LECTURE NOTES

ON

TRANSPORTATION ENGINEERING – II (A70143)

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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 (Visakhapatnam)
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, Chakradharpur, 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,Thiruvananthapuram
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.

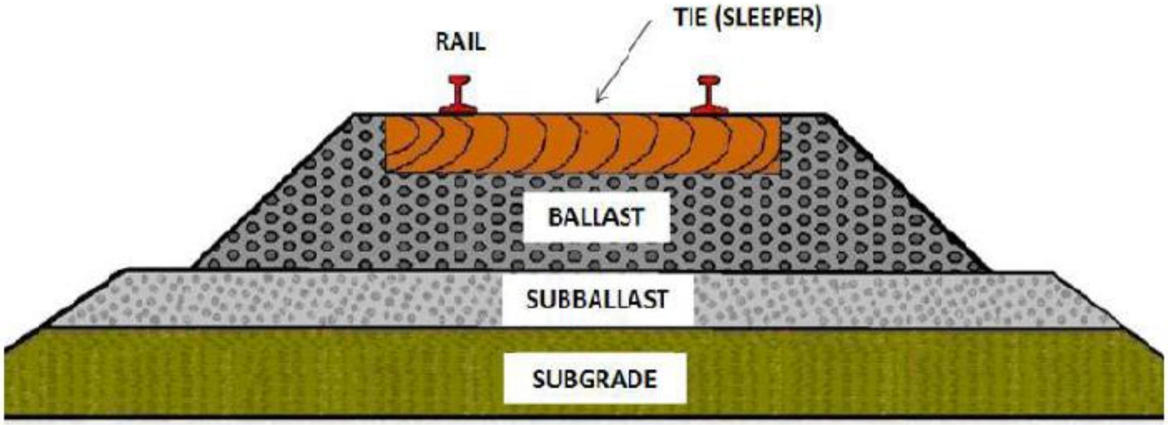
There are fourteen public undertakings under the administrative control of the Ministry of Railways:

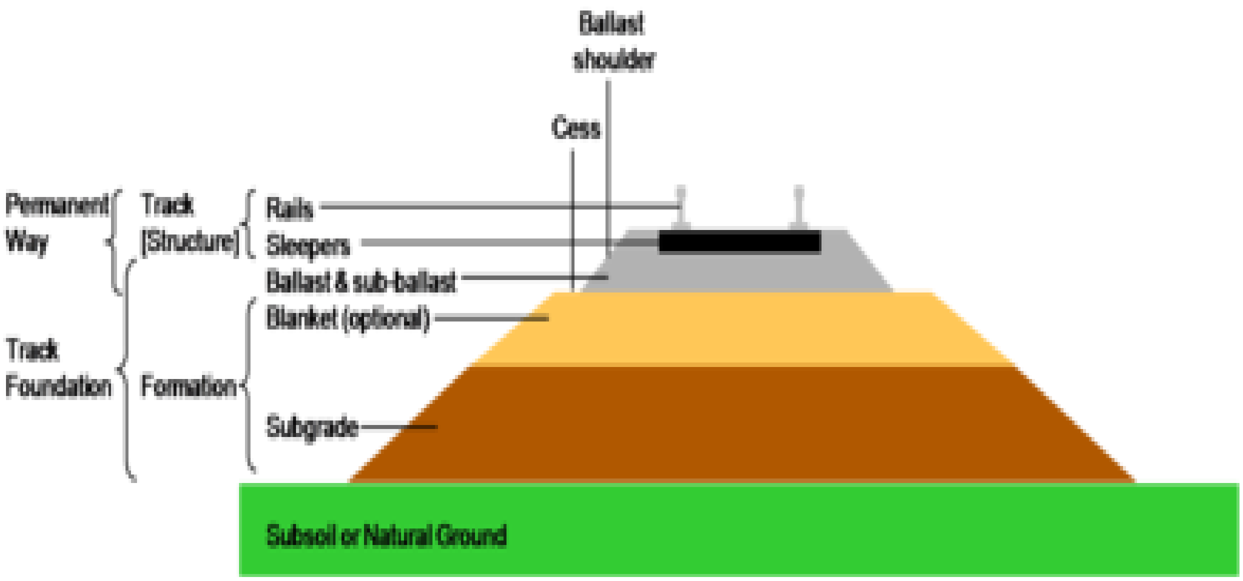
Bharat Wagon and Engineering Co. Ltd. (BWEL)

- 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)

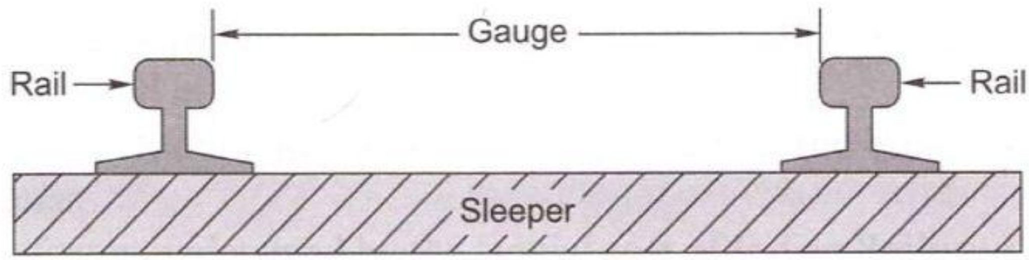
Lecture-2 Component parts of railway track

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.

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.

***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:

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 signaling 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

Meter gauges

Q -routes

Speed> 75kmph

Traffic density >2.5 GMT

R-routes

Speeds < 75kmph and capable of travelling > 75kmph

Traffic density little more than 1.5 GMT

Sub classified into R1, R2,R3

S-routes

Speeds < 75kmph

Traffic density < 1.5 GMT

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 any 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 unit-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

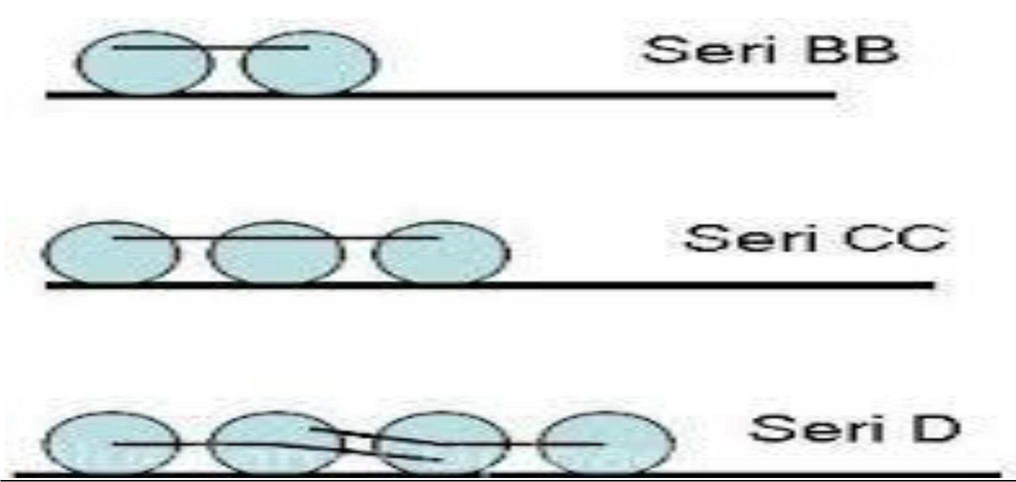
Here the examples have been taken is 2-8-8-2. This 2-8-8-2 indicates that there are 2 sets of 4 driving axles. When we say there are 2 sets of 4 driving axles, it means we are having 8 wheels in one set and 8 wheels again in another set. That is why in the central location we are having 8 and 8, still 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:

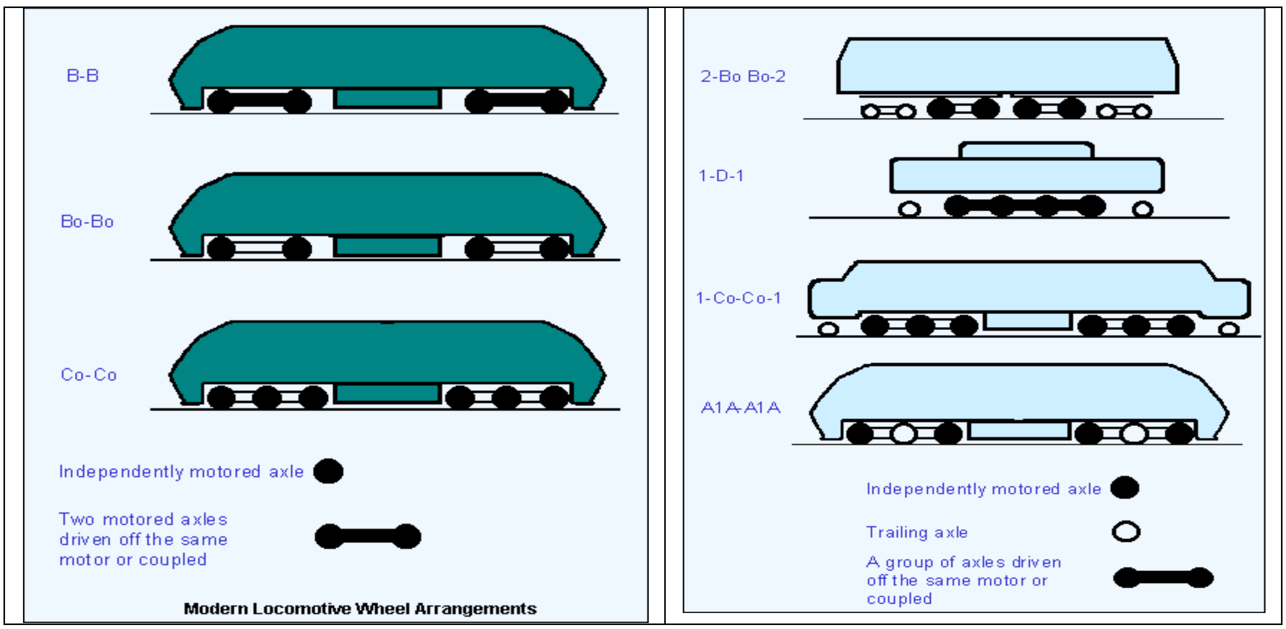
The European arrangement says that they count the axles then the wheels. As we have taken the example previously, here it was 2-4-2 condition where the wheels were counted with 2 front, 4 central and 2 trailing wheels. Here in this case, it will be transformed into 1-2-1 where there is 1 axle in the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



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

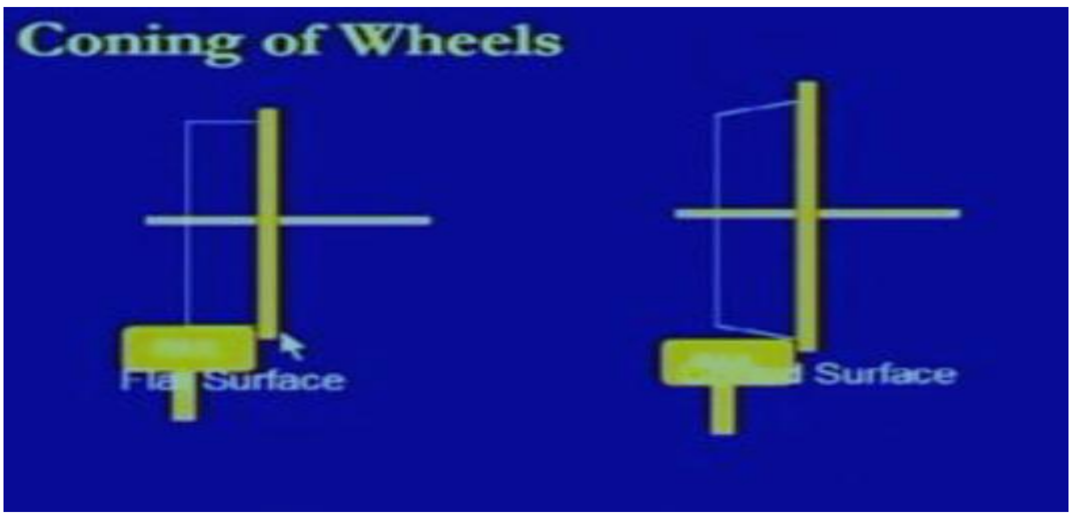
Electronic control and signalized arrangements

Use centralized monitoring control systems for monitoring safety

Availability of relief mechanisms in case of mis happenings

Coning of Wheels

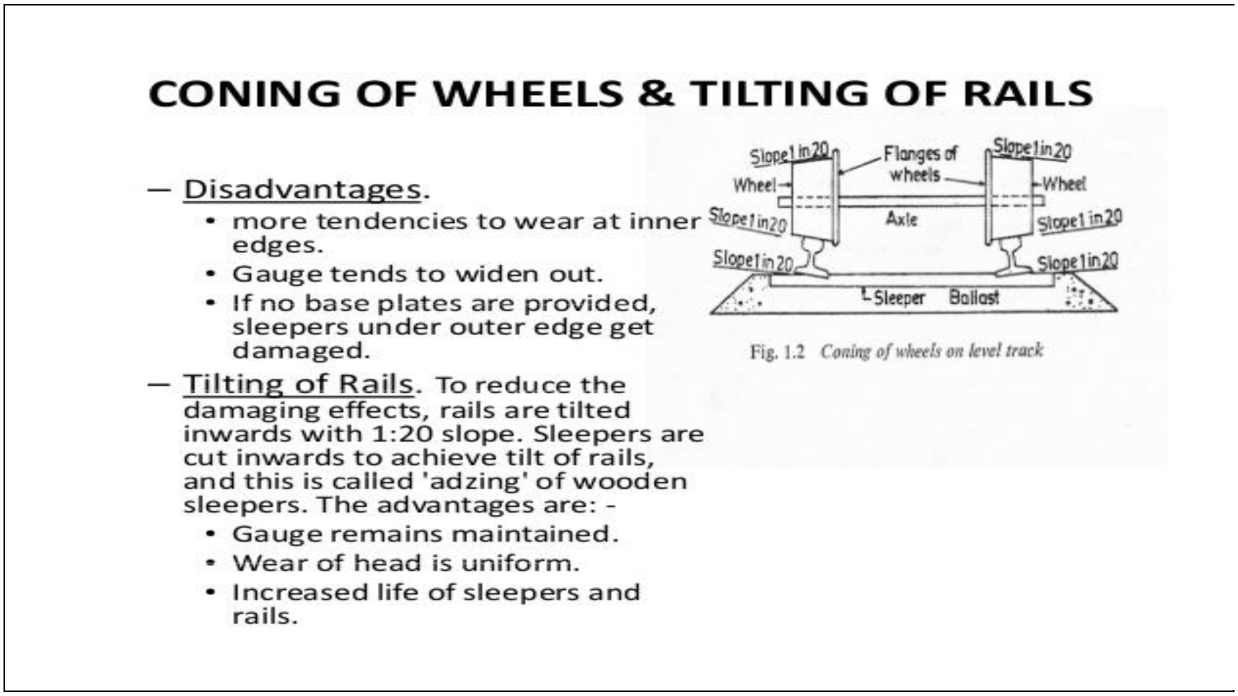
It is provision of conical surface or slopped surface to the wheel to overcome various disadvantages like sway, wear and tear which occur during the movement of locomotives and transfer their load to rails.



Advantages of coning of wheels

Reduces effect of lateral sway 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.

Smooth movement on curved sections 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 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.



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

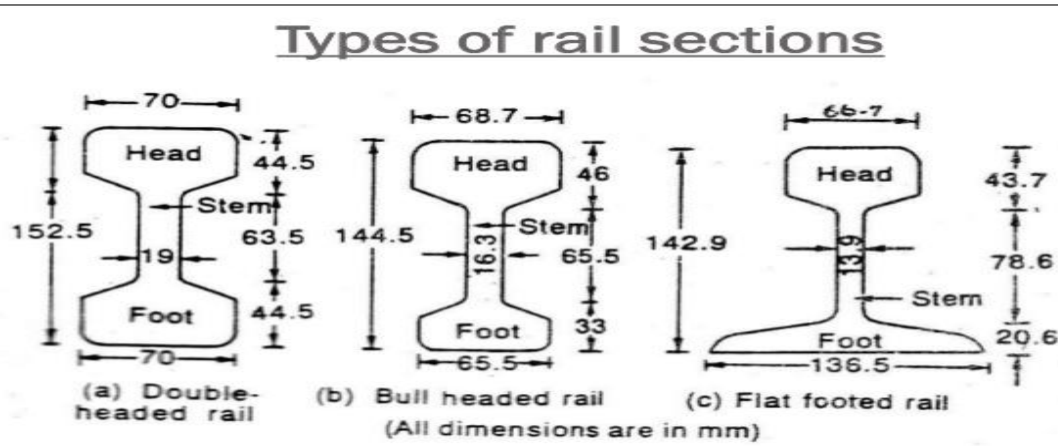


Fig.2.1 Rail Sections

REQUREMENTS OF AN IDEAL RAIL SECTION

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. The requirements of an ideal rail section 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

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 proper

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

g) 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.

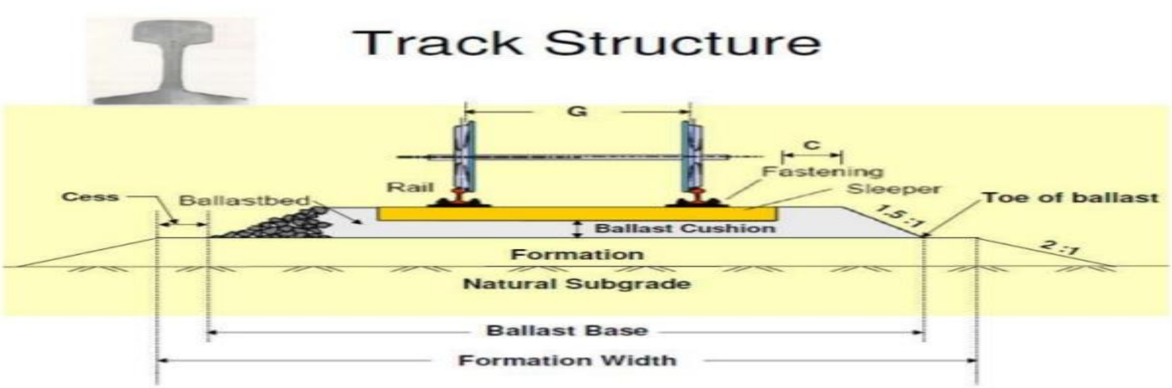
(b) It bears the load transmitted to it from the moving load through the ballast

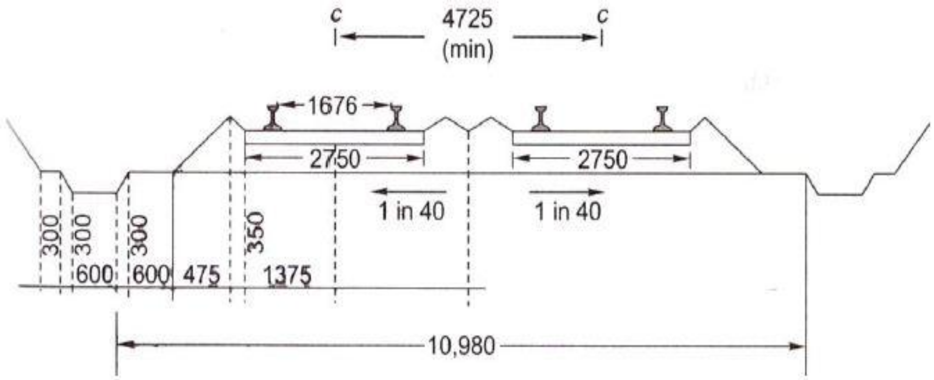
(c) It facilitates drainage.

(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 :-

1. The gauge of the permanent way should be uniform, correct and it should not get altered.
2. Both the rails should be at the same level on tangent (straight) portion of the track.
3. Proper amount of super elevation should be provided to the outer rail above the inner rail on curved portion of the track.
4. The permanent way should be sufficiently strong against lateral forces.
5. The curves, provided in the track, should be properly designed.
6. An even and uniform gradient should be provided through out the length of the track.
7. The tractive resistance of the track should be minimum.
8. 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.
9. It should provide adequate elasticity in order to prevent the harshness of impacts between the
10. Rails and the moving wheel loads of a train.
11. It should be free from excessive rail joints and all the joining should be properly designed and constructed.
12. All the components parts such as rails, sleepers, ballast, fixtures and fastenings, etc. should satisfy the design requirements.

13. 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.
14. All the points and crossings, laid in the permanent way, should be properly designed and carefully constructed.
15. It should be provided with fence near level crossings and also in urban areas.
16. It should be provided with proper drainage facilities so as to drain off the rain water quickly away from the track.
17. It should be provided with safe and strong bridges coming in the alignment of the track.
18. It should be provided with safe and strong bridges coming in the alignment of the track.
19. 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.

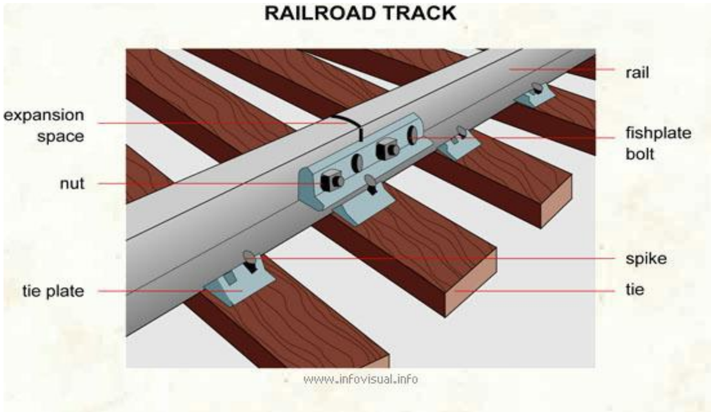
Creep Indicators

The following symptoms indicate creep over a rail section

<u>Closing of joints in the direction of creep</u> 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.

