Railway and Bridge Engineering

(Code : 22403)

SECOND YEAR DIPLOMA

Maharashtra State Board of Technical Education (MSBTE)

Semester IV - Civil Engineering Groups (CE/CR/CS)

Strictly as per new revised syllabus of 'I' Scheme w.e.f. academic year 2018-2019

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Syllabus

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
Unit – I **Basics of Railway Engineering** **Refer chapter 1** 12 M	1a Describe with sketches the given components of railway track in the diagram. 1b Suggest the remedy for the specified fault railway track with justification. 1c Suggest the type of rail track joint for the given situation with justification. 1d Suggest the type of fixture and fastening for the given rail section with justification.	1.1 Role of transportation in the development of nation; Modes of transportation system - land way, waterway, airway, roadway and railway; Classification of Indian Railways, zones of Indian Railway. 1.2 Permanent way: Ideal requirement, Components; Rail Gauge, types, factors affecting selection of a gauge. 1.3 Rail material, Rail Joints - requirements, types. 1.4 Creep of rail: causes and prevention of creep. 1.5 Sleepers - functions and Requirement, types - concrete sleepers and their density. 1.6 Ballast - function and types, suitability. 1.7 Rail fixtures and fastenings - fish plate, spikes, bolts, keys, bearing plates, chairs-types of anchors and anti creepers.
Unit - II **Track Geometrics, Construction and Maintenance** **Refer chapter 2** 16 M	2a Explain the factors affecting the alignment of railway for the given terrain. 2b Explain with sketches the turn outs, points and crossings with for the given situation. 2c Describe with sketches the track geometrics elements for the given terrain. 2d Describe the process of rail track maintenance for the given season 2e Describe the functions of the given tools and equipment required for maintaining the track in the specified terrain.	2.1 Alignment- Factors governing rail alignment. 2.2 Track Cross sections - standard cross section of single and double line in cutting and embankment. Important terms-permanent land, formation width, side drains. 2.3 Railway Track Geometrics : Gradient, curves- types and factors affecting, grade compensation, super elevation, limits of Super elevation on curves, cant deficiency negative cant, grade compensation on curves, Coning of wheel, tilting of rail. 2.4 Branching of Tracks-Points and crossings-Turn out-left and right hand turnout, components and their functions, important technical terms, components, types and inspection, track junctions: crossovers, scissor cross over, diamond crossing, track triangle. 2.5 Station and Yards-Purpose, requirement of railway station, important technical terms, types of railway station, factors affecting site selection for railway station. 2.6 Station yard-Classification-Passenger, goods, locomotive and marshalling yards-function & drawbacks of marshalling yards. 2.7 Steps involved in construction of rail track 2.8 Track Maintenance- Necessity, Classification, Tools required for track maintenance with their function, Organization of track maintenance, duties of permanent way inspector, gang mate and key man.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
Unit - III **Overview of Bridge Engineering** **Refer chapter 3** 16 M	3a Propose the relevant type of bridge for the given situation on the basis of relevant criteria with justification. 3b Identify the components of a given type of bridge with their functions. 3c Explain with sketches the bridge section for the given site conditions. 3d Propose the relevant type of foundation for the given type of bridge for the given situation with justification.	3.1 Classification of bridges according to span, purpose, material, life, alignment, H.F.L., Loading, level of bridge floor. 3.2 Site selection and investigation, affecting selection of site for bridge alignment-Factors controlling. 3.3 Important technical terms- waterway, economic span, afflux, scouring, freeboard, cut water, ease water. 3.4 Component parts of bridge: pier, abutment, wing wall, foundation, bearing 3.5 Piers-function, requirements, types. 3.6 Abutment – function, types. 3.7 Wing walls - functions and types. 3.8 Foundation - function. types of bridge foundations 3.9 Bearing - functions, types of bearing
Unit - IV **Construction and Maintenance of bridge** **Refer chapter 4** 10	4a Compare the structure of the permanent and temporary bridge with reference to the given criteria. 4b Suggest the type of bridge for the given site condition with justification. 4c Describe the construction procedure for given type of bridge. 4d Describe the maintenance and repair procedure for the given type of bridge.	4.1 Temporary Bridge- Necessity, Causeway- Fhish, low level and high level causeway 4.2 Permanent Bridges- Types of RCC Bridges- Slab, Girder, RCC girder. 4.3 Pre-stressed bridge-Advantage and disadvantages. 4.4 Culvert-Types-Arch, Open or slab, Pipe and box. 4.5 Choice of type of bridge, Types of bridge foundations. 4.6 Steps involved in bridges construction 4.7 Inspection of bridges-General points to be observed, Pre and post monsoon inspection. 4.8 Maintenance of bridges- types - routine and special Maintenance.
Unit - V **Construction and Maintenance of Tunnels** **Refer chapter 5** 16	5a Describe the criteria for selection of the tunnel for given situation with justification. 5b Choose the relevant method of constructing the tunnel in the given situation with justification.	5.1 Tunnel - Classification of tunnels according to purpose, conveyance, material, position or alignment, shape and size of tunnels. 5.2 Tunnels: Cross sections for highways and railways, Tunnel investigations and surveying, Tunnel Shaft - its purpose and construction. 5.3 Methods of tunnel ling in Soft rock-needle beam method, fore-poling method. Line plate method, shield method. 5.4 Methods of tunnelling in Hard rock-Full-face heading method, Heading and bench method, drift method.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
	5c Explain the process of lining of the tunnel in the given situation justification. 5d Describe the type of ventilation provided for the given type of tunnel. 5e Describe the procedure of maintenance and repair for the given type of tunnel.	5.5 Drilling equipment-drills and drills carrying equipments, Types of explosives used in tunnelling. 5.6 Tunnel lining -purpose, factors affecting type of lining, and methods 5.7 Tunnel ventilation and drainage- Purpose and method. 5.8 Tunnel Maintenance - Purpose and measure to be taken for proper maintenance.

CHAPTER 1

Basics of Railway Engineering

12 mark

Syllabus

- Role of transportation in the development of nation; Modes of transportation system – land way, waterway, airway. Merits and demerits of roadway and railway; Classification of Indian Railways, zones of Indian Railway
- Permanent way: Ideal requirement, Components; Rail Gauge, types, factors affecting selection of a gauge.
- Rail material, Rail Joints - requirements, types.
- Creep of rail: causes and prevention of creep.
- Sleepers - functions and Requirement, types - concrete sleepers and their density
- Ballast - function and types, suitability.
- Rail fixtures and fastenings – fish plate, spikes, bolts, keys, bearing plates, chairs-types of anchors and anti creepers.

1.1 Definition : Transportation engineering

→ (MSBTE - W-17)

Q. Define Transportation system. W-17

☞ ***Definition of Transportation engineering:*** *Transportation engineering is a branch or basic area of Civil engineering which deals with design, development, construction and maintenance of roadways, railways, airports, harbours, docks, tunnels and bridges.*

In short, it is the technology by which a proper communication facility is planned, designed and constructed for easy transport of human being and goods from one place to another.

Syllabus Topic : Role of transportation in the development of nation

1.1.1 Role of Transportation in the Development of Nation

→ (MSBTE - W-14, S-15, S-17, W-17, S-18)

Q. State the role of transportation in development of Nation. W-14, S-15, S-17, W-17, S-18

Role of transportation is an essential accessory of development of nation for the following purposes :

(i) Easy and quick transportation of men, machines, animals, materials and goods can be made.

(ii) Areas which are connected by proper means of transport can be developed fast.

(iii) Remote areas and rural areas become accessible and communicable if connected by proper means of transport.

(iv) During the days of emergency e.g. wars, efficient and developed transportation system plays a vital role for quick and easy transportation of soldiers, food and ammunition.

(v) Transportation through airways also plays an important role of communication to the people staying in remote areas and also helps the people in difficulties during floods. E.g. Helicopters can help the people at the time of floods.

The choice of transportation depend upon the following factors ;

1. The length of haul
2. Weight and size of consignment
3. Traffic density
4. Nature of route
5. Quality of service

Syllabus Topic : Modes of transportation system

1.2 Modes of Transportation System

→ (MSBTE - S-17, S-18)

Q. Enlist various modes of transportation system. S-17, S-18

Modes of transportation system are roads, railways, airways and waterways.

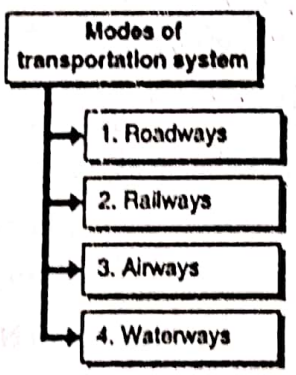


Fig. C1.1 : Modes of Transportation System

Syllabus Topic : Land Way, Merits and Demerits of Roadway

1.2.1 Necessity of Roadways

→ (MSBTE - S-18)

Q. Enlist two characteristics of road transport. S-18

The roads serve the following purposes :

(i) Quick and easy transportation of men, material, food grains, vegetables and other goods from one place to another.

(ii) Roads develope the area quickly.

(iii) Roadways are the only means of transport in isolated locations of country where other means of transport cannot be used.

(iv) It provides door to door service.

(v) It is ideal for non bulk cargo movement.

☞ **Merits of road ways**

(i) It is economical structure.

(ii) It is very convenient for passenger and small goods transport.

(iii) Destination and starting points are not necessarily defined.

(iv) Small vehicles can be driven on roads for personalized transport.

☞ **Demerits of road ways**

(i) Tractive resistance of wheels of vehicles to the road is more, hence there is a early wear to the road pavement.

(ii) Overall maintenance of road is more.

(iii) There is a speed limit or speed is restricted.

(iv) It is suitable for small distance only.

(v) It is not suitable for bulk cargo movement.

Syllabus Topic : Merits and Demerits of Railway

1.2.2 Railways

→ (MSBTE - S- 17)

Q. Enlist two advantages of railways. S-17

- Railways or railway transport is now a days, the life line of the nation and more essential for mass transportation of men and materials for long distances.
- The part on which the railway actually moves consists of steel rails, wooden or pre-cast concrete sleepers, ballast (crushed stones and metals) and sub-grade (i.e. compacted soil underneath the ballast).
- Railway is commonly termed as permanent way for transportation means.

☛ **Merits of railways**

(i) It provides economic means of transportation for common people.

(ii) Traveling in railway is safe and comfortable.

(iii) Heavy goods and raw materials can be transported for long distance only by railway.

(iv) It gives the maximum revenue to the country.

(v) It requires less power to drive.

(vi) It gives the employment to the maximum peoples.

(vii) Tractive resistance of railway is less.

☛ **Demerits of railways**

(i) Initial cost of construction is more.

(ii) It requires maintenance frequently.

(iii) The goods have to loaded and unloaded at station yard only and then it is transported by road to require place, hence uneconomical.

(iv) Door to door delivery is not possible.

(v) Special turning and heavy Lifting devices are required.

(vi) Sharp curve and steep gradients cannot be provided.

Syllabus Topic : Airway

1.2.3 Airways

This is the quickest mode of transportation. The mode of journey is continuous and without any disturbances.

☛ **Merits of airways**

(i) It requires less time to reach to the required destination as compared to other mode of transport.

(ii) Long distance can be covered within hours.

(iii) It plays very important role at the time of war.

(iv) It provides medical and emergency services within very short time.

(v) It can reach to the places where other mode of transport can not reach.

☛ **Demerits of airways**

(i) It is costly affair transport system.

(ii) It can not be afforded by common people.

(iii) It depends on favourable condition of climate and can not be driven in storms and fogs and heavy rain fall.

(iv) Initial investment is more.

Syllabus Topic : Waterway

1.2.4 Water Ways

Water transportation is the cheapest mode of transportation and it exists from olden days and it exists from olden days and it is suitable for transporting heavy material.

☞ Merits of Waterways

(i) Waterways is the cheapest mode of transport.

(ii) It is suitable for transporting very heavy materials like oil, steel, food grains, timber etc.

(iii) It can carry very heavy goods over a long distance.

(iv) It is environment friendly mode of transport.

☞ Demerits of Waterways

(i) It require more time to reach to the destination because ship moves with slow speed.

(ii) Storms and hurricanes in sea disturb the journey and damage the cargo.

(iii) Due to this method sometimes oil spills and marine life may get affected.

1.2.5 Comparison Between Modes of Transportations

Sr. No.	Road Ways	Railways	Air ways	Water ways
1.	Door to door delivery is possible	Door to door delivery is not possible	Door to door delivery is not possible	Door to door delivery is not possible.
2.	Suitable for shorter distance	Suitable for longer distance	Suitable for longer distance	Suitable for longer distance
3.	Costly as compare to water ways	Costly as compare to roadways	Costly transportation system	Cheapest mode of transportation
4.	Fastest mode of transport as compare to water ways	Fastest as compare to roadways	Fastest mode of transport	Slowest mode of transport
5.	Starting and Destination points are not fixed	Starting and Destination points are fixed	Starting and destination points are fixed	Starting and Destination points are fixed
6.	Traffic by bus, scooters, rickshaws, cycles.	Traffic by trains only	Traffic by aeroplanes, Helicopters	Traffic by ships
7.	Suitable for hilly areas	Not suitable for hilly area's	Suitable for hilly are as	Not suitable for hilly areas.

1.3 Comparison between Roadways and Railways

Sr. No.	Roadways	Railways
1.	Suitable to all types of traffic. Provides door to door service.	Suitable for only from one station to another station.
2.	Roadways consist of a suitable pavement with specified width.	Railways consist of a pair of steel rails having constant gauge throughout the track.
3.	Load carrying capacity is less than railways.	Load carrying capacity is more than roadways.
4.	Suitable for any distance.	Suitable for long distance.
5.	Suitable for steeper gradients.	Limitations on the steeper gradients.
6.	Maintenance cost is less.	Maintenance cost is more.
7.	No turning devices or provisions are constructed.	Special turning devices or provisions in the form of points and crossings are made.

Syllabus Topic : Classification of Indian Railways

1.4 Classification of Indian Railways

→ (MSBTE - W-17)

Q. Give the classification of Indian Railways. W-17

- Railways are classified according to type of gauge. They are mainly :

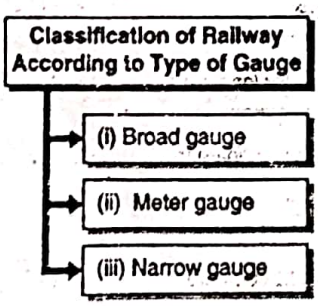


Fig. C1.2 : Classification of Railway According to Type of Gauge

- The main difference in these classifications are of gauge width which is shown as follows :

Sr. No.	Type of gauge	Gauge width in (m)
1.	Broad gauge (B.G.)	1.676
2.	Meter gauge (M.G.)	1.000
3.	Narrow gauge (N.G.)	0.610 or 0.762

Syllabus Topic : Zones of Indian Railway

1.5 Zones of Indian Railway

→ (MSBTE - W-14)

Q. What are the various zones of Indian Railways ? W-14

- For long distance passenger and goods traffic railway is cheapest mode of transport.
- The railways are classified under following zones :

Sr. No.	Name of Zone (abb.)
1.	Eastern Railway (ER)
2.	South Eastern Railway (SER)
3.	Northern Railway (NR)
4.	North Eastern Railway (NER)
5.	Southern Railway (SR)
6.	Central Railway (CR)
7.	Western Railway (WR)
8.	North East Frontier Railway (NEFR)
9.	South Central Railway (SCR)

Syllabus Topic : Permanent way

1.6 Permanent Way

→ (MSBTE - S-17)

Q. Define permanent way. S-17

- The permanent way constitutes the combination of ballast; rails and fixtures. It consists of a pair of rails fixed to sleepers which rest on ballast.
- First of all, ballast is laid on formation and then sleepers are placed according to rail positions and alignment required and then they are packed or fixed with fastening.
- The main purpose of permanent way is to provide safe and quick movement between starting and destination station.
- Similar to permanent way, temporary tracks are also laid for temporary work and they are removed after completion of work.

The combination of rails and sleeper resting on ballast and subgrade is known as perment way

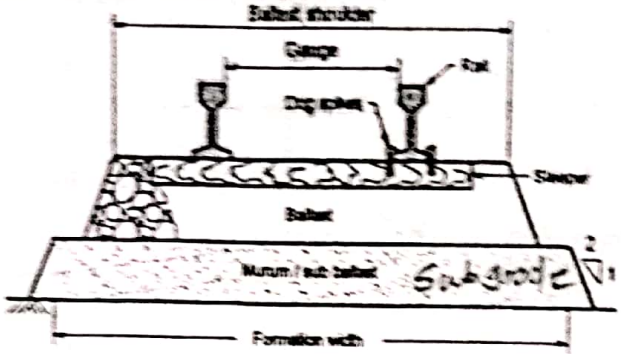


Fig. 1.6.1 : Cross-section of permanent way

Syllabus Topic : Permanent Way Components

1.6.1 Component Part of Permanent Way

The component parts of permanent way are

(1) Rails

(2) Sleepers

(3) Fixtures and fastening

(4) Ballast

(5) Formation or sub grade.

Syllabus Topic : Ideal Requirement

1.6.2 Ideal Requirement of Permanent Way

→ (MSBTE - W-16)

Q. Explain ideal requirements of permanent way. **W-16**

(1) The level of both rail should be same.

(2) It should resist lateral forces.

(3) Gradient should be easy and uniform.

(4) The gauge of permanent way should be uniform and correct.

(5) On curved portion of the track, proper elevation should provided between outer rail to inner rail.

(6) Alignment should be correct.

(7) Joints, crossing should be designed properly.

(8) Track should have electricity.

Syllabus Topic : Rail Gauge

1.7 Rail Gauges

→ (MSBTE - W-14, W-15, S-16, S-17, S-18)

Q. Define rail gauge. W-14

Q. Define gauge of railway track. W-15, S-16, S-17

Q. Explain rail gauge along with sketch compare meter gauge, broad gauge and narrow gauge. S-18

Definition of gauge of rail : *The clear horizontal distance between top of the inner faces of two rails on the railway track is called as* ***gauge of rail.***

The distance 'd' in the given Fig. 1.7.1 is called the gauge of rail.

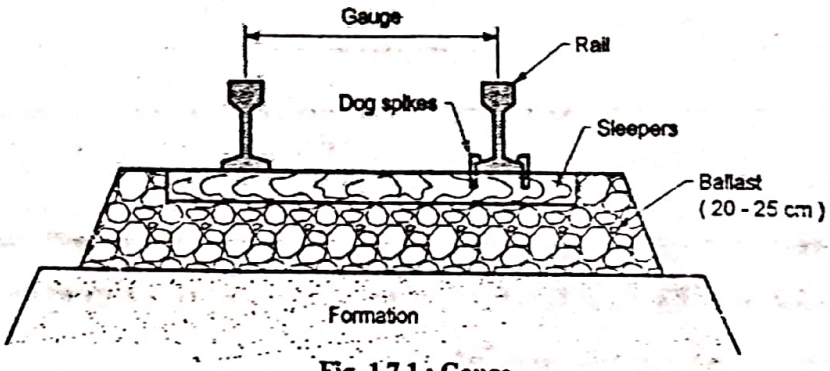


Fig. 1.7.1 : Gauge

Syllabus Topic : Rail Gauge types

1.7.1 Common Gauges used by Indian Railway

→ (MSBTE - W-16)

Q. Explain different gauges of railway track. W-16

The common gauges used by Indian railway are

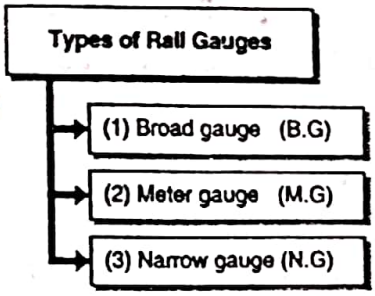


Fig. C1.3 : Types of Rail Gauge

→ **(1) Broad Gauge**

- In broad gauge, the clear horizontal distance between the inner faces of two parallel rails forming track is 167.6 cm or (1.676 m)

- In India, normally Broad gauge is preferred. It is most suitable in plain and dense populated area. It is also adopted when traffic intensity is more and demand is high.
- It is also suitable when sufficient funds are available and prospects of revenue are bright.

→ **(2) Meter Gauge**

☞ ***Definition of Meter Gauge :*** *When the clear horizontal distance between the inner faces of two parallel rails forming track is 100 cm or (1 m), the gauge is called as meter gauge.*

- This type of gauge is suitable where the position of revenue generation is medium and the traffic intensity is moderate but likely to grow in future. when the prospect of revenue is not bright

→ **(3) Narrow Gauge**

☞ ***Definition of Narrow Gauge :*** *When the clear horizontal distance between the inner faces of two parallel rail forming track is 61 cm (0.610 m) or 72.6 cm (0.726 m), then the gauge is called as narrow gauge.*

- It is suitable where the wider gauge is restricted due to topography like sharp curve, tunnels and When prospect of revenue is not so high. The narrow gauge having width 61 cm is also called as feeder gauge or light gauge. It is generally used for feeding raw material in manufacturing industries like steel plants, oil refineries etc.

Syllabus Topic : Factors Affecting Selection of a Gauge

1.7.2 Factors Affecting Selection of Gauge

→ **(MSBTE - S-16)**

Q. State the factors affecting selection of gauge. S-16

There are number of factors affecting the selection of gauge. Few of them are mentioned below :

(1) Funds availability

(2) Cost of construction.

(3) Volume of traffic : Heavy or light.

(4) Revenue generation : Whether prospect is more or less.

(5) Intensity of population : Thick or thin population.

(6) Topography of the country.

(7) Prospect of future development.

1.7.3 Break of Gauge

- In a railway track when upto some distance journey is by one type of gauge and remaining journey is by other type of gauge that means when the uniformity of the gauge is not there throughout between the destinations then it is known as breaking of gauge.
- In such cases the gauges are non uniform in nature.

☞ **Advantages of non uniform gauges :**

(1) According to topography different gauges are conveniently used.

(2) By providing different gauges, economy can be achieved in railway project.

(3) Rail facilities can be provided to the undeveloped areas.

1.7.4 Difficulties due to Break of Gauge or Non Uniform Gauges

The following are the difficulties arises due to break gauge :

(1) Timetable for different trains with different gauges is not possible to maintain.

(2) It causes inconvenience to passenger due to changing of trains. The transportation of passengers and goods from one track to another involves hardship to travel delay in transit and increases the cost.

(3) Another set of station equipment and facilities required at the junction where two gauges are meet.

(4) Wagons and locomotive of one gauge can not be used for another gauge.

(5) It is very difficult and uneconomical to convert existing gauge into another gauge.

(6) Large sheds are required for storage of goods during waiting periods.

(7) Transfer of goods from one track to another causes difficulties and increases transportation cost.

(8) It creates labour problems.

1.7.5 Necessity of Uniform Gauge

- The breaking of gauge results in wastage of time and causes delay in movement of people and goods. It involves extra labour for unloading and reloading.
- The goods due to which goods are like to be damage. It also requires provision of extra and costly transhipment yards godowns, sheds etc.
- Locomotive of one gauge cannot be used for another gauge and hence to overcome the above said difficulties uniform gauge is necessary.

1.8 Rails

☞ ***Definition of Rails :*** *Rails are the rolled steel sections laid end to end in two parallel lines over the sleepers to form a railway track is called as rails.*

☞ **Functions of rails**

(1) It transmits the moving loads to sub grade through sleepers.

(2) It provides hard, strong, smooth and continuous level surface for the movement of train.

(3) It serves as lateral guide to the running wheels.

1.8.1 Types of Rails

There are three different sections of rails in use :

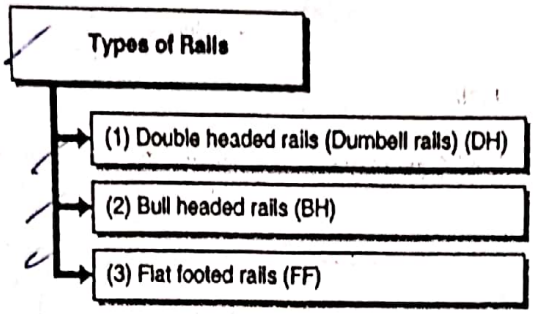
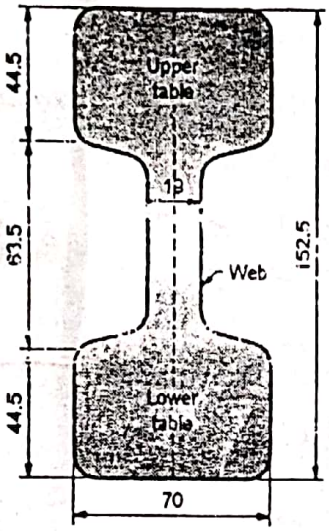
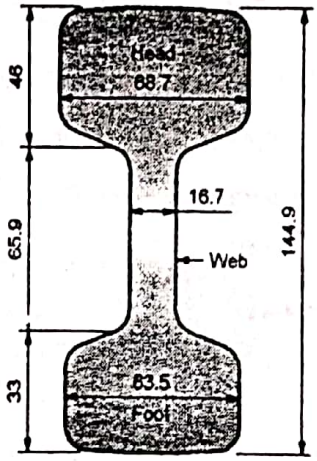


Fig. C1.4 : Types of Rails

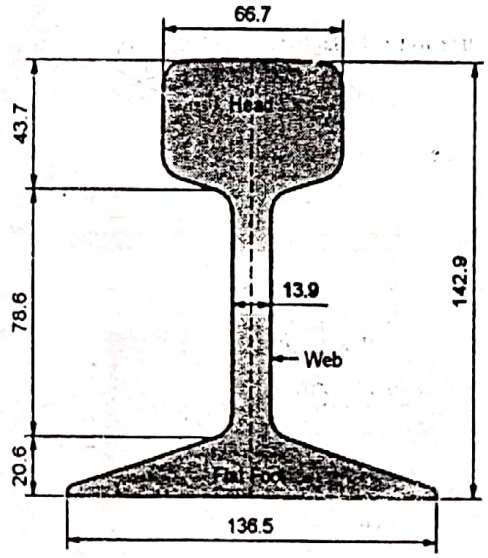
➜ **(1) Double headed rails (Dumbell rails)**



(a) Double headed rail



(b) Bull headed rail



(c) Flat footed rail

(Dimensions are in mm)

Fig. 1.8.1 : Types of rails

- In double headed rails both head and foot are of same dimensions.
- These rails require chairs for holding them in position.
- These types of rails are not used now a days by Indian railways.
- They are designed by taking into view that if the head portion is worn out, it could be inverted and reused with foot portion placing at top.
- But due to impact bottom, foot portion is also corrugated and thus could not be reused. Sketch of double headed rails is shown in Fig. 1.8.1(a).

➜ **(2) Bull headed rails**

Definition of Bull Headed Rails: *The rail section in which the head portion is having more dimension than that of foot are called as bull headed rails.*

- These rails also required chairs to hold them in position. Renewal of these types of rail is easy as they can be removed and replaced easily.
- Due to chairs these rails keep better alignment. These type of rails requires more fastening and hence cost of construction is more. The tracks formed by these rails required more attention and hence maintenance cost is high.
- For better understanding, the sketch of bull headed rail is shown in Fig. 1.8.1(b).

➜ **(3) Flat footed rails**

- In these rail sections, their foot is rolled to flat. These types of rails are commonly used in India as they are strong and stiff.
- It has got higher lateral and vertical strength.
- These types of rails does not requires chairs to fix them in position. They are simple and easy in fixing but for better results steel bearing plates are provided in between flat footed rails and wooden sleepers as under heavy loads. These rails may sink into sleeper.
- It distributes load properly over the sleepers and thus increases life of sleepers.
- The sketch of flat footed rails is shown in Fig. 1.8.1(c).

Syllabus Topic : Rail Joints, Rail Material

1.8.2 Rail Joints

Definition of Rail joints: *To ensure continuity of railway track, rail joints are necessary. This connection of any two adjoining rails in correct position is called as rail joint.*

- The railway track is constructed with rails of standard length and these rails are joined together by means of two fish plates one on either side of a joint.
- Normally a gap of 6 to 15 mm is kept in between rail ends to allow free expansion of rails.
- Rail joint forms the weakest part of the track. To give more stability to track, sleepers are placed closer at rail joint.

Syllabus Topic : Rail Joints - Requirements

1.8.3 Requirement of Standard Rail Joint

→ (MSBTE - W-15)

Q. Mention the ideal requirements of rail joints. W-15

(1) It should be strong, stiff and give same strength as that of the original rail section.

(2) Under lateral and varying load, it should maintain the gauge distance of track.

(3) It should be cheap and durable.

(4) It should not allow rail end to be battered in any case.

(5) To absorb shocks and vibrations produced due to movement of train, it should be elastic both laterally and vertically.

(6) It should facilitate easy removal and replacement of rails without disturbing the whole track.

(7) It should be capable of maintaining the two rails at the same level.

(8) It should provide free expansion and contraction due to temperature.

Syllabus Topic : Rail Joints - Types

1.8.4 Types of Rail Joint

→ (MSBTE - W-14, W-15)

Q. Enlist four types of Rail joint. W-14, W-15

The following are the types of rail joint commonly used by Indian Railway.

☞ **According of location of the sleepers**

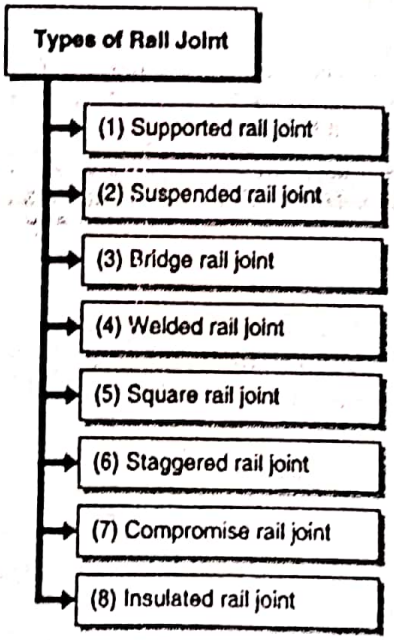


Fig. C1.5 : Types of Rail Joint

➜ **(1) Supported rail joint**

In this rail joint, both the ends of adjoining rails rest on single sleeper. The running on these joint is rough as sleeper is subjected to heavy stresses and wears out quickly. This joint is not used now a days.

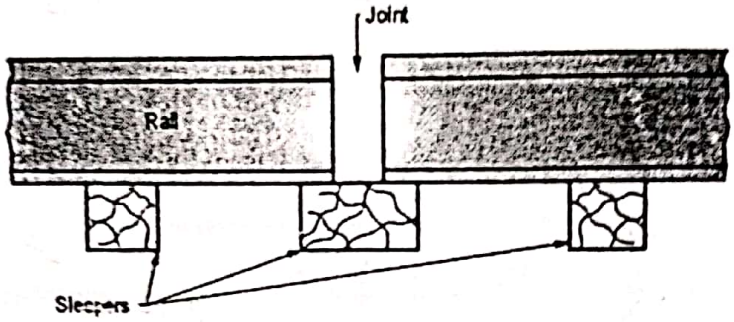


Fig. 1.8.2 : Supported rail joint

➜ **(2) Suspended rail joint**

- It is the rail joint in which both the adjoining ends of rails remain projected beyond shoulder sleeper.
- Shoulder sleepers are those adjacent sleeper placed near to rail joint on either side.
- These are normally used by Indian railway.

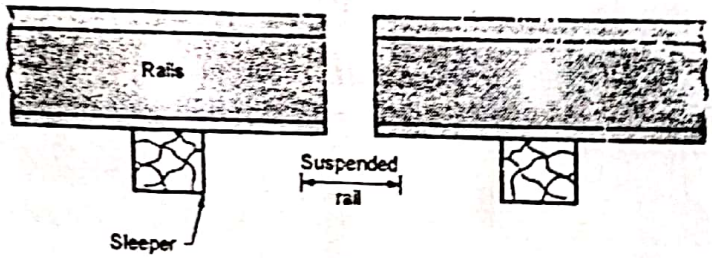


Fig. 1.8.3 : Suspended rail joint

➜ **(3) Bridge rail joint**

In this type of joint, both the adjoining ends of rails are carried by flat or corrugated metal plate bridging between shoulder and sleeper.

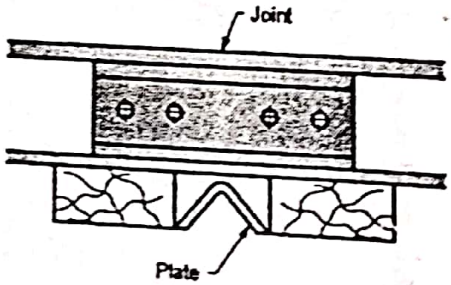


Fig1.8.4 : Bridge rail joint

➜ **(4) Welded rail joint**

- To increase length of rails and to reduce the number of fish plate joints, the rails are welded together by suitable type of welding and hence it is known as welded rail joint.

- The welded joints in rails are treated as an ideal joint because they fulfil nearly all the requirement of an ideal or perfect rail joint for increasing the length of rails by reducing the number of fish plate joints.

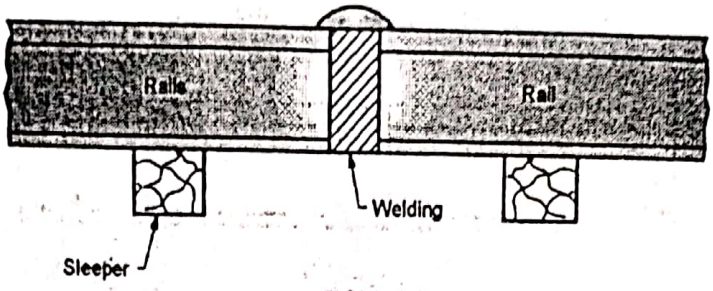


Fig. 1.8.5 : Welded rail joint

➜ **(5) Square rail joint**

When joint in one rail is exactly opposite to joints of other rail, it is called as square rail joint.

Fig. 1.8.6 : Square rail joint

➜ **(6) Staggered joint**

When joint of one rail of track is not directly opposite to joints of other rail, they are called staggard or broken rail joints. These types of joints are provided on curved portion.

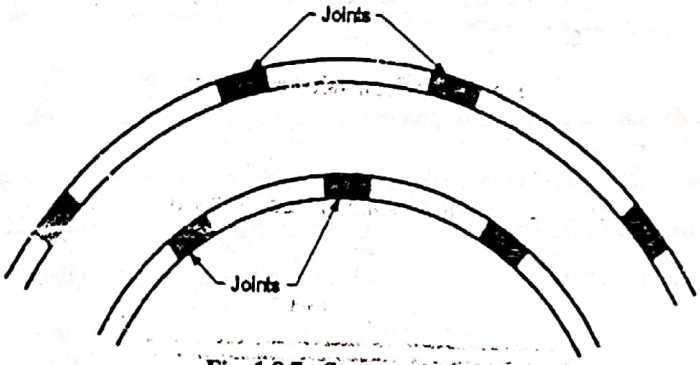


Fig. 1.8.7 : Staggered joint

➜ **(7) Compromise joint**

It is the joint where two rails of different sections are required to be joined together.

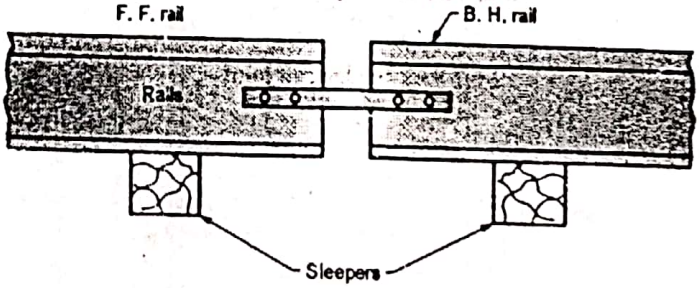


Fig. 1.8.8 : Compromise rail joint

➜ **(8) Insulated rail joint**

In case of insulated joints, insulated material is inserted to stop flow of electric current. These joints are used in track circuiting areas.

Syllabus Topic : Creep of Rail

1.9 Creep of Rail

➜ **(MSBTE - W-14, S-15)**

Q. What is meant by creep of rail ? **W-14**

Q. What are the possible effects of creep **S-15**

☛ ***Definition of Creep of Rail : The creep of rails is the longitudinal movement of rails in a track. It is also called as travel of rails.***

☛ **Effects of creep**

(1) Sleeper may move out affecting gauge and alignment.

(2) Points and crossing may get distorted.

(3) Ballast may come out from permanent way.

(4) The surface of track may disturbed which results in uncomfortable journey.

Syllabus Topic : Causes of Creep

1.9.1 Causes of Creep of Rail

➜ **(MSBTE - W-14, S-15)**

Q. What are causes of creep of rail? **W-14, S-15**

Enlist causes of occurrence of creep of rail. The following are the causes of creep :

(1) Wave action or wave theory

As train is passing under the rolling wheel, the portion under rolling wheel is compressed and depressed slightly due to wheel loads.

As wheel moves, this depression also moves and the portion which is under depression previously comes back to its original position. This produces wave action which causes creep in forward direction.

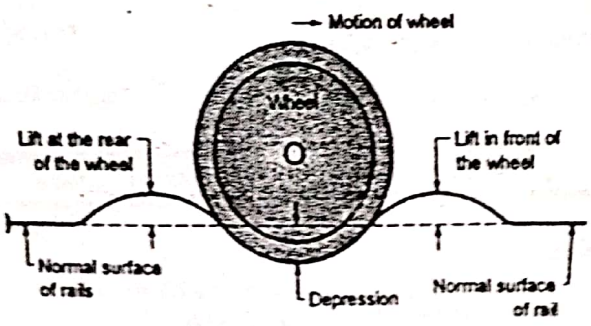


Fig. 1.9.1 : Wave theory of creep

(2) Percussion theory

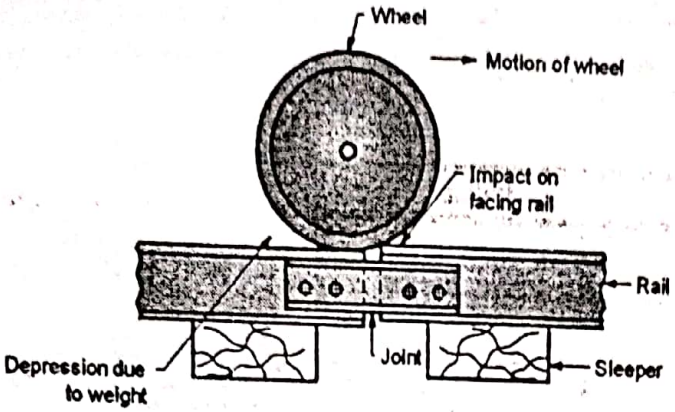


Fig. 1.9.2 : Percussion theory of creep

This type of rail creep occurs mainly due to impact of wheel. In this type, when wheel pass over joint, the trailing rail depresses down and wheel gives impact to the end of facing rail which results in creep.

(3) Accelerating or starting of a train

At time of acceleration, wheel gives backward thrust which causes creep.

(4) De-accelerating or stopping of train, due to application of breaks

If sudden stopping takes place, breaking effect tends to push the rail forward and thus causes creep in forward direction.

(5) Alignment of track

Creep is more on curved portion than straight portion.

(6) Expansion and contraction of rails is happened due to temperature variation. Creep may also cause due to expansion and contraction of rails.

(7) In addition to this, creep may also cause due to following reasons

- Improper consolidation of formation bed of track.
- Insufficient number of ballast is laid.
- Improper packing of ballast.
- Use of improper and faulty sleepers.
- Poor drainage work.
- Improper maintenance of track gauges and joints.
- Creep is more on track having steep gradient.

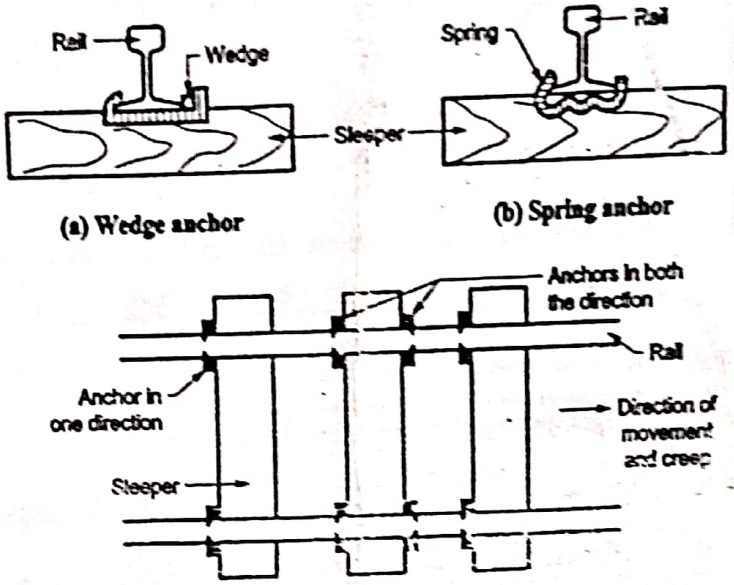
Syllabus Topic : Prevention of Creep

1.9.2 Prevention of Creep

The following measures should be adopted if any creep is visible :

- Pulling back the rail to original position.

- Provision of anchors and anti-creepers should be done.
- One should increase number of sleepers per rail length.
- One should provide sufficient ballast and packing with care.
- For good grip steel sleepers are used.



(a) Wedge anchor (b) Spring anchor

(c) Anchor Location

Fig. 1.9.3 : Anti-creep devices

1.9.3 Measurement of Creep

Creep indicator is used to measure creep. The process of measurement of creep is as follows :

After laying track, two post of rails are embedded on both sides of track such that line joining centre of these post is perpendicular to the centreline of track. The top level of post is kept in level with top surface of sleepers. Chisel marks are made on the post and thin string is stretched between them where string touches bottom flanges of rail marks are also made.

