UNIT-5
HARBOUR ENGINEERING

Water transportation:

The water transportation can further be subdivided into two categories:

- inland transportation and
- Ocean transportation.

Inland Water transportation

- Inland Water transportation is either in the form of river transportation or canal transportation.
- Ocean Water transportation is adopted for trade and commerce.
- It is estimated that about 75 per cent of international trade is carried out by shipping.
- The development of navy force is intended for national defense.
- Ocean water transportation has an limitation and it possesses high flexibility.

Definitions

Harbours:

- A harbour can be defined as a sheltered area of the sea in which vessels could be launched, built or taken for repair; or could seek refuge in time of storm; or provide for loading and unloading of cargo and passengers.

Harbours are broadly classified as:

- Natural harbours
- Semi-natural harbours
- Artificial harbours.

Natural harbours:

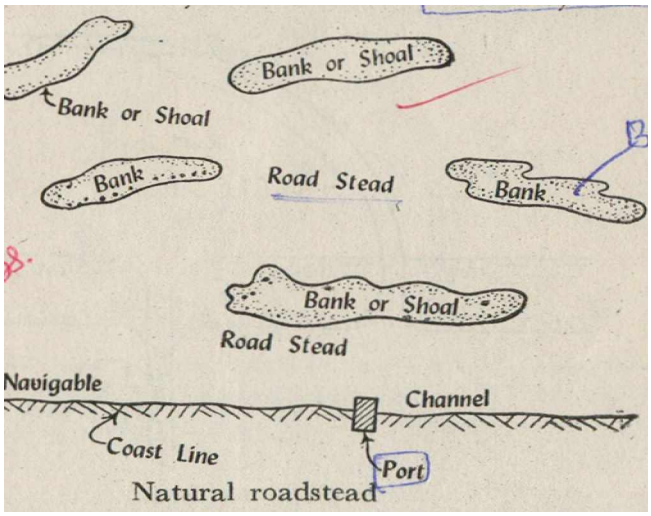
- Natural formations affording safe discharge facilities for ships on sea coasts, in the form of creeks and basins, are called natural harbours.
- With the rapid development of navies engaged either in commerce or war, improved accommodation and facilities for repairs, storage of cargo and connected amenities had to be provided in natural harbours.
- The size and draft of present day vessels have necessitated the works improvement for natural harbours.
- The factors such as local geographical features, growth of population, development of the area, etc. have made the natural harbours big and attractive. Bombay and Kandla are, examples of natural harbours

Semi-natural harbours:

- This type of harbour is protected on sides by headlands protection and it requires man-made protection only at the entrance.
- Vishakhapatnam is a semi-natural harbour.

Artificial harbours:

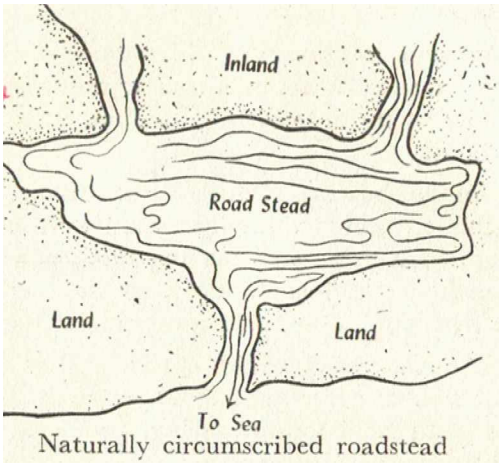
- Where such natural facilities are not available, countries having a seaboard had to create or construct such shelters making use of engineering skill and methods, and such harbours are called artificial or man-made harbours.
- Madras is an artificial harbour.
- Thus, a naval vessel could obtain shelter during bad weather within a tract or area of water close to the shore, providing a good hold for anchoring, protected by natural or artificial harbour walls against the fury of storms



Natural roadstead

Natural roadsteads:

- A deep navigable channel with a protective natural bank or shoal to seaward is a good example of a natural roadstead as shown in fig..



