DEPARTMENT : CIVIL ENGINEERING

YEAR & SEM : IV B.TECH I SEM

SUBJECT : TRANSPORTATION ENGINEERING – II

B. Tech IV-I Sem. (C.E) **L T P C**
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15A01702 **TRANSPORTATION ENGINEERING – II**

Course *Objective:*
This subject deals with different components of Transportation Engineering like Railway, Airport Engineering, Ports & harbours. Sound knowledge can be acquired on components of airports, railways, docks and harbours after completion of course

Unit – I:

Railway Engineering:

Introduction – Permanent Way Components – Cross Section Of Permanent Way – Functions And Requirements Of Rails, Sleepers And Ballast – Types Of Gauges – Creep Of Rails – Theories Related To Creep – Coning Of Wheels – Adzing Of Sleepers – Rail Fastenings.

Unit – II:

Geometric Design Of Railway Track:

Gradients – Grade Compensation – Cant And Negative Super Elevation – Cant Deficiency – Degree Of Curves – Safe Speed On Railway Track – Points And Crossings – Layout And Functioning Of Left Hand Turn Out And Right Hand Turn Outs – Station Yards – Signaling And Interlocking.

Unit –III:

Airport Engineering:

Airport Site Selection – Factors Affecting Site Selection And Surveys- Runway Orientation – Wind Rose Diagram – Basic Runway Length – Correction For Runway Length – Terminal Area – Layout And Functions – Concepts Of Terminal Building – Simple Building , Linear Concept, Pier Concept And Satellite Concept – Typical Layouts

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Unit – IV:

Geometric Design Of Runways And Taxiways:

Aircraft Characteristics – Influence Of Characteristics On Airport Planning And Design – Geometric Design Elements Of Runway – Standards And Specifications As Per - Functions Of Taxiways – Taxiway Geometric Design – Geometric Elements And
Standard Specifications – Runway And Taxiway Lighting

Unit – V:

Ports and Harbours:

Requirements Of Ports And Harbours – Types Of Ports – Classification Of Harbours – Docks And Types Of Docks – Dry Docks, Wharves And Jetties – Breakwaters: Layouts Of Different Types Of Harbours And Docks – Dredging Operations – Navigation Aids.

Text Books:

1. A Text Book of Railway Engineering-S.C.Saxena and S.Arora, Dhanpatrai and Sons, New Delhi.
2. Transportation Engineering:Railways,Airports,Docks and Harbours, Bridges and Tunnels, by C.Venkataramaiah, Universities Press, Hyderabad (2016)
3. Airport Planning and Design- S.K. Khanna and M.G Arora, Nemchand Bros.

References:

1. Highway, Railway, Airport and Harbour Engineering – K.P. Subramanian, Scitech pubilishers.
2. Harbour, Dock and Tunnel Engineering – R. Srinivasan, Charotar Publishing House Pvt. Limited, 2009
3. A Text book of Transportation Engineering – S.P.Chandola – S.Chand & Co. Ltd. – (2001).
4. Dock and Harbour Engineering – Hasmukh P Oza, Gutam H Oza, Chartor Publishers pvt ltd.

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).

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.

DIFFERENT GAUGES ON 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. In 1871, the Government of India wanted to construct cheaper railways for the development of the country and 1000 mm metre gauge was introduced. In due course of time, two more gauges of widths 762 mm (2 '6 ") and 610 mm (2 '0 ") were introduced for thinly populated areas, mountain railways, and other miscellaneous purposes.

Broad Gauge: -

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

Suitability: -

Broad gauge is suitable under the following Conditions:- (i) When sufficient funds are available for the railway project. (ii) When the prospects of revenue are very bright. This gauge is, therefore, used for tracks in plain areas which are densely populated i.e. for routes of maximum traffic, intensities and at places which are centers of industry and commerce.

2. Metre Gauge: -

When the clear horizontal distance between the inner faces of two parallel rails forming a track is 1000mm, the gauge is known as Metre Gauge (M.G) The other countries using Metre gauge are France, Switzerland, Argentine, etc. 40% of India_s railway tracks have been laid to this gauge. Suitability:- Metre Gauge is suitable under the following conditions:- (i) When the funds available for the railway project are inadequate. (ii) When the prospects of revenue are not very bright. This gauge is, therefore, used for tracks in under-developed areas and in interior areas, where traffic intensity is small and prospects for future development are not very bright.

3. Narrow Gauge:-

When the clear horizontal distance between the inner faces of two parallel rails forming a track is either 762mm or 610mm, the gauge is known as Narrow gauge (N.G) The other countries using narrow gauge are Britain, South Africa, etc. 10% of India_s railway tracks have been laid to this gauge. Suitability: - Narrow gauge is suitable under the following conditions:- (i) When the construction of a track with wider gauge is prohibited due to the provision of sharp curves, steep gradients, narrow bridges and tunnels etc. (ii) When the prospects of revenue are not very bright. This gauge is, therefore, used in hilly and very thinly populated areas. The feeder gauge is commonly used for feeding raw materials to big government manufacturing concerns as well as to private factories such as steel plants, oil refineries, sugar factories, etc.

CHOICE OF GAUGE

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

Cost considerations

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

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

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

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

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

Traffic considerations

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

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

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

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

UNIT 3

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 labour and staff, particularly during strikes

Inefficient use of rolling stock

As wagons have to move empty in the direction of the trans-shipment point, they are not fully utilized. Similarly, idle wagons or engines of one gauge cannot be moved on another gauge. Hindrance to fast movement of goods and passenger traffic Due to change in the gauge, traffic cannot move fast which becomes a major problem particularly during emergencies such as war, floods, and accidents.

Additional facilities at stations and yards

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

Difficulties in balanced economic growth

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

Difficulties in future gauge conversion projects

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

UNI-GAUGE POLICY OF INDIAN RAILWAYS

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

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

The uni-gauge system will be highly beneficial to rail users, the railway administration, as well as to the nation. Following are the advantages of a uni-system: No transport bottlenecks There will be no transport bottlenecks after a uniform gauge is adopted and this will lead to improved operational efficiency resulting in fast movement of goods and passengers. No trans-shipment hazards.

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

Provisions of alternate routes

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

Better turnaround

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

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

Balanced economic growth The areas currently served by the MG will receive an additional fillip, leading to the removal of regional disparities and balancing economic growth. No multiple tracking works

The uni-gauge project will eliminate the need for certain traffic facilities and multiple tracking works, which will offset the cost of gauge conversions to a certain extent

Better transport infrastructure Some of the areas served by the MG have the potential of becoming highly industrialized; skilled manpower is also available

The uni-gauge policy will help in providing these areas a better transportation infrastructure.

Boosting investor's confidence With the liberalization of the economic policy, the uni-gauge projects of Indian Railways have come to play a significant role. 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.

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.

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 or 2-8-4 have been joined together so as to haul the traffic or the passengers or the freight. 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.

Coning wheels has the following disadvantages:

1. In order to minimize the above below disadvantages the tilting of rails is done. i.e. the rails are not laid flat but tilted inwards by using inclined base plates sloped at 1 in 20 which is also the slope of coned surface of wheels.

2. The pressure of the horizontal component near the inner edge of the rail has a tendency to wear the rail quickly.

3. The horizontal components tend to turn the rail outwardly and hence the gauge is widened sometimes.

4. If no base plates are provided, sleepers under the outer edge of the rails are damaged.

5. In order to minimize the above mentioned disadvantages the tilting of rails is done. i.e. the rails are not laid flat but tilted inwards by using inclined base plates sloped at 1 in 20 which is also the slope of coned surface of wheels.

Advantages of Tilting of Rails

1. It maintains the gauge properly.

2. The wear at the head of rail is uniform.

3. It increases the life of sleepers and the rails

VARIOUS RESISTANCES AND THEIR EVALUATION

Introduction

Various forces offer resistance to the movement of a train on the track. These resistances may be the result of movement of the various parts of the locomotives as well as the friction between them, the irregularities in the track profile, or the atmospheric resistance to a train moving at great speed. The tractive power of a locomotive should be adequate enough to overcome these resistances and haul the train at a specified speed.

RESISTANCE DUE TO FRICTION

Resistance due to friction is the resistance offered by the friction between the internal parts of locomotives and wagons as well as between the metal surface of the rail and the wheel to a train moving at a constant speed. This resistance is independent of speed and can be further broken down into the following parts.

Journal friction

This is dependent on the type of bearing, the lubricant used, the temperature and condition of the bearing, etc. In the case of roll bearings, it varies from 0.5 to 1.0 kg per tonne.

Internal resistance

This resistance is consequential to the movement of the various parts of the locomotive and wagons.

Rolling resistance

This occurs due to rail-wheel interaction on account of the movement of steel wheels on a steel rail. The total frictional resistance is given by the empirical formula

$$R1 = 0.0016\ W$$

Where R1 is the frictional resistance independent of speed and W is the weight of the train in tonnes.

RESISTANCE DUE TO WAVE ACTION

When a train moves with speed a certain resistance develops due to the wave action in the rail. Similarly, track irregularities such as longitudinal unevenness and differences in cross levels also offer resistance to a moving train. Such resistances are different for different speeds. There is no method for the precise calculation of these resistances but the following formula has been evolved based on experience: R2 = 0.00008 WV Where R2 is the resistance (in tonnes) due to wave action and track irregularities on account of the speed of the train, W is the weight of the train in tonnes, and V is the speed of the train in kmph.

RESISTANCE DUE TO WIND

When a vehicle moves with speed, a certain resistance develops, as the vehicle has to move forward against the wind. Wind resistance consists of side resistance, head resistance, and tail resistance, but its exact magnitude depends upon the size and shape of the vehicle, its speed, and the wind direction as well as its velocity. Wind resistance depends upon the exposed area of the vehicle and the velocity and direction of the wind. In Fig. below, V is the velocity of wind at an angle θ. The horizontal component of wind, V cosθ, opposes the movement of the train. Wind normally exerts maximum pressure when it acts at an angle of 60° to the direction of movement of the train. Wind resistance can be obtained by the following formula: R3 =0.000017AV2 Where A is the exposed area of vehicle (m2) and V is the velocity of wind (kmph).

R3 = 0.0000006 W V2

Where R3 is the wind resistance in tonnes,

Vis the velocity of the train in km per hour, and

W is the weight of the train in tonnes.

RESISTANCE DUE TO GRADIENT

When a train moves on a rising gradient, it requires extra effort in order to move against gravity as shown in Fig. below. Assuming that a wheel of weight W is moving on a rising gradient OA, the following forces act on the wheel.

(a) Weight of the wheel (W), which acts downward

(b) Normal pressure N on the rail, which acts perpendicular to OA

(c) Resistance due to rising gradient (R4), which acts parallel to OA

These three forces meet at a common point Q and the triangle QCD can be taken as a triangle of forces. It can also be geometrically proved that the two triangles QCD and AOB are similar.

RESISTANCE DUE TO CURVATURE

When a train negotiates a horizontal curve, extra effort is required to overcome the resistance offered by the curvature of the track. Curve resistance is caused basically because of the following reasons

(a) The vehicle cannot adapt itself to a curved track because of its rigid wheel base. This is why the frame takes up a tangential position as the vehicle tries to move in a longitudinal direction along the curve as shown in Fig. below. On account of this, the flange of the outer wheel of the leading axle rubs against the inner face of the outer rail, giving rise to resistance to the movement of the train.

(b) Curve resistance can sometimes be the result of longitudinal slip, which causes the forward motion of the wheels on a curved track. The outer wheel flange of the trailing axle remains clear and tends to derail. The position worsens further if the wheel base is long and the curve is sharp.

(c) Curve resistance is caused when a transverse slip occurs, which increases the friction between the wheel flanges and the rails.

(d) Poor track maintenance, particularly bad alignment, worn-out rails, and improper levels, also increase resistance.

(e) Inadequate superelevation increases the pressure on the outer rail and, similarly, excess superelevation puts greater pressure on the inner rails, and this also contributes to an increase in resistance.

The value of curve resistance can be determined by the following equation:

$$\text{Curve resistance} = C \times (FG/R)$$

where F is the force of sliding friction,

G is the gauge of the track,

R is the mean radius of the curve, and

C is the constant, which is dependent on various factors.

This equation indicates that

(a) curve resistance increases with increase in gauge width and

(b) resistance is inversely proportional to the radius, i.e., it increases with an increase in the degree of the curve.

Empirical formulae have been worked out for curve resistance, which are as follows:

Curve resistance for BG (R5) = 0.0004 WD

Curve resistance for MG (R5) = 0.0003 WD

Curve resistance for NG (R5) = 0.0002 WD

Compensated gradient for curvature

Curve resistance is quite often compensated or offset by a reduction in the gradient. In this way, the effect of curve resistance is translated in terms of resistance due to gradient. The compensation is 0.04 per cent on BG, 0.03 per cent on MG, and 0.02 per cent on NG lines for every 1° of the curve. This will be clear through the solved example given below.

RESISTANCE DUE TO STARTING AND ACCELERATING

Trains face these resistances at stations when they start, accelerate, and decelerate. The values of these resistances are as follows:

Resistance on starting, R6 = 0.15 W1 + 0.005 W2

Resistance due to acceleration, R7 = 0.028 aW

where W 1 is the weight of the locomotive in tonnes,

W2 is the weight of the trailing vehicles in tonnes,

W is the total weight of the locomotive and vehicle in tonnes. i.e. W1 + W2, and a is the acceleration, which can be calculated by finding the increase in velocity per unit time, i.e., (V2 – V1)/t, where V2 is the final velocity. V1 is the initial velocity, and t is the time taken.

