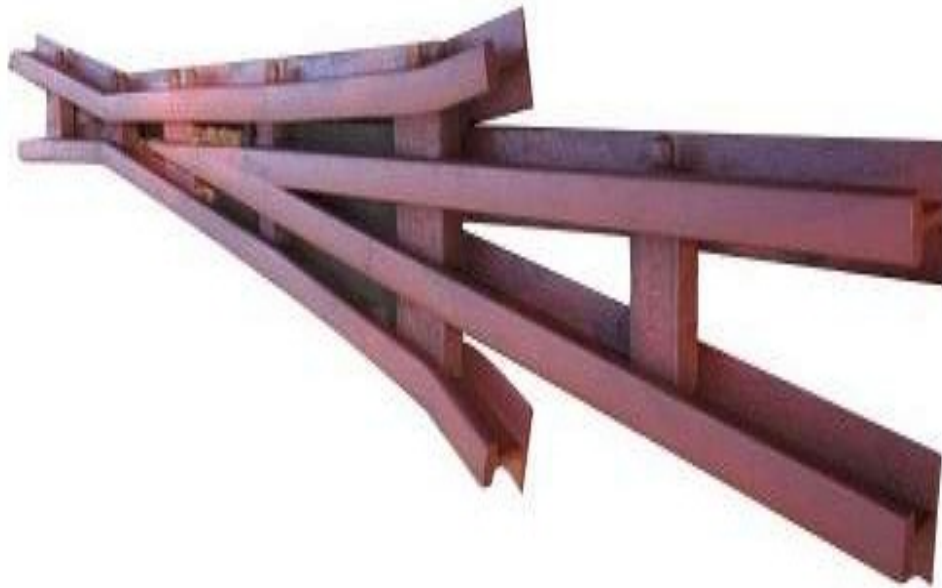
Theoretical Toe of Switch:

Theoretical toe of Switch is the point of intersection of gauge lines of tongue rail and stock rail in the closed position. It is imaginary point in field.

Crossing:

Crossing is a device introduced at the junction where two rails cross each other to permit the passing of the wheel flange of rolling stock, to pass from one track to another track. It is also known as “frog”.

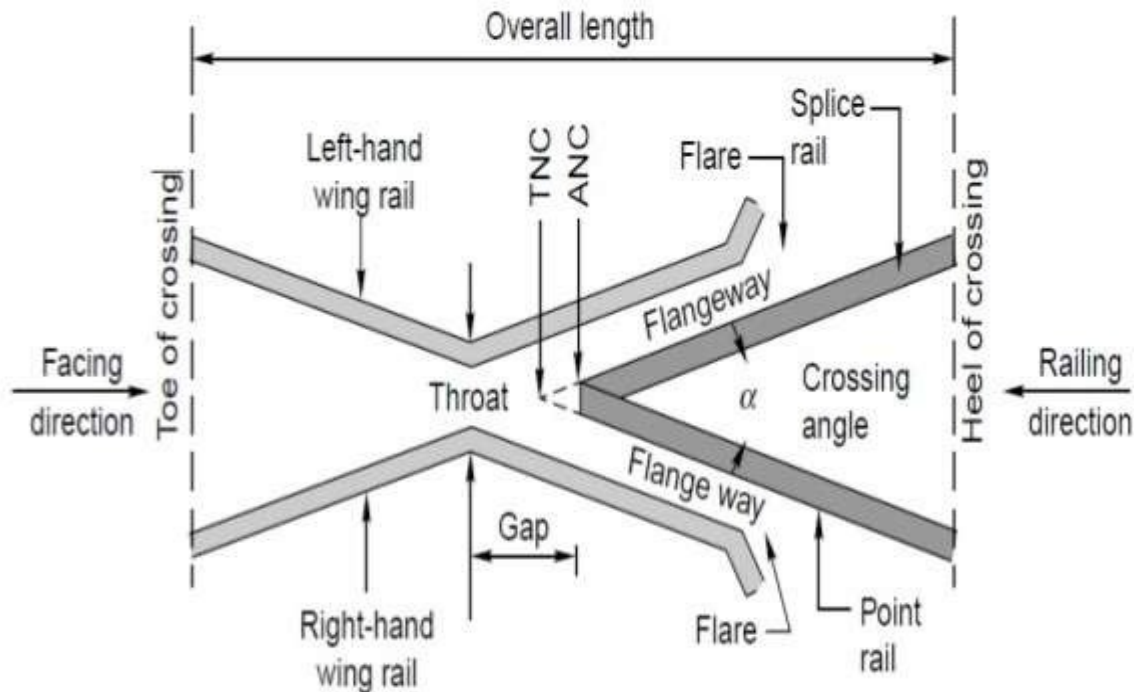




Theoretical Nose of Crossing: (TNC)

Theoretical nose of crossing is a theoretical point of intersection of two gauge lines of crossing.

TNC is used as a reference for all Calculations.



Actual Nose of Crossing: (ANC)

Theoretical Nose of Crossing is the point which is not practically possible to provide in track. Some thickness is provided (Equal to web thickness of rail section) at nose to give strength to the nose.

Hence actual nose of crossing is the point which spreads between the gauge lines of crossing at 'pointed end' which have sufficient thickness in view of giving strength and manufacturer consideration.

Throat of Crossing:

Throat of crossing is the portion at which the converging wing rail of crossing has minimum distance (closest position)

Note: Normally Throat clearance is kept 51mm.

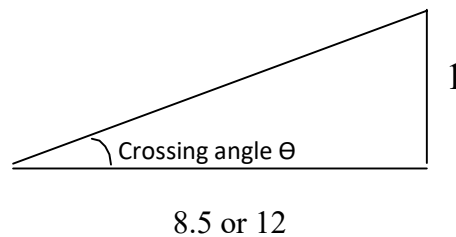
Number of Crossing OR Crossing Number:

Number of crossing is the co-tangent value of the crossing angle.

Normally it is denoted as 1 in N, where N is crossing number. For

Example: 1 in 8 ½, 1 in 12 etc

Both are standard crossing for IRS and are in use.



Crossing Angle:

Angle subtended between gauge lines of crossing nose piece is known as crossing Angle. It is measured at Theoretical Nose of crossing

The typical value of crossing angle is as below

$$1 \text{ in } 8 \frac{1}{2} = 6^\circ-42'-35''$$

$$1 \text{ in } 12 = 4^\circ-45'-49''$$

Numerical Problems (ANC to TNC Distances):

Question 1 . Calculate the distance from ANC to TNC for 1 in 12 Crossing of 60 kg rail

Answer; For 60 kg rail section, web thickness = 16.5 mm

$$\text{Now Cot } \Theta = \frac{12}{1}$$

The distance from ANC to TNC is = $16.5 \times 12 = 198\text{mm}$

Question 2 . Calculate the distance from ANC to TNC for 1 in 12 Crossing of 52 kg rail

Answer; For 60 kg rail section, web thickness = 15.5 mm

$$\text{Now Cot } \Theta = \frac{12}{1}$$

The distance from ANC to TNC is = $15.5 \times 12 = 186\text{mm} \approx 187 \text{ mm}$.

Check Rail:



At the throat of crossing wheel flange jumps from one rail to another to cross the rail in gap.(flange way gap). In order to ensure that this wheel negotiate the gap properly and does not strike the nose, the other wheel is guided with the help of a parallel fixed rail at specified distance. This rail is called check rail.

As per SOD Minimum = 44mm
Maximum = 48 mm

Turn Out:

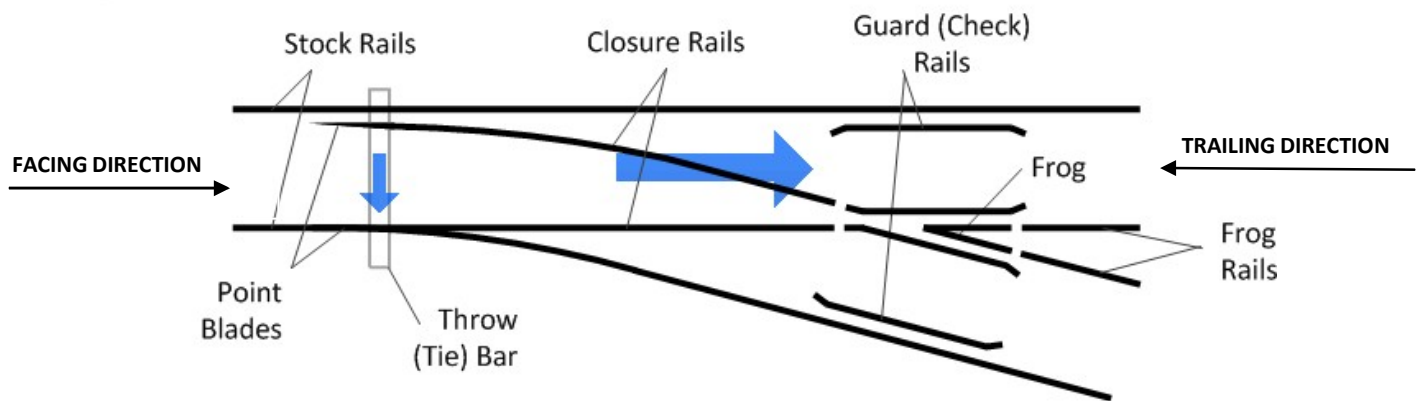


Turnout is a device which is used to direct the vehicle from one track to another.

OR

It is an arrangement of points and crossing with lead rails by means of which rollingstock (Vehicles) may be diverted from one track to another track.

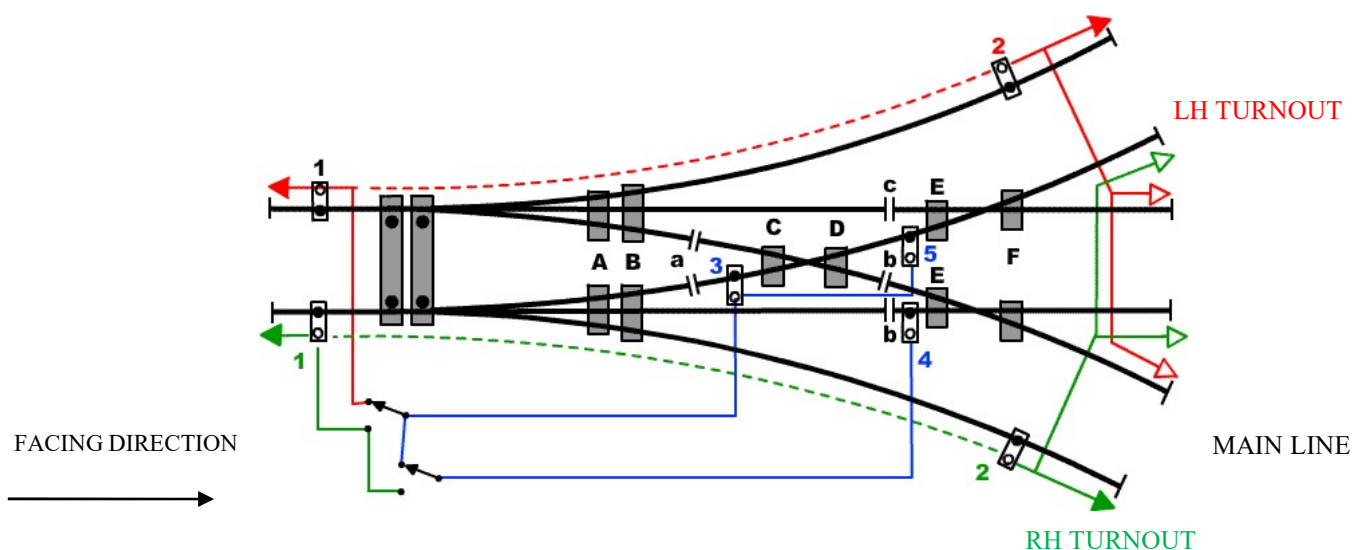
Facing Direction and Trailing Direction:



Train passing on turnout if first passes/crosses the point and then crossing. The direction of train / vehicle is to be known as **Facing Direction**.

Train passing on turnout if first passes/crosses crossing portion and then switchportion. The direction of train will be identified as **Trailing Direction**.

Left-hand & Right Hand Turnout:



A turn out is designated as right hand or left hand depending upon whether the traffic is directed to right or to left respectively .

The vehicle approaching to turn out from facing direction if diverts right hand then it is denoted as Right Hand T/out if diverts left hand side – it will denoted as left hand turn out .