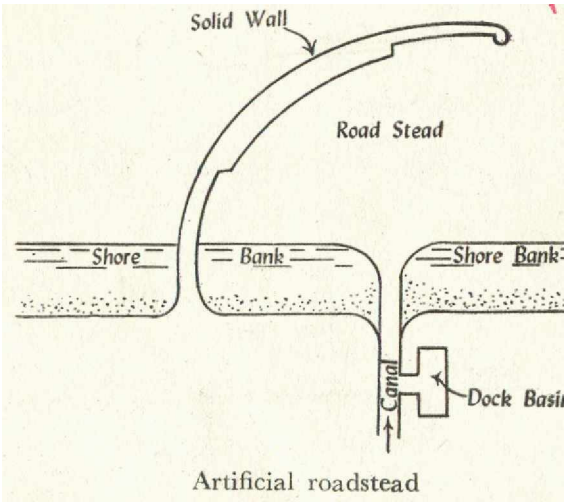
Naturally circumscribed roadstead

- A confined area naturally enclosed by islands as in a creek if available is

known as a circumscribed natural roadstead.

Artificial roadsteads:

- These may be created suitably by constructing a breakwater or wall parallel to the coast or curvilinear from the coast



Artificial roadstead

- As an alternative a circumscribed artificial roadstead could be formed by enclosing tract provided good anchorage, by projecting solid walls called jetties, from the shore.
- Another method is to create a confined basin of small area having a narrow entrance and exit for ships.
- Such roadsteads with smaller inner enclosures and wharf and with loading and unloading facilities are commonly provided for fishing vessels.

From their utility and situation, harbours are further classified into three major types:

- Harbours of refuge including naval bases
- Commercial harbours, connected with ports
- Fishery harbours.

It is necessary to study the requirements of these types of harbours and provide for such requirements.

Requirements of harbour of refuge:

- Ready accessibility
- Safe and commodious anchorage
- Facilities for obtaining supplies and repairs

Requirements of commercial harbour:

- Spacious accommodation for the mercantile marine.
- Ample quay space and facilities for transporting; loading and unloading cargo.
- Storage sheds for cargo.
- Good and quick repair facilities to avoid delay.

- More sheltered conditions as loading and unloading could be done with advantage in calmer waters.

Accessibility and size of harbours

- Accessibility depends on the location of the harbours.
- The harbour entrance should be designed and located for quick easy negotiation by ships, overtaken by storms.
- At the same time, it should be narrow enough not to expose the harbour to the effects of the stormy sea.
- Maximum dimensions upto 180 have been adopted
- The entrance is generally placed of the sea, with a passage to the interior of the harbour so arranged as to minimize the effect of rough seas.

Thus; the size is determined by:

- Accommodation required.
- Convenience for maneuvering and navigation.
- Adaptability to natural features.

Site selection:

The guiding factors which play a great role in choice of site for a harbour are as follows

- Availability of cheap land and construction materials
- Transport and communication facilities
- Natural protection from winds and waves
- Industrial development of the locality
- Sea-bed subsoil and foundation conditions
- Traffic potentiality of harbour
- Availability of electrical energy and fresh water
- Favorable marine conditions
- Defence and strategic aspects

Shape of the harbour:

The following principles should be kept in mind:

- In order to protect the harbour from the sea waves, one of the pier heads should project a little beyond the other.
- Inside the pier heads, the width should widen very rapidly.
- The general shape of the harbours should be obtained by a series of straight lengths and no re-entrant angle should be allowed

Harbour planning:

The important facts to be studied and scrutinized can be enumerated as follows:

- It is necessary to carry out a thorough survey of the neighbourhood including the foreshore and the depths of water in the vicinity
- The borings on land should also be made so as to know the probable subsurface conditions on land. It will be helpful in locating the harbour works correctly

- The nature of the harbour, whether sheltered or not, should be studied.
- The existence of sea insect undermine the foundations should be noted.
- The problem of silting or erosion of coastline should be carefully studied.
- The natural metrological phenomenoa should be studied at site especially with respect to frequency of storms, rainfall, range of tides, maximum and, minimum temperature and of winds, humidity, direction and velocity of currents, etc.

