LECTURE NOTE

RAILWAY AND BRIDGE ENGINEERING

5TH SEMESTER

Diploma (Civil Engineering)

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Chapter-1

INTRODUCTION

Transportation is regarded as an index of economic, social and commercial progress of a country. The transport industry, which undertakes nothing more than mere movement of persons and things from one place to another has constituted one of the most important activities of men in every stage of advanced civilization. No country can ever flourish if it lacks adequate transport facilities.

The first public railway in the world was opened to traffic on 27 September 1825 between Stockton and Darlington in the UK. The first railway in Germany was opened from Nuremberg to Furth in 1835. The USA opened its first railway line between Mohawk and Hudson in 1833.

The first railway line in India was opened in 1853. The first train, consisting of one steam engine and four coaches, made its maiden trip on 16 April 1853, when it traversed a 21-mile stretch between Bombay (now Mumbai) and Thane in 1.25 hours. Starting from this humble beginning, Indian Railways has grown today into a giant network consisting of 63,221 route km and crisscrossing this great country from the Himalayan foothills in the north to Cape Comorin (Kanyakumari) in the south and from Dibrugarh in the east to Dwarka in the west.

1.1 : RAILWAY TERMINOLOGY:

The commonly used terms in Railway Engineering includes:-

Railway Engineering: Railway Engineering is that branch of civil engineering which deals with the construction and maintenance of the railway tracks for safe and efficient movement of trains on it.

Rails: Rails are steel girders which provide the hard and smooth surface for movement of wheels of a locomotive and railway vehicles.

Sleepers: Sleepers are the members laid transversely under the rails which are meant to support the rails over them and transfer the load from rails to ballast.

Gauge: The gauge of a track is the minimum distance between the inner running faces of the two rails.

Metre Gauge: The gauge of a track in which distance between the running faces of two track rails is one metre is called Metre Gauge.

Broad Gauge: The gauge of a track in which distance between the inner running faces of the two rails is 1.676 metres is termed as Broad Gauge.

Narrow Gauge: The gauge of track in which the distance between the running faces of two rails is 0.762 metre is known as Narrow Gauge.

Railway Track: Railway track is the structure provided by rails fitted on sleepers, resting on ballast and subgrade for passage of wheels.

Bearing Plates: To reduce the intensity of pressure, particularly on soft variety of sleepers, a rectangular plate of mild steel or cast iron is introduced between the rails and sleepers. This plate is known as Bearing Plate. This plate distribute the loads on large area.

Ballast: Ballast is the granular material packed under and around the sleepers to transfer loads from sleepers to ballast. It helps in providing elasticity to the track.

Coning of wheels: The wheels are coned at a slope of 1 in 20 to prevent from rubbing the inside face of the rail head and to prevent lateral movement of the axle with its wheels. This is known as coning of wheels.

Creep of rails: Creep is the longitudinal movement of rails in a track. The effect of creep tends to drag the track if the ballast are insufficient to hold the rails.

Guard rails: Guard rails are extra rails provided over bridges to prevent damage and danger in case of derailment occurring on the bridge.

Embankments: The raised structure above the ground level for carrying the railway track is called embankment. When the height of the embankment is more, the side slopes are stepped for better stability of slopes.

Hogged rails: Those rails which get battered due to impact of wheels over the end of the rails are called hogged rails. These rails are get bent down and deflected at the ends.

Gradient: Any departure of the railway track from

The level is known as grade or gradient. It is called up gradient when the track rises in the direction of motion, and a down gradient when track falls in the direction of motion.

Fish plates: These plates resembling in shape to a fish, are used to provide the continuity between the two rails at the rail-joints. They also provide the required gap for expansion and contraction of rails due to temperature variations.

Locomotive: It is a machine which transfers chemical energy of fuel in mechanical energy of motion. Fuel may be water and coal or diesel or electricity.

Level crossing: When the railway line and a road cross each other at the same level, it is called level crossing.

Momentum Gradient: It is rising gradient, which takes advantages of falling gradient in developing the momentum and kinetic energy, tp negotiate this rising gradient.

Permanent Track: It is the track which is permanent nature and handles the normal commercial traffic for which it is meant. It is also called permanent way.

Points and crossings: Points, crossings, cross-overs and turnouts, etc. are arrangements by which different routes either parallel or diverging are connected to afford for the train to move from one track to another.

Pusher Gradient: The gradient which requires one or more additional locomotives for hauling the load over the rising gradient is called a pusher gradient.

Ruling Gradient: It is the maximum rising gradient which is provided keeping in view the power of the locomotives.

Railway Track: Railway track is the structure provided by rails fitted on sleepers, resting on ballast and subgrade for passage of wheels.

Sleeper Density: Sleeper density represents the number of sleepers per rail length in meters.

Track circuit: The length of track, which is connected by electric circuit to signal cabin, block telegraph apparatus, etc. required for indication of light or bell, is called a track circuit.

Turnouts: A complete set of points and crossing with the intervening lead rails is called a Turnout.

Derailment: Derailment occurs when moving wheels of a train or bogie get out of the rails. It causes by an accident and often results in loss of lives of property damages.

Super elevation or cant: On curves, to counter act the effect of centrifugal force, the level of outer rail is raised above the inner rail by a certain amount. This raising of outer rail over the inner rail is called super elevation or cant.

Cant deficiency: The equilibrium cant is provided on the basis of the average speed of different trains on the track. This equilibrium will fall short of that required for speeds higher than average speed. This shortage of can is called cant deficiency.

Buckling of rails: The railway track gets out of the original position due to buckling if the expansion of rails due to rise in temperature is prevented during hot weather. This is known as buckling due to rise in temperature.

Packing: The process of ramming the ballast underneath the sleeper is known as packing.

Wear of rails: Due to movement of very heavy loads at high speeds, the concentrated stresses often exceed the elastic limit of metal, resulting the metal flow. This flowed materials of rails is chipped off by the striking of wheels. The rail is them called worn out rail and this happening is called wear of rails.

1.2: ADVANTAGES OF RAILWAYS:

Railways have brought about many political, social and economic changes in the life of Indian people.

(a) Political advantages:

(i) Railways have united the people of different castes, religions customs and traditions.

(ii) With the adequate network of railways, the central administration has become more easy and effective.

(iii) Railways have contributed towards development of a national mentality in the minds of people.

(iv) The role of railways during emergencies in mobilizing troops and war equipment has been very significant.

(v) Railways has helped in the mass migration of the population.

(b) Social advantages:

(i) The feeling of isolation has been removed from the inhabitants of the Indian people.

(ii) By travelling together into the compartment without any restriction of caste, the feeling of caste difference has disappeared considerably.

(iii) The social outlook of the masses has been broadened through railway journeys.

(iv) Railway has made it easier to reach places of religious importance.

(v) Railways provide a convenient and safe mode of transport for the country.

(c) Economic Advantages:

(i) Mobility of people has increased, there by congested areas can be relieved of congestion and the sparsely populated areas can be developed.

(ii) Mobility of labour has contributed to industrial development.

(iii) During famines, railways has played the vital role in transporting food and clothing to the affected people.

(iv) Growth of industries has been promoted due to transportation of raw materials through railways.

(v) Railways provide employment to millions of people and thus solving the problem of unemployment in the country.

(vi) Trade developed due to railways thereby has increased the earnings and standard living of Indian people.

(vii) Due to mobility of products through railways, the price stabilization of commodities could be possible.

(d) Techno-Economic Advantages:

(i) Cost saving in transportation of long haul bulk traffic.

(ii) Energy-efficiency (iii) Environment friendliness.

(iv) Higher safety.

(v) Efficient land use and ease in capacity expansion.

1.3: Classification of Indian Railways:

(A) Classification based on importance of route, traffic carried and maximum permissible speed on the routes.

1. Trunk routes
2. Main lines
3. Branch lines

1. Trunk routes: The standards of trunk routes includes:-

ITEMS	B.G	M.G
Maximum permissible speed	120 km.p.h	80 km.p.h
Rail section	52 kg/m	37.5 kg/m
Sleeper density	n+7	n+7
Ballast cushion	25 cm below sleeper	25 cm below sleeper
Design speed for new track	160 km.p.h	100 km.p.h
Example	1. Delhi-MughsaraiHowrah	1. LucknowGorakhpur-Guwahati
	2. Delhi-kotaMumbai 3. Delhi-Jhansi-Nagpur-Chennai 4. Howrah-BagpurMumbai 5. MumbaiGuntakul-Chennai 6. Howrah-VijayawadaChennai	2. DelhiJaipur-Ahmedabad 3. ChennaiMaduraiTrivandrrum

2. Main lines: All lines other than trunk routes carrying 10 Gross Million Tonnes (GMT) per annum or more for B.G and 2.5 G.M.T or more for M.G. or where maximum permissible speed allowed is 100 km.p.h for B.G and 75 km.p.h for M.G. are classified as main lines.

ITEMS	B.G	M.G
GMT/annum	≥ 10	≥ 2.5
Maximum permissible speed	100 km.p.h	75 km.p.h
Rail section	52 kg/m	37.5 kg/m
Design speed for new track	120 km.p.h	75 km.p.h

3. Branch lines: These are classified on the basis of following criteria:

   All those B.G lines which carry less than 10 GMT per annum and have max. Permissible speed of less than 100 km.p.h are classified as Branch lines.

   For M.G tracks, all those lines which carry less than 2.5 GMT per annum and have max. Permissible speeds less than 75 km.p.h are classified as Branch lines.

(B) Classification based on speed criteria:

According to this B.G railway lines are classified into 5 groups:-

1. ***Group 'A' lines*****:** They consists of those trunk routes on which the trains are running or are meant for running the trains at a speed of 160 km.p.h or more.

   Example-i. New delhi-howrah by Rajdhani route

ii. New Delhi-Mumbai central iii.

New Delhi-Chennai central iv.

Howrah- Mumbai V.T.

2. ***Group 'B' lines:*** They consists of those routes on which the trains with a maximum sanctioned speed of 130 km.p.h are running or are intended to run. At present nearly 13 routes come under this category e.g., Allahabad to Bhusaval, Kalyan to Chennai, Kharagpur to Vijayawada, Howrah to New jalpariguri, Sitarampur to Mughalsarai, Kiuli to Barharwa, Delhi to Kolkata, Ambala to Pathankot, Ambala to Mughalsarai, Arkonam to Coimbatore, Vadodara to Ahmedabad and Jalanpet to Bangalore.
3. ***Group 'C' lines:*** They consists of all suburban routes of Mumbai, Kolkata and Delhi.
4. ***Group 'D' lines:*** All other routes in the country where maximum permissible speed at present is 100 km.p.h.
5. ***Group 'E' lines:*** The other routes and branch lines where the permissible speed limits are less than 100 km.p.h.

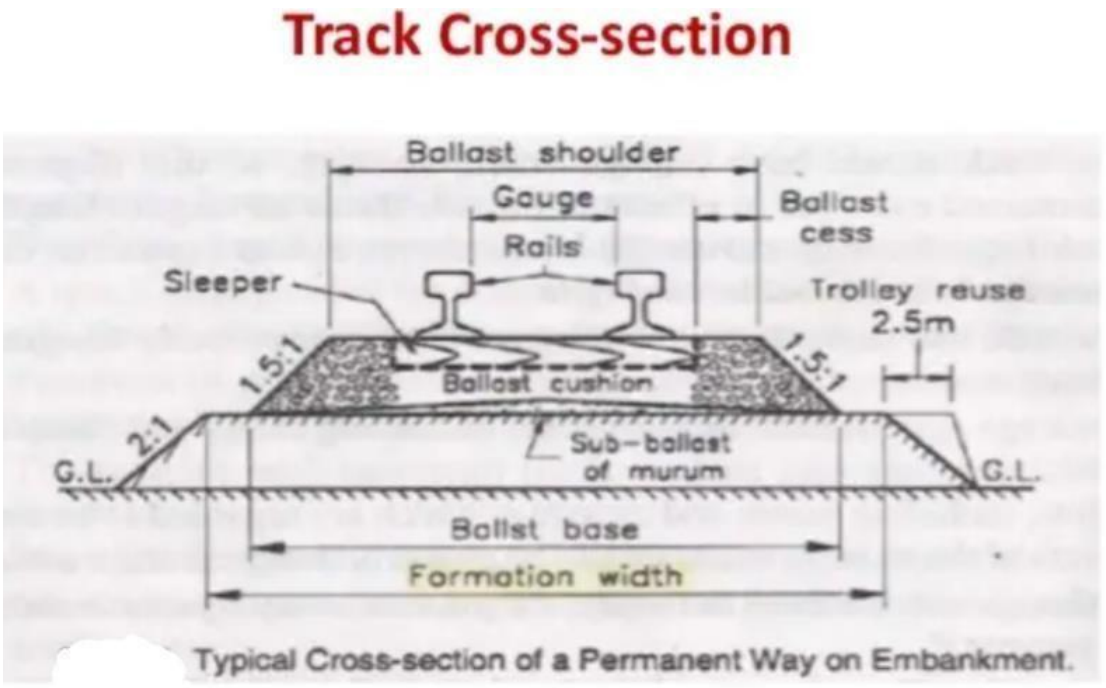
2.1 Definition and components of a permanent way

The combination of rails, fitted on sleepers with the help of fixtures and fastenings and resting on ballast and subgrade is called the railway track or permanent way.

Basically a track consists of two parallel rails having a specified distance between them, known as gauge and fastened to the sleepers. These sleepers are embedded in a layer of ballast of specified thickness, spread over the formation. The rails are joined to each other by fish plates and bolts and the rails are fastened to the sleepers with the help of various fittings such as spikes and keys. The sleepers are spaced at a specified distance and are held in position by embedding in ballast.

A track or permanent way is consisted of the following components:

- Rails
- Sleepers
- Fittings and fastenings
- Ballast
- Formation



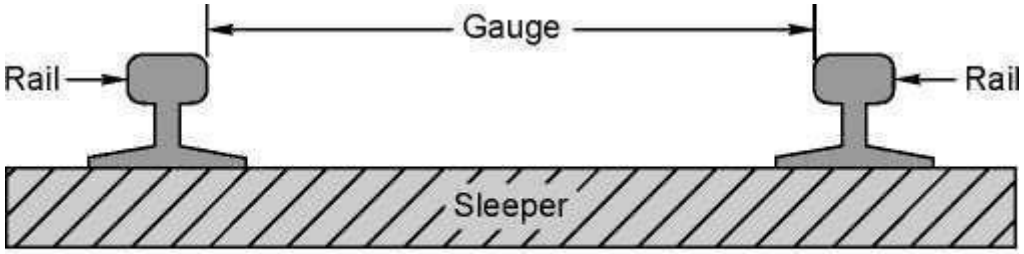
Functions of track components :

- *Rails:* rails are steel girders over which the train moves and transmit the wheel loads of trains to the sleepers below.
- *Sleepers:* The sleepers hold the rails in proper position amd provide a correct gauge with the help of fittings and fastenings and transfer the train load to the ballast below.
- *Ballast:* Ballast holds the sleepers in position and provides a uniform level surface. They also provide drainage to the track and transfer the train load to a larger area of formation below.

