UNIT-III

SUB STRUCTURE CONSTRUCTION

2 MARKS

1) What is a cofferdam? When it used? (A.U. MAY/JUNE 2006, NOV/DEC 2009, 2010, APR/MAY 2010)

Cofferdam is a temporary structure constructed to exclude water from the site to construct a permanent sub-structure, without the interface of water. It is used when the well foundation is to be carried in running water.

2) What is a caisson? What are the types of caisson? (A.U. NOV/DEC 2010,2011)

It is a special type of foundation used for the construction of bridge piers in prevent very deep water, where it is either difficult to construct a cofferdam or to prevent its leakage.

Types:

a) Box caisson

b) Open caisson

c) Pneumatic caisson

3) What are the components of well foundation?

The components of the well foundations are,

a) Well curb

b) Cutting edge

d) Steining

4) What are the operations involved in open caisson method of foundation?

The open caisson method of foundation consists of the following operations:

a) Constructing or fabricating the caisson and preparing site to receive it.

b) Placing the caisson over the site of the pier.

c) Excavating the soil from the interior of the caisson and advancing the

d) Caisson so that its cutting edge is at or below the bottom of the excavation and continuing this process until the foundation in the hard stratum is reached.

d) Sealing the bottom of the caisson to exclude water and soil.

5) What is meant by sheet pile? (A.U. MAY/JUNE 2009)

One of a group of piles made of timber, steel, or prestressed concrete set close together to resist lateral pressure, as from earth or water Compare bearing pile is known as sheet pile.

5) What are the uses of sheet piles? (A.U. NOV/DEC 2009, APR/MAY 2010, NOV/DEC 2011)

The uses of sheet piles are,

a) For preventing leakage of pile material and water.

b) For preventing the structure from shocks, vibrations, etc,.

c) For deep excavations to enclose soils to prevent lateral crust or pressure.

6) What is a shoring? (A.U. MAY/JUNE 2006, NOV/DEC 2010)

Shoring is a temporary structure used to support tilted or endangered walls .The walls might have been endangered due to unequal settlement of foundation, removal of adjoining structures or making large opening in the walls.

7) What is meant by pipe jacking? (A.U. MAY/JUNE 2009. NOV/DEC 2008, 2011)

Pipe jacking is a method of installing a pipe under roadway, railway or highways without using an open cut trench .The pipe jacking procedure uses a casing pipe of sheet or reinforced concrete ie, jacked through the soil.

8) What is dewatering? Where it is used?

Dewatering means removal of excess water from the saturated soil.

It is used where the water table is very high or in the case of deep excavations the foundation trenches for buildings and other structures, are filled with seeped water.

9) What is a under-ream pile?

It is a pile with one or more bulbs in its vertical shaft .These bulbs are known as under-reams and it increases the bearing capacity of the soil.

10) Write about spacing of piles?

For piles to be driven on hard stratum the minimum center to center spacing is 2.5 times the pile diameter. In case of friction piles minimum spacing of 3 times the diameter of the pile shaft is provided. In case of loose soil filled up area or sand the minimum center to center spacing is twice the pile diameter.

11) Explain about suspended scaffolding.

During repair cleaning and painting various types of working platforms are required at various levels which can be easily provided and removed. Such types of platforms can be suspended by ropes or chains from parapet wall of buildings or cantilever beams placed at the top of the structure. These types of working are called suspended scaffolding.

12) Write about centering and shuttering?

Centering is a temporary structure used for the construction of arches , whereas shuttering is a temporary structure used for the construction of

R.B. or R.C.C. structures such as beam, slab, balcony, porch, etc,. Centering are wooden shaped frames and shuttering are known as mould.

13) What is a Kent ledge?

In well sinking, to overcome the increased skin friction and the in weight of the well due to buoyancy, additional loading is applied on the well . It is called Kent ledge.

14) What are the methods used for tunnel driving?

Following are the methods generally used for driving a tunnel,

a) Full face heading

b) Heading and bench method

c) Drifts method

d) Pilot tunneling

15) What is mucking?

The operation of removal of excavated material in tunneling operation is called mucking.

16) What are the advantages of drift method?

Drift method of tunnel excavation has the following advantages:

a) It helps to determine the region of bad rock or excessive ground water before actually taking up the full excavation, so as to enable to take up the corrective measures.

b) The drift provides ventilation while driving the main tunnel.

c) It reduces the consumption of explosives.

17) Explain about cement grouting .Uses.

In this method, cement grout which is a mixture of cement, sand and water is used. The process consists of making a number of holes in ground and then filling these holes by cement grout under pressure. This process is continued till no grout is coming up through the hole.

Uses:

a) The grouting procedure can be used in stopping leakages from rock.

b) It can also be used to fill the voids in soil so as to strengthen the soil and to make the rock or soil water tight.

18) Write the situations under which pile foundation is recommended. **(A.U. NOV/DEC 2011)**

The pile foundation is recommended for the following situations:

a) When spread footing, raft and grillage foundations are uneconomical.

b) When heavy concentrated loads are to be transmitted by the foundations.

c) Where there is scouring in the soil near the foundations.

d) Where the soil is made up and of a compressible nature.

19) Write the essential features of a pump to be used for dewatering.

The pump to be used for dewatering process should have the following features:

a) The pump should be portable so that it can be easily moved as and when required.

b) The pump should be capable of handling water mixed with impurities such as sand, earth, etc,.

c) The pump should be of strong make.

d) The performance of pump should be reliable.

20) What is the equipment used for driving a pre-cast pile in a sandy soil?

The equipment used for driving a pre-cast pile in a sandy soil is a hammer. Hence maximum stresses are developed at the top due to direct strokes and at the point in overcoming the resistance to penetration. Therefore additional reinforcement is provided.

21) Give instances where box jacking techniques are usually employed? **(A.U. MAY/JUNE 2006)**

Box jacking is jacking a large precast reinforced concrete box horizontally through the ground, usually beneath a road or railroad that must not be interrupted. The major advantage of the process is its essential simplicity. Only the exact prism of earth that will be filled by the jacked box is excavated. No intermediate ground supports are needed. The structure is built away from the roadway, in the clear, without the constraints of shoring and traffic controls.