Ports:

- The term port is used to indicate a harbour where terminal facilities, such a stores, landing of passengers and cargo, etc. are added to it.
- Thus, a harbour consists of the waterways and channels as far as the pier head lines and a port includes everything on the landward side of those lines i.e. piers, slips, wharves, sheds, tracks, handling equipment, etc.

Classification of ports:

Depending upon the location, the ports can be classified as;

- Canal ports
- River ports and
- Sea ports
  - The term free port is used to indicate an isolated, enclosed and policed area for handling of cargo; etc. for the purpose of reshipping without the intervention of customs.
  - It is furnished with the facilities for loading and unloading; for storing goods and reshipping them by land or water; and for supplying fuel.
  - Free port thus indicates an area within which goods can be landed, stored, mixed, blended, repacked, manufactured and reshipped without payment of duties and without the intervention of custom department.
  - Depending upon the commodities dealt with or their use, the ports can also be classified as grain ports, coaling ports, transhipment ports, ports of call, etc.
  - Depending upon the size and location, the ports can also be grouped as major ports, intermediate ports and minor ports
  - A major port is able to attract trade and it commands a really pivoted position for the extension of communications.

Port design:

The design of a port should be made while keeping in mind the following requirements:

- The entrance channel should be such that the ships can come in and go out easily.
- The ships should be able to turn in the basin itself.
- The alignment of quays should be such that the ships can come along side easily even when there is an on-shore wind.
- The width behind the quay should be sufficient to deal with the goods.
- There should be enough provision for railway tracks to take care for loading and unloading of cargo.

Requirements of a good port

- It should be centrally situated for the hinterland. For a port, the hinterland is that part

of the country behind it which can be served with economy and efficiency by the port.

- It should get good tonnage i .e. charge per tonne of cargo handled by it.
- It should have good communication with the rest of country.
- It should be populous
- It should be advance in culture, trade and industry.
- It should be a place of defence and for resisting the sea-borne invasion
- It should command valuable and extensive trade.
- It should be capable of easy, smooth and economic development.
- It should afford shelter to all ships and at all seasons of the years
- It should provide the maximum facilities to all the visiting ships including the servicing of ships.

TIDES AND WAVES:

Some of the natural and meteorological phenomena which primarily affect the location and design of the harbour.

They are as follows:

- Coastal currents and evidences of sitting, including littoral drift or coast erosion.
- Tides and tidal range.
- Wind, wave and their combined effect on harbour structures.

Tides:

- Tides on the coast-line are caused by the sun and moon.
- The effect of tides is to artificially raise and lower the mean sea level during certain stated periods.
- This apparent variation of mean sea level is known as the tidal range.

Spring tides and Neap tides:

- At new and full moon or rather a day or two after (or twice in each lunar month), the tides rise higher and fall lower than at other times and these are called Spring tides.
- Also one or two days after the moon is in her quarter i.e. about seven days from new and full moons (twice in a lunar month), the tides rise and fall less than at other times and are then called neap tides.

Waves and wind:

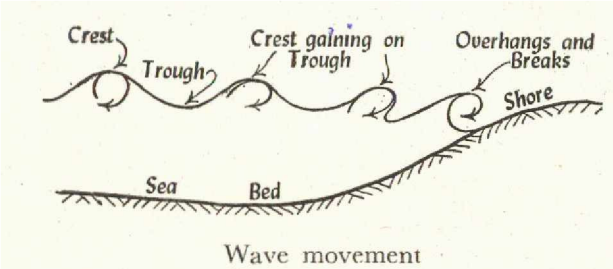
- The 'sea wave' is by far the most powerful force acting on harbour barriers and against which the engineer has to contend.
- The wave has the impulse of a huge battering ram and equipped with the point of a pick axe and chisel edge".
- It is the most in compressible natural phenomena.
- The formation of storm waves takes place in the open sea due to the action of wind.