- *Fittings and fastenings:* They provide a grip between rails and sleepers. The rails are fastened with the sleepers by fittings and fastenings.
- *Formation:* Formation is the base of the track. It gives a level surface where the ballast rests. It takes the total load of track and the trains move on it.

2.2 Concept of gauge :

The clear horizontal distance between the running inner faces of the two rails forming a track is known as gauge.



Gauge

Different gauges prevalent in India and suitability of these gauges under different conditions:

The different gauges prevalent in India are of the following 3 types:

1. Broad Gauge
2. Metre Gauge
3. Narrow Gauge

Broad Gauge :

When the clear horizontal distance between the inner faces of two parallel rails forming a track is 1676mm (5’ -6"), 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.

Suitability: BG is suitable under the following conditions:

- When sufficient funds are available for the railway project
- When the prospects of revenue are very bright

This gauge therefore was adopted for main cities and routes of maximum traffic intensities.

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.

Suitability : MG is suitable under the following conditions:

- When the funds available for the railway project are inadequate
- When the prospects of revenue are not very bright.

This gauge , therefore, was used for undeveloped areas and in interior areas where trafbrigis very small and development of future prospects aren't very bright.

Narrow Gauge :

When the clear horizontal distance between the inner faces of 2 parallel rails forming a track is either 762mm (2’-6") or 610mm (2’), the gauge is known as narrow gauge.

The gauge of 610mm(2') is also sometimes called feeder gauge

Suitability : NG is suitable under the following conditions :

- When the construction of a track with wider gauge is prohibited due to provision of sharp curves, steep gradients, narrow bridges and tunnels etc.
- When the prospects of revenue aren't very bright.

In hilly regions , where broad and metre gauges aren't possible due to steep gradients & sharp curves & to develop the thinly populated are as by joining the under develop areas with developed / urbanised areas narrow gauges are used.

Long Question

1. Define the political, social & economic advantages of railways?
2. Describe the railway Boards classification based on the importance of route, traffic carried and maximum permissible speed.
3. Definition & components of a permanent way?
   The combination of rails, fitted on sleepers with the help of fixture and fastening's and resting on ballast & subgrade is called the railway track or permanent way.
4. Define gauge of a railway track.

Enumerate different gauges used in India and discuss their suitability at different locations with reason?

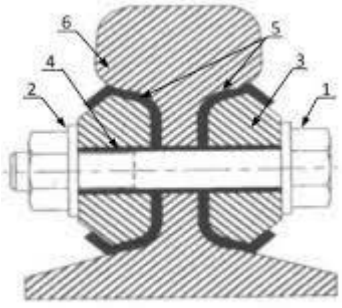
Shorts Notes on

5.**Ballast**: - Ballast is the granular material packed under and around the sleepers to transfer loads from sleepers to ballast. It helps in providing elasticity to the track.

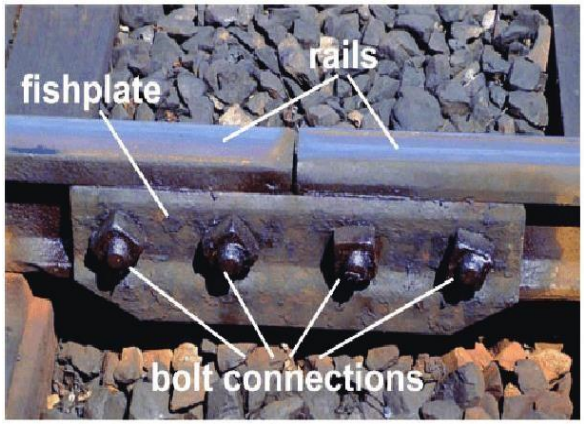
Buckling Rails: The railway track gets out of the original position due to buckling if the expansion of rails. Due to rise in temperature is prevented during hot weather. This is known as buckling due to rise in temperature rails.

Fish plates: Those plates, resembling in shape to a fish, are used to provide the continuity between the two rails at the rail-joints. They also provide the required gap for expansion & contraction of rails due to temperature variations. They are made of steel.

1. **Gauge**: The gauge of a track in India is measured as the minimum distance between the inner running of gauge faces of the two rails.
2. **Joint in rails:** For holding together the two adjoins rail in correct position the rail joints are provided. Joints are the weakest part in the track.
3. **Junction station:** when two or more railway lines meet at a station it is called a junction station. The lines may be of same gauge or of different gauges.



1. Fish Bolt & Nut
2. Backing Plate
3. Fish Plate
4. Ferrule
5. Epoxy (Glue)
6. End Post



Narrow Gauge : The gauge of track in which the distance between the running face of two track railsis either 0.762 meter on 0.61 meter.

1. **Sleeper: -** sleeper are the members laid transversely under the rails over them & tyranny or the load from rails & to ballast.

2.**Train** :- The unit of locomotive & passenger coaches is called a passenger train and unit of locomotive and goods wagons is called a good & train.

Long Question

6.Draw a typical cross-section of a permanent way?

CHAPTER -2 **RAILWAY MATERIALS**

INTRODUCTION

Definition

Railway engineering is a multi-faceted engineering discipline dealing with the design, construction and operation of all types of rail transport systems :

Advantages of railways

Economical aspects:

¬ Due to railways, the industrial development in for off places is possible, increasing the land values & standard of living of the people.

¬ Mobility of labour has contributed to industrial development.

¬ During famines, railways have played the vital role in transporting food &

clothing to the affected areas.
¬ Commercial farming is very much helped by the railway network throughout the country.
¬ Speed movement of the commodities is possible through railways.
Cultural & Social aspects:
¬ Railway has made it easier to reach places of religious importance
. ¬ Railway provides a convenient & safe mode of transport through out the country.
¬ During travel as people of different caste & religions sit together the interaction is developed.
Political aspects:
¬ Railways have helped in the mass migration of the population
. ¬ Railways have created the sense of unity among the people of different religions, areas, castes & traditions.
¬ With adequate network of railways, the central administration has become easy & effective.

PERMANENT WAY

Definition:

A permanent way or a railway track can be defined as the combination of rails, fitted on sleepers and resting on ballast and sub grade

. Components of a Railway Track:

The Typical components are:

1. Rails
2. Sleepers (or ties)
3. Fasteners
4. Ballast (or slab track)
5. Sub grade

Requirements of an ideal permanent way:

- The gauge should be uniform and correct.
- Both the rails should be at the same level in a straight track.
- On curves proper super elevation should be provided to the outer rail.
- The permanent way should be properly designed so that the load of the train is uniformly distributed over the two rails.
- The track should have enough lateral strength.
- The radii and super elevation, provided on curves, should be properly designed. • The track must have certain amount of elasticity
- All joints, points and crossings should be properly designed.
- Drainage system of permanent way should be perfect.
- All the components of permanent way should satisfy the design requirements.
- It should have adequate provision for easy renewals and repairs.

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 rails.
Various Gauges in Indian Railways:
Name of GaugeWidth(m) Broad gauge(BG) 1.676 Meter gauge(MG) 1.00 Narrow gauge(NG) 0.762

1. 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. 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 centres 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). 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) .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

RAILS

Definition:

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.

Functions of Rails:

Rails are similar to steel girders.

They perform the following functions in a track:

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

¬ 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.

¬ They serve as a lateral guide for the wheels.

¬ 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.

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

:**Requirements of an ideal Rail section**

¬ The rail should have the most economical section consistent with strength, stiffness, and durability

. ¬ The centre of gravity of the rail section should preferably be very close to the midheight of the rail so that the maximum tensile and compressive stresses are equal.

¬ 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 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.

¬ 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.

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

Types of Rails:

The rails used in the construction of railway track are of following types:

1. Double headed rails (D.H. Rails)
2. Bull headed rails (B.H.Rails)
3. Flat footed rails (F.F.Rails)

Double headed rails:

The rail sections, whose foot and head are of same dimensions, are called Double headed or Dumb-bell rails. In the beginning, these rails were widely used in the railway track. The idea behind using these rails was that when the head had worn out due to rubbing action of wheels, the rails could be inverted and reused. But by experience it was found that their foot could not be used as running surface because it also got corrugated under the impact of wheel loads. This type of rail is not in use in Indian Railways now-days.

Bull headed rails:

The rail section whose head dimensions are more than that of their foot are called bull headed rails. In this type of rail the head is made little thicker and stronger than the lower part by adding more metal to it. These rails also require chairs for holding them in position. Bull headed rails are especially used for making points and crossings

. **Merits:**

¬ B.H. Rails keep better alignment and provide more smoother and stronger track.

¬ These rails provide longer life to wooden sleepers and greater stability to the track.

¬ These rails are easily removed from sleepers and hence renewal of track is easy

Demerits:

¬ B.H. rails require additional cost of iron chairs.

¬ These rails require heavy maintenance cost.

¬ B.H. rails are of less strength and stiffness

Flat footed Rails:

The rail sections having their foot rolled to flat are called flat footed or vignole`s rails. This type of rail was invented by Charles Vignole in 1836. It was initially thought that the flat footed rails could by fixed directly to wooden sleepers and would eliminate chairs and keys required for the B.H. rails. But later on, it was observed that heavy train loads caused the foot of the rail to sink into the sleepers and making the spikes loose. To remove this defect, steel bearing plates were used in between flat footed rails and the wooden sleeper. These rails are most commonly used in India.

Merits:

¬ F.F. rails have more strength and stiffness.

¬ No chairs are required for holding them in position.

¬ These rails require less number of fastenings.

¬ The maintenance cost of track formed with F.F. rails is less.

Demerits:

¬ The fittings get loosened more frequently.

¬ These rails are not easily removed and hence renewal of track becomes difficult.

¬ It is difficult to manufacture points and crossings by using these rails.

Length of rail:

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. 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.

RAIL JOINTS

Definition:

A rail joint is an integral part of the railway track as it holds together the adjoining ends of rails in correct position, both in horizontal and vertical planes.

Effects of Rail joints:

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.

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 c

¬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

i. Supported Joints
ii. Suspended joints
iii. Bridge joints

Supported joint:

In this type of joint, the ends of the rails are supported directly on a sleeper called as 'joint sleeper'. 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. The duplex sleeper is an example of a supported joint

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 or a corrugated plate known as a bridge plate. This type of joint is generally not used on Indian Railways..

WELDING OF RAILS

Welding is the best joint as it fulfils all the requirements of an ideal rail joint or perfect joint.

Purpose of Welding of Rails:

¬ To increase the length of the rails by joining two or more rails & thus to reduce the no of joints & requirements of fish plates which lead to economy and strength

. ¬ To repair the worn out or damaged rails thus increasing their life.

¬To build up worn out points and rails on sharp curves.

¬ To build up the burnt portion of rail head which is caused due to slippage of wheels over the rails or other defects or spots in rail steel.

Advantages of Welding of Rails:

¬ It satisfies the condition of a perfect joint and hence increases the life of rail as also the reduction in maintenance cost of track by about 20 to 40%. ¬ It reduces the creep doe to increase in length of rail and in turn friction as well

. ¬ It reduces expansion effect due to temperature.

¬ Due to discontinuity of joints, a source of track weakness is reduced

. ¬ It increases the life of rails due to decrease in the wear of rails at joints. ¬ Welded rails provided on large bridges for the span length are helpful as they result in better performance.

¬ The cost of track construction by welding of rails decreases due to les no of joints.

CREEP OF RAILS

Definition:

Creep of rails can be defined as the longitudinal movement of rails with respect to sleepers in a track. 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 centimetres in a month at few places, while at other locations the movement may be almost negligible.

Causes of Creep:

The main factors responsible for the development of creep are as follows. ¬ **Ironing effect of the wheel:**

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

. ¬ **Starting and stopping operations**

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

¬ **Changes in temperature**

Creep can also develop due to variations in temperature resulting in the expansion and contraction of the rail. Creep occurs frequently during hot weather conditions.

¬ **Unbalanced traffic**

In a double-line section, trains move only in one direction, i.e., each track is unidirectional. Creep, therefore, develops in the direction of traffic. In a single-line section, even though traffic moves in both directions, the volume of traffic in each direction is normally variable. Creep, therefore, develops in the direction of predominant traffic.

Poor maintenance of track

Some minor factors, mostly relating to poor maintenance of the track, also contribute to the development of creep. These are as follows:

- Improper securing of rails to sleepers
- Limited quantities of ballast resulting in inadequate ballast resistance to the movement of sleepers
- Improper expansion gaps
- Badly maintained rail joints
- Rail seat wear in metal sleeper track
- Rails too light for the traffic carried on them
- Yielding formations that result in uneven cross levels
- Other miscellaneous factors such as lack of drainage, and loose packing, uneven spacing of sleepers

Prevention of Creep:

The remedies of creep are as follows:

1. Pulling back the rails
2. Provision of anchors or anti creepers
3. Use of steel sleepers

Pulling back the rails:

When creep is in excess of 150 mm resulting in maintenance problems, the same should be adjusted by pulling the rails back. The various steps involved in the adjustment of creep are as follows:

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

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

¬ 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.

¬ 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 a rope, a blow is given to them using a cut rail piece of a length of about 5 m.

Provision of Anchors and anti creepers:

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 is most popular. The creep anchor should fit snugly against the sleeper for it to be fully effective.

Use of steel sleepers:

Sleepers should be of such a type & such fittings that they effectively prevent

the rails from creeping on them. The sleepers must have a good grip with the ballast to resist the movement of the sleepers in the ballast. And steel sleepers are the best for this purpose. Increase in no of steel sleepers will help in the prevention of creep.

SLEEPERS

Definition:

Sleepers are transverse members of the track placed below the rails to support and fix them in position.

Functions of Sleepers:

Sleepers serve the following functions:

¬To hold the rails to proper gauge.

¬To transfer the loads from rails to the ballast.

¬ To support and fix the rails in proper position

. ¬To keep the rails at a proper level in straight tracks and at proper super elevation on curves.

¬To provide elastic medium between the rails and the ballast.

¬To provide stability to the permanent way on the whole.

Requirements of good sleepers:

The following are the requirements of good sleepers:

¬ The sleepers should be sufficiently strong to act as a beam under loads. ¬ The sleepers should be economical.

¬ They should maintain correct gauge.

¬ They should provide sufficient bearing area for the rail.

¬ The sleepers should have sufficient weight for stability.

¬ Sleepers should facilitate easy fixing and taking out of rails without disturbing them.

¬ They should facilitate easy removal and replacement of ballast.

¬ They should not be pushed out easily of their position in any direction under maximum forces of the moving trains.

¬ They should be able to resist impact and vibrations of moving trains.

¬ They should be suitable to each type of ballast.

¬ If track-circuiting is done, it should be possible to insulate them from the rails.