22) What is meant by underpinning? **(A.U. NOV/DEC 2008, 2009)**

Underpinning is the process of strengthening the foundation of an existing building or other structure. Underpinning may be accomplished by extending the foundation in depth or in breadth so it either rests on a more supportive soil stratum or distributes its load across a greater area.

- ✓ The original foundation is simply not strong or stable enough.
- ✓ The usage of the structure has changed.
- ✓ The properties of the soil supporting the foundation may have changed (possibly through subsidence) or were mischaracterized during design.

23) Define the term sinking cofferdam. **(A.U. MAY/JUNE 2009)**

The sinking construction technology for bottomless double wall large steel cofferdam is introduced in the paper, which provides valuable experience for the sinking construction of similar projects in future.

24) Differentiate cofferdam from caisson. **(A.U. NOV/DEC 2009)**

COFFERDAM

(1) A cofferdam shall be designed by a qualified engineer and shall be constructed and maintained in accordance with the design.

(2) If overtopping of the cofferdam by high waters is possible, then means shall be provided for controlled flooding of the work area.

(3) Warning signals for the evacuation of employees in case of an emergency shall be developed and posted.

(4) A cofferdam shall have not less than 2 means of egress. Runways, bridges, or ramps shall be provided with guardrails.

CAISSON

(1) An employee who enters a caisson shall be protected by a steel or concrete casing designed by a qualified employee and approved by a registered engineer.

(2)A copy of the design specifications of the casing shall be maintained at the jobsite.

(3)In the case of belled-bottom caissons, the steel or concrete casing shall be provided for the full depth of that part of each caisson hole that is above the bell.

(4)An employee shall not be permitted to work below the casing in running or unstable soil.

25) What do you understand about diaphragm walls? **(A.U. NOV/DEC 2009)**

A slit is excavated in the soil using special clamshell-shaped diggers or slit-cutters. To stabilize the hollow space which is created, the soil which has been removed is exchanged with supporting slurry (diaphragm wall compound). The diaphragm wall is thereby incorporated into a natural layer of soil (clay, marl) with low water permeability, with the result that a trough which is non-permeable to water is created.

26) What is 'Slip form'? **(A.U. NOV/DEC 2009, APR/MAY 2010)**

Slip forming, continuous poured, continuously formed, or slip form construction is a construction method in which concrete is poured into a continuously moving form. Slip forming is used for tall structures (such as bridges, towers, buildings, and dams), as well as horizontal

structures, such as roadways. Slip forming enables continuous, non-interrupted, cast-in-place "flawless" (i.e. no joints) concrete structures which have superior performance characteristics to piecewise construction using discrete form elements. Slip forming relies on the quick-setting properties of concrete, and requires a balance between quick-setting capacity and workability.

27) What is a box caisson? Where do we use it? (A.U. APR/MAY 2010)

A floating steel or concrete box with an open top which will be filled and sunk at a foundation site in a river or seaway. Also known as American caisson; stranded caisson. A watertight chamber used in construction work under water or as a foundation

28) Name some equipment used for underground open excavation. (A.U. APR/MAY 2010)

- Backhoes
- Dozers
- Excavators
- Front End Loaders
- Frost Ripper
- Gravel Trucks
- Mini Excavator
- Road Grader
- Skid Loaders
- Street Sweeper

29) Mention the advantages of slip forms. (A.U. NOV/DEC 2010)

- ✓ Careful planning of construction process can achieve high production rates
- ✓ Slip form does not require the crane to move upwards, minimizing crane use.
- ✓ Since the formwork operates independently, formation of the core in advance of the rest of the structure takes it off the critical path – enhancing main structure stability.
- ✓ Availability of the different working platforms in the formwork system allows the exposed concrete at the bottom of the rising formwork to be finished, making it an integral part of the construction process.
- ✓ Certain formwork systems permit construction of tapered cores and towers.

- ✓ Slip form systems require a small but highly skilled workforce on site.

30) Give the names of any four types of piling techniques. **(A.U. NOV/DEC 2010)**

1. Timber piles
2. Precast concrete piles
3. Sheet piles
4. H piles
5. Group piles

31) How are steel trusses fabricated and grouped? **(A.U. APR/MAY 2011)**

All truss products are designed and fabricated in-house by our skilled team. Each truss is built to your exact specifications, using only the highest quality number and materials.

The manufacturing process is divided into several steps.

1. Step 1 – Design the truss
2. Step 2 – Picking the lumber
3. Step 3 – Cutting the lumber
4. Step 4 – Roof truss fabrication
5. Step 5 – Delivery

32) Define well foundation and caisson foundation. **(A.U. NOV/DEC 2012)**

Well foundation

- ✓ The basis or groundwork of anything the moral foundation of both society and religion
- ✓ The natural or prepared ground or base on which some structure rests
- ✓ The lowest division of a building, wall, or the like, usually of masonry and partly or wholly below the surface of the ground
- ✓ The act of founding, setting up, establishing, etc., a policy in effect since the foundation.
- ✓ The act of being founded.

Caisson foundation

- ✓ Caisson foundations are poured into the ground, unlike piles which are generally manufactured off-site and pounded into the ground.
- ✓ In many countries caissons are referred to as piles, and they are sometimes also called piers.
- ✓ A caisson is created by auguring the deep hole into the ground, then filling it with concrete. Steel reinforcement is often inserted for at least part of the caisson's length.

33) What are the two types of anchoring system for the cable in case of suspension bridge?

- Under-spanned suspension bridge
- Self-anchored suspension bridge

34) What are the common uses of diaphragm wall walls?

. To provide structural support for the construction

. To provide retaining wall

. To provide deep diaphragms

35) List out the advantages of tunnel boring machines

- There is very less danger of fall outs in machine bored tunnels, since adjacent or surrounding rocks are undistributed as no blasting is done.
- Mucking is also safe and convenient, since muck is conveyed from the face to the rear of the machine and is loaded automatically by means to the rear of the machine and is loaded automatically by means of belt conveyors.
- Higher speed of excavation.
- Reduction in the tunnel supports requirement.
- Less manpower requirement.