<u>Opening of joint at point from where the creep starts</u> 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.

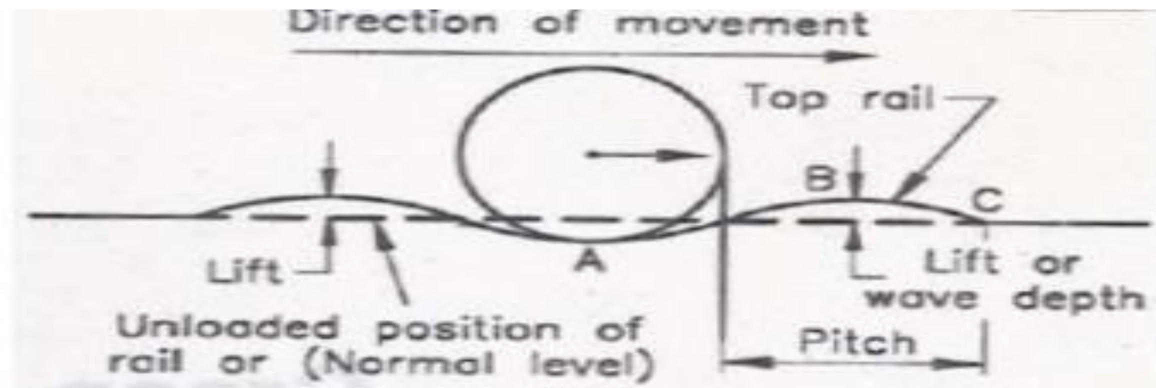


Fig. 8.2. Wave Theory of Creep (Formation of Wave)

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

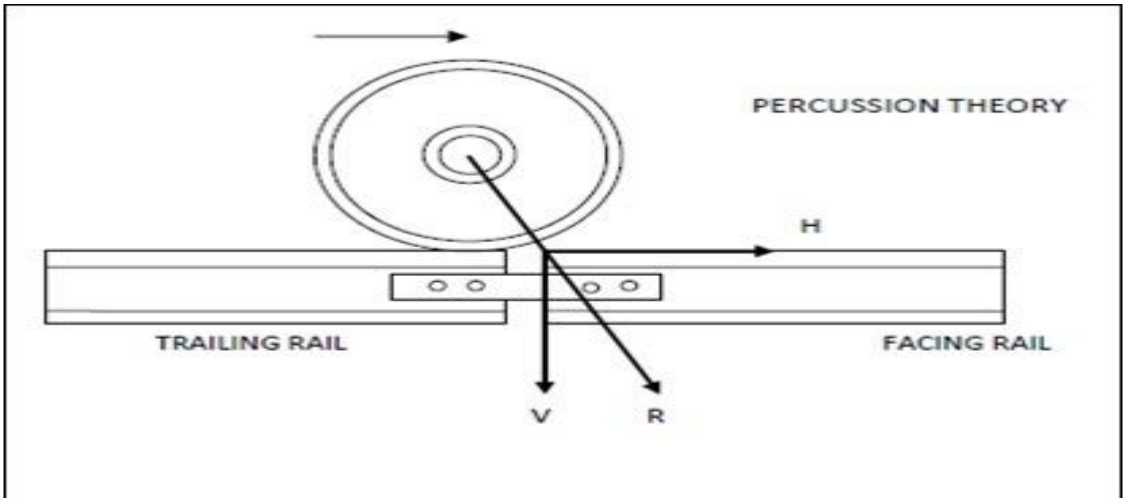
Wave action is controlled by pitch and depth of wave

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

UNIT 2

GEOMETRIC DESIGN OF RAILWAY TRACK

The geometric design of a railway track includes all those parameters which determine or affect the geometry of the track. These parameters are as follows.

1. Gradients in the track, including grade compensation, rising gradient, and falling gradient.
2. Curvature of the track, including horizontal and vertical curves, transition curves, sharpness of the curve in terms of radius or degree of the curve, cant or super elevation on curves, etc.
3. Alignment of the track, including straight as well as curved alignment. It is very important for tracks to have proper geometric design in order to ensure the safe and smooth running of trains at maximum permissible speeds, carrying the heaviest axle loads. The speed and axle load of the train are very important and sometimes are also included as parameters to be considered while arriving at the geometric design of the track.

Necessity for Geometric Design:

The need for proper geometric design of a track arises because of the following considerations

(a) To ensure the smooth and safe running of trains

(b) To achieve maximum speeds

(c) To carry heavy axle loads

(d) To avoid accidents and derailments due to a defective permanent way

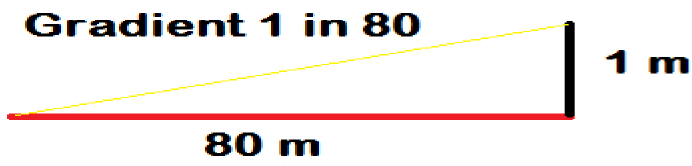
(e) To ensure that the track requires least maintenance.

(f) For good aesthetics

Gradients:

Gradients are provided to negotiate the rise or fall in the level of the railway track.

A rising gradient is one in which the track rises in the direction of the movement of traffic and a down or falling gradient is one in which the track loses elevation in the direction of the movement of traffic. A gradient is normally represented by the distance travelled for a rise or fall of one unit. Sometimes the gradient is indicated as per cent rise or fall.



Gradients are provided to meet the following objectives.

(a) To reach various stations at different elevations

(b) To follow the natural contours of the ground to the extent possible

(c) To reduce the cost of earthwork.

Types of gradients used on the railways :

(a) Ruling gradient:

The ruling gradient is the steepest gradient that exists in a section. It determines the maximum load that can be hauled by a locomotive on that section. While deciding the ruling gradient of a section, it is not only the severity of the gradient but also its length as well as its position with respect to the gradients on both sides that have to be taken into consideration. The power of the locomotive to be put into service on the track also plays an important role in taking this decision, as the locomotive should have adequate power to haul the entire load over the ruling gradient at the maximum permissible speed.

The extra force P required by a locomotive to pull a train of weight W on a gradient with an angle of inclination q is

$P = W \text{ Sin}q$

$= W \text{ tan}q$ (approximately, as q is very small)

$= W \times$ gradient

(b) Pusher or helper gradient **:**

In hilly areas, the rate of rise of the terrain becomes very important when trying to reduce the length of the railway line and, therefore, sometimes gradients steeper than the ruling gradient are provided to reduce the overall cost. In such situations, one locomotive is not adequate to pull the entire load, and an extra locomotive is required. When the gradient of the ensuing section is so steep as to necessitate the use of an extra engine for pushing the train, it is known as a pusher or helper gradient.

(c) Momentum gradient:

The momentum gradient is steeper than the ruling gradient and can be overcome by a train because of the momentum it gathers while running on the section. In valleys, a falling gradient is sometimes followed by a rising gradient. In such a situation, a train coming down a falling gradient acquires good speed and momentum, which gives additional kinetic energy to the train and allows it to negotiate gradients steeper than the ruling gradient. In sections with momentum gradients there are no obstacles provided in the form of signals, etc., which may bring the train to a critical juncture.

Grade Compensation on Curves:

Curves provide extra resistance to the movement of trains. As a result, gradients
are compensated to the following extent on curves

(a) On BG tracks, 0.04% per degree of the curve or $70/R$, whichever is minimum

(b) On MG tracks, 0.03% per degree of curve or $52.5/R$, whichever is minimum

(c) On NG tracks, 0.02% per degree of curve or $35/R$, whichever is minimum

Radius or degree of a curve:

A curve is defined either by its radius or by its degree. The degree of a curve (D) is
the angle subtended at its centre by a 30.5-m or 100-ft chord.

The value of the degree of the curve can be determined as indicated below.

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

$$=\frac{360°}{2\pi R}\times 30.5$$

=1750/R (approx)

R is in meters

In cases where the radius is very large, the arc of a circle is almost equal to the chord connecting the two ends of the arc. The degree of the curve is thus given by the following formulae

$D = 1750/R$ (when R is in meters)

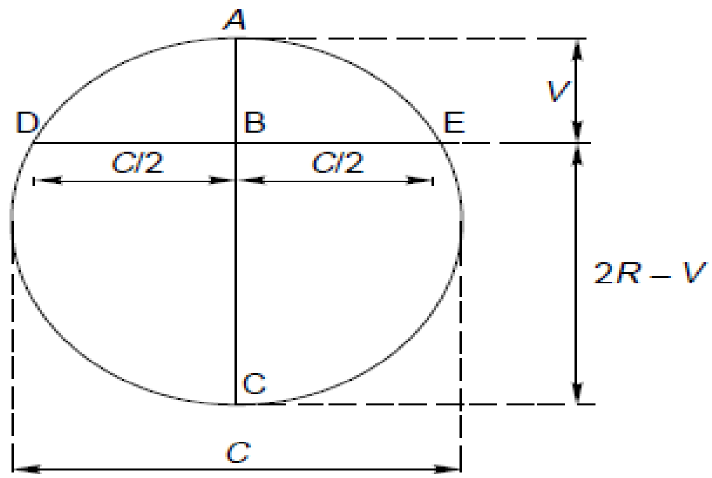
$D = 5730/R$ (when R is in feet)

A 2° curve, therefore, has a radius of 1750/2 = 875 m..

Maximum degree of a curve The maximum permissible degree of a curve on a track depends on various factors such as gauge, wheel base of the vehicle, maximum permissible superelevation, and other such allied factors.

Relationship between radius and versine of a curve:

The versine is the perpendicular distance of the midpoint of a chord from the arc of a circle. The relationship between the radius and versine of a curve can be established as shown in Figure. Let *R* be the radius of the curve, *C* be the length of the chord, and *V* be the versine of a chord of length *C*.



- The relationship between the radius and versine of a curve can be established as shown
- AC and DE being two chords meeting perpendicularly at a common point B,simple geometry can prove that

AB × BC = DB × BE

or

$V(2R - V) = (C/2) \times (C/2)$

or

$2RV - V^2 = C^2/4$

V being very small, V^2 *can be neglected. Therefore,*

$2RV = C^2/4$

$V = C^2/8R$

V, C, and R are in the same unit, say, meters or centimeters. This general equation can be used to determined versines if the chord and the radius of a curve are known.

Super elevation

The following terms are frequently used in the design of horizontal curves.

Super elevation or cant Super elevation or cant (*C*a) is the difference in height between the outer and the inner rail on a curve. It is provided by gradually lifting the outer rail above the level of the inner rail. The inner rail is taken as the reference rail and is normally maintained at its original level. The inner rail is also known as the *gradient rail*. The main functions of super elevation are the following.

(a) To ensure a better distribution of load on both rails

(b) To reduce the wear and tear of the rails and rolling stock

(c) To neutralize the effect of lateral forces

(d) To provide comfort to passengers

Equilibrium speed When the speed of a vehicle negotiating a curved track is such that the resultant force of the weight of the vehicle and of radial acceleration is perpendicular to the plane of the rails, the vehicle is not subjected to any unbalanced radial acceleration and is said to be in equilibrium. This particular speed is called the equilibrium speed. The equilibrium speed, as such, is the speed at which the effect of the centrifugal force is completely balanced by the cant provided.

Maximum permissible speed This is the highest speed permitted to a train on a curve taking into consideration the radius of curvature, actual cant, cant deficiency, cant excess, and the length of transition. On curves where the maximum permissible speed is less than the maximum sectional speed of the section of the line, permanent speed restriction becomes necessary.

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

Centrifugal Force on a Curved Track:

A vehicle has a tendency to travel in a straight direction, which is tangential to the curve, even when it moves on a circular curve. As a result, the vehicle is subjected to a constant radial acceleration:

Radial acceleration = $g = V2/R$

Where V is the velocity (meters per second) and R is the radius of curve (meters).

This radial acceleration produces a centrifugal force which acts in a radial direction away from the centre. The value of the centrifugal force is given by the formula

Force = mass × acceleration

$F = m \times (V2/R)$

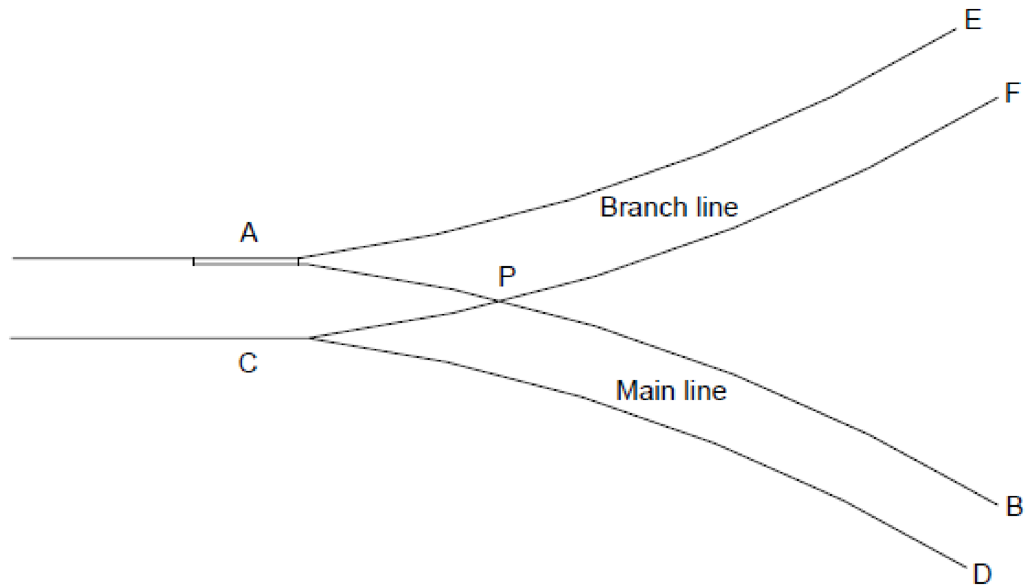
$= (W/g) \times (V2/R)$

Where F is the centrifugal force (tones), W is the weight of the vehicle (tones), V is the speed (meter/sec), g is the acceleration due to gravity (meter/sec2), and R is the radius of the curve (meters).

To counteract the effect of the centrifugal force, the outer rail of the curve is elevated with respect to the inner rail by an amount equal to the *super elevation*. A state of equilibrium is reached when both the wheels exert equal pressure on the rails and the super elevation is enough to bring the resultant of the centrifugal force and the force exerted by the weight of the vehicle at right angles to the plane of the top surface of the rails. In this state of equilibrium, the difference in the heights of the outer and inner rails of the curve known as *equilibrium super elevation*.

Negative Super elevation:

When the main line lies on a curve and has a turnout of contrary flexure leading to a branch line, the super elevation necessary for the average speed of trains running over the main line curve cannot be provided. In Fig. 13.9, AB, which is the outer rail of the main line curve, must be higher than CD. For the branch line, however, CF should be higher than AE or point C should be higher than point A. These two contradictory conditions cannot be met within one layout. In such cases, the branch line curve has a negative super elevation and, therefore, speeds on both tracks must be restricted, particularly on the branch line



Safe Speed on Curves:

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.

Earlier it was calculated empirically by applying Martin's formula:

For BG and MG

Transitioned curves

$V = 4.4 R - 70$

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

Non-transitioned curves Safe speed = four-fifths of the speed calculated using above equation.

For NG

Transitioned curves

$V = 3.65 R - 6$

(Subject to a maximum of 50 km/h).

Non-transitioned curves

$V = 2.92 R - 6$

(Subject to a maximum of 40 km/h).

Indian Railways no longer follows this concept of safe speed on curves or the stipulations given here.

Curves New Formula for Determining Maximum Permissible

Speed on Transitioned

Earlier, Martin's formula was used to work out the maximum permissible speed or safe speed on curves. This empirical formula has been changed by applying a formula based on theoretical considerations as per the recommendations of the committee of directors, chief engineers, and the ACRS. The maximum speed for transitioned curves is now determined as per the revised formulae given below.

On Broad Gauge

$$\boldsymbol{V} = \sqrt{\left(\frac{(\boldsymbol{Ca} + \boldsymbol{Cd}) \times \boldsymbol{R}}{\mathbf{13.76}}\right)}$$

Where *V* is the maximum speed in km/h, *C*a is the actual cant in mm, *C*d is the permitted cant deficiency in mm, and *R* is the radius in m. This equation is derived from Eqn (13.6) for equilibrium super elevation and is based on the assumption that *G* = 1750 mm, which is the centre-to-centre distance between the rail heads of a BG track with 52-kg rails.

On Meter Gauge

This is based on the assumption that the centre-to-centre (c/c) distance between the rail heads of an MG track is 1058 mm.

$V=0.347(\sqrt{(C_a + C_d)*R})$

Narrow Gauge (762 min.)

V = 3.65 *R* - 6 (subject to a maximum of 50 km/h)

POINTS AND CROSSINGS

Points and crossings are provided to help transfer railway vehicles from one track to another. The tracks may be parallel to, diverging from, or converging with each other. Points and crossings are necessary because the wheels of railway vehicles are provided with inside flanges and, therefore, they require this special arrangement in order to navigate their way on the rails. The points or switches aid in diverting the vehicles and the crossings provide gaps in the rails so as to help the flanged wheels to roll over them. A complete set of points and crossings, along with lead rails, is called a *turnout*.

IMPORTANT TERMINOLOGY:

The following terms are often used in the design of points and crossings.

Turnout It is an arrangement of points and crossings with lead rails by means of which the rolling stock may be diverted from one track to another. Figure 14.1(a) shows the various constituents of a turnout. The details of these constituents are given in Table 14.1.

Direction of a turnout A turnout is designated as a right-hand or a left-hand turnout depending on whether it diverts the traffic to the right or to the left. In Fig. 14.1(a), the turnout is a right-hand turnout because it diverts as the traffic towards the right side. Figure 14.1(b) shows a left-hand turnout. The direction of a point (or turnout) is known as the *facing direction* if a vehicle approaching the turnout or a point has to first face the thin end of the switch. The direction is *trailing direction* if the vehicle has to negotiate a switch in the trailing direction i.e., the vehicle first negotiates the crossing and then finally traverses on the switch from its thick end to its thin end. Therefore, when standing at the toe of a switch, if one looks in the direction of the crossing, it is called the *facing direction* and the opposite direction is called the *trailing direction*.

Tongue rail It is a tapered movable rail, made of high-carbon or -manganese steel to withstand wear. At its thicker end, it is attached to a running rail. A tongue rail is also called a *switch rail*.

Stock rail It is the running rail against which a tongue rail operates.

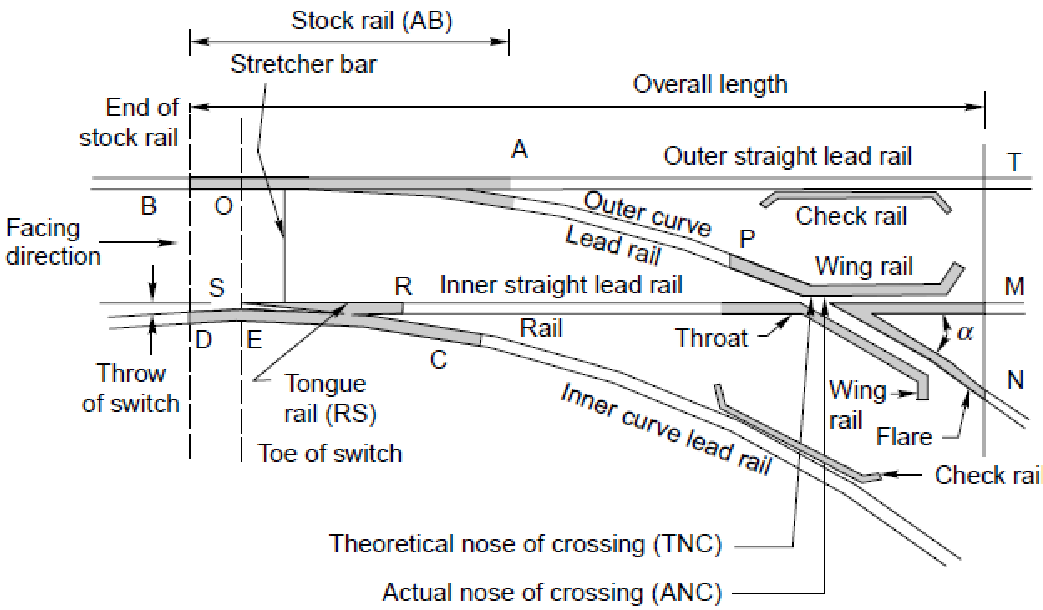


Fig. 14.1 (a) Constituents of a turnout

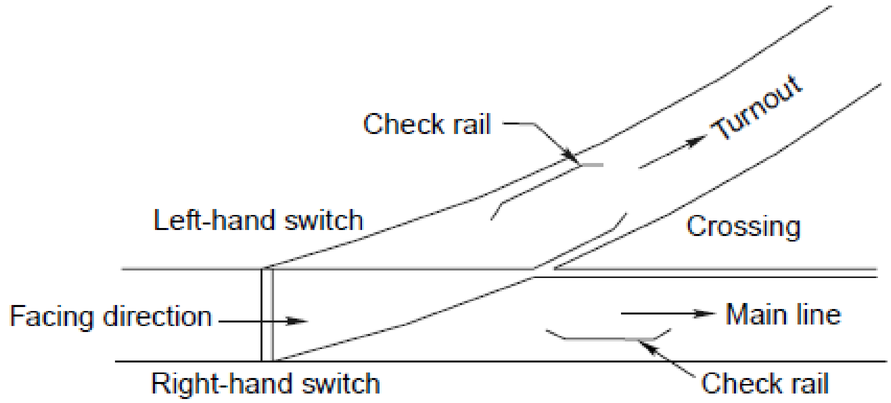


Fig. 14.1 (b) Left-hand turnout

Points or switch A pair of tongue and stock rails with the necessary connections and fittings forms a switch.