Types of Sleepers:

Sleepers are of the following types:

1. Wooden sleepers.
2. Steel sleepers.
3. Cast iron sleepers.
4. R.C.C. sleepers.
5. Pre stressed concrete sleepers.

1. Wooden Sleepers:

These sleepers are regarded to be the best as they satisfy all the requirements of good sleepers and are the only sleeper suitable for track circuiting. The life of

wooden sleepers depends upon their ability to resist wear, attack by white ants and quality of timber used. Timbers commonly used in India for sleepers are Sal, Teak, Deodar and chair wood. The standard sizes of wooden sleepers for different gauges are as follows: For B.G. – 2740 mm X 250 mm X 130 mm For M; .G. – 1830 mm X 203 mm X 114 mm For N.G. – 1520 mm X 150 mm X 100 mm

Advantages:

¬ Timber is easily available in all parts of India.
¬ Wooden sleepers are suitable for all types of ballast.
¬ Wooden sleepers require less fastening and simple in design.
¬ These sleepers give less noisy track.
¬ These sleepers absorb shocks and vibrations more than any other sleepers.
¬ These sleepers are best suited for track circuiting.

Disadvantages:

¬ The life of wooden sleeper is less as compared to other types of sleepers.
¬ It is difficult to maintain gauge of the track in case of wooden sleepers. ¬ These sleepers are subjected to wear, decay, and attack by white ants etc.
¬ Track laid over wooden sleepers is easily disturbed.
¬ Maintenance cost is more as compared to other sleepers.

2.Steel Sleepers:

These sleepers consist of steel troughs made of 6 mm thick sheets, with its both ends bend down to check the running out of ballast. At the time of pressing of sleepers, an inward slope of 1 in 20 on either side is provided to achieve required tilt of rails. The standard length of these is 2680 mm.

Advantages:

¬ Steel sleepers are light in weight and can be handled easily.
¬ These require fewer fastenings.
¬ The life of steel sleepers is more than the wooden sleepers.
¬ The gauge can be easily maintained and adjusted.
¬ The scrap value is more than the wooden sleepers.
¬ The track laid on steel sleepers has good lateral and longitudinal rigidity.
¬ Creep of rails can be checked by using steel sleepers.

Disadvantages:

¬ Initial cost of these sleepers is more than wooden sleepers.
¬ Cracks are developed at rail seat of these sleepers.
¬ Steel sleepers are not suitable for track circuiting.
¬ These are not suitable for all types of ballast.
¬ These are liable to corrosion.

3.Caste Iron Sleepers

The sleepers made of cast iron, known as cast iron sleepers, have been extensively used in India as compared to other countries in the world.

Advantages:

¬ The life of C.I sleepers is more.
¬ The maintenance cost of these sleepers is low.
¬ Gauge can be easily maintained and adjusted with these sleepers.
¬ These sleepers are more durable.
¬ Creep rails can be checked by using these sleepers.

Disadvantages;

¬ More ballast is required than any other type of sleepers.
¬ The number of fittings required is more
. ¬ These sleepers are liable to break.
¬ C.I. Sleepers are liable to break.
¬ These are not suitable for all types of ballast.

4. R.C.C. Sleepers:

Reinforced cement concrete sleepers are of two types:

(i) Through type
(ii) Block and tie type

Through type R.C.C. Sleeper:

This is also known as one piece or mono-block sleeper. In this type of sleeper cracks develop on the tension side when stressed. These cracks are very small and almost invisible but tend to enlarge with the repetition of impact loading, causing failure.

Block and tie type R.C.C. Sleeper:

This type of sleeper consists of two R.C.C. blocks connected by a metal tie of invertedTsection. These sleepers are not subjected to any degree of tensile stress as in through type.

Advantages:

¬ Concrete sleepers have long life, generally 40to 60 years.
¬ These are free from natural decay and attack by insects etc.
¬ These sleepers require less fittings
. ¬ Track circuiting is possible in these sleepers.
¬ These sleepers provide more lateral and longitudinal rigidity as compared to other sleepers.
¬ The maintenance cost is low.
¬ Due to higher elastic modulus, these can withstand the stresses due to fast moving trains.

Disadvantages:

¬ Due to heavy weight, handling and transportation of these sleepers are difficult.
¬ If not handled properly, the chance of breaking is more.
¬ The renewal of track laid with these sleepers is difficult.
¬ The scrap value is nil.

5. Pre stressed Concrete Sleepers:

Pre stressed concrete sleepers are now-a-days extensively used in Indian Railways. These sleepers have high initial cost but are very cheap in long run due to their long life. In these sleepers, high tension steel wires are used. These wires are stretched by hydraulic jack to give necessary tension in the wires. The concrete is then put under a very high initial compression. These sleepers are heavily damaged in case of derailment or accidents of trains.

BALLAST

Definition:

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

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.

Requirements of good ballast:

¬ It should have sufficient strength to resist crushing under heavy loads of moving trains.

¬ It should be durable enough to resist abrasion and weathering action.

¬ It should have rough and angular surface so as to provide good lateral and longitudinal stability to the sleepers.

¬ It should have good workability so that it can be easily spread of formation. ¬ It should be cheaply available in sufficient quantity near and along the track. ¬ It should not make the track dusty or muddy due to its crushing to powder under wheel loads.

¬ It should allow for easy and quick drainage of the track.

¬ It should not have any chemical action on metal sleepers and rails.

Types of Ballast:

In India, the following materials are used as ballast.

1. Broken stone
2. Gravel
3. Sand
4. Ashes or Cinders

5. Kankar
6. Moorum
7. Blast furnace slag
8. Brick ballast
9. Selected earth

LONG QUESTIONS

1.What is permanent way? Describe the components of a permanent way?
2.what is gauge?describe different types of gauges?
3.what is the function of rails?define different type of rail sections?
4.what is rail joint?describe different types of rail joints?
5.what is the cause of creep?what is its prevention?
6.what is the function of sleepers?what is its requirements?
7.classify different types of sleepers and its advantages and disadvantages?
8.what is the function and requirement of ballast?

FIXTURES AND FASTENING

CHAPTER-3

Definition:

Fixtures and fastenings are fittings required for joining of rails end to end andalso for fixing the rails to sleepers in a track.

Functions of Fixtures and Fastenings:

Rail fixtures and fastenings have the following functions:

To join the rails end to end to form full length of track

.¬ To fix the rails to sleepers

.¬ To maintain the correct alignment of the track.

¬ To provide proper expansion gap between rails

.¬ To maintain the required tilt of rails.

¬ To set the points and crossings in proper position.

Types of Fixtures and Fastenings:

Fixtures and fastenings commonly used in a permanent way are of followingtypes:

1. Fish plates
2. Bearing plates
3. Spikes
4. Chairs
5. Bolts
6. Keys
7. Anti creepers

Fish Plates:

Fish plates are used in rail joints to maintain the continuity of the rails. Two typesof fish plates are commonly used on Indian Railways for joining F.F. and B.H. rails,each fish plate is 457 mm long and provided with four holes 32 mm dia. at a spacing of 114 mm c/c. These are manufactured of steel and are so designed thatthey fit in between the head and foot of the rail.

Bearing Plates:

Bearing plates are cast iron or steel plates placed in between the F.F rail and wooden sleepers of a railway track. F.F. rails if fixed directly on wooden sleepers sink in the sleeper due to the heavy loads of trains and thus loosen the spikes. Toovercome this difficulty bearing plates are used under F.F. rails to distribute the load over a wider area and bring the intensity of pressure within limit. Bearing plates give the required 1 in 20 inward slope to the rail directly and no adzing is required in the wooden sleeper. These are fixed to sleepers by spikes.

Spikes:

Spikes are used to fix rails to wooden sleepers. Spikes are of following types:

(a) Dog spikes

(b) Round spikes

(c) Screw spikes

(d) Elastic spikes

Dog spikes are the cheaper type of spikes which hold the rails at correct gauge and¬ can be easily fixed and removed. These are commonly used for holding F.F.rails. Four dog spikes are used per sleeper, two on either side of the rail. The disadvantage of dog spikes is that these become loose under the wave action caused by the moving train.

Round spikes are used for fixing chairs of B.H. rails to wooden sleepers and alsofor¬ fixing slide chairs of points and crossings. These have either cylindrical or hemispherical head or blunt end.

Screw spikes are tapered screws with V-threads. Their head is circular with a¬ square projection and are used to fasten rails with wooden sleepers. The holding power of these spikes is more than double to that of dog spikes and can resist thelateral thrust better than the dog spikes.

Elastic spikes are used for fixing F.F. rails to wooden sleepers. These give better¬grip and result in reduction of wear and tear of rail. The advantage of this type of spike is that it is not pulled up by the wave action of the moving train.

Bolts:

Different types of bolts used in Indian Railway are:

(a) Fish bolts

(b) Hook bolts

(c) Fang bolts

Fish bolts are used for connecting fish plates with the rails. Four bolts are required¬ for each pair of fish plates. These bolts are inserted from outside the track and bolted on the inside of the track. Fish bolts have to withstand shear dueto heavy transverse stresses, hence they are• manufactured of medium or high carbon steel. The length of fish bolt depends on the type of fish plate used. For 44.70kg rail, the fish bolts of 25 mm dia and 127.6 mm length are used. These bolts get loosened due to vibration of moving train and hence these are to be tightened time ot time. Too much tightening of bolts is prohibited as it prevents free expansion or contraction of rails due to temperature vibrations.

Hook bolts are also known as dog bolts due to the shape of their heads. These bolts are used to fix sleepers which rest directly on a girder. Two bolts per sleeperare used. Dog bolts are of two types.

(i) Sloping lips- for fixing sleepers to plate girder spans.

(11)Straight lips- for fixing sleepers to joist spans

Fang bolts are used for fixing side chairs to sleepers. These are alternative to screw¬ or round spikes. The fang bolts are found to be more effective but are notgenerally used, because fixing and removal of these bolts are difficult

Keys:

These are small tapered pieces of timber or steel used to fix rails to chairs onmetal sleepers. Keys are of two types

1. Wooden keys
2. Metal keys

Wooden keys are small straight or tapered pieces of timber. These are cheap and¬ easily prepared. These are not strong and become loose under vibrations.These require frequent maintenance. Wooden keys are not used now-a days in Indian Railways.

Metal keys are small tapered or spring like pieces of steel. These keys are much¬more durable than wooden keys. Metal keys are of two types.

(i) Stuart`s key and
Morgan key

Anti-Creepers:

Anti-creepers are used to prevent creep in a railway track. Different shapes of anti-creepers are available and are fixed to the foot of rail.**QUESTIONS**

1. WHAT IS FIXTURES AND FASTENING?

2. WHAT IS THE FUNCTION OF FIXTURE AND FASTENING?

3. WHAT ARE THE TYPES OF FIXTURES AND FASTENING?

4. WHAT IS FISH PLATE?

5. **WHAT IS BEARING PLATE?**

6. **WHAT IS SPIKES?**

7. **WHAT IS DIFFERENT TYPES OF BOLTS?**

8. **WHAT IS CHAIR?**

9. **WHAT IS KEYS?**

10. **WHAT IS ANTI CREEPERS?**

GEOMETRIC DESIGN OF RAILWAY

CHAPTER-4

Introduction:

Geometric design of a railway track discusses all those parameters which affectthe geometry of the track. These parameters are as follows:

1. Gradients in the track
2. Curvature of the track: radius or degree of the curve, cant or super elevation on curves
3. Alignment of the track

Necessity of Geometric Design:

The need for proper geometric design of a track arises because of the followingconsiderations:

To ensure the smooth and safe running of trains

- To achieve maximum speeds
- To carry heavy axle loads
- To avoid accidents and derailments due to a defective permanent way
- To ensure that the track requires least maintenance

¬ For good aesthetics¬

Gradients:

Gradients are provided to negotiate the rise or fall in the level of the railway track. A rising gradient is one in which the track rises in the direction of movement of traffic and in a down or falling gradient the track loses elevation thedirection of movement of traffic. Gradients are provided to meet the following objectives:

To reach various stations at different elevations

¬ To follow the natural contours of the ground to the extent possible

¬ To reduce the cost of earthwork

¬ To drain off rain water¬

Types of gradient:

1. Ruling gradient
2. Momentum gradient
3. Pusher gradient
4. Station yard gradient

Ruling Gradient:

Ruling gradient is the maximum gradient to which the track may be laid in a particular section. It depends on the load of the train and additional power of thelocomotive. 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

Momentum Gradient:

The gradient which is steeper than ruling gradient and where the advantage of momentum is utilized is known as momentum gradient. A train gets momentum when moving in down gradient and this momentum can be utilized for up gradient. A train while coming down a gradient gains sufficient momentum. This momentum gives additional kinetic energy to the moving train which would helpthe train to rise a steeper gradient than the ruling gradient for a certain length ofthe track. This rising gradient is called momentum gradient. In such gradients no signals are provided to stop the train.

Pusher or Helper Gradient:

Pusher gradient is the gradient where extra engine is required to push the train. These are steeper gradient than ruling gradient and are provided at certain placesof mountains to avoid heavy cutting or to reduce the length of track. A pusher gradient of 1 in 37 on Western Ghats with B.G. track is provided. On Darjeeling Railway with N.G. track, a ruling gradient of 1 in 25 is provided.]

Station Yard Gradient:

Station yard gradient is the minimum gradient provided in station yard for easy draining of rain water. In station yards, maximum limit of gradient is fixed as 1 in400 and minimum gradient recommended is 1 in 1000 for easy drainage of rain water. 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 dueto the combined effect of gravity and strong winds. (b) It reduces the additional resistive forces required to start a locomotive to the extent possible.

Grade compensation on curves:

Grade compensation on curves is the reduction in gradient on curved portion of atrack. On curves extra pull is required to pull the train due to more tractive resistance. It is expressed as percentage per degree of curve. The grade compensation provided on Indian Railways is as follows:

a. On B.G. curves – 0.04 percent / degree or 70/R, whichever is minimum

b. On M.G. curves – 0.03 percent / degree or 52.5/R, whichever is minimum

c. On N.G. curves – 0.02 percent / degree or 35/R, whichever is minimum where R is the radius of the curve in metres

Radius or Degree of Curve:

A curve is denned either by its radius or by its degree. The degree of a curve (D) isthe angle subtended at its centre by a 30.5 m or 100 ft arc. The value of the degree of the curve can be determined as indicated below. Circumference of a circle = 2ΠΙr

- Angle subtended at the centre by a circle with this circumference = 360°
- Angle subtended at the centre by a 30.5 m arc, or
- Degree of curve = 360°/2πR x30.5 = 1 750/R (approximately R is in meter)

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

D = 1750/R (when R is in metres

)• D = 5730/ R (when R is in feet)•

Maximum permissible degree of curves:

The maximum permissible degree of a curve on a track depends on various factors such as gauge, wheel base of the vehicle, maximum permissible super elevation, and other such allied factors. The maximum degree or the minimumradius of the curve permitted on Indian Railways for various gauges is given in Table below. Gauge On plain track On turnouts Max. Degree Min. Radius Max.Degree Min. Radius B.G 10 175 8 218 M.G 16 109 15 116 N.G 40 44 17 103

Superelevation:

Superelevation is the raised elevation of the outer rail above the inner rail at a horizontal curve. It is denoted by ‘e’. When a vehicle moves on curve it is

subjected to a centrifugal force. The centrifugal force exerts a horizontal force onthe outer rail and the weight on the outer rail increases. This horizontal force anduneven load on rails will cause derailment. This centrifugal force can be counteracted by introducing the centripetal force by raising the outer rail with respect to inner rail. This raising of outer rail with respect to inner rail is known as‘superelevation’ or ‘canting’.