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HAULING CAPACITY AND TRACTIVE EFFORT

Introduction

The tractive effort of a locomotive is the force that the locomotive can generate for hauling the load. The tractive effort of a locomotive should be enough for it to haul a train at the maximum permissible speed. There are various tractive effort. Curves available for different locomotives for different speeds, which enable the computation of the value of tractive effort. Tractive effort is generally equal to or a little greater than the hauling capacity of the locomotive. If the tractive effort:-much greater than what is required to haul the train, the wheels of the locomotive may slip. A rough assessment of the tractive effort of different types of locomotive.-provided in the following sections.

Steam Locomotive

The tractive effort of a steam locomotive can be calculated by equating the total power generated by the steam engine to the work done by the driving wheels.

Assume P to be the difference in steam pressure between the two sides of the infer, A the area of the piston of the engine, a' the diameter of the piston of the ;iF, L the length of the stroke of the engine, D the diameter of the wheel of locomotive, and Te the mean tractate effort of the locomotive. Work done by /o-cylinder steam engine

= 2 X difference in steam pressure X area of the piston x 2 X length of the stroke

= 2P x A x 2L

= 2P x (πd2/4)x 2L

= πd2L

work done in one revolution of the driving wheel of the locomotive: = tractive effort x circumference of the wheel = Tc π D
squaring above two equations, πd2L = Tc π D Tc = d2L/D
is clear from above Equation that tractive effort increases with an increase in n pressure difference and the diameter and length of the piston, but decreases an increase in the diameter of the driving wheel of the locomotive.

Diesel Locomotive

Tractive effort of a diesel-elective locomotive can be assessed by the following empirical formula.

$$Te = (308 \times RHP) / V$$

where Te is the tractive effort of a diesel-electric locomotive,

RHP is the rated horsepower of the engine, and

V is the velocity in km per hour.

Electric Locomotive

Tractive effort of an electric locomotive varies inversely with the power of speed. The empirical formulae for calculating the approximate value of tractive effort are as follows

For an dc electric locomotive: Te = a / V3

For an ac electric locomotive: Te = a / V5

where a is a constant depending upon the various characteristics of the locomotive.

.HAULING POWER OF A LOCOMOTIVE

Hauling power of a locomotive depends upon the weight exerted on the driving s and the friction between the driving wheel and the rail. The coefficient of friction depends upon the speed of the locomotive and the condition of the rail surface. The higher the speed of the locomotive, the lower will be the coefficient of friction, which is about 0.1 for high speeds and 0.2 for low speeds. The condition of the rail surface, whether wet or dry, smooth or rough, etc., also plays an important role in deciding the value of the coefficient of function. If the surface is very smooth, the coefficient of friction will be very low.

Hauling power = number of pairs of driving wheels x weight exerted on each driving axle

X coefficient of friction

Thus, for a locomotive with three pairs of driving wheels, an axle load of 20 tonnes, and a coefficient of friction equal to 0.2, the hauling power will be equal to 3 x 20 x 0.2 tonne, i.e., 12 tonnes.

Example :

Calculate the maximum permissible load that a BG locomotive with three pairs of driving wheels bearing an axle load of 22 tonnes each can pull on a straight level track at a speed of 80 km/h. Also calculate the reduction in speed if the train has to run on a rising gradient of 1 in 200. What would be the further reduction in speed if the train has to negotiate a 4° curve on the rising gradient? Assume the coefficient of friction to be 0.2.

RAIL

Introduction

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. Standard rail sections, their specifications, and various types of rail defects are discussed in this section.

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 tyre and a metalled 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

DOUBLE HEADED RAIL

BULL HEADED RAIL

FLAT-FOOTED RAIL

REQUIREMENTS OF AN IDEAL RAIL SECTION

The requirements of an ideal rail section are as follows:

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

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

(c) A rail primarily consists of a head, a web, and a foot, and there should be an economical and balanced distribution of metal in its various components so that each of them can fulfill its requirements properly.

The requirements, as well as the main considerations, for the design of these rail components are as follows:

Head

The head of the rail should have adequate depth to allow for vertical wear. The rail head should also be sufficiently wide so that not only is a wider running surface available, but also the rail has the desired lateral stiffness. Web The web should be sufficiently thick so as to withstand the stresses arising due to the loads bore by it, after allowing for normal corrosion.

Foot

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

Fishing angles

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

Height of the rail

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

Weight of rails

Though the weights of a rail and its section depend upon various considerations, the heaviest axle load that the rail has to carrv olavs the most important role.

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.

UNIT 2

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. The characteristics of these sleepers and their suitability with respect to load conditions are described in this section.

FUNCTIONS AND REQUIREMENTS 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

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

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

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

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

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

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

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

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

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

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 metres 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 number of sleepers in a track can also be specified by indicating the number of sleepers per kilometre of the track, for example, 1540 sleepers/km. This specification becomes more relevant particularly in cases where rails are welded and the length of the rail does not have much bearing on the number of sleepers required. This system of specifying the number of sleepers per kilometre exists in many foreign countries and is now being adopted on Indian Railways as well.

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 The sleepers mostly used on Indian Railways are

(i) wooden sleepers,

(ii) cast iron (CI) sleepers,

(iii) steel sleepers, and

(iv) Concrete sleepers.

BALLAST AND BALLAST REQUIREMENTS

Introduction

Ballast is a layer of broken stones, gravel, rnoorum, 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. Different types of ballast materials and their specifications are discussed in this chapter.

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 ir.d steel trough sleepers in areas where traffic densitv is verv 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. The comparative advantages, disadvantages, and suitability of different types of ballast are given in Table below.

SIZES OF BALLAST

Previously, 50 mm (2") ballasts were specified for flat-bottom sleepers such as concrete and wooden sleepers, and 40 mm (1.5") ballasts for metal sleepers such as CST-9 and trough sleepers. Now, to ensure uniformity, 50 mm (2") ballasts have been adopted universally for all types of sleepers.

Points and crossings are subjected to heavy blows of moving loads and hence are maintained to a higher degree of precision. A small sized, 25 mm (1") ballast: s. therefore, preferable because of its fineness for slight adjustments, better compaction, and increased frictional area of the ballast. For uniformity sake, the Indian Railways has adopted the same standard size of ballast for the main line as well as for points and crossings.

This standard size of ballast should be as per Indian Railways specification. The specification provides grading of ballast from 25 mm to 65 mm, maximum quantity of ballast being in the range of 40 mm to 50 mm size.

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.

DESIGN OF BALLAST SECTION

The design of the ballast section includes the determination of the depth of the ballast cushion below the sleeper and its profile. These aspects are discussed as follows. 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. Though the lines of equal pressure are in the shape of a bulb as discussed in, yet for simplicity, the dispersion of load can be assumed to be roughly 45° to the vertical. In order to ensure that the load is transferred evenly on the formation, the depth of the ballast should be such that the dispersion lines do not overlap each other. 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

Subgrade is the naturally occuring 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 balla

(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 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.

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.

Permanent way is the generic term for the track (rails, sleepers and ballast) on which railway trains run. Although the configuration of the track today would be recognized by engineers of the 19th century, it has developed significantly over the years as technological improvements became available, and as the demands of train operation increased.

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 permanet way should have the following characteristics:

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

REQUIREMENTS OF AN IDEAL PERMANENT WAY

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

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

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

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

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

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

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

vii. The tractive resistance of the track should be minimum

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

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

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

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

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

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

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

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

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

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

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

WEAR AND FAILURE IN RAILS

RAIL WEAR

Due to the passage of moving loads and friction between the rail and the wheel, the rail head gets worn out in the course of service. The impact of moving loads, the effect of the forces of acceleration, deceleration, and braking of wheels, the abrasion due to rail-wheel interaction, the effects of weather conditions such as changes in temperature, snow, and rains, the presence of materials such as sand, the standard of maintenance of the track, and such allied factors cause considerable wear and tear of the vertical and lateral planes of the rail head. Lateral wear occurs more on curves because of the lateral thrust exerted on the outer rail by centrifugal force. A lot of the metal of the rail head gets worn out, causing the weight of the rail to decrease. This loss of weight of the rail section should not be such that the stresses exceed their permissible values. When such a stage is reached, rail renewal is called for. In addition, the rail head should not wear to such an extent that there is the possibility of a worn flange of the wheel hitting the fish plate.

Types of Wear on Rails

A rail may face wear and tear in the following positions:

(a) On top of the rail head (vertical wear)

(b) On the sides of the rail head (lateral wear)

(c) On the ends of the rail (battering of rail ends) Wear is more prominent at some special locations of the track.

These locations are normally the following:

(a) On sharp curves, due to centrifugal forces

(b) On steep gradients, due to the extra force applied by the engine

(c) On approaches to railway stations, possibly due to acceleration and deceleration

(d) In tunnels and coastal areas, due to humidity and weather effects

Measurement of Wear Wear on rails can be measured using any of the following methods:

(a) By weighing the rail

(b) By profiling the rail section with the help of lead strips

(c) By profiling the rail section with the help of needles

Methods to Reduce Wear Based on field experience,

some of the methods adopted to reduce vertical wear and lateral wear on straight paths and curves are as follows-

(a) Better maintenance of the track to ensure good packing as well as proper alignment and use of the correct gauge

(b) Reduction in the number of joints by welding

(c) Use of heavier and higher UTS rails, which are more wear resistant

(d) Use of bearing plates and proper adzing in case of wooden sleepers

(e) Lubricating the gauge face of the outer rail in case of curves

(f) Providing check rails in the case of sharp curves

(g) Interchanging the inner and outer rails

(h) Changing the rail by carrying out track renewal

Rail End Batter

The hammering action of moving loads on rail joints batters the rail ends in due course of time. Due to the impact of the blows, the contact surfaces between the rails and sleepers also get worn out, the ballast at places where the sleepers are joined gets shaken up, the fish bolts become loose, and all these factors further worsen the situation, thereby increasing rail end batter. Rail end batter is measured as the difference between the height of the rail at the end and at a point 30 cm away from the end. If the batter is up to 2 mm, it is classified 'average', and if it is between 2 and 3 mm, it is classified as 'severe'. When rail end batter is excessive and the rail is otherwise alright, the ends can be cropped and the rail reused.

OTHER DEFECTS IN RAILS

Rail wear and battering of rail ends are the two major defects in rails. However some other types of defects may also develop in a rail and necessitate its removal in extreme cases. These are as follows:

Hogging of rails

Rail ends get hogged due to poor maintenance of the rail joint, yielding format, loose and faulty fastenings, and other such reasons. Hogging of rails causes the quality of the track to deteriorate. This defect can be remedied by measured she packing.

Scabbing of rails

The scabbing of rails occurs due to the falling of patches or chunks of metal from the rail table. Scabbing is generally seen in the shape of an elliptical depression; whose surface reveals a progressive fracture with numerous cracks around it.

Wheel burns

Wheel burns are caused by the slipping of the driving wheel of locomotives on the rail surface. As a consequence, extra heat is generated and the surface of the rail gets affected, resulting n a depression on the rail table. Wheel burns are generally noticed on steep gradients or where there are heavy incidences of braking or near water columns.

Shelling and black spots

Shelling is the progressive horizontal separation of metal that occurs on the gauge side, generally at the upper gauge corner. It is primarily caused by heavy bearing pressure on a small area of contact, which produces heavy internal shear stress.

Corrugation of rail:

Corrugation consists of minute depressions on the surface of rails, varying in shape and size and occurring it irregular intervals. The exact cause of corrugation is not yet known, though many theories have been put forward. The factors which help in the formation of rail corrugation, however, are briefly enumerated here,

a) Metallurgy and age of rails

(i) High nitrogen content of the rails

(ii) Effect of oscillation at the time of rolling and straightening of rails

(b) Physical and environment conditions of track

(i) Steep gradients

(ii) Yielding formation

(iii) Long tunnels

(iv) Electrified sections

(c) Train operations

(i) High speeds and high axle loads

(ii) Starting locations of trains

(iii) Locations where brakes are applied to stop the train

(d) Atmospheric effects

(i) High moisture content in the air particularly in coastal areas

(ii) Presence of sand.

RAIL FAILURE

A rail is said to have failed if it is considered necessary to remove it immediately from the track on account of the defects noticed on it. The majority of rail failures originate from the fatigue cracks caused due to alternating stresses created in the rail section on account of the passage of loads. A rail section is normally designed to take a certain minimum GMT of traffic, but sometimes due to reasons such as an inherent defect in the metal, the section becomes weak at a particular point and leads to premature failure of the rail.

(b) Physical and environment conditions of track

(i) Steep gradients

(ii) Yielding formation

(iii) Long tunnels

(iv) Electrified sections

(c) Train operations

(i) High speeds and high axle loads

(ii) Starting locations of trains

(iii) Locations where brakes are applied to stop the train

(d) Atmospheric effects

(i) High moisture content in the air particularly in coastal areas

(ii) Presence of sand The corrugation of rails is quite an undesirable feature.

When vehicles pass over corrugated rails, a roaring sound is produced, possibly due to the locking of air in the corrugation. This phenomenon is sometimes called 'Roaring of rails'. This unpleasant and excessive noise causes great inconvenience to the passengers. Corrugation also results in the rapid oscillation of rails, which in turn loosens the keys, causes excessive wear to fittings, and disturbs the packing.

Causes of Rail Failures

The main causes of failure of rails are as follows:

Inherent defects in the rail

These are due to manufacturing defects in the rail, such as faulty chemical composition, harmful segregation, piping, seams, laps, and guide marks. Defects due to fault of the rolling stock and abnormal traffic effects Flat soots in tvres, engine burns, skidding of wheels, severe braking, etc.

Excessive corrosion of rails

This generally takes place due to weather conditions, the presence of corrosive salts such as chlorides and constant exposure of the rails to moisture and humidity in locations near water columns, ashpits, tunnels, etc. Corrosion normally leads to the development of cracks in regions with a high concentration of stresses.

