Road Construction and Maintenance - Level-III

Based on September 2023, Curriculum Version II

Module Tittle: Pile Construction Operations

Module code: EIS RCM3 013 0923

Nominal duration: 60 Hour

Prepared by: Ministry of Labor and Skill

September, 2023

Addis Ababa, Ethiopia

Contents

Acknowledgement

The **Ministry of Labor and skill, HELVETAS, and B2P Ethiopia wish** to thank MoLS experts, **HELVETAS** Leaders & experts, regional labor and skill bureaus, TVT trainers, university lecturers and industry experts who contribute their time and professional experience to the development of this **Training module** for Road construction and maintenance .

We would like to express our appreciation to the **Ministry of Labor and skill, HELVETAS and, B2P Ethiopia for** their technical and financial support and workshop facilitation of this training module development.

Acronyms

ASTM	American Standard for Testing Material
EBCS	Ethiopian Building Code Standard
ERA	Ethiopian Road Authority (Currently: Ethiopian Road Administration)
LAP	Learning Activity Performance Test
LG	Learning Guide
M	Module
OS	Occupational Standard
OSH	Occupational Safety and Health
PPE	Personal Protective Equipment
RCM	Road Construction and Maintenance
TTLM	Teaching, Training and Learning Materials

Introduction to the module

This Module covers the boring of cast in-situ piles and driving of piles in the civil construction industry. It includes planning and preparing, locating pile positions, placing concrete and establishing piling rig plants, driving piles, removing piling rigs, and cleaning up.

Module units

- Pile construction planning
- Pile positions
- Boring and piling rig
- Piling rig plant establishment
- Drive pile and clean-up work place

Learning objectives of the module

At the end of this session, the students will able to:

- Introduce Pile construction plan
- Locate and preparing pile positions.
- Remove boring and piling rig
- Locate pile positions and establishing piling rig plant
- Identify drive pile and cleaning up work place

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below.
3. Read the information written in the information Sheets
4. Accomplish the Self-checks

Unit One: Pile Construction Planning

This learning unit is developed to provide the trainees the necessary information regarding the following content coverage and topics:

- Relevance document
- Safety requirements.
- Traffic signage.
- Plant, tools and equipment.
- Environmental protection

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Interpret relevance document
- Obtain Safety requirements.
- Identify, obtain and implement traffic signage.
- Select plant, tools and equipment.
- Identify environmental protection

1.1. Relevant documents

Compliance documents used to provide evidences and successfully implement their compliance program to agencies to show that adhering to the required laws and regulation

Relevant documentation is information including records, reports, observations and verbal responses required to verify compliance with standards by a facility or program. The purpose of documentation is to outline the process for work health and safety (WHS) document control and record management at the related legislative system requirement for the success of work safety management system allowing for consistency and uniformity applying health and safety in the work place boring of cast in-situ piles and to the driving of piles in both boring of cast in-situ piles and to the driving of piles. Typical documents also include plans, polices, procedures, guidelines and forms that define the system.

All documentation that is used or introduced to the safety and well-being website forms part of the work safety management system.

Document creation: - the requirement or need for new or additional documentation to be introduce to the safety and management system. The requirement and system should be based on:

- **Legislation** : Ethiopian Roads Authority (ERA)
- Work cover code of conduct and performance standards for self-insures.
- Organization and site requirements and procedures
- Manufacturer's guidelines specifications and standards
- Acts and regulations dealing with worksite safety and health
- Worksite inspection
- OHS explosives employment and workplace relations legislation
- Equal employment opportunity and disability discrimination legislation

Any controlled system documentation requires regular review process includes consideration of the following:

- Suitability and relevance to the work place
- Identify areas requiring improvement
- Effectiveness in achieving desired outcomes

- Corrective action is required

Document format: - the following standard format is applicable to all WHS procedures**:**

- Title
- Purpose
- Definition
- Roles and responsibility
- Procedural content
- Performance measures
- Reference

1.2. Safety requirements

Safety is always a consideration when working with hot materials. Occupational safety and health (OHS) requirements in accordance with state or territory legislation and regulations, organizational safety policies and procedures, and project safety plan, including protective clothing and equipment, use of tools and equipment, workplace environment and safety, handling of materials, use of firefighting equipment, use of first aid equipment, hazard control and hazardous materials and substances.

i. Protective clothing and equipment

Overall Cloth: Protects the normal clothes from dust, grease and other spilling materials. To stay safe, workers may have to wear PPE such as safety helmets, gloves, eye or hearing protection, high-visibility clothing, safety footwear and harnesses. It reduce the risk of injury from breathing in dust, mist, gas or fume, falling materials hitting people flying particles.