Objects of Providing Superelevation:

The following are the objects of providing superelevation:

To introduce centripetal force to counteract the centrifugal force to avoidderailment¬ and reduce the side wear of rails.

To distribute the wheel loads equally on the two rails. This reduces the top wearof¬ rails and results in saving of maintenance cost.

To ensure comfortable ride to passengers and safe movements of goods.¬

Analysis of Superelevation:

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

Radial acceleration: a = V2¬ /R, Where V is the velocity (metres per second) andR is the radius of curve (metres). This radial acceleration produces a centrifugal force which acts in a radial direction away from the centre.

The value of the centrifugal force is given by the formula:¬ Force = mass * acceleration, F = m x (V2 /R) = (W/g)x (V2 /R), Where F is the centrifugal force (Kilo Newton), W is the weight of the vehicle (tonnes), V is the speed (m/s), g is the acceleration due to gravity (m/s2), and R is the radius of the curve in metres.

To counteract the effect of the centrifugal force, the outer rail of the curve iselevated¬ with respect to the inner rail by an amount equal to the superelevation.

A state of equilibrium is reached when both the wheels exert equal pressure on the¬ rails and the superelevation is enough to bring the resultant of the centrifugal force and the force exerted by the weight of the vehicle at right anglesto the plane of the top surface of the rails. In this state of equilibrium, the difference in the heights of the outer and inner rails of the curve is known as equilibrium superelevation.

Equilibrium Superelevation:

In Fig. above, if θ is the angle that the inclined plane makes with the horizontal line,¬ then superelevation:

tan θ = Superelevation / Gauge = e/ G

- tan θ = Centrifugal force/weight = F/W
- From these equations:¬ e/ G = F/W
- e = f x G/W e

• = W/g x V2 /R x G/R e = GV2 / gR Here, e is the equilibrium superelevation in metres, G is the gauge in metres, V is the velocity in metres per second, g is theacceleration due to gravity, and R is the radius of the curve in metres.

In the metric system equilibrium superelevation is given by the formula:¬ e = GV2 / 127R Where e is the superelevation in millimetres, V is the speed in km perhour, R is the radius of the curve in metres, and G is the dynamic gauge in millimetres, which is equal to the sum of the gauge and the width of the rail headin millimetres. This is equall to 1750 mm for BG tracks and 1058 mm for MG tracks.

Cant Deficiency:

Cant deficiency is the difference between the actual cant provided and equilibrium cant necessary for the maximum permissible speed on a curve. Cantdeficiency should be as low as possible and is limited due to following reasons: Higher discomfort to passengers due to higher cant deficiency

¬ Higher cant deficiency results in higher unbalanced centrifugal force and henceextra¬ pressure and lateral thrust on the outer rails, requiring strong track and more fastening for stability.

Side wear and creep of outer rails of the track are more due to higher cantdeficiency.¬

QUESTIONS

1. **WHAT IS GEOMETRIC DESIGN RAILWAY?**
2. **WHAT IS GRADIENT?WHAT ARE THE TYPES OF GRADIENT?**
3. **WHAT IS RULLING GRADIENT?**
4. **WHAT IS MOMENTUM GRADIENT?**
5. **WHAT IS GRADE COMPENSATION OF CURVES?**
6. **WHAT IS SUPER ELEVATION?**
7. **WHAT IS CANT DEFICIENCY?**

POINTS AND CROSSINGS

CHAPTER -5

Definition:

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

Turnout:

Turnout is an arrangement of points and crossings with lead rails by which trainsmay be diverted from one track to another moving in the facing direction.

Parts of a Turnout:

1. A pair of tongue rails
2. A pair of stock rails
3. Two check rails
4. Four lead rails
5. A Vee crossing
6. Slide chairs
7. Stretcher bar
8. A pair of heel blocks
9. Switch tie plate or gauge tie chair
10. Parts for operating points – Rods, cranks, levers etc.
11. Locking system which includes locking box, lock bar, plunger bar etc

Tongue Rails along the stock rails in a turnout form a pair of points or switches.The¬ tongue rails facilitate the diversion of a train from the main track to a branch track.

Stock Rails are the main rails to which the tongue rails fit closely. The stockrails¬ help in smooth working of tongue rails.

Check rails are provided adjacent to the lead rails, one in main track and anotherin¬ branch track. These rails check the tendency of wheels to climb over the crossing.

Lead Rails lead the track from heel of switches to the toe of crossing.¬

A Vee crossing is formed by two wing rails, a point rail and a splice rail. It provides¬ gaps between the rails so that wheel flanges pass through themwithout any obstruction.

Slide chairs are provided to support the tongue rail throughout their length andto¬ allow lateral movement for changing of points.

Stretcher bar connects toes of both the tongue rails so that each tongue railmoves¬ through the same distance while changing the points.

Heel Blocks keep the heel ends of both the tongue rails at fixed distance fromtheir¬ respective stock rails.

Switch Tie Plate holds the track rigidly to the definite gauge at the toe ofswitches.¬ These are provided below the slide chairs

Direction of a turnout:

A turnout is designated as a right-hand or a left-hand turnout depending on¬whether it diverts the traffic to the right or to the left.

The direction of a point (or turnout) is known as the facing direction if a vehicle¬approaching the turnout or a point has to first face the thin end of the switch.

The direction is trailing direction if the vehicle has to negotiate a switch in the¬ trailing direction, that is, the vehicle first negotiates the crossing and then finally traverses on the switch from its thick end to its thin end.

Therefore, when standing at the toe of a switch, if one looks in the direction of¬the crossing, it is called the facing direction and the opposite direction is called the trailing direction.

Switches:

A set of points or switches consists of a pair of stock rails, a pair of tongue rails, apair of heel blocks, several slide chairs, two or more stretcher bars, and a gauge tie plate.

Types of Switches:

Switches are of two types, namely stud switch and split switch. In a stud type of switch, no separate tongue rail is provided and some portion of the track is

moved from one side to the other side. Stud switches are no more in use on Indian Railways. They have been replaced by split switches. These consist of a pairof stock rails and a pair of tongue rails. Split switches may also be of two types:

Loose heel type¬

Fixed heel type.¬

The toe of the switches may be of the following types.

Undercut switch:

In this switch the foot of the stock rail is planned to accommodate¬ the tonguerail.

Overriding switch:

In this case, the stock rail occupies the full section and the¬ tongue rail is planedto a 6 mm (0.25")-thick edge, which overrides the foot of the stock rail.

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 tractto 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 crossing consists of the following components:

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 forma 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 stopa wheel running in the facing direction from hitting the nose.

Two wing rails consisting of a right-hand and a left-hand wing rail that convergeto¬ 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.

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

: Crossings can be classified as follows: On the basis of shape of crossing:

1. Square crossing
2. Acute angle or V-crossing or Frog
3. Obtuse angle or Diamond crossing

On the basis of assembly of crossing:

1. Ramped crossing
2. Spring or movable crossing.

Square Crossing:

Square crossing is formed when two straight tracks of same or different gauge, cross each other at right angles. This type of crossing should be avoided on mainlines because of heavy wear of rails.

Acute Angle Crossing

: Acute angle crossing is formed when left hand rail of one track crosses right hand rail of another track at an acute angle or vice versa. This type of crossing

consists of a pair of wing rails, a pair of check rails, a point rail and a splice rail.This crossing is widely used. This is also called V-crossing or frog.

Obtuse Angle Crossing:

Obtuse angle crossing is formed when left hand rail of one track crosses right hand rail of another track at an obtuse angle or vice versa. This type of crossingconsists mainly of two acute angle and two obtuse angle angle crossings. This isalso called Diamond crossing.

QUESTIONS

1. **WHAT IS POINTS AND CROSSINGS?**
2. **WHAT IS TURNOUT?**
3. **WHAT ARE THE PARTS OF TURNOUT?**
4. **WHAT IS STOCK RAIL?**
5. **WHAT IS TONGUE RAIL?**
6. **WHAT IS CHECK RAIL?**
7. **WHAT IS VEE CROSSING?**
8. **WHAT IS CROSSINGS?WHAT ARE ITS COMPONENTS?**
9. **WHAT IS SQUARE CROSSING?**
10. **WHAT IS ACQUATE ANGLE CROSSING?**

Chapter 7

LAYING AND MAINTENANCE OF TRACK

Modern Methods of Track Maintenance

Introduction

Modern methods of track maintenance employ track machines and other modern track equipment for the maintenance of tracks as opposed to the traditional methods of manual packing. The methods used generally are the following.

(a) Mechanized maintenance of track with the help of track machines

(b) Measured shovel packing (MSP)

(c) Directed track maintenance (DTM), which is maintenance based on need, particularly if DTM is done by MSP.

In these methods, the emphasis is not only on modern maintenance techniques but also on the identification and rectification of defects, the implementation of

proper quality control in a systematic manner, and the use of proper tools and equipment.

For over a century, tracks on Indian Railways have been maintained by the method of 'beater packing' using manual labour and the performance has been excellent. It is now being felt that this method of manual maintenance, which has stood the test of time, may require a revision in view of all the recent technological and social advancements. The European Railways, which was also in a similar position a few decades ago, has already switched over to modern methods of maintenance to suit the requirements of the modern track. Such a system of maintenance of track has given the men working on the permanent way a better social status, as it requires lesser physical strength and higher mechanical skill on their part. The system has also enabled them to maintain the modern track more economically and effectively in order to cater to the requirements of higher speeds and heavier axle loads. There is no doubt that the mechanized maintenance of track has become a technical necessity for the modern track structure with its long welded rails and concrete sleepers. In spite of changes in our socio-technical background and the increasing emphasis on the modernization of the track to allow for higher speeds the following question arises: Is there really a need for the complete mechanization of the process of track maintenance, particularly when India has such a large labour force and is faced with a serious problem of unemployment?

Mechanized Methods of Track Maintenance

The need to switch over from manual to mechanized methods of track maintenance is progressively being felt due to the following reasons.

(a) Beater packing is a very hard and strenuous job and thus the labourers have a tendency to shirk from doing this type of work.

(b) It is difficult to ensure the uniform quality of the compaction under the sleepers carried out by manual means due to the uncertainties associated with the varying physical strength of the labourers, commitment of the workers, varying weather conditions, and other allied factors.

(c) The intensity of the pressure and shock that the ballast is subjected to when the beater is being used is very high and in many cases exceeds the crushing strength of the stone. This results in the progressive clogging of the ballast section.

(d) Traffic densities, axle loads, and speeds have increased considerably on Indian Railways considerably in the recent past. Beater packing does not enable track geometry to be maintained within the tolerances prescribed for a satisfactory length of time.

(e) The retention of the packing done via manual maintenance is not very good and the track geometry gets distorted in a short time due to high-speed traffic.

(f) Manual maintenance is not much suited to the modern track, which consists of long welded rails and heavy concrete sleepers.

(g) With the increase in traffic density, the time available between trains is becoming progressively short. It is, therefore, becoming increasingly difficult to maintain tracks by manual methods, which take a considerably long time.

(h) When a track is maintained manually, it takes considerable time for it to get fully consolidated and, therefore, speed restrictions exist for a long period after track renewal work has been completed.

i)Manual methods do not emphasize on the identification of defects and monitoring of the work being done. These are, however, done in the case of modern methods of track maintenance, thereby giving move effective results.

Measured Shovel Packing

Measured shovel packing (MSP) is an improved form of manual packing, which aims to provide a scientific method of track maintenance that does not use any sophisticated mechanical aid. This method, which was perfected on SNCF (French Railways) about 40 years ago, was the standard method of track maintenance in the UK prior to the introduction of mechanical maintenance. Even today, tracks on SNCF are mostly maintained by MSP. This method makes it possible to maintain fish-plated and LWR tracks for speeds of up to 160 km/h in these countries. As such, this method has the potential of being used as a standard method of maintenance for high-speed routes, particularly for flat-bottomed sleepers. It is definitely an asset for controlling the overall economy by way of direct savings in labour and maintenance of the track, and long-term savings in terms of longer life of rails, sleepers, and fastenings due to improved track maintenance.

1 Essentials of MSP

MSP essentially consists of taking accurate measurements of track defects, particularly of any existing unevenness and voids, caused in the course of service and attending to the same by placing a measured quantity of small-sized stone chips under the sleeper to bring the track levels to their predetermined state. The compaction of these stone chips occurs as a consequence of the passage of traffic. The extent to which the track is required to be lifted is calculated by measuring the longitudinal unevenness in the track once the cross levels and the voids under the sleepers have been corrected. The longitudinal levels are measured with the help of two optical instruments-the *viseur and the mire*-while the voids under the sleeper bed are assessed by a ball-ended rod called *canne-a-boule* and checked with the

help of a mechanical device called the *dansometer*. The track is lifted by 40 mm by means of special types of non-infringing jacks, and a measured quantity of stone chips is then placed in the sleeper bed with the help of a particular type of packing shovel. The jacks are then tripped off and the alignment is finally corrected.

2 Scope of MSP

The process of MSP is suitable for the following types of work.

(a) Through packing of flat-bottomed sleepers

(b) Packing of joint wooden sleepers in metal sleeper tracks

(c) Through packing of points and crossings with wooden and steel sleepers

(d) Dehogging of rail ends

3 Advantages and Disadvantages of MSP

Even though MSP is an excellent method of track maintenance, it does have its drawbacks. The following are the advantages and disadvantages of MSP.

Advantages of MSP

(a) The work carried out is precise, wherein the track is worked upon as close to the tolerances as possible because of the finer adjustments that are permissible in MSP.

(b) The retentivity of packing, particularly for joint sleepers, is more in the case of MSP as compared to other modes of maintenance.

(c) MSP gives increased output per gangman and is, therefore, economical.

(d) A minimum clean ballast cushion is not needed when work is done through MSP.

(e) MSP does not require any traffic blocks.

(f) MSP does not damage the undersides of wooden sleepers, which are otherwise damaged in manual methods of maintenance.

(g) MSP is less strenuous and labourers do not shirk in doing the required work.

(h) The gangman and the supervisory staff are able to pick up the uncomplicated technique with very little training and experience.

Disadvantages of MSP

(a) Normally, MSP can be done only in the case of flat-bottomed sleepers and this puts a severe limitation on the scope of its application.

(b) This procedure requires special size stone chips, which may not be easily available.

(c) MSP is not effective in maintaining newly screened tracks. A consolidated bed is a prerequisite for maintaining a track by means of MSP.

