LECTURE NOTES

ON

RAILWAY & BRIDGE ENGINEERING (TH-3)

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SECTIONA

RAILWAYENGINEERING

Chapter-1

INTODUCTION

Indian Railways is an Indian state-owned enterprise, owned and operated by the Government of India through the Ministry of Railways. It is one of the world's largest railway networks.

Railways werefirst introducedtoIndia intheyear 1853 fromBombaytoThane, nationalizedas one unit, theIndianRailways, becoming one of the largest networks inthe world. IR operates both long distance and suburban rail systems on a multi-gauge network of broad, metre and narrow gauges. It also owns locomotiveand coach production facilities at several places in India and areassigned codes identifying their gauge, kind of power and type of operation.

On23April2014,IndianRailwaysintroduceda mobileappsystemtotracktrainschedules.

Rolling stock used on railways in the earliest days evolved from carriages and wagons which ran on highways to carry both people and bulk materials.

As railway experience was gained, the design of rolling stock also evolved. Springing, body structure, wheels and axles all are subject to varying loads and stresses, when comparing slower speeds on rough roads to much faster speeds on railways, with a comparatively smoother ride.

Railway rolling stock generally runs on hard wheels on hard rails. The wheels are notonlysupported by the rails but are guided by them. The only exception to this is for a small number of metros where rubber tyres have been introduced. In this case the supporting function of the rail may be separated from the guiding function.

Inallcases railwayrollingstock willtransmit vertical, horizontalandlongitudinalforces tothetrack and its supports. Most railways haveadoptedtwinrails and flanged wheels. Forces aretransmittedtotherail structure either by direct bearing on the rail top from the wheel tyre, or by bearing laterally through the flange, or by longitudinal friction. Potential ‘overturning’ forces, caused by centrifugal force on curves, coupled with wind forces on exposed locations are resisted by vertical dead weight and super-elevation or ‘cant’ on curves.

AdvantagesofRailways

Therailways offers various advantages andfor thepurposeofconvenience, theycanbedescribed in following three categories.

1. <u>EconomicAdvantages</u>
   i) Employmenttopeopleintheformofstaffrequiredforsmoothworkingof railways.
   ii) Encouragementtocommercialfarming.
   iii) Increaseincostoflandtherebyincreaseofnational wealth.
   iv) Industrialdevelopmentandgrowthbecauseofmobilityoflabour andrawmaterials.

v) Stabilizationofpricesduetoeasy,speedy&efficientmobilityofproducts&natural resources.

vi) Increaseinmobilityofpeopleandtherebyrelievingsomeextentthecongestionofbigcities.

vii) Transportingfoodandclothesintimesof emergencieslikefloodsandfaminesetc.

2. PoliticalAdvantages

i) Easycontrolofthecentraladministration.

ii) Developmentofa nationalmentalityinthemindsofpeople.

iii) Migratingpopulationonamassscale.

iv) Mobilizingtroopsandwarequipmentsintimesofwarandemergencies.

v) Unityofpeopleofdifferentcastes,customsandreligions.

3. SocialAdvantages

i) Broadening the social outlook ofmasses as people can visit all the parts of country and be proud of this great country.

ii) Easyaccesstoreligiousplacesofimportance.

iii) Providingconvenientandsafemodeoftransport.

iv) Removal of feeling of isolationas therailwayhas provedto bethe most safe, economic and comfortable mode of conveyance.

ClassificationofIndianRailways

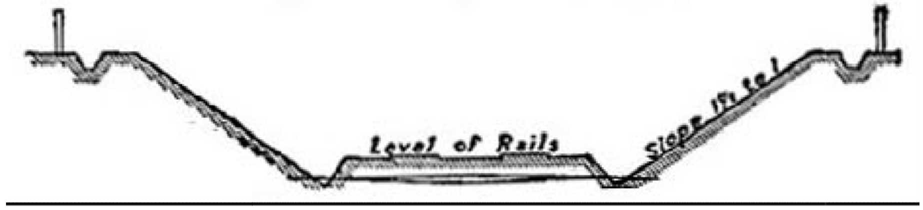
Indianrailwaysystems accordingtothreeclasses:-

ClassI- Railwayswithgrossannualearningsofover Rs50lakhs(Rs50,00,000).[1]

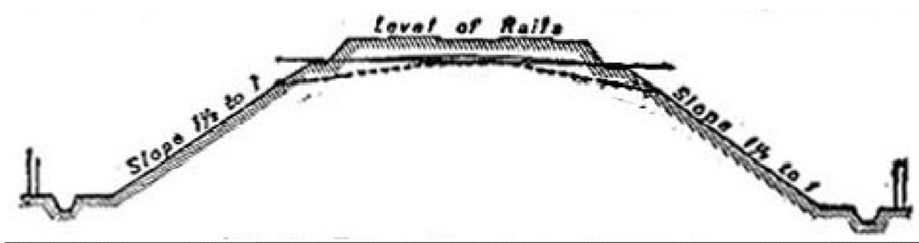
Class II-Railwayswithgrossannualearnings ofbetweenRs10and50lakhs. Class III - Railways with gross annual earnings of under Rs 10 lakhs.

CHAPTER-2

Permanentway

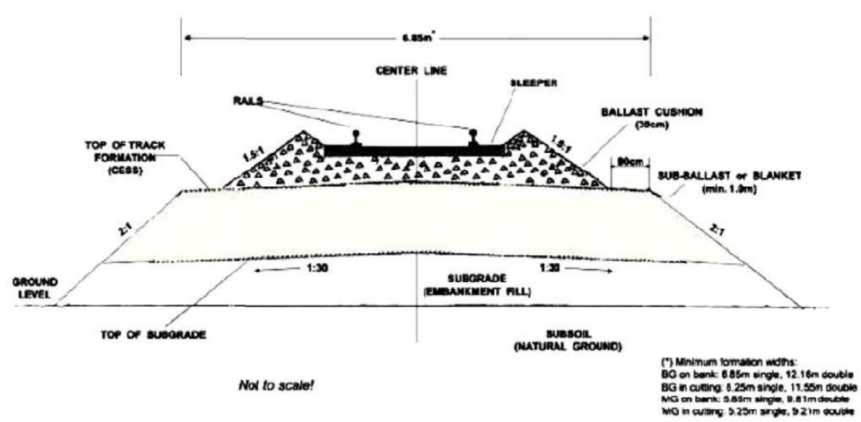


TypicalSectionofRailwayinCutting.

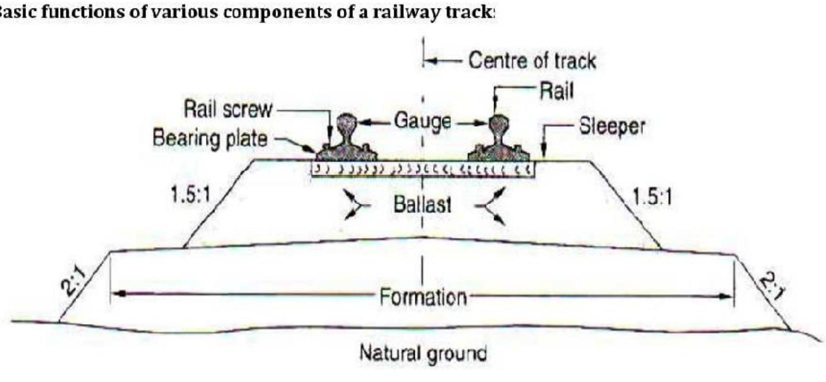


TypicalSectionofanembankment.

Cross section of a permanent way:



Basic functions of various components of a railway track:



Thefinishedor completedtrackofa railwaylineiscommonlyknownasPermanentWay. Itessentially consists of following three parts.

1. Rails
2. Sleepers
3. Ballast

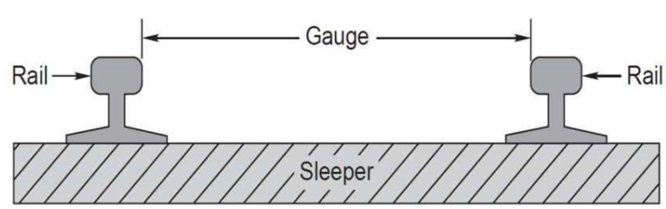
The rails are fixed with each other by means of various rail fastenings and they rest on sleepers whichare laidat right angles tothem. Thesleepers in turnrest onballast which is spread over the formation ground prepared for the railway track.

Requirementsofanidealpermanentway

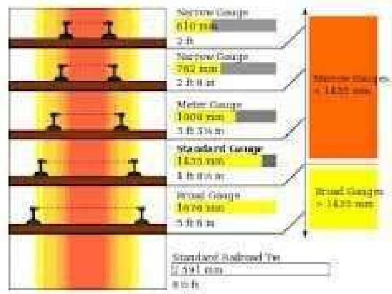
1. Thegaugeoftrackshouldbeuniformandthereshouldnotbevaryinggauges.
2. Thereshouldbeminimumfrictionbetweenthewheelsofrollingstockandtherails.
3. Facilities should be provided at various points along the permanent way to repair, replace or renew the damaged portion of the track.
4. The design of the permanentway should be such that the load of the train isuniformly distributed over it.
5. The components of thepermanent way should beso selected as to produce a permanent way with a certain degree of elasticity to prevent the shocks due to impact.
6. Thegradient providedonthepermanent wayshouldbeevenanduniform.
7. Thespecialattentionshouldbegivenonthedesignofpermanentwayoncurves.
8. Theoverallconstructionofthepermanentwayshouldbesuchthatitrequiresminimum maintenance.
9. Thepermanentwayshouldpossesshighresistancetodamageatthetimeofderailment.
10. Thedrainagefacilityshouldbeperfect.
11. Therailjoints shouldbeproperlydesignedand maintained.
12. Theprecautionsshouldbetakentoavoidtheoccurrenceof creep.
13. Variouscomponentsofthepermanentwayshouldpossessanti-sabotageandanti-theftqualities.

RailGauges

In India, the gauge of a railway track is defined as the clear minimum perpendicular distance between the inner faces of the two rails.



Gauge



Thedifferentgauges usedinIndiacanbebroadlyclassifiedasfollowingfourtypes.

1. BroadGauge:Width1676mmto1524mm.
2. StandardGauge:Width1435mmand1451mm.
3. MeterGauge:Width1067 mm,1000 mmand915mm.
4. NarrowGauge:Width762mmand610mm.

<u>Suitabilityofthesegaugesunderdifferentconditions</u>

1. Traffic condition → Iftheintensity of trafficon the track is likely to be more,a gaugewiderthan the standard gauge is suitable.
2. Development of poor areas → The narrow gauges are laid in certain parts of the world to develop a poor area and thus link the poor area with the outside developed world.
3. Cost of track → The cost of railway track is directly proportional to the width of gauge.Hence,if the funds available is not sufficient to construct a standard gauge, ameter gauge or a narrow gaugeis preferred rather than to have no railways at all.
4. Speed of movement → The speed of a train is a function of the diameter of wheels which in turn is limited by the gauge. The wheel diameter is usually about 0.75 times the gauge width and thus, the speed ofa trainis almost proportional tothegauge. If higher speeds aretobeattained, theB.G. track is preferred to the M.G. or N.G. track.
5. Nature of Country → Inmountainouscountry,it is advisable to have anarrow gauge of track since it is more flexible and can be laid to a smaller radius on the curves. This is the reason why some important railways, coveringthousands of kilometers, arelaid with a gauge as narrow as 610 mm.

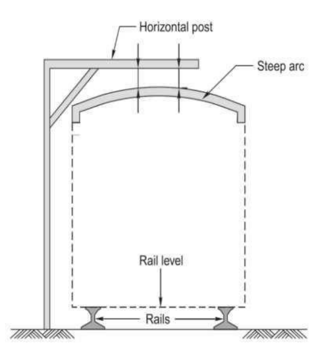
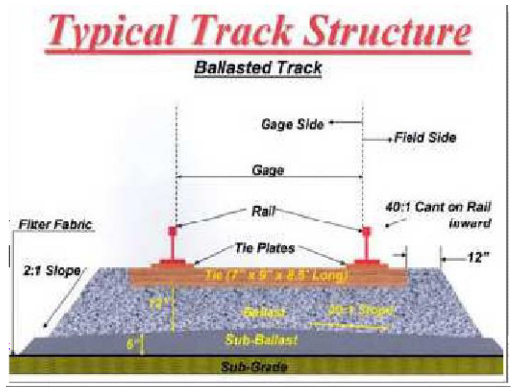


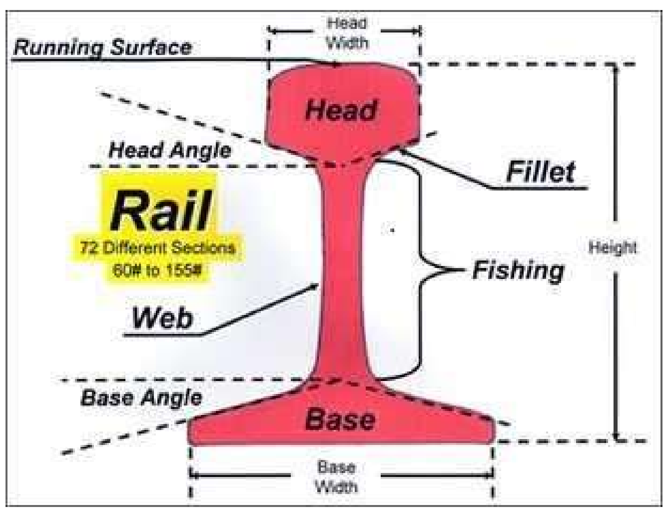
Fig. 2.2 Loading gauge

CHAPTER-3

TRACKMATERIALS



RAILS



FunctionofRails

- Totransmitthemovingloads tothesleepers
- Toprovidestrong,hardandsmoothsurfaceforthetrainjourney.
- Tobearthestresses developedinthetrackduetotemperaturechanges andloadingpatterns. To serve
- as lateral guide to the running wheels.
- Toresist breakingforcescausedduetostoppageof trains.

RequirementsofanIdealRail

1. The rail section consists of three components: head, web and foot. It should be designedfor optimum nominal weight to provide for the most efficient distribution of metal in its various components.
2. The bottom of head and top of the foot should be given such shapes that fish-plates can easily be fitted.
3. The C.G. of the rail section should be located very near to the centre of height of rail so that maximum tensile and compressive stresses are more or less the same.
4. Thedepthofheadofrailshouldbesufficienttoallowforadequatemarginofverticalwear.
5. Therailshouldpossess adequatelateralandverticalstiff nesses.
6. Thereshould bebalanced distribution of metal in the head,web and foot of rail so that each of them is able to fulfill its assigned function.
7. The surfaceofrailtableandgaugefaceofrailshouldbehardandshouldbecapableofresisting wear.
8. Thethicknessofwebofrailshouldbesufficienttotakesafelytheloadcomingontherail.

TYPES OFRAIL SECTIONS

Doubleheadedrails:

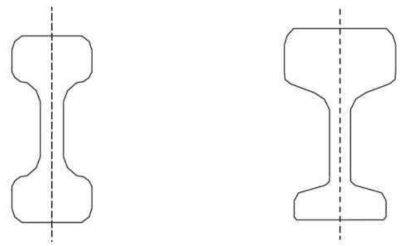
These were the rails which were used in the beginning, which were double headed and consisting of a dumb-bellsection. Theidea behindusingtheserailswasthatwhentheheadwaswornout incourseoftime, the rail can be inverted and reused. But as time passed indentations were formed in the lower table due to which smooth running over the surface at the top was impossible.

Bullheadedrails:

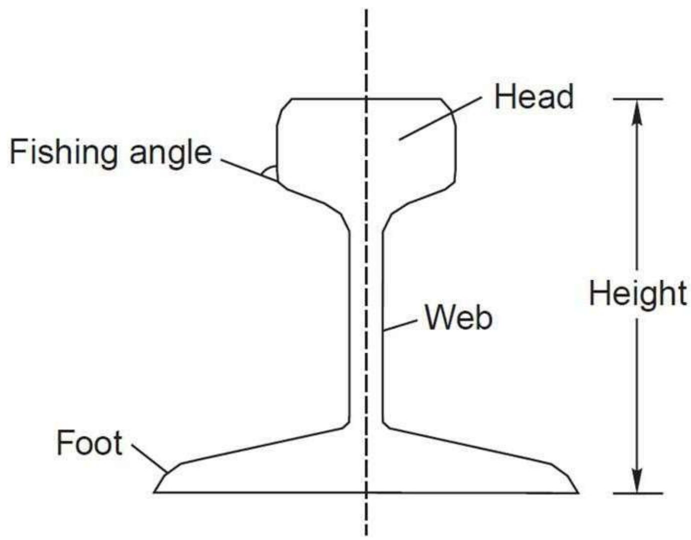
Inthistypeofrailtheheadwas madea littlethicker andstronger thanthelower partbyaddingmore metal to it, so that it can withstand the stresses.

Flatfootedrails:

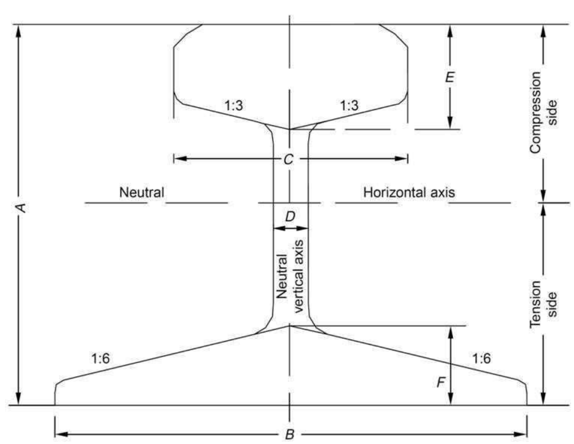
These rails are also called as vignole's rails. Initially the flat footed rails were fixed to the sleepers directlyandnochairs andkeys wererequired. Later on dueto heavytrainloads problems arosewhich lead tosteelbearingplates betweenthesleeper andtherail. atrailjoints andother important places thesearethe rails which are most commonly used in India.



Double headed rail Bull headed rail



Flat-footed rail



Standard flat-footed rail section

LengthoftheRails:

From the consideration of strength of the track maximum possible length is advisable as it will reduce the number of the joints, less number of fittings and fixtures and economical maintenance. But in practice the following factors are considered to decide the length of rails.

i) Easeoftransportation
ii) Reasonablecostofmanufacture
iii) Easeinloadingintotheavailable wagons
iv) Developmentoftemperaturestresses

IndianRailwayshaveadoptedthefollowinglengthofrails inpractice.

i) ForBGtracks=13m(42')
ii) ForMG&NGtracks = 12m(39')

RailJoints

Rail joints arenecessary to hold the adjoining ends of therails in thecorrect position, both in the horizontal and vertical planes.

TypesofRailjoints→Thefollowingarethetypeofrailjoints

Supportedrailjoints:

Whentherailendsrestona singlesleeper itistermedassupportedjoint.Theduplexjointsleeper withother sleepers is an example of the supported joint.

Suspendedrailjoint:

When rail ends are projected beyond sleepers it is termed as suspendedjoint. This type of joint is generally used with timber and steel through sleepers.

Bridgejoints:

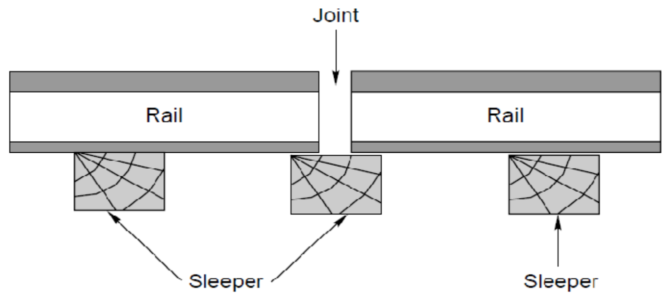
Whentherail ends areprojectedbeyondsleepers as inthecaseof suspendedjoint andtheyareconnectedby a flator corrugated plate called as bridge plate it is termed as a bridge joint.

Insulatedjoint:

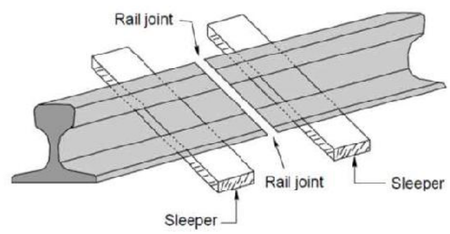
When an insulating medium is inserted in a rail joint ot stop the flow of current beyond the track circuitedpart then that type of joint is called an insulated joint.

Compromisejoint:

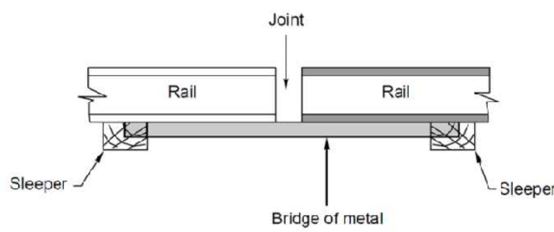
Wheretwo different rail sections arerequired to be joined together it is doneby means of fish plated which fit both rails and this joint is termed as compromise joint.



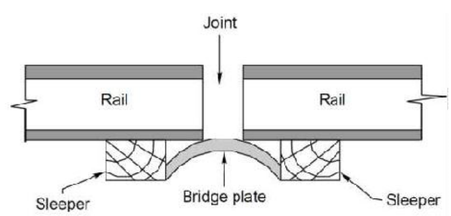
Supported rail joint



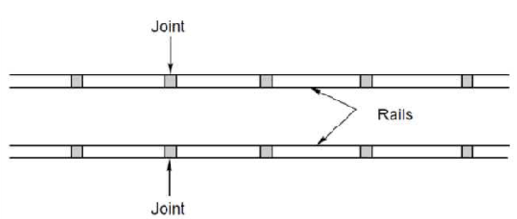
Suspended joint



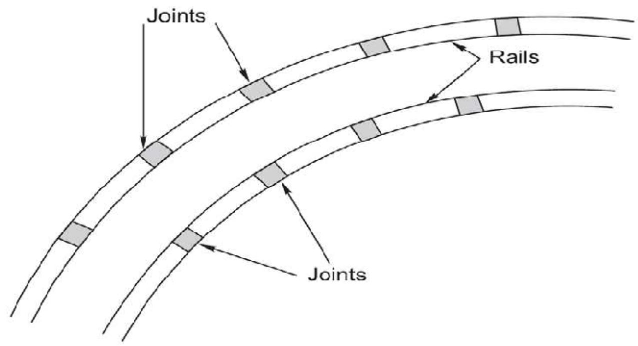
Bridge joint with metal flat



Bridge joint with bridge plate



Square joint



Staggered joint

<u>RequirementsofanIdealRailJoint</u>

i) Ends toremaintrue
ii) Shouldbestrongandstiff
iii) Provisionforexpansion
iv) Perfectlyelastic
v) Endsshouldnotgetbattered
vi) Provisionforeasyremovalandreplacement
vii) Economicalincost

<u>PurposeofWeldingofRails</u>

Welded rail joint

Purposeofwelding:

- Toincreasethelengthoftherails
- Torepairthewornoutor damaged rails
- Tobuildupwornout pointsandrailsonthesharpcurves

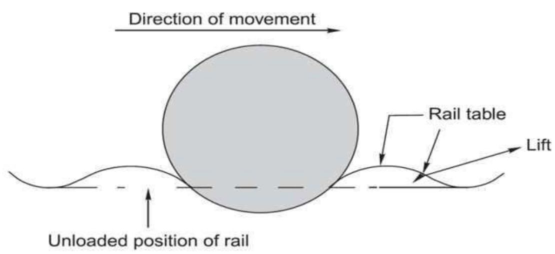
Advantagesofweldingrails:

- Reducesthecreepandfrictionduetoincreaseinlengthof rail.
- Expansioneffect duetoreductionintemperature.

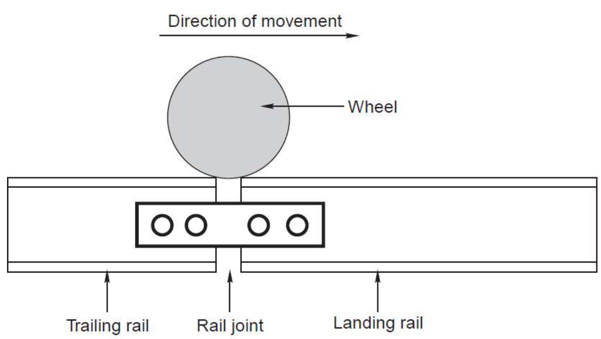
- Increasethelifeoftherailsduetodecreaseinwear.
- Itfacilitatestrackcircuitingonelectrifiedtracks.
- Thecostdecreasebecauseasthelengthincreaseautomaticallythenumberofjoints decreases.
- Highfrequencyvibrations duetoheavymovingloadsaredecreasedduetotheheaviness oftherails.

CREEP

Creepinrailsdenoteslongitudinalmovementofrailsinthetrack.

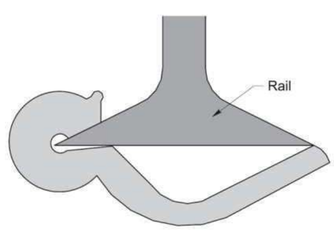


Wave motion theory for development of creep

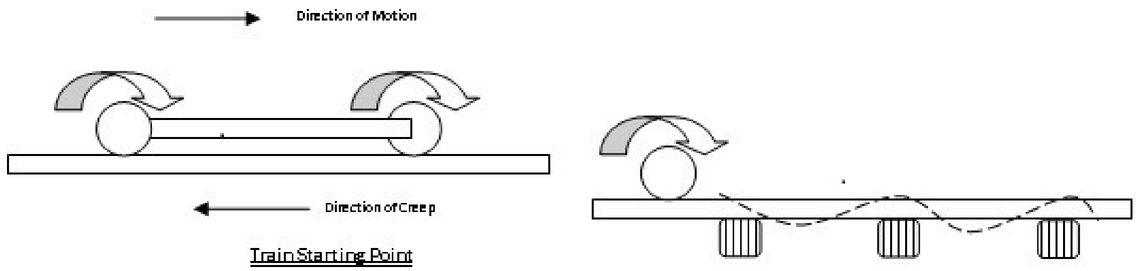


Percussion theory for development of creep

ThefollowingfigureshowsatypeofFairV-anchorwhichisusedinthetracktopreventcreep of rails.



Fair V anchor



Itisdefinedasthelongitudinalmovementofrailswithrespecttosleepersinatrack.

Causesofcreep:

1. Closingofsuccessiveexpansionspacesatrailjointsinthedirectionofcreepandopeningoutof joints at the point from where the creep starts.
2. Marksonflangesandwebs ofrails madebyspikeheadsbyscrapingorscratchingastherails slide.

EffectsofCreep:

1. Sleepersmoveout ofpositionwhichleads tothechangeingaugeandalignmentofthetrack.
2. Rail joints are opened out of theirlimit in some case and stresses are set up in fish plates and bolswhich leads to the breakage of the bolts.
3. Pintsandcrossingsgetdisturbed.
4. Maintenaceandreplacementoftracksbecomes difficult.
5. Smashingoffishplatesandbolts,bendingofbars,kinksatjointsareothereffectsofcreep.

Sleepers&Ballast

Definition:

Sleepers (known in the US as railroad ties) are used as a base for laying railway tracks. Sleepers were traditionally madefrom woodbut arenowusually madefromconcrete.Ties arelaidontop ofsand, gravel or heavy crushed stone - called ballast.

Functionsofsleepers

Thefunctionsof sleepersareasfollows

1. To hold therails in correct gauge i.e exact gauge in the caseof straight and flat curves, loose gauge in the case of sharp curves and tight gauge in the case of diamond crossings.
2. Toactasanelasticmediumbetweentheballastandrailtoabsorbtheblowsandvibrationsof moving loads.
3. Theyalsoaddtothelongitudinalandlateralstabilityofthepermanent trackonthewhole.
4. Theyalsoprovidemeanstorectifytrackgeometryduringservicelife.
5. Tosupporttherailsatproperlevelinstraight tracks andatpropersuperelevationoncurves.
6. Todistributetheloadfromtherails totheindex area of ballast underlaying it or to thegirders in the case of bridges.
7. Toholdtherails inproper level.

RequirementsofGoodSleepers

1. It shouldbeeconomical
2. Itshouldbeminimumpossibleinitialandmaintenancecosts.
3. Thefittings shouldbesuchthattheycanbeeasilyadjusted.
4. Weightshouldnotbetooheavyor toolight.
5. ItshouldnotbeeasilydamagedbyantiNationals.
6. Theyshouldbecapableofresistingshocks andvibrations.
7. Theinsulationofrailsshouldbepossiblefortrackcircuiting,ifrequiredthroughsleepers.
8. Itshouldbedesignedthatit couldnot bedisturbedfromits positioneasilybythepassageoftrains.

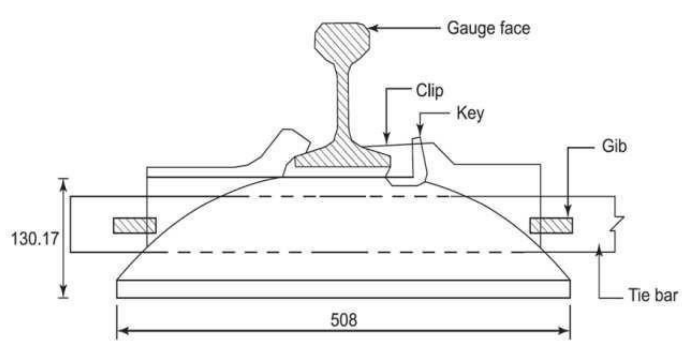
ClassificationofSleepers

Sleeperscanbeclassifiedintothefollowingtypesaccordingtothematerialofconstruction.

1. Woodensleepers

2. Metalsleepers

- Castironsleepers



CI pot sleeper (dimensions in mm)

3. Steelsleepers

4. Concretesleepers

- Reinforceconcretesleepers
- Prestressedconcretesleepers

TimberorWoodenSleepers

wooden sleepers are regarded as the best as they satisfy almost all the requirements of a good sleeper. The life of timber sleepers depend upon their ability to resist

- Wearandtear
- Decay
- Attackbywhiteants
- Qualityofthetimberused

Advantages:

It is easilyavailableinallpartsofindia

Fittings are few and simple in design

Theyareeasytolay, relay, pack, liftandmaintain

They are suitable for all types of ballast

Theyareabletoresist theshocks andvibrations of theheavy movingloads

They are economical

Disadvantages:

Theyaresubjectedtodecay, attackbywhiteants, warping, crackingandendsplitting It

is difficult ot maintain the gauge in the case of wooden sleepers.