Some protective clothing equipment is:

- **Goggle:** Protects eyes of the workers during welding of metal works and when placing reinforcement in the form work wear eye protection.
- **Hard Hat:** Protects head of the worker from any falling objects dropping from high level during construction. Wear brimless plastic hard hats
- **Mask:** Protects eyes of the worker from other endangering object and dust during construction.
- **Glove**: Protects the workers from oils, chemicals, and dust and other dangerous material that affect the skin.

- **Safety Shoe (Boot):** Protects the worker form nail, sharp objects and heavy falling objects by hard-rolled leather shoes with metal toe caps.
- **Safety Belt**: Secures laborers working in a plane where the construction is done at high level.

ii. Use of tools and equipment,

- Always wear eye protection.
- Wear the right safety equipment for the job.
- Use tools that are the right size & right type for your job.
- Follow the correct procedure for using every tool.
- Keep your cutting tools sharp and in good condition.
- Don't work with oily or greasy hands.

iii. workplace environment and safety,

A safe workplace is one where employees feel secure and enjoy a safe space, company values, and a positive co-working environment that encourages respect for everyone.

iv. handling of materials,

make sure the load is safely held while stakes are remove When unloading shells and other pile material from a truck, use of firefighting equipment,

v. Use of first aid equipment

All workplaces, leisure centers, homes and cars should have first aid kits. The kits for workplaces or public places must conform to legal requirements and be clearly marked in a green box with a white cross and easily accessible. Any first aid kit must be kept in a dry place, and checked and replenished regularly. All first aid kits should contain essential equipment to protect yourself and client from harm in an emergency.

vi. Hazard control and hazardous materials and substances :

Preventing hazards associated with moving machinery, dangerous materials like:

- Contaminated risings or groundwater and contact with hazardous materials or dusts.
- Noise, vibration
- Contact with plant or machinery during lifting, slewing and pitching of piling

elements, the movement of piling rigs etc.

- Plant instability caused by gradients, variable ground conditions, and/or inadequate bearing capacity
- Hazards of buried or overhead services
- Collapse of excavations, nearby structures etc.

vii. Safe parking practices

These are the general safety rules for **parking on** site:

- Access ways are clear,
- equipment/machinery is away from overhangs and refueling sites,
- Safe distance are kept from excavations, and
- Areas secured from unauthorized access or movement

viii. Safe operating procedures

Safety rules to adhere to include**:**

- Lift piles with proper slings or other equipment, with workers properly trained in their use.
- Pick up piles from the side opposite of other operations.
- Clear workers when piles are hoisted into the leads.
- A hand rope shall be tied to a pile that is being hoisted to guide and control its movement. When a pile is guided into position, workers shall not put their hands or arms between the pile and the inside guide, but shall use a rope for guiding.

Recognizing and preventing hazards associated with uneven/unstable terrains are:

- Wear footwear suitable for the conditions.
- Plan route carefully to avoid most uneven ground.
- Ensure you can see where you are putting your feet before walking.
- Avoid working in poor light conditions.

Preventing hazards associated with trees, pits, poles, trip hazards

- Provide personal protective equipment (PPE)

- Identify and avoid hazards before starting the job.
- Stay clear of power lines.
- Use proper fall protection and climbing techniques.
- Stand clear of drop zones.
- Plan a retreat path when felling a tree.
- Evaluate the strength of the tree.
- Clear walkways, stairs, and lobbies of anything that might be a tripping hazard, such as cords, wires, empty boxes, and clutter

Driving Safety Checklist: Before Beginning

Before beginning everyone understands the objective and a plan is in place in case of emergency.

