MODULE IV

TRACK MAINTENANCE AND RAILWAY ACCIDENTS

MAINTENANCE

The difference in the maintenance requirements of railway track and other civil engineering structures is due to following considerations:

(1) Foundations: The foundations of most of the civil engineering structures like buildings, dams, bridges, etc. are solid and they do not get unduly strained with the loads coming on them. The railway track on the other hand rests on a floating foundation of ballast.

(2) Nature of structure: The civil engineering structures are massive in nature and the live loads imposed on them are small. The structure of a railway track is delicate as compared to the heavy vehicles which run at high speed over it. The natural elements like rains, floods, winds, temperature variations, etc. will also exert their influence on the maintenance of a railway track.

NECESSITY FOR MAINTENANCE OF TRACK

There are mainly two reasons for maintaining the track in proper order:

(1) **New track**: The newly laid railway track will settle down slowly and hence special gangs are to be employed to bring the embankment to the proper formation level. The number of men required will depend upon various factors. But generally 4 men are employed per kilometre length of the track for this purpose.

(2) **Constant use:** The railway tracks are being constantly used by trains and hence they require some treatment to remain in the working condition. This is achieved by providing maintenance gangs all along the railway track. The main function of these gangs is to keep the track in good condition. The railway track is divided into suitable sections, each having a length of about 6 km for main line and 8 km for branch line section and one gang is attached to this section. The number of men required to maintain the railway track will depend on the volume of traffic nature of soil and strength of the permanent way

Following are the advantages of good track:

(i) The chances of derailment and accident are considerably reduced
(ii) The delicate goods can be conveniently and safely carried in the train
(iii) The high speeds of the trains can be maintained.
(iv) The life of rolling stock and track is increased.
(v) The train journeys become easy, smooth and comfortable.
(vi) There is reduction in the operational cost of the trains.

MAINTENANCE OF TRACK PROPER

A gang consists of gangmate or ganger, one keyman and nine to ten workers for B.G. and above four to five workers for M.G. Each gang works in a length of about 90 metre day. About ten to fifteen gangs are placed under a Sub-Permanent Way Inspector and one Permanent Way Inspector, commonly known as P.W.I., looks after two three Sub-Permanent Way Inspectors.

Duties of a gangmate or a ganger: Following are the duties of a gangmate

(i) The ganger is the head of the gang and he is personally responsible for the upkeep of track in his section.

(ii) The ganger must keep his section in good running condition at all time

(iii) The ganger is responsible for maintaining the track in his section at correct alignment and level.

(iv) The ganger has to arrange for tools and other equipments required for his gang.

(v) The points and crossings should be periodically checked and examined by the ganger.

(vi) In case of emergency, the ganger should stop or slow down a running train by the use of temporary signals.

(vii) In case of an accident, the ganger should look after the broken fitting of the rolling stock and track components and see that these articles are not disturbed till they are seen and recorded by a responsible person

(viii) The ganger should be fully conversant with the details of his section such as number and location of points and crossings, level-crossings, etc

(ix) The ganger should prevent trespass of persons or cattle in the railway limits under his charge. He should also report of any unauthorized construction in his section.

(x) Sometimes the ganger is given miscellaneous duties such as noting high flood level of small bridges, cutting branches of trees obstructing vision of signals, repairing fencing, etc.

Duties of a keyman: Following are the duties of a keyman:

(i) The position of a keyman in the gang is next to the ganger and hence, in the absence of the ganger, the keyman performs the duties of the ganger. He is so named because it is he who attends to the bolts and keys for maintaining the gauge and bad places are attended to by the rest of the gang.

(ii) The keyman is responsible for the upkeep and inspection of all fastenings and joints. He moves along his section everyday and personally inspects all the fastenings and joints. He carries with him 1 hammer, 1 wrench, 2 red flags, 1 green flag, 8 detonators and such other tools, as required. The special arrangements are to be made by keyman during rainy season or such similar circumstances.

(iii) At unguarded level-crossings, the keyman should clean the flange-ways between the guard rails and the running rails and maintain them in good condition. If a serious defect such as a broken rail or washing away of the ballast is noticed by the keyman during his routine inspection, he should immediately make arrangements to protect the line and to report the matter to the higher authorities.

(iv) If materials such as dynamo-belts, engine tools, articles of passengers, etc. are found on line by the keyman during his routine inspection, he should collect them and should arrange to hand over the same to the station master of the nearest railway station.

(v) The keyman should arrange his programme in such a way that at least once in a year, all the joints are opened out and refitted.

Duties of a Permanent Way Inspector (P.W.I.): Following are the duties of a P.W.I.:

(i) The P.W.I. is personally responsible for detecting and repairing any defect in his section and also for keeping his section in good running condition. For this purpose, the P.W.I. travels over the track by push-trolley and watches the defects on the track.

(ii) The P.W.I. has also to carry out the renewals of rails and sleepers.

(iii) The P.W.I. should specially maintain records of wear of rails in his section. He should make a programme for the lubrication of rail joints in such a way that all the rail joints are lubricated in a year during the cold weather season. This period may be extended for two years, if it is found that the lubricant is able to retain its effectiveness.

(iv) The P.W.I. should make arrangements to correct creep in his section and he is personally responsible to maintain the correct gauge and super-elevation on the curves.

(v) The P.W.I. should also arrange for the suitable ballast for his section and he should see that the track is sufficiently elastic.

(vi) The P.W.I. should guide properly the persons working under him and he should see that a team spirit is maintained among his subordinates. He should also arrange for the welfare and regular payment of his staff.

(vii) The P.W.I. should maintain the level-crossings under him in perfect running order. During his visit to the level-crossing, he should check the working of the gateman and instruct him, if necessary.

(viii) At the time of accidents, the P.W.I. has to restore the traffic in the shortest possible time and further, he should set up inquiries regarding the causes of accidents.

In case of track maintenance, careful attention should be given to the maintenance of the rail joints. It is found that share of the maintenance of rail joints from total track maintenance is about 20% to 40%.

Maintenance of track

It can be divide into two types:

- Daily maintenance:
  - Carried out by full time staff maintained throughout the year.
  - Railway track divided into sections of 5-6 km.
  - One gang is attached to each section.
- Periodic maintenance:
  - Carried out after an interval of 2-3 years.
  - Gauge, levels, alignment, points and crossings etc are thoroughly checked, defects are detected, causes are determined and remedial measures are taken.

Items of track maintenance

It includes following items:

1. Maintenance of Surface of rails
2. Maintenance of Track alignment
3. Maintenance of Gauge
4. Maintenance of Proper drainage
5. Maintenance of Track components
6. Maintenance of Bridges and its approaches
7. Maintenance of Rolling stock
8. Maintenance of Points and crossings
9. Maintenance of Level crossings
10.
11. Maintenance of Tunnels

Maintenance of surface of rails

Top surface should be kept in the same plane or level, whether the track is on rising gradient or falling gradient or on a level stretch. On curves proper superelevation should be maintained.

Maintenance of surface of rails involves the following operations:

a) ***Packing*** – It is the method of forcing and packing stone ballast below sleepers by ramming with beater-cum-pick-axe. Packing is necessary because ballast get loose due to heavy load and vibrations caused by running trains. Three methods: through packing, scissor packing and shovel packing.
b) ***Surfacing the track*** – whole of the track is brought to a condition of vertical evenness, i.e., uniform level.

c) ***Boxing and dressing the track*** – filling ballast between the sleepers and beyond the ends of the sleepers to the required shape of ballast section and then track is dressed neatly.

d) ***Levelling of the track*** – process of bringing the rails to equal elevation transversely. Cross levels are checked.

e) ***Lifting of the track*** – depressed track is lifted to required height.

f) ***Surface defects and remedies*** – if proper care is not taken in maintenance of rail points and surface, it may result in following defects:

- ***High joint or a riding joint***: A rail joint which is higher than the rail level is known as a high joint or a riding joint and it is developed when sleepers near the rail joint are overpacked or when intermediate sleepers sink. This defect is removed by proper packing of the intermediate sleepers.
- ***Blowing joints:*** A rail joint surrounded by a fine layer of dust is termed as a blowing joint and it not only indicates that the ballast contains a considerable amount of dust but the joint sleepers are also loose. The battered rail ends, weak sleepers and wide expansion gaps accelerate the process of formation of the blowing joints. The good packing, screening of ballast, reduction of expansion gaps, pouring of water on the ballast, replacement of unserviceable sleepers, etc. are some of the remedial measures for this defect of the rail joints.
- ***Pumping joints:*** A blowing joint, when affected by moisture, as in case of rainy season, is converted into a pumping joint and this defect is primarily responsible to the poor drainage of the track. Hence, In order to prevent the formation of pumping joints, suitable drains may be provided to dispose off the water. Sometimes the ballast slightly away from the ends of sleeper is dug right upto the bottom of the section and the water is taken out. This is a temporary measure and it is known as the bleeding of sleepers.
- ***Buckling of track:*** During hot weather, track goes out of alignment on tangents or curves due to overtightening of fish plates or insufficient expansion joints. This defect can be rectified by tightening the fish bolts properly, proper lubrication of rail joints, use of steel sleepers.
- ***Centre bound track:*** Settlement of ballast under rail seats is always more than at the centre and hence deflection of sleepers is more at ends than centre. This defect is known as centre bound track. This defect is rectified by loosening the ballast at centre and packing ballast thoroughly at ends of sleepers.

g) ***Spot packing and track lifting*** – spot packing consists correcting the defect at a particular point and involves lifting of 5 to 7 sleepers. Track lifting is carried out when the defect extends over a considerable length.

Maintenance of track alignment

If the track goes out of alignment, i.e., shifts sideways on straights or at curves due to any one of the following causes, it may result in bad riding and consequent derailments.

Causes of distortion in track alignment

- Increased hammering action of wheels on one rail due to variation in cross levels, inadequate superelevation, non-uniformity of gauge etc.
- Due to hammering action on forward rail at the joint, the track is pushed forward and subsequently when an eccentric force comes on joint, a kink is formed.
- Due to variation of centrifugal force by variable superelevation, tilting or spreading of gauge occurs.
- Due to temperature variations, thermal stresses and heavy creep may result in horizontal displacement of track known as buckling of track.

Realignment of straight tracks

- ***By use of crow bars:*** by pushing the track horizontally by using crow bars by unpacking ballast. After correcting alignment ballast should be properly packed. Process of pushing track is known as **slewing**.
- ***By use of track liners:*** two to three persons are employed. A track liner consists of two parts: a) the base and b) the upper lever holder.

Realignment of curved tracks

- ***By eye:*** Alignment can be checked by eye. Sighting should be always done on outer rail of curve. Very approximate method and hence unsatisfactory.
- ***By theodolite***: In this method, survey of existing curves is done, results are plotted, alterations from original perfect alignment are worked out and revised alignment is set out. Its tedious process and hence generally not adopted.
- ***By string line method:*** A string of definite length is stretched with its ends on rails. The versines of series of chords are measured. The versine of original and existing curves is compared. Any alteration in alignment is corrected. Easier method yielding excellent results.

Maintenance of gauge

Uniformity of gauge throughout should be properly maintained. Non-uniform gauge affects riding quality of track. The variation in gauge may occur due to following causes:

(i) Loosening of track fittings resulting in widening of gauge.
(ii) Loosening of sleeper fittings.

Uniformity of the gauge can be maintained by tightening the track fittings and proper maintenance of correct joints, creep anchors etc.

The following special devices are used to maintain uniform gauge:

(i) A **Gauge rod** with two jaws, one fixed and another movable, is used to grip outer edges of foot rails and to prevent spreading of rails.

(ii) A **Rail brace** with four movable jaws on screwed rod is used to grip all the four edges of foot rails and to prevent spreading or tightening of gauge.

Maintenance of proper-drainage

Drainage is important to ensure smooth riding and longer life of the track. The proper drainage of the track can be maintained by following methods:

(i) C***leaning of ballast***: if the water retained for a long time in ballast, it may percolate in the subgrade and may result in many defects of track. So cleaning of ballast should be done by removing weeds, removal of dust etc.

(ii) ***Cleaning of cess:*** portion between toe of ballast and edge of formation is known as cess. Cess should be cleaned to prevent collection of water by providing proper slope and removing vegetation.

(iii) ***Surface drainage:*** side drains should be of sufficient capacity and should be cleaned before and after monsoon to remove water quickly from toe of formation.

(iv) ***Underground drainage:*** it is necessary to drain off excessive moisture or to prevent water-logging in beds of embankments and cuttings.

Maintenance of track components

It includes maintenance and renewal of rails, sleepers and track fittings.

(i) Maintenance and renewal of rails:

- Spot renewal should be done by used rails instead of new rails since table of new rails would become higher than the adjoining rail and results in damage of rail ends.
- If rail is found broken or cracked, then a sleeper is placed immediately under fracture and spiked, until the rail is replaced.
- Kink should be rectified using jim-crow
- If wear is found on check rail, it should be immediately renewed.
- If corrosion of rails is found, apply waste oil to foot and web of rails.

(ii) Maintenance and renewal of sleepers:

- During packing process beaters should not hit sleepers.
- During squaring process, crow bars should be used.
- In case of wooden sleepers, while driving a spike, first few and last few strokes should be light to set spike in position and to prevent damage.
- In case of steel sleepers, over-tightening of keys must be avoided.
- In case of cast iron sleepers, loose fittings result in dynamic impact due to loads on sleepers and hence break the sleepers.

Renewal of sleepers is done by spot renewal and through renewal.

(a) Spot renewal: defective sleeper, spikes or fittings are renewed. For this, ballast little below sleeper is removed and sleeper is taken out from under

the rail, a new sleeper is placed in pposition and the spikes or fittings are set in.

(b) ***Through renewal:*** rails are removed, ballast taken out from cribs and defective sleepers are replaced by new sleepers. After laying sleepers in position, the rails are lined and the crib ballast put back, after screening if necessary.

(iii) ***Maintenance of fittings:***

- Fish plates and fish bolts should be lubricated periodically.
- Fish bolts should be properly tightened.
- Fish plates should be renewed before they touch web of rails.
- Graphiting (application of lubricant containing graphite and grease) of fish plates is done to prevent corrosion, allow free expansion and contraction of rails, to increase life of fish plates and bolts. It is done before hot weather sets in.

Maintenance of bridge and its approaches

The maintenance of bridge and its approaches is of great importance since an accident that takes place on such spot causes huge loss of lives and national property. Inspection of culverts and bridges are carried out by P.W.I and Bridge Engineers.Maintenance of bridge can be divided into ***maintenance of foundation, maintenance of sub-structure and protection works, maintenance of super structure*** and ***maintenance of track on bridge and its approaches.***

(i) ***Maintenance of foundation***

- The soundings are to be taken in the river bed and depth of scour near the abutments and piers is to be detected.scour holes are filled with heavy stone rubble.
- If floors are damaged, provide drop-wall at downstream. Scour beyond drop-wall is filled with rubble.

(ii) ***Maintenance of sub-structure and protection works***

- *Substructure (piers and abutments):*
  - Small cracks are cement pointed and large cracks are grouted with cement mortar.
  - Bridge consisting of masonry structure should be cleaned of weeds or vegetation.
- *Protection works (embankments):*
  - Scour holes are filled with boulders
  - If pitching is damaged, it is rectified. If pitching is heavily damaged, it should be grouted.

(iii) ***Maintenance of super structure***

- Bearings of girder should be coated with oil periodically.
- The corroded portion of girder bridges should be painted with red lead at least once in 5 years.

- The rivets should be carefully inspected at regular intervals and all defective rivets should be punched off and replaced.
- The reinforced concrete bridges should be plastered under pressure by grouting machines because smoke from locomotives develops cracks in concrete.

(iv) ***Maintenance of track on bridge and its approaches***

- If masonry ballast wall retaining earth and ballast bulge out due to dynamic wheel loads, then they should be replaced by reinforced concrete walls.
- Timber frames can be used to control bad-riding due to change in level and elasticity of bridge. One end of slab is laid at slab or girder and other end on bridge approaches.
- Hook bolts provided to hold sleepers to girder should be frequently tightened
- The area of girder which is in contact with sleepers is likely to get corroded. In such cases sleepers should be shifted and contact area of girders should be painted.

Maintenance of rolling stock

The rolling stock includes locomotives, coaches and wagons. The rolling stock has to be maintained in perfect running order and the following special points need attention during the process of maintenance:

- The lubrication of all reciprocating parts and bearings should be carried out.
- The worn-out parts from the rolling stock should be replaced from time to time.
- It is very necessary to clean the different parts of the rolling stock everyday.
- All axles which have run 322 000 km should be replaced by new ones.
- The locomotive boilers have to be carefully maintained and they are renewed every 15 years. Just to create a spirit of competition and to inspire the performance of staff, contest should be held periodically to select the best black beauty of a particular zone of railways.
- The useful life of passenger vehicle is taken as about 30 years. Even if it is not worn out after this period is over, it is to be dismantled and re-assembled.