CROSSING

Classification of Crossing:

The Crossings are classified in following two aspects:

1. Based on Crossing Angle(Track Condition)
2. Based on methods of manufacturing

Based on Crossing Angle:

On basis of Crossing Angle the crossings are classified in three types

1. Acute Crossing / V- Crossing
2. Obtuse Crossing / Diamond Crossing
3. Square Crossing

Acute Angle Crossing:

An acute angle crossing or V-crossing is that in which the intersection of two gauges faces (gauge line of pieces) forms an acute angle. In Indian Railway, acute angle crossing is used for all turnouts and cross over.



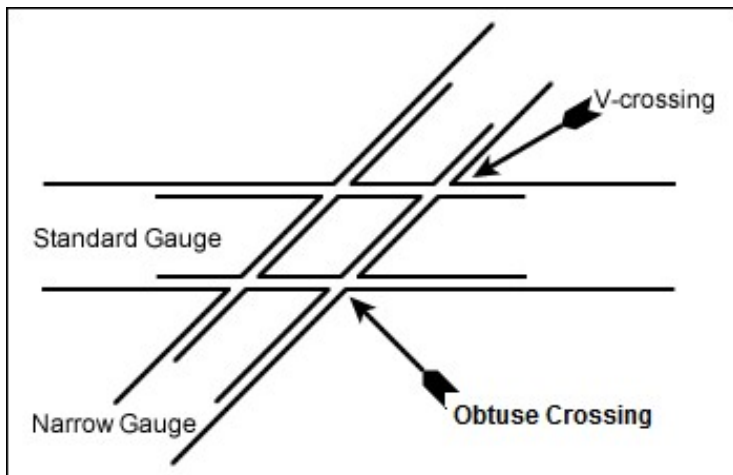
Obtuse Angle Crossing:

Obtuse crossing is that crossing in which the two gauge faces meet at an obtuse angle.

OR

When gauge faces or gauge line of a crossing intersect each other in such a way that angle between it forms an obtuse angle, the crossing is called obtuse angle crossing.

Since this type of crossing is only used in diamond layout hence it is also known as Diamond Crossing.



Square Crossing:

It is formed at the locations where two tracks cross each other at right angle. Because of unguided/Unchecked/ Unprotected flange moment at the nose (due to non-provision of checkrail), there are chances of derailment are more. Hence use of this type of crossing in Indian railway is not in practice.



Based on method of Manufacturing:

In this basis of methods of the crossing is classified into two

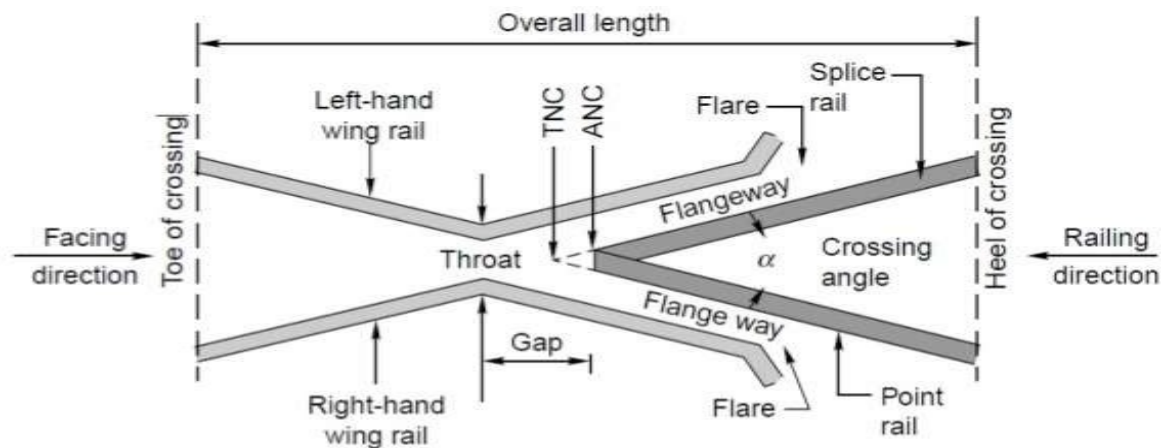
1. Built Up Crossing
2. Cast Steel Crossing

Built up Crossing:

In this type of crossing two flared wing rail and one nose or V-piece (combination of point & Splice rail) are connected by means of iron distance blocks, nut and bolts.

This type of crossing is broadly used on Indian Railways. The major advantage of this type of crossing is

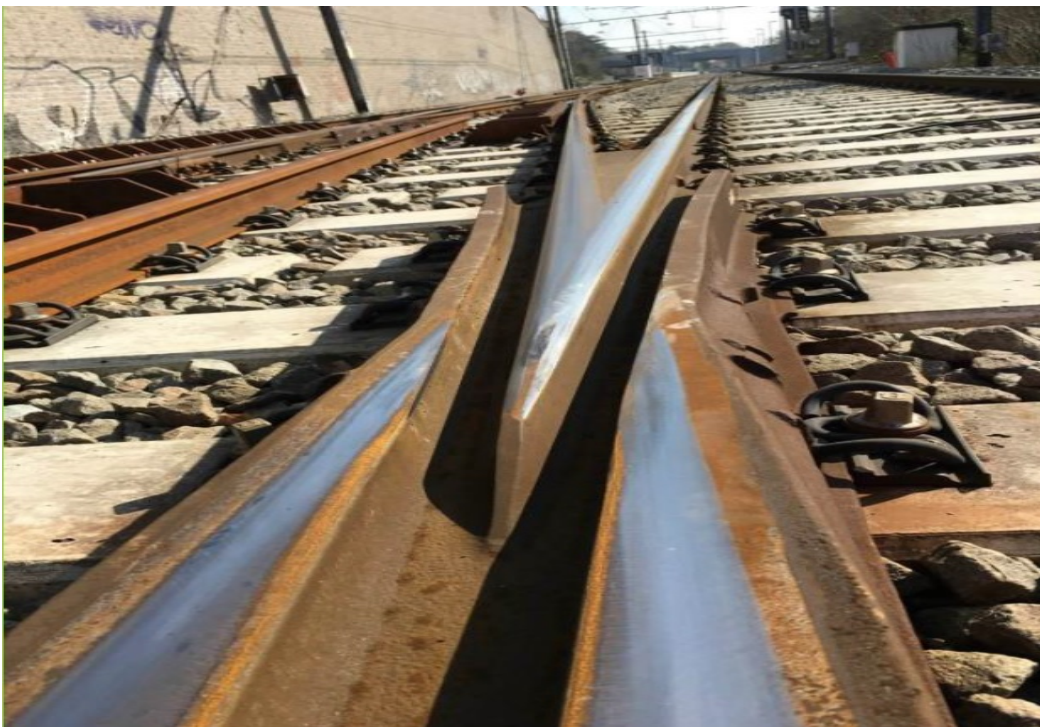
- I. Initial fabrication cost is low.
- II. Wear can be repaired at site without replacing the crossing.



Cast Steel Crossing (Cast Manganese Steel Crossing):

This type of crossing is manufactured by casting process in one piece

In this Series / Type of crossing, CMS (Cast Manganese Steel) crossing is adopted by Indian Railway and it is standard crossing for modern high speed track/Fan Shape turnout.



Advantages of CMS Crossing;

1. It is more rigid crossing in one mass and having no loose parts like bolts, nut etc:- resulting it needs very little maintenance as well as very low maintenance cost .
2. Although the initial manufacturing cost of crossing is high but due to its metallurgical composition (having high manganese percentage) and manufacturing process. It has very good anti-wear capacity even under heavier axle load.
3. Due to its chemical and physical properties it has very long life and about four times in comparison to ordinary built up crossing.
4. Very useful on heavy traffic density routes where traffic block margin is very less.

PROTECTION

TYPES OF SIGNALS

The signals to be used for controlling the movement of trains shall be -

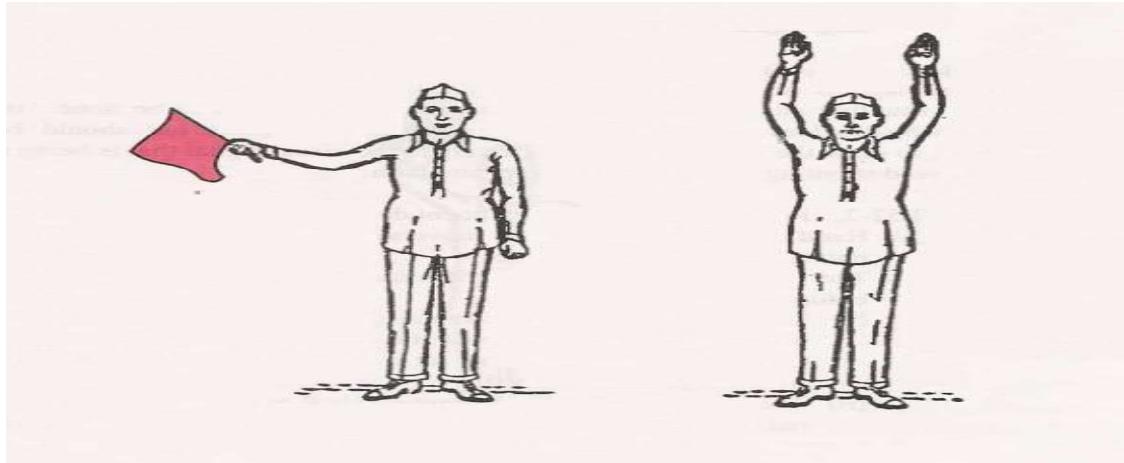
- (a) Fixed signals,
- (b) Hand signals,
- (c) Detonating signals, and
- (d) Flare signals.

Stop: Hand Signal

Indication: Stop dead

How given by day:

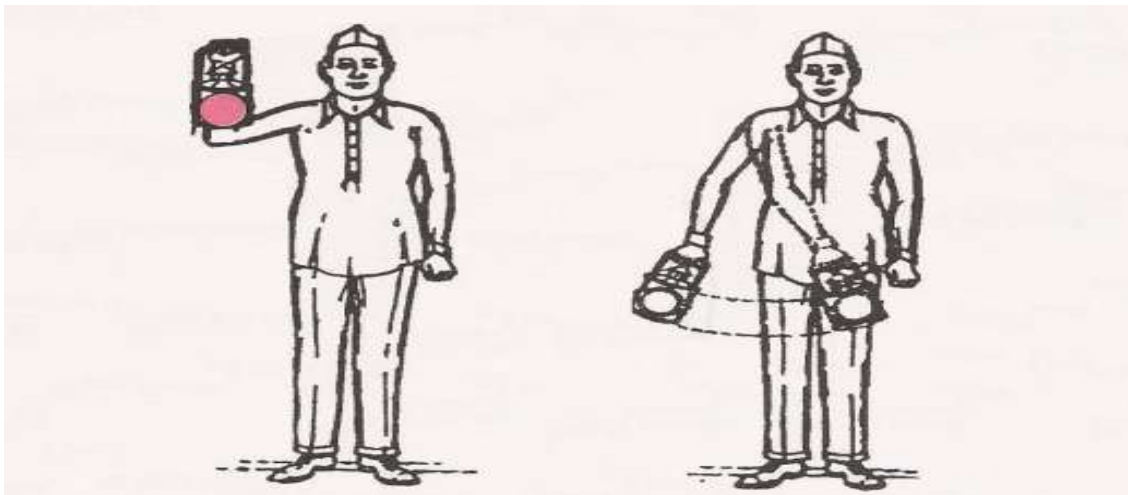
By showing a red flag or by raising both arms with hands above the head as illustrated :



How given by night:

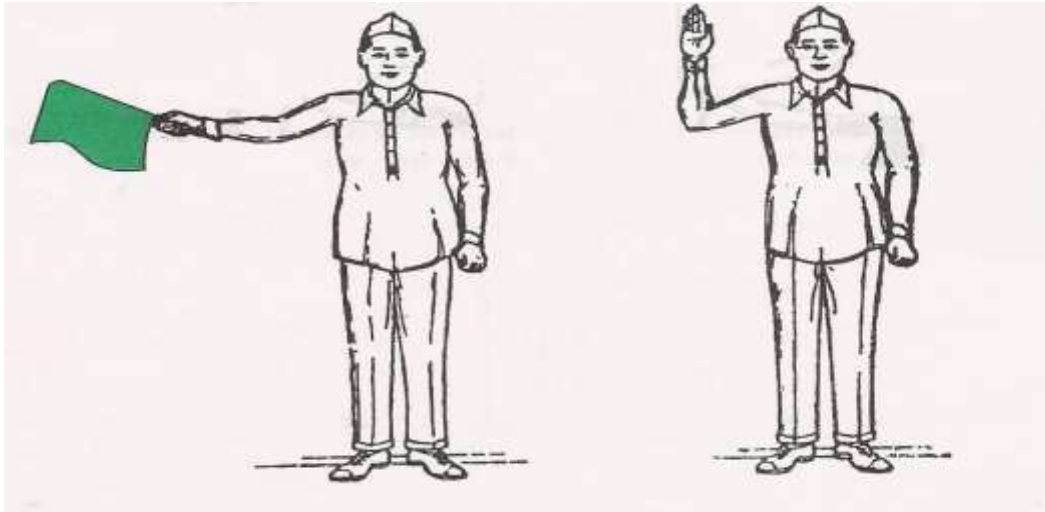
By showing a red light or by violently waving

a white light horizontally across the body of the person showing the signal as illustrated :-