- Check that a first-aid kit is onsite and fully stocked.
- Make sure that at least one employee is trained in first-aid in case of emergency.
- Research and provide clear, written directions to the nearest hospital in case of emergency.
- Provide the phone numbers of people who should be contacted if an accident occurs.
- Meet with employees to explain the safety rules. Print out a copy of the rules for the employees to take home and review.
- Have the superintendent review the project's safety information, operating plan and OSHA recordkeeping requirements.

Pile Driving Safety Checklist: Site Conditions

Site conditions play a large role in the overall safety of a pile driving working environment.

- Keep work areas free of loose materials or debris.
- Walkways that are more than four feet off the ground or in a hazardous location should feature a secure handrail with a toe board.
- Drain any muddy area onsite (when possible) and provide plank runways across trenches if necessary.
- Sand slippery walkways.
- Salt walkways in freezing weather.
- If night work is to occur, construction areas should be properly lit.

1.3. Signage Requirements

Signage requirements from the project traffic management plan in to project are:

i. **Escort vehicle signage**: a warning device to forewarn the public of a potential danger.

ii. **Temporary signage for the benefit of motorists and pedestrians**: provides advance notice of pedestrian activity

iii. **Highway traffic signs**: are signs erected at the side of or above roads to give instructions or provide information to road users. The earliest signs were simple wooden or stone milestones.

Figure 1-1 Highway traffic signs

iv. **Site Safety signage**: warn employees and visitors of the potential hazards associated with demolition.

Figure 1-2 Site safety notice

v. **Barricades:** an improvised barrier erected across a street or other thoroughfare to prevent or delay the movement of opposing forces.

Figure 1-3 Barricades

vi. **Traffic conditions signage**: are used to identify warnings and provide information to ensure others are safe from serious accidents.

Figure 1-4 Traffic conditions signage

Traffic Symbol Signs or Road Symbols to facilitate road traffic and to increase road safety through the adoption of uniform traffic rules: it include

- Congested urban environments
- Low traffic rural areas
- Off-road un-trafficked areas
- Buildings
- Parking sites
- Pedestrian areas

1.4. Plant, tools and equipment

Piling is the process of driving or boring pile foundations into the ground beneath a building that is under construction. These piles transfer loads from the structure to the ground, helping to support it. Pile foundations are often used where the ground is too weak to underpin the structure.

Piling equipment and methods are used in construction to create deep foundations that can support heavy loads.

Some common types of piling equipment include

- Bore piling machine
- Pile drivers, and
- Piling air, hydraulic hammers.
- crane mounted vibrators
- concrete pile breakers
- Piling rigs(both Drilling rigs, Rotary piling rig)
- Piling winches
- Hanging leader
- Hammer guides
- Helmet, driving cap, dolly, and packing
- Augers, shovels and crow bars
- Measuring tapes
- Spirit levels
- Plumb bobs
- Compressors
- Concrete vibrators
- High pressure hoses
- Scaffolding
- Pile hammers (static weight, diesel injection and hydraulic)

Use of equipment:

- **Leveling Equipment**: is used in the construction field to set up level points and to check elevations. It is an optical instrument used mainly in surveying and building but is also useful for transferring, setting, or measuring horizontal levels.

Figure 1-5 Leveling equipment

- **Shovels**: Shovel is a tool used to dig as well as to move loose, granular materials (like dirt, gravel, grain, or snow) from one spot to another. Spade is a tool used for digging straight-edged holes or trenches, slicing and lifting sod, and edging flower beds or lawns.

Figure 1-6 Shovels

- **Lifting Equipment**: is any work equipment for lifting and lowering loads, and includes any accessories used in doing so (such as attachments to support, fix or anchor the equipment).

Figure 1-7 Lifting equipment

- **Crow Bars:** A crowbar, also known as a pry bar, wrecking bar, gorilla bar or pinch bar, is a metal bar tool with flatted points at each end, often with a small fissure. The function of this fissure is to help remove nails or prise two materials or objects apart

Figure 1-8 Crow bar

- **Hammers**: is a tool, most often a hand tool, consisting of a weighted "head" fixed to a long handle that is swung to deliver an impact to a small area of an object.

Figure 1-9 Hammers

- **Scaffolding,** also called scaffold or staging, is a temporary structure used to support a work crew and materials to aid in the construction, maintenance and repair of buildings, bridges and all other man-made structures.