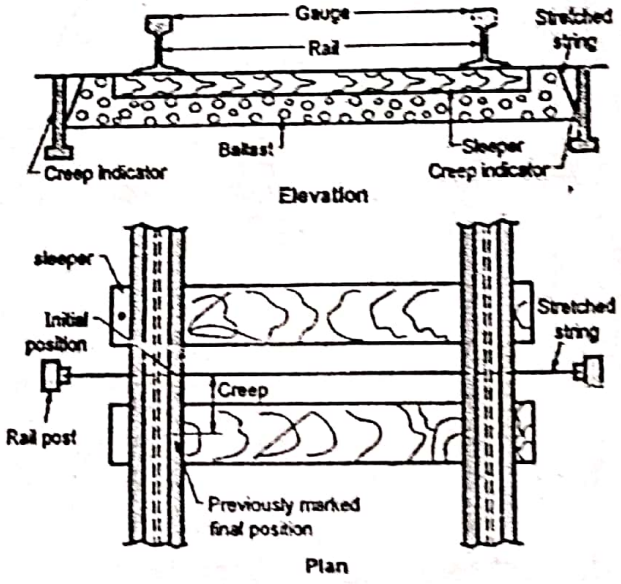


Fig. 1.9.4 : Measurement of creep

When the creep is to be measured, a string is stretched between the marks made on the post. The distance between string and marks made on bottom flanges indicate the creep of rails at that place.

Syllabus Topic : Sleepers

1.10 Sleepers

Definition of Sleepers : These are the members laid transversely, under the rail for supporting and fixing them at the gauge distance apart are known as sleepers.

Syllabus Topic : Sleepers - Functions

1.10.1 Main Functions of Sleepers

1. They maintain alignment of track.
2. They hold the rails to proper gauge firmly and evenly.
3. They distribute load over large area of ballast.
4. To absorb vibrations caused by train, they will act as an elastic medium between rails and ballast.
5. They not only support rails but they also helps in maintaining proper super elevation on curves.
6. They provides overall stability to the permanent way.

Syllabus Topic : Sleepers - Requirement

1.10.2 Requirement of Good Sleepers

The following are the requirements for a good sleeper :

1. They should be durable.
2. They should be able to maintain correct gauge.
3. They should have moderate weight.
4. They should be able to resist impact and vibrations.
5. They should have less maintenance cost.
6. They should provide good holding capacity on track geometry.
7. They should able to provide good track circuiting.
8. They should have such fittings that they can easily be removed, replaced, packed and lifted when required.
9. They should be such that they will not get damaged easily during packing operations.
10. They should have high scrap value.
11. They should have non absorbent qualities.

Syllabus Topic : Sleepers Types - Concrete Sleepers

1.10.3 Types of Sleepers

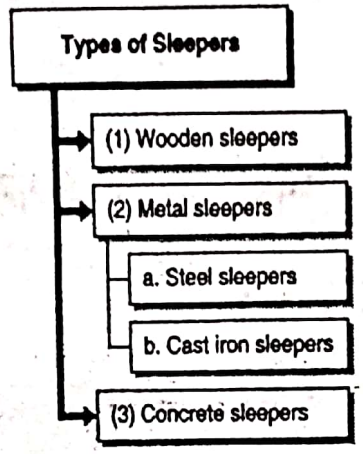


Fig. C1.6: Types of Sleepers

➜ **(1) Wooden sleepers**

- These are wooden logs of Sal, Nahar and soft woods such as Chir and Deodar.
- These sleepers should be made from thoroughly sound and well seasoned wood.
- Timber should be free from all defects and it should be sawn parallel on the top and bottom with square ends.
- In order to increase the life of sleepers, their ends are bound with steel wires with prevents end splitting.

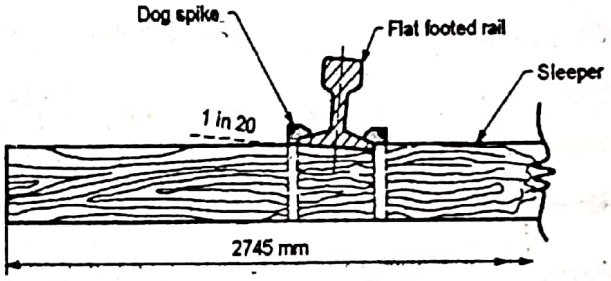


Fig. 1.10.1 : Wooden sleepers

☞ **Advantages of wooden sleepers**

1. Sleepers are cheap and easy to manufacture.
2. Sleepers requires less fastening and are also simple in design.
3. Sleepers are suitable for all types of ballast.
4. These are best suited for track circuiting.
5. The material i.e. timber is available in India in large quantity.

☞ **Disadvantages of wooden sleepers**

1. There might be chances of decay, wear, cracking, splitting, rail cutting etc.
2. Maintenance of these sleeper is high.

3. These sleepers may attack by ants and vermines.
4. Connection between wooden sleepers and rails are not so strong and hence it is difficult to maintain gauge of track.
5. Scrap value of material is very low.

➜ **(2) Metal sleepers**

These are usually made of cast iron and steel. These are mostly preferred due to their strength and durability. See Fig. 1.10.2.

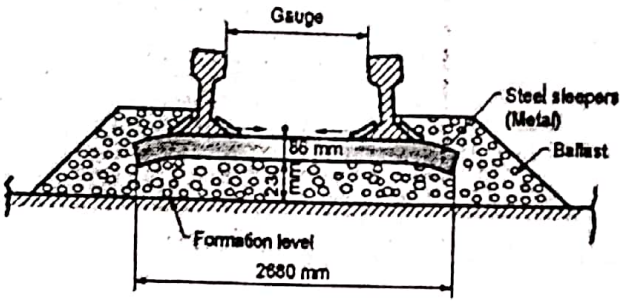


Fig. 1.10.2 : Metal sleepers

☞ **Advantages of metal sleepers**

1. These sleepers are durable.
2. The lateral and longitudinal stability is more.
3. These sleepers have greater strength.
4. Gauge length can maintained effectively.
5. Metal sleepers have more scrap value.

☞ **Disadvantages of metal sleepers**

1. These sleepers are liable to rust.
2. These sleepers requires more fitting.
3. In case of accidents, these sleepers causes more damage.
4. These sleepers requires more quantity of ballast.

☞ **Types of metal sleepers**

➜ **(1) Steel sleepers**

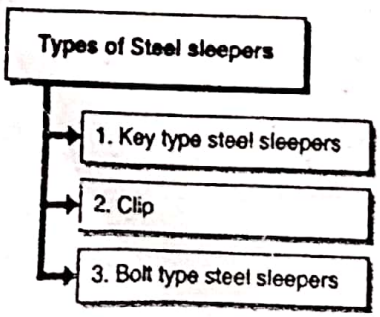


Fig. C1.7 : Types of Steel sleepers

➜ **(2) Cast iron sleepers**

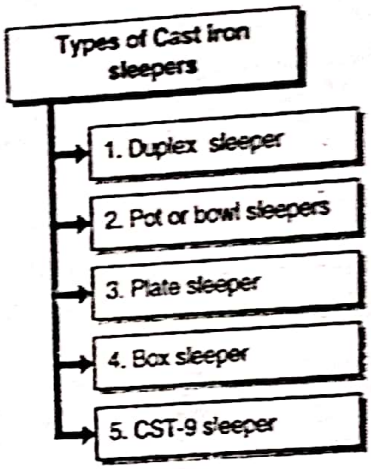


Fig. C1.8 : Types of Cast iron sleepers

➜ **(3) Concrete sleepers**

The sleepers made of concrete are known as concrete sleepers. See Fig. 1.10.3.

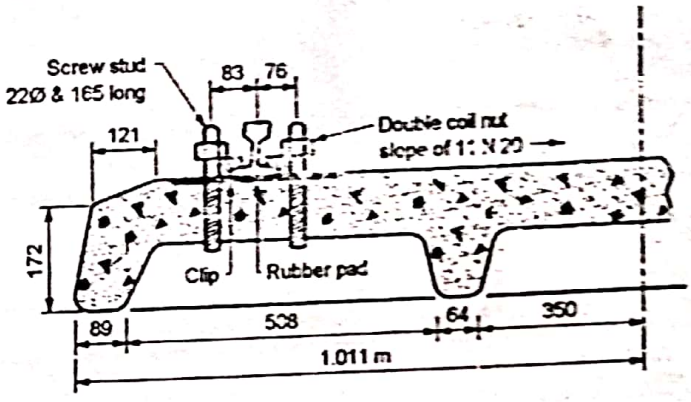


Fig. 1.10.3 : Concrete sleepers

☞ **Advantages of concrete sleepers**

1. These type of sleepers requires less fitting.
2. These sleepers has got long life.
3. Gauge adjustment is easy.
4. These are free from attack by white ants and are not affected by weather condition.
5. No difficulty in track circuiting.
6. These sleepers are durable.
7. Lateral and longitudinal rigidity of track laid with these sleeper is more.

☞ **Disadvantages of concrete sleepers**

1. Initial cost is high.
2. Heavy equipment is required for handling.
3. These sleepers may break under rough handling.

4. During packing the edges may get damage.

5. Scrap value is nil.

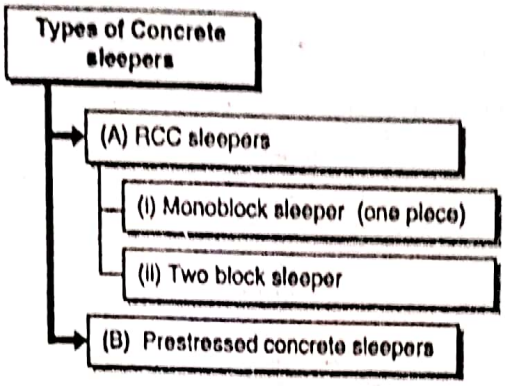


Fig. C1.9 : Types of Concrete sleepers

1.10.4 Differentiation between Wooden and Concrete Sleeper

Sr. No.	Wooden sleepers	Concrete sleeper
1.	These sleepers are less durable.	These sleepers are durable.
2.	Scrap value is more as compare to concrete sleepers.	Scrap value is nil.
3.	These are attacked by ants and vermines.	There are not attacked by ants and vermines.
4.	Initial cost is less.	Initial cost is high
5.	Lateral and longitudinal rigidiy of track laid with these sleepers is less as compare to concrete sleepers.	Lateral and longitudinal rigidiy of track laid with these sleepers is more.
6.	Heavy equipments are not needed	Heavy equipments are needed fes handliage.
7.	Sleepers will not break under rough handling.	Sleepers may break under rough handling.
8.	Maintenance of these sleepers is high.	Maintenance of these sleepers is less.

Syllabus Topic : Density

1.11 Sleeper Density

Definition of Sleeper Density : *It is number of sleeper used per rail length on a track is known as sleeper density.*

- It is usually specified as (n + x).

  Where, n = length of rail in m

  x = Number

- Generally, sleeper density provided by Indian Railway varies from (n + 3) to (n + 6) for main track.
- The spacing of sleeper is not uniform.

The shoulder sleepers are kept close together. Shoulder sleepers means three or four sleepers on either sides of joint. To avoid loosening of ballast, the joint sleepers are kept closer. Space at joint sleepers is 300-450 mm and that between next sleepers is 750-900 mm.

1.11.1 Factors Affecting Sleeper Density

The density of sleeper mainly depends upon following factors :

- Axle load which the track is expected to carry.
- Method of providing rail joint.
- Speed of train.
- Lateral thrust of train.
- Type of sleeper.
- Type of ballast.

1.11.2 Example on Sleeper Density

Ex. 1.11.1 : A.M.G. track has a sleeper density of n + 5 if the track is laid with rails of 13 meter length. Find the number of sleepers under one rail length.

Soln. :

Given n = length of rail = 13 m

x = 5

Number of sleepers required under one rail length.

or sleeper density = n + x

= 13 + 5 = 18 ...Ans.

Syllabus Topic : Ballast

1.12 Ballast

Definition of Ballast : *Ballast is a material like broken stone, gravel or any other granular material spread and packed below and around the sleeper.*

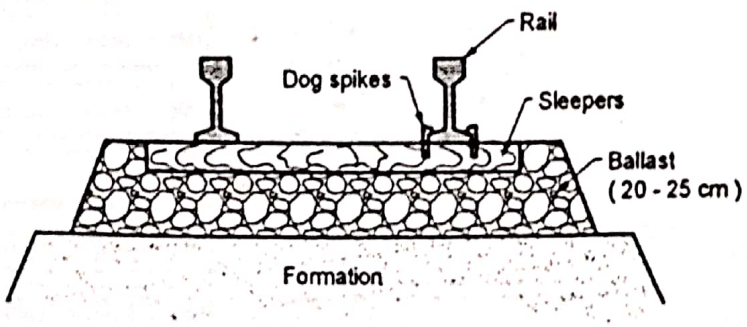


Fig. 1.12.1 : Ballast

Syllabus Topic : Ballast - function

1.12.1 Function of Ballast

→ (MSBTE - W-14)

Q. Write any four functions of Ballast. **W-14**

1. It provides support to sleeper and distribute load uniformly on ground or subgrade.
2. It hold sleepers in correct position by preventing movements caused by lateral load.
3. It provide good drainage for the track.
4. It prevent growth of weeds.

1.12.2 Requirement of Good Ballast

1. It should be strong and resistant to wear and tear.
2. It should be resistant against weather.
3. It should not create dust that means its crushing strength must be more.
4. It should not have any bad effect on rails and metal sleepers.
5. It should be cheaply available nearby site.
6. It should have angular and rough surface so as to provide stability to the sleepers.

Syllabus Topic : Ballast- Types, Suitability

1.12.3 Types of Ballast

The following are the materials which is used as a ballast :

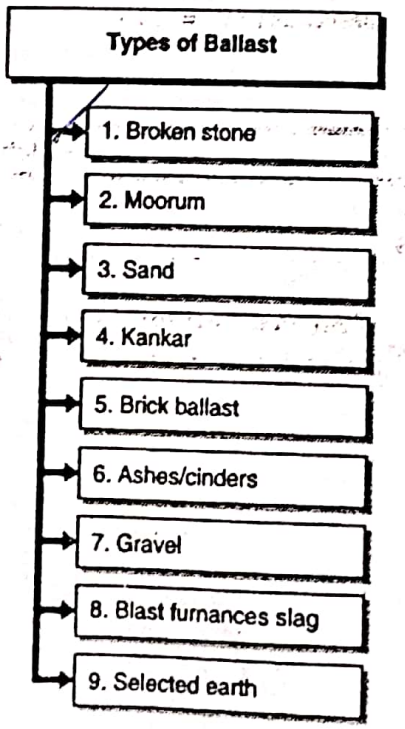


Fig. C1.10 : Types of Ballast

➜ **(1) Broken stone**

These are obtained from hard stones and it should be strong, hard, tough, durable, angular and does not flake when broken and hence **Indian Railway adopt it very frequently.**

☞ **Advantages**

- These are strong, durable and provides maximum stability to track.
- **These are mostly used for high speed track in India.**
- These types of ballast are cheaper in long run.

☞ **Disadvantage**

The main disadvantage of this type of ballast is that its initial cost is more.

➜ **(2) Moorum**

It is normally used as an initial ballast in new construction. It is of red or sometimes yellow in colour. **It is suitable for station yards.**

☞ **Advantages**

- It is cheaper.
- It may serve as soiling where stone ballast is spread afterwards.
- Drainage property is good.

☞ **Disadvantages**

- It may turns into powder under heavy loads.
- It may produces dusty track.
- Maintenance of track with this type of ballast laid is difficult.

➜ **(3) Sand**

Coarse sand is generally used as ballast and is a moderate material to use as ballast.

☞ **Advantages**

- It is cheap.
- It is easily available.
- It has good drainage property.
- It produces less noisy track.
- It will not allow vegetation to grow on track.
- **It is used for temporary and unimportant track.**

☞ **Disadvantages**

- Maintenance of tracks laid by these ballast is difficult.
- Sand may blown by wind or may washed by rain.
- It may spread due to vibrations and thus maintenance is difficult.
- It may leads to wear if it gets into the moving part of train.

➜ **(4) Kankar**

Kankar are also used as ballast where other material for ballast is not easily available.

☞ **Advantages**

- It is cheap.
- It has got good drainage property.
- Used for M.G. and N.G. tracks having light traffic.

☞ **Disadvantages**

- It is soft and hence it may convert into powder under heavy load.
- It may have corrosive action on rails.
- Maintenance of track is difficult.

➜ **(5) Brick ballast**

It is generally in form of broken over burnt brick.

☞ **Advantages**

- It is cheap material for use as ballast.
- It's drainage property is good.
- It prevents growth of vegetation.
- It is easily available.

☞ **Disadvantages**

- It may have adverse effect on rails and metal sleepers as it may corrugate them.
- Maintenance of track laid with this material as ballast is difficult.
- It may produce dusty track as it turns into powder under heavy load.
- It is used for temporary and unimportant track.

➜ **(6) Ashes**

These are residue obtained from coal. It is also used as ballast.

☛ **Advantages**

- It is cheap and very economical as it is by - product of every railway.
- Available in abundant quantity.
- It has very good drainage property.

☛ **Disadvantages**

- It has got corrosive property and hence affect the rails and metal sleepers.
- It may laid track dusty as it gets easily reduced to powder under heavy load.

➜ **(7) Gravel**

It is one of the best material used as ballast next to broken stone consisting of smooth round shaped material obtained from riverbed.

☛ **Advantages**

- It is cheaper than broken stone.
- It's drainage property is good.
- It is useful for main line.

☛ **Disadvantages**

- Due to rounded shape, it can easily rolls down due to vibrations and results in loosening of sleepers.
- Washing is required if gravels are obtained from pits.
- Screening is required as there is variation in size and quality.
- In short, uniform grading of gravel is required.

➜ **(8) Blast furnace slag**

A by product obtained from manufacture of iron can also be used as ballast.

☛ **Advantages**

- It is cheap.
- It has good drainage property.
- It is strong and holds track in correct gauge and alignment.

☛ **Disadvantages**

It is not available in large quantity.

➜ **(9) Selected earth**

These are indurated clay and decomposed rocks. These are used as ballast when tracks to be laid on new formation.

After consolidation, the surface becomes hard then good type of ballast is laid.

Advantages

- It prevents loss of good ballast on new formation.
- It may be used on sidings and tracks.

Syllabus Topic : Rail Fixtures and Fastenings

1.13 Rail Fixtures and Fastening

Fixtures and fastening

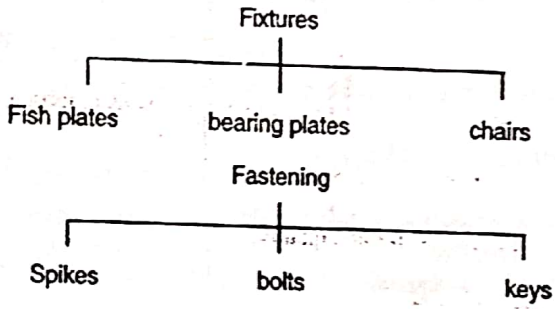
Definition of fixtures and fastening : *The arrangement required for connecting the rail end together and for fixing rails to sleepers in a track is called as fixtures and fastening.*

- The railway track is made permanently fix with sleepers.

Definition of fixtures : *The rail which are fix permanently with each other and the fitting required for this is known as fixtures.*

Definition of fastening : *The arrangement which is just required for securing connections between rails and sleepers and rail and rail are known as fastening.*

Mainly,



The various fixtures and fastening of rails are

1. Fish plates
2. Spikes
3. Bolts
4. Chairs
5. Blocks
6. Keys and cotters
7. Plates-bearing plates.
8. Anchors.

Syllabus Topic : Fish Plate

1.13.1 Fish Plates

→ (MSBTE - W-14, S-15)

Q. Draw the sketch of Fish plate. S-15

Q. State two purpose of fish plates. W-14

Definition of fish plates : *The plates which are used to join one rail with other rail to maintain continuity of rails in a track are known as fish plates.*

- These are 456 mm long and 20 mm thick plates, having 32 mm holes at 114 mm centre to centre.
- At every rail joint, two fish plates on either side are provided. They are fixed together with the help of fish bolts which are passing through the web holes.
- These web holes are drilled slightly bigger for expansion and contraction of rails.

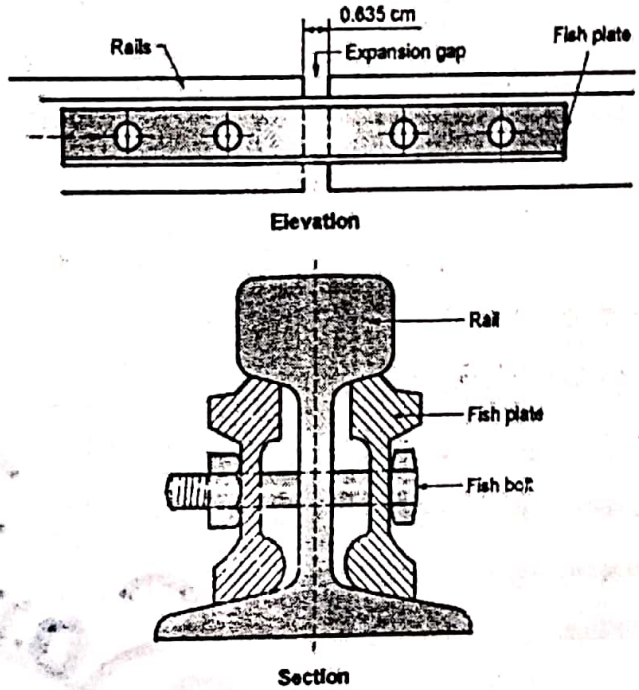


Fig. 1.13.1 : Fish plates

Functions of fish plates

1. It maintains continuity of rails in a track.
2. It helps in maintaining alignment of railway track both vertically and horizontally.
3. It will helps in minimizing variations caused by temperature and prevents expansion and contractions of rails.

Syllabus Topic : Bearing Plates

1.13.2 Bearing Plate

→ (MSBTE - S-15)

Q. What is difference between fish plate and bearing plate? Draw labelled sketch of bearing plate. S-15

- These are the plates which are provided in between the flat footed rails and wooden sleepers.
- These are made up of either steel, cast iron etc.

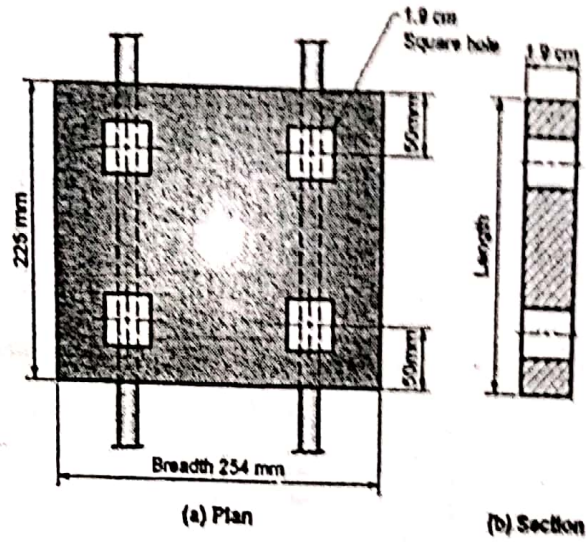


Fig. 1.13.2 : Bearing plate

Advantages and functions of bearing plates

(1) It protect sleeper from sinking and damage caused by heavy load and thus increases life of sleeper.

(2) It properly distribute load over larger area of sleeper.

(3) It helps fastening to remain in position under varying load.

(4) Bearing plates are normally used under at rail joints, on curves and under points and crossing. These plates are not used in case of B. H. and D.H. rails since they are fixed in chairs.

Difference between Fish plate and bearing plate

Sr. No.	Fish plate	Bearing plate
1.	These plates are used to join one rail with other rail.	These are provided in between the flat fasted rail and wooden sleepers.
2.	It helps in maintaining alignment of railway track.	It helps in protecting sleeper from sinking and damage.
3.	It helps in minimizing variation caused by temperature and prevent expansion and contraction of rails.	It helps in fastering to remain in position under varying load.

Syllabus Topic : Spikes

1.13.3 Spikes and their Functions

Spikes are used to fix rails, bearing plates or chairs to the wooden sleepers.

Different types of spike commonly used are :

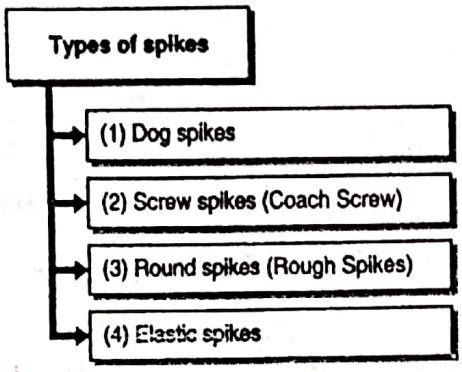


Fig. C1.11: Types of spikes

➜ **(1) Dog spikes**

- These are cheap, easily fixed and removed from sleepers and hence commonly used by Indian railway to fix rail to the wooden sleeper. The name is given due to its shape of head.

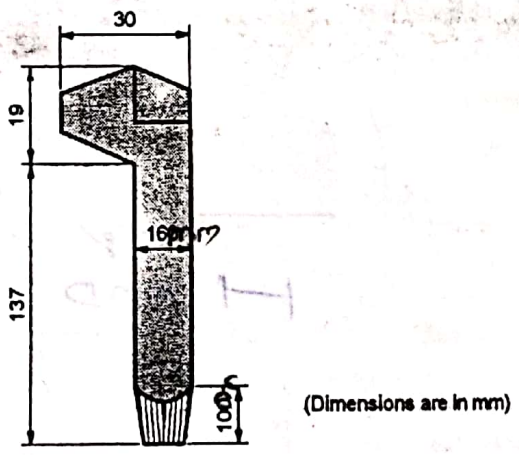


Fig. 1.13.3 : Dog spikes

- They are simple strout nails with square in section and their lower end is blunt.
- Generally, two spikes are required on either end of the rail. They are driven on either end of the rail in the pre bored holes of slightly smaller in section than that of the spikes.
- The main disadvantage of dog spikes is that these are pulled out due to wave action of rail, under varying loads which may leads to formation of creep.

➜ **(2) Screw spikes (Coach screw)**

- These are spikes with screw threads. Their head is circular with square projection. For broad gauge track; 165 mm long screw spikes are used.
- They are strong as compared to dog spikes as far as holding power and resistant to lateral thrust is concerned but they are not suitable as they provide difficulty in the maintenance of gauge.

Fig. 1.13.4 : Screw spikes

➜ **(3) Round spikes (Rough spikes)**

- These are either cylindrical or hemispherical. They are 19 mm in diameter with 38 mm diameter head. Their end is blunt. Its length varies with the gauge of the track.
- These are used for fixing chairs of B.H. rails to wooden sleepers.

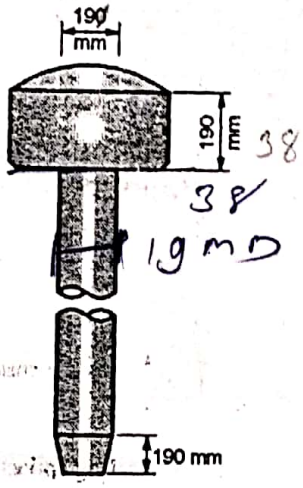


Fig. 1.13.5 : Round spikes

➜ **(4) Elastic spikes**

Elastic spikes have special head and are provided with a steel spring. As shown in Fig. 1.13.6, these spikes provide better grip with test of rail and they are not driven out due to wave motion of rail under varying load.

☞ **Requirement of good spike**

- They should be cheap.
- They should withstand against varying loads and hold rails and bearing plates and chairs in proper position.
- They should be strong enough.
- They should not driven out under vibrations.
- They should keep track in proper position.

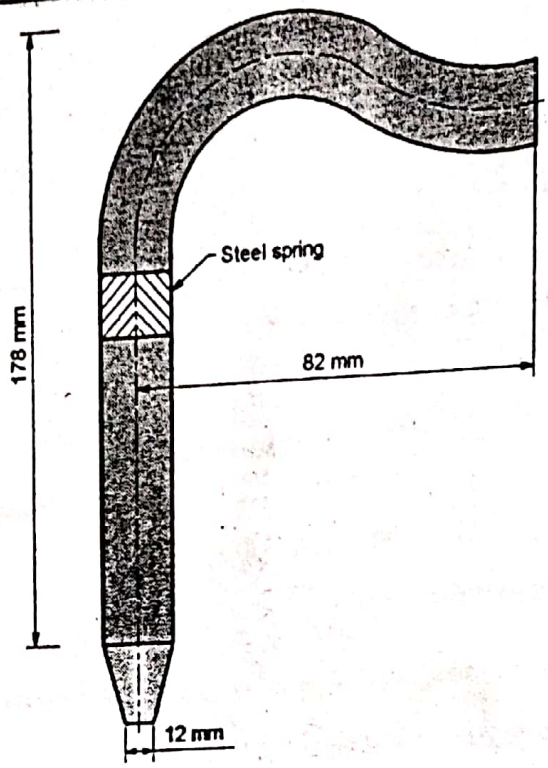


Fig. 1.13.6 : Elastic spikes

Syllabus Topic : Bolts

1.13.4 Bolts

Bolts are used for connecting fish plates to the rails at rail joint, bearing plates and chairs to wooden sleepers etc. The different and important types of bolts are described as below :

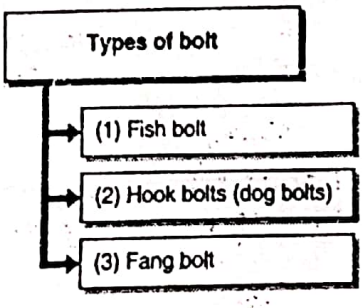
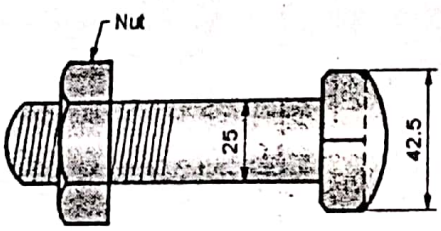


Fig. C1.12: Types of bolt

➜ **(1) Fish bolt**



Fish bolt

(Dimensions are in mm)

Fig. 1.13.7 : Fish bolt

- These are normally used to connect fish plates to the rails. They are made from medium to high carbon steel to withstand shear.
- They are usually inserted from outside and bolted on inside of track. They are either square or hexagonal in shape.

➜ **(2) Hook bolts (dog bolts)**

- These are generally used to fix wooden sleepers to bridge girders.
- The hole is driven to wooden sleeper and it is inserted from bottom and then it is tightened with bolts.
- The head of hook bolt grips with the flange of girder. Usually two bolts per sleeper is sufficient for fixing purpose.

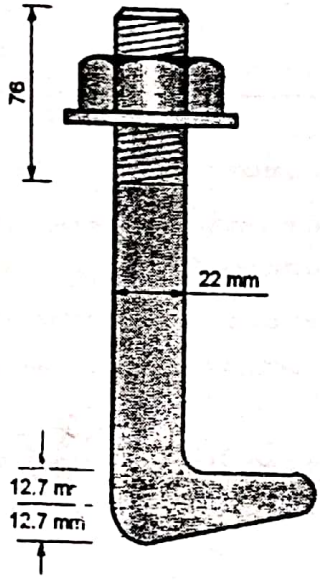


Fig. 1.13.8 : Hook bolts

➜ **(3) Fang bolt**

These bolts are used for fixing side chairs to sleepers. It is provided with square nut with special projection to grip sleeper from bottom. They are quite effective but due to their fixing and removal is difficult. They are not generally used.

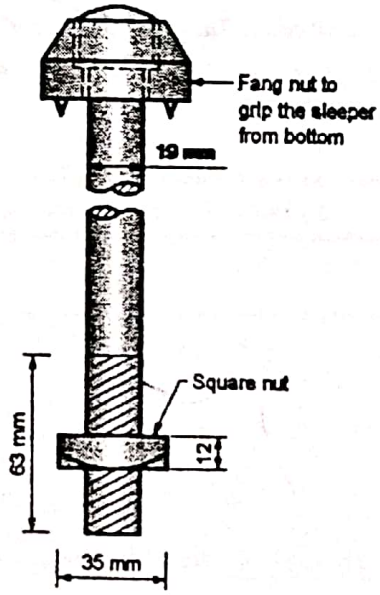


Fig. 1.13.9 : Fang bolts

Syllabus Topic : Keys

1.13.5 Keys

→ (MSBTE - S-15)

Q. State various types of keys in rail joint. S-15

Q. Explain Stuart's Key with sketch. S-15

Keys are small tapered pieces of timbers and steel used for fixing rails to sleepers.

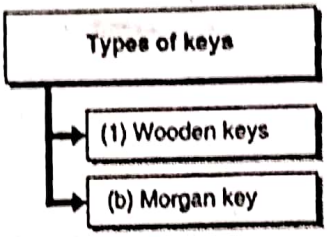


Fig. C1.13: Types of keys

→ **(1) Wooden keys**

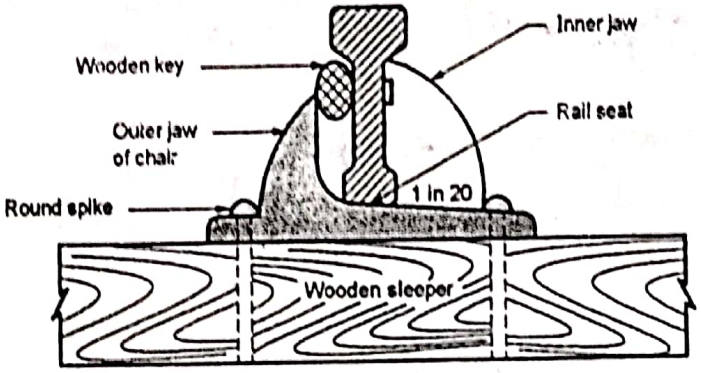


Fig. 1.13.10 : Wooden keys

- Wooden keys are used for fixing DH/BH rails to chairs. These are straight or tapered pieces of timber.
- These are cheap but are likely to attack by insects and are not so strong.
- These may get loose under vibration and hence they should be checked frequently, which thus increases maintenance cost.

→ **(2) Metal keys**

There are made up of steel. These are quite strong and durable as compare to wooden keys and hence maintenance cost is less. The various types of metal keys used by Indian Railways are described below :

(a) Stuart's key

It is steel plate bent in the form of 'E' and a steel wedge is inserted at end to keep the key tight against the rail web and outer jaw of the chair.

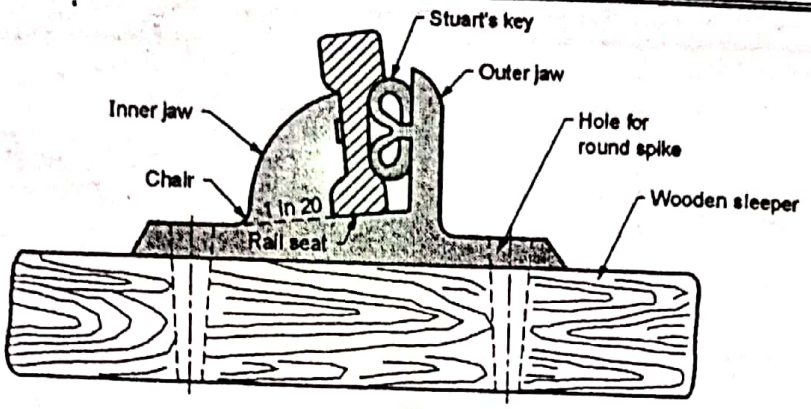


Fig. 1.13.11 : Stuart's Key

(b) Morgan key

- Morgan key is about 180 mm long and is tapered with a slope of 1 in 32 just like steel wedge.
- These are used to connect rails to C. I. chairs, plate sleepers and steel sleepers. These keys are light in weight.

Syllabus Topic : Anchors and Anti Creepers

1.13.6 Anchors or Anti Creepers

- Anchors or anti creepers are the devices used for preventing the creep in a railway track.
- They are fixed to the sleepers and foot of rails at some interval. They are available in different shape.

□□□

Chapter Ends

CHAPTER 2

Railway Engineering

16 mark

Syllabus

- Alignment- Factors governing rail alignment.
- Track Cross sections – standard cross section of single and double line in cutting and embankment. Important terms- permanent land, formation width, side drains,
- Railway Track Geometrics : Gradient, curves- types and factors affecting, grade compensation, super elevation, limits of Super elevation on curves, cant deficiency negative cant, grade compensation on curves, Coning of wheel, tilting of rail.
- Branching of Tracks Points and crossings- Turn out-left and right hand turnout, components and their functions, important technical terms, components, types and inspection, track junctions: crossovers, scissor cross over, diamond crossing, track triangle.
- Station and Yards-Purpose, requirement of railway station, important technical terms, types of railway station, factors affecting site selection for railway station.
- Station yard-Classification-Passenger, goods, locomotive and marshalling yards-function & drawbacks of marshalling yards.
- Steps involved in construction of rail track.
- Track Maintenance- Necessity, Classification, Tools required for track maintenance with their function, Organisation of track maintenance, duties of permanent way inspector, gang mate and key man.

Syllabus Topic : Alignment

2.1 Alignment

→ (MSBTE- S-16, W-17)

Q. What is rail alignment ? W-17

Q. Define 'Alignment'. S-16

☞ ***Definition of Alignment : It is the centreline of a proposed track in a plan.***

- It should be properly selected by taking into consideration the cost of construction, maintenance, safety and easy to travel etc.

2.1.1 Factors Governing Rail Alignment

→ (MSBTE - W-14, S-16, W-16, W-17, S-18)

Q. State factors governing rail alignment. W-14, S-16, W-17

Q. What are the basic requirements for good alignment for railway track ? W-16

Q. Write factors affecting rail alignment. S-18

(1) The alignment should be short and straight.

(2) The alignment must be safe for traffic operations.

(3) The alignment should be economical.

(4) It should take care of obligatory points such as location of river crossing.

(5) It should be such that raw materials for constructions should easily available near the site.

(6) Marshy and low lying area should be avoided.

(7) Track should be located such that they should not responsible for delay and congestion of traffic during passing of train. So it should be advisable to bypass the built up area.

(8) It should facilitate easy slopes and curve if any.

(9) Funds available.

(10) Length of detail railway track.

(11) Topographical features of the country.

(12) It should connect important stations and industrial area.

(13) Traffic density.

(14) Road railway crossing or level crossing.

(15) Cost of maintenance and construction.

(16) Gauge of track.

(17) Position of tunnels in hilly areas.

Syllabus Topic : Track Cross sections - standard cross section of single and double line in cutting and embankment

2.2 Rail Track Cross Sections

→ (MSBTE- W-14, W-15, S-16, W-16, S-17, S-18)

Q. Draw neat sketch of standard c/s of B.G. in cutting and embankment. W-14

Q. Draw a neat labelled cross section of single line B. G. railway track in embankment. W-15

Q. Draw a neat labelled cross-section of double line BG track in embankment. S-16

Q. Draw neat cross section of Broad Gauge (B.G.) Single track in embankment and label its parts. W-16

Q. Draw a c/s of A broad gauge double line railway track in Embankment. S-17

Q. Draw standard cross section of B.G. Double track in cutting and name its component parts. S-18

Syllabus Topic : Important terms - permanent land, formation width, side drains, curves - types

2.2.1 Important Term

1. **Permanent land**

☞ *Definition of Permanent land : The area of land acquired and reserved for construction and development of road along its alignment is called as permanent land.*

2. **Formation width**

☞ *Definition of Formation width : The top width of highway embankment or bottom width of highway cutting excluding the side drains are called formation width.*

3. **Side drains**

☞ *Definition of Side drains : The drains provided on either sided railway track are called as side drain.*

4. Curves

☞ *Definition of Curves : The geometrical area provided to change alignment of track are called as curves.*

☞ **Necessity**

1. To bypass natural / artificial obstruction.
2. To avoid acquisition of costly land.
3. To avoid excess cutting or filling.
4. To have or provide easy gradient to form straight route.

