LECTURE NOTE

ON

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FOR

DIPLOMA IN CIVIL ENGINEERING

(5TH SEMESTER STUDENTS)

AS PER SCTE&VT SYLLABUS

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Dt - 19/12/19

Ch-1

In-Introduction

Advantages of Railways —

→ Cause save in transportation on long bulk traffic.
→ Environmental friendliness.
→ speedy distribution of finished products.
→ Mobility of people has been increased reliving consition in populated areas.
→ Growth of industries has been promoted due to transportation of raw material.
→ Trade development due to railways has increased the earning and living standards of people.
→ It provides convinient and safe mode of transportation.
→ It helps in mass migration of population.
→ It is energy efficient.

→ Efficient land use and ease in capacity expansion.

Railway terminologies –

① **Ballast** :–

It is a granular material packed under and around the sleepers to transfer load from the sleeper to ballast. It provides elasticity to the track.

② **Gauge** –

The gauge of a track is measured as the minimum distance between the inner running or gauge bases of the two rails.

→ There are 3 types of gauge –

1. Narrow gauge
2. Metre gauge
3. Broad gauge

③ **Sleepers** –

These are the members laid transversely under the rails which are meant to support the rails over them and transverse the load from rails to ballast.

④ **Sleeper density** –

It is the no. of sleepers per rail length in metres.

⑤ **Turn out** –

A complete set of points and crossing with the intervening lead rails.

⑥ **Tractor Resistance** –

The force which resists the forward movement and speed of train are called as tractive resistance.

⑦ **Switch** –

A switch consists of a set of stock and tounge rail. These are tapped rails with a thicker end known as hill fixed to the main track while thinner

end known as toe is kept movable.

(8) Rulling gradient —
It is the maximum rise in gradient which is provided keeping in view the power of locomotive.

(9) Saddle plate —
A saddle shaped plate is used for strengthening the tough type steel sleepers below the rail sheet.

(10) Cant - (super elevation)
On curves to counter act the effect of centrifugal force the level of outer rail is raised above the level of inner rail by certain amount. This is known as super elevation or cant.

(11) Cant deficiency —

(12) Coning of wheels —
The wheels are conned at a slope of 1 in 20 to prevent from rubbing the inside face of rail & to prevent lateral movement.

(13) Keys -
Keys are the tapered piece of timber or steel to fix the rails to chairs on metal skepers.

(14) Points & Crossing —
These are a set of arrangements by which different loops either parallel or diverging are connected to effect for the train to move from one track to another.

(K) Signalling –

It is the technic by which the movement of trains is controlled efficiently to maintain safety on scheduled services.

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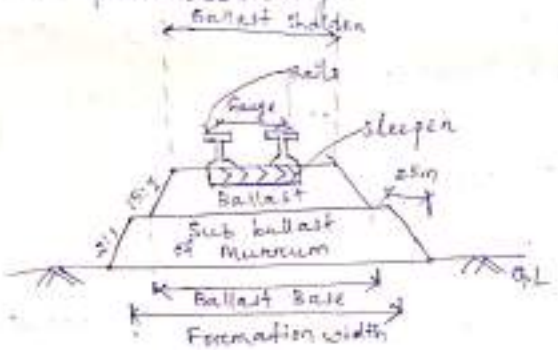
Permanent way –

The combination of rail fitted on slipper and resting on ballast and subgrade is called rail track on permanent way.



Requirements of permanent way –

1. The gauge should be correct & uniform.
2. Rails should be in proper level.
3. Track should be elastic in order to absorb shocks and vibrations of running track.
4. Radius and super elevation on curves.
5. Alignment should be correct.
6. Drainage system should be perfect in terms of safety and durability.
7. Track structure should be strong, low in initial cost as well as in maintenance cost.

Gauges in India –

Gauge of railway track is defined as the clear distance between the inner or running face of two tracks. The distance between the inner faces of a pair of wheels is called as wheel gauge.

Types of gauges –

Type of Gauge	width
Standard/Broad gauge (BG)	1.676 m
Meter gauge	1 m
Narrow gauge	0.720 m
Light gauge	0.610 m

Selection of gauge –

① Cost of construction.

② Volume & Nature of traffic
(Greater traffic volume and greater load carrying capacity. The trains should be run by a better traction technique. For heavy load and high speed Light gauge is used)

③ Development of the area.
(Narrow gauge can be used to develope thinly populated areas joining the under developed area with organised)

④ Physical features of country.
(Narrow gauge is used in hilly areas and in areas where there is a possibility of stiff gradients and sharp curves)

⑤ Speed of movement.

Diameter = 0.75 gauge

Speed of train is proportional to the gauge width. Thus for high speed broad gauge is preffered.

Uniformity of gauge –

① Difficulty in loading and unloading are avoided.

② Possibility of theft and misplacement is avoided.

③ Locomotive can be effectively used.

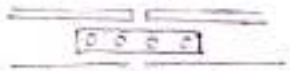
④ No time is wasted in changing personal and equipment from one vehicle to another.

⑤ Delay cause cost and hardship in transiping passengers & goods from one vehicle to another is avoided.

Type of Rails –

① Double headed Rail
② Bull headed Rail
③ Flat footed rail (proper grip)

Fish plates



to connect two rails fish plates are used.
[Rail with sleeper – bearing plate)

Functions of Rails –

① Rails provide strength, durability & lateral guidance to the track.

② The rails help in transmitting the axial load through the sleeper to ballast cushion.

(3) Rails bear the stresses developed due to heavy vertical loads and stresses due to temp. variations.

(4) To provide continuous and leveled surface for movement of train

(5) To resist breaking forces caused due to stoppage of trains.

(6) These provide a path which is smooth and has very less friction.

(7) These are I sections made off high carbon steel to provide a most economical smooth and level surface for the smooth passage of heavily loaded vehicles with a greater speed.

Requirement of rails :—

(1) They should be properly composed of steel.
(2) The vertical stiffness should be high enough to transmit the load.
(3) Rails should be capable of withstanding lateral forces.
(4) Foot should be wide enough such that, they are stable against overturning.
(5) The centre of gravity of the rail section must lie approximately at the middle head, so that maximum tension and compression stresses are equal.
(6) The fillet radii must be large to reduce the stress concentration. (4)

Types of Rail section

Flat footed rails	Double headed or Bull headed Rails
(1) More strength and stiffness for same weight.	(1) Less strength & stiffness for same weight
(2) Easy and simplier arrangements at points, crossing & at sharp curves.	(2) Complicated & difficult arrangements at points, crossing & at sharp curves.
(3) Initial cost is less.	(3) Initial cost is high.
(4) No daily inspection is necessary.	(4) Inspections of wooden keys is necessary.
(5) Maintenance cost is less.	(5) Maintenance cost is high.
(6) Replacement is difficult.	(6) Replacement is easy.
(7) More suitable due to better stability, economy, strength & stiffness.	(7) More suitable when lateral loads are important than vertical.

Length of Rails -

As per Indian Rail standared the lengths of rail are as following -

① For Bread gauge - Length = 13m (Std)
② For meter gauge - Length = 12m. (Std)

* Length of Rails depends upon following factors -

① Manufacturing cost shall be reasonable.
② Depends upon transportation facilities.
③ Limited by the facilities of lifting and handling during loading & unloading ~~from~~ of waggons.

Requirements of an Ideal joints -

① Two rails ends should remain true in line both Laterally & vertically when trains move on the track.
② Rail joints should provide enough space for free expansion and contraction.
③ It should not allow the rail ends to get ~~fractured~~ battered in any case.
④ It should be economical (minimum initial & maintenance cost).
⑤ The rail joint should be strong & stiff.

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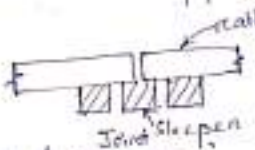
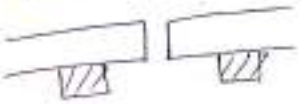
Types of Rail Joints -

① Supported rail joints :-

When the rail ends rest on single sleepen called as a joint sleepen is termed as supported joints.



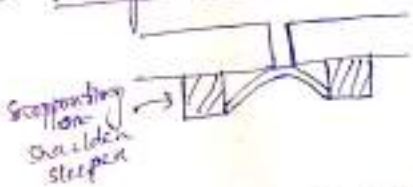
② Suspended Joints -



~~Suspended~~

When rail ends are projected beyond sleepers called shoulder sleepers. It is termed as suspended joints.

③ Bridge Joints -

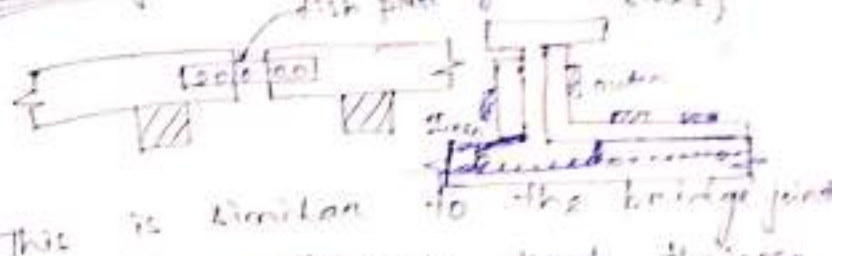


When the rail ends jams projects beyond sleepers and they are connected by flat or rectangular plate called a bridge plate and termed as bridge joint.

④ Staggered Joint :-
These also called as broken joint. In this type of joint, the joints of one rail track are not directly ~~from~~ opposite to the joints of the outer rail track. These are generally provided on curves.

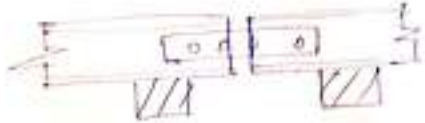
⑤ Square or even joint :-
The joints of one rail track are directly opposite to the joint of other rail track.

⑥ Base joint :-



This is similar to the bridge joint with the difference that the inner fish plate one of base type and outer fish plate one of special angle in which the horizontal leg is extended over the sleeper and bolted to the sleeper.

⑦ Compromise Joint :-
When two different rail sections are required to be join together it is done by means of fish plate. It is termed as compromise joint.



⑧ Welding Joint :-
These are the best joints and are also ideal. These are the most perfect and strongest type of joints.

③ Expansion Joint -

For expansion in rails the gape is 2.2cm. fore meter joint.

Purpose of Welding -

① To increase the real length of rail by joining two or more rails.
② To repair the damaged rails.
③ To built-up the burnt portion of rail head.
④ To built up worn out points and rails on sharp curves.

Dt. 13/1/20

Advantages of welding Rails -

① To reduce the creep due to increased in the length of rail and in term friction as well.
② Expansion effect due to temperature is reduced which in term also reduces the creep.
③ Long rail lengths being heavier than dampens intensity of high frequency vibration.
④ welding facilities track circuiting on electrified tracks.
⑤ Welding increases the life of rails due to decrease in the wear of rails at joints.
⑥ The cost of track construction by welding of rails decreases due to less no. of rail joints.

Creep of rails -

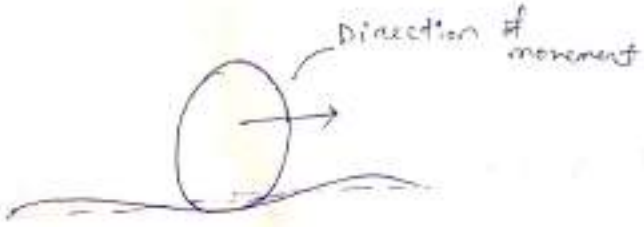
It is defined as the Longitudinal movement of rails with respect to sleepers in a track.

→ Creep is a commonly occuring factor in all rail tracks but, wearing in magnitude considerating.

Causes of creep -

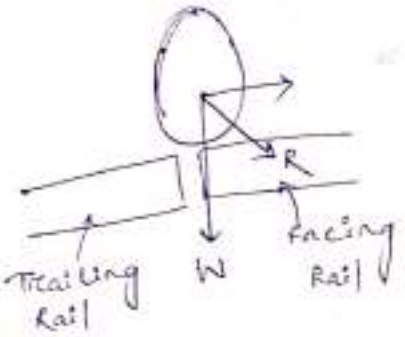
(A) Wave theory or wave action -

Wave motion is set up by moving Loads of wheels.



(B) Percussion theory -

This theory states that the creep is due to impact of wheels at the rail end ahead of joint.



(E) Drag theory —

It states that backward thrust on driving wheels of the Locomotive of train has got a tendency to push the rails off the track backward. This results in creep of rails in the direction of motion of train.

(D) Starting, accelerating, slowing down or stopping of a train:-

(E) Expension or contraction of Rails due to temperature.

(F) Unbalanced treaffic —

Effects of creep —

(1) Sleepers move out of square and out of position, this affects the gauge and alignment of track.

(2) Rail joints are opened out of their limits in some cases and stresses are set up in fish plates & bolts.

(3) The rail ends get battered due to excessive gapes at joints. While at other places joints are jamked and prevent required expansion.

(4) Points and crossings get deformed.

(5) Smashing of fish plates and fish bolts, bending of bars and fogging of ballast are common effects of creep.

Dt - 20/1/20

Sleepers

Functions of sleepers —

1. Holding the rail in their correct gauge & alignment.
2. Giving a firm and even support to the rails.
3. Transferring the load evenly from the rails to a wider area of the ballast.
4. Providing Longitudinal & Lateral Stability to the permanent way.
5. Acting as an elastic medium between the rails and the ballast to absorb the blows and vibrations caused by moving loads.

Requirements of sleeper —

1. Initial as well as the maintenance cost should be minimum.
2. The weight of the sleeper should be moderate so that it is convinient to handle.
3. Sleeper should be such that it is possible to maintain and adjust the gauge properly.
4. The designs of the sleeper and the fastening should be such that it is possible to fix and remove the rails easily.
5. The sleepers should have sufficient bearing area so that the ballast underneath is not crushed.
6. The sleeper should be capable of resisting vibrations and shocks caused by the passage of fast moving trains.
7. The sleeper should have anti-cavetage and anti-theft features.