Badly maintained joints

Poor maintenance of joints such as improper packing of joint sleepers and loose fittings. Defects in welding of joints These defects arise either because of improper composition of the thermit weld metal or because of a defective welding technique. Improper maintenance of track Ineffective or careless maintenance of the track or delayed renewal of the track. Derailments The rails are damaged during derailment.

Classification of Rail Failures

The classification of rail failures on Indian Railways has been codified for easy processing of statistical data. The code is made up of two portions—the first portion consisting of three code letters and the second portion consisting of three or four code digits. First portion of the code

The three code letters make up the first portion and denote the following.

(i) Type of rail being used (O for plain rail and X for points and crossing rails)

(ii) Reasons for withdrawal of rail (F for fractured, C for cracked, and D for defective

(iii) Probable cause failure (S for fault of rolling stock, C for excessive corrosion, D for derailment, and O for others) Second portion of code

within fish plate limits and 2 for other portions on the rail),

(ii) Second digit indicate the position in the rail section from where the failure started (0 for unknown, 1 for within rail head, 2 for surface of rail head, 3 for web, and 4 for foot).

(iii) Third digit indicate the direction of crack or fracture (0 to 9).

(iv) Any other information about the fracture, where it is necessary to provide further subdivision. No specific system is recommended for this code. Metallurgical Investigation

(v) The following types of defective rails should normally be sent for metallurgical investigation,

(vi) Rails that have been removed from the track as a result of visual or ultrasonic detection

(vii) (ii) Rail failures falling in categories in which cracks or surface defects develop at specified locations

CREEP OF RAIL

Introduction

Creep is defined as the longitudinal movement of the rail with respect to the sleepers. Rails have a tendency to gradually move in the direction of dominant traffic. Creep is common to all railway tracks, but its magnitude varies considerably from place to place; the rail may move by several centimeters in a month at few places, while at other locations the movement may be almost negligible.

THEORIES FOR THE DEVELOPMENT OF CREEP

Various theories have been put forward to explain the phenomenon of creep and its causes, but none of them have proved to be satisfactory. The important theories are briefly discussed in the following subsections.

Wave Motion Theory

According to wave motion theory, wave motion is set up in the resilient track because of moving loads, causing a deflection in the rail under the load. The portion of the rail immediately under the wheel gets slightly depressed due to the wheel load. Therefore, the rails generally have a wavy formation.

Percussion Theory

According to percussion theory, creep is developed due to the impact of wheels at the rail end ahead of a joint. As the wheels of the moving train leave the trailing rail at the joint, the rail gets pushed forward causing it to move longitudinally in the direction of traffic, and that is how creep develops. Though the impact of a single wheel may be nominal, the continuous movement of several wheels passing over the joint pushes the facing or landing rail forward, thereby causing creep.

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 and trailing wagons 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.

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

• 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

EFFECTS OF CREEP

The following are the common effects of creep.

Sleepers out of square The sleepers move out of their position as a result of creep and become out of square. This in turn affects the gauge and alignment of the track, which finally results in unpleasant rides

Expansion in gaps get disturbed Due to creep, the expansion gaps widen at some places and close at others. This results in the joints getting jammed. Undue stresses are created in the fish plates and bolts, which affect the smooth working of the switch expansion joints in the case of long welded rails.

Distortion of points and crossings Due to excessive creep, it becomes difficult to maintain the correct gauge and alignment of the rails at points and crossings. **Difficulty in changing rails** If, due to operational reasons, it is required that the rail be changed, the same becomes difficult as the new rail is found to be either too short or too long because of creep.

Effect on interlocking The interlocking mechanism of the points and crossings pets disturbed bv creep. Possible buckling of track If the creep is excessive and there is negligence in the maintenance of the track, the possibility of buckling of the track cannot be ruled out.

Other effects There are other miscellaneous effects of creep such as breaking of bolts and kinks in the alignment, which occur in various situations.

MEASUREMENT OF CREEP

Creep can be measured with the help of a device called creep indicator. It consists of two creep posts, which are generally rail pieces that are driven at 1 km intervals on either side of the track. For the purpose of easy measurement, their top level is generally at the same level as the rail. Using a chisel, a mark is made at the side of the bottom flange of the rail on either side of the track. A fishing string is then stretched between the two creep posts and the distance between the chisel mark and the string is taken as the amount of creep. According to the prescribed stipulations, creep should be measured at intervals of about three months and noted in a prescribed register, which is to be maintained by the permanent way inspector (PWI). Creep in excess of 150 mm (6 in.) should not be permitted on any track and not more than six consecutive rails should be found jammed in a single-rail track at one location. There should be no creep in approaches to points and crossings.

ADJUSTMENT OF CREEP

When creep is in excess of 150 mm resulting in maintenance problems, the same should be adjusted by pulling the rails back. This work is carried out after the required engineering signals have been put up and the necessary caution orders given.

The various steps involved in the adjustment of creep are as follows:

(i) A careful survey of the expansion gaps and of the current position of rail joints is carried out.

(ii) The total creep that has been proposed to be adjusted and the correct expansion gap that is to be kept are decided in advance.

(iii) (iii) The fish plates at one end are loosened and those at the other end are removed. Sleeper fittings, i.e., spikes or keys, are also loosened or removed.

(iv) The rails are then pulled back one by one with the help of a rope attached to a hook.

The pulling back should be regulated in such a way that the rail joints remain central and suspended on the joint sleepers. The pulling back of rails is a slow process since only one rail is dealt with at a time and can be done only for short isolated lengths of a track. Normally, about 40-50 men are required per kilometre for adjusting creep. When creep is required to be adjusted for longer lengths, five rail lengths are tackled at a time. The procedure is almost the same as the preceding steps except that instead of pulling the rails with i rope, a blow is given to them using a cut rail piece of a length of about 5 m.

CREEP ADJUSTER

A creep adjuster is normally used when extensive work is involved. The creep adjuster is set at the centre of the length of the track, to be tackled, with the wide joints behind it and the jammed joints ahead of it.

The following steps are adopted while using a creep adjuster: (i) Expansion liners of the correct size are put in all the expansion gaps, (ii) All the keys on the side (with wide joints) of the creep adjuster are removed and all fish bolts loosened, (iii) The creep adjuster is then used to close up the gaps to the required extent by pushing the rails forward. A gap of a few inches is left between the rail ends opposite the adjuster, (iv) The corrected rails are then fastened with keys. After that, the rails on the other side of the adjuster are tackled, (v) The operation leaves some of the expansion gaps too wide which are tackled by the creep adjuster when it is set in the next position, (vi) The corrected rails are then fastened and the adjuster is shifted to the new position, (vii) The whole process is repeated again and again till the requisite attention has been paid to the entire length of the rail. In the end it may be necessary to use a rail with the correct size of closure (bigger or smaller) to complete the work.

RAIL JOINTS

Introduction

Although a rail joint has always been an integral part of the railway track, it is looked upon as a necessary evil because of the various problems that it presents. Earlier, rails were rolled in short lengths due to difficulties in rolling and the problem of transportation. With increase in temperature, rails expand and this expansion needs to be considered at the joints. It was, therefore, felt that the longer the rail, the larger the required expansion gap, and this too limited the length of the rail. A rail joint is thus an inevitable feature of railway tracks, even though it presents a lot of problems in the maintenance of the permanent way. This chapter discusses the various types of rail joints and their suitability on a railway track.

ILL EFFECTS OF A RAIL JOINT

A rail joint is the weakest link in the track. At a joint, there is a break in the continuity of the rail in both the horizontal and the vertical planes because of the presence of the expansion gap and imperfection in the levels of rail heads. A severe jolt is also experienced at the rail joint when the wheels of vehicles negotiate the expansion gap. This jolt loosens the ballast under the sleeper bed, making the maintenance of the joint difficult. The fittings at the joint also become loose, causing heavy wear and tear of the track material. Some of the problems associated with the rail joint are as follows.

Maintenance effort

Due to the impact of moving loads on the joint, the packing under the sleeper loosens and the geometry of the track gets distorted very quickly because of which the joint requires frequent attention. It is generally seen that about 30 per cent extra labour is required for maintenance of a joint.

Bonded main line 6-bolt rail joint on a segment of 76.9 kg/m rail. Note how bolts are oppositely oriented to prevent complete separation of the joint in the event of being struck by a wheel during a derailment.

Lifespan

The life of rails, sleepers, and fastenings gets adversely affected due to the extra stresses created by the impact of moving loads on the rail joint. The rail ends particularly get battered and hogged and chances of rail fracture at joints are considerably high due to fatigue stresses in the rail ends.

Noise effect

A lot of noise pollution is created due to rail joints, making rail travel uncomfortable.

Sabotage chances

Wherever there is a rail joint, there is a potential danger of the removal of fish plates and rails by miscreants and greater susceptibility to sabotage.

Impact on quality

The quality of the track suffers because of excessive wear and tear of track components and rolling stock caused by rail joints**.**

Fuel consumption

The presence of rail joints results in increased fuel consumption because of the extra effort required by the locomotive to haul the train over these joints.

REQUIREMENTS OF AN IDEAL RAIL JOINT

An ideal rail joint provides the same strength and stiffness as the parent rail. The characteristics of an ideal rail joint are briefly summarized here.

Holding the rail ends: An ideal rail joint should hold both the rail ends in their precise location in the horizontal as well as the vertical planes to provide as much continuity in the track as possible. This helps in avoiding wheel jumping or the deviation of the wheel from its normal path of movement.

Strength: An ideal rail joint should have the same strength and stiffness as the parent rails it joins.

Expansion gap: The joint should provide an adequate expansion gap for the free expansion and contraction of rails caused by changes in temperature

Flexibility It should provide flexibility for the easy replacement of rails, whenever required. Provision for

wear: It should provide for the wear of the rail ends, which is likely to occur under normal operating conditions.

Elasticity: It should provide adequate elasticity as well as resistance to longitudinal forces so as to ensure a trouble-free track.

Cost: The initial as well as maintenance costs of an ideal rail joint should be minimal.

TYPES OF RAIL JOINTS

The nomenclature of rail joints depends upon the position of the sleepers or the joints.

Classification According to Position of Sleepers Three types of rail joints come under this category.

Supported joint In this type of joint, the ends of the rails are supported directly on the sleeper. It was expected that supporting the joint would reduce the wear and tear of the rails, as there would be no cantilever action. In practice, however, the support tends to slightly raise the height of the rail ends. As such, the run on a supported joint is normally hard. There is also wear and tear of the sleeper supporting the joint and its maintenance presents quite a problem.

Suspended joint

In this type of joint, the ends of the rails are suspended between two sleepers and some portion of the rail is cantilevered at the joint. As a result of cantilever action, the packing under the sleepers of the joint becomes loose particularly due to the hammering action of the moving train loads. Suspended joints are the most common type of joints adopted by railway systems worldwide, including India

Bridge joints

The bridge joint is similar to the suspended joint except that the two sleepers on either side of a bridge joint are connected by means of a metal flat [Fig. (a)] or a corrugated plate known as a bridge plate [Fig. 16.3(b)]. This type of joint is generally not used on Indian Railways.

Staggered joint In this case, the joints in one rail are somewhat staggered and are not opposite the joints in the other rail. Staggered joints are normally preferred on curved tracks because they hinder the centrifugal force that pushes the track outward.

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 in railways.

a) Gas pressure welding

b) Electric arc or metal arc welding

c) Flash butt welding

d) Thermit welding

BEARING PLATES, ANTI-CREEP DEVICES

ADJUSTMENT OF CREEP

When creep is in excess of 150 mm resulting in maintenance problems, the same should be adjusted by pulling the rails back. This work is carried out after the required engineering signals have been put up and the necessary caution orders given.

The various steps involved in the adjustment of creep are as follows:

(v) A careful survey of the expansion gaps and of the current position of rail joints is carried out.

(vi) The total creep that has been proposed to be adjusted and the correct expansion gap that is to be kept are decided in advance.

(vii) The fish plates at one end are loosened and those at the other end are removed. Sleeper fittings, i.e., spikes or keys, are also loosened or removed.

(viii) The rails are then pulled back one by one with the help of a rope attached to a hook. The pulling back should be regulated in such a way that the rail joints remain central and suspended on the joint sleepers. The pulling back of rails is a slow process since only one rail is dealt with at a time and can be done only for short isolated lengths of a track. Normally, about 40-50 men are required per kilometre for adjusting creep. When creep is required to be adjusted for longer lengths, five rail lengths are tackled at a time. The procedure is almost the same as the preceding steps except that instead of pulling the rails with i rope, a blow is given to them using a cut rail piece of a length of about 5 m.

CREEP ADJUSTER

A creep adjuster is normally used when extensive work is involved. The creep adjuster is set at the centre of the length of the track, to be tackled, with the wide joints behind it and the jammed joints ahead of it. The following steps are adopted while using a creep adjuster:

(ix) Expansion liners of the correct size are put in all the expansion gaps,

(x) All the keys on the side (with wide joints) of the creep adjuster are removed and all fish bolts loosened

(xi) The creep adjuster is then used to close up the gaps to the required extent by pushing the rails forward. A gap of a few inches is left between the rail ends opposite the adjuster,

(xii) (xi) The corrected rails are then fastened with keys. After that, the rails on the other side of the adjuster are tackled,

(xiii) (xii) The operation leaves some of the expansion gaps too wide which are tackled by the creep adjuster when it is set in the next position,

(xiv) (xiii) The corrected rails are then fastened and the adjuster is shifted to the new position,

(xv) (xiv) The whole process is repeated again and again till the requisite attention has been paid to the entire length of the rail. In the end it may be necessary to use a rail with the correct size of closure (bigger or smaller) to complete the work.