Crossing A crossing is a device introduced at the junction where two rails cross each other to permit the wheel flange of a railway vehicle to pass from one track to another.

Switches

A set of points or switches consists of the following main constituents

(a) A pair of stock rails, AB and CD, made of medium-manganese steel.

(b) A pair of tongue rails, PQ and RS, also known as switch rails, made of medium-manganese steel to withstand wear. The tongue rails are machined to a very thin section to obtain a snug fit with the stock rail. The tapered end of the tongue rail is called the *toe* and the thicker end is called the *heel*.

(c) A pair of heel blocks which hold the heel of the tongue rails is held at the standard clearance or distance from the stock rails.

(d) A number of slide chairs to support the tongue rail and enable its movement towards or away from the stock rail.

(e) Two or more stretcher bars connecting both the tongue rails close to the toe, for the purpose of holding them at a fixed distance from each other.

(f) A gauge tie plate to fix gauges and ensure correct gauge at the points.

Crossing

A crossing or *frog* is a device introduced at the point where two gauge faces cross V each other to permit the flanges of a railway vehicle to pass from one track to another .To achieve this objective, a gap is provided from the throw to the nose of the crossing, over which the flanged wheel glides or jumps. In order to ensure that this flanged wheel negotiates the gap properly and does not strike the nose, the other wheel is guided with the help of check rails.

Types of Crossings

A crossing may be of the following types.

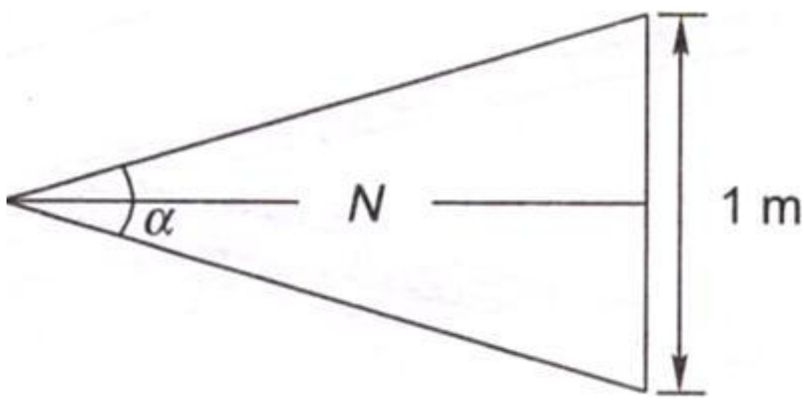
(a) An acute angle crossing or 'V crossing

(b) An obtuse or diamond crossing.

(c) A square crossing

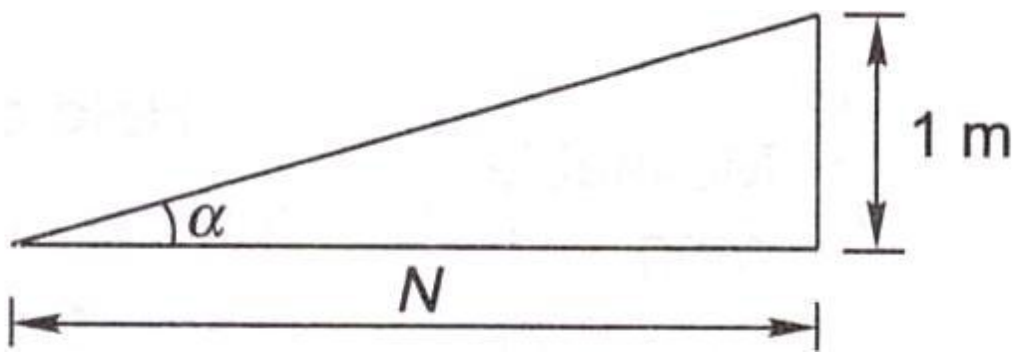
NUMBER AND ANGLE OF CROSSING A crossing is designated either by the angle the gauge faces make with each other or, more commonly, by the number of the crossing, represented by N. There are three methods of measuring the number of a crossing, and the value of N also depends upon the method adopted. All these methods are illustrated below.

Centre line method This method is used in Britain and the US. In this method, N is measured along the centre line of the crossing.



Right angle method

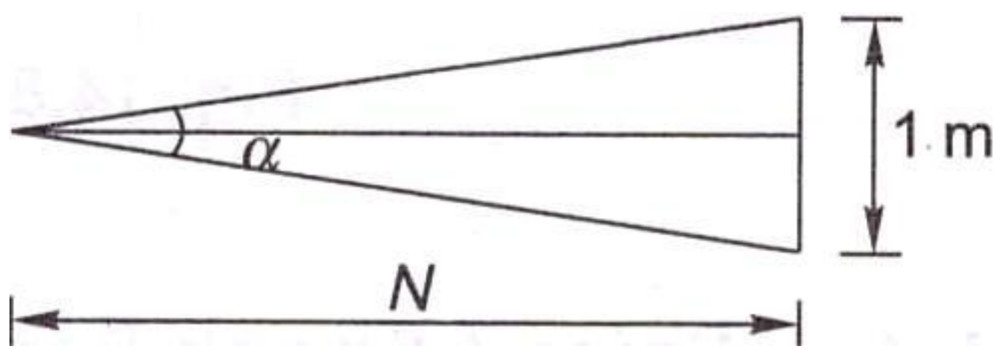
This method is used on Indian Railways. In this method, *N* is measured along the base of a right-angled triangle. This method is also called Coles method. *Cot α/2 – N = N /1/2 or N = 1/2 Cot α/2*



Cot α = N /1 or N = Cot α

Isosceles triangle method

In this method, N is taken as one of the equal sides of an isosceles triangle.



Sin α/2 = ½ /N or N = 1/2N

Cosec α/2 = 2N

N = ½ Cosec α/2

The right angle method used on Indian Railways, in which TV is the cotangent of the angle formed by two gauge faces, gives the smallest angle for the same value of *N*.

To determine the number of a crossing-on site, the point where the offset gauge face of the turnout track is 1 m is marked. The distance of this point (in metres) from the theoretical nose of crossing gives *N*.

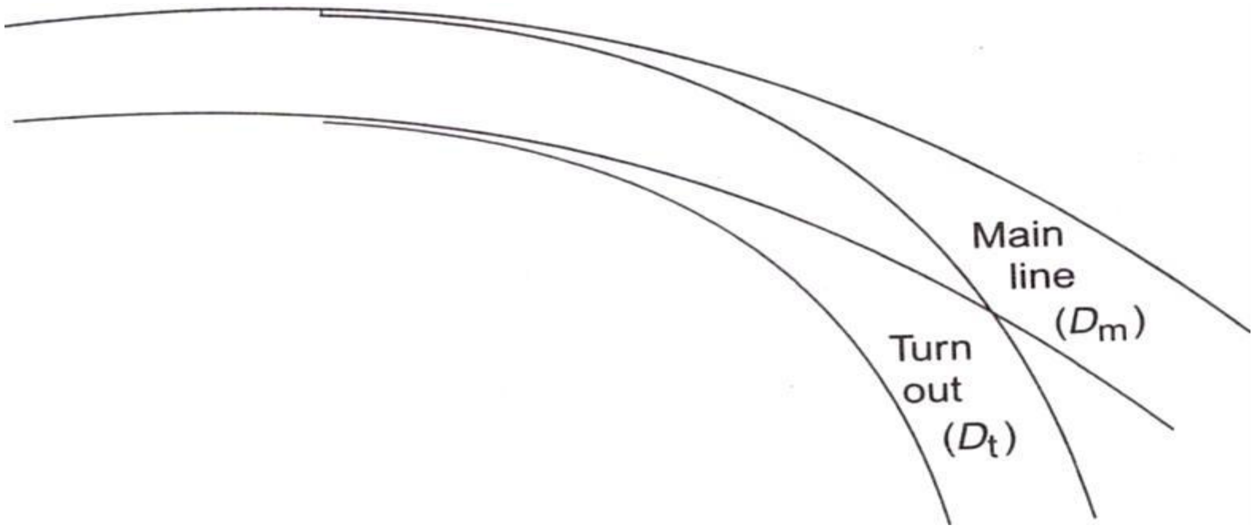
TURNOUTS

Introduction The simplest arrangement of points and crossing can be found on a turnout taking off from a straight track. There are two standard methods prevalent for designing a turnout.

These are the (a) Coles method and (b) IRS method. These methods are described in detail in the following sections. The important terms used in describing the design of turnouts are defined as follows:

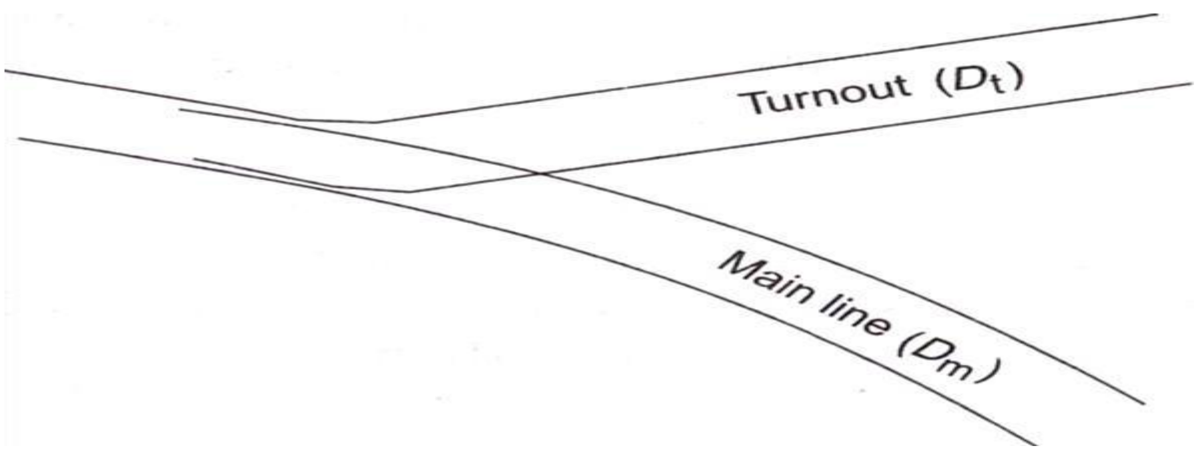
Curve lead (CL) This is the distance from the tangent point (T) to the theoretical nose of crossing (TNC) measured along the length of .the main track.
Switch lead (SL) This is the distance from the tangent point (T) to the heel of the switch (TL) measured along the length of the main track.
Lead of crossing (L) This is the distance measured along the length of the main track as follows:
Lead of crossing (L) = curve lead (CL) - switch lead (SL)
Gauge (G) This is the gauge of the track.
Heel divergence (d) This is the distance between the main line and the turnout side at the heel.
Angle of crossing (a) This is the angle between the main line and the tangent of the turnout line.
Radius of turnout (R) This is the radius of the turnout. It may be clarified that the radius of the turnout is equal to the radius of the centre line of the turnout (/?,) plus half the gauge width. *R* = *R}*+ 0.5,G As the radius of a curve is quite large, for practical purposes, *R* may be taken to be equal to .ft,.
Special fittings with turnouts Some of the special fittings required for use with turnouts are enumerated as follows:
Distance blocks Special types of distance blocks with fishing fit surfaces are provided at the nose of the crossing to prevent any vertical movement between the wing rail and the nose of the crossing.
Flat bearing plates As turnouts do not have any cant, flat bearing plates are provided under the sleepers
Spherical washers These are special types of washers and consist of two pieces with a spherical point of contact between them. This permits the two surfaces to lie at any angle to each other.
Slide chairs These are provided under tongue rails to allow them to move laterally. These are different for ordinary switches and overriding switches.
Grade off chairs These are special chairs provided behind the heel of the switches to give a suitable ramp to the tongue rail, which is raised by 6 mm at the heel.
Gauge tie plates These are provided over the sleepers directly under the toe of the switches, and under the nose of the crossing to ensure proper gauge at these locations.
Stretcher bars These are provided to maintain the two tongue rails at an exact distance.

TURNOUT OF SIMILAR FLEXURE A turnout of similar flexure (Fig.) continues to run in the same direction as the main line curve even after branching off from it. The degree of the turnout curve will be higher than that of the main line curve.



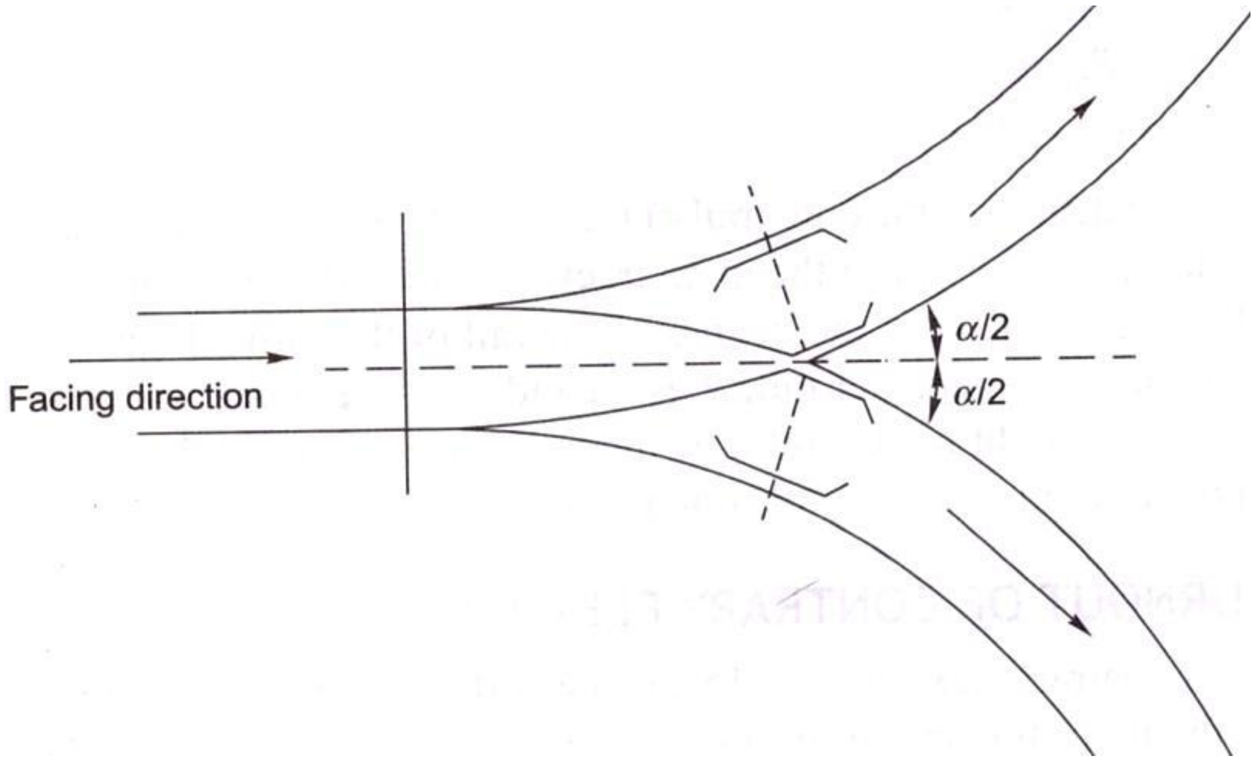
Turnout of contrary flexure: A turnout of contrary flexure (Fig. 15.2) takes off towards the direction opposite to that of the main line curve. In this case, the degree and radius of the turnout curve are given by the following formulae: $Dt = Ds\text{-}Dm$

$Rt = Rs\ Rm\ /(Rm - Rs)$ Here, *Dm* is the degree of the rail of the main track on which the crossing lies, i.e., the outer rail in Fig. below.



Symmetrical split:

When a straight track splits up in two different directions with equal radii, the layout is known as a symmetrical split (Fig. below). In other words, a symmetrical split is a contrary flexure in which the radii of the two curves are the same.



THREE-THROW SWITCH

In a three-throw arrangement, two turnouts take off from the same point of a main line track. Three-throw switches are used in congested goods yards and at entry points to locomotive yards, where there is much limitation of space. A three-throw switch has two switches and each switch has two tongue rails placed side by side. There is a combined heel block for both the tongue rails of the switch. The switches can be operated in such a way that movement is possible in three different directions, that is, straight, to the right, and to the left. Three-throw switches are obsolete now as they may prove to be hazardous, particularly at higher speeds, because the use of double switches may lead to derailments.

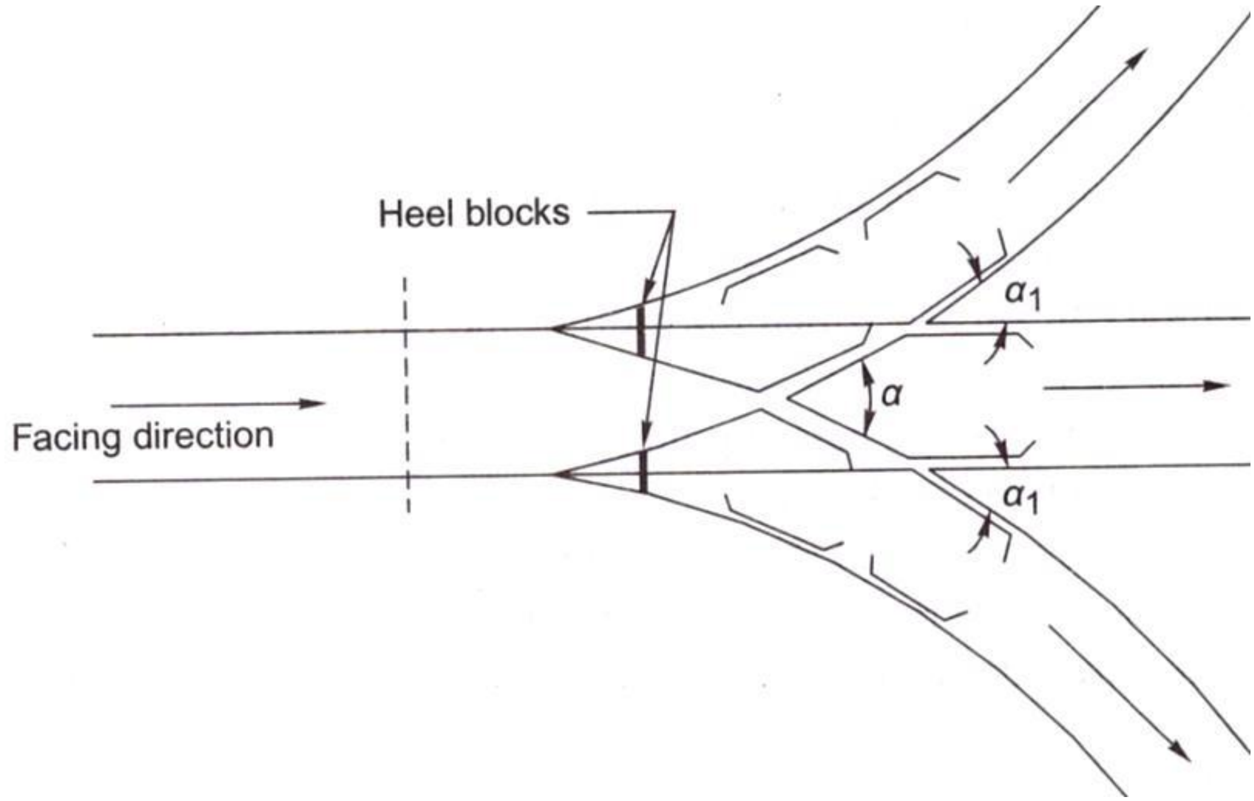
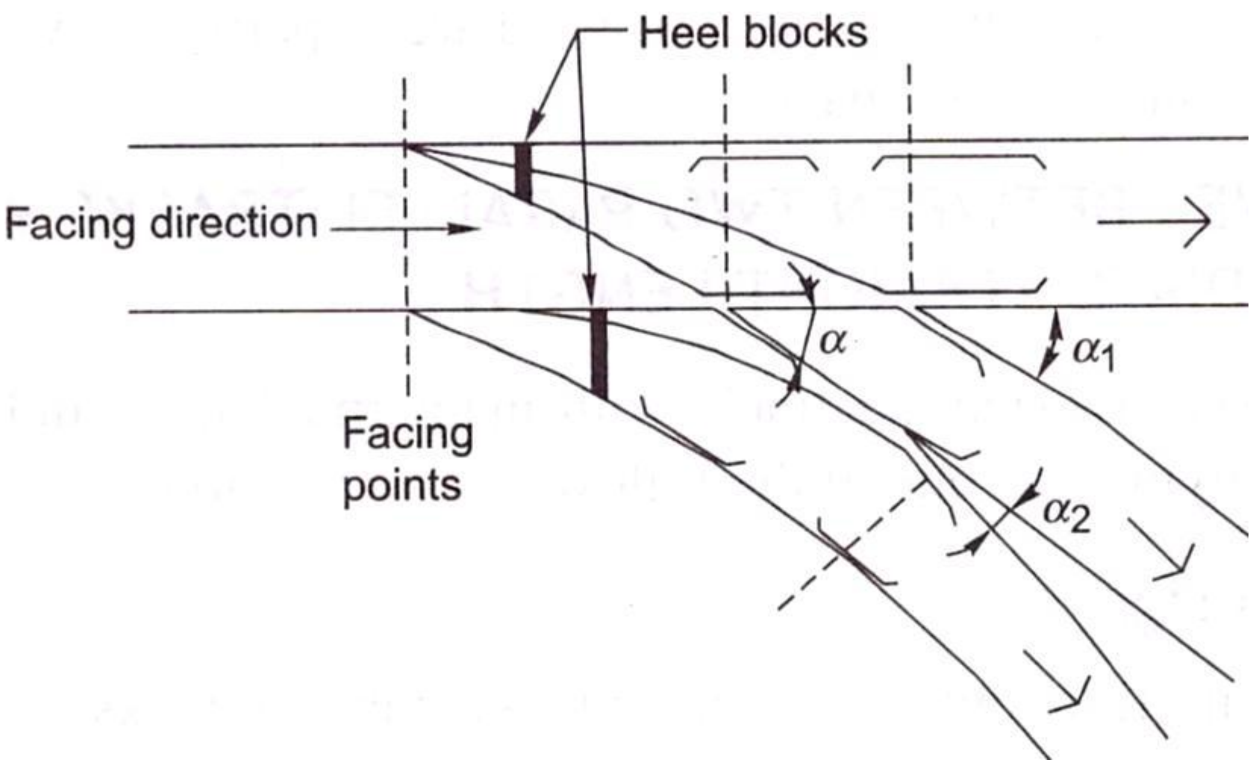
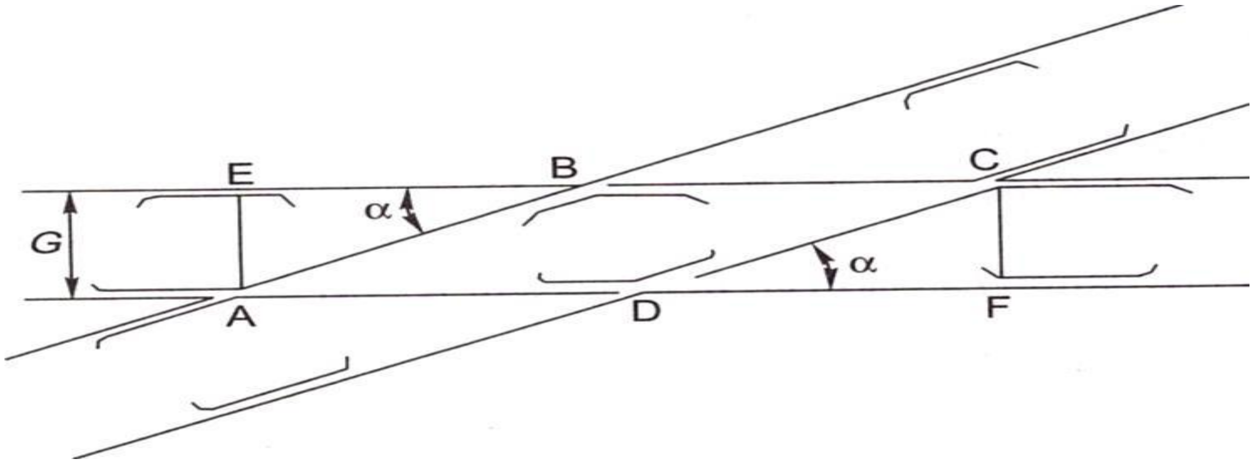