Types of sleeper —

1. Wooden sleeper —

Advantages

1. These are cheaper than others & easy to manufacture.
2. Light in weight thus easy to transport & handle.

Disadvantages

1. Life span is very less compare to others.
2. Weak against fire.
3. Easily affected by humidity & termites. (termites)

④ fasteners can be easily installed.

⑤ Suitable for any type of gauges & rail section.

⑤ Well suitable for coastal area.

④ Poor creep resistance.

⑤ High maintenance.

② Concrete sleeper –

~~Advantages~~ ~~Disadvantages~~

These are most suitable for high speed rails.

→ Most of the concrete sleepers are made from pre-stressed concrete.

Advantages.

① They have long life span so economical.

② They have good fire resistance.

③ Corrosion is not occur in concrete sleeper.

④ Concrete sleepers are heavier than all other types Hence gives good stability.

⑤ Buckling strength is more.

⑥ Concrete is good insulator & suitable to all types of soil & moisture conditions.

Disadvantages

① Damage may occur while transportation.

② Because of heavy weight handling is difficult.

③ For tracks on bridges and at crossing concrete sleepers are not suitable.

③ Steel sleeper –

Dt - 22/1/20

Advantages

① These are light in weight so easy to transport.

② They are recycleable hence possess good scrap value.

③ Good resistant against fire & creep and vermins.

④ Life span is more than 30 yrs.

⑤ Suitable for high speed & large loaded tracks.

Disadvantages

① Can be easily effected by chemicals.

② Requires high maintenance.

③ Not suitable for all types of ballast, rail section & gauges.

④ Derailment is very dangerous in this case.

④ Cast iron sleeper

Advantages

① Life span is more than 60 yrs.

② Manufacturing is easy so can be done locally before installation.

③ It provides strong seat to rail.

④ The damaged cast-iron sleepers can be remoulded into new sleepers hence have good scrap value.

Disadvantages

① As it is brittle can be damaged by handling transportation & placing.

② Can be damaged badly by derailment.

③ These are susceptible to corrosion by salt water.

④ As cast iron is expansive these are uneconomical.

⑤ Composit sleepers

Advantages

① They have a life span of about 50yrs

② These are eco-friendly sleepers.

③ They are light in weight but posses good strength.

④ They can be used for any type of rail section as they can be easily reshaped.

⑤ Vibrations from rails are reduced well by the composit sleepers.

Disadvantages

① The cost of sleepers may increase for large scale production.

② These are not much good fire resistant.

Ballast

Functions of ballast -

① It transverse load from sleepers to subgrade.

② It holds the sleeper in position and prevents the lateral and longitudinal movement due to dynamic loads & vibrations.

③ It imparts some degree of elasticity to the track.

④ It provides easy means for maintenance of the level of the track and for the Uses of a track and for correcting track alignment.

⑤ It provides good drain, foundation immediately below the sleepers &

help to protect the top surface of the formation.

Requirement of good ballast -

1. It should be able to withstand hard packing without disintegration.
2. It should not make the track dusty or muddy due to powder under dynamic wheel loads.
3. It should allow for easy drainage with minimum shokage and the voids should be large enough to prevent capillary action.
4. It should offer resistance to abrassion & weathering.
5. It should not produce any chemical action with rail and metal sleepers.
6. The size of stone ballast should be 5cm for wooden sleepers, 4cm for metal sleepers and 2.5cm for turnout & cross over.
7. The ballast should be available in near by quarries.

Types of ballast -

1. **Broken stone** -
   - These are the best materials for ballast as they possess non-porous, hard & angular which doesn't flake when broken.
   - Igneous rocks such as hard trap, quartzite and granite make excellent ballast and are used for high speed track in India.
2. **Gravel** - (River pebbles or shingles)
   - These are obtained from either river beds or from gravel pits.
   - These stones posses best drainage quality.
   - It requires greater cousing and also requires ballast wall to prevent spreading.
3. **Ashes or shingles** -
   - These type of ballast material prevents vegetable growth and possesses fairly good drainage.
   - These are mainly used in case of emergency when the material is available in large quantity in short time for repairing

formation.

→ Its major demerit is it makes the track dusty and also corrodes metal sleepers & foots of rails.

→ It is very soft & light in weight.

Dt - 27/1/20

④ Sand -

It is reasonably a good material for ballast. As it is cheap & provides good drainage.

The greatest draw back of the sand is its blowing effect due to vibrations & also causes heavy wearing when gets into the moving parts of track.

⑤ Moorum -

It is a soft aggregate as a result of decomposition of laterite. It is available in Red & sometimes yellow colour. The best moorum for ballast is the one which consists of small stones of laterite.

⑥ Blast furnance slag -

It is a biproduct obtained in the manufacture of pig iron. Slag suitable for use as ballast is obtained by pouring molten slag into shallow pits of thin layers, allowing it to cool then digging, crushing & screening.

Fixtures of fore rail section -

Connection fore fish plate - [strengthen depth

Fish plates are used to maintain the continuity in the rail and also to allow expansion and contraction of the rails due to temp. variation. Further they also help in maintaining correct alignment both horizontaly and vertically of the rails.

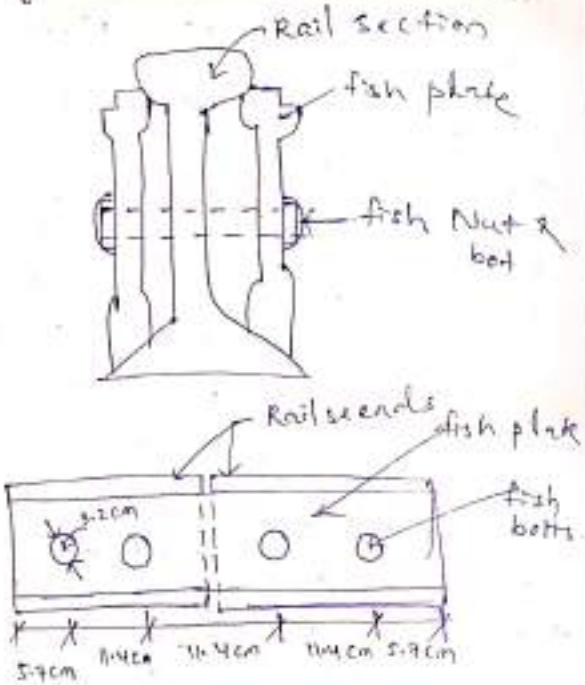
Requirements of fish plate: They must support the under side of rail and top of foot.

→ They must allow free movement of the rail for expansion & contraction. Thus, they shouldn't touch the web of rail section.

→ They should be provided against the be wear of fish plate

due to impact expansion & contraction.

The standared section for fish plate used in India is the bone section fish plate. In order to increase the strength of fish plate. the depth of fish plate is increased. Thus, other sections of fish plates are also used widely.



the failure of fish plate is due to wear & tear abbrasion on top of fish plate & also because of cracks developed at fish holes extends towards top of fish plate & vice versa.

Fish bolts - Standardize

The fish bolts are made of medium or high carbon steel. for 44.70 kg rail a bolt of 2.5 cm dia and 12.7 cm length is used.

Generally the length of bolt depends on type of fish plate. Too much tightening of fish bolts is prohibited as it prevents free expansion & contraction of rails.

Generally a projection of 6mm of the shank area is left out after the nut is tightened.

Ch-4

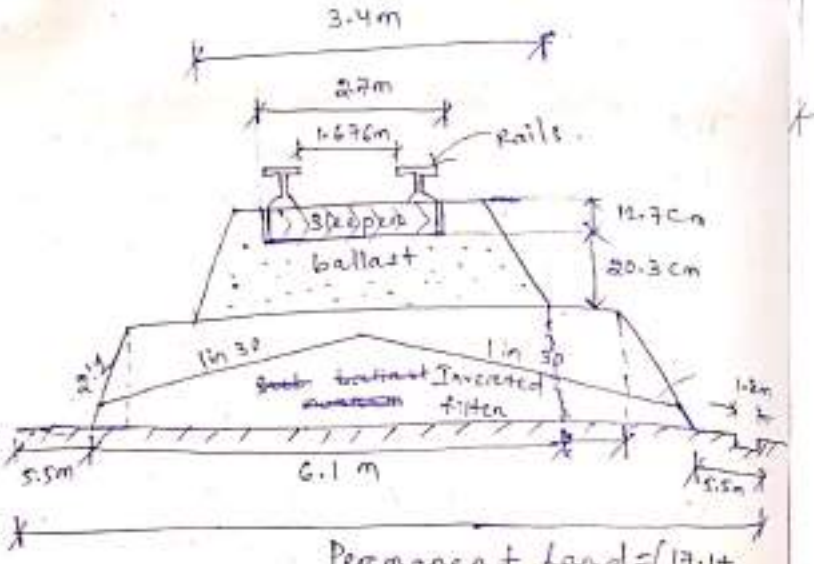
Geometrey of track

Straight track

Cutting width

Single Lane = 5.49 m.

double lane = 10.06 m



Permanent Land = (17.14 + 1 X depth of cutting)

Cross section of BG in Embankment (Single Lane)

Width BG Single lane :- 6.5 m

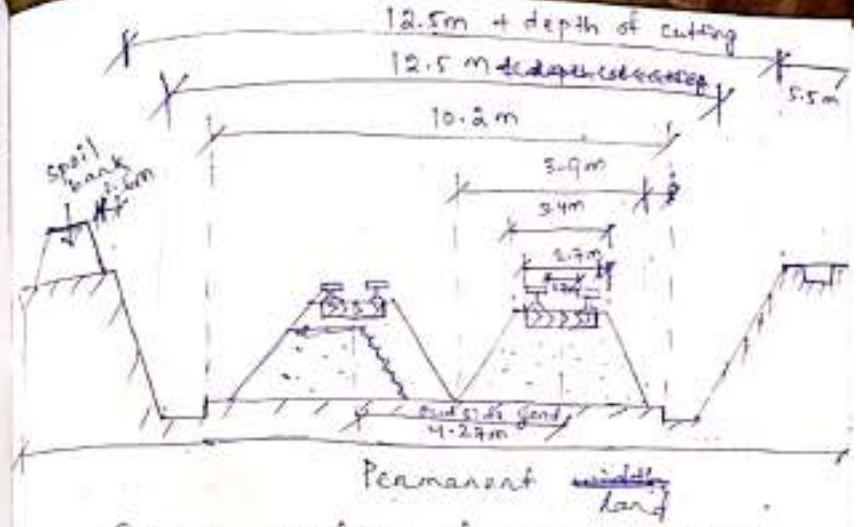
Width BG double lane :- 10.67 m

Slope = 2:1

C/c distance

Inside yared 4.73m

outside yared 4.27m.



Cross section of 2 Lane (B.G) in Permanent Land = (21.6 + 3 X depth of Cutting + spoil Bank)

Gradients in Railway

Any departure of the treack from the level is known as grade or gradient.

Grades are provided on the treack due to the following reasons —

① To provide uniform rise or fall.

② To reach various stations located at different elevation.

Various gradients used in Railway

1. Rulling gradient
2. Momentum gradient
3. Pushen or helpen gradient
4. Gradient in station yard

Rulling gradient –

It is defined as the gradient which determines the maximum load that the engine can haulon the section.

plain terrain – 1in 150 to 1in 200
Rolling/ hilly terrain – 1in 100 to 1 in 150

Once the rulling gradient is specified for a section there should be no gradient steepere than the rulling gradient.

② Momentum gradient –

This raising gradient is called as momentum gradient and a steeper grade than rulling grade can be adopted. It doesn't determine the maxm load of train but on account of their favourable position of track the train before approaching such gradient acquired sufficient momentum to negociate them is called as momentum gradient.

③ Pushen or helpen gradient –

Pushen gradients are very important in mountanous terrain where steep gradients are necessary to reduce the length of the track. In such case one locomotive being incapable extra engines are provided. Hence such gradients on which the pushen or helpen engines are provided along with the locomotive are called as pushen or helpen gradient.

④ Gradients in station yared –

The gradient at station yared should be such that it should prevent the following action.

1. The movement of standing vehicle on the track due to gravitational effect or strong winds.
2. To prevent additional resistance due to grade on the standing vehicle.

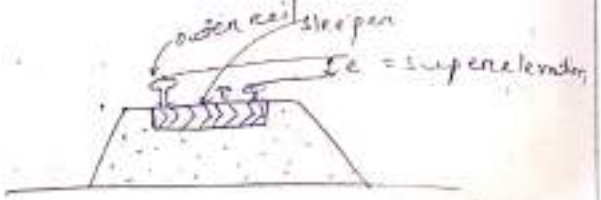
Grade Compensation on Curves

In order to avoid the resistance beyond the allowable limit the gradient is reduced on curves and this reduction ingredient is known as grade compensation on curves.

The grade compensation is different on different gauge.

BG = 0.04%
MG = 0.03%
NG = 0.02%

Super elevation



To counter act the effect of centrifugal force the level of outer rail is raised above the inner rail by a certain amount to introduce the centrifugal force. This raised elevation of the outer rail about the inner rail on a horizontal curve is called as super elevation or cant.