Itisdifficulttomaintainthealignment inthecaseofwoodensleepers.

Theyhavegotminimumservicelife(12 to15 yrs)ascomparedtoothertypes ofsleepers

ConcreteSleepers

Concrete sleepers are made of a strong homogeneous material, impervious to effects of moisture and unaffected by the chemical attacks. It is moulded easily to sizeand shaperequired and it is an ideal material to with stand stresses introduced by fast and heavy traffic.

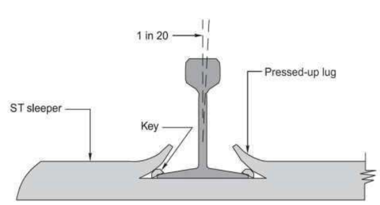
Advantages

1. The concrete sleepersare quite heavy andthusprovide longitudinal,lateraland vertical stability. Because of their weight, these sleepers are more suitable to LWR tracks.
2. Theconcretesleepersresultinreducedrailbendingstresses.
3. Theconcretesleepersreducethewearofrollingstocks.
4. The concrete sleepersproduce lessverticalmotion and thusprovide a comfortable journey due to less noise.
5. Theconcretesleepers haveflat bottoms. That'swhy mean modern method of trackmaintenancei.e. MSP and machine maintenance can be suitably employed.
6. Theconcretesleepersareneitherinflammablenorsubjectedtodamagebycorrosionortermite.
7. Thesesleepershavealongusefullifeof50years.Itmeansrailandsleeperrenewalscanbe matched.
8. Theconcretesleeperswiththeirfasteningsystemmaintaingauge,crosslevels,twist,alignment, longitudinal level and unevenness of the track.
9. Theconcretesleepers aresuitablefortrackcircuiting.
10. Theconcretesleeperscanbemanufacturedfromlocalresources.

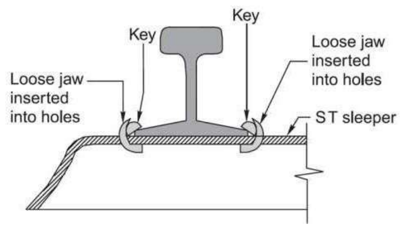
Disadvantages

1. Theyarenoteconomicalbecauseofhighcostof construction.
2. Incaseofderailments,heavydamageiscaused.
3. Highstandardofmaintenanceoftrackisrequired.
4. Thedesignandconstructionarebothcomplicated.
5. Theyaremorerigid.
6. Theydonothaveanyscrapvalue.

Steelsleepers



ST sleeper with pressed-up lugs



Sleeper with loose jaws inserted into holes

Steelsleepersarelightweight,dimensionallymoreaccuratethanwoodenorconcreteandregardedasan effective technical solution for modern rail networks.

AdvantagesofsteelSleepers

1. Theyaremanufacturedbyasimpleoperation.
2. Theycanbeeasilyhandledasthesesarelightinweightascomparedtoothertypesofsleepers. Hence, damages during handling and transporting are less.
3. Lessnumberoffasteningsarerequiredandthattoosimpleinnature.
4. Themaintenanceandadjustment ofgaugeareeasyas comparedtotheotherof sleepers.
5. Thesesleepersarerolledsections inonepiece.
6. Theirlifeislongerthanthatofother typesofsleepers.
7. Theyprovidebetter lateralrigiditytothetrack.
8. Theyarenotattackedbyvermins.
9. Theyarenotsusceptibletofirehazards.
10. Theirscrapvalueisgood.

DisadvantagesofSteelofSleepers

1. Thesteelsleeperspossessthefollowingdisadvantages:
2. Theygeteasilyrustedandcorroded.
3. Theydevelopcracksatrailseatsor nearlugs.
4. Theirlugsgetbrokeneasily.
5. Thesteelsleepersdonotprovideeffectivetrackcircuiting.
6. Thesteelsleeperscanonlybeforthetypeofrailsforwhichthesesare manufactured.
7. Thesedevelopthetendencytobecomecenterboundbecauseofslopeat bothends.
8. Theoverallcost ofsteelsleepersismorethanthat oftimbersleepers.

Ballast

Definition:

Itisalayerofbrokenstones,graveloranyothersuchgrittymateriallaidandpackedbelowandaround sleepers.

Functionsofballast:

- Todistributetheloads uniformlyoverthesubgrade.
- Toprovidegooddrainageforthetrackstructure.
- Toprovideelasticityandresiliencetotrackforgettingproperridingcomfort.
- Toheldthetrackstructuretolineand grade.
- Toreducedust.
- Topreventgrowthofbrushandweeds.

RequirementsofGoodBallast

1. It shouldbetoughandshouldnotcrumbleunderheavyloads.
2. Itshouldnot makethetrackdustyormuddy.
3. Itshouldofferresistancetoabrasionandweathering.
4. Itshouldnotproduceanychemicalreactionwithrailsandsleepers.
5. Thematerialsshouldbeeasilyworkable.
6. Itshouldretainitspositionandshouldnotbe distributed.

MaterialsusedasBallast

1. Broken Stone → Broken stone is one of the best materials for railway ballast to be used on the railway tracks. Almost all the important railway tracks are provided with broken stone. The stone to be used as railway ballast should be hard, tough nonporous and should not decompose when exposed to air and light. Igneous rocks like quartzite and granite forms the excellent ballast materials. When these are not available then lime stone and sand stone can also be used as good ballast material.

AdvantagesofBrokenStone

1. It holds thetrackinposition
2. Itisgoodfor heavytraffic
3. Itcanservehighspeedsequallywell.

Disadvantages of Broken Stone

1. Themaindisadvantageisthatitisexpensiveinitsinitialcost.

2. Gravel → Gravel ranks next in its suitability for useas materials for ballast and is used in many countries of the world in very large quantities. Gravel consists of worn fragments of rocks occurring in natural deposits. Gravel or shingle maybe obtained fromriver bed or it maybe dug out from gravel pits.

AdvantagesofGravel

1. Itischeaperinitscostasit hasnottobebrokenaslikestoneballast

2. Ithasgotexcellent drainageproperties,ifproperlycleaned

Disadvantages of Gravel

1. Iteasilyrollsdownunder thevibrations andpackingunderthesleepers gettense

2. Thevariationinsizeis considerableandhencerequiresscreeningbeforeuse

3. Grovel as obtained from gravel pits, is full of earth and hence requires proper cleaning if proper drainage of the track is to be done.

3. Cinders Or Ashes →Theresiduefromthecoal inlocomotives or other furnaces is calledcinder or ashes. It is one of theuniversal forms of ballast as it is a byproduct of all therailway which uses coal as a fuel.

AdvantagesofCindersorAshes

1. Handlingofthematerialisnotcumbersomethismaterialcanbehandleeasily

2. Costisverylowandhencecanalsobeusedforsidings

3. Ithasgot fairlygooddrainageproperties

4. Largequantities ofthismaterialcanbemadeavailableatshortnotice.

5. In case of emergence such as caused by the destruction of portion of railway track during floods. Thismaterial proves to be very useful and isused in the formation repairing as well as forpacking of track.

DisadvantagesofCindersorAshes

1. Itishighlycorrosiveandcannot beusedwheresteelsleepersarefixed

2. Thefootoftherailsgetaffectedduetouseofthistypeofmaterialasballast

3. It is very soft and can easily bereduced to powder under vibrations and hencethetrack becomes very dusty. This is objectionable particularly in dry weather.

4. Sand → Sand is another good materials for railway ballast , coarser sand is to be preferred to finersand and the best sandis that which contains a quantity of fine gravel varyingin size from1/8 upwards.

AdvantagesofSand

1. Ifthesandisfreefromearthandvegetationthenithasgoodexcellentpropertiestodrainoff water immediately

2. Itischeaperifavailableinnearbylocality

3. Itproducesverysilenttrackandhencearesuitablefor packingcastironpotsleepers.

Disadvantages of Sand

1. Itgetseasilydisturbedundervibrationsandhenceitsmaintenanceisverydifficult

2. Thesandcanbeeasilywashedofforblownawayandhencerequiresfrequentrenewal.

3. Thesandparticles may get intothe movingparts of the vehicles andproduces friction. This leads to heavy wear of vehicles.

5. Kankar →Kankara limeagglomerateisfoundinmanyplacesintheformofnodulesof varyingsizes.

Advantages of Kankar

1. Kankar is suitable Materials for ballast when other good material for ballast is not available or if available

uneconomically.

2. Kankar isgoodforlighttrafficonmetreandnarrowgauges

Disadvantages of Kankar

1. Itisverysoft andcanbereducedtopowderformeasily,hence,makingthetrackdusty.

2. Themaintenanceoftrackisverydifficult

6. Moorum→ Thedecomposition oflateriteresults into theformation of moorum. It has red and sometimes yellow color. The best moorum is that which contains large quantities of small laterite stones.

AdvantagesofMoorum

1. Moorumisgoodmaterialsforballastwhenothermaterialforballastisnotavailable.

2. Moorum can be safely used on newly laid track and acts as a soling when broken stones are laid afterwards.

3. Moorumhasgotgooddrainageproperties

Disadvantages of Moorum

1. Moorumisverysoftandreducestopowderand hencetodustforminshorttime.

2. Maintenanceoftrackslaidwiththismaterialis difficult

7. Brick BallastOrBrick Bats→Sometimesthe brokenpiecesofoverburntbricks,called brickbats,are used as materials for ballast.

AdvantagesofBrickBallast

1. Ithasgotexcellentdrainageproperties

2. They can beusedas good ballast material wheresuitable material for ballast is either unavailable or uneconomical

DisadvantagesofBrickBallast

1. Brickbatsturndownintopowderformeasilyandhencethetrackbecomes dusty

2. Maintenanceofthetracklaidwiththismaterialasballastisverydifficult.

3. Railsareoftencorrugatedonthetrackslaidwiththismaterialasballast

8. Selected Earth →Selected earth maybeused as material for railwayballast for sidings andalso for newly laid tracks.

Trackfixturesfor BG

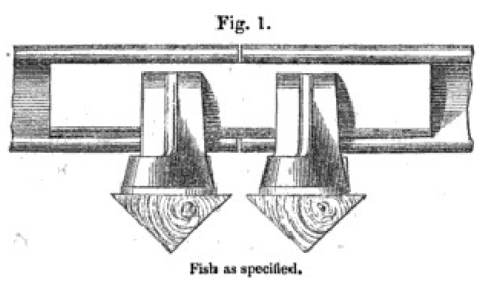
Railjoints–Fishplates–Fishbolts-Fangbolts-Hookbolts–Railchairsandkeys–Bearingplates– Blocks – Spikes-Elastic fastenings- Anchors & Anti creepers

Fastening

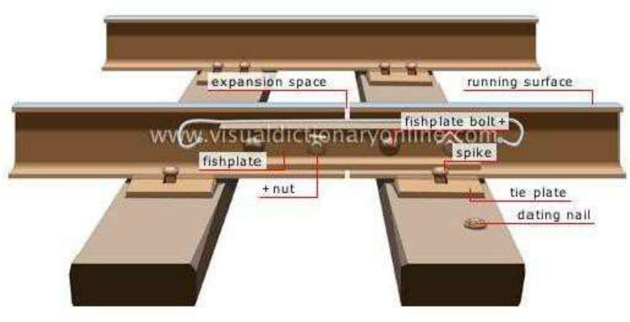
A rail fastening system is a means of fixing rails to railroad ties. Theterms rail anchors, tieplates, chairs and trackfasteners areused to refer toparts or all of a railfasteningsystem. Various types of fastening have been used over the years.

FishPlates

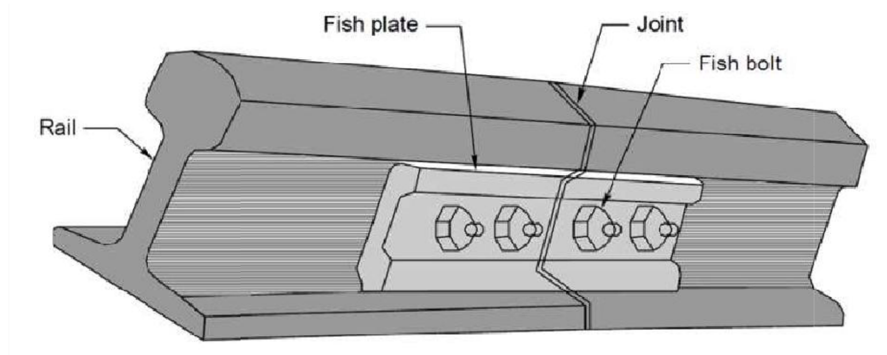
In railterminology, a fishplate, splicebar or joint bar is a metalbar that is bolted to the ends oftwo rails to join them together in a track. The name is derived from fish, a wooden bar with a curved profile used to strengthen a ship's mast. Thetop and bottom edges are tapered inwards so the device wedges itself between the top and bottom of the rail when it is bolted into place. In rail transport modelling, a fishplate is often a smallcopper or nickelsilver platethat slips ontobothrails toprovidethefunctions of maintainingalignment and electrical continuity.



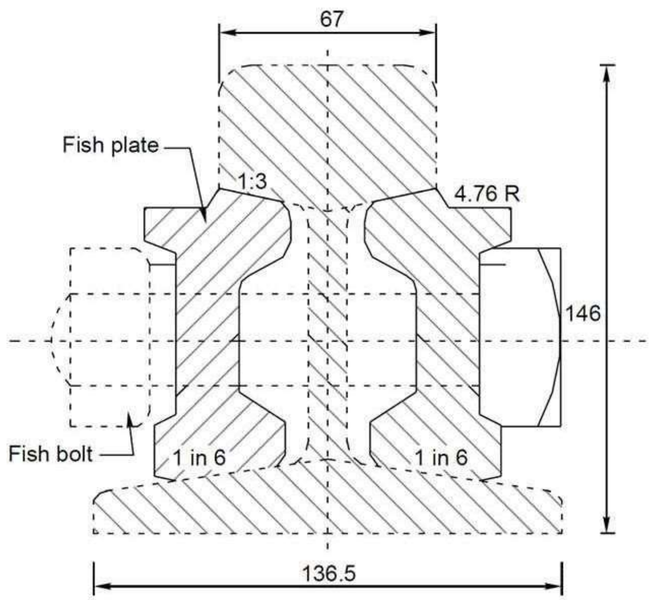
Thefirstrailwayfishplate



RAIL-TO-RAILFastenings

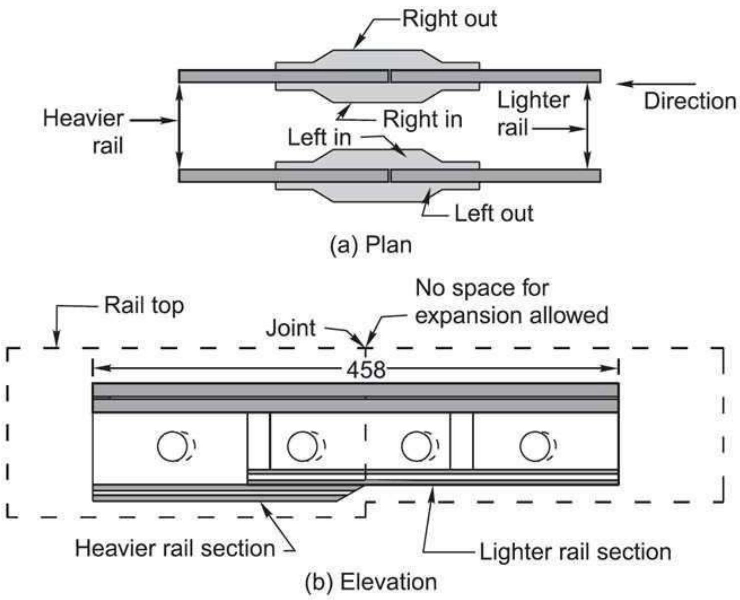


Fish plate

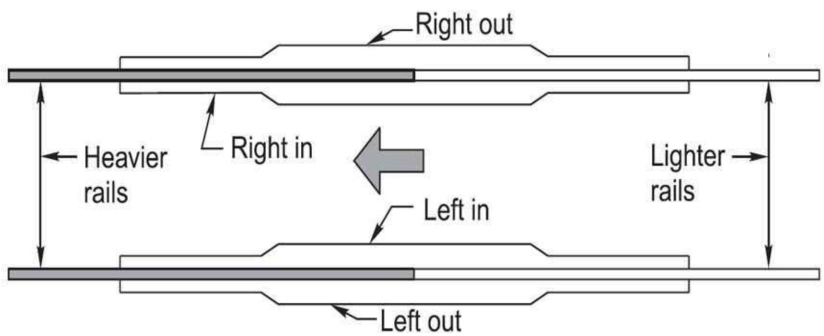


Fish plate for 90 R rails

CombinationFishPlates

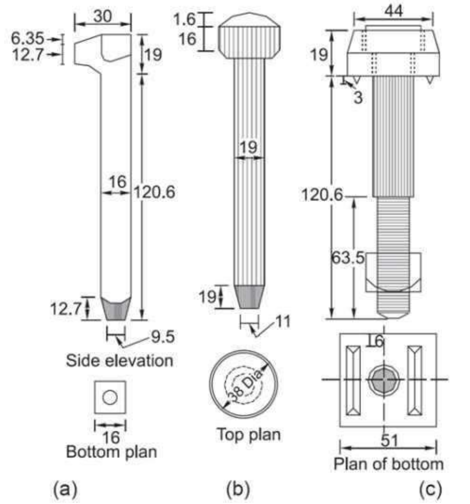


Combination fish plate (dimensions in mm)



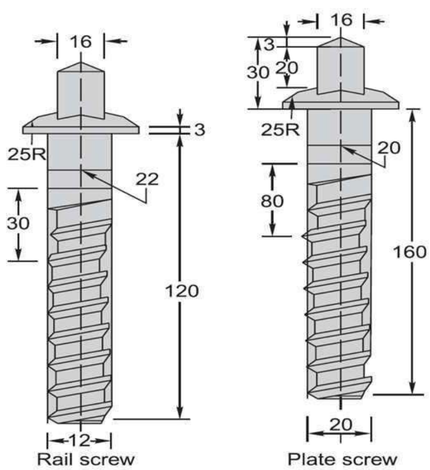
Marking of combination fish plates

<u>FangBolts</u>



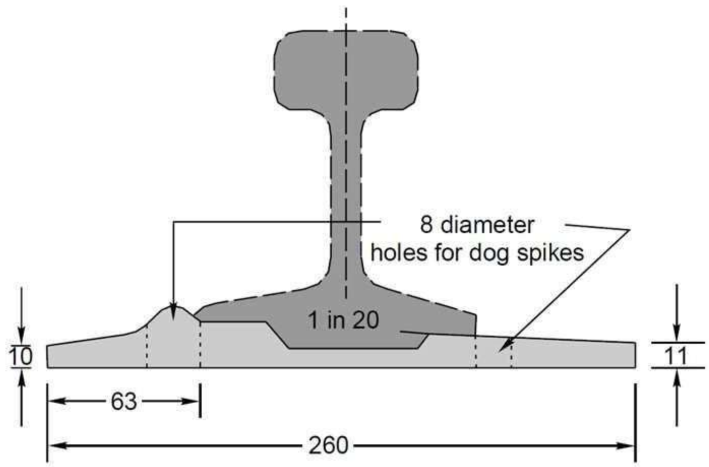
(a) Dog spike, (b) round spike, (c) fang bolt

ScrewSpikes

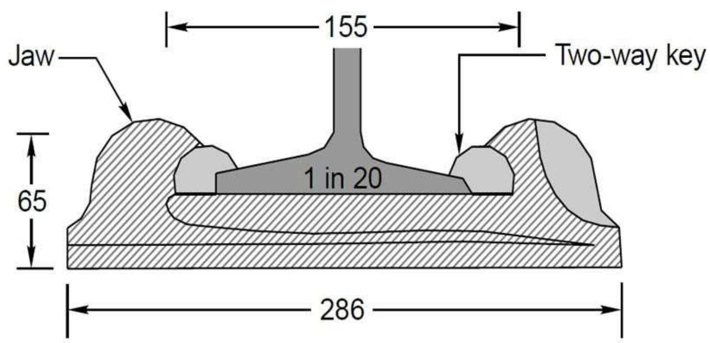


Screw spikes

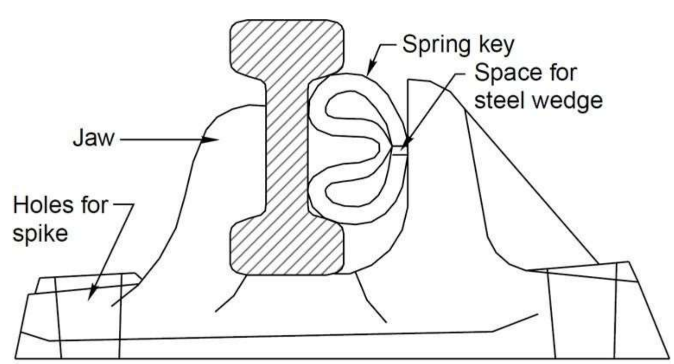
BearingPlates



Canted MS bearing plate for 90 R (dimensions in mm)

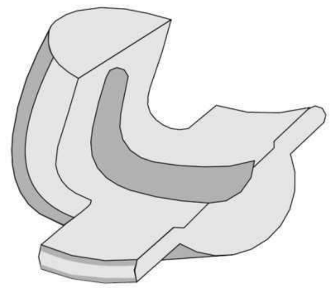


CI anticreep bearing plate



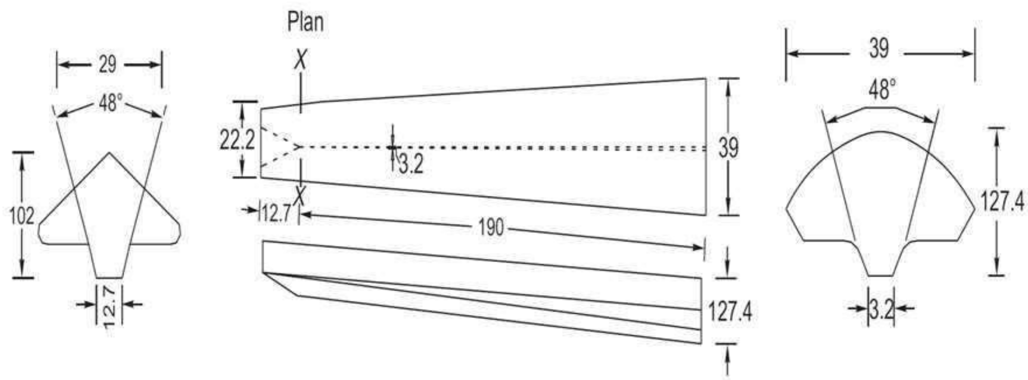
CI bearing plate for BH rail

FittingsofSteelTroughSleepers



Spring steel loose jaw

RubberCoated&Epoxy-coatedFishPlates

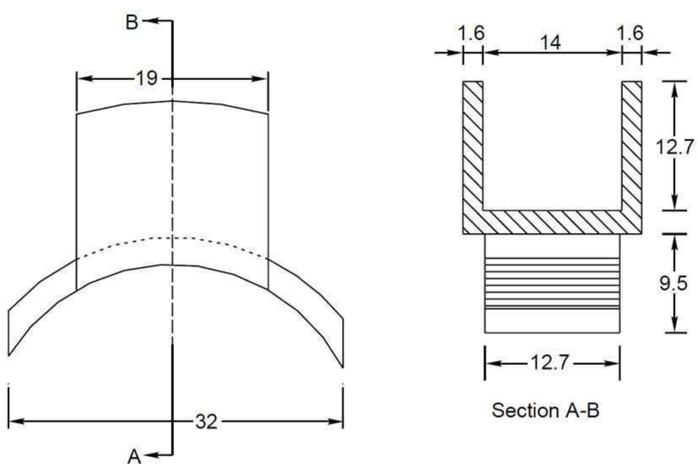


(a) Section XX

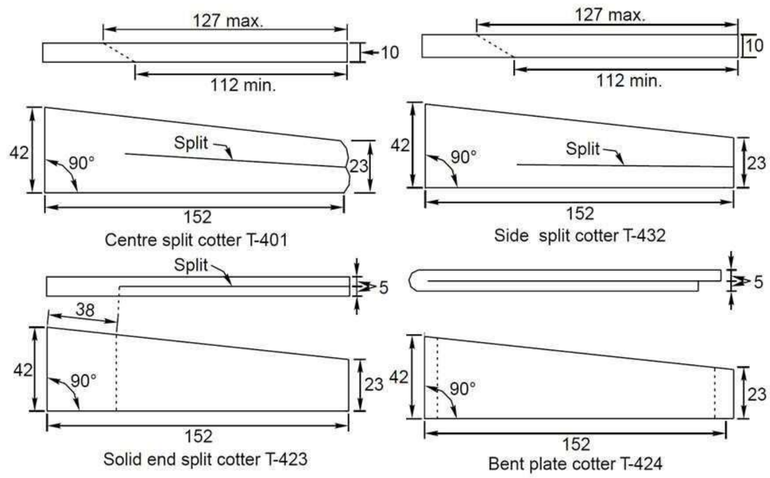
(b) Elevation

(c) End elevation

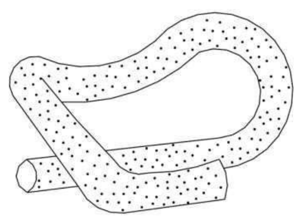
Two-way keys (dimemions in mm)



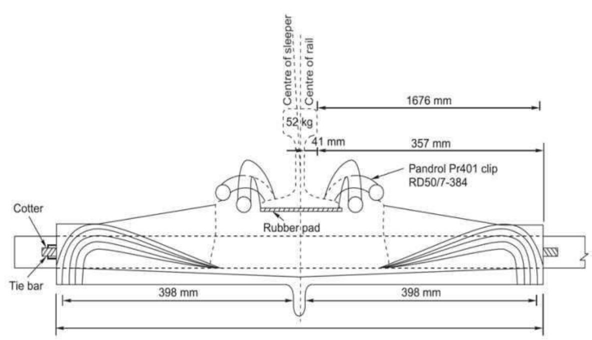
Mota Singh liner (all dimensions are in mm)



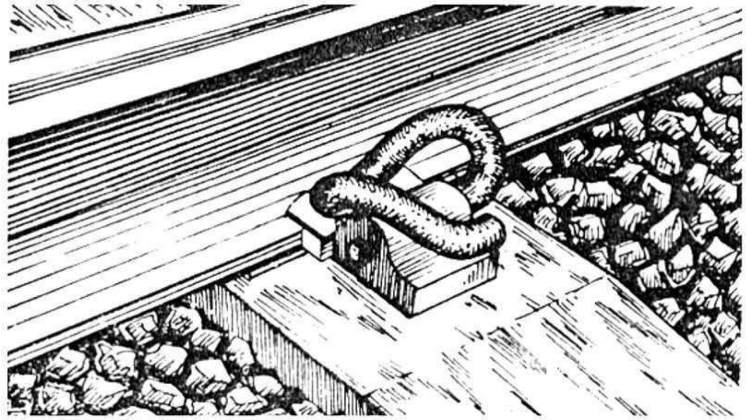
MS cotters (all dimensions are in mm)