(d) MSP makes use of delicate instruments and devices that can get damaged easily.

(e) Although MSP is not a complicated process, it still requires a certain amount of skill, for which the labourers have to be educated and trained.

Directed Track Maintenance

As the name suggests, directed track maintenance (DTM) is a method of maintaining the track on the basis of directions that are given in this regard every day, and not as a prescribed routine. Directed track maintenance essentially consists of need-based maintenance rather than routine maintenance. In the case of DTM, track maintenance is done by proper identifying any defects in track geometry and rectifying these defects by attending to the track at the affected locations under close supervision, thereby maintaining the track at predetermined standards.

1 Objectives

The two main objectives of DTM are as follows.

(a) To maintain high standards of track maintenance as per predetermined tolerances.

(b) Reduction in the cost of maintenance mainly by the avoidance of unnecessary work.

In order to achieve the desired objectives, the following special features are incorporated in DTM vis-�-vis the conventional system of maintenance.

(a) The level of supervision is improved by hiring a well-trained and qualified permanent way mistry.

(b) A thorough record of the track defects identified before and after the completion of work is maintained to assess the inputs and also to help devise remedial measures of a more permanent nature by carrying out a scientific study based on the assimilated facts.

(c) Increasing the length of the unit especially on single lines increases the number of the gangmen available, resulting in an improvement in the productivity of the gang as well as the quality of work.

(d) The track is aimed to be brought to a predetermined level of service tolerances.

2 Work Done Under DTM

The maintenance operations to be carried out in a section where DTM has been introduced can be placed into the following four categories.

(a) Systematic overhauling In DTM, while the emphasis is on need-based maintenance, the intention is not to completely dispense with routine maintenance works such as systematic overhauling. Instead, the frequency of systematic overhauling is suitably increased, say by three to four years or as decided by the chief engineer, depending on local factors such as the condition of the track and the formation, traffic density, permissible speed, and rainfall. A certain number of working days in the appropriate months of the year are earmarked for this work so as to cover one-third or one-fourth of the gang length by systematic overhauling, depending on the site conditions.

(b) Periodic maintenance work This includes works such as the lubrication of joints, cleaning of side drains, catch water drains, and repairs of the formation and cess. In the annual program, an adequate number of working days should be set aside during the appropriate months for periodic maintenance work.

(c)Occasional maintenance work This includes other works such as scattered renewal of rails, sleepers, and other track components, adjusting creep, restoring correct spacing between sleepers, building damaged rail ends, realigning curves, overhauling level crossings as well as points and crossings, and properly removing any deficiencies in the ballast section. The permanent way inspector assesses the quantum of such works that are to be carried out periodically in the order of their priority and draws up a programme in consultation with engineers

after taking into consideration the availability of track material, ballast, welding parties, etc.

(d) Need-based maintenance The remaining working days in the annual programme are devoted to need-based maintenance, which is a new concept and forms the main distinguishing feature of DTM as compared to the conventional system of maintenance. The operations involved in need-based maintenance are as follows.

(a) Location of defects by analysing the results of the track recording car/ oscillograph car/hallade recorder and by foot plate/rear vehicle/trolley/foot inspection.

(b) Identification of defects by means of systematic inspection and by ground measurements taken by trained supervisors using precision instruments.

(c) Recording of the observations.

(d) Rectifying track defects by attending only to the defective portion followed by a post check of the same portion conducted by the supervisor to check its quality and output.

DUTIES OF ASSISTANT ENGINEER

(a) The Assistant Enginer is generally responsible for the maintenance and safety of all way andworks in his charge, for the accuracy, quality and progress.
(b) He is responsible for control over all expenditure in relation to budget allotment.
(c) Inspection and maintenance of track and structures in a satisfactory and safe condition.
(d) Preparation of plan and estimates, execution and measurement of works including track works.
(e) Verification of stores held by stock-holders.
(f) Submission of proposals for inclusion in track renewal programme and works programme.
(g) He shall observe all the rules and procedures laid down in the General

and Subsidiary Rules, the Indian Railway permanent Way Manual, the Indian Railway Works Manual, the Indian Railway Bridge Manual, the Engineering Code and other departmental codes and orders and circulars issued from time to time. He shall ensure that all the staff under him are acquainted with the relevant rules and working methods connected with their duties and that they perform their allotted duties.

(h) The Assistant Engineer should co-operate effectively with officers and staff of other departments in matters that warrant co-ordination.

(i) The Assistant Engineer has to accompany a periodical or special inspection by higher officers.

(j) The Assistant Engineer shall conduct inspection in his jurisdiction as per Schedules laid down by the Administration from time to time.

6.1.1 Inspection of Permanent Way – The important inspections to be carried out by the Assistant Engineer are as under :

(a) Trolley Inspection – The entire sub-division should be inspected by trolley once a 2 months/ on branch lines having GMT < 2 - once in 3 months, on prorate basis, as much inspection as possible being done by push trolley. The inspection by trolley should be intensive, which should include checking of attendance of gang, gang work and equipment and examination of gang charts/diary books with reference to the prescribed schedule of track maintenance. During his inspection, he should check the work done by one or two gangs in each PWI's jurisdiction and record the result of his inspection.

(b) Fast Train Inspection – The entire sub-division should be covered by Engine (foot plate) or last vehicle of a fast train once in a month.

(c) Inspection of level Crossings – He should inspect all the manned level crossings once in six months.

(d) Checking of Points and Crossings- He shall inspect once a year all points and crossing on passenger lines and 10 percent of the points and crossings on other lines.

(e) Checking of Curves – The assistant Engineer shall check at least one curve in each PWI's jurisdiction every quarter by verifying its versine and super elevation.

Note - The designation of PWI has been re-designated as SE (P.Way) or JE (P.Way) (Section Engineer and Junior Engineer respectively)

(f) Monsoon Patrolling- When Monsoon Patrolling is introduced he should check the work of patrol men at night once in a month, either by Train or Push or Motor Trolly.

(g) Track on Bridges – The track on Girder Bridges should be inspected as a part of the annual Bridge inspection, besides normal track inspections.

(h) Scrutiny of Registers during Inspections- He should scrutinize the registers maintained byPWI such as Creep register. Curve register. Points and Crossing register, SEJ and Buffer rail

(i) Inspections of L.W.R./C.W.R. Track – The Assistant Engineer shall inspect the SEJ s/Bufferrails provided in the LWR/CWR track once in every six months. He shall check the creep records of LWR/CWR regularly.

6.1.2. Inspection of Works - The Assistant Engineer should ensure that all works are carried out according to plans and specifications laid down. The Assistant Engineer shall examine the track at kilometrages where renewals are required before submitting proposals to the Divisional Engineer for inclusion in the Preliminary Works programme.

6.1.3. Measurement of works- The assistant Engineer may either measure and record the measurement of ballast himself or carry out 100% check on quality and quantity, if the measurement isrecorded by Inspectors.

6.1.4. Action in case of accidents- In case of accident he should proceed to the site by the quickest available means. He should also take all possible measures to restore the traffic quickly.

(Bank payment)

6.1.6. Inspection of Inspector's office-The Assistant Engineer shall carry out an inspection of eachInspector's office and Stores at least once a year.

6.1.7. <u>Misc.duties- The Assistant Engineer will ensure that :</u>

(a) Strict discipline is maintained within the frame work of the rules.

(b) Service and leave records are maintained correctly and up-to-date.

(c) Appeals and representation are dealt with promptly,

(d) Selection for the various posts like Mates and Keymen are made in time and the posts promptlyfilled up.

6.2. DUTIES OF PERMANENT WAY INSPECTORS (SR. SECTION ENGINEER)

(a) Permanent Way Inspector is responsible for maintenance and inspection of track in asatisfactory and safe condition for traffic.

(b) He should ensure efficient execution of all works incidental to track maintenance, including trackrelaying works.

(c) He is also responsible for accountal and periodical verification of stores and tools in his charge.

(d) Maintenance of land boundaries between stations and at unimportant stations as may specifiedby the administration.

(e) Permanent Way Inspector shall be acquainted with the rules regulations and proceduresconcerning his work and duties as enjoined in the codes and manuals.

(f) He shall ensure that staff working under him are well acquainted with the relevant rules andworking methods and efficiently perform their duties.

(g) Permanent Way Inspector shall keep close co-ordination with the works, Bridge, Signaling andElectrical Staff when they are required to work jointly.

(h) Permanent Way Inspector shall see to the security of rails, chairs, sleepers and other materialsin his charge.

(i) Permanent Way Inspector shall devote sustained attention to Permanent way as regards tosafety, smooth running, economy and neatness.

(j) He shall carry out foot plate inspection at least once a month.

(k) He should accompany the track recording/oscillograph car runs over his section.

6.2.1 Inspection of Track

(a) The permanent Way Inspector shall inspect the entire section by push trolley at least once in afortnight when no inspection carried out by JE-SSE/ once in a month (being Incharge). During

6.3 DUTIES OF MATES

Every Mate shall see that his length of line is kept safe for the passage of trains. Kilometrages needing urgent attention shall be picked up without waiting for orders from the Permanent Way Inspectors.

6.3.1 Knowledge of Rules and Signals :

Every Mate, shall have the correct knowledge of handling hand and detonating signals and shall beconversant with the following rules :

(a) Protecting the line in an emergency and during work affecting the track.

(b) Method of fixing and safety range of detonators.

(c) Action to be taken when a train is noticed to have parted.

(d) 'Safety First' rules.

(e) Action to be taken where sabotage is suspected, and patrolling in emergencies.

6.3.2 Equipments at site of works :

Every Mate shall ensure that the following tools and equipment are with him at the site of work :

(a) Level-cum gauge, square, hemp cord, metre stick, keying and/ or

spiking hammer, fish bolt spanner, 2 set of H. S. flags, 12 detonators and marking chalk. Rail thermometer 2 H.S. lampsin the night.

(b) Sufficient number of shovels or Phowrahs, beaters, crow bars, ballast forks or rakes and mortar pans or baskets, wooden mallet.

The mate shall keep in his charge in the tool box, other tools and equipment as may be prescribed.

6.3.3 Other duties of Mate :

1. Every Mate shall see that the signals supplied to the gang are kept in good order and ready for use and that every man in his gang has a correct knowledge of all signals.
2. The Mate shall see that the prescribed system of track maintenance is adhered to and the tasks allotted according to verbal instructions or entries made in his gang chart diary and explained to him are efficiently carried out. If capable of entering details of work in his gang diary, the Mate should do so.
3. The Mate should see that the whole of his gang length is kept neat and tidy and that all loose materials are collected and brought to stations, gang quarters or gate lodges.
4. The mate shall be, responsible for the safe custody of tools used by him, the Keymen and Gangmen. He should see that gangmen on work remove their tools clear of the track on the approach of a train. After the day's work, the mate should secure the tools in the tool box.
5. If a Mate or his Keyman considers that the line is likely to be rendered unsafe or that any train is likely to be endangered in consequences of defect in the permanent way or works or abnormal rain or flood or any other occurrence, he shall take immediate steps to secure the safety of trains by using the prescribed signals to "Proceed with caution" or to "Stop" as necessity may require and shall as soon as possible report the circumstances to the nearest station master and the permanent way inspector.
6. During abnormal rainfall, the Mate should organize patrolling on the gang-length whether or not patrolmen are on duty. In the event of damage being detected, action should be taken to safeguard traffic by protecting the line.
7. The Mate shall inspect the whole gang length once a week on which day he will carry out the Keyman's work and duties and the Keymen will remain in-charge of the Gang.
8. The mate should prevent trespass and theft of P.Way fittings.
9. The mate should make relief arrangements of Keymen, patrol-men,gatemen and watchmen in emergencies.
10. On requisition from the Station master, the mate of a yard gang may depute, if available, two gangmen for placing of detonators during times of poor visibility in the rear of approach signals of the station.

such inspections he shall check the work of gang done earlier and ensure prompt action on items requiring attention. Arrange to give the programme of work to the gang. Record details of track maintenance work in gang chart and diaries, check the attendance of the gang and instruct men the methods of maintenance.

(b) He shall ensure that all the level crossings are opened out once a year/ 2- years (on PRC) to examine the condition of rails, sleepers and fastening and defects are rectified.

(c) The Permanent Way Inspector shall carry out inspection of Points & Crossings of all lines once in 3 months by rotation with his assistance and another lines once in 6 months by rotation.

(d) He should carry out inspection of curves once in 6 months in rotation with his assistant.

(e) He shall maintain an inspection diagram of all the inspections carried out during the months as per the schedule in the proforma.

(f) The Permanent Way Inspector is directly responsible for the safety of the track. He shall be vigilant. To locate faults in the permanent way and promptly remedy them.

(g) He shall ensure execution of works affecting track are in safe condition.

(h) In case of emergencies such as accidents/breaches or affecting any part of track, the PWI should immediately proceed to site by the quickest available means and ensure restoration of track.

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(j) The Permanent Way Inspector should also ensure that staff are fit for medical examination as per the relevant instruction in force. He shall maintain his Service Records/leave account of all the permanent staff working under him.

(1) He shall ensure proper training of men working under him at an appropriate time and arrange for prompt filling up of the vacancies.

(l) The Permanent Way Inspector shall keep his correspondences up to date and see that the office records, registers and stores are maintained systematically.

QUESTIONS

1.what is mechanized maintenance of track?

2.what is measured shovel packing of track?

3.what is directed track maintenance?

4.what are the duties of assistance engineer?

5.what are the duties of section engineer?

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BRIDGE ENGINEERING

SECTION-B CHAPTER-7

DEFINATION

The following definitions of certain important terms used in Bridge Engineering are given below:

1. Bridge: - A structure is facilitating a communication route for carrying road traffic or other moving loads over a depression or obstruction such as river, stream, channel, road or railway. The communication route may be a railway track, a tramway, a roadway, footpath, a cycle track or a combination of them.

2. High Level Bridge or Non-submersible Bridge: - The Bridge which does not allow the high flood waters to pass over them. All the flood water is allowed to pass through its vents. In other words it carries the roadway above the highest flood level of the channel.

3. Submersible Bridge: - A submersible bridge is a structure which allows fold water to pass over bridge submerging the communication route. Its formation level should be so fixed as not to cause interruption to traffic during floods for more than three days at a time nor for more than six times in a year.

4. Causeway: - It is a pucca submersible bridge which allows floods to pass over it. It is provided on less important routes in order to reduce the construction cost of cross drainage structures. It may have vents for low water flow.

5. Foot Bridge: - The foot bridge is a bridge exclusively used for carrying pedestrians. Cycles and animals.

6. Culvert: - When a small stream crosses a road with linear waterway less than about 6 meters. The cross drainage structure so provided is called culvert.

7. Desk Bridge: - These are the bridge whose floorings are supported at top of the superstructures.

8. Through Bridge. These are the bridges whose floorings are supported or suspended at the bottom of the superstructures.

9. Semi-Through Bridges: - These are the bridges whose floorings are supported at some intermediate level of the superstructure.