☞ **Functions**

1. It provide gradual change in direction.
2. It provide gradual change in gradient.
3. Helps in easy turning of train.

☞ **Types of curves**

The curves are broadly classified into following types :

1. Horizontal curve
2. Vertical curve

1. Horizontal curve

These are the curves provided at turning points by the alignment of track. These are further classified as,

(i) Simple curve

(ii) Compound curve

(iii) Reverse curve

(iv) Derivation curve

(v) Transition curve

2. Vertical curve

- These are provided at change of gradient in alignment of track.
- It helps in provide gradual change in grade provides adequate visibility and safety of traffic and also comfort to the passenger.
- These are further classified as

1. Summit curves 2. Valley curve

Rail track cross-sections are shown in the following Figures :

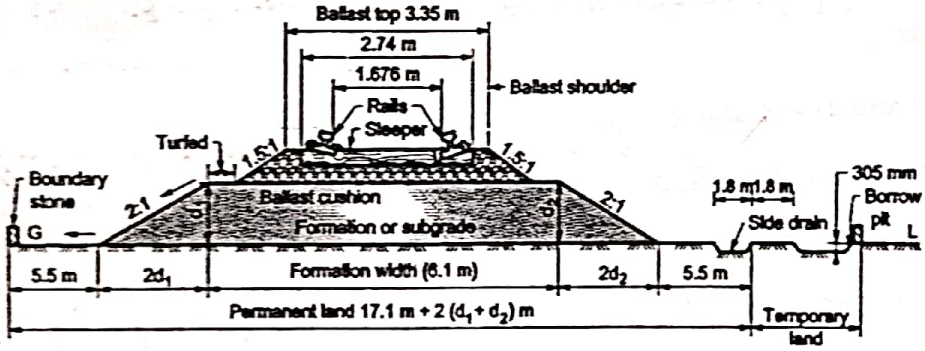


Fig. 2.2.1 : Cross-section of a single broad gauge track in embankment

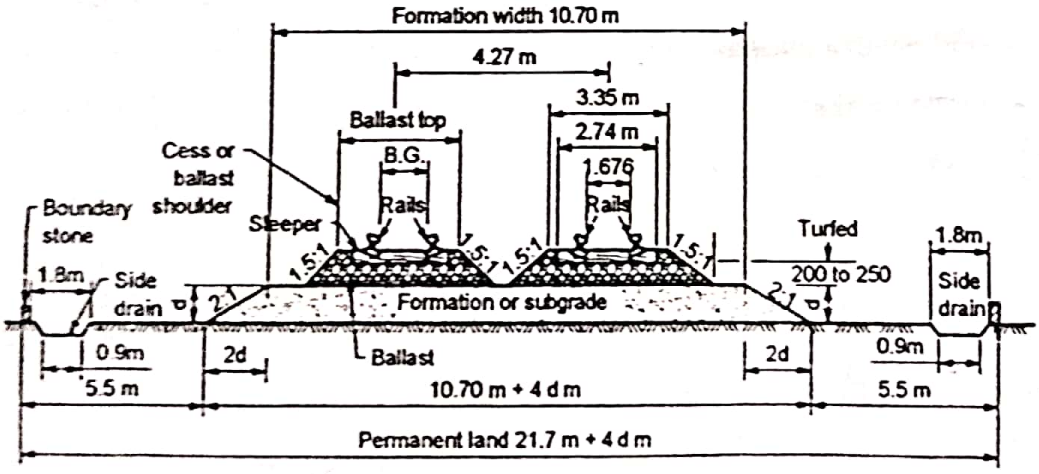


Fig. 2.2.2 : Cross-section of a double broad gauge track in embankment

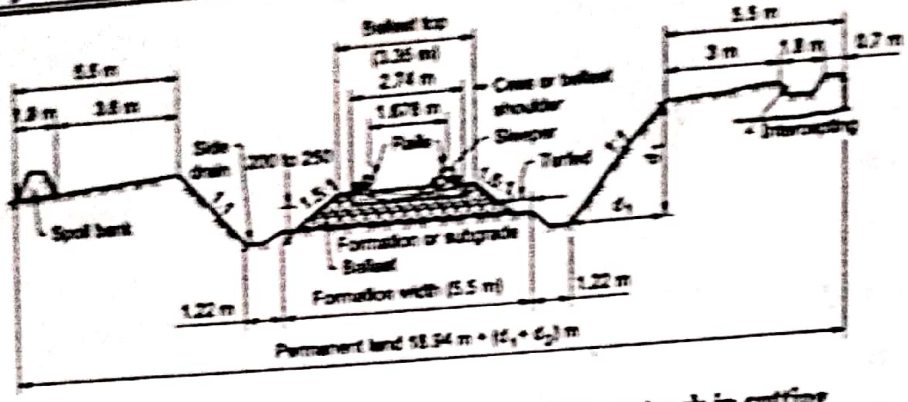


Fig. 2.2.3 : Cross-section of a single broad gauge track in cutting

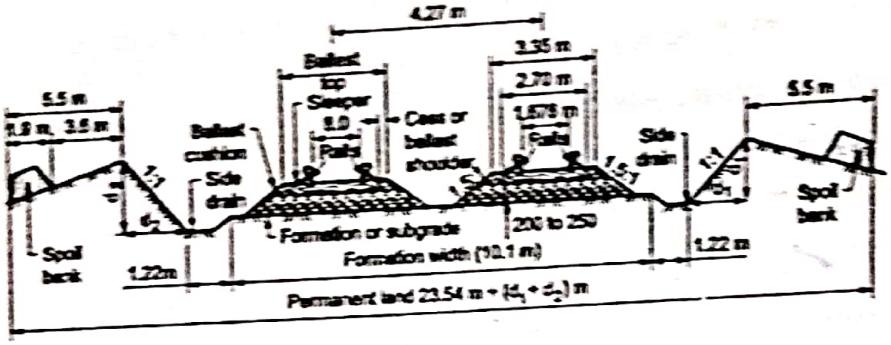


Fig. 2.2.4 : Cross-section of a double broad gauge track in cutting

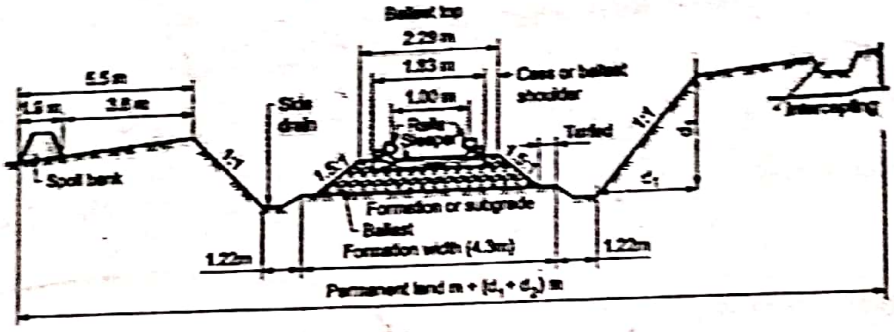


Fig. 2.2.5 : Cross-section of a single meter gange track in cutting

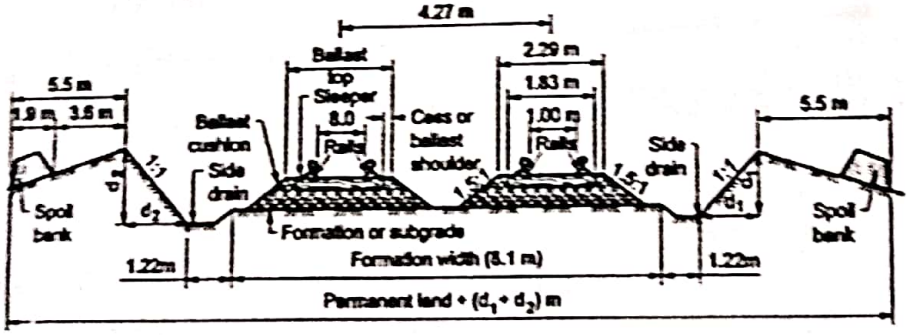


Fig. 2.2.6 : Cross-section of a double meter gauge track in cutting

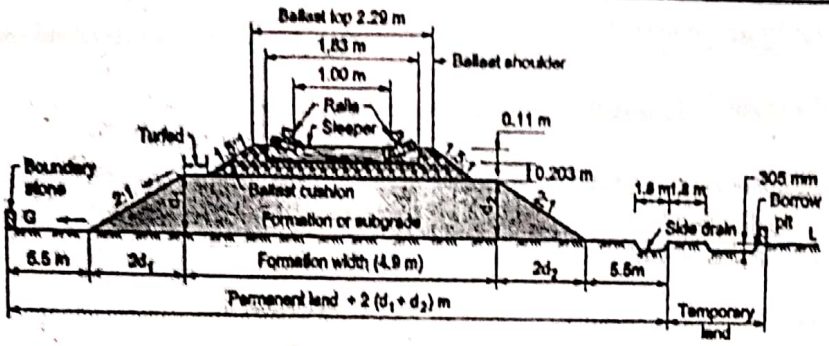


Fig. 2.2.7 : Cross-section of a single meter gauge track in embankment

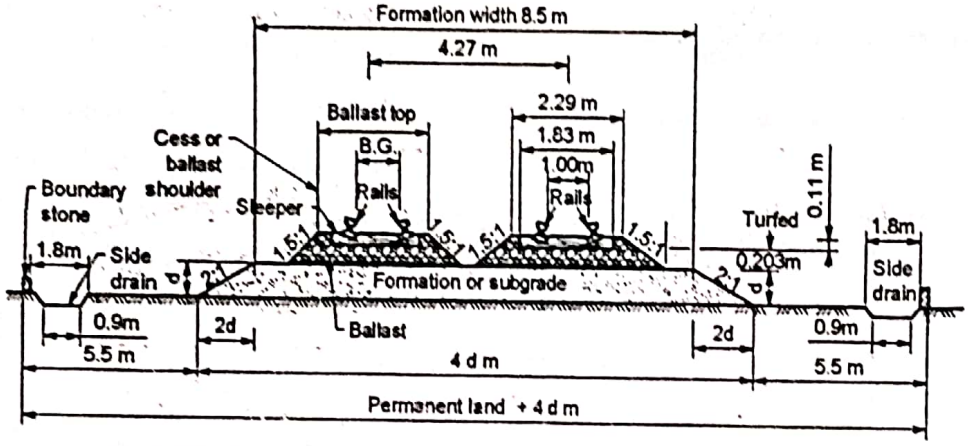


Fig. 2.2.8 : Cross-section of a double meter gauge track in embankment

Syllabus Topic : Railway Track Geometrics - Gradient

2.3 Gradient

→ (MSBTE - W-14, S-16, S-17, S-18)

Q. What is gradient. **W-14**

Q. Define 'Gradient'? **S-16, S-17, S-18**

Definition of gradient : The rate of rise or fall provided to the formation of a railway track along its alignment is called as gradient.

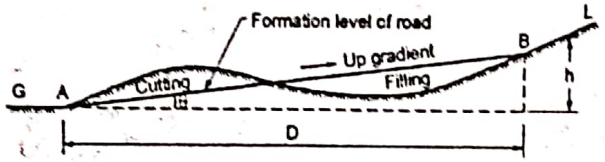


Fig. 2.3.1 : Gradient

2.3.1 Types of Gradient

→ (MSBTE - W-14, S-15, S-16, S-17)

Q. What are types of gradient ? **W-14**

Q. Explain four types of gradient with sketches. **S-15**

Q. State the types of gradient **S-16**

Q. Explain two types of gradient. **S-17**

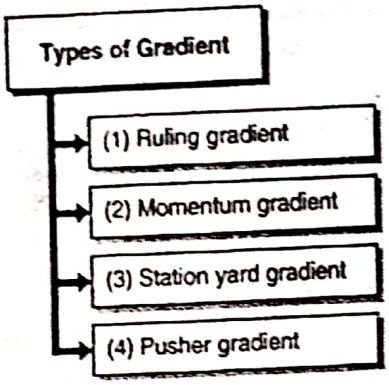


Fig. C2.1 : Types of Gradient

➜ **(1) Ruling gradient**

It is the maximum gradient allowed on the track over which a train is hauled by one locomotive. It is generally 1 in 150 to 1 in 200 for plane and 1 in 100 to 1 in 150 for hilly regions.

➜ **(2) Momentum gradient**

Sometimes rising gradient is followed by falling gradient. In that case when train travelling due to falling gradient, it acquires momentum and due to which it becomes easy to travel in rising gradient. This type of gradient is known as momentum gradient.

➜ **(3) Station yard gradient**

The gradient provided in station yard for easy drainage is known as station yard gradient. It has been recommended for easy drainage of rain water and it is in between 1 in 400 to 1 in 100 for maximum and minimum respectively.

➜ **(4) Pusher gradient**

Definition of Pusher gradient : *These are steeper than ruling gradient. In this type of gradient, an extra engine is attached to push the train and hence called as pusher gradient.*

These are helpful in the regions where heavy cutting is to be avoided and to reduce the route length.

Sr. No.	Ruling gradient	Pusher gradient
1.	The permissible gradient usually provided in a railway track is called as ruling gradient.	The gradient which requires one or more additional locomotive for pulling train up the track is called pusher gradient.
2.	Not steeper	These are steeper than puling gradient
3.	Not suitable in hilly area's	Suitable on tracks in mountains.
4.	The ruling of gradients adopted in India are 1:150 to 1 in 200	The pusher gradients upto 1 in 20 can also be provided.

2.3.2 Necessity of Gradient

Gradient is necessary for the following purposes :

1. Gradient is essential to drain off the rain water very quickly and easily.
2. Gradient provides the economy in the earthwork.
3. It is useful to reach to the stations situated at different levels or altitudes.
4. It provides the uniform rate of rise or fall.

Syllabus Topic : Super Elevation

2.4 Super Elevation or Canting of Rail

→ (MSBTE - W-14, S-17)

Q. Define super elevation. W-14

Q. Explain super elevation. S-17

Definition of super elevation : The inner rail of track is kept low as compare to outer rail at different curves. This rising of outer rail is known as super elevation.

- The term 'cant' and 'banking' is frequently used in this case. It is denoted by 'e' or S. E.

2.4.1 Necessity of Super Elevation

(1) It permit running of trains at high speed on curved track without derailment.

(2) It reduces wear and creep of rail on curved path.

(3) It provides comfortable ride to passengers and safe movement of goods.

Syllabus Topic : Limits of Super Elevation on Curves

2.4.2 Limit of Super Elevation

- The maximum value according to IRB is usually $1/10^{th}$ of gauge of track. Therefore, the permissible values are :

$$\text{For B. G.} = \frac{1}{10} \times 1.676 \times 100 = 16.76 \text{ cm}$$

$$\text{For M. G.} = \frac{1}{10} \times 1 \times 100 = 10 \text{ cm}$$

$$\text{For N. G.} = \frac{1}{10} \times 0.762 \times 100 = 7.62 \text{ cm}$$

But for high speed i.e. from 160 km/hr. upto 1600 km/hr; broad gauge value of super elevation may be allowed to 18.5 cm and under ordinary conditions when speed is less than 100 km/hr, the values of super elevation are 14.1 cm, 9 cm, and 6.5 cm, for B.G. M.G. and N.G. respectively.

2.4.3 Theory of Super Elevation

- As per different gauges for radius of curvature, the values of super elevation is different.
- Let QR be the super elevation.

'pq' be the rail reaction.

'ps' be the horizontal component of rail reaction.

'pr' be the vertical component of rail reaction.

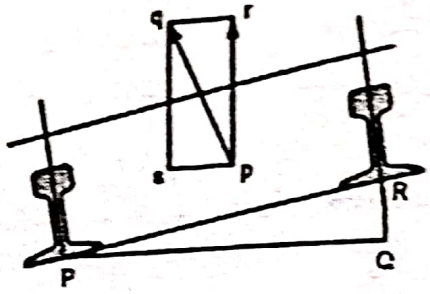


Fig. 2.4.1 : Super elevation

∴ In Δ PQR and prq,

$$\frac{QR}{PQ} = \frac{qr}{ps} = \frac{ps}{pr}$$

as PS is counteracting force,

$$ps = \frac{W}{R} \times \frac{V^2}{g}$$

Where,

W = Weight of axle load

V = Velocity of speed in km/hr

R = Radius of curvature

g = acceleration due to gravity

$$QR = PQ \times \frac{W V^2}{R \times g} \times \frac{1}{pr}$$

As PQ be the gauge length G.

$$= G \times \frac{W V^2}{R \times g} \times \frac{1}{W} \qquad \text{...as } pr = W$$

$$\therefore QR = \frac{G V^2}{R \times g}$$

i.e. QR = e = super elevation and $g = 9.81\ m/s^2$.

$$\text{Then, } e = \frac{G V^2}{127 R}$$

Method of providing super elevation

- It should be provided uniformly and smoothly using transition curves between straight and circular curve of track.

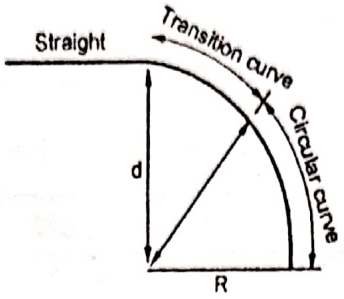


Fig. 2.4.2 : Method of providing super elevation

- It should be uniformly vary from zero at beginning to full value at junction of transition curve with circular curve and constant super elevation to its value should be maintained throughout.

Syllabus Topic : Cant Deficiency

2.5 Cant Deficiency

→ (MSBTE - S-15, W-16)

Q. Explain cant deficiency. S-15
Q. Define cant deficiency. W-16

Definition of Cant Deficiency : *The difference between equilibrium cant necessary for maximum permissible speed on curved track and the actual cant provided is known as cant deficiency.*

- It should be as low as possible, as higher cant deficiency result in extra pressure, more side wear and creep of outer track and results in discomfort to passenger.
- For different gauges, cant deficiency prescribed by Indian Railway for speed upto 100 km/hrs is 7.6 cm, 5.1 cm, 3.8 for B. G. M. G and N. G respectively and for speed more than 100 km/hr, it will be 10 cm for B. G. only.

Syllabus Topic : Negative cant

2.5.1 Negative Cant

→ (MSBTE - W-14, S-15, W-16, S-17)

Q. Define Negative cant. W-14, W-16
Q. Explain with a neat sketch negative cant. S-15
Q. Explain negative cant. S-17

Definition of negative cant : *On the curve where main track and branch track meets then the stage occurs such that the outer rail is below the inner rail, then it is called as negative cant or negative super elevation.*

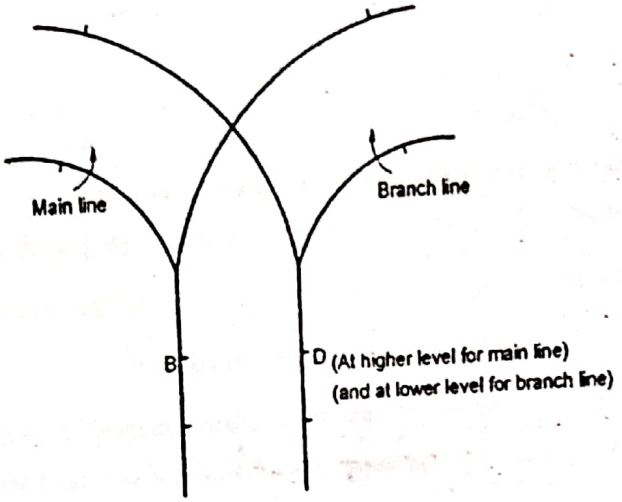


Fig. 2.5.1 : Negative cant

- The negative cant helps the locomotive to change its direction from main line to branch line irrespective that outer rail should kept at higher level.
- Now from Fig. 2.5.1, it shows the main track and branch track. The points 'D' is at higher elevation than B as in case of main track. But for branch track or turnout track, elevation of B should be higher than 'D' and thus super elevation provided is negative for branch track and this is called negative cant.

Syllabus Topic : Grade Compensation on Curves

2.6 Grade Compensation on Curves

- On curved portion if gradient is more, train require extra power due to resistance offered.

Definition of grade compensation on curves : *To overcome this resistance to a certain limit and maintain pull of train with same speed, gradient on curves are reduced and this reduction of gradient on curved portion of railway track is called as grade compensation on curves.*

- The recommended values are :

For B. G. – 0.04%

M. G. – 0.03%

N. G. – 0.02%

Syllabus Topic : Coning of wheel

2.7 Coning of Wheels

→ **(MSBTE - W-14, S-15, S-16, S-17, W-17)**

Q. Explain with neat sketch coning of wheels. What is the necessity of tilting of rails ? **W-14**

Q. Explain coning of wheels. **S-15**

Q. What is coning of wheel ? Explain behaviour of coned wheel on curved path. S-16

Q. Explain with sketch coning of wheels. S-17, W-17

- If the flanges of the wheel are flat then due to shocks there will be movement between wheel and the rails and due to which, vehicle will not be maintained in central portion and there will be unequal distribution of load.
- Therefore the flanges are made in the shape of cone with a slope of 1 in 20. This is termed as coning of wheel.
- It will also helps in decreasing the wear and tear of the flanges and the rail.
- To prevent rubbing inside face of rail and flanges, the distance between inside edge of flanges kept less than the gauge and thus the pressure is always maintained at the inner edge of rail due to coning of wheel.

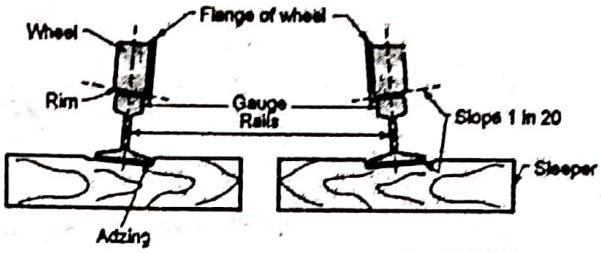


Fig. 2.7.1 : Coning of wheels

☞ Behaviour of coned wheels on curved track

- On curve outer wheel have to travel greater distance than inner wheels due to centrifugal force the axle moves towards outer rail and due to coning the diameter of wheels on outer rail increases and decreases on inner rails.
- This helps to cover greater distance than inner wheels without adverse effect.

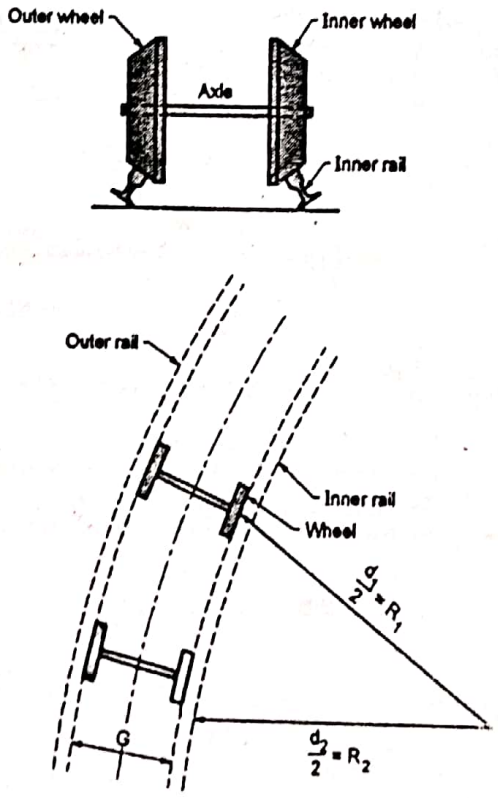


Fig. 2.7.2 : Behaviour of coning wheel on curved track

2.7.1 Adzing of Sleepers

Generally, the rails are provided at an inward slope of 1 in 20. To give this inward slope, the wooden sleepers are cut and give the required slope so that the rail ends are properly fixed to the sleepers.

This process of cutting the wooden sleeper to provide inward slope of 1 in 20 at rail seat is known as adzing of sleeper.

Syllabus Topic : Tilting of Rail

2.8 Tilting of Rails

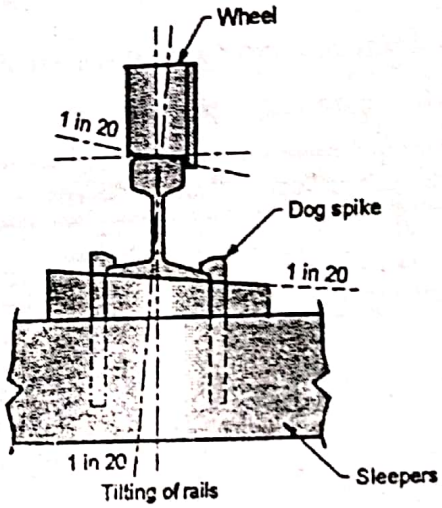


Fig. 2.8.1 : Tilting of rails

☞ *Definition of tilting of rails : The rails are placed with an inward slope of 1 in 20 on the railway track. This art of placing of rails is called as tilting of rails.*

- If the rails are placed exactly vertical, the top surface of rail will not come in contact with wheels fully and whole pressure is exerted on inner face due to which inner face may worn out quickly.
- So to avoid this and to make full contact of top surface of rail, these are placed at an inward slope of 1 in 20 which is known as tilting of rail.

☞ **Advantages of tilting of rails**

(1) The wear of rail head is uniform.

(2) The life of rail and sleeper increases.

(3) The gauge can be properly maintained.

Syllabus Topic : Branching of Tracks-Points and crossings

2.9 Points and Crossing

→ (MSBTE - W-14, S-17, W-17, S-18)

Q. Define points and crossing. W-14, S-17, W-17

Q. Define crossing. S-18

2.9.1 Turn Out

Definition of Turn out : Turn out is a combination of points and crossing by which a train is diverted from one track to another track.

- If the set of points and crossing facilitates the diversion of a train from main track to words right of main route in the facing direction it is known as right hand turn out and if a train from main track is directed to the left of the main route in the facing direction it is called left hand turn out.

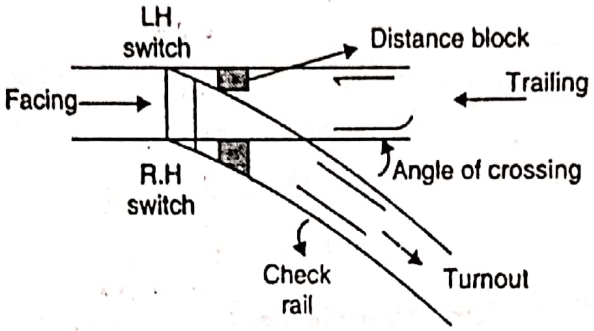


Fig. 2.9.1 : A right hand turn out

Component parts of turn out on :

1. **stock rail pair :** It facilitate smooth working of tongue rail.
2. **A pair of tongue rail :** It facilitate the direction of a train in main track to branch track.
3. **Four lead rails :** It leads the track from heel of switches to toe of crossing.
4. **A vee crossing :** It provides gaps between rails to be crossed so that wheel flanges can pass through them.
5. **Two checkrails :** It check tendency of wheel to climb over crossing.
6. **Stretcher bar :** It connects both tongue rail together.
7. **Slide chair :** It support tongue rails throughout their length and allows lateral movement for changing point.
8. **A point of heel block :** It keep the heel ends of both the tongue rails at fixed distance from stock rail.
9. **Switch tie plate :** It hold the track rigidly to definite gauge.
10. Rods crunks lever for operating point.
11. Locking box for locking system.

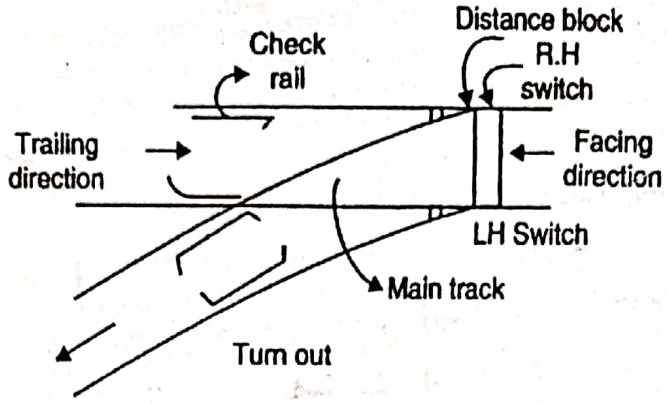


Fig. 2.9.2 : A left hand turn out

2.9.2 Switches

Definition of Switch : *The combination of two tongue rails and two stock rails with necessary fitting is called as switch.*

The inner rail is tongue rail which is thinner in section at toe. These rails are pivoted about point called as wheel, and they are fixed with stretcher bar. The tongue rail and stock rail are rigidly fixed by means of distance block or heel blocks, nuts and bolts.

2.9.3 Simple Split Switch Turnout

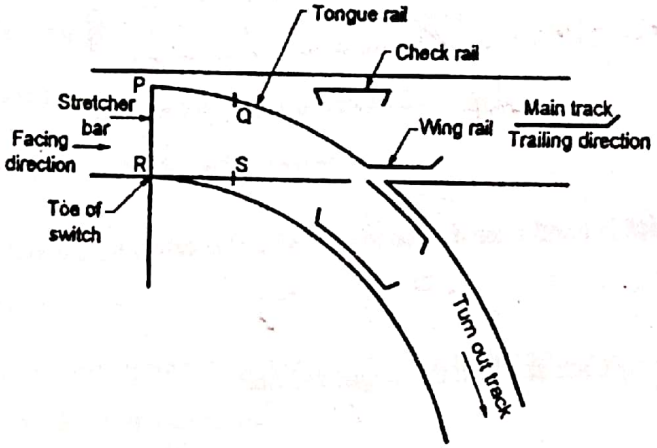


Fig. 2.9.3 : Simple split switch

- These types of switches are mostly used by Indian Railways as it provides more lateral rigidity to turnout.
- It consist of a pair of tongue rail and stock rails. The Fig. 2.9.3 shows tongue rail PQ and RS moves about point QS, to fit properly to respective stock rail. These tongue rails are tapered at their toes P and R.

Syllabus Topic : Components and their Function

2.9.4 Components of Switches

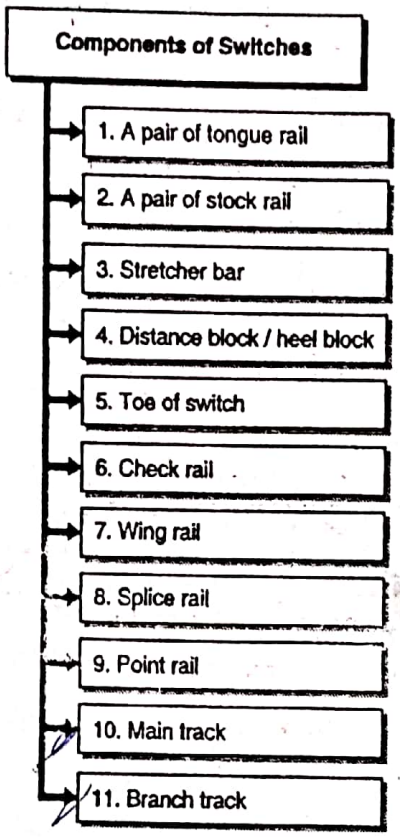


Fig. C2.2 : Components of Switches

1. Tongue rail

The inner tapered rail which is fixed against respective stock rail is called tongue rail.

2. Stock rail

It is the fixed rail in a railway track at which the tongue rail fits.

3. Stretcher bar

It is also called as connecting rod. At these connecting rod, two tongue rails are connected together. It helps tongue rail to move through same distance while changing points.

4. Distance block

These are also called as heel blocks. These are the blocks on which tongue rail and lead rails are bolted to respective stock rail.

5. Toe of switch

The end of tongue rail is tapered and this tapered end is movable is known as toe of switch.

➜ **6. Check rail**

The rail length generally is provided on opposite sides of crossing to check tendency of wheel to climb over t crossing is known as check rail.

➜ **7. Wing rail**

The bent up length of rail used in front of nose of crossing which helps in channelising train wheels in proper route known as wing rail.

➜ **8. Splice rail**

Splice rail is the rail of branch track which meet point rail at nose of crossing.

➜ **9. Point rail**

The rail of main railway track forming nose of crossing is called a point rail.

➜ **10. Main track**

It is the main track from which a train is to be diverted.

➜ **11. Branch track**

It is the track on which train is diverted from a main track.

☞ **Functions of various components**

(1) **Stock rails :** Stock rails helps in smooth working of tongue rails.

(2) **Tongue rails :** Tongue rails facilitate the diversion of train from main track to branch track.

(3) **Heel blocks :** It keep heel ends of both tongue rails at fixed distance from their respective stock rails.

(4) **Check rails :** These rails check the tendency of wheels to climb over crossing.

(5) **Stretcher bar :** It is connected to toes of tongue rails and keep them at a same distance while chaining the points.

(6) **Tie plate :** It hold the track rigidly to the definite gauge at the toe of switches.

(7) **Rods cranks :** It helps in operating points.

(8) **Locking box bare :** For locking system.

Syllabus Topic : Track Junctions - Crossovers, Scissor cross over, Diamond crossing, Track triangle

2.9.5 Line Sketches of Track Junction Cross-over

➜ (MSBTE - W-14

Q. Draw the line sketch of diamond crossing and cross-over ? W-14

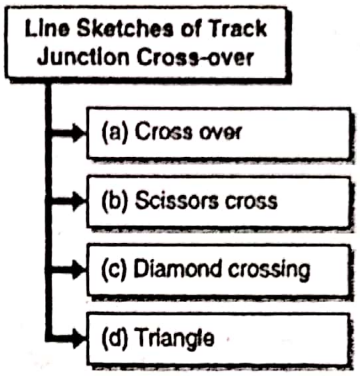


Fig. C2.3 : Line Sketches of Track Junction Cross-over

➔ **(a) Cross over**

➔ **(MSBTE - W-16)**

Q. Draw the line sketch cross over. **W-16**

Definition of Cross over : The arrangement is made for transferring a train from one track to the other is called as cross over.

- See Fig. 2.9.3(a) for better understanding.
- In such case, a slightly diverging tracks is provided between two adjacent parallel track so as to change the track of train.
- Cross over consists of two pairs of switches, two acute angle crossings and four check rails.
- When the train approaches from one direction only, then cross over is useful to transfer the train from one track to the other track which may be parallel or slightly diverging.
- Line sketches of track junction cross-over are shown in Fig. 2.9.3(a), (b), (c) and (d).

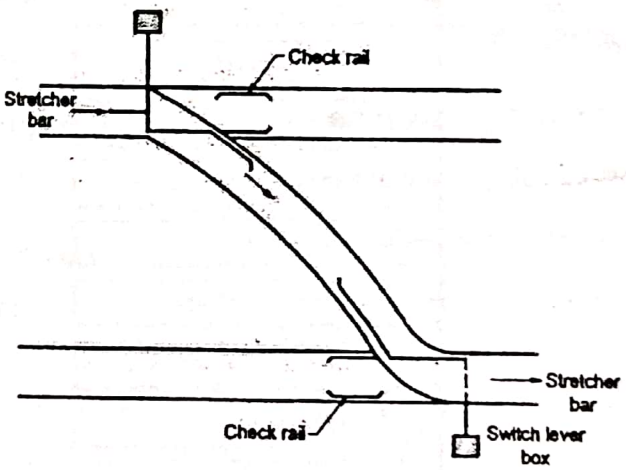


Fig. 2.9.3(a) : Layout of crossover

➔ **(b) Scissors cross**

➔ **(MSBTE - S-16)**

Q. Draw a neat line sketch of scissor cross over. **S-16**

Definition of Scissors Cross** – The arrangement of two cross overs which overlaps each other and provided between two adjacent parallel or slightly diverging tracks so as to change the track for trains when approaches from both the direction is called as **scissors cross.

– See Fig. 2.9.3(b) for details.

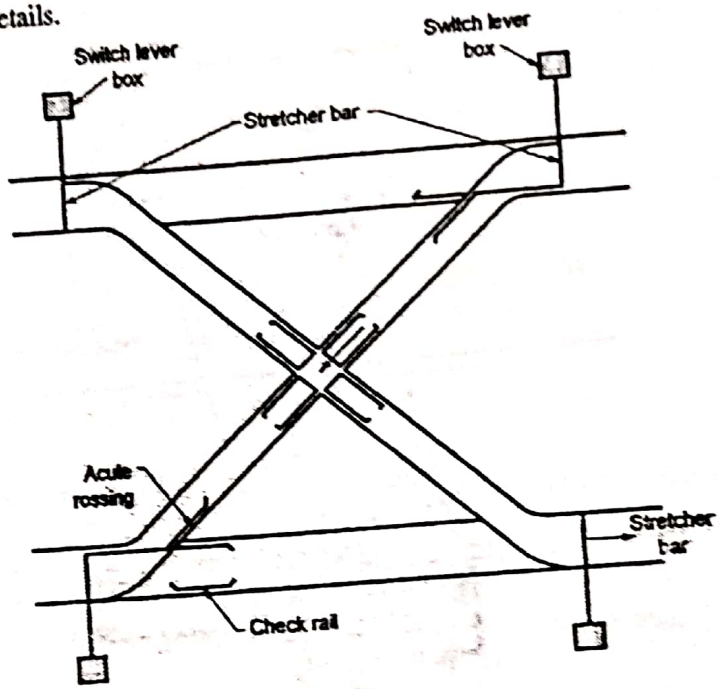


Fig. 2.9.3(b) : Layout of scissors cross

– It consists of the following components :

1. Four parts of switches.
2. Four acute angle crossing and a diamond crossing.
3. Check rails.
4. Straight lengths.

– When enough space for two separate cross overs is not available and when shunting operations are very rare, then scissors cross overs are more advantageous.

– It is expensive and need maintenance which should be done carefully.

→ (c) Diamond crossing

→ (MSBTE - W-14, S-16, W-16, S-17, S-18)

- Q. Draw neat sketch of diamond crossing. W-14
- Q. Draw a neat line sketch of Diamond crossing. S-16
- Q. Draw the line sketch diamond crossing. W-16
- Q. Draw neat sketch of neatly diamond crossing. S-17
- Q. Draw line sketches of points and crossing-scissor cross over and diamond crossing. S-18

Definition of Diamond Crossing : *The crossing in which one track crosses with another track having same or different gauge at an obtuse angle is called as diamond crossing. It is also called an obtuse angle crossing.*

- [See Fig. 2.9.3(c) for details.]
- It is called as diamond crossing due to the shape of its layout. It consists of two acute angle and two obtuse angles crossing as shown in Fig. 2.9.3(c).

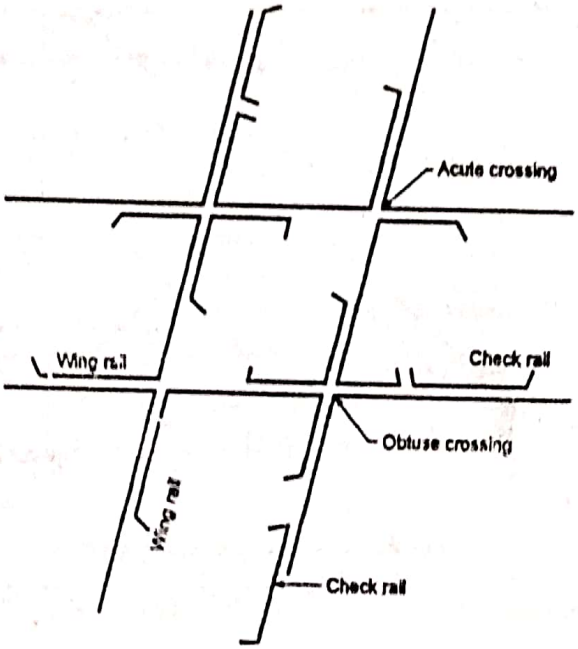


Fig. 2.9.3(c) : Diamond crossing

(d) Triangle

Definition of Triangle : *The arrangement in which a triangular shape of track is made for changing the directions of engines is called as triangle.*

- See Fig. 2.9.3(d).

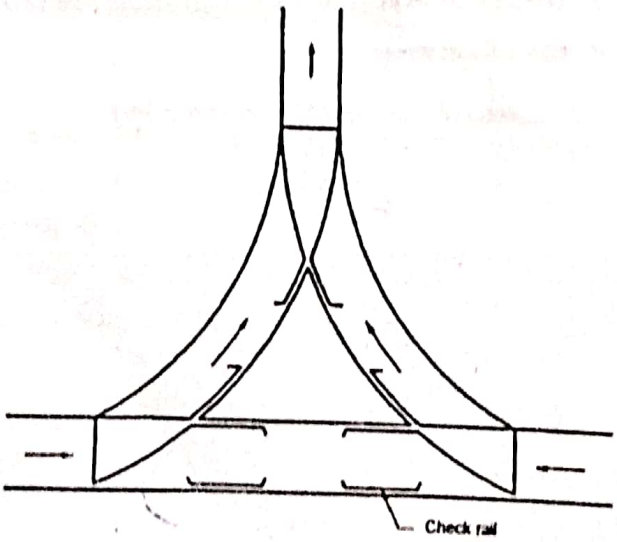


Fig. 2.9.3(d) : Layout of triangle

- It consists of following components :

1. Three length of track in the form of a triangle.
2. Three acute angle crossings.
3. Three pair of switches.
4. Six check rails etc.

- When enough area is available, then triangle is used for changing the direction of engines.

Syllabus Topic : Inspection of Points and Crossing

2.9.6 Inspection of Points and Crossing

Inspection of points and crossing should be done systematically and thoroughly and after inspection the defects should be rectified immediately.

The various items to be checked during inspections are as follows :

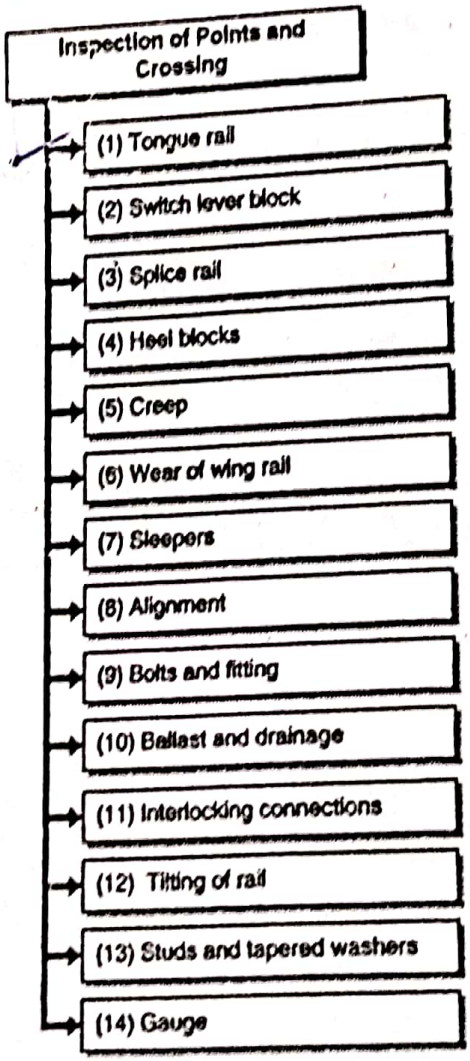


Fig. C2.4 : Inspection of Points and Crossing

→ **(2) Switch lever block**

The working should be checked properly.

→ **(3) Splice rail**

The movement of splice rail should be checked.