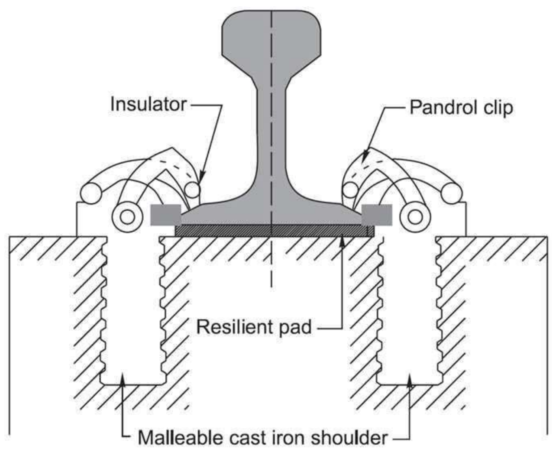
Pandrol clip or elastic rail clip



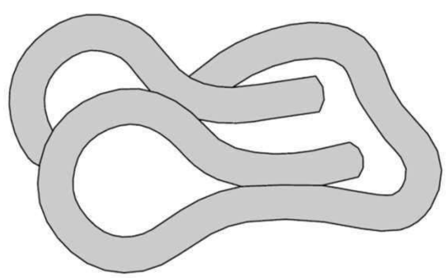
Isometric view of Pandrol clip



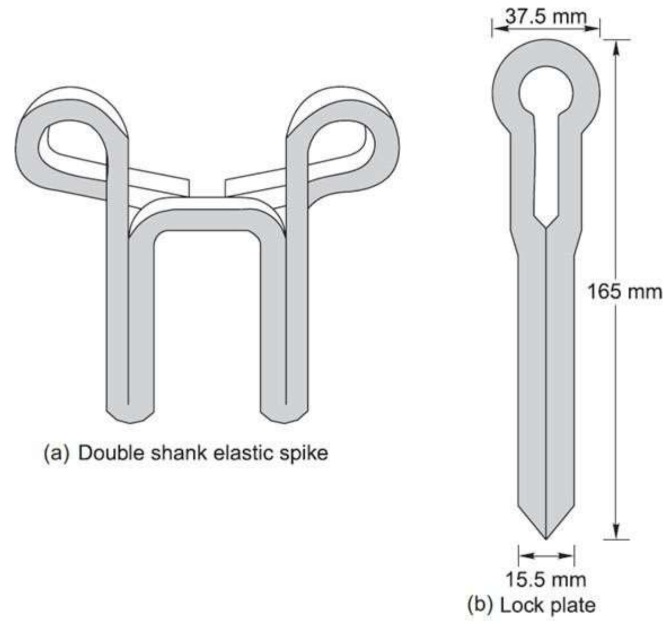
Pandrol clip fixed to the rail seat



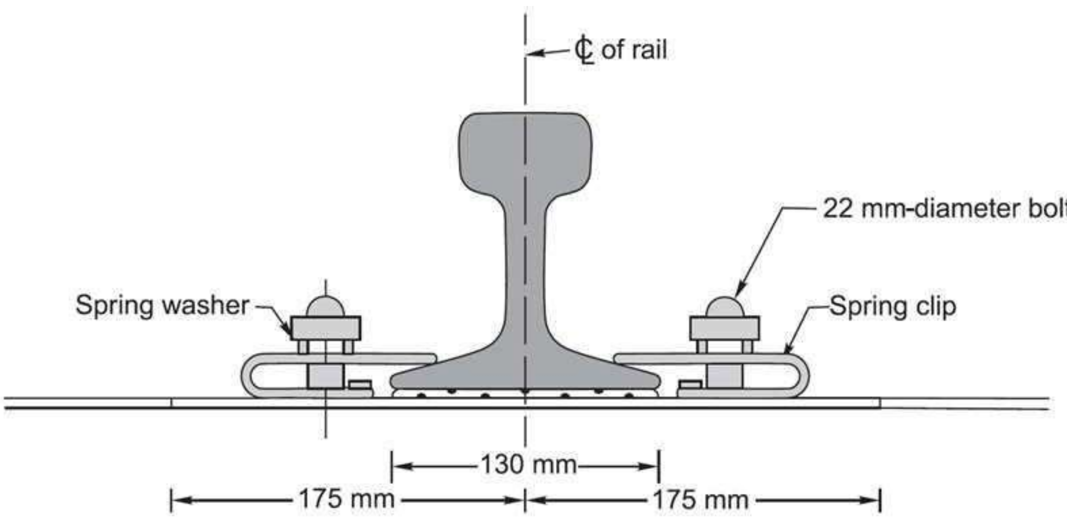
Insulated liners



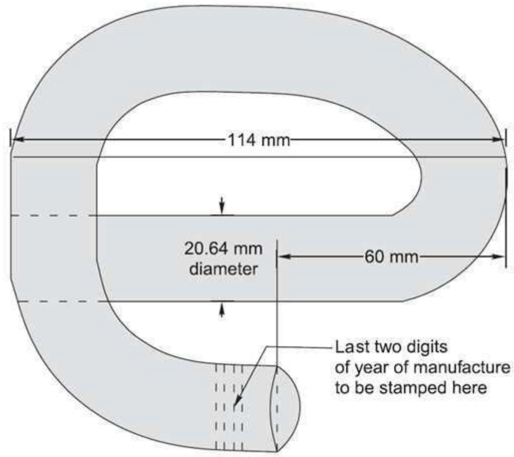
IRN 202 clip



Lock spike

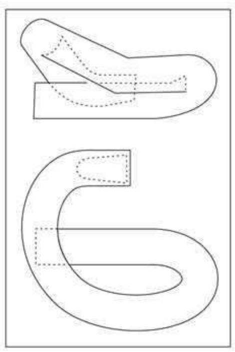


Spring steel clip



Pandrol clip (ERC rail clip) MK III

New ElasticFastening(GClip)

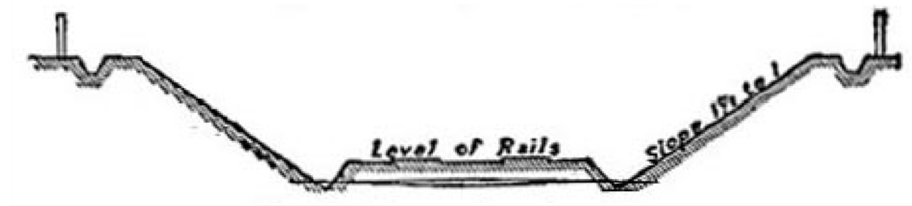


Logwell G clip

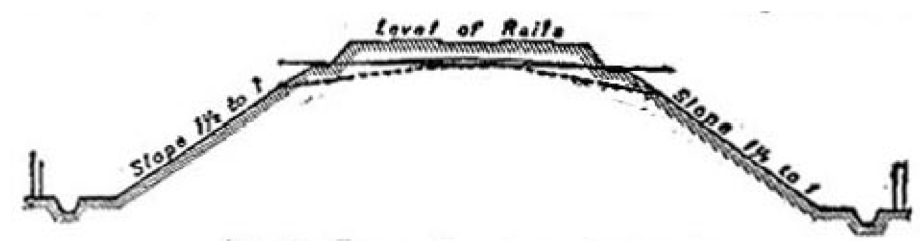
Isometric view of G clip assembly

CHAPTER-4

GeometricforBroadgauge



TypicalSectionofRailwayinCutting.



TypicalSectionofanembankment.

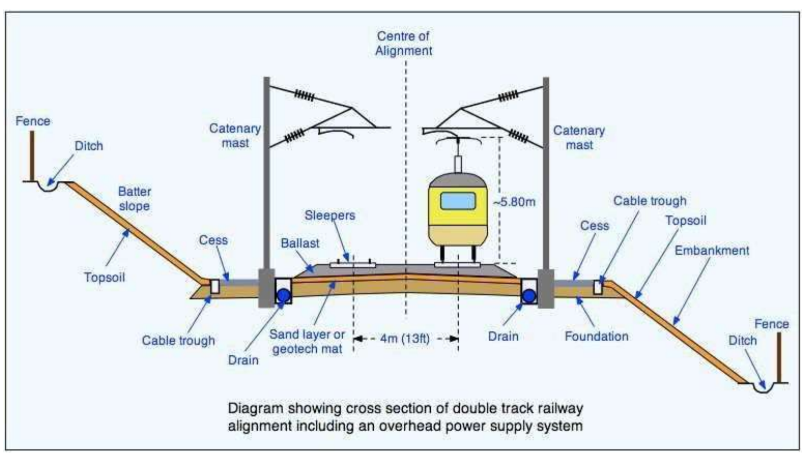


Diagram showing cross section of double track railway alignment including an overhead power supply system

ClassificationofRailway Land. Witha viewto determine what thedisposition of theland willprobablybe on the completion of the work for which it had been acquired, the classification given in paragraph 818 etc. should be adopted.

Onrailways,landisdividedintotwoclasses,viz.,

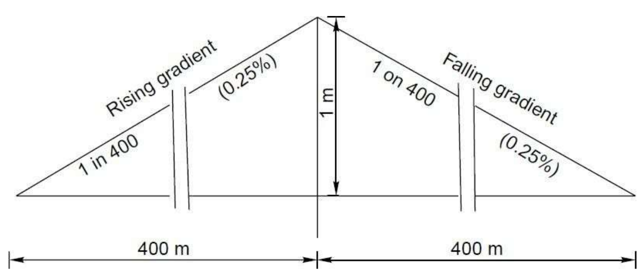
- (i)permanentlandwidth

- (ii)temporarylandwidth

Permanent land width is land which will be required permanently after the railway is open for traffic and the work of construction is complete. Under this head will be included all land to be occupied by the formation of the permanent line of railway with side slopes of banks and cuttings, and the berms connected therewith; catchwater drains and borrowpits or such parts of them as it isnecessary to retain; the entrances to tunnels and shafts belonging to them; the sites of bridges, and protection or training works; station yards; landing places for railway ferries; ground to be occupied by works belonging to the railway such as gas works, arrangements for water supply, septic tanks, collecting pits, filter beds and pumping installations, & c., ground for the storage manufacture or acquisition of materials; land for sanitary zones, cemeteries, churches, plantations; gardens, and recreation grounds, sites for stations, offices, workshops;dwelling houses and other buildings required for thepurposes of therailway, or theaccommodation of thestaff, with the grounds, yards, roads, & c., appertaining thereto. Under this head will also be included land outside the permanent railway boundary, which will be required for the permanent diversion of roads or rivers, or for other works incidentaltotheconstruction oftherailway, whicharemadefor publicpurposes and will not on completion of the works be maintained by the railway authorities.

Temporary land width is land which is acquired for temporary purposes only, and which is disposed of after the work of construction is completed.

<u>Gradientsfordrainage</u>



Rising and falling gradient

Drainage is defined as interception, collection and disposal of water away from track. Drainageis themost important factor intrack maintenanceandfor stability ofbanks/cuttings. When water seeps into the formation, it weakens the bonds between the soil particles, softens the soil and results in creation of ballast pockets. On one hand, ingress of water into bank/cutting adds to weight of soil mass trying to slide, thereby increasing propensity for slope-slide, on the other hand, it reduces shear strength of soil, thereby decreasing factor of safety for stability of slope. Therefore, quick disposal of water from formation top/slopes is very essential. Drainagesystemshouldbeeffectiveinpreventingthestagnation of water andallowquick disposal of water. At present, drainage is not being given its due importance in field. Provisions relating to drainage havebeendetailedinvariousguidelinesissuedbyRDSOfromtimetotime, however, thepresent Guidelines highlight the salient features of drainage arrangement in embankment as well as cuttings.

CONVENTIONALDRAINAGESYSTEMS

- SURFACEDRAINAGE
- SIDEDRAINS
- CATCHWATERDRAINS
- SUBSURFACEDRAINS

SUPERELEVATION

(1) **Cantorsuperelevation**istheamount bywhichonerail israisedabovetheother rail. It ispositive when the outer rail on a curved track is raised above inner rail and isnegative when the inner rail on a curved track is raised above the outer rail.

(2) **Equilibriumspeed** is thespeedat whichthecentrifugalforcedevelopedduringthemovement of the vehicle on a curved track is exactly balanced by the cant provided.

(3) **Cantdeficiency-**Cantdeficiencyoccurswhena traintravelsarounda curveata speedhigher than the equilibriumspeed. It is the difference between the theoretical cant required for such higher speed and actual cant provided.

(4) **Cant excess -** Cant excess occurs when a train travels around a curve at a speed lower than the equilibriumspeed. It is thedifferencebetweentheactualcant andthetheoreticalcant requiredfor sucha lower speed.

(5) Maximumpermissiblespeed ofthecurve-It is thehighestspeed which maybepermitted onacurve takingintoconsiderationtheradius ofthecurvature, actualcant, cant deficiency, cant excess andthelength oftransition. Whenthemaximumpermissiblespeed on a curveis less thanthemaximumsectionalspeed of the section of a line, permanent speed restriction becomes necessary.

(6) **Cantgradient** andcant deficiencygradient indicatetheamount bywhichcant or deficiencyofcant isincreasedor reducedina givenlengthoftransitione.g., 1in1000meansthatcantordeficiencyofcant of 1 mm. is gained or lost in every 1000mm. of transition length.

(7) **Rate of change of cant** or rate of change of cant deficiency is the rate at which cant or cant deficiencyisincreasedor reducedper second, atthemaximumpermissible speedofthevehiclepassingover the transition curve, e.g., 35 mm. per second means that a vehicle when traveling at a maximumspeed permitted will experiencea changein cant or deficiency of cant of 35mm. in each second of travel over the transition.

(8) Transition curve is an easement curve, in which the change of radius is progressive throughout its length and is usually provided in a shapeof a cubic parabola at each end of thecircular curve. It affords a gradualincreaseofcurvaturefromzeroat thetangent point tothespecifiedradius ofcirculirareandpermits a gradual increase of super elevation, so that the full superelevation is attained simultaneously with the curvature of the circular arc.

Superelevation,CantdeficiencyandCantexcess

(1) Superelevation/cant

(a) Theequilibriumsuperelevation/cantnecessaryfor anyspeediscalculatedfromtheformula

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

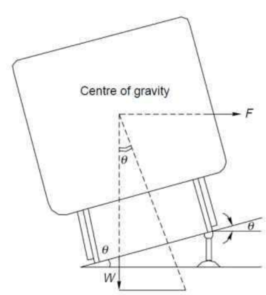
WhereC iscant/superelevationinmm. Gisthegaugeoftrack+widthofrailheadinmm. R istheradiusof the curve in metres.

<u>NecessityofSuperElevation</u>

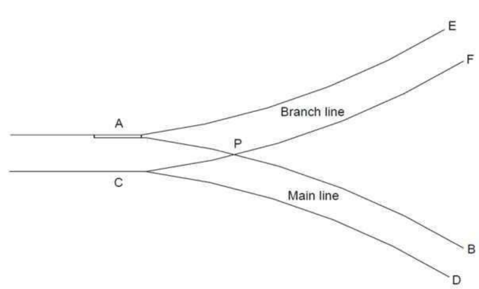
In order to counteract the effect of centrifugal force the outside rail of the curve may be elevated above the inside rail effectively moving the centre of gravity of the rolling stock laterally toward the inside rail. This procedure is generally referred to as super elevation.

If the combination of lateral displacement of the centre of gravity provided by the super elevation, velocity of the rolling stock and radius of curve is such that resulting force becomes centered between and perpendicular to a line across the running rails the downward pressure on the outside and inside rails of the curve will be the same.

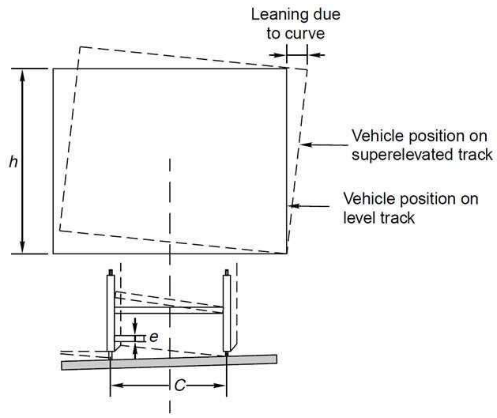
Thesuper elevation that produces this conditionfor a given velocityandradius ofcurveis knownas the balanced or equilibrium elevation.



Equilibrium superelevation



Negative superelevation



Effect of lean due to superelevation

LimitationofSuperelevation

ForMixedPassenger&FreightRoutes

Typical early railway operation resulted in rolling stock being operated at less than equilibrium velocity (all wheels equally sharing the rolling stock weight), or coming to a complete stop on curves. Under such circumstances excess super elevation may lead to a downward force sufficient to damage the inside rail of thecurve, or causederailment ofrolling stock towardthecentreofthecurve when draft forceis applied to a train. Routine operation of loaded freight trains at low velocity ona curvesuper elevatedtopermit operation of higher velocity passenger trains will result in excess wear of the inside rail of the curve by the freight trains.

Thusonthesetypesofroutes, superelevationisgenerallylimitedto not morethan6inches. For

High Speed Passenger Routes

Modernhighspeedpassenger routes, donot carryslower speedtrains, nor expect trainsto stoponcurves, so it is possibleto operatethese routes with higher track super elevation values. Curves on these types of route are also designed to be relatively gentle radius, and are typically in excess of 2000m(2km) or 7000m(7km) depending on the speed limit of the route.

CHAPTER-5.0

POINTSANDCROSSING

Necessity:-

I. Pointsandcrossingareprovidedto helptransfer railwayvehiclefromonetracktoanother.

II. The track may be parallel to diverging from or converging with each other pointand crossing are necessary because the wheels of railway vehicles are provided with inside flange and therefore they require this in special arrangement in order to navigate their way on the rail.

III. Thepoints or switches aidin divertingthevehicles and thecrossingprovidegaps intherails so as to help the flanged wheels to roll over them.

IV. Acompletesetofpointsandcrossings,alongwithleadrails,iscalleda***turnout.***

PointsorSwitches

Apairoftonguerailandstockrailwithnecessaryconnectionandfittingforms a switch

Crossing:-itisadeviceintroducedatthejunctionwhere tworailscrosseachothertopermitthewheel flanges of a railway vehicle to pass from one track to another

Switches

- Apairofstockrail,ABandCDmadeofmedium-manganesesteel.
- A pair of tongue rails, PCS and RS also known as switch railsmade withstand wear. The tongue rails are machined to very thin section to obtain a snug fit with the stock rail is called 'toe' and thicker end is called the 'heel'
- Ano.ofslidechairstosupportthetonguerailand enablefromstockrail.
- Two or more stretcher bars connecting both the tongue rails close to the toe for the purpose of holding them at a fixed distance from each other.
- Agaugeties platetofixgauges andensurecorrect gaugeat thepoints.

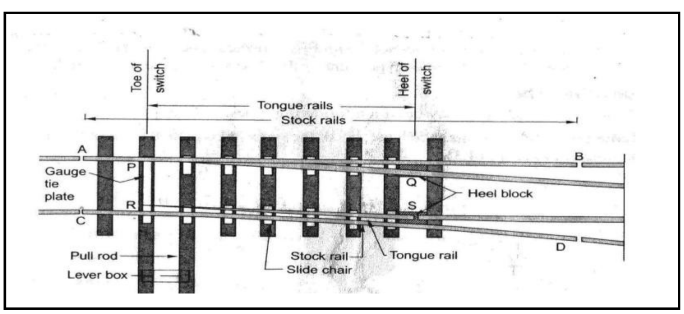


FIGURE:DETAILSOFSWITCH

TypesofSwitches

Switchesareoftwotypes,namely'studswitches'and'splitswitch'.

In 'studswitch' noseparatetongue rail is providedand some portionof thetrackis moved fromone side to the other side.

In'splitswitch'apairofstockrailandpairoftonguerailsarepresent,splitswitchesaretwotypes:-

1) **LooseHeeltype:-**
   - In this type of split switch, the switch or tongue rail finishes at the heel of the switch to enable movement of the free end of the tongue rail.
   - Thefishplates holdingthetonguerailmaybestraightorhightlybent.
   - Thetonguerailis fastenedtothestockrailwiththehelp of afishingfitblockandfourbolts.
   - Allthefishboltsintheleadrailare tightenedwhile thoseinthe tongue railarekeptlooseor snug to allow free movement of the tongue.
   - Asthediscontinuityofthetrackattheheelisaweaknessinthestructure,theuseofthese switches is structures, the use of these switches is not preferred.

(2) **FixedHeelType:-**

In this type of split switch thetonguerail does not end at theheel of theswitch, but extends further and is rigidly connected. The movement at the toe of the switch is made possible on account of flexibility of tongue rail.

Crossing:-

A crossing or Frog is a device introduced at the point/junction where two gauge faces / railscrosseach other to permit the wheel flanges of a railway vehicle to pass fromone track to each other.

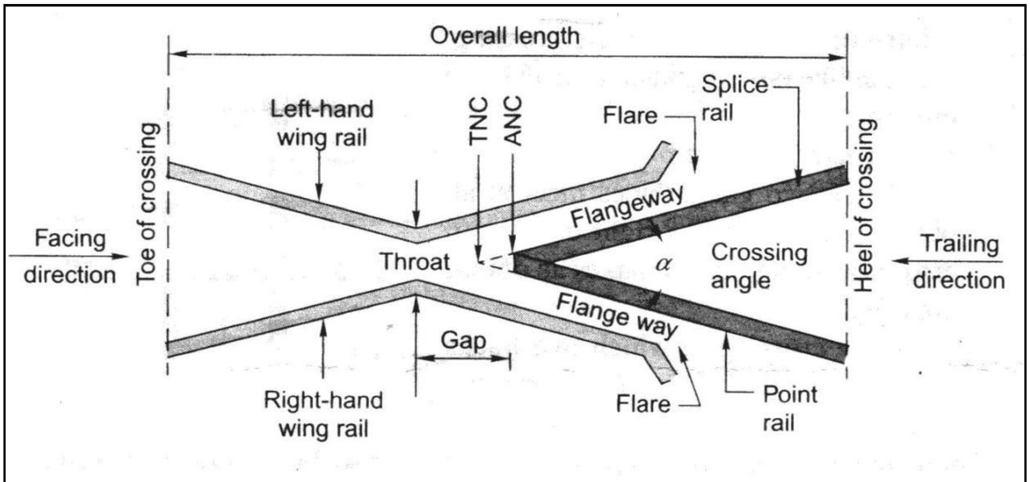


Figure :- Details of Crossing

Acrossing consistsofthefollowingcomponents.

(i) Two rails, ***point rails and splice rails***, which are machined to form a nose. The point rail ends at the nose whereas the splice rail joins it a little behind the nose.

Theoretically, thepoint railshould end ina point andbemadeas thinas possible, but a knife edge of point rail would break off under the movementof traffic. The point rail therefore, has its fineend slightly cut offto forma blunt nose, witha thickness of 6mm. Thetoeof the blunt nose is called the ***actual nose of crossing (ANC)*** and the theoretical point where the gauge faces form both sides intersect is called the ***theoretical nose of crossing (TNC).***The 'V'railis planed toa depth of6mm(1/4'')at thenoseandruns out in89mmtostop a wheel running in the facing direction from hitting the nose.

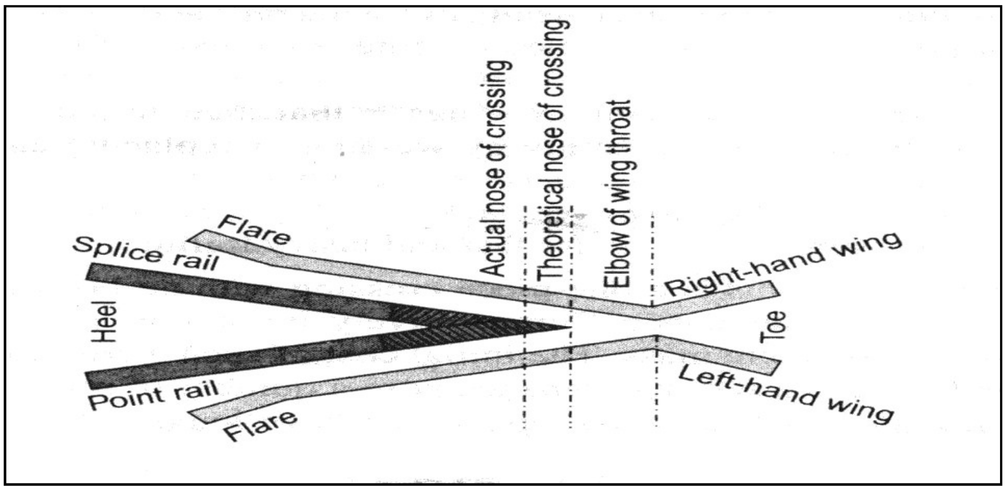


Figure:-PointRailandSpliceRail

(ii) Two wing rails consisting of a right hand and a left hand wing rail that converge to from 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.

(iii) A pair o f check rails to guide the wheel flanges preventing them from moving sideways which would otherwise may result in the wheel hitting the nose of the crossing as it movesin the facing direction.

TYPESOFCROSSING:

Acrossingmaybeofthefollowing types:-

(a) **Anacute angle crossing or 'V' crossing**in whichthe intersection of two gaugefaces forms on acute angle, For example when a right rail crosses a left rail, it makes an acute crossing. So unlike rail crossing from an acute crossing.

(b) **Anobtuseor diamond crossing**in whichthetwo gaugefaces meet at anobtuseangle. Whena right on left rail crosses a similar rail, it makes an obtuse crossing.

(c) **Asquarecrossing** inwhichtwotrackscrossingatright angles, suchcrossingsarerarelyusedin actual practice. For manufacturing purposes, crossing is of following types.

Accordingtomanufacture,thecrossingmaybeclassifiedasmentionedunder:-

(a)Builtup crossing:-

In a built-up crossing two wing rails and a V-section consisting of spliceand point rails are assembled together by means of bolts and distance blocks to forma crossing.

Advantages:-

(a) Initialcostislow.
(b) Repaircanbecarriedout bywelding.

(b)Caststeelcrossing:-

Thisisonepiececrossingwithnoboltsandthereforerequiringverylittlemaintenance.

Comparatively

Advantages:-

(a) Longerlife.

Disadvantages:-

(a) Initialcostishigh.
(b) Repair andmaintenancecausesa noofproblem.

(c) Combinedrailandcastcrossing:-.

is a combination of a built-up and cast steel crossing and consists of a cast steel nose finished to ordinary rail faces to formthe two legs of the crossing.

Through it allows the welding of worn-out wing rails, the nose is still liable to fracture suddenly.

CMS Crossing:- Due to increase in traffic and the use of heavier axle loads, the ordinary built-up crossing manufacturer from medium –manganese rails subjected to vary heavy wear and tear, especially in fast lines and suburban sections with electric traction. Past experience has shown that life of such crossings varies six months to two years, depending on their location and service conditions. CMS crossings possese higher strength, offer more resistance to wear and consequently have a longer life.

Advantages:-

- Lesswear andtear.
- Longerlife.
- Freefromboltsaswheelasothercomponentsthatnormallytogetlooseasaresultof movement of traffic.

SpringorMovableCrossing:-

In a spring crossing, one wing rail is movable and held against the V of the crossing with a stronghelicalspringwhiletheotherwingrailiskeptfixed.Whenavehiclepassesonthemaintrack,the movable wing rail is snug with crossing and the vehicle does not need to negotiate any gap at the crossing. In case the vehicle has to pass over a turnout track, the movable wing is forced out by the wheel flanges and the vehicle has to negotiate a gap as in normal turnout

This type of crossing is useful when there is high-speed traffic on the main track and slow-speed traffic on the turnout track

CHAPTER6

METHODSOFLYING&MAINTENANCEOFTRACK:-

EssentialofTrackMaintenance:-

1. Thegaugeshouldbecorrectorwithinthespecifiedlimits.
2. Thereshouldbenodifferenceincrosslevels exceptoncurves, wherecrosslevels varyin order to provide superelevation.
3. Longitudinallevelsshouldbeuniform.
4. Thealignmentshouldbestraight andkink-free.
5. Theballastshouldbeadequateandsleepers shouldbewellpacked.
6. Thetackdrainageshouldbegoodandformationshould bewelltrained.

Railway track can be maintained either conventionally by manually labour or by the application of modern methods of track maintenance, such as mechanical tamping or measured shovel packing. The major maintenance operations performed in a calendar year (12-months) are as follows for achieving the above mentioned standards:-

1) **ThroughPacking-:**
2) **SystematicOverhauling**
3) **Pickingupslacks**

1) ThroughPacking

ThroughPackingiscarriedoutinasystematicandsequentialmannerasdescribedas follows:-

- **Openingofroad:-**

Theballastisdugoutoneithersideoftherailseatforadepthof50mm(2")belowthe bottom ofthe sleeperwiththehelpofashovelwithawire claw .Onthe outside,thewidthofthe opening should extend up to the end of the sleeper.

On theinside itshould extend from the railseatto a distance of450mm (18")in case of BG, 350mm (14") in case of MG, and 250mm (10") in case of NG.

- **Examinationofrails,sleepersandfastening:-**

Therails,sleepersandfasteningtobeusedarethoroughlyexamined.Defectivesleepersare removed and loose fastening are tightened. Any kinks in rails are removed.

- **Squaringofsleepers:-**

(a) Todothisoneoftherailsistakenasthesightingrailandthecorrectsleeperspacingis marked on it.
(b) Theposition of thesleeper is checked with referenceto thesecond rail with the help ofa T-square.

(c) The sleeperattendedtoafterthisdefectshave beenestablished,whichmayinclude their being out of square or at incorrect spacing.

➢ **Aligningthetrack:-**

(a) Thealignmentofthetrackisnormallycheckedvisually,whereintherailisvisually assessed form a distance of about four rail lengths or so.

(b) Small errors in the alignment are corrected by slewing the track after loosening the cores at the ends and drawing out sufficient ballast at the ends of the sleeper.

(c) Slewingis carried out byplantingcrowbar deepintotheballast atananglenot morethan30 form the vertical.

AdvantagesofTrackMaintenance:-

1. If the track is suitably maintained, the life of the track as well as that of the rolling stock increases since there is lesser wear and tear of their components.
2. Regulartrackmaintenancehelpsinreducingoperatingcostsandfuelconsumption.
3. Small maintenance jobs done at the appropriate time, such as tightening a bolt or key,hammering the dog spike, etc., help in avoiding loss of concerned fitting and thus saving on the associated expenditure.
4. When track maintenance is neglected for along time, it may render the track beyond repair, calling for heavy track renewals that entail huge expenses

Gauging:-

The gauge should be checked and an attemptshould be made to provide auniform gaugewithin permissible tolerance limits.

2. <u>Systematicoverhauling:-</u>

Thesystematic overhauling of thetrack should normally commence after thecompletion of one cycle of through packing. It involves the following operations in sequence:-

(a) Shallowscreeningandmakingupofballast section.

(b) Replacingdamagedorbrotherfittings.

(c) Includingallitemsinthroughpacking.

(d) Makingupthe cess.

3. <u>Pickingupstacks:-</u>

Stacks are those points in the track where the running of trains is faculty. Slacks generally occur in the following cases:-

(a) Stretchesofyieldingformation.

(b) Improperlyalignedcurves.

(c) Portionsoftrackwithpoordrainage.

(d) Approachestolevelcrossing,girderbridgesetc.

(e) Sectionwithaninadequateor uncleanballast cushion.

Nothroughpackingis doneduringtherainingseasonandslacks areonlypickedup inorder to keep the track safe and in good running condition.

DutiesofapermanentwayInspector(PWI)

ThePWIisgenerallyresponsibleforthefollowing:-

(a) Maintenanceandinspectionofthetracktoensuresatisfactoryandsafeperformance.
(b) Efficientexecutionofallworksincidentaltotrackmaintenance,includingtrackrelayingwork.
(c) Accountsandperiodicalverificationofthestoresandtoolsinhisorhercharge.
(d) Maintenance of land boundaries between stations and at important stations as may be specified by the administration.

ThePWIalsocarries out inspectionofthefollowingfactsofatrack.

(a) Testingthetrack.
(b) Inspectionoftrackandgauge.
(c) Levelcrossinginspection.
(d) Pointandcrossinginspection.
(e) Curveinspection.
(f) Safetyoftrack.

Inadditiontotheinspections,aPWIalsocarriesoutfollowingduties:-

(a) Checktheproximityoftreesthatarelikelyto damagethetrackandgetthemremoved.
(b) Checknightpatrollingatlastonceamonthbytrainaswellasbytrolley.
(c) Takes the necessary safety measures wile executing maintenance work that affects the safety of the track.
(d) PeriodicallyinspectsandrespectiveLWRtackstoensuretheir safety.
(e) Ensuresthecleanlinessofstationyards.
(f) Keepsproperrecordsofthetrainingoutofballast.
(g) Looks after all establishment work, including the welfare of the staff working under his charge and maintenance their service records.
(h) Ensuresthesafetyofthetrackduringtheexecutionofworkthataffectsthetrack.