There are limits to the amount of super elevation that can be provided on a curve. The maximum value of super elevation according to the railway board is 1/10th of the gauge. (Norm 1/10th to 1/12th of gauge)

Max^m Super elevation

	V < 100 kmph	V > 100 kmph	V > 160 kmph
BG	14	16.5	16.5
MG	9	—	—
NG	6.5	—	—

Necessity of SE -

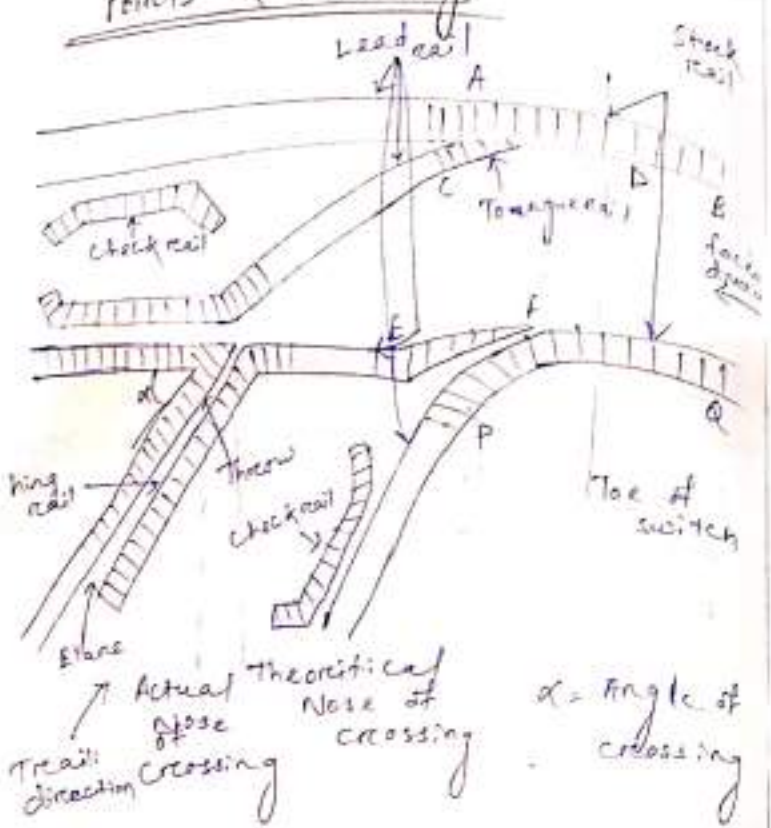
$$e = \frac{GV^2}{127R}$$

$$e = \frac{V^2}{gR}$$

G = Gauge (in m)
V = in kmph

1. To introduce the centripital force for counter acting the effect of centrifugal force.
2. To provide equal distribution of wheel load on the rails
3. To provide and even and smooth running track to ensure comfortable ride to the passanger.

Points & Crossing



Points, crossing, Turnout are the arrangements by which different rails either parallel or diverging are connected and afforded the means per train to move from one rail to another.

Necessity of points & crossing

(i) Points & crossing provide flexibility of movement by connecting on line to another according to requirement.

(ii) They also help for imposing restriction over turnout which necessarily retard the movement.

(iii) For safety aspect it is also important as points and crossing are weak points in tracks, where the vehicle is susceptible to derailment.

Right hand & Left hand turnout -

If a train from main track is diverted towards the right of main root in the facing direction, This diversion is known as right hand turn out and the vice versa is known as Left hand turnout in the facing direction.

Types of switch -

Stub switch -

This type of switch no separate tongue rail is provided and some portion of the track is move from side to side.

This is one of the oldest type of switch adopted. This type of switch is no more use.

Split switch -

In this type of switch a tongue rail is connected or combined with the stock rail split switch are classified as below.

i) Loose hill type -

In this type tongue rail are joint to lead rail by means of fish plate.

- This is suitable for short length switches.

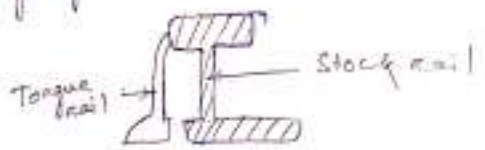
- It is also called as switch type switch.

(v) fix hill type switch

This is also called as spring type or flexible type of switch.
- The fix hill type switch is suitable in long tongue rail only.

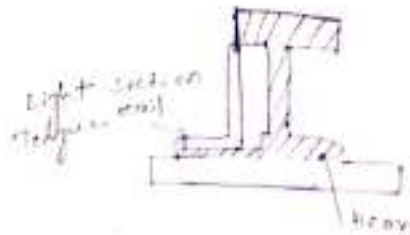
(vi) Undercut switch -

If the height of stock rail and tongue rail is same it is desirable to cut out a portion of flange. at the toe of the stock rail so the of the tongue rail is accomodated under the head of the stock rail.
- These are generally used in narrow gauge rail.



(vii) Over riding switch -

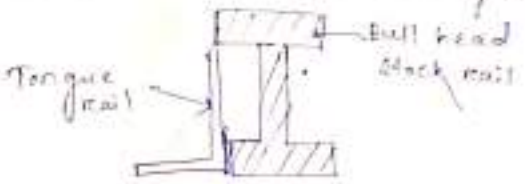
In this type of switch separate rail section of the stock rail & tongue rail are adopted.
- The tongue rail in this type rides over
- The flange of stock rail such switches are termed as over riding switch.



It is generally used for B.G & M.G track

(viii) Straight cut switch -

In this type the tongue rail is cut straight in the line with the stock rail. This type switch is suitable for bull headed rail.
- This is done to increase the thickness at toe of tongue rail.



Straight cut switch

Assignment

1. What is gradient compensation and write the standard value compensation for MG.
2. Determine causes of buckling of rail what is buckling of rail.
3. Write down the function of check rail & wing rail.
4. Differentiate between
   Cant - deficiency
   Cant - axis.
5. Flat & Bullheaded rail

(6) Write the advantages of prestressed concrete sleepers.

(7) Factor affecting the selection of gauge.

(8) What do you mean by spike.

(9) Define sleeper density. What is the min^m spacing between sleeper for packing of ballast.

(10) Draw the C/S of single lane BG in cutting.

Double lane BG in embankment

Dt - 10/2/20

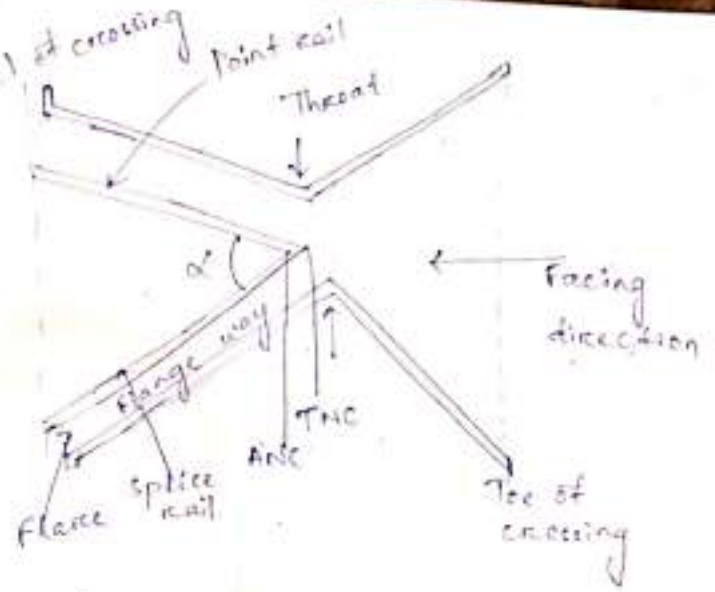
Types of crossing

A crossing or a frog is a device which provides the flange ways through which the wheels of the flanges may move. When two rails intersect each other at an angle.

The crossings can be classified as below —

A - On the basis of shape of crossing -

(1) Acute angle crossing

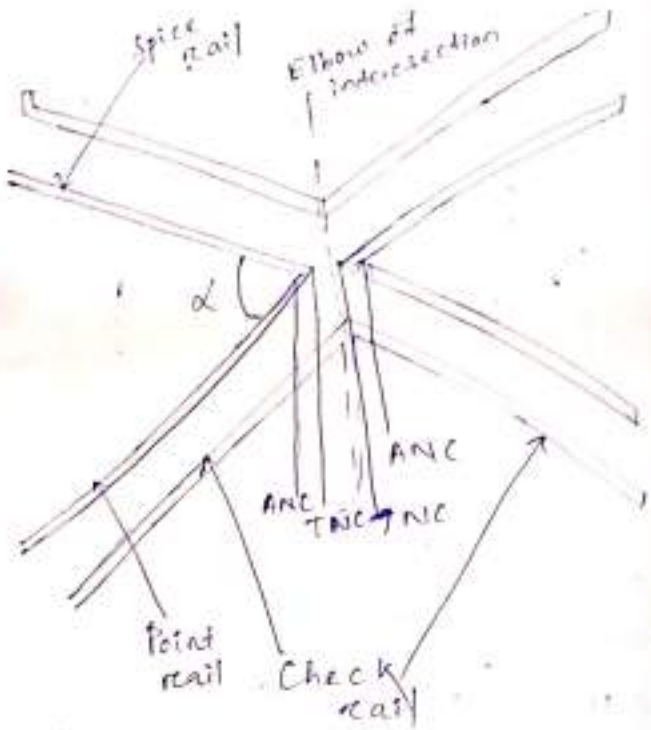


If the angle of the intersection between the two rails is acute then the crossing is called as Acute angle crossing.

It is the most commonly used type of crossing.

→ When the left hand rail of one track crosses the right hand rail of another track or vice-versa than this type of crossing is obtained.

② Obtuse angle crossing -

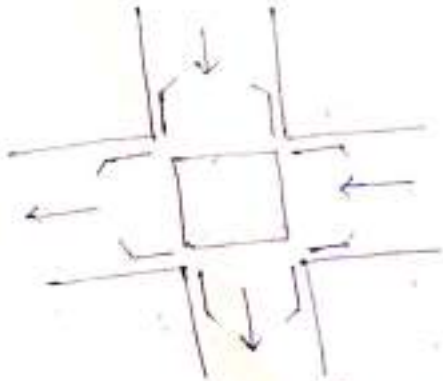


This crossing is obtained when a left hand rail crosses the right hand rail at an obtuse angle. This type of crossing is mostly used in the diamond of crossing. Unlike in acute angle crossing here the wing rails doesn't carry the wheel load more over they act as check rails.

③ Square crossing -

When two straight tracks cross each other at right angle these types of crossing are obtained.

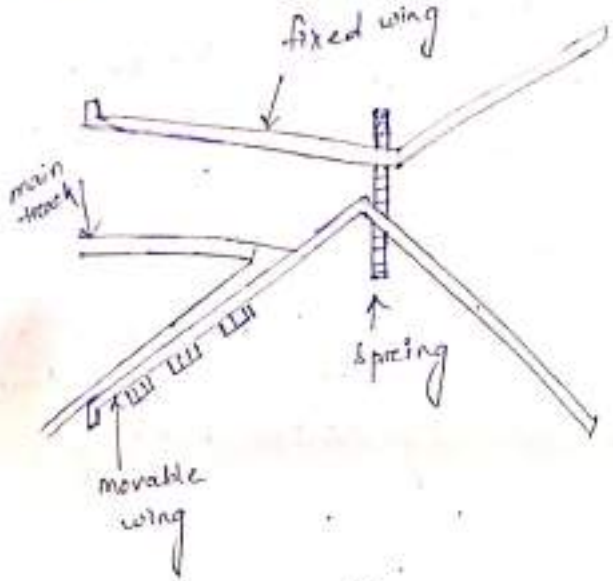
This type of crossing shall be avoided on the main line as they cause huge wear & tear due to dynamic loading.



⑧ On the basis of assembly of crossing -

① Springing or movable crossing -

In such a crossing one wing rail is movable and is held against the Vee of crossing. By doing so it meets that the main track continuous. This is mainly used for high speed traffic.



② Ramped crossing.

This type of crossing is generally used for low speed or slow speed traffic hence it is most commonly used in yards. And in this type of crossing the load is transferred through the flange.

Maintenance of tracks -

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Maintenance of track

Necessity of Maintenance -

→ The strength of track goes on deteriorating or reducing due to movement of high speed trains.

→ The track structure is subjected to other deteriorating effects like rain water, wind etc.

→ The elastic structure of rail track gets disturbed in alignment because of movement of high speed trains.

→ The track structure also undergoes wear & tear due to curvature, speed & load, point & crossing, bridge approaches etc.

Maintenance of railway track -

The maintenance of track can be done either manually or by using some mechanical machinery or components.

→ The maintenance of track can be divided into two types -

① Daily maintenance

② Periodic maintenance

Daily maintenance –

The daily maintenance is carried out by the full time staff throughout the year.

→ In this kind of maintenance the rail tracks are divided into different sections each upto 5 to 6 kms. where each one section is attached with 1 set up workers.

Periodic maintenance –

It is carried out after an interval of one to two years. During this maintenance the points & crossing, gauge, level, alignment etc are thoroughly checked. And the defects are identified and the causes are determined, remedial measures are also done.

→ The maintenance of track includes the following items of maintenance.

(A) Surface of rails :-

→ The top surface should be kept in some pioneer elevation.

→ The maintenance of surface of rails involves the following operations.

(1) Packing
(2) Surfacing the track
(3) Boxing & dressing of track
(4) Levelling of the track
(5) Lifting of the track
(6) Surface defects & remedies

(1) Packing :-

It is the method of forcing & packing stone ballast below the sleepers by ramming.

The width of packing of ballast under the sleeper are as follows

(1) Broad gauge — 45.7 cm
(2) Meter gauge — 35.6 cm
(3) Narrow gauge — 25.4 cm

The depth of ballast to be provided is usually 5cm to 7.5cm.

④ Surfacing of the track —

It is the process where in the rail tracks are brought to the condition of vertical evenness.

Dt - 19/2/20

③ Boxing & dressing of track —

It is the process of filling ballast between the sleepers & beyonds the ends of the sleepers to the required shape.

④ Levelling of the track —

The process of bringing the rails to equal elevation throughout is known as levelling of the track.

⑤ Lifting of the track —

The depressed tracks are required to be lifted.

If the lifting of the track is done under traffic it should be done in direction opposite to the traffic.

Both the rails are simultaneously lifted when substantial lifting of the track is done in two to three stages.

⑥ Surface defecting & remedies —

Without proper care the following defects are detected on the surface & points of the rails.

① High joint or riding joint —

When the level of the joint is highen than the rail level then it is known as high joint or riding joint.

② Blowing joint.

It is caused when a joint is situated on a loose or dusty ballast.

The remedial measure to these defects are —

① To clean the dusty ballast and repack the joint with additional ballast.

② Reduction of the expansion gap etc.

③ Pumping joints —

A blowing joint when effected by water gets converted into a pumping joint.