The maintenance of rolling stock is carried out at main workshops where locomotives, coaches and wagons have to go for complete overhaul on a strict periodical schedule. The day-to-day repairs are carried out in locomotive sheds and sick lines for coaches and wagons. The sizes of these workshops vary from big ones to small ones.

Maintenance of points and crossings

These are weakest points of track and most derailment occurs at points and crossings. It is desirable to examine points and crossings under moving train loads because certain defects which are not noticed otherwise can be detected under moving loads.

- The gauge should be perfect at all the places except at the toe where gauge should be a little slack. Any variation should be immediately rectified.
- The condition of wear on top and sides of the stock and point rails and crossings should be examined. The tongues which have bent should be straightened. The worn-tongue rails can also be rectified by welding.
- Creep of rails should be prevented by use of creep anchors. If creep occurs, it should be rectified.
- The leads and radii of turnout should be checked for given section of rail and angle of crossing. Any variation should be correctly realigned.
- Clearances between check rail, wing rail and tongue rail should be checked with specific values and should be rectified if necessary.
- The periodic displacement of sleepers should be corrected. All sleepers should be thoroughly packed.
- Proper tightening of bolts should be done daily.
- The ballast should be repacked and screened periodically.
- Interlocking connection should be cleaned of ballast and all connections must be fitted tightly.
- Adequate drainage must be maintained at all points.

Maintenance of level crossings

In level crossings, the road is kept at rail level and grooves are left in the road surface along the inner edges of rails for the wheel flanges.

- The rails and fittings should be tarred once a year by opening out the level crossings.
- On level crossings with less road traffic, the area of crossing should have water bound macadam surfacing to facilitate removal and replacement.
- On level crossings with heavy road traffic, the area of crossing should have bituminous pavement, so that track is least disturbed.
- The approaches of level crossings should also be inspected as sinking of approaches may lead to rough riding and defects which should be rectified.

Maintenance of tunnels

- Portals at ends should be checked. Any defect as signs of slip above top, crushing or cracking of masonry, percolation of catch water-drains into tunnel, bulging etc should be detected and rectified.

- Track materials like rails, fittings and sleepers should be examined. If they are being affected by corrosion, the remedial measures should be undertaken.
- The walls and roofing should be carefully examined. If any defects are found, the proper treatment should be given.
- All the ventilation shafts should be clear of any obstruction or vegetation etc.
- The lighting arrangement in the tunnel should be checked for its adequacy.
- The level and alignment of track and its approaches should be checked, and defect, if any, should be rectified.
- The level pillars and reference marks should be checked periodically.
- The P.W.I. should inspect the tunnel at least once in a year. He should examine all the possible defects and rectify the same immediately.

SIGNALLING DURING MAINTENANCE

When maintenance is going on, it becomes essential to warn the driver of the train regarding the conditions existing ahead. This is achieved by means of providing temporary signals and in some cases, by additional audible signals also. If the work is of very short duration, suitable flags are used as temporary, signals. But if the work is to last for a long period, the temporary fixed signals of semaphore type are provided and suitable lights are provided at night. Normally, if the repairs are to be carried out for less than three days, it is treated as a repair work of short duration. If the repair work is to last for more than three days, is to be treated as a repair work of long duration. As an additional precaution, sometimes a flat circular container with suitable, explosive is put up on the top of the rail so that there is explosion with a loud voice when a wheel of the vehicle passes over the rails. This arrangement is known as the audible signal or fog signal or detonator or torpedo. All railways have established their own rules for the safety of workers when explosives are to be used.

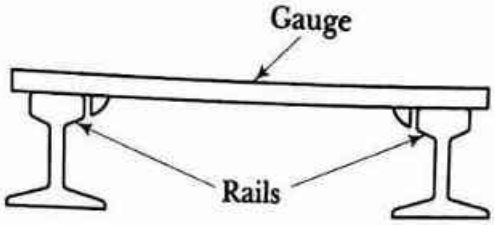
TOOLS REQUIRED DURING MAINTENANCE

The maintenance staff is provided with tools and training is given to staff members to make proper use of these tools. The tools are maintained in good working condition so that they are available for use at any time.

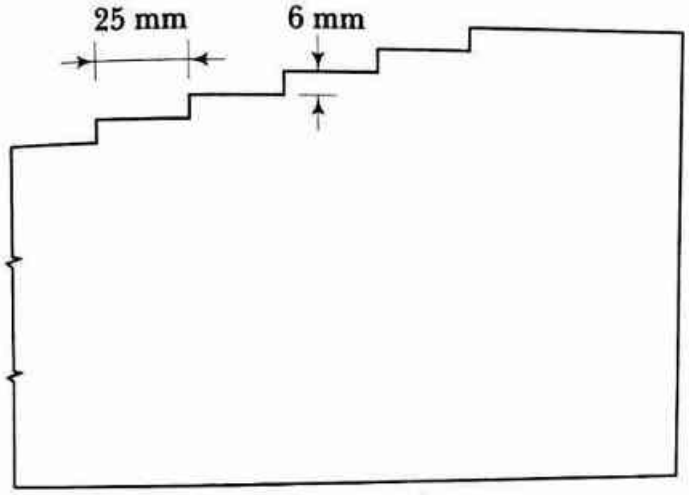
TABLE 18-1
TOOLS REQUIRED DURING MAINTENANCE

No.	Name of the tool	Use
1.	Beater cum pickaxe (fig. 18-1)	To pack ballast under sleeper.
2.	Rail gauge (fig. 18-2)	To verify the distance between inner faces of rails i.e. gauge.
3.	Cant board (fig. 18-3)	To verify cant.
4.	Powrah (fig. 18-4)	To handle the ballast.
5.	Spanner (fig. 18-5)	To tighten or loose fish-bolts.
6.	Jim crow (fig. 18-6)	To bend the rails.
7.	Auger	To drill holes for the spikes.
8.	Chisel	To cut rails, bolts, etc.
9.	Lifting jacks	To lift the track.
10.	Rail tongs (fig. 18-7)	To lift the rails.
11.	Shovels	To handle the ballast.
12.	Spirit level	To verify cross levels.
13.	Crowbars	To align the track slightly.
14.	Hand hammer	To drive spikes, etc.
15.	Adzes	To do adzing to the wooden sleepers.
16.	Ballast screens	To screen the ballast.
17.	Claw bar	To take out dog-spikes from sleepers.
18.	Sledge hammer	To do heavy duty work such as to hit chisel for cutting rails, etc.
19.	Sleeper tongs (fig. 18-8)	To lift sleepers.
20.	Wire claw (fig. 18-9)	To clean the ballast.

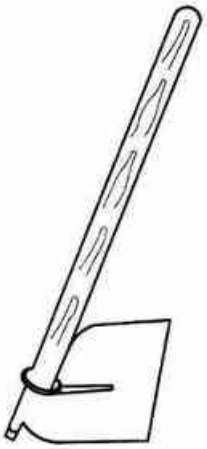
Beater cum pickaxe
FIG. 18-1



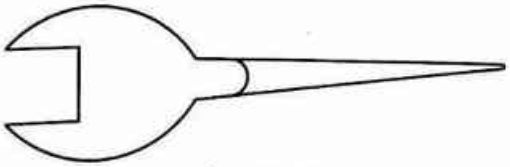
Rail gauge
FIG. 18-2



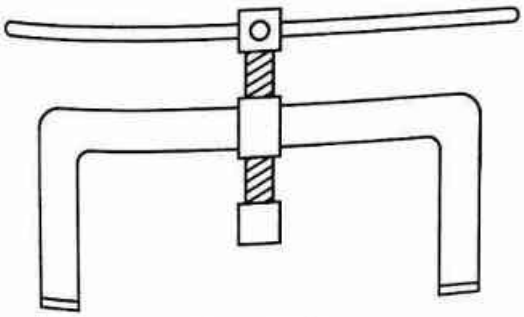
Cant board
FIG. 18-3



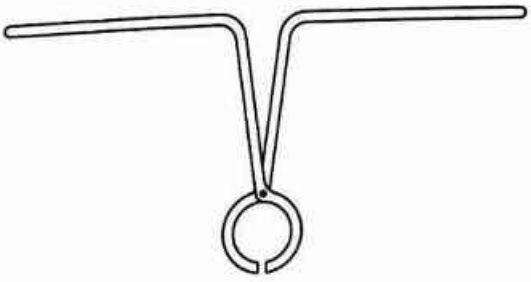
Powrah
FIG. 18-4



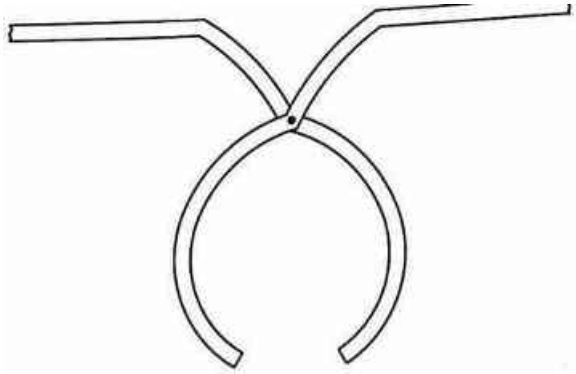
Spanner
FIG. 18-5



Jim crow
FIG. 18-6



Rail tongs
FIG. 18-7



Sleeper tongs
FIG. 18-8

Wire claw
FIG. 18-9

PACKING

Due to movements of vehicles over the track, the ballast under the sleepers becomes loose and in order to keep the track in good running condition, the ballast under the sleepers should be regularly packed. Packing is the method of forcing and packing stone ballast below the sleepers. The packing of ballast may be achieved by any of the following three methods:

1) Through packing
2) Scissor packing
3) Shovel packing

Through packing

This is the process of packing ballast under the sleepers in required width and depth.

The width of packing depends on the gauge. For B.G., M.G. and N.G., the widths are respectively ends of sleeper to 460 mm, 360 mm and 255 mm, inside of the rail-seats. The usual depth of ballast layer to be taken out is about 50 mm to 75 mm. The sequence of operations of packing is as follows:

(i) The track is opened out and ballast around sleeper is pulled aside..

(ii) The rails, sleepers and fastenings are carefully examined and defects, if any, are corrected.

(iii) The track is slewed to correct alignment.

(iv) The gauge of track is checked and corrected, if necessary. The maximum tolerances of gauge, including wear on the sides of rail, are as follows:

(a) B.G.: For straights and curves upto 4°, 3 mm tight to 6 mm slack. For curves sharper than 4°, 13 mm slack.

(b) M.G.: For straights and curves upto 6°, 3 mm tight to 6 mm slack. For curves of 6 to 10°, 13 mm slack.

(c) N.G.: For straights, 3 mm tight to 6 mm slack.

For curves upto 4°, 6 mm slack.

For curves of 4 to 20°, slack = $6 + \frac{D-4}{1.26}$

Where D is the degree of curvature.

For curves sharper that 20°, 19 mm slack.

(v) The sleepers which have moved from their original place are squared up by fixing crowbars firmly against the sleeper and pushing it. In no cases, a hammer should be used for this purpose. Sleepers are brought to specified spacing at straight lengths and curves.

(vi) Ballast is packed under sleepers by means of beaters, until the rail level is raised to the required height. The better method of packing is to first raise sleeper by means of a crow-bar to a desired height and then provide ballast packing under the sleeper track. Lifting jacks can also be used.

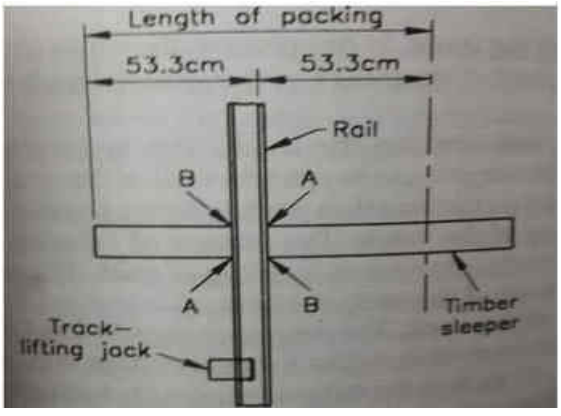
(vii) The cross-levels are checked by means of spirit levels. Cant is checked using cant board.

(viii) After packing sleepers, the ballast is lightly packed and levels in the cribs are brought to the required section.

(2) Scissor packing

Packing diagonally under a rail-seat is known as the scissor packing and it is found to give better results.

In scissor packing, two gangmen take their positions back to back and pack the corners with beater pick axe in the direction A – A. After several blows, they take position at the other corners and pack in the direction B – B. For quick and sound packing, the blows must be simultaneous.



- Whether each sleeper has been packed to the correct level or not should be checked by the gangmate. He stands at a little distance away and checks the level by keeping his eye near the top of the rail. Sometimes the sighting boards are used for this purpose.

- The track lifting jacks may be employed when a considerable portion of the track is to be lifted up. But in this case, both the rails should be raised simultaneously.
- The pneumatic or electric tie tampers are used for packing the ballast instead of ordinary hand-operated beaters. They are quick in operation and economical in maintenance cost.
- In case of pot sleepers, the packing is done with the help of steel bars through holes in the pots. For heavy packing, the ballast is packed under the rim of the sleeper also.
- In straight portions, at first, rail joints are properly packed and then intermediate sleepers are scissor packed.
- On curves, the inner rail is first packed for a distance and then outer rail is packed. The superelevation is checked by cant board placed on inner rail.

(3) Shovel packing

The shovel packing consists of raising the track by means of jacks and then spreading a layer of stone chips of size varying from 6 mm to 10 mm by means of a trowel. It is adopted for points and crossings where the use of beaters for packing becomes difficult due to closer spacing of sleepers. The chips are allowed to consolidate by running trains. This method of packing is excellent for wooden sleepers but unsuitable for steel or concrete sleepers.

The advantage. are as follows:

(i) The centre binding of the sleeper is avoided by resorting to shovel packing.

(ii) The life of wooden sleepers is prolonged because the underside of sleepers is not damaged during the process of measured shovel packing. It is an excellent method for the maintenance of wooden sleepers.

(iii) The process in general proves to be economical in respect of labour required for the maintenance of the track.

The disadvantages are as follows:

(i) It is suitable only for flat bottom sleepers like timber and concrete. It does not give good results for steel sleepers or long welded rails. Thus it has limited scope of application.

(ii) It requires special sized stone chippings which may not be readily available.

(iii) It requires skilled and trained labour even for daily maintenance of track.

SCREENING OF BALLAST

The ballast used on the railway track is to be renewed from time to time due to the following reasons:

(1) Due to constant hammering action of the wheels, some portion of the ballast is converted into powder form. This powder fills the voids between the ballast particles and together with dust, sand, ashes from locomotives, etc. it forms an impervious layer. This layer prevents the easy flow of water through ballast.

(2) The ballast under the sleepers is constantly pressed in the formation. This reduces the quantity of the ballast and also the elasticity of the railway track is affected. In order to remove these defects, the ballast is cleaned at regular intervals by means of screening. The process of screening is carried out as follows:

(i) The surface ballast is generally clean and hence it is removed by means of ballast forks. It is then carefully stored separately at suitable place.

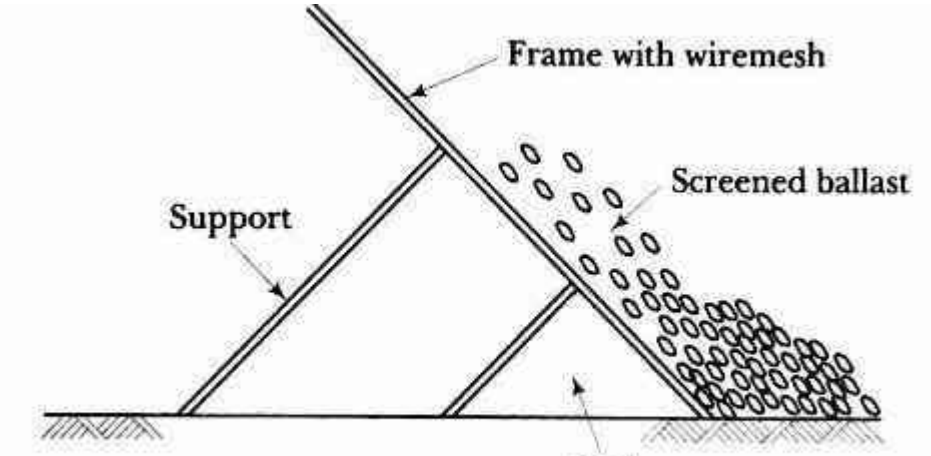
(ii) The dirty ballast is then made loose by means of equipment such as picks.

(iii) The frames, about 1500 mm x 1200 mm with expanded metal mesh, are put parallel to the track. These frames are kept in inclined position at a convenient angle.

(iv) The dirty ballast is then thrown on these frames. When a basket containing the dirty ballast is thrown on the frame, the dust and other small particles pass through the mesh and fall on the other side of the frame. The screened ballast is collected on the front side of the frame.