SECTION-B

CHAPTER-7

BRIDGEENGINERRING

DEFINATION

Thefollowingdefinitionsofcertainimportantterms usedinBridgeEngineeringaregivenbelow:

1. **Bridge: -** A structureis facilitating a communication routefor 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. **HighLevel Bridge or Non-submersible Bridge: -** The Bridge which does not allowthehigh 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 interruptionto traffic duringfloods formorethan three days at a time nor for morethan six timesin 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. Itmay 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. **DeskBridge:-**Thesearethebridgewhoseflooringsaresupportedattopofthesuperstructures.
8. Through Bridge. Thesearethebridges whose floorings aresupported or suspended at thebottom of the superstructures.
9. **Semi-ThroughBridges: -**Thesearethebridges whosefloorings aresupported atsomeintermediate level of the superstructure.
10. **SimpleBridges:-**Theyincludeallbeam,girderortrussbridgeswhoseflooringissupportedat some intermediate level of superstructure.
11. **Cantilever Bridges:-** Bridges which are more orless fixed at one end and free at other. It can beused for spans varying from 8 meters to 20 meters.
12. **ContinuesBridges:-**Bridgeswhichcontinueovertwoormorespans.Theyareusedforlarge spans and where unyielding foundations are available.

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. Thesebridges can beused up to span about 20 meters. Generally this type of bridge is not found economical for spans less than 10 meters.
15. **SquareBridge: -**Thesearethebridges atright anglestoaxis oftheriver.
16. **SquareBridge: -**Thesearethebridgesnot atright anglestoaxisoftheriver.
17. **SuspensionBridges:-**Thesearethebridgeswhicharesuspendedoncables anchoredatends.
18. **Under-Bridges:-**Itisabridgeconstructedtoenablearoadtopassunderanotherworkor obstruction.
19. **Over-Bridges:-**itisabridgeconstructedtoenableonefromoflandcommunicationovertheother.
20. **Class AA Bridges: -** These are bridgesdesigned 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. **ClassABridges:-**Thesearepermanentbridges designedforI.R.C.classAloading.
22. **ClassBBridges:-**ThesearepermanentbridgesdesignedforI.R.C.classBloading.
23. **Viaduct:-** Itis along continuesstructure which carriesa road orrailwayslike Bridge overadry valley composed of series of span over trestle bents instead of solid piers.
24. **Apron:-**It isalayer ofconcrete, masonrystoneetc. placedlikeflooringattheentranceor outofa culvert to prevent scour.
25. **Piers:-**Theyaretheintermediatesupports ofabridgesuperstructureandmaybesolidofopentype.
26. **Abutments:-**Theyaretheendsupports ofthesuperstructure.
27. **CurtainWall:-**It isathinwallusedasaprotectionagainstscouringactionastream.
28. **Effective Span: -** The centre to centre distance between any two adjacent supports is called as the effective span of a bridge.
29. **ClearSpan:-**Thecleardistancebetweenanytwoadjacent supportsofa bridgeiscalledclearSpan.
30. **Economic Span: -** the span, for which the total cost of bridge structure is minimum is known as economic span.
31. **Afflux: -** dueto construction of the Bridgethere is a contraction in waterway. This results in rise of water level above its normal level while passing under the Bridge. This riseis 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:-**Headroomisthevertical distancebetweenthehighest pointsofa vehicleor vesseland the lowest points of any points of any protruding member of a Bridge.
34. **Lengthof the Bridge: -** The length of a Bridgestructure willbetaken as the overall length measure along the centre line of the Bridge fromthe end to end of the Bridge deck.

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 surfaceobtained 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 FloodLevel(H.F.L.):-**It isthelevel of highest floodeveryrecordedor thecalculatedlevel for the highest possible flood.
39. **Effective Liner Waterway: -** Effective linear waterway is the total width of waterway of a bridge minusthe effective width of obstruction. For calculatingtheeffective linear waterways, thewidthof 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.

COMPONENTSOFABRIDGE

Thebridgestructureisdividedmainlyintotwocomponents:

1) Substructure

- The function of substructure is similar to that of foundations, columns and walls etc. of a building. Thus thesubstructuresupportsthesuperstructureand distributes theloadintothesoilbelowthrough foundation.
- Thesubstructureconsistsoffoundationpiersandabutmentpiers, foundationfor thepiers, abutments, wing walls, and approaches.
- Theaboveallsupportsthesuperstructureofthebridge.

2) Superstructure

- Thesuperstructureofa bridgeis analogues toa singlestorybuildingroofandsubstructure to that of walls, columns and foundations supporting it.
- Superstructureconsistsofstructuralmemberscarryingacommunicationroute
- Itconsistsof handrails,parapets,roadways,girders,arches,walltrussesover whichtheroad is support.
- Itisthatpartofthebridgeoverwhichthetrafficmovessafely

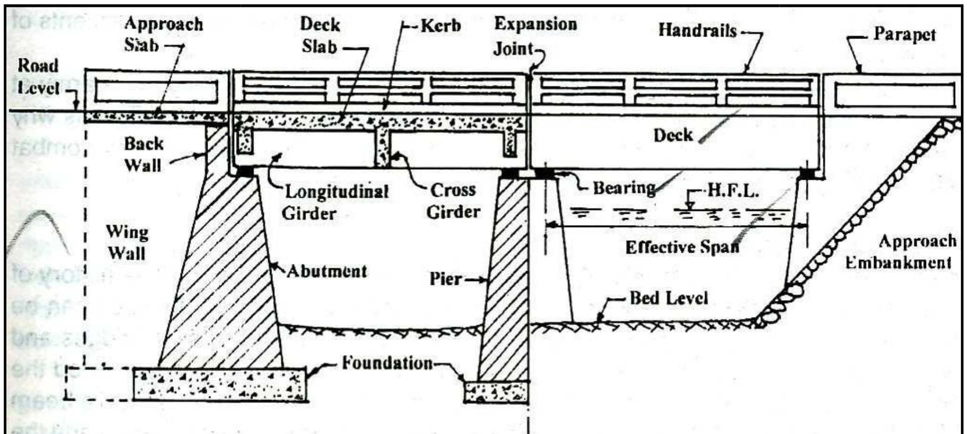


Figure 1 Components of a Typical Bridge.

ClassificationofaBridge:-

Thebridgesmaybeclassifieddependinguponthefollowingfactors:-

(a) Theirfunctionsorpurposeasrailway,highwayFootBridge,aqueduct etc.

(b) Theirmaterialofconstructionusedastimbermasonry,R.C.C.Steel,prestressesconcreteetc.

(c) Natureorlifespansuchastemporarypermanent bridgeetc.

(d) Theirrelativepositionoffloorsuchasdeepbridge,throughbridgesetc.

(e) Typeofsuper-structuresuchasarchedgirder,truss,suspensionbridge etc.

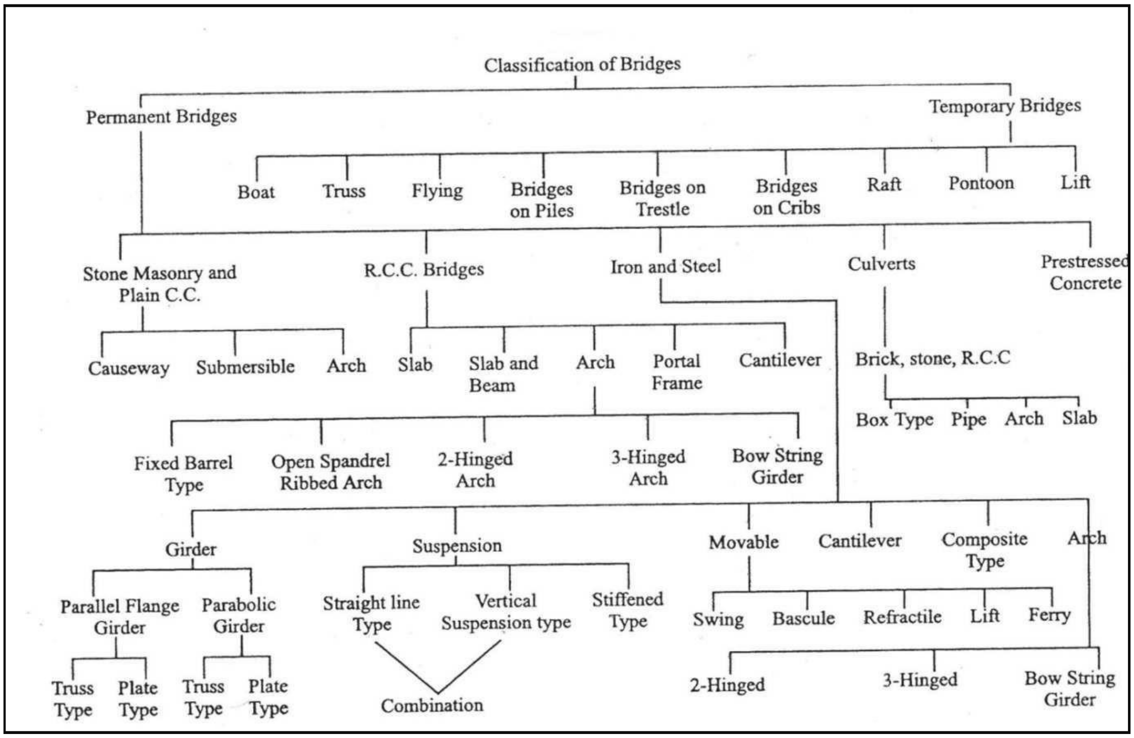
(f) Loadings:-RoadBridges andculverts havebeenclassifiedbyI.R.C.intoclassAA, ClassA, ClassB bridges according to the loadings they are designed to carry.

(g) SpanLength:-Underthis categorythebridgescanbeclassifiedas

- Culverts(SpanLessthan8m)i.e.BOXType, HumePipeType,
- Minor Bridge(Spanlength=8to30m)i.e.BOXtype,GirderType
- MajorBridge(SpanLength=abovethan30m)

(h) DegreeofRedundancy:-Under thisthebridgescanbeclassifiedasindeterminatebridges

(i) TypesofConnection:-Underthiscategorythesteelbridgescanbeclassifiedaspinnedconnected, riveted or welded bridges.



ClassificationofBridge

REQUIRMENTSOFANIDEALBRIDGE:-

An ideal bridge meets the following requirements to fulfil the three criteria of efficiency, effectiveness and equity

- Itserves theintendedfunctionwithutmost safetyandconvenience
- Itisaestheticallysound
- Itsi economical

ThesitecharacteristicofanIdealBridgehasbeendiscussedbelow:

1. Thestreamatthebridgesideshouldbewelldefinedandasnarrowaspossible.
2. Thereshouldbeastraightreachofstreamat bridgesite
3. Thesiteshouldhavefirm,permanent,straightandhighbanks.
4. Te flow ofwaterin the stream at the bridge site should be in steady regime condition. It should be free from whirls and cross-current
5. Thereshouldbenoconfluenceoflargetributariesinthevicinityofbridgesite
6. Itshouldbereliabletohavestraight approachroads andsquarealignment,i.e.right-angledcrossing
7. Thereshouldbeminimumobstructionofanaturalwaterwaysoastohaveminimumafflux
8. In order to achieve economy there should be easy availability of labour, construction material andtransport facility in the vicinity of bridge site.
9. In order to have minimum foundation cost, the bridge site should besuch that no excessive work is to be carried inside the water
10. Atbridgesiteitshouldbepossibletoprovidesecureandeconomicalapproaches.

11. Incase 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. Thereshouldbenoadverseenvironmentalinput
13. Thebridgesiteshouldbesuchthatadequateverticalheight andwaterwayisavailable
14. Underneaththebridgefor navigationaluse.

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 layoutof a bridge as follows:

i. Gradeonalignment,
ii. GeographicalConditions,
iii. Governmentrequirements,
iv. Commercialinfluences,
v. Adjacentpropertyconsideration,
vi. Generalfeaturesofthebridgestructure,
vii. Futuretrendsforenlargement,
viii. TimeConsideration,
ix. FoundationConsiderations,
x. Constructionfacilitiesavailable,
xi. ErectionConsideration,
xii. Aesthetics,
xiii. Maintenanceandrepairs,
xiv. EnvironmentImpact

CHAPTER-8

BridgeAlignment:-

Dependinguupontheanglewhichthebridgemakeswithteeaxis oftheriver, thealiment anmeoftwotypes:

a) SquareAlignments:-Inthisthebridgeisatrightangletotheaxisoftheriver.

b) SkewAlignments:-Inthis thebridgeis at someangletotheaxis oftheriver whichis not a right angle.

Note:- As faras possible, it is always desirabletoprovidethesquarealignment. theskewalignments suffers from the following disadvantages:-

(i) Agreat skillisrequiredfor theconstructionofskewBridges. Maintenanceofsuchtypeof Bridges is also difficult.

(ii) The water-pressureon piers incaseof skewalignment is also excessivebecause of non-uniform flow of water underneath the bridge superstructure.

(iii) Thefoundationofskewbridgeismoresusceptibletoscouraction.

FloodDischarge:-

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 usea few convenient formulae or past records.

Note:-Thisfaultydeterminationofflooddischargewhichledtofailureofmanyhydraulic 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) Fromtherainfallandothercharacteristicsofthecatchment.

(i) Byuseofanempiricalformulaappliedtothatregion,or

(ii) Bya rationalmethod, provideditispossibletoevaluatefor theregionconcernedthevarious

factors employed in the method.

(b) From thehydrauliccharacteristicsofthestream suchascross-sectionalarea,andslopeofthestream allowing for velocity of flow.

(c) Fromtherecords available, ifany, ofdischarges observed onthestreamatthesiteofthe bridge, or atany other site vicinity.

EmpiricalMethodsforEstimationofFloodDischarge:-

Inthesemethodsareofbasinor catchmentisconsideredmainly.Allother factorswhichinfluence peak flow are merged in a constant.

Ageneralequation maybefollowedintheform:-

$$Q=C.M^{n}$$

Here, Q=PeakFloworrateofmaximumdischarge C= a constant for the catchment

M=areaofcatchment,and'***n***'isanindex

Theconstantforcatchmentisarrivedat,aftertakingthefollowingfactorsintoaccount:

(A) BasinCharacteristics

a) Area
b) Shape
c) Slope

(B) StromCharacteristics

a) Intensity
b) Duration
c) Distribution

Limitations

Thesemethods donottakefrequencyoffloodintoconsideration. These methods cannot be applied universally

Fixingofconstantisverydifficultandexacttheorycannotbeputforthforitsselection.

1) Dicken'sFormula

$$Q=C.M^{3/4}$$

Here, Q=Dischargeincum/sec

C= a constant

M=areaofcatchmentinsq.km.

2) Tyve'sformula

$$Q = C.M^{2/3}$$

Here, Q=Dischargeincum/sec

C=6.74 forareawithin24kmfromcoastor,

C=8.45forareaswithin24-161kmfromcoastor, C=

10.1 for limited hilly areas

InworstcaseCgoesupto40.5

M=areaofcatchmentinsq.km.

3) InglisFormula

ThisformulausedonlyMahastrastateandherethreedifferentcasesaretakenintoconsideration.

(a) Forsmallareasonly(Itisalsoapplicablefor fan-shapedcatchment)

$$Q= 123.2\sqrt{M}$$

(b) Forareasbetween160to1000squarekm. (

$$Q= 123.2\sqrt{M} - 2.62(M - 259)$$

c)For all type of catchment

$$Q=123.2M/\sqrt{(M+10.36)}$$

Inallequations,M=areaofcatchment insq.km.

4) NawabJangBahadur'sFormula:-

$$Q=C(M/2.59)(a-b.\log A)$$

Here,a,b,andCareconstant.

a=0.993andb=1/14

C=59.5forNorthIndiaor,

=48.1forSouthIndia

5) Creager'sFormula:-

$$q= C.Mn$$

Here, q=thepeakflowpersq.kmofabasin

M=areaofcatchmentinsq.km.and'***n'***issomeindex

By multiplyingbothsidesoftheaboveequationareofthebasinM,weget

$$Q=C.M^{n+1}$$

WhereQispeak value

EquationgivenbyCreager,JustinandHindsis

$$Q=46.CM^{(0.849M-0.048)}$$

6) Khosla'sFormula:-

It is a rational formula, It si based on the equation **P= R + L**

Or **R=P-L**

Here,Risroundoff, PisrainfallandLislosses.

L=4.82 Tm, where L is in mm and Tm is in centigrade {inC.G.S.System}

R= P - 4.82Tm

7) Besson'sFormula:-

Thisformulaisveryrationalandcanbeusedinanycase:

$$Q_m=(P_m X Q_r)/ (P_r)$$

Here, Q_m=Peakflowexpected

Q_r=Someobservedpeakflow P_r=

Observed rainfall

P_m=expectedrainfall

RationalMethodsforEstimationofFloodDischarge:-

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) ClimateorRainfallFactors.Thisincludes

(a)Intensity(b)Distributionand(c)DurationofRainfall

(ii) CatchmentAreaFactors.Thisincludes:

(a)Catchment Area(b)itsslope(c)itsshape(d)porosityofsoil

(e)Vegetablecover(f)initialstateofwetness

WATERWAY

Thearea through which the water flows under a bridge superstructure is known as the waterway of thebridge. Thelinear measurement ofthisarea alongthebridgeisknownasthelinear waterway. Thislinear waterway is equal tothe sum of all the clear spas. This maybe called as artificial linear waterway.

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 bridgeto be minimum. The overall cost of a bridge depends upon the following factors

a. Costofmaterialanditsnature.
b. Availabilityofskilledlabour
c. SpanLength.
d. Natureof streamtobebridged.
e. Climaticandother conditions.

Notes:-

It is not in the hand of engineers to bring down thecost 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.ThecostofSuperStructure=Thecost oftheSub-Structure

AFFLUX

When a bridge is constructed, the structure such as abutments and piers causethe reduction of natural waterway area. The contraction of stream is desirable because it leads to tangible saving in the cost speciallyfor alluvialstreamwhosenatural surfacewidth is too largethanrequiredfor stability. Therefore, to carrythe maximum flood discharge, the velocityunder a bridge increases. This increased velocitygives rise tosudden headingup of water ontheupstreamside of thestream. Thephenomenon o0f heading up of water on the upstream side of the stream is known as "**AFFLUX**"

Greaterthe afflux greaterwill be thevelocity underthe downstreamsideofthebridgeand greater will be the depth of scour and consequently greater will be depth of foundations required.

Affluxiscalculatedbyoneofthefollowing formula

(A) Marriman'sFormula

$$h_a = (V^2/2g)\{(A/Ca)^2 - (A/A_1)\}$$

Here, h_a=Affluxinmeters

V=Velocityofapproachinmeterspersecond A=

Natural Waterway area at the site a=Contracted

area in square meters

A_1= Theenlargedareaupstreamofthebridgesquaremeters

C=CoefficientofDischarge=0.75+0.35(a/A)-0.1(a/A)^{2}approximately

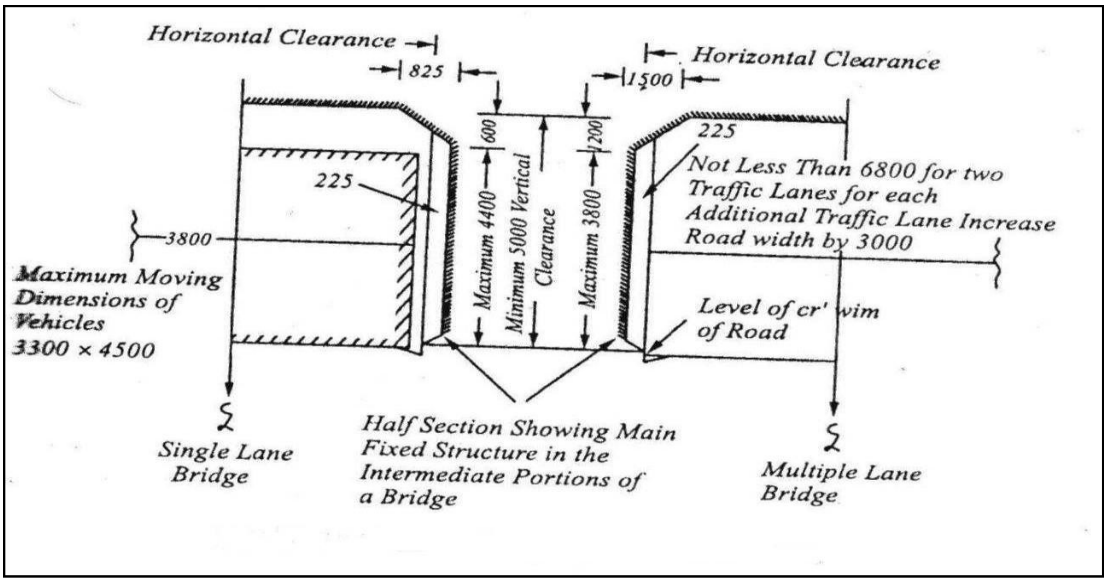
(A)Molesworth's Formula

$$h_a = \left(\frac{V^2}{17.9} + 0.015 \right) \{(A/a)^2 - 1\}$$

Here,V,Aandahavethesamemeaningas intheMarriman'sFormula

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 diagramin the figure below.



ClearanceDiagramforRoadBridges

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.*

FREEBOARD

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.

Itis essentialtoprovidethefreeboardinalltypes ofbridgesforthefollowingreasons:-

- 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 bridgesin case of navigable rivers. The value of free-broad depends upon the types of the bridge.

CollectionofBridgeDesignData:-

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.

Thefollowingdrawingscontaininginformationasindicatedshouldbeprepared

1. INDEX MAP
2. CONTURESURVEYPLAN
3. SITEPLAN
4. CROSS-SECTION
5. LONGITUDINALSECTION
6. CATCHEMENTAREAMAP
7. SOILPROFILE

Designdataformajorbridge:-

A- General data:-

(i) Nameoftheroadanditsclassification.

(ii) Nameofthestream.

(iii) Locationof nearestG.T.S.benchmarkanditsreducedlevel.

(iv) Chainageatcentrelineofthestream.

(v) Existingarrangementfor crossingthestream.

a) DuringMonsoon b) Duringdryseason

(vi) Liabilityofthesitetoearthquakedisturbance

B-CatchmentAreaandRunOffData:-

(i) CatchmentArea

(a) HillyArea b)Inplains

(ii) Maximumrecordedintensityandfrequencyofrainfallincatchment.

(iii) Rainfallincementerperyearinareason

(iv) Lengthofcatchment inkilometres.

(v) Widthofcatchment inkilometres.

(vi) Longitudinalslopeofcatchment.

(vii) Crossslopeof catchment.

(viii) Thenatureofcatchmentanditsshape.

C-DataRegardingNatureofStream

Sub-Surface Investigation:-

Sub-Surfaceinvestigation is essential for to knowtheproperties ofthebridgesitesoil. Thefieldand laboratory investigations required to obtain the necessarysoil data for the design are called soil exploration.

Theprincipalrequirementsofacompleteinvestigationcanbesummarizedasfollows:-

1. Natureofthesoildepositsuptosufficient depth.
2. Depth,thicknessandcompositionofeachsoilstratum.
3. Thelocationof groundwater.
4. Depthtorockandcomposition ofrock.
5. Theengineeringpropertiesofsoilandrockstratathataffectthedesignofthestructure.

Inexplorationprogrammetheextentofdistributionofdifferentsoilsbothinthehorizontaland vertical directions can be determined by the following methods:

1. Byuseofopenpits.
2. Bymakingboreholesandtakingout samples.
3. BySoundings.
4. Byuseofgeophysicalmethods.

EquipmentsforlaboratoryWork:-

Thedisturbedsoilsampleastakenfrombedleveltoscour level at everyonemeter interval or at depths wherever strata changes ate tested to determine the following properties:-

1. LiquidLimit, Plastic,LimitandPlasticityIndex
2. OrganicContent
3. HarmfulSalts
4. SieveAnalysis
5. SiltFactor

Theundisturbedsoilsamples as takenbelowthescour leveltoa levelwherethepressureis about 5% of the pressure at the base are tested to determine

1. Particlesizeanalysis.
2. Valuesofcohesionandangleofinternalfrictionbyshear test.
3. Compressionindexandpre-consolidationpressurebyconsolidationtest.
4. Densityspecificgravityandmoisturecontent.

AdvantageofSub-SurfaceInvestigation:-

Therearemanifoldadvantages ofcarefullyplannedinvestigationprogramme. Thesecanbesummarizedas below:-

1. Asuitableandeconomicalsolutioncanbeworked out.
2. Theconstructionschedulecanbeproperlyplanned.
3. Theextent andnatureofdifficultieslikelytobemetwithcanbedetermined.
4. Therateandamountofsettlementscanbedetermined.
5. Thevariationinthewater–table,ofthepresenceofartesianpressurescanbefound out.

CHAPTER9

DepthofScour:-

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, guidebank, spur and groyene. Codal provisions are seen to produce too large a scour depth around bridge elements resulting in bridge sub-structures thatleadtoincreasedconstructioncosts. Limitations that exist inthecodes ofpracticeareillustrated inthis paper using examples. The methods recently developed for estimation ofthescour aredescribed. Newrailwayand 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. Thepresent paper provides a critical noteon the practices followed in India for estimating the design scour depth.

Indianpracticesonestimationofdesignscour depth

1. Lacey–Inglismethod
2. CommentsonLacey'smethod

- 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 beforethescour 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) Thedesigndischargebeinggreaterthantheflooddischargeobserved.

(ii) Theincreaseinvelocityduetotheconstrictionofwaterwaycausedbyconstructionofthebridge.

(iii) Theincreaseinscourintheproximityofpiers andabutments.

- 4.6.3 In thecase of natural channels flowing in alluvial beds wherethe 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

$$\mathbf{D=0.473(Q^{f}/f)^{1/3}}$$

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 duetoconstriction of waterway, the width is less thanLacey's regime widthfor 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:

$$\mathbf{D=1.338(Q_{f}^{2}/f)^{1/2}}$$

Where 'Q_f ' 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 theformula:$f= 1.76\sqrt{m}$wherem isweightedmeandiameterofthe bedmaterialparticlesinmm. Values of 'f' for different types of bed material commonly met with are given below :

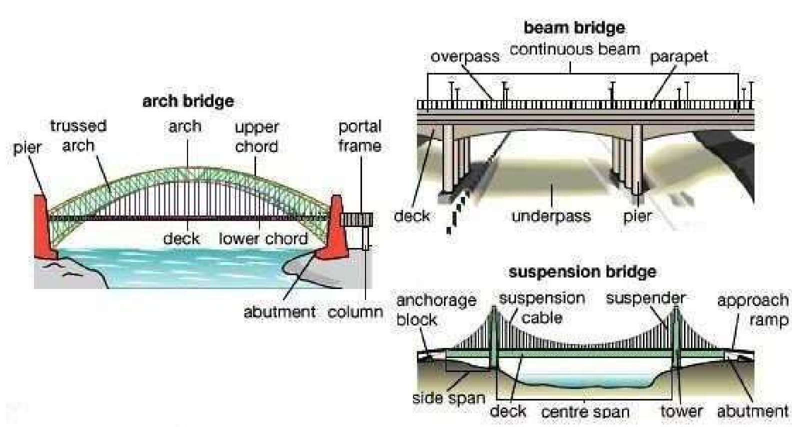
Typeofbed	MaterialWeightedmean diaofparticle(mm)	Valueof'f'
(i)Coarsesilt	0.04	0.35
(ii)Finesand	0.08 0.15	0.50 0.68
(iii)Mediumsand	0.3 0.5	0.96 1.24
(iv)Coarsesand	0.7 1.0 2.0	1.47 1.76 2.49

Thedepthcalculated(videclause4.6.3and4.6.4above)shallbeincreasedasindicatedbelow,toobtain maximum depth of scour for design of foundations, protection works and training works:-

Natureoftheriver	**Depthof scour**
Ina straightreach	1.25D
Atthemoderatebendconditionse.g.alongapronofguidebund	1.5D
Ataseverebend	1.75D
Atarightanglebendoratnoseofpiers	2.0D
Insevereswirlse.g. againstmoleheadofa guidebund.	2.5to 2.75D

In case of clayey beds, wherever possible, maximum depth of scour shall be assessed from actual observations.

TypesofBridge

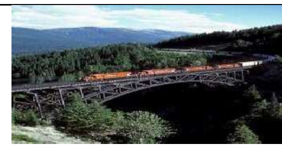
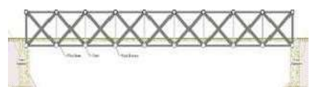


TypesofBridge

Archbridge	
Archbridge(concrete)	
Througharchbridge	
Beambridge	
Logbridge(beambridge)	
CavitywallViaduct	
Bowstringarch	
Boxgirderbridge	

Cable-stayedbridge	
Cantileverbridge	
Cantileversparcable-stayed bridge	
Clapperbridge	
Coveredbridge	
Girderbridge	
Continuousspangirderbridge	
Moonbridge	
Movablebridge	

Pigtailbridge	
Plategirderbridge	
Pontoonbridge	
Rovingbridge	
Segmentalbridge	
Self-anchoredsuspensionbridge	
Side-sparcable-stayedbridge	
Simple suspensionbridge(Incarope bridge))	
Step-stonebridge	
Stressedribbonbridge	
Suspensionbridge	

Transporterbridge	
Trestle	
Trussarch bridge	
Trussbridge	
Vierendeelbridge	
Browntruss	
Coveredbridge	
Latticetrussbridge(To wnlatticetruss	
Tubularbridge	

BridgeFoundation:-

Definition:- A foundation is the part of the structure which is in direct contact with the ground. It transfers the load of the structure to the soil below. Before deciding upon its size, we must ensurethat:

(i) Thebearingpressureatthebasedoesnotexceedtheallowablesoilpressure.

(ii) Thesettlement offoundationiswithinreasonablelimits

(iii) Differentialsettlement istolimitedas nottocauseanydamagetothestructure.

Broadly,foundationmaybeclassifiedundertwocategoriesi.e.