(A) Buckling of tracks -
Under hot weather conditions when the track goes out of alignment on curves under tightened fish plates or insufficient gapes in expansion joint it is called as buckling of track. It also occurs in welded rails.

(B) Centre bound track -
The deflection of sleepers is more at the ends than at the centre because of the rolling loads on the tracks.
This defect is called as centre bound track.

(C) Hogged rails -

(D) Corrugated or wearing rails -

(E) Spot packing & track lifting.

(b) Maintenance of track alignment -
If the track goes out of alignment that is shift side wise on the straights or at curves due to the following reason -

① The increased hammering action of the wheels on one rail only may displace the original alignment of the track.

② Due to hammering action of wheels loads on the ends of forward rails.

③ Due to variation of centrifugal force.

④ Due to temperature variation in hot weather.

(C) Maintenance of gauge -
The uniformity of gauge throughout should be properly maintained then, to provide a proper gauge.
The variation of gauge may occurs due to following causes -

① The loosening of track fitting which results in widening of the gauge.

→ The track gauge becomes irregular with the passage of time mainly due to loosening of sleeper fitting.

* Some special devices are used to maintain uniform gauge at some interval in wooden sleeper tracks, those are gauge rod & rail bracing.

(d) Maintenance of proper drainage

Drainage is most important to ensure smooth riding & longer life of the track.

The drainage property of the track can be maintained by (i) cleaning of ballast.

(ii) Surface drainage.

(iii) Underground drainage

(e) Maintenance of track component

Its maintenance includes -

(i) renewable of rail

(ii) spot removal of the rail is done under heavy traffic & its maintenance shall be done regularly.

(2) Maintenance of sleeper -

The sleeper maintenance can be done by spot renewable & thorough renewable. (break the sleeper & change it)

(3) Maintenance of fitting -

It includes lubricating the fish plates & fish bolts periodically.

(f) Maintenance of bridges & its approached -

This can be divided into the following sub division.

(a) Maintenance of foundation.
(b) Maintenance of substructure
(c) Maintenance of superstructure
(d) Maintenance of track on bridge.

Maintenance of bridges and its approaches is of greater importance because if any accident occurs at this spot it may fatal and may result into huge loss of life and national property.

(G) Maintenance of rolling stock —

Rolling stock include locomotive, coaches, and wagons.

→ The maintenance of rolling stock by cleaning the rolling stock daily, the boiler of locomotive shall be maintain and replace in every 15 yrs. Proper lubrication of the reciprocating parts of the rolling stock shall be carried out etc.

(H) Maintenance of points & crossing.

(1) Proper drainage must be adopted.
(2) Ballast repadking and screening done periodically.
(3) Clearance between check rail wing wall & tounge rail shall be checked.
(4) Creep should be prevented by creep anchors.
(5) The leads and radii of turn out shall be checked.
(6) Proper tightening of bolt shall be done daily.
(7) The displacement of sleeper shall be corrected.

(I) Maintenance of level crossing

1- In level crossing the road level is kept at the rail level.
2- The rails & fitting shall be checked once a yean by opening the level crossing.
3. The level crossing with less road traffic should have water bound macadam.
4. With heavy traffic should have bituminous pavement.

Maintenance of tunnels —

→ Portals at the ends should be checked.
→ Track material should be examined & maintained.
→ Wall & roofing should be carefully examined.
→ All the ventilation shafts should be clear of any obstruction.
→ The pavement way inspection is done in one yean.

Duties of permanent way inspector —

(a) Duties in the field work —

(I) He inspects the track by push trolly.
(II) He imparts instructions to gang nape, key man, gate man.
(III) The PWI is personally responsible for maintaining the track in a safe condition.
(IV) At the time of accident he should make the track safe in shorten period.

(b) Duties in office work —

(i) He maintains the estimate of maintenance work.

(ii) He controls the work shops. (smith, welding, carpentering etc)

(iii) He takes care of materials, labour etc.

(c) Miscellaneous Duties —

(i) To ~~attend~~ attend the monthly meetings of PWI.

(ii) He officiates as assistant engineer in his absence as and when required in his absence.

(iii) He also attends the inspection of Govt. inspector on railway.

Dt - 24/02/20

Bridge

A bridge is an arrangement made to cross an obstacle in the form of low ground or a stream of a river or over a gape without closing the way beneath.

Components of bridges -

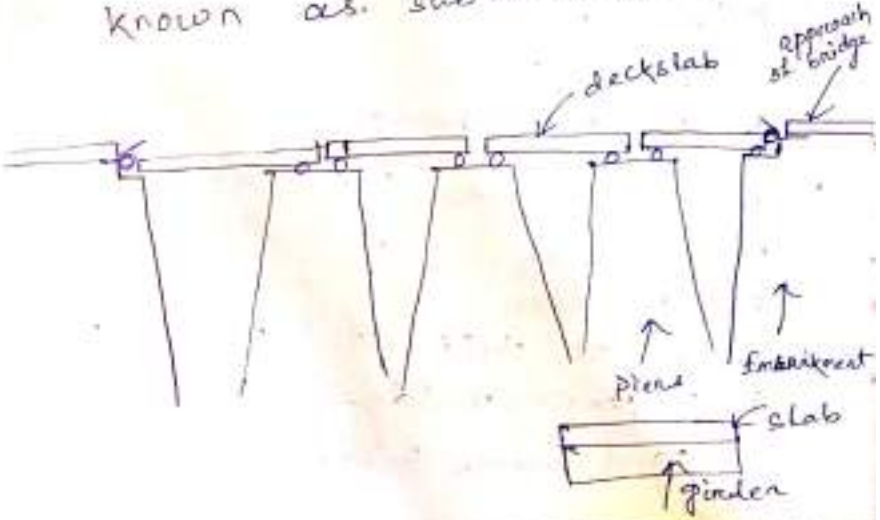
Bridge components are divided into two parts - (1) Superstructure
(2) Substructure

Superstructure -

The components of the bridge above the level of bearing is called as superstructure.

Substructure -

The components of the bridge below the level of bearing is known as substructure.



Culvert, minor bridge & major bridge

* If the span of bridge or opening of bridge is ≤ 6 m than it is called as culvert.
* from 6 m to 30 m is called as minor bridge.
* > 30 m is called major bridge.

Classification of bridges —

(a) According to flexibility of superstructure
  (1) Movable
  (2) Fixed span
  (3)

(b) According to Position of bridge floor relative
  (1) Deck bridge
  (2) Through bridge
  (3) Semi through bridge

(c) According to Inter span relation —
  (1) Continuous
  (2) Cantilever

(d) According to type of superstructure
  (1) Suspension Bridge
  (2) Rigid frame Bridge

(e) According to material of construction
  (1) Cement concrete
  (2) Steel
  (3) Timber
  (4) Masonry

(f) According to utility period
  (1) Permanent
  (2) Temporal

(g) According to function
  (1) Road
  (2) Railway
  (3) Rail cum road
  (4) Pipeline

(h) According to method of connection
  (1) Pin
  (2) Welded
  (3) Riveted

(i) According to length of span
  (1) Culvert
  (2) Major bridge
  (3) Minor bridge

(j) According to degree of redundancy
  (1) Indeterminate
  (2) Determinate

(K) According to alignment –
① straight
② skew

(L) According to level crossing of Railway & Highway
① Over bridge (Road over railway)
② Under bridge (Railway over road)

(M) According to IRC Loading –
① class AA
② class A
③ class B

for railway
major bridge > 12 m
minor bridge < 12 m

ch-2

Dt - 2/3/20

Selection of Bridge site –

① Connection of Roads
② freeboard (2ft to 3ft)
③ Embankment
④ foundations
⑤ Larger Tributaries (branches of river)
⑥ Materials & Labour
⑦ Minimum obstruction to waterway
⑧ right angle crossing
⑨ scouring & silting
⑩ straight streach of River
⑪ Velocity of flow
⑫ Width of River

$V_s \downarrow \rightarrow V_f$

$V_f > V_s$ No silting

$V_f < V_s$ silting

velocity → greater – scouring
lesser – silting

Dt - 3/3/20

Bridge alignment –

Flood Discharge

Empirical formula

Rational formula

① Dicken's (N.I) formula
$Q = CM^{3/4}$
(m^3/sec)
M = Area of catchment (sq km)
C = Constant
North India = 11.37
Central India = 13.77 – 19.28
Western India = 22.04

② Ryve's Formula
$Q = CM^{2/3}$
C = 6.84 (area within 24 km from coast)
= 8.45 (24–161 km)
= 10.1 (Hilly areas)
(South India)

For small Areas
① $Q = 123.2\sqrt{M}$
for area bet^n (160 to 2000 km^2)
② $Q = 123.2\sqrt{M} - 2.62(M - 259)$

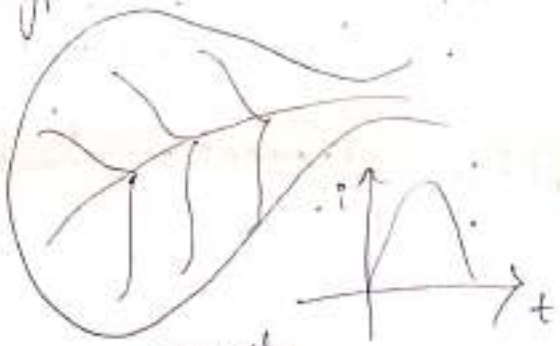
English formula (Maharashtra)

(iii) All types -

$$Q = \frac{123.2M}{\sqrt{M+10.36}}$$

Q → m^3/sec, M → km^2

It is also applicable for fan type catchment area.



fan catchment.

It has low discharge

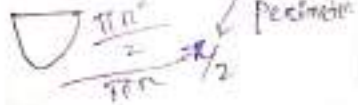
→ Long duration - (4-5 days)

Chezy's formula

$V = C\sqrt{RS}$ → S: slope

R: hydraulic radius = $\frac{A}{\text{wetted perimeter}}$

C: Chezy's coefficient.



Manning's formula

$$V = \frac{1}{n} \cdot R^{2/3} S^{1/2}$$

n: manning's coefficient

$Q = AXV$

Lacy's formula

$$V = 11 R^{2/3} S^{1/3}$$

Afflux - because of obstructions when water level increases is known as afflux.

→ Linear water way.
→ Artificial water way.

* Free board ≯ 600mm.
* Clearance for discharge
  > $300 m^3/s$ then
  min clearance = 900 mm.
→ discharge > $3000 m^3/s$ then
  min clearance = 1500 mm.

Economic span:

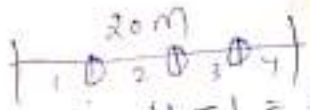
It is the one particular length decided according to economic conditions for the construction of a bridge. at which overall cost of bridge is minimum

Cost of superstructure = cost of substructure

= (cost per 1 abutment X2)

= (cost of 1 pier X(n-1))

n: no of span



4 - 1 = 3 pier.

cost ∝ sea level.
span ∝ cost
depth ∝ cost

Bridge alignment -

Depending on the angle which the bridge makes with the axis of the river is called alignment and is classified into two types -

① Square alignment -

② In this the bridge is at right angle to the axis of river.

② Skew alignment -

In this the bridge makes some other angle (other than 90°) with the axis of the river.

→ Skew alignment of a bridge requires some essential characteristics as follows.

① There should be smooth entry and exit of water underneath the skew bridge.

② Skew alignment should not be curved.

③ For the maintenance and construction of skew bridges greater skill workers are required.

④ The foundation of skew bridge is susceptible to scouring.

⑤ The foundation and piers of skew bridges suffer excessive water pressure.

Economic span -

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 on cost of material, availability of skilled labours, span length, nature of stream, climatic and other conditions.

$L = \sqrt{\frac{P}{a}}$ where, $a = \frac{P}{L^2}$

P = avg. cost of pier

a = a constant.

Span in m	4	6	8	12
Superstructure	1700	4500	9000	16000
Substructure	2200	22500	23200	23000

Q/ find economic span.

a = 100.25 125 109.375 111.11

L = 14.45 13.42 14.56 14.39

14.2 m

Water way

The area through which the water flows under a bridge superstructure is known as water way of the bridge.

- The linear measurement of this area along the bridge is known as linear waterway.
- The linear water way is = the sum of all the clear span.

Hence this is also called as artificial water way.

- The natural water way is the one which flows in the un obstructed area.

Afflux

When a bridge is constructed the natural water way area is reduced. The contraction of the stream occurs due the obstruction in natural flow path. Therefore to carry the maximum flood discharge the velocity under a bridge increases.

- This increased velocity gives rise to a sudden heading up of water on the upstream side of the stream, which is called as afflux.
- * Greater the afflux greater is the velocity of stream on the down stream side.
- Hence greater will be the scouring.

Further greater will be the depth of foundation.

Free board.

Free board is the vertical distance between the designed high flood level allowing the afflux and the level of the crown of the bridge at its lowest point.

Importance of free board

(1) It is required to allow floating debris, fallen tree trunks.
(2) It is also required to allow the afflux during maximum flood discharge.
(3) It is also required to allow the vessels to cross the bridge in case of river navigation.

High level bridge - 600 mm ft
Arch bridge - 300 ft
gradient bridge - 600 - 900 mm ft.
Navigational streams - 2400 - 3000 mm ft.

Collection of bridge Design Data

1. General Data
2. Catchment area & Runoff Data
3. Nature of stream

1) General Data -

(a) Name of Road & its classification
(b) Name of stream
(c) Location of nearest bench mark
(d) Chainage at centreline of stream.
(e) existing arrangement for crossing the stream.

2) Catchment area & Runoff Data -

(a) Catchment area
(b) Maximum recorded intensity & frequency of rainfall.
(c) Rainfall in cm per year.
(d) Length & width of catchment in km.
(e) Longitudinal slope of catchment
(f) Nature of catchment → soil type
(g) Presence of artificial or natural storage of water in catchment.
(h) Possibility of change in nature of catchment because of afforestation, erosion etc.