PORTIONS OF TRACK SUSCEPTIBLE TO CREEP

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

. • The point where a steel sleeper track or CST-9 sleeper track meets a wooden sleeper track

• Dips in stretches with long gradients

• Approaches to major girder bridges or other stable structures

• Approaches to level crossings and points and crossings

• Steep gradients and sharp curves

MEASURES TO REDUCE CREEP

To reduce creep in a track, it should be ensured that the rails are held firmly to the sleepers and that adequate ballast resistance is available. All spikes, screws, and keys should be driven home. The toe load of fastenings should always be slightly more than the ballast resistance. Creep anchors can effectively reduce the creep in a track. At least eight of these creep anchors must be provided per panel. Out of the large number of creep anchors tried on Indian Railways, the 'fair T' and 'fair V anchors, have been standardized for use. The fair 'V anchor, which is more popular, is shown in Fig. below. The creep anchor should fit snugly against the sleeper for it to be full;- effective.

The following measures are also helpful in reducing creep,

(a) The track should be well maintained—sleepers should be properly packed and the crib and shoulder ballast should be well compacted.

(b) (b) A careful lookout should be kept for jammed joints that exist in series. In the case of a fish- plated track, more than six consecutive continuously jammed joints should not be permitted. In the case of SWR tracks, more than two consecutive jammed joints should not be permitted at rail temperatures lower than the maximum daily temperature (Tm) in the case of zones I and II and lower than (Tm - 5°C) in the case of zones III and IV.

UNIT 3

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

DETAILS OF GEOMETRIC DESIGN OF TRACK

The geometric design of the track deals with alignment of railway track and Curves Details regarding curves and their various aspects.

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 movement of traffic and in a down or falling gradient the track loses elevation the direction of 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. For example, if there is a rise of 1 m in 400 m, the gradient is 1 in 400 or 0.25 per cent.

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

The following types of gradients are used on the railways:

(a) Ruling gradient

(b) Pusher or helper gradient

(c) Momentum gradient

(d) Gradients in station yards

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.

In plain terrain: 1 in 150 to 1 in 250

In hilly terrain: 1 in 100 to 1 in 150

Once a ruling gradient has been specified for a section, all other gradients provided in that section should be flatter than the ruling gradient after making due compensation for curvature.

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.

. **Momentum Gradient**

The momentum gradient is also 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.

Gradients in Station Yards

The gradients in station yards are quite flat due to the following reasons: (a) It prevents standing vehicles from rolling and moving away from the yard due to the combined effect of gravity and strong winds. (b) It reduces the additional resistive forces required to start a locomotive to the extent possible. It may be mentioned here that generally, yards are not levelled completely and certain flat gradients are provided in order to ensure good drainage. The maximum gradient prescribed in station yards on Indian Railways is 1 in 400, while the recommended gradient is 1 in 1000.

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 cent per degree of the curve or 70/R, whichever is minimum

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

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

where R is the radius of the curve in metres. The gradient of a curved portion of the section should be flatter than the ruling gradient because of the extra resistance offered by the curve.

SUPERELEVATION

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

Superelevation or cant (Ca)

It is the difference in height between the outer and the inner rail on a curve. It is provided by gradually raising the outer rail above the level of the inner rail. The inner rail, also known as the gradient rail, is taken as the reference rail and is normally maintained at its original level.

The main functions of superelevation 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.

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 (Cd)

It 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.

Cant excess (Ce)

It occurs when a train travels around a curve at a speed lower than the equilibrium speed. It is the difference between the actual cant provided and the theoretical cant required for such a low speed.

Cant gradient and cant deficiency gradient

These indicate the increase or decrease in the cant or the deficiency of cant in a given length of transition. A gradient of 1 in 1000 means that a cant or a deficiency of cant of 1 mm is attained or lost in every 1000 mm of transition length.

Rate of change of cant or cant deficiency

This is the rate at which cant deficiency increases while passing over the transition curve, e.g., a rate of 35 mm per second means that a vehicle will experience a change in cant or a cant deficiency of 35 mm in each second of travel over the transition when travelling at the maximum permissible speed.

CANT DEFICIENCY AND NEGATIVE SUPERELEVATION

Cant deficiency is the difference between the equilibrium cant that is necessary for the maximum permissible speed on a curve and the actual cant provided.

Cant deficiency is limited due to two considerations:

1. Higher cant deficiency causes greater discomfort to passengers

2. Higher cant deficiency leads to greater unbalanced centrifugal force, which in turn leads to the requirement of stronger tracks and fastenings to withstand the resultant greater lateral forces.

The maximum values of cant deficiency prescribed on Indian Railways are given in Table below.

Table Allowable cant deficiency:

GAUGE	GROUP	NORMAL CANT DEFICIENCY
BG	A &B	75
BG	C,D AND E	75
MG	ALL ROUTS	50
NG		40

The limiting values of cant excess have also been prescribed.

- Cant excess should not be more than 75 mm on BG and 65 mm on MG for all types of rolling stock.

- Cant excess should be worked out taking into consideration the booked speed of the trains running on a particular section.
- In the case of a section that carries predominantly goods traffic, cant excess should be kept low to minimize wear on the inner rail.

NEGATIVE SUPERELEVATION

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. below, AB, which is the outer rail of the main line curve, must he 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.

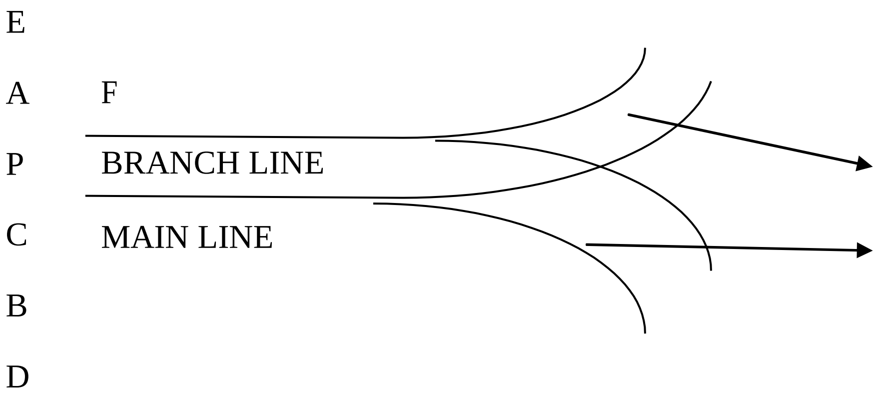


Fig: Negative super elevation

The provision of negative super elevation for the branch line and the reduction in speed over the main line can be calculated as follows:

(i) The equilibrium super elevation for the branch line curve is first calculated using the formula e = GV2 / 127R

(ii) The equilibrium super elevation e is reduced by the permissible cant deficiency Cd and the resultant super elevation to be provided is x = e - Cd where x is the super elevation, e is the equilibrium super elevation, and Cd is 75 mm for BG and 50 mm for MG. The value of Cd is generally higher than that of e, and, therefore, x is normally negative. The branch line thus has a negative super elevation of x.

(iii) The maximum permissible speed on the main line, which has a super elevation of x, is then calculated by adding the allowable cant deficiency (x + Cd). The safe speed is also calculated and the smaller of the two values is taken as the maximum permissible speed on the main line curve.

SAFE SPEED ON CURVES

For all practical purposes safe speed refers to 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 = 3.65(R -6)1/2

where V is the speed in km per hour and R is the radius in metres.

Non-transitioned curves

Safe speed = four-fifths of the speed calculated using Eqn. above .

New Formula for Determining Maximum Permissible Speed on Transitioned Curves

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:

For BG

$V = ((Ca + Cd) \times R/ 13.76)1/2$

$= 0.27((Ca + Cd) \times R)1/2$

where V is the maximum speed in km per hour,

Ca is the actual cant in millimetres,

Cd is the permitted cant deficiency in millimetres,

R is the radius in millimetres.

This equation is derived from Eqn for equilibrium super elevation and is based on the assumption that G = 1 750 mm, which is the centre-to-centre distance between the rail heads of a BG track with 52 g rails.

For MG

$V = 0.347((Ca + Cd) \times R)1/2$

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.

For NG (762 mm.)

V = 3.65(R – 6)1/2 (subject to a maximum of 50 kmph)

(i) Maximum sanctioned speed of the section

This is the maximum permissible speed authorized by the commissioner of railway safety. This is determined after an analysis of the condition of the track, the standard of interlocking, the type of locomotive and rolling stock used, and other such factors.

(ii) Maximum speed of the section based on cant deficiency

This is the speed calculated using the formula given in Table above. First, the equilibrium speed is decided after taking various factors into consideration and the equilibrium superelevation (Ca) calculated. The cant deficiency (Cd) is then added to the equilibrium superelevation and the maximum speed is calculated as per this increased superelevation (Ca + Cd).

(iii) Maximum speed taking into consideration speed of goods train and cant

excess Cant (Ca) is calculated based on the speed of slow moving traffic, i.e., goods train. This speed is decided for each section after taking various factors into account, but generally its value is 65 km per hour for BG and 50 km per hour for MG. The maximum value of cant excess (Ce) is added to this cant and it should be ensured that the cant for the maximum speed does not exceed the value of the sum of the actual cant + and the cant excess (Ca + Ce).

(iv) Speed corresponding to the length of the transition curves

This is the least value of speed calculated after considering the various lengths of transition curves given by the formulae listed in Table below.

UNIT 4

POINT AND CROSSING-II

Introduction

A tongue rail may be either straight or curved. Straight tongue rails have the advantage that they are easily manufactured and can be used for right-hand as well as left-hand turnouts. However, trains get jolted while negotiating with tongue rail turnouts because of the abrupt change in the alignment. Straight rails are normally used for l-in-8.5 and l-in-12 turnouts on Indian Railways. Curved tongue rails are shaped according to the curvature of the turnout ft the toe to the heel of the switch. Curved tongue rails allow for smooth trains, but can only be used for the specific curvature for which they are Curved switches are normally used for 1-in-16 and 1-in-20 IRS (Indian Standard) turnouts on Indian Railways. Recently Indian Railways has also laying 1-in- 8.5 and 1-in-12 turnouts with curved switches on important li

Length of Tongue

Rails The length of a tongue rail from heel to toe varies with the gauge and the switch. The longer the length of the tongue rail, the smoother the entry to the switch because of the smaller angle the switch rail would make with the fixed heel divergence. The longer length of the tongue rail, however, occupies too much layout space in station yards where a number of turnouts have to be laid in space. The length of the tongue rail should be more than the rigid wheel a four-wheeled wagon to preclude the possibility of derailment in case the move from their position when a train is running on the switch.

CROSSING

A crossing or frog is a device introduced at the point where two gauge faces across each other to permit the flanges of a railway vehicle to pass from one tract to another (Fig. below). 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.

(a) Two rails, point rail and splice rail, which are machined to form a nose. Tic point rail ends at the nose, whereas the splice rail joins it a little behind the nose. Theoretically, the point rail should end in a point and be made as thin as possible, but such a knife edge of the point rail would break off under the movement of traffic. The point rail, therefore, has its fine end slightly cut off form a blunt nose, with a thickness of 6 mm (1/4"). The toe of the blunt nose is called the actual nose of crossing (ANC) and the theoretical point where the gauge faces from both sides intersect is called the theoretical nose of crossing (TNC). The 'V rail is planed to a depth of 6 mm (1/4") at the nose and runs out in 89 mm to stop a wheel running in the facing direction from hitting the nose.

(b) Two wing rails consisting of a right-hand and a left-hand wing rail that converge to form a throat and diverge again on either side of the nose. Wing rails are flared at the ends to facilitate the entry and exit of the flanged wheel in the gap.

(c) A pair of check rails to guide the wheel flanges and provide a path for them, thereby preventing them from moving sideways, which would otherwise may result in the wheel hitting the nose of the crossing as it moves in the facing direction.

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

For manufacturing purposes, crossings can also be classified as follows.

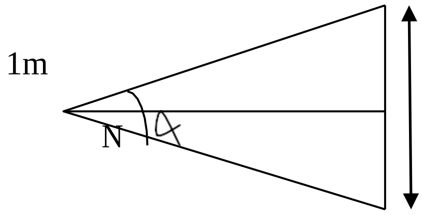
- Built-up crossing
- Cast steel crossing
- Combined rail and cast crossing

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

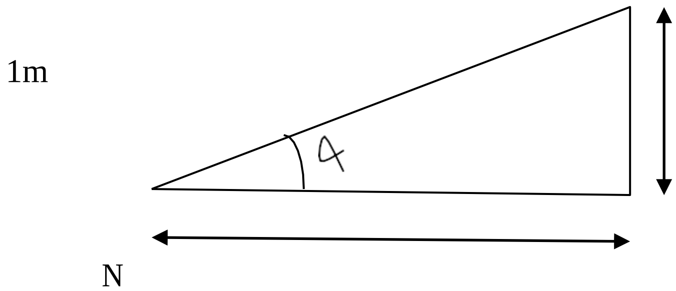
This method is used in Britain and the US. In this method, N is measured along the centre line of the crossing.



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.

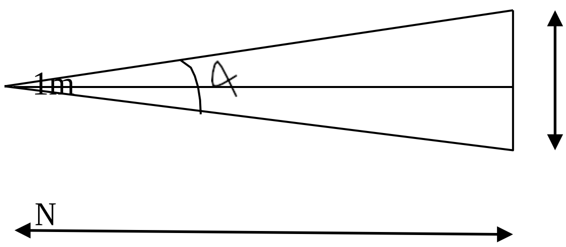
$\text{Cot } \alpha/2 – N = N /1/2$ or $N = 1/2 \text{ Cot } \alpha/2$



$\text{Cot } \alpha = N /1$ or $N = \text{Cot } \alpha$

Isosceles triangle method

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



Sin $\alpha/2$ = ½ /N or N = 1/2N

Cosec $\alpha/2$ = 2N

N = ½ Cosec $\alpha/2$

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.These washers are used for connecting two surfaces that are not parallel to one another. Normally, tapered washers are necessary for connecting such surfaces. Spherical washers can adjust to the uneven bearings of the head or nut of a bolt and so are used on all bolts in the heel and the distance blocks behind the heel on the left-hand side of the track.