(v) The required quantity of additional ballast is added to the screened ballast so as to make up the deficiency and then the railway track is packed with this ballast as before.

It is found that about 2 men will be required to screen ballast for a rail length in a day by this method.



Screening of ballast

ACCIDENTS

A rail accident is termed as any occurrence which does or may affect the safety the railways, its engine rolling stock, permanent way, works, passengers or servants which either does or cause delays to trains or loss to the railways. Railway accidents can be classified into following categories:

- ***Death or injury to persons:*** most grevious type. Case of injury arising is classified as follows:
  - Serious injury – when injured is not in a position to resume his normal occupation for a period of 20 days
  - Minor injury: when injured is not in a position to resume his normal occupation for a period of 2-19 days
  - Trivial injury: when injured is not in a position to resume his normal occupation for a period of 2 days
- ***Damage to the property***
- ***Detention of the traffic:*** interruption to an important through line likely to last for 24 hours or more is considered as serious detention.

CLASSIFICATION OF ACCIDENTS IN INDIAN RAILWAYS

The accidents in Indian Railways are classified as follows:

a) Class A: Collisions – Sub classified A1 to A5 based on circumstances of collision, degree of losses such as human life, injury, property damage and interruption of communications.
b) Class B: Derailments – Sub classified into B1-B5 based on circumstances of derailment of trains and degree of losses as in 'A'.
c) Class C: Averted Collisions - Sub classified into C1-C4 based on collision of a train with another train, against obstruction, or vehicle under varying conditions.
d) Class D: Train Passing Signal at Danger - Sub classified into D1, D2 based on a train passing stop signal without proper authority, with or without passengers.
e) Class E: Breach Of Block Rules - Sub classified into E1-E4 based on authority or receiving a train on a wrong line, a catch siding or sand hump etc.
f) Class F: Fire In Trains - Sub classified into F1-F4 based on fire in trains with or without passengers, in railway premises or in railway structures, such as bridge, viaduct etc.
g) Class G: Train Running Into Road Traffic At Level Crossings - Sub classified into G1-G4 based on a train loaded or unloaded, and shunting engines with or without vehicles running into road traffic at level crossings.
h) Class H: Failure Of Engine And Rolling Stock - Sub classified into H1-H6 based on failure of an engine of a loaded or unloaded train, or of a rolling stock under varying conditions.

i) Class J: Failure Of Permanent Way - Sub classified into J1-J3 based on failure of permanent way due to track components, railway structures, floods, breaches, landslides, etc.
j) Class K: Train Wrecking - Sub classified into K1-K3 based on attempted wrecking while on track a loaded train, unloaded train or no train.
k) Class L: Other Train And Trolley Accidents - Sub classified into L1-L6 based on accidents involving elements such as loaded train, unloaded train, portion of the train, trollies, Lorries due to obstruction, train being out of control or defect in points etc.
l) Class M: Casualities - Sub classified into M1-M4 based on casualities of person or persons or cattle resulting in loss of life or injuries either by falling out of train or knocked down by the train.
m) Class N: Unusual Incidents - Sub classified into N1-N3 based on incidents such as death or grievious hurt, murder or suicide, robbery or theft of a person/persons in railway premises including trains.
n) Class P: Miscellaneous - Those accidents which are not included in other classes.

CAUSES OF ACCIDENTS

(i) Wrong judgements of railwaymen: All possible steps should be taken to reduce the number of accidents due to this cause. The railwaymen should be properly trained for their duties.

Failure of human elements include

a. Drivers running at excessive speed, when
    i. On section of line
    ii. On a station over turnouts
    iii. After passing an automatic signal
b. Driver passing signal at danger
c. Reception of train on occupied lines at stations
d. Despatch of trains in occupied block stations and sections

(ii) Natural calamities: The accidents have occurred due to unexpected heavy floods, storms, earthquakes, breaches and landslides, etc.

(iii) Use of defective materials in the preparation of the track: If defective materials are used for making the track, there are chances for derailments or collisions of the trains.

(iv) Failure of the locomotives and rolling stock: This may be due to faulty design of the locomotives and rolling stock, failure of the couplings and draft gear; the axles, the brake apparatus, the tires and wheels, etc.

(v) Sabotage: The accidents occur due to intentional damage done by workers. The site for sabotage is generally selected at mid-section where trains run at full speed. The casualty figures are high when accidents occur due to sabotage. It is clear that it is practically impossible to keep a constant watch on the entire track all the time. However the anti-

sabotage measures such as use of long welded rails, may be adopted to minimise the accidents due to this cause.

(vi) Level-crossings: It is found that more accidents occur at unguarded unmanned level-crossings than at guarded or manned level-crossings.

The road-users are primarily the victims in such accidents and damages the railway property is much less, but considerable dislocation of traffic takes place. The accidents at level-crossings also receive lot of media attention and affect the reputation of the railways as a transport organization

The efforts should be made to educate the mind of road-users and notice boards giving indication of the unguarded level-crossing should be placed on the approach road. The whistle boards on the track near unguarded level-crossings should be provided and engine drivers should be instructed to whistle continuously from the limit of whistle board to the crossing of unguarded level-crossing.

(vii) Spread of gauge: It may occur on permanent way laid with wooden sleepers due to the fact that fittings such as dog-spikes, etc. become loose as sleepers decay.

(viii) Twist in the track: The difference in cross levels of track is known as the twist and it mainly occurs due to poor packing under the sleepers or differential settlement of formation or both.

(ix) Buckling of track: The buckling of track takes place on jointed track at locations where creep is excessive and the track maintenance is poor.

(x) Culverts and bridges: The sudden failure of a culvert or a bridge along the track may result into a serious derailment of train.

(xi) Formation: The accident may occur due to sudden heaving up or shrinkage of formation. The former occurs due to peculiar properties of soil such as black cotton soil and the latter occurs due to low bearing strength of the formation ground.

Points to be observed at the time of accident:

Whatever may be the cause, the following points are to be observed when an accident has taken place:

(i) The line affected by the accident should be cleared as early as possible. No time should be wasted in finding the fault. But every effort should be put up to start through communication.

(ii) The line should be protected by temporary signals and by lamps at night when the repairing work is going on.

(iii) It is easier to unload the derailed vehicle before re-railing it.

(iv) The clear and concise messages should be sent to the concerned local, civil and police authorities.

(v) The break-down vans equipped with the materials required during accidents should be kept ready at all times at all important stations. The break-down trains are more elaborate and include equipments such as lifting cranes, ambulance cars, etc.

(vi) If the accident is such that more time is required to clear obstructions, suitable diversion of track should be constructed and thus the through traffic should be established.

(vii) In case of major accidents, special attention has to be paid for relief operations of fatal, deadly and serious injuries. The arrangement should be made to intimate the relatives of the victims who are identified. The dead bodies should be disposed off by observing legal procedure prescribed by the authority.

(viii) The cause of the accident should be thoroughly investigated to find out remedies to prevent repetition of the same in future.

Preventive measures:

Following are some of the preventive measures which may be employed to minimise the occurrence of accidents:

[Conventional remedies for prevention of accidents due to failure of human element are: proper education (safety camp), punishable action, rewards, psychological approach, propaganda campaign]

(i) Safety camps: The railways should sponsor safety camps at regular intervals and in these camps, the railway staff such as guards, station masters, drivers, cabinmen, etc. should be given instructions relating to their duties.

(ii) Safety organization: A sort of organization to study the causes of accidents and to recommend preventive measures should be set up. In India, a safety organization has been set up and in addition to inquire into the details of an accident, its functions are manifold such as surprise checks at stations, loco-sheds, etc., organizing safety camps, man-to-man contact with staff, mass propaganda, etc. It is assisted by safety officers and counsellors.

(iii) Propaganda campaign: A sense of duty should be created by all possible means of mass contact. A propaganda campaign may include T.V. films showing safety measures, tear-off calenders with messages of safety, playing cards with safety motifs, safety slogans at important places of work, bulletins, illustrated leaflets, etc. Also, brouchers, pamphlets, etc. giving instructions to road-users, may be circulated free among public. This will at least minimise the occurrence of accidents at unguarded level-crossings•

(iv) Rewards: The staff showing extraordinary alertness in case of an accident should be rewarded with cash and similarly, a sort of competition for record of safety may be created between various sections of the railway line.

(v) Psychological and other tests: It is surprising to note that it is possible to group a small section of workers as accident-repeaters. If psychological tests are carried out and if this small group is removed or trained, the chances of accidents are minimised. With this object, the Indian railways have set up the Psycho-Technical Cell since 1964 and it is primarily concerned with identifying the accident-prone workers of the staff so that they can developed rider be helped to overcome their shortcomings. The Cell has also for many psycho-technical tests to assess the inherent abilities essential • safe working of the trains. These tests are also accommodated in the s. recruitment process of all the staff connected with the safety of train

(vi) Proper maintenance of track: The railway track should be kept constant watch by experienced personnel.

The fittings should be maintained tight to avoid spread ofgauge. The ballast should be regularly replenished and should be of adequate quantity. The culverts and bridges should be repaired and maintained ingood condition. They should be carefully watched, inspected and repaired regularly. The formations should be provided with enough drainage facilities and should be under constant observation. The day-to-day maintenance of track plays a great role in avoiding accidents.

(vii) Bumps near level-crossings: It has been found that if bumps or speed brakers are constructed on the approaches to level-crossings, the road-users, if they are not otherwise attentive, would become alert due to sudden shock at bumps. Such a measure is of great help at unmanned or unguarded level-crossings.

(viii) Road surface: The road surface near the level-crossings should be maintained in good condition for easy clearance of the road vehicles without getting stuck up.

(ix) Warning signs: The road authorities should provide necessary warning signs for the road-users at the approaches to the level-crossings. The railways should also provide stop boards on the road approaches to the unmanned level-crossings, with an indication of engine and the legend Danger and Stop, look both the sides before crossing. These boards are provided 5 metres from the centre of the nearest track.

(x) Visibility: The presence of trees, cuttings, sharp curves, etc. obstruct the view for the road-users. In the case of unmanned level-crossing, the visibility for the road-users should be such that they can see an approaching train when it is at an adequate distance before he decides to cross the level-crossing.

(xi) Speed: The speed of the road vehicles should be restricted in the vicinity of the level-crossings.

(xii) Standards: The various standards prescribed for the construction and maintenance of the level-crossings of different classifications are to be meticulously observed.

(xiii) Warning bells: The level-crossing gates situated on sections provided with automatic signalling should be provided with the warning bells operated by the approaching trains.

(xiv) Flashing red lamps: These should be focussed in the direction of the highways and are provided to warn the road-users about an approaching train from an adequate distance depending upon the train speed.

(xv) Train detection scheme: With the introduction of the high speed trains, the road-users and the gatemen would be encountering trains at speeds much higher than what they have been accustomed till now. As a result, the time available between sighting the trains and reaching the level-crossing proves to be less than actually required by the road-users to get across in the case of an unmanned level-crossing and for the gateman at the manned level-crossing to close the gate in time. These implications warrant an efficient, cost-effective and reliable train detection scheme which would trigger the warning system for the road-users of the level-crossing in the face of an approaching train when the same happens to be about 1 km away.

- Conventional and general remedies:
  - Conventional remedies for prevention of accidents due to failure of human element are:
    - proper education
    - punishable action
    - rewards
    - psychological approach
    - propaganda campaign
- Advanced Technical Remedial Aids or Measures:
  - Automatic warning devices
  - Speed recorders
  - Electronic speed governors

    Automatic warning devices: to prevent the drivers passing signals at danger positionthere are automatic warning devices in which brakes are applied automatically if the driver ignores the warning given earlier. Mechanical devices, magnetic devices, inductive devices are the 3 types automatic warning devices.

    b) **Speed recorders:** the speed recorders with an automatic device for giving an audible or visible warning to the driver, whenever the actual speed exceeds the predetermined or allowable speed.

    c) **Electronic speed governors**: these devices in India are in the experimental stage at present. They will apply the brakes automatically and warn the driver with the sound of a buzzer, when the speed exceeds the predetermined limit by more than 5% due to driver's failure.

MODULE 5

TUNNEL ENGINEERING

Tunnel Engineering: Tunnel - sections - classification - tunnel surveying - alignment, transferring centre, grade into tunnel – tunnel driving procedure - shield method of tunneling, compressed air method, tunnel boring machine, Tunnel lining, ventilation - lighting and drainage of tunnels.

Tunnels are underground passage used for transportation. They could be used for carrying freights and passengers, water, sewage gas etc.

Open Cut: Open to sky passage excavated through huge soil mass of obstacle in required directions to connect two roads or railways

Bridge: Over-ground construction to cross over obstacles without disturbing the natural way below it

Necessity/Advantages of a Tunnel:

The necessity of constructing a tunnel may arise because of one of the following considerations.

- A tunnel may be required to eliminate the need for a long and circuitous route for reaching the other side of a hill, as it would considerably reduce the length of the railway line and may also prove to be economical.
- It may be economical to provide a tunnel instead of a cutting, particularly in a rocky terrain. Depending upon various factors, a rough calculation would indicate that for a small stretch of land the cost of constructing a tunnel is equal to the cost of a cutting in a rocky terrain.
- In hills with soft rocks, a tunnel is cheaper than a cutting.
- In metropolitan towns and other large cities, tunnels are constructed to accomodate underground railway systems in order to provide a rapid and unobstructed means of transport.
- A tunnel constructed under a river bed may sometimes prove to be more economical and convenient than a bridge.

- The maintenance cost of a tunnel is considerably lower than that of a bridge or deep cutting.

  However, the construction of tunnels is also disadvantageous in certain ways, as enumerated here.

  - The construction of a tunnel is costly as it requires special construction machinery and equipment.
  - The construction of a tunnel involves the use of sophisticated technology and requires experienced and skilled staff.
  - It is a time-consuming process

Tunnel approaches: These are open cuts at either ends. The cost depends on the topography. The approach is very short. At very high altitudes the approaches are likely to get snow bound in winter or may get blocked by heavy landslides. These factors may consider in deciding the choice of cut or tunnel.

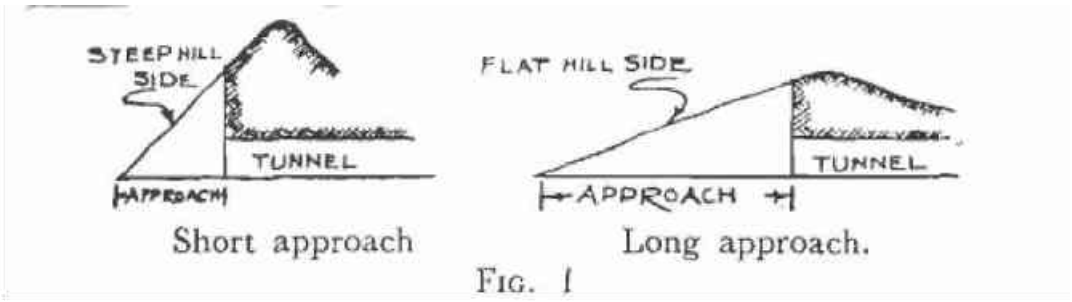


FIG. 1

TUNNEL SURVEYING

Investigations are made to find necessary information for proposed tunnel site. Informations To be collected are:

1. Origin of soil mass.
2. Hydrology in surrounding proposed tunnel site.
3. Presence of foul gases.
4. Temperature of soil nearby.
5. Physical and mechanical strength of soil mass existing at proposed site.
6. Location of weak geological features like faults , folds , etc.

Investigations to collect information are made in the following stages:

- Investigations before planning

- Investigations at the time of planning.
- Investigations at the time of construction.

1. INVESTIGATIONS BEFORE PLANNING

   Geological investigations are made to determine relation between bed rock and top soil for knowing the morphology, stratigraphy, etc of the explored surface. Geophysical methods like electrical resistivity methods are used to locate positions of weak zones.

2.INVESTIGATIONS AT THE TIME OF PLANNING

- Investigations at the time of planning are made through drilling holes either by
  - Percussion
  - Rotary percussion
  - Rotary

Percussion or rotary percussion methods are used for investigation in loose soils while rotary drilling is used in rocky soils.

A spacing 300m-500m is commonly adopted between adjacent bore holes. In disturbed areas , spacing is reduced to 50m-100m. Depth of bore hole is 20m-50m deeper than proposed invert level of tunnel. Detailed undisturbed observations are made by excavating shafts.

3.INVESTIGATIONS AT THE TIME OF CONSTRUCTION

- It is achieved by either of the following:
  - Heading
  - driving drift

Heading

- it is part of tunnel construction excavated for a small length.
- Does not require extra cost.
- Headings gives information at the time of construction.

Driving drift

- It is a part of tunnel cross section excavated for entire length of tunnel.
- Drift gives complete information prior to construction.
- Does not require extra cost.

Heading or drift provide following informations:

- Shows rock stratification , horizontal or steep or gentle sloping.