→ **(4) Heel blocks**

The tightness of nuts and bolts should be checked and in loose type switches front bolt should be sufficiently loose so as to allow necessary lateral movement.

→ **(5) Creep**

Stock rails should be check for creep.

→ **(6) Wear of wing rail**

Wear of wing rail should be checked near throat and brighteners of nose and if found worn out then welding may be done.

→ **(7) Sleepers**

The packing of sleepers should be checked.

→ **(8) Alignment**

Alignment should be check regularly as far as straight and turnout track is considered.

→ **(9) Bolts and fitting**

These should be tight except few heel bolts.

→ **(10) Ballast and drainage**

Sufficient and good quality ballast should be there and special care for drainage should be checked.

→ **(11) Interlocking connections**

Proper functioning of interlocking connections should be checked.

→ **(12) Tilting of rail**

It should be checked and if required make corrections.

→ **(13) Studs and tapered washers**

These should be checked properly.

→ **(14) Gauge**

Thorough checking should be done at toe centre and heel of switch, the nose and heel of crossing.

2.10 Railway Station

Definition of Railway Station : *It is the place on a railway track where trains are stopped for exchange of passengers, goods and for control of train movements etc. are known as railway station.*

Syllabus Topic : Factors Affecting Site Selection For Railway Station

2.10.1 Site Selection for Railway Station

→ (MSBTE - S-15, W-17)

Q. State the factors affecting site selection of railway station. S-15

Q. State points to be considered while selection of site for a railway station. W-17

The following points should be taken into consideration while selecting site for railway station :

- The site should be near to the town.
- It should have proper approach roads connecting nearby town.
- From future point of view for expansion and development, sufficient land area should be available near the site.
- Sufficient quantity of drinkable water is available nearby site.
- Station should fulfill requirement from all point of view. i.e. civil military requirement.
- Land should be fairly level ground.

Syllabus Topic : Requirement of Railway Station

2.10.2 Requirement of a Railway Station

→ (MSBTE - S-16)

Q. What are the requirements of railway station ? S-16

It should satisfy the following requirement :

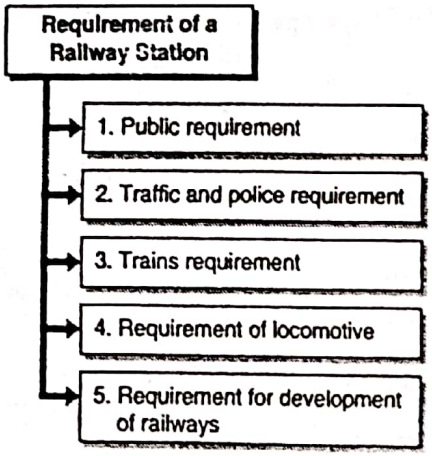


Fig. C2.5 : Requirement of a Railway Station

➜ **(1) Public requirement**

- A booking office for issuing tickets and for booking of goods.
- Passenger and goods platform.
- Waiting rooms and retiring rooms.
- Name board of station.
- Arrangement for drinking water.
- W/C and bath room arrangement.
- Suitable light arrangement.
- An enquiry office.
- Microphones to announce arrival and departure of train.
- Others like telephone, stalls, telegraph office, police help etc.

➜ **(2) Traffic and police requirement**

- Staffroom.
- Retiring room and rest houses.
- Residential quarters for railway staff.

➜ **(3) Trains requirement**

The following arrangement should be there for the control of trains movement :

- Arrangement for controlling the movement of trains by signal.
- Sufficient number of siding for receiving, sorting, storing and despatching trains.
- Sufficient number of platform for handing passenger and goods.

➜ **(4) Requirement of locomotive**

The Railway station should provide following facilities for locomotives :

- For changing the direction of engine; a turn table must be there.
- Arrangement for cleaning, examining, inspecting and maintaining the locomotives such as ash pits, inspection pits, etc. should be provided.
- Coal lifting cranes, water columns for supply of fuel and water should be provided.

➜ **(5) Requirement for development of railways**

The railway station should provide the following facilities for development of railway :

- Easy and comfortable approach roads.
- Big waiting halls.

- Guide map of city separate arrival and departure of trains.
- Sufficient number of coolies on station platform.

Syllabus Topic : Important Technical Terms

2.10.3 Important Technical Term

1. **Running line :** The railway track used by train for entering or leaving station or when passing through a station or between station is called running line.
2. **Main line :** The railway track is used for running trains through stations is called main link.
3. **Loop line :** It is additional railway track connected to main line at both of its end. It permit faster train to overtake slow train.
4. **Siding :** The additional track connected to main track at one of its end is called siding.

Syllabus Topic : Types of Railway Station

2.10.4 Types of Railway Station

→ (MSBTE - W-16)

Q. State different types of railway stations. W-16

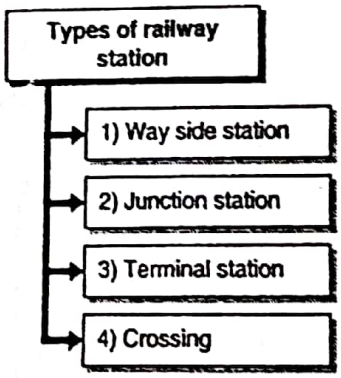


Fig. C2.6 : Types of railway station

→ **(1) Way side stations**

- These type of stations are located on running lines. They are having an arrangement to facilitate faster train to overtake a slower train. For this; loop line and siding are provided.
- Way side station are further divided into following types :

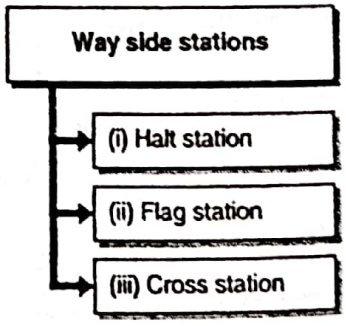


Fig. C2.7 : Way side Station

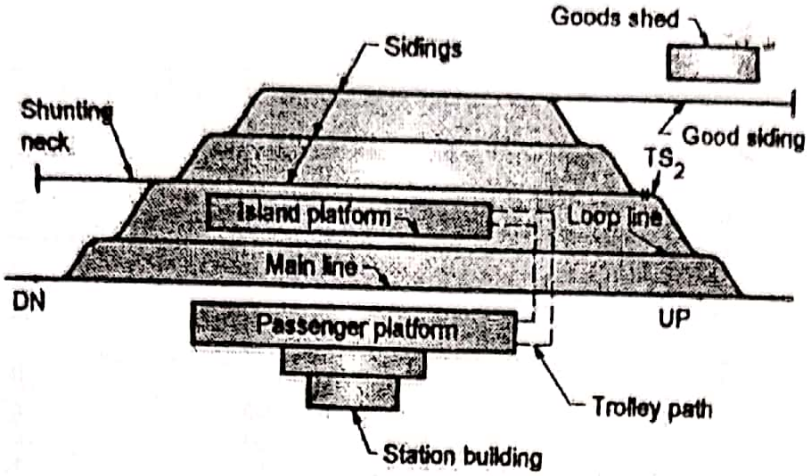


Fig. 2.10.1 : Way side station in single line

➜ **(i) Halt station**

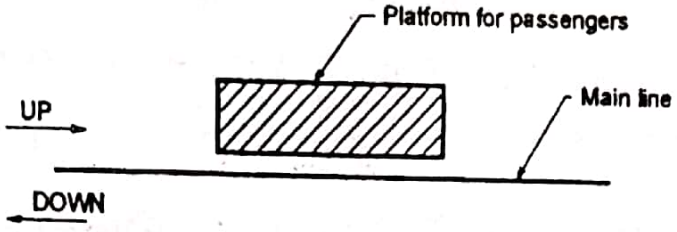
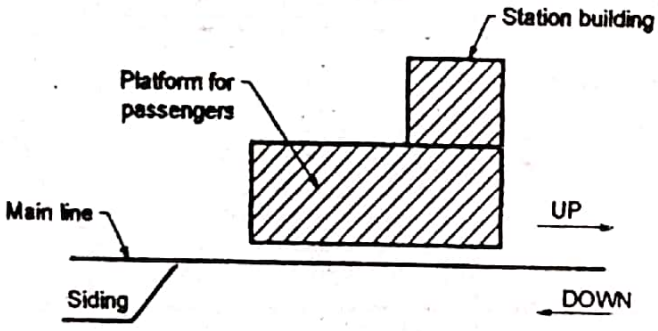


Fig. 2.10.2 : Halt station

- In this type of way side station, there is platform with name board of the station but don't It is just stopping place for entrain and detrain of passenger.
- In some cases, tickets are issued by T. T. and for facility of issuing tickets, a separate comp
- This type of way station is provided where traffic is less.

➜ **(ii) Flag station**

- In this type of way stations, movement of trains is controlled by flag hence name is given a
- In this type of way station, building and staffs are provided. At some stations telegraph facil
- At some flag stations, sidings are provided for detachment of wagon for loading and unload



☞ Crossing type way side station on single line track

- In this type of station trains from opposite directions can cross each other.
- It consist of one main line, one loop line, a passenger platform, station building, goods platform, goods loop etc.

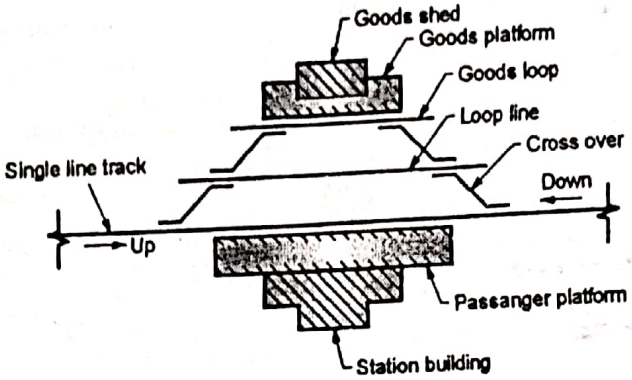
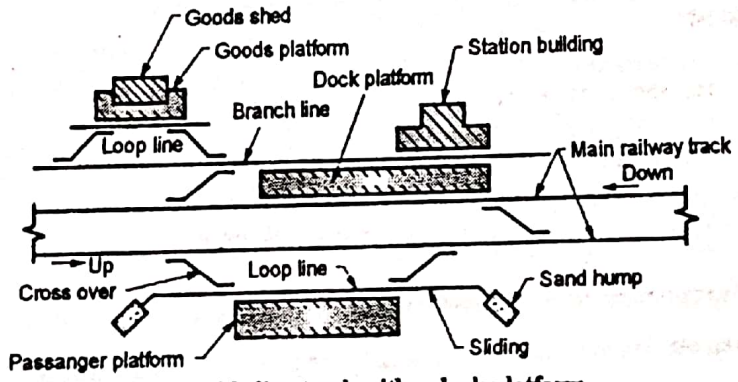


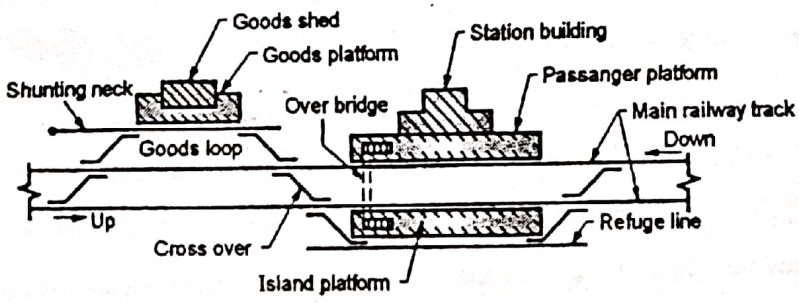
Fig. 2.10.4 : Layout of crossing type wayside station on a single line track

☞ Crossing type way station on double line track

- In this type of station, it permits the train from opposite direction to cross another and also allows fast moving train to overtake a slow goods train.
- It consist of two main line station building, passenger platform, crossover an over bridge to facilitate the movement of passenger, are fugue line for fast moving train to overtake slow moving train. A goods loop, goods platform and shunting yard and sand hump.



(a) Double line track with a dock platform



(b) Double line track with island platform

Fig. 2.10.5 : Layout of a crossing type wayside station on a double track line

Crossing type way side station on a triple line track

- In this type of way station, a main line consist of two loop line one on either side.
- It consist of one main line, two last line, a station building, one platform for passenger, one crossover fast over bridge, yard hump etc.

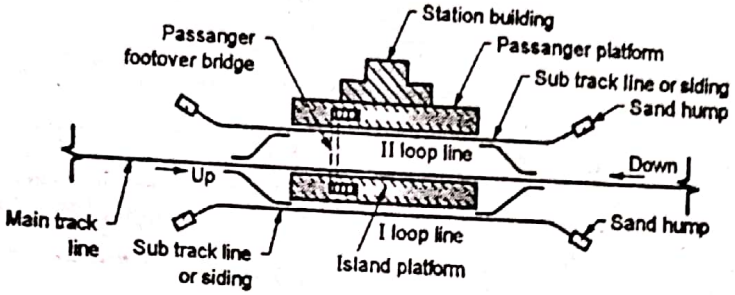


Fig. 2.10.6 : Layout of a crossing type wayside station on a triple line track

(2) Junction station

- In this type of stations, lines from three or more directions meet. The junction may have minimum one main line, one branch line or two main line, two branch line etc.
- This types of stations are very helpful from passenger and goods point of view to change over from one line or direction to other.

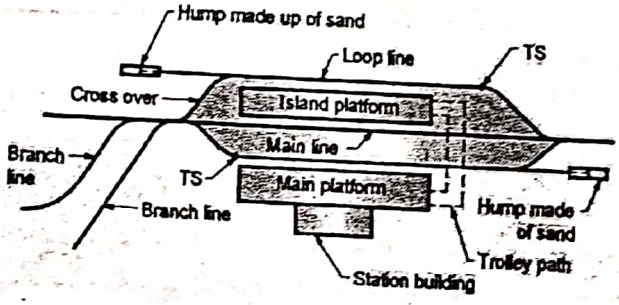


Fig. 2.10.7 : Junction

- For smooth traffic minimum three platforms will be required and it consist of turn table, locomotive shed, goods shed, retiring room etc. The rail lines may be of different gauges or of same gauges.

(3) Terminal station

Definition of Terminal station : *The dead end of incoming track, or the station at which railway line ends or terminates is called as terminal station.*

- At terminal station arrangements like hydraulic buffers, turn table, number of siding examination pits, etc are provided and the area is directly attached with the road.
- Terminal station facilities like servicing of engines and vehicles, reversing of engines and for marshalling vehicles are provided.

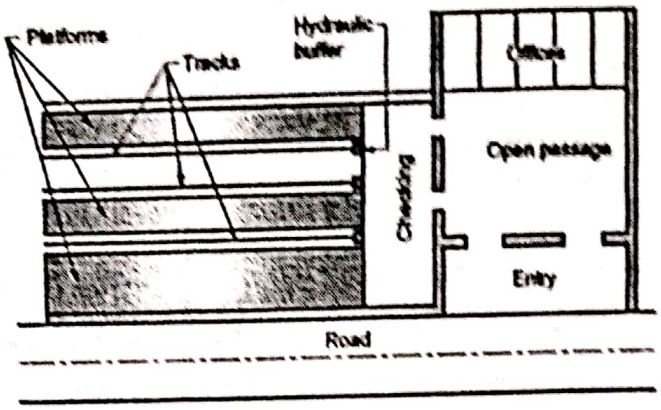


Fig. 2.10.8 : Terminal

Syllabus Topic : Station yard

2.11 Station Yards

- It is a place on the track where train stops for clearing passengers and goods traffic and proceed only after clearan from station authorities.
- In this yards, movement of train is controlled by prescribed norms, rules and regulations and signals or spec instruction.

Syllabus Topic : Station yard Classification - Passenger, goods, locomotive and marshalling yards, function & drawbacks of marshalling yard.

2.11.1 Types of Station Yard

→ (MSBTE-W-

Q. Enlist four types of yards

The station yards are classified as under :

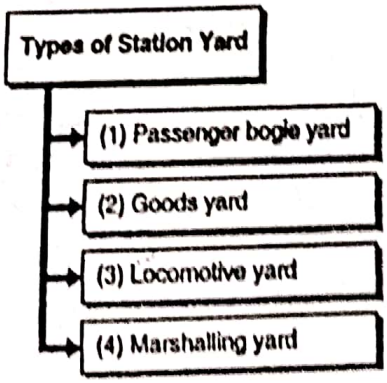


Fig. C2.8 : Types of Station Yard

→ **(1) Passenger bogie yard**

The safe movement of passengers and boggies are the prime object of these yards.

The main objects of these yards are :

- To provide the safe movement of passengers.
- To provide facilities like banking enquiry and waiting place for passengers.

At these yards extra boggies can be attached to train or detached from train and their cleaning, washing and storing is done.

It consist of mainly the following facilities : Booking office, signal cabin, clock room, number of platform parking zones, waiting room, telegraph office, telephone booths, elevators; number of siding, washing line, shunting lines and battery charging facilities.

➜ **(2) Goods yard**

- The yard where receiving, loading; unloading delivery of goods is done is called as goods yard. All types of station except flag and half station are provided with goods yard.
- The ideal requirement for goods yard are as follows : Approach way for outer vehicles for loading and unloading, booking office, weigh bridge to weigh wagons and carts, weighing machine, cranes for loading and unloading number of siding, platforms etc.

➜ **(3) Locomotive yard**

➜ (MSBTE - W-17)

Q. Explain purpose of locomotive yards. State the requirements of locomotive yards. Draw a layout of rectangular Locomotive Yards.

☞ ***Definition of Locomotive Yard:*** *The yard where all facilities for maintenance like cooling, watering, repairing, oiling, cleaning etc. are provided for locomotive and are called as locomotive yard.*

These are placed generally on same side of marshalling yard and at junction station at suitable interval. These yards are used for repairing, cleaning, oiling, servicing etc. They are either circular or rectangular but normally rectangular type is preferred. If circular type is adopted then there must be provision of turn table.

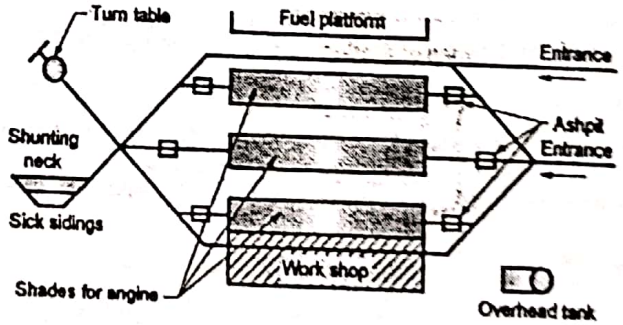


Fig. 2.11.1 : Loco - yard

☞ **Requirements of locomotive yard**

The following are the requirements of locomotive yard :

- It should be properly arranged so that it should carry maintenance in proper sequence.

- It must be located near passenger or goods yard.
- For lifting engines; there should be facility of hydraulic jack.
- It should be provided with locoshed, water column and fuel platform.
- It should have overhead tank for supply of water with various pressure.
- It should have sufficient space for future expansion.
- It should be provided with ash pits, inspection pits.

☞ **Difference Between Goods Yard and Locomotive Yard**

Sr. No.	Goods yard	Locomotive yard
1.	The yard where receiving loading unloading delivery of goods is done is called as goods yard.	The yard where all facilities for maintenance like cooling, repairing, watering, repairing oiling cleaning etc. are provided for locomotive are called as locomotive yard.
2.	No need of water column.	It should be provided with water column.
3.	No need for ash pit and inspection chamber.	Ash pits and inspection chambers are required.

➜ **(4) Marshalling yard**

➜ **(MSBTE -S-15, W-15, S-16, S-18)**

Q. Explain functions of Marshalling yard with sketch. **S-15**
Q. Explain with neat sketch the functioning of hump yards. **W-15**
Q. Enlist the types of Marshalling yard. **S-16**
Q. What is Marshalling yard ? State its functions and different types. **S-18**

- It is like distribution centre for trains. In this yard trains and goods are received, sorted and new trains are sorted and dispatched.
- In this yard from different lines; empty wagons are received. These wagons are then separated, sorted for different destination and dispatched to respective destination. They are arranged in order of station so that they can be detached smoothly.

☞ **Functions and drawbacks of Marshalling yard**

The main functions of marshalling yard are as follows :

- Sorting of wagons
- Reception of empty or loaded wagon
- Departure of wagons in form of train

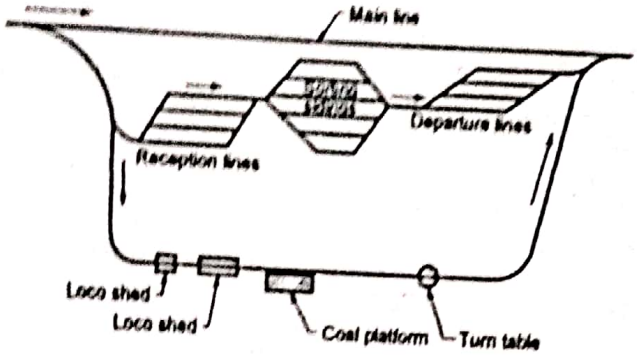


Fig. 2.11.2 : Marshalling yard

Types of Marshalling yard

Following are the different types of marshalling yard :

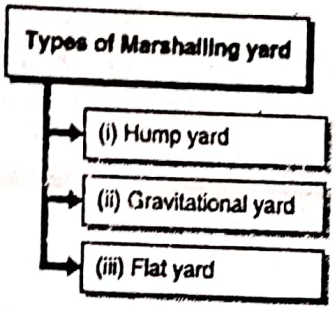


Fig. C2.9 : Types of Marshalling yard

(I) Hump yard

In this type of yard. Humps are constructed and wagons are released from hump point to roll down the flatter gradient these are mostly used due to economy and no power is required to move wagons.

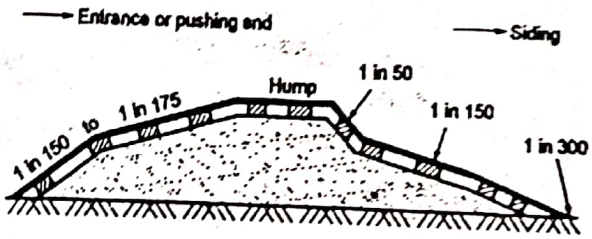


Fig. 2.11.3 : Hump yard

(II) Gravitational yard

In this type of yard; wagons are moved into various dead ends sidings with gravity only. For that purpose; tracks are laid with gradients. The movement is controlled by wagon brakes manually.

(iii) Flat yard

Where space is restricted these types of yards are preferred. In this type of marshalling yard, the tracks are laid on horizontal ground and total surface of yard is almost levelled and entire sorting work and movement of work is carried out by engines.

2.11.2 Water Column

→ (MSBTE - S-16)

Q. Explain water column with neat sketch. S-16

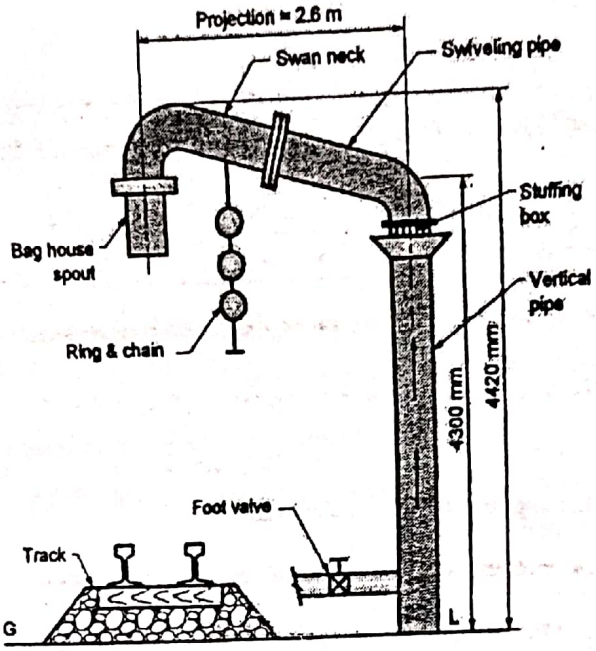


Fig. 2.11.4 : Water column

- To meet various purposes, station yard is equipped with number of equipment. Water column is one of them.
- These are provided for supply of water to locomotives.
- They are provided at the end of platform so that engines can take water while halting on station. Sometimes they are installed on ash pits so that engine may remove ash simultaneously.
- It consists of vertical pipe and attached with either horizontal or swan neck pipe with movable adjustment as foot valve is provided to regulate flow of water.
- In water column the height of water column is 4.42 m above ground and projection from vertical pipe is 2.25 m. So as to reach water into the tank without splashing, funnel name bag nose spout is provided at the end of swivelling pipe.

Syllabus Topic : Track Maintenance

2.12 Track Maintenance

☞ ***Definition of Track Maintenance :*** *The method of keeping the component of permanent way i.e. ballast, sleepers, rails and their fitting in good condition so as to provide safe and smooth movement of traffic is called as* ***track maintenance.***

- Irrespective of well designed and well constructed track is there, periodic maintenance is essential from safety and convenience point of view.

2.12.1 Object of Track Maintenance

The main object is to provide safe and convenient movement of passenger.

Syllabus Topic : Track Maintenance Necessity

2.12.2 Necessity of Track Maintenance

→ (MSBTE - W-16, S-17, S-18)

Q. State the necessity of railway track maintenance. W-16
Q. State the necessity of track maintenance. S-17
Q. State any four necessities of periodic track maintenance. S-18

☞ **The necessity of track maintenance arises due to the following reason**

- Due to weathering effects, the wear and tear of track component is likely to take place.
- The new track may disturbed due to heavy axle load, frequency in trains. So it has to be checked frequently and periodically for its alignment, gauge and surface level of rails.
- At points and crossings on curves there might be chances of deterioration due to high speed and heavy wheel loads.
- Due to moving loads there may be loss of ballast, wear and tear of different parts of track.

Syllabus Topic : Track Maintenance Classification

2.12.3 Types of Track Maintenance

→ (MSBTE - S-15, W-15)

Q. State various types of track maintenance. S-15
Q. State the types of track maintenance. W-15

Maintenance of track is divided into the following categories.

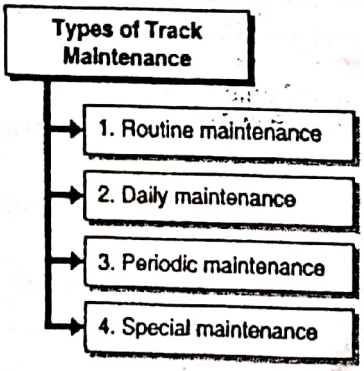


Fig. C2.10 : Types of Track Maintenance

➜ **(1) Routine maintenance**

Definition of routine maintenance : *The maintenance carried out daily or periodica routine maintenance.*

It again classified into two types :

- Daily maintenance
- Periodic maintenance

➜ **(2) Daily maintenance**

Definition of daily maintenance : *The maintenance carried out through out year is maintenance.*

It mainly includes the following operations :

- Daily inspection of the track.
- Track fitting - tightening of loose fish bolt, loose keys; cotters etc.
- Picking up slack.
- Oiling of slide chair at points and crossing.
- Cleaning of flange way.

All these daily maintenance is done by the 'gang'. For this purpose; railway track is divided into s length generally 5-6 km and each gang is deputed for this section.

➜ **(3) Periodic maintenance**

Definition of Periodic Maintenance : *The track maintenance carried out by depar after an interval of 2 to 3 years is called periodic maintenance.*

It involves following maintenance job :

- Maintenance of alignment of track.
- Maintenance of components of track.
- Maintenance of rails.
- Maintenance of gauges.

➔ **(4) Special maintenance**

➔ **(MSBTE - S-15)**

Q. Explain special maintenance. **S-15**

Definition of Special maintenance : *The track maintenance is carried out whenever necessity arises is called special maintenance.*

- These types of maintenance arises in case of derailment or accident of train when some components are to be replaced due to wear and tear.
- It includes mainly : Replacement of all types of defective components i.e. sleepers, rails, fixture and fastening etc.

Syllabus Topic : Organisation of Track Maintenance

2.12.4 Organisation for Track Maintenance

- In this organisation Chief Engineer is main and under Chief Engineer; there is Deputy Chief Engineer. Under this chief engineer; there is District and or divisional Engineer.
- He is in charge of approximately 300 to 650 km length of railway track and station. The length of track under divisional engineer depends upon the intensity of traffic, importance of place and tracks.
- Under each divisional engineer there are number of Resident or Assistant engineer. Under each Assistant or Resident engineer; there are number of Permanent way inspectors (P.W.I s) and Inspectors of works (I.O.W s).
- Permanent way inspector is incharge of 80 to 120 km of railway track and under each permanent engineer there are three to four Assistant permanent way inspectors and under each Assistant permanent way inspector (APWIs) there are 10 to 15 gangs.
- Each gang consist of 8 to 10 gang man (workers), one gang mates and one key man. Gang mate is incharge of one gang.
- The inspector of works (I.O.W) looks after maintenance of station building and rest houses etc.

☞ **Track maintenance organisation**

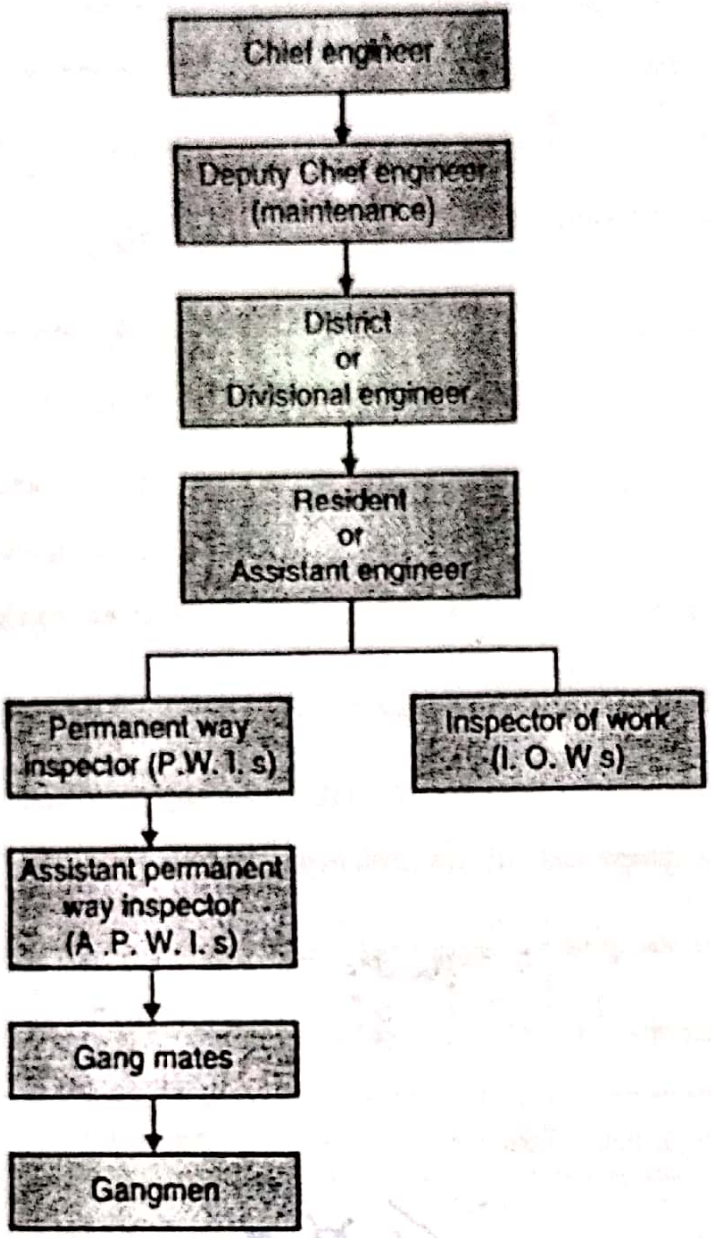


Fig. C2.11 : Track maintenance organisation

Syllabus Topic : Steps involved in construction of r

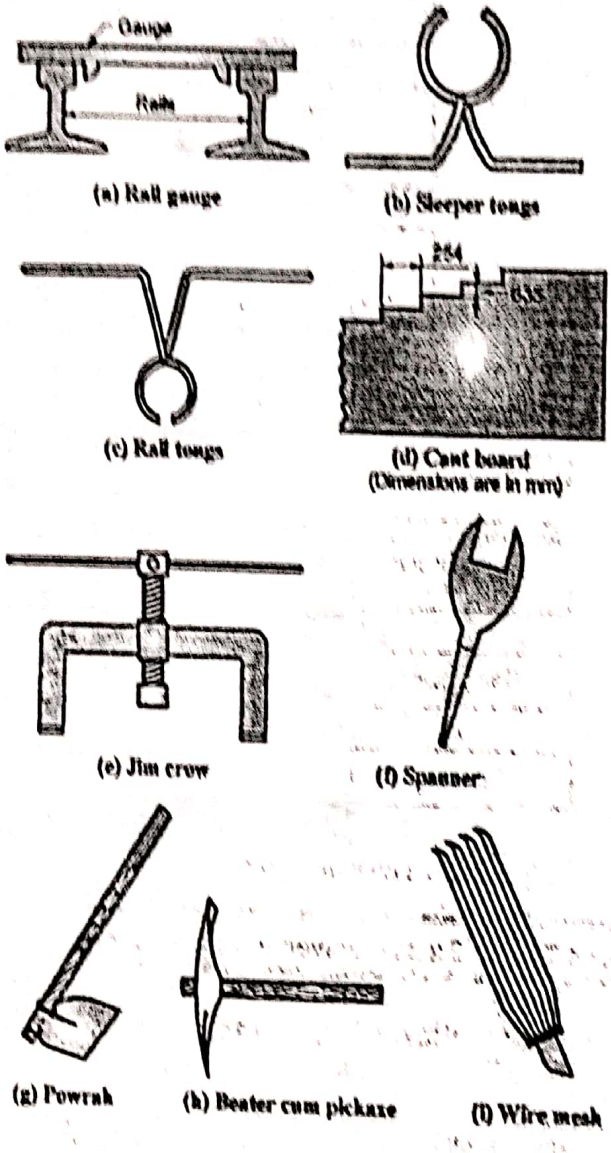
2.13 Steps involved in Construction of Rail Track

Depending upon traffic, rolling stock, signaling and other facilities to be provide railway lines are constructed in three stages.

1. Stage I : The

Syllabus Topic : Tools Required for Track Maintenance with their Function

2.14 Tools Required During Track Maintenance



(a) Rail gauge (b) Sleeper tongs

(c) Rail tongs (d) Cant board (Dimensions are in mm)

(e) Jim crow (f) Spanner

(g) Powrah (h) Beater cum pickaxe (i) Wire mesh

Fig. 2.14.1 : Tools for track maintenance

The following are the tools required during track maintenance

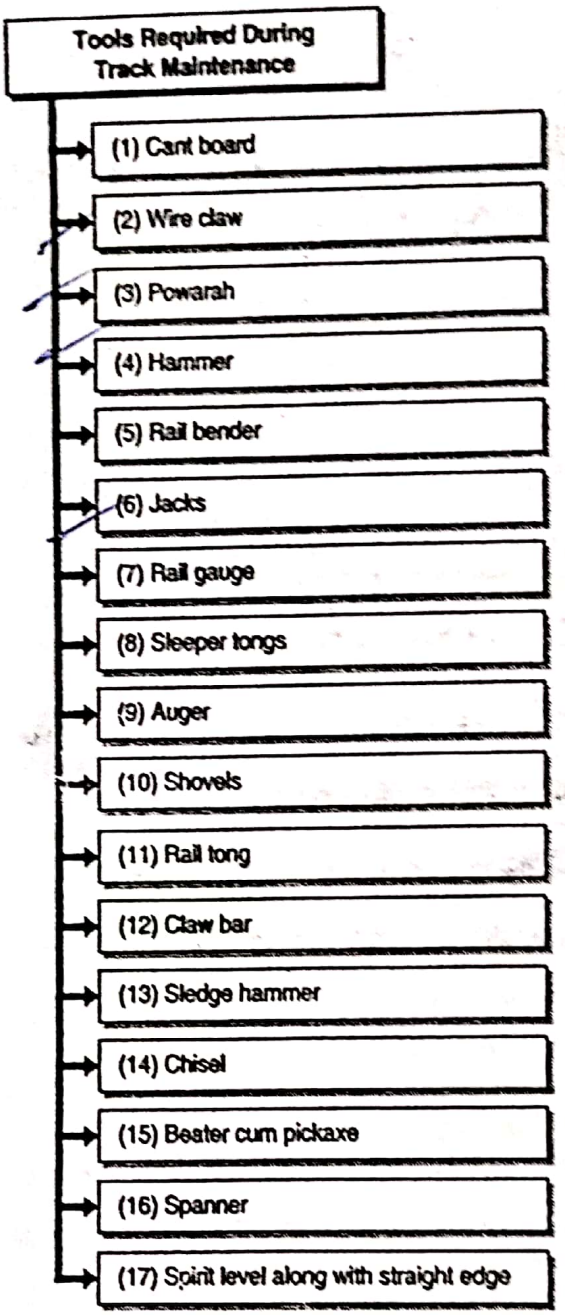


Fig. C2.12 : Tools Required During Track Maintenance

➜ **(1) Cant board**

It is used to check cant on curve.

➜ **(2) Wire claw**

It is used to clean the ballast.

➜ **(3) Powarah**

It is used to spread ballast.

➜ **(4) Hammer**

It is used to drive spikes.

➜ **(5) Rail bender**

The main function of rail bender is to bend rail to keep them in desired position.

➜ **(6) Jacks**

The main function of jack is to lift the track.

➜ **(7) Rail gauge**

To check the rail gauge width.

➜ **(8) Sleeper tongs**

It is used to lift the sleepers.

➜ **(9) Auger**

It is used to drill holes.

➜ **(10) Shovels**

It is used to handle ballast.

➜ **(11) Rail tong**

It is used to lift rail.

➜ **(12) Claw bar**

It is used to take out spikes from sleeper.

➜ **(13) Sledge hammer**

It is used to cut rails by chisel.

➜ **(14) Chisel**

It is used to cut the rails.

➜ **(15) Beater cum pickaxe**

It is used to pack ballast under the sleepers.

Syllabus Topic : Duties of Permanent Way Inspector

2.15 Duties of Permanent Way Inspector

→ (MSBTE - W-15, W-16, W-17, S-18, W-18, S-19, W-19)

Q. Explain the duties of permanent way inspector. [2]

Q. State any four characteristics of permanent way inspector. [2]

Q. State the duties of permanent way inspector. [2]

- He is in charge of his section and he has to keep all record of programme to rectify defects and make maintenance of
- He has to prepare estimates of the maintenance of work. It is his responsibility to distribute the work to every
  gang mate and key man and to see that whether they perform their duties correctly.
- He has to inspect his section at least twice in a week and he should check the gauge, super elevation, depth of
  etc.
- If he founds any defect he has to make necessary corrections. He has to keep points and crossing in good condition
  he has to look after station yards also.

Syllabus Topic : Duties of Gang Mate

2.15.1 Duties of Gang Mate

→ (MSBTE - S-17, S-18, W-18, S-19, W-19)

Q. State the duties of gang mate. [3]

Q. State any two duties of Ganger. [3]

Definition of Gang mate : Gang mate means the person incharge of gang of work men employed on permanent way.

- He is responsible for the maintenance of track.
- It is his duty to arrange for tools and other requirement for his gang.
- He has to allot duties to each of his gang man and to check their work.
- He has to maintain record of work, reports of key man.

Syllabus Topic : Duties of Key Man

2.15.2 Duties of Key Man

- He is responsible for keeping all fastenings and rail joint in good condition i.e. fish bolt, spikes sleepers, keys etc.
- It is his duty to grease fish plates and fish bolts. If he observes serious defect, he should immediately report to his authorities in absence of gang mate.
- He has to perform his duties.

CHAPTER 3

Overview of Bridge Engineering

16 marks

Syllabus

- Classification of bridges according to span, purpose, material, life, alignment, H.F.L., Loading, level of bridge floor.
- Site selection and Investigation, Factors affecting selection of site for bridge. Bridge alignment-Factors controlling.
- Important technical terms- waterway, economic span, afflux, scouring, freeboard, cut water, ease water.
- Component parts of bridge: pier, abutment, wing wall, foundation, bearing
- Piers-function, requirements, types.
- Abutment – function, types.
- Wing walls – functions and types.
- Foundation – function, types of bridge foundations
- Bearing – functions, types of bearing

3.1 Bridge Engineering

Definition of Bridge Engineering : The branch of Civil Engineering which deals with the design, construction and maintenance of bridges is called 'Bridge Engineering'.

A bridge is an structure which facilitate communication route to cross an obstacle in the form of low ground or a stream or a river without closing the way beneath.