36) List out the types of well point systems

1. Pumping from open sumps
2. Pumping from well points

   Well point systems are installed in two ways:

   a)Line system

   b) Ring system

3. Pumping from bored wells

37) List out the types of piles.

- ✓ Driven piles
- ✓ Driven and cast-in place piles
- ✓ Bored piles
- ✓ Composite piles

38) What are problems normally developed during deep excavations?

- To prevent the collapsing of sides of the trenches
- To prevent water oozing or coming out from the sides and bottom

39) What are the remedial measures to avoid the problems deep excavation?

- Providing shoring for the trenches
- Dewatering of the trenches

40) Write the functions of sheet piles.

1. To enclose a site or part thereof to prevent the escape of loose subsoil, such as sand, and to safeguard against settlement.
2. To retain the sides of the trenches and general excavation.
3. To protect river banks.
4. To protect the foundations from scouring actions of nearby river, stream etc. To construct costal defense works

41) List out the types of cofferdam.

1. Cantilever sheet pile cofferdam
2. Braced cofferdam
3. Embankment protected cofferdam
4. Double wall cofferdam

42) What is line system? Explain with neat sketches.

This system is employed when excavation area is long. The header is laid out along the sides of the excavation, and the pumping is continuously in progress in one length as further points are jetted ahead of the pumped down section and pulled up from the completed and back filled lengths and repeated till entire length is completed. For narrow excavation, like trenches, header is laid only on one laid, while for wide excavations, the header are required to be placed on both sides of the area.

43) What is ring system? With neat sketches

When excavation is done in area of appreciable width, line system is inadequate. The ring system is used in such condition and the header main surrounds the excavations completely. This system is used for rectangular excavations such as for piers or basements.

44) Where is grout anchors used in constructions?

In most cases, however anchorages may be embedded below ground level, with backstays connecting them to adjacent towers, or they may constitute the end abutments of the end spans. In addition to stability sliding, the anchorage structure must also be checked for stability against tilting and overturning.

45) Where is method of Underpinning?

1. Pit Method
2. Pile Method
3. Miscellaneous Method

46) What is well cap?

It is a R.C.C slab laid at the top of well steining. It transfer the load to steinings is known as well cap.

UNIT-III

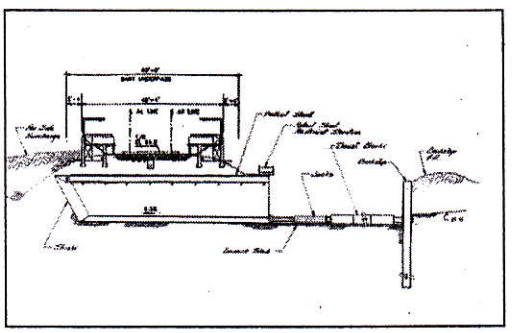
SUB STRUCTURE CONSTRUCTION

16 MARKS

1) Describe the box jacking method of construction of a bridge. In what circumstances this technique is adopted? (A.U. MAY/JUNE 2006, NOV/DEC 2009, 2012)

- ✓ Box Jacking is an innovative approach to provide for large conduits where Trenchless technologies are desired. They can be of any size but are most often found when the conduit size is larger than 10' diameter pipe. The process typically consists of first constructing a backstop that can be pushed against by the jacks.
- ✓ Next the launch slab is constructed which will form a good way for the box. The box is then cast on site using similar techniques to those used for reinforced concrete box culverts.
- ✓ Once the box is cured, jacking begins. This is a sequential process that includes pushing the box, excavating the face and hauling spoils, and extending the thrust members. This process is repeated until the box reaches its final position.
- ✓ The loads that are required to check the box are dependent on the ground type, the size of the box, the overburden, and the amount of build up allowed to accumulate in the face of the box. Boxes can be jacked through embankments that have a wide range of ground types.
- ✓ The most cost effective arrangement is to have the top of the jacked box well below the road surface. However, it is possible for the box to be only a few feet below the roa67d as was the case of a project we completed for Caltrans in 1998 where the box was 23' wide but only 4' beneath the freeway. In cases where the cover is minimal, the box can be jacked across the road or the tracks into final position during a brief outage.

- ✓ Box jacking is jacking a large precast reinforced concrete box horizontally through the ground, usually beneath a road or railroad that must not be interrupted. The major advantage of the process is its essential simplicity. Only the exact prism of earth that will be filled by the jacked box is excavated. No intermediate ground supports are needed.
- ✓ The structure is built away from the roadway, in the clear, without the constraints of shoring and traffic controls. When the structure is ready, a shield is fitted to the front, hydraulic jacks are installed behind, and the box is pushed into final position while simultaneously the earth is excavated from within.
- ✓ The actual jacking generally takes only a few days to a week. During that time, traffic is proceeding overhead normally, unaware of the construction below. The non-disruptive nature of the process together with its inherent safety, simplicity and economy make box jacking a useful tool for the practicing civil engineer.
- ✓ This intends to bring a greater familiarity with the box jacking process to the reader and then give some considerations and guidelines to assist engineers in designing a project that can be built using the box jacking method.



Applications

- ✓ Some examples of potential box jacking projects include storm drains, bike or pedestrian trails, livestock or wildlife under crossings, conveyors, pipe ways and other industrial uses, small bridges, and roadways up to 4 lanes wide.
- ✓ Basically, applications of box jacking depend only on the creativity of the civil engineer designing the project. Most box jacks Berkeley Engineering has been involved with have been of drainage. The paving incidental to increased urbanization causes larger instant runoffs and larger storm drains are then required. Where these larger channels must pass beneath highways, railroads or the like, tunneling will often be required. Up to 8' or 10' diameter, pipe jacking will often be utilized. But larger sizes are generally rectangular.

Placing these larger channels by box jacking will often be the most economical and least disruptive method.

- ✓ In principal, box jacking is very simple. During jacking, lubricant is pumped around the box to ease its passage through the ground. Upon reaching final location, grout is injected to displace the lubricant and permanently support the overlying ground.