10. Simple Bridges: - They include all beam, girder or truss bridges whose flooring is supported at some intermediate level of superstructure.

11. Cantilever Bridges: - Bridges which are more or less fixed at one end and free at other. It can be used for spans varying from 8 meters to 20 meters.

12. Continues Bridges: - Bridges which continue over two or more spans. They are used for large spans and where unyielding foundations are available. 46

13. Arch Bridge: - These are the bridges which [produce inclined pressures on supports under vertical loads. These bridges can be economically used up to spans about 20 meters. The arches may be in the barrel from or in the form of ribs.

14. Rigid Frame Bridges: - In these bridges the horizontal deck slab is made monolithic with the vertical abutments walls. These bridges can be used up to span about 20 meters. Generally this type of bridge is not found economical for spans less than 10 meters.

Bridge15. Square: - These are the bridges at right angles to axis of the river.

16. Square Bridge: - These are the bridges not at right angles to axis of the river. **17. Suspension Bridges**: - These are the bridges which are suspended on cables anchored at ends.

18. Under-Bridges: - It is a bridge constructed to enable a road to pass under another work or obstruction.

19. Over-Bridges: - it is a bridge constructed to enable one from of land communication over the other.

20. Class AA Bridges: - These are bridges designed for I.R.C. class AA loading and checked for class A loading. Hey are provided within certain municipal limits, in certain existing or contemplated industrial area, in other specified areas, and along certain specified highways.

21. Class A Bridges: - These are permanent bridges designed for I.R.C. class A loading.

22. Class B Bridges: - These are permanent bridges designed for I.R.C. class B loading.

23. Viaduct: - It is a long continues structure which carries a road or railways like Bridge over a dry valley composed of series of span over trestle bents instead of solid piers.

24. Apron: - It is a layer of concrete, masonry stone etc. placed like flooring at the entrance or out of a culvert to prevent scour.

25. Piers: - They are the intermediate supports of a bridge superstructure and may be solid of open type.

26. Abutments: - They are the end supports of the superstructure.

27. Curtain Wall: - It is a thin wall used as a protection against scouring action a stream.

28. Effective Span: - The centre to centre distance between any two adjacent supports is called as the effective span of a bridge.

29. Clear Span: - The clear distance between any two adjacent supports of a bridge is called clear Span.

30. Economic Span: - the span, for which the total cost of bridge structure is minimum is known as economic span.

31. Afflux: - due to construction of the Bridge there is a contraction in waterway. This results in rise of water level above its normal level while passing under the Bridge. This rise is known as afflux.

32. Free Board: - Free Board at any point is the difference between the highest flood level after allowing for afflux, if any, and the information level of road embankment on the approaches or top level of guide bunds at the points.

33. Headroom: - Headroom is the vertical distance between the highest points of a vehicle or vessel and the lowest points of any points of any protruding member of a Bridge.

.34 Length of the Bridge: - The length of a Bridge structure will be taken as the overall length measure along the centre line of the Bridge from the end to end of the Bridge deck. 47

35. Liner Waterway: - The liner waterway of a Bridge shall be the length available in the bridge between extreme edges of water surface at the highest flood level, measures at right angles to the abutment faces.

36. Low Water Level (L.W.L.): - The low water level is the of water surface obtained generally in the dry season.

37. Ordinary Flood Level (O.F.L.):- It is average level of a high flood which is expected to occur normally every year.

38. Highest Flood Level (H.F.L.):- It is the level of highest flood every recorded or the calculated level for the highest possible flood.

39. Effective Liner Waterway: - Effective linear waterway is the total width of waterway of a bridge minus the effective width of obstruction. For calculating the effective linear waterways, the width of mean obstruction due to each pier shall be taken as mean submerged width of the pier at its foundation up to maximum scour level. The obstruction at ends due to abutments or pitched slopes should be ignored.

COMPONENTS OF A BRIDGE

The bridge structure is divided mainly into two components:

1) Substructure The function of substructure is similar to that of foundations, columns and walls etc. of a building. Thus the substructure supports the superstructure and distributes the load into the soil below through foundation. The substructure consists of foundation piers and abutment piers, foundation for the piers, abutments, wing walls, and approaches. The above all supports the superstructure of the bridge.

2) Superstructure The superstructure of a bridge is analogues to a single story building roof and substructure to that of walls, columns and foundations supporting it. Superstructure consists of structural members carrying a communication route It consists of handrails, parapets, roadways, girders, arches, wall trusses over which the road is support. It is that part of the bridge over which the traffic moves safely

Classification of a Bridge:

- The bridges may be classified depending upon the following factors:

(a) Their functions or purpose as railway, highway Foot Bridge, aqueduct etc.

(b) Their material of construction used as timber masonry, R.C.C. Steel, prestresses co

(c) Nature or life span such as temporary permanent bridge etc.

(d) Their relative position of floor such as deep bridge, through bridges etc.

(e) Type of super-structure such as arched girder, truss, suspension bridge etc.

(f) Loadings: - Road Bridges and culverts have been classified by I.R.C. into class AA, Class A, Class B bridges according to the loadings they are designed to carry.

(g) Span Length:- Under this category the bridges can be classified as • • •

(h) Degree of Redundancy: - Under this the bridges can be classified as indeterminate bridges

(i) Types of Connection:- Under this category the steel bridges can be classified as pinned connected , riveted or welded bridges.

The bridges may be classified depending upon the following factors:-

(a) Their functions or purpose as railway, highway Foot Bridge, aqueduct etc.

(b) Their material of construction used as timber masonry, R.C.C. Steel, prestresses co

(c) Nature or life span such as temporary permanent bridge etc.

(d) Their relative position of floor such as deep bridge, through bridges etc. structure such as arched girder, truss, suspension bridge etc. d Bridges and culverts have been classified by I.R.C. into class AA, Class A, Class B bridges according to the loadings they are designed to carry. Under this category the bridges can be classified as Culverts (Span Less than 8m) i.e. BOX Type, Hume Pipe Type, Minor Bridge (Span length = 8 to 30m) i.e. BOX type, Girder Type Major Bridge (Span Length =above than 30m) Under this the bridges can be classified as indeterminate bridges Under this category the steel bridges can be classified as pinned

connected , 48 (b) Their material of construction used as timber masonry, R.C.C. Steel, prestresses concrete etc. d Bridges and culverts have been classified by I.R.C. into class AA, Class A, Class B 8m) i.e. BOX Type, Hume Pipe Type, Minor Bridge (Span length = 8 to 30m) i.e. BOX type, Girder Type Under this the bridges can be classified as indeterminate bridges Under this category the steel bridges can be classified as pinned connected , 49 Classification of Bridge

REQUIRMENTS OF AN IDEAL BRIDGE:-

An ideal bridge meets the following requirements to fulfil the three criteria of efficiency, effectiveness and equity It serves the intended function with utmost safety and convenience It is aesthetically sound It si economical The site characteristic of an Ideal Bridge has been discussed below:

1. The stream at the bridge side should be well defined and as narrow as possible. 2. There should be a straight reach of stream at bridge site
3. The site should have firm, permanent, straight and high banks.
4. Te flow of water in the stream at the bridge site should be in steady regime condition. It should be free from whirls and cross-current
5. There should be no confluence of large tributaries in the vicinity of bridge site 6. It should be reliable to have straight approach roads and square alignment, i.e. right-angled crossing
7. There should be minimum obstruction of a natural waterway so as to have minimum afflux
8. In order to achieve economy there should be easy availability of labour, construction material and transport facility in the vicinity of bridge site.
9. In order to have minimum foundation cost, the bridge site should be such that no excessive work is to be carried inside the water
10. At bridge site it should be possible to provide secure and economical approaches. 50
11. In case of curved alignment the bridge should not be on the curve, but preferably on the tangent since otherwise there is a greater like hood of accident as well as an added centrifugal force which increases the load effect on the structure and will require modification of design.
12. There should be no adverse environmental input
13. The bridge site should be such that adequate vertical height and waterway is available
14. Underneath the bridge for navigational use. In actual practice the determination of best possible site for any proposed bridge is truly an economic problem. The various factors which should be carefully examined before setting finally upon the layout of a bridge as follows:

i. Grade on alignment,
ii. Geographical Conditions,
iv. Government requirements,
v. iv. Commercial influences ,
vi. v. Adjacent property consideration,
vii. vi. General features of the bridge structure,
viii. vii. Future trends for enlargement,
ix. viii. Time Consideration,
x. ix. Foundation Considerations,
xi. x. Construction facilities available,
xii. xi. Erection Consideration,
xiii. xii. Aesthetics,
xiv. xiii. Maintenance and repairs,
xv. xiv. Environment Impact

QUESTIONS

1.What is bridge?
2.what is the components of bridge ?
3.what are the classifications of bridge ?
4.what are the requirements of ideal bridge ?

CHAPTER 8

BRIDGE ALIGNMENT

Bridge Alignment:-

Depending upon the angle which the bridge makes with tee axis of the river, the aliment an me of two types:

a) Square Alignments: - In this the bridge is at right angle to the axis of the river.

b) Skew Alignments: - In this the bridge is at some angle to the axis of the river which is not a right angle

. Note: - As far as possible, it is always desirable to provide the square alignment. the skew alignments suffers from the following disadvantages:

- (i) A great skill is required for the construction of skew Bridges. Maintenance of such type of Bridges is also difficult.

(ii) The water-pressure on piers in case of skew alignment is also excessive because of non-uniform flow of water underneath the bridge superstructure.

(iii) The foundation of skew bridge is more susceptible to scour action.

Flood Discharge: - One of the essential data for the bridge design is fair assessment of the maximum flow which could be expected to occur at the bridges site during the design period of the bridge. The conventional practice in India for determination of flood discharge is to use a few convenient formulae or past records.

Note: - This faulty determination of flood discharge which led to failure of many hydraulic structures. As per I.R.C. recommendation the maximum discharge which a bridge on a natural stream should be designed to pass determined by the following methods:-

(a) From the rainfall and other characteristics of the catchment.

(i) By use of an empirical formula applied to that region, or

(ii) By a rational method, provided it is possible to evaluate for the region concerned the various factors employed in the method

. (b) From the hydraulic characteristics of the stream such as cross-sectional area, and slope of the stream allowing for velocity of flow.

(e) From the records available, if any, of discharges observed on the stream at the site of the bridge, or at any other site vicinity.

Empirical Methods for Estimation of Flood Discharge:

- In these methods are of basin or catchment is considered mainly. All other factors which influence peak flow are merged in a constant. A general equation may be followed in the form:-

$Q = C . M^n$

Here, Q= Peak Flow or rate of maximum discharge

C= a constant for the catchment

M= area of catchment, and 'n' is an index The constant for catchment is arrived at, after taking the following factors into account:

(A) Basin Characteristics

a) Area

b) Shape

c) Slope

(B) Strom Characteristics

a) Intensity

b) Duration

c) Distribution Limitations

These methods do not take frequency of flood into consideration. These methods cannot be applied universally Fixing of constant is very difficult and exact theory cannot be put forth for its selection.

1) Dicken's Formula Q = C. M 3/4

Here, Q= Discharge in cum/sec

C= a constant

M= area of catchment in sq .km. 53

2) Tyve's formula Q = C. M 2/3 Here,

Q= Discharge in cum/sec

C= 6.74 for area within 24 km from coast or,

C= 8.45 for areas within 24-161 km from coast or

, C= 10.1 for limited hilly areas

In worst case C goes up to 40.5

M= area of catchment in sq .km.

3) Inglis Formula This formula used only Mahastra state and here three different cases are taken into consideration.

(a) For small areas only (It is also applicable for fan-shaped catchment) Q = 123.2 √M

(b) For areas between 160 to 1000 square km. Q = 123.2 √M – 2.62(M – 259)

(c) For all type of catchment

Q = 123.2 M / √(M + 10.36) In all equations

, M= area of catchment in sq .km.

4) Nawab Jang Bahadur's Formula :- Q = C (M / 2.59) (a - b. log A)

Here, a, b, and C are constant. a= 0.993 and b= 1/14 C = 59.5 for North India or, = 48.1 for South India

5) Creager's Formula :- q = C.M n

Here, q=the peak flow per sq. km of a basin

M= area of catchment in sq. km. and 'n' is some index By multiplying both sides of the above equation are of the basin M, we get Where Q is peak value Q= C. M n+1 54 Equation given by Creager , Justin and Hinds is

6) Khosla's Formula :- It is a rational formula, It si based on the equation P= R + L Or R= P - L Here, R is round off, P is rainfall and L is losses. L=4.82 Tm, where L is in mm and Tm is in centigrade {in C.G.S. System} R= P - 4.82Tm

7) Besson's Formula :- This formula is very rational and can be used in any case: Qm = (Pm X Qr) / (Pr) Here, Qm = Peak flow expected Qr = Some observed peak flow Pr = Observed rainfall Pm= expected rainfall

Rational Methods for Estimation of Flood Discharge:-

This method is applicable for determination of flood discharge for small culverts only. In order to arrive at a rational approach, a relationship has been established between rainfall and runoff under various circumstances. The size of flood depends upon the following factors.

(i) Climate or Rainfall Factors. This includes

(a) Intensity

(b) Distribution and

(c) Duration of Rainfall

(ii) Catchment Area Factors. This includes:

(a) Catchment Area

(b) its slope

(c) its shape

(d) porosity of soil

(e) Vegetable cover

(f) initial state of wetness

WATERWAY

The area through which the water flows under a bridge superstructure is known as the waterway of the bridge. The linear measurement of this area along the bridge is known as the linear waterway. This linear waterway is equal to the sum of all the clear spas. This may be called as artificial linear waterway. Q=46. CM (0.849M-0.048) 55 Due

to the construction of a bridge the natural waterway gets contracted thereby increasing the velocity of flow under a bridge. This increased velocity results into heading up of water on the upstream of the river or stream, known as Afflux.

Economic Span: - the economic span of a bridge is the one which reduces the overall cost of a bridge to be minimum. The overall cost of a bridge depends upon the following factors

a. Cost of material and its nature.

b. Availability of skilled labour

c. Span Length.

d. Nature of stream to be bridged

. e. Climatic and other conditions.

Notes:- It is not in the hand of engineers to bring down the cost of living index or price of the materials like cement, steel, timber, etc. but they can help in bringing down the cost of bridges by evolving economical designs. Considering only variable items, the cost of superstructure increases and that of sub-structure decreases with an increase in the span length. Thus most economic span length is that which stultifies the following :- i.e. The cost of Super Structure= The cost of the Sub-Structure

AFFLUX

When a bridge is constructed, the structure such as abutments and piers cause the reduction of natural waterway area. The contraction of stream is desirable because it leads to tangible saving in the cost specially for alluvial stream whose natural surface width is too large than required for stability. Therefore, to carry the maximum flood discharge, the velocity under a bridge increases. This increased velocity gives rise to sudden heading up of water on the upstream side of the stream. The phenomenon o0f heading up of water on the upstream side of the stream is known as "AFFLUX" Greater the afflux greater will be the velocity under the downstream side of the bridge and greater will be the depth of scour and consequently greater will be depth of foundations required.