1. Shallowfoundation
2. DeepFoundation

Shallow Foundation:-According to Trezaghi,a foundation is said to be shallow if its depth is equal or lessthan its width.

DeepFoundation:-AccordingtoTrezaghi, a foundationissaidtobedeep, thedepthisgreater thanitswidth and it cannot be prepared by open excavation.

TypesofBridgeFoundation:-

Theselectionoffoundationtypesuitableforaparticularsitedependsonthefollowingconsiderations:-

1)NatureofSubsoil

2) Natureandextentofdifficulties,e.g.presenceofboulder,buriedtreetrunks, etc.Likelytobemetwith,and

3) Availabilityof expertiseandequipment.

Dependinguupontheirnatureanddepth,bridgefoundationcanbecategoriesasfollows:

i. **OpenFoundation,**
ii. **RaftFoundation,**
iii. **PileFoundation,**
iv. **Well foundation,**

(i)OpenFoundationinBridges:-

1. Anopenfoundationorspreadfoundationisatypeoffoundationandcanbelaidusingopen excavation by allowing natural slopes on all sides.
2. This type of foundation is practicablefor a depth of about 5mand is normally convenient abovethe water table.
3. Thebaseofthepierorabutmentisenlargedorspreadtoprovideindividualsupport.
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) RaftFoundation:-

1. Araftfoundationormatisacombinedfootingthatcoverstheentireareabeneathabridgeand 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 arealso used where thesoil mass contains compressible lenses so that the differential settlement would be difficult to control.
4. Therafttendstobridgeover theerraticdepositsandeliminatesthedifferentialsettlement.

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. Usuallywhenhardsoilis not availablewithin1.5to2.5maraftfoundationisadopted.
7. Theraftiscomposedofreinforcedconcretebeamsarelativelythinslabunderneath,figure

(iii) PilefoundationinBridges:

1. Thepilefoundationisconstructionsforthefoundationofabridgepierorabutmentsupportedon piers.
2. Apileisanelementofconstructioncomposedoftimber,concreteor steelor combinationofthem.
3. Pilefoundation maybe defined as a column support type of foundation which maybecast-in-situ or precast.
4. Thepiles maybeplaceseparatelyor they maybeplacedinformofa cluster throughout thelengthof the pier or abutment.
5. Thistypeofconstructionisadoptedwhentheloosesoil extendstogreatdepth.
6. Theloadofthebridgeis transmittedbythepiles tohardstratumbelow or it is resistedbythefriction developed on the sides of piles.

Classificationofpiles:-

Pilesarebroadlyclassifiedintotwocategories:-.

i- Classificationbasedonthefunction

ii- Classificationbasedonthematerialsandcomposition

Classificationbasedonthefunction

- BearingPile.
- FrictionPile.
- ScrewPile.
- CompactionPile.
- UpliftPile.
- BatterPile.
- SheetPile.

Classificationbasedonthefunction

- Cementconcretepiles.
- TimberPiles.
- SteelPiles.
- SandPiles.
- CompositePiles.

(iv) WellFoundationinbridges

a) Wellfoundations arecommonlyusedfor transferring heavyloads to deep stratainriver 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 makesthe 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 considerablyreducingbearingpressuretransmittedtothefoundation 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 areheavier than thesoil 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.

Caisson:-

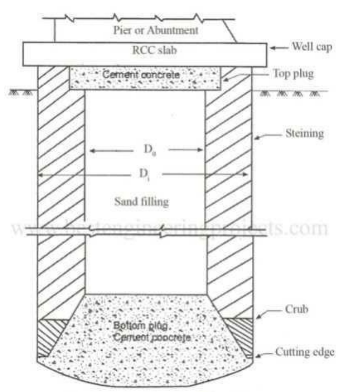


Fig 1 Parts of a Well Foundation

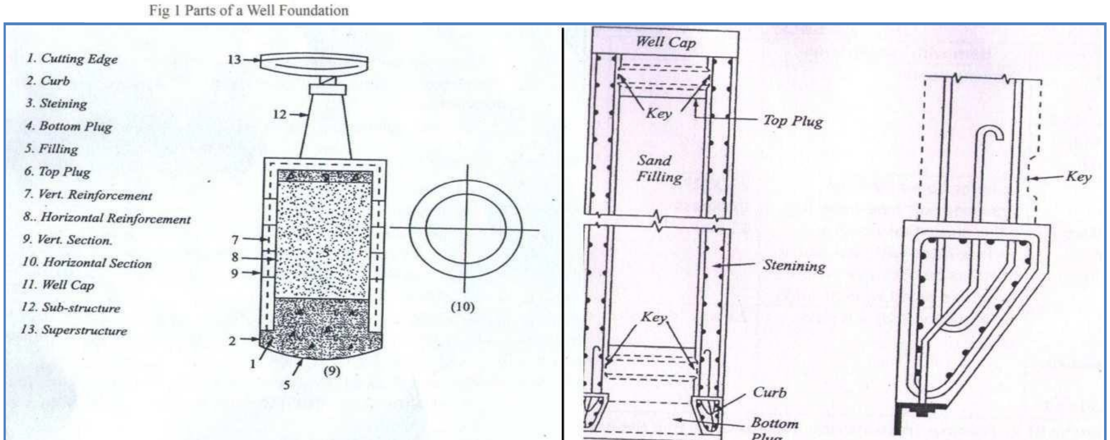


Figure :- DETAILS OF WELL FOUNDATION

Caisson: - Thecaisson is a structureused for thepurpose of placingas foundation incorrect position under water. The term caisson is derived from the French word 'caisse' meaning a box. It is a member with hollowportion, which after installing in palaceby any means is filled with concrete or othermaterial. Caissons are prepared in sandy soils the caissons can be divided in the followingthree groups

a. BoxCaissons
b. OpenCaissonsorWells
c. PneumaticCaissons

<u>Wellcomponentsandtheirfunctions:</u>

- ***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 edgeand alsoprovided support tothe wellsteining andbottomplug whileafter sinking it transfers the load to the soilbelow. 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.

$$t=K\ \{(H/100)+(D/10)\}$$

Here, t=minimumconcretesteiningthickness.

H=welldepthbelow bed

D=ExternaldiameterofWell

K=aconstantwhichis1.0forsandystrata.

- Bottom Plug:-Itsmainfunctionistotransfersloadfrom thesteiningtothesoil below.
- SandPlug: -Its utilityis doubtful. It is supposedtoaffordsomerelief tothesteining by transforming directly a portion of load from well cap to bottom plug.
- TopPlug:-Theopinionisdividedaboutthetopplug.It,atleast,servesasa shuttering for laying well cap.
- Reinforcement: – It provides requisite strength to the structure during sinking andservice.

- Well Cap: - It is needed to transfer the loads and moments from the pier to the well or wells below. The shape of well cap is similar to that of the well with a cantilevering of about 15cm. Whenever 2 or 3 wells of smalldiameter areneededto support the sub-structure , the well cap designed as a slab resting over the well or wells with partial fixity at the edges of the wells.
- Depth of Well Foundation:- As per I.R.C. Bridge Code (Part-III), the depth of well foundation is to be decided on the following consideration
    1. The minimum depth of foundation below the H.F.L. should be1.33D, WhereD is theanticipated max. Depth of scour below H.F.L. Depth should provided proper grip according to some rational formula.
    2. The max bearing pressure on the subsoil underthe foundationresulting form any combination of the loads and forces except windand seismic forces should not exceed the safe bearing capacity of thesubsoil, after taking into account the effect of scour.

       Withwindandseismicforcesinaddition, themax. Bearingpressure should not exceedthe safe bearing capacity of the subsoil by more than 25%.
    3. While calculating max. Baring pressure on the foundation bearing layer resulting from the worst combination of direct forces and overturning moments, the effect of a passive resistance of the earth on sides of the foundation structure may be taken into account below the max, depth of the scour only.
    4. The effect of skin friction may beallowed on theportions below the max, depthof scour. Accordinglyfor decidingthe depth of wellfoundation, we require correct estimation of the following.
        1. Max.Sourdepth.
        2. Safebearingcapacity.
        3. Skinfriction.
        4. Lateralearthsupportbelowmax.Scourlevel.

It is always desirable to fix the level of a well foundation on a sandy strata with adequate bearing capacity. Whenever a thin stratum of clay occurring between two layers of sand is met with, in that case well must bepierced through the clayey strata. If at all foundation has to be laid on clayey layer it should be ensured that the clay is stiff.

Design loads and Forces. The forces acting o n a bridge structure, to be consideredfo the design of a well foundation, are as follows:

Vertical

(i) Deadload,

(ii) Liveload,

(iii) Buoyancy.

Horizontal

(i) Windforce.

(ii) Forceduetowatercurrents.

(iii) Longitudinal forces caused by the tractive effort of vehicle or by braking effect ofvehicles.

(iv) Longitudinal force on account of resistance of the bearing against movement dueto variations of temperature.

(v) Seismicforce.

(vi) Earthpressure.

(vii) Centrifugalforce.

The I.R.C. Bridge code II stipulates the magnitude of above loads and forces. The magnitude, directionandpoint ofapplicationofalltheaboveforces canberesolvedintotwo horizontal forces, P and Q and a single vertical force W under the worst possible combinations.

Chapter10

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 seismicareas, 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.

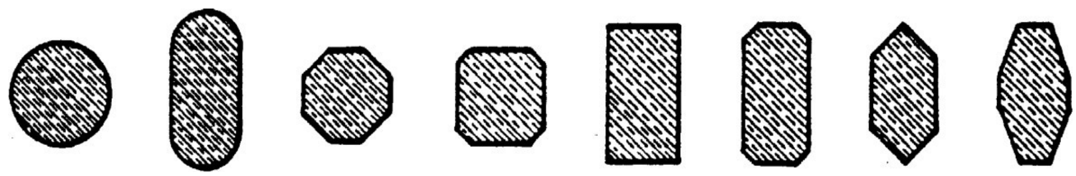


FIGURE:1:Typicalcross-sectionshapesofpiersforovercrossingsorviaductsonland.

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.

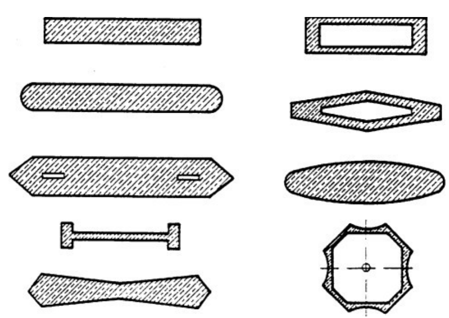


FIGURE:-2Typicalcross-sectionshapesofpiersforriverandwaterwaycrossings.

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 bebased 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 piersofriver andwaterwaycrossings. Often, pier typesaremandatedbygovernmentagenciesor owners. Many state departments of transportation in the United States have their own standard column shapes.

Broadlypiersareclassifiedunderfollowingtwocategories:-

I. SolidPiers.

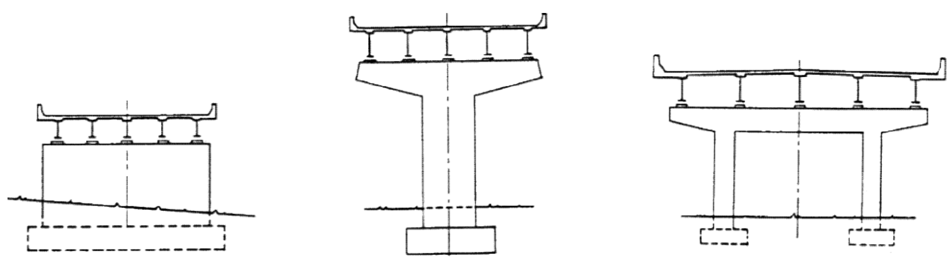
II. OpenPiers.

Solid wall piers, as shown in Figures 3-a and 4, 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, as shown in Figure 3-b, are often found in urban areas where space limitationis 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 beamand supportingcolumns forminga frame.

Column bent piers,as shown in Figure 3-c and Figure 27.5, can 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. Thecolumns can beeither circular or rectangular incross section. They areby far themost popular forms of piers in the modern highway system.

A pile extension pierconsists of a drilled shaft as the foundation and the circular column extended fromtheshaft toformthesubstructure. An obvious advantage ofthis type ofpier is that it occupies minimal amount ofspace. Wideningan existingbridgeinsome instances mayrequirepileextensions becauselimited space precludes the use of other types of foundations.



(a) Solid wall pier (b) Hammerhead pier (c) Rigid frame pier

FIGURE-3

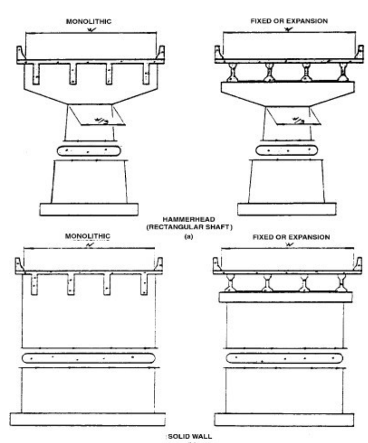
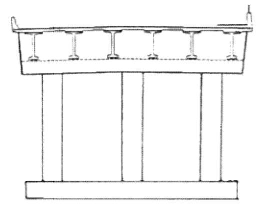
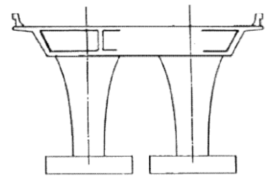


FIGURE-4



(a) Bent for precast girders



(b) Bent for cast-in-place girders

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 archtype of superstructure, the abutment top is made skew. Weep holes areprovided at different levels through the body of the abutment to drain of the retained earth.

Thesalientfeaturesofbridgeabutments arelistedbelow.

(a) Height.Theheightoftheabutmentsiskeptequaltothatofthepiers.

(b) Abutment batter. Thewater faceof theabutment isusuallykept vertical or couldbegivena 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 abutmentshould provide enough space for the bridge seat and for the construction of a dwarf wall to retain earth up to theapproach level.

(d) LengthofAbutment.Thelengthofabutmentiskeptatleast equaltothewidthofthebridge.

(e) Abutmentcap.Thedesignissimilar tothatofpiercap.

Abutments can be spill-through or closed. The spill through abutment generally has a substantial bermto help restrain embankment settlement at the approach of the structure.

Approach embankment settlement can also beaccommodated by approach slabs to eliminatebumps 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,abutmentsareclassifiedunderthefollowingcategories.

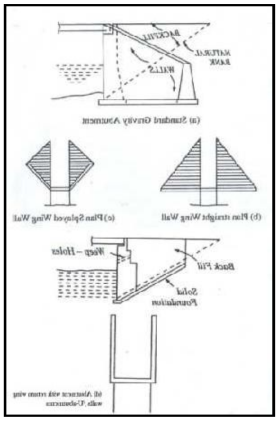
1. Abutmentswithwingwalls
2. Abutmentswithoutwingwalls

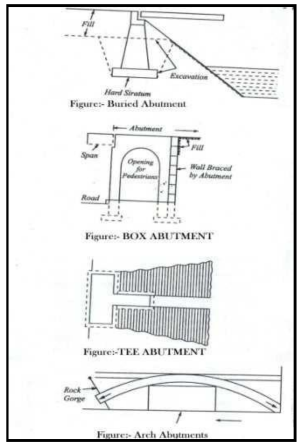
Abutments with wing walls

(a) StraightWingwalls
(b) SplayedWing walls
(c) Return Wing Walls

Abutmentswithoutwingwalls

(a) BuriedAbutments
(b) Box Abutments
(c) TeeAbutments
(d) ArchAbutments





FIGURES: -ABUTMENTS

BuriedAbutments: -This typeofabutments is generallybuilt prior totheplacing ofthefill. Sinceit is filled on both sides the earth pressureis 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 andresist earth pressure of the approaches. It is most often used overpass work where the short span may be employed for pedestrian passage (see figure).

TeeAbutments: -ThistypelookslikeT inplanandhas nowbecomeabsolute(seefigure)

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. (see figure)

WING WALLS:

In a bridge, the wing walls are adjacent to the abutments and act as retainingwalls. 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 earthfilling oftheapproaches. Their designperioddepends uponthenatureoftheembankment anddoes not depend upon the type or parts of the bridge.[1]

Thesoilandfillsupportingtheroadwayandapproachembankmentareretainedbythewingwalls,which canbeatarightangletotheabutmentorsplayedatdifferentangles.Thewingwallsaregenerally constructed at the same time and of the same materials as the abutments.

Classificationofwingwalls

Wingwalls canbeclassifiedaccordingtotheir position inplan withrespect tobanks andabutments.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: Theseareused for bridges across rivers. They providesmooth 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.

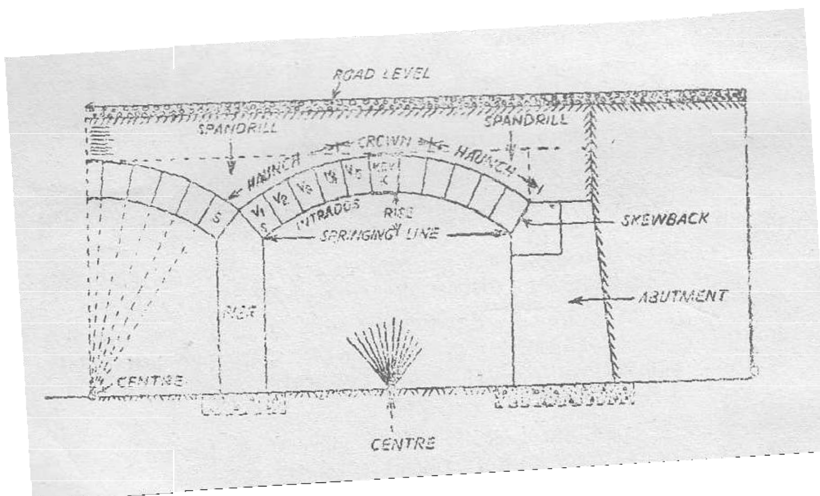
3. Return Wing walls: They are used where banks are high and hard or firm. Their top width is 1.5 m and face is vertical and back battered 1 in 4. Scourcan be a problem for wing walls and abutments both, as the water in the stream erodes the supporting soil.[

CHAPTER-11

PERMANENTBRIDGES

MasonryBridges:-

Bridge unit the spandrel, which supports the bridge roadway. The spandrel ismadefrom gravel or crushed stonebacking held in by lateral (side) walls made of concrete masonry or stonework or in theformof an open mainload-bearingstructures aremadeof naturalstone, brick, or concreteblocks. Sucha bridge is always arched, with massive supports. The main load-bearing element of a masonry bridge is the arch, overwhich is structure of small arches resting on crosswalk. The advantagesof amasonry bridge are its architectural attractiveness and its durability. Masonry bridges are known that have been in use for more than 1,000 years. The basic short comings that limit the use of masonry bridges are their complexity and labor intensiveness ofconstruction.. Their simplicity, economyandeasewithwhichpleasingappearancecan be obtained make them suitable for this purpose.



Classificationofsteelbridges

Steelbridgesareclassifiedaccordingto

- thetypeof trafficcarried
- thetypeofmainstructuralsystem
- thepositionofthecarriagewayrelativetothemainstructuralsystem These

are briefly discussed in this section.
Classificationbasedontypeoftrafficcarried

Bridgesareclassifiedas

- Highwayorroadbridges
- Railwayorrailbridges
- Road-cum-rail bridges

Classificationbasedonthe mainstructuralsystem

Many different types of structural systems are used in bridges depending upon the span, carriageway width and types of traffic. Classification, accordingto makeup of main load carryingsystem, is as follows:

(i) Girder bridges - Flexure or bending between vertical supports is the main structural action in this type. Girder bridges may be either solid web girders or truss girders or box girders. Plate girder bridges are adopted for simply supported spans less than 50 m and box girders for continuous spans up to 250 m. Cross sections ofa typicalplate girder andbox girder bridges areshown inFig.7.2 (a)andFig. 7.2(b)respectively. Truss bridges [See Fig.7. 2(c)] are suitable for the span range of 30 m to 375 m.Cantilever bridgeshave been built with success with main spans of 300 m to 550 m. . They may be further, sub-divided into simple spans, continuous spans and suspended-and-cantilevered spans, as illustrated in Fig.7. 3.

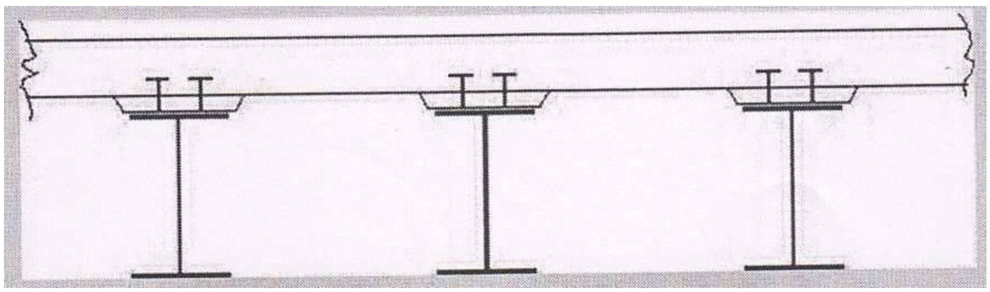


Fig.7.2(a)Plategirderbridgesection

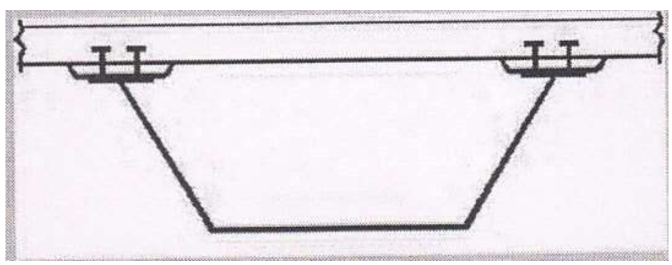


Fig.7.2(b)Boxgirderbridgesection

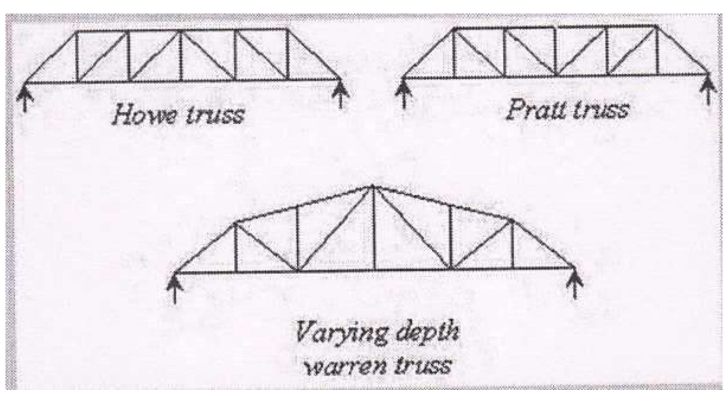


Fig.7.2(c)Someofthetrusses usedinsteelbridges

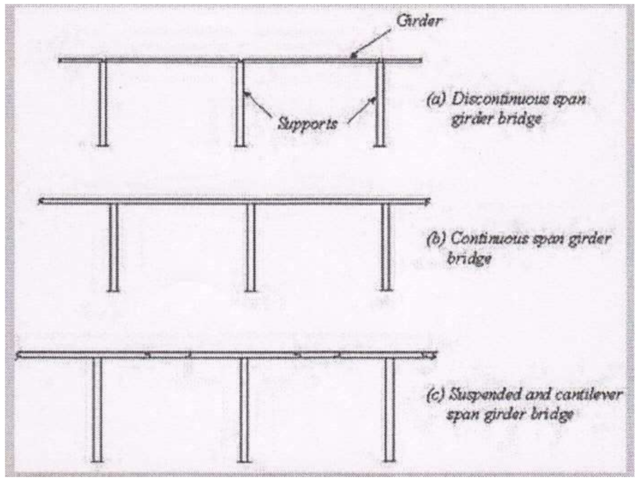


Fig.7.3Typicalgirderbridges

(ii) Rigid frame bridges - In this type, the longitudinal girders are made structurally continuous with the vertical or inclined supporting member by means of moment carrying joints [Fig.7.4]. Flexure with some axial force is the main forces in the members in this type. Rigid frame bridges are suitable in the span range of 25 m to 200 m.

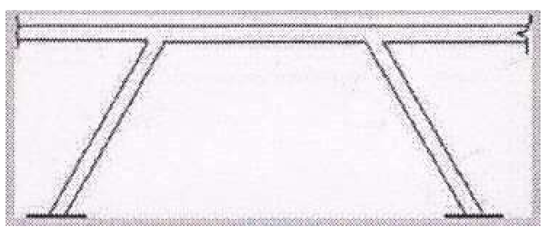
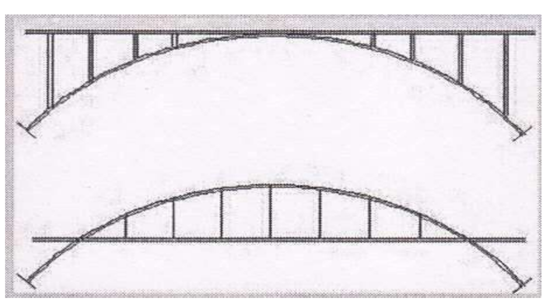


Fig.7.4Typicalrigidframebridge

(iii) Archbridges

The loads are transferred to the foundations by arches acting as the main structural element. Axial compression in arch rib is the main force, combined with some bending. Arch bridges are competitive in span range of 200 m to 500 m.



(iv) Cablestayedbridges-Cablesintheverticalornearverticalplanessupportthemainlongitudinal girders.Thesecablesarehungfromoneormoretalltowers,andareusuallyanchoredatthebottomtothe girders. Cablestayedbridges areeconomical whenthespanis about 150mto700 m. Layout ofcablestayed bridges are shown in Fig. 7.6.

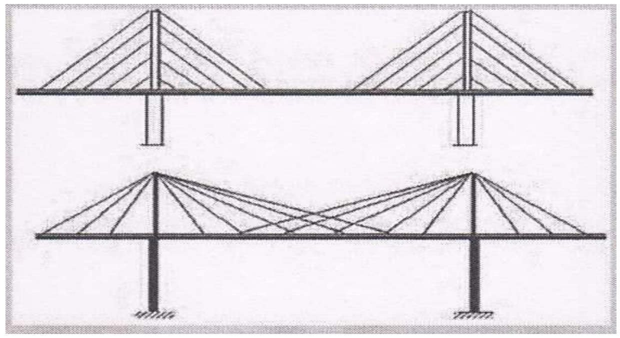


Fig.7.6Layoutofcablestayedbridges

(v) Suspension bridges - The bridge deck is suspended from cables stretched over the gap to be bridged, anchored to the ground at two ends and passing over tall towers erected at or near the two edges of the gap. Currently, the suspension bridge is best solution for long span bridges. Fig. shows a typical suspension bridge. Fig. 7.8 shows normal span range of different bridge types.

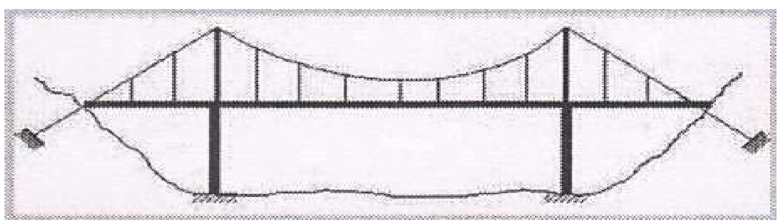


Fig.7.7Suspensionbridge

Classificationbasedonthepositionofcarriageway

Thebridges maybeofthe"decktype", "through type"or "semi-throughtype". Thesearedescribedbelow with respect to truss bridges:

(i) Deck type bridge -The carriageway rests on thetop of the main load carrying members. In the deck type plate girder bridge, the roadway or railway is placed on the top flanges. In the deck type truss girder bridge, the roadway or railway is placed at the top chord level as shownin Fig. 7.9(a).

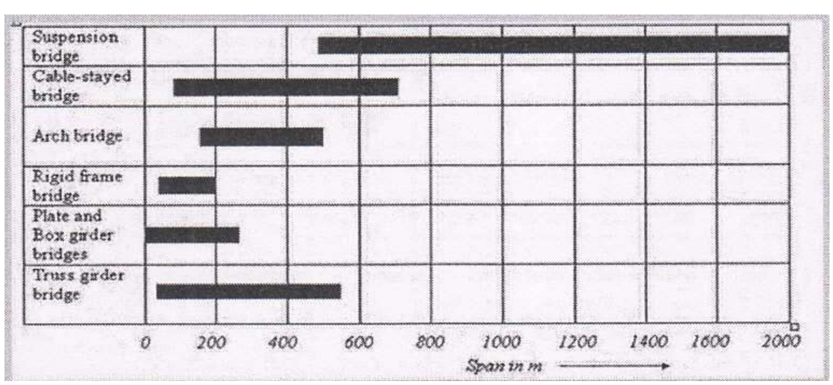
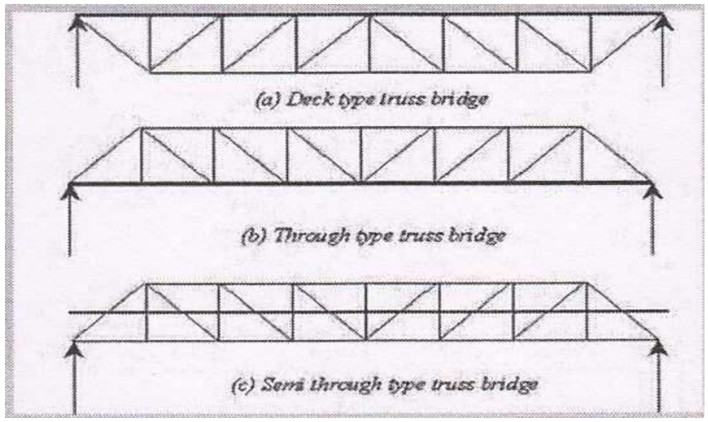


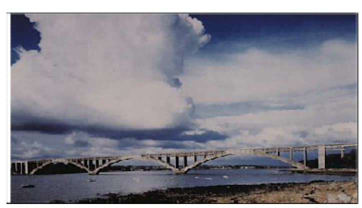
Fig.7.8Normalspanrangesofbridgesystem



TYPESOFCONCRETEBRIDGES

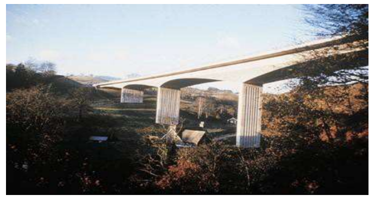
ArchBridges

Arch bridges derive their strength fromthe fact that vertical loads on the arch generate compressive forces in the arch ring, which is constructed of materials well able to withstand these forces. The compressive forces in the arch ring result in inclined thrusts at the abutments, and it is essential that arch abutments are well founded orbuttressed to resist the vertical and horizontal components of these thrusts. If the supports spread apart the arch falls down. Traditionally, arch bridges were constructed of stone, brick or mass concrete since these materials are very strong in compression and the arch could be configured so that tensile stresses did not develop. Modern concrete arch bridges utilize prestressing or reinforcing to resist the tensile stresses which can develop in slender arch rings.