- ✓ The box is best precast in one large block to the full length required. This is optimal, as rigidity and accuracy can be fairly guaranteed. Where space is limited the box can be cast in halves, thirds, or even more pieces. Although this reduces the total length of thrust column required, it introduces the requirement of employing great care in constructing subsequent box sections to make sure they are exactly aligned with the initial pieces.

- ✓ The box jacking process can be described in terms of its constituent subsystems, most critical and primary of which is dimensioning. The box must closely fill the hole being cut by the shield at the front, and obviously, not even slightly, overfill it. The mechanical subsystems are as follows:

- ✓ Jacking - backstop, thrust columns, hydraulic pumps, and jacks
- ✓ Excavation - shield, face control, digging equipment, transport.
- ✓ Ventilation - gas testing, fans and fan line.
- ✓ Lubrication - mixers, pumps, distribution piping
- ✓ Guidance - lasers, levels, steering provisos.

The essential subsystems can be outlined thus:

1. Site preparation — access, dewatering, etc.

2. Jacking pit

a) Shoring and reaction wall

b) Launch slab

3. RC Box and adaptation for jacking

a) Dimensional modifications and extra rebar.

b) Extra close external tolerances

c) Shield on front

d) Embeds for lubricating slurry distribution

e) Pressure cells and instrumentation

f) Grout holes

4. Jacking System

a) Jacks

b) Hydraulic pumps, plumbing, oil reservoir

c) Thrust columns to

5. Excavation System

a) Face excavation

b) Muck Transportation to Shaft

c) Removal from Shaft

6. Ventilation System

7. Guidance System

a) Steering Provisos

b) Lasers

8. Communication Systems

Box jacking is basically quite simple and straightforward. Such projects will always be easier and more economical if consideration is given in the design stage to the box jacking option. There are critical areas such as tolerance, face control, and effective lubrication which bear importantly on a successful outcome. Some owners have opted for prequalification of the jacking contractor. Another approach, gaining favor, is to put the job out as design-build. In any case, explicitly allowing box jacking as an option can return significant benefits to the public.

2) **Explain the methods of dewatering foundation excavations.** **(A.U. NOV/DEC 2007, 2009)**

In many of the civil engineering work such as stability of natural slopes and cuts, upstream and downstream slopes of dams and levees, excavation for structures, etc. the groundwater and seepage control needs a most significant consideration. The adopted control should be ensured during construction period and as well after construction.

The necessary controls required during construction are to (Hunt, 1986):

1. Provide a dry excavation and permit construction to proceed effectively.
2. Reduce lateral loads on sheeting and bracing in excavations.
3. Stabilize "quick" bottom conditions and prevent heaving and piping.
4. Improve supporting characteristics of foundation materials.

5. Increase stability of excavation slopes and side-hill fills.
6. Cutoff capillary rise and prevent piping and front heaving in pavements.
7. Reduce air pressure in tunneling operations.

METHODS OF GROUND WATER CONTROL

Ground water can be controlled depending on the geological conditions and characteristics of the soil. In such a site condition, ground water can be controlled by adopting one or more types of dewatering systems or drain appropriate to the size and depth of excavation. The type of method is chosen based on the conditions the site and the availability of resources; Bureau of Indian Standards, (BIS: 9759-1981) has recommended various types of drainage systems which may be considered most suitable based on the grain-size distribution of soils.

Following are some o the methods:

1. **Pumping**
   a. From open sumps and ditches.
   b. From well-points systems.
   c. From deep-well drainage.
   d. From vacuum dewatering.
2. **Electro-osmosis**
3. **Elimination or reduction of ground water by**
   a. Cement grouting
   b. Chemical consolidation
   c. Displacement grouting
   d. Freezing
4. **Other methods**

Open Sumps and Ditches

The essential feature of the method is a sump below the ground level of the excavation at one or more corners or sides.

In fairly permeable soils the head is low and flow does not emerge through the excavation slopes, in such cases pumping out ca be done by collecting the seepage in the sump.

Well-point Systems

Filter wells or well-points are small well screens of sizes 50 to 80 mm in meter and 0.3 to 1m length.

Well-points are made of brass or stainless steelm screens and of closed ends or self-jetting types. When well-points are required to remain in the ground for a long period disposable plastic well-points are used.

The advantages of well-point systems are as follows:

1. It prevents the bottom of excavation from heaving under excess hydrostatic pressure.
2. It prevents slope failure or sloughing.

Deep-Well Drainage

If the solid formation is such that it is previous with depth, large diameter deep-wells are suitable for lowering the ground water table.

An advantage of this system is that it can be installed outside the zone of construction operation and drainage is effected to the depth of excavation.

Vacuum De-watering System

Gravity methods explained so far are not very effective in fine-grained soils. Such soils can be stabilized y means of a vacuum well or well point system.

A vacuum dewatering system primarily consists of well or well-points with the screen and riser pipes.

De-watering by Electro-osmosis

This is also a method applicable for fine grained soils. This is not a general pumping method but collecting the water through some process to a well and pumping out.

Cement Grouting

Grouting is a process whereby stabilizers, either in the form of suspension or solution, are injected into surface soil or rock for control of ground water during construction and strengthening adjacent foundation soils to protect them against damage during excavation, pile driving, etc.,

Chemical Consolidation

This method is also called as solution grout. Solution grouting is done using "one-shot" or "two-shot" systems. In the one-shot system all required chemicals are injected together after mixing. In two-shot system where one chemical is injected followed by injection of second chemical.

Displacement Grouting

Displacement or compaction grouting is a specialized techiqye used for controlled densification of in-situ soils at depth. This is different from the conventional grouting.

Freezing grouting

Freezing of pore water in the soil is the most effective method of thermal stabilization. It has been popular recently.

This technique has some disadvantages which are as follows:

1. There is possibility of heave.
2. It takes long time to commence the project.

Other methods

Other methods which are commonly used for soil stabilization can also be adopted to some extent in the ground water control.

Vibration method and heavy tamping are the two methods.

Vibro compaction

It can be effectively used for rapid densification of saturated non-cohesive soils.