- Thickness of individual layer.
- Composing constituents.
- Structure and texture of rocks.
- Hardness to determine method of excavation.
- temperature.
- Possibility of landslides and rock falls.
- Presence of foul gases.
- Effect of earthquakes and artificial of vibrations.

The results of rock examinations and interpretations of findings by geologist can be tabulated as:

- ✓ Intact rock:
  little or no support is required for tunnel excavation.
- ✓ Stratified rock:
  may or may not require support depending upon thickness of layers , composition and nature of joints, etc.
- ✓ Moderately jointed rocks:
  rocks having joints or fractures with large spacing and requires support only at joints.
- ✓ Crushed rock:
  badly fragmented and require support .
- ✓ Blocky and seamy rock:
  joints are loose and hence require support
- ✓ Schistose rock:
  Micaceous rocks containing closely spaced cleavage planes along which rock can be separated. Requires support.
- ✓ Squeezing rock:

Contain clay material causing it to squeeze or flow. Hence always need support.

- ✓ Swelling rock:

Contain anhydrides of minerals , undergo expansion. Hence require heavy support.

- ✓ Popping rock:

Contain internal stresses requires light support.

SHAFT

- These are vertical or inclined tunnels excavated to get information for areas surrounding proposed tunnel and tunnel section itself , under expert personal observations.
- shafts can be:
    - ❖ Temporary shaft
    - ❖ Permanent shaft

- TEMPORARY SHAFT
    - The sole purpose of these shaft is to get informations about the proposed site.
    - section – 3mx1.5m or 3mx2m
    - Must be refilled before construction as it drain the rain water to tunnel.
- PERMANENT SHAFT
    - If the shaft is used for getting extra faces to work upon and provide permanent ventilation during and after construction of tunnel.
    - Section – 3mx4m or 3mx6m

ALIGNMENT OF TUNNEL

- The selection of route of tunnel will naturally depends on the topography of the area
- And also convenient points of its entrance and exit.

Two important considerations are:

1) In some case, it will be very difficult to securing, tunnel working through privately owned properties. Then the tunnel alignment changed to some other route having minimum trouble.
2) If the tunnel alignment having unfavourable geological condition, then we select another.

Selection of site of tunnel

1) Alignment restrain

➔ Underground area having many problems like water table, meeting high temperature zone and heterogeneous mass etc. are solved

➔ In similar way, the work of human being such as filled up ground, presence of service line are solved.

➔ A thorough detailed inspection and evaluation of existing alignment are to be made.

➔ The above factors are considered for tunnelling technology.

2) Environmental consideration

The site of tunnel should be selected in such a way that the least difficulty is expereince4d for various environmental factors such as disposal of exhaust gas, ground water etc.

CLASSIFICATION OF TUNNELS

The tunnels can be classified in various ways as shown below.

(1) Classification according to alignment

(2) Classification according to purpose.

(3) Classification according to type of material met with at the time of construction.

1. ***Classification according to alignment*** : Tunnels according to alignment or position are classified as follows.

(i) Off- spur tunnels , i.e., short length tunnels to negotiate minor local obstacles, is very high projections on the way, which cannot be followed with permitted curves.

(ii) Saddle or base tunnels i.e. tunnels constructed in the valleys along the natural slope till the slope does not exceed the ruling gradient.

(iii) Slope tunnels i.e. tunnels constructed in steep hills for economic and safe operations of roads and railways.

(iv) Spiral tunnels i.e. tunnels provided in narrow valleys in the form of loops in the interior of mountain so as to increase the length of tunnel to avoid steep slopes.

2. ***Classification according to purpose.*** : Tunnels according to their purpose are classified as follows

(i) Conveyance tunnels and they include sewer tunnels, water supply tunnels, hydro – electric power tunnels etc.

(ii) Traffic tunnels and they include highway tunnels, railway tunnels, pedestrian tunnels, navigation tunnels and subway tunnels

3. ***Classification according to type of material met with at the time of construction:*** tunnels according to the material through which are driven or constructed are classified as follows.

i) Tunnels in hard rock

ii) Tunnels in soft material

iii) Tunnels underneath river bed or in water bearing soils.

TUNNEL LINING

Necessity of lining

- Lining means finishing touch given to the cross section of tunnel.
- Lining will not be required for tunnel passing through hard soil or impervious rock.
- Hard rock not affected by chemical action of water. Hence lining is not required.
- In soft rock, the cohesion between the material surroundings the tunnel is not sufficient. Therefore lining is required.
- If the tunnel is subjected to internal or external pressure or heavy ground pressure, then there lining is required.

Lining two type:

1) Temporary lining: which is provided for supporting roof and walls of tunnel during construction.
2) Permanent lining which is provided in soft ground, which is always liable to disintegrate.

Objects of tunnel lining

Objects of permanent linings are

- It give correct section to the tunnel.
- It withstands soil pressure when driven in soft soils
- It reduces losses by friction.
- It form good protective covering.
- Inside of tunnel free from water perculation.
- It support large slab of rock.
- It prevent chemical action of water.
- It provided strength to the weak section of tunnel.
- It reduces maintenance cost of tunnel.
- Stability of tunnel increases.
- It provided to the tunnel an appearance of neatness and cleanliness.

Material for lining

The strength and durability are the main consideration for selectiny the type of material.

(1) Masonry

- Brick masonry was the standard material for tunnel lining.
- Now, it is mostly used in the case of underground sevens. Because, bricks are more acid resisting and suitable to carry sewage.
- The great disadvantage in brick lining is the difficulty in back packing the space between the tunnel roof and extract as of the arch.
- It is costly.
- Joints are weak.
- Arch is imperfect due to hand packing.

(2) Stone masonry

It has more or less the same disadvantage as brick lining and in addition, it is very heavy necessitating very strong centers. But it still used for lining the sides.

(3) Cement concrete

- Cement concrete has become standard material for tunnel lining in both rock and soft soil.
- The main advantage lies in its plasticity which allow it to be well packed.
- Concrete has water proof quality ,it provide first class water tight lining.
- It is a form a unbroken ring
- Thickness could be controlled and reinforced according to the soil pressure.
- The maintenance cost minimum
- It provide smooth surface.

(4) Timber

- It is one of the oldest lining materials
- It is used temporary support during construction and permanent support later
- The main advantage of timber lining Are that it can easily and rapidly constructed.
- It is cheap
- It give graining sound before tends to collapse.
- The main disadvantage is that it is liable to decay.
- It cannot used where water peculate and it is likely to cause fire hazards.

(5) Cast iron

For shield driven tunnels particularly in sub – aqueous regions. Advantages are

(i) It can withstand jacking thrust

(ii) Made effectively water proof.

(iii) It accurately

(iv) Attain full strength immediately

Modern practice is to use either timber for semi-permanent lining and cement concrete as standard practice.

Design thickness of lining

- Stress in tunnel lining primarily originates in earth pressure
- The tunnel lining is provided to resist the following loads
    - Weight and impact of traffic load
    - Load develop due to temporary construction
    - Weight of internal structure
    - Dead weight
    - Weight and presence of surrounding ground

General practice provided in lining are indicates in figure

Empirical formula

T = 82D

T = thickness of lining in mm

D= diameter of tunnel in m

DRAINAGE OF TUNNELS

TUNNEL WATER

- Mainly 2 sources
- Wash water, which is used to wash the drill hole
- Ground or sub soil water, from the ground through which tunnel is driven
- The quantity water obtained from first source can be find out easily but from second wants a careful investigation.
- An exploding charge may open up a ground water source, admitting a very large quantity of water in to the tunnel. Such a sudden rush of water indicates one of the following 2 conditions
    - An underground pocket or lake has been trapped
    - An underground river has been trapped

- The progress of tunnelling works and the maintenance of tunnel after its construction primarily depends on the good drainage of tunnel. If it is improper ,it leades to more wear and tear and may even cause serious accidents.
- The drainage arrangements are classified broadly in to 3 systems
- 1.Pre drainage
- 2.dewatering
- 3.permenent drainage

PRE DRAINAGE

- It will prevent the entry of excess water from entering the tunnel before starting the construction work
- It basically consists of preventing the surface water and subsoil water adjoining the tunnel interfering with the construction work
- Where seepage is small & come down from the tunnel roof , it is made to flow over a temporary corrugated sheets on to longitudinal side drains and so led out.

DEWATERING

- Removing the water that are entered the tunnel during the construction of tunnel
- The simple method for removal of water is by giving a open drains or ditches along the tunnel. but it only possible in hard rock bases &water resistant soils
- Disadvantages
- The flow of water may be blocked by muck or debris on the drains
- The construction of open drains in sides leads to weakens the section of tunnel
- The valuable working space loses due to the open drains

Due to the drawbacks the open drains are not use so we are using method of pumping

Method of pumping

- The quantity of water that accumulates is collected in sump and then pumped out of the tunnel
- The sump are located at regular intervals of about 300m to500m or at a wet spots
- The pumping system can be used centrifugal pumps of diameter 80mm to150mm are generally used
- The pumping system is non clogging as water moves heavily through it
- The power used for the centrifugal pump is electrical or pneumatic motors

PERMANENT DRAINAGE

- Keeping water off the tunnel after its completion
- Construct drainage ditches longitudinally sloping towards the portals or shafts

- The drain should have enough capacity to accommodate the quantity of water with out submerging the floor of tunnel
- If the water trickles from the roof of the tunnels, false roof of corrugated GI sheets may be provided
- If the water trickles from the side of the tunnels and obstructs the traffic, the sheets can also be provided on the side walls
- Permanent drainage is depend on various factors such as type of soil, quality of water involved in drainage, nature of tunnel, type of lining used etc.

TUNNEL VENTILATION

GENERAL:

The ventilation means supply of air, light and keeping the level of noise to bearable to human beings. The ventilation is to be provided can be put under the following two heads.

(i) Temporary ventilation: When ventilation is to be provided at the time of construction only, such ventilation system is known as temporary ventilation.

(ii) permanent ventilation: When ventilation is to be provided after the construction work is over, such ventilation system must be on permanent basis and hence it is known as permanent ventilation.

Temporary ventilation:

Ventilation at the time of construction is known as temporary ventilation.

(1) Objects:

The technique of providing fresh air inside the tunnel during and after construction is known as ventilation.

Following are the four main objects of tunnel ventilation:

(i) To supply fresh air to the working crew.

(ii) To remove injurious and obnoxious fumes and gases of explosion

(iii) To remove safely the dust caused by drilling, blasting and mucking.

(iv) To reduce temperature in tunnel situated at great depth.

Natural and mechanical ventilation:

When a drift is driven from portal to portal, it provides fair ventilation naturally during the enlarging operations particularly when the tunnel is a short one and of large diameter. Natural ventilation is achieved due to difference in temperature inside and outside the tunnel and it will be effective only when the orientation of tunnel is along the wind direction

The length of tunnel up to which natural ventilation would suffice depends on the following two factors

(i) If the tunnel alignment contains curves or the grades which are changing, the quantity of natural air expected to provide natural ventilation is considerably reduced and the tunnel length up to which natural draft can be expected to take care of ventilation drastically reduced.

(ii) The flow of traffic (in one direction or in both directions) will also affect the tunnel length for natural ventilation. Normally for one directional traffic in tunnel, comparatively longer length of tunnel may not require mechanical ventilation.

In general, it may be mentioned that for straight reaches with uniform grade, the tunnels up to about 100m length would not require any mechanical ventilation.

In long tunnels, this natural ventilation is inadequate and mechanical ventilation becomes necessary

Requirements of a temporary ventilating system:

Following are the requirements which are to be satisfied by a good tunnel ventilating system :

(i) The fumes' and smokes must be cleared as early as possible from the working face so that work can be resumed without serious delay.

(ii) The amount of dust produced by the natural operations should be brought within permissible safe limits

(iii) The system should provide an atmosphere at the working face where workers can do their job safely and comfortably.

(iv) The accumulation of dangerous fumes should be prevented at any point along the length of the tunnel

Volume of air considerations:

During working each worker should be supplied with 6 m^3 to l4 m^3 of fresh air per minute constantly in the working area. Any compressed air used for the drills is usually contaminated with oil and dust when released from drills and should not be expected to be helpful. After each explosion, the air near the face is filled with fumes and dust and is unfit for breathing. This foul air has to be exhausted and replaced with fresh air, before the workmen start removing the debris from the explosion. The time lapse between exploding the charge and commencing of mucking will be about 30 minutes within which time, the ventilating system, should clear the tunnel and supply fresh air. Generally, the following conditions determine the form and capacity of the ventilating system:

(i) Length and size of tunnel

(ii) Amount of explosive and frequency of blasting.

(iii) Temperature and humidity inside the tunnel

(iv) Gases liable to be encountered during driving operations and due to accidental causes

(v) Amount of carbon dioxide thrown in the atmosphere by men, materials and explosives.

(vi) Heat produced by men, animals, light and certain types of rocks

(5) Causes of making the tunnel atmosphere foul:

Various causes contributing the conditions favourable for the fouling of tunnel atmosphere can be split up into two categories namely; those during construction and those after construction.

During construction work of tunnel, the atmosphere inside the tunnel is disturbed by fumes from blasting operations , dust of the falling debris, burning of lamps , dust from drilling, crowding of men in restricted space, gases due to decomposition of organic matter, etc.

When the construction work is completed and the tunnel is put to use, the atmosphere of the tunnel is likely to be spoiled by various conditions such as heavy density of traffic, smoke of the trains for railway tunnels, gases formed due to improper ventilation etc

Natural ventilation:

Natural ventilation at the time of construction of tunnel takes place after a very low period as there are no ways for the fule gases to leave tunnel. This condition forces to make artificial or mechanical arrangements for removal of foul gases.

Mechanical ventilation

Mechanical ventilation is provided by one or more electric fans or blowers, which may blow fresh air into a tunnel or exhaust the dust and foul air from the tunnel. There are three systems of ventilation

(i) Blowing or Plenum process

(ii) Exhausting or vacuum process

(iii) Combination of blowing and exhausting

(i) Blowing or Plenum process

Fresh clean air is blown through pipes near to the working face and as it flows back to the portal through the tunnel, it moves the dust ad gases with it. This system has the advantage of supplying fresh air right near the working face, but the disadvantage lies

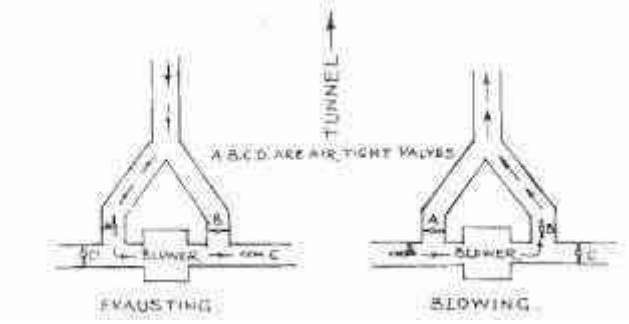
in that the foul air, smoke and dust slowly move out, fogging the atmosphere inside the tunnel, especially in long tunnels. Thus, the approach to the working face from portal becomes unhealthy with poor visibility.

(ii) Exhausting or vacuum process

In this method, the foul air and dust, are drawn into an exhausting duct near the working face, thereby creating a flow of fresh air naturally into the tunnel from the entrance or portal. This method has the special advantage of quick removal of dust and smoke from the working face. But the draw back of this method is that the fresh air has to travel a long distance before it reaches the working face and it is quite likely that it may absorb during this time moisture, heat and foul gases of the hauling equipment resulting in an unpleasant working condition at face. Workers at face of attack feel for a few seconds that there is no air near face of attack to inhale.

(iii) Combination of blowing and exhausting

Many recent system have tried to combine both blowing and exhausting, utilizing the advantage in either system. Immediately after the balsting operation, the exhausting system is operated for 15 to 30 minutes to immediately remove the objectionable which, the blowing system operates for the working period to supply fresh air of operations can be carried out by a valve duct arrangement as shown in figure.



The fan used in combination of blowing and exhausting system is reversible type. The reversible fan Rotate in clockwise direction, when bed switch type switch is operated for the first time. When same bed switch type switch is operated for second time , the reversible type fan rotates in anti – clockwise direction.

Over and above to the fan rotation in anti clockwise and clock wise direction for exhausting and blowing air from and to the face of attack, the flow of air is to be concentrated through duct between face of attack and fan. Duct is a flexible hose made of reinforced thick cloth. The duct between face of attack and fan is open and free to

be moved near the face of attack, while the duct is permanently connected to the fan. The connection of duct to the fan is shown in figure.

The duct is bifurcated in two ducts near the fan. One of the bifurcation is connected to the air duct of fan, and other bifurcation is connected to the outlet duct of fan. The air tight valves A and B are sets on bifurcating ducts, valves D and C are set on inlet and outlet duct. For exhausting of foul air from face of attack immediately after blasting or excavation, valves B and D are closed and valves A and C are opened as shown in fig.