ReinforcedSlabBridges

For short spans, a solidreinforced concreteslab, generallycast in-situ rather than precast, is thesimplest design. It is also cost-effective, since the flat, level soffit means that false work and formwork are also simple. Reinforcement, too, is uncomplicated. With larger spans, the reinforced slab has to be thicker to carry the extra stresses under load. This extra weight of the slab itself then becomes a problem, which can be solved in one of two ways. The first is to use prestressing techniques and the second is to reduce the deadweight of the slab by including 'voids', often expanded polystyrene cylinders. Up to about 25m span, such voided slabs are more economical than prestressed slabs.



BeamandSlabBridge

Beamandslab bridges areprobablythemost common formofconcretebridgeintheUKtoday, thanks tothe success of standard precast prestressed concrete beams developed originally by the Prestressed Concrete Development Group (Cement & Concrete Association) supplemented later by alternative designs by others, culminating in the Y-beam introduced by the Prestressed Concrete Association in the late 1980s.

They have the virtue of simplicity, economy,wide availability of the standard sections, and speedof erection.The precast beams are placed on the supporting piers or abutments, usually on rubber bearings which are maintenance free. An in-situ reinforced concrete deck slab is then cast on permanent shuttering which spans between the beams.

The precast beams can be joined together at the supports to form continuous beams which are structurally more efficient. However, this is not normally done because the costs involved are not justified by the increased efficiency.

Simplysupportedconcretebeamsandslabbridgesarenowgivingwaytointegralbridges whichoffer theadvantages of less cost and lower maintenance due to the elimination of expansion joints and bearings.

Techniques ofconstructionvaryaccordingtotheactualdesignandsituationofthebridge, therebeingthreemain types:

1. Incrementallylaunched
2. Span-by-span
3. Balancedcantilever

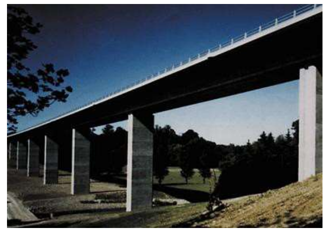
Incrementallylaunched

As the name suggests, the incrementally launched technique creates the bridge section by section, pushing the structureoutwards fromtheabutment towardsthepier.Thepracticallimit onspanfor thetechniqueisaround75m.

Span-by-span

Thespan-by-spanmethodisusedformulti-spanviaducts,wheretheindividualspancanbeupto60m.

Thesebridges areusuallyconstructedin-situ withthefalsework movedforwardspanbyspan, but canbebuilt of precast sections, put together as single spans and dropped into place, span by span.



Balancedcantilever

In the early 1950's, the German engineer Ulrich Finsterwalder developed a way of erecting prestressed concrete cantilevers segment by segment with each additional unit being prestressed to those already in position. This avoids the need for false work and the system has since been developed.

Whether created in-situ or using precast segments, the balanced cantilever is one of the most dramatic ways of buildinga bridge. Workstarts withtheconstructionoftheabutments andpiers. Then, fromeachpier, thebridgeis constructed in both directions simultaneously. In this way, each pier remains stable - hence 'balanced' - until finally the individual structural elements meet and is connected together. In every case, the segments are progressively tied back to the piers by means of prestressing tendons or bars threaded through each unit.

IntegralBridges

One of the difficulties in designing any structure is deciding where to put the joints. These are necessary to allow movement as the structure expands under the heat of the summer sun and contracts during the cold of winter. Expansion jointsin bridgesare notoriously prone to leakage. Waterladenwith road salts can then reach the tops of the piers and the abutments, and this can result in corrosion of all reinforcement. The expansive effects of rust cansplit concreteapart. Inaddition, expansionjoints andbearings areanadditionalcost so moreand morebridges are being built without either. Such structures, called 'integral bridges', can be constructed with all types of concrete deck. They areconstructed with their decks connected directlytothe supportingpiers andabutments and with no provision in the form of bearings or expansion joints for thermal movement. Thermal movement of the deck is accommodated by flexure of thesupporting piers and horizontal movements of theabutments, with elastic compression of the surrounding soil.

Already used for lengths up to 60m, the integral bridge is becoming increasingly popular as engineers and designers find other ways of dealing with thermal movement.

Cable-StayedBridges

For really large spans, one solution is the cable-stayed bridge. These types of bridges first developed in west Germany. They consists of cables provided above the deck and are connected to the towers. The deck is either supported by a number cables meeting in a bunch at the tower or by joining at different levels on the tower. The multiple cables would facilitate smaller distance between points of supports for the deck girders. This results in reduction of structure depth. The cables can arrange in one plane or two planes. The two plane system requires additional widths to accommodate the towers and deck anchorages. Singly plane system requires less width of deck.Where all elements are concrete, the design consists of supporting towers carrying cables which support thebridgefrombothsides ofthetower. Most cable-stayedbridges arebuilt usinga formofcantilever construction which can be either in-situ or precast.

The cable stayed bridges are similar to suspension bridges except that there are no suspenders in the cable stayed bridges and the cables are directly stretched from the towers to connect with decking. No special anchorage is required for the cables as incase of suspension bridges because the anchorage at one end is done in the girder and at the other on top of tower. The cable-stayed bridges have been found economical for up to span 300m. Howeverdue to cantilevereffect their deflection is rather high and hence they are not preferred for very long span in railways.

SuspensionBridges

Concrete playsan importantpart in the construction of a suspension bridge suspension bridgsare ideal solution for bridging gaps in hilly areasbecause of their construction technology and capacity of spanning large gaps. There will be massive foundations, usually embedded in the ground, that support the weight andcableanchorages .The cable takes shape of catenary between twopoints of suspension. The flooring of bridge supported by the cable by virtue of tension developed in its cross section. The vertical members are known as **suspenders** are provided to transferload from bridge floorto suspension cable. There will also be the abutments,again probably in mass concrete, providingthevital strengthandabilitytoresist the enormous forces, andinaddition, theslender superstructures carryingtheupper ends ofthesupportingcables arealsogenerally madefromreinforcedconcrete.

Typicaldeck,throughandsemi-throughtypetrussbridges

(ii) Through Type Bridge - The carriageway rests at the bottom level of the main load carrying members.In the through type plate girder bridge, the roadway or railway is placed at the level ofbottom flanges. In the through type truss girder bridge, the roadway or railway is placed at the bottom chord level. The bracing of the top flange or lateral support of the top chord under compression is also required.

(iii) Semi through Type Bridge - The deck lies in between the top and the bottom of the main load carrying members. Thebracing ofthetop flangeor top chordunder compression is not doneandpart of the load carrying system project above the floor level The lateral restraint in the system is obtained usually by the U-frame action of the verticals and cross beam acting together.

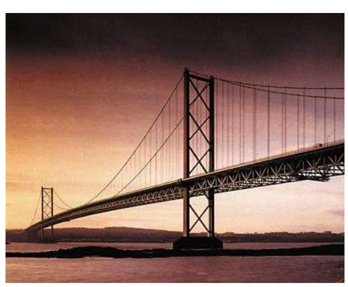
Concretebridges-

Theycanbedividedintothefollowingmainclasses

(1)Unstiffened suspension Bridges.

(2)StiffenedsuspensionBridges.

Un-stiffened suspension Bridges:-Incase of Un-stiffened suspension Bridges the moving load is transferred direct to the cables by each suspender. These are used for light construction such as foot bridges forest train structures, etc where the moving load is negligible and deflection requirements are not controlling. Alsotheplaces wherespanis verylong andtheratiodeadto movingload intensityis so great to render stiffening unnecessary.



Stiffened suspension Bridges:-In stiffened type suspension Bridges moving loads are transformed to thecables through mediumoftrusses called **stiffening girders** .Thestiffening girder assists thecableto become more rigid and prevent change in shape and gradient of roadway platform. It is therefore adopted for heavy traffic .

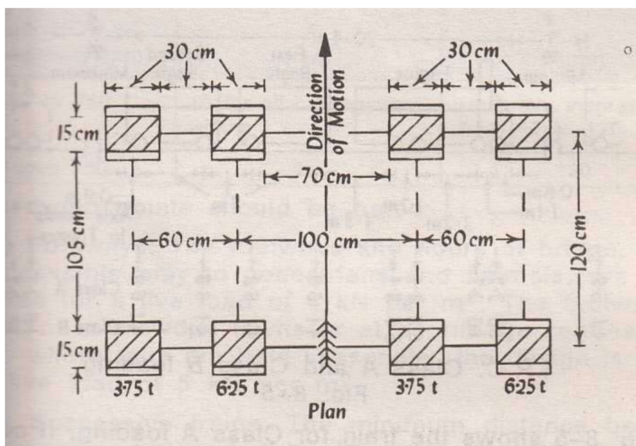
IRCBridgeloading:-

The public roads in India are managed and controlled by the Government and hence bridgesto be constructedforroadsto bedesigned asperstandardssetupby standardauthorities.For highwaybridges standardspecifications arecontainedintheIndianRoadCongress (I.R.C)Bridgecode. In India, highway bridges are designed in accordance with IRC bridgecode. IRC: 6 - 1966 – Section II gives the specifications for the various loads and stresses to be considered in bridge design. There are three types of standard loadings for which the bridges are designed namely,

(a) IRCclassAAloading,
(b) IRCclassAloading
(c) IRCclassBloading.

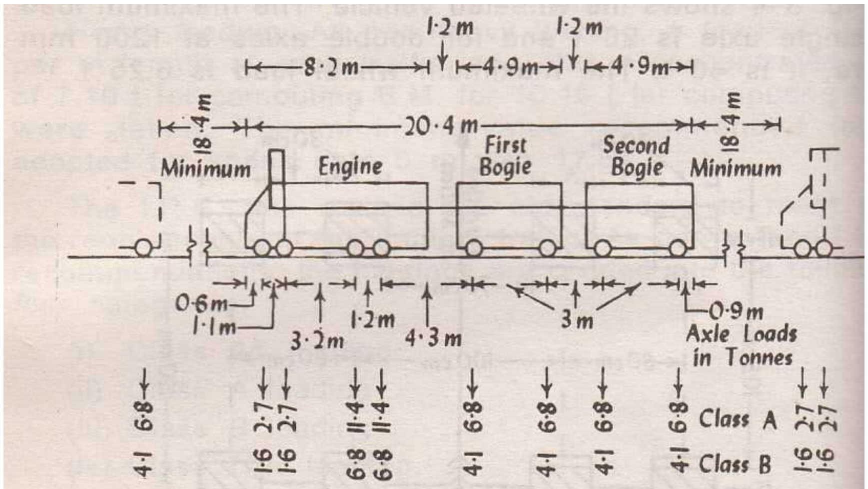
IRCclassAAloading:-

IRC class AA loading consists of either a tracked vehicle of 70 tonnes or a wheeled vehicle of 40 tonnes with dimensions as shown in Fig. Theunits in the figureare mm for length and tonnes for load. Normally, bridges on national highways and state highways are designed for these loadings. Bridges designed for class AA should be checked for IRC class A loading also, since under certain conditions, larger stresses may be obtained under class A loading. Sometimes class 70 R loading given in the Appendix - I of IRC: 6 - 1966 - Section II can be used for IRC class AA loading. Class 70 Rloading is not discussed further here.



I.R.C. Class *AA* loading—wheeled vehicle

IRC class A loading:-Class A loading is based on heaviest type commercial vehicle consists ofa wheel load train composed of a driving vehicleand two trailers of specified axlespacings. This loading is normally adopted on all roads on which permanent bridges are constructed.



I.R.C. Class *A* and Class *B* loading

. **IRCclassBloading**:-ClassBloadingisadoptedfor temporarystructuresandfor bridgesinspecified areas. For class A and class B loadings, reader is referredtoIRC:6-1966–SectionII.

CHAPTER-12

CULVERTSANDCAUSE WAYS

Culvert- Aculvert is defined as a small bridge constructed over a stream which remains dry most part of the year. It is across drainage workhavingtotal length not exceeding6mbetween faces of abutment.

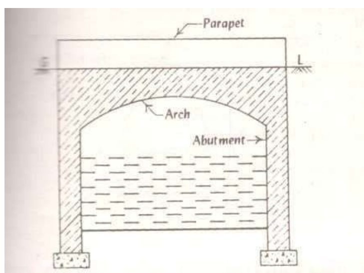
TypesofCulverts;-

Thefollowingaresixdifferenttypeculvert.

1. Archculvert
2. Boxculvert
3. PipeCulvert
4. SlabCulvert

Archculvert:-

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 is shown in figure.



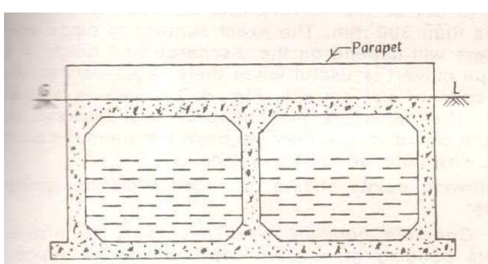
Arch culvert
FIG. 6–1

Boxculvert:-

Incaseofboxculverttherectangularboxesareformedofmasonry,R.C.Corsteel.TheR.C.Cbox culverts are very common and they consist of the following two component

(i) Thebarrelorboxsectionofsufficient lengthtoaccommodatetheroadwayandtheKrebs.

(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.6-2showsanR.C.Cboxculvertwithtwoopenings.Followingpointsshouldbenoted.

(i)Foundation:The box culverts prove to be safe where good foundations are easily available.

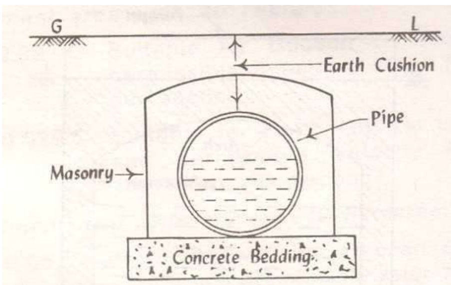
(ii)Height: The clear vent height i.e. the vertical distance between top and bottom of the culvert rarely exceeds 3 meters.

(iii) Sap:The box culverts areprovided 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:Dependinguponthesiteconditions, thetop level of box maybeat theroad level or it can even be at a depth below road level with filling of suitable material.

PipeCulvert:

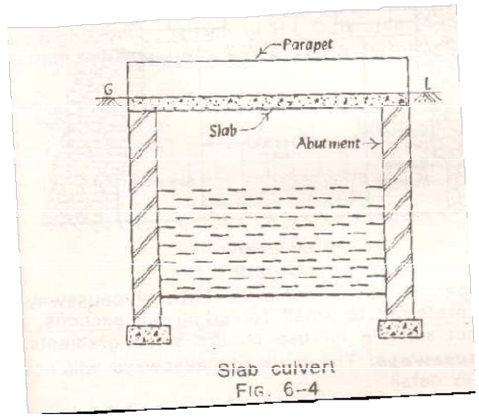
They are provided when discharge of stream is small or when sufficient headway is not available. Usually one or more pipes of diameter not less than 60cm are placed side by side. Their exact number and diameter depend upon the discharge and height of bank. For easy approach of water splayed type wing walls areprovided infig. 6.3 shows a Hume pipes culvert of single pipe. The pipes can bebuilt 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 thepipe should not beless than 1000.



Pipe culvert
FIG. 6–3

SlabCulvert:

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 amaximum span of 2.50 m or so.HowevertheR.C.Cculvertsofdeckslabtypecaneconomicallybeadopteduptospansofabout8 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.



Slab culvert
FIG. 6-4

Theconstructionof slabculvertsisrelativelysimpleastheframeworkcaneasilybearranged, reinforcementcanbesuitablyplacedandconcretingcanbedoneeasily.Thistypeofculvertcanbe usedfor highwayas wellas Railway Bridge. Dependinguponthespanof culvert andsiteconditions the abutment and wing walls of suitable dimensionsmay be provided. The parapet or hand rail of at least750 mm height should be provided on the slab to define the width of culvert.

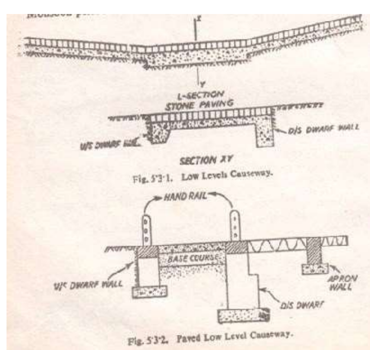
CAUSEWAYS:

Aroad causeway is a pucca dip whichallows floods to pass over it. It may or may not have openingor ventsfor lowwater toflow. Ifit hasventsfor lowwater toflowthenit is knownashighlevel causeway or submersible bridge ; otherwise a low level causeway.

TYPESOFCAUSEWAY:

A) **Lowlevelcauseway**:

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 earthworks in cutting for bridge approaches .Banks of such types of streams are cut down at an easy slope.For streams 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 150cmondownstreamsideisprovided.Fig.5.3.1belowshowsthedetailsofatypicalIrishbridge.

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

B) **HighlevelCauseway**:

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 morethan three days ata timenotfor morethansix times ina year.Asufficient numbers of openings areprovided to allow the normal flood discharge to pass through them with the required clearance. They areprovided with abutments and piers, floors and slabs or arches to formthe 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 orhardermasonry 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 causewaysused for an emergency military operations areformed eitherby using timber stringers and planking over cribs usedas piers or byconstructing a culvert usingpipes.

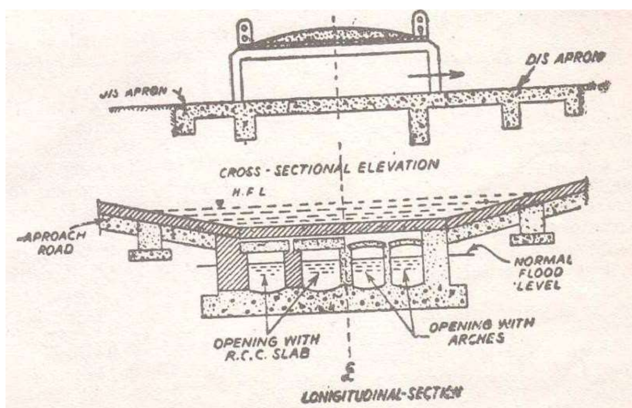


Fig. 5·3·3. High Level Causeway.

SECTION:C:DOCKS&HARBOURS

CHAPTER-13

INTRODUCTION

DefinitionofHarbours:

Harbour can be defined as a protected area of the sea in which vessels/ships could be launched, built or taken for repairs; or could take refuge in time of storm; or provide facilities for loading of cargo and passengers.

NecessityofHarbours:

Followingsarethenecessityofharbours.

(i) Toprovidesheltertotheshipsduringtheircruise.

(ii) Tolaunchaship.

(iii) Tofacilitatetheloadingandunloadingofcargoaswellaspassangersfromtheship.

(iv) Toprovideshelter totheshipsduringstorm.

(v) Toprovidespaceforrepairof ships.

Types ofHarbour:

Harbourscouldbeclassifiedas**natural**or**functional**.The**naturalclassification**canbeas below:

(1) **Natural harbour** is protected from storms and waves by the natural land contours, rocky outcrops, or islands. The entrance to such a harbour is so formed that it permits navigation but, ensures calmness in the harbour. Examples of natural harbours areKandla, Mumbai, New York, San Francisco, London, and Rio de Janeiro.

(2) **Semi- natural** harbour is protected on sides by headlands and requiresman-made protection only to the entrance. Vishakhapatnam is example of semi-natural harbours.

(3) **Artificial harbour or man-made harbour**, is protected fromstorms and waves by construction of breakwaters, or is created by dredging. Hamburg, Le Havre and Madras are some of the examples. Similarly, lagoon harbours of Paradip and Mangalore, created by protective breakwaters at the entrance are other examples.

The**functionalclassification**isasgivenbelow.

(1) **Commercial harbour** is in which facilities areprovided for loading and unloading of cargo. Docks and berths are provided for the purpose of handling cargo. Either as a part of the bigger harbour complex, or independently as a unit, single commodity harbour or terminal is provided, such as oil terminal, coal port, ore port, and so on. A fishery harbour is also provided for fishing crafts and trawlers. These are all specialised unit-purpose types of commercial harbours. Madras, Kandla, and Okha are examples of commercial harbours.

(2) **Military harbour**, or naval base, is one which is meant for the purpose of accommodating naval crafts and serving as a supply depot. Hampton Roads and Pearl Harbour are the examples. Mumbai harbour is essentiallya commercial complex withanoilterminal andgeneralcargoberths, but it has a naval base also; so is the case with Cochin.

(3) **Harbour of refuge** is that which is use as a haven for ships in a storm, or it may be a part of a commercial harbour.The requirements of sucha harbour area good anchorageandan easy andsafe access from the sea. Sand bay on the east coast of U.S.A is a well known harbourof refuge. Doverin England and outer harbours of Madras and Vishakhapatnam are examples of combined harbours of refuge and commercial harbours.

ComponentsofaHarbour:

Main function of a harbour is to provide safe and suitable accommodation for vesselsseeking refuge, supplies, refuelling, repairs or thetransfer ofcargoandpassengers. Ina harbour therearea variety of elements such as entrance, approach channel, breakwater, wharves jetties, locksand dry docks, dependingon the necessity of these. Such elements can be of different types.

(1) *Harbour Entrances:* The entrancetoa harbour is usually more exposedto waves as comparedtothe harbour itself. Due to this, depth and width required at the entrance are more than those required in thechannel. The width of entrance depends upon the density of the traffic and number of entrances, besides the navigational requirements and the degree of protection the channel has and what is desired within the harbour. The entranceshould be wide enough for navigation requirements and so as to avoid dangerous tidal currents. It should not, however, be too wide to increase wave height within harbour.

(2) *Approach channel:* Ideally, the depth of waternaturally available in the entire harbour area should be sufficient for navigation of design vessel at all the times. When such ideal condition do not prevail, a channel within sufficient depth and width must be dredged too provide for a passage of ships between the harbour entranceand the docks. The alignment and the dimensions of channel are determined after considering factors involved in channel design. The terminology approach channel is used for the dredged fairwaythrough which ships proceed fromthe open sea to the harbour basin. The portion of channel which lies beyond the harbour entrance in the open sea is called an outer channel. The portion lying between the harbour entrance and harbour basin is called an inner channel. The inner channel is protected from storms and waves by natural configurations or by breakwaters.

(3) *Turning Basin*:It is the area required formanoeuvring the ship when it goes to or leaves the berth, so that a ship can leave head-on. The size of the turning basin primarily depends on the design vessel. It should preferably be designed to have a ship turn under continuous headway without help of tug. This means that the turningbasin should be large enough to permit a free turning.

(4) *Sheltered Basin:* It is the area protected by shore and breakwaters. In this basin are located other elements of harbour including area for anchorage of vessels.

(5) Breakwaters: The main function of a breakwater, or a system of breakwaters, is to protect the enclosed area of water from storm waves. Thus, a breakwater helps in achieving calmness in the harbour and thereby contributes to the safety of the vessel within and its easy working. The monolithic structure usually provided at thetip of thebreakwater is called the pier-head.

(6) *Wharves and Quays:* These are usually constructed parallel to shore or breakwaterwithin the harbour and are meant to permit berthing of vessel alongside for cargo working. They have backfill of earth or other material and have wide platform at top.

(7) *Jetties and Piers:* These are solid or open type of structures with a wide platform on top to permit cargo working of vessels berthed alongside. They are built out from the shore to reduce silting and dredging, permitting free flow of tidal currents.

(8) *Lock* and *Locked Basin:* Locked basin is an enclosed basin wherein a number of vessels can be berthed and has an entrance which is controlled by lock gate(s). The water within locked basin can be independent of outside water level changes.

(9) *Dry Docks and Slipways*: These are essentially provided formaintenance, repairs and constructionof ships. A dock for the construction of ships is termed as a building dock. They can be kept dry for easy working. Dry dock has a gate in the entrance which is closed after taking the vessel in and the water is pumped out to render it dry.

(10) *Ancillaries:* These include moorings, anchors, buoys, lights, transit sheds and warehouses, fire protection towers, and other service units as required at different locations in the harbour and port complex.

Layoutofharbour

There are no specified rules governing the layout of a harbour. Varied layouts have worked successfully to the credit of their designers. Conception, creativity, and experience are very important in the laying out of a harbour. Seaham harbour on the rocky exposed north-east coast of U.K., lying in the lee of steep cliffs without anyrelief; Vishakhapatnamharbour, ontheeast coast ofIndia, with an ingenious system to protect the navigation channel from fouling by sand littoral drift; Madras with its strong breakwaters as a protection against stormy seas, although having passed through vicissitudes, are a few examples of bold conception and ingenuity in design.

There are two main considerations, in the harbour layout; of littoral drift and protection from the storm waves. Thethird point is thesize and shape of the harbour, and the layout of wharves and jetties, and spending beaches, soas to reduce the effect of sub-marine waves and eliminate ranging inthe harbour as far as possible.

Wherebreakwaters arelaid out toprotect harbours, one of thetwo measures is, sometimes, possible against littoral drift. In one case, particularly for shallow draught harbours, openings are kept from near the shore in thebreakwater to permit comparative easy flow of littoral drift across to the other side. This means that the mainbreakwater is connectedtotheshorebya sort ofbridge. Theother measureis toprovidea sand trap, in the lee of the breakwater, as in the case of Vishakhapatnam. Here, between the shore and the breakwater, an opening was left for the littoral sand to flow in the trap provided in the sheltered area before the navigation channel. sometimes, no specific remedy to handle littoral drift is adopted and the material being accumulated is simply mechanically removed,as in case of Madras .There are, on the other hand,ports of Veraval, porbandar and Okha, on the west coast of India, where the problem of littoral drift is of minor significance.

It must be realised that, littoral drift or otherwise, in any harbour where there is shipping, there is bound to be siltation. There is no escape from it. In some situations or in some deep water harbours the ill effect of siltation may not be felt immediately.

A moderatecurrent intheapproach channel is desirable. Considerablematerial is carried in suspensionby tidal riversor streams. The river Hoogly, at the time of flood, is stated to carry sediment by in the ratio of 1 to 575. Practically the same will be the case at rising spring tide at Bhavnagar. If, therefore, there is ebb current, the maintenance dredging of the fairway will be reduced.

Harbours which are inland, such as Calcutta, Kandla or Bhavnagar, are safe from the sea waves. There are some others, such as Okhaand Mumbai,which are afforded protection naturally by the existence,of rocksor islands on their weather side. Otherwise, artificial protection, in the form of breakwaters, is necessary to be constructed, to provide asheltered waterareaof adequate size forvessels to work.It is best to arrive at the breakwater alignment by model tests.

Very careful consideration is needed for selecting the harbour approach and its width. It is advisable to protect the entrance by a longer breakwater on the weather side. The width of the entrance may not be less than the length of the biggest vessel using theharbour. If there are likely to be wavesofhigh amplitude at the harbour entrance, the possibility of the entering vessel touching the bottom must be considered. It is knownthat the surface of thetrough of a wave is about one-thirdthe wave height belowthestill-water level. If, therefore, there is a 6 m wave, it would lower the depth some 2 m in the trough. It follows that a vessel drawing9 mruns the risk of striking the bottom in a depth of water of 11 m.

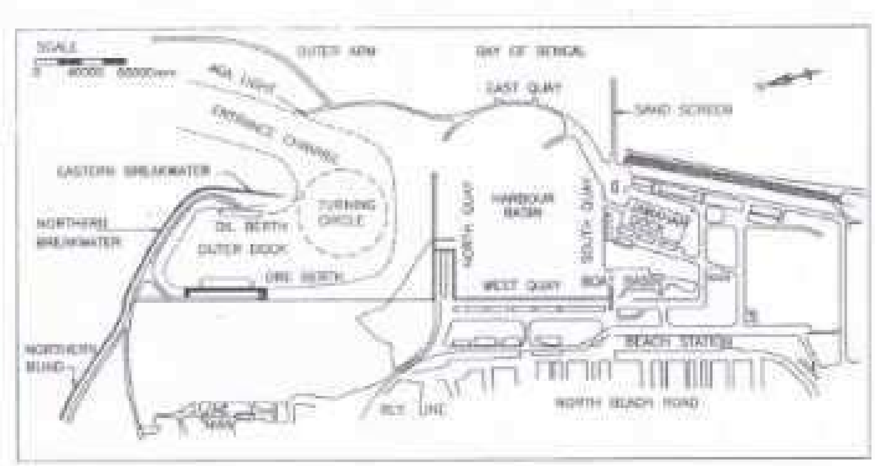


Fig.13.1LayoutofMadrasHarbourwithouterDock

Fig. 13-1 is of madras harbour with outer dock. This is an example of how adverse nature has beensought to betackled, and what experienceteaches in retrospect. It shows the original entrance from the east had to be closed and anew entrance from the north,with sheltering arm,had to be provided. It also shows the advance of the shore line to the south of the harbour.

