Caissons
Module III
Course Content

- Definition, uses, construction material, types of caissons, loads on caisson, design features of caissons, floating of caissons, cutting edges, sinking of caisson, tilting of caisson. Caisson diseases.
Definition of Caissons

• Caisson is a water tight structure made of wood, steel, R.C.C i.e. reinforced cement constructed in connection with excavation for the foundation of bridges, piers in rivers, dock structures etc.
Uses of Caissons

• Caissons are more suitable for the deep foundation under water where the foundation should be extended up to or below the river bed so as to obtain the proper stability.

• Caissons as type of well foundation is constructed in connection with excavation for foundation of piers and abutments in rivers and lake, bridges, break water dock structures for the point of view of shore protection, lamp house etc.

• When the construction of well foundation to be done under water. The construction of caisson are more preferable.

• When depth of water in river, lake, or sea etc. are more, than caisson structure is used.

• Caisson are used as foundation for bridges piers, and abutments in rivers, seas, lakes, break waters and other shore construction works.

• It is also used for pump house which are subjected to huge vertical as well as horizontal forces.

• It is also occasionally used for large and multi-storey building and other structures.
Construction Material

• The Material used for the construction of caisson are as follows:
  • Wood
  • Steel
  • Reinforced Concrete
Shapes of Caissons

Caisson are constructed into two basic shapes and combination of basic shape.

Shapes of Caissons:
(I) Basic Shape
(II) Combination of Basic Shape

Basic Shape:
(I) Circular
(II) Rectangular
(III) Square
(IV) Octagonal
Shapes of Caissons

(a) Square
(b) Rectangular
(c) Circular
(d) Double circular
(e) Double rectangular
(f) Octogonal
(g) Double octogonal
(h) Double hexagonal
(i) Double - D
Combination of Basic Shapes

- Double Circular
- Double Rectangular
- Double hexagonal
- Double-D
- Double Octagonal
Types of Caissons

- The Caissons is used for the purpose of placing a foundation in correct position under water.
- Types of Caissons
  - Open Caisson
  - Box Caisson
  - Pneumatic Caisson
Types of Caissons
Open Caissons

- It is a box type of structure which is open at the top and at the bottom. Open Caisson are normally used on sandy soils or soft bearing stratum and where no firm bed is available at a higher depth.
- According to the shape of caissons, open caissons can be further classified into three types as;
  - Open Caisson
  - Single Wall Open Caisson
  - Cylindrical Open Caisson
  - Open Caissons with dredging wells.
Open Caisson

(a) Sectional elevation at A-A

(b) Plan

Fig. 3.3.5: Open caissons (Double D-shaped type)
Open Caisson
Construction of Open Caissons:

- The sinking process of open caisson can be done in the following conditions:
- Dry
- Dewatered Construction
- Artificial Island
- In case of an artificial island called as sand island method, the island can be made by raising the ground surface above water level temporarily for obtaining relatively dry area for the sinking process. The size of sand island should be sufficient so that it can provide more working space all around the caisson.
Construction of Open Caissons

- If **dry Conditions is not possible on site**, then caisson is built in barges or slipways. Then it is **towed to its final position by floating**. Guide piles are normally used for sinking the first few lifts. **Note that sinking of Caissons are directly done in open water.**

- Excavation of soil by dredging the well sinks the caisson by its own weight and the excavation process is done by dredging with the help of grab buckets. The soil besides the cutting edge can be removed by man power. **Water Jets** are used on exterior walls side so-as to run the sinking process more easily.

- When the caisson is constructed to the required stage, then concrete seal cap is provided caisson is dewatered by the method of pumping.
Advantages and Disadvantages of Open Caissons

• Advantages of Open Caissons:
• Following are the advantages of Open Caissons:
• This type of Caisson can be extended up to large depths.
• Cost of Construction is relatively less on bed level or lower side.
Advantages and Disadvantages of Open Caissons

• Disadvantages of Open Caissons:

• Following are the disadvantages of open Caissons;

• Since the placing of concrete is done for concrete seal under water, it may not be satisfactory.

• If any obstruction of boulders or logs are encountered, then progress of work becomes slow.