Syllabus Topic : Classification of bridges according to span, purpose, material, life, alignment, H.F.L., Loading, level of bridge floor

3.1.1 Classification of Bridges

→ (MSBTE - W-15, S-16, W-16, S-17)

Q. List the types of bridges as per alignment. **W-15**

Q. Classify the bridges according to function, material, span length and alignment. **S-16, S-17**

Q. Classify bridges according to function, materials, span and according to level of bridge floor. **W-16**

Bridge can be classified into various types, depending upon the following factors

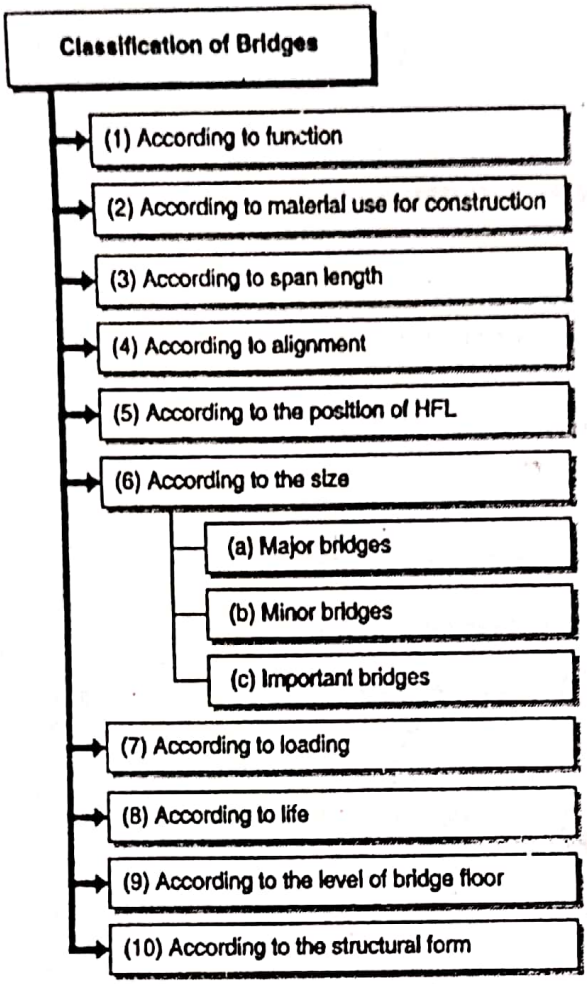


Fig. C3.1 : Classification of Bridges

➜ **(1) According to function**

(a) Aqueducts (b) Viaducts

(c) Grade separations (d) Foot bridge

(e) Highway bridges (f) Railway bridges

➜ **(2) According to material use for construction**

(a) Timber bridges (b) Masonry bridges

(c) Iron and steel bridges (d) Reinforced cement concrete bridges

(e) Prestressed concrete bridge

➜ **(3) According to span length**

(a) Culverts (b) Minor bridges

(c) Major bridges (d) Long span bridges

➜ **(4) According to alignment**

(a) Straight bridge (b) Skew bridge

→ **(5) According to the position of HFL**

(a) Submersible bridge (b) Non-submersible

→ **(6) According to the size**

- The classification of bridge with reference to the size has been done differently in our country by the road and rail engineers.
- According to the road engineers, the bridge are classified on the basis of lineal water way as follows

(a) Culvert upto 6 m. (b) Minor bridge 6 m to 30 m.

(c) Major bridge over 30 m.

- According to the Indian Railways the bridges are classified as follows :

(a) Major bridges : Total water way more than 18 m or having any span of clear water way of 12 m or over.

(b) Minor bridges : Total waterway less than 18 m or having any span of clear water way less than 12 m.

(c) Important bridges : Those major bridges having total waterway of 18 m and more or more the 110 m.

→ **(7) According to loading**

(a) Class 'AA' bridges (b) Class 'A' bridges

(c) Class 'B' bridges

→ **(8) According to life**

(a) Temporary bridges (b) Permanent bridges

→ **(9) According to the level of bridge floor**

(a) Deck bridge (b) Semi- through bridge

(c) Through bridge

→ **(10) According to the structural form**

(a) Beam type bridge : Such as R. C. C. tee beam, balance cantilever, steel girder etc.

(b) Arch type bridge : Such as barrel and rib type, filled spandrel etc.

(c) Suspension type bridge.

Syllabus Topic : Site Selection and Investigation

3.2 Site Selection and Investigation

- The first step in laying out a bridge is the selection of its site.
- In order to ensure safety of the bridge structure and to achieve economy in its construction a suitable site for bridge must be selected.
- The careful investigation at the preliminary stage avoids many errors at a later stage

Syllabus Topic : Factors affecting selection of site for bridge

3.3 Factors Affecting Selection of Site of a Bridge

→ (MSBTE - W-14, S-15, W-15, S-16, S-17

- Q. State factors affecting site selection for bridges.
- Q. Explain various data required for design of bridge.
- Q. What are the informations required to be collected for design data of bridges ?
- Q. List any eight factors needed for selection of ideal site for bridge.
- Q. Explain the factors controlling selection of ideal site for bridge.
- Q. Describe in brief factors affecting bridge site selection.
- Q. Explain eight factors affecting selection of site of bridge with their importance.

Following are the factors to be carefully considered while selecting the ideal site for a proposed bridge.

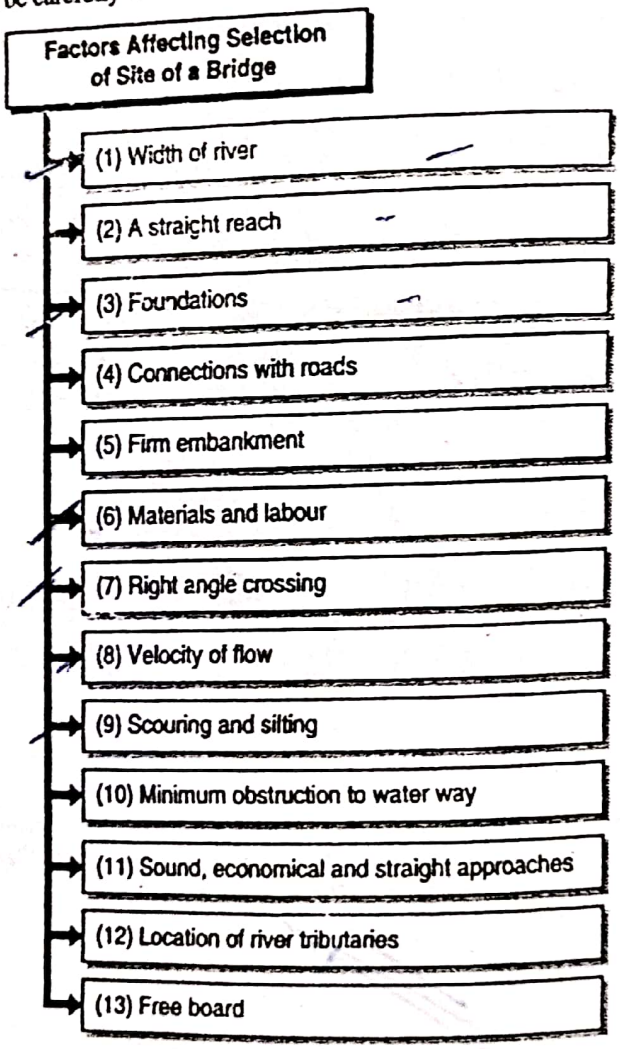


Fig. C3.2 : Factors Affecting Selection of Site of a Bridge

➜ **(1) Width of river**

- The width of river indicates length of bridge.
- It is desirable to have well defined and a narrow channel at bridge site as far as possible which will help in providing least possible length of bridge.
- The smaller the width of river, the cheaper will be the bridge in its initial cost as well as maintenance cost.

➜ **(2) A straight reach**

- The river should have straight reach over a reasonable long distance on upstream side and downstream side of the bridge site so that the utility of bridge can be maintained for the design period.
- On the other hand the curved reach of river is not desirable as it creates problems during construction and maintenance of bridge.

➜ **(3) Foundations**

- The nature of soil at bridge site should be such that good sound foundations should be available at reasonable depth.
- Such type of bridge site will save expense, labour and time required.

➜ **(4) Connections with roads**

- The bridge is constructed to connect the road on either side of a river.
- The bridge site should therefore form a proper link between the roads on either side of a river.
- The approaches at the bridge site should be such that they do not involve heavy expenditure.

➜ **(5) Firm embankments**

- The embankment at bridge site should high, permanent, straight, solid and firm.
- Such embankments will not get disturbed at the time of heavy floods and they do not allow the course of stream to alter.

➜ **(6) Materials and labour**

- The site of the proposed bridge should be such that labour, construction material should easily available nearby site.
- The transportation charges for material and labour at the bridge site should be minimum.
- This type of bridge site will provide economy in the overall cost of construction.

➜ **(7) Right angle crossing**

- At bridge site, the direction of flow of water should be nearly perpendicular to the centre-line of bridge. Such crossing is known as right angle crossing.
- This type of site will help in providing square alignment of bridge which will result in easy and economy in bridge construction.

➜ **(8) Velocity of flow**

- The velocity of flow at bridge site should be between the range of non - silting and non scouring.
- This type of site will result in minimum maintenance cost.

➜ **(9) Scouring and silting**

- There should be no scouring and silting at bridge site, which will result in minimum maintenance cost.

➜ **(10) Minimum obstruction to water way**

- There should be minimum obstruction to natural water way at the site of bridge.

➜ **(11) Sound, economical and straight approaches**

- The bridge site should provide sound, economical and straight approaches.
- In case of curved alignment, the bridge should be on the tangent and not on the curve, since it is difficult to construct and maintain a curved bridge.

➜ **(12) Location of river tributaries**

- The bridge site should be away from the point of influence of large tributaries as far as possible.
- As it will help to protect the bridge from the possible harmful disturbances.

➜ **(13) Free board**

- Sufficient free board should be available for the passage of boats, ships under the bridge superstructure if the river is used for navigation purpose.

Syllabus Topic : Bridge Alignment : Factors Controlling

3.4 Bridge Alignment

➜ **(MSBTE - S-17, S-18)**

Q. Define the term alignment in bridge. **S-17**

Q. Define bridge alignment and two types of bridge alignment. **S-18**

☞ ***Definition of bridge alignment :*** *The location of centre line of a communication route to be carried by the bridge at selected site is called* ***bridge alignment.***

- After the site of bridge is decided, the next step is to set out the centre - line i.e. alignment.
- The following factors should be considered while locating the alignment of a bridge.

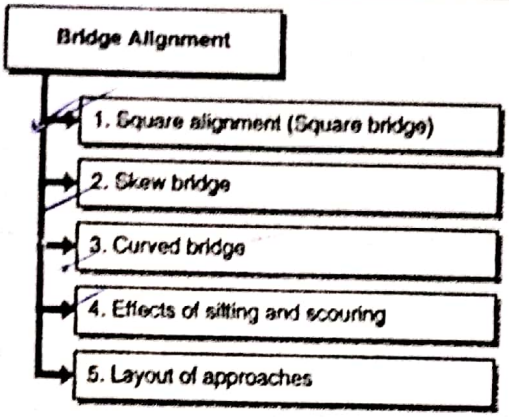


Fig. C3.3 : Bridge Alignment

➜ **1. Square alignment (Square bridge)**

- As far as possible, centre line of bridge should be at right angle to the axis of river.
- This type of alignment is always preferred because it is easy to construct and maintain.

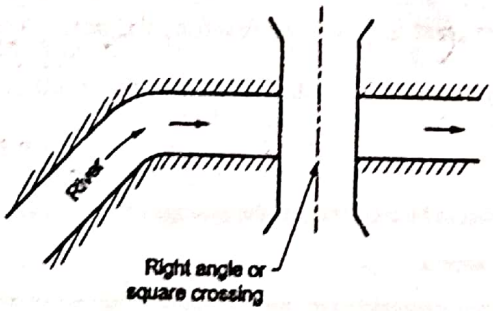


Fig. 3.4.1 : Square alignment

➜ **2. Skew bridge**

- As far as possible, the skew bridges should be avoided i.e. avoid skew alignment.

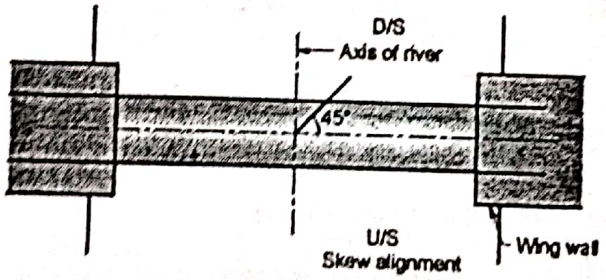


Fig. 3.4.2 : Skew alignment

- Since it is difficult to construct and maintain a skew bridge.

→ **3. Curved bridge**

- As far as possible, the alignment should not be skew.
- Since it is difficult to construct and maintain curve bridge.

→ **4. Effects of silting and scouring**

- The necessary precautions should be taken along the bridge alignment to bring down the effects of scouring to the minimum possible extent.

→ **5. Layout of approaches**

- If the existing road alignment is such that it results in an inclined alignment, the curved approaches adopted to form right angle or square crossing as shown in Fig. 3.4.3.

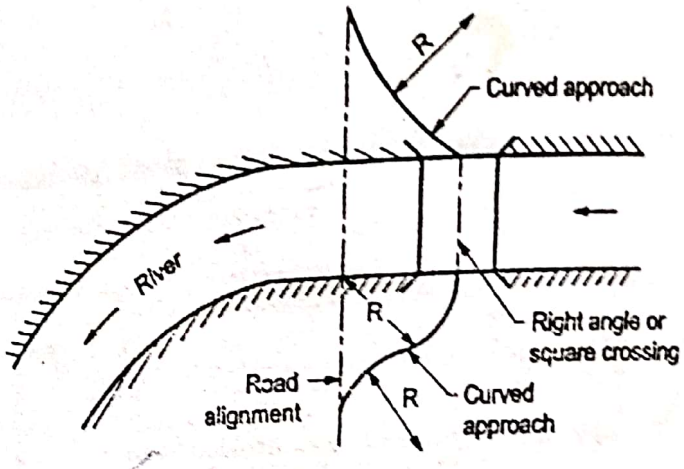


Fig. 3.4.3 : Layout of approaches

Syllabus Topic : Important technical terms- waterway, economic span, afflux, scouring, freeboa

3.5 Important Technical Terms

→ (MSBTE – W-14, S-15, W-15, S-16, W-16, S-

Q. Define H.F.L.

Q. Explain clear span, effective span and economical span of bridges.

Q. Explain with sketch, effective span, clear span, economical span and waterway of bridge.

Q. Define HFL and freeboard related to bridge.

Q. Define the term - Afflux, scouring, HFL and freeboard, Effective span and clear span.

Q. Define afflux and scour.

Q. Draw plan of bridge showing all important component parts. Also define the following terms.
(i) Effective span (ii) Afflux
(iii) Water way (iv) Wing wall

Q. Define the terms :
(1) Afflux (2) Effective span
(3) Economic span (4) Clear span

Q. Define Afflux.

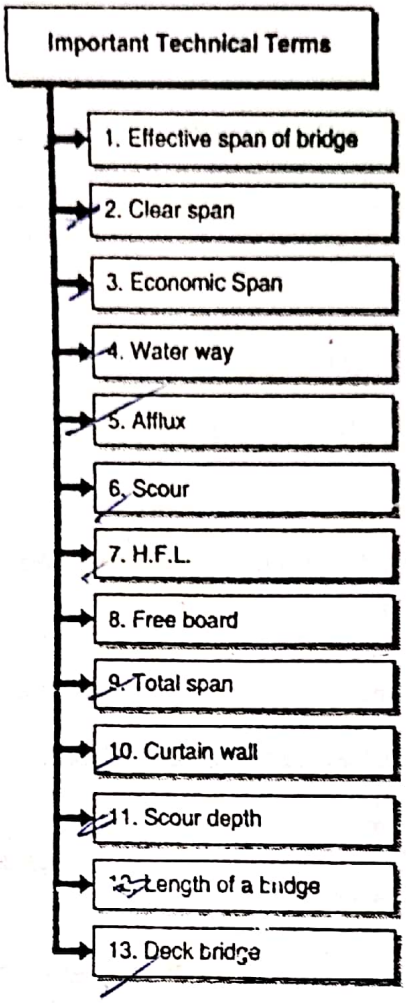


Fig. C3.4 : Important Technical Term

→ 1. Effective span of bridge

☞ *Definition of Span or Effective Span of Bridge : The center to center distance between any two adjacent supports of the bridge superstructure is called span or effective span of bridge (distance may be abutment and pier or between two piers).*

→ 2. Clear span

☞ *Definition of Clear Span : The clear distance between any two adjacent support of the bridge superstructure is called clear span.*

→ 3. Economic span

☞ *Definition of Economic Span : The span for which, total cost of bridge is minimum is called economic span.*

→ 4. Water way

☞ *Definition of Waterway : The sectional area at the site of a bridge through which water flows is termed as waterway.*

➜ **5. Afflux**

☞ *Definition of Afflux : The maximum increase in water level due to obstruction in the path of flow of water is called as afflux.*

➜ **6. Scour**

☞ *Definition of Scour : The vertical cutting of river bed is called scour.*

➜ **7. H.F.L.**

☞ *Definition of Highest Flood Level : The level of the highest flood ever recorded or the calculated level for the highest possible flood is called Highest Flood Level (H.F.L.)*

➜ **8. Free board**

☞ *Definition of Free Board : The difference between the highest flood level after allowing the afflux if any and the lowest point on the underside of the bridge superstructure is called free board.*

➜ **9. Total span**

☞ *Definition of Total Span of Bridge : The centre to centre distance between the abutment of a bridge is termed as total span of bridge.*

➜ **10. Curtain wall**

☞ *Definition of Curtain Wall : It is a thin wall used as a protection against scouring action of a river.*

➜ **11. Scour depth**

☞ *Definition of Scour Depth : The depth upto which a flowing stream erodes soil is known as scour depth.*

➜ **12. Length of a bridge**

☞ *Definition of Length of Bridge : The overall length measured along the centre line of the bridge from end to end of the bridge deck is called length of bridge.*

➜ **13. Deck bridge**

☞ *Definition of Deck Bridge : The bridge having its floor supported at top of super structure is called deck bridge.*

Syllabus Topic : Component Parts of Bridge

3.6 Component Parts of Bridge and their Functions

➜ **(MSBTE - S-17, S-18)**

Q. State component parts of bridges. **S-17**

Q. Draw sectional elevation of bridge show all components. **S-18**

The components of a bridge can be split up into three parts namely.

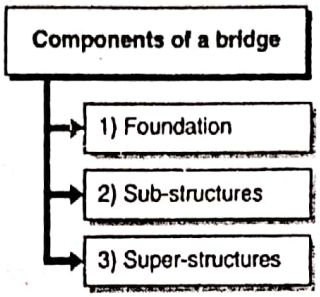


Fig. C3.5 : Components of a bridge

Syllabus Topic : Piers , Abutment, Wing wall - Function, Requirements and Types, Cut-water and Ease-water

3.6.1 Substructures

→ (MSBTE - S-15, S-17)

Q. State component part of substructure. S-15

Q. Define substructure of bridge S-17

Definition of Substructure : The lower part of the bridge consisting of structural system in the form of abutments, piers, etc. along with their foundation which supports the superstructure is called Substructure.

Function of substructure

1. To support superstructure.
2. To provide access to the traffic to the level of bridge superstructure through approaches.

– Substructure of bridge consists of following components

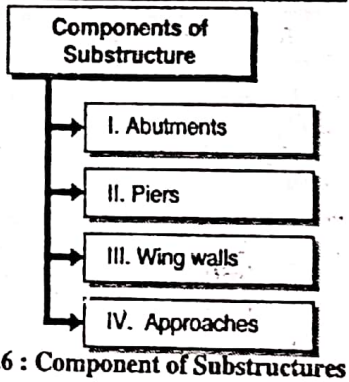


Fig. C3.6 : Component of Substructures

→ I. Abutments

→ (MSBTE - W-14, S-15, W-15, S-16, W-16, S-17, W-17)

Q. State the functions of abutments. W-14, S-15

Q. Draw a neat sketch of plan and longitudinal section of bridge and show component parts of it. W-15

Q. Draw a neat sketch of plan and L-section of bridge? Show component parts their on. S-16

Q. Define abutment of a bridge. State its functions. W-16

Q. Draw a neat sketch of a bridge. Show and label all the component parts. S-17

Q. Define Abutment and Wing walls. S-17

Q. State functions of Abutments and state requirements of good abutments. W-17

Q. Draw the plan and Section Bridge Label all the parts. W-17

☞ **Definition of Abutments :** The end supports of a bridge superstructure are known as abutments. (Refer Fig. 3.6.1)

☞ **Functions**

1. To support the superstructure.
2. To transmit the load of superstructure to foundations.
3. To provide final formation level to the bridge superstructure.

☞ **Types of abutments**

Bridge abutments are of following types, according to their layout in plan

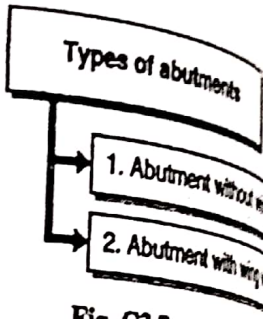


Fig. C3.7 : Types of

☞ **Requirement of good abutment**

The requirement of good abutments are :

(1) It should be strong enough to take load and transmit it to sub soil.

(2) It should be stable against side erosion.

(3) It should be easily constructed.

(4) It should be durable.

➜ **1. Abutment without wing walls**

These abutments are suitable when :

(a) Bank of river at bridge site is sufficiently firm.

(b) Velocity of flow of river water is less.

(c) There is no danger of side erosion.

☞ **Types**

When the abutments are without wing walls, they may be of following types :

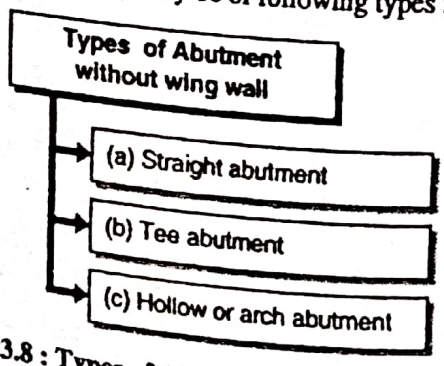


Fig. C3.8 : Types of Abutment without wing walls

➜ **(a) Straight abutment**

- The abutment usually rectangular in plane are known as straight abutment.
- Such abutment will be useful for brid

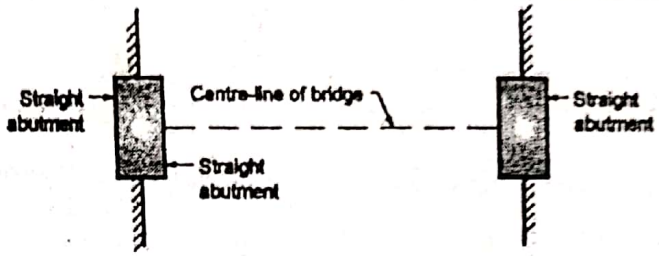


Fig. 3.6.1 : Straight abutment

➜ **(b) Tee abutment**

- The abutment of the 'T' shape in plan are known as Tee abutment.
- This type of abutment provides more stability than straight abutment because of its projected leg.

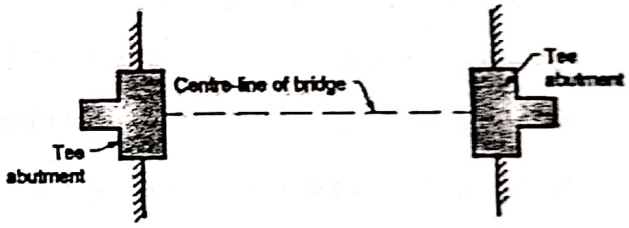


Fig. 3.6.2 : Tee abutment

➜ **(c) Hollow or arch abutment**

- The abutment curved in plan is known as Hollow or arch abutment.
- This types of abutment are suitable in case of under bridge or grade separation.

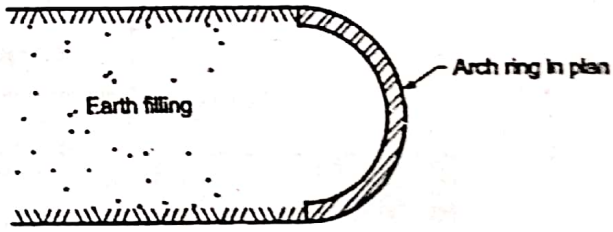


Fig. 3.6.3 : Hollow or arched abutment

➜ **2. Abutments with wing walls**

- These abutments are suitable in when :

(a) Height of approach embankment is more.

(b) Velocity of flow of river is high.

(c) There is a danger of side erosion.

☞ **Types**

When the abutment are with wing walls, they may be of following types

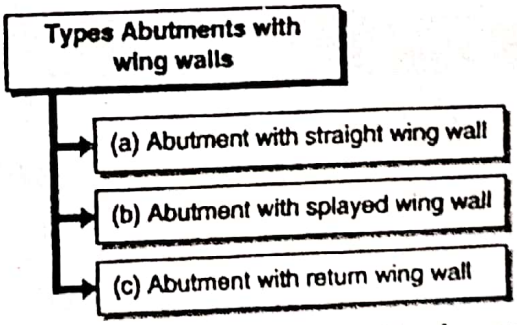


Fig. C3.9 : Types of Abutments with wing walls

(a) Abutment with straight wing wall

- When the wing wall is in line with abutment, such abutment is called abutment with straight wing wall.
- These types of abutment are suitable for under bridge or grade separation.

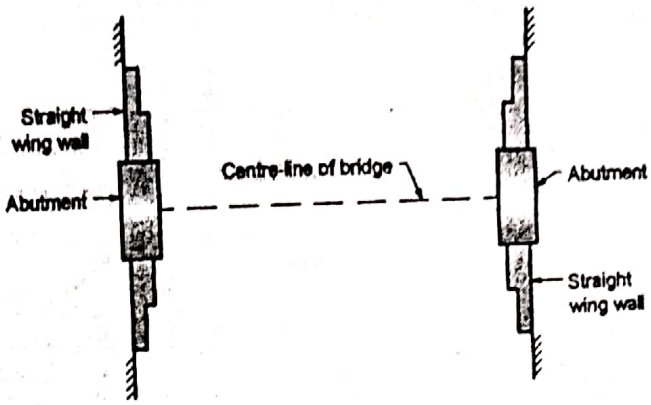


Fig. 3.6.4 : Abutment with straight wing wall

(b) Abutment with splayed wing walls

- The abutment provided with splayed wing walls are known as abutment with splayed wing walls.
- Such abutments are common for the bridge with waterway as it permits smooth entry and exit of water under the bridge.

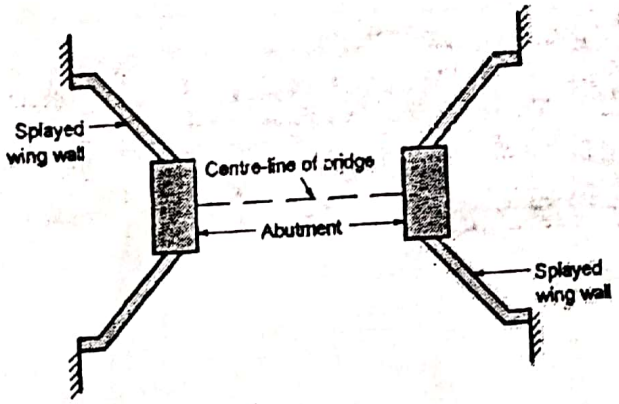


Fig. 3.6.5 : Abutment with splayed wing wall

(c) Abutment with return wing walls

- The abutment provided with return wing walls are known as abutment with return wing walls.

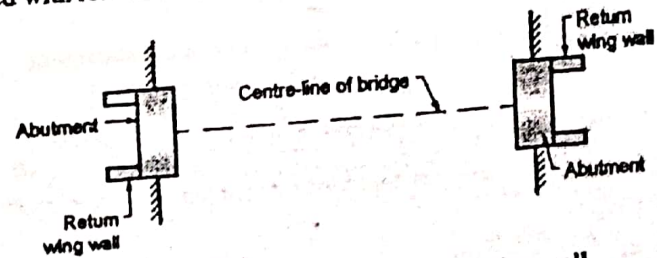
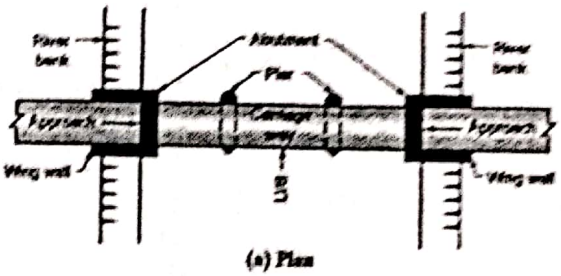
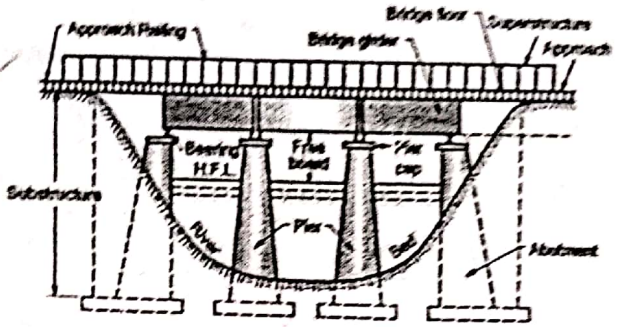


Fig. 3.6.6 : Abutment with return wing wall

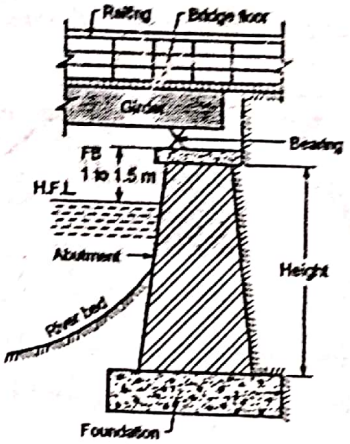
- These abutment are suitable when
  - (a) The height of the embankment is more.
  - (b) There is danger of side erosion.



(a) Plan



(b) Section



(c) Showing component parts of an abutment

Fig. 3.6.7 : Components parts of an abutment

➜ II. Pier

➜ (MSBTE - W-14, S-15, S-17, S-18)

Q. Define the pier.	
Q. Write two requirement of Piers.	W-14
Q. Define piers, State function, requirements and types of piers.	W-14
Q. Enlist two requirements of Piers.	S-15
Q. Explain functions, requirement and types of piers along with neat sketch.	S-17
	S-18

Definition of Piers : The intermediate support of a bridge superstructure are known as piers.

☞ **Function**

1. To transmit the load form the bridge superstructure to the sub soil lying underneath.
2. To divide the total length of bridge into suitable spans with minimum obstruction of the river.

☞ **Requirement of piers for bridge**

(1) It should be easily and cheaply constructed.

(2) It should be constructed of durable material.

(3) It should have sufficient bearing area at its top to receive the bearings supporting the bridge girder.

(4) It should be stable against lateral and longitudinal thrust of water.

(5) It should be strong enough to take loads.

(6) It should involve less maintenance cost.

☞ **Types of Bridge Piers**

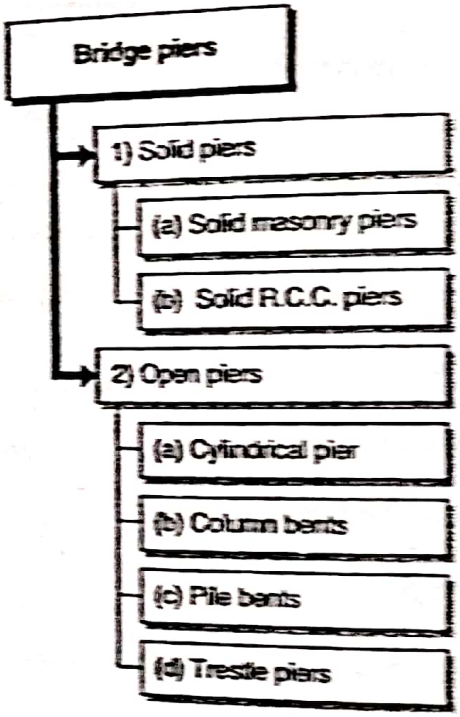
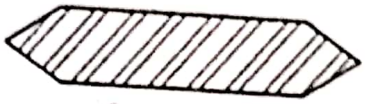


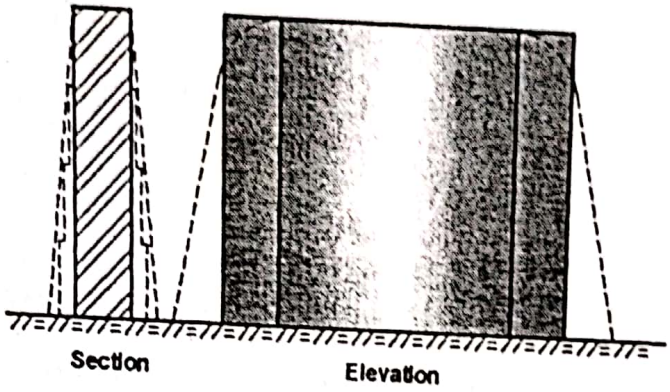
Fig. C3.10 : Bridge piers

➔ **(1) Solid piers**

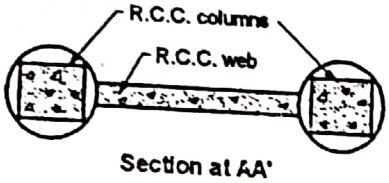
☞ *Definition : The piers which have a solid section i.e. abutments, piers and end walls are known as solid piers.*

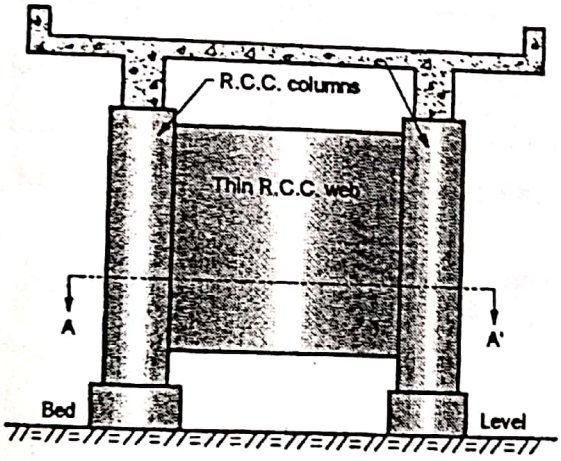
- Solid piers are suitable in water subjected to ice or debris.
- Solid piers may be of following type :
  - (a) Solid masonry pier
  - (b) Solid R.C.C. piers



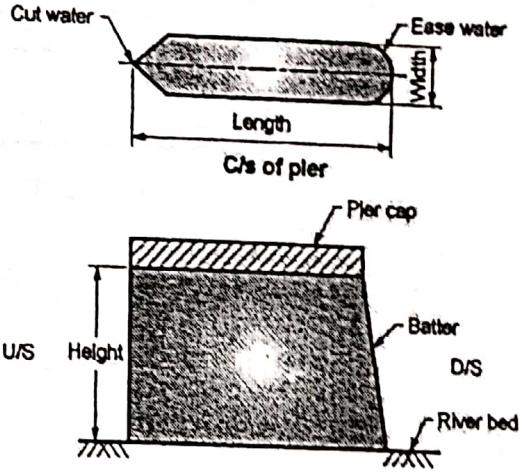


(a) A solid masonry pier





(b) Dumb-well pier (Solid R.C.C. pier)



(c) Cut-water and Ease-water

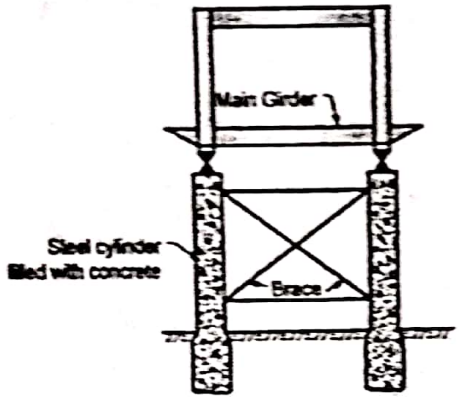
Fig. 3.6.8

➜ **(2) Open pier**

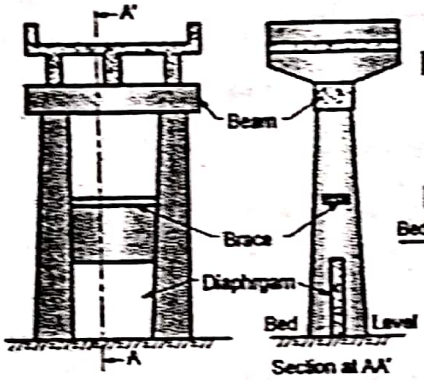
- The pier which do not have a solid section throughout their length and allow free passage of water through their structure are known as open piers.
- Open piers may be of following types :

(a) Cylindrical pier (b) Column bents

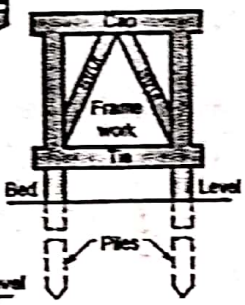
(c) Pile bents (d) Trestle piers



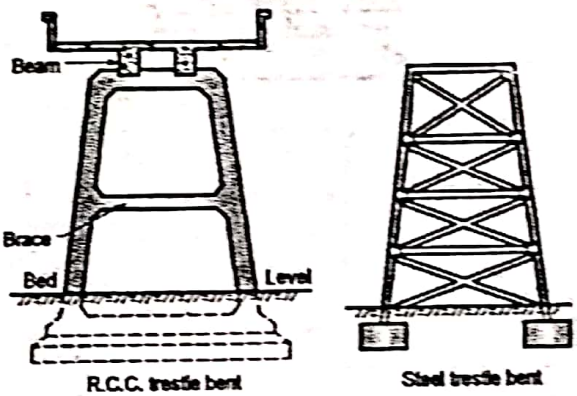
(a) Cylindrical pier



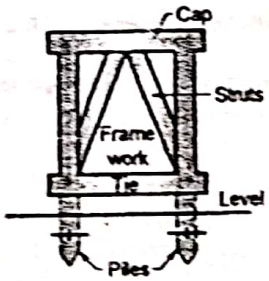
(b) R.C.C. column bent



(c) Pile bent



(d) Trestle bents



(e) Pile bent

Fig. 3.6.9

III. Wing wall

→ (MSBTE - W-14, S-15, W-15, S-18)

- Q. Define wing wall. — W-14
- Q. State functions of wing wall. — S-15
- Q. Define wing wall and list different types of wing walls. — W-15
- Q. State any two functions of wing wall. — S-18

Definition : The walls constructed on either side of an abutment to support and protect the embankment are known as wing walls.

Function

(1) To protect earth banks from the action of water.

(2) To provide a smooth entry of water into the bridge site.

(3) To support and protect embankment.

Types

Following are the types of wing walls :

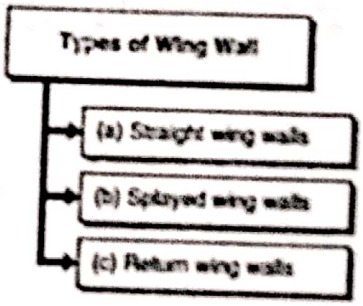


Fig. C3.11 : Types of wing walls

(a) Straight wing walls

- The wing walls constructed in line with the abutment they are known as straight wing wall.
- Such walls are suitable for small bridge and culverts which are constructed across the drains having low banks.

(b) Splayed wing walls

- The wing walls constructed at an acute angle with the abutment at both of their ends are known as splayed wing walls.
- The splay or inclination of wing wall is usually 45°.
- Such walls are suited for small as well as big bridge on rivers.
- The splayed wing walls are best suited when the width of road is to be reduced while crossing the bridge.

(c) Return wing walls

- When angle of wall becomes 90° the wing walls are known as the return wing walls.
- These type of wing walls are suitable in case when the embankment of approaches are very high.

IV. Approaches

Q. Define Approaches

Q. Compare bridge approaches in cutting and embankment.

☞ *Definition : The length of communication route affected by the layout and design of the bridge, are known as approaches.*

☞ **Function**

(1) Function of approaches is to carry the communication route to the level of bridge floor.

(2) To enable the vehicles running on a road railway track.

☞ **Types :**

Bridges approaches are of following types :

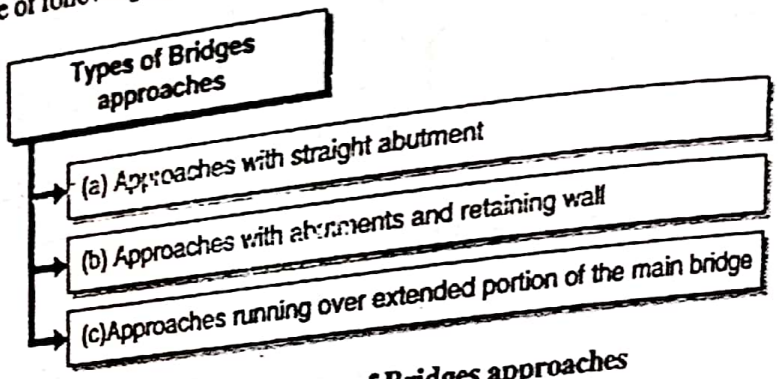


Fig. C3.12 : Types of Bridges approaches

➜ **(a) Approaches with straight abutments**

Where the height of the approach embankment is small these types of approaches are suitable.

➜ **(b) Approaches with abutment and retaining wall**

In urban areas where the land is costly these types of approaches are suitable.

➜ **(c) Approaches running over extended portion of the main bridge**

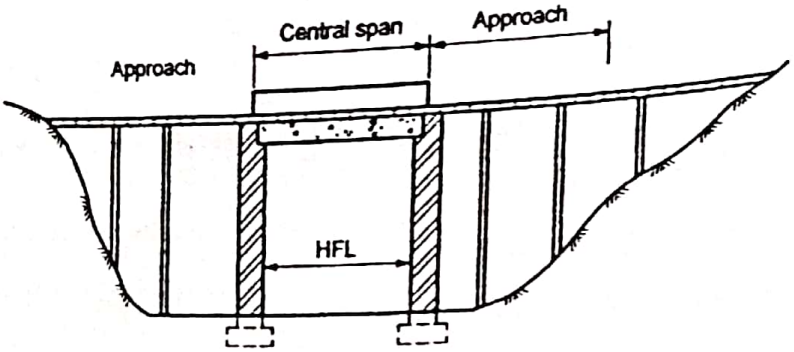


Fig. 3.6.10 : Approaches in embankment

These types of approaches are suitable under following situations

(1) When it is not economical to cover the total span of the bridge, particularly in case of an arch or suspension bridge.