Fig Three-throw switch (contrary flexure)



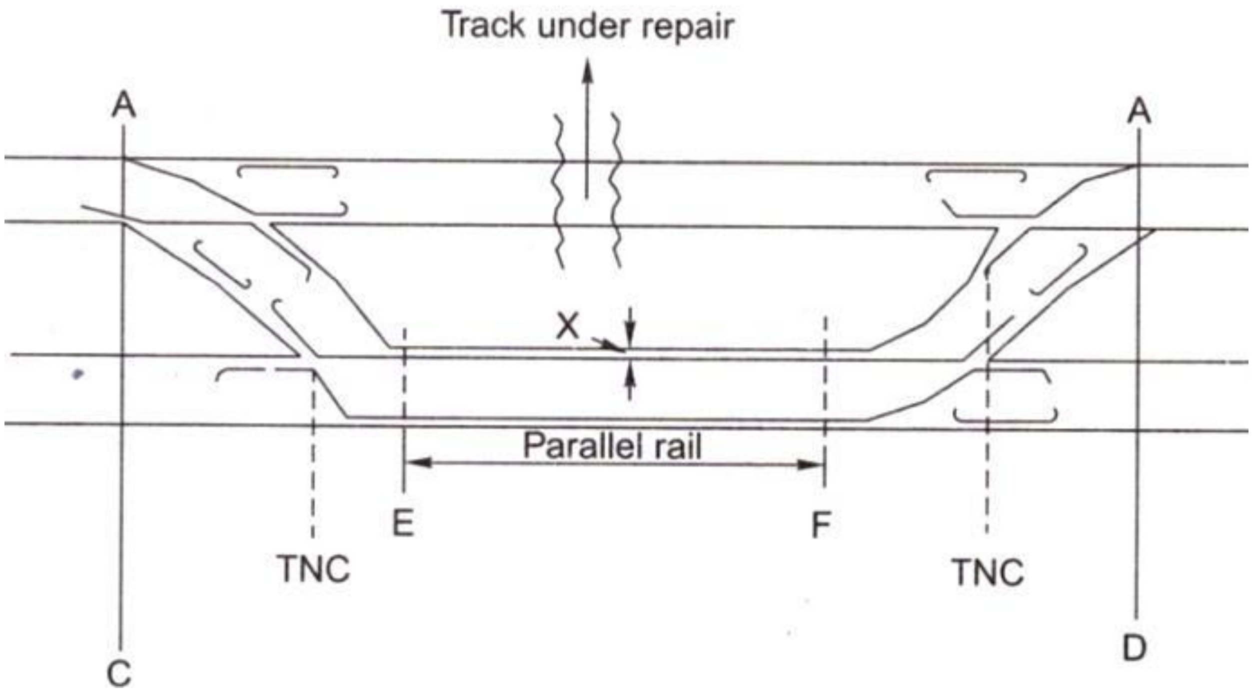
Three-throw switch (similar flexure)

DIAMOND CROSSING A diamond crossing is provided when two tracks of either the same gauge or of different gauges cross each other. It consists of two acute crossings (A and C) and two obtuse crossings (B and D).



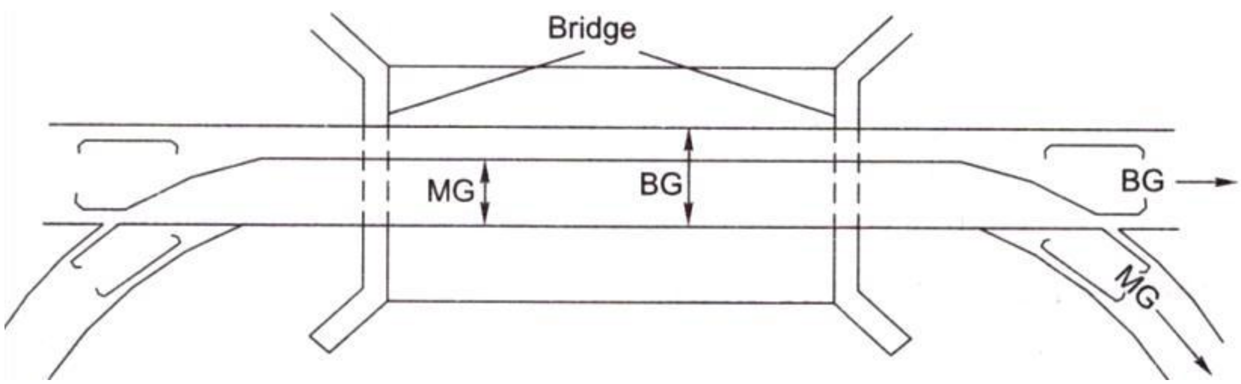
Single Slip and Double Slip In a diamond crossing, the tracks cross each other, but the trains from either track cannot change track. Slips are provided to allow vehicles to change track. The slip arrangement can be either single slip or double slip. In single slips, there are two sets of joints, the vehicle from only one direction can change tracks. In double slips, there are four sets of joints, the vehicle from both directions can change tracks

Gauntleted track Gauntleted track is a temporary diversion provided on a double-line track to allow one of the tracks to shift and pass through the other track. Both the tracks run together on the same sleepers. It proves to be a useful connection when one side of a bridge on a double-line section is required to be blocked for major repairs or rebuilding. The specialty of this layout is that there are two crossings at the ends and no switches



Gauntletted track

Gauntletted tracks are also used on sections where trains have to operate on mixed gauges, say, both BG and MG, for short stretches. In such cases, both the tracks are laid on the same set of wooden sleepers [(b)].



Gauntletted track for mixed gauge

SIGNALS

In the early days of railway operation, there was seldom need for more than one train to operate on a section of track at any given time. As traffic increased, it became necessary to operate trains in both directions over single track. The purpose of signaling and interlocking is primarily to control and regulate the movement of trains safely and efficiently. Signaling includes operations and interlocking of signals, points, block instruments, and other allied equipment in a predetermined manner for the safe and efficient running of trains.

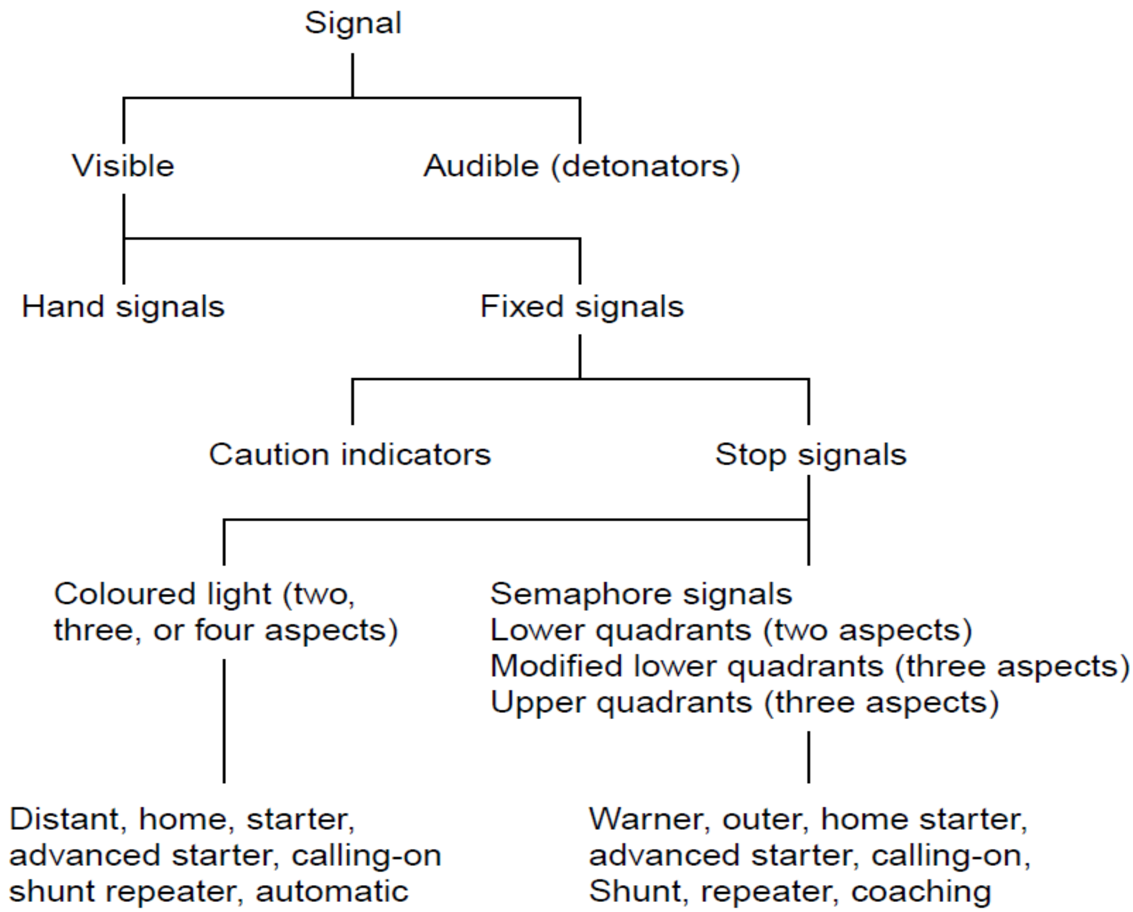
OBJECTIVES OF SIGNALLING

The objectives of signaling are as follows:

- To regulate the movement of trains so that they run safely at maximum permissible speeds
- To maintain a safe distance between trains those are running on the same line in the same direction
- To ensure the safety of two or more trains that has to cross or approach each other
- To provide facilities for safe and efficient shunting
- To regulate the arrival and departure of trains from the station yard
- To ensure the safety of the train at level crossings when the train is required to cross the path of road vehicles

CLASSIFICATION OF SIGNALS Railway signals can be classified based on different characteristics as presented in Table below.

Characteristics	*Basis of classification*	*Examples*
Operational	Communication of message in visual form	Fixed signals
Functional	Signaling the loco pilot to stop, move cautiously, proceed, or carry out shunting operations	Stop signals, permissive Signals, shunt signals
Locational	Reception or departure signals	Reception: Outer, home, Departure: Starter, and advanced starter signals
Constructional	Semaphore or color light signals	Semaphore: Lower quadrant or upper quadrant. Color light: Two aspects or multiple aspects.
Special characteristics	Meant for special purposes	Calling-on signals, repeater signals, coaching signals, etc.



Audible Signals

Audible signals such as detonators and fog signals are used in cloudy and foggy weather when hand or fixed signals are not visible. Their sound can immediately attract the attention of drivers. Detonators contain explosive material and are fixed to the rail by means of clips. In thick foggy weather, detonators are kept about 90 m ahead of a signal to indicate the presence of the signal to the drivers. Once the train passes over the detonators thereby causing them to explode, the driver becomes alert and keeps a lookout for the signal so that he/she can take the requisite action.

Hand signals

These signals are in the form of flags (red or green) fixed to wooden handles that are held by railway personnel assigned this particular duty. If the flags are not available, signaling may be done using bare arms during the day. In the night, hand lamps with movable green and red slides are used for signaling purposes.

Fixed signal

These are firmly fixed on the ground by the side of the track and can be further subdivided into caution indicators and stop signals.

Caution indicators

These are fixed signals provided for communicating to the driver that the track ahead is not fit for the running the train at normal speed. These signals are used when engineering works are underway and are shifted from one place to another depending upon requirement.

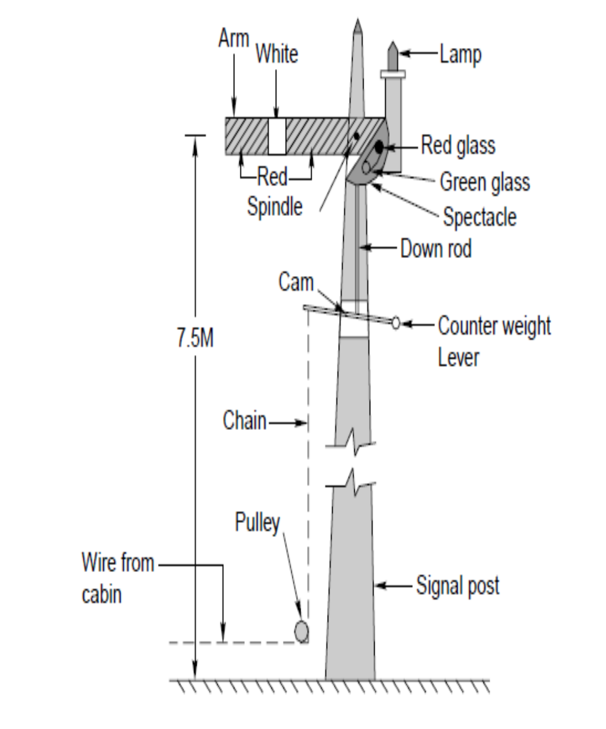
Trap indicator

- A trap is a device fitted on the track, which in its open position derails the vehicle that passes over it. When the trap is closed, the vehicle passes over it as it would over a normal track.
- A trap indicator reveals whether the trap is in an ‘open’ or ‘closed’ position.

Position of trap	*Day indication*	*Night indication*
Trap open	Red target	Red light
Trap closed	Green target	Green light

Semaphore signals:

The word ‘semaphore’ was first used by a Greek historian. ‘Sema’ means sign and ‘phor’ means to bear. A semaphore signal consists of a movable arm pivoted on a vertical post through a horizontal pin as shown



The arm of the semaphore signal on the side facing the driver is painted red with a vertical white stripe. The other side of the signal is painted white with a black vertical stripe. The complete mechanical assembly of the signal consists of an arm, a pivot, a counterweight spring stop, etc., and is housed on top of a tubular or lattice post. In order for the signal to also be visible at night, a kerosene oil or electric lamp, operated through a twilight switch, is fixed to the post. A spectacle is also attached to the moving signal arm, which contains green and red coloured glasses. The red glass is positioned at the upper end and the green glass is positioned at the lower end of the spectacle so that the red light is visible to the driver when the arm is horizontal and the green light is visible when the arm is lowered

Lower quadrant system:

Lower quadrant semaphore signals move only in the fourth quadrant of a circle and have only two color aspects. In order to provide the drivers with further information

Position of signal	*Position of arm*	*Colour during night*	*Indication*
On	Horizontal	Red	Stop or danger
Off	Inclined 45° to 60° below horizontal	Green	Proceed or line is clear

This system of signalling was designed so that the semaphore arm of the signal could be kept either horizontal or lowered. The lower left-hand quadrant of a circle is used for displaying a semaphore indication to the driver of a train. This concept was possibly developed based on the left-hand driving rules applicable on roads in the UK and in India.

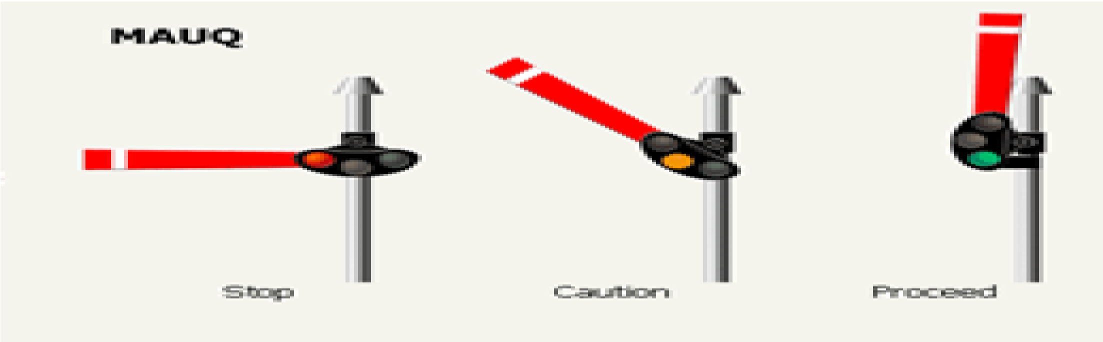
Upper quadrant signaling system:

In lower quadrant signaling, the semaphore arm of the signal can only take two positions, namely, horizontal or lower; it is not possible to include a third position for the semaphore arm, such as vertically downward position, due to design as well as visibility problems, since as the semaphore arm would, in that case, be super imposed on the signal post. Due to this limitation, the upper quadrant system was developed, which can display more than two aspects. In this system, it is possible to incorporate three positions of the semaphore arm, namely,

(a) Horizontal,

(b) Inclined at an angle of about 45° above the horizontal level, and

(c) Vertical, i.e., inclined at an angle of 90° above the horizontal level.



STOP SIGNALS

The various types of stop signals with reference to their location on a station are discussed here in detail.

Outer signal on double-line section*:* This is the first semaphore stop signal at a station that indicates the entry of a train from a block section into the station limits. This signal is provided at an adequate distance beyond the station limits so that the line is not obstructed once the permission to approach has been given. It is provided at a distance of about 400 m from the home signal. The signal has one arm but has a warner signal nearly 2 m below on the same post.

Home signal on double-line section*:* After the outer signal, the next stop signal towards the station side is a home signal. It is provided right at the entrance of the station for the protection of the station limits. The signal is provided about 50 m short of the points and crossings. The arms provided on a home signal are generally as many as the number of reception lines in the station yard. The signal for the main line is provided on a 'doll', which is higher than others.

Routing signal*:* The various signals fixed on the same vertical post for both main and branch lines are known as routing signals. These signals indicate the route that has been earmarked for the reception of the train. Generally, the signal for the main line is kept at a higher level than that for the loop line. It is necessary for the driver of a train approaching a reception signal to know the line on which his or her train is likely to be received so that he or she can regulate th speed of the train accordingly. In case the train is being received on the loop li 3, the speed has to be restricted to about 15 km per hour, whereas if the reception s on the main line, a higher speed is permissible.

Starter signal:

The starter signal is a stop signal and marks the limit up to which a particular line can be occupied without infringing on other lines. A separate starter signal is provided for each line. The starter signal controls the movement of the train when it departs from the station. The train leaves the station only when the starter signal is in the ‘off’ (or proceed) position. As this signal controls the departure of a train, it comes under the category of departure signals.

Advanced Starter signal:

- This is the last stop signal provided for the departure of trains from a station.
- The signal is provided about 180 m beyond the outermost points or switches and marks the end of the station limits.
- A block section lies between the advanced starter signal of one station and the outer signal of the next station.
- No train can leave the station limits until and unless the advance starter is lowered.

Signaling arrangement under Modified Lower Quadrant Signaling System :

Since lower quadrant semaphore two aspect signaling system is capable of conveying limited information to the loco pilot, the arrangement was modified to be known as Modified Lower Quadrant Signaling. In this an arrangement a Warner is provided on the same doll as that of mainline home signal.

COLOURED LIGHT SIGNALS These signals use coloured lights to indicate track conditions to the driver both during the day and the night. In order to ensure good visibility of these light signals, particularly during daytime, the light emission of an electric 12 V, 33 W lamp is passed through a combination of lenses in such a way that a parallel beam of focused light is emitted out. This light is protected by special lenses and hoods and can be distinctly seen even in the brightest sunlight. The lights are fixed on a vertical post in such a way that they are in line with the driver's eye level. The system of interlocking is so arranged that only one aspect is displayed at a time. Coloured light signals are normally used in automatic signalling sections, suburban sections, and sections with a high traffic density Coloured light signals can be of the following types.