Vibrating probe

It is also known as Terra/probe which is a patented process used to densify loose sands.

Vibro-Displacement Compaction

In this vibration technique the soil particles are displaced and the vacant space is filled with soil if necessary. Three methods which are in use are explained below:

Compaction Piles:

Highly permeable and partially saturated soils can be densified by driving displacement piles at close spacings. Pipe piles with closed bottom can be effectively used.

Vibrofloatation:

It is a technique for densifying in-situ non-cohesive soils with simultaneous vibration and saturation. The equipment required for vibroflotation involves a vibrofloat probe accompanying power supply, water pump, crane, and front end loader.

3) **With the help of a neat sketch, explain the method of sinking a pneumatic caisson.**

(A.U. NOV/DEC 2008, 2009)

- ✓ Pile groups are connected by a pile cap. Group capacity is increased if the pile cap is fully embedded in soil. The pile group capacity increases by 5 to 15 % when the pile cap rests in contact with the soil. Pile caps are made of reinforced concrete. For detailed treatment on pile group reference may be made to Purushothama Raj, (2008).

- ✓ Sessions and well foundations are structural boxes or chambers. These are in place through the ground or water by excavating below the bottom of the unit which enables the caisson to reach the final depth. These structures have a large cross - sectional area and hence provides high bearing capacity, which is much larger than what may be offered by a cluster of piles.

- ✓ Pneumatic caissons have bottomed and top are closed with an open working chamber. Compressed air is used to stop the entry of water into the working chamber. The excavation and concreting are done in a dry condition. The caisson is sunk as the excavation is proceeding. After reaching the desired depth the working chamber is filled with concrete.

Construction Procedure of Caissons

- ✓ Heavy engineering equipments are needed for construction of caissons. Varied problems have to be overcome during the construction of caissons. Caissons may be constructed in slipways, or barrages or on sand islands. Sometimes, the caissons are floated to the required place with a false bottom. For the first phase of sinking guide piles are commonly used.

- ✓ Blasting of hard stratum, if any, during sinking may have to be removed by blasting. Cutting edges are provided at the bottom of open caissons (Fig. 6.12). This forms the lowermost portion of the shoe.

- ✓ This shoe has outer vertical steel skin plates and a battered inner steel haunch plate. Steel trusses are used in both directions for proper bracing.

- ✓ The provision of trusses is to prevent the distortion of the shoe during fabrication, during towing to site and during the early stages of sinking. After the initial sinking the space between the skin plates is filled with concrete which is called as staining. Keeping the rigid shoe as the base, the staining is extended by placing reinforced concrete between formwork.

- ✓ As the soil is excavated at the bottom the caisson sinks on its own weight. Additional lifts are successively installed while the sinking operation progresses. After reaching the desired depth, the bottom of the caisson is plugged by a concrete seal by depositing a layer of concrete under water in the bottom of wells.

- ✓ The wells are pumped out and more concrete is placed. Sand or concrete is filled inside the caisson depending on the condition followed by a top - concrete shell.

- ✓ Open caissons are preferred in soils which are soft such as clays or silts since excavation by grabbing will be easiest. Box caissons are made out of reinforced cement concrete. They are primarily constructed on land and after concrete attains sufficient strength they are floated to position. During floating care should be taken to avoid tipping or capsizing.

- ✓ Box caissons can be found on a rock formation, on a crushed rock blanket over rocky surface or on piles raft.

- ✓ In locations where there is a possibility of erosion box caissons are not preferred. It shows some methods of founding box caissons.

- ✓ 'Pneumatic caissons are preferred in locations where the soil flow in the excavated area is faster than it can be removed.

- ✓ It is also suitable in areas of varied soil conditions. Pneumatic caissons claim several advantages, over other types of caissons.

4) What do you understand by shoring? Describe in brief various types of shores. **(A.U. NOV/DEC 2008, APR/MAY 2010)**

- ✓ **Shoring** is a general term used in construction to describe the process of supporting a structure in order to prevent collapse so that construction can proceed. The phrase can also be used as a noun to refer to the materials used in the process. Buildings- It is used to support the beams and floors in a building while a column or wall is removed. In this situation vertical supports are used as a temporary replacement for the building columns or walls.

- ✓ Trenches - During excavation, shoring systems provide safety for workers in a trench and speed excavation. In this case, shoring should not be confused with shielding. Shoring is designed to prevent collapse where shielding is only designed to protect workers when collapses occur.

- ✓ Concrete structures shoring, in this case also referred to as piecework, provides temporary support until the concrete becomes hard and achieves the desired strength to support loads. Ships - It is used on board when damage has been caused to a vessel's integrity, and to hold leak-stopping devices in place to reduce or stop incoming water.

- ✓ Generally consists of timber 100 mm x 100 mm and used in conjunction with wedges, to further jam shoring in place, pad pieces to spread the load and dogs to secure it together. Also used on board is mechanical shoring as a quick, temporary solution, however it isn't favored due to its inability to move with the vessel.

Raking Shore

Raking Shores consists of one or more timbers sloping between the face of the structure to be supported and the ground. The most effective support is given if the raker meets the wall at an angle of 60 to 70 degrees. A wall-plate is typically used to increase the area of support.

Foundations

Shoring is commonly used when installing the foundation of a building. A shoring system such as piles and lagging or shortcut will support the surrounding loads until the underground levels of the building are constructed.

Hydraulic Shoring

Hydraulic shoring is the use of hydraulic pistons that can be pumped outward until they press up against the trench walls. They are typically combined with steel plate or plywood, either being 1-1/8" thick plywood, or special heavy Finland Form (FINFORM) 7/8" thick.

Beam and Plate

Beam and Plate steel I-beams are driven into the ground and steel plates slide in amongst them. A similar method that uses wood planks is called soldier boarding. Hydraulics tend to be faster and easier; the other methods tend to be used for longer term applications or larger excavations.

Soil Nailing

Soil nailing is a technique in which soil slopes, excavations or retaining walls is reinforced by the insertion of relatively slender elements - normally steel reinforcing bars. The bars are usually installed into a pre-drilled hole and then grouted into place or drilled and grouted simultaneously. They are usually installed untensioned at a slight downward inclination. A rigid or flexible facing (often sprayed concrete) or isolated soil nail heads may be used on the surface.