(2) When the bridge is extended into the bank for some distance to provide better substructure to the approaches and to protect them.

The situation where approaches in embankment are required are in case of high level bridges and culverts.

The main function of approaches are to carry. The communication route to the level of bridge floor therefore when height of approach embankment is small approaches with straight abutments are suitable.

In Urban area's where land is costly approaches with abutment and retaining wall are used. When it is not possible or economical to cover total span of bridge. Special care should be taken to protect approaches.

☞ **Comparison of bridge approaches in cutting and embankment**

Sr. No.	Bridge approaches in cutting	Bridge approaches in embankment
1.	In submersible bridges, cause ways approaches are constructed in Cutting	In high level bridges and culverts approaches are constructed in Embankment
2.	Borrow pit near is possible	Borrow pits near embankment is not possible
3.	Top of approaches always get submerged during floods	Top of approaches rarely gets submerged during floods

3.6.2 Superstructures

→ (MSBTE - S-18)

Q. Define superstructure of bridge. S-18

☞ *Definition of Superstructure : The upper part of a bridge consisting of structural system in the form of beams, girders, arches suspension cables etc. carrying the communication route is called superstructure.*

☞ **Function**

(1) It provides carriage way.

(2) It helps to serve the intended functions with safety and convenience.

Syllabus Topic : Foundation

3.7 Foundations

→ (MSBTE - W-14, W-15, S-17, S-18)

Q. State types of bridge foundations. W-14

Q. List various types of foundation of bridges and explain any two types of foundation provided for RCC bridge. W-15

Q. Enlist types of bridge foundation. Explain any one type with neat sketch. S-17

Q. Explain any four types of bridge foundations along with its suitability and sketches. S-18

- The lowermost part of bridge structure is called foundation.
- The component designed to carry the total weight of the bridge are known as foundation.
- Almost all parts of bridge substructure such as abutments, wing walls and piers rest on foundation.

Syllabus Topic : Foundation – Function

3.7.1 Functions of foundations

(1) To take the load of bridge.

(2) To distribute the load of abutment, pier etc over a larger area.

(3) To prevent tilting and overturning of the abutments and piers.

(4) To provide base to the bridge structure.

(5) To provide stability to the bridge on the whole.

Syllabus Topic : Types of Bridge Foundations

3.7.2 Types of foundation

Bridge foundation can be divided into following categories

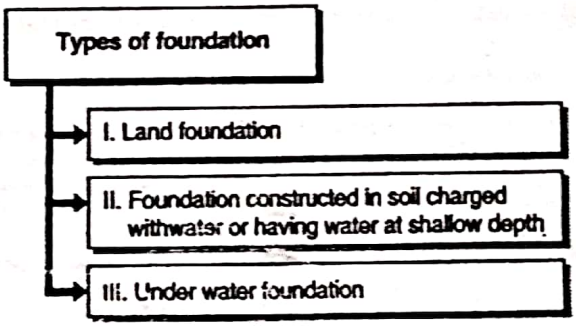


Fig. C3.13 : Types of Foundation

➜ **I. Land foundation**

1. Foundation which are constructed on dry land are known as land foundations.
2. It is easy to construct such type of foundation as they are mostly shallow.
3. Also no need for special provision for their construction.
4. These foundations are further classified into following types :
   - Spread or open foundation
   - Raft foundation
   - Grillage foundation

- Inverted arch foundation
- Pile foundations

➔ **II. Foundations constructed in soil charged with water or having water at shallow depths**

If suitable arrangement is made to exclude the water from the foundation site. Then construction of such foundation is similar as land foundation.

➔ **III. Under water foundations**

- The bridge foundations constructed under water are known as under water foundations.
- This are considered as deep foundation.
- Such foundations are difficult to construct.
- Special provision of cofferdams are made to exclude water from the foundation site.
- Types of underwater foundations :

  (a) Well foundations

  (b) Caisson foundations

(a) Well foundations

➔ (MSBTE - W-16)

Q. State the suitability of well foundation used for bridges. W-16

1. Well foundation is suitable where the soil stratum comprises of sand or stiff clay.
2. It is suitable in under water construction.

Syllabus Topic : Bearing - Functions

3.8 Bridge Bearing

➔ (MSBTE - S-15, S-17, S-18)

Q. What is bearing ? State requirements and types of bearing. Explain any one bearing with sketch. S-15

Q. Define bearing. S-17

Q. Write any four functions of bridge bearings. S-18

Definition of Bridge Bearings : The devices fixed on abutments and piers for free expansion, contraction and deflection of the bridge superstructure are known as Bridge Bearings.

Function

1. To distribute the load received over large area.
2. To allow for longitudinal expansion or contraction due to changes in the temperature.
3. To allow for angular movement at support due to deflection of girders.

4. To allow for vertical movement due to sinking of supports.
5. To transfer horizontal forces occurring due to application of brakes to the vehicle etc.
6. To keep the compressive stress within safe limits.

3.8.1 Requirement of Ideal Bearing

→ (MSBTE - W-

Q. Give the requirements of ideal bearings.

(1) It should cost moderately.

(2) It should be easy to install.

(3) It should be capable to distribute the load uniformly.

(4) It should compensate internal stresses properly.

(5) It should strong enough to transmit horizontal forces occurring due to application of breaks by vehicles.

(6) It should sufficiently capable of allowing angular movement and vertical movement.

(7) It should allow longitudinal movement due to variation in temperature.

Syllabus Topic : Types of Bearing

3.9 Types of Bearings

→ (MSBTE - W-

Q. State types of bearings for steel bridges along with suitable sketches.

The various bearings, being used for **steel girder bridges** are broadly classified into the following two categories

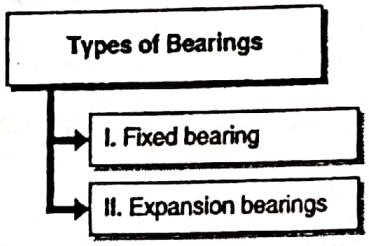


Fig. C3.14 : Types of Bearings

3.9.1 Fixed Bearing

→ (MSBTE - S-17, W-

Q. Draw neat sketches if fixed plate bearing.

Q. State the functions of bridge bearings. State the types of Bridge bearings and explain any one.

- The bearings which do not permit any longitudinal movement of the bridge girders are known as fixed bearing.
- Usually angular movement or deflection of girders are allowed by fixed bearing.

Types of fixed bearings

Fixed bearings are further classified into the following type :

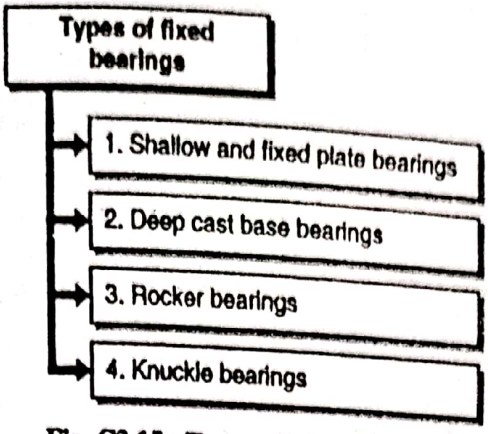


Fig. C3.15 : Types of Fixed Bearing

1. Shallow or fixed plate bearings

- This is simplest type of fixed bearings.
- It consists of flat rectangular steel plate attached to the lower flange of the bridge girder.

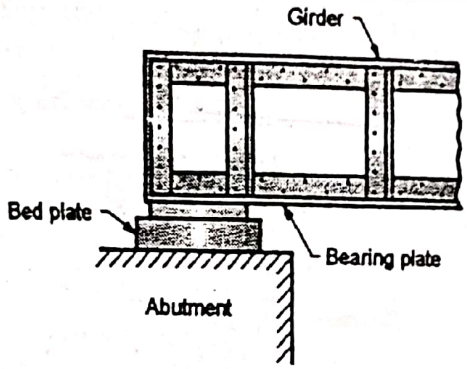


Fig. 3.9.1 : Shallow or fixed plate bearing

- Two anchor bolts are used to the anchored down the steel plate one on each side of the girder on the top of bridge pier or abutment as shown in Fig. 3.9.1.
- It is suitable upto 12 m span of steel girder bridge.

2. Deep-cast base bearings

- In this case deep cast base is attached to the underside of the bridge girder as shown in Fig. 3.9.2.
- This type of bearings avoids the concentration of reaction at the inner edge of bearing.
- Thus distributes the load over abutments.
- It is suitable for span of 12 to 20 m span of steel girders bridge.

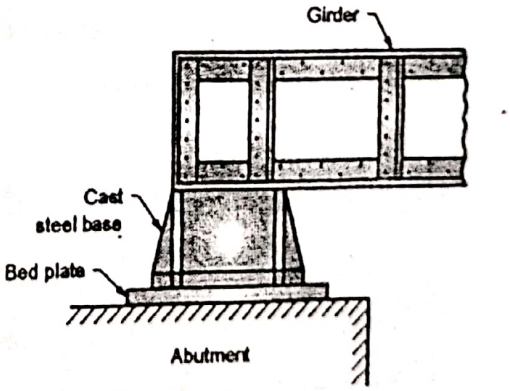


Fig. 3.9.2 : Deep cast base bearing

3. Rocker bearings

→ (MSBTE - S-17)

Q. Draw neat sketches if rocker bearing. **S-17**

Definition of rocker bearing : A fixed bearing which rocks about pin like hinge is known as a rocker bearing.

- Rocker pin is provided between the top and bottom shoe.

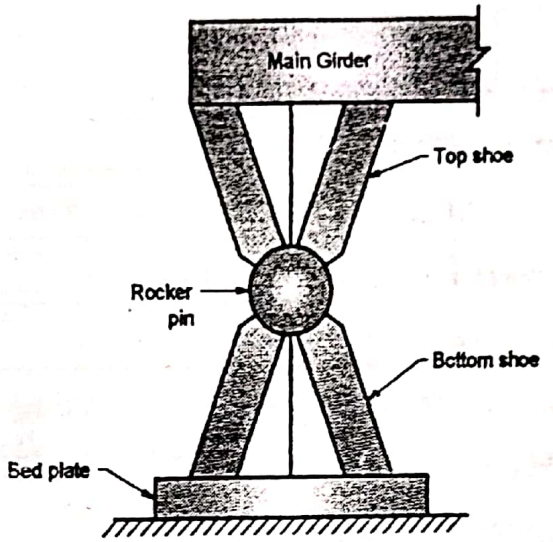


Fig. 3.9.3 : Rocker bearing

- This bearing allows only free angular movement of the main girder.
- Also, it transmits the pressure centrally to the bed plate.
- This type of bearing is suitable for long spans (cover 20 m) of girder bridges.

4. Knuckle bearings

- In this type of bearing the top of bottom shoe and the bottom of top shoe are given semi-circular shapes as shown in Fig. 3.9.4.

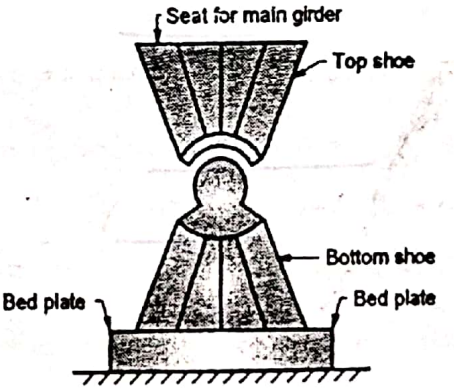


Fig. 3.9.4 : Knuckle bearing

- The knuckle bearing is adopted when it is desired to provide only for angular movement of the girder which is fixed to the top shoe.
- This type of bearing is suitable for long spans (cover 20 m) of girder bridges.

3.9.2 Expansion Bearings

Definition of Expansion or free bearing - The bearings which allow longitudinal movement of the bridge girders are known as Expansion or free bearing.

Types of Expansion Bearings

- Expansion bearings are further classified into the following types

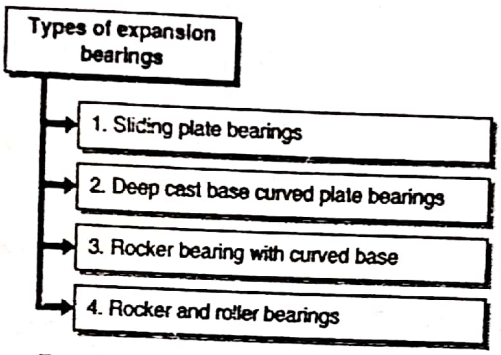


Fig. C3.16 : Types of Expansion Bearings

1. Sliding plate bearings

- This is the simplest type of expansion bearing.
- It consists of sole plate which is provided between main girder and bed plate as shown in Fig. 3.9.5.

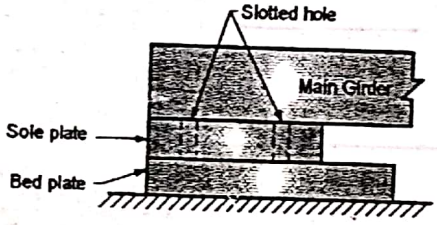


Fig. 3.9.5 : Sliding bearing

- The bed plate is fixed rigidly to abutment by anchor bolts.
- The sole plate is attached to the bed plate by bolts through the slotted holes of the sole plate.
- The sliding bearing allows only longitudinal movement of main girder.
- This type of bearing is also suitable for span 12 to 20 m.

2. Deep cast base curved plate bearings

- This type of bearing consists of a sole plate which is fixed to the underside of the main girder.
- Sole plate rests on a deep case base with curve bed plate.
- Curve bed plate is fixed to abutment.
- This type of bearing is useful to allow free angular movement of the main girder.
- This type of bearing is suitable for span 12 to 20 m.

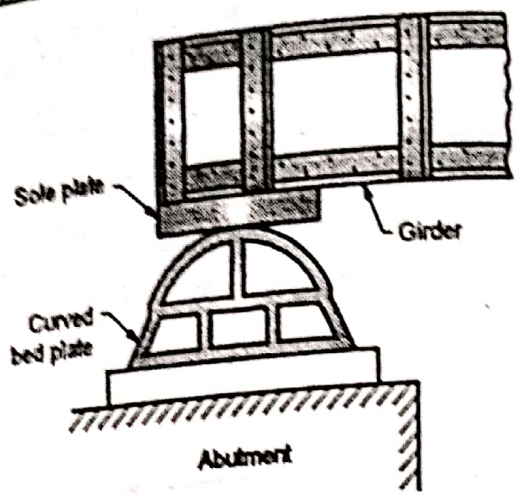


Fig. 3.9.6 : Deep cast base with curved plate bearing

3. Rocker bearing with curved base

- This is a type of Rocker bearing.
- In this type of bearing the bottom shoe is given a circular shape.
- The top shoe is provided with drill holes for fixing of the girder.
- This type of bearing allows for the deflection and expansion of the bridge girder with a reduced horizontal for

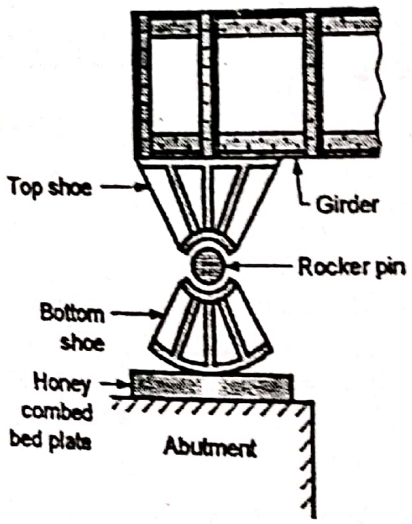


Fig. 3.9.7 : Rocker bearing with curved bottom base

4. Rocker and roller bearings

→ (MSBTE - W-14, W-15, S

Q. What is Rocker-Roller bearing ? Draw a neat sketch of it.
Q. Explain with sketch roller rocker bearing.
Q. Explain Rocker-Roller bearing with neat sketch.

- This type of bearing consists of a rocker pin which is provided between the top shoe and the bottom shoe.
- Bottom shoe rest on number of steel rollers as shown in Fig. 3.9.8

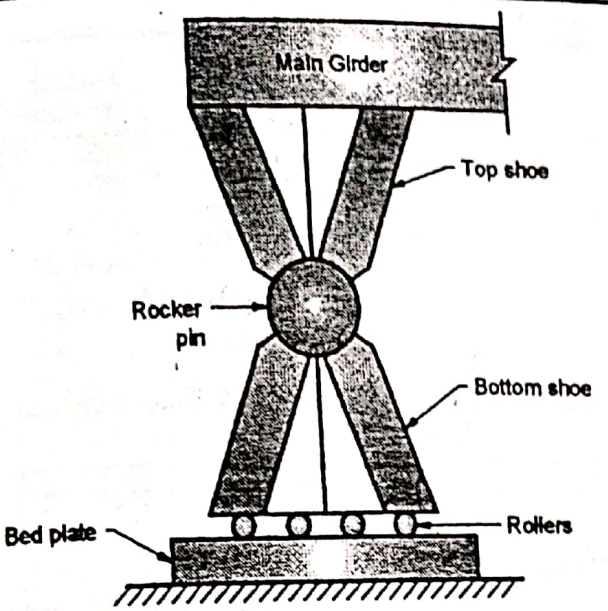


Fig. 3.9.8 : Rocker and roller bearing

- Steel rollers rest on bed plate which is attached to top of abutment.
- This type of bearing allows for free longitudinal as well as angular movements of the bridge girder.
- This type of bearing is suitable for spans more than 20 m.

□□□

Chapter Ends...

CHAPTER 4

Construction and Maintenance of Bridge

Syllabus :

- Temporary Bridge- Necessity, Causeway-Flush, low level and high level causeway
- Permanent Bridges- Types of RCC Bridges-Slab, Girder, RCC girder
- Pre-stressed bridge-Advantage & dis-advantages
- Culvert-Types-Arch, Open or slab, Pipe and box
- Choice of type of bridge, Types of bridge foundations
- Steps involved in bridges construction
- Inspection of bridges-General points to be observed, Pre and post monsoon inspection
- Maintenance of bridges- types – routine and special Maintenance

Syllabus Topic : Temporary Bridge - Necessity

4.1 Temporary Bridges

☞ ***Definition of Temporary Bridges*** *- The bridges which can be constructed as well as maintained at low cost and have short span of useful life are known as temporary bridges or low cost bridges.*

☞ **Necessity of temporary bridges**

1. When there is shortage of fund, time
2. Repair of main bridges needs to carry
3. Lack of skills resources
4. Temporary need of crossing stream or driver

Syllabus Topic : Causeway-Flush, low level and high level causeway

4.2 Causeways

→ (MSBTE - W-15)

Q. State and explain two situations where causeways are provided. **W-15**

☞ ***Definition of Causeways :*** *A causeway is defined as a small submersible bridge at or about the bed level which will allow the floods to pass over it. It is also known as* ***Irish causeways.***

Causeway may be provided under the following conditions :

(1) The seasonal flow is less.

(2) When the depth of water in the stream is very low.

(3) In hilly areas, where a number of small streams cross the road.

(4) When sufficient funds are not available.

☞ Types of cause ways

Causeways are classified into the following types :

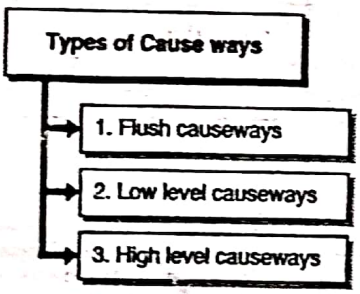
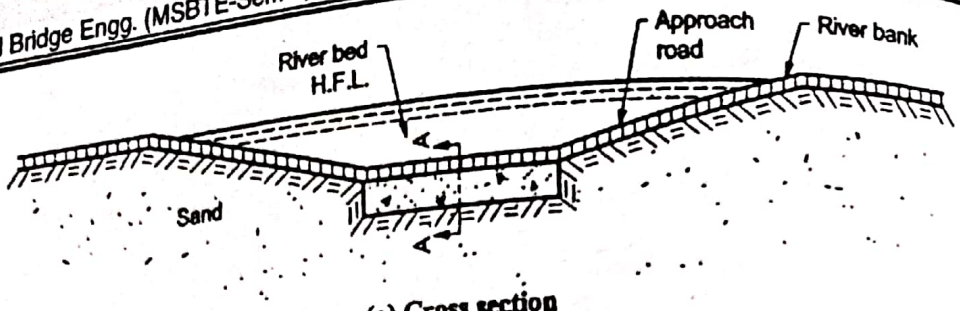


Fig. C4.1 : Types of Cause ways

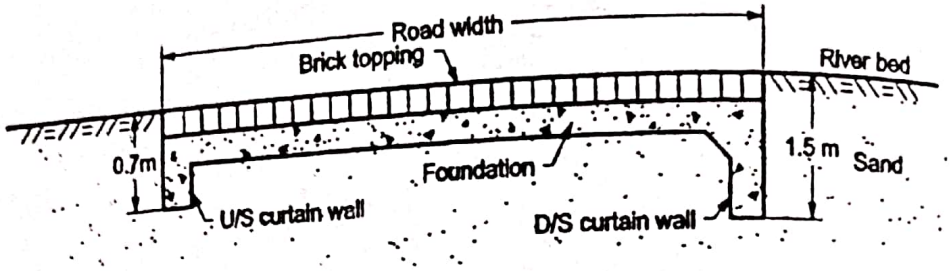
1. Flush causeways

☞ ***Definition of Flush causeways :*** *The causeways having their floor flush with the bed of the stream without any vent are known as* ***flush causeways.***

- This type of causeways are usually provided in hill roads for shallow non-perennial streams where maximum depth of water during floods is less than 1.75 m.
- Where flood water runs only for short period (10 to 15 days in a year).
- Such type of causeway consists of R.C.C. slab provided in the bed for smooth surface.



(a) Cross section

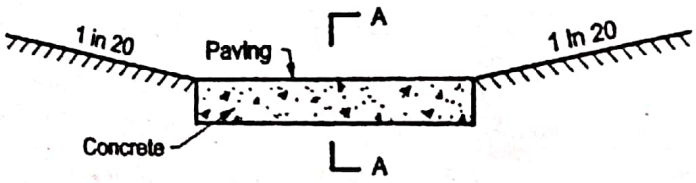


(b) Enlarged section at A - A'

Fig. 4.2.1 : Flush causeway or metal dip

2. Low level causeways

Definition of Low level causeway : The causeways having one or more vent provided under the roadway slab for passing the small discharge through them during dry season are known as low level causeway.



Longitudinal section

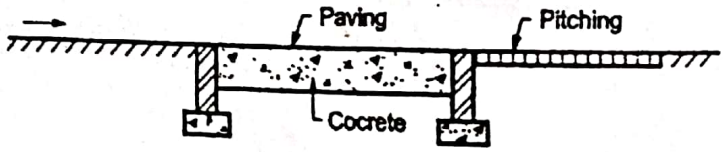


Fig. 4.2.2 : Low level causeway

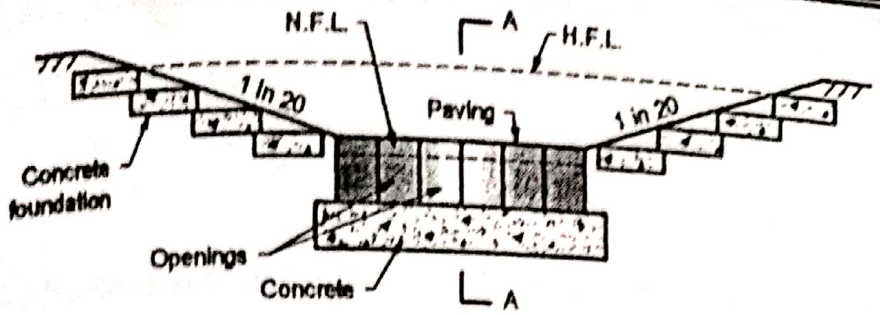
- This type of causeway is suitable for shallow perennial rivers, where discharge is small for most of the year and where heavy discharge flows in rainy season for few hours.

3. High level causeways

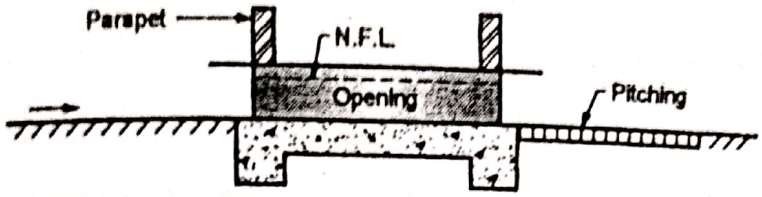
Q. Explain high level causeway with sketch. → (MSBTE - S-15)

Definition of submersible bridge : A high level causeway is submersible road bridge designed to be overtopped in floods, it is also known as submersible bridge.

- High level causeway consists of sufficient number of openings, to allow the normal flood discharge to pass through them.



Longitudinal section



Section on A-A

Fig. 4.2.3 : High level causeway

- They are provided with abutment and piers, floors and slabs or arches to form required number of opening.
- High level causeway are suitable on river with small widths and straight reaches when the duration of high flood does not exceed 3 days in a year and for bus traffic on unimportant roads.

Syllabus Topic : Permanent Bridges

4.3 Permanent Bridge

Definition of Permanent Bridge : *The bridge constructed as well as maintained at high cost and have long span of useful life are known as permanent bridge.*

Syllabus Topic : Types of RCC Bridges - RCC girder

4.3.1 R.C.C. Girder Bridge

Definition of R.C.C Girder Bridge : *The bridge having its superstructure consisting of R.C.C. girders and slab which support the bridge floor is known as R.C.C girder bridge.*

- R.C.C. girder bridge is suitable for span between 10 to 20 meters.
- In such types of bridge the flooring is carried by two or more R.C.C. main girders, supported on abutments and piers with R.C.C. slab on their top.
- **Types of R.C.C. Girder bridges**

R.C.C. girder bridges are classified into following types

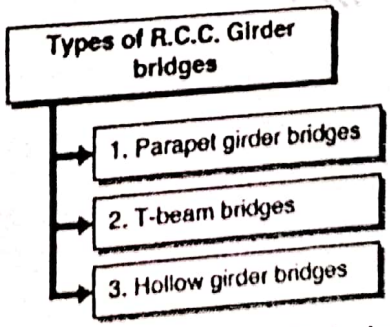


Fig. C4.2 : Types of R.C.C. Girder bridges

(1) Parapet girder bridge

Definition of Parapet girder bridge : *When main supporting members are parapet girders with thick R.C.C. slab or transverse beam with thinner R.C.C. slab, cast monolithically with tee parapet girder at their bottom, such R.C.C. bridge are known as parapet girder bridge.*

- It is used for roadway bridge with narrow width.
- It is generally used for pedestrian traffic.

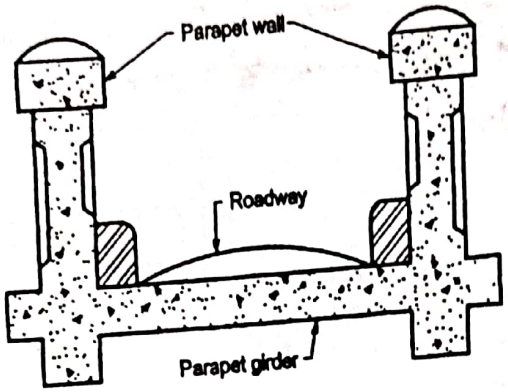
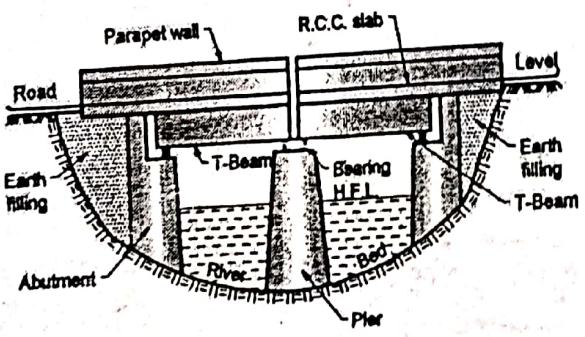


Fig. 4.3.1 : Parapet girder type

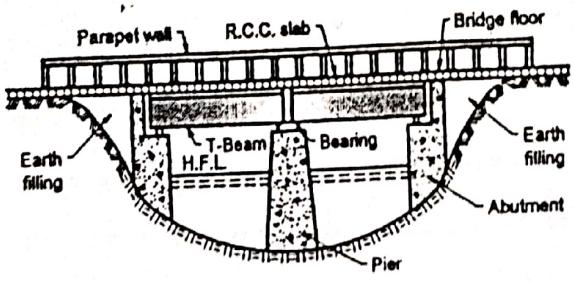
(2) T-beam bridges

Definition of T-beam bridges : *When the main supporting members are T beams then such R.C.C. girder bridge is known as T-beam bridge.*

- The T-beams may be simply supported, continuous, cantilever etc.
- They can be used for spans greater than 45 m.



(a) R.C.C. T-beam and slab bridge



(b) Tee-beam type

Fig. 4.3.2 : T-beam bridge

(3) Hollow girder

Definition of Hollow girder : *When closed box-sections of R.C.C. girders are used which may be made multi-cellular of rectangular or trapezoidal shaped cells then such R.C.C. girder bridge is called Hollow girder.*

- Such bridges are economical for spans between 25 to 30 meter.

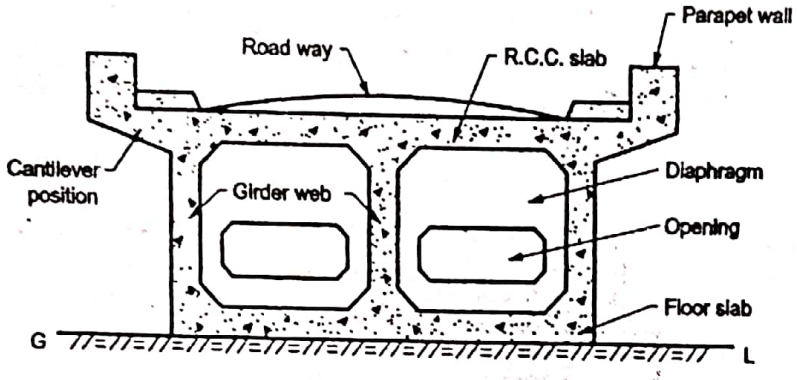


Fig. 4.3.3 : Hollow girder

Syllabus Topic : Pre-stressed bridge-Advantage & Disadvantages

Prestressed Girder Bridge

(MSBTE - W-16)

Q. With the help of neat sketch explain prestressed girder bridge. W-16

Definition of Prestressed Girder Bridge : *The bridge having their superstructure consisting of prestressed concrete members in any structural form, which support the bridge floor are known as prestressed concrete bridge.*

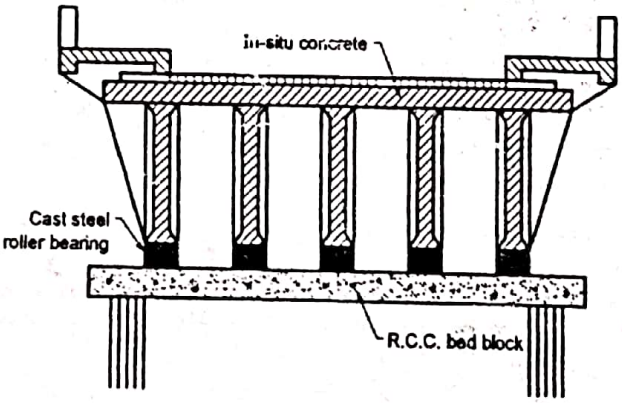


Fig. 4.3.4 : Prestressed girder bridge

Advantages

1. They have the fewer expansion joint.
2. They are light in construction.

3. They have the higher load carrying capacity.
4. They reduces deflection of girders.
5. Maintenance cost is less.
6. They have better resistance to fatigue due to elimination of cracking of its members due to the heavy traffic load.
7. They provide more smooth deck for high speed driving.
8. Their aesthetic appearance is good.

☞ **Disadvantages**

1. Prestressed concrete members requires high tensile steel, which is much costlier than ordinary mild steel.
2. Skill supervision is required.
3. More special equipment are used in the construction.

– Such types of bridge are specially suitable as 'urban highway bridges'.

– These are suitable for long span.

Syllabus Topic : Choice of type of bridge

4.3.3 Choice of Type of Bridges

1. Nature of river.
2. River bed condition.
3. Volume of traffic to be carried.
4. Hydraulic delta at site.
5. Climatic condition.
6. The length of bridge to be constructed.
7. Physical features of site.
8. Material, labors available at site.
9. Time available.
10. Funds available.
11. Geological condition of the site.
12. Length of bridge to be constructed.

Syllabus Topic : Culvert-Types-Arch, Open or slab, Pipe and box

4.4 Culverts

Q. Define culvert. Enlist its types. → (MSBTE - W-14, S-

Q. What is culvert ? Explain slab culvert with neat sketch.

☞ ***Definition of Culvert :*** *A culvert is defined as a small bridge constructed over a stream which remains dry for most part of the year.*

Types of culverts

Culverts are classified into following type :

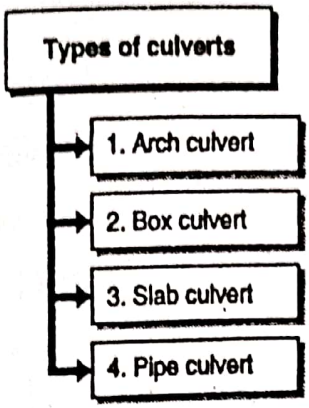


Fig. C4.3 : Types of Culverts

1. Arch culvert

Definition of Arch culvert : *The culvert having its superstructure consisting of single or number of arches constructed of any suitable masonry is known as* ***arch culvert.***

- The arch culvert is provided with the abutments, wing walls and parapet.

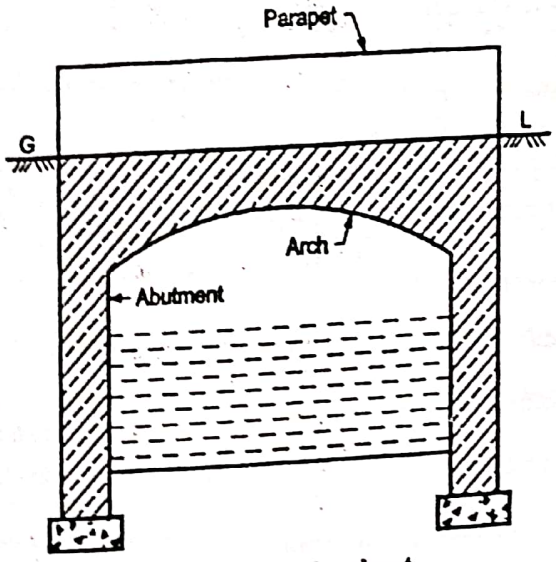


Fig. 4.4.1 : Arch culvert

- An arch culvert of stone masonry may be adopted for span ranges of 2 m to 6 m.
- Arch culvert are specially suitable where the approaches are to be constructed in cuttings.

2. Box culvert

- In case of box culvert rectangular or square boxes are formed of masonry, R.C.C.
- Box have their floor and top slabs constructed monolithically with abutment and piers.
- Box culvert is provided one or more number of units with individual spans ranging from 1 m to 4 m.
- This type of culvert can be conveniently used for a single span of 3 m or for a double span of 6 m.
- Box culverts are specially suitable when soil is soft and the load has to be distributed over wider foundation area.

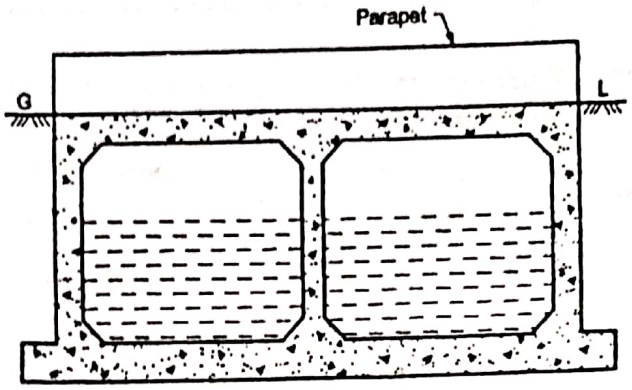


Fig. 4.4.2 : An R. C. C. Box culvert

3. Slab culvert

- A slab culvert consists of stone slabs or R.C.C. slabs supported on masonry wall as shown in Fig. 4.4.3.
- These culverts are constructed up to the span of 3 m.
- The construction of slab culvert is relatively very simple.
- This type of culvert can be used for highway, railway and bridges.

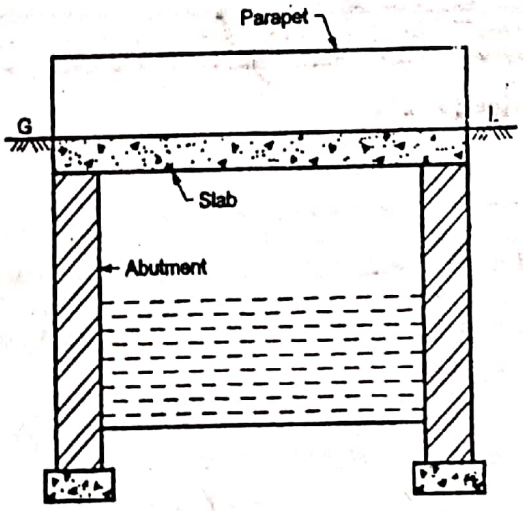


Fig. 4.4.3 : Slab culvert

- Slab culvert are suitable where the bed of stream or canal is sufficiently firm.

4. Pipe culvert

Definition of Pipe culvert : *For small stream crossing the road or railway embankments one or more pipes may be laid to act as the culvert, such culvert is known as pipe culvert.*

- The diameter of pipe is always more than 300 mm.
- Such type of culvert consists of cast Iron, steel or R.C.C. pipes held in position over concrete base.
- The exact number of pipes and their diameters will depend on the discharge an height of bank.
- Pipe culverts are suitable where the flow of water in the stream is very less and when discharge is low say upto 10 m^3/sec.

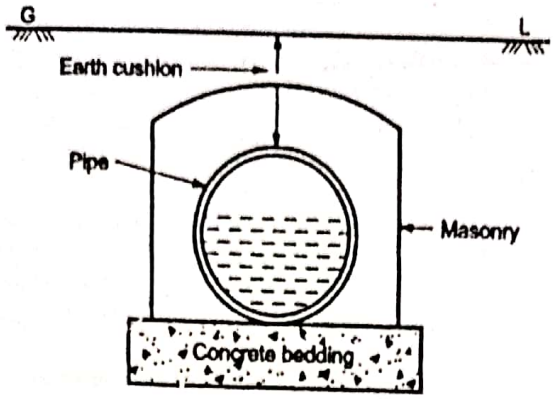


Fig. 4.4.4 : Pipe culvert

Syllabus Topic : Types of Bridge Foundations

4.5 Foundations

→ (MSBTE - W-14, W-15, S-18)

Q. State types of bridge foundations. W-14

Q. List various types of foundation of bridges and explain any two types of foundation provided for RCC bridge. W-15

Q. Explain any four types of bridge foundation along with its suitability and sketches. S-18

☞ ***Definition of Foundation :*** *The lowermost part of bridge structure is called foundation.*

- The component designed to carry the total weight of the bridge are known as foundation.
- Almost all parts of bridge substructure such as abutments, wing walls and piers rest on foundation.
- Functions of foundations

(1) To take the load of bridge.

(2) To distribute the load of abutment, pier etc over a larger area.

(3) To prevent tilting and overturning of the abutments and piers.

(4) To provide base to the bridge structure.

(5) To provide stability to the bridge on the whole.

☞ **Types of foundation**

Bridge foundation can be divided into following categories

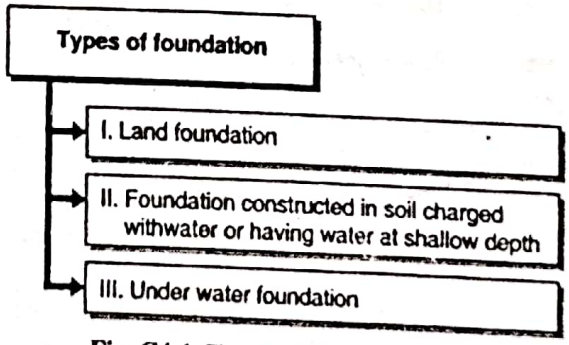


Fig. C4.4: Types of Foundation

➜ **I. Land foundation**

☞ ***Definition of Land foundation : Foundation which are constructed on dry land are known as land foundations.***

1. It is easy to construct such type of foundation as they are mostly shallow.
2. Also no need for special provision for their construction.
3. These foundations are further classified into following types :
   - Spread or open foundation
   - Raft foundation
   - Grillage foundation
   - Inverted arch foundation
   - Pile foundations

➜ **II. Foundations constructed in soil charged with water or having water at shallow depths**

If suitable arrangement is made to exclude the water from the foundation site. Then construction of such foundation is similar as land foundation.

➜ **III. Under water foundations**

☞ ***Definition of Under water foundations : The bridge foundations constructed under water are known as under water foundations.***

- This are considered as deep foundation.
- Such foundations are difficult to construct.
- Special provision of cofferdams are made to exclude water from the foundation site.

Types of underwater foundations :

(a) Well foundations (b) Caisson foundations

- Well foundation is suitable for soil stratum comprises of sand or stiffly.