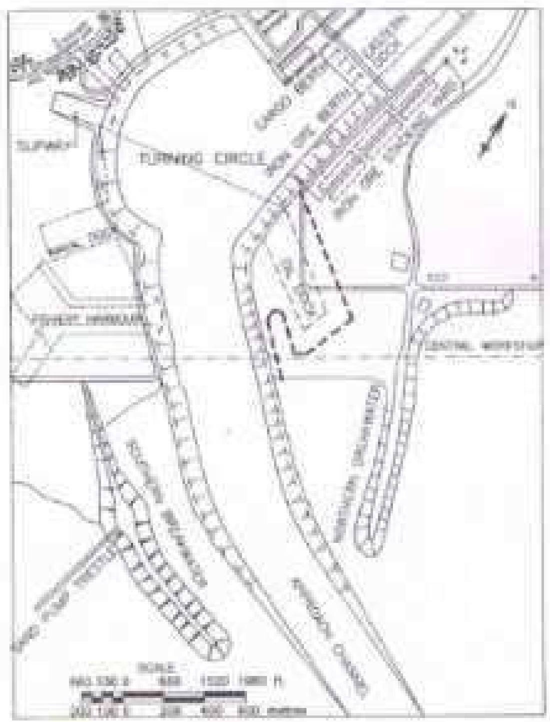


Fig.13.2LayoutofParadip Harbour

Fig. 13-2 is of Paradip harbour. This is also is aman-made harbour. It is a lagoon type harbour. It hascarved out from an inhospitable shore and two short lengths of breakwaters are provided to shelter the approach fromthe sea. Technically, a lagoon-type harbour is easier to create; breakwaters are lighter, quays can be constructed in dry, and lagoon can excavated in dry before opening it up to the sea. But it requires land area and its growth potential is somewhat restricted.

Criteriaforselectionofsiteforagoodharbour

In selection of a site for harbour, apart from engineering considerations, commercial, defence and strategic aspects should also be examined. In addition, dueconsideration of Coastal Regulation Zone (CRZ) as notified by the government of India under the Environment Protection Act (EPA) 1986 should be given. The guiding criteria in the selection of a site for good harbour are:

(1) Seaapproachandmarineconditions
(2) Sea-bed,sub-soilandfoundationconditions
(3) Transportandcommunicationlinks
(4) Seabornetrafficpotential
(5) Industrialinfrastructureandindustrialdevelopmentorpotentialinthehinterland
(6) Agriculturalbaseofthehinterlandandalsoitsminingresources
(7) Electricalenergyandfreshwatersupplies
(8) Availabilityofcheaplandandproximityofconstructionalmaterials

The site should have maximum natural protection from winds and waves. Sufficiently large pool of water,with adequatedepth,should be available to accommodate theexpected shipping needsaswellas to permit future expansions. The marine conditions should be favourable for structures as well as navigation. This would require low tidal rangeand small tidal currents, not too severe wind and waves, less littoral drift and no fog nuisance. The sea-bed should be such that it will hold ship anchors and that which would not involve excessive capital and maintenance dredging cost. Siltation should not be excessive nor scour pose a problem.

Other conditions ofsub-soil for foundation purposes should befavourable. Thesiteto beselectedshould preferably be on established trade route. The link with other parts of the country through rail, road, air and telephone should be relatively easy. The hinterland should be productive enough to support the trade. Also, the sea-traffic in the region should be showing signs of possible development. Availability of industrial infrastructure, electrical energy and fresh water supplies, cheap land,materials of construction and labourare also significant factors.

These are all desirable features, but not necessarily indispensable.As the world commerce and trade have expanded, more favourable harbour sites have been utilised and less advantageous ones are being developed. The modern engineering technology enables to overcome what formerly were considered to be formidable barriers: artificial protection(breakwater) could be afforded to hitherto unsafe places; even rocky sea-bed could be deepened; overland transport and communication in inaccessible places could be provided; difficult foundation condition could be mastered; and so on.

CHAPTER–14

Breakwaters

Definition: *A breakwater is, a structure meant to reflect and dissipate the force of wind-generated waves and thereby to prevent their incidence on a water area it is intended to protect*.

Functions of Breakwaters: There are sites on the coast, or inland places, which are naturally protected from the fury of the sea. But, if a harbour is to bebuilt on an open coast, as at Madras, it needs to beprotectedartificiallybybreakwaters.Themainfunctionofbreakwater is tobreakthe momentumof water by means of wave breakers. Sometimes the inner side of a breakwater is constructed as quay for cargo handling and is known as a mole.

Types of breakwaters: Breakwaters are two types: (i) vertical wall type (ii) rubble mound type. Where the depth of water is very great, or the bearing capacity of the sea bed needs to be improved, a compositetype with a vertical wall on a rubble mound baseis used. Thereare many examples of composite types andtheconsiderations willpredominatedependingupon whether therubblemound or thevertical wall part dominates.

(i) VerticalWallBreakwaters:

Itwasstated,in the XVIIIthInternationalNavigationcongressheldatLisbonin July1953that vertical wall breakwaters should be constructed, when:

a. The vertical wall breakwater should not be constructed in a depth of water less than twicethe greatest storm wave as may approach the site of the proposed structure.
b. Seabedisresistant toerosion.
c. Foundationsarenotsubjecttounevensettlement.

Even if the sea bed is not resistant to erosion, concrete block apron for protection can be provided. Also, load bearing characteristics of sea bed could be improved in various ways. If the top strata contain material likesilt, soft clay, or finesand, it is best to removethis strata, by trenching with a dredger. If the sea bed has inadequate bearing capacity, it could be improved by preparing a rubble base so as to distribute the load on a wider base. In moderate depths, a double row of sheet piles could be driven, to confine the soil, to improve its bearing capacity.

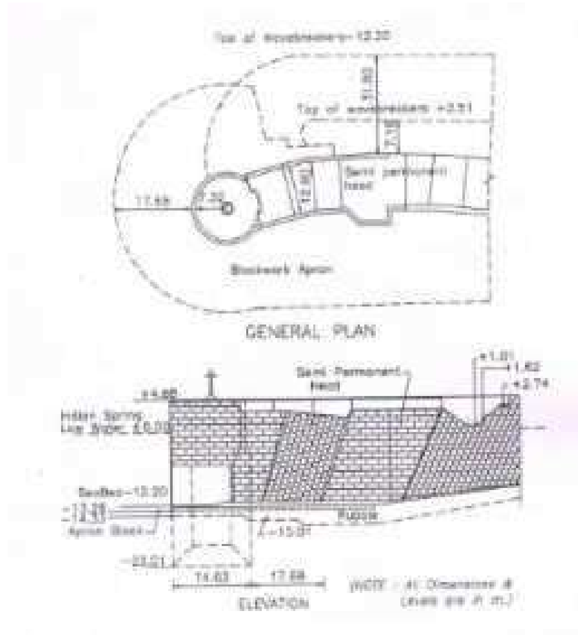


Fig.14.1VerticalBreakwater wallatMadras

(ii) RubbleMoundBreakwater:

A rubble mound breakwater is comparatively safe. The looseness of the elements permits them to settle without damage and the broad base helps in distributing the load on a wider area and thus reducing unit load on the base. But, also quite some time, usually two years, must be allowed to pass, after laying the rubble mound, before a concrete cap is cast.

Fig. 14.2.ARubblemoundbreakwater

Fig. 14. 2 is a typical rubble mound breakwater. In case of a rubble mound breakwater, the waves expend their energy on the structure. The disturbing influence of waves is most keenly felt between high water andlow water levels. It is in this regionthat the structure is most severely tested.

A rubble mound breakwater consists of a central portion, called the core, and protectivelayers, called the armour. The core can consist of small pieces of stones and quarry run. But the armour layer is very important. In between the core and the armour layer, graded stones should be provided, both for the better dissipation of energyandalsotoprotect the finer core materialfrombeing sucked out on the return wave.

(iii) FloatingBreakwater:

Floating breakwater, which are a type of floating structure and differessentially, in this respect, from gravity breakwaters which arepermanently fixed to sea bottom, should bein moreuse. Aschematic diagram, indicating the basic idea, is given as in Fig. 14.3.

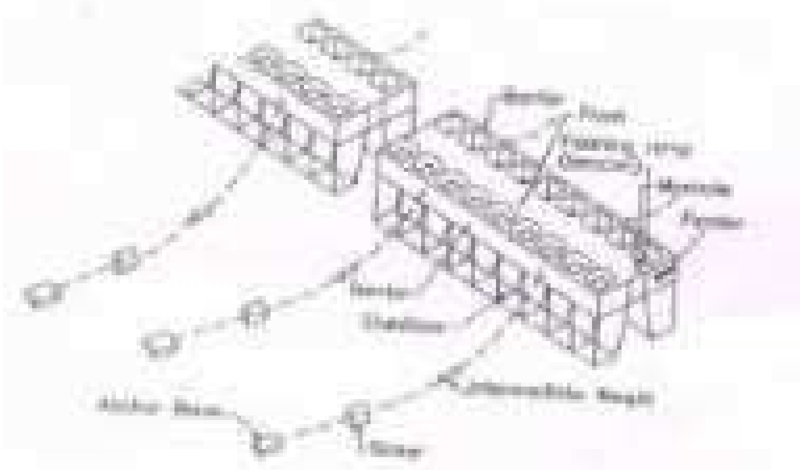


Fig.14.3.Schematicdiagramoffloatingbreakwater

CHAPTER-15

Docks

Definition:

Docksareenclosedareasforberthingships,tokeepthemafloatatauniformlevel,tofacilitate loading and unloading cargo. These docks are also known as wet ducks.

FunctionsofDocks

A. Wetdocks

(i) Docks are necessary because discharging of the cargo of ships requires a number of days during which period, if the ship is subjected to vertical movement by the tide, great inconvenience will be caused and special arrangements will have to be made for the lifting of thecargo. Thus, theuniformlevel of water as maintained in the docks byproviding locks and gates is very convenient for handling the cargo.

(ii) Harbours are prone to be affected by tides, which may cause changes in water level. If at low tides, the level of water is insufficient to ground the ships, in such cases ships could be berthed in ducks.

(iii) Duckspreventrubbingoftheships'sidesagainstquaywalls.

(iv) Effectofstormsintheouterseaandharbourdonotobstructthedockenclosure.

(v) Fig. 15.1(a) and (b) show the location of docks with lock, gates, breakwaters etc. on river and sea side's respectively.

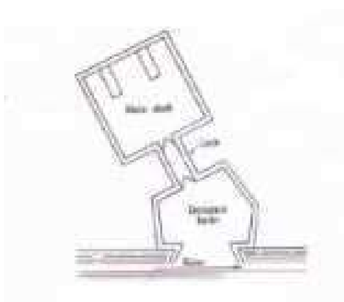


Fig. 15.1(a)Wetdocklocationonriverside

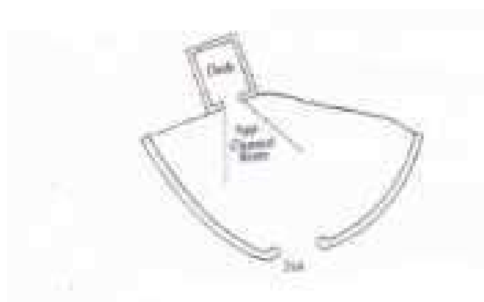


Fig.15.1(b)Wetdocklocationandbasinformation

B. RepairDocks

(i) Repair docks are necessary for the execution of repairs, cleaning and painting of ships' bottoms.

(ii) Hence,thesedocksanddockingarrangementsshouldbesuchastoexposetheship's exterior fully and keep it out of water during the progress of repairs or renovation.

(iii) Thesedocksareimportantincaseofmajorseaports.Thebottomsofshipsrequire scraping and cleaning at intervals so that he ships can maintain the speed.

Therearegenerallyfourclassesofsuchdocks,viz.:

- Gravingordrydock
- Floatingdock
- Marinerailway
- Liftdocks.

DryDock:

As the namesuggests, the arrangement in a dry dock is to take in a ship, closethe gate, and pump out the water. Sometimes, it is possible to take advantage of tidal variation so as to reduce the need of pumping. We shall consider these cases.

Fig.15.2ApictorialviewofAlfredoDaSilvadock

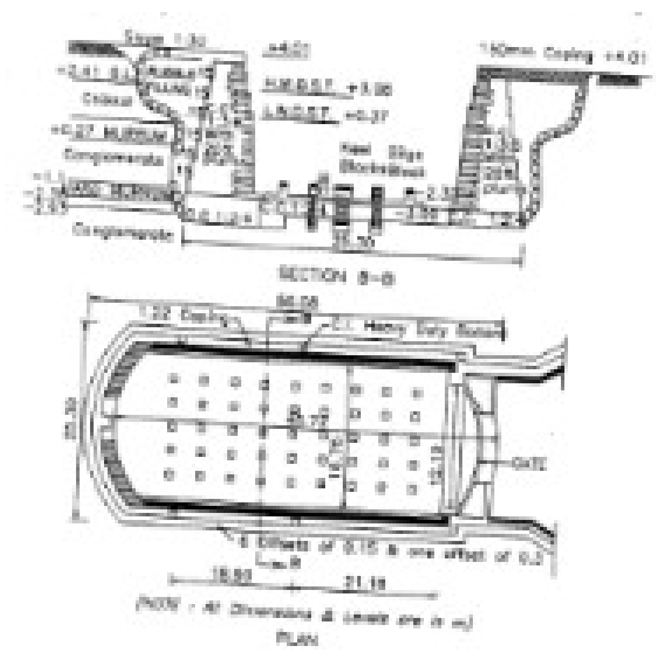


Fig.15.3.PorbandarDryDock

Fig.15.2 shows pictorial view of the dry dock at Alfredo Da Silva. Fig. 15.3 shows the plan and section of the Porbandar dry dock (1961). Both in the plan and section, a number of blocks -named keel blocks and bilge blocks - will be seen. These are meant for the vessel to sit on, and their top timbers are generally adapted to the shape of the vessel.

Thesequenceofoperationofthedrydockis asfollows:

(i) At low tide, after the ‘’blocks” are arranged to receive the vessel,water from sea side is allowed to flood the dock. This is doneby permitting the entry of water from outsidethrough the sluice valves.

(ii) The gate is then opened and the water level in the dock will rise with the rise in tide. It will be seen that, with proper sluices, the dock could have been flooded just before the high water also. When the water level has raised enoughsoas to clear theship, with adequate margin over thecill that is over the gate bottom, the ship to be dry-docked is manoeuvred in.

(iii) The ship is then properly aligned so that with the withdrawal of water either with the receding tides, or by pumping, the ship exactly sits on the pre-arranged blocks. Then, the gate is closed and water is pumped out.

CHAPTER 16

INTRODUCTIONTOAIRPORTENGINEERING

INTRODUCTION

Airport engineering deals withthecivil engineeringaspects ofair transportation that covers planning, layout and design of airport facilities. These include the runways and taxiways, terminal buildings and other ancillaries. It is comparatively a new subject. Air transportation is an important and in fact fastest mode of modern daytransportationsystem. Inadditiontothis, air transportation has another desirablefeature:a good record of safety. This sector has witnessed a significant growthin the secondhalf of the twentieth century.

TYPESOFAIRPORT

Airport is a facility, consisting of civil works, building, installations and equipment, intended to beused for the arrival, departure and movement of aircraft.

Airportsareoftwotypes,viz.,

1. Civilairports,servingthescheduledairlinesandallphases ofgeneralaviation
2. Militaryairports,servingdefenceneeds

The Civilian Airports are of three types, viz.,

1. Aircarrierairports,whichservescheduledaircarriers.Example:PalamAirport,Delhi
2. General aviation airport, which cater to business and executive flying, air taxi operations, Flying clubs, aerialshowing, medicalservices, firefighting, forest patrol etc. ExampleSafdar jungAirport, Delhi.
3. A mixture of the above two, catering to both scheduled air carriers and general aviation. Example: Ludhiana Airport, whichallows landing Vayudoot and at thesametimeallows use bya flyingclub.

Airportscanbeclassifiedasunderaccordingtothetypeofairtravelcateredto:

1. International Airport: An international airport is one which is designed as port of entry or departure for international flight and which has facilities for inspection by customs and immigration.
2. Nationalor DomesticAirport:Anairportcateringtodomesticservicesisknownasnationalairport.

Further, dependingonthetypeoflandingandtakeoffAirport canbedividedintofourtypes.Theyare:

1. STOL:Short Take-OffandLanding, havingrunways ofless than600 minlengthandcateringtothe special aircraft which requires only short take off and landing runway length.
2. VTOL:VerticalTake-OffandLandingAirport,designedforlift-offandlandingvertically.A Heliport is a VTOL facility.
3. CTOL:ConventionalTake-OffandLandingAirport.
4. RTOL:ReducedTake-OFFandLandingAirport,cateringtoaircraftaccommodatingupto150 passengers which can take off and land in runway 100 - 1200 mlong.

LOCATIONOFANAIRPORT

The location of an airport or selection of site for an airport is governed by many factors. Thefactors can be put under three important headings listed below:

1. **Economicfactors**

   a) The proposed airport must be able to generate and attract the estimated passenger and cargo traffic. Therefore, the population of the area is an important determining factor for the location of the airport. The pattern and growth of the cities under the service of the proposed airport andthe location of the industrial centres also govern the location of the airport.

   b) The existence airports in the proximity and the expected function the proposed airport play an important role in the selection of location of the airport.

2. **Meteorologicalfactors**

   a) The orientation of the runway is decided on the basis of wind velocity, frequency, turbulence, and gust as these are these parameters have significant influence on the airport operations and safety. Crosswinds are crucial factor as they may prevent safe usage of runway. Runway orientation is so selected as to minimise the effect of crosswind components.

   b) The altitude above the mean sea level influences runway length. Other parameters remaining the same, higher altitude requires longer runway length. Approximately, for every 300 m altitude, 7% increase in runway length is required.

   c) Average temperature of the hottest month also influences the runway length. The higher is the temperature, the longer is the runway.

   d) Visibility condition arising out of fogs, mist, rain, smoke, low clouds, dust storms etc., has a considerable effect on the aircraft landing and take-off. Sites unfavourable in this regard must be eliminated.

   e) Icingrecords

3. **PhysicalandEngineeringFactors**

   a) FairlyLevelGround:Theselectedlocationshould havea fairly levelarea with gentle contours. This will minimise the cost of earthwork for levelling and keep the runway length to a minimum. Every 1% increase in the average longitudinal slope of the country causes 10% increase in the runway length.

   b) EasyAcquisition ofLand:Theacquisition ofland needed for therunway, apronandterminalshould be easy and convenient. For a smallairport, 20 to 40 hectares of land mayadequate. However, large airports require as much as 6,000 to 15,000 hectares of land.

   c) Scope for Future Expansion: There should be ample land for future expansion if need be. The presence of built up area such as industrial establishments, hills, rivers, harbours, etc., act as an obstruction to future expansion.

   d) Elevated Site : An elevated site is ideal from many considerations as it is usually free from obstructions in the approach zone. It is easy to drain, often less prone to fog and adverse wind conditions.

e) Favourable Soil Condition: Available subgrade soil with higher supporting strength considerably reduces the airfield pavement thickness. Drainage potential of soil improves the performance of pavements. The soil should not be susceptible to frost action.

f) Proper Drainage condition: An ideal location is the one having naturaldrainage whereas a high water table significantly reduces the bearing strength of the site.

g) Free from Obstruction:As far as possible the approachesof the proposed location of the airport must befreefromall obstructions likehills, tall buildings, towers, chimneys, and transmissionlines.

h) Accessibility: The proposed airport should be easily accessible from the nearbyresidential, industrial and commercial areas, else the very advantage of airport is lost.

i) Availability of Construction Material: Construction materials, stone aggregates in particular should be available at economic leads.

j) Deterrence to Birds: The vicinity of the proposed location of the airport should be from featuressuch as slaughter houses and refuse dumps. These elements attract birds, which cause bird hits.

CHAPTER-17

AIRPORTLAYOUTCOMPONENTS

Themaincomponentsofanairportlayoutare:

1. Airfieldconsistingofthefollowing:
    a. Landingstrip,consistingofarunway, shouldersandstop-ways
    b. Taxiways
    c. Apron
2. Terminalarea,consistingofthefollowing:
    a. Gates
    b. Terminalbuilding
    c. Aircraftservicefacilities

3. Flightsupportarea,consistingofstructuresandfacilitiesfor airtrafficcontrol, navigationalaids, fuelling the aircrafts etc.

Runway:

Runwayis a strip providedspecifically for landingand takeoff. It is generallypaved. Shoulders areprovided on either side of a runway to serve as safety zone should an aircraft go off the runway sideways during landing or take-off.. They are generally unpaved. Stop-ways are provided at the ends of a runway, again for safety, to accommodate an aircraft that overshoots or undershoots a runway during landing and has an aborted take-off.

Taxiway:

Taxiwayisastripconnectingrunwaywithoneanotherandwiththeaircraft-parkingapron.

Apron:

Apron is the hard-standing area adjacent to terminal building where aircrafts are parked. It is meant for enplane or deplane of passengers. Cargo is also loaded or unloaded here. Fuelling and other servicing is also carried out here. The number of spaces proposed for aeroplanes depend upon the time of occupancy of an aircraft as well as the number of aircraft expected to use the apron at one time.

Thetime of occupancy is moreat terminalairports thanfor *en route*stops.Thetimerequiredfor loadingand unloading varies from 20 to 45 minutes, depending upon the aircraft size and handling equipments. The gradient of apron shouldbeadequate to drain the surface run-off but not in excess of 1.0 per cent.

Holdingapron:

At busy airports, aircrafts haveto lineup for take-off. Holding apron (also called run up area) is that portion provided near the ends of a runway for engine run-up and for hitching (hold-up) and unhitching vehicles towing the aircraft. They also serve an area for aircraft waiting for take-off. Holding-aprons are also called run-up pads or holding bays.

Gate:

Gateis theopening intheterminalbuildingthrough whichpassengers enter or leavethe terminalbuilding on arrival or departure from an aircraft parked in the apron. The transfer of passengers from the gate to the aircraft is accomplished by various systems.

Terminalbuilding:

Terminalbuildingisdesignedforhandlingofpassengers,cargoandairmanfromgroundtoair.

Hangars:

Hangersare buildingswhere servicing and repairof aircrafts are carried out. The sizeof hangars depends upon the dimensions of the aircraft they serve.

Flightsupportarea:

Flightsupportareaconsistsofanumbersofstructuresandfacilities ofairtrafficcontrol,navigationalaids and fuelling the aircraft.

RUNWAY

Runwayis a strip providedspecifically for landingand takeoff. It is generallypaved. Shoulders areprovided on either side of a runway to serve as safety zone should an aircraft go off the runway sideways during landing or take-off.. They are generally unpaved. Stop-ways are provided at the ends of a runway, again for safety, to accommodate an aircraft that overshoots or undershoots a runway during landing and has an aborted take-off.

ConfigurationsofRunways

Variousconfigurationsofrunwaycommonlyinuseareasfollows.

a) Singlerunway

b) Parallelrunways,whichaddtothecapacityofsinglerunways

c) Intersectingrunways:Tworunwaysintersectingeachotheratsomeconvenientangleformsthis runway. These runways are used where strong winds blow in more than one directions.

d) Open- Vrunways:Tworunways aligned indifferent directions forma Open -Vrunway. Eachrunis used when under favourable wind condition.

Theconfigurationsof theaboverunwaysareshownintheFigure 17.1

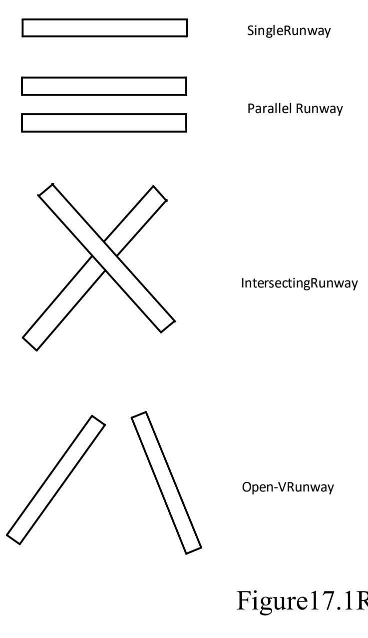


Figure17.1RunwayConfiguration

RunwayOrientation/OrientationofAirport

The orientation of runway is decided after careful analysis, direction and duration over the past years. The crosswind component may prevent the safe usage of a runway. The alignment should be so selected that the crosswind components are minimised. It should be ensured that the aircraft may land at least 95% of time with crosswind components not exceeding 25 kilometres per hours which is considered to be safe limit for light and medium weight aircraft. However, this limit is not relevant formodern heavy jets which in any case can land with wind speed higher than this. This requirement can be met by deciding the orientation on the basis of past data on the occurrence of winds of various velocities and direction. Orientation of runway should be parallel to the city boarder so that flights do not occur over the populated areas causing noise nuisance.

RunwayDimensions

Therunwaylengthisinfluencedbythefollowingfactors.

a) Typeofaircraft,itstake-offandlandingcharacteristics

b) Elevationoftheairport

c) Gradientofrunways

d) Pavementconditions

e) Temperatureofthearea

Basedontheaircraftcharacteristics,usuallythreecriticalconditionsareexamined:

1. The runway length should be sufficient for the aircraftto accelerate to the point of take-off and then in case of failure of criticalengines, the aircraft be braked and broughtto stop within the limits of the runway.

2. In case of failure of critical engine occurs at a point of take-off, the aircraft should be capable of take-offsontheoperatingengine(engines). Theaircraftpoweredbyreciprocatingengines mustbe able to clear the runway by15 mand those powered by turbine engines at an elevation of 11 m.

3. In landing, theaircraft should clear the end of therunwayby15 mandbe landedandbrought to halt within 60% of the available runway length. The later condition guarantees that even if the aircraft lands at a speed exceeding the design value, the landing is taken care of by the length so provided.

Withthecriteria asabove, andknowledgeoftake-offandlandingcharacteristics, it istheoreticallypossible to calculate the runway length. Another approach; however is to use experimental data on aircraft performance during landing and take-off as established by flight tests.

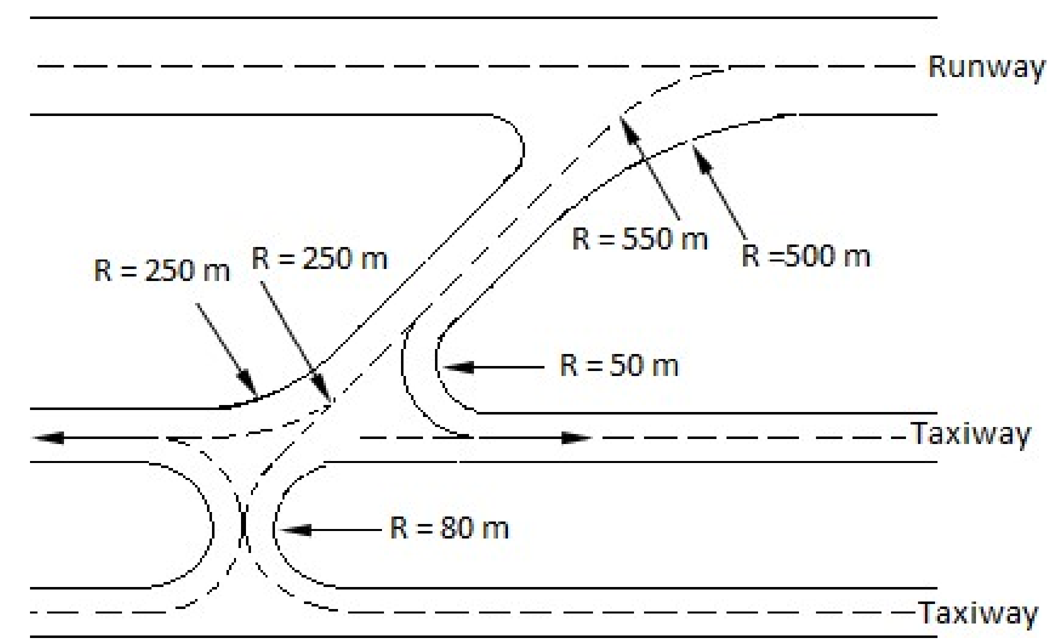


Figure17.2RunwayandTaxiwayExitDetails

Adimensionalsketchofarepresentativerunwayshowingtypicalfeatures is given inFigure. Alsoshownin the Figure 17.2 is the interconnectivity between runway and taxiway.

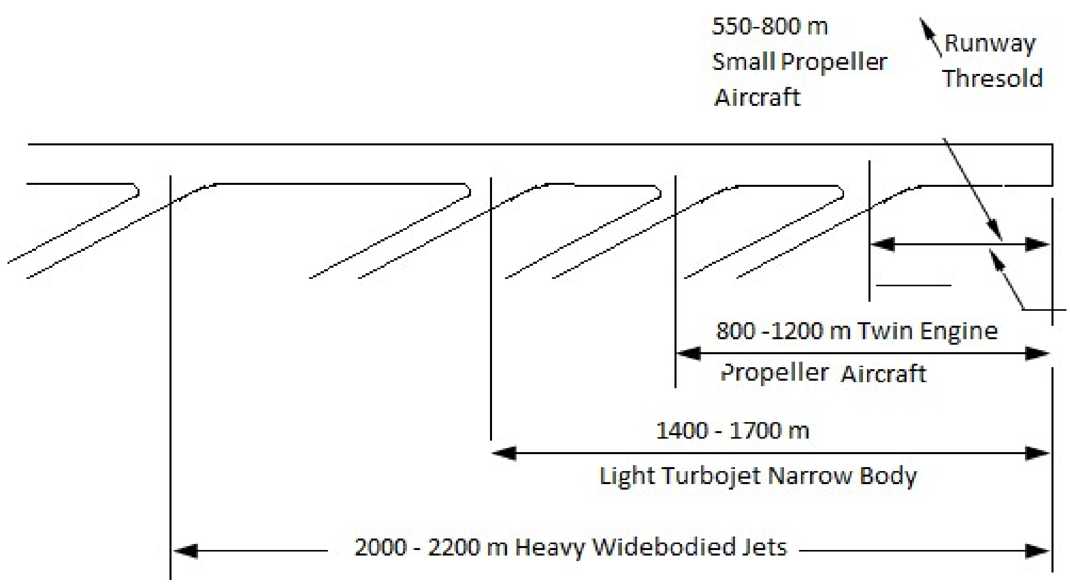


Figure17.3TaxiwayExitDetailsforVariousTypesof Aircraft

TAXIWAYS

Taxiway is a strip ofpavement connectingrunway with oneanother and withtheaircraft-parkingapron. The dimensional requirements of taxiways are lower than that for the runways as the aircrafts travel at a much-reduced speed than they don on runways.