Run the reversible fan in exhaust condition for 15 to 20 minutes, then immediately supply fresh air by blowing air with reversible fan to the face of attack by closing valves B and D, simultaneously opening valves A and C. Run the reversible fan in this condition for 30 to 60 minutes. Such a system of irreversible fan with the ducts and valves is portable. Hence this system can be moved as and when required in direction of work to reach new face of attack.

PERMANENT VENTILATION:

(1) General : Such ventilatio n is required after tunnel is left open for traffic

Because of pressure difference, temperature difference inside and outside the tunnel natural movement of air (Blowing) takes place, but it is intermittent and hence it is not dependable.

The vehicular traffic use gasoline, diesel or gas that produce CO (Carbon Monoxide).

When CO % is < 0.02% human beings are not affected

CO = 0.04% human beings feel uneasiness.

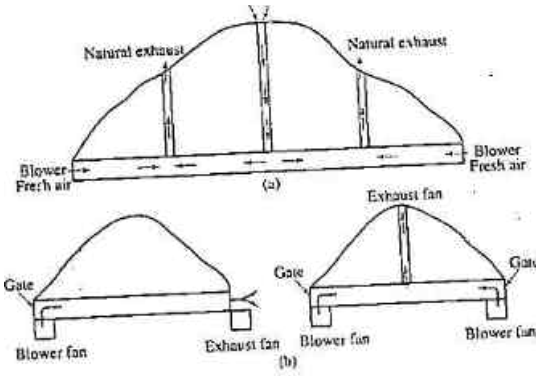
If same is inhaled for more than 1.5 hours, human beings develop headache. If inhaled for more than 2 hours cause unconsciousness. If CO% is ≥ 0.06% and inhaled for 2.5hours proves fatal.

Hence the circumstances force the authorities to provide artificially fresh air known as permanent ventilation when tunnel length is greater than 750m.

(2) Permanent ventilation for long tunnels: Blower fans are provided at each of the ends of tunnel plus at the central shaft. While exhaust is naturally made by shafts adjacent to the central shaft to its left and right. Traffic has to resist air resistance especially in longitudinal direction where air is blasted at high velocities.

Systems or methods of permanent ventilation:

(i) ***Longitudinal system of ventilation:*** The forced air movement can be from one portal to other portal when tunnel is short. Refer figure



Longitudinal system

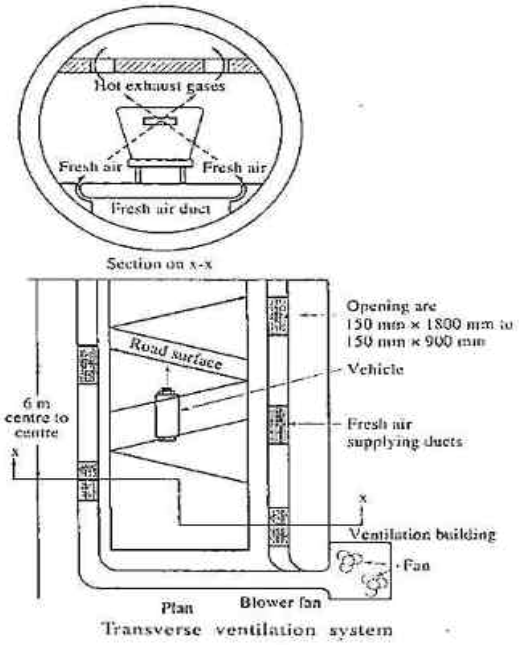
In this method, fresh air is supplied along length of tunnel.

(a) Fresh air is supplied in direction of motion of train or bus, which requires fresh air velocity to be greater than velocity of train or bus, for the passengers to get fresh air.

(b) fresh air supplied in direction of opposite to direction of motion of train. This system supply diluted fresh air to passengers.

(c) when blower is provided at each of ends with an exhaust fan adjusted at the central shaft .

(ii) ***Transverse Ventilation System :*** Air is blasted in lateral or traverse direction to length of tunnel from invert level and foul air is collected at crown



Transverse ventilation system

Advantages of lateral system

(a) Foul an d lighter air is collected at crown of tunnel

(b) Provide good vision while top and bottom system does not provide clear vision

(c) In high way tunnel with pedestrian traffic the blower openings are at tread level of pedestrians.

(d) This system of ventilation does not interfere with traffic and removes foul gases by shortest way.

(e) But it is very costly.

(iii) ***Combination of longitudinal and transverse systems methods:*** In Semi-lateral or combination of longitudinal and transverse system supply of fresh air is similar to transverse or lateral system of ventilation but the foul air is removed through shafts instead of ventilation tubes.

Ventilation for passenger is known as primary ventilation, while ventilation for plants known as secondary ventilation. The direction of ventilation can be changed as per season.

Equipments for ventilation

The equipments required for tunnel ventilation may either be in the form of fans and pipes.

Fans are always driven by electric motor and they may either be of centrifugal type or disc blower type.

Pipes of various varieties such as wire reinforced fabrics, riveted or welded steel pipes, flexible cloth fabrics etc. are available for tunnel ventilation. The coupling of pipes should be air – tight to prevent leakage and they should be of such pattern that they can be easily installed and removed. The size of pipes varies from 100mm to 750mm.

DUST PREVENTION:

(1) General: Various operations involved in tunnel excavation, such as drilling, blasting and handling muck cause dust accumulation in the tunnel atmosphere. This dust laden air constitutes a serious health risk, unless the dust concentration is limited. In rock tunnels particularly, this hazard is very serious, as extended breathing of the silica dust causes a dangerous lung disease known as silicosis, which often proves fatal.

In fact, State laws control tunnelling practices and are designed to safeguard workers, by permitting a limited dust concentration inside the tunnel, which could be safe.

(2) Dust control methods: Various methods used to minimize dust accumulation are as follows

(i) Wet Drilling : Modern drilling machines carry arrangements by which water could be used

to wet and remove the cuttings from the drilled holes. This prevents dust flying to a considerable extent. The quantity of water forced into the hole will depend on the speed of operation and the class of drill used in the process. This method gives fairly good results and it is widely used in practice. However, it does not lead to complete dust proof condition because of the escape of microscopic dust particles even in the stream of water.

(ii) Use of vacuum hood: A hood is fitted around the drill steel at the rock face, which is connected to an exhaust pipe, through which the drilled rock dust is sucked and removed safely out of the tunnel (fig. 3-a). This system works satisfactorily with wet drills.

(iii) Use of respirators: Well designed respirators worn by the miners offer the best and most up-to-date protection against dust inhalation. It is a method which is becoming increasingly popular in modern tunnelling practice.

Fig 3 – a

In addition to the above methods, suitable precautions should be taken to minimize the dust formation. For instance, the muck pile during mucking operations should be sprinkled with water to keep down the dust. There should be adequate and efficient ventilation near the portal of the tunnel.

TUNNEL LIGHTING:

(1) General: various activities and operations in tunnelling work cannot be effectively and satisfactorily carried out, if there is poor light in the tunnel. The situation which demand adequate light can be mentioned as obstruction in tunnel drilling and mucking zones, bottoms of shafts, storage pumping stations, underground repair shops, etc.

The spacing of lights will depend on various factors such as tunnel dimensions, size of light source, nature of rock surface, etc. on the whole, sufficient lights should be installed in the tunnel so as to reduce the intensity of darkening effect on the drivers entering the tunnel.

It is desirable to have more lights of small wattage rather than few lights of larger wattage. It will avoid the formation of dangerous dark spot in case of failure of a light bulb.

Lights are either mounted directly on walls of the tunnel or they are placed in recesses in walls at suitable heights and these recesses are then provided with flush glazed windows. The overall provision of lights in tunnel should be such that uniform illumination without dizzling is achieved.

The electric circuit of the lighting in tunnel should be divided into a number of independent circuits with their isolators, and fuse boxes separate. Such an arrangement would facilitate the repair work. It is possible to switch off only the affected portion and the rest of circuits will not be disturbed.

All hauling equipments are to be provided with their own lighting system. These lights would permit the hauling equipment to cross the tunnel in case of an emergency when the fixed light system has failed.

It is necessary to make provision of flood lights at suitable intervals, in addition to the normal lighting so as to enable to have detailed inspection for any particular length of spot.

(2) Types of tunnel lights: Following are the types of lights which are in common use in tunneling work:

(i) ***Lanterns and lamp burning oil*** : these are used in survey work and during the use of instruments . they are carried in hand and burning gasoline is used to get light from them.

(ii) ***Coal Gas Lighting*** : In this method, cola gas is taken in a pipe from a gas plant and it is then burnt. The light developed is brilliant and steady, but at the same time, explosion takes place, if there is any leakage in the gas pipe.

(iii) ***Acetylene gas lighting*** : In this method, acetylene gas is used to develop light in tunnel. Its use is however not common at present.

(iv) ***Electric lighting*** : Electricity has become most popular of tunnel lighting at present as it possess advantages like

(a) Absence of smoke

(b) Removal, extensions of wires is convenient

(c) Non consumption of oxygen

(d) Can have desired brilliant light intensity

TUNNEL SURVEYING – Refer Note

DESIGN SHAPE AND SIZE OF TUNNEL – Refer Note

TUNNEL DRIVING PROCEDURE

Tunnel Boring Machine (TBM) method

TBM is used as an alternative to drilling and blasting (D&B) methods. TBMs are used to excavate tunnels with a circular cross section through a variety of subterranean matter; hard rock, sand or almost anything in between. As the TBM moves forward, the round cutter heads cut into the tunnel face and splits off large chunks of rock. The cutter head carves a smooth round hole through the rock -- the exact shape of a tunnel. Conveyor belts carry the rock shavings through the TBM and out the back of the machine to a dumpster. Tunnel lining is the wall of the tunnel. It consists of precast concrete segments that form rings, cast in-situ concrete lining using formwork or shotcrete lining.

Tunnels boring machines (TBM's) are available in different types suitable for different ground conditions. These machines can be used in difficult conditions such as below the water table etc. A special pressurized compartment is provided for TBM to work in below water table conditions. The workers should not enter that compartment except for repair works. Care should be taken while TBM is in working conditions. The only difficulty with this TBM is its heavy weight. So, transportation is difficult and costlier.

TUNNEL CONSTRUCTION USING TBM'S

Tunnelling projects using shielded TBM involve the following activities:

- ✓ Excavation and support of working shafts
- ✓ Excavation and support of undercut and tail tunnel
- ✓ Excavation of the tunnel itself
- ✓ Disposal of soil from tunnel face
- ✓ Hoisting the soil to ground level
- ✓ Lining the tunnel
- ✓ Extending services and rail tracks (if necessary)
- ✓ Excavation and support of the removal shaft

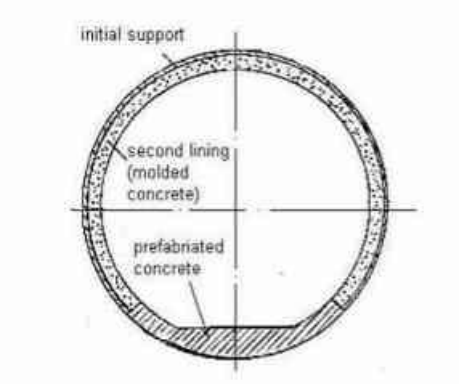
Advantages:

- ✓ Minimal ground disturbances
- ✓ Minimal support requirements
- ✓ Higher advance rates
- ✓ Continuous mining, non-cyclical
- ✓ Improved safety.
- ✓ There are no explosives, and reduces chances of rocks falling on workers' heads.

Disadvantages:

- ✓ It is expensive

- ✓ Hard, abrasive rock causes problems for cutters
- ✓ It is difficult for the machines to cut through weathered, sheared, and highly jointed rock
- ✓ Actual tunnelling time is reduced by frequent break-downs.



Tunnelling With Shield/ Shield Method Of Tunneling:

Shield means to protect. Shield is a metal cylinder made of hard steel- plates bent to required curvature and thickness. The workers assemble the lining while sitting in the rear portion of shield so that they will be safe against roof fall or landslides. The shield may be open at both ends (front and rear) or can be closed in front.

Shields are used for tunnelling under rivers, for construction o roads and tube railways, through silt, clay and sand.

Shield is an equipment which acts as a bridge with roof for workers, to work on extension of lining on one hand and face of attack on the other hand.

Dimensions of shield

Length: depends on storage required in shield and problem of governing or changing direction of motion.

Shape: circular rectangular, square or hexagonal sections.

Cross-sectional area: depends upon diameter of shield.

Parts of shield

1) Cutting edge or leading edge
2) Central part or trunk portion
3) Tail or rear portion

1) Cutting edge

It is the part that has to cut the soil in the front, when the shield is moved forward. The diameter of shield and the nature of soil to be cut decides the type of cutting edge. With cutting edge a detachable roof known as hood may be provided for top half section of shield so that in loose soils the workers can work under protection of hood.

2) **Trunk portion:**
This part provides strength to shield. Trunk portion of shield accommodates propelling jacks. Shield moves forward in form of reactions of jack shoes with primary lining. Movement of shield in forward direction is known as **shove of shield**.

3) **Tail portion:**
It is the backward most or rear part of shield. This part is store of shield which accommodates segments of primary lining, generator set, welding set etc. It provides space for boom, assembly of lining rings etc.

MECHANIZED SHIELDS:

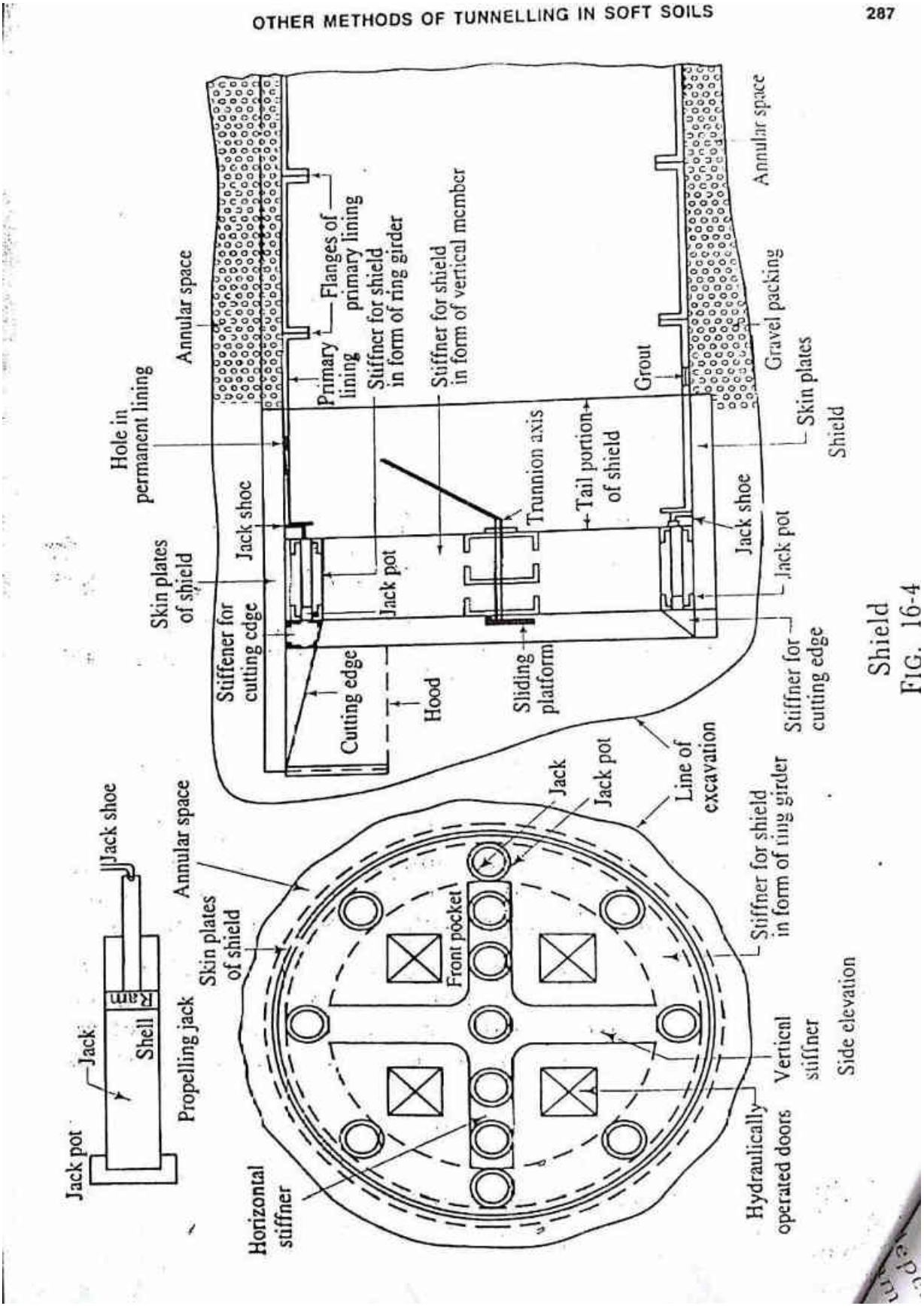
These are machines including shields with cutter heads in which peripheral cutters do not cut gauge of tunnel, but the gauge is obtained by cutting edge of shield. Mechanised shields are classified as:

Rotary wheel type: On the front face of shield either radial arms or discs are fitted with cutting tools.