4.6 Inspection and Maintenance of Bridge

Syllabus Topic : Maintenance of Bridges

4.6.1 Maintenance of Bridge

☞ ***Definition of Maintenance of Bridge : The art of keeping the bridge components in good condition to keep the bridges in best serviceable order for a longer period is known as bridge maintenance or maintenance of bridges.***

(1) After the bridge is constructed and opened to traffic, its components such as foundations, pier, abutments, wing walls, approaches, flooring system, railing etc are subjected to damages due to so many reasons. Therefore it is necessary to maintain bridge in such condition that it functions properly.

(2) Maintenance of bridge becomes essential to keep them in best serviceable condition for a longer period.

Syllabus Topic : Maintenance of Bridges types – routine and special Maintenance

4.7 Classification of Bridge Maintenance Jobs

The maintenance of bridges can be broadly classified into the following two types :

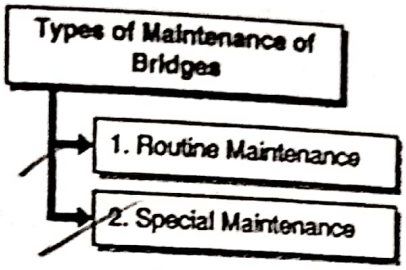


Fig. C4.16 : Types of Maintenance of Bridges

→ **(1) Routine maintenance**

Definition of Routine maintenance : *The maintenance work which is carried out regularly on the basis of routine inspection is known as routine maintenance.*

- This type of maintenance is carried out annually after general routine inspection in order to rectify defects of general character.
- Routine maintenance of bridges includes the following maintenance jobs

1. To check proper functioning of weep holes.
2. To check proper functioning of drainage devices.
4. To check proper functioning of bearings and expansion joints.
4. To repair the defective piers and abutments.
5. Maintenance of water proofing coats.
6. Maintenance of wearing coat of the bridge floor.
7. Maintenance of kerbs, railings etc.
8. Careful examination of steel structures for corrosion and developments of cracks.

→ **(2) Special maintenance**

→ (MSBTE - W-14)

Q. What type of maintenance work is included under special maintenance of bridges ? W-14

Definition of special maintenance : *The maintenance work of special character which is carried out after certain period on the basis of detailed inspection is called special maintenance.*

- This type of maintenance is carried out, once in 3 to 5 years, after detailed visual examination of all bridges components in order to rectify defects of special character.
- Special maintenance of bridges includes the following maintenance jobs :
  1. To check and rectify the foundation settlement and movements.
  2. To check and repair damaged members.
  4. To repair the cracks in concrete and metal work.
  4. To check the loose connections.
  5. To check the area of past repairs.
  6. To repair the exposed reinforcement.

Syllabus Topic : Inspection of bridges

4.8 Inspection of Bridge

→ **(MSBTE - W-14, W-15, S-16)**

Q. Write short note on inspection of bridges. **W-14**

Q. List any four points for inspection of bridge substructure and superstructure. **W-15**

Q. Explain the four points which should be inspected in bridge substructure and bridge superstructure. **S-16**

- It is necessary that every part of the bridge structure is kept under constant observation. For this purpose, inspection is done by well qualified and experienced engineers.
- The regular inspection of bridge is of great importance, since the early detection of trouble and prompt attention may avoid costly repairs.
- The following points should be kept in view while inspecting a bridge :
  1. Behaviour of expansion joints.
  2. Condition of concrete work.
  4. Condition of wearing coat and its thickness.
  4. Condition of reinforcement.
  5. Any sign of development of cracks in concrete abutments and piers.
  6. Any sign of settlement of foundations.
  7. Any sign of scour along with maximum depth of scour.
  8. Conditions of paints.
  9. Condition of parapet walls.
  10. Condition of kerbs and railings.

4.8.1 Classification of Inspection Work

The inspection work can be classified into following two types :

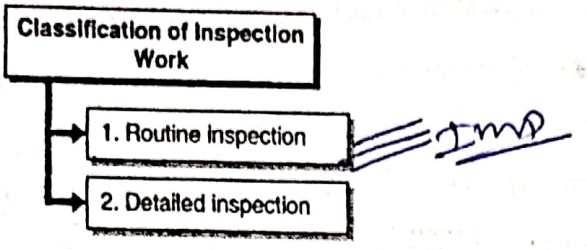


Fig. C4.36 : Classification of Inspection Work

→ **1. Routine inspection**

Definition of Routine inspection : *The inspection work which is carried out at regular intervals for the general examination of structure is known as* ***routine inspection.***

- It is generally done for short span bridges.
- Usually routine inspection is conducted prior to the monsoons.

→ **2. Detail inspection**

- The detailed inspection includes the visual examination of all the components of bridge.
- A check list of items is inspected either visually or with the help of standard instrument is prepared.
- The structural analysis of bridges is done by experienced bridge design engineers.
- It is carried out once in two years.

4.9 Comparison between Temporary Bridges and Permanent Bridges

Sr. No.	Temporary Bridge	Permanent Bridge
1.	The bridges which can be constructed as well as maintained at low cost and have short span of useful life are known as "temporary bridge".	The bridge constructed as well as maintained at high cost of have long span of useful life are known as "permanent bridge".
2.	Initial cost is low.	Initial cost is high
4.	Easy in construction	Difficult in construction
4.	Maintenance cost is low	Maintenance cost is high
5.	Can take light loads	Can take heavy loads.
6.	These are constructed from timber, steel wire, etc.	These are constructed of Bricks stones, steel, RCC.

4.10 Situation where following Components can be used

(i) R.C.C. slab culvert

The R.C.C. slab provided for highway railway bridges and where the bed of stream or canal is sufficiently firm.

(ii) The high level cause way

It suitable on river with small widths and straight reaches when the duration of high flood does not exceed 3 days in a year of for bus traffic on unimportant roads.

(iii) Steel suspension bridge

Such type of bridge is suitable for light as well as heavy traffic for large span between 600 to 1200 meters.

(iv) Prestressed concrete girder bridge

Such type of bridge are specially suitable as "urban highway bridges" and it suitable for long span.

□□□

Chapter Ends

CHAPTER 5

Construction and Maintenance of tunnels

16 marks.

Syllabus

- Tunnel - Classification of tunnels according to purpose, Conveyance, Material, Position or alignment, Shape and size of tunnels.
- Tunnels: Cross sections for highways and railways, Tunnel investigations and surveying, Tunnel Shaft - its purpose and construction.
- Methods of tunnelling in Soft rock-needle beam method, fore-poling method. Line plate method, shield method.
- Methods of tunnelling in Hard rock-Full-face heading method, Heading and bench method, drift method.
- Drilling equipment-drills and drills carrying equipments, Types of explosives used in tunnelling .
- Tunnel lining –Purpose, factors affecting type of lining, and methods
- Tunnel ventilation and drainage - Purpose and methods
- Tunnel Maintenance - Purpose and measures to be taken for proper maintenance

5.1 Tunnel Engineering

→ (MSBTE - W-14)

Q. Define Tunnel Engineering. W-14

Definition : The branch of civil Engineering which deals with the design, construction and maintenance of tunnel is known as tunnel Engineering.

5.1.1 Definition of Tunnels

→ (MSBTE - S-17)

Q. Define tunnel. S-17

The underground passages which are constructed without disturbing the ground surface are known as tunnels.

5.1.2 Use of Tunnels

→ (MSBTE - W-17)

Q. State any two uses of tunnel. W-17

Q. Enlist two purpose of tunnel lining. W-17

1. They are used for transportation of men, material and goods.
2. They are used for conduction of water to generate power.
3. They are used for carrying oil, sewage, gas etc.

5.1.3 Necessity of Tunnels

→ (MSBTE - W-14, W-17)

Q. State the necessity of tunnels. W-14

Q. What is the necessity of tunnel ventilation? W-17

1. When the two terminal stations, separated by a mountain are to be connected by the shortest route.
2. When depth of open cut for reaching the other side of a hill is more than 20m and it is costlier to construct and maintain it, than a tunnel.
3. When acquisition of valuable land and property for a railway or road project is to be avoided.
4. When the provision of a bridge for carrying road or railway traffic across the river is more inconvenient and costlier than a tunnel under the river bed.
5. When the route of a railway track or road at high altitudes is to be protected from blockage due to snow fall or landslides.

5.1.4 Advantages and Disadvantages of Tunnels

→ (MSBTE - W-14, S-15, W-15, S-18)

Q. State the advantages and disadvantages of tunnels. W-14, S-15, W-15

Q. State any two advantages of tunnel. S-18

Advantages

Following are the advantages of providing tunnels :

1. They connect the two terminal stations by the shortest route.
2. They facilitate less route length and thus results in less transportation cost.
3. They carry railway lines, roads and public utilities like water, oil, gas etc across a stream or mountain.
4. They help in avoiding acquisition of costly valuable land and property for road or railway projects.
5. They eliminate excessive cost of maintenance of an open cut subjected to land slide.
6. They provide free movement of traffic throughout the year even during snowfall and land slide.
7. They facilitate conduction of water to generate power.

Disadvantages

→ (MSBTE - S-17)

Q. State any two disadvantages of tunnel. S-17

Following are the disadvantages of tunnels :

1. They require special equipment and method for their construction.
2. They require more time for their construction.
3. Skilled labour and supervision is required in their construction.
4. They may cause suffocation if not properly ventilated.

Syllabus Topic : Classification of Tunnels According to Purpose, conveyance, position or alignment

5.2 Classification of Tunnels

→ (MSBTE - W-14, S-15, W-17, S-18)

Q. State classification of tunnels. W-14, W-17

Q. State detailed classification of tunnels. S-15

Q. State types of tunnels used for highways and railways with the sketch. S-18

Tunnel are generally classified on the basis of :

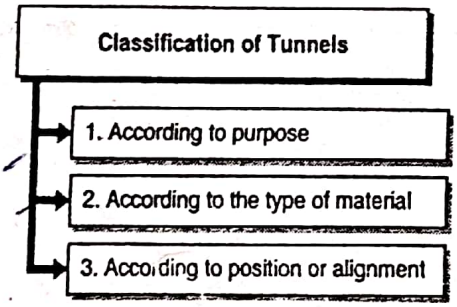


Fig. C5.1 : Classification of Tunnels

→ 1. Classification of tunnels according to the purpose

→ (MSBTE - W-14)

Q. Classify tunnels according to the purpose. W-14

I) **Traffic tunnel**

a) Railway tunnels
b) Highway tunnels
c) Pedestrian tunnels
d) Navigation tunnels
e) Subway tunnels

II) Conveyance tunnel

a) Hydro power tunnels
b) Water supply tunnels
c) Sewage tunnels
d) Tunnels for industrial use.

→ 2. Classification of tunnels according to the type of material

a) Tunnels in hard rock
b) Tunnels in soft rock
c) Tunnels in quick sand
d) Tunnels under river bed

→ 3. According to the position of alignment

a) Saddle and base tunnels
b) Spiral tunnels
c) Off spur tunnels
d) Slope tunnels

Syllabus Topic : Shape and Size of Tunnels

5.3 Shape and Size of Tunnels

5.3.1 Shapes of Tunnels

→ (MSBTE - W-14, S-17, S-18)

Q. Classify tunnels based on shape. Draw four types of shapes of tunnels used in highways. W-14
Q. Enlist any four types of tunnel as per shapes. S-17
Q. Draw box type, circular, segmental shape and horse shoe shape tunnels. Label the parts. S-18

- The shape of a tunnel is represented by its sectional profile.
- The shape of tunnels depend upon :
  (i) The type and nature of ground through which the tunnel is to be driven.
  (ii) The purpose for which tunnel is to be used.
  (iii) The size of opening is required.
- Shape of a tunnel should fulfill the following requirements :
  (i) Shape of tunnel should be able to serve the purpose of tunnel advantageously.
  (ii) Walls and roof of the tunnel should be able to withstand external and internal pressures to which they are subjected.
  (iii) Shape selected should be able to avoid complicated supporting arrangement for walls and roof of the tunnels.

The following shapes are commonly adopted which fulfil the above requirements :

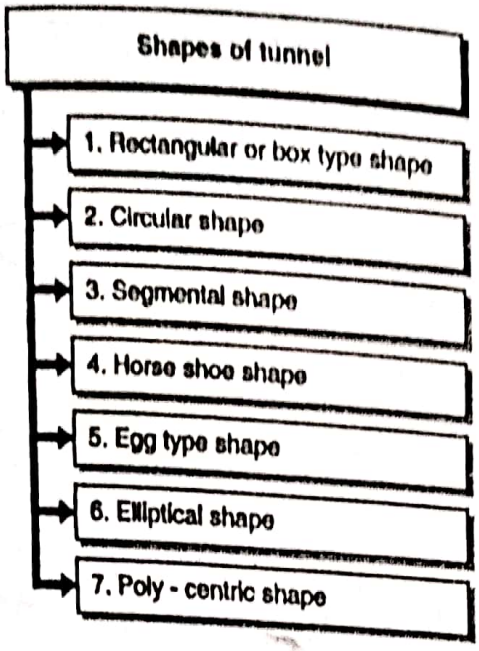


Fig. C5.2 : Shapes of tunnel

1) Rectangular or box type shape

- The tunnels of rectangular shapes are small in depth.
- These tunnels are suitable for pedestrian tunnels.
- These tunnels are rarely used now a days because their construction is difficult. The roof of such tunnels is subjected to bending stresses and therefore, steel girders are provided to form the roof lining.

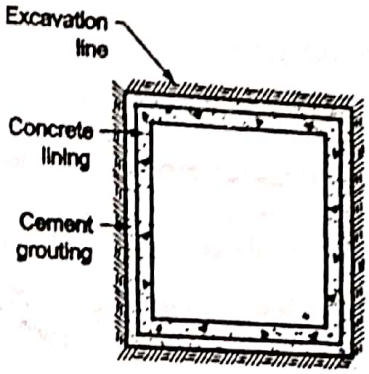


Fig. 5.3.1 : Rectangular shaped tunnel section

2) Circular shape

- These tunnels are commonly use for carrying water under pressure.
- The tunnels of circular shape are best for resisting external and internal pressures.
- These tunnels provides the greatest cross sectional area for the least perimeter.
- Circular shape tunnels can be easily constructed in soft rock.
- Their lining is difficult.
- These tunnels require costly filling to form flat base for providing a road or railway.

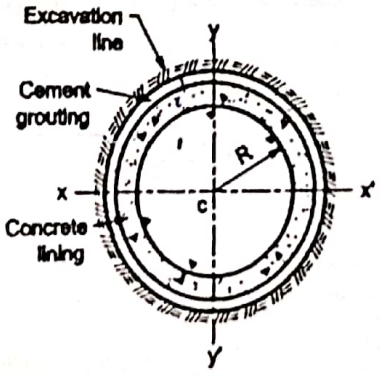


Fig. 5.3.2 : Circular shaped tunnel section

→ 3) **Segmental or D shape**

- Such tunnels have roofs segmental in shape with vertical sides and flat floor in the form of the letter 'D'.

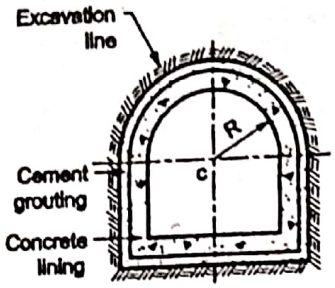


Fig. 5.3.3 : Segmental shaped tunnel section

- Segmental tunnels are suitable as traffic tunnels.
- These tunnels are commonly used in subways or as navigation tunnels.
- The tunnels of this shapes are easy to construct.
- Lining thickness is more.
- Difficult to construct in soft rock.

→ 4) **Horse - shoe shape**

- The tunnels of this shape have nearly flat bottom and curved sides and roof.
- These tunnels are suitable in soft rock.
- Tunnels of this shapes are commonly used as traffic, tunnels for road and railway routes in all country.

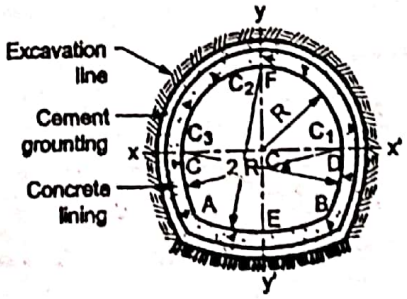


Fig. 5.3.4 : Horse-shoe shaped tunnel section

- These tunnels resist the external pressure by arch action also at their bottom.
- They are difficult to construct.
- They are not suitable as water tunnel.

→ 5) **Egg - type shape**

- Such type of tunnels have small cross - section at the bottom.
- Such tunnels maintain self cleaning velocity for flow of sewage in dry and wet seasons.
- Such tunnels resist internal as well as external pressure due to their arch action.

Spur Offs pm

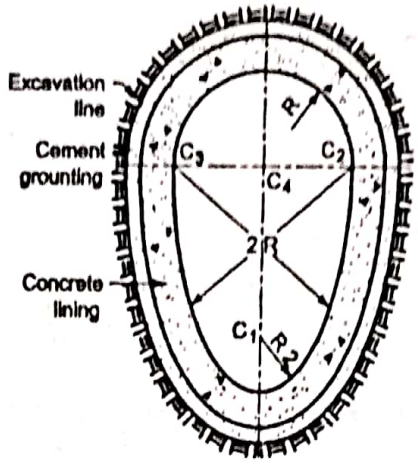


Fig. 5.3.5 : Egg-shaped tunnel section

- These tunnels are difficult to construct.
- They are not suitable as traffic tunnels.

➜ **6) Elliptical shape**

- The major axis of these tunnels is kept vertical as shown in Fig. 5.3.6 for resistance to external pressure.
- These tunnels are provided in softer materials.
- These tunnels do not provide a wider base hence they are not suitable for transportation of traffic.
- These tunnels are suitable for carrying water.
- The lining of these tunnels is difficult.

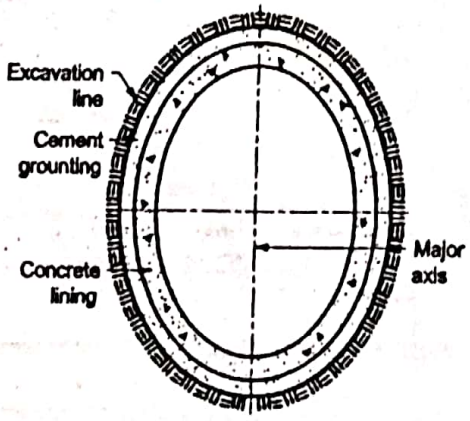


Fig. 5.3.6 : Elliptical shaped tunnel section

➜ **7) Poly - centric shape**

- The tunnels of this shape are constructed from a number of centres. Such tunnels provide flat base to suit traffic tunnels for road and railway traffic.
- These tunnels can resist external and internal pressure due to their arch action. The lining of these tunnels is difficult.
- Such tunnels are difficult to construct.

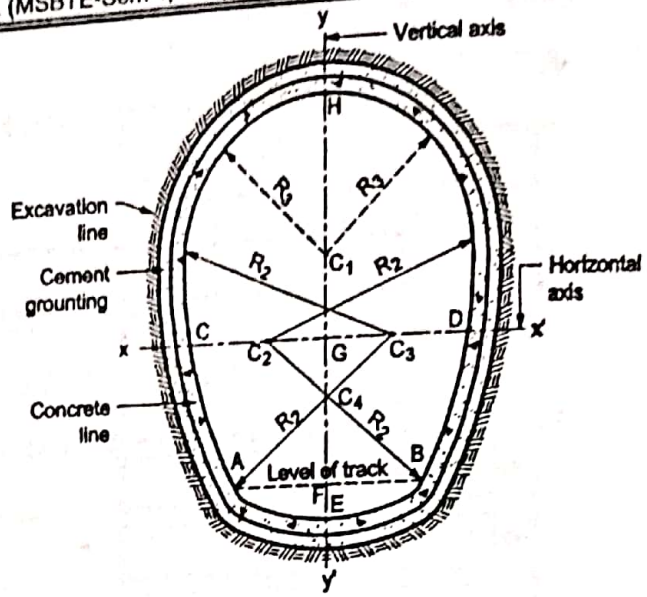


Fig. 5.3.7 : Poly-centric shaped tunnel section

The factors affecting the size of traffic tunnel are :

1. Volume and type of traffic.
2. The size of clear opening required.
3. The thickness and allowance of lining.
4. Drainage facilities required.

1. Volume and type of traffic

Total volume and type of traffic including size and speed of vehicles will affect size of tunnel.

2. The size of clear opening required

Depending upon single or double track the size should be selected.

3. Thickness and allowance of lining

As lining thickness varies from material to material it also affect size of tunnel.

4. Drainage facilities

The suitable drainage system also affect size of tunnel.

Syllabus Topic : Tunnels Cross Sections for Highways and Railways

5.4 Tunnel Cross - Sections for Highway and Railways

→ (MSBTE - S-15, S-17)

Q. Draw cross section of tunnel for single track lane for Broad Gauge. S-15

Q. Draw tunnel cross-section for railway track. S-17

- Since the construction of a tunnel is costly, only minimum dimensions required must be adopted.
- The dimensions should be convenient for the actual movement of traffic and also for the maintenance work of communication route which includes :

ventilation pipes, water pipes, drainage system, signal wires etc.

b) Space for gangmen to move freely.

It is essential to have some clear space for the door when opened, to prevent accidents.

The cross - section of a tunnel, showing the dimensions for a two lane highway (NH) is given in Fig. 5.4.1.

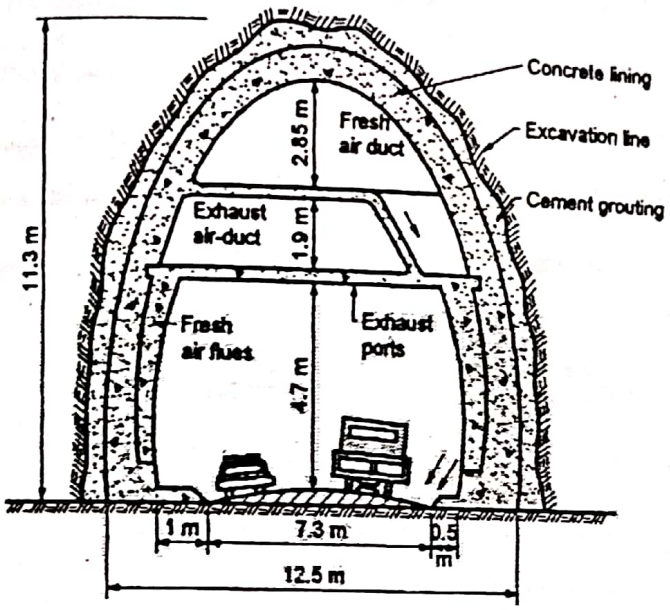


Fig. 5.4.1 : Cross-section of tunnel for a national highway

The cross - section of a tunnel, showing the dimensions for a single lane. Broad gauge railway trace is given in Fig. 5.4.2 below :

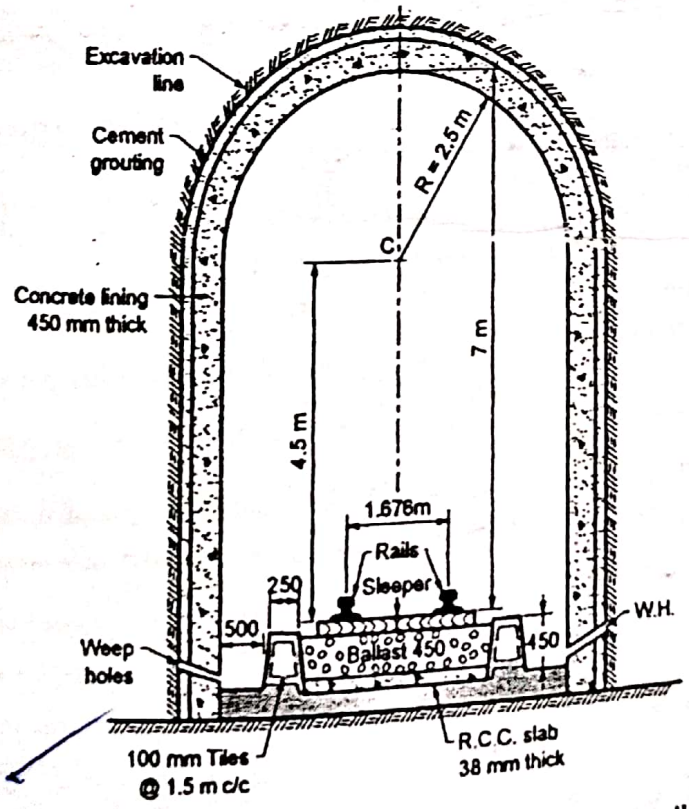


Fig. 5.4.2 : Cross-section of tunnel for a single line broad gauge railway track

- The cross - section of a tunnel, showing the dimensions for a double line, Broad gauge railway track is given in Fig. 5.4.3 below :

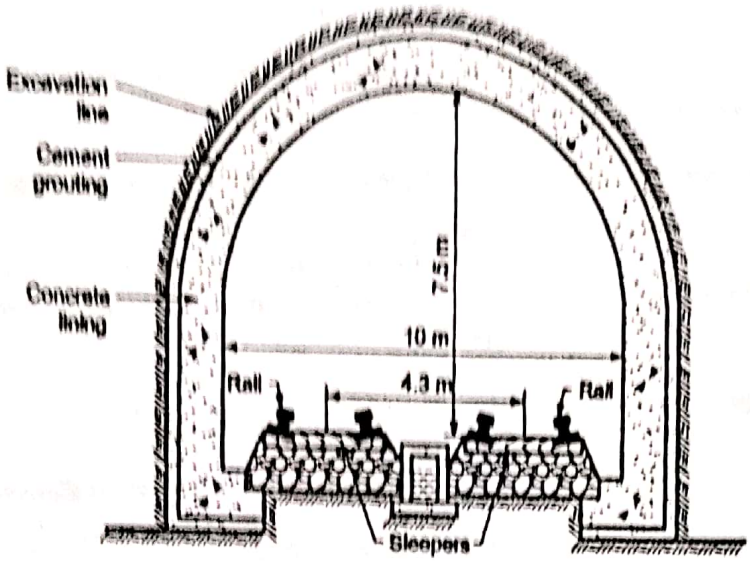


Fig. 5.4.3 : Cross-section of tunnel for a double line broad gauge railway track

5.5 Tunnel Investigations and Surveying

Syllabus Topic : Tunnel Investigations

5.5.1 Tunnel Investigations

→ (MSBTE - S-18)

Q. Explain tunnel investigation in detail. S-18

- ***Definition of Tunnel Investigation:*** *The field and laboratory investigations of the area to obtain the necessary subsurface and general data for the safe and economical design and layout of the tunnel are known as tunnel investigation.*

- The tunnel investigation include the following aspects :

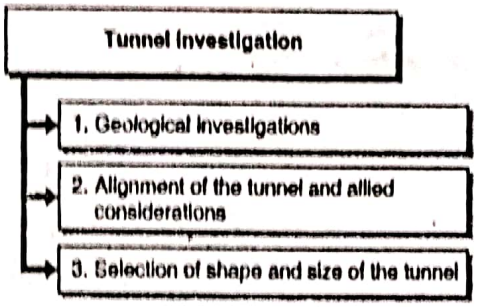


Fig. C5.3 : Tunnel investigation

→ **1. Geological investigations**

- ***Definition of geological investigations :*** *The field and laboratory investigations of the area so as to know the nature and type of strata through which tunnelling is to be done are known as geological investigations.*

☞ **Objects**

Following are the objects of geological investigations :

1) To locate underground presence of water, fault planes etc, so as to overcome problems which are likely to occur during tunnelling .

2) To know the nature and type of strata through which the tunnel is to be driven so as to decide a suitable method of tunnelling .

➜ **2. Tunnel alignment and its allied considerations**

- The position occupied by the centre line of a tunnel in plan is called tunnel alignment.
- While selecting the alignment of a tunnel, the following points should be considered :

i) Tunnel should pass through the hard rock, as the chances of accidents are much less as compared to soft rock.

ii) The alignment should be such that the excavation work is minimum.

iii) The alignment should not be near water channel.

iv) The portal of the tunnel should be near the dumping yard so that the muck may be disposed off in lesser time.

v) The alignment should be as straight as possible.

vi) Minimum possible grade should be provided in tunnel.

➜ **3. Selection of shape and size of the tunnel**

After considering the above two points its shape and size may be decided, depending upon the nature of ground and purpose for which it is to be used.

5.5.2 Tunnel Surveying

➜ (MSBTE - W-14)

Q. Explain the type of survey required during tunnel construction including laying its centre line. W-14

☞ ***Definition of Tunnel Surveying :*** *The process of setting out the alignment of the tunnel on the ground and then transferring the same to inside of the tunnel through shafts is called tunnel surveying.*

- The survey work of a tunnel involves the following operations :

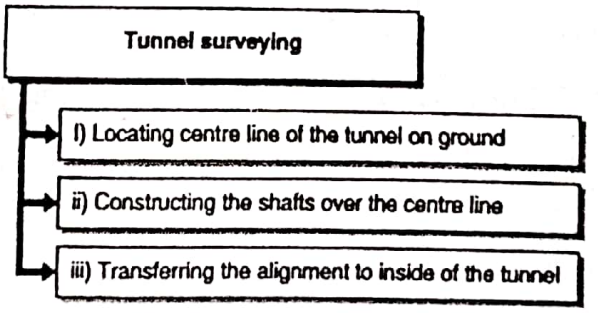


Fig. C5.4 : Tunnel surveying

➜ **i) Locating centre line of the tunnel on ground**

- After fixing the route for the tunnel, its centre line (alignment) is accurately set out on the hills or ground.
- When the length of tunnel is small, the centre line can be located by means of theodolite.
- When the tunnel is long, and to be constructed under high mountains, the centre line is set out by triangulation preferably with the help of a micrometer transit theodolite.
- In the ground, pegs are driven at regular intervals and centre line is marked.
- If it is not possible to drive pegs into the ground, the surface of the rock pointed white and centre line is marked with black paint on it.
- The alignment is then finally set out by permanent monuments of stone or concrete.

➜ **ii) Constructing the shaft over the centre line**

After locating centre line, shafts are constructed at regular interval.

➜ **iii) Transferring the alignment to inside of the tunnel**

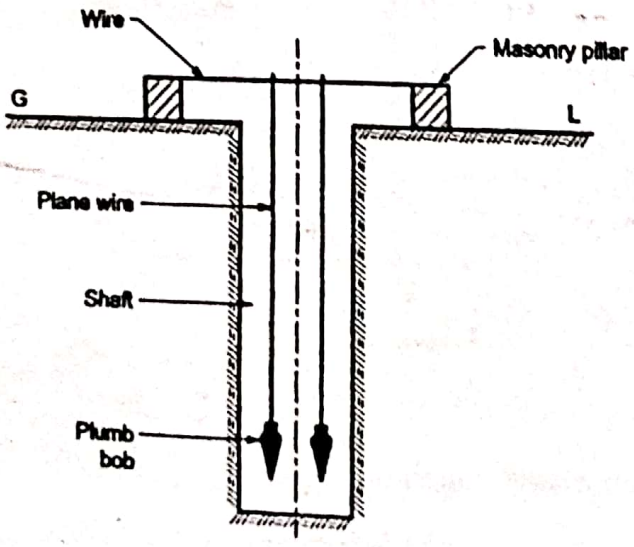
➜ (MSBTE - S-15, S-17, W-17, S-18)

Q. Explain the method of transferring the centre line inside the tunnel. S-15

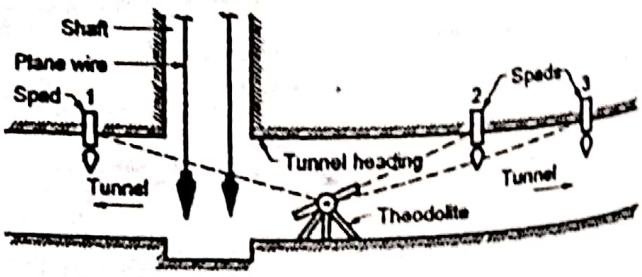
Q. Explain in brief transferring of centre line is inside the tunnel with a neat sketch. S-17, S-18

Q. With the help of neat sketch explain the procedure of transferring centre line inside the tunnel. W-17

- After constructing the shafts, the alignment of the tunnel is to be transferred down the shafts.
- For this, two small pillars are constructed on opposite edges of the shaft along the centre line of the tunnel.
- On the top of these pillars, the points corresponding to the centre line are correctly marked and wire is then stretched between them.



(a) Transferring the alignment (centre line) at the bottom of the shaft



(b) Transferring the alignment to inside of the Tunnel

Fig. 5.5.1 : Method of transferring the alignment to inside of the tunnel

- Two plumb bobs are suspended inside the shaft as shown in above figure i.e. 5.5.1(a).
- By lowering both plumb - bobs to the bottom of the shaft, two points are marked.
- The line joining the points represents the centre line of the tunnel marked on the ground.
- This line is further extended into the tunnel, as work advances, by a theodolilte placed in the shafts as shown in Fig. 5.5.1(b).

Syllabus Topic : Tunnel Shaft

5.5 Shafts

→ (MSBTE - S-17, W-17, S-18)

[illegible] shafts ? W-17

[illegible] S-17

[illegible] short note on shafts for tunnel. S-18

Definition of shafts : *The vertical wells or passages constructed along the alignment of a tunnel are known as shafts.*

Syllabus Topic : Tunnel Shaft - its purpose

5.5.1 Purposes of Shafts

→ (MSBTE - S-17, W-17)

[illegible] for purposes of providing shafts in tunnel. S-17

[illegible] the purpose of providing shaft. W-17

i) To provide opening for removal of muck.

ii) To expedite the construction work of the tunnel by starting excavation at several points at the same time.

iii) To provide passageway for pumping out the water from the tunnel.

iv) To provide natural ventilation during construction of the tunnel.

Syllabus Topic : Tunnel Shaft Construction

5.5.2 Construction of Shafts

The construction of shaft consists of following operations :

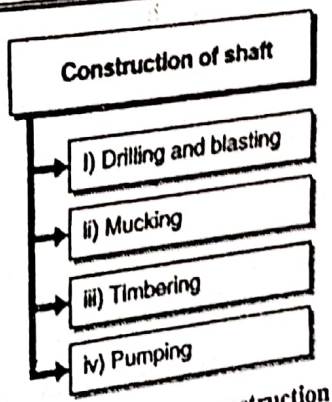


Fig. 5.5.1 : Operations in construction of shaft

i) Drilling and blasting

- In drilling of the material, stepped down technique is adopted to allow drilling and mucking operation together as shown in Fig. 5.6.1.
- Jack hammers are generally used to drill hard rock.
- Where as simple tool are used to excavate the material in case of soft rock.

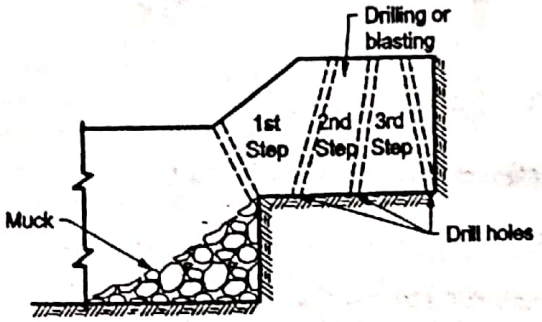


Fig. 5.6.1

ii) Mucking

(MSBTE - W-14, S-15)

Q. Define what do you mean by mucking. W-14

Q. Explain mucking process of construction of shafts. S-15

Definition of mucking : *The operation of removing the excavated material of a tunnel and dumping the same at a predetermined site is known as mucking.*

- Mucking can be carried out by manual labour, belt conveyors, mechanical shoves and by mine cars.
- Mucking is usually done in the following three steps :

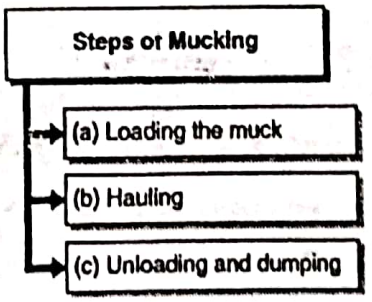


Fig. C5.6 : Steps of Mucking

(a) Loading the muck

- This operation can be done by manual labour, belt conveyor or mechanical shovels depending upon the type of job.
- For big jobs, loading of muck is usually done by a variety of muck loader.

➜ **(b) Hauling of muck**

- This operation is usually done by mine cars, as shown in Fig. 5.6.2.
- Mine cars are pulled with a locomotive.

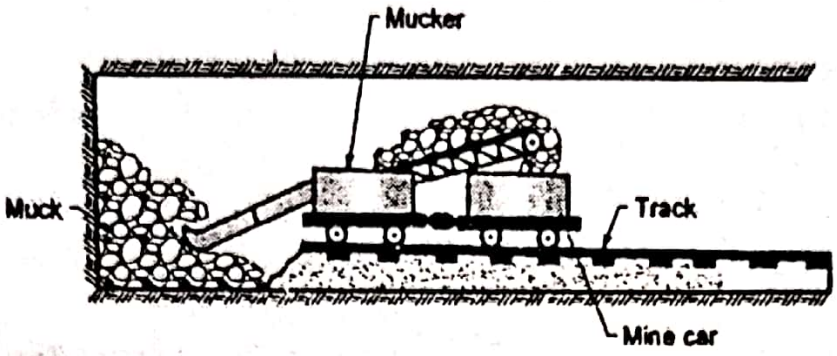


Fig. 5.6.2 : Mucker in operation

➜ **(c) Unloading and dumping of muck**

- After above two operations muck is dumped at predetermine site.
- The operation of loading and dumping was previously done manually. But nowadays, self trip used.

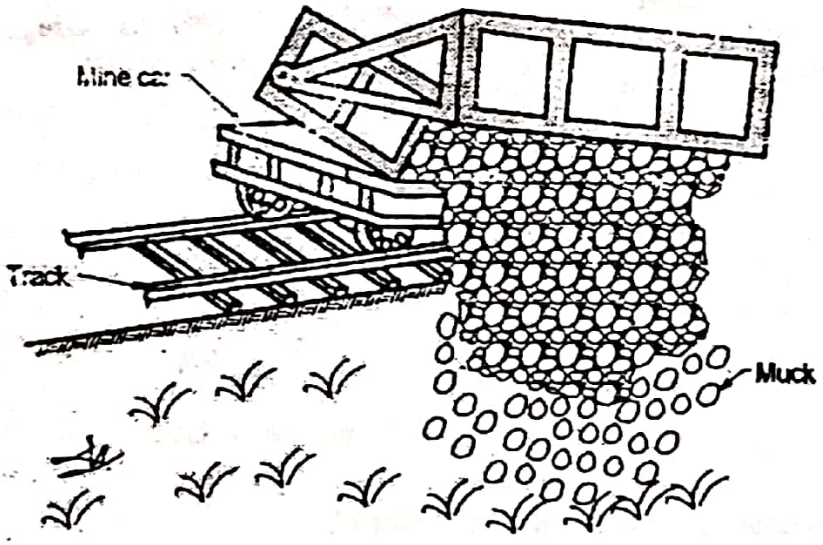


Fig. 5.6.3 : Self -tripping mine car unloading the muck

➜ **iii) Timbering**

- The art of supporting sides of the shaft to prevent them from sliding down excavation is known a
- Timbering varies with the type of ground and depth of shaft.
- In case of soft ground, timbering of the shaft becomes necessary immediately after excavation is

Syllabus Topic : Methods of tunnelling in Soft rock-needle beam method, fore-poling method, Line plate method, shield method

5.7 Methods of Tunnelling in Soft Rock

→ (MSBTE - S-18)

Q. Enlist various operations involved and different methods adopted for tunnelling in soft rock. Explain any one method with a suitable sketch. S-18

- Tunnelling in soft rock is comparatively cheap.
- It also requires less care in carrying out the excavation work.
- Timbering is provided soon after excavation is started.
- These temporary supports are later replaced by permanent lining.
- For tunnelling in soft rock following operations are usually carried out :
  - (i) Setting up and excavation
  - (ii) Timbering
  - (iii) Mucking
  - (iv) Lining

5.7.1 Methods of Tunnelling in Soft Rocks

- For tunnelling in soft rock, such tunnelling methods are used which provides support to ground as soon as excavation is started.
- Following methods can be adopted for tunnelling in soft rock

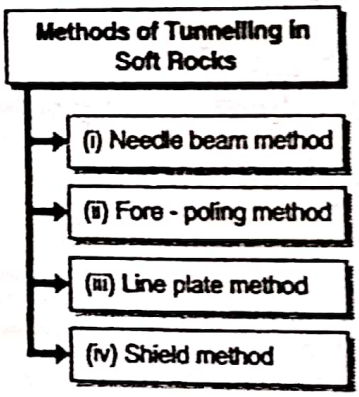


Fig. C5.7 : Methods of Tunnelling in Soft Rocks

→ **(i) Needle beam method**

→ (MSBTE - S-15, S-17, W-17)

Q. Explain needle beam method of constructing tunnel w.r.t. construction steps, sketch, merits and demerits. S-15

Q. Explain needle beam method of tunnelling in soft rock with sketch. S-17

Q. Explain Needle Beam Method with a neat sketch, also state its advantages. W-17

...main temporary support during ...de excavation.

...nstruction steps

(1) First of all a small drift of about 1 × 1m is prepared on the working face of tunnel.

(2) The roof of this drift is then supported on lagging provided on wooden segments which are carried on the trench jacks as shown in the Fig. 5.7.1.

(3) The needle beam is placed horizontally, whose front end rests on drift and the rear end is supported on vertical stout post.

(4) After excavation, the lining is provided to the tunnel section and mucking is done.

...dvantages of needle beam method

(1) This method is economical.

(2) Brick lining can be easily done by this method.

...isadvantages of needle beam method

(1) Concrete lining by mechanical method is difficult.