Water waves are of two kinds:

- Waves of oscillation and
- Waves of translation;
  - The former are stationary, while the latter possess forward motion.
  - But all translatory waves originally start as waves of oscillation

and, become translatory by further wind action.

- The harbour engineer's main concern is the translatory wave.



Wave movement

Breakwaters:

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

Alignment:

- A good alignment for a breakwater is to have straight converging arms so that the angle of inter section does not exceed 60 degrees.
- It is desirable to avoid straight parallel or diverging arms running out to sea.

Design of breakwaters:

Following information should he collected before the design of a breakwater:

- Character of coastal currents
- Cost and availability of materials of construction
- Directions and force of prevailing winds
- Nature of the bottom or foundation
- Probable maximum height, force and intensity of waves. !

The three important rules to be observed in the design of a breakwater are as under:

- The design should be based on the extreme phenomena of the wind and waves, and not on the mean or the average.
- The height of the wave should he determined by Using the equation H = 034¥Fand the height of wall should be decided accordingly by making sufficient allowance for freeboard.
- It should be seen that the material in the foundation is not subject to scour.

Detrimental forces acting on breakwaters:

Hydrostatic force:

- This force reduces the apparent weight and hence, the marine structures suffer these losses to a great extent unless the foundations are absolutely impervious.

External forces:

- The intensity of external forces, especially wind and wave action, is enormous.
- The power of wind produces vibrations in the masonry structure and weakens the different courses of masonry.
- In a similar way, the wave when it recedes induces 'suction action and it results in the erosion of the foundation unless it is made safe and secure.

Solvent action of sea water:

- This quality of sea water causes damage to the materials of construction

Sea insects:

- The concentrated action of sea insects results in the undermining of the hardest and the soundest building material and it is for this reason that the marine structures are made specially bulky and strong.

Classification of breakwaters:

Breakwaters are classified mainly into three types:

- Heap or mound breakwater
- Mound with superstructure
- Upright wall breakwater.

Heap or mound breakwater

- It is a heterogeneous assemblage of natural rubble, undressed stone blocks, rip rap, supplemented in many cases by artificial blocks of huge bulk and weight, the whole being deposited without any regard to bond or bedding.
- This is the simplest type and is constructed by tipping or dumping of rubble stones into the sea till the heap or mound emerges out of the water, the mound being consolidated and its side slopes regulated by the action of the waves.
- The quantity of rubble depends upon the depth, rise of tides and waves and exposure.
- On exposed sites, the waves gradually drag down the mound, giving it a flat slope on the sea face.
- As far as possible, such flattening has to he protected.
- The disturbing action of the waves is the most between the high and low water levels.
- Consequently, all protective methods are adopted above the low water level.
- Protection is also very necessary to the top of the mound and outer or exposed face.

WHARVES

- Platforms or landing places are necessary for ships to come, close enough to the shore, for purposes of embarkation, disembarkation, etc. at the same time.
- These platform locations should give sufficient depth of water for the ship to float.
- Such platforms are, called wharves.
- They are built out into or on to. the water
- Thus, a wharf affords a working platform alongside the ship in continuity of the shore.
- A wharf is quay but the term wharf is generally used for an open structure of piles or posts with bracings, jutting from the shore towards the sea.
- A wharf may be a sheet pile wall or it may consist of a piled projection with or without artificial retention of soil some distance behind or it may be a gravity wall.
- Wharves may either be parallel to the shore and abutting against it or they may

project into the water either at right angles or oblique to the shore.