3) Data Regarding Nature of stream -

(a) Type of soil present in the bank of river.
(b) Stream can be perennial or seasonal.
(c) The extend of meandering of river.
(d) Banks at the proposed site.
(e) Nature of stream in the vicinity of the proposed site
(f) Low water level
(g) Ordinary flood level & high flood level.
(h) RL and location of maximum scour previously occur.
(i) Bearing capacity of the strata.
(j) Angle of internal friction, cohesion & angle of skin friction.
(k) clearance required for navigable streams.

Dt - 11/3/20.

Data regarding alignment & approach -

1. Details of bridge visibility
2. Proposed type of superstructure
3. The proposed bridge alignment can be square or skew.

Superstructure data :-

a. Proposed width of foot path cycle track and clear road way.
b. Gradient of the road, camber, side distance and formation level of the road over the bridge at the sector.

③ Foundation data :-

The type of foundation that can be adopted are open foundation, well foundation, sheet pile foundation.

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Scouring Bridge foundation

When the velocity of stream exceeds the limiting velocity which the erodable particles of bed material can stand, the scouring occurs.

→ The normal scour depth is the depth of water in the middle of the stream when it is scaning peak flood discharge.

For safe & sound design of a bridge it is important to measure scour depth either by practical or theoretical methods.

Scour depth of Alluvial stream :

Scour depth $d = 0.473 \left(\frac{Q}{f}\right)^{1/3}$

(Linear waterway not less than regime width)

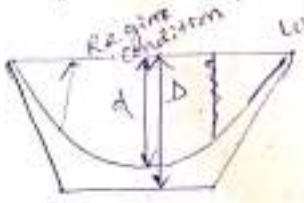
Q → cumpen sec

$d_1 = d \left(\frac{W}{L}\right)^{0.61}$ (Less than regime width)

d_1 = Normal depth
d = Regime depth

W = Regime width
L = Length of waterway

Weighted perimeter → discharg velocity.



Regime condition

→ No scouring
No silting

D - normal depth
d - Regime depth.

The alluvilian stream bed & banks are composed of loose granular material. These streams tend to scour till it acquires such a cross section & slope that resulting velocity is no scouring & no silting. When such a stage occcures the stream becomes stable & maintains the acquired shape. Hence such stream is called Regime channel.

Scour depth of ~~stream~~ soil — quasi alluvilian

$$d_1 = d\left(\frac{W}{L}\right)^{0.56}$$

This type of alluvilian stream has got rigid banks & erodable bed. The maximum scour depth for this a type of stream is not uniform and depends upon the nature of stream & flow condition.

Bridge foundation

Types —

The selection of foundation type suitable for a particular site depends on following consideration.

(a) Nature of sub soil.
(b) Nature & extent of difficulties likely to be matter.
(c) Availability of ~~&~~ Equipment
(d) Depending upon their nature & depth the bridge foundation is classified as are follows —

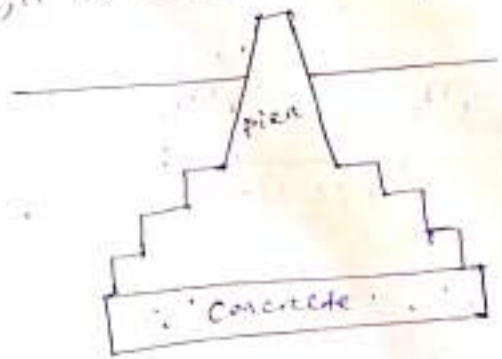
1. Open foundation
2. Raft foundation
3. Pile foundation
4. Well foundation

(1) Open foundation —

It is also called as spread foundation.

It is a type of shallow foundation practicable upto a depth of 5m. This is the most common type of foundation and can laid by open excavation. This type of foundation is provided for bridges of moderate ~~pier~~ height and sufficiently dry ground.

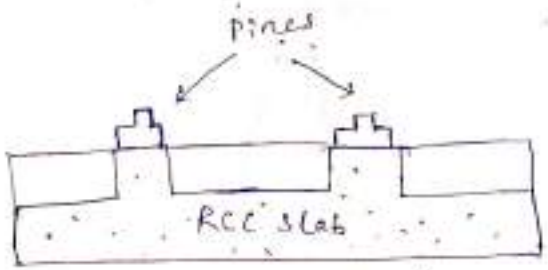
As this type of foundation is constructed by open excavation hence, it is called as open foundation.



Raft Foundation

It is also called as Matt foundation. It is a type of combine foundation that covers the entire area under the structure. It is used when the soil pressure is low & the bridge loads are heavy. It is also economical to use raft foundation. When the spread footing covers more than half of area under the structure. With raft foundation the risk of differential sattlement can be avoided. A raft foundation may undergo large sattlement without causing harmful differential settlement.

This type of foundation can be adopted when hard soil is not available within 1.5 to 2.5 m depth.



Pile foundation

It is a type of deep foundation. Pile foundation is an element of construction composed of timbers concrete or a combination of them. The pile foundation is adopted when the loose soil is extended to a greater depth. And the load of the bridge is transmitted by the pile to hard strata. The piles are classified into two categories —

(a) Based on function
(b) Based on material & composition.

(a) Based on function

(1) Bearing pile

The bottom of this type of pile rests on a hard stratum. Hence the load is transferred by bearing.

(2) Friction pile

When the loose soil is extended upto a greater depth. The piles are driven upto such a depth that the frictional resistance developed on the sides of the piles equals the load coming on the piles.

Date - 18/3/20

(3) Screw pile

It consists of a hollow cast iron of steel cylinder with one or more blades at the bottom. This type of pile is used for gravely ground, sand mixed

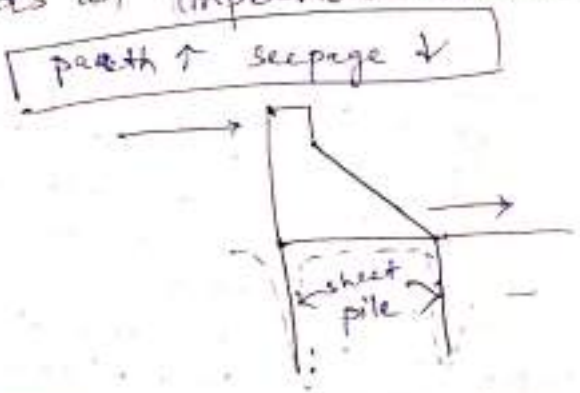
ground, soft rock.

④ Compaction pile -
It is used to increase the bearing capacity of loose soil under compaction.
- these piles doesn't carrey any load.

⑤ Uplift pile -
These piles are used in case of hydrostatic pressure or overturning movement of a structure. As it anchors the structure and reduces the uplift pressure.

⑥ Batten pile - (inclined pile)
This piles are used to reduce horizontal or inclined forces.

⑦ Sheet pile -
These a type of piles are used to reduced seepage and to act as an impervious stratem.



(b) Based on material & composition -
① Cement concrete pile
② Timber pile (coastal areas)
③ Steel pile
④ Sand piles
⑤ Composite piles

Pile deiving -
The process of forcing a pile into the groundine is termed as pile deiving.
- The equipments used for pile deiving are pile frame, pile hammer, leads and winches.

Pile frame -
It is the steel frame of height 10 to 25m. It is used to supporet deiven, engines, winches etc.

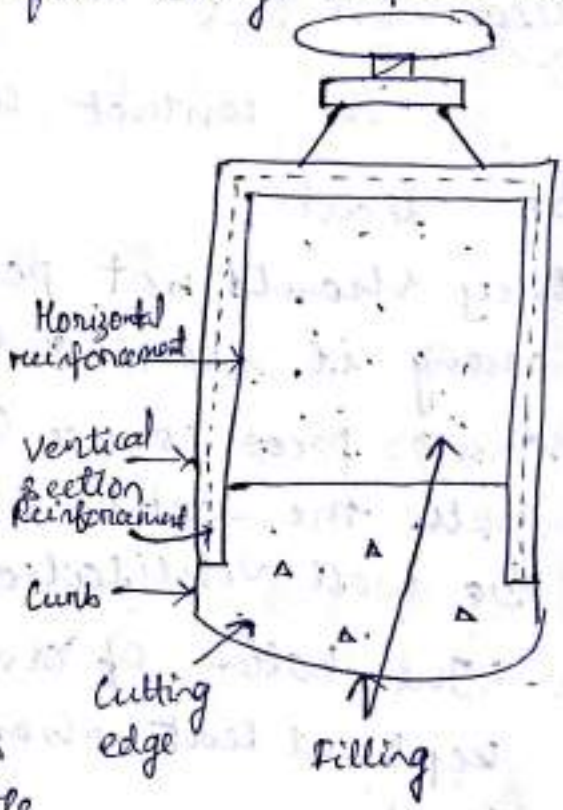
Pile hammer -
The ha is guided by two parallel steel members known as leadand they are of following types -
(a) Drop hammer
(b) single acting steam hammer
(c) Double acting steam hammer.
(d) Differential acting steam hammer
(e) diesel hammer
(f) vibraton

* Well Foundation:

It is also called as open caisson. Well foundation is a hollow cylinder made of concrete open at top & bottom. These are used on sandy or soft bearing stratum liable to scour & where no firem bed is available for large depths below the surface.

Sinking of Well

In case of well sinking on dry grounds, an open excavation upto half metre above subsoil water-level is carried out & the well curbs is laid. If the wells are to be sunk midstream, a suitable cofferdam is constructed around the site of the well & islands are made. Wooden sleepers are inserted below the cutting edge at regular interval so as to distribute the load. Initially the well steining should be built to a height not more than 5m, the well is sunk by excavating material from inside under curbs. After sinking of one stage is complete all the damaged portion of the steining at the top of the first stage should be repaired.

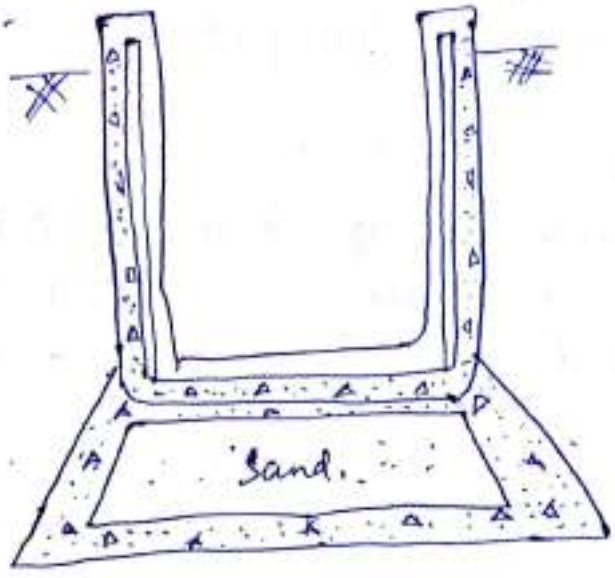


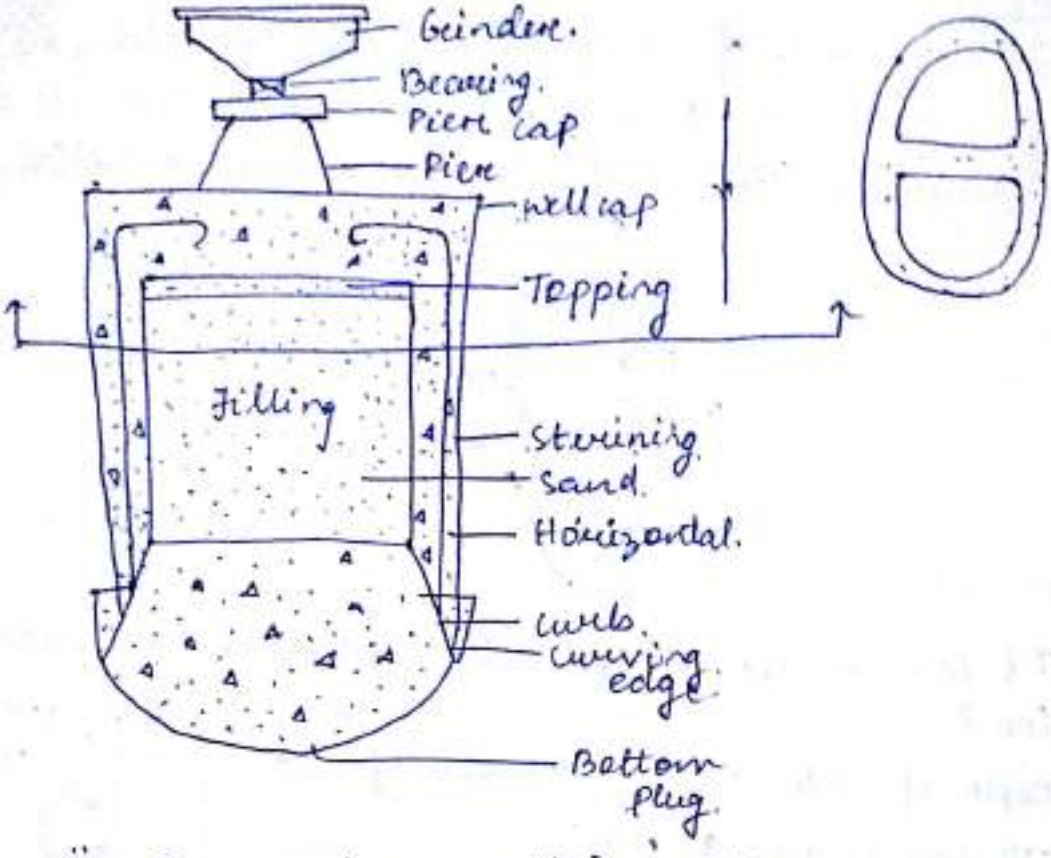
Caisson :

It is a type of cylinder (hollow) which may are may not be open at the bottom & top.

(i) Box Caisson:

Box is open at top but closed at bottom. It may be made up of RCC or steel or timber. Box caisons are prepared under the following conditions. when depth of the water is more than 6-8 m. when bad materials consist of soft or loose material. The velocity of flow is not large.





(ii). Open caision - well foundation

(iii). Pneumatic caision :-

It is open at bottom & closed at top. This is useful at locations where it is not possible to adopt wells. They are suitable when depth of water is more than 12m. In this the compressed air is used to remove water from the working chamber & the foundation work is carried out in dry conditions.