(a) Two-aspect, namely green and red

(b) Three-aspect, namely green, yellow, and red

(c) Four-aspect, namely green, double yellow, and red

In India, mostly three-aspect or four-aspect coloured light signalling is used. In the case of three-aspect signalling, green, yellow, and red lights are used. Green indicates 'proceed', yellow indicates 'proceed with caution', and red indicates 'stop

Colour of signal	*Interpretation*
Red	Stop dead, danger ahead
Yellow	Pass the signal cautiously and be prepared to stop at the next signal
Two yellow lights displayed together	Pass the signal at full speed but be prepared to pass the next signal, which is likely to be yellow, at a cautious speed
Green	Pass the signal at full speed, next signal is also off

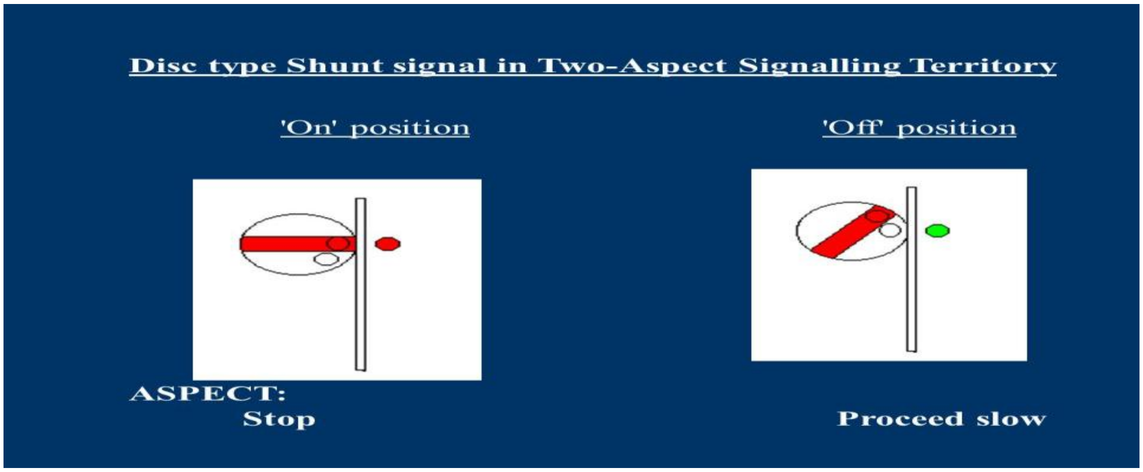
Co-acting signal: In case a signal is not visible to the driver due to the presence of some obstruction, such as an overbridge or a high structure, another signal is used to move along the main signal on the same post. This signal, known as the co-acting signal, is an exact replica of the original signal and works in unison with it.

Repeater signal: In case where a signal is not visible to the driver from an adequate distance due to sharp curvature or any other reason or where the signal is not visible to the guard of the train from his position at the rear end of a platform, a repeater signal is provided at a suitable position at the rear of the main signal.

Shunt signals:

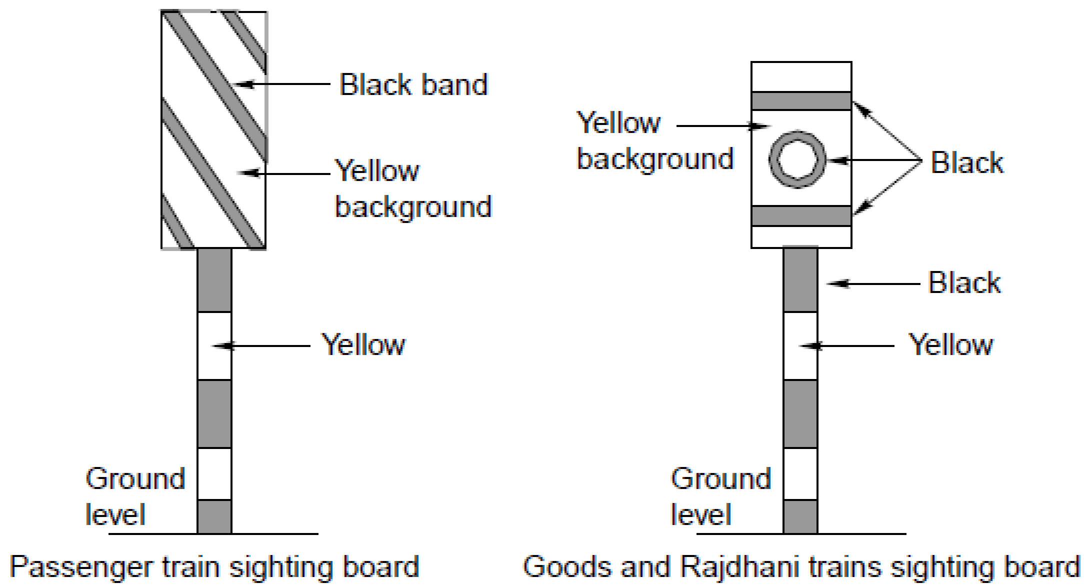
These are miniature signals and are mostly used for regulating the shunting of vehicles in station yards. Unlike fixed signals, these are small in size and are placed on an independent post of a running signal post. In semaphore signalling areas, the shunt signals are of the disc type.

The disc type of shunt signal consists of a circular disc with a red band on a white background. The disc revolves around a pivot and is provided with two holes, one for the red lamp and the other for the green lamp, for the purpose of night indication. At night, the 'on' position of the signal is indicated by the horizontal red band and the red light, indicating danger. During the day the red band inclined to the horizontal plane and during the night the green light indicate that the signal is 'off'



Sighting board

- The function of a sighting board is to allow the driver to estimate the location of the next stop signal from the current location so that he/she starts applying brakes in case the first stop signal is in an 'on' position.



Trap indicator

- A trap is a device fitted on the track, which in its open position derails the vehicle that passes over it. When the trap is closed, the vehicle passes over it as it would over a normal track.
- A trap indicator reveals whether the trap is in an 'open' or 'closed' position.

Position of trap	*Day indication*	*Night indication*
Trap open	Red target	Red light
Trap closed	Green target	Green light

Caution indicators:

When the track is undergoing repair, trains are required to proceed with caution at restricted speeds and may even have to stop. Caution indicators help the driver of a train to reduce the speed of (or even stop) the train at the affected portion of the track and then return it to the normal speed once that portion has been covered.

The following indicators are used for this purpose.

Caution indicator This cautions the driver to get ready to reduce the speed.

Speed indicator The driver has to reduce the speed (or stop) at this location.

Stop indicator or stop board The driver has to stop the train at this location.

Termination indicator This indicates that the driver can assume normal speed and that the speed restriction zone has ended.

These indicators are also called temporary fixed engineering signals and are provided in the direction of the approaching train in the case of double lines and in both directions in the case of single lines.

SIGNALLING SYSTEMS:

The signaling system can be broadly classified into two main categories. (a) Mechanical signaling system (b) Electrical signaling system In addition to these two main categorisignaling systems, electronic or solid-state signaling system is also in use. Each system of signaling comprises five main components.

(a) Operated units such as signals and points

(b) Interlocking system

(c) A transmission system such as single- or double-wire transmission or electrical transmission through cables

(d) Operating units such as levers and press buttons

(e) Monitoring units such as detectors, treadle bars, and track circuits The comparison between mechanical and electrical signalling based on these five broad components is given in Table below.

Component	*Mechanical*	*Electrical*
Operated units signals	Mechanically operated signals as per lower quadrant or upper quadrant and modified lower quadrant signalling	Coloured light signals with two- aspect, three-aspect or four-aspect signalling
Points	Mechanically operated points; locking with the help of point locks, stretcher bars, and detectors	Electrically operated points (by converting the rotary movement of electric motors into linear push or pull); locking with the help of slides and solid rods
Level crossing gates	Interlocking of manually operated swing leaf gate or operation and Interlocking of mechanically operated lifting barriers	Operation and Interlocking of electrically operated lifting barriers
Transmission systems	Single or double wire transmission to the requisite	Electrical transmission through overhead wires or underground

	points by means of rods or double wires	cables
Operating units	Hand levers with a range of 500 to 2000 m used in collaboration with single wire or double wire lever frames	Push buttons, rotary switches, or electrical signalling equipment
Interlocking units	Mechanical interlocking with plungers attached with levers and tappets moving across in a locking trough	Interlocking through electromagnetic switches known as relays or solid-state switching devices
Monitoring units	Monitoring of points with the help of mechanical detectors; monitoring of the passage of trains using a treadle, which is an electro-mechanical device	Monitoring with the help of direct current track circuits, alternating current track circuits, electronic track circuits, axle counters, etc.

INTERLOCKING

Points

Points are set mechanically and are kept in locks and stretcher bars. The mechanical arrangement for operating them includes a solid rod with a diameter of 33 mm running from the lever provided in the cabin and connected to the point through cranks and compensators. Owing to transmission losses, the operating points with rods is restricted to a specified distance from the cabin. The following devices are used to ensure that the points are held rigidly in the last operated position under a moving train and to ensure absolute integrity of the same.

(a) Point locks to hold the point in the required position and to rigidly hold the point in the position of the last operation

(b) Facing point lock with lock bars to prevent the movement of points when a train is passing over them

Point locks A point lock is provided to ensure that each point is set correctly. It is provided between two tongue rails and near the toe of the switch assembly. The point lock consists of a plunger, which moves in a plunger casing of facing point lock. The plunger is worked by means of a plunger rod, which is connected to the signal cabin through a lock bar. Additionally, there is a set of stretcher blades and each blade is connected to one of the tongue rails. Each blade has two notches and they move inside the facing point lock plunger casing along with the tongue rails. When the points are set correctly for a particular route, the notch in the stretcher blade rests in its proper position and the plunger rod enters the notch, locking the switch in the last operated position.

INTERLOCKING:

Interlocking is a device or a system meant to ensure the safety of trains. With the increase in the number of points and the signals and introduction of high speeds, it has become necessary to eliminate human error, which would otherwise lead to massive losses of life and property. The points and signals are set in such a way that the cabin man cannot lower the signal for the reception of a train unless the corresponding points have been set and locked. The signal is thus interlocked with the points in a way that no conflicting movement is possible and the safety of trains is ensured. Interlocking may therefore, be defined as a technique, achieved through mechanical or electrical means by which it is ensured that before a signal is taken 'off, the route which the signal controls is properly set, locked and held till such time the entire route is traversed by the train and at the same time all the signals and points, the operation of which would lead to conflicting movements, are locked against the feasibility of such conflicting movements. The signal and interlocking system is so designed that the failure of any equipment results in the turning 'on' of the signal, thus ensuring train safety.

ESSENTIALS OF INTERLOCKING

Lever frames and other apparatus provided for the operation and control of signals, points, etc., must be so interlocked and arranged as to comply with the following essential regulations.

(a) It should not be possible to turn a signal off unless all points for the line on which the train is to be received are correctly set, all the facing points are locked, and all interlocked level crossings are closed and inaccessible to road traffic.

(b) The line should be fully isolated before the signal is turned off, i.e., no loose wagons should be able to enter this line.

(c) After the signal has been turned off, it should not be possible to make adjustments in the points or locks on the route, including those in the isolated line. Also, no interlocked gates should be released until the signal is replaced in the ‘on’ position.

(d) It should not be possible to turn any two signals off at the same time, as this can lead to conflicting movements of the trains.

(e) Wherever feasible, the points should be so interlocked as to avoid any conflicting movement.

Typical Cases of Interlocking The following typical cases of interlocking are usually encountered.

Normal locking In this case, pulling one lever locks the other lever in its normal position. Such locking shall be required in situation like the signal lever locking a point lever, when the signal requires the point to be moved for train movement.

Back locking or release locking In this case, when the lever is in its normal position, it also blocks the other lever in its normal position, but when this lever is pulled it releases the other lever, which can then be pulled. Furthermore, once the second lever is also pulled, the first lever gets locked in the 'pulled' position and cannot be returned to its normal position unless the second lever is restored to its normal position.

Both-way locking In this case, once a lever is pulled, it locks the other lever in its current position that is, in the normal or pulled position. Such type of locking is normally required in situations when the lock on point is to lock the point in either position. Here, if the point is to be locked in normal condition, the point lever shall get locked as it is by pulling back the lever.

Special or conditional locking In this case, the pulling of one lever locks the other lever only when certain conditions are fulfilled, say the third lever being in a normal or pulled position as the case may be. Such a locking is normally required when a signal leads to more than one route.

Welding

- Welding is a fabrication or sculptural process that joins materials, usually metals or thermoplastics, by causing fusion.
- Welding a Rail Joint
- The purpose of welding is to join rail ends together by the application of heat and thus eliminate the evil effects of rail joints. There are four welding methods used on railways.

(a) Gas pressure welding

(b) Electric arc or metal arc welding

(c) Flash butt welding

(d) Thermit welding

UNIT 3

AIRPORT ENGINEERING

Since its beginning in the early twentieth century, civil aviation has become one of the most fascinating, important, and complex industries in the world. The civil aviation system, particularly its airports, has come to be the backbone of world transport and a necessity to twenty-first-century trade and commerce. In 2008, the commercial service segment of civil aviation, consisting of more than 900 airlines and 22,000 aircraft, carried more than 2 billion passengers and 85 million tons of cargo on more than 74 million flights to more than 1700 airports in more than 180 countries worldwide. Millions more private, corporate and charter ―general aviation‖ operations were conducted at thousands of commercial and general aviation airports throughout the world. In many parts of the world, commercial service and general aviation serve as the primary, if not the only method of transportation between communities. The magnitude of the impact of the commercial air transportation industry on the world economy is tremendous, contributing more than $2.6 trillion in economic activity, equivalent to 8 percent of the world gross domestic product, and supporting 29 million jobs

Objectives of Civil Aviation Ministry

a) To ensure aviation safety, security

b) Effective regulation of air transport in the country in the liberalized environment

c) Safe, efficient, reliable and widespread quality air transport services are provided at reasonable prices

d) Flexibility to adapt to changing needs and circumstances e) To provide all players a level-playing field

f) Encourage Private participation

g) Encourage Trade, tourism and overall economic activity and growth

h) Security of civil aviation operations is ensured through appropriate systems, policies, and practices

Airport Classification Airports are presently classified in the following manner:

1. International Airports
2. Custom Airports:
3. Model Airports:
4. Other Domestic Airports:
5. Civil Enclaves in Defense Airport:

MAJOR PROBLEMS FACED BY AIRLINES

- Need for replacement of old Aircrafts
- Congestion at airports

- Inadequacy of infrastructure
- Shortage of trained personnel

AIRCRAFT CHARACTERISTICS THAT GOVERN AIRPORT DESIGN

Aircraft characteristics which govern design of airport are

Speed

Size and dimensions

Weight, Landing gear and Tire pressure

AIRCRAFT CHARACTERISTICS THAT GOVERN DESIGN OF AIRPORT

Speed: The main attraction of air travel is speed. Whereas the Dakota (DC -3) of the1940 could cruise at around 300 kmph, modern wide bodied jets (Boeing-747, Airbus 300 for example) can run 1000kmph .The chord cruises at 2750 kmph, much faster than sound,

Size and dimensions The Size and dimensions of aircraft depend upon the number of passengers carried and range of operations

Weight, Landing Gear and Tire Pressure: The max weight of aircraft is when it is loaded with fuel and is at take off

RUNWAY

It is a defined rectangular area prepared for landing and takeoff operations over which the aircrafts move on ground

Runway orientation:

Runways are always orientated in the direction of the prevailing winds, so that we can utilize the force of the wind during take-off and landing operations. In the case of take-off operations, this wind will help us in generating the lift, whereas during the landing operations the same wind will help in generating the drag, so as to stop the landing aircraft. So, that is what is important as far as the orientation of runway is concerned.

The direction of the runway controls the layout of the other airport facilities such as passenger terminals, taxiways, apron configurations, circulation roads and parking facilities - means the rest of the facilities which needs to be provided on any of the airport are governed by the orientation of the runway and with respect to that because the movements of the aircraft will be there and therefore, the facilities have to be placed in such a way, so that it takes minimum of the time so as to approach a facility or so as to operate that facility. According to FAA standards, runways should be orientated so that aircraft can take-off and or land at least 95% of the time without exceeding the allowable crosswinds. So, if there cross winds available on any of the airport, which is mostly are, then in that case, as per the FAA standard it says that for 95% of the time period, the aircraft should be able to take-off or they should be able to land, without taking an effect of the allowable crosswinds into consideration.

Calm period: is the one when the wind intensity remains below 6.4 kilometers per hour and this is common to all directions and hence can be added to wind coverage for that direction.

Runway Configurations:

The term ―runway configuration‖ refers to the number and relative orientations of one or more runways on an airfield. Many runway configurations exist. Most configurations are combinations of several basic configurations. The basic configurations are
(1)single runways, (2) parallel runways, (3) intersecting runways, and (4) open-V runways.

Single Runway: It has been estimated that the hourly capacity of a single runway in **VFR** (visual flight rules) conditions is somewhere between 50 and 100 operations per hour, while in **IFR** (instrument flight rules) conditions this capacity is reduced to 50 to 70 operations per hour, depending on the composition of the aircraft mix and navigational aids available.

Parallel Runways:

The capacities of parallel runway systems depend on the number of runways and on the spacing between the runways. Two, three, and four parallel runways are common. The spacing between parallel runways varies widely. For the purpose of this discussion, the spacing is classified as close, intermediate, and far, depending on the centreline separation between two parallel runways. Close parallel runways are spaced from a minimum of 700 ft (for air carrier airports) to less than 2500 ft. In IFR conditions an operation of one runway is dependent on the operation of other runway. Intermediate parallel runways are spaced between 2500 ft to less than 4300 ft. In IFR conditions an arrival on one runway is independent of a departure on the other runway. Far parallel runways are spaced at least

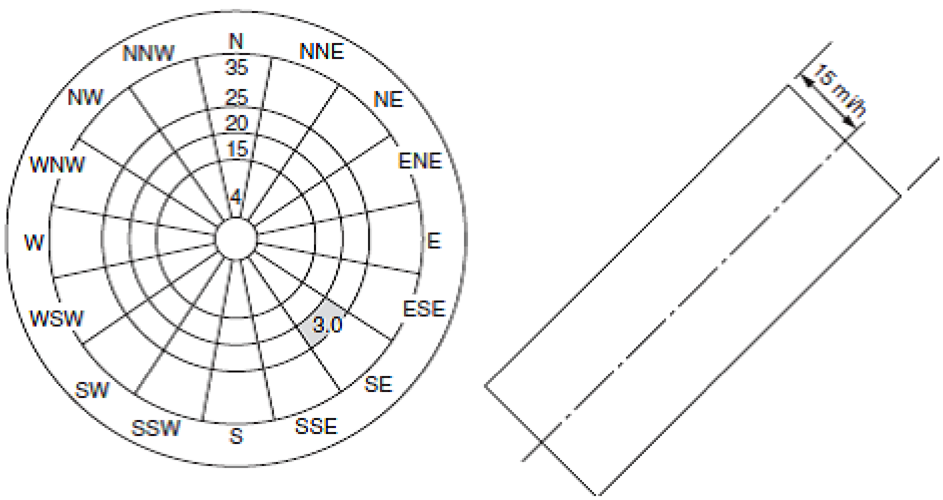
4300 ft apart. If the terminal buildings are placed between parallel runways, runways are always spaced far enough apart to allow room for the buildings, the adjoining apron, and the appropriate taxiways. When there are four parallel runways, each pair is spaced close, but the pairs are spaced far apart to provide space for terminal buildings. In VFR conditions, close parallel runways allow simultaneous arrivals and departures, that is, arrivals may occur on one runway while departures are occurring on the other runway. Aircraft operating on the runways must have wingspans less than 171 ft for centerline spacing at the minimum of 700 ft. The hourly capacity of a pair of parallel runways in VFR conditions varies greatly from 60 to 200 operations per hour depending on the aircraft mix and the manner in which arrivals and departures are processed on these runways. Similarly, in IFR conditions the hourly capacity of a pair of closely spaced parallel runways ranges from 50 to 60 operations per hour, of a pair of intermediate parallel runways from 60 to 75 operations per hour, and for a pair of far parallel runways from 100 to 125 operations per hour.

Intersecting Runways: Many airports have two or more runways in different directions crossing each other. These are referred to as intersecting runways. Intersecting runways are necessary when relatively strong winds occur from more than one direction, resulting in excessive crosswinds when only one runway is provided. When the winds are strong, only one runway of a pair of intersecting runways can be used, reducing the capacity of the airfield substantially. If the winds are relatively light, both runways can be used simultaneously. The capacity of two intersecting runways depends on the location of the intersection (i.e., midway or near the ends), the manner in which the runways are operated for takeoffs and landings, referred to as the runway use strategy, and the aircraft mix. The farther the intersection is from the takeoff end of the runway and the landing threshold, the lower is the capacity. The highest capacity is achieved when the intersection is close to the takeoff and landing threshold.

Open-V Runways:

Runways in different directions which do not intersect are referred to as open-V runways. Like intersecting runways, open-V runways revert to a single runway when winds are strong from one direction. When the winds are light, both runways may be used simultaneously. The strategy which yields the highest capacity is when operations are away from the V and this is referred to as a diverging pattern. In VFR the hourly capacity for this strategy ranges from 60 to 180 operations per hour, and in IFR the corresponding capacity is from 50 to 80 operations per hour. When operations are toward the V it is referred to as a converging pattern and the capacity is reduced to 50 to 100 operations per hour in VFR and to between 50 and 60 operations per hour in IFR.