(2) It requires large number of french jacks and the interfere with the efficient working of the labour gang.

(3) Pushing of beam by hand is difficult and cumber some.

...Suitability

...is method is useful for tunnelling in soft ground whose roof soil can stand without support for few minutes.

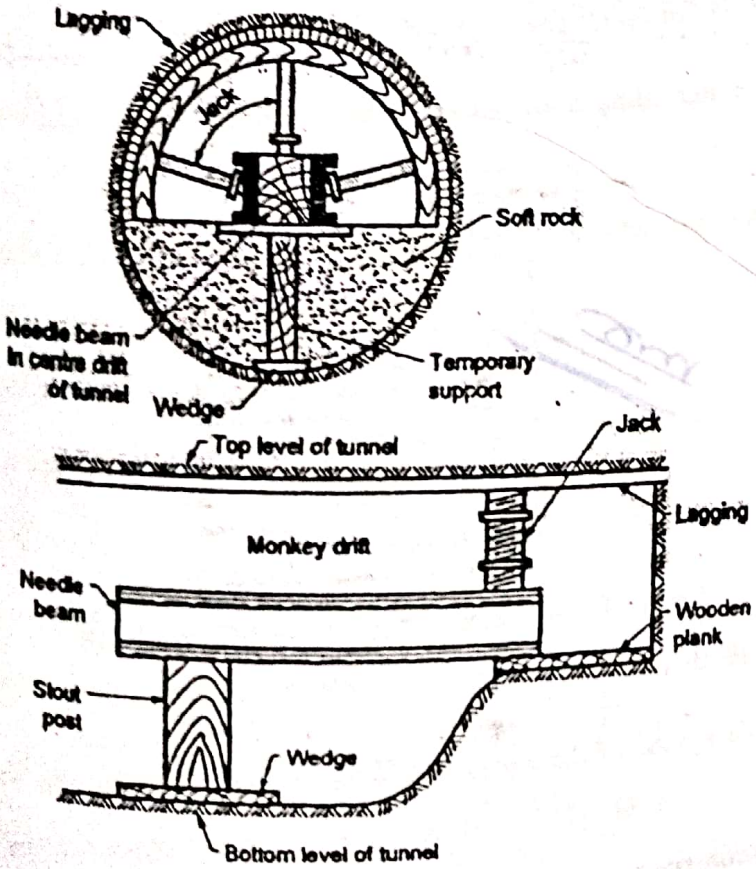


Fig. 5.7.1

(ii) Fore-poling method of tunnelling in soft rock

- It is an ancient method of tunnelling , but now it has been replace by compressed air method.
- Skilled labours are required for tunnelling by this method.
- Skilled supervision is required.
- This methods is used for the construction of small dimensions tunnels required for laying sewers, gas pipes etc.
- This method needs large quantity of timber for supporting the ground.
- This method is slow and tedious.

Construction steps

- In this method, a frame in the form of letter 'A' is prepared and placed near the face of the tunnel covered with suitable planks as show in Fig. 5.7.2.
- The poles are then inserted at the top and continued to a depth upto which they can be easily taken up.
- These poles are supported by vertical posts.
- Now excavation can be done under the forepoles.
- The excavation is also done on sides and are supported by suitable timbering.
- In this way the full section of the tunnel is excavated.

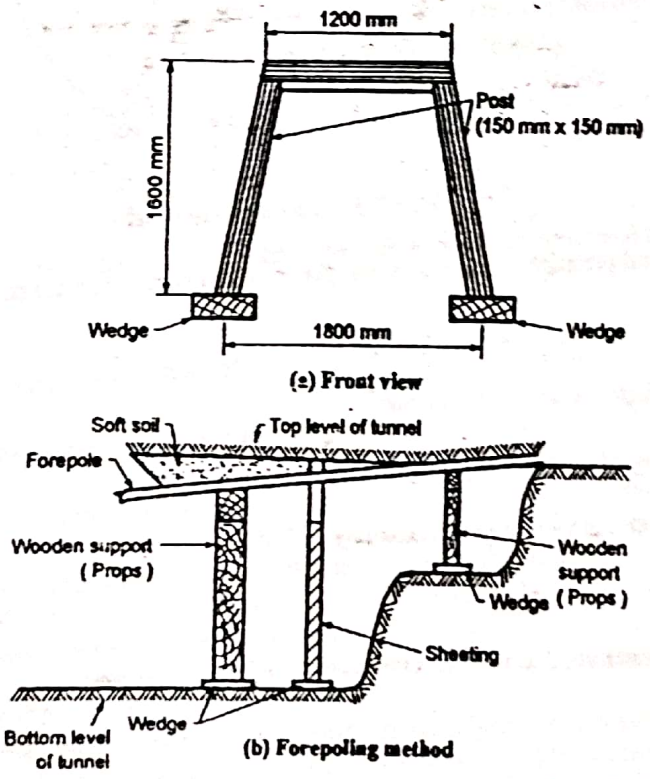


Fig. 5.7.2

(iii) Line plate method

- In line plate method, timbering is replaced by standard sized pressed steel plates.
- The pressed steel plate is of 40 cm wide and 90 cm with all four edges flanged over 5 cm.

Construction steps

(a) In this method, first of all 40 cm deep hole is cut.

(b) Roof is trimmed carefully and crown plate is set.

(c) The excavation is then widen out and the adjacent plates set on each side as shown in Fig. 5.7.3.

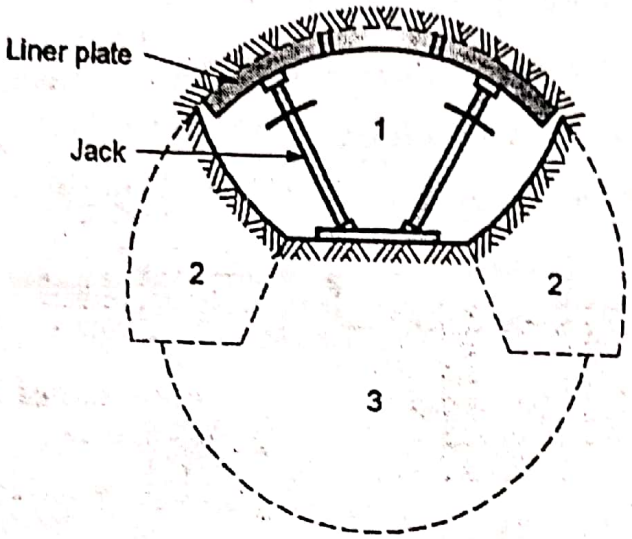


Fig. 5.7.3 : Line plate method

(d) If there is any ground pressure on the plates, the plates are supported with the help of jack.

Advantages

(1) The line plates are light, hence handled easily.

(2) Unskilled labours can also erect the line plates.

(3) They are fire proof, hence they can be used safely.

(iv) Shield method

- Shield method of tunnelling has now become more popular than old methods.
- The latest development in tunnelling is the invention of mechanical tunneler called mole.
- Mole is a machine which has number of steel grinding discs on its surface.
- These disc rotates at high speed to cut the soft rock or ground.
- These machine also moves forward leaving behind full size of the tunnel.
- Shield method do not require use of timbering.

Syllabus Topic : Methods of tunnelling in Hard rock-Full-face heading method, Heading and bench method, drift method.

5.8 Tunnelling in Hard Rock

- In hard rock tunnelling is comparatively easy and more safe.
- In these case less timbering is required.
- Great care is essential in carrying out the excavation work.
- For tunnelling in hard rock following operations are usually carried out :

(a) Setting up and drilling.
(b) Loading holes and firing the explosive.
(c) Ventilation and mucking.
(d) Removing ground water, if any
(e) Timbering
(f) Grouting and lining.

5.8.1 Methods of Tunnelling in Hard Rock

→ (MSBTE - W-14, S-15, S-17)

Q. Enlist methods of tunnelling in hard rock. S-15
Q. List the methods of tunnelling in hard rock and explain any one in detail. S-17
Q. Name methods used for tunnelling in hard rock. Explain any one with sketch. W-14

There are various methods of tunnelling in hard rock common methods are given below :

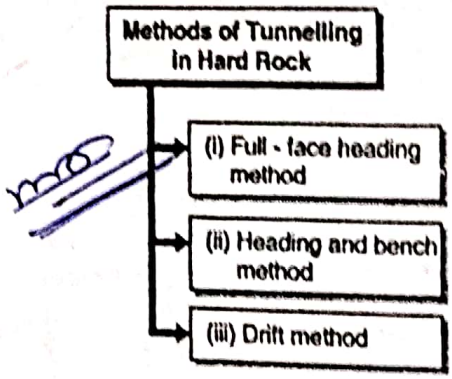


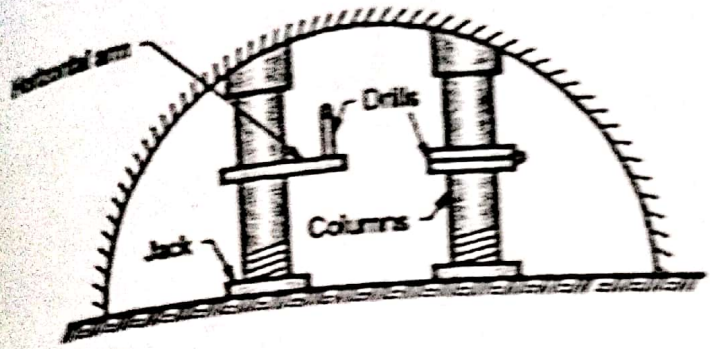
Fig. C5.8 : Methods of Tunnelling in Hard Rock

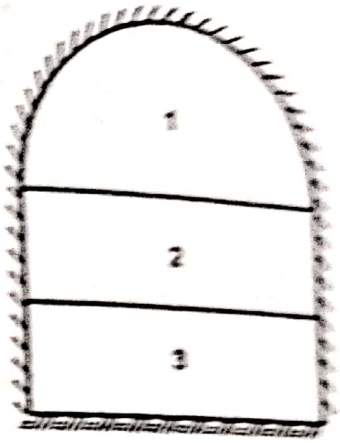
→ **(i) Full - face heading method**

- As in this method whole section of the tunnel is attacked at the same time, this method is called as full - face heading methods.
- In this method, vertical columns are fixed at the face of the tunnel and drilling is done on the whole section of the proposed tunnel.
- The drill holes are charged with explosive and ignited at a time.
- The size of the hole may vary from 10mm to 40 mm.

...muck is removed before ...

...Tunnel Boring Machine are well suited for full face method.





(a) When tunnel is small (b) When tunnel is large

Fig. 5.8.1 : Full face heading method

Construction steps :

Tunnelling by full face heading is done in the following steps :

(a) Setting up and drilling

(b) Charging and blasting

(c) Scaling (The operation of removing loose rock fragments and hammering off projecting pointed rocks is known as scaling).

(d) Mucking

(e) Tunnel supporting

(f) Grouting and lining

Suitability

This method is adopted for tunnels whose length is more than 3 meters and upto 6 m diameters large size tunnel in rocks are always driven by these methods.

Advantages of full face heading method :

(1) In this method progress of work is more as compared to other methods.

(2) Mucking can be done easily.

(3) Ribbing can be continuously done for the whole section.

Disadvantages of full face heading method

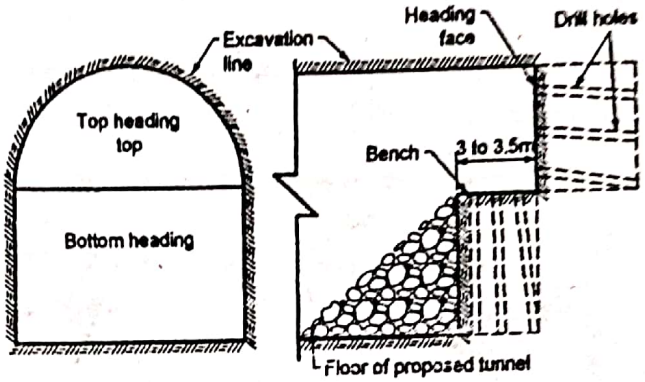
(1) This method is not suitable for unstable rock.

(2) Heavy mechanical equipments are required to carry out the work.

(3) Unexpected problems may arise in water bearing area.

(ii) Heading and bench method

- In this method, the driving of the tunnel is done in two portions of its section. The top portion is known as heading and bottom portion is known as bench.
- The driving of top portion is done in advance of the bottom portion as shown in Fig. 5.8.2.
- In this method of tunnelling the top portion or heading will be about 3 to 3.5m ahead of the bottom portion as shown in Fig. 5.8.2.
- The holes are drilled into head and bench.
- Then these holes are loaded together with explosive and then blasted.



(a) Cross section (b) Longitudinal section

Fig. 5.8.2 : Heading and bench method

- Firing of bench holes is done just before the heading holes are fired. After this mucking is done manually.

Suitability

This method is suitable when large section of the proposed tunnel is to be drived and the quality of rock is not very satisfactory.

Advantages of heading and bench method

(1) This method requires less labour than that in full face method.

(2) In this method, quantity of explosive required is less than that for full face heading method.

(3) In this method, benching provides a platform for working on heading.

(4) In this method drilling and mucking is done simultaneously.

Disadvantages of heading and bench method

(1) Progress of work is slow as compared to that of full face heading method.

(2) Use of machinery for mucking becomes difficult.

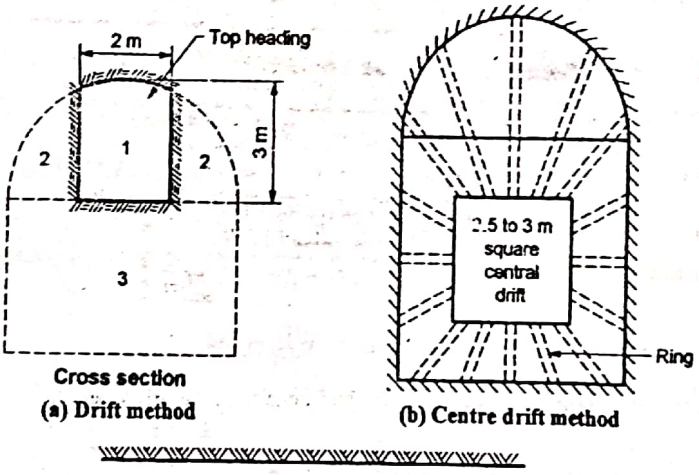
(3) Removal of muck from the heading is difficult.

(iii) Drift method

→ (MSBTE - S-15)

Q. Explain drift method with sketch. **S-15**

- It consists in driving small size heading. Centrally at top or bottom of the face, which is later enlarged by widening and benching. The main operations involved in this method are as follows :
  - (i) Boring or blasting a top centre heading of drift.
  - (ii) Widening and enlarging.
  - (iii) Benching in stages.
- In this method, a drift of 2.5m × 3m (minimum) size or sufficient to accommodate the tunnelling machinery, labour and mucking equipment etc.
- After making the central drift, holes are drilled for widening the face of the proposed tunnel.



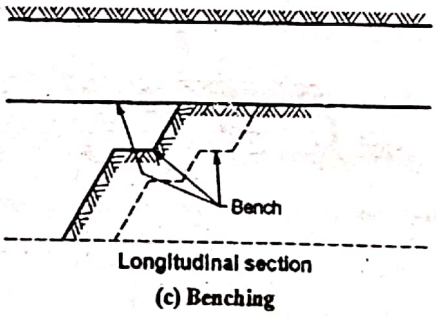


Fig. 5.8.3

- These drilled holes are then loaded with suitable explosive and fired step by step as shown in Fig. 5.8.3 and Fig. 5.8.4 shows types of drift.

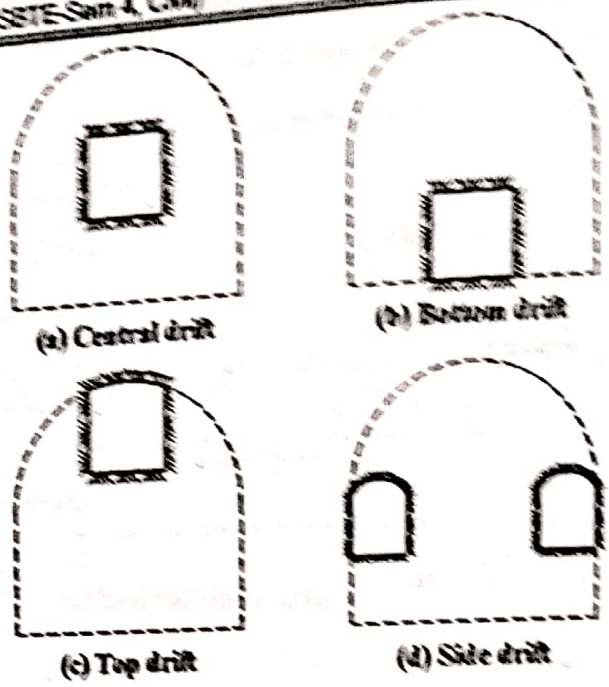


Fig. 5.8.4 : Types of drift

☞ **Advantages of drift method**

1. This method provides good ventilation during construction of tunnel.
2. The quantity of explosive required is reduced.
3. In this method, nature and type of rock to be encountered are known in advance of excavating full section.
4. The side drift provides facility to install timbering to provide support to the roof.

☞ **Disadvantages of drift method**

1. Cost of drilling and handling muck will be high.
2. In this method, more labour is required.
3. Driving of main tunnel get delayed until the drift is finished.
4. This method requires complicated supporting arrangement of tunnels.

5.9 Precautions In Construction of Tunnels

→ (MSBTE - S-17)

Q. State the precautions to be taken while construction of tunnels. **S-17**

1. Depending on the purpose of tunnel, shape should be decided.
2. Cross - sectional dimensions of the tunnel should be decided to achieve economy in its construction.
3. In order to make proper use of labour and equipment, sequence of operation must be well planned previously.
4. Labour should be well organized to maintain continuous progress of the tunnelling operations.
5. The use of outdated and unsuitable tools must be avoided.
6. Each and every operation must be completed in scheduled time as far as possible.

7. Loading and hauling of muck should be carried out efficiently.
8. In order to achieve economy, the sequence and type of lining should be determined in advance.
9. Selection of multipurpose and uniform type of equipment should be made, according to the size and shape of the tunnel.
10. Pattern of blasting the material in different locations should be decided for maintaining speed of driving and safety.

5.9.1 Comparison between Tunnelling in Hard Rock and Soft Rock

Sr. No.	Tunnelling in hard rock	Tunnelling in soft rock
1.	Cost of construction is more.	Cost of construction is less.
2.	Stability during construction is more.	Stability during construction is less.
3.	Skilled labour and heavy machines required.	Not so much skill labour and heavy machineries required.
4.	Progress of work is slow as compare to tunnelling in soft rock.	Progress of work is fast as compare to tunnelling in hard rock.
5.	Explosive needed duri: g construction.	Explosives are not required during construction.
6.	Stability during construction is more.	Stability during construction is less.

Syllabus Topic : Drilling equipment

5.10 Drilling Equipments

→ (MSBTE - W-14, W-17)

Q. List the important equipments and machines used in tunnel construction with their use. W-14

Q. List the commonly used drilling machines in tunnelling. W-17

☞ *Definition of drilling equipment :-The equipments required for drilling holes of required size and length in suitable pattern in the tunnel heading is known as drilling equipment.*

☞ **Equipments and machines used in tunnel construction with their use**

Sr. No.	Equipment's /Machine	Uses of equipment's/Machine
1.	Theodolite	For making the alignment of tunnels.
2.	Plumb-bobs with piano wires	For transferring the alignment (center line) of tunnel to the bottom of shaft.
3.	Spads	For making the center line inside the proposed tunnel.

Sr. No.	Equipment's /Machine	Uses of equipment's/Machine
4.	Electrical detonators	For firing the holes drilled and loaded with explosives.
5.	Drilling equipment's	To drill the holes.
6.	Trench jacks	For centering and formwork of tunnels.
7.	Locomotives	For hauling the muck.
8.	Travelling forms	For lining
9.	Grouting machines	For placing grout to seal-off water entering the tunnel
10.	Loading machines such as shovels, fully revolving shovel, crawler shovel, con-way digger, mine car loaders etc.	For mucking.

- The drilling equipments are divided into the following two points :

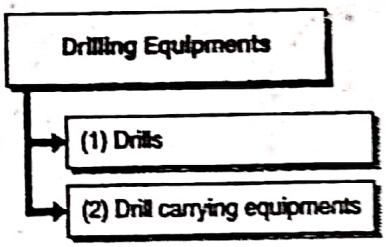


Fig. C5.9 : Drilling Equipments

Syllabus Topic : Drills

5.10.1 Drills

☞ ***Definition of drills :*** *The mechanical devices used for drilling holes in the tunnel heading are known as drills.*

- Drills are made up of high carbon steel.

☞ **Types of drills**

The following types of drills are commonly used :

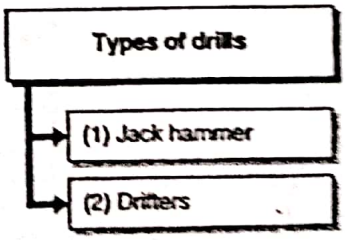


Fig. C5.10 : Types of drills

➜ **(1) Jack hammer**

- These drills break the rock to small pieces by impact from repeated blow .
- The number of blow per minute are 2000.

☞ **Types of jack hammer**

The jack hammer is of three types :

(1) Light weight jack hammer

(2) Medium weight jack hammer

(3) Heavy weight jack hammer.

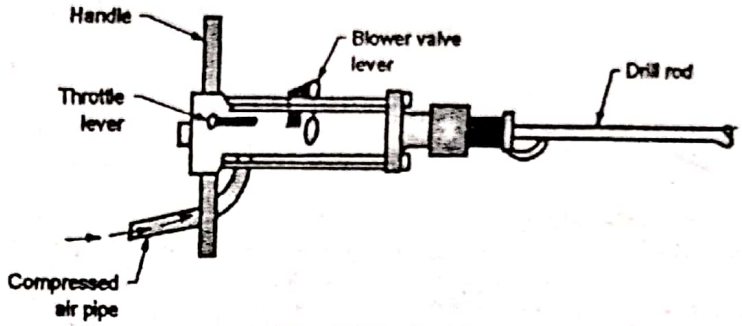


Fig. 5.10.1 : Jack hammer

- Jack hammer requires on an average 2 to 2.3 cum of compressed air per minute at a pressure of 5.5 to 7 kg/cm^2.
- A light jack hammer can drill 3 to 4 cm diameter holes upto 2 meters deep.

➜ **(2) Drifters**

- These are heavier than jack hammer.
- Their weight is 50 to 100 kg
- For drilling holes drifters are mounted on stands.
- They can drill holes upto 6 m deep.

Syllabus Topic : Drills Carrying Equipments

5.10.2 Drill Carrying Equipments

☞ ***Definition of drill carrying equipment :*** *The equipment used for carrying the drills while drilling hole in the tunnel heading is known as drill carrying equipment.*

- The following equipment is required for carrying the drills :

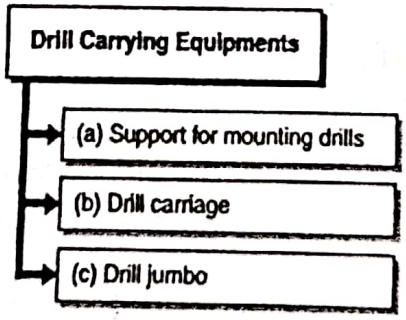


Fig. C5.11 : Drill Carrying Equipments

➜ **(a) *Support for mounting drills***

- Usually columns are used to support for mounting drills. These columns consists of steel pipe supports, strutted between roof and floor of the tunnel.

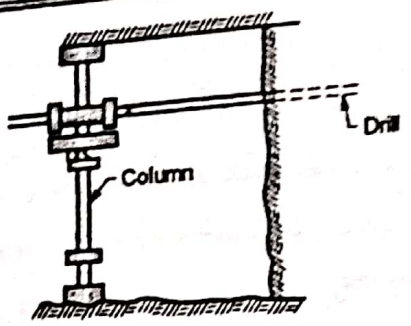


Fig. 5.10.2 : Drill mounted on a column

➜ **(b) Drill carriage**

- It is a portable carriage which is used for carrying drills, mounted on its cradle.

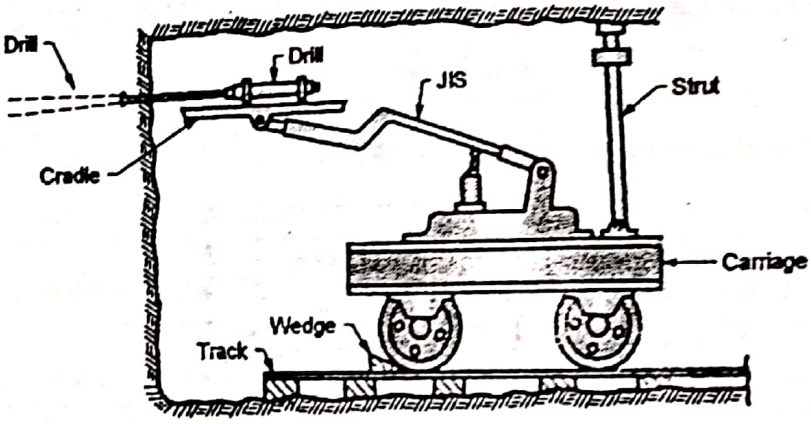


Fig. 5.10.3 : A drill carriage during drill operation

- It is provided with a wheeled base.
- A strut to hold it in position.
- It is used for drilling small and medium size tunnels.

➜ **(c) Drill jumbo**

- It is a movable steel frame type drill carriage.
- It is fully equipped for drilling the heading of a tunnel.
- It consists of a number of platforms, known as decks to support drills as shown in Fig. 5.10.4.
- For drilling large size tunnels, drill jumbo are commonly used.

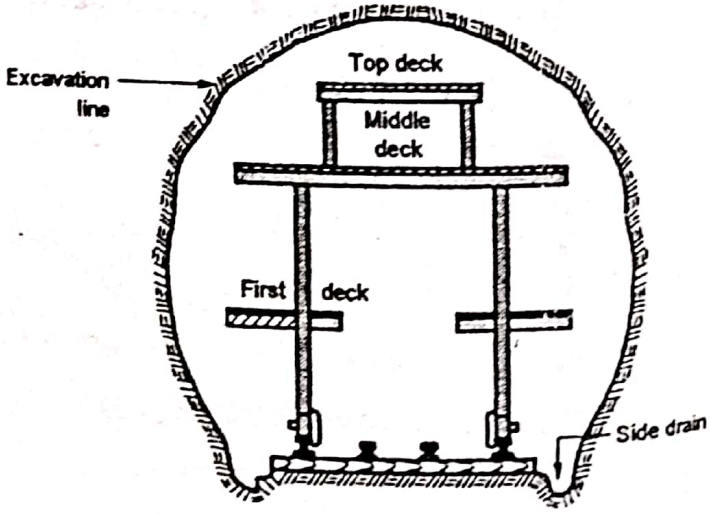


Fig. 5.10.4 : Drill jumbo

5.11 Explosive

It is a material, either a pure single substance or a mixture of substances which is capable of producing an explosion by its own energy.

Syllabus Topic : Types of Explosives Used in Tunnelling

5.11.1 Explosives Used in Tunnelling

→ (MSBTE - W-14, S-17, W-17)

- Enlist the explosive commonly used in tunnelling work. W-14
- Describe in brief types of explosives used in tunnelling. S-17
- Mention various explosives used in tunnelling. What precautions you will ensure while explosions? W-17

Following three types of explosives are mainly used for tunnelling :

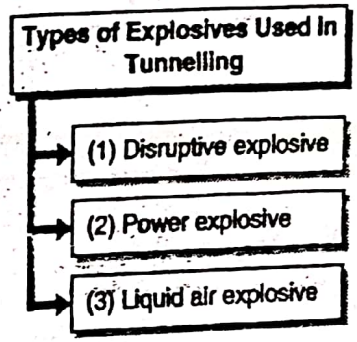


Fig. C5.12 : Types of Explosives Used in Tunnelling

→ **(1) Disruptive explosives**

- These are commonly used explosives for tunnelling.
- They are available in the market in the form of cartridges of size 2.5 cm to 20 cm in diameter and 20 cm to 70 cm in length.
- Common type of disruptive explosives used in tunnelling are :
  - (a) Straight dynamite
  - (b) Gelatine dynamite
  - (c) Semi - gelatine
  - (d) Ammonia dynamite
  - (e) Blasting gelatine

→ **(2) Power explosives**

- These explosives are not commonly used in tunnelling
- Types of power explosives used for tunnelling are :
  - (a) Blasting powder
  - (b) Nitrate explosive
  - (c) Nitraman

- Blasting powder is slow in burning, therefore it is not commonly used in these days.
- Nitrate explosive and nitraman is highly explosive but a special primer is required to detonate it, therefore it is rarely used in tunnelling .

➜ **(3) Liquid air explosive**

- These explosives usually consists of 95% oxygen at temperature of 191°C, which is absorbed by dipping a cartridge of absorbent.
- Such explosives require special skill in their manufacture, transporting and storing.
- Therefore, not commonly used.

Syllabus Topic : Tunnel lining –Purpose, Methods, Factors Affecting Type of Lining

5.12 Tunnel Lining

➜ (MSBTE - S-17, S-18)

Q. Define tunnel lining and give purpose of lining of tunnel. S-17

Q. What is tunnel lining? State different types of linings adopted in tunnelling with the materials used. S-18

☞ ***Definition of Tunnel Lining :*** *A layer of timber, iron, masonry or concrete provided on the inside of a tunnel is known as lining.*

- **Objects of lining or purpose of lining :**

(1) To provide the correct, desired shape to the tunnel.

(2) To support the loosened rock pieces during blasting.

(3) To increase the structural strength of soft places in the tunnel.

(4) To improve the appearance of tunnel.

(5) To prevent percolation of water inside the tunnel.

(6) To reduce the maintenance cost of tunnel.

(7) To house electrical fitting.

(8) To withstand soil pressure when driven in soft rocks.

☞ **Factors affecting type of lining are**

(1) Type and nature of rocks.

(2) Purpose and tunnel for which it is constructed.

(3) Funds available.

(4) Aesthetic consideration.

☞ **Types of tunnel lining**

Following types of lining are used :

(i) Timber - lining
(ii) Stone - masonry lining
(iii) Brick lining
(iv) Iron lining
(v) Cast steel lining
(vi) Precast pipe lining
(vii) Pressed steel plate lining
(viii) Precast block lining
(ix) Concrete lining
(x) Reinforced concrete lining

5.12.1 Reinforced Concrete Lining

Such type of lining are commonly used now a days.

☞ **Method of concrete lining**

- Modern equipments and technology have made concrete lining an easy and quick job.

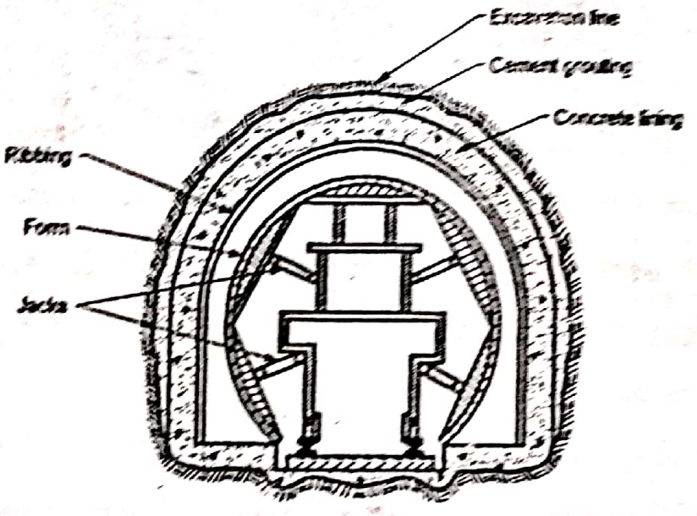


Fig. 5.12.1 : Form carrier in concreting operation

☞ **The steps involved in concrete lining are :**

(1) Laying the form - work

- The form - work may consist of separate form or single unit form. Which are fixed in the position at one section by means of jack as shown in Fig. 5.12.1.

(2) Batching and mixing of concrete

- After laying the form work, the batching and mixing of concrete is done in the mixing plant.
- The concrete may be mixed at the top or bottom of shaft or the mixing plant may be kept inside the tunnel.

(3) Placing of concsrete

After hauling of concrete, the concrete is placed in position either by manual labour or by pumps.

(4) Compaction of Concrete

After placing the concrete in position, it is compacted by vibrators.

(5) Curing

After 24 hrs of placing and compacting of concrete, it is cured for two weeks.

☛ **Advantages of plain of reinforced cement concrete lining**

(i) Maintenance cost is less.
(ii) Water tight.
(iii) It can be moulded to any shape.
(iv) It provides homogenous construction.
(v) It is not subjected to the attack of insects or fungi.

Syllabus Topic : Tunnel Ventilation - Purposes and Method

5.13 Ventilation of Tunnels : Purposes

→ (MSBTE - W-14, S-15, S-17, S-19)

Q. What is the necessity of ventilation of tunnels ? Write four points, name methods of ventilation. [W-14]
Q. State objects and methods of tunnel ventilation. [S-15]
Q. Define tunnel ventilation. [S-17]
Q. Enlist methods of ventilation of tunnel and explain any one method with neat sketch. [S-17]
Q. State objectives of tunnel ventilation. Enlist methods of tunnel ventilation. [S-19]

☛ ***Definition of ventilation in tunnels :*** *The art of providing freshness of air inside tunnels during or after their construction is known as* ***ventilation in tunnels.***

☛ **Object of tunnel ventilation**

1. To supply fresh air inside the tunnel.
2. To remove poisonous gases, dust smoke etc.
3. To reduce temperature in tunnel situated at great depth.
4. The traffic moving in a tunnel after its construction, produces smoke, foul gases which may cause suffocation and inconvenience to the passengers if the tunnel is not properly ventilated.

5.13.1 Methods of ventilation in tunnels

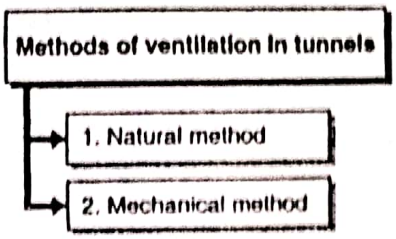


Fig. C5.13 : Methods of ventilation in tunnels

(1) Natural method

- Natural ventilation is possible automatically due to difference of temperature inside and outside the tunnels. Good ventilation is not possible by this method.
- Natural ventilation can be improved by providing shafts at a suitable interval along the alignment of a tunnel during its construction.

This method is suitable when :

(a) Tunnel is to be laid in the direction of wind.

(b) A drift is driven from portal to portal.

(c) Diameter of the tunnel is large but its length is small.

(2) Mechanical method

- Mechanical ventilation is done by blowing fresh air into a tunnel or by exhausting the foul air or dust from the tunnel by any system listed below :
- There are three system of mechanical ventilation :

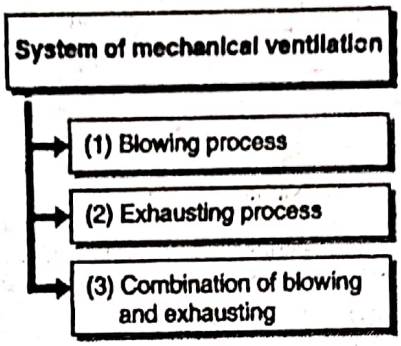


Fig. C5.14 : System of mechanical ventilation

(1) Blowing process

- In this method of mechanical ventilation, fresh air is forced by one or two blowers through the ducts, provided in the tunnel.
- By this method, positive supply of fresh air at the working place can be obtained.
- But the disadvantage lies in that the foul air, smoke and dust slowly move out, fogging the atmosphere inside the tunnel, especially in long tunnels.
- This method is also known as propulsion method.

(2) Exhausting process

- In this method of mechanical ventilation, air is sucked by one or two exhaust fans installed near the tunnel heading.
- This creates vacuum due to which fresh air enters inside the tunnel.
- This method has the special advantage of quick removal of dust and smoke from the working face.
- This method is also known as vacuum method.

(3) Combination of blowing and exhausting process

- In this method, blower and exhaust fans are provided for forcing fresh air in the tunnel and sucking foul air from the tunnel.
- The blower and exhaust fans are installed in suitably spaced inlet and outlet shafts connected to the tunnel.
- Immediately after the blasting operation, the exhausting system is operated for 15 to 30 minutes, to remove the objectionable air.
- After which blowing system is operated for forcing fresh air in the tunnel. This method provides the most efficient ventilation system of tunnels.

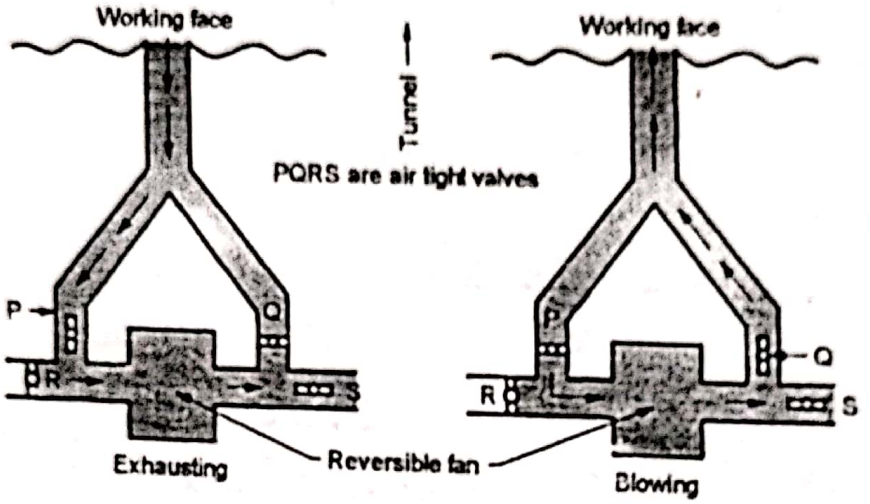


Fig. 5.13.1 : Combination of blowing and exhausting process

5.14 Advantages and Disadvantages of Rectangular and Circular Shaped Tunnel Sections

Rectangular shape tunnel

Advantage

(1) The roof of such tunnels is subjected to bending stresses and therefore, steel girders are to be provided to form the roof line.

(2) It is small in depth.

Disadvantage

(1) It is suitable for only pedestrian.

(2) It is not use in carrying water or oil.

Circular shape tunnel

Advantage

(1) It is best for resisting external and internal pressure.

(2) Easily constructed in soft rock.

Disadvantage

(1) These tunnels requires costly filling to flat base for providing a road or railway.

(2) Lining is difficult.

Syllabus Topic : Tunnel Drainage Purposes and Method

5.15 Permanent Drainage System

☞ **Tunnel drainage**

It is collection and removal of water entering the tunnel during and after construction.

☞ **Necessity of drainage**

It reduces wear and tear of communication and achieve safety of moving vehicle.

The drainage system provided after construction of tunnel are called as permanent drainage system. The various methods of permanent drainage system are

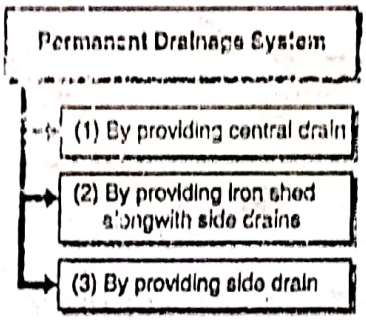


Fig. C5.15 : Permanent Drainage System

➜ **(1) By providing central drain**

The central drain is provided in between railway track or road pavement. These are suitable when a huge quantity of water does not come through roof and side walls of tunnel.

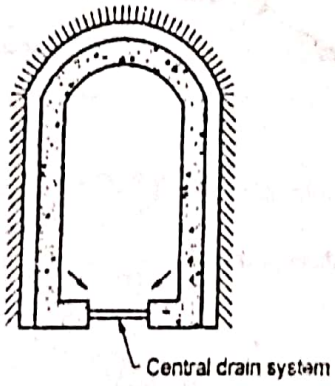


Fig. 5.15.1

➜ **(2) By providing iron shed alongwith side drains**

In this method corrugated iron shed is provided along with side drains. It is suitable where water leakage is more through roof or side walls. This is costly and needs more maintenance as iron sheds are subjected to corrosion.

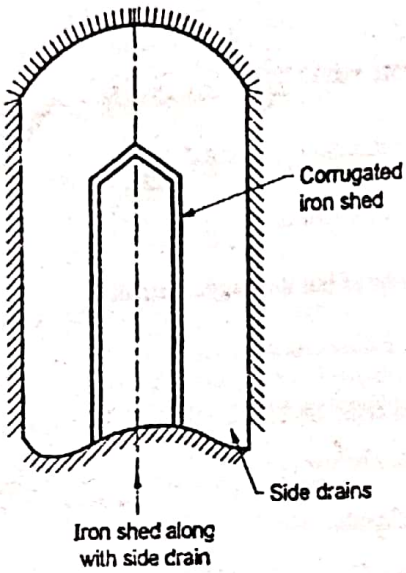


Fig. 5.15.2

➜ **(3) By providing side drains**

In this method single side drain is provided. These are suitable where there is small quantity of water entering in tunnel.

Syllabus Topic : Tunnel Maintenance

5.16 Tunnel Maintenance

The following measures should be taken for tunnel maintenance.

1. Portals should be check carefully i.e. crack in masonry, seepage of water, sign of slip etc.
2. The weep holes should be checked thoroughly.
3. The roofs and walls should be check for cracks seepage bulging etc.
4. The lightning arrangement should be checked.
5. The shaft should be check thoroughly any obstruction found should be cleared.
6. The levels, reference marks should be checked.

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Chapter Ends