• Through cleaning and inspection at the bottom of caisson is very difficult and hence not possible.

• The help of divers may be required for excavation near haunches at the cutting edges.
Box Caissons

• **Box caisson is similar to open caisson**, only difference is that it is closed at the bottom.

• **Box caisson is cast and cured properly on ground** and then it is launched in water by filling sand or gravel or concrete in the empty spaces.
Box Caissons
Pneumatic Caissons

• This type of caisson is **open at the bottom and close at the top**. Pneumatic caisson is specially used at the place where it is not possible to construct the well.

• It is suitable for the depth of water **more than 12 m**.

• **In the construction of Pneumatic Caisson, the compressed air is used to remove water from the working chamber** and the foundation work is carried out in dry condition.

• This type of caisson can be made of **timber, concrete or steel**.
Pneumatic Caissons
Components of a Pneumatic Caissons

Following are the various components of a pneumatic caissons:

Air Shaft

A passage connecting in between the working chamber and air lock is termed as 'air shaft'

This passage or air shaft is used by the workmen or workers to reach to the working chamber to ground surface. If caisson is too large in size, the separate unit of air shaft may be provided for workers and material.

Air Shaft is made up of steel material. The joint involved in air shaft are sealed by rubber gasket air lock is provided on each air shaft at top. When sinking process is going on, air shaft is extended above the water level.
Components of a Pneumatic Caissons

- **Working Chamber:**
  - Working Chamber height is about 3 m and is totally air tight and made up of structural steel.
  - To prevent the entry of air and water into the chamber, the air inside the chamber is kept at a pressure just more than atmosphere pressure. External surface of chamber is kept thick. Chamber is leak proof and smooth to reduce skin friction. To facilitate the proper processing of sinking, a cutting edge is provided at the bottom.
Components of a Pneumatic Caissons

• **Air Lock:** A chamber made of steel provided at the upper end of the air shaft above the water level is called as 'Air Lock'. Air lock allows the worker or workmen to enter or exit from the caisson without releasing the air pressure in the working chamber.

• The air locks has two air tight doors, one door opens into shaft and another door opens to the atmosphere. When workmen enters the airlocks through the outside door, then pressure in the chamber is kept at atmospheric level. Pressure is increased gradually till it becomes equal to the working chamber. Under this condition workmen is allowed to go into the air shaft. Complete procedure is again done when workmen comes out of the air shaft to air lock.

• By opening a valve in the airlock, fresh air is circulated in the shaft workers or workmen are allowed to work into the working chamber up to 2 hrs.

• The maximum limit of working into the chamber is 2 hrs.
Components of a Pneumatic Caissons

- **Miscellaneous Equipments**
- Different types of miscellaneous equipments used in pneumatic caisson are as follows:
  - Pumps
  - Motors
  - Air Compressors
- These equipments are normally placed above the bed level.
- Through compressed air pipe, can be applied to the working chamber.
Air shaft:

A passage connecting in between the working chamber and air lock is termed as ‘air shaft’ as shown in Fig. 3.3.7.

Fig. 3.3.7: Components of pneumatic caissons
Advantages and Dis-advantages of Pneumatic Caissons

• Following are the various advantages of pneumatic caissons:

• **Quality control is good because work is done in dry conditions.**

• **Insitu soil tests are possible to determine the bearing capacity.**

• **There is direct and easy passage to reach the bottom of caisson, hence any obstruction can easily be removed.**

• **Concrete gain more strength due to dry conditions.**

• **For major projects, greater depths in bed rocks can be possible.**

• **There is no danger of settlement of adjoining structures because of no lowering of ground water table.**
Disadvantages of Pneumatic Caisson

• Following are some of the disadvantages of pneumatic caisson.

• Construction of pneumatic caissons is much expensive than open caissons.

• During working the various constructional activities, a proper care has to be taken, otherwise it may lead to fatal accidents.

• Maximum depth below water table is limited to 30 m to 40 m. Beyond 40 m depth, construction is not possible.

• There is more chances of caisson diseases to workmen working under high pressure.