The Wind Rose: The appropriate orientation of the runway or runways at an airport can be determined through graphical vector analysis using a wind rose. A standard wind rose consists of a series of concentric circles cut by radial lines using polar coordinate graph paper. The radial lines are drawn to the scale of the wind magnitude such that the area between each pair of successive lines is centered on the wind direction.



The shaded area indicates that the wind comes from the southeast (SE) with a magnitude between 20 and 25 mi/h. A template is also drawn to the same radial scale representing the crosswind component limits. A template drawn with crosswind component limits of 15 mi/h is shown on the right side of Fig. above. On this template three equally spaced parallel lines have been plotted. The middle line represents the runway center line, and the distance between the middle line and each outside line is, to scale, the allowable crosswind component (in this case, 15 mi/h). The template is placed over the wind rose in such a manner that the center line on the template passes through the center of the wind rose.

By overlaying the template on the wind rose and rotating the centreline of the template through the origin of the wind rose one may determine the percentage of time a runway in the direction of the centerline of the template can be used such that the crosswind component does not exceed 15 mi/h. Optimum runway directions can be determined from this wind rose by the use of the template, typically made on a transparent strip of material. With the center of the wind rose as a pivot point, the template is rotated until the sum of the percentages included between the outer lines is a maximum. If a wind vector from a segment lies outside either outer line on the template for the given direction of the runway, that wind vector must have a crosswind component which exceeds the allowable crosswind component plotted on the template. When one of the outer lines on the template divides a segment of wind direction, the fractional part is estimated visually to the nearest 0.1 percent. This procedure is consistent with the accuracy of the wind data and assumes that the wind percentage within the sector is uniformly distributed within that sector. In practice, it is usually easier to add the percentages contained in the sectors outside of the two outer parallel lines and subtract these from 100 percent to find the percentage of wind coverage.

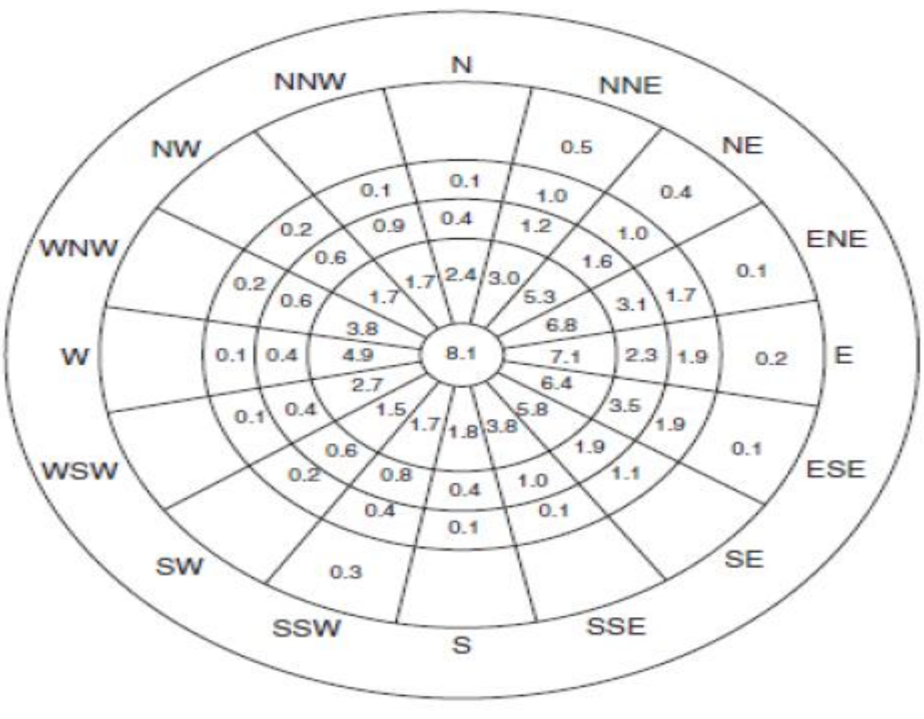


FIGURE: Wind data in wind rose format.

BASIC RUNWAY LENGTH AND CORRECTIONS

Introduction

Length of runway decided taking following assumptions:

- Airport altitude at sea level
- Temperature at airport is standard (150C)
- Runway is level in longitudinal direction
- No wind is blowing on runway
- No wind is blowing en route to destination
- Aircraft is loaded to its full capacity
- En route temperature standard

The basic runway length is determined form the performance characteristics of aircraft using airport. The following cases are usually considered

Normal landing case

Normal takeoff case

Engine failure case

For jet engine aircraft all three cases are considered but for piston engine air craft first and third case are usually considered. The longest runway length is finally adopted.

- The landing case requires that aircraft should come to stop within 60% of the landing distance. The full strength pavement is provided for entire landing distance.
- The normal takeoff requires a clear way which is an area beyond the runway and is alignment with the centre line of the runway. The width of the clear way is not less than 150m (500 ft) and is kept free from obstruction. The clearway ground area any object should not protrude a plane upward at a slope of 1.25% from the runway end.
- Engine failure case may require either a clearway or a stop way or both. Stopway is defined as the area beyond runway and centrally located in alignment with the centreline of the runway. It is used for decelerating the aircraft to stop during aborted takeoff. The strength of the stop way should be sufficient to carry the weight of the aircraft without casing any structural damage. If engine fail at a speed less than the designated engine failure speed, the pilot decelerate the aircraft and use the stop way. If however engine fails at a speed higher than the designated speed, there is no other option to pilot take-off. The pilot may latter take turn and make a landing. For piston engine aircrafts full strength pavement is provided for entire takeoff distance and the accelerated stop distance.

Correction for elevation, temperature and gradient

Airports are constructed in different elevation different atmospheric temperature and gradient, in contrast to the assumption made for basic runway length. Therefore correction required for changes in each components.

Correction in elevation All other things being equal, the higher the field elevation of the airport, results the less dense the atmosphere, requiring longer runway lengths for the aircraft to get to the appropriate groundspeed to achieve sufficient lift for takeoff. For airports at elevation above sea level, the design runway length is 300 ft plus 0.03 ft for every foot above sea level. ICAO recommends the basic runway length should increase at rate of 7% per 100 m rise in elevation over MSL.

Correction in temperature: With rise of reference temperature same effect is there as that of elevation. The airport reference temperature defined as monthly mean of average daily temperature (Ta) for the hottest month of the year plus one third the difference of this temperature and monthly mean of the maximum daily temperature(Tw) for same month of the year. Reference Temperature = Ta + (Tw – Ta)/3

ICAO recommends the basic runway length after have been corrected for elevation, should further increase at the rate of 1% for every 10C increase of reference temperature. If both correction increases more than 35% ICAO recommended specific site study should be conducted.

Correction for gradient:

Steeper gradient require greater consummation of energy and longer length of runway to attain the desired speed. ICAO does not recommend any correction. FAA recommends after correction for elevation and temperature a further increase in runway length at arte of 20% for every 1 percent effective gradients.

Effective gradient: is defined taking maximum difference between elevation between lowest point and highest point in the runway divided by length of the runway.

GEOMETRIC ELEMENTS DESIGN

Taxiways and Taxi lanes Taxiways are defined paths on the airfield surface which are established for the taxiing of aircraft and are intended to provide a linkage between one part of the airfield and another. Basically it established the connection between runway, terminal building and hanger. The term ―dual parallel taxiways‖ refers to two taxiways parallel to each other on which airplanes can taxi in opposite directions. An apron taxiway is a taxiway located usually on the periphery of an apron intended to provide a through taxi route across the apron. A taxi lane is a portion of the aircraft parking area used for access between the taxiways and the aircraft parking positions. ICAO defines an aircraft stand taxi lane as a portion of the apron intended to provide access to the aircraft stands only. In order to provide a margin of safety in the airport operating areas, the traffic ways must be separated sufficiently from each other and from adjacent obstructions. Minimum separations between the centerlines of taxiways, between the centerlines of taxiways and taxi lanes, and between taxiways and taxi lanes and objects are specified in order that aircraft may safely maneuver on the airfield.

Taxiway and Taxi lane Separation

Requirements FAA Separation Criteria

The separation criteria adopted by the FAA are predicated upon the wingtips of the aircraft for which the taxiway and taxi lane system have been designed and provide a minimum wingtip clearance on these facilities. The required separation between taxiways, between a taxiway and a taxi lane, or between a taxiway and a fixed or movable object requires a minimum wingtip clearance of 0.2 times the wingspan of the most demanding aircraft in the airplane design group plus 10 ft. This clearance provides a minimum taxiway centerline to a parallel taxiway centerline or taxi lane centerline separation of 1.2 times the wingspan of the most demanding aircraft plus 10 ft, and between a taxiway centerline and a fixed or movable object of 0.7 times the wingspan of the most demanding aircraft plus 10 ft. The taxilane centerline to a parallel taxilane centerline or fixed or movable object separation in the terminal area is predicated on a wingtip clearance of approximately half of that required for an apron taxiway. This reduction in clearance is based on the consideration that taxiing speed is low in this area, taxiing is precise, and special guidance techniques and devices are provided. This requires a wingtip clearance or wingtip-to-object clearance of 0.1 times the wingspan of the most demanding aircraft plus 10 ft.

Holding Aprons

Holding aprons, holding pads, run-up pads, or holding bays as they are sometimes called, are placed adjacent to the ends of runways. The areas are used as storage areas for aircraft prior to takeoff. They are designed so that one aircraft can bypass another whenever this is necessary. For piston-engine aircraft the holding apron is an area where the aircraft instrument and engine operation can be checked prior to takeoff. The holding apron also provides for a trailing aircraft to bypass a leading aircraft in case the takeoff clearance of the latter must be delayed for one reason or another, or if it experiences some malfunction. There are many configurations of holding aprons. The important design criteria are to provide adequate space for aircraft to maneuver easily onto the runway irrespective of the position of adjacent aircraft on the holding apron and to provide sufficient room for an aircraft to bypass parked aircraft on the holding apron. The recommendations for the minimum separation between aircraft on holding aprons are the same as those specified for the taxiway object-free area.

Terminal building:

The terminal area is the major interface between the airfield and the rest of the airport. It includes the facilities for passenger and baggage processing, cargo handling, and airport maintenance, operations, and administration activities. The passenger processing system is discussed at length in this chapter. Baggage processing, cargo handling, and apron requirements are also discussed relative to the terminal system.

The Passenger Terminal System:

The passenger terminal system is the major connection between the ground access system and the aircraft. The purpose of this system is to provide the interface between the passenger airport access mode, to process the passenger for origination, termination, or continuation of an air transportation trip, and convey the passenger and baggage to and from the aircraft.

Components of the System:

The passenger terminal system is composed of three major components. These components and the activities that occur within them are as follows:

1. The access interface where the passenger transfers from the access mode of travel to the passenger processing component. Circulation, parking, and curbside loading and unloading of passengers are the activities that take place within this component.

2. The processing component where the passenger is processed in preparation for starting, ending, or continuation of an air transportation trip. The primary activities that take place within this component are ticketing, baggage check-in, baggage claim, seat assignment, federal inspection services, and security.

3. The flight interface where the passenger transfers from the processing component to the aircraft. The activities that occur here include assembly, conveyance to and from the aircraft, and aircraft loading and unloading. A number of facilities are provided to perform the functions of the passenger terminal system. These facilities are indicated for each of the components identified above.

The Access Interface

This component consists of the terminal curbs, parking facilities, and connecting roadways that enable originating and terminating passengers, visitors, and baggage to enter and exit the terminal. It includes the following facilities:

1. The enplaning and deplaning curb frontage which provide the public with loading and unloading for vehicular access to and from the terminal building

2. The automobile parking facilities providing short-term and long-term parking spaces for passengers and visitors, and facilities for rental cars, public transit, taxis, and limousine services

3. The vehicular roadways providing access to the terminal curbs, parking spaces, and the public street and highway system

4. The designated pedestrian walkways for crossing roads including tunnels, bridges, and automated devices which provide access between the parking facilities and the terminal building

5. The service roads and fire lanes which provide access to various facilities in the terminal and to other airport facilities, such as air freight, fuel truck stands, and maintenance. The ground access system at an airport is a complex system of roadways, parking facilities, and terminal access curb fronts.

The Processing System: The terminal is used to process passengers and baggage for the interface with aircraft and the ground transportation modes. It includes the following facilities:

1. The airline ticket counters and offices used for ticket transactions, baggage check-in, flight information, and administrative personnel and facilities

2. The terminal services space which consists of the public and nonpublic areas such as concessions, amenities for passengers and visitors, truck service docks, food preparation areas, and food and miscellaneous storage
3. The lobby for circulation and passenger and visitor waiting
4. Public circulation space for the general circulation of passengers and visitors consisting of such areas as stairways, escalators, elevators, and corridors
5. The outbound baggage space which is a nonpublic area for sorting and processing baggage for departing flights
6. The intraline and interline baggage space used for processing baggage transferred from one flight to another on the same or different airlines
7. The inbound baggage space which is used for receiving baggage from an arriving flight, and for delivering baggage to be claimed by the arriving passenger
8. Airport administration and service areas used for airport management, operations, and maintenance facilities
9. The federal inspection service facilities which are the areas for processing passengers arriving on international flights, as well as performing agricultural inspections, and security functions.

AIRPORT MAKING AND LIGHTING

Visual aids assist the pilot on approach to an airport, as well as navigating around an airfield and are essential elements of airport infrastructure. As such, these facilities require proper planning and precise design. These facilities may be divided into three categories: lighting, marking, and signage. Lighting is further categorized as either approach lighting or surface lighting. Specific lighting systems described in this chapter include

1. Approach lighting
2. Runway threshold lighting
3. Runway edge lighting
4. Runway centerline and touchdown zone lights
5. Runway approach slope indicators
6. Taxiway edge and centerline lighting

Airfield lighting, marking, and signage facilities provide the following functions:

1. Ground to air visual information required during landing

2. The visual requirements for takeoff and landing

3. The visual guidance for taxiing

The Airport Beacon

Beacons are lighted to mark an airport. They are designed to produce a narrow horizontal and vertical beam of high-intensity light which is rotated about a vertical axis so as to produce approximately 12 flashes per minute for civil airports and 18 flashes per minute for military airports. The flashes with a clearly visible duration of at least 0.15 s are arranged in a white-green sequence for land airports and a white yellow sequence for landing areas on water. Military airports use a double white flash followed by a longer green or yellow flash to differentiate them from civil airfields. The beacons are mounted on top of the control tower or similar high structure in the immediate vicinity of the airport.

Obstruction Lighting:

Obstructions are identified by fixed, flashing, or rotating red lights or beacons. All structures that constitute a hazard to aircraft in flight or during landing or takeoff are marked by obstruction lights having a horizontally uniform intensity duration and a vertical distribution design to give maximum range at the lower angles (1.5° to 8°) from which a colliding approach would most likely come.

The Aircraft Landing Operation:

An aircraft approaching a runway in a landing operation may be visualized as a sequence of operations involving a transient body suspended in a three-dimensional grid that is approaching a fixed two-dimensional grid. While in the air, the aircraft can be considered as a point mass in a three-dimensional orthogonal coordinate system in which it may have translation along three coordinate directions and rotation about three axes. If the three coordinate axes are aligned horizontal, vertical, and parallel to the end of the runway, the directions of motion can be described as lateral, vertical, and forward. The rotations are normally called pitch, yaw, and roll, for the horizontal, vertical, and parallel axes, respectively. During a landing operation, pilots must control and coordinate all six degrees of freedom of the aircraft so as to bring the aircraft into coincidence with the desired approach or reference path to the touchdown point on the runway. In order to do this, pilots need translation information regarding the aircraft‘s alignment, height, and distance, rotation information regarding pitch, yaw, and roll, and information concerning the rate of descent and the rate of closure with the desired path.

Alignment Guidance:

Pilots must know where their aircraft is with respect to lateral displacement from the centerline of the runway. Most runways are from 75 to 200 ft wide and from 3000 to 12,000 ft long. Thus any runway is a long narrow ribbon when first seen from several thousand feet above. The predominant alignment guidance comes from longitudinal lines that constitute the centerline and edges of the runway. All techniques, such as painting, lighting, or surface treatment that develop contrast and emphasize these linear elements are helpful in providing alignment information.

Approach Lighting:

Approach lighting systems (ALS) are designed specifically to provide guidance for aircraft approaching a particular runway under night time or other low-visibility conditions. While under night time conditions it may be possible to view approach lighting systems from several miles away, under other low-visibility conditions, such as fog, even the most intense ALS systems may only be visible from as little as 2500 ft from the runway threshold. Studies of the visibility in fog have shown that for a visual range of 2000 to 2500 ft it would be desirable to have as much as 200,000 candelas (cd) available in the outermost approach lights where the slant range is relatively long. Under these same conditions the optimum intensity of the approach lights near the threshold should be on the order of 100 to 500 cd. A transition in the intensity of the light that is directed toward the pilot is highly desirable in order to provide the best visibility at the greatest possible range and to avoid glare and the loss of contrast sensitivity and visual acuity at short range.

Taxiway lighting: Either after a landing or on the way to takeoff, pilots must maneuver the aircraft on the ground on a system of taxiways to and from the terminal and hangar areas. Taxiway lighting systems are provided for taxiing at night and also during the day when visibility is very poor, particularly at commercial service airports. The following overall guidance should be applied in determining the lighting, marking, and signing visual aid requirements for taxiways:

- In order to avoid confusion with runways, taxiways must be clearly identified.

- Runway exits need to be readily identified. This is particularly true for high-speed runway exits so that pilots can be able to locate these exits 1200 to 1500 ft before the turnoff point.
- Adequate visual guidance along the taxiway must be provided.
- Specific taxiways must be readily identified.
- The intersections between taxiways, the intersections between runways and taxiways, and runway-taxiway crossings need to be clearly marked.
- The complete taxiway route from the runway to the apron and from the apron to the runway should be easily identified. There are two primary types of lights used for the designation of taxiways. One type delineates the edges of taxiways and the other type delineates the center line of the taxiway.

Runway Guard Lights:

Runway guard lights (RGLs) are in-pavement lights located on taxiways at intersections of runways to alert pilots and operators of airfield ground vehicles that they are about to enter onto an active runway. RGLs are located across the width of the taxiway, approximately 2 ft from the entrance to a runway, spaced at approximately 10-ft intervals,

Runway Stop Bar:

Similar to runway guard lights, runway stop bar lights are in-pavement lights on taxiways at intersections with runways. As opposed to RGLs that provide warning to pilots approaching a runway, runway stop bar lights are designed to act as ―stop‖ lights, directing aircraft and vehicles on the taxiway not to enter the runway environment. Runway stop bar lights are activated with red illuminations during periods of runway occupancy or other instances where entrance from the taxiway to the runway is prohibited. In-pavement runway stop bar lighting is typically installed in conjunction with elevated runway guard lights located outside the width of the pave

UNIT IV

PORT AND HARBOUR ENGINEERING

Water transportation:

The water transportation can further be subdivided into two categories:

Inland transportation and Ocean transportation.

- Inland Water transportation.
- Inland Water transportation is either in the form of river transportation or canal

Transportation.

Ocean Water transportation is adopted for trade and commerce.

It is estimated that about 75 per cent of international trade is carried out by shipping.

The development of navy force is intended for national defense.

Ocean water transportation has an limitation and it possesses high flexibility.

Definitions

Harbours:

A harbour can be defined as a sheltered area of the sea in which vessels could be launched, built or taken for repair; or could seek refuge in time of storm; or provide for loading and unloading of cargo and passengers.

Harbours are broadly classified as:

- Natural harbours
- Semi-natural harbours
- Artificial harbours.
- Natural harbours:
- Natural formations affording safe discharge facilities for ships on sea coasts, in the

form of creeks and basins, are called natural harbours.

With the rapid development of navies engaged either in commerce or war, improved accommodation and facilities for repairs, storage of cargo and connected amenities had to be provided in natural harbours.

The factors such as local geographical features, growth of population, development of the area, etc. have made the natural harbours big and attractive. Bombay and Kandla are, examples of natural harbours

Semi-natural harbours:

- This type of harbour is protected on sides by headlands protection and it requires man-made protection only at the entrance.
- Vishakhapatnam is a semi-natural harbour.

Artificial harbours:

- Where such natural facilities are not available, countries having a seaboard had to create or construct such shelters making use of engineering skill and methods, and such harbors' are called artificial or man-made harbors.
- Madras is an artificial harbor.
- Thus, a naval vessel could obtain shelter during bad weather within a tractor area of water close to the shore, providing a good hold for anchoring, protected by natural or artificial harbor walls against the fury of storms

Site selection:

The guiding factors which play a great role in choice of site for a harbour are as follows

- Availability of cheap land and construction materials
- Transport and communication facilities
- Natural protection from winds and waves
- Industrial development of the locality
- Sea-bed subsoil and foundation conditions
- Traffic potentiality of harbour
- Availability of electrical energy and fresh water
- Favorable marine conditions
- Defence and strategic aspects

Shape of the harbour:

The following principles should be kept in mind:

- In order to protect the harbour from the sea waves, one of the pier heads should project a little beyond the other.
- _ Inside the pier heads, the width should widen very rapidly.

- The general shape of the harbours should be obtained by a series of

straight lengths and no re-entrant angle should be allowed

- The term port is used to indicate a harbour where terminal facilities, such a stores,
- landing of passengers and cargo, etc. are added to it.
- Thus, a harbour consists of the waterways and channels as far as the pier head lines
- and a port includes everything on the landward side of those lines i.e. piers, slips,

wharves, sheds, tracks, handling equipment, etc.