* Cofferdam:

It is a temporary structure which is built to remove water from an area & make it possible to carry on the construction work under reasonably dry conditions. It is usually measured for project such as dams, locks & construction of bridge piers & abutments.

Types of cofferdam:

1. Earth fill cofferdam
2. Rock fill cofferdam
3. Rock fill Crib "
4. Single wall "
5. Double wall "
6. Cellular "

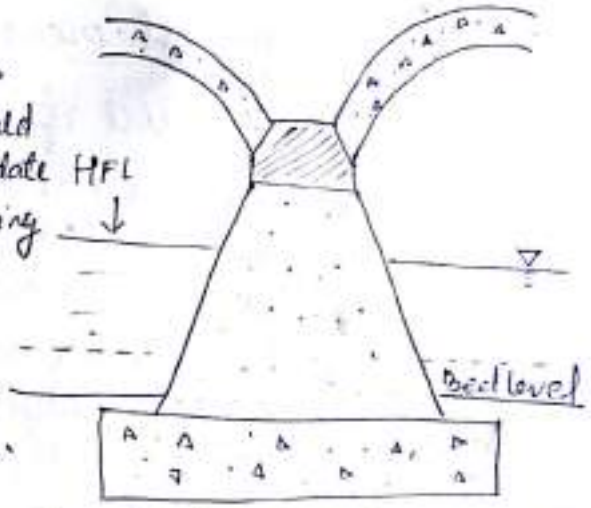
Bridge Substructure & Approaches

* Types of piers :

- (a) Solid piers
- (b) Open piers
  - (c) Multiple bent
  - (d) Pile bent
  - (e) Cylindrical Piers
  - (f) Trestle Piers

* (a). Solid piers :

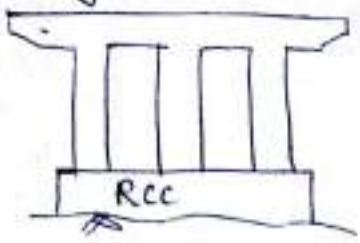
It may be constructed either of masonry or mass concrete. The pier top is kept 1 to 1.5m above HFL of the river or stream as free board. The top width of the pier should be sufficient to accomodate the seats of two bearing and a clearence of 15 cm. The pier ends are shaped fore easy passage of water. The pier cap covers the entire area of the top of the pier & projects 7.5cm beyond the pier dimension. The pier cap is built of RCC which corresponds to M150 grade concrete.



(b). Open piers :

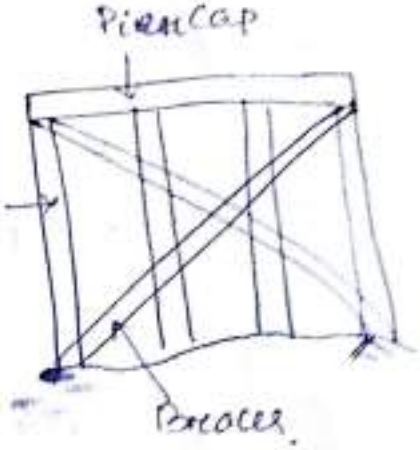
(i) Multiple Bent :

They are often used on ground. It is needed in overpass work where traffic runs parallel close to the bent to reduce damage to the columns in case of accident. It is lighter & may be more



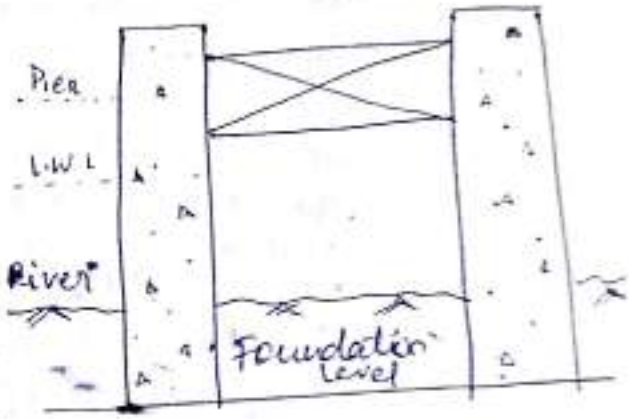
economical than the solid pier.

(ii) Pile Bent:



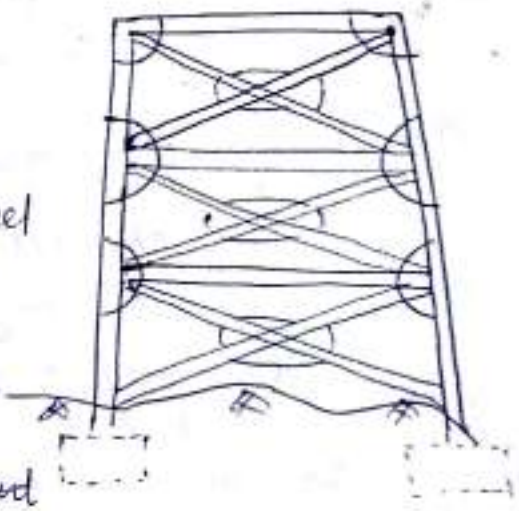
It is used for low piers over unstable ground. They consist of RCC/steel piles driven into the ground, provided with a capping at their top to support the main girder. They are laterally connected by RCC or steel bracers. The pile is used both for resistance & for a column by projecting above ground.

(iii) Cylindrical piers:



They consist of mild steel or cast iron cylinders which are filled with concrete when cylinders are used for bridges of greater width two cylinders are sunk a slight distance apart & suitable bracing is provided.

(iv) Trestle Piers:



They are used for temporary work & for timber work. They are made up of RCC or steel vertical, horizontal & diagonal members. In order to avoid moments transferred from deck to the columns & two hinged concrete hinges are introduced between the top of the columns & the bent cap.

* Abutments:-

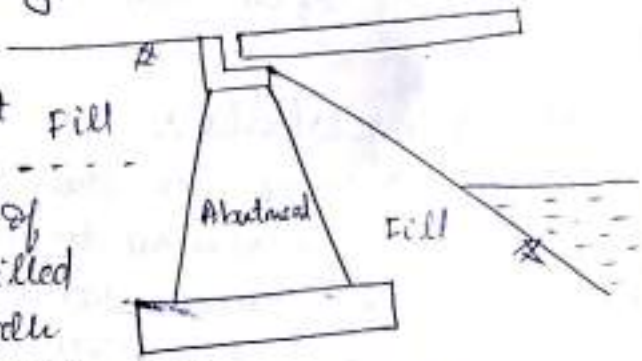
Where are the end supports of the superstructure, retaining earth on their back. They are built either with masonry, stone or brick work or RCC. The water face of the abutment is usually kept vertical or given a batter of 1 in 12 to 1 in 24. & the earth retaining face is given a batter of 1 in 6.

Types of Abutment

- Abutment with wing walls
  - Buried Abutments
  - Box Abutments
  - Tee Abutments
  - Arch Abutments
- Abutment without wing walls
  - Straight wing walls
  - Splayed wing walls
  - Return wing walls.

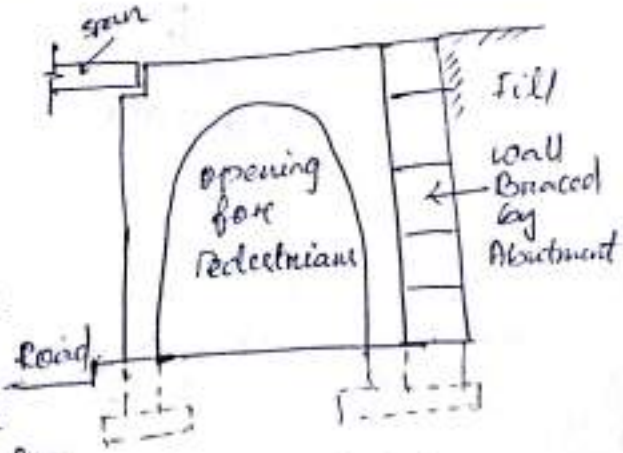
(i). Abutment without wing walls:

(a). Buried Abutment:



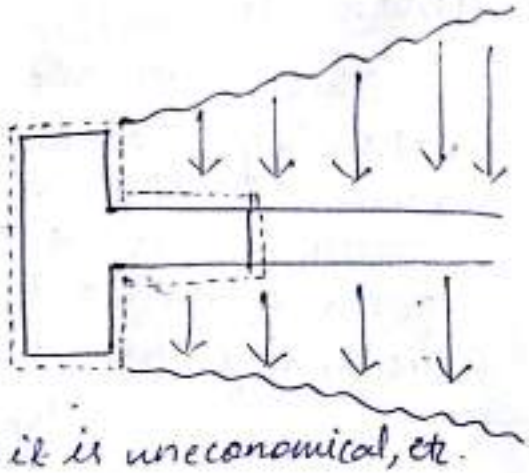
This type of abutment is generally built prior to the placing of the fill. Since it is filled on both sides the earth pressure is low. Superstructure erection can begin before placement of fill.

(b). Box Abutment



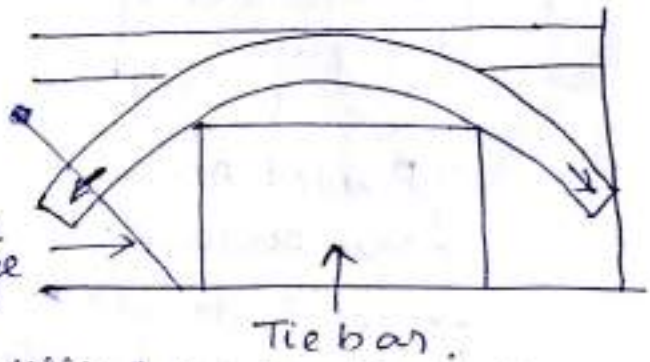
This employs a short span of bridge built integral with columns to act as a frame & resist earth pressure of the approaches. It is most often used for overpass work, where the short span may be employed for pedestrian passage.

(c). Tee Abutments :



This type of abutments looks like T in plan & has now become obsolete. It is usually not recommended because it doesn't protect the embankment of river, & it is uneconomical, etc.

(d). 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. Thus they are often used for span over gorges.

* Wing Walls :-

These are the walls provided at both ends of the abutments to retain the earth filling of the approach road. These are constructed with the same material as those of the main abutment.

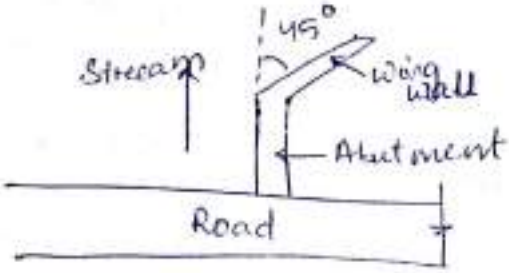
Two Types of Wing walls

- Masonry Wing walls
- Reinforced Concrete Wing wall.
  - Straight wing walls.
  - Splayed wing walls.
  - Return wing walls

(i)* Straight Wing Walls:

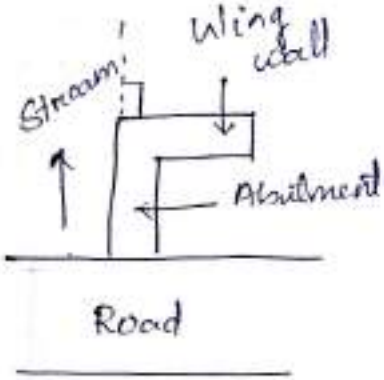
These are suitable for small bridges constructed across drains with low banks. Generally they are built for a railway bridges specially in cities, where the cost of the land is high. In case of hard & rock foundation, the wing walls may be constructed in steps. When the soil is loose, the foundation should be taken to a uniform depth.

(ii)* Splayed Wing Walls:



They are constructed generally at 45° with abutment & are straight or curved in plan. They provide a smooth entry & exit to the flowing water. They are best suited for the crossing of a river. They are also adopted when the road has to narrow on crossing the bridge.

(iii)* Return Wing Walls:



These are walls built at right angles to the abutment at its both ends. They are designed to retain the earth filling of the approach road. These are suitable where the banks are high & rocky. These are adopted when the cost of the land is high.

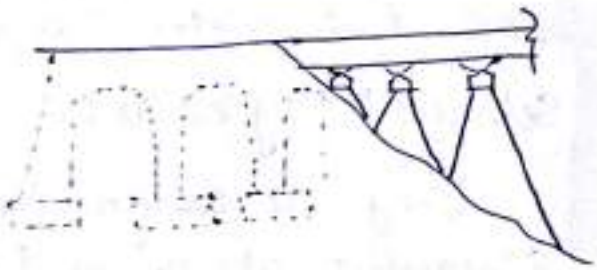
* Approaches:-

The approaches are the lengths of the communication route at both ends of the bridge. As per I.R.C the minimum length of the approaches shall be 15 m on either side of bridges. In case of horizontal or vertical curves the necessary lengths can be provided as per IRC beyond the straight length.

* Types of Approaches :-

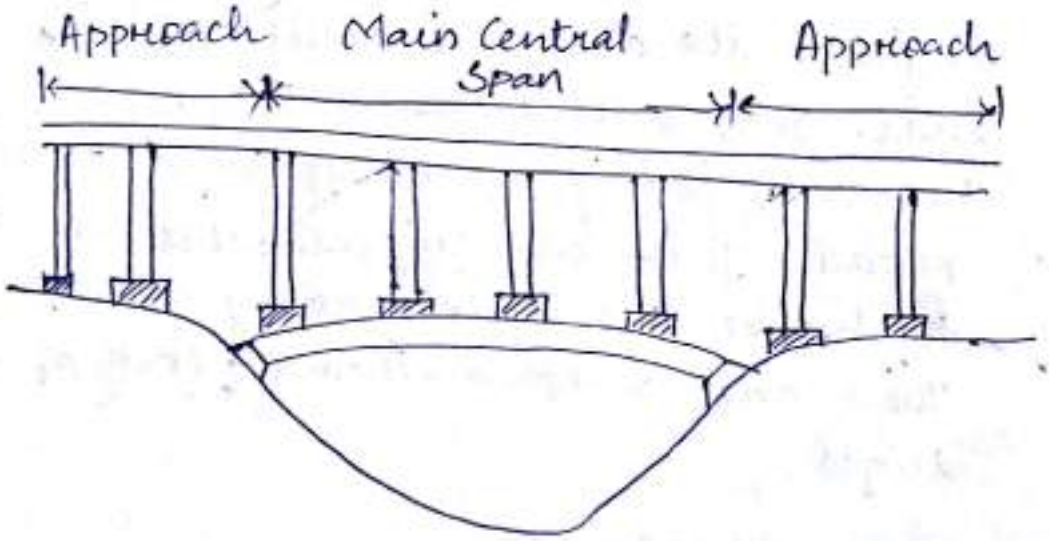
For different bridges based on ~~site~~ the approaches are provided in embankment while for submersible bridge & causeways they are provided in cutting.