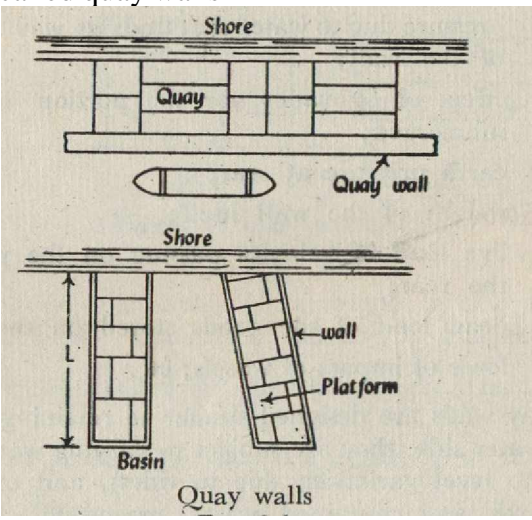
- The former type is adopted at places where depth of water is sufficient for the ships to berth, say 10 m to 12 m
- The latter type is adopted at places where depth of water near the shore is not enough for the ships to enter safely.
- The level of wharf should be above the high water level. But at the same time, it should be economical to load the vessels when the water level is low.
- Wharf should act as a unit when there is an impact from any vessel.
- Hence, it should be properly braced and bolted. It is desirable to provide rounded corners for wharves which art likely to be used by large vessels.
- Such a construction will result in a smooth entry of vessels into the slips

PIERS

- The structures which are built perpendicular or oblique to the shore of a river or sea are known as piers.
- In the sea the piers are constructed where the sea is not deep and the natural harbour is not convenient for allowing the ships to berth adjacent to the shore.
- In many cases, the piers are constructed with piles, columns and braces leaving good space for the ocean current to flow without causing any obstruction.
    - The dimensions of a pier should be worked out very carefully.
    - Its length should be sufficient to accommodate the longest ship likely to take its advantage.
    - In other words, it should project beyond the bow or stern of the ship so as to protect its hull. Its width should be sufficient to satisfy its utility.
    - It can be stated that the pier should be of sufficient width to allow easy unloading of cargo without any undue delay.

QUAYS

- Wharves along and parallel to the' shore, are generally called quays and their protection walls are called quay walls



Quay walls

Design of quay walls:

They are built to retain and protect the embankment or filling:

- Factors affecting the design are as follows
- Character of foundation;
- Pressure due to water that finds its way to the real of the wall;
- Effect of buoyancy for the portion of the wall submerged;
- Earth pressure at rear;
- Weight of the wall itself;
- live load of vehicles passing on the platform at the rear;
- dead load of the goods stored on the platform;
- force of impact of vessels; etc.
    - Quay wails are designed similar to retaining walls;
    - But on the water side, they are subject to varying water pressure (owing to level variations due to tides), and on the land side, earth and contained water pressures, with proper allowances for surcharge.

JETTIES:

- These are the structures in the form of piled projections and they are built out from the shore to deep water and they may be constructed either for a navigable river or in the sea.
- In rivers, the jetties divert the current away from the river bank and thus, the scouring action is prevented.
- As the current is diverted to deep waters, the navigation is also controlled.
- In the sea, the jetties are pr at places where harbour entrance is affected by littoral drift or the sea is shallow for a long distance.
- Thus, they extend from the shore to the deep sea to receive the ships.
- In a limiting sense, a jetty is defined as a narrow structure projecting from the shore into water with berths on one or both sides and sometimes at the end also.
- Jetties are exposed to severe wave action and their structural design is similar to that of breakwater.
- However, the designed standards may be released to a certain extent due to the fact that the jetties are usually built normal to the most dangerous wave front.
- The impact caused by the berthing ships will depend on the skill of the berthing officer, local condition of currents, wind, etc.
- The berthing velocity depends upon the condition of approach, wind, etc. and it decreases with the increase in the size of the ships

FENDER:

- The cushion which is provided on the face of jetty for ships to come in contact is known as fender.
- It is provided for various forms and is made of different materials.
- The common material used as fender for jetties is the framework of timber pile driven into the sea bed at a short distance from the jetty and filling the space with coiled rope, springs, rubber, buffers, etc.
- The fender system controls the relative motion between dock and ship caused by wind and waves.
- Hence, it also prevents the paint of ships being damaged.