• Labor cost is high.
## Difference between Open Caisson and Pneumatic Caissons

<table>
<thead>
<tr>
<th>Pneumatic caissons</th>
<th>Open caissons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labour cost is more</td>
<td>Labour cost is less as compared to Pneumatic caisson</td>
</tr>
<tr>
<td>Special compressed air in working chamber is needed for dredging</td>
<td>No compressed air is required and only ordinary excavation method is required for dredging.</td>
</tr>
<tr>
<td>High risk to workmen’s life. They may suffer from caisson disease.</td>
<td>No risk to workmen’s life</td>
</tr>
<tr>
<td>Special medical treatment and care is being taken to maintain their health from caisson disease.</td>
<td>No precaution are required since there is no caisson disease in open caisson.</td>
</tr>
<tr>
<td>Bottom of this type of caisson is cleaned in dry condition.</td>
<td>Cleaning is done under water.</td>
</tr>
<tr>
<td>In this type, obstacles can easily be observed and tackled during excavation.</td>
<td>In this type, it is not possible to see or observe any obstacles during excavation.</td>
</tr>
<tr>
<td>There is direct access or passage upto bottom of caisson for manual excavation.</td>
<td>Direct access or passage to the bottom of caisson is not possible.</td>
</tr>
<tr>
<td>Excavation is possible in any type of soil structure.</td>
<td>Excavation in hard strata is very difficult by dredging.</td>
</tr>
<tr>
<td>In this case, there is limit to depth of foundation below water table.</td>
<td>There is no limit to depth of foundation below water table.</td>
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Loads on Caissons

Caisson is a well acted upon by the following loads:

- Dead load of super-structure
- Load of bearing pier
- Various horizontal forces

Caissons is liable to acted upon by the following various horizontal forces:

- Wind force
- Earth Pressure
- Seismic load
- Centrifugal forces
- Water current forces
- Bracking and tractive efforts of the moving vehicles
- Force offered by the bearing against movement because of variation of temperature.
Loads on Caissons
Floating of Caissons

• When Caisson are casted away from the site or off-site, then these **caisson are transported to the required location by means of floating**, then it is called as floating of caissons. In short, method of transportation the casted caisson off-site to the desired location by floating is called as floating of caissons.

• Floating Caissons are commonly termed as box caisson. A box caisson is cast and cured on land and when required, it is launched in water and towed to the site by floating for sinking operation.
Floating Caisson

- After Casting the box Caisson, it is taken to the site by floating in water, then it is called as 'floating' Caisson.

- Sinking Process can be made-faster by increasing the self weight of caisson, self weight is increased by adding sand or gravel inside the caisson.

- Floating caisson are not provided by cutting edge as compared to the other caisson. This type of caisson is simple rest on a hard or level strata. In this way, load carrying capacity is a function the resistance at the base since there is no skin friction on sides.

- On the top of Caission, a concrete cap is provided to carry the loads uniformly from the super structure. To prevent the scouring at the base of floating caisson, rip-rap is provided around the base for better understanding.
Floating Caisson
Construction of Floating Caissons

Following are the various steps involved in the construction process of floating caissons:

Floating Caisson are cast and cured on land. After casting and proper curing, it is floated to the desired location. Caissons are filled with gravel or sand so as to facilitate proper sinking process.

The required base location is excavated and levelled. Then Caisson is sunk to required location and depth.

Rip-Rap is provided all around the base of caisson which prevents the scouring.

Concrete cap is casted at the top of caisson so as to carry the loads uniformly from superstructure.

Floating caissons are constructed in reinforced cement concrete or steel. When it is to floated and placed in rough waters, internal strutting and diaphragm walls are used.
Advantages and Disadvantages of floating Caissons

- Advantage of floating Caissons;
- Since concrete are pre-casted, good quality control is possible
- Its installation is quick and more convenient
- These types of caissons are less expensive as compared to other types of caissons
Advantages and Disadvantages of floating Caissons

• The foundation of floating caisson:
• The foundation bed require levelled surface before installation of a floating caisson
• Rip-rap should be provided to protect the caisson from scouring
• Floating caisson or box caisson is only advantageous when hard strata is available.
• Its load carrying capacity is less as compared to other caisson of equal and same size.
Components of Well Foundation