Slide chairs These are provided under tongue rails to allow them to move laterally. These are different for ordinary switches and overriding switches.

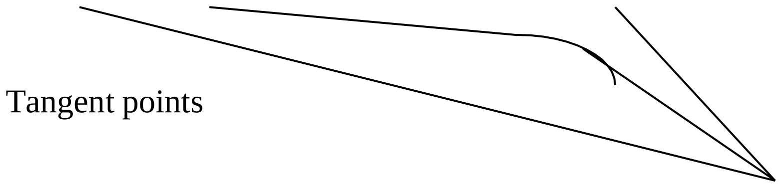
Grade off chairs These are special chairs provided behind the heel of the switches to give a suitable ramp to the tongue rail, which is raised by 6 mm at the heel.

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.

Coles method

This is a method used for designing a turnout taking off from a straight track (Fig. 14.11). The curvature begins from a point on the straight main track ahead of the toe of the switch at the theoretical toe of switch (TTS) and ends at the theoretical nose of crossing (TNC). The heel of the switch is located at the point where the offset of the curve is equal to the heel divergence. Theoretically, there would be no kinks in this layout, had the tongue rail been curved as also the wing rail up to the TNC. Since tongue rails and wing rails are not curved generally, there are the following three kinks in this layout.



On Indian Railways, normally 1-in-8.5 turnouts are used for goods trains while 1-in-12 and 1-in- 16 turnouts are used for passenger trains. Recently 1-in-20 and 1 -in-24 turnouts have also been designed by the RDSO, to be used to permit higher speeds for fast trains on the turnout side. The maximum speeds permitted on these turnouts are given in Table below.

Table: Permissible speeds on turnouts

Gauge	**Type of turnout**	**Switch angle**	**Permissible speed (kmph)**
BG	1 in 8.5	1°34'27"	10* for straight switch and 15 for curved switch for 52/60 kg rails on PSC sleepers
BG	1 in 8.5	Symmetrical split (SS) 0°27'35"	30 for curved switch as well as SS with 52/60 kg on PSC sleepers; 15* for curved switch for 52/60 kg on PSC sleepers*
BG	l-in-16	1°8'0" 0°24'27"	50 or 601
MG	1 in 8.5	1°35'30" 0°29'14"	10 for straight as well as curved switch

MG	l-in-12	1°09'38" 0°24'27"	1 5 for straight switch and 1 5 for partly curved switch
MG	l-in-16	0°24'27"	30

DESIGN OF TURNOUTS

A turnout, after branching off from the main track, may run into various directions of which running parallel to the original track is most common. The design calculation of various turnout are based on following three factors:

(i) Method of calculating various leads

(ii) Method employed for crossing angle

(iii) Type of tongue rail used

Notation used in design calculation

Following notation have been used in various methods for design of turnouts:

CL = Curve lead

= Distance between theoretical nose of the crossing (T.N.C.) and the tangent point

T measured along the length of main track.

SL = Switch lead

= Distance between tangent point T and the heel of the switch (H.S.) measured along the length of the track

L = Lead or crossing lead

= Distance between T.N.C. and the heel of the switch (H.S.) measured along the length of the track

Lead rails, being curved rails, are not measured along their curve length, long their projected length along the straight rail.

Therefore, CL, SL and L, it is clear that

CL = SL + L or L = CL – SL

β = Angle of the switch, i.e. the angle between the gauge faces of switch rail and stock rail

α = Angle of the crossing

d = Heel divergence or clearance

R0 = Radius of the outer turnout

R = Radius of centre line of the turnout

G = Gauge of the track

N = Number of the crossing

D = Distance between T.N.C. and tangent point of crossing curve

UNIT 5

AIRPORT SCENARIO IN INDIA

Introduction

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.

Air transport scenario in India

The first commercial flight in India was made on February 18, 1911 by Henri Piquet, a frenchman. The flight was planned from Allahabad to Naini junction which is a distance of 7 km L5 miles). Same year Sir George Loyd undertook the rganization of air flying between Bombay and Karachi. Air xvice between these cities were considered as purely mporary and was taken as a government venture.

In 1927 British government established Civil Aviation epartmenl and (his organization helped in building up of a w aerodromes and bringing up of some flying clubs. A gular weekly service commenced between Karachi and elhi in 1929 under Imperial Airways Service. In 1939 Tata \rways Limited started internal air services between Allahabad, Calcutta and Colombo. Later, Indian Trans-Continental Airways mited was formed for the foreign flights in 1933. The second world War helped this country for having large tmber of technical personnel. Air Transport Licensing Board came into being in 1946. Tata airlines changed its name as Air India Limited in July 1946 here were about eleven operating units by 1947. The nigbt rvic.escommenced in 1949. For external air services, the Jvernment of India entered in agreement in November 1947, th a new formed organization, named as Ait India International mited. It inaugurated its first international service to London June 8, 1948 via Cairo and Geneva with a fleet of three constellation-749 aircraft. The initial frequency of one flight a week was gradually stepped up to seven Super-Constellation services a week with alternate stops at Paris, Prague, Duesseidorf, Zurich, Geneva, - Rome, Cairo, Beirut and Damascus. Master Committee 1952 recommended the formation of Civil Aviation Board as a statutary body. Air Transport Corporation Bill was passed on May 14, 1953. Under this bill two corporations were established, one for operating international services and the other for domestic services. The domestic operations were taken over by the Indian Airlines Corporation. Similarly, Air India. International Limited was renamed as Air India International Corporation. On August 1, 1953 airlines were nationalised. In April 1960, Air India celebrated entry into the jet age by starting Boeing 707 services to London and later in May to New York—thus becoming the first Asian carrier to operate over the Atlantic. In July 1967, the Government, of India set up the International Airports Committee under the chairmanship of Mr. J. R. D Tata to advise the Government regarding the improvement which are required in the existing international airports it India in view of the continuous growth of air traffic and the likely introduction of very large subsonic and supersonic aircrafts in near future. The interim report of the committee was submitted to the Government in April, 1968. On January 2, 1971, Indian Airlines inaugurated the daily Boeing 737 service on the Bombay- Calcutta and Delhi-Bombay sectors. The country for domestic flights is divided in to four flight information regions with centres at Delhi, Bombay Madras and Calcutta. International Airport Authority of India (IAAI) was set u in April 1972 for the operation, management, planning an development of the four international airports. The first commercial flight in India was made on February 18, 1911, when a French pilot Monseigneur Piguet flew airmails from Allahabad to Naini, covering a distance of about 10 km in as many minutes. Tata Services became Tata Airlines and then Air-India and spread its wings as Air-India International. The domestic aviation scene, however, was chaotic. When the American Tenth Air Force in India disposed of its planes at throwaway prices, 11 domestic airlines sprang up, scrambling for traffic that could sustain only two or three. In 1953, the government nationalized the airlines, merged them, and created Indian Airlines. For the next 25 years JRD Tata remained the chairman of Air-India and a director on the board of Indian Airlines. After JRD left, voracious unions mushroomed, spawned on the pork barrel jobs created by politicians. In 1999, A-I had 700 employees per plane; today it has 474 whereas other airlines have 350. For many years in India air travel was perceived to be an elitist activity. This view arose from the ―Maharajah‖ syndrome where, due to the prohibitive cost of air travel, the only people who could afford it were the rich and powerful. In recent years, however, this image of Civil Aviation has undergone a change and aviation is now viewed in a different light - as an essential link not only for international travel and trade but also for providing connectivity to different parts of the country. Aviation is, by its very nature, a critical part of the infrastructure of the country and has important ramifications for the development of tourism and trade, the opening up of inaccessible areas of the country and for providing stimulus to business activity and economic growth. Until less than a decade ago, all aspects of aviation were firmly controlled by the Government. In the early fifties, all airlines operating in the country were merged into either Indian Airlines or AirIndia and, by virtue of the Air Corporations Act, 1953; this monopoly was perpetuated for the next forty years. The Directorate General of Civil Aviation controlled every aspect of flying including granting flying licenses, pilots, certifying aircrafts for flight and issuing all rules and procedures governing Indian airports and airspace. Finally, the Airports Authority of India was entrusted with the responsibility of managing all national and international air ports and administering every aspect of air transport operation through the Air Traffic Control. With the opening up of the Indian economy in the early Nineties, aviation saw some important changes. Most importantly, the Air Corporation Act was repealed to end the monopoly of the public sector and private airlines were reintroduced.

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

STAGES OF DEVELOPMENT

Introduction

An airport system plan is a representation of the aviation facilities required to meet the immediate and future needs of a metropolitan area, region, state, or country. The system plan presents the recommendations for the general location and characteristics of new airports and heliports and the nature of expansion for existing ones to meet forecasts of aggregate demand. It identifies the aviation role of existing and recommended new airports and facilities. It includes the timing and estimated costs of development and relates airport system planning to the policy and objectives of the relevant jurisdiction. Its overall purpose is to determine the extent, type, nature, location, and timing of airport development needed to establish a viable, balanced, and integrated system of airports. It also provides the basis for detailed airport planning such as that contained in the airport master plan.

The airport system plan provides both broad and specific policies, plans, and programs required to establish a viable and integrated system of airports to meet the needs of the region. The objectives of the system plan include:

1. The orderly and timely development of a system of airports adequate to meet present and future aviation needs and to promote the desired pattern of regional growth relative to industrial, employment, social, environmental, and recreational goals.

2. The development of aviation to meet its role in a balanced and multimodal transportation system to foster the overall goals of the area as reflected in the transportation system plan and comprehensive development plan.

3. The protection and enhancement of the environment through the location and expansion of aviation facilities in a manner which avoids ecological and environmental impairment.

4. The provision of the framework within which specific airport programs may be developed consistent with the short- and long-range airport system requirements.

5. The implementation of land-use and airspace plans which optimize these resources in an often constrained environment.

6. The development of long-range fiscal plans and the establishment of priorities for airport financing within the governmental budgeting process.

7. The establishment of the mechanism for the implementation of the system plan through the normal political framework, including the necessary coordination between governmental agencies, the involvement of both public and private aviation and nonaviation interests, and compatibility with the content, standards, and criteria of existing legislation. The airport system planning process must be consistent with state, regional, or national goals for transportation, land use, and the environment.

The elements in a typical airport system planning process include the following:

1. Exploration of issues that impact aviation in the study area

2. Inventory of the current system

3. Identification of air transportation needs

4. Forecast of system demand

5. Consideration of alternative airport systems

6. Definition of airport roles and policy strategies

7. Recommendation of system changes, funding strategies, and airport development

8. Preparation of an implementation plan Although the process involves many varied elements, the final product will result in the identification, preservation, and enhancement of the aviation system to meet current and future demand. The ultimate result of the process will be the establishment of a viable, balanced, and integrated system of airports.

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 Defence Airport

SITE SELECTION

Introduction

The emphasis in airport planning is normally on the expansion and improvement of existing airports. However if an existing airport cannot be expanded to meet the future demand or the need for a new airport is identified in an airport system plan, a process to select a new airport site may be required.

i Identification

ii Screening

iii Operational capability

iv Capacity potential

v Ground access

vi Development costs

vii Environmental consequences

viii Compatibility with area-wide planning ix Selection

THE AIRPORT MASTER PLAN

An airport master plan is a concept of the ultimate development of a specific airport. The term development includes the entire airport area, both for aviation and nonaviation uses, and the use of land adjacent to the airport. It presents the development concept graphically and contains the data and rationale upon which the plan is based. Master plans are prepared to support expansion and modernization of existing airports and guide the development of new airports. The overall objective of the airport master plan is to provide guidelines for future development which will satisfy aviation demand in a financially feasible manner and be compatible with the environment, community development, and other modes of transportation.

More specifically it is a guide for

1. Developing the physical facilities of an airport
2. Developing land on and adjacent to the airport
3. Determining the environmental effects of airport construction and operations
4. Establishing access requirements
5. Establishing the technical, economic and financial feasibility of proposed developments through a thorough investigation of alternative concepts
6. Establishing a schedule of priorities and phasing for the improvements proposed in the plan
7. Establishing an achievable financial plan to support the implementation schedule
8. Establishing a continuing planning process which will monitor conditions and adjust plan recommendations as circumstances warrant

Guidelines for completing an airport master plan are described by ICAO and in the United States by. A master plan report is typically organized as follows:

- Master plan vision, goals, and objectives
- Inventory of existing conditions
- Forecast of aviation demand
- Demand/capacity analysis and facility requirements
- Alternatives development
- Preferred development plan

 Implementation plan

 Environmental overview

 Airport plans package

 Stakeholder and public involvement

OBSTRUCTION AND ZONING LAWS

IMAGINARY SURFACES

In order to determine whether an object is an obstruction to air navigation, several imaginary surfaces are established with relation to the airport and to each end of a runway. The size of the imaginary surfaces depends on the category of each runway (e.g., utility or transport) and on the type of approach planned for that end of the runway (e.g., visual, nonprecision instrument, or precision instrument).

They are described as follows:

1. **Primary surface.** The primary surface is a surface longitudinally centered on a runway. When the runway is paved, the primary surface extends 200 ft beyond each end of the runway. When the runway is unpaved, the primary surface coincides with each end of the runway. The elevation of the primary surface is the same as the elevation of the nearest point on the runway centerline.