Proceed: Hand signal

- Indication: Proceed
- How given by day:
- By holding a green flag or by holding one arm steadily as illustrated below:



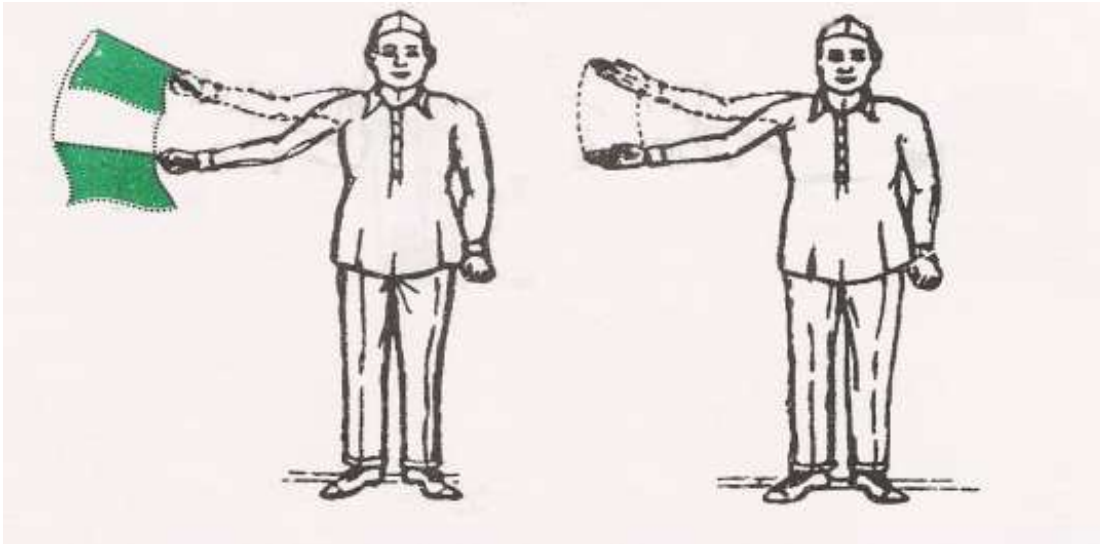
How given by night:

By holding a green light steadily as illustrated



Proceed with caution hand signal:

- Indication: Proceed slowly reducing speed further if the signal is given at a progressively slower rate.
- How given by day:
- By waving a green flag vertically up and down or by waving one arm in a similar manner as illustrated :



- *How given by night:*
- By waving a green light vertically up and down as illustrated :



Detonating Signals

Detonating signals otherwise known as detonators or fog signals are appliances, which are fixed on the rails, and when an Engine (or vehicle) passes over them, they explode with a loud sound so as to attract the attention of the Driver.

ENGINEERING INDICATORS

Engineering Indicators

Temporary Engineering Indicators

- i) Caution Indicator.
- ii) Speed Indicator.
- iii) Stop Indicator.
- iv) Termination indicators (T/P & T/G).

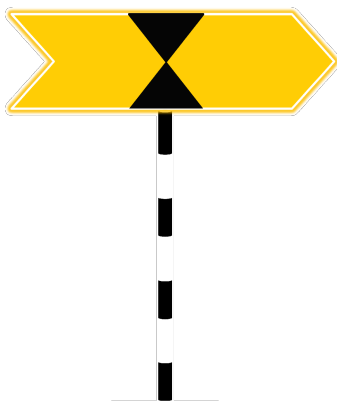
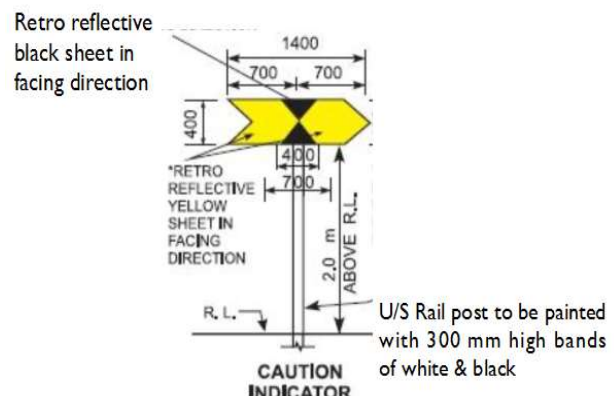
Permanent Speed Restriction Indicators

(i) Caution Indicator :-

This cautions the driver to get ready to reduce the speed. Caution indicator shall be provided at 800m in rear of the speed indicator and at 1200m where the trains are required to stop dead as in this case more braking distance is required by driver.

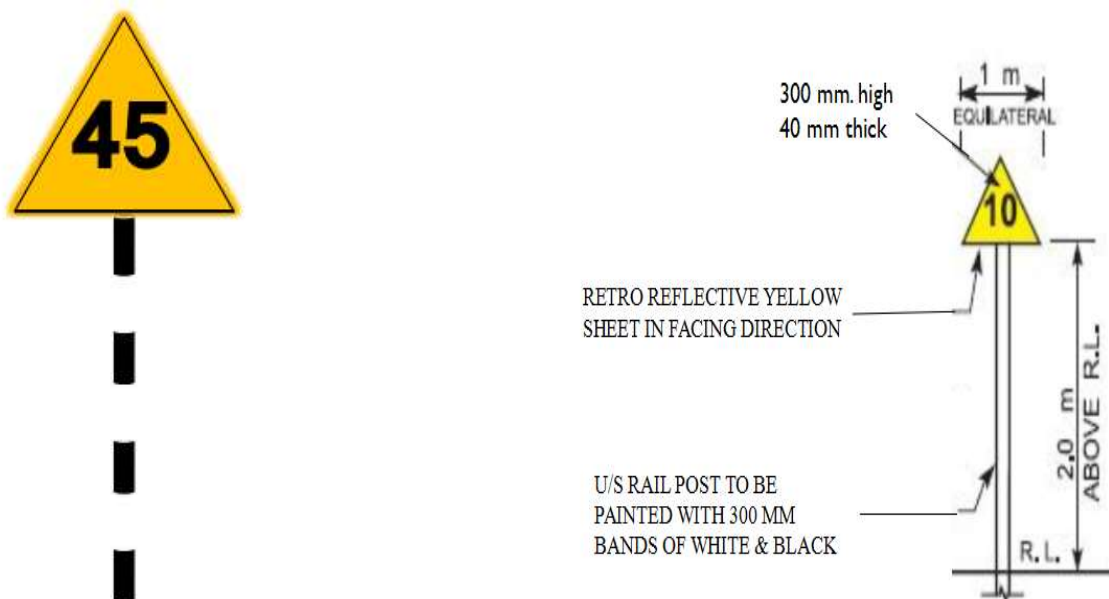
This shall consist of 1400mm long, 400mm wide. Fish tailed at one end and pointed at the other having 130mm dia. holes 2 nos. for showing yellow lights at night. The board shall be painted yellow & black.

Height of the board (bottom of the board) shall be 2.0m from rail level post will have 300mm high bend of white and black. Indicator shall be used in case of permanent as well as temporary restrictions. Temp. Engg. Indicator shall display at night 2 yellow lights to approaching trains or provided with fluorescent tape luminous paint or retro- reflective indicators (need not to lit at night).



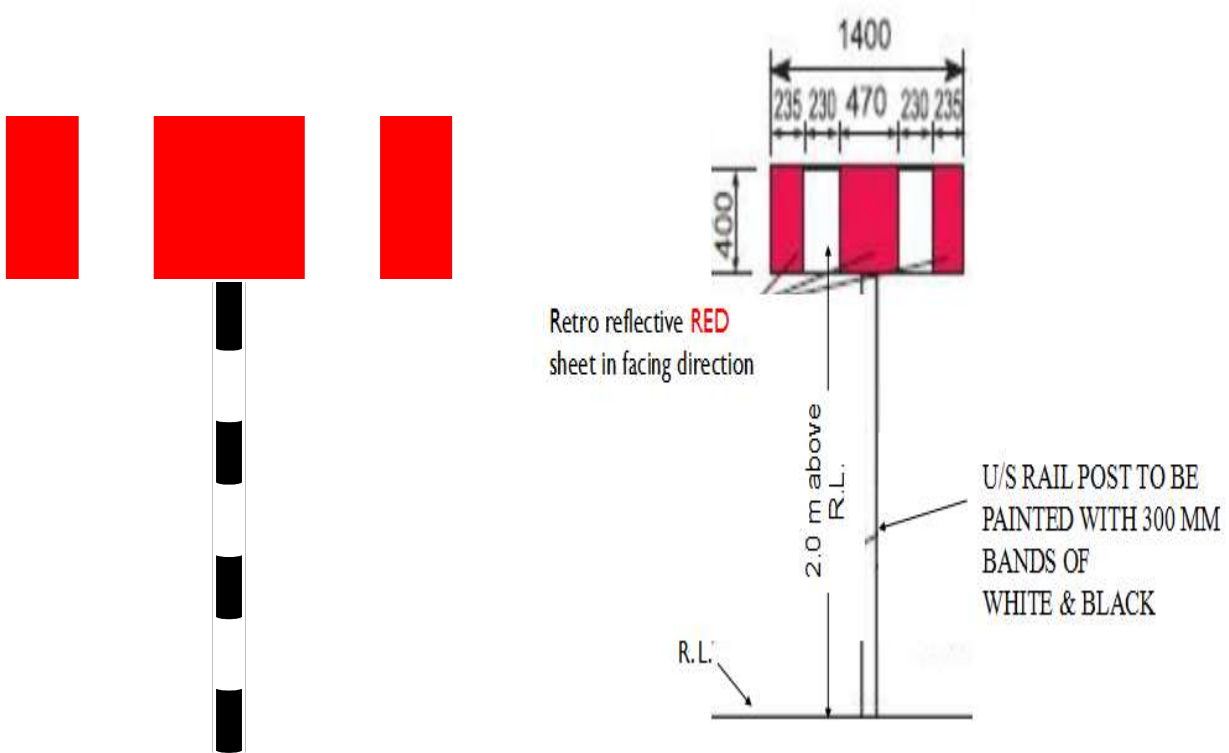
ii) **Speed Indicator :-**

It indicates to the driver to reduce the speed as indicated. This shall be provided 30m in rear from the point of commencement of speed restriction. Indicator shall consist of an equilateral triangular board with 1 meter sides having yellow base, 300mm high and 40 mm thick figures in black indicating the speed at which the train may proceed. The board shall be provided on a 2.0m high post (from the rail level to bottom of the board) painted with 300mm high white and black bands. Indicator shall be illuminated at night by fixing a hand signal lamp in front of it or provided with luminators.



(iii) **Stop Indicator :-**

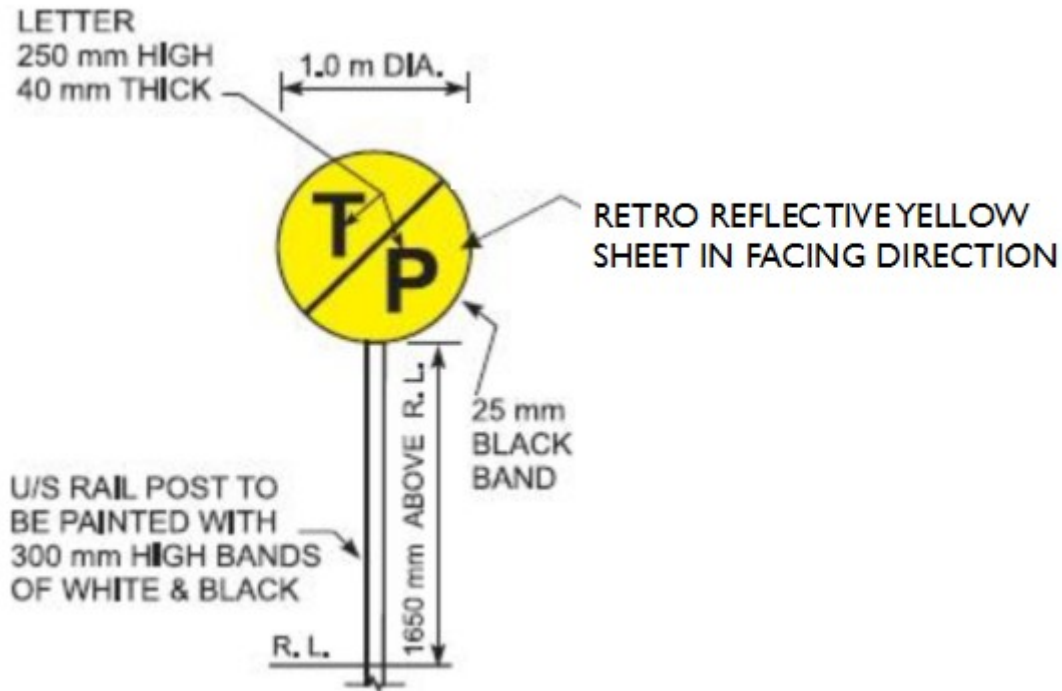
It indicates to the driver to stop the train short of indicator. Indicator shall be provided 30m m in rear of the commencement of stop dead restriction. This shall consist of a rectangular board 1400mm x 400 mm in size having 130mm dia. holes 2 Nos. for showing red lights at night painted with red and white vertical strips or provided with fluorescent tape luminous paint or retro reflective indicator. The board shall be fixed 2.0 meter high from rail level to the bottom of the board) painted with 300 mm high bands of white & black.