Planetary cutting assemblies: Cutter tools are fitted at the ends of rotating beam, rotating cross and on rotating disc.

Oscillatory type mechanized shield: Oscillating cutters can be advantageously used in tunnelling through soft soils and running soils. The cutting arms oscillate ,like wipers. The upper and lower sets of wiping cutters are controlled separately.

Auger head cutting assemblies: Behind the cutting edge in air tight. portion, there are number of manholes with closing plates. A cylindrical shape conveyor tube is set in one of the manholes. In this tube an auger shaped conveyor projecting beyond forward end of shield is set. The projecting tip of conveyor can cut the soil on face of attack and at the same time take up excavated material for transporting in the rear part of shield.



Shield
FIG. 16-4

PLENUM PROCESS OF TUNNELLING OR COMPRESSED AIR METHOD:

(l) Bulkhead: It is a solid wall constructed across the tunnel section to separate out two zones of pressure viz. at the front end high air pressure zone and at the rear end or outer end the atmospheric pressure zone. Hence wall must be sufficiently strong to resist this pressure difference. Usually, the bulkhead is constructed of R.C.C. or C.C. or steel or masonry at times of emergency of timber. Emergency bulkheads are kept ready for immediate use at the time of blow condition.

(2) Air-lock: It is reserved space constructed in bulkhead for transferring man and materials from one zone of pressure to another zone of pressure. Usually the space is cylindrical - 2 m to 3 m, in diameter, 25 m long. The air-lock has two doors one at each of the ends of air-lock opening only in forward direction. Only any one of the doors can be opened at a time. If the pressure in the air-lock is atmospheric, only rear door can be opened. If the pressure in the air-lock is made equal to the air pressure in working zone the front door of air-lock can be opened. The doors are made leak proof by fixing gaskets with them and are opened or closed hydraulically. Inside the lock the necessary arrangements for sitting, sleeping, reading, bathing, lighting, communicating, etc. are provided. Bulls eye for sighting on each of doors are provided. The changes of pressure for opening or closing any of the doors should be gradual otherwise sudden changes may prove to be fatal for human being.

Types of air-locks:

(1) Man air-lock
(2) Material air-lock
(3) Emergency air-lock.

(i) Man air-lock:

The size of man air-lock varies from 1.8 m diameter to 2 m diameter with doors of 0.75 m 1.2 m 0.75 m is decided from width of stretcher. Length may be upto 25 m. Man air-lock is provided for transferring officers, workers and others from one zone to other zone without undue stressing the man. Hence pressure changes must be most gradual. For entering to working zone first the pressure in the air-lock should be made equal to atmospheric pressure then rear door of man air-lock is opened and the gang of workers is allowed to enter into man air-lock. After closing the rear door of air-lock the pressure in the air-lock is gradually increased till it reaches the air pressure that exists in the working chamber. Now the front door can be opened and the gang of workers is allowed to enter the working zone. At this time the rear door cannot be opened. Usually man air-lock is set in horizontal.

(ii) Material air-lock

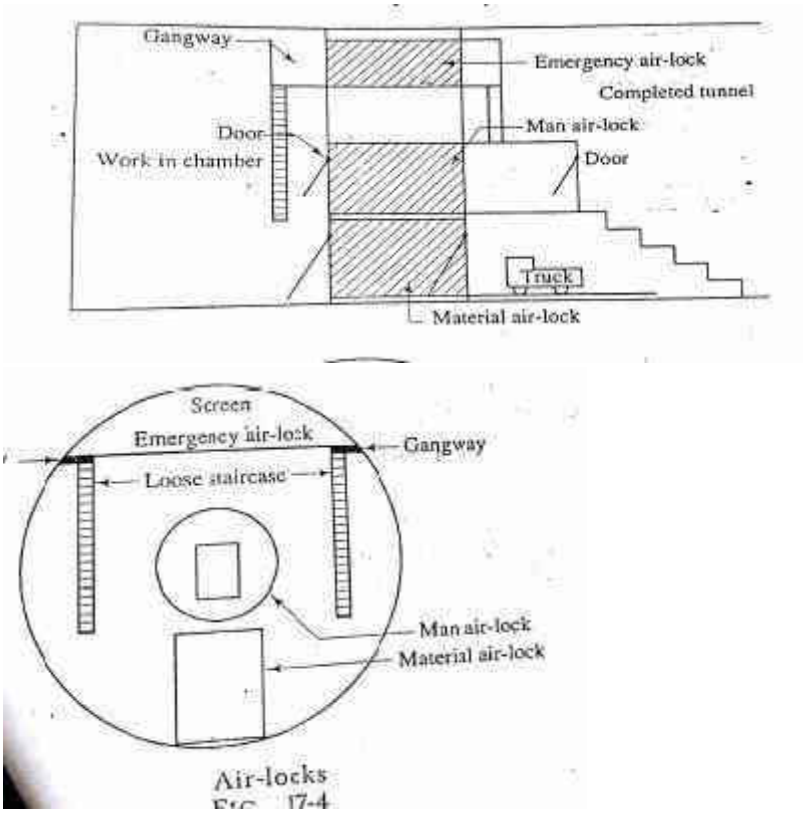
The size of material air-lock is 1.8 mx2m x 3m diameter with respective door size of (1 m x 1.2 m) (1.2 m x 1.5 m) (1.7 m x 1.9 m). Length of material air-lock is decided depending upon cart size, wagon size or truck size. In material

transfer the main advantage is materials are not affected by sudden changes in air pressure. Hence to take advantage of sudden change of air pressure material transfer is not done through man air-lock. Also the volume of materials to be transferred to and fro is too large, hence if combined with man air-lock the working rate will definitely suffer. Hence material transfer must be made through separate air-lock.

Man air-lock is to be provided above invert level to keep it clean. The floor of material lock and invert level of tunnel be kept same so the truck movement in or out of material lock is convenient and easy. Also size of material lock should be minimum = 1 truck size.

(iii) Emergency air lock:

Used during blow condition or emergency situation. Condition producing fog, fire and flood at a time in the working chamber is termed as blow condition. For counteracting against the three `F ' or blow condition there are two alternatives. Firstly one has to run away via emergency air-lock or secondly one has to -fight blow condition from within the working chamber and from outside the air-lock. When workers reach the gangway, open the door of emergency air-lock and all must rush into the emergency air-lock and close the front door of air-lock and operate the valve to reduce the compressed pressure to atmospheric pressure and open the rear door of emergency air-lock and come out of air-lock systematically.



Air-locks

MODULE VI

HARBOUR AND DOCK ENGINEERING

- **Harbour** can be defined as a basin or haven or road stead of navigable waters well protected naturally or artificially from action of wind and waves, and is situated along sea shore or river or lake or canal connected to sea.

❑**PORT:-**

A port is a harbour where marine terminal facilities are provided.

A port is a place which regularly provides accommodation for the transfer of cargo and passengers to and from the ships.

Port = Harbour + Storage Facility + Communication Facility + Other Terminal Facility.

every port is a harbour

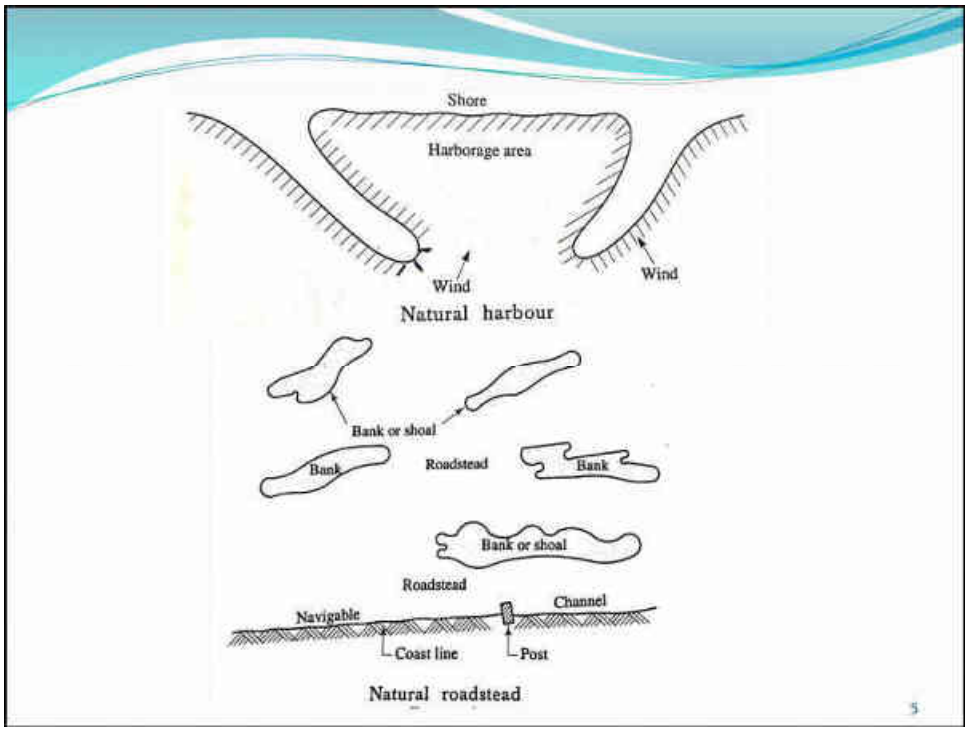
3

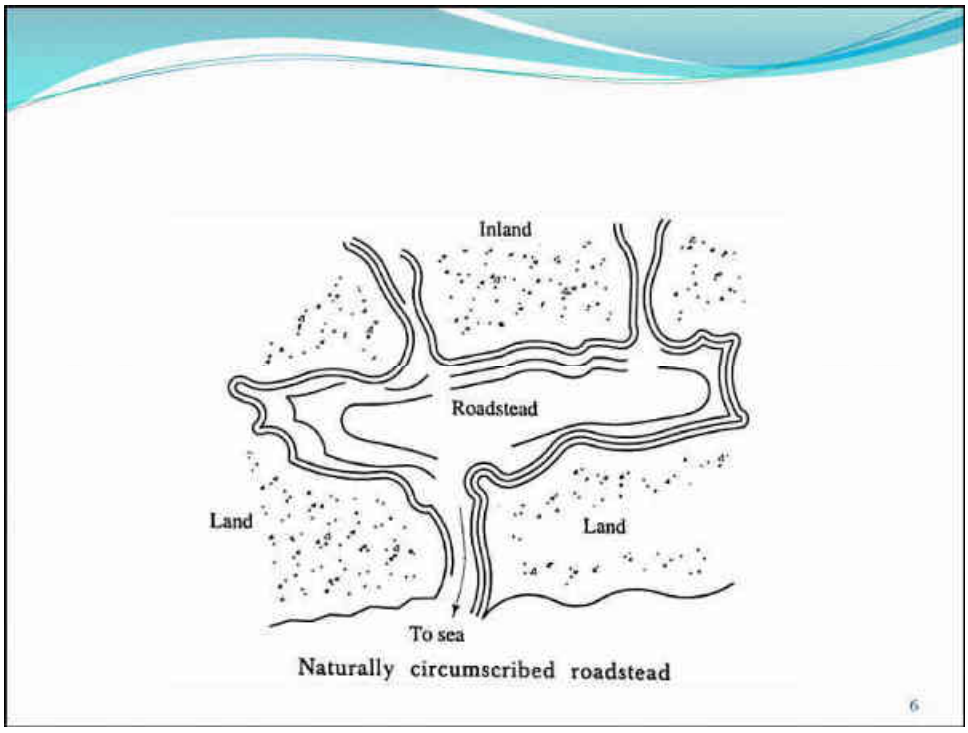
CLASSIFICATION OF HARBOURS:-

❑**CLASSIFICATION BASED ON THE PROTECTION NEEDED**

✓**Natural Harbour:-**

Harbour protected by storms and waves by natural land contours, rocky out crops, or island that is called Natural Contour. **(Eg. Kandla port, Cochin port & Mumbai Harbour)**


Shore
Harborage area
Wind
Wind
Natural harbour
Bank or shoal
Bank
Roadstead
Bank
Bank or shoal
Roadstead
Navigable
Channel
Coast line
Post
Natural roadstead
5

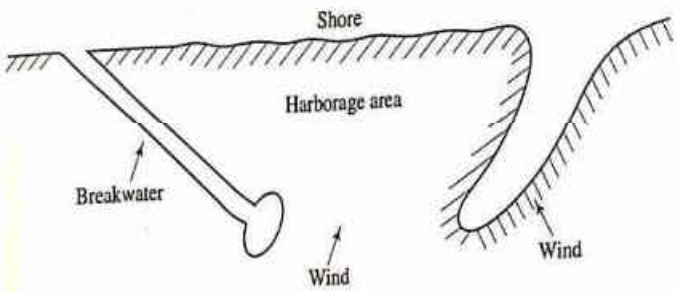

Inland
Roadstead
Land
Land
To sea
Naturally circumscribed roadstead
6

CLASSIFICATION OF HARBOURS:-

❑ **CLASSIFICATION BASED ON THE PROTECTION NEEDED**

✓ **Semi - Natural Harbour:-**

A semi – natural harbour is protected on the sides by the contours of land and requires manmade protection only to the entrance. **(Eg. Visakhapatnam port)**



Semi-natural harbour

8

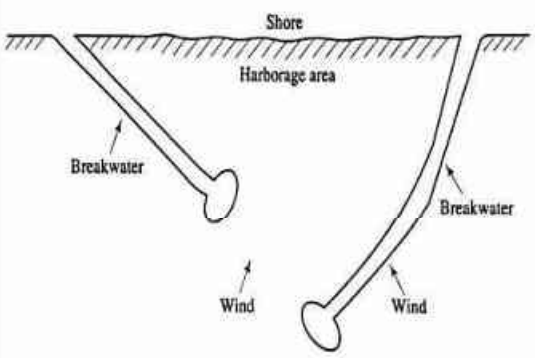
CLASSIFICATION OF HARBOURS:-

❑ **CLASSIFICATION BASED ON THE PROTECTION NEEDED**

✓ **Artificial Harbour:-**

An artificial harbour is one which is manmade and protected from storms and waves by engineering works.

(Eg. Chennai Harbour)



Artificial harbour

CLASSIFICATION OF HARBOURS:-

❑ **CLASSIFICATION BASED ON UTILITY**

✓ **Commercial Harbour:-**

It is an harbour in which docks are provided with necessary facilities for loading and unloading of cargo.

✓ **Refuge Harbour:-**

These are used as a heaven for ships in a storm or it may be part of a commercial harbour.

CLASSIFICATION OF HARBOURS:-

✓ **Military Harbour:-**

It is a naval base for the purpose of accommodating naval ships or vessels and it serves as a supply depot.

(Eg. Mumbai Harbour & Cochin Harbour)

✓ **Fishing Harbour:-**

These harbours have facilities for departure and arrival of fishing ships. They have also necessary arrangement to catch fish.

Marina harbours:

Marina harbour providing facilities of fuel, food, showers, washing machine, telephone etc. For small boat owners having temporary or permanent berths.

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CLASSIFICATION OF HARBOURS:-

❑**CLASSIFICATION BASED ON LOCATION**

- ✓Ocean Harbour
- ✓River Harbour
- ✓Canal Harbour
- ✓Lake Harbour

14

ACCESSIBILITY OF HARBOUR

- Depends on the location of the harbour.
- The harbour entrance should be designed and located for quick and easy navigation by ships, overtaken by storms.

15

- It should be narrow enough not to expose the harbour to the effects of the stormy sea.
- Maximum dimensions upto 180 m have been adopted
- Size of harbour depends upon the number and size of ships likely to use the harbour at one time.

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SIZE OF HARBOUR

- **Factors determining size:**

1. Accommodation required
2. Convenience for manoeuvring the navigation.
3. Adaptability to natural features.

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SITE SELECTION OF HARBOUR

- Availability of cheap land and construction material
- Transport and communication facilities.
- Natural protections from the winds and waves.
- Industrial development of the locality
- Traffic potentiality of the harbour.

18

- Availability of electrical energy and fresh water.
- Seabed, subsoil, and foundation condition.
- Defence by strategic aspects.
- Favourable marine conditions

19

SHAPE OF HARBOUR

- One of the pier heads should project a little beyond the other, To protect the harbour from sea waves.
- Inside the pier head the width should widen very rapidly.
- The general shape of the harbour should be obtained by a series of straight line.

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DEPTH OF THE HARBOUR

- The channel depth is generally determined from the formula.

$$D = D_1 + \frac{H}{3} + D_2$$

- D_1= draft of the largest ship to be accommodated.
- D_2= allowance for squat of the moving ship
- H= height of storm waves.