For the purpose of classification, the fenders can be classified in the following four categories:

Rubbing strips:

- In its simplest form, the fender system adopted for small vessels consists of rubbing strips of timber, coir padding or used rubber tyres
- It is also convenient to use pneumatic inflated tyres, either by suspending them or installing them at right angles to jetty face.
- The inflated big-size tyres are useful to transfer cargo between mother ship and daughter ships.
- The pneumatic rubber fenders are very useful for transferring cargo from ship to ship of big sizes.

Timber grill:

- This system consists merely of vertical and horizontal timber members fixed to the face piles.
- This is a simple form of fender and to make it more effective, energy fender piles may be driven along the jetty face with cushion or spring inserted between them.

Gravity-type fendering system:

- As the ships grew in size, this s came into force and in its simplest form, it consists of a weighty fender which is raised up when there is an impact of the berthing ship and thus, the initial energy of shock, is absorbed.

Rubber tendering:

- Due to the development of rubber technology and with, further growth in ship size, rubber fendering is preferred at present.
- The shapes of rubber fenders may be cylindrical, square, V-shape or cell type.

NAVIGATIONAL AIDS

Necessity for signals:

The mariner and his ship have to be guided by proper signals during navigation, especially,
(1) to avoid dangerous zones like hidden rocky outcrop and sand bars,
(2) to follow proper approaches and

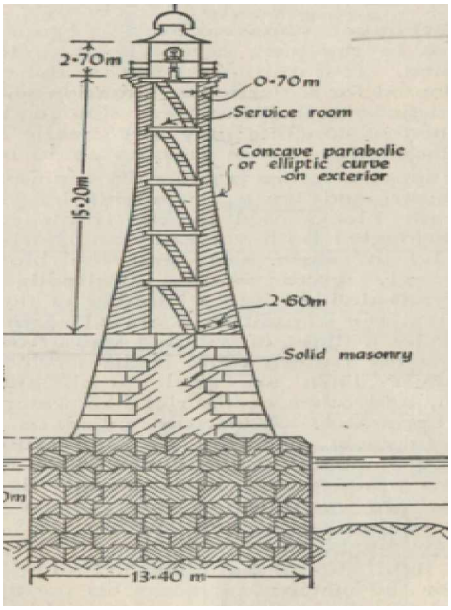
(3) to locate ports.

Fixed and floating light stations:

- The light stations when they are built on land are called fixed as in the case of permanent lighthouse structures.
- Such structures are located either in the hinterland close to the shore or in the sea on submerged outcrops and exposed to the fury of the waves.
- Alternately, where there are difficulties in establishing proper foundations; floating light rations in the form of a light vessel may be adopted.
- Buoys of standard shapes also belong to the 'floating type and are generally used to demarcate boundaries of approach channels in harbour basins.

Lighthouse:

- It is a lofty structure popularly built of masonry or reinforced concrete in the shape of a tall tower on a high pedestal.
- The tower is divided into convenient number of floors, the topmost floor containing powerful lighting equipment and its operating machinery.
- The lower floors are used, as stores and living rooms necessary for the maintenance and working of the light station.
- The main parts of a typical lighthouse tower are illustrated in fig.
- Lighthouses may be located on shore or on islands away from the mainland as in the case of warning light stations.



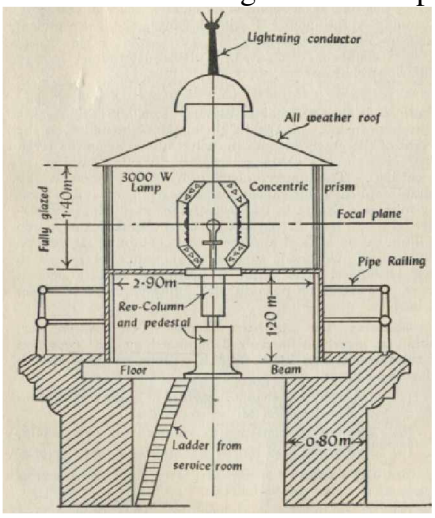
- In the former case, the lighthouse may be easily connected with the nearest village or township by proper communications, while in the later situation it is located far habited area.
- In either case as a matter of convenience and urgency, all the requirements for the efficient and unfailing maintenance and working of the lighthouse, like stores and staff quarters are provided in the lighthouse shaft.