(iv) Termination Indicator :-

This indicates that the driver to resume normal; speed and last vehicle has cleared the restricted zone. This indicator shall be fixed at a distance equal to the longest length of passenger/goods train running in the section beyond the restricted zone.

The indicator shall be in accordance with the diagram & shall consist of one meter diameter disc painted yellow bearing 250mm high and 40mm thick letter T P and T.G. in black. The board shall be painted with 25mm thick black band at the circumference. It shall be fixed on a post 1650mm high (from rail level to the bottom of the disc) and shall be painted with 300mm high bands of black & white. The indicator shall be lighted at night by a fixed hand signal lamp or provided with fluorescent tape luminous paint or retro reflective indicator.



Temporary Engineering Indicators:

These indicators are used in connection with execution of some engineering work and removed as soon as the work is over. These indicators are flood lit at night. Retro-reflective indicators need not to lit at night. Significance of each indicator is given as below:

PERMANENT SPEED RESTRICTION INDICATORS:

(i) These indicators are same as mentioned above but used at the locations requiring permanent speed restriction (less than maximum sanctioned speed) such as weak bridge, sharp curve, weak formation turn out etc. As these restrictions last beyond the currency of the working time table hence mention of such restrictions are made in the working time table. Indicators provided are not lit at night.

(ii) Siding Boards – Siding boards indicating speed restriction are provided at facing of an outlying siding letter „S” is painted in 300 mm height with black paint on 1 metre dia circular board having yellow base. These boards are provided in addition to caution & speed indicator where maximum sanctioned speed of the section doesnot exceed 59 kmph.

Works at Times of Poor Visibility:-

No work which may cause obstruction to the passage of train shall be undertaken during foggy or tempestuous weather impairing visibility except in case of emergency. When such works are undertaken 2 detonators, 10 m apart shall be fixed 270 m in rear of caution indicator and caution hand signal exhibited to approaching trains.

Speed Restriction:-

In case where the trains are required to pass with restricted speed from site of work, the following temporary Engineering Indicators shall be exhibited.

(i) **Caution Indicator** – At 800m in rear of the obstruction.

(ii) **Speed Indicator** – At 30m in rear of the obstruction.

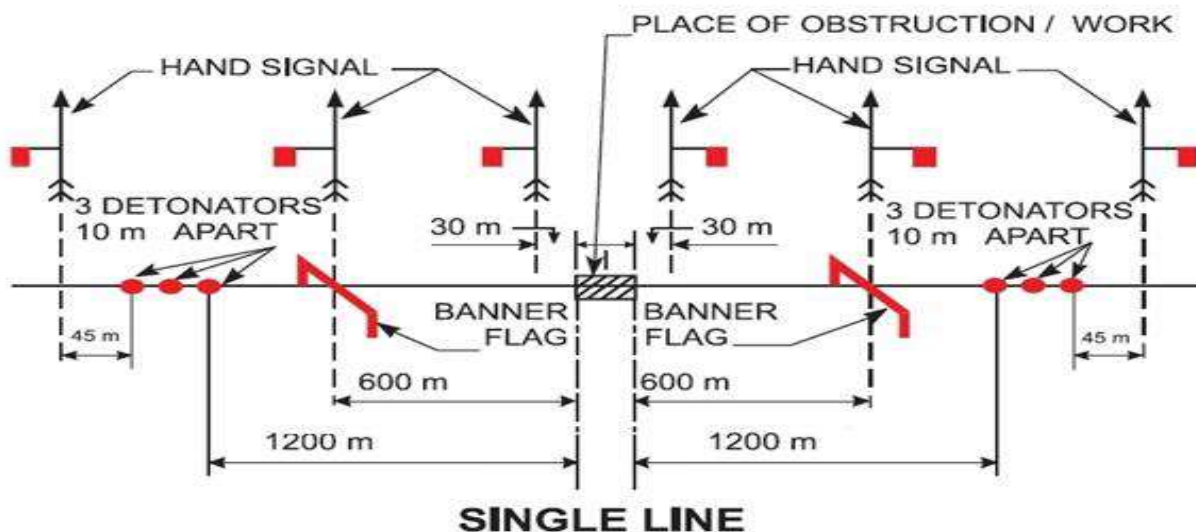
(iii) **Termination Indicators for passenger & goods train** – At a place from where the driver may resume normal speed, which is the length of longest passenger/goods train running in the section.

PROTECTION:-

1. Protection During Emergency
2. Protection During Short Duration Work
3. Protection During Long Duration Work
 - i. When stop dead & 10 KMPH is required
 - ii. When only speed restriction is required

Protection During Emergency:

WORKS OF SHORT DURATION - PROTECTION OF LINE IN CASE OF STOP DEAD RESTRICTION



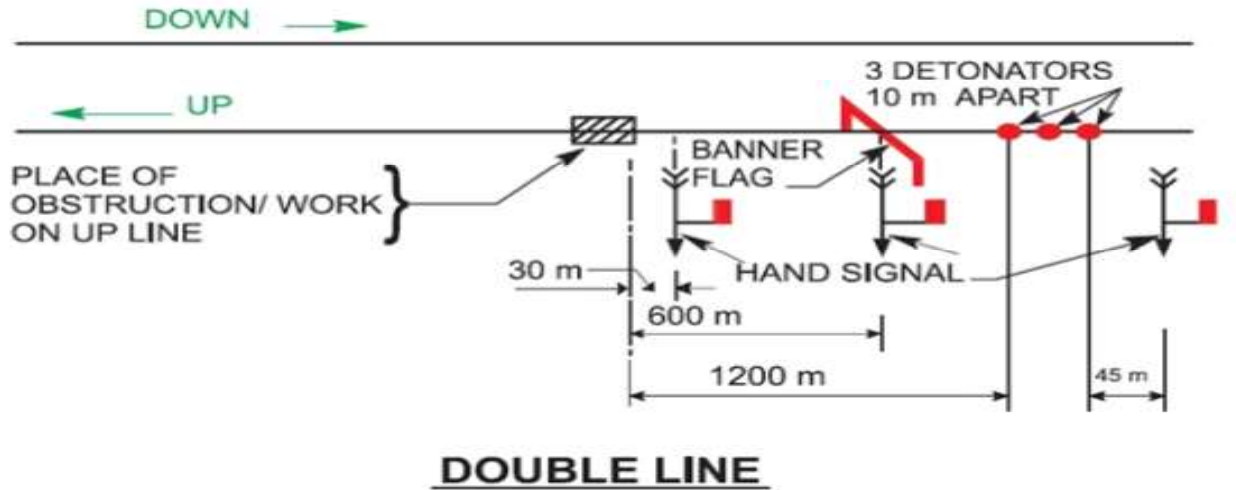
Key Man Having (1). 6 Nos of detonators (2) 2 Red flag & 1 Green Flag

Note:

1. Red hand signal Flag (HS Red Flag) for day and Hand signal red lamp is considered as a danger signal.
2. All distances should be measured from the danger zone
3. Single line protection will be made in both direction and in double line protection will be

made in direction from which the train as to come.

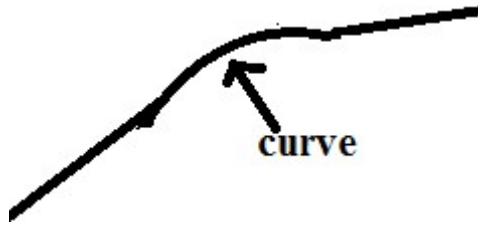
4. In case of emergency concerned railway person will take his own decision to stop the train in any how before reaching the danger zone.



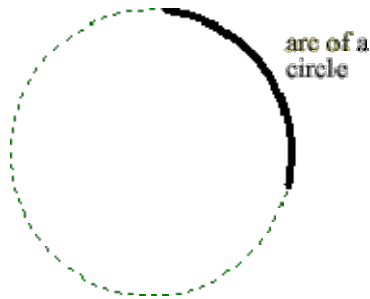
CURVE

Definitions: –

Curve: The geometrical “ARC” provided at the change of Alignment or Gradient is known as “Curve”



Arc: Any part of circumference of a circle is known as ARC.



Tangent: It is the straight line which touches the circumference of a circle only at one point. It is always at right angle to the radius at the point of contact. From any point outside the circle only two tangents can be drawn.

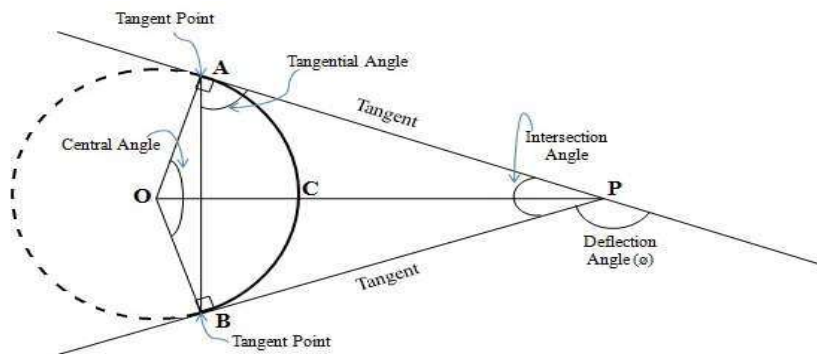


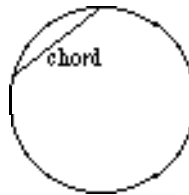
Figure 1.1

Tangent Point: It is the point of contact of Tangent and Circle (see Fig.1.1)

Tangent Length: It is the distance between the tangent point and the external point from where the two tangents are drawn. (AP & BP in Fig.1.1)

$$\text{Tangent Length (TL)} = R \cdot \left(\frac{\theta}{2} \right) \text{ Where } \theta = \text{Deflection angle}$$

Chord: It is a straight line joining two points of the curve



Short Chord: In Indian railways (Particularly on high speed), 20 mtrs length of short chord is considered as standard for track geometry measurement.

Long Chord: It is a straight line joining the two tangent points of a curve (AB in Fig.1.1.)

Longest Chord: The diameter of the circle is its longest chord.

Apex: It is the highest point on the curve which is also at middle of the ARC (Point „C“ in Fig.1.1.)

Apex Distance: It is the distance between intersection points of the tangents and middle of the Arc (CP in Fig.1.1.)

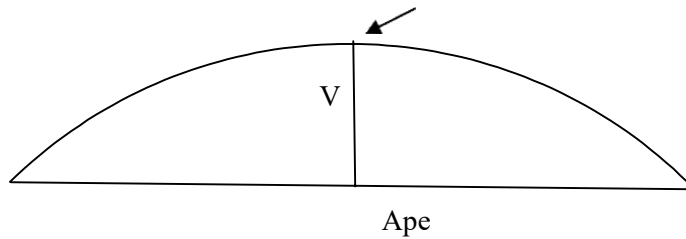
Deflection Angle: It is angle through which the curve turns. It is taken as an external angle between intersection points of two tangents (refer Fig.1.1.)

Intersection Angle: It is the internal angle of two intersecting tangents (refer Fig.1.1.)

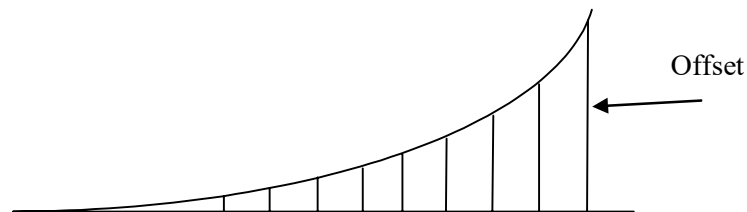
Tangential Angle: It is the angle which is formed by the long chord and tangent (refer Fig.1.1.)
It is equal to half of the deflection angle

$$\text{Tangential Angle} = \frac{1}{2} (\text{Deflection Angle})$$

Central Angle: The angle subtended at the centre of the circle by the curve selected is called Central angle. It is also equal to the deflection angle of that selected curve.