Continuous Flight Augering

Continuous Flight Augering (CFA) is a method used to create concrete piles to support soil so that excavation can take place nearby. A Continuous Flight Augering drill is used to excavate a hole and concrete is injected through a hollow shaft under pressure as the auger is extracted. This creates a continuous pile without ever leaving an open hole.

5) Explain the piling techniques in detail (or) What are all the pile driving techniques available in the field and explain any one techniques with neat sketches. (A.U. MAY/JUNE 2009 APR/MAY 2011, NOV/DEC 2012, MAY/JUNE 2013)

- ✓ Pile are slender structural members normally installed by driving by hammer or by any other suitable means. Piles are usually placed in groups to provide as foundations for structures. Piles may be classified according to their material composition, installation method, ground effect and their function as a foundation.
- ✓ Piles classification based on material composition are discussed below. For other classification of piles reference may be made to Purushothama Raj (2008).
- ✓ A foundation is said to be deep foundation when the superstructure load is transferred to deeper strata for some reason or the other. The design and construction of deep foundation for transferring the weight of the superstructure through soft or weak soil, to deep load bearing strata is a challenging job for civil engineers.
- ✓ Piles, drilled caissons, caissons and well foundations are the most common piles of deep foundations. For any system the mechanism of deriving support from the soil or rock below and adjacent to the foundation is similar. However, each system differs in its method of construction.
- ✓ A timber pile should have a uniform taper with sound quality and free from any defects and straight. Defects in timber are identified by signs of decay, splits, size of knots, holes, etc. The maximum length of a pile is about 20 m. As per Bureau of

Indian Standard piles have been classified as Class A or Class B depending on the use. Class A piles are those which are used for railway and highway bridges, trestles, docks and wharves.

- ✓ These piles are of butt diameter or the sides of square not less than 30 cm. Class B tiles are wedge action is required, tapered piles are used. The cross-section of these are usually of square or octagonal as these shapes are easy to cast in horizontal poition. Typical details of square and octagonal piles are shown in Fig. 6.1.

- ✓ The section and the quantity ofreniforcement are decided based on the handling stresses. These piles have to be lifted for transportation to some place and as well placing them on position for driving. The pick-up positions and the corresponding minimum moment in a pile are shown in Fig. 6.2. The pick-up points should be early painted so as to avoid unnecessary handling stresses. For piles of length up 7.5 m a single point of lifting is sufficient. Multiple point pj~lfi'ng may be necessary for long blogs.

- ✓ In order to withstand high impact stresses, additional closely spaced ties or materials should be provided near the tip and the butt. The diameter of the transverse reinforcement bars should not be less than 5 mm.

- ✓ The minimum cover is usually 4 mm but in sea environment or in aggressive soils it is about 5 to 7.5 mm. The concrete mix usually used for normal driving is 1:2:4. But for hard driving 1:1:2 mix in the butter and tip regions and 1 : 1% : 3 for the rest of the pile portion is used.

- ✓ Ordinary Portland cement or sulfate resisting cement does not show deterioration of strength with time when exposed to tropical conditions. In order to reduce total time and to gain early strength high alumina cement is used. It is reported that such piles have been found to have less strength when exposed to tropical conditions.

- ✓ Invariably in precast piles the exact pile length can not be assessed. Thus the piles require splicing or cutting off after they are driven to the required level.

- ✓ For Splicing the concrete is broken at the top of the pile and reinforcements are exposed for a length of 40 times the diameter of the rods. An additional reinforcement cage for the extended length welds at the joints or lapped for the full length of 40 d.

- ✓ The spliced portion is then concreted and allowed to mature. For reducing the length, the excess portion is cut - off by chiseling the concrete and exposing the

reinforcing. The reinforcements are then cut with a hacksaw or burnt with torch.

- ✓ Concrete piles are permanent in nature in normal environment. But when exposed to sea environment or in salt water condition and in cold weather condition the life of the concrete tiles is reduced.

Pre-stressed Concrete Piles

- ✓ Pre-stressed concrete piles are provided with longitudinal reinforcements of high tensile strength so as to resist handling and lifting stresses. In order to withstand driving stresses link reinforcements of mild steel are provided.
- ✓ A rich concrete is used to provide high resistance to driving and to withstand aggressive action of ground water or sea 'water.
- ✓ Pre - stressing is done by pre - tensioning for ordinary square or hexagonal sections up to 40 am wide. For large diameter sections post - tensioning is adopted.
- ✓ Pre-stressed concrete piles are constructed, handled and driven like ordinary precast piles.
- ✓ As the pre-stressed concrete piles have reinforcement in the order of 0.5 to 1 percent of the cross - sectional area, splicing pose some difficulties.
- ✓ Hollow pre-stressed concrete piles generally have a width greater than 50 cm.
- ✓ They are driven to the required depth and the hole is filled with concrete.

6) What is a cofferdam? With the help of sketches explain various types of cofferdams. **(A.U. APR/MAY 2010, 2011, MAY/JUNE 2012, 2013)**

- ✓ A **cofferdam** also called a **coffer** is a temporary enclosure built within, or in pairs across, a body of water and constructed to allow the enclosed area to be pumped out, creating a dry work environment for the major work to proceed.
- ✓ Enclosed coffers are commonly used for construction and repair of oil platforms, bridge piers and other support structures built within or over water.
- ✓ These cofferdams are usually welded steel structures, with components consisting of sheet piles, wales, and cross braces. Such structures are typically dismantled after the ultimate work is completed.