The term free port is used to indicate an isolated, enclosed and policed area

- for handling of cargo; etc. for the purpose of reshipping without the
- intervention of customs.
- It is furnished with the facilities for loading and unloading; for storing goods
- and reshipping them by land or water; and for supplying fuel.
- Free port thus indicates an area within which goods can be landed, stored, mixed, blended, repacked, manufactured and reshipped without payment of duties and without the intervention of custom department.
- Depending upon the commodities dealt with or their use, the ports can also be
- classified as grain ports, coaling ports, transhipment ports, ports of call, etc.
- Depending upon the size and location, the ports can also be grouped as major
- ports, intermediate ports and minor ports
- A major port is able to attract trade and it commands a really pivoted position
- for the extension of communications.

Port design:

The design of a port should be made while keeping in mind the following requirements:

- The entrance channel should be such that the ships can come in and go out easily.
- The ships should be able to turn in the basin itself.
- The alignment of quays should be such that the ships can come along side easily even when there is an on-shore wind.
- The width behind the quay should be sufficient to deal with the goods.
- There should be enough provision for railway tracks to take care for loading and unloading of cargo.

Requirements of a good port

- It should be centrally situated for the hinterland. For a port, the hinterland is that part of the country behind it which can be served with economy and efficiency by the port.
- It should get good tonnage i .e. charge per tonne of cargo handled by it.
- It should have good communication with the rest of country.
- It should be populous
- It should be advance in culture, trade and industry.
- It should be a place of defence and for resisting the sea-borne invasion
- It should command valuable and extensive trade.
- It should be capable of easy, smooth and economic development.
- It should afford shelter to all ships and at all seasons of the years
- It should provide the maximum facilities to all the visiting ships including the servicing of ships.

TIDES AND WAVES:

Some of the natural and meteorological phenomena which primarily affect the location and design of the harbour.

They are as follows:

_ Coastal currents and evidences of sitting, including littoral drift or coast erosion.

_ Tides and tidal range.

_ Wind, wave and their combined effect on harbour structures.

Tides:

_ Tides on the coast-line are caused by the sun and moon.

_ The effect of tides is to artificially raise and lower the mean sea level during certain stated periods.

_ This apparent variation of mean sea level is known as the tidal range.

Spring tides and Neap tides:

_ At new and full moon or rather a day or two after (or twice in each lunar month), the tides rise higher and fall lower than at other times and these are called Spring tides.

_ Also one or two days after the moon is in her quarter i.e. about seven days from new and full moons (twice in a lunar month), the tides rise and fall less than at other times and are then called neap tides.

Breakwaters:

_ The protective barrier constructed to enclose harbours and to keep the harbour waters undisturbed by the effect of heavy and strong seas are called breakwaters.

Alignment:

_ A good alignment for a breakwater is to have straight converging arms so that the angle of inter section does not exceed 60 degrees.

_ It is desirable to avoid straight parallel or diverging arms running out to sea.

Design of breakwaters:

Following information should he collected before the design of a breakwater:

• Character of coastal currents

• Cost and availability of materials of construction

• Directions and force of prevailing winds

• Nature of the bottom or foundation

• Probable maximum height, force and intensity of waves. !

The three important rules to be observed in the design of a breakwater are as under:

Rubbing strips:

_ In its simplest form, the fender system adopted for small vessels consists of rubbing strips of timber, coir padding or used rubber tyres

_ It is also convenient to use pneumatic inflated tyres, either by suspending them or installing them at right angles to jetty face.

_ The inflated big-size tyres are useful to transfer cargo between mother ship and daughter ships.

_ The pneumatic rubber fenders are very useful for transferring cargo from ship to ship of big sizes.

Timber grill:

_ This system consists merely of vertical and horizontal timber members fixed to the face piles.

_ This is a simple form of fender and to make it more effective, energy fender piles may be driven along the jetty face with cushion or spring inserted between them.

Gravity-type fendering system:

_ As the ships grew in size, this s came into force and in its simplest form, it consists of a weighty fender which is raised up when there is an impact of the berthing ship and thus, the initial energy of shock, is absorbed.

Rubber tendering:

_ Due to the development of rubber technology and with, further growth in ship size, rubber fendering is preferred at present.

_ The shapes of rubber fenders may be cylindrical, square, V-shape or cell type.

NAVIGATIONAL AIDS

Necessity for signals:

The mariner and his ship have to be guided by proper signals during navigation, especially,

(1) to avoid dangerous zones like hidden rocky outcrop and sand bars,

(2) to follow proper approaches and

(3) to locate ports.

Fixed and floating light stations:

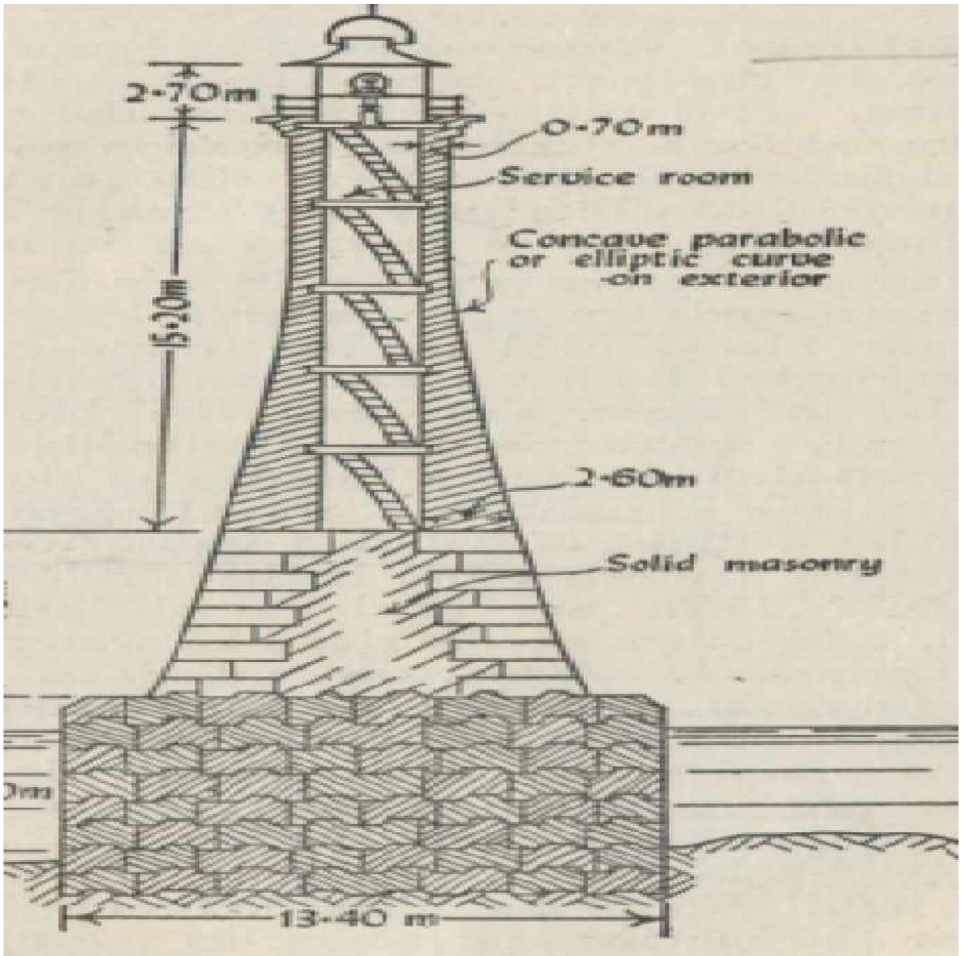
_ The light stations when they are built on land are called fixed as in the case of permanent lighthouse structures.

_ Such structures are located either in the hinterland close to the shore or in the sea on submerged outcrops and exposed to the fury of the waves.

_ Alternately, where there are difficulties in establishing proper foundations; floating light rations in the form of a light vessel may be adopted.

_ Buoys of standard shapes also belong to the ‘floating type and are generally used to demarcate boundaries of approach channels in harbour basins.

Lighthouse:



Signals:

_ The approach channel of a modern port should be clearly defined o

Demarcated by the provision of suitable signals.

Thus, signals will be required at the following places:

_ Light ships have to be provided at important changes in the direction of the Route of ships.

_ Lighted beacons are to be fixed on river banks

_ Buoys are required at entrance channels to ports.

Types of signals:

The signals are broadly divided into the following three categories':

1. Light signals
2. Fog signals
3. Audible signals.

The first classification of light signals is very important. Fog signals and audible signals are occasionally used

Light signals

These signals are subdivided into three types:

(1) Light ships

(2) Beacons

(3) Buoys.

<u>Lightships:</u>

1. Small ships displacing about 500 tones are used for this purpose.
2. The lantern is carried on an open steel tower approximately 9 m to 12 m above the water level and erected amidships.
3. The light apparatus consists of four pairs of mirror reflectors placed around the light and made to revolve at a suitable speed emitting ,a predetermined number of flashes.
4. The ship is with service personnel and is securely anchored or moored.
5. light ships are more stable and the lights in them more steady which is an important factor for a mariner.
6. The hulls of light ships are built of steel and they are generally painted with red colour.
7. The name of the station is painted in white colours on both sides of light ship.
8. The superstructures are also provided with white colours.
9. The storm warning signals are also installed on the light ships.
10. When the light ships are being overhauled, red colour relief light ships with the word ‘Relief’ on the sides are used.

<u>Beacons:</u>

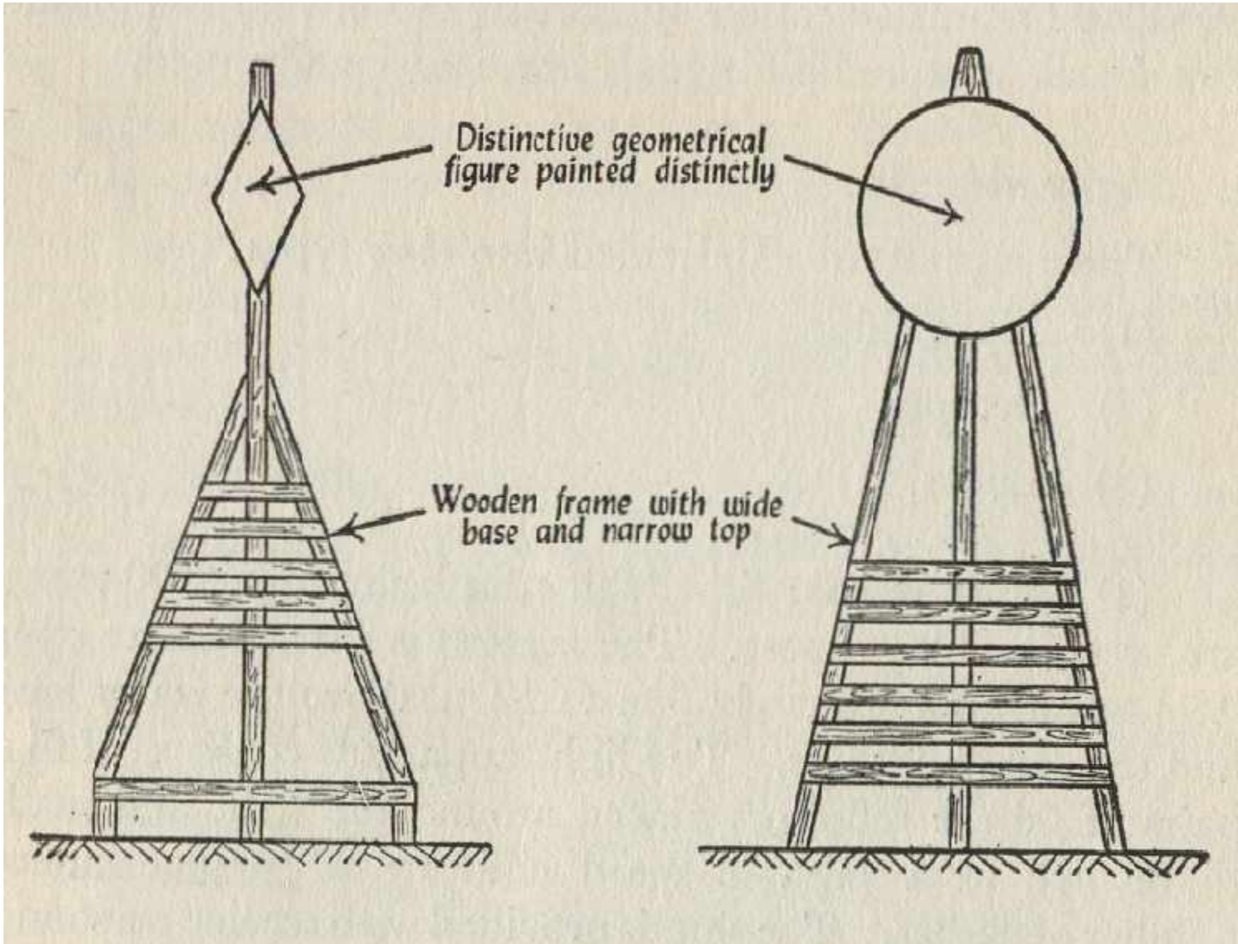
• Any prominent object, natural or artificially constructed, easily identifiable and capable of being used as a means to indicate and guide in navigation is generally designated as a beacon.

• Lofty topographical feature like hill summit, building or structure like a church

Steeple, or factory chimney, could all be made use of as beacons.

• Alternately, a beacon could be built in the form of an open tapering frame work, with a wide stable base and gradually narrowed top, terminating in a distinctive figure, like a triangle or circle as shown in fig.

• The distinctive geometrical figure is suitably painted so as to cause prominence.



Beacons

Buoys:

• Buoys are floating structures of small size employed for demarcation like entrances, approach channel used for indicating direction changes in means of alignment. Beacons are thus of the navigation.

• Beacons are navigation or as immense help in boundaries and so on.

• They are moored to sinkers, or heavy anchors, with the help of heavy chains, whose length are two to three times the depth of water and which are 70 to 90 mm in diameter.

Mooring buoys:

_ In harbour interiors, buoys are pro vided in fixed positions to which ships could be moored during their stay in the harbour without using anchors.

_ These buoys are called mooring buoys. Some common types of mooring buoys in use in India are shown in fig.

Wreck buoys:

These arc of peculiar shape and are used to locate wrecks in harbour exteriors or open seas. They are also used for sea cable crossing locations

Unit 5

Intelligent Transportation System

Intelligent Transportation Systems (ITS) is the application of computer, electronics, and communication technologies and management strategies in an integrated manner to provide traveler information to increase the safety and efficiency of the road transportation systems. This chapter mainly describes ITS user services, ITS architecture and ITS planning. The various user services offered by ITS have been divided in eight groups have been briefly described.

The ITS architecture which provides a common framework for planning, defining, and integrating intelligent transportation systems is briefly described emphasizing logical and physical architecture. Integration of ITS in transportation planning process which follows a systems engineering approach to develop a transportation plan is also briefly described

Introduction:

Intelligent Transportation Systems (ITS) is the application of computer, electronics, and communication technologies and management strategies in an integrated manner to provide traveler information to increase the safety and efficiency of the surface transportation systems. These systems involve vehicles, drivers, passengers, road operators, and managers all interacting with each other and the environment, and linking with the complex infrastructure systems to improve the safety and capacity of road systems.

As reported by Commission for Global Road Safety(June 2006) , the global road deaths were between 750,000 to 880,000 in the year 1999 and estimated about 1.25 million deaths per year and the toll is increasing further. World health organization report (1999), showed that in the year 1990 road accidents as a cause of death or disability were the ninth most significant cause of death or disability and predicted that by 2020 this will move to sixth place. Without significant changes to the road transport systems these dreadful figures are likely to increase significantly. Traditional driver training, infrastructure and safety improvements, may contribute to certainextent to reduce the number of accidents but not enough to combat this menace. Intelligent Transport Systems are the best solution to the problem. Safety is one of the principal driving forces behind the evolution, development, standardization, and implementation of ITS systems

ITS improves transportation safety and mobility and enhances global connectivity by means of productivity improvements achieved through the integration of advanced communications technologies into the transportation infrastructure and in vehicles. Intelligent transportation systems encompass a broad range of wireless and wire line communication based information and electronics technologies to better manage traffic and maximize the utilization of the existing transportation infrastructure. It improves driving experience, safety and capacity of road systems, reduces risks in transportation, relieves traffic congestion, improves transportation efficiency and reduces pollution.

ITS user services:

1. Travel and traffic management
2. Public transportation operations
3. Electronic payment
4. Commercial vehicle operations
5. Advance vehicle control and safety systems
6. Emergency management
7. Information management
8. Maintenance and construction management

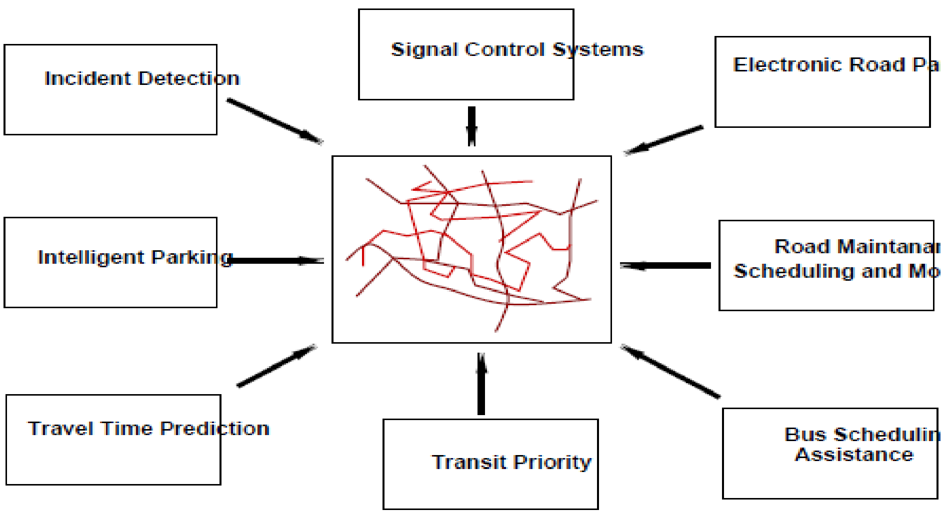


Figure5-1

Travel and traffic management:

The main objective of this group of services is to use real time information on the status of the transportation system to improve its efficiency and productivity and to mitigate the adverse environmental impacts of the system. This group of user service is further divided in 10 user services. Most of these services share information with one another in a highly integrated manner for the overall benefit of the road transportation system. These services are described as below:

Pre trip information:

This user service provides information to the travelers about the transportation system before they begin their trips so that they can make more informed decisions regarding their time of departure, the mode to use and route to take to their destinations. The travelers can access this information through computer or telephone systems at home or work and at major public places. Pre travel information can be accessed through mobile phones as shown in Fig. 5.2.Different routes and respective travel time durations indicated on VMS are shown in Fig. 5.3The information include real time flow condition, real incidents and suggested alternate routes, scheduled road construction and maintenance tasks, transit routes, schedules, fares, transfers, and parking facilities.

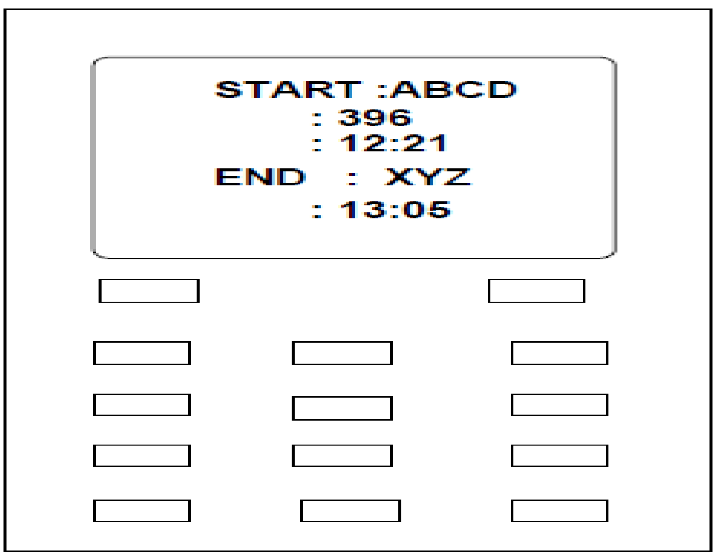


Figure 5-2 Pre trip Information

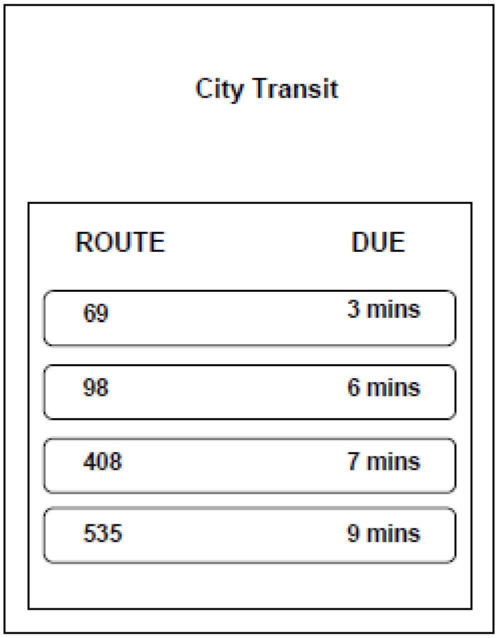


FIGURE 5-3Pre Trip information

En-route driver information:

This user service provides travel related information to the travelers en route after they start their trips through variable message signs (VMS), car radio, or portable communication devices.

Fig. 5:4 shows the various congested and non congested routes shown on display screen.

VMS indicating different routes and travel time is shown in Fig. 5.5. This helps the travelers to better utilize the existing facility by changing routes etc to avoid congestion. This also provides warning messages for roadway signs such as stop signs, sharp curves, reduced speed advisories, wet road condition flashed with in vehicle displays to the travelers to improve the safety of operating a vehicle. The information can be presented as voice output also.