• **Cutting Edge:**
  - Sharp edge which is provided at the lower end of the well or open and pneumatic caisson for accelerating sinking operation is called cutting edge. It is made up steel or it is made in R.C.C. Its angle to vertical is $30^\circ$ and normally slope of 1 horizontal to 2 vertical given better result.
  - In concrete caissons, the lower part of the cutting edge is rigidly fastened with 12 mm steel plates with the help of steel strap.
  - The cutting edge should be sharp so as to penetrate into the soil and it should resist the various stresses caused by blows, boulders, blasting, etc.
  - A sharp vertical edge is generally provided to the outside face of the caisson. Edge facilities the rate of sinking.
Components of Well Foundation

- **Topping**
  - Covering provided over the well or caisson is called as topping.
  - Sand is filled in between topping and bottom plug. Topping also acts as a part of shuttering for laying the well cap.

- **Bottom Plug:**
  - The lower portion of well is sealed by the concrete is called as bottom plug.

- **Stening**
  - Stening is constructed in concrete or masonary work.
  - Use of stening is to provide dead load during sinking operation.
Components of Well Foundation

- **Well Curbs**
  - It is made of concrete or brick. Cutting edge of well or caisson is attached to well curb. During sinking operation well curb impart to the well-stening and facilities the formation of bottom

- **Well Cap**
  - R.C.C Slab covering provided over the top of well is termed as well cap.

- **Sand filling**
  - The portion between top and bottom plug is filled with sand so as to increase the self weight of the well and makes safe during earthquake.
Components of Well Foundation
Sinking of Caissons

- **Sinking of Caisson in dry river bed:**
- **Construction of caisson curb or well curb:**
- Well curb or caisson curb is built in case of a dry river bed, so as to place at the correct position after excavating the bed for about 15cm for seating. If the depth of water is upto 5m, then sand island is constructed. For even distribution of load, wooden sleeps can be placed below cutting edge. When the shuttering of caisson curb is done, then reinforcement for the curb is placed in position. Concreting of curb is done in one stroke and it should be done without gap so as to obtain monolithic concreting structure.
Sinking of Caissons

• Construction of Caisson steining or well stening:

• For a height of 1.5 m, the caisson steining is constructed at a time when the caisson reaches at a depth of 6 m below ground stening can be raised with a height of 3 m at a time. Sinking of Caisson is commenced after concrete is set for 24 hrs.
Sinking of Caissons

- **Sinking process:**
- When the curb is cast, then sinking operation is started.
- The first stage of stening is ready after curing. In inner material if comes as a obstruction can be excavated manually or mechanically. If hard rock comes in the way, then blasting may be done.
- For proper sinking operation, additional loading termed as kentledge is used if required. Sand bags can be used as kentledge which can be placed on a suitable platform on the top surface of caisson.
- When caisson reaches at a depth of 10 m, dewatering is done by pumping. Jetting of water is also helpful in sinking operation. Proper care has been done by adopting the proper measures and techniques so as to avoid shifts and tilts of caisson during sinking
Sinking of Caissons

Fig. 3.8.1: Sinking of caissons
Sinking of Caissons
Tilting of Caissons

• At the time of sinking process caisson should sink exact vertically downward, straight and at the corner position without any tilting of caisson.

• If the caisson tilt any one side from its position while sinking operation, then it is called as tilting of caisson. During sinking operation, it may also shift way from the required position. Hence it is much essential to take the suitable precautions so as to avoid tilting and shifting of caisson.
Precautions to be taken to avoid tilts and shift

• The cutting edge of caisson must be thick and sharp pointed
• The external surface of steining and caisson curb should be smooth.
• Dredging should be done uniformly on all sides and in all pockets of caisson.
• Caisson should be symmetrically placed.
• The diameter (D) of the curb must be placed from 40 mm to 80 mm or larger or more than external diameter of steining.
Remedial Measures to Rectify Tilt and Shift

• Following are the remedial measures to be carefully implemented to avoid tilting of caisson during sinking process:

• Water Jetting:

• This is one of the methods used to prevent tilting. In this method, water jet is forcibly applied on tilt.

• Application of water jetting on higher side reduces skin friction. Thus the tilting is rectified.