- ✓ For dam construction, two cofferdams are usually built, one upstream and one downstream of the proposed dam, after an alternative diversion tunnel or channel has been provided for the river flow to bypass the dam foundation area.
- ✓ These cofferdams are typically a conventional embankment dam of both earth- and rock-fill, but concrete or some sheet piling also may be used.
- ✓ Typically, upon completion of the dam and associated structures, the downstream coffer is removed and the upstream coffer is flooded as the diversion is closed and the reservoir begins to fill.
- ✓ Dependent upon the geography of a dam site, in some applications, a "U"-shaped cofferdam is used in the construction of one half of a dam.
- ✓ When complete, the cofferdam is removed and a similar one is created on the opposite side of the river for the construction of the dam's other half.
- ✓ The cofferdam is also used on occasion in the shipbuilding and ship repair industry, when it is not practical to put a ship in dry dock for repair or alteration.
- ✓ An example of such an application is certain ship lengthening operations. In some cases a ship is actually cut in two while still in the water, and a new section of the ship is floating in to lengthen the ship. Torch cutting of the hull is done inside a cofferdam attached directly to the hull of the ship, and is then detached before the hull sections are floated apart.
- ✓ The cofferdam is later replaced while the hull sections are welded together again. As expensive as this may be to accomplish, use of a drydock may be even more expensive. See also caisson.
- ✓ A 100 ton open caisson that was lowered more than a mile to the sea floor in attempts to stop the flow of oil in the Deepwater Horizon oil spill has been called a cofferdam.
- ✓ It did not work as methane hydrates froze in the upper levels preventing the containment.
- ✓ A cofferdam is a type of watertight construction designed to facilitate construction projects in areas that are normally submerged, such as bridges and piers. One is installed in the work area and water is pumped out to expose the bed of the body of water so that workers can construct structural supports, enact repairs, or perform other types of work in a dry environment.
- ✓ In some regions of the world, this construction is better known as a caisson. Working inside a cofferdam can be hazardous if it is installed improperly or not safely pressurized, but advances in engineering have led to increased safety for workers using this unique work environment.

- ✓ A variety of materials can be used to construct a cofferdam, which is truly a feat of engineering.
- ✓ Although it is a temporary structure, it must reliably hold water back from the work area and also withstand very high pressures in order to be safe, and the construction is often used as a project for engineers learning their craft.
- ✓ The most basic type uses sheet metal, which is pounded into the bed of the body of water to create a watertight wall. Next, pumps are used to pull water out of the enclosure so that it will be dry.
- ✓ Some are built from wood or concrete, while others use a double walled mechanism, with filler made from aggregate materials in between the two walls.

7) **Describe the procedure involved in Tunneling Techniques. (A.U. NOV/DEC 2010, 2012)**

The choice of a particular method of tunneling depends on the type of ground. The type of ground met with generally are (vazrani and Chandola, 1989):

1. Firm ground
2. Soft ground
3. Running ground
4. Rock

Tunnelling in Firm Ground:

In firm ground sufficient period is available for installing conventional support. Further the method to be adopted depends on the shape, size and available equipments.

Full Face Method

This method is suitable in comparatively firm soil where the excavated portion can hold itself for sufficient time till to permit mucking and supporting operations to be completed. Here the proposed cross-section of the tunnel is excavated in comfortable sections. The excavation to be done is divided into three or more sections. First the top section I is cut and removed. This is followed by cutting sections II and III in turn. This methods is recommended for tunnels of small size.

Top Heading and Benching Method:

- ➢ This method is adopted when the excavated portion cannot hold itself till mucking and supporting operations are carried out. So the heading is excavated first and supported to the full length or part length of the tunnel before benching is started.

- The heading is always awhead of benching by a covenient length. This may be formed by excavating full width of the tunnel above the springing line. The principle of the method is shown in fig.
- In the case of large size tunnels a pilot tunnel or drift is made in the side or at the centre of the tunnel. Drill holes are driven from the drift towards the periphery and drift widened. The drift provides suitable arrangement for supporting the excavation.
- The drift location depends on the type of tunnel accordingly the methods are classified as wall plate drift, side drift and multiple drift.

Tunnelling in Soft Ground

- Instantaneous support is needed in case of soft soil before drilling and blasting. In such cases the traditional method adopted is Fore poling method.
- This method consists of driving boards ahead to support the ground ahead of rib which are known as spiles.
- The forepoles act as cantilevers beyond blasting and carry the weight of the ground.
- They carry till the forward ends are supported by the steel rib.
- The spils are installed as far around the pheriphery as necessary. After removing the breast boards and the new rib is erected in postion and then the soil is excavated. Afterwards breast boards are fixed and the operation is repeated.

Tunnelling in Running Ground

In this type of ground special treatment has to be resorted to before starting the excavation. Following methods are adpted:

Tunnelling with Liner Plates

On medium stiff ground this method is employed for driving steel lined small section drifts or headings. The first liner plate is kept at the crown in a pre-excavated cavity. Two adjacent liner plates are bolted to it on either side after widening the hole. These plates are supported by trench hacks or by props carefully tightened. Then the arch section is widened gradually down to the spinning line. This arrangements in combination with stiffner rings it is suitable for use in very large tunnels.

Needle Beam Method

In this method full section of the tunnel is broken out. At the time of excavation plates are placed one by one. These plates are supported by radially set trench jacks from a centrally placed longitudinal girder called needle beam. The needle beam is kept at the bottom of the top heading. After placing of the beam the trench jacks are removed. Concreting is done at top and bottom.

Tunnelling in Rock

Tunnels in rock are driven by repeating the following sequence of operations:

1. Drilling hole on the rock face
2. Loading the holes with explosives
3. Blasting
4. Removing the debris
5. Disposing off the broken rock.

In each sequence full cross-section of the tunnel may be excavated/ instead one or more drifts may be excavated in advance. The following methods are adopted.

Full Face Method

The full face method explained for tunnels in firm ground jmay be adopted in rocks also.

Top Heading and Benching Method

This method explained in previous section for tunnels in firm ground may be adopted in rocks also.

Drift Method

As explained earlier this method can be adopted in rocks also. Here prior to excavating the full bore is driven as a small tunnel. Depending on the location of the drift the method is known as central drift, bottom drift, top drift or side drift.

8) Describe the procedure involved in underwater construction in diaphragm walls and basement. **(A.U. MAY/JUNE 2012)**

✓ A slit is excavated in the soil using special clamshell-shaped diggers or slit-cutters. To stabilize the hollow space which is created, the soil which has been removed is exchanged with supporting slurry (diaphragm wall compound).