→ Sometimes for better substructure the bridge is extended into the banks for some distances. this extended portion may not be same as the bridge proper.



→ In urban areas where land is costly, the approaches are made of retaining walls constructed on either end of road widths.

→ In case of arch & suspension bridges, it is economical to cover only the central major portion of bridge. The approaches in such cases may be provided in the form of series of small spans from the banks to main structure.



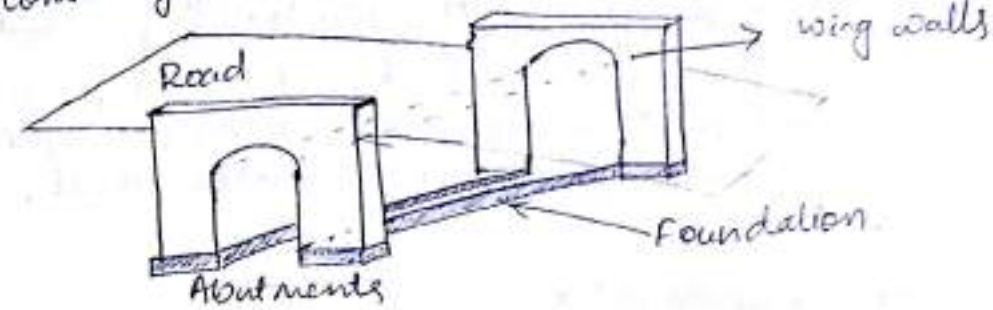
Ch-12 Culverts & Causeways :-)

* Culvert :->

It is a small bridge for carrying water beneath a road railway. It is used when the linear waterway does not exceed 12m. The waterway is provided in 1 to 3 spans. In case of road culvert, span is limited to 5m in length, whereas in case of railway span is limited to 6m. The common types of culverts are classified as follows:

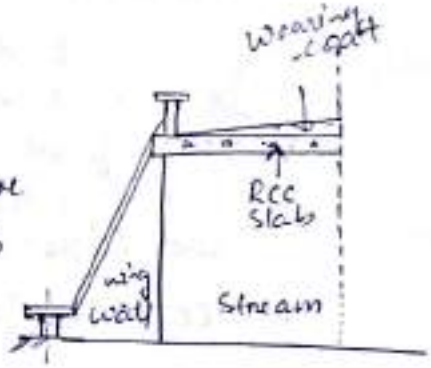
(i). Arch Culvert :

It consists of abutments, wing walls, parapets & the foundations. The construction materials commonly used are brick work or concrete.



(ii). Slab Culvert :-

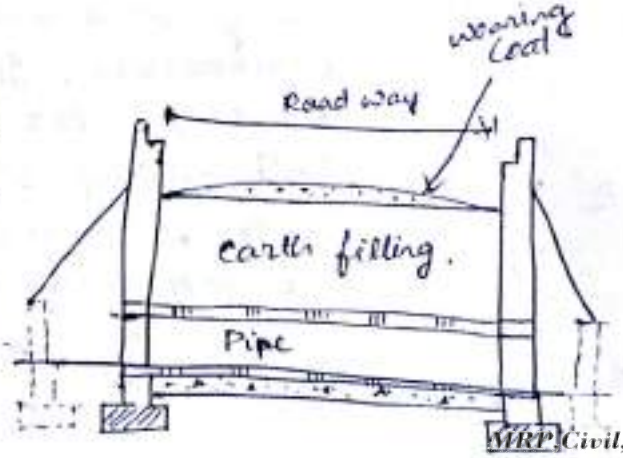
It consist of RCC slab either with or without beams on a stone slab. The deck slab should be designed as one way slab.



The culverts on important highways should be designed for IRC class AA track vehicle.

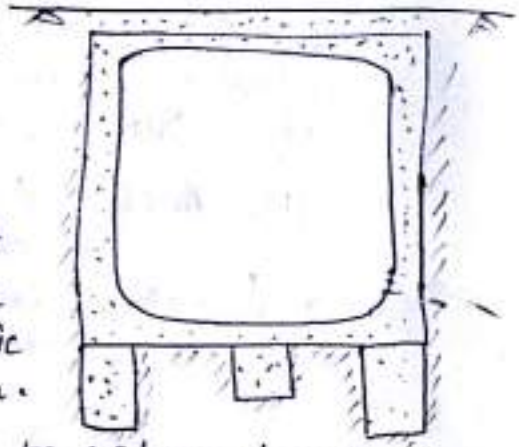
(iii). Pipe Culvert :-

These are provided when discharge of stream is small & when sufficient headway is not available. Usually one or more pipes of diameter not less



than 60cm are placed side by side. The number and diameter depends upon discharge & height of bank. A bedding should also be given below the pipes & earth cushion of sufficient thickness on the top to protect the pipe & their joints.

(iv). Box Culvert :-



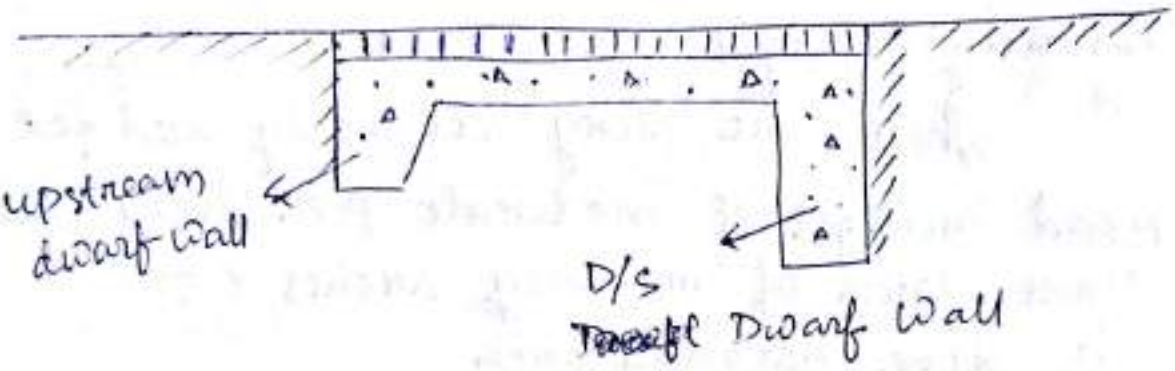
They comprise one or more number of rectangular or square openings. These are adopted to distribute the load to a wider area. The abutment top & bottom slabs are all made into a monolithic rigid frame as shown. The height of vent shall be not greater than 3 m. These are provided with splayed wing walls to retain the embankment.

* Causeways :→

It 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. There are two types of causeways i.e. low level causeway and high level causeways.

(i). Low level Causeways :-

The beds of small rivers or streams which remain dry for most part of the year, are generally passable without a bridge. It is also known as Irish bridge. This involves heavy earth work in cutting for bridge approaches. To prevent against possible scour & undermining a cut off or dwarf wall usually 60cm deep on the upstream side & 120 to 150 cm on downstream side is provided. The low level causeway



could be provided with openings formed by concrete lime pipes, in case of moreoms under continuous flow.

(iii). High Level Causeway:-

It 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. If the bridge has vents for low waters to flow then it is known as high level causeway are submersible bridge. A sufficient number of openings are provided to allow the normal flood discharge to pass through them with the required clearance.

Ch - 11 Permanent Bridges

* Masonry Bridges:

There are very commonly used for road bridges of moderate span. There are three classes of masonry arches i.e.

(i). Stone Masonry arch.
(ii). Brick masonry arch.
(iii). Cement Concrete masonry arch.

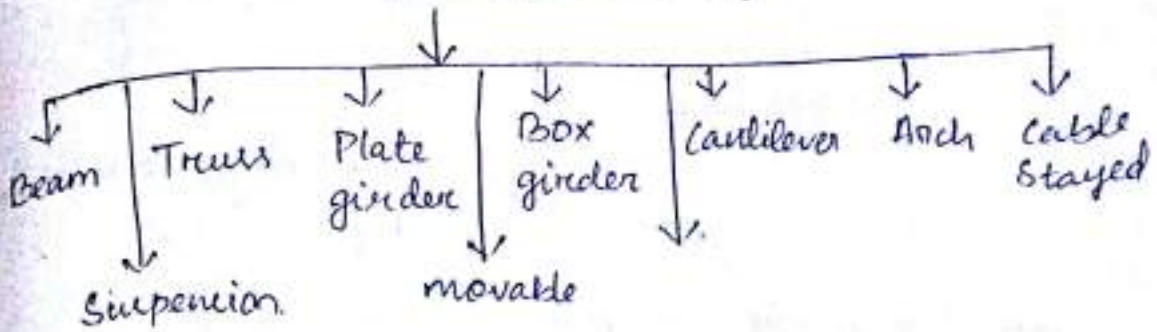
Arches vary in shape from very flat to very having a rise greater than a span. The common types of arch shapes are segmental, semi-circular, elliptical, parabolic, pointed & multi centred. Elliptical & parabolic arches are not so strong as segmental type & are more difficult to construct. Thus the segmental arch is more popular & generally used for masonry bridges for median span length.

* Steel Bridges:

These are built for many purposes carrying a highway, a railway track, etc. The steel bridge is generally adopted because of the following advantages:

- High quality material
- Speed of construction
- High tensile & compressive strength.
- uniformity.
- Can retain fatigue.
- High strength to weight ratio.
- Follows Hooke's law.
- Can easily be modified.

Types of Steel Bridges

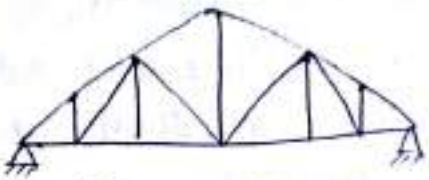


(i) **Beam Bridges:**

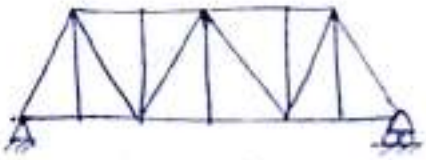
In case of beam bridges rolled steel I-beams with or without cover plate are used as main girders. The cross I-beams act as bracing for the main I-beams. These bridges are used for culverts. This type of construction has the advantage of speedy erection.

(ii) **Truss Bridge:**

A truss bridge is economical for spans greater than 30m and are suitable for span range of 40 to 375m. The primary forces in its members are axial forces. Its erection is considerably simple because of the relative lightness of the component members.



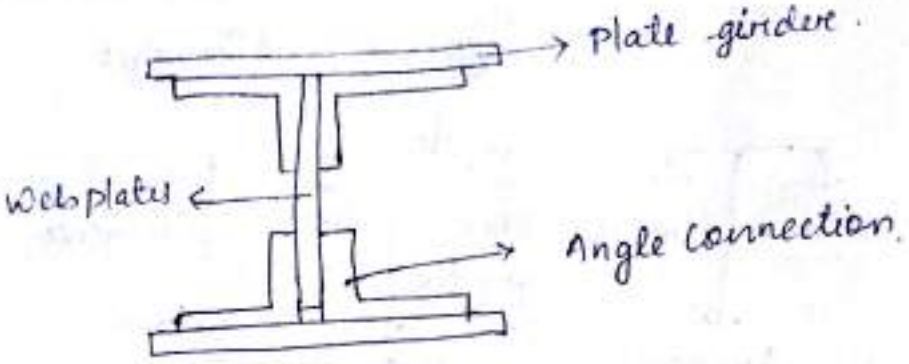
Parker Truss



Warren Truss

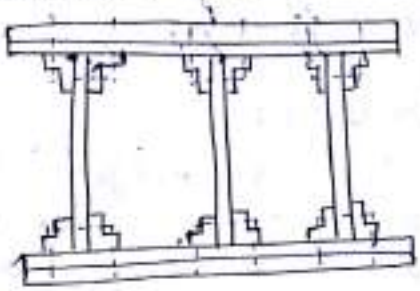
(iii) **Plate Girder:**

It is just a built-up beam to carry heavier load over longer spans. This simplest type of riveted plate girder consists of pair angles connected to solid web plate. These bridges can be used as curved or continuous bridges for urban highway structures like flyovers.



(iv). Box girder Bridge:

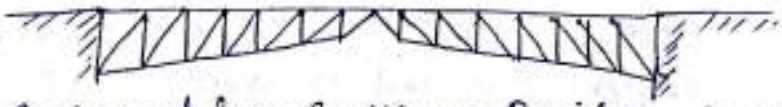
For better lateral stability the box girder which consists of four plates connected by angle irons are used. The box girders can be made more strongers by using more than two webs & also by using more cover plates. Box girder bridges have exceptional torsional rigidity & better transverse load distribution.



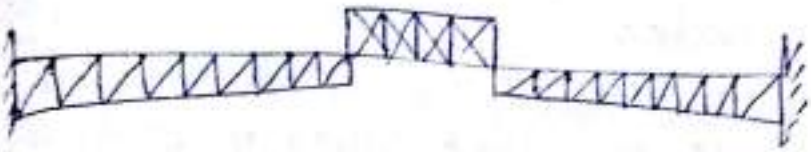
(v). Cantilever Bridges:

These are provided over deep valleys where it is not possible to have any centering. They are also suitable at locations where foundation bed is liable to settle under the load. There are two types of Cantilever Bridges.