Versine : It is the perpendicular distance from the middle of the chord drawn to the curve.



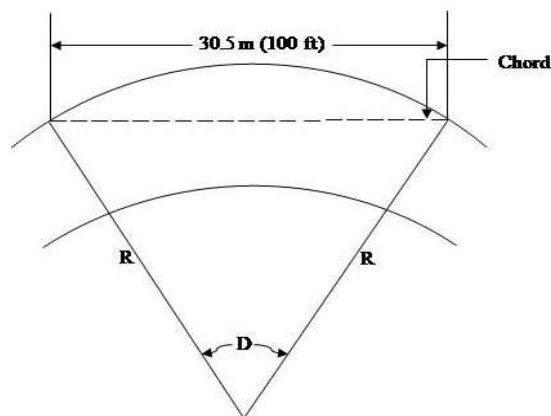
Offset: It is the perpendicular distance from the tangent to arc of circle.

Degree of Curve:

Definition:

A curve is defined either by its radius or by its Degree. **Degree of curve (D)** is the angle subtended at its centre by a chord of 30.5 meters/100 feet length.

Since railway curves are very flat (i.e., when Radius is very large, an arc of a circle is almost equal to the chord connecting the two ends of the arc) hence the degree of curve for all practical purposes is also defined as the angle subtended by a curve of 30.5metres/100 feet length at its centre.



Maximum Limit of Degree of Curve in Indian Railways

1. Broad Gauge (1676mm) :- 10^0
2. Meter Gauge (1000mm) :- 16^0
3. Narrow Gauge (762mm) :- 40^0

Relation between Degree & Radius of Curve:

Circumference of a circle = $2\pi R$

Angle subtended at the centre by a circle with this circumference = 360° Angle subtended at the centre by a 30.5-m chord, or degree of curve

$$= \frac{360^\circ}{2\pi R} \times 30.5 = \frac{1747.52}{R}$$
$$= \frac{1750}{R} \text{ approx., (where } R \text{ is in metres)}$$

The degree of the curve is thus given by the following formulae

$$D = \frac{1750}{R} \text{ (where } R \text{ is in metres)}$$

Hence radius of the curve in terms of degree of curve will be given by

$$R = \frac{1750}{D} \text{ (where } D \text{ is in degree)}$$

Value of versine in terms of chord:

Let “C” be the length of the chord AB and “V” be the Versine of the curve of radius „R”

From the property of curve we know that

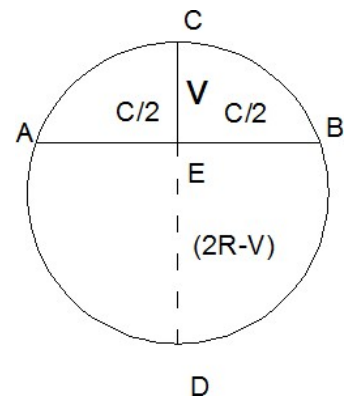
$$AE \times EB = CE \times DE$$

$$\frac{C}{2} \times \frac{C}{2} = V \times (2R - V)$$

$$\frac{C^2}{4} = 2RV - V^2$$

Since the value of V is very low, V^2 will be much lower and can be neglected

$$\frac{C^2}{4} = 2RV ; \quad V = \frac{C^2}{8R}$$



Question: Find out the length of the chord in meters for which Versine in cm is Equal to degree of the curve.

Given: Versine in cm = Degree of the curve

To Find: Length of chord “C” in meter.

Formula to be used: $V = \frac{C^2}{8R}$

In the above versine formula, the chord length “C” and radius “R” are in meters. Let us convert their units in cms.

$$\text{Then } V = \frac{C^2}{8R}$$

$$V = \frac{C^2}{8R} \times 100\text{cm}$$

$$V = \frac{25C^2}{2R} \text{ cm} \dots\dots\dots (1)$$

$$\text{We know that } D = \frac{1750}{R} \dots\dots\dots (2)$$

Equating equations (1) and (2), i.e. $V = D$ (Since from the given condition)

$$\frac{25C^2}{2R} = \frac{1750}{R}$$

$$C^2 = \frac{1750 \times 2 \times R}{25 \times R} = 140$$

$$C = \sqrt{140}$$

$$C = 11.8 \text{ mtrs}$$

NOTE: It means Versine measured in cm on **11.8 mtrs** chord length is equal to the degree of the curve

[In FPS System: Degree of curve = Versine on 61.8 ft chord]

Numerical Problem:

1. Find out the value of degree of curve having following radius
a. 1750 mtrs b. 825 mtrs c. 1000 mtrs d. 3500 mtrs

Solution

Formula used: $D = \frac{1750}{R}$

a. $D = \frac{1750}{1750} = 1^\circ$

b. $D = \frac{1750}{825} = 2^\circ$

c. $D = \frac{1750}{1000} = 1.75^\circ$

d. $D = \frac{1750}{3500} = 0.5^\circ$

2. Find out the Radius of the curve having following Degree
a. 0.5° b. 1.5° c. 3° d. 2.9°

Solution

Formula used: $R = \frac{1750}{D}$

a. $R = \frac{1750}{0.5} = 3500 \text{ mtrs}$

b. $R = \frac{1750}{1.5} = 1166.66 \text{ mtrs}$

c. $R = \frac{1750}{3} = 583.33 \text{ mtrs}$

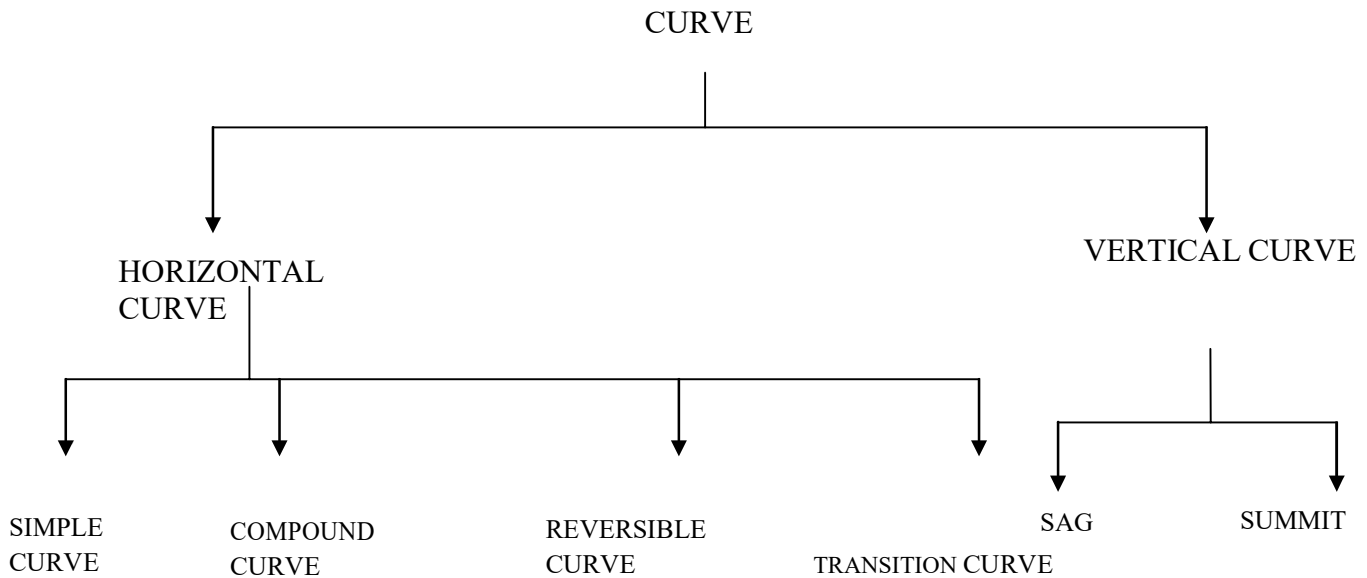
d. $R = \frac{1750}{2.9} = 603.448 \text{ mtrs}$

Necessity of curve:

Although laying and maintenance both are easy in straight line but due to the following reasons. It is essential to lay Curved Track.

1. To avoid Rivers, Mountains and other obstructions.
2. To avoid construction of major bridges, tunnels and deep cuttings
3. To connect the important cities with main line.

Classification of curve:

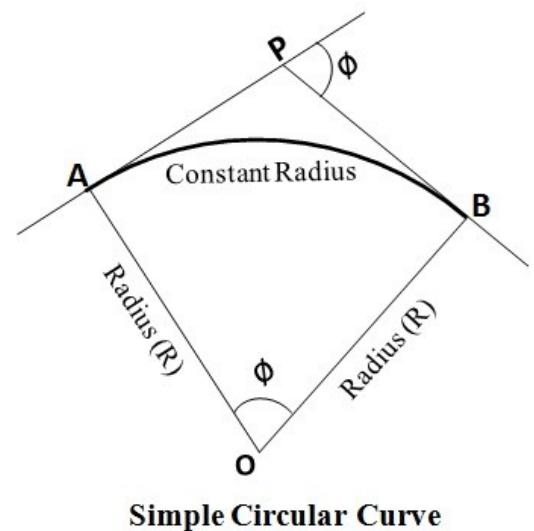


Horizontal Curve

The Curve laid on horizontal Plane is known as Horizontal Curve.

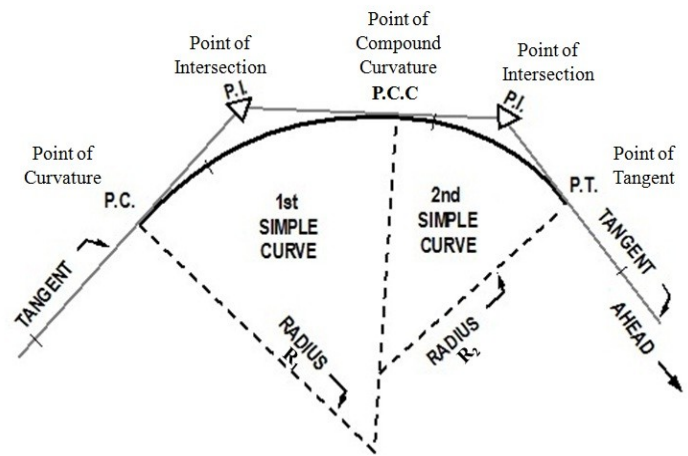
Simple Circular Curve:

Normally this curve is simple curve which connects two straight alignments (Line/Track). Since it has uniform radius and degree of curvature throughout its length, it is considered as standard and it is the most used type of curve used in Indian railways



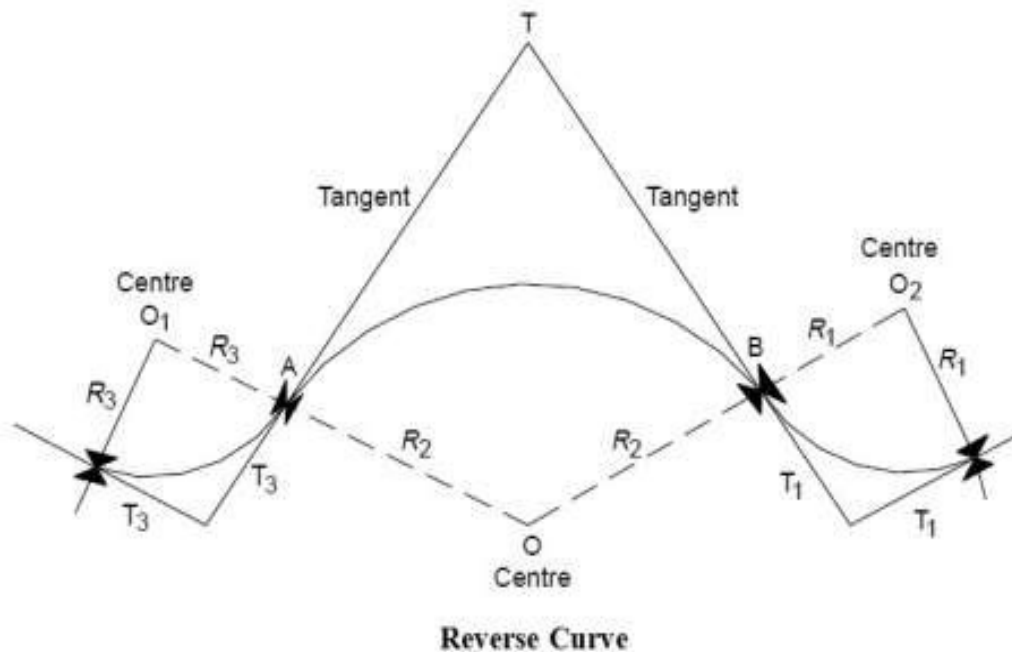
Compound Curve:

A compound curve is formed by the combination of two circular curves of different radii curving in the same direction. A common transition curve may or may not be provided between the two circular curves of a compound curve



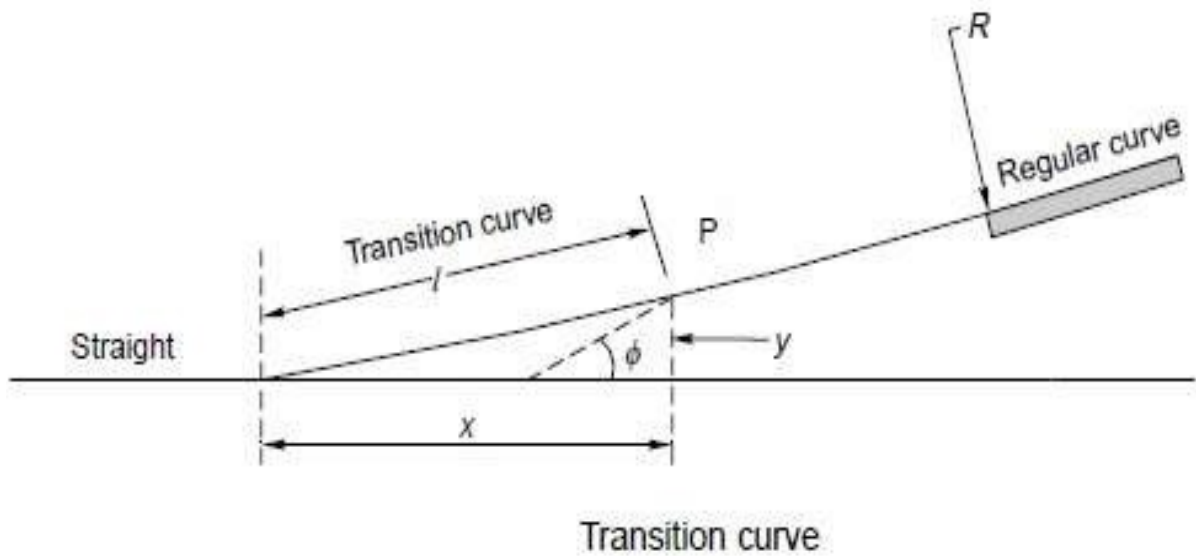
Reverse Curve:

When two curves of same (or) different radius are laid next to each other in such a way that their flexures lay in opposite directions, then this is known as reverse curve. In this case the centre of the two curves will always lie in opposite direction. On account of the shape it is also known as „S” curve. There may or may not be transition curve in between the two curves.



Transition Curve:

It is a curve having varying radius throughout its length. In Indian Railways this curve is laid at both ends of simple curve for gaining /losing the degree of curve from /to straight. Its shape is cubic parabola and it is also known as easement of curve.



❖ Vertical Curve

The curve which is provided in vertical plane and used to ease on the change of gradients is called a Vertical Curve.

Necessity:

When two gradients meet each other, an angle is formed at the junction forming the “Sag”(or) “Summit”. In case of Sags there is a danger for derailment due to motion of vehicles and in case of Summits, there is danger of train parting. Therefore to eliminate the sags and summits, vertical curves are provided.

Causes of Sag and Summit:

S. No	Sag	Summit
1		
2		
3		
4		
5		

Note:

1. Since vertical curves are very short, hence for all practical purpose it is treated as simple curve.
2. Vertical curve shall be provided only at the junction of two gradients either equal to or more than 4mm/m or 0.4%.

Minimum Radius of Vertical Curve:

As per IRPWM and LWR manual the minimum value of radius of vertical curve is as below

BG: For A route, minimum $R = 4000$ mtrs

For B route, minimum $R = 3000$ mtrs

For C route, minimum $R = 2500$ mtrs

MG: For all routes, minimum $R = 2500$ mtrs

Super Elevation on Curves**Cant or Super-elevation:**

It 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 when the inner rail on a curved track is raised above the outer rail.

Necessity for providing cant:

When a vehicle moves on a curved track, it is the tendency of the vehicle to take a straight path. While doing so the flange of leading outer wheel exerts pressure on outer rail. In reverse of it outer rails also exert pressure on wheel flange, which helps the wheel to move on curve path.

Hence the flange force is essential for motion of wheel on curve.

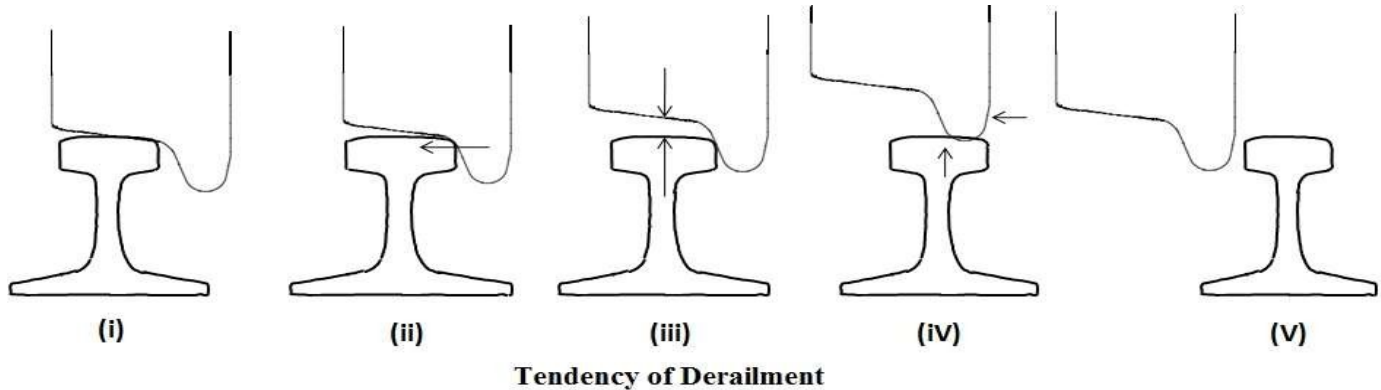
As soon as vehicle enters a curved path, it is also subjected to pseudo-force i.e., centrifugal force whose direction is always away from centre of the curve. Due to the centrifugal force, flange pressure increases on the outer rail.

Since the flange force is considered as a derailment force (by Nadal's equation) and due to this additional centrifugal force (mv^2/R), the amount of derailment force is increased enormously. Hence, it is essential to counter act (balance) this by another force.

In normal condition on straight track, the center of gravity of the vehicle passes through the centre of the track. It is considered as a balanced condition. Due to the additional flange force, the centre of the gravity of the vehicle gets misaligned towards the inner side of the curve and hence deviates from the center of the track. This causes the unbalanced condition which leads to

derailment. Hence it is necessary to re-obtain the balanced condition i.e., the center of gravity of the vehicle should pass through centre of the track.

This force is generated by changing direction of self-weight (W) of the moving vehicle. For this outer rail is raised in comparison to inner rail, in such a manner, such that the resultant of the centrifugal force/flange force and weight of the vehicle (stabilization force) should pass through the centre of the track is at right angles to the plane of the top of rails.



Purpose of providing Super elevation:

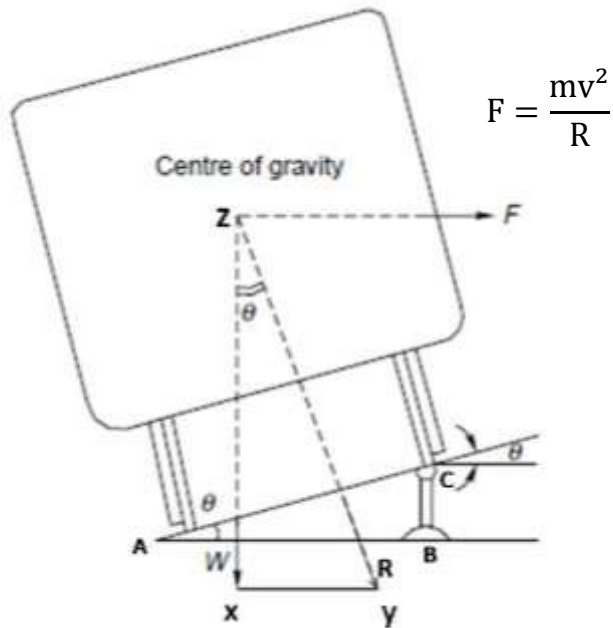
1. To counter balance the centrifugal force.
2. For proper distribution of load on both rails (Inner & Outer).
3. For better comfort of passengers.
4. To reduce the chances of wheel mounting.
5. To reduce wear and tear of the rail as well as the rolling stock.

Maximum Value of SE on BG Track

1. For Group 'A' & 'B' Routes : 185 mm
2. For Other Routes : 165 mm

Note: On all routes, maximum design cant to be limited to 140mm on track with turnouts.

Derivation of Formula for Super Elevation



Given:

AB=AC= Track Gauge

$$\text{BC} = \text{Super elevation}$$

W = Weight of the Vehicle

R = Resultant of Weight „W“ and
Centrifugal force „F“

$$\text{In } \Delta ABC \quad \tan \theta = \frac{BC}{AB} \quad \text{--- (1)}$$

$$\text{In } \Delta XYZ \text{ Tan}\phi = \frac{XY}{XZ} \text{----- (2)}$$

Equating Eqⁿs 1 & 2

$$\frac{BC}{AB} = \frac{XY}{XZ}$$

$$\text{BC} = \frac{\text{XY}}{\text{XZ}} \cdot \text{AB}$$

$$\text{BC} = \frac{\text{F}}{\text{W}} \cdot \text{AB}$$

Where,

SE (Super elevation or Cant) is in mm

G (Gauge) is in mm

V (Velocity) is in Km/hr

R (Radius) is in meters

$$\mathbf{SE} = \frac{\mathbf{G} \mathbf{v}^2}{\mathbf{g} \mathbf{R}}$$

For MKS System Putting Value

$$\text{Track gauge} = \frac{G}{1000} \text{ meter}$$

$$V \text{ (Speed in Km/hr)} = \frac{1000}{60 \times 60} V \text{ m/sec} = \frac{5}{18} V \text{ m/sec}$$

Thus,

$$SE = \frac{G v^2}{g R} = \frac{G}{1000} \times \frac{5}{18} V \times \frac{5}{18} V \times \frac{1}{9.81} \times \frac{1}{R} \times 1000$$

$$SE = \frac{G \times 25 \times v^2}{18 \times 18 \times 9.81 \times R} = \frac{25G v^2}{3175 R} \text{ mm}$$

$$SE = \frac{G v^2}{127 R} \text{ mm}$$

Equilibrium Speed and Equilibrium Super Elevation

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.

For a particular curve on a particular speed super-elevation provided by Formula $\frac{GV^2}{127R}$ is known as Equilibrium Super Elevation and the particular speed is known as Equilibrium Speed. Provision of Equilibrium Super Elevation in track is not possible due to the following reasons

1. Provision and maintenance of much cant in track is not comfortable.
2. It's effect on slow moving track will be as below
 - a. Chances of derailment of inner wheel will increase.
 - b. Reaction on inner rail is increased.
 - c. In storm, chances of overturning of wagon will be increased.

Note: The equilibrium state means effect of centrifugal force (C.F) on curve is totally counter balanced and resultant of C.F and vehicle weight (W) passing perpendicularly to rail level plane in centre of track.

Cant Deficiency:

When a vehicle runs on a curved track at a speed more than the equilibrium speed, cant deficiency is observed.

The difference between the super elevation required for maximum permissible speed on the curve and the actual super elevation provided on the curve is known as cant deficiency.

$$\text{Cant Deficiency} = C_{\text{mps}} - C_{\text{Actual}}$$

Where, C_{mps} is the Cant on Maximum Permissible Speed C_{Actual} is the Actual Cant Provided.

Maximum Value of Cant Deficiency on BG Track:

For Nominated Rolling Stocks = **100 mm/150 mm**

Note 1: For Rolling stocks permitted with 150 mm cant deficiency, cant deficiency to be limited to 115 mm on track with turnout with crossing on outer rail and on track with expansion device.

Note 2: Nominated stock shall be permitted cant deficiency of 100 mm/115 mm/150 mm after found satisfactory during oscillation trial and specified as such in speed certificate

issued by RDSO.