The exit taxiway from a runway can be either right-angled or at some other angle convenient for manoeuvring of aircraft. An angle of about 30^0 permits aircraft to clear the runway quickly of the order of 100 km per hour. These exit taxiways can be suitably located at about 800 m, 1200 m, 1800 m, and 200 m fromtherunway threshold such that a variety of aircraft can beserved. Taxiway exit details are exhibited in Figure 17.2 and 17.3.

APRON

Apron is the hard-standing area adjacent to terminal building where aircrafts are parked. It is meant for enplane or deplane of passengers. Cargoisalsoloaded or unloaded here. Fuellingandother servicingisalso carried out here. The number of spaces proposed for aeroplanes depend upon the time of occupancy of an aircraft as well as the number of aircraft expected to use the apron at one time.

Thetime of occupancy is moreat terminalairports thanfor *en route*stops.Thetimerequiredfor loadingand unloading varies from 20 to 45 minutes, depending upon the aircraft size and handling equipments. The gradient of apron shouldbeadequate to drain the surface run-off but not in excess of 1.0 per cent.

AIRPORTLAYOUT

A typical Airport Layout with all therepresentative details discussed in the previous paragraphs is shown in the Figure 17.4.

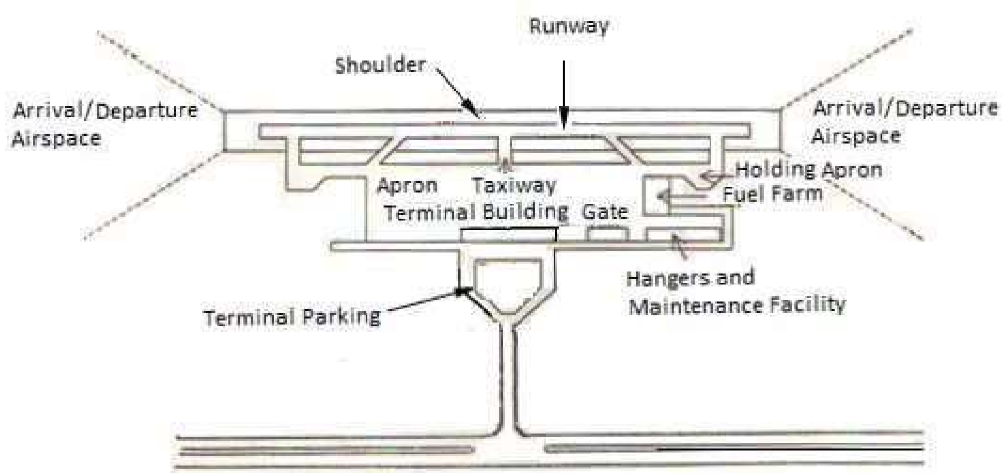


Figure17.4TypicalLayoutof Airport

CHAPTER18

TUNNELING

DEFINITION

Tunnel is anunderground engineeringstructureusedfor transportation of traffic, water, oiland minerals etc. Atunnel maybeconstructedbeneaththeground, under thebedofthewater bodies suchas river or ocean, or through the hills or mountains.

It is believed that the history of tunnel construction stretches back to very early age of human civilization. Thefirst tunnel is saidto havebeen built by Egyptians about 4000 years ago. Thesaid tunnel connected two buildings in Babylonia. The first under-water tunnel was constructed in Egypt under the Eupharates river connecting the Royal Palace to Temple of Love.

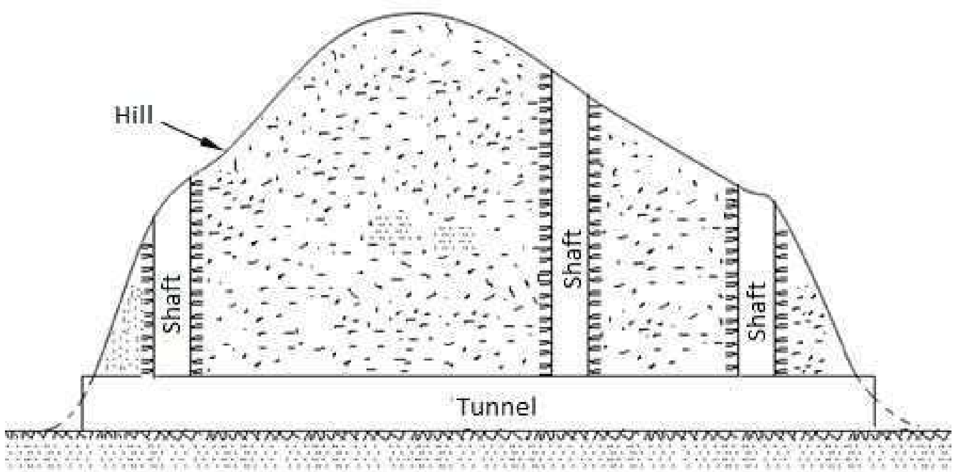


Figure18.1Longitudinalsectionoftunnel

CLASSIFICATIONOFTUNNELS

Tunnels areclassifiedonthebasisofthefollowingconsiderations.

I. Thepurposeofconstructionof tunnels
II. Thetypeofsoil materialthrough whichthetunnels pass
III. Thepositionoralignmentofthetunnels

I. Classificationbasedonthepurposeofconstruction

The two broad purposes of tunnel are the transportation of traffic and conveyance of utilities. On this basis the tunnels are classified as (i) Traffic tunnels and (ii) Conveyance tunnels. The two types of tunnels are further classified as follows.

i. Traffictunnels
Basedonthetypeoftraffic,traffictunnelsaredividedintothefollowingcategories.

a. Pedestriantunnel
b. Roador Highwaytunnel

c. Railwaytunnel
d. Navigationtunnel
e. Subwaytunnel

ii. Conveyancetunnel

Basedontheutilities ofconveyance,conveyancetunnelsaredividedintothefollowingcategories.

a. Watersupplytunnel
b. Sewertunnel
c. Transportingtunnelsinindustries
d. Hydro-electricpowertunnel

II. Classificationbasedonthetypeofsoilmaterialthroughwhichthetunnelspass

Basedonthequalityofsoil materialthroughwhichthetunnelspass,theyareclassifiedas follows.

a. Tunnelsinhard rock
b. Tunnelsinsoftrock
c. TunnelsunderneathwaterbodiesorUnderwatertunnels
d. Open-cuttunnels

III. Classificationbasedonthepositionoralignmentofthetunnel

Basedonthepositionorthealignment ofthetunnels,theyareclassifiedas

a. Slope tunnel: Slope tunnels are constructed in steep hills and mountains to ensure safe and economic operation of railway and highway routes through them.
b. Spiral tunnels: To avoid steep slopes in narrow valleys, tunnels with spiral shape are provided which require a series of loops in the interior of mountain.
c. Off-spur tunnels: These are the tunnels constructed to short-cut the local minor obstructions. They are very short in length.
d. Saddle or Basetunnels: To minimizethe length of the tunnel, it is taken through the valley as long as the naturalslopeofthevalley does not exceedtherulinggradient oftheroute. Suchtunnels arecalledSaddle or Base tunnels.

SHAPEANDSIZEOFTHETUNNELS

Size and shape are the two important geometrical features of a tunnel. They decide the sectionalprofile of thetunnel. Shape of thetunnel is guidedbythepressure exertedbytheunsupportedwallandthus thetypeof soil. Size of the tunnel depends on its functional purpose such as for carrying water, sewage, railway or highway. Single-way or two-way highway or railway also influences the size of the tunnel.

Shapeoftunnels

Thecommonlyadoptedshapesorsectionsofthetunnelsare

a. Circularsection
b. Segmentalsection
c. Horse-shoesection
d. Rectangularsection
e. Egg-shapedsection
f. Ellipticalsection

The advantages and disadvantages of all theabove sections are discussedalongside the specific uses of each of these.

CircularSection

These sections are commonly used for tube-railways, highway tunnels, sewer and hydro-electric tunnels. Figure 18.2 shows a typical circular cross section of a tunnel.

Advantagesofcircularsection:

i. Circularsectionistheoreticallythebestoneforresistinginternalaswellasexternalpressure.
ii. Itprovidesgreatestcross-sectionalareafortheleastperimeterandhenceitiseconomical.
iii. Itisbest suitedfornon-cohesivesoilandfortunnelsdrivenbyshield method
iv. Thissectionisbestsuitablefor sewersandwatercarryingpurposes

Disadvantages of circular section:

i. Circular section is unsuitable for railways and highways as greater quantity of filling is required in order to have a flat base.
ii. Theconstructionofcircularsectionisdifficultthanother sections
iii. Placementofconcreteliningisdifficult.

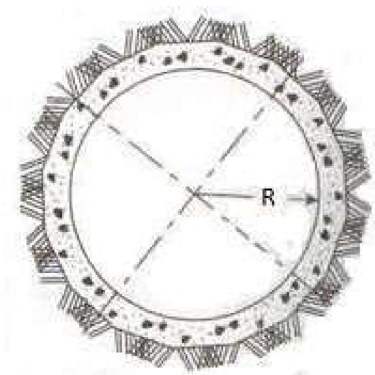


Figure18.2Circular Section

Segmental-roofSection

Segmental-roof section also known as D-section is a popular tunnel section. This section consists of segmental roof supported over vertical side walls. The segmental roof takes the external load and transfers the same to the vertical side walls. This section is suitable for hard rocks. In case of soft soils, the vertical side walls need to be constructed in R.C.C. This section is suitable for sub-ways or navigation tunnels. A typical segmental cross section is shown in Figure 18.3

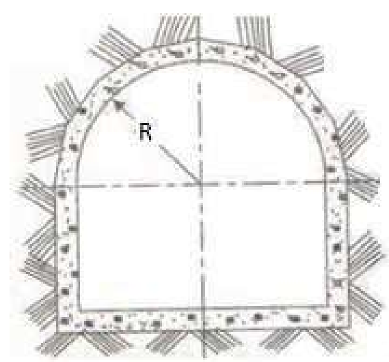


Figure18.3SegmentalSection

Horse-ShoeSection

Horse-shoe section is a popular tunnel section. It has a semi-circular roof along with arched sides and a curved invert. It offers a good resistance to external ground pressure. This imbibes advantages of both circular sectionas wellas thesegmentalsectionand offsets thelimitations ofthetwo. Acharacteristic horse- shoe section is shown in Figure 18.4.

Advantages:

i. The floor of the tunnel is flat enough to provide working space to the workers for storing materials during construction
ii. Theexternalpressureis resistedbythecurvedsidesandarchaction.
iii. Thesectionismostsuitableforsoftrocks
iv. This section is bestsuited forroad and railway traffic and is very commonly used forrailway and highway tunnels in all countries.
v. This section is also suitable for carrying water orsewage as the wetted perimeter in this section is also not much greater than that of a circular section.

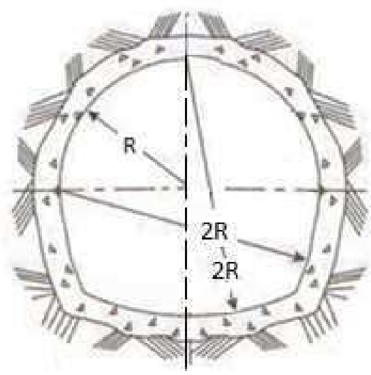


Figure18.4Horse-ShoeSection

RectangularSection

Rectangular sectionissuitableincaseof hardrocks. Constructionofthissectionisnot onlydifficult but also thecost of construction is comparatively high. Thesesections aresmaller in depth and arenormally adopted for pedestrian traffics. However, rectangular sections are almost not in use these days. A representative rectangular section of tunnel is shown in Figure 18.5

Figure18.5Rectangular Section

Egg-shapedSection

Egg-shaped section is commonly used for sewers because it gives self-cleansing velocity even in Dry Weather Flow (D.F.W). Like circular section this is also good in resisting external as well as internal pressure. Figure 18.6 shows a representative egg-shaped section.

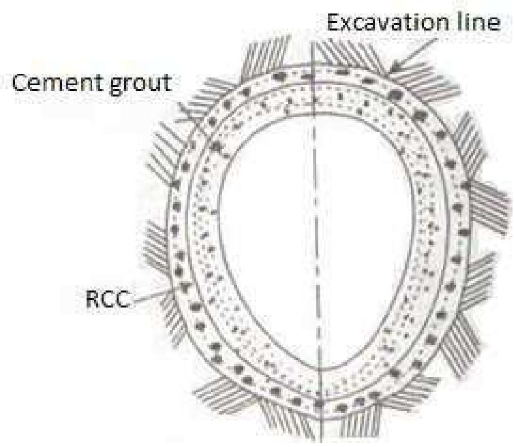


Figure18.6Egg-shapedSection

EllipticalSection

Elliptical section with its major axis vertical is suitable in soft soil. However these sections arenot commonly in use these days. Figure 18.6 shows a typical elliptical tunnel section.

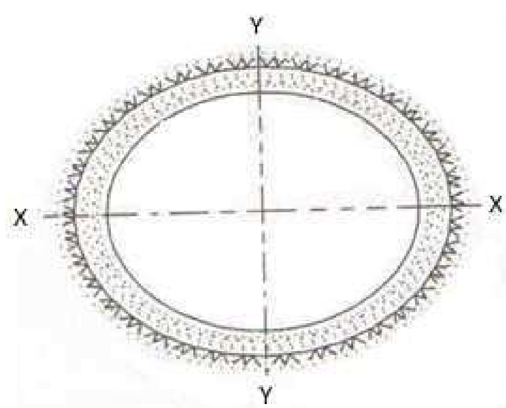


Figure18.7EllipticalSection

Sizeoftunnels

Size of tunnels depends mainly on the functional purpose for which it is used, such as for carrying single-way or two-way highwayor railway, for carrying sewage water or for hydro-electric purposes.

Followingaspectsaremainlyconsideredindeterminingthesizeofthetunnel.

a. Volumeoftraffictobehandled

Total Volume of the traffic to be handled will govern the size of the tunnel. Size and magnitude, speed and tonnage of traffic also influence the size of the tunnel.

b. Typeoftraffic
Thetype of traffic for which tunnels areto beconstructed such as pedestrian, road, railway, etc. has significant influence on the size of the tunnel.

c. Sizeoftheclearopeningrequired
In tunnels for single railway track, a clear spacing between the tunnel wall and the side of largest locomotiveshouldbe at least 75 cm. Anda clear spacingbetween the roof of thetunnelandtheroof of the locomotiveshould beat least 100 cm. In case of a doubletrack tunnel, theclearancebetween two tracks should be at least 60 cm.

d. Thicknessoftunnellining
The thickness of lining varies the material penetrated. An allowance for movement of side walls towards each other may amount to 5 to 7.5 cmshould beallowed without elsetheir stability may be put to danger.

e. Drainagefacilitiesrequired
The drainage condition and type of drainage system adopted willalso influence the size of the tunnel.

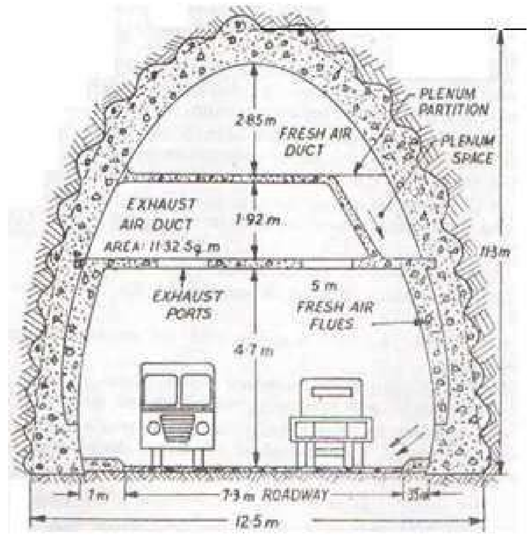
f. Ventilationmethodtobeadopted

TUNNELCROSSSECTIONSFORRAILWAYSANDHIGHWAYS

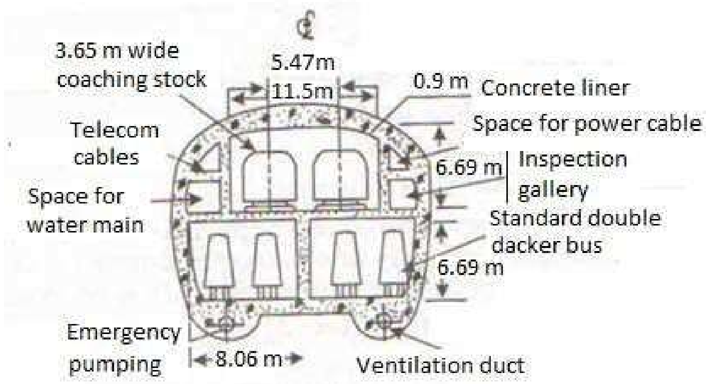
The Indian Railway hasentered the high speed age.Keepingthisinviewaproposalofhighspeed railway linebetweenMumbai and Poona has been prepared. In this proposal the maximum speed of the train has been assumed as 250 Km/hr and the time taken fromMumbai to Poona will be 45 minutes only.

In the proposal 1.84 km long tunnel from Victoria Terminus up to Appalo Bunder will have two railway tracks. The cross-sect ion of the proposed tunnel shall be as shown in Figure. In the proposal the under-sea tunnel of 9.84 km from Apallo Bunder shall be multi-purpose tunnel, carrying two railway tracks, two lane roadtraffic, spacefor carryingwater pipelines, power andcommunicationcables, andaninspectiongallery. The cross-section of the proposed multi-purpose tunnel shall be as shown in Figure.

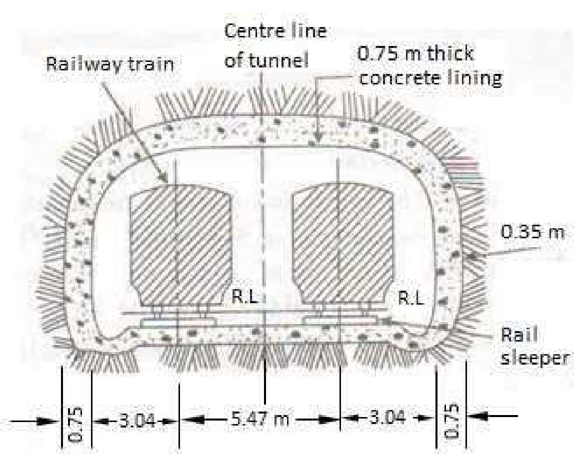
The vertical and lateral pressure acting on the tunnel mainly depends on the quality and inherent strength of therock. Incaseof greater magnitudeoflateralthrust,circular sectionaltunnelsshallbemoreeconomical. If the rocks are solid, arched roof section can be used without any lining. To reduce the tensile stresses in the crown, ellipticalsectionwith1.6times itswidthshouldbeprovidedinsteadofcircular sections. Shapeofthe tunnel should be properly selected and designed.



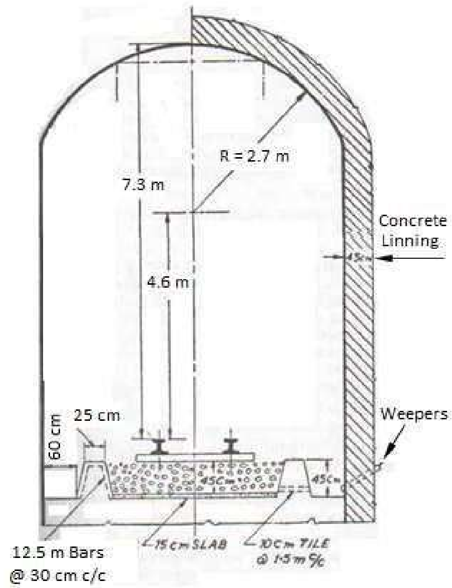
FigureTypicalTwo-laneHighwayTunnel



FigureTypicalCross-sectionofMultipurposeTunnel



FigureTypicalCross SectionofTwo-LaneRailwayTunnel



FigureTypicalCrossSectionofSingleTrackRailwayTunnel

SHAFTS

Shafts are vertical wells or communication passages sunk along the line of a tunnel at one or more points between the starting and terminating points of the proposed tunnel. When the length of the tunnel is comparatively small, the starting and terminating points of the proposed tunnel or underground passage can be easily located. However, in case of long and serpentine tunnels or underground passage, it becomes very difficult to markthestarting, intermediate andterminatingpoints. Insuchcases thepoints onthe ground can be transferred to the underground location by means of shafts excavated from the surface right up to the corresponding position inside the tunnel. In case of smaller tunnels, the starting and ending points can be readily located and the excavation work can be started from one end on the basis of the proposed alignment. Onthe other hand, incaseof comparativelylarger tunnels havingcomplicatedfeatures, the excavation work is carried out in different divisions by sinking a number of shafts, at suitable places, from the surface. Each additional shaft provides two additional working faces as shown in the Figure 1. This division of work provides a number of working faces and thus the progress of work is expedited.

Advantages/Purposeofshafts:

Theadvantagesofshaftsareenumeratedasfollows.

1. Shaftsfacilitatecorrectalignmentandhelptotransfer thecentrelineintothetunnel.
2. Shaftsprovideadditionalworkingfacestocarryoutexcavationwork.
3. Inthecaseoflongtunnels, theyareusedforthepurposeofventilation.
4. Theycanbeusedaspumpingshafts incasethereisheavyinflux ofwaterinthetunnel.
5. Theyserveas outletsfor excavated materialsandprovideaccess intothetunnelfor thebuilding materials.

Sizeandlocationofshafts:

Thesize ofthe shaftdependsuponthepurposeoftheproposedshaft

CONSTRUCTIONOFSHAFTS

The method to be adopted for the construction of the shaft mainly depends on the nature of the ground. In commonpracticetheshafts areusuallysunk downfromthetop towardthetunnel. Inspecial cases, however, the shafts can be constructed from the tunnel in upward direction. The construction of theshaft in the upward direction is cheaper as the muck is dropping down and can bedirectly trapped into the muck carrying cars.

CONSTRUCTIONOFSHAFTINROCK

Followingarethemainoperationsfortheconstructionoftheshaftsintherocks.

1. Drillingandblasting
2. Mucking
3. Timbering
4. Pumping

DrillingandBlasting

Holes are drilled in the rocks by various drilling machines and equipments, such as jackhammers and pneumatic compressed air operated equipments. The large size shafts are excavated by 'stepped down' technique to permit mucking and drilling operation goes together.

Mucking

Theprocess ofremoval of excavated materialand dumping ofthesameoutsideat suitableplaceis knownas mucking. The mucking operation can be carried out either manually or mechanically by cranes. Mucking operation by craneis shown in the Figure. In crane operated mucking operation, when onebucket is loaded, the other is hoisted to the surface.

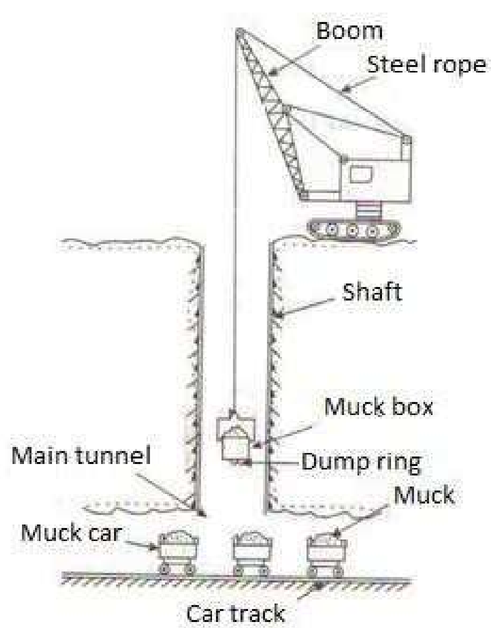


Figure18.8MuckingOperationbyCar

Timbering

The process of providing temporary supports to the cut soil sides against falling till lining is done or finally filled up after the completion of the work. Figure 4, 5 show two differentmethodsof timbering in small shaft and deep shaft respectively. In self-supporting ground excavation work up to 20 m can be carried out without timbering. In non-self-supporting ground timbering may be necessary immediately after the excavation.

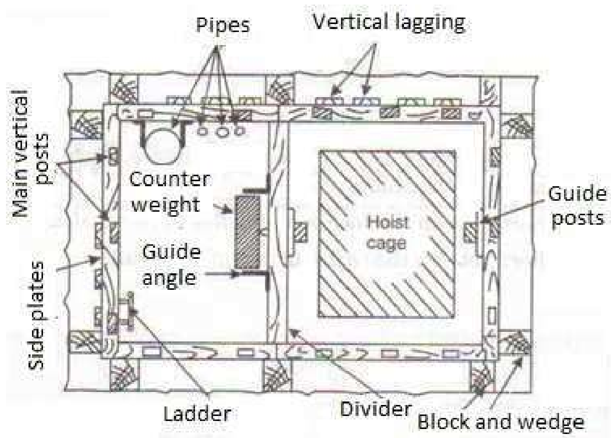


Figure18.9TimberingforSmallShafts

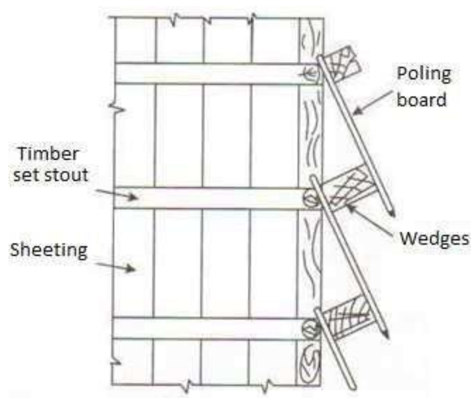


Figure18.10TimberingforDeepShafts inSoftSoil

Pumping

Water present in the shaft due to the seepage underground or water used due during construction operation need to be removed. The bucket used for removing the muck can be used for removal of water. However, pump sets are generally used to remove the water from the shaft. In very deep shafts pumping is costly and so grouting is doneinseams toseal offtheflow of water tosome extent. Water is collected inthesump near the wet seam and is pumped out to the surface.

CONSTRUCTIONOFSHAFTINSOFTSOIL

Sinking of shaft in soft soil is simpler and can be carried out in several ways. Mining or excavation is done by simple tools and mucking is done by hoisting buckets. Method of shaft sinking depends on the nature of ground, depth of shaft, and the equipment available. Three commonly used methods are explained below.

1. The method of timbering for small shafts in soft ground is shown in Figurexxx24. A hole about 15 cm deep is dug. In this hole, two sets of timber are assembled, plumbed and braced with diagonals. Excavation is then started underthe bottom of the sheeting,and sheeting isdriven down keeping the sides vertical. Another set of sheeting is started within thetimbers of first set as shownin the Figurexxx. A slight margin is given to the second sheeting which is closed by nailing short boards. This system of shafts has been successfully used for depth up to 1.7 m. Pneumatic hammer may be used for driving the sheeting.

   For deep shafts, fore poles of 1.5 to1.7 mlong areusedtosupport the ground as shown in Figure yyy25. In firm soils like clay, excavation may be done upto 3metres and more. Planks of wood are set against thetrimmed walls and are held until other timbers are placed. Shafts may then deepen in stages of 1.5 m or so and walls suitably lagged and wedged so as to ensure tightness of every plank against the wall. Pressed steel liner plates are often used for lining the shafts.

2. In this method of shaft sinking, a pit is excavated and a number of rings of segmental cast iron, steel or reinforced concrete lining are built into the pit. Depending upon the stability of the ground, the pitis taken to a depth of two to three rings of the lining or more. Shaft sinking is continued by excavating the centre of the hole, under-cutting the line already erected and erecting further segments of the lining, thus building up additional rings. the space behind the lining is grouted.

3. In this method of shaft sinking, a ring of steel sheet piling is driven through the first 7 m or so of the ground. The excavated materials are removed from inside the pit. The first section of the shaft is then built inside this.

CONSTRUCTIONOFSHAFTBYCAISSON

In softwater bearing stratum, caissons are used for economical construction of shafts. Compressed air is used forexclusion of water from the pit. The caissoning generally commences from the ground. The first ring has a V-shaped bottom forming a cutting edge. The weight of the caisson is generally very small and hence it is ballasted for sinking. On the top of the first caisson, normal rings without any cutting edge are erected till the required depth of the shaft is reached. The rings are normally built up from cast iron or reinforced concrete segments. Caissons are of two types.

A. Dropcaissons

Drop caissons are used in water bearing sand or gravel stratum. Drop caissons are heavily reinforced. Dredging is commenced within the well and as the lower edge is undercut, the caisson will sink due to its own weight. To increase the weight, it may be necessary sometimes to put additional weights on the top. Pushing of caisson is accomplished by undercutting one edge of the caisson more than the other. Water jets may be used for loosening the ground if necessary. Figure zzz shows a typical R.C.C caisson.

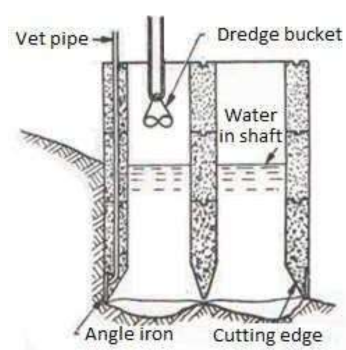


Figure18.11TypicalRCCCaisson

B. Pneumaticcaissons

Indifficult groundwithhighwater bearingstratum, compressedair isusedfor safeexcavation. Insuchcases the shaft lining mustbe stronger. Air locks of vertical type are located above the expected water leveland areconnected to working chambers. Muck is raised by small air hoists or pumped through a blowpipe. The sinking operation is controlled through the working chamber. A typical pneumatic caisson is shown inFigure hhh.

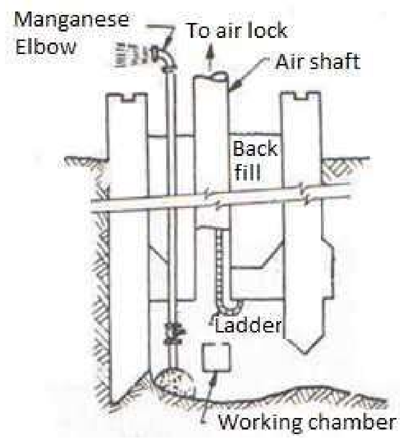


Figure18.12TypicalPneumaticCaisson