2. **Horizontal surface.** The horizontal surface is a horizontal plane 150 ft above the established airport elevation, the perimeter of which is constructed by swinging arcs of

specified radii from the center of each end of the primary surface of each runway and connecting each arcs by lines tangent to those arcs.

3. **Conical surface.** The conical surface is a surface extending outward and upward from the periphery of the horizontal surface at a slope of 20 horizontal to 1 vertical for a horizontal distance of 4000 ft.

4. **Approach surface.** The approach surface is a surface longitudinally centered on the extended runway centerline and extending outward and upward from each end of a runway at a designated slope based upon the type of available or planned approach to the runway.

5. **Transitional surface.** Transitional surfaces extend outward and upward at right angles to the runway centerline plus the runway centerline extended at a slope of 7 to 1 from the sides of the primary surface up to the horizontal surface and from the sides of the approach surfaces. The width of the transitional surface provided from each edge of the approach surface is 5000 ft.

AIRCRAFT CHARACTERISTICS

Introduction

One of the great challenges for airport planning and design is creating facilities that accommodate a very wide variety of aircraft. Aircraft vary widely in terms of their physical dimensions and performance characteristics, whether they be operated for commercial air service, cargo, or general aviation activities.

There are a large number of specifications for which aircraft may be categorized. Depending on the portion of the area of the airport, certain aircraft specifications become more critical. For example, aircraft weight is important for determining the thickness and strengths of the runway, taxiway, and apron pavements, and affects the takeoff and landing runway length requirements at an airport, which in turn to a large extent influences planning of the entire airport property. The wingspan and the fuselage length influence the size of parking aprons, which in turn influences the configuration of the terminal buildings. Wingspan and turning radii dictate width of runways and taxiways, the distances between these traffic ways, and affects the required turning radius on pavement curves. An aircraft‗s passenger capacity has an important bearing on facilities within and adjacent to the terminal building.

Since the initial success of the Wright Flyer in 1903, fixed-wing aircraft have gone through more than 100 years of design enhancements, resulting in vastly improved performance, including the ability to fly at greater speeds and higher altitudes over larger ranges with more revenue generating carrying capacity (known as payload) at greater operating efficiencies. These improvements are primarily the results of the implementation of new technologies into aircraft specifications, ranging from materials from which the airframes are built, to the engines that power the aircraft. Of great challenge to airport planning and design, historically has been to adapt the airport environment to accommodate changes in aircraft physical and performance specifications. For example:

• The introduction of ―cabin-class‖ aircraft, such as the Douglas DC-3, in the mid-1930s resulted in the need for airports to construct longer, paved runways from the shorter grass strips that previously existed.

• The introduction of aircraft equipped with turbofan and turbojet engines in the late 1950s added requirements for longer and stronger runways, facilities to mitigate jet-blast, and policies to reduce the impact of aircraft noise at and around the airport.

• The introduction of ―jumbo-jet‖ or ―heavy‖ aircraft, such as the Boeing-747, in the late 1960s added new requirements for runway specifications, as well as terminal area design requirements for accommodating large volumes of passengers and cargo.

• The proliferation of regional jet aircraft, introduced because of more efficient engine technologies, resulted in the need for airports to modify many terminal areas that had accommodated larger jets or smaller turbo-prop aircraft.

Most recently, the introduction of the world‗s largest passenger aircraft, the Airbus A-380, as well as the smallest of certified general aviation jet aircraft, continues to affect design specifications of airport airfield and terminal areas.

UNIT 6

Introduction

A runway is a rectangular area on the airport surface prepared for the takeoff and landing of aircraft. An airport may have one runway or several runways which are sited, oriented, and configured in a manner to provide for the safe and efficient use of the airport under a variety of conditions. Several of the factors which affect the location, orientation, and number of runways at an airport include local weather conditions, particularly wind distribution and visibility, the topography of the airport and surrounding area, the type and amount of air traffic to be serviced at the airport, aircraft performance requirements, and aircraft noise.

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.

Combinations of Runway Configurations

From the standpoint of capacity and air traffic control, a single-direction runway configuration is most desirable. All other things being equal, this configuration will yield the highest capacity compared with other configurations. For air traffic control the routing of aircraft in a single direction is less complex than routing in multiple directions. Comparing the divergent configurations, the open-V runway pattern is more desirable than an intersecting runway configuration. In the open-V configuration an operating strategy that routes aircraft away from the V will yield higher capacities than if the operations are reversed. If intersecting runways cannot be avoided, every effort should be made to place the intersections of both runways as close as possible to their thresholds and to operate the aircraft away from the intersection rather than toward the intersection.

ORIENTATION AND CONFIGURATION

Introduction

The orientation of a runway is defined by the direction, relative to magnetic north, of the operations performed by aircraft on the runway. Typically, but not always, runways are oriented in such a manner that they may be used in either direction. It is less preferred to orient a runway in such a way that operating in one direction is precluded, normally due to nearby obstacles. In addition to obstacle clearance considerations, which will be discussed later in this chapter, runways are typically oriented based on the area_s wind conditions. As such, an analysis of wind is essential for planning runways. As a general rule, the primary runway at an airport should be oriented as closely as practicable in the direction of the prevailing winds. When landing and taking off, aircraft are able to maneuver on a runway as long as the wind component at right angles to the direction of travel, the crosswind component, is not excessive.

The FAA recommends that runways should be oriented so that aircraft may be landed at least 95 percent of the time with allowable crosswind components not exceeding specified limits based upon the airport reference code associated with the critical aircraft that has the shortest wingspan or slowest approach speed. When the wind coverage is less than 95 percent a crosswind runway is recommended.

The allowable crosswind is 10.5 kn (12 mi/h) for Airport Reference Codes A-I and B-I, 13 kn (15 mi/h) for Airport Reference Codes A-II and B-II, 16 kn (18.5 mi/h) for Airport Reference Codes A-III, B-III, C-I, C-II, C-III and C-IV, and 20 knots (23 mph) for Airport Reference Codes A-IV through D-VI [5].

ICAO also specifies that runways should be oriented so that aircraft may be landed at least 95 percent of the time with crosswind components of 20 kn (23 mph) for runway lengths of 1500 m more, 13 kn (15 mi/h) for runway lengths between 1200 and 1500 m, and 10 kn (11.5 mi/h) for runway lengths less than 1200 m.

Once the maximum permissible crosswind component is selected, the most desirable direction of runways for wind coverage can be determined by examination of the average wind characteristics at the airport under the following conditions:

1. The entire wind coverage regardless of visibility or cloud ceiling

2. Wind conditions when the ceiling is at least 1000 ft and the visibility is at least 3 mi

3. Wind conditions when ceiling is between 200 and 1000 ft and/or the visibility is between . and 3 mi.

The first condition represents the entire range of visibility, from excellent to very poor, and is termed the all weather condition. The next condition represents the range of good visibility conditions not requiring the use of instruments for landing, termed visual meteorological condition (VMC). The last condition represents various degrees of poor visibility requiring the use of instruments for landing, termed instrument meteorological conditions (IMC). The 95 percent criterion suggested by the FAA and ICAO is applicable to all conditions of weather; nevertheless it is still useful to examine the data in parts whenever this is possible.

In the United States, weather records can be obtained from the Environmental Data and Information Service of the National Climatic Center at the National Oceanic and Atmospheric Administration located in Ashville, N.C., or from various locations found on the Internet. Weather data are collected from weather stations throughout the United States on an hourly basis and recorded for analysis.

The data collected include ceiling, visibility, wind speed, wind direction, storms, barometric pressure, the amount and type of liquid and frozen precipitation, temperature, and relative humidity. A report illustrating the tabulation and representation of some of the data of use in airport studies was prepared for the FAA. The weather records contain the percentage of time certain combinations of ceiling and visibility occur (e.g., ceiling, 500 to 900 ft; visibility, 3 to 6 mi), and the percentage of time winds of specified velocity ranges occur from different directions (e.g., from NNE, 4 to 7 mi/h). The directions are referenced to true north.

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.

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 enroute to destination
- Aircraft is loaded to its full capacity
- Enroute 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 require 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 stopway 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 stopway. 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 recommend after correction for elevation and temperature a further increase in runway length at arte of 20% for every 1 percent effective gradient.

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 Taxilane 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 taxilane system have been designed and provide a minimum wingtip clearance on these facilities. The required separation between taxiways, between a taxiway and a taxilane, 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 taxilane 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.

Sight Distance and Longitudinal Profile

As in the case of runways, the number of changes in longitudinal profile for taxiways is limited by sight distance and minimum distance between vertical curves. The FAA does not specify line of sight requirements for taxiways other than those discussed earlier related to runway and taxiway intersections. However, the sight distance along a runway from an intersecting taxiway needs to be sufficient to allow a taxiing aircraft to enter or cross the runway safely. The FAA specifies that from any point on the taxiway centerline the difference in elevation between that point and the corresponding point on a parallel runway, taxiway, or apron edge is 1.5 percent of the shortest distance between the points. ICAO requires that the surface of the taxiway should be seen for a distance of 150 m from a point 1.5 m above the taxiway for aerodrome code letter A runways, for a distance of 200 m from a point 2 m above the taxiway for aerodrome code letter B runways, and for a distance of 300 m from a point 3 m above the taxiway for aerodrome code letter C, D, or E runways. In regard to longitudinal profile of taxiways, the ICAO does not specify the minimum distance between the points of intersection of vertical curves. The FAA specifies that the minimum distance for both utility and transport category airports should be not less than the product of 100 ft multiplied by the sum of the absolute percentage values of change in slope.

Exit Taxiway Geometry

The function of exit taxiways, or runway turnoffs as they are sometimes called, is to minimize runway occupancy by landing aircraft. Exit taxiways can be placed at right angles to the runway or some other angle to the runway. When the angle is on the order of 30°, the term high-speed exit is often used to denote that it is designed for higher speeds than other exit taxiway configurations. In this chapter, specific dimensions for high-speed exit, right-angle exit (low- speed) taxiways are presented.

Aircraft paths in the test approximated a spiral. A compound curve is relatively easy to establish in the field and begins to approach the shape of a spiral, thus the reason for suggesting a compound curve. The following pertinent conclusions were reached as a result of the tests [13]:

1. Transport category and military aircraft can safely and comfortably turn off runways at speeds on the order of 60 to 65 mi/h on wet and dry pavements.

2. The most significant factor affecting the turning radius is speed, not the total angle of turn or passenger comfort.

3. Passenger comfort was not critical in any of the turning movements.

4. The computed lateral forces developed in the tests were substantially below the maximum lateral forces for which the landing gear was designed.

5. Insofar as the shape of the taxiway is concerned, a slightly widened entrance gradually tapering to the normal width of taxiway is preferred. The widened entrance gives the pilot more latitude in using the exit taxiway.

6. Total angles of turn of 30° to 45° can be negotiated satisfactorily. The smaller angle seems to be preferable because the length of the curved path is reduced, sight distance is improved, and less concentration is required on the part of the pilots.

7. The relation of turning radius versus speed expressed by the formula below will yield a smooth, comfortable turn on a wet or dry pavement when f is made equal to 0.13.

8. The curve expressed by the equation for R2 should be preceded by a larger radius curve R1 at exit speeds of 50 to 60 mi/h. The larger radius curve is necessary to provide a gradual transition from a straight tangent direction section to a curved path section. If the transition curve is not provided tire wear on large jet transports can be excessive.

9. Sufficient distance must be provided to comfortably decelerate an aircraft after it leaves the runway. It is suggested that for the present this distance be based on an average rate of deceleration of 3.3 ft/s2. This applies only to transport category aircraft. Until more experience is gained with this type of operation the stopping distance should be measured from the edge of the runway.

Location of Exit Taxiways

The location of exit taxiways depends on the mix of aircraft, the approach and touchdown speeds, the point of touchdown, the exit speed, the rate of deceleration, which in turn depends on the condition of the pavement surface, that is, dry or wet, and the number of exits. While the rules for flying transport aircraft are relatively precise, a certain amount of variability among pilots is bound to occur especially in respect to braking force applied on the runway and the distance from runway threshold to touchdown. The rapidity and the manner in which air traffic control can process arrivals is an extremely important factor in establishing the location of exit taxiways. The location of exit taxiways is also influenced by the location of the runways relative to the terminal area.

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. Holding pads must be designed for the largest aircraft which will use the pad. The holding pad should be located so that all aircraft using the pad will be located outside both the runway and taxiway object-free area and in a position so as not to interfere with critical ILS signals.

AIRPORT LAYOUTS AND TERMINAL BUILDING

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 interline 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-I

Introduction

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

The proper placement of these systems is described in this chapter but no attempt has been made to describe in detail the hardware or its installation. Airfield marking and signage includes

1. Runway and taxiway pavement markings

2. Runway and taxiway guidance sign systems

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 Requirements for Visual Aids

Since the earliest days of flying, pilots have used ground references for navigation when approaching an airport, just as officers on ships at sea have used landmarks on shore when approaching a harbor. Pilots need visual aids in good weather as well as in bad weather and during the day as well as at night.

In the daytime there is adequate light from the sun, so artificial lighting is not usually required but it is necessary to have adequate contrast in the field of view and to have a suitable pattern of brightness so that the important features of the airport can be identified and oriented with respect to the position of the aircraft in space. These requirements are almost automatically met during the day when the weather is clear.

The runway for conventional aircraft always appears as a long narrow strip with straight sides and is free of obstacles. It can therefore be easily identified from a distance or by flying over the field. Therefore, the perspective view of the runway and other identifying reference landmarks are used by pilots as visual aids for orientation when they are approaching the airport to land. Experience has demonstrated that the horizon, the runway edges, the runway threshold, and the centreline of the runway are the most important elements for pilots to see.