For other Rolling Stocks not covered above = 75 mm

Adverse Effect of Cant Deficiency:

1. Wear and Tear of outer rail & outer wheel flange will be increased.
2. Lateral disturbance of track due to unbalanced centrifugal force
3. Discomfort to the passengers.
4. Chances of Derailment of vehicle/wagon will be increased

Cant Excess:

When a vehicle runs on a curve at a speed lower than the equilibrium speed, cant Excess is observed.

It is the difference between the actual cant and the theoretical cant required for such a lower speed.

$$\text{Cant Excess} = C_{\text{Actual}} - C_{\text{minimum Speed}}$$

Maximum value of Cant Excess = 75mm

Adverse effect of Cant Excess:

1. Wear and tear of inner rail and inner wheel flange is increased.
2. Chances of derailment of vehicle are increased due to „Off-loading“ of outer wheel.
3. Discomfort to passengers.
4. In heavy winds, Chances of overturning of vehicle is increased.
5. Chances of displacement of consignment in wagon

Maximum permissible speed (MPS) of the curve-

The highest speed which may be permitted on a curve is known as Maximum Permissible Speed of the curve.

The speed is permitted by taking into consideration of the following factors

- i. The radius of the curvature

- ii. Actual cant Provided
- iii. Cant deficiency/Cant excess
- iv. Transition Length of the Curve

When the maximum permissible speed (MPS) on a curve is less than the maximum sectional speed (MSS) of the section of a line, permanent speed restriction becomes necessary.

So a permanent speed restriction is imposed on that particular curve.

Maximum Sanctioned / permissible Speed of Section (MSS)

The highest speed permitted by Commissioner of Railway Safety (C.R.S) for a particular section is known as Maximum Sanctioned / permissible Speed of Section (MSS)

This depends upon the track structure and locomotives used for that section. Driver should never cross this speed in any case.

Booked Speed:

It is the Speed on which a particular train is allowed or booked to run in a particular section. Normally this speed is lesser by 10-12% from the MSS.

Cant gradient and Cant deficiency gradient

This indicates amount by which cant or deficiency of cant is increased or decreased in a given length of transition.

Ex.: 1 in 1000 means that cant or deficiency of cant of 1 mm is gained or lost in every 1000 mm/1m of transition length.

Rate of change of cant or rate of change of cant deficiency

This is the rate at which cant or cant deficiency is increased or decreased per second at the maximum permissible speed of the vehicle passing over the transition curve.

Ex.: 35 mm. per second means that a vehicle when travelling at a maximum speed permitted will experience a change in cant or deficiency of cant of 35mm. in each second of travel over the transition Curve.

Preferably it should be **35 mm/sec** in BG Track. In the worst case it should not be more than **55 mm/sec** in BG Track.

Speed on Curve for 'D' and 'E' Route (M.S.S=100 kmph)

1. Assumption of Equilibrium Speed

Equilibrium Speed = $\frac{3}{4}$ of the M.S.S. of section

2. Assumption of Safe Speed

For all practical purposes safe speed means a speed which protects a carriage from the danger of overturning and derailment and provides a certain margin of safety.

a) Transitioned Curves

The maximum permissible speed for transitioned curves should be determined (based on the assumption that the centre-to-centre distance between railheads is 1750 mm) using the following formulae:

$$\text{Safe Speed, } V = 0.27 \sqrt{R (Ca + Cd)} \text{ Kmph}$$

Where,

V = Speed in Kmph.

R = Radius in metres.

Ca = Actual cant in mm.

Cd = Permissible cant deficiency in mm.

b) Non-transitioned Curves

$$\text{Safe Speed} = \frac{4}{5} \text{ Kmph}$$

Where, V is the speed in km/h and R is the radius in meters.

JOINTS AND WELDING

TYPES OF THE JOINTS

1. Ordinary fish plated joints [Normal joint]
2. Joggle fish plated jointed [on ward fracture joints]
3. Insulated joints [in track circulating areas]
4. Glued Joint [In track circulating areas]
5. Switch Expansion Joint [SEJ] in end of LWR/SWR.

Defects of joints

1. **Hogged joint:** - in this defect, rail at joint bends permanently in downwards and arail at end is permanently subjected with vertical kinks. These type of joints are known as hogged joints.
2. **Battered joint:** Flattering of rail end at joints is known as battering this flatteringof rail end occurred during service by hitting of wheel. This types of joint is known as battered joint.
3. **High joint** : During the work of maintenance sometimes joints are packed more than required, resulting it becomes high than running on such joints becomes very bad because these joints give some vehicle lift while passing at the wheel.
4. **Low joint** : in sufficient packing of joints gives down leveling of joints resulting bad running (or) riding of train. After sometimes these joints are converted in hogged and battered joints. if not attended with in short time period.
5. **Blowing joints:** when within dust blows from joints under the moving train the joints. In such joints there are always white dusts in surroundings of joints. These joints are generated due to
 1. Low maintenance level of the track joint
 2. Packing with dirty ballast
 3. Bad quality of soil

Maintenance of such types of joints is very necessary

6. **Pumping joints** : In raining season the blowing joint converts into pumping joints . In rainy season the water fills in the underived water packets [which are generated due to blowing of joints/ weak soils] and mud comes out while passing of trains from on it, maintenance of such joints are very difficult due to weak

Formation ballast penetration under the formation and packing does not retain under these sleepers.

Necessity for welding of rail joints

In the modern age of track technology with concept of high speed routes, the welding of joints becomes necessary due to following reasons:

1. Due to impact of moving load at joint ballast under the joint sleepers gets loosen particularly on loose / defective fish plated joints (F/P) regularly. Hence maintenance of joints need more attention money and labor
2. Due to different joints defects like hogging, battering etc the service life of track components gets reduced
3. A lot of noise pollution is created on fish plated track particularly on loose/ defective joints. Resulting discomfort to passengers.
4. Due to loose / defective joints chances of derailment are much more at fishplate
5. Chances of sabotage at fishplate joints are more and easy because it can be done by easily removal of fish plate from track
6. Service life of components of rolling stock is also reduced on fish plated track due to different types of wear and impact
7. Resistance developed by fish plate joints against rolling of rolling stocks increases fuel consumptions is more
8. 50 % to 80% extra labour / time/money is required to maintain the joint in fish plated track
9. Due to above various reasons. It is difficult to run the train on high speed on fish plated track
10. Fish plated track is not suitable for modern methods of maintenance of track.

Advantages of welding of rail joints

1. More than 50% maintenance cost reduced in welded track compared to fish plated track
2. By eliminating rail joints an uniform smooth floating track is achieved which results smooth running of train.

3. Easy to maintain track parameters with uniform ballast cushion which gives the high speed on track
4. Due to achieving uniform and good parameters on welded track , chances of derailment is reduced
5. Life of track components as well as rolling stock increases
6. Safe and anti-sabotage type of track achieves resulting curtailing in extraexpenditure on security
7. Noise pollution reduces resulting increase in comfort level of the passengers
8. Low friction pathway achieved resulting haulage cost reduced.
9. Track capacity increases
10. Fuel efficiency increases
11. Suitable for modern method of packing(Track Maintenance)

Types of Welding

The various types of rail welding techniques are as follows

1. Oxy- acetylene welding
2. Electric arc welding
3. Flash butt Welding
4. Alumino-thermit welding

Oxy Acetylene or Gas Welding

In this type of welding necessarily heat is produced by a combination of oxygen and acetylene gas. The rail ends to be welded are brought together and heat is applied through a burner. Temperature up to 1200°C to 1400°C is achieved, so that the metal of the rail ends gets melted and fusion takes place, welding the rail ends together.

Electric Arc welding

In this method the heat is created by the passage of electric current across a gap between two conductors. About 3500°C temperature is achieved causing the two rail ends weld together

Flash Butt Welding

In this method heat is generated by electric resistance. The two rail ends are brought together so that they almost touch each other. The electric energy is switched on there by

allowing an electric current of about 5 volt and 35000 ampere to pass between faces of two rails, lot of flashing takes place and considerable heat is generated rising the temperature from 1000°C - 1500°C. At this time the rail ends are pressed together with 100 bar butting pressure, causing welding of the rails.

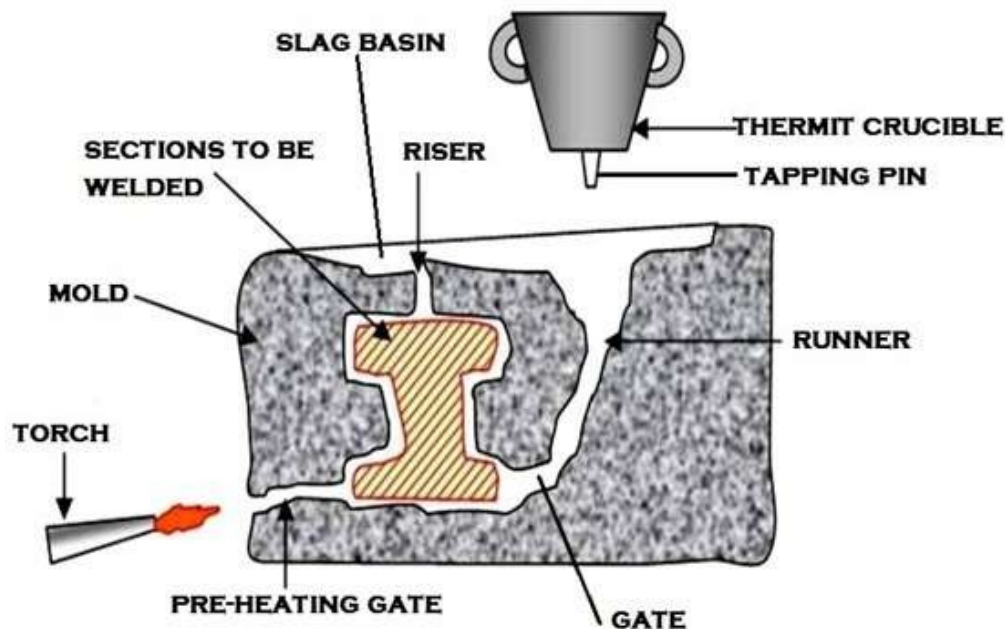


ALUMINO – THERMIT WELDING:

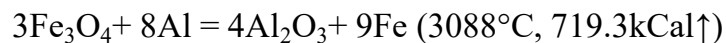
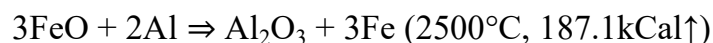
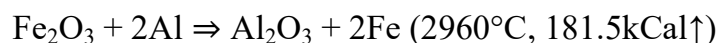
This is the only form of site welding. Its principle is that when a mixture of finely divided aluminium and iron oxide called thermit mixture is ignited a chemical reaction takes place with evolution of heat, producing iron and Aluminium oxide. The iron released from the reaction is in molten condition (2450°C), which is poured in the gap between the two rails, welding the rail ends together. The equation which follows is:



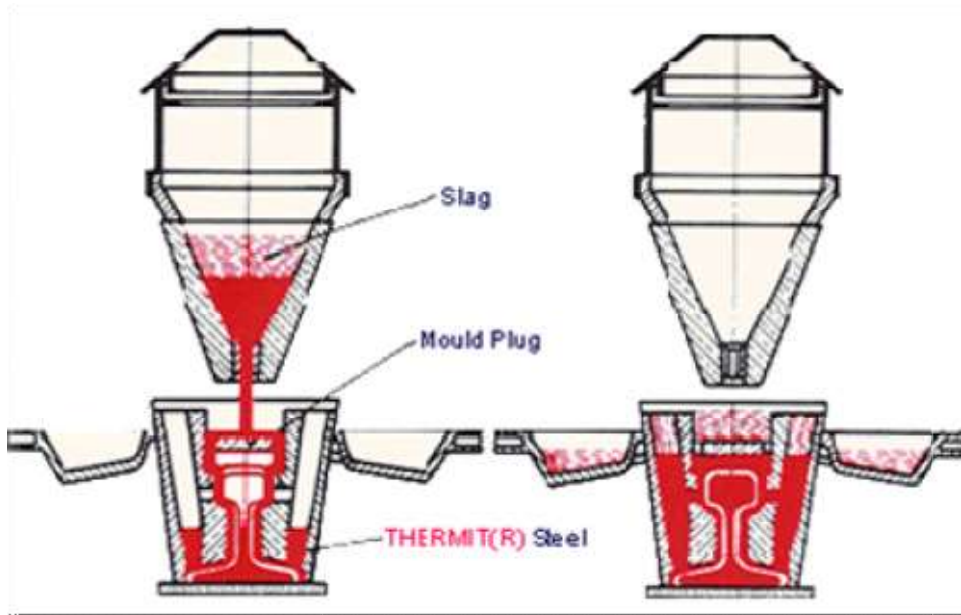
THERMIT WELDING SET-UP



Thermit reaction details: Aluminum reacts with iron oxides, particularly ferric oxide, in highly exothermic reactions, reducing the iron oxides to free iron, and forming a slag of aluminum oxide.