- ✓ The diaphragm wall is thereby incorporated into a natural layer of soil (clay, marl) with low water permeability, with the result that a trough which is non-permeable to water is created. The barrier formed to thereby provide a watertight enclosure around landfill sites, for example, in order to protect the groundwater from contamination. In addition, diaphragm walls are manufactured for securing excavations and renovating dykes.

- ✓ A distinction is made between two techniques for creating diaphragm walls:

  • **Two-phase procedure:** for this procedure, the panels of the diaphragm wall are first formed under the protection of a supporting fluid, generally a bentonite suspension; these are then exchanged in a second phase using the diaphragm wall building material, under a contract or procedure.

  • **Single-phase procedure:** in this procedure the diaphragm wall panels are formed protected by a self-hardening suspension. In addition to bentonite, the suspensions used as building materials in such cases already contain a binding agent, which slowly hardens after the excavation work and produces a solid structure.

  The **thin diaphragm wall** is a special form of diaphragm wall. For this, no soil is excavated; instead, initially a steel sheet panel is rammed into the soil. The hollow cavity created by extracting this panel is filled under pressure with a special building material. The overlapping sequencing of these elements creates a sealing barrier in the subsoil (thin diaphragm wall), as is often used in damming for flood protection.

- ✓ Diaphragm walls can be used in most ground conditions to construct underground stations in city centers, multi-level underground car parks, road junctions and underpasses, and open cut and cut & cover rail tunnels – as well as deep shafts for tunnel ventilation, intervention shafts and water treatment plants.

- ✓ Diaphragm walls are often located in confined inner- city areas where space is at a premium. Diaphragm walls are typically constructed in reinforced concrete to provide the required structural capacity, but they may also be designed as unreinforced plastic cut offs (or slurry walls) to stop water flow through porous strata. Diaphragm walls are typically 20m to 50m deep, but may extend to considerably greater depth.

  Advantages

  • Box outs can be incorporated in diaphragm walls to facilitate easy connections for slabs, stairs, etc.

  • Water bar can be incorporated

- Less joints required than a piled wall
- Top-down basement construction gives significant advantages in programmed.

✓ Diaphragm walling refers to the in-situ construction of vertical walls by means of deep trench excavations. Stability of the excavation is maintained by the use of a drilling fluid, usually a bentonite suspension.

✓ The walls are constructed in discrete panel lengths ranging typically between 2.5m and 7.0m using purpose built grabs or, in appropriate circumstances, milling machines (hydromills).

✓ Excavation is typically carried out using either rope-suspended mechanical or hydraulically operated grabs. Standard grabs range in weight from 8-20 tonnes. The grabs are mounted on 80- 120 tonne hydraulic base crane units providing stability and suitable line pull.

✓ Specific applications and ground conditions demand the use of hydromills – hydraulically operated reverse circulation trench cutters where the excavation technique is by 'cutting' as opposed to 'digging'.

✓ This technique is appropriate for deeper diaphragm walls and walls located in granular materials and soft rock.

✓ Where panels are constructed in a line, abutting one another to form a retaining wall, the term diaphragm walling applies.

✓ Purpose made stop ends are used to form the joints between adjacent panels and a water bar can be incorporated across these joints. Where additional bending moment capacity or wall stiffness is required more complicated arrangements can be constructed, e.g. 'L' shaped or 'T' shaped panels.

✓ Standard widths of diaphragm walling equipment are 600, 800, 1000, 1200 and 1500mm although greater can be provided.

✓ Depths are typically constructed up to 50m using grabs and up to 80m using standard hydromills.

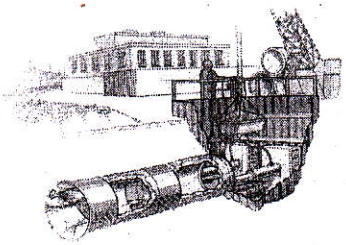
✓ One significant advantage of using diaphragm walling is the facility to incorporate floor slab connections and recessed formwork into the walls.

9) **Explain with neat sketch techniques for pipe jacking and tunneling.** **(A.U. NOV/DEC 2012)**

- ✓ In 1995, a 31m long tunnel between two shafts was constructed in the marine sand at Kwun Tong site by pipe jacking. During the construction of this tunnel several ground difficulties were encountered.
- ✓ Since the greater part of the work of laying a sewer takes place underground and as the space required at ground level is small, life and commerce can go on virtually undisturbed. Pipe-jacking results in significantly lower lost sales for merchants than the open-trench method of pipe laying, which impairs or prevents access to their businesses. Noise, dirt and smell are minimized. The jacking doesn't depend on weather conditions.

Jacking pipes offer significant advantages for trenchless applications with its features and benefits:

□ **Long service life**

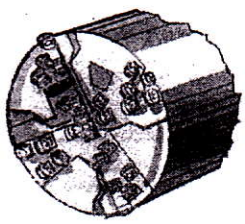
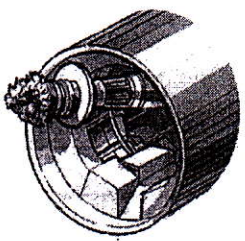
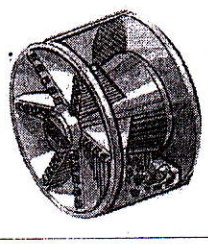
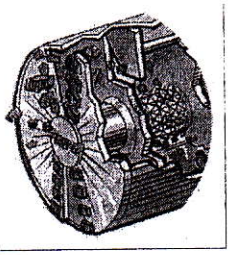


- 50 years minimum
- 100 year design capability

□ **Versatile manufacturing processes:**

- Lengths can be varied to suit application

□ **Light weight materials:**

- Lower transport costs
- Significant installation & handling savings

□ **Superior jacking capabilities:**

- High compression strength
- Lowest jacking force required for any drive length
- Smooth non-absorbing external surface

□ **Flush Coupling:**

- Provides a smooth flush external surface for minimal interference during installation

□ **Superior hydraulic performance:**

- Smooth internal bore means less friction loss

- Large bore for higher flow rates

- Large bore for higher flow rates