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MARINE SURVEY

- Topographic survey
- Hydro graphic survey

22

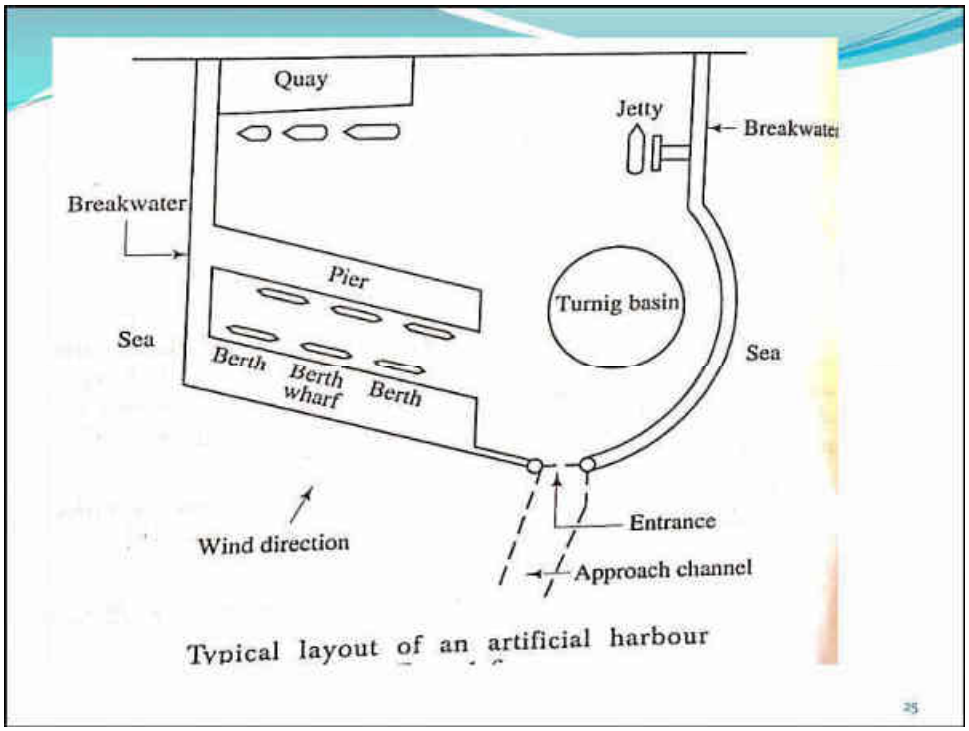
FEATURES/COMPONENTS OF A HARBOUR

- Entrance channel
- Break water
- Turning basin
- Docks
- Berthing basin

23

- breakwaters
- quays and wharves
- jetties and piers
- docks
- slipways
- godowns, sheds etc.

24



Typical layout of an artificial harbour

25

REQUIREMENTS OF A GOOD HARBOUR

- Sufficient depth for the draft of the vessels visiting the harbour.
- Secured anchorage to hold the ships against the force of high winds.
- The land masses or beak waters must be provided.
- The harbour entrance should permit ready passage for ship and should be narrow enough to restrict the transmission of excessive amounts of wave energy during storm.

26

SHIP CHARACTERISTICS

- **Load line or Plimsoll mark:**-line or set of lines on the outside of the merchant ships, showing the water level to which they may legally be loaded.
- **Displacement load:** The weight of ship and its contents when fully loaded with cargo to the load line is known as displacement load.

27

- **Displacement light:** The weight of ship in kN without cargo, fuel and stores
- **Dead weight tonnage:** The difference between the displacement load and light
- **Gross Tonnage :** The carrying capacity of a ship expressed in volume measurement

28

- **Net tonnage:** The difference between gross tonnage and the space provided for the crew, machinery, engine room and fuel.
- **Cargo tonnage:** It is a commercial expression which forms the basis of freight charge.
- **Ballast:** The weight added to improve the stability of ship when it has discharged its cargo.

NATURAL AND METEOROLOGICAL PHENOMENA

- Littoral drift
- Tides
- Wind and waves

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LITTORAL DRIFT

- Sand drifts occurring in the proximity of foreshore
- Harbour constructed in the path of littoral drift results in accumulation of sand on one side and erosion on the other side
- Direction depends on wave direction
- Quantity of material depends on velocity of tidal currents.

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TIDES

- Due to gravitational force of sun and moon there is rise and fall in ocean water. The rise in water level is called **high tide** or tide, and fall in water level is called **low tides or ebb.**

33

- **Spring Tide:-** These are highest tides which occur when sun, moon and earth fall in line.
- **Neap Tide:-** These are lowest tides which occur when the lines connecting the earth with the sun and the moon form right angle.

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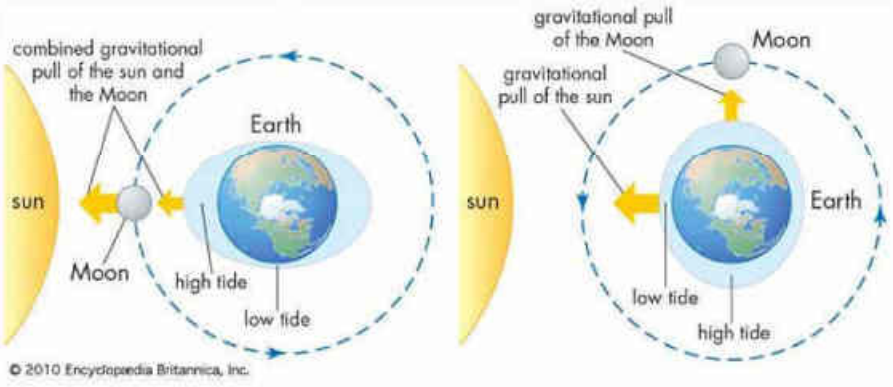

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LUNAR TIDES

- **Diurnal tide:** An area has a diurnal tidal cycle if it experiences one high and one low tide every lunar day.
- **Semidiurnal tide:** An area has a semidiurnal tidal cycle if it experiences two high and two low tides of approximately equal size every lunar day
- **Mixed tide:** An area has a mixed semidiurnal tidal cycle if it experiences two high and two low tides of different size every lunar day.

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USES OF TIDES

✓Tides can be used for harnessing the power.

✓Tides are used for entry and exit of ships in the harbour.

✓Fisherman takes an advantage of tides.

✓Ports remain clean due to tides.

✓High tide water can be used for harvesting salt.

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WIND AND WAVES

Wind is **horizontal movement of air** due to differences in air pressure which are caused by differential heating and cooling.

In short wind means **air in motion.**

38

- Waves are **periodic undulations** of the sea surface. Water waves are **generated** by transfer of energy **from air moving over the water.**

39

Types of wind water waves

- Waves of oscillation- stationary
- Waves of translation- possess forward motion

40

❑Causes of Sea Waves:-

✓Wind,

✓Revolution of the earth,

✓Gravitational force of the moon and sun,

✓Earthquake,

✓Land slide along seashore

WAVE PARAMETERS

❑ **Wave Velocity:-**

$$V = \frac{L}{T}$$

Where, L = Length

T = Wave Period

❑ **Fetch:-**

Straight line stretch of open water available for wave growth without the interruption of land is called fetch.

$$H = 0.34\sqrt{F}$$

Where, H = Wave Height (m)

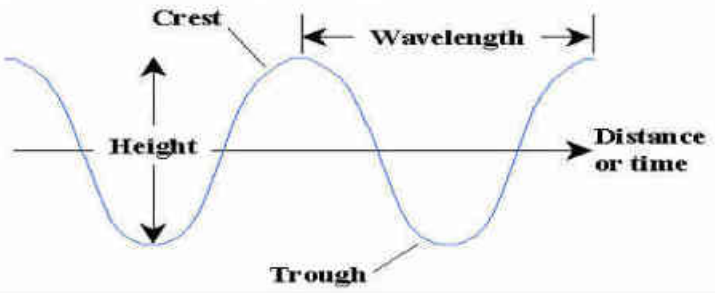
F = Fetch (km)

- **Wave Length:-**

$$L = \frac{T^2}{2\pi} * g$$

Where, L = Length of wave (m) = $1.56\ T^2$

T = Wave Period (sec)



BREAK WATERS

Break waters

- The protective barrier constructed to enclose harbours and to keep the harbour waters undisturbed by the effect of heavy and strong seas are called break waters.

45

Design considerations

- Cost and availability of materials of constructions
- Directions and force of winds
- Nature of the bottom or foundation
- Probable maximum height , force and intensity of waves

48

- The three important rules to be observed in the design of a breakwater are;
  - The design should be based on the extreme phenomena of the wind and wave.
  - The height of wave should be determined by the equation
    - $H = 0.34 \sqrt{F}$
  - The material in the foundation should not subject to scour.

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Forces acting on break waters

- Hydrostatic forces
- External forces
- Solvent action of sea water
- Sea insects

50

Hydrostatic forces

Hydrostatic force reduces the apparent weight of the marine structures

51

External forces

It is due to wind and wave

Wind produces vibrations in masonry structure

Wave induces suction action and it results erosion of the foundation

52

Solvent action of sea water

sea water causes damage to the construction materials

53

Sea insects

The concentrated action of sea insects results in the undermining of the building material. So the marine structures should made strong.

54

Types of break waters

55

- Heap or mound breakwater
  - Rubble mound break water
  - Concrete mound break water
  - Rubble mound break water supplemented by concrete blocks
  - Rubble mound break water supplemented by patented stones
- Mound with super structure or composite breakwater
- Upright wall break water
- Special breakwaters

56

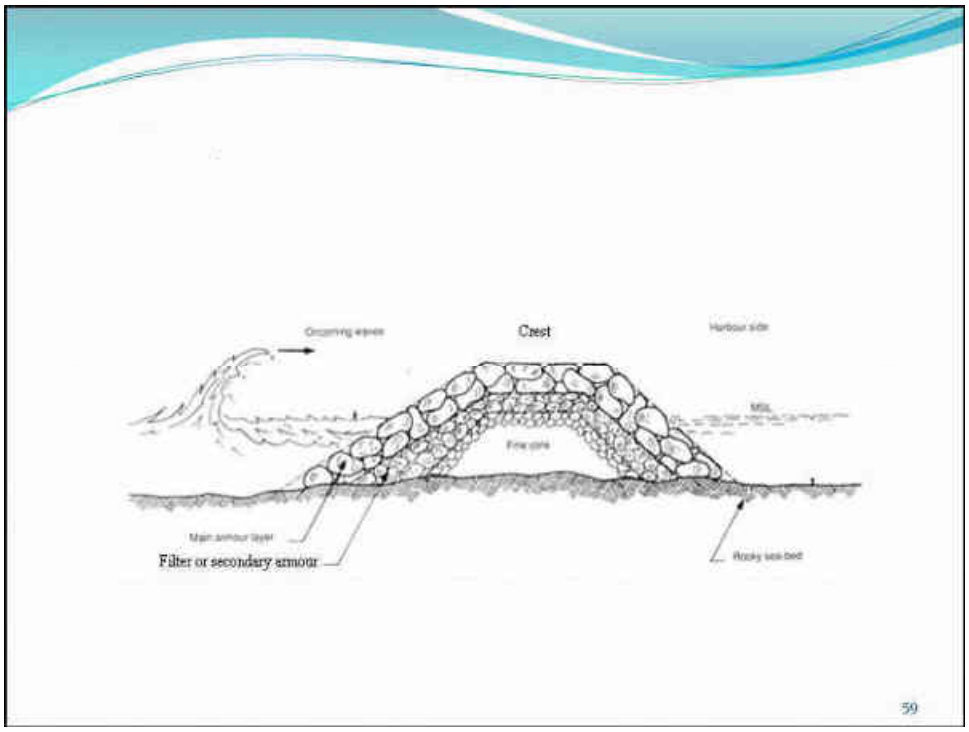
Heap or mound breakwater

- It is a combination of natural rubbles , undressed stone blocks and the artificial block of huge size and weight
- It is deposited without any bond or binding material
- The side slope of these break water is regulated by the action of wave

57

- Components of Heap or mound breakwater
  - Core
  - Secondary armours
  - Armour blocks

58


Crest
Filter or secondary armour
59

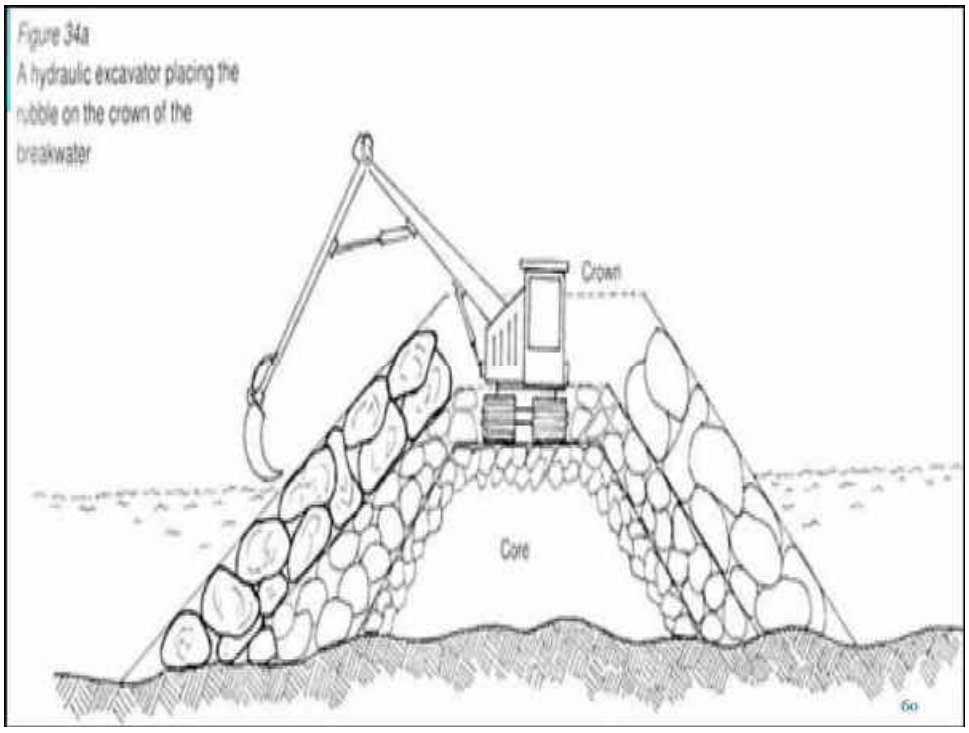


Figure 34a
A hydraulic excavator placing the
rubble on the crown of the
breakwater
Crown
Core
60

Characteristics

- Dissipation of kinetic energy – successfully by different layers of mound
- Natural foundation is unprepared
- No special bond – no binding materials are provided
- No possibility of sliding

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- No possibility of overturning
- No possibility of uplift
- The (mound) construction is porous or pervious
- The mound construction is flexible
- Unskilled labor can used in construction

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- Rubble mound break water
  - Large volume of core is used
  - Armour stone have different weights at different level
  - It is two types
    - Type 1 & type 2

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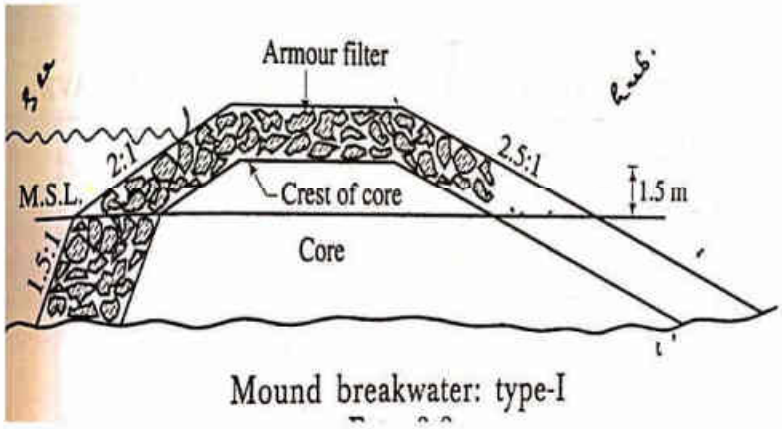