In order to enhance the visual information during the day, the runway is painted with standard marking patterns. The key elements in these patterns are the threshold, the centreline, the edges, plus multiple parallel lines to increase the perspective and to define the plane of the surface. During the day when visibility is poor and at night, the visual information is reduced by a significant amount over the clear weather daytime scene. It is therefore essential to provide visual aids which will be as meaningful to pilots as possible.

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.

UNIT 7

Tunnel Engineering

Introduction:

[1] A tunnel is an underground or underwater passageway, enclosed except for entrance and exit, commonly at each end.

[2] A tunnel may be for foot or vehicular road traffic, for rail traffic, or for a canal. The central portions of a rapid transit network are usually in tunnel. Some tunnels are aqueducts to supply water for consumption or for hydroelectric stations or are sewers.

[3] Utility tunnels are used for routing steam, chilled water, electrical power or telecommunication cables, as well as connecting buildings for convenient passage of people and equipment.

[4] Secret tunnels are built for military purposes, or by civilians for smuggling of weapons, contraband, or people. Special tunnels, such as wildlife crossings, are built to allow wildlife to cross human-made barriers safely.

[5] A tunnel is relatively long and narrow; the length is often much greater than twice the diameter, although similar shorter excavations can be constructed such as cross passages between tunnels.

[6] Much of the early technology of tunneling evolved from mining and military engineering. The etymology of the terms "mining" (for mineral extraction or for siege attacks), "military engineering", and "civil engineering" reveals these deep historic connections.

Geotechnical Consideration of tunneling

Introduction:-

- Geotechnical Information is needed from the very moment planning begins on any tunnel project.
- This type of information provides the greater freedom the owner and designer can have in their selection of alignment and construction methods thus the greater the potential cost savings.
- Geotechnical information can be invaluable in the selection of the general corridor as well as the detailed alignment of a tunnel project.

CHALLENGES OF THE UNDERGROUND

The underground condition, deal with challenges to the geotechnical and tunnel design teams. It is important that this uncertainty, and its associated risk, be fully appreciated by all parties, especially the management and legal staff of the owner.

Some of the numerous challenges are discussed below:-

Underground projects have vast uncertainty

• The cost, and indeed feasibility, of the project is dominated by geology

- Every aspect of the geologic investigation for tunnels is more demanding than investigations for traditional foundation engineering projects
- Regional geology and hydrogeology must be understood
- Groundwater is the most difficult condition/parameter to predict and the most troublesome during construction
- Engineering properties change with a wide range of conditions, such as time, seasons, rate and direction of loading, etc.; sometimes drastically
- It is guaranteed that the actual stratigraphy, groundwater flow, and behavior observed during construction will be compared to your predictions

WHEN TO CONDUCT GEOTECHNICAL INVESTIGATIONS:-

- The planning of each exploration phase should be based on the results of the previous phase.
- The geotechnical exploration, including evaluation and report, must be available to the decision makers on the design team in a timely manner

. • Significant geotechnical work will be necessary during the early portions of preliminary and of final design interspersed with relatively low levels of effort.

During the latter stages of final design when contract documents are finalized, there should be a significant geotechnical effort to support the preparation of the Geotechnical Baseline Report (GBR) and the rest of the contract documents.

Geotechnical investigation and design:

• A tunnel project must start with a comprehensive investigation of ground conditions by collecting samples from boreholes and by other geophysical techniques. An informed choice can then be made of machinery and methods for excavation and ground support, which will reduce the risk of encountering unforeseen ground conditions.

• In planning the route the horizontal and vertical alignments will make use of the best ground and water conditions.

• Conventional desk and site studies (desk study and walk-over survey) may yield insufficient information to assess such factors as the blocky nature of rocks, the exact location of fault zones, or the stand-up times of softer ground. This may be a particular concern in large-diameter tunnels. To give more information, a pilot tunnel, or drift, may be driven ahead of the main drive.

• This tunnel will be easier to support should unexpected conditions be met, and will be incorporated in the final tunnel. Alternatively, horizontal boreholes may sometimes be drilled ahead of the advancing tunnel face.

Other key geotechnical factors include:

• Stand-up time is the amount of time a tunnel will support itself without any added structures. Knowing this time allows the engineers to determine how much can be excavated before support is needed. The longer the stand-up time is the faster the excavating will go. Generally certain configurations of rock and clay will have the greatest stand-up time, and sand and fine soils will have a much lower stand-up time.

• Groundwater control is very important in tunnel construction. If there is water leaking into the tunnel stand-up time will be greatly decreased. If there is water leaking into the shaft it will become unstable and will not be safe to work in. To stop this from happening there are a few common methods. One of the most effective is ground freezing. To do this pipes are inserted into the ground surrounding the shaft and are cooled until they freeze. This freezes the ground around each pipe until the whole shaft is surrounded frozen soil, keeping water out. The most common method is to install pipes into the ground and to simply pump the water out. This works for tunnels and shafts.

• Tunnel shape is very important in determining stand-up time. The force from gravity is straight down on a tunnel, so if the tunnel is wider than it is high it will have a harder time supporting itself, decreasing its stand-up time. If a tunnel is higher than it is wide the stand-up time will increase making the project easier. The hardest shape to support itself is a square or rectangular tunnel. The forces have a harder time being redirected around the tunnel making it extremely hard to support itself.

MICROTUNNELLING

The Principles

Micro tunnelling was originally defined as mechanised pipe jacking for non man entry size tunnels. As the process was developed and greater sophistication applied, it is perhaps now more correctly defined as pipe jacking employing a remote-controlled tunnelling machine.

The History

Pipe jacking has been used since at least the mid-20th-century. This is the principal of pushing a rigid pipe into the ground into a tunnel bore that has been pre-excavated. Generally this is carried out from a shaft which has been sunk from ground level to the depth where the pipe jack pipe has to be installed. Originally the tunnel excavation was carried out by a man at the front of the pipe being installed. For various reasons such as:

• The requirement to install smaller diameter pipes

• Safety concerns

• The ability to operate in more difficult grounds Engineers sought to develop mechanised equipment to replace the man at the front of the pipe. Much of the original development was carried out in Japan because of their requirement to:

• Maximise the utilisation of underground space

• Install a significant new sewerage network in the late 20th century. Japanese made mechanised equipment was imported into Europe in the 1980‘s where it was appreciated and the principles copied. Throughout the 1990‘s a number of other manufacturers became established in Asia, Europe and USA. Microtunnelling is now established worldwide with several hundred kilometres of microtunnelled pipeline being installed annually using the principle.

The Techniques

Micro tunnelling can be broken into two broad techniques:

• Auger based (also known as the pressure balance UPP) systems

• Slurry systems

Auger Systems employ an open tunnel machine head with a cutter that feeds into a screw conveyor. This transports the –spoil‖ material from the head to the exit shaft or into another conveyancing method. Auger Systems may offer the following advantages:

• They may be simpler (less costly) to manufacture

• In ideal ground conditions (typically clays and non granular materials) they may operate faster

• They may offer greater flexibility permitting the installation of different pipe diameters using the same machine.

Slurry systems employ a cutter head in a tunnel machine that is sealed against any penetration by liquid or solids. Typically a crusher chamber will texturise the excavated ground so that it can be carried away from the head of the machine through a sealed pumped slurry network. This delivers the spoil outside of the tunnel. Slurry systems may offer the following advantages:

•The crusher may offer a larger range of soils through which they can tunnel

• They can operate more easily below ground water

•They may operate over a longer distances employing intermediate discharge pumps

•Using flexible hoses they offer the ability to pipe jack on curved alignments.

Any microtunnelling operation commences with the sinking of a shaft to access the tunnel horizon. Within this shaft a jacking frame is installed which will initially pushed the machine into the ground. Thereafter it continues to push

pipes into the ground behind the machine thereby both propelling the machine and lining the tunnel. This process continues until arrival at an exit shaft.

The pipes that are utilised must be designed to accommodate:

• The permanent loading of ground

• The liquid pressure inside and outside the pipeline

• The installation jacking pressures.

Pipes are typically made from:

• Concrete

• Polymer concrete

• GRP (or FRP)

• Steel

• Clay or ceramic Due to the installation loads, the design of joints are critical for jacking pipes. Frequently the highest loads are at misaligned pipe joints.

The remote-controlled tunnelling machine is operated and guided from the outside of the tunnel. This is frequently at ground level from a control cabin but also occasionally from within the shaft. The operator controls issues such as:

• Steering of the machine

• Cutter head rotation direction

• Cutter head pressure

• Cutter head torque

• Auger flight controls

• Slurry pressures

• Volume of slurry flow

• Jacking pressures in the rams

Alignment of the tunnel results from the steering of the Microtunnelling machine. This is frequently monitored and controlled using a laser that is shone the length of the installed tunnel. There are also other sophisticated steering control methods using computers for dynamic positioning calculations.

Common Applications Microtunnelling is used generally where there are constraints on trench excavation. These might include:

Installation being carried out in an urban environment

• Installation underneath an obstruction such as a river, motorway or rail lines

• Installation at a depth at which trenching is not a commercial or technically viable alternative.

Micro tunnelling is widely employed for the installation of all types of utilities including

•Water pipelines

•Sewerage pipelines

•Storm water pipelines

•Gas pipelines

•Electricity cable ducts

•Telecommunication cable ducts

•Oil pipelines

It is also employed for some sophisticated ground support operations such as for the installation of pipe arches. These consist of steel or concrete pipelines installed adjacent to one another (often ―clutched‖ together) in order to provide support under which an excavation can be made.

Using the Microtunnelling principle pipes may be installed from 200 mm diameter up to in excess of 2500 mm diameter.

Cost Issues

Costs frequently play an important part in the determination of whether Microtunnelling is employed. Perceived additional costs attaching to Microtunnelling include:

•The cost of the sophisticated equipment

•The additional cost of highly skilled operatives

•The higher cost of jacking pipe compared to conventional pipe.

In balance to these additional costs Microtunnelling offers the following potential savings:

•Micro tunnelling at depth may not be much more expensive than at shallow depth (trenching increases in cost as depth increases)

• Microtunnelling may save cost for the reinstatement of roads or buildings adjacent to a trenchexcavation.

- Microtunnelling may offer reduced safety costs
- Microtunnelling reduces the cost of spoil cart away
- Microtunnelling reduces the cost of imported backfill materials

In general the greater the obstacle to trenching, the more competitive Micro tunnelling might be. Micro tunnelling might be viewed as a competitive alternative to trenching at depths exceeding 2.5 to 4 m. In addition to the direct cost advantages that might accrue to Microtunnelling, there are also frequent social cost benefits. These are due to the reduced disruption caused by Microtunnelling compared with conventional installation

UNIT 8

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:

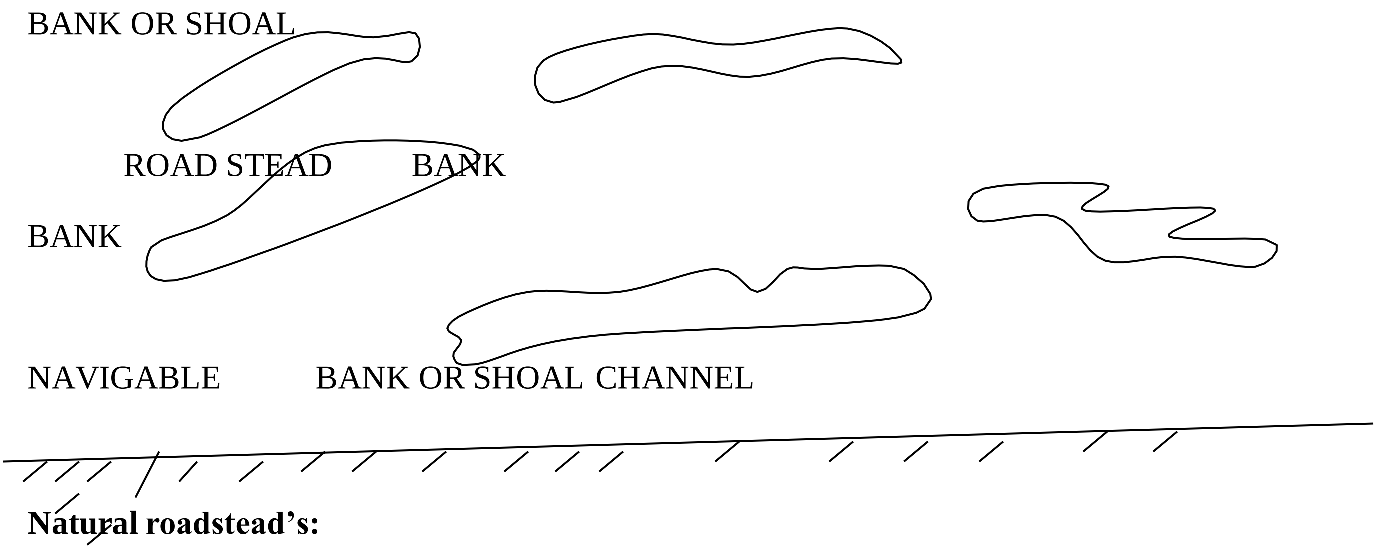
- Natural formations affording safe discharge facilities for ships on sea coasts, in the form of creeks and basins, are called natural harbours.
- With the rapid development of navies engaged either in commerce or war, improved accommodation and facilities for repairs, storage of cargo and connected amenities had to be provided in natural harbours.
- The size and draft of present day vessels have necessitated the works improvement for 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 harbours are called artificial or man-made harbours.
- Madras is an artificial harbour.
- Thus, a naval vessel could obtain shelter during bad weather within a tract or area of water close to the shore, providing a good hold for anchoring, protected by natural or artificial harbour walls against the fury of storms.