Lighthouse construction:

- It is quite evident that the type of foundation to be adopted for a particular situation will depend on the characteristics of soil of that area.
- On good rock or hard soil, a thick bed of concrete may serve while on submarine or marshy locations, piles or caissons could be used.
- The superstructure is generally a masonry or an R.C.C tower constructed on a prominent basement.
- The stone or concrete blocks used in the construction of the basement are joggled both vertically and horizontally as shown in fig.
- To secure and bind the blocks together and resist strongly forces tending to dislodge or move them.
- The tower is divided into a number of floors and the light is housed at the summit in a glazed room.
- The floors are accessible by a flight of winding stairs from bottom to top.
- Just below the lantern room is the service room and other rooms lower down are used for oil and general stores, personnel, and other accessories like water storage and fire fighting apparatus.
- A narrow gallery is provided outside the lantern room protected by pipe railing.
- The dimensions and geometrical shapes shown in the figure are adopted in modern practice and more recent lighthouse like the Eddystone are examples of

this type of construction.

- The light should be identified and its distance ascertained, for the mariner to locate his position.
- These lights are made 'fixed' or flashing for easy identification by the navigator and are classified accordingly to their illuminating power.
- The height of the tower above sea level determines the geographical range and the intensity or power of the light the luminous range.
- These two are important factors, deciding the range of visibility.
- The illumination is both refracted through powerful lenses and prisms and reflected or flashed by highly polished hyperbolic concave mirrors fig.shows the details of the light apparatus.
- Fixed lights are likely to be confused with the private lights of the neighbourhood and hence, it is desirable to avoid fixed lights as far as possible.



Signals:

- The approach channel of a modern port should be clearly defined o demarcated by the provision of suitable signals.

Thus, signals will be required at the following places:

- Light ships have to be provided at important changes in the direction of the route of ships.
- Lighted beacons are to be fixed on river banks
- Buoys are required at entrance channels to ports

Requirements of a signal

- It should be conspicuously visible, from a long distance.
- It should not vary in character and should be positively recognizable.
- It should be simple for identification.

Types of signals:

The signals are broadly divided into the following three categories':

1. Light signals

2. Fog signals
3. Audible signals.

The first classification of light signals is very important. Fog signals and audible signals are occasionally used.

Light signals

These signals are subdivided into three types:

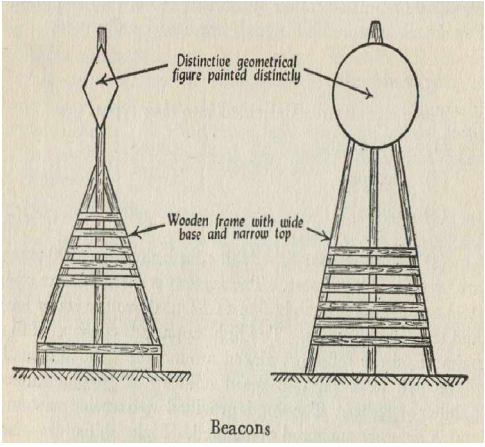
(1) Light ships
(2) Beacons
(3) Buoys.

Light ships:

- Small ships displacing about 500 tonnes are used for this purpose.
- The lantern is carried on an open steel tower approximately 9 m to 12 m above the water level and erected amidships.
- The light apparatus consists of four pairs of mirror reflectors placed around the light and made to revolve at a suitable speed emitting ,a predetermined number of flashes.
- The ship is with service personnel and is securely anchored or moored.
- light ships are more stable and the lights in them more steady which is an important factor for a mariner.
- The hulls of light ships are built of steel and they are generally painted with red colour.
- The name of the station is painted in white colours on both sides of light ship.
- The superstructures are also provided with white colours.
- The storm warning signals are also installed on the light ships.
- When the light ships are being overhauled, red colour relief light ships with the word 'Relief' on the sides are used.