• This method is not more effective but gives the better result if used with the combination of other methods.
Remedial Measures to Rectify Tilt and Shift
Remedial Measures to Rectify Tilt and Shift

- **Eccentric loading:**
- The caisson is normally given the additional loading called kentledge in order to have necessary sinking effort. In this method, eccentric loading or kentledge is applied in higher side so as to have greater sinking effort.
- For proper application of eccentric loading a platform with projection on higher side can be placed over the top of caisson
- The eccentric load is kept on projected part of platform. Thus tilt can be rectified.
Remedial Measures to Rectify Tilt and Shift
Remedial Measures to Rectify Tilt and Shift

- **Excavation under cutting edge**;
- During sinking process, filled caisson will not set or straighten due to unbroken stiff strata on its higher side. In such situation, dewatering is preferably done to loosen stiff strata. If dewatering is not possible or unsafe, then drivers are sent to loosen the stiff strata.
- Sometimes if possible and safe, an open excavation is done under the cutting edge.
Excavation under cutting edge;

Fig. 3.9.3: Excavation on higher side
Remedial Measures to Rectify Tilt and Shift

• Regulation of Excavation;
• Sinking of caisson on higher side due to excess excavation is more. This is all right in the early stages, otherwise dewatering of caisson or well is needed and open excavation may be done on higher side.
Remedial Measures to Rectify Tilt and Shift

- Providing temporary obstacles below the cutting edge:
- Rectification of tilt can be done by inserting the wooden sleeper temporarily as an obstacles below the cutting edge on the lower side so as to prevent further tilt of the well or caisson.
- Later on, wooden sleeper can be removed, for better understanding.
Providing temporary obstacles below the cutting edge:
Remedial Measures to Rectify Tilt and Shift

- Pushing the caissons or well with jack:
- Mechanical jack or hydraulic jack can be used to rectify the tilt of well or caisson. Well or caisson can be pushed by jack to bring it a vertical position.
Pushing the caissons or well with jack:

Fig. 3.9.5: Pushing of caisson by jack
Remedial Measures to Rectify Tilt and Shift

• **Pulling the well or caisson:** This method is most suitable and effective in preliminary or early stages of sinking operation. Steel ropes or cables are used pull the caisson or well. Pulling of caisson or well is done on higher side of well or caisson
Pulling the well or caisson
Remedial Measures to Rectify Tilt and Shift

• Strutting the caissons or well:
  • Method of strutting the caisson or well is used to prevent any further and possible rise in tilting of the caisson or well.
  • The caisson or well is supported on the tilting side by giving inclined support of a strong wooden member. This inclined wooden member is called as a strut.
  • The caisson or well steining is provided so as to distribute the uniform pressure or load from strut.
Strutting the caissons or well
Caisson Diseases

• In case of sinking process of pneumatic caisson, workers or workmen have to work in working chamber under compressed air. If the compressed air pressure is less than 0.35 N/mm$^2$ to 0.4 N/mm$^2$, then workmen may suffer from the following pains:
  • **Workmen may suffer from giddiness**
  • **There is pains in ears of workmen**
  • **There is breaking of ear drums of workmen**
  • **There is bursting of blood vessels in the nose or ears of workmen**
  • The above mentioned pains are not that serious or fatal, but workmen is actually suffering during decompression and effect causing depression is called caisson disease.
Caisson Diseases

• Following are the caisson disease caused by decompression:
  • Severe pains in joints leading to bends
  • It may cause paralytic death
  • Excessive oxygen get absorbed in the blood and tissues during decompression is more trouble some to workmen. Absorbed oxygen gas is thrown out of blood in the form of bubbles which can block in vessels and may cause bursting of vessels.
  • If bubbles are developed in joints it causes bends
  • If the bubbles are developed in spinal cord, it causes paralysis and if the bubble are developed in heart, it causes heart attack.
  • Caisson diseases can be controlled by recompression followed by slow decompression.
Caisson Diseases

Inhaled oxygen \((O_2)\) enters the bloodstream

Lung

Oxygen leaves the blood and enters the tissue

Caisson Disease

A case of the bends, or Caisson Disease

[Diagram of blood circulation and atelectasis]
Thanks