Natural roadstead's:

- A deep navigable channel with a protective natural bank or shoal to seaward is a good example of a natural roadstead

Artificial roadsteads:

- These may be created suitably by constructing a breakwater or wall parallel to the coast or curvilinear from the coast
- As an alternative a circumscribed artificial roadstead could be formed by enclosing tract provided good anchorage, by projecting solid walls called jetties, from the shore.
- Another method is to create a confined basin of small area having a narrow entrance and exit for ships.
- Such roadsteads with smaller inner enclosures and wharf and with loading and unloading facilities are commonly provided for fishing vessels.

From their utility and situation, harbours are further classified into three major types:

- Harbours of refuge including naval bases
- Commercial harbours, connected with ports
- Fishery harbours.

It is necessary to study the requirements of these types of harbours and provide for such requirements. Requirements of harbour of refuge:

•Ready accessibility

• Safe and commodious anchorage

•Facilities for obtaining supplies and repairs

Requirements of commercial harbour :

- Spacious accommodation for the mercantile marine.
- Ample quay space and facilities for transporting; loading and unloading cargo.
- Storage sheds for cargo.
- Good and quick repair facilities to avoid delay.
- More sheltered conditions as loading and unloading could be done with advantage in calmer waters.

Accessibility and size of harbours

•Accessibility depends on the location of the harbours.

•The harbour entrance should be designed and located for quick easy negotiation by ships, overtaken by storms.

•At the same time, it should be narrow enough not to expose the harbour to the effects of the stormy sea.

•Maximum dimensions upto 180 have been adopted

•The entrance is generally placed of the sea, with a passage to the interior of the harbour so arranged as to minimize the effect of rough seas.

Thus; the size is determined by:

- Accommodation required.
- Convenience for maneuvering and navigation.
- Adaptability to natural features.

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

Harbour planning:

- The important facts to be studied and scrutinized can be enumerated as follows:
- It is necessary to carry out a thorough survey of the neighbourhood including the foreshore and the depths of water in the vicinity
- The borings on land should also be made so as to know the probable subsurface conditions on land. It will be helpful in locating the harbour works correctly
- The nature of the harbour, whether sheltered or not, should be studied.
- The existence of sea insect undermine the foundations should be noted.
- The problem of silting or erosion of coastline should be carefully studied.
- The natural metrological phenomenoa should be studied at site especially with respect to frequency of storms, rainfall, range of tides, maximum and, minimum temperature and of winds, humidity, direction and velocity of currents, etc.

Ports :

- 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.

Classification of ports:

Depending upon the location, the ports can be classified as;

•Canal ports

•River ports and

•Sea ports

- 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.

Waves and wind:

- The ‗sea wave' is by far the most powerful force acting on harbour barriers and against which the engineer has to contend.
- The wave has the impulse of a huge battering ram and equipped with the point of a pick axe and chisel edge‖.
- It is the most in compressible natural phenomena.
- The formation of storm waves takes place in the open sea due to the action of wind.

Water waves are of two kinds:

• Waves of oscillation and

•Waves of translation;

The former are stationary, while the latter possess forward motion.

But all translatory waves originally start as waves of oscillation

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:

• Chara cter of coasta l curre nts

• Co st and avai labil ity of mater ials of con struct ion

• Dire ction s and forc e of pr evai ling winds

• Natur e of the bot tom or fou ndation

• Probab le maxi mum he ight, forc e and intens ity of waves. !

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

- The design should be based on the extreme phenomena of the wind and waves, and not on the mean or the average.
- The height of the wave should he determined by Using the equation H = 034¥Fand the height of wall should be decided accordingly by making sufficient allowance for freeboard.
- It should be seen that the material in the foundation is not subject to scour.

Detrimental forces acting on breakwaters:

Hydrostatic force:

• This force reduces the apparent weight and hence, the marine structures suffer these losses to a great extent unless the foundations are absolutely impervious.

External forces:

• The intensity of external forces, especially wind and wave action, is enormous.

• The power of wind produces vibrations in the masonry structure and weakens the different courses of masonry.

• In a similar way, the wave when it recedes induces _suction action and it results in the erosion of the foundation unless it is made safe and secure.

Solvent action of sea water:

• This quality of sea water causes damage to the materials of construction Sea insects:

• The concentrated action of sea insects results in the undermining of the hardest and the soundest building material and it is for this reason that the marine structures are made specially bulky and strong.

Classification of breakwaters:

Breakwaters are classified mainly into three types:

- Heap or mound breakwater
- Mound with superstructure
- Upright wall breakwater.

Heap or mound breakwater

- It is a heterogeneous assemblage of natural rubble, undressed stone blocks, rip rap, supplemented in many cases by artificial blocks of huge bulk and weight, the whole being deposited without any regard to bond or bedding.
- This is the simplest type and is constructed by tipping or dumping of rubble stones into the sea till the heap or mound emerges out of the water, the mound being consolidated and its side slopes regulated by the action of the waves.
- The quantity of rubble depends upon the depth, rise of tides and waves and exposure.
- On exposed sites, the waves gradually drag down the mound, giving it a flat slope on the sea face.
- As far as possible, such flattening has to he protected.
- The disturbing action of the waves is the most between the high and low water levels.
- Consequently, all protective methods are adopted above the low water level.
- Protection is also very necessary to the top of the mound and outer or exposed face.

WHARVES

- Platforms or landing places are necessary for ships to come, close enough to the shore, for purposes of embarkation, disembarkation, etc. at the same time.
- These platform locations should give sufficient depth of water for the ship to float.
- Such platforms are, called wharves.
- They are built out into or on to. the water

- Thus, a wharf affords a working platform alongside the ship in continuity of the shore.
- A wharf is quay but the term wharf is generally used for an open structure of piles or posts with bracings, jutting from the shore towards the sea.
- A wharf may be a sheet pile wall or it may consist of a piled projection with or without artificial retention of soil some distance behind or it may be a gravity wall.
- Wharves may either be parallel to the shore and abutting against it or they mayproject into the water either at right angles or oblique to the shore.
- The former type is adopted at places where depth of water is sufficient for the ships to berth, say 10 m to 12 m
- The latter type is adopted at places where depth of water near the shore is not enough for the ships to enter safely.
- The level of wharf should be above the high water level. But at the same time, it should be economical to load the vessels when the water level is low.
- Wharf should act as a unit when there is an impact from any vessel.
- Hence, it should be properly braced and bolted. It is desirable to provide rounded corners for wharves which art likely to be used by large vessels.
- Such a construction will result in a smooth entry of vessels into the slips

PIERS

- The structures which are built perpendicular or oblique to the shore of a river or sea are known as piers.
- In the sea the piers are constructed where the sea is not deep and the natural harbour is not convenient for allowing the ships to berth adjacent to the shore.
- In many cases, the piers are constructed with piles, columns and braces leaving good space for the ocean current to flow without causing any obstruction.
- The dimensions of a pier should be worked out very carefully.
- Its length should be sufficient to accommodate the longest ship likely to take its advantage.
- In other words, it should project beyond the bow or stern of the ship so as to protect its hull. Its width should be sufficient to satisfy its utility.

- It can be stated that the pier should be of sufficient width to allow easy unloading of cargo without any undue delay.

JETTIES :

- These are the structures in the form of piled projections and they are built out from the shore to deep water and they may be constructed either for a navigable river or in the sea.
- In rivers, the jetties divert the current away from the river bank and thus, the scouring action is prevented.
- As the current is diverted to deep waters, the navigation is also controlled.
- In the sea, the jetties are pr at places where harbour entrance is affected by littoral drift or the sea is shallow for a long distance.
- Thus, they extend from the shore to the deep sea to receive the ships.
- In a limiting sense, a jetty is defined as a narrow structure projecting from the shore into water with berths on one or both sides and sometimes at the end also.
- Jetties are exposed to severe wave action and their structural design is similar to that of breakwater.
- However, the designed standards may be released to a certain extent due to the fact that the jetties are usually built normal to the most dangerous wave front.
- The impact caused by the berthing ships will depend on the skill of the berthing officer, local condition of currents, wind, etc.
- The berthing velocity depends upon the condition of approach, wind, etc. and it decreases with the increase in the size of the ships

FENDER:

- The cushion which is provided on the face of jetty for ships to come in contact is known as fender.
- It is provided for various forms and is made of different materials.
- The common material used as fender for jetties is the framework of timber pile driven into the sea bed at a short distance from the jetty and filling the space with coiled rope, springs, rubber, buffers, etc.
- The fender system controls the relative motion between dock and ship caused by wind and waves.

- Hence, it also prevents the paint of ships being damaged. For the purpose of classification, the fenders can be classified in the following four categories: 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:

- It is a lofty structure popularly built of masonry or reinforced concrete in the shape of a tall tower on a high pedestal.
- The tower is divided into convenient number of floors, the topmost floor containing powerful lighting equipment and its operating machinery.
- The lower floors are used, as stores and living rooms necessary for the maintenance and working of the light station.
- The main parts of a typical lighthouse tower are illustrated in fig.
- Lighthouses may be located on shore or on islands away from the mainland as in the case of warning light stations.
- In the former case, the lighthouse may be easily connected with the nearest village or township by proper communications, while in the later situation it is located far habited area.
- In either case as a matter of convenience and urgency, all the requirements for the efficient and unfailing maintenance and working of the lighthouse, like stores and staff quarters are provided in the lighthouse shaft.

Lighthouse construction :

- It is quite evident that the type of foundation to be adopted for a particular situation will depend on the characteristics of soil of that area.

- On good rock or hard soil, a thick bed of concrete may serve while on submarine or marshy locations, piles or caissons could be used.
- The superstructure is generally a masonry or an R.C.C tower constructed on a prominent basement.
- The stone or concrete blocks used in the construction of the basement are joggled both vertically and horizontally as shown in fig.
- To secure and bind the blocks together and resist strongly forces tending to dislodge or move them.
- The tower is divided into a number of floors and the light is housed at the summit in a glazed room.
- The floors are accessible by a flight of winding stairs from bottom to top.
- Just below the lantern room is the service room and other rooms lower down are used for oil and general stores, personnel, and other accessories like water storage and fire fighting apparatus.
- A narrow gallery is provided outside the lantern room protected by pipe railing.
- The dimensions and geometrical shapes shown in the figure are adopted in modern practice and more recent lighthouse like the Eddystone are examples of this type of construction.
- The light should be identified and its distance ascertained, for the mariner to locate his position.
- These lights are made ‗fixed' or flashing for easy identification by the navigator and are classified accordingly to their illuminating power.
- The height of the tower above sea level determines the geographical range and the intensity or power of the light the luminous range.
- These two are important factors, deciding the range of visibility.
- The illumination is both refracted through powerful lenses and prisms and reflected or flashed by highly polished hyperbolic concave mirrors fig.shows the details of the light apparatus.
- Fixed lights are likely to be confused with the private lights of the neighbourhood and hence, it is desirable to avoid fixed lights as far as possible.

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

Requirements of a signal

- It should be conspicuously visible, from a long distance.
- It should not vary in character and should be positively recognizable.
- It should be simple for identification.

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.

Light ships:

• Small ships displacing about 500 tonnes are used for this purpose.

• The lantern is carried on an open steel tower approximately 9 m to 12 m above the water level and erected amidships.

• 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.

• The ship is with service personnel and is securely anchored or moored.

• light ships are more stable and the lights in them more steady which is an important factor for a mariner.

• The hulls of light ships are built of steel and they are generally painted with red colour.

•The name of the station is painted in white colours on both sides of light ship.

•The superstructures are also provided with white colours.

• The storm warning signals are also installed on the light ships.

•When the light ships are being overhauled, red colour relief light ships with the word ‗Relief' on the sides are used.

Beacons:

• Any prominent object, natural or artificially constructed, easily indentifiable 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.

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.

• They are useful in indicating approach channel widths, two rows of buoys being used one along each boundary.

•These buoys are denominated _Star board-hand‘ or _port-hand‘ buoys according to their positions being to the left or right of the navigator respectively as he approaches the harbour.

•Buoys are of different designs and patterns. They are designed not only to support their own weight, but also the weight of cables or chains by which they are moored.

• The surface of buoy structure near water line should be protected by the provision of stout wooden fendering so that it is not seriously damaged in case of an impact.

•Thus, buoys are floating signals and they are usually prepared of steel and iron plates of minimum thickness 6 nun. Buoys are hollow structures and they are constructed in two watertight sections so that in case one of them is leaky, at least the other one may prevent it from sinking.

•The maxi mum distance between consecutive buoys is about 16Q0 m in estuaries and in narrow channels, it is about 150 m to 300 m.

• The diameter of a buoy varies from 1 80 m to 3 m.

• In tidal places, the depth of water is liable to fluctuation and hence, in such cases, the buoys are not steady and they do not give correct guidance regarding alignment.

• The presence of buoys also indicates the proximity of places with shallow depth of water.

• Buoys are also classified according to their size, shape, colour, weight, purpose, etc. Brief descriptions of buoyage system, mooring buoys and wreck buoys are given below.

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

Fog signals: These signals are to be provided at places likely to be seriously affected by fog and they take the following forms:

- Ordinary bells struck by hand.

- Ordinary bells operated by mechanism.
- Submarine bells struck by mechanism.
- Whistles or sirens blown by compressed air or steam.

Audible signals:

- These signals are to be used in emergency to bring immediate attention of the mariners and they take up the form of explosive signals, electric oscillators, sirens, bells and diaphones.
- Thus, audible or sound signals are very useful during heavy mists or fogs. It should also be noted that sound transmitted through the air gives sometimes the misleading idea about the direction of sound.