Beacons:

- Any prominent object, natural or artificially constructed, easily indentifiable and capable of being used as a means to indicate and guide in navigation is generally designated as a beacon.
- Lofty topographical feature like hill summit, building or structure like a church steeple, or factory chimney, could all be made use of as beacons.

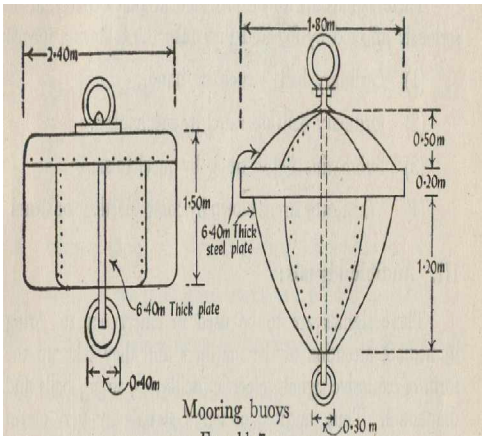


Beacons

- Alternately, a beacon could be built in the form of an open tapering frame work, with a wide stable base and gradually narrowed top, terminating in a distinctive figure, like a triangle or circle as shown in fig.
- The distinctive geometrical figure is suitably painted so as to cause prominence.

Buoys:

- Buoys are floating structures of small size employed for demarcation like entrances, approach channel used for indicating direction changes in means of alignment. Beacons are thus of the navigation.
- Beacons are navigation or as immense help in boundaries and so on.
- They are moored to sinkers, or heavy anchors, with the help of heavy chains, whose length are two to three times the depth of water and which are 70 to 90 mm in diameter.
- They are useful in indicating approach channel widths, two rows of buoys being used one along each boundary.
- These buoys are denominated 'Star board-hand' or 'port-hand' buoys according to their positions being to the left or right of the navigator respectively as he approaches the harbour.
- Buoys are of different designs and patterns. They are designed not only to support their own weight, but also the weight of cables or chains by which they are moored.
- The surface of buoy structure near water line should be protected by the provision of stout wooden fendering so that it is not seriously damaged in case of an impact.
- Thus, buoys are floating signals and they are usually prepared of steel and iron plates of minimum thickness 6 nun.



- Buoys are hollow structures and they are constructed in two watertight sections so that in case one of them is leaky, at least the other one may prevent it from sinking.
- The maxi mum distance between consecutive buoys is about 16Q0 m in estuaries and in narrow channels, it is about 150 m to 300 m.
- The diameter of a buoy varies from 1 80 m to 3 m.
- In tidal places, the depth of water is liable to fluctuation and hence, in such cases, the buoys are not steady and they do not give correct guidance regarding alignment.
- The presence of buoys also indicates the proximity of places with shallow depth of water.
- Buoys are also classified according to their size, shape, colour, weight, purpose, etc. Brief descriptions of buoyage system, mooring buoys and wreck buoys are given below.

Mooring buoys:

- In harbour interiors, buoys are pro vided in fixed positions to which ships could be moored during their stay in the harbour without using anchors.
- These buoys are called mooring buoys. Some common types of mooring buoys in use in India are shown in fig.

Wreck buoys:

These arc of peculiar shape and are used to locate wrecks in harbour exteriors or open seas. They are also used for sea cable crossing locations

Fog signals:

These signals are to be provided at places likely to be seriously affected by fog and they take the following forms:

- Ordinary bells struck by hand.
- Ordinary bells operated by mechanism.
- Submarine bells struck by mechanism.
- Whistles or sirens blown by compressed air or steam.

Audible signals:

- These signals are to be used in emergency to bring immediate attention of the mariners and they take up the form of explosive signals, electric oscillators, sirens, bells and diaphones.
- Thus, audible or sound signals are very useful during heavy mists or fogs. It should also be noted that sound transmitted through the air gives sometimes the misleading idea about the direction of sound.
- Hence, resort is made to submarine sound signals in such a way that they can be heard from a great distance with easy identification of the direction.