Mound breakwater: type-I

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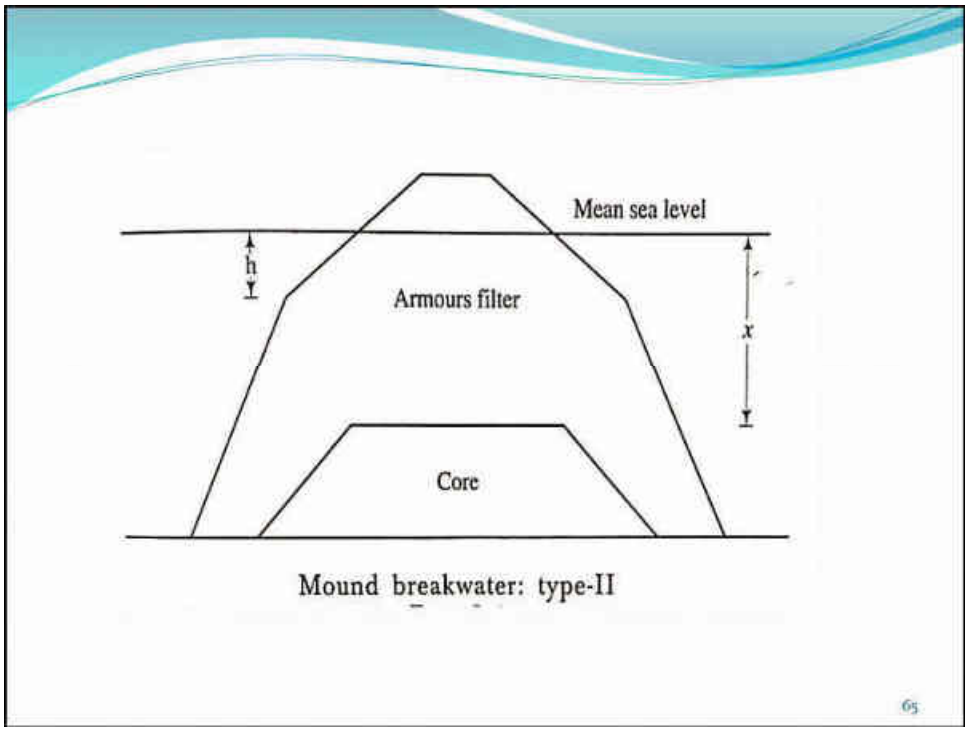

Mound breakwater: type-II

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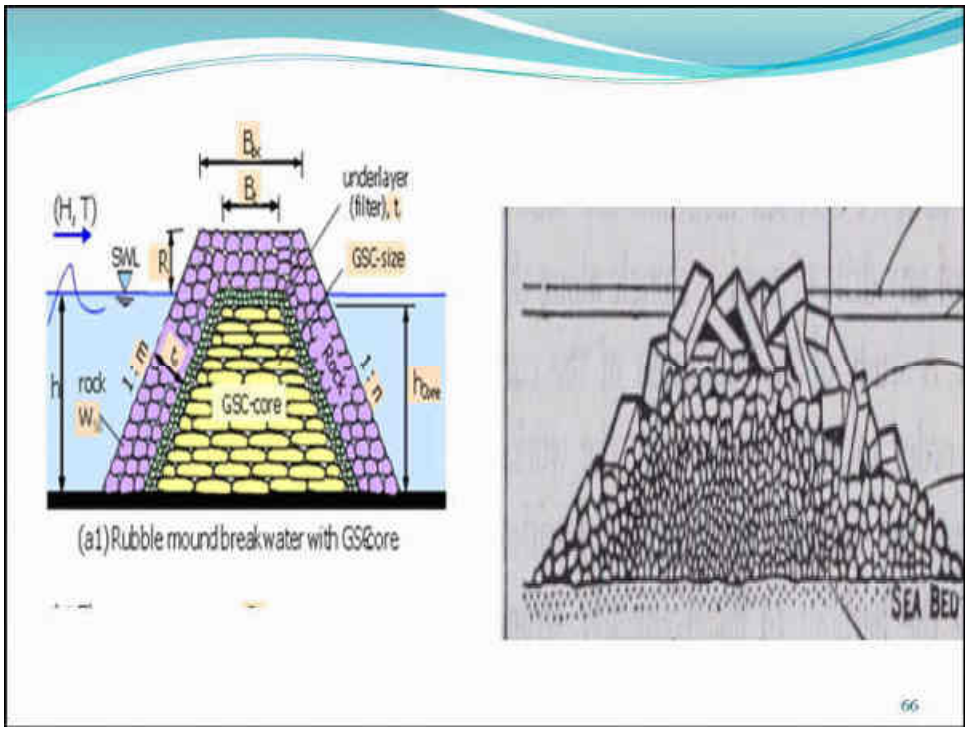


(a1) Rubble mound breakwater with GSCore

66

Concrete mound break water

- Casting of concrete blocks are difficult
- High transportation cost
- It is rare type

67

68

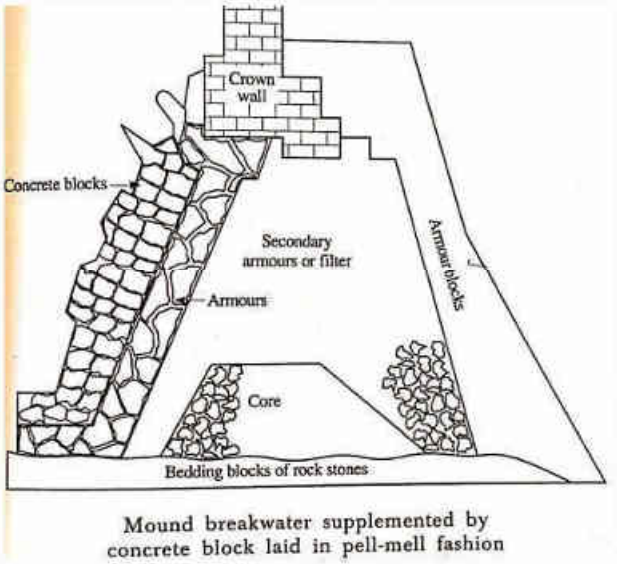
Rubble mound break water supplemented by concrete blocks

- Concrete block with reinforcement take more force than natural rubble stones
- Construction is similar to rubble mound break water

69

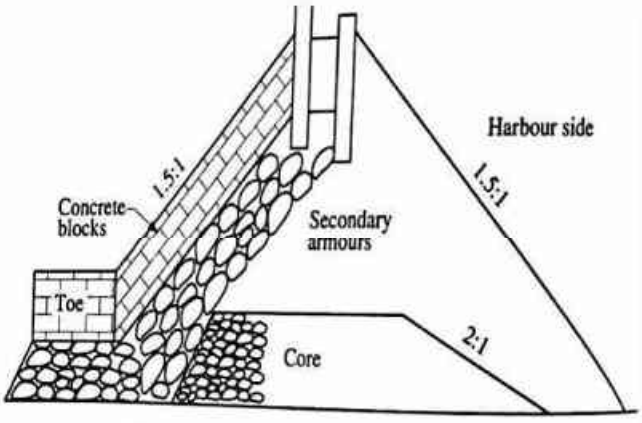
- The concrete block can be laid in
  - Pell-mell fashion
  - Well compacted fashion

70



Mound breakwater supplemented by concrete block laid in pell-mell fashion

71



Mound breakwater supplemented by well compacted concrete blocks

72

Rubble mound breakwater supplemented by patented stones

- Tetrapods
- Tri bars
- Modified Cubes

73

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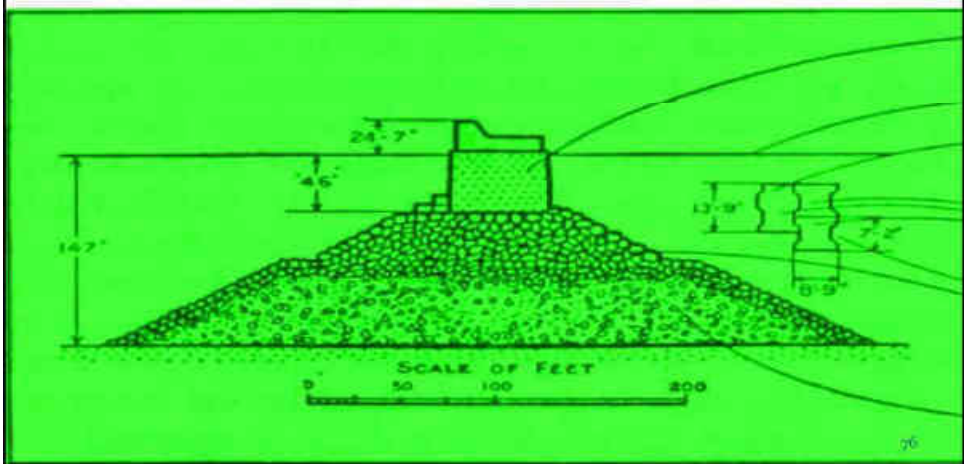
Mound with super structure or composite breakwater

- In which mound construction in top part made solid



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Upright wall break water

- Upright wall is defined as a big regular wall raised to construct a harbour basin to resist the force and their components generated by incoming water and waves.
- It reduce the amount of material.
- Avoids unequal settlement.
- Maintenance cost is least.
- It required special care and costly method of construction.

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Components of harbour

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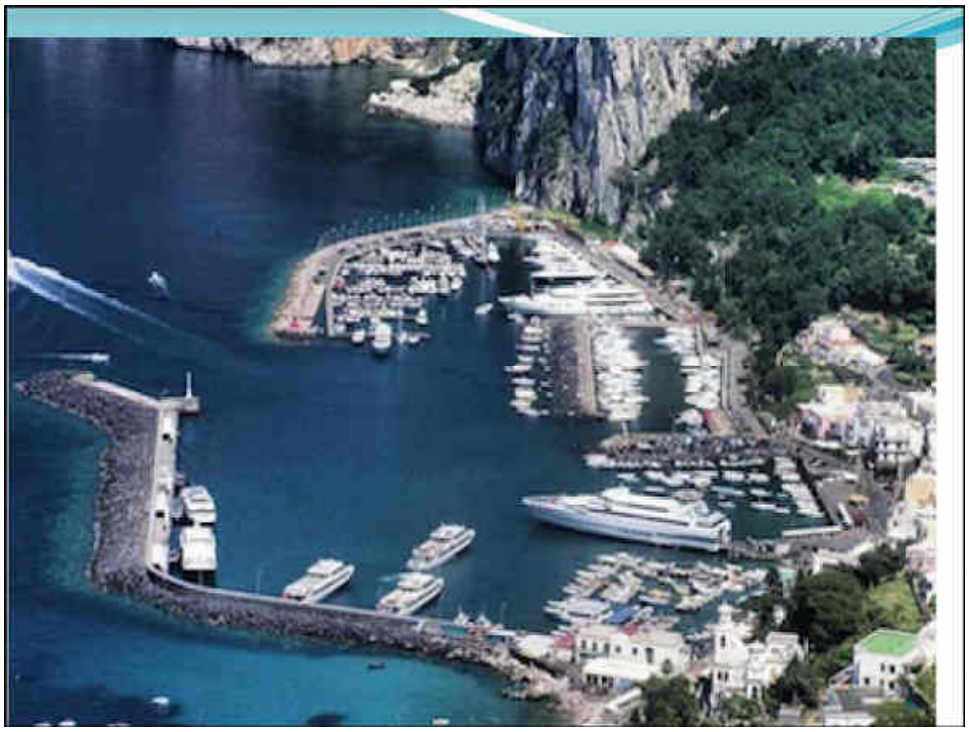
WHARVES

The landing place or platform in the form of wall built near shore for vessels to berth is known as wharf.

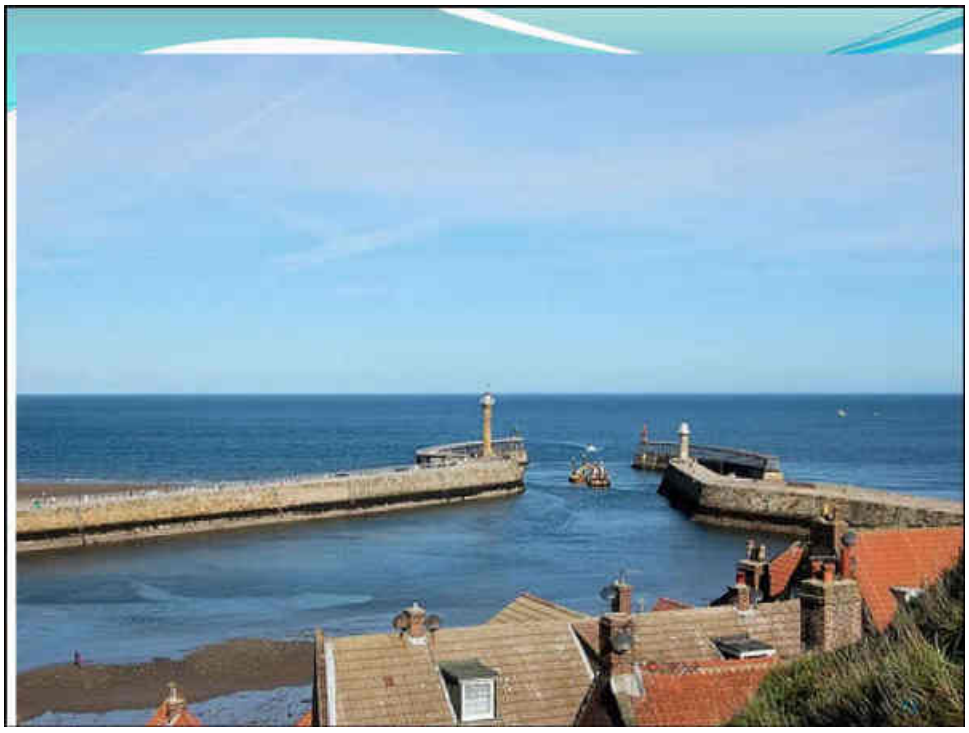


- It is desirable to provide rounded corner for wharves for the smooth entry of vessels.
- It should be located where sufficient water is available for ship to float.

- Design of wharf involves;
  - Provision for the berthing of ship
  - Handling and storage facility of cargo

PIERS

structure which are perpendicular or oblique to the shore of a river or sea



DOLPHINS

It is used for tying up ships

Also for transferring cargo from one ship to another

86

JETTIES

These are the structures in the form of piled projections and they are built out from the shore to the deep sea

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NAVIGATIONAL AIDS

- Purposes of navigational aids;
  - To avoid dangerous zones
  - To follow proper harbour approaches
  - To locate ports especially during night & bad weather conditions
- Necessity for signals
  - For the safe , economic , efficient and comfortable travel of ships in in rivers harbours oceans etc

91

- Requirements of a signal
- It should be easily visible from a long distance
- It should not vary in character
- It should be simple for identification

92

Types of signals

- Light signals
  - Light ships
  - Beacons
  - Buoys
- Fog signals
- Audible signals

93

1.Light signals

- Light ships
  - Small ships are used for this purposes
  - These are built of steel and painted with red colour
  - The name of the station is painted in white colours on both sides of light ship

94

- Beacons
  - Beacons are used for indicating direction changes in navigation
  - It could be built in the form of an open tapering frame work with a wide base and gradually narrowed top

95

- Buoys
  - These are floating structures
  - It is useful to indicating approach channel , entrances & boundaries

97

2. Fog signals

- Provided at places affected by fog
- Fog signal are in the form of
  - Ordinary bells struck by hand
  - Ordinary bells operated by mechanism
  - Submarine bells struck by mechanism
  - Sirens blown by compressed air

99

3. Audible signals

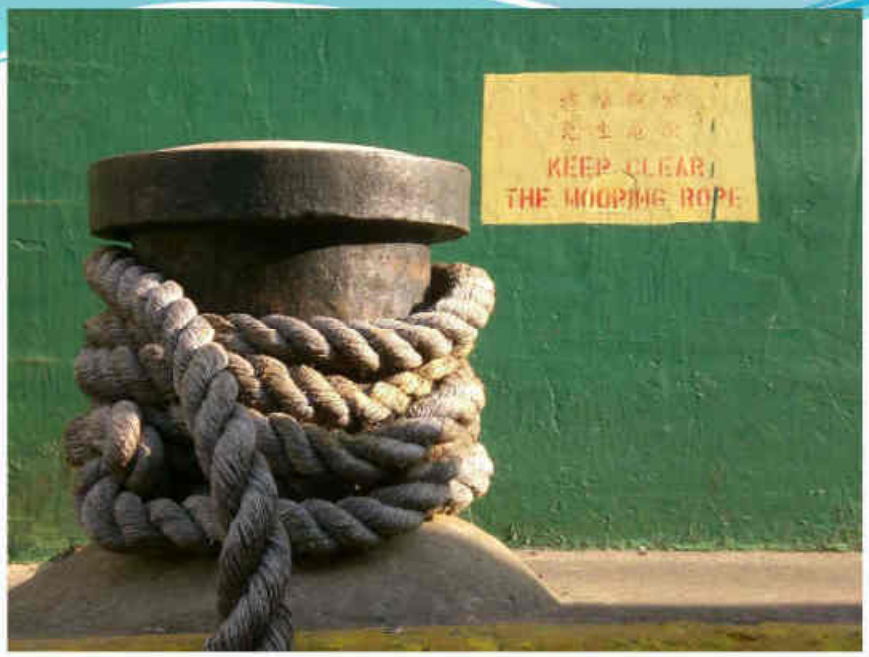
- These signals are to be used in emergency to bring immediate attention of the mariners during heavy mists or fogs.

100

Moorings

- These are the devices which are provided where anchorage water is limited.
- Moorings are out of the path of approach channel and it required sufficiently deep anchorage area.

101



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