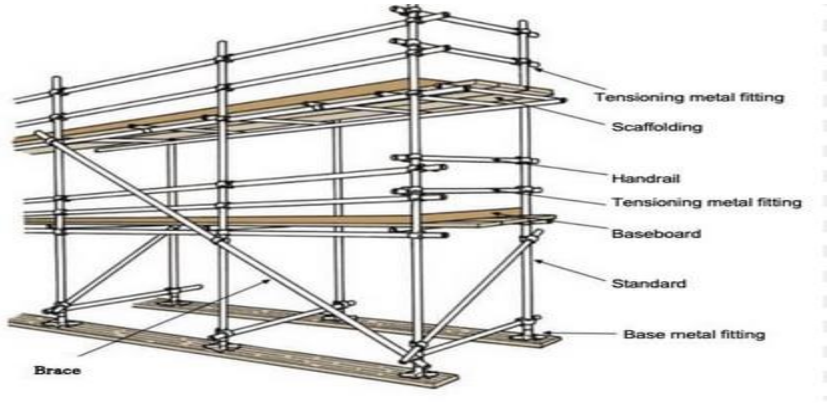

Figure 1-10 Scaffolding

- Au**gers**: Auger cast piles are often referred to by a number of different names, including augers, auger cast-in-place piles, augered piles, continuous flight auger piles and more. Augers are constructed by drilling a continuous flight, hollow shaft auger into the ground to a specified depth that suits your individual project needs. Then, a high-strength grout is injected into the hollow shaft when the auger is removed. Auger cast piles offer benefits for deep foundations, including limited cost, installation time, vibration and noise. Augers work well in sandy, silty soils with low cohesiveness and are designed for sands and clays. They're regularly utilized for car parks and office buildings, being a worthwhile alternative to driven piles.

Figure1-11 Augers

- **A Spirit Level**: is a tool used to indicate how parallel (level) or perpendicular (plumb) a surface is relative to the earth. A spirit level gets its name from the mineral spirit solution inside the levels.

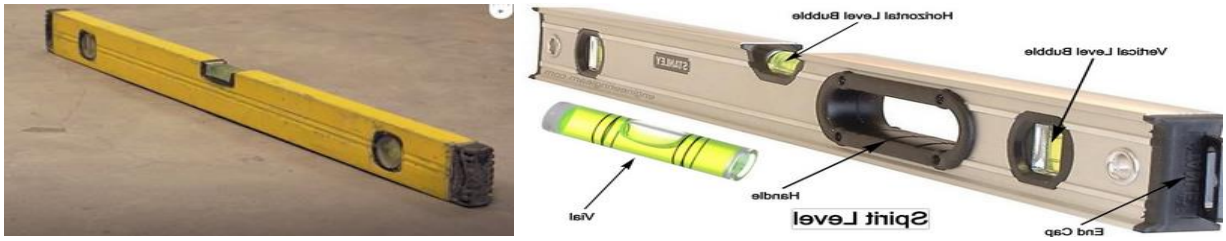

Figure 1-12 Levels

- **A plumbs bob:** is a pointed weight attached to the end of the string and is **used to find a vertical reference line called plumb**. Plumb is the vertical equivalent to a spirit level. Plumb bob has been around for thousands of years, dating back to Ancient Egypt.

Figure 1-13 Plumbs bob

- **A compressor** is a machine or tool used to **reduce the volume of gas or air and increase pressure**. Compressors are used in various applications, such as in industry, agriculture, and household appliances
- **A concrete vibrator**: is a concrete tool that produces stronger concrete by vigorously shaking the concrete right after you pour it to eliminate the air bubbles or air pockets.

Figure 1-14 concrete vibrators:

- **Hydraulic impact pile hammers:** are modernized versions of the diesel impact hammer which use hydraulic power packs as its fuel source. Hydraulic hammers are capable of driving not only steel piles like pipe, sheets, or beams, but also timber and precast concrete piles. The driving systems used to rise and lower hammers consist of four components: the lead, the hammer cushion, the helmet, and the pile cushion. Each component of the drive system can impact both the performance of the hammer as well as how it transfers its energy to a pile.