(a). Unbalanced type Cantilever Bridge: in this the height of the bridges goes on decreasing towards the free end from the fixed end.

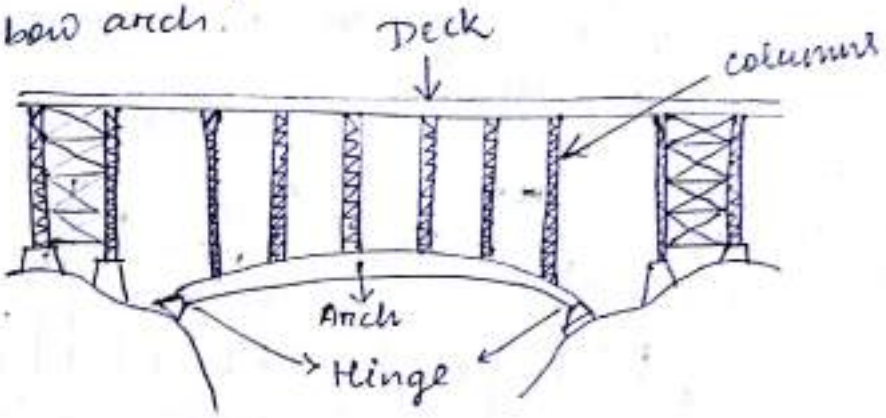


(b). Balanced type Cantilever Bridge: in this one portion of a span is suspended from or rests over, or is hinged with other portion or portions.



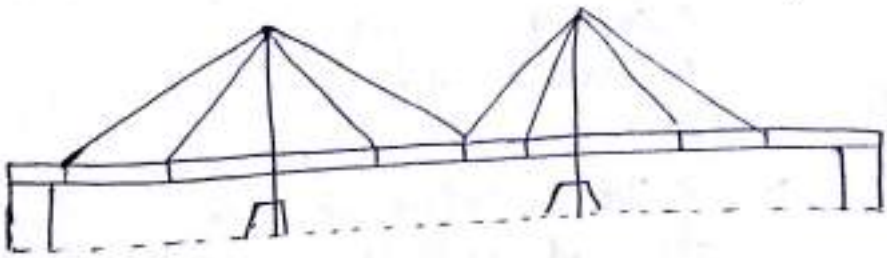
(vi) Arch Bridges:-

Steel arch bridges are generally adopted for spans between 30m & 150m. They consist of trusses or plate-girders used in form of curved beams called arch ribs. They may be two hinged or three hinged. In case of through & semi-through steel arch bridges, the construction is similar to a RCC bow arch.



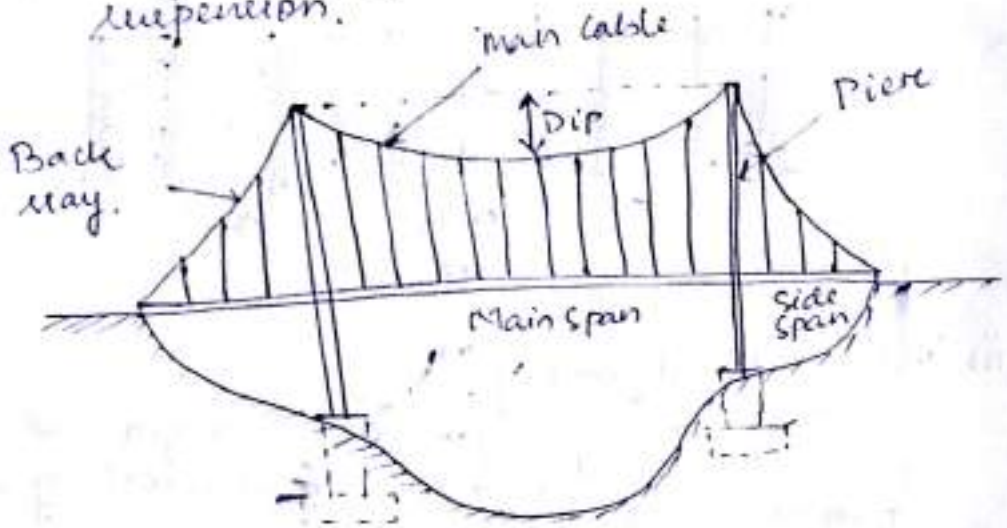
(vii) Cable Stayed Bridge:-

These bridges provide a larger width for purposes of navigation by eliminating intermediate piers. They consist of cables provided above the deck & are connected to the towers. The deck in case of cable stayed bridge is either supported by a number of cables melting in a bunch at the tower. The multiple cables would facilitate smaller distance between points of supports for the deck girders. This results in reduction of structural depth.



(viii) Suspension:

These are used in places where it is difficult to adopt other types of bridges. These are generally single span bridges. There are two main cables on each side of the roadway. They are carried over solid piers & are securely anchored to the banks. The roadway is suspended from two main cables by means of suspenders. Sometimes two side spans are also added which may or may not be supported by suspension.



(ix) Movable Steel Bridges:

movable spans of bridges are sometimes used over the navigable channels where permanent & sufficient clear waterway cannot be provided. They are needed in order to provide a passage for the masted vessels or steamers, when the bridge is to be across a navigable river or dock. These bridges can be of following types:

→ Swing bridges
→ Bascule bridges
→ Traversers bridges
→ Transporter bridges
→ Lift bridges.

* RCC Bridge :→

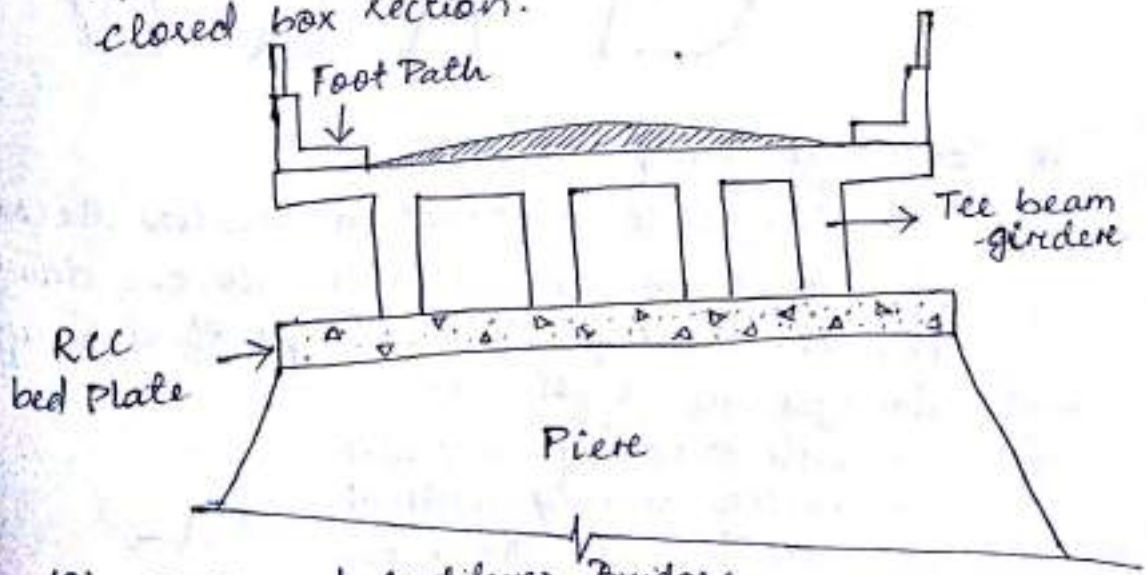
With the introduction of RCC construction it was felt that this material would produce maintenance free structure. There are numerous types of bridges built in RCC. The following are in general use:

(a). Slab Bridges:-

This is the simplest type of RCC bridge & easiest to construct. This type is most suitable as submersible bridge. It is suitable for spans up to 8m. The cost of form work & labour is much less in case of deck slab bridges.

(b). Girder Bridges:-

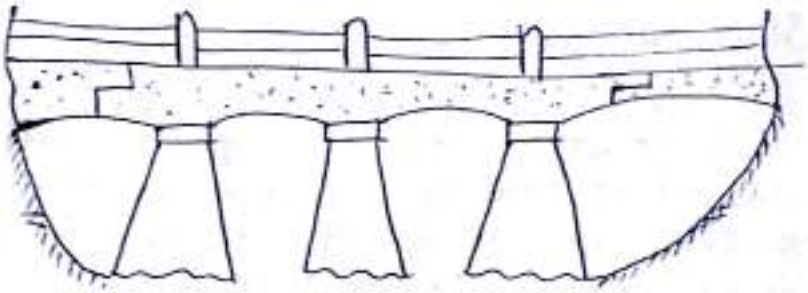
This type of bridge is economical for spans between 10m to 20m. Depending on the width of the roadway, following are the types of girder bridges: Parapet girder bridges (these type of bridges are used for narrow width roadway), Tee beam bridges (in these bridges the Tee beams function as main girders) & Hollow girder bridges (these bridges are economical for spans between 25 to 30m & they comprise of closed box section.



(c). Balanced Cantilever Bridge:-

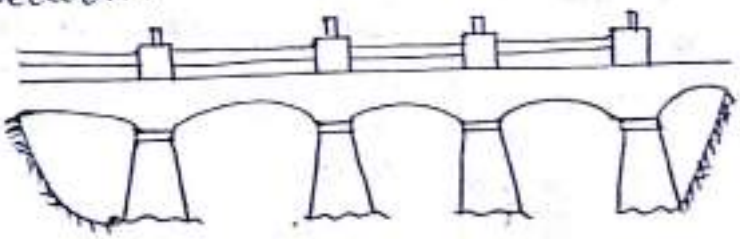
A balanced cantilever bridge consists of spans simply supported over cantilevers. These can be used for spans from 35m to 60m. In yielding river beds, where foundation

are expensive & small spans are uneconomical, it can be used with advantage. The connection between the suspended span & the edge of the cantilever is known as articulation.



(d). Continuous Bridges:

They are used for large spans & where unyielding foundations are available, as high stresses are introduced even if slight settlements of piers or abutments occur. The deck can be in the form of slab, T-beam or box section.



* Composite Bridges:

Composite construction involves the combination of two dissimilar materials into one structural element. Some of the advantages of this type of bridges are as follows:

- leads to speedy erection.
- better quality control.
- cost of form work is low.
- leads to savings in foundations for abutment
- leads to reduction in deflections & vibrations.

A composite girder is comprised of steel beam with cover plate or built up section, cast in situ R.C. slab & shear connectors.

* Prestressed Concrete Bridges :-

The inherent advantage of prestressed concrete bridges are the high load carrying capacity & fewer expation joints with light weight & best artistic treatment. This technique helps eliminate cracking & is very effective in construction of long span bridges because of its tensile strength. This technique reduces the maintainance cost, increases shear capacity of concrete, reduces impact & vibration loads, etc. where as the prestressed concrete members require high tensile steel which is more expensive than ordinary mild steel, and also requires spacial equipments like anchorees, jacks, etc for prestressing.

* Loads on Bridges :->

1. Dead load :-

It is the weight of the structure & the weight of the portion of the superstructure. Some bridges carry water or utility lines that may add weight.

2. Live Loads :-

There are further classified as follows :-

(A) IRC class 70R loading :

This loading is generally adopted to all roads on which permanent bridges & culverts are constructed. This loading specifys a 70 tonnes tracked vehicle with the minimum spacing between vehicles as 30m. Bridge designed for this loading should also be checked for class A loading.

(b). IRC class AA loading :-

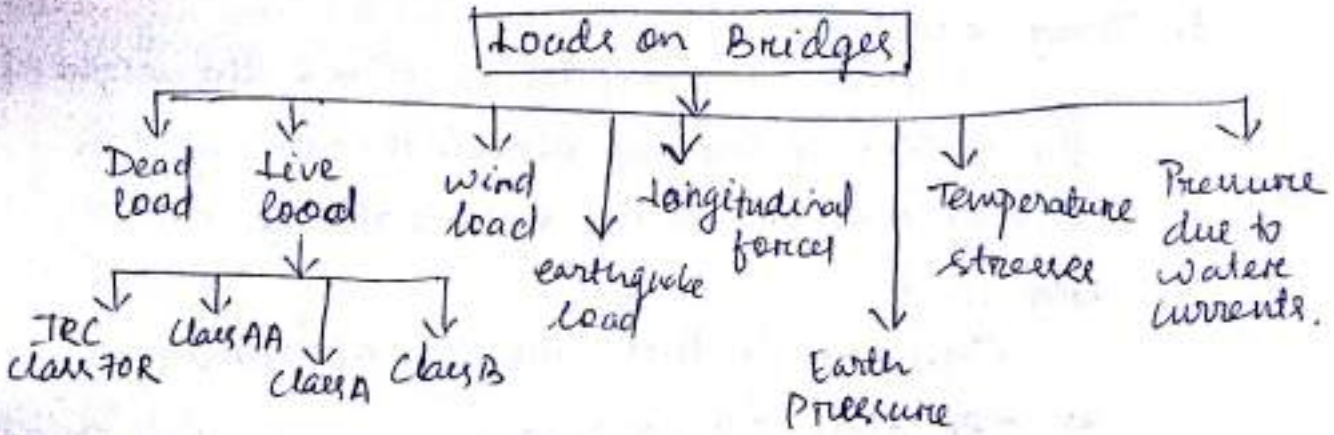
This loading corresponds to the class 70R i.e. specifies a 70 tonne vehicle both wheeled & Tracked (with spacing as 90m). This loading is generally adopted within certain municipal limits. Bridge designed for class AA loading should be checked for class A loading.

(c). Class A loading :-

This load was comp prepared with the object of covering the worst combination of axle loads & axle spacings likely to arise from the various types of vehicles that are normally expected to use the road. This loading is generally adopted on all roads on which permanent bridges & culverts are constructed.

(d). Class B Loading :-

This loading is normally adopted for temporary structures & for bridges in specified areas. It is similar to class A loading. It is generally applied to timber bridges.



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