Figure 5-4 congested routes

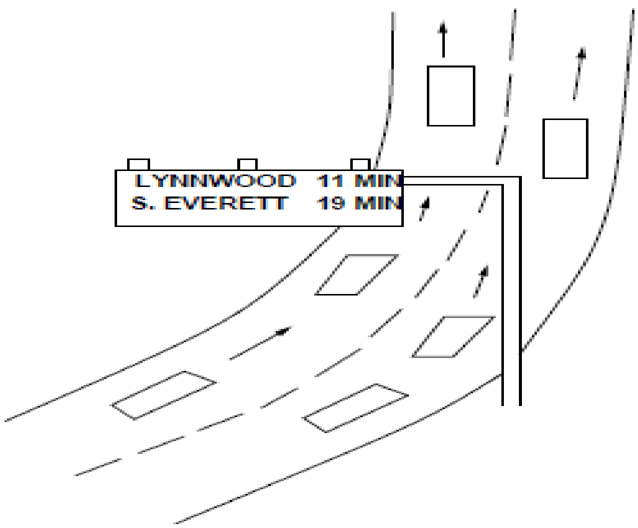


Figure 5-5VMS showing routes and travel times

Route guidance:

This service provides information to the travellers with a suggested route to reach a specified destination, along with simple instructions on upcoming turns and other manoeuvres. This also provides travellers of all modes the real-time information about the transportation system, including traffic conditions, road closures, and the status and schedule of transit systems. The benefits of this service are reduced delay and drivers stress levels particularly in an unfamiliar area.

Ride matching and reservation:

This user service provide real-time ride matching information to travelers in their homes, offices or other locations, and assists transportation providers with vehicle assignments and scheduling.

Traveler Services Information:

This service provides a business directory of information on travel-related services and facilities like the location, operating hours, and availability of food, lodging, parking, auto repair, hospitals, gas stations and police facilities. This also makes reservations for many of these traveler services. The traveler services information are accessible in the home, office or other public locations to help plan trips. These services are available en-route also.

Traffic Control:

This service collects the real time data from the transportation system, processes it into usable information, and uses it to determine the optimum assignment of right-of-way to vehicles and pedestrians. This helps in improving the flow of traffic by giving preference to transit and other high occupancy vehicles or by adjusting the signal timing to current traffic conditions. The information collected by the Traffic Control service is also disseminated for use by many other user services.

Incident Management:

This service aims to improve the incident management and response capabilities of transportation and public safety officials, the towing and recovery industry, and others involved in incident response. Advanced sensors (close circuit TV cameras), data processors and communication technologies are used to identify incidents quickly and accurately and to implement response which minimizes traffic congestion and the effects of these incidents on the environment and the movement of people and goods.

Travel Demand Management:

This user service develops and implements strategies to reduce the number of single occupancy vehicles while encouraging the use of high occupancy vehicles and the use of more efficient travel mode. The strategies adopted are:

1. Congestion pricing
2. Parking management and control
3. Mode change support
4. Telecommuting and alternate work schedule.

Emissions Testing and Mitigation:

The main objective of this service is to monitor and implement strategies to divert traffic away from sensitive air quality areas, or control access to such areas using advanced sensors. This also used to identify vehicles emitting pollutants exceeding the standard values and to inform drivers to enable them to take corrective action. This helps in facilitating implementation and evaluation of various pollution control strategies by authorities.

Highway Rail Intersection:

This service is to provide improved control of highway and train traffic to avoid or decrease the severity of collisions between trains and vehicles at highway-rail intersections. This also monitors the condition of various HRI equipments.

PUBLIC TRANSPORTATION OPERATIONS

This group of service is concerned with improving the public transportation systems and encouraging their use. This group is divided in four services which are described as below:

Public Transportation Management:

This user service collects data through advanced communications and information systems to improve the operations of vehicles and facilities and to automate the planning and management functions of public transit systems. This offers three tasks:

1. To provide real-time computer analysis of vehicles and facilities to improve transit operations and maintenance by monitoring the location of transit vehicles, by identifying deviations from the schedule, and offering potential solutions to dispatchers and operators.
2. To maintain transportation schedules and to assure transfer connections from vehicle to vehicle and between modes to facilitate quick response to service delays.
3. To enhance security of transit personnel by providing access management of transit vehicles.

En-Route Transit Information:

This service is intended to provide information on expected arrival times of vehicles, transfers, and connections to travelers after they begin their trips using public transportation. This also provides real-time, accurate transit service information on-board the vehicle, at transit stations and bus stops to assist travelers in making decisions and modify their trips underway.

Personalized Public Transit:

The aim of this service is to offer public transport facility to travelers by assigning or scheduling vehicles by

1. diverting flexibly routed transit vehicles.
2. Assigning privately operated vehicles on demand which include small buses, taxicabs, or other small, shared-ride vehicles. Under this service, travelers provide information of their trip origin and destination to service station. The center then assigns the closest vehicle to service the request and to inform the travelers regarding arrival of such vehicles well in advance to reduce their anxiety.

Public Travel Security

This user service creates a secure environment for public transportation operators and support staff and monitors the environment in transit facilities, transit stations, parking lots, bus stops and on-board transit vehicles and generates alarms (either automatically or manually) when necessary. It also provides security to the systems that monitor key infrastructure of transit (rail track, bridges, tunnels, bus guide ways, etc.).

ELECTRONIC PAYMENT

This user service allows travelers to pay for transportation services with a common electronic Payment medium for different transportation modes and functions. Toll collection, transit fare Payment and parking payment are linked through a multi-modal multi-use electronic system. With an integrated payment system a traveler driving on a toll road, using parking lot would be able to use the same electronic device to pay toll, parking price and the transit fare. Fig. 48:8 shows the electronic payment facility by radio car tag.

COMMERCIAL VEHICLE OPERATIONS

The aim is to improve the efficiency and safety of commercial vehicle operations. This involves following services:

1. CV electronic clearance
2. Automated road side safety inspection
3. On-board safety monitoring administrative process

4. Hazardous material incident response
5. Freight Mobility

ADVANCED VEHICLE CONTROL AND SAFETY SYSTEMS

This user service aims to improve the safety of the transportation system by supplementing drivers' abilities to maintain vigilance and control of the vehicle by enhancing the crash avoidance capabilities of vehicles. Following user services are included in this group:

Longitudinal Collision Avoidance:

This user service provides assistance to vehicle operators in avoiding longitudinal collisions to the front and/or rear of the vehicle. This is achieved by implementing rear-end collision warning and control, Adaptive Cruise Control (ACC), head-on collision warning and control and backing collision warning to the drivers.

Lateral Collision Avoidance:

This helps drivers in avoiding accidents that result when a vehicle leaves its own lane of travel, by warning drivers and by assuming temporary control of the vehicle. This service provides to the drivers the lane change/blind spot situation display, collision warning control and lane departure warning and control.

Intersection Collision Avoidance:

This user service is specifically aimed at providing vehicle operators with assistance in avoiding collisions at intersections. The system tracks the position of vehicles within the intersection area through the use of vehicle-to-vehicle communications or vehicle to infrastructure communications.

Vision Enhancement for Crash Avoidance:

This service helps in reducing the number of vehicle crashes that occur during periods of poor visibility by in vehicle sensors capable of capturing an image of driving environment and providing a graphical display of the image to the drivers.

Safety Readiness:

This helps to provide drivers with warnings regarding their own driving performance, the condition of the vehicle, and the condition of the roadway as sensed from the vehicle.

Pre-Crash Restraint Deployment:

This service helps in reducing the number and severity of injuries caused by vehicle collisions by anticipating an imminent collision and by activating passenger safety systems prior to the Actual impact.

Automated Vehicle Operations (AVO):

This service provides a fully automated vehicle-highway system in which instrumented vehicles operate on instrumented roadways without operator intervention.

EMERGENCY MANAGEMENT

This service has two functions:

1. Emergency notification and personal security - This is to provide travellers the ability to notify appropriate emergency response personnel regarding the need for assistance due to emergency or non-emergency situations either by manually or automatically from the vehicle on the occurrence of an accident.

2. Emergency vehicle management - This user service is to reduce the time from the receipt of an emergency notification to the arrival of the emergency vehicles at incident location thereby reducing the severity of accident injuries.

INFORMATION MANAGEMENT

This service is aimed to provide the functionality needed to store and archive the huge amountsof data being collected on a continuous basis by different ITS technologies.

MAINTENANCE AND CONSTRUCTION MANAGEMENT

This user service is aimed to provide the functionality needed for managing the fleets of maintenance vehicles, managing the roadway with regards to construction and maintenance and safe roadway operations.

ITS Architecture

The ITS Architecture provides a common framework for planning, defining, and integrating intelligent transportation systems. It specifies how the different ITS components would interact with each other to help solving transportation problems. It provides the transportation professionals to address their needs with wide variety of options. It identifies and describes various functions and assigns responsibilities to various stake-holders of ITS. The ITS architecture should be common and of specified standards throughout the state or region so that it can address solution to several problems while interacting with various agencies.

1. Interoperability - The ITS architecture should be such that the information collected, function implemented or any equipment installed be interoperable by various agencies in different state and regions.
2. Capable of sharing and exchanging information - The information by traffic operations may be useful to the emergency services.
3. Resource sharing - regional communication towers constructed by various private agencies are required to be shared by ITS operations.

National ITS architecture

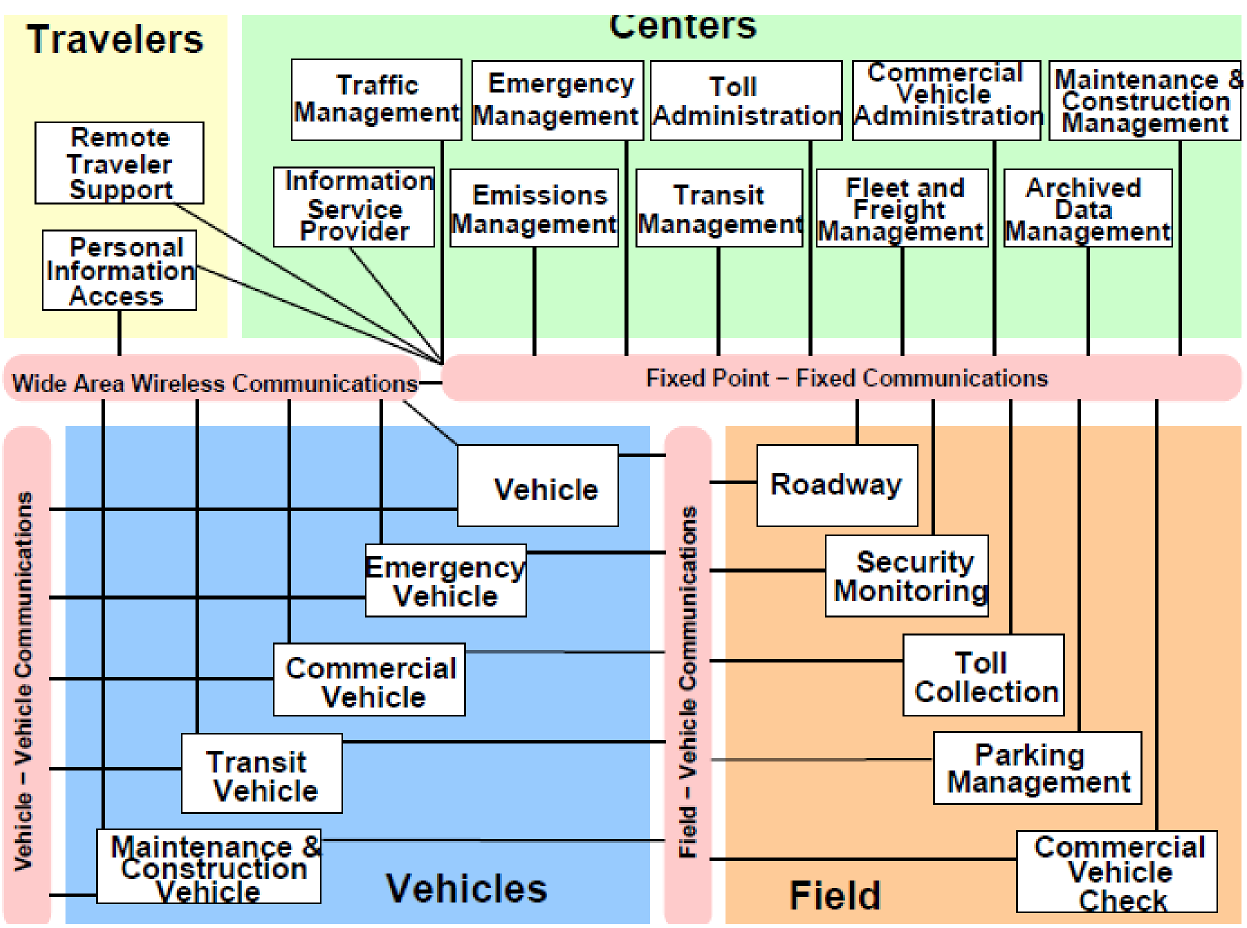
This is developed by US Department of Transportation to provide guidance and co-ordinate all regions in deploying ITS. It documents all information available and keep updating continuously. The national architecture contains the following components:

User services and their requirements

A number of functions are needed to accomplish the user services. These functional statements are called user services requirements. For all the user services the requirements have been specified. If any new function is added, new requirements are to be defined. Table. 48:1 shows an illustration of user service requirements for traffic control user service.

Logical architecture

To accomplish user service requirements many functions or processes are needed. The logical architecture defines a set of functions (or processes) and information flows (or data flows) that respond to the user service requirements. It describes the lower end interaction of different components of ITS. Processes and data flows are grouped to form particular functions. These are represented graphically by data flow diagrams (DFDs).



Vehicle group consists of five different types of vehicles. The traveler group represents different ways a traveler can access information on the status of the transportation system.

There are four different types of communication systems.

1. Fixed point to fixed point
2. Wide area wireless
3. Vehicle - vehicle communication
4. Field - vehicle communication

Through the communication systems all the subsystems are interconnected and transfer the required data.

ITS Planning

ITS planning is to integrate ITS into the transportation planning process.

Transportation planning and ITS:

Transportation planning helps in shaping a well balanced transportation system that can meet future demands. Transportation planning is an iterative process which includes problem identification, solution generation, analysis, evaluation and implementation. This can be integrated with ITS using computers, communication systems and software. As planning is normally made for long period, installing ITS facilities needs to be updated and one should ensure that the equipments and technologies are compatible for future improvement and expansion. The steps in traditional transportation planning are as follows:

1. Establish goals and objectives
2. Inventory existing conditions
3. Analyze existing conditions
4. Long range/ short range element
5. Forecast land use, population/employment
6. Forecast future travel/trips
7. Develop and evaluate alternative transportation plans
8. Prepare recommended plans and programs

ITS transportation planning process differs from the traditional transportation planning process. ITS has the unique capability to integrate different modes of transportation such as public auto, transit, and infra-structural elements through communications and control. The multi-modal integration potential provides a great opportunity for planning across modes. The comparison between ITS approach and conventional approach for solving various transportation problems.

INTEGRATING ITS INTO TRANSPORTATION PLANNING

Integrating ITS into transportation planning process require overcoming some obstacles and some changes in the business practices of many institutions. The major challenges in main streaming ITS into everyday operations of transportation agencies are:

• Institutional coordination and cooperation for sharing information and data

• Technical compatibility among ITS projects

• Human resource needs and training

• Financial constraints and opportunities to involve the private sector

Most public agencies are aware of the challenges in mainstreaming ITS into transportation planning process where ITS projects are part of traditional transportation programs on local or state level to achieve the best output from transportation investments.

ITS STANDARDS AND THEIR NEEDS

ITS STANDARDS help in generalizing any system. Also they bring homogeneity in the design. The standards help the non-transportation designers to adhere to some guidelines so that the system is sound technically.

Need of ITS standards

The need of ITS standards can be explained by five aspects:

• Product behavior.

• Interface.

• Performance.

• Co-ordination and interaction.

• Benefits to vendors, manufacturers and government.

CLASSIFICATION OF STANDARDS:

Just like ITS services are classified into user services the standard are to be classified in some five groups depending upon the interface it is made for. These classifications are termed as application areas. The various application area in ITS standards are:

• Center - roadside interface

• Center - center interface

• Center - vehicle interface

• Roadside - vehicle interface

• Roadside - roadside interface

Each of the class has some sub classes or sub-groups. For each sub-group some set of standards are to be used. Each sub-group may have more than one standard to follow. This takes care for the standard to be effective in all aspects.

Center - roadside interface :

Standards are made for the interface that exists between a center device and a roadside device. These are standards for communications between transportation management center and roadway equipment. Majority of the ITS services can be grouped under this. Various fields included are:

• Data collection and monitoring

• Dynamic message system

• Ramp metering

• Traffic signal

• Vehicle sensors

Center - vehicle interfaces:

It provides standards for communication between management center and vehicle. The number of application area in this interface may be less but they assume high importance in ITS services. There effective implementation helps in overall effective use of ITS. Fields included are:

• Mayday

• Transit vehicle communications

Roadside - vehicle interfaces:

This interface provides standards for wireless communication between roadside and vehicles. These are implemented to increase the service of any system and their by increasing its quality. Communication takes place between a vehicle and roadside equipment by automatic means. Fields included are:

•Toll/fee collection

•Signal priority

Roadside - roadside interfaces:

This area involves standards for communications between roadside and railroad wayside equipment. The most important of it is the interaction between the road and rail equipment.

ITS Evaluation

Just like testing is done for standards the whole ITS system is also needed to be evaluated in stages. It helps in judging any project and its deployment. It minimizes the risk of project failure. It helps in identification of current performance of system.

Types of evaluation

The various types of evaluation stages are:

- Planning level evaluation
- Deployment tracking
- Impact assessment
- RP and SP survey

Planning level evaluation

Evaluation is done before the project is implemented. During the planning stage this type of evaluation can be done. Previous data can be used for doing this. Two methods of this are:

- Benefit cost analysis- the benefits of the project need to be evaluated. The cost of the project is also to be found out. Then depending upon the ratio the evaluation is done.
- Relative ranking- it is a weight based method. Weight given to criteria and the value of each alternative is calculated.

S = _K × V (49.1)

Where, S is the value of alternative, V is the value of one criterion, and K is the weight of that criterion the value of that criteria is denoted by V . Study is to be conducted to calculate the value of the criteria. K denotes the importance of that criteria to the alternative. It is a global entity and does not change with the value of the criteria. For example, consider a case of providing thesignal priority system on a certain link. For evaluating this system an important criteria is thetravel time on a corridor. The value of the travel time will be the V value. Also the weightageto this parameter will be K.

Deployment tracking:

This evaluation is done when the project is being implemented. It gives the idea regarding the difference in the goals and actual work undertaken. We can determine the current progress rate of the work. The future directions needed to to be taken can also be assessed. Effective way of knowing this is the amount of data transfer between various agencies.

Impact assessment:

After an ITS system is deployed it is allowed to collect data over a period of time. The data collected is regarding the parameters from which assessment can be done. The criteria and the measure of effectiveness is mentioned in table. 49:1.

ITS Evaluation tools

Some tools are used which help in evaluation of the ITS technologies. They are just the means of evaluation. The basic principle of evaluation remains the same. It can be done in 2 ways.

Traffic simulation models

This is a model based technique. In this method, models such as 'INTEGRATION', 'DYNASMART', 'DYNAMIT' are used for evaluation. It is a cost effective way of analysis.

Performance Criteria	Measure of Effectiveness
Safety	Crashes Injuries Fatalities
Travel time	Travel time/delays for selected O-D survey Network travel time
Throughput	Vehicles / persons using the facility
Customer satisfaction	Ratings of travel experience
Air Quality	CO NO_2 VOC HC Ozone
Fuel consumption	Reduction or not

In these models simulation is done considering the future ITS installment in the facility. The facility is reproduced in the software. The future changes to be made in the facility are added. Then it is simulated to show the desired results in terms of some traffic parameters. Also simulation is done without the introduction of the new facility. The parameters are again calculated. These two analyses give the difference in the facility that may arise in the facility. This gives instant evaluation of the facility of ITS. Also it is cost effective as less personnel are required and the data collection is not a major issue. Evaluation can be done before the implementation of any facility. Thus cost savings in selection of alternative facilities is also observed. If the present technology used is not found satisfactory then some improved technology can be procured to fulfill our requirements.

Smart car:

As mentioned earlier the car is equipped with all the new electronic gadgets. It helps the user to use service efficiently. Some of the features of SMART CAR are:

• GPS and on-board communications

• Anti-collision sensors

(AIDE) projectries

To maximize the efficiency and safety of advanced driver assistance systems, while minimizing the workload and distraction imposed by in-vehicle information systems. Smart cars present promising potentials to assist drivers in improving their situational awareness and reducing errors. With cameras monitoring the driver's gaze and activity, smart cars attempt to keep the driver's attention on the road ahead. Physiological sensors can detect whether the driver is in good condition. The actuators will execute specified control on the car without the driver's commands. The smart car will adopt active measures such as stopping the car in case that the driver is unable to act properly, or applying passive protection to reduce possible harm in abrupt accidents, for example, popping up airbags.

Vehicle to infrastructure communications:

These involve advanced vehicle to infrastructure interface. The communication takes place between a vehicular device and a infrastructure equipment. It is an improvement over I2I services. Large communication is possible with this type of communication. Some examples of V2I communication are:

• Blind merge warning

• Curve speed warning

- Weather warning
- Intelligent on-ramp metering
- E call

Vehicle to vehicle communications:

Each vehicle communicates with other vehicles and assess the required data. It is the most advanced technique implemented in ITS. It requires very less communication with the center or infrastructure. All vehicles will communicate with each other and decisions will be made by the vehicle device only. For ex, the ramp meter will work all by itself and no infrastructure device will be required. Some real time services cannot be provided by infrastructure. In these cases such type of communication will be helpful

- Approaching vehicle warning
- Blind spot warning
- Co-operative cruise control
- Collision warning
- Lane change assistant