Afflux is calculated by one of the following formula

(A) Marriman's Formula Here

, ha = Afflux in meters

V= Velocity of approach in meters per second

A= Natural Waterway area at the sit

a=Contracted area in square meters

A1= The enlarged area upstream of the bridge square meters

ha = (V2 / 2g) {(A/Ca) 2 - (A/A1)}

C= Coefficient of Discharge = 0.75+0.35 (a/A)- 0.1(a/A)2 approximately

(A) Molesworth's Formula Here,

V, A and a have the same meaning as in the Marriman's Formula

CLEARANCE To avoid any possibility of traffic striking any structural part clearance diagram are specified. The horizontal clearance should be the clear width and vertical clearance of the clear height, available for the passage of vehicular traffic as shown in the clearance diagram in the figure below. Clearance Diagram for Road Bridges Note : - For a bridge constructed on a horizontal curve with superelevated road surfaces, the horizontal clearance should be increased on the side of inner kerb by an amount equal to 5m multiplied by the superelevation. The minimum vertical clearance should be measured from the super elevated level of roadway.

V2 ha = + 0.015 { (A/a)2 -1} 17.9 57

FREE BOARD Free board is the vertical distance between the designed high flood level, allowing for the afflux, if any, and level of the crown of the bridge at its lowest point. It is essential to provide the free board in all types of bridges for the following reasons:- Free Board is required to allow floating debris, fallen tree trunks and approaches waves top pass under the bridge. Free board is also required to allow for the afflux during the maximum flood discharge due to contraction of waterway. Free board is required to allow the vessels to cross the bridges in case of navigable rivers. The value of free-broad depends upon the types of the bridge. Collection of Bridge Design Data: - For a complete and proper appreciation of the bridge project the engineer in charge of the investigation should carry out studies regarding its financial, economic, social and physical feasibility. The detailed information to be collected may cover loading to be used for design based on the present and anticipated future traffic, hydraulic data based on stream characteristics, geological data, subsoil data, climatic data, alternative sites, aesthetics, cost etc.

The following drawings containing information as indicated should be prepared

1. INDEX MAP
2. CONTURE SURVEY PLAN
3. SITE PLAN
4. CROSS-SECTION
5. LONGITUDINAL SECTION
6. CATCHEMENT AREA MAP
7. SOIL PROFILE

Design data for major bridge:-

A- General data:-

1-Name of the road and its classification.

(ii) Name of the stream.

(iii)Location of nearest G.T.S. bench mark and its reduced level.

(iv) Chainage at centre line of the stream.

(v) Existing arrangement for crossing the stream.

a) During Monsoon

b) During dry season

(vi) Liability of the site to earthquake disturbance

B- Catchment Area and Run Off Data:-

(i) Catchment Area

(a) Hilly Area

b) In plains

(ii) Maximum recorded intensity and frequency of rainfall in catchment.

Rainfall in cementer per year in a reason

(iv) Length of catchment in kilometres

(iv) Width of catchment in kilometres.

(v) Longitudinal slope of catchment.

Cross slope of catchment.

(viii) The nature of catchment and its shape.

C- Data Regarding Nature of Stream Sub-Surface Investigation:- Sub-Surface investigation is essential for to know the properties of the bridge site soil. The field and laboratory investigations required to obtain the necessary soil data for the design are called soil exploration. The principal requirements of a complete investigation can be summarized as follows:-

1. Nature of the soil deposits up to sufficient depth.
2. Depth, thickness and composition of each soil stratum.
3. The location of ground water.
4. Depth to rock and composition of rock.
5. The engineering properties of soil and rock strata that affect the design of the structure. In exploration programme the extent of distribution of different soils both in the horizontal and vertical directions can be determined by the following methods:

1. By use of open pits.
2. By making bore holes and taking out samples

. 3. By Soundings.

By use of geophysical methods

. Equipments for laboratory Work:- The disturbed soil sample as taken from bed level to scour level at every one meter interval or at depths wherever strata changes ate tested to determine the following properties:-

1. Liquid Limit, Plastic ,Limit and Plasticity Index
2. Organic Content
3. Harmful Salts

4. Sieve Analysis

5. Silt Factor The undisturbed soil samples as taken below the scour level to a level where the pressure is about 5% of the pressure at the base are tested to determine

1. Particle size analysis.

2. Values of cohesion and angle of internal friction by shear test.

3. Compression index and pre-consolidation pressure by consolidation test.

4. Density specific gravity and moisture content.

Advantage of Sub-Surface Investigation:- There are manifold advantages of carefully planned investigation programme. These can be summarized as below:-

1. A suitable and economical solution can be worked out.

2. The construction schedule can be properly planned.

3. The extent and nature of difficulties likely to be met with can be determined

. 4. The rate and amount of settlements can be determined.

4. The variation in the water –table, of the presence of artesian pressures can be found out

questions

1. **What is bridge alignment ?**
2. **What is the determination of flood discharge ?**
3. **What is water way ?**
4. **What is economic span ?**
5. **What is afflux ?**
6. **What is fee board ?**
7. **What is clearance ?**

CHAPTER 9 BRIDGE FOUNDATIONS

Depth of Scour:

- DEPTH OF SCOUR (D) is the depth of the eroded bed of the river, measured from the water level for the discharge considered. Well-laid foundation is mostly provided in road and railway bridges in India over large and medium-sized rivers. The age-old Lacey–Inglis method issued for estimation of the design scour depth around bridge elements such as pier, abutment, guide bank, spur and groyene. Codal provisions are seen to produce too large a scour depth around bridge elements resulting in bridge sub-structures that lead to increased construction costs. Limitations that exist in the codes of practice are illustrated in this paper using examples. The methods recently developed for estimation of the scour are described. New railway and road bridges are required to be built in large numbers in the near future across several rivers to strengthen such infrastructure in the country. It is strongly felt that provisions in the existing codes of practice for determination of design scour depth require immediate review. The present paper provides a critical note on the practices followed in India for estimating the design scour depth. Indian practices on estimation of design scour depth

1. Lacey–Inglis method

2. Comments on Lacey's method •

The probable maximum depth of scour for design of foundations and training and protection works shall be estimated considering local conditions. • Wherever possible and especially for flashy rivers and those with beds of gravel or boulders, sounding for purpose of determining the depth of scour shall be taken in the vicinity of the site proposed for the bridge. Such soundings are best taken during or immediately after a flood before the scour holes have had time to silt up appreciably. In calculating design depth of scour, allowance shall be made in the observed depth for increased scour resulting from:

(i) The design discharge being greater than the flood discharge observed.

(ii) The increase in velocity due to the constriction of waterway caused by construction of the bridge.

(iii) The increase in scour in the proximity of piers and abutments.

.3 In the case of natural channels flowing in alluvial beds where the width of waterway provided is not less than Lacey's regime width, the normal depth or Scour (D) below the foundation design discharge (Qf) level may be estimated from

Lacey's formula as indicated below D = 0.473 (Qf / f) 1/3 Where D is depth in metres Qf is in cumecs and 'f' is Lacey's silt factor for representative sample of bed material obtained from scour zone. • Where due to constriction of waterway, the width is less than Lacey's regime width for Qf or where it is narrow and deep as in the case of incised rivers and has sandy bed, the normal depth of scour may be estimated by the following formula: D = 1.338 (Qf 2 / f) ½ 61 Where 'Qf ' is the discharge intensity in cubic metre per second per metre width and f is silt factor The silt factor 'f' shall be determined for representative samples of bed material collected from scour zone using the formula : f = 1.76 √m where m is weighted mean diameter of the bed material particles in mm.

TYPES OF BRIDGE

Arch bridge
Arch bridge (concrete)
Through arch bridge
Beam bridge
Log bridge (beam bridge)
Cavity wall Viaduct
Bowstring arch Box girder bridge
Cable-stayed bridge
Cantilever bridge
Cantilever spar cablestayed bridge
Clapper bridge
Covered bridge
Girder bridge
Continuous span girder bridge
Moon bridge
Movable bridge
Pigtail bridge
Plate girder bridge
Pontoon bridge
Roving bridge
Segmental bridge
Self-anchored suspension bridge
Side-spar cable-stayed bridge
Simple suspension bridge (Inca rope bridge))
Step-stone bridge
Stressed ribbon bridge
Suspension bridge
Transporter bridge
Trestle Truss arch bridge
Truss bridge
Vierendeel bridge
Brown truss
Covered bridge
Lattice truss bridge
(Town lattice truss
Tubular bridge

Bridge Foundation:

- Definition:-

A foundation is the part of the struct the load of the structure to the soil below. Before deciding upon its size, we must ensure that

: (i) The bearing pressure at the base does not exceed the allowable soil pressure.

11)The settlement of foundation is within reasonable limits

(iii) Differential settlement is to limited as not to cause any damage to the structure structure.

Broadly, foundation may be classified under two categories i.e.

1. Shallow foundation

2. Deep Foundation Shallow Foundation:-According to Trezaghi, a foundation is said to be shallow if its depth is equal or less than its width. Deep Foundation:- According to Trezaghi, a foundation is said to be deep , the depth is greater than its width and it cannot be prepared by open excavation.

Types of Bridge Foundation:- The selection of foundation type suitable for a particular site depends on the following considerations:-

1) Nature of Subsoil

2) Nature and extent of difficulties, e.g. presence of boulder, buried tree trunks, etc. Likely to be met with, and

3) Availability of expertise and equipment.

Depending upon their nature and depth, bridge foundation can be categories as follows:

i. **Open Foundation**,

ii. **Raft Foundation**,

iii. **Pile Foundation**,

iv**. Well foundation**

(i)Open Foundation in Bridges:-

1. An open foundation or spread foundation is a type of foundation and can be laid using open excavation by allowing natural slopes on all sides

. 2. This type of foundation is practicable for a depth of about 5m and is normally convenient above the water table.

3. The base of the pier or abutment is enlarged or spread to provide individual support.

4. Since spread foundations are constructed in open excavation, therefore, they are termed as open foundation.

5. This type of foundation is provided for bridges of moderate height built on sufficiently form day ground.

6. The piers in such cases are usually made with slight batter and provided with footings widened at bottom. Where the ground is not stiff the bearing surface is further extended by a wide layer of concreter at bottom (see the figure)

. **(ii) Raft Foundation**:-

1. A raft foundation or mat is a combined footing that covers the entire area beneath a bridge and supports all the piers and abutments.

2. When the allowable soil pressure is low, or bridge loads are heavy, the use of spread footing would cover more one-half of the area, and it may prove more economical to use raft foundation

3. They are also used where the soil mass contains compressible lenses so that the differential settlement would be difficult to control.

4. The raft tends to bridge over the erratic deposits and eliminates the differential settlement.

5. Raft foundation is also used to reduce the settlement above highly compressible soils by making the weight of bridge and raft may undergo large settlement without causing harmful differential settlement. For this reason, almost double settlement of that permitted for footings is acceptable for rafts.

6. Usually when hard soil is not available within 1.5 to 2.5 m a raft foundation is adopted.

7. The raft is composed of reinforced concrete beams a relatively thin slab underneath, figure

(**iii)Pile foundation in Bridges**:

1. The pile foundation is constructions for the foundation of abridge pier or abutment supported on piers.

2. A pile is an element of construction composed of timber, concrete or steel or combination of them

. 3. Pile foundation may be defined as a column support type of foundation which may be cast-in-situ or precast.

4. The piles may be place separately or they may be placed in form of a cluster throughout the length of the pier or abutment.

5. This type of construction is adopted when the loose soil extends to great depth.

6. The load of the bridge is transmitted by the piles to hard stratum below or it is resisted by the friction developed on the sides of piles

. Classification of piles:-

Piles are broadly classified into two categories:-

. i- Classification based on the function

ii- Classification based on the materials and composition

Classification based on the function

Bearing Pile

. Friction Pile.

Screw Pile.

Compaction Pile

. Uplift Pile

. Batter Pile.

Sheet Pile.

Classification based on the function

Cement concrete piles.

Timber Piles.

Steel Piles.

Sand Piles.

Composite Piles.

(iv)Well Foundation in bridges

a) Well foundations are commonly used for transferring heavy loads to deep strata in river or sea bed for bridges, transmission towers and harbour structures. The situation where well foundations are resorted are as below as) Wherever consideration of scour or bearing capacity require foundation to be taken to depth of more than 5 M below ground level open foundation becomes uneconomical. Heavy excavation and dewatering problem coupled with effort involve in retaining the soil makes the open foundation costlier in comparison to other type of foundation.

b) Soil becomes loose due to excavation around the open foundation and hence susceptible to scouring. This is avoided in well foundation which is sunk by dredging inside of the well.

c) From bearing pressure considerations, a well foundation can always be left hollow thereby considerably reducing bearing pressure transmitted to the foundation material. This is very important in soils of poor bearing capacity, particularly in clayey soils. In other type of foundation, the soil displaced is occupied by solid masonry/concrete which are heavier than the soil displaced and hence this does not give any relief in respect of adjusting bearing capacity. However in case of well foundation this is easily achieved because of cellular space left inside the well.

Well components and their functions:

Cutting edge: - It provides a comparatively sharp edge to cut the soil below during sinking operation. It is usually consists of a mild steel equal angle of side 150mm.

Curb: - It has a two-fold purpose. During sinking it acts as an extension of cutting edge and also provided support to the well steining and bottom plug while after sinking it transfers the load to the soil below. It is made up of reinforced concrete using controlled concrete of grade M200.

Steining:- It is the main body of the well. It is serves dual purpose. It acts as a cofferdam during sinking and structural member to transfer the load to the soil below afterwards. The steining may consist of brick masonry or reinforced concrete. The thickness of steining should not be less than 4.5 cm not less than that given by equation

1. **What is the scour depth of foundations ?**
2. **What are the types of foundations ?**
3. **What is spread foundations ?**
4. **What is piles foundations ?**
5. **What is raft foundations ?**
6. **What is well foundations ?**

CHAPTER -10

BRIDGE SUBSTRUCTURE AND APPROACHES

1 Piers:-

Piers provide vertical supports for spans at intermediate points and perform two main functions: transferring superstructure vertical loads to the foundations and resisting horizontal forces acting on the bridge. Although piers are traditionally designed to resist vertical loads, it is becoming more and more common to design piers to resist high lateral loads caused by seismic events. Even in some low seismic areas, designers are paying more attention to the ductility aspect of the design. Piers are predominantly constructed using reinforced concrete. Steel, to a lesser degree, is also used for piers. Steel tubes filled with concrete (composite) columns have gained more attention recently:. Pier is usually used as a general term for any type of substructure located between horizontal spans and foundations. However, from time to time, it is also used particularly for a solid wall in order to distinguish it from columns or bents. From a structural point of view, a column is a member that resists the lateral force mainly by flexure action whereas a pier is a member that resists the lateral force mainly by a shear mechanism. A pier that consists of multiple columns is often called a bent piers for river and waterway crossings. There are several ways of defining pier types. One is by its structural connectivity to the superstructure: monolithic or cantilevered. Another is by its sectional shape: solid or hollow; round, octagonal, hexagonal, or rectangular. It can also be distinguished by its framing configuration: single or multiple columns bent; hammerhead or pier wall. Selection of the type of piers for a bridge should be based on functional, structural, and geometric requirements. Aesthetics is also a very important factor of selection since modern highway bridges are part of a city's landscape. Figure-1 shows a collection of typical cross section shapes for overcrossings and viaducts on land and Figure-2 shows some typical cross section shapes for piers of river and waterway crossings. Often, pier types are mandated by government agencies or owners. Many state departments of transportation in the United States have their own standard column shapes. 73 Broadly piers are classified under following two categories:-

I. Solid Piers.

II . Open Piers.