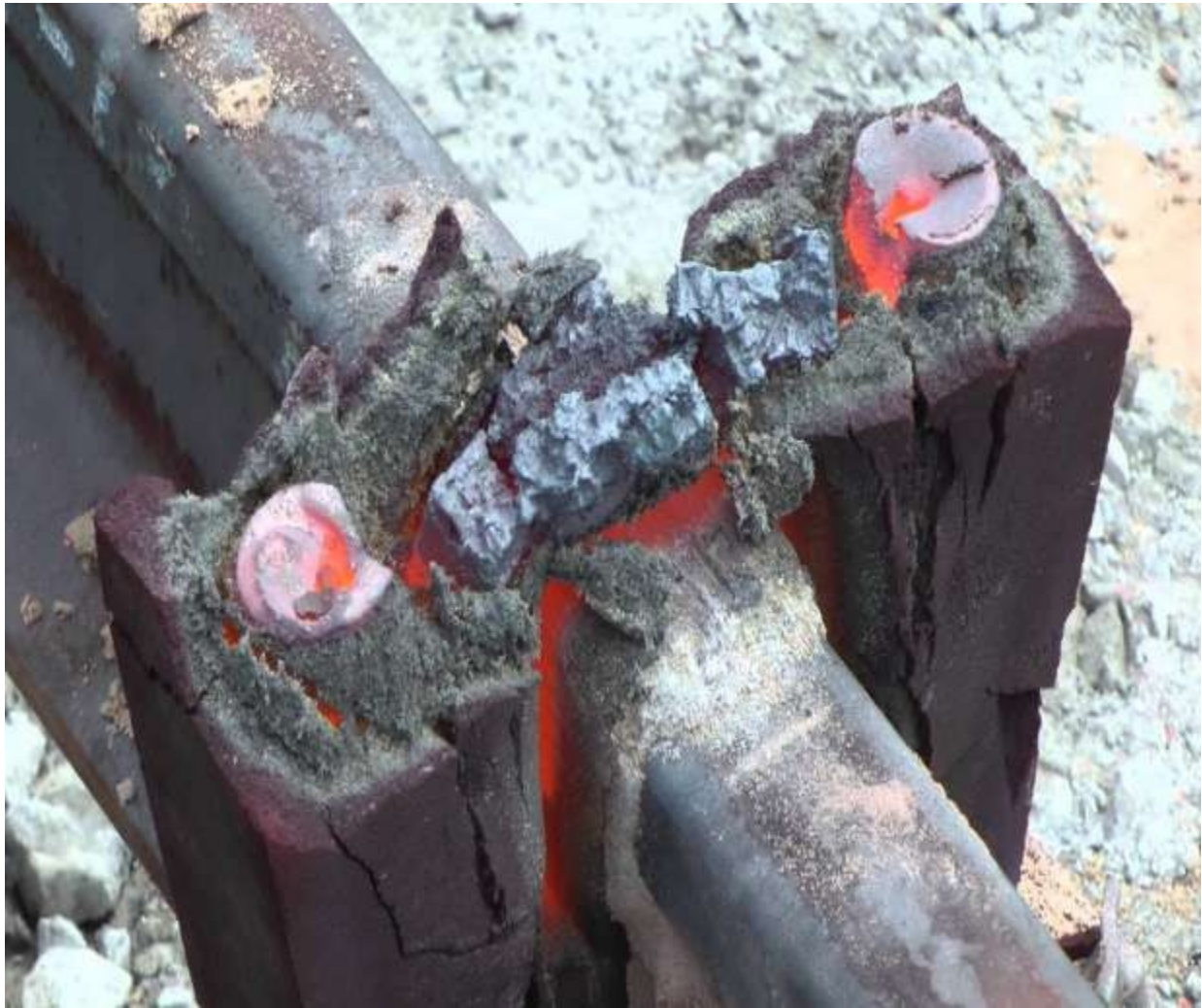


SKV or SPW (Short pre-Heat welding)

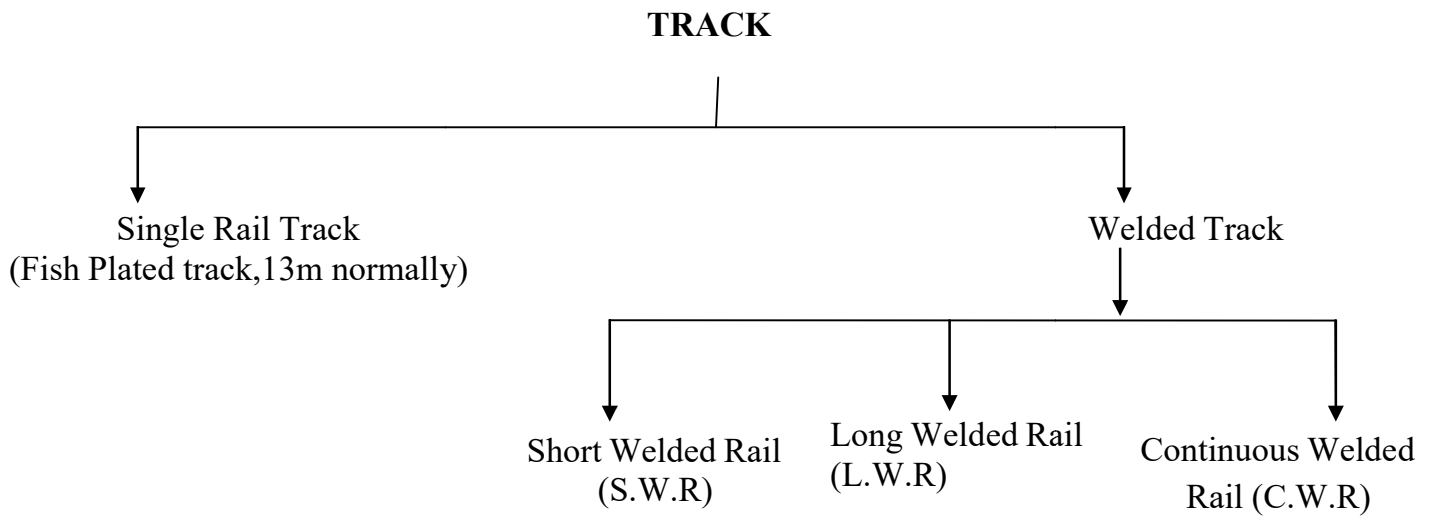


Difference between Flash Butt and AT Welding

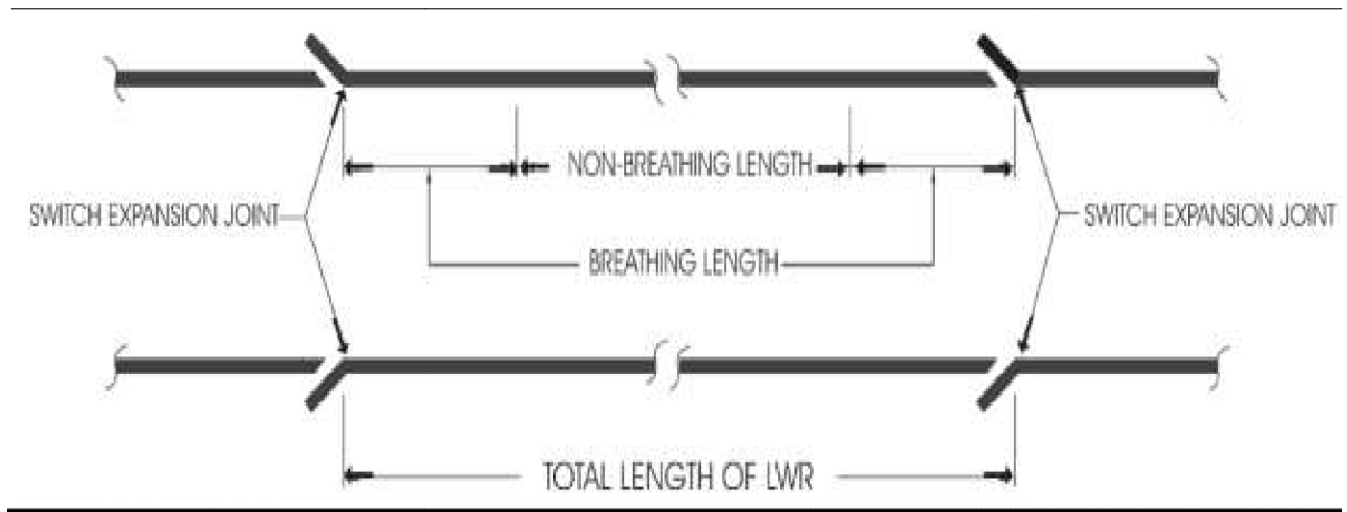
S.No	Description	Flash Butt Welding	A.T Welding
1	Principle of welding	Welding is done by passing of 5 volt, a 3500 ampere electric current between two rail ends	Welding done by an exothermic chemical reaction between Iron oxide and aluminum
2	Quality of Welding	Excellent	Good
3	Strength of Welding	Good in Fatigue	Weak in fatigue
4	Time required for welding	About 3 to 6 minutes	50 minutes but normally a block of about 1 ½ hrs is required
5	Possible places for welding	Both Site and workshop but normally done in workshop	Welding at site
6	Tolerance	Very tight tolerance	Normal Tolerances
7	Cost of Welding	Rs 700 to 900 per weld	Rs 900 to 1200 per weld
8	Quality of Welding	By help of a welding recorder	Depends upon only by good work and no monitoring is possible



RAILWAY TRACK:



Long Welded Rail



IMPORTANT DEFINITIONS:

1. L.W.R. (Long Welded Rail):

It is a welded rail, central part of which does not have any longitudinal movement due to temperature variation. Length of rail more than 250 meter in B.G. and 500 m. in M.G. should function as L.W.R.

2. S.W.R. (Short Welded Rail):

It is a welded rail, which contracts and expands throughout its length. It is generally three rail length long.

3. Breathing Length:

It is the length at each end of L.W.R. or C.W.R. which is subjected to contraction or expansion on account of variation in temperature.

4. S.E.J. (Switch Expansion Joint):

It is an expansion joint installed at each end of L.W.R.. to permit expansion or contraction of the adjoining breathing length due to temperature variation.

5. Anchor Length:

It is the length of the track required to resist the pull exerted on rail by rail tensor during distressing.

For B.G., Anchor length = $L_a = 2.5 (t_o^{\circ}\text{C} - t_p^{\circ}\text{C})$ in meter.

For M.G., $L_a = 4.5 (t_o^{\circ}\text{C} - t_p^{\circ}\text{C})$ in meter

Where, t_o = stress free temperature.

t_p = Prevailing rail temperature.

6. De-stressing:

The operation under taken with or without rail tensor to secure stress free condition in L.W.R. at a specified rail temperature is called de-stressing.

7. Rail Temperature:

It is the temperature of rail as recorded by an approval type of rail thermometer at site.

8. Mean Rail Temperature :

Mean rail temperature of section is the average of maximum and minimum rail temperature recorded for that section for last five years.

$$\text{Mean rail temperature } t_m = \frac{\text{Max}^m \text{ Rail temp.} + \text{Min}^m \text{ R.T.}}{2}$$

Range Of Temperature:

$$\begin{aligned} &= \text{Max}^m \text{ Rail temp.} - \text{Min}^m \text{ Rail temp.} \\ \text{Ex. } &= 60^\circ\text{C} - (-10^\circ\text{C}) \\ &= 70^\circ\text{C} \end{aligned}$$

Temperature map of Indian Railway shows the range of temperature and mean rail temperature of different places in India.

$$\text{Ex.} - \text{Bombay } 60^\circ\text{C} (20^\circ\text{C})$$

$$\text{Range of temperature} = 60^\circ\text{C}$$

$$\text{Mean Rail temperature} = 20^\circ\text{C}$$

9. Prevailing Temperature:

It is the rail temperature prevailing at the time when any operation connected with de-stressing is carried out, denoted by t_o .

10. Stress Free Temperature (t_o):

It is the rail temperature at which the rail is free of all thermal stress. At this

temperature, there is no thermal stress in the rail panel.

11. De-stressing temperature (t_d):

It is the average rail temperature during the period of fastenings of rails to sleepers after de-stressing the L.W.R. without using tensor. If rail tensor are used, for all practical purpose, t_d can be taken as t_o . De-stressing temperature ranges are as follows.

Rail section	De-stressing temperature range (t_d-range)			
1) 52 Kg & higher section	-	$t_m + 5$	to	$t_m + 10$
2) Other section	-	t_m	to	$t_m + 5$

By:-IRTMTC/ALD