Solid wall piers, , are often used at water crossings since they can be constructed to proportions that are both slender and streamlined. These features lend themselves well for providing minimal resistance to flood flows.

Hammerhead piers, are often found in urban areas where space limitation is a concern. They are used to support steel girder or precast prestressed concrete superstructures. They are aesthetically appealing. They generally occupy less space, thereby providing more room for the traffic underneath. Standards for the use of hammerhead piers are often maintained by individual transportation departments. A column bent pier consists of a cap beam and supporting columns forming a frame

. **Column bent pierscan** either be used to support a steel girder superstructure or be used as an integral pier where the cast-in-place construction technique is used. The columns can be either circular or rectangular in cross section. They are by far the most popular forms of piers in the modern highway system.

A pile extension pier consists of a drilled shaft as the foundation and the circular column extended from the shaft to form the substructure. An obvious advantage of this type of pier is that it occupies minimal amount of space. Widening an existing bridge in some instances may require pile extensions because limited space precludes the use of other types of foundation.

Abutments:- They are the end supports of the superstructure, retaining earth on their back. They are built either with masonry, stone or brick work or ordinary mass concrete or reinforced concrete. The top surface of the abutment is made flat when the superstructure is of trusses or girders or semi-circular arch. In case of segmental or elliptical arch type of superstructure, the abutment top is made skew. Weep holes are provided at different levels through the body of the abutment to drain of the retained earth.

The salient features of bridge abutments are listed below

. (a) Height. The height of the abutments is kept equal to that of the piers

. (b) Abutment batter. The water face of the abutment is usually kept vertical or could be given a batter of 1 in 12 to 1 in 24 as of piers. The face retaining earth is given a batter of 1 in 6 or may be stepped down.

(c) Abutment Width. The top width of the abutment should provide enough space for the bridge seat and for the construction of a dwarf wall to retain earth up to the approach level.

(d) Length of Abutment. The length of abutment is kept at least equal to the width of the bridge

. (e) Abutment cap. The design is similar to that of pier cap. Abutments can be spill-through or closed. The spill through abutment generally has a substantial berm to help restrain embankment settlement at the approach of the structure. Approach embankment settlement can also be accommodated by approach slabs to eliminate bumps at the bridge ends, closed abutments partially or completely retain the approach embankments from spilling under the span, and Bridges of several spans require expansion at the abutments. Therefore they are no usually required to resist the longitudinal forces that develop.

Broadly, abutments are classified under the following categories.

1. Abutments with wing walls
2. Abutments without wing walls Abutments with wing walls

(a) Straight Wing walls

(b) Splayed Wing walls

(c) Return Wing Walls

Abutments without wing walls

(a) Buried Abutments

(b) Box Abutments

(c) Tee Abutments

(d) Arch Abutments –

Buried Abutments: - This type of abutments is generally built prior to the placing of the fill. Since it is filled on both sides the earth pressure is low. Superstructure erection can be begin before placement of fill .

Box Abutments: - This employs a short span of bridge built integral with columns to act as a frame and resist earth pressure of the approaches. It is most often used overpass work where the short span may be employed for pedestrian passage (see figure).

Tee Abutments: - This type looks like T in plan and has now become absolute (see figure)

Arch Abutments: - This type of abutment is used where arches are employed because of their economy in certain conditions. The high inclined skewback thrusts are difficult to handle unless the abutment can be seated in rock. Therefore, they are often used for span over gorges

WING WALLS:

In a bridge, the wing walls are adjacent to the abutments and act as retaining walls. They are generally constructed of the same material as those of abutments. The wing walls can either be attached to the abutment or be independent of it. Wing walls are provided at both ends of the abutments to retain the earth filling of the approaches. Their design period depends upon the nature of the embankment and does not depend upon the type or parts of the bridge.[1] The soil and fill supporting the roadway and approach embankment are retained by the wing walls, which can be at a right angle to the abutment or splayed at different angles. The wing walls are generally constructed at the same time and of the same materials as the abutments. Classification of wing walls Wing walls can be classified according to their position in plan with respect to banks and abutments. The classification is as follows:

1. Straight Wing walls: They are used for small bridges, on drains with low banks and for railway bridges in cities (weep holes are provided).

2. Splayed Wing walls: These are used for bridges across rivers. They provide smooth entry and exit to the water. The splay is usually 45°. Their top width is 0.5 m, face batter 1 in 12 and back batter 1 in 6, weep holes are provided.

3. Return Wing walls: They are used where banks are high and hard or firm. Their top width is 1.5 m and face is vertical and back battered 1 in 4. Scour can be a problem for wing walls and abutments both, as the water in the stream erodes the supporting soil.

Questions

1. **What is piers ?**
2. **What are the types of abutments ?**
3. **What is wing wall ?**
4. **What are the components of wing wall ?**

Culvert and cause ways

Culvert- A culvert is defined as a small bridge constructed over a stream which remains dry most partof the year. It is across drainage work having total length not exceeding 6m between faces of abutment.

Types of Culverts;-

The following are six different type culvert.

1. Arch culvert
2. Box culvert
3. Pipe Culvert
4. Slab Culvert

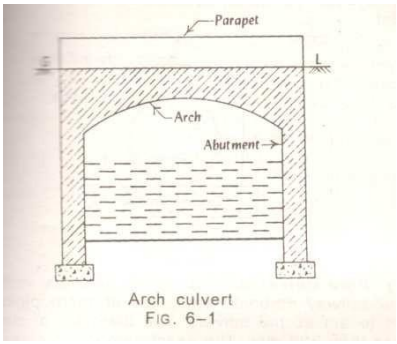
Arch culvert:-

An arch culvert consists of abutments wing walls, arch, parapets and the foundation. The construction

materials commonly used are brick work or concrete. Floor and curtain wall may or may not be

provided depending upon the nature of foundation soil and velocity of flow. A typical arch

culvert isshown in figure.



Arch culvert
FIG. 6–1

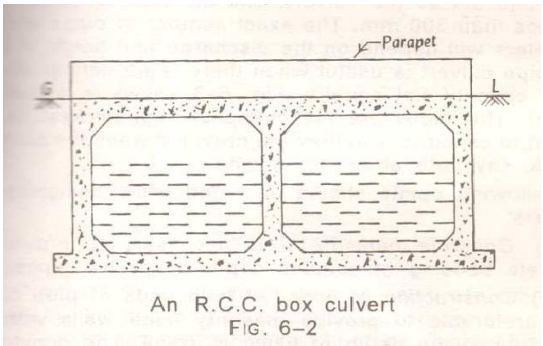
Box culvert:-

In case of box culvert the rectangular boxes are formed of masonry, R.C.C or steel. The

R.C.C boxculverts are very common and they consist of the following two component

(i) The barrel or box section of sufficient length to accommodate the roadway and the Krebs.

(ii) The wing walls splayed at 45 for retaining the embankment and also guiding the flow of water into and out of the barrel.



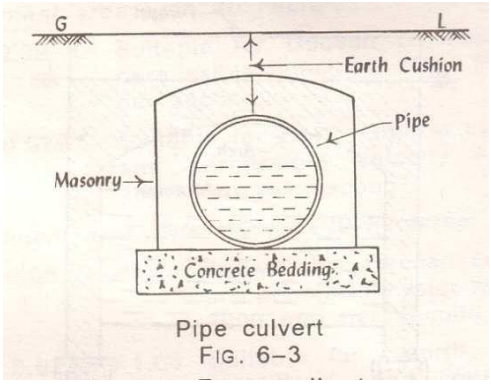
An R.C.C. box culvert
FIG. 6–2

Fig. 6-2 shows an R.C.C box culvert with two openings. Following points should be noted.

(i)Foundation: The box culverts prove to be safe where good foundations are easily available.
(ii)Height: The clear vent height i.e. the vertical distance between top and bottom of the culvert rarelyexceeds 3 meters.
(iii) Sap: The box culverts are provided singly or in multiple units with individual span exceed about 6 m or so, it requires thick section which will make the construction uneconomical.
(iv)Top: Depending upon the site conditions, the top level of box may be at the road level or it can even be at a depth below road level with filling of suitable material.

Pipe Culvert:

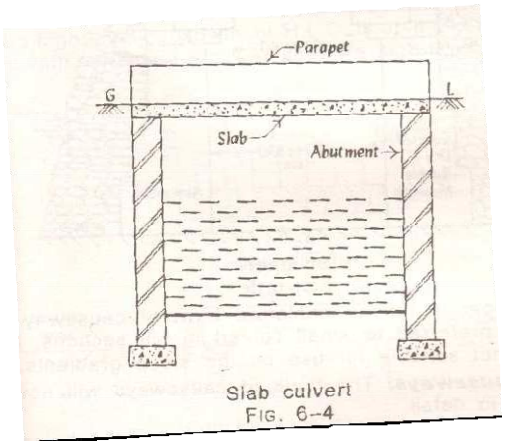
They are provided when discharge of stream is small or when sufficient headway is not available. Usually one or more pipes of diameter not less than 60cm are placed side by side. Their exact number and diameter depend upon the discharge and height of bank. For easy approach of water splayed type wing walls are provided in fig. 6.3 shows a Hume pipes culvert of single pipe. The pipes can be built of masonry. Stone ware, cement concrete, cast iron or steel. Concrete bedding should also be given below the pipes and earth cushion of sufficient thickness on the top to protect the pipes and their joints. For Economic reason road culverts should have non-pressure heavy duty pipes of type ISI class NP3 conforming to IS:458-1961. As far possible the gradient of the pipe should not be less than 1000.



Pipe culvert
FIG. 6–3

Slab Culvert:

A slab culvert consists of stone slabs or R.C.C slab, suitably support on masonry walls on either side.As shown in fig 6-4. The slab culverts of simply type are suitable up to a maximum span of 2.50 m or so. However the R.C.C culverts of deck slab type can economically be adopted up to spans of about 8
m. However, the thickness of slab and dead weight may sometimes prove to be the limiting factors for deciding the economical span of this type of culverts.



The construction of slab culverts is relatively simple as the frame work can easily be arranged,

reinforcement can be suitably placed and concreting can be done easily. This type of culvert can be used for highway as well as Railway Bridge. Depending upon the span of culvert and site conditions the abutment and wing walls of suitable dimensions may be provided. The parapet or hand rail of at least 750 mm height should be provided on the slab to define the width of culvert.

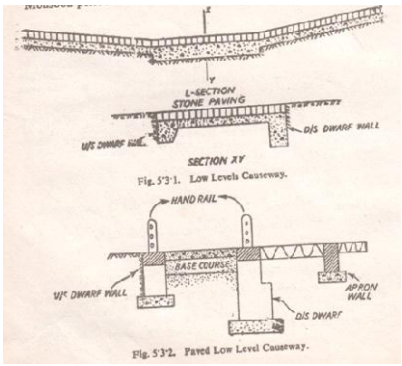
CAUSEWAYS :

A road causeway is a pucca dip which allows floods to pass over it. It may or may not have opening or vents for low water to flow. If it has vents for low water to flow then it is known as high level causewayor submersible bridge ; otherwise a low level causeway.

TYPES OF CAUSEWAY:

A) **Low level causeway**:

It is also known as Irish Bridge. The beds of small rivers or streams, which remain dry for most part of the year, are generally passable without a bridge. This involves heavy earth works in cutting for bridge approaches .Banks of such types of streams are cut down at an easy slope. Forstreams of rivers in plains having sandy beds, it is often sufficient to lay bundles of grass over and across the sandy track. The bundles may be of 20 to 25cm in



diameter whose ends are secured by longitudinal fascines pegged down by stakes.

For crossings important from traffic point of view it is essential to lay a metal or pucca paving of stone or brick set in lime mortar on a substantial bed of concrete. To prevent

against possible scour and undermining a cut off or dwarf wall usually 60cm deep on the upstream side and 120 to 150cm on downstream side is provided. Fig. 5.3.1 below shows the details of a typical Irish bridge.

The low level causeway could be provided with openings formed by concrete Hume pipes if there is acontinuous flow stream during the monsoon periods.

B) High level Causeway:

A high level causeway is submersible road bridge designed to be overtopped in floods. Its formation level is fixed in such a way as not to cause interruption to traffic during floods for more than three days at a time not for more than six times in a year. A sufficient numbers of openings are provided to allow the normal flood discharge to pass through them with the required clearance. They are provided with abutments and piers, floors and slabs or arches to form the required number of openings. The slope of the approaches is kept as 1 in 20.When the velocity is high and stream bed is soft the aprons could be of concrete or harder masonry upto a certain distance. Similarly, the road can be formed of a cement concrete slab or stone blocks set in cement mortar. A typical type of high level causeway is shown in Fig.5.3.3.If railing are provided in the bridge, they should be of collapsible type.Temporary causeways are used for an emergency military operations formed either by using

timber stringers and planking over cribs used as piers or by constructing a culvert using pipes.

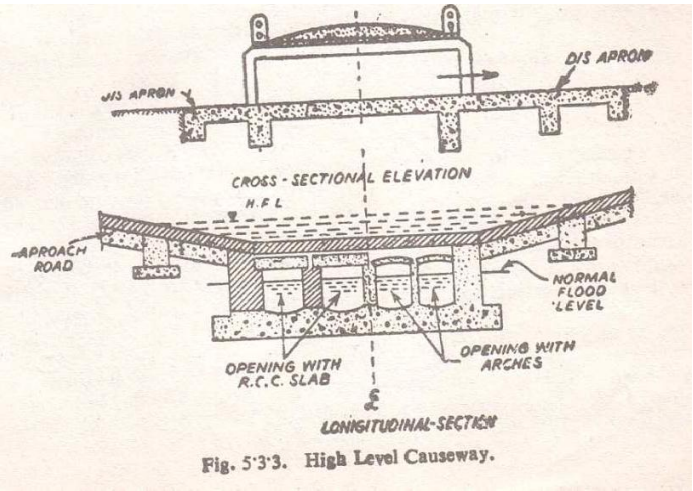


Fig. 5·3·3. High Level Causeway.

Questions

1.what are the types of culvert ?

2.what are the types of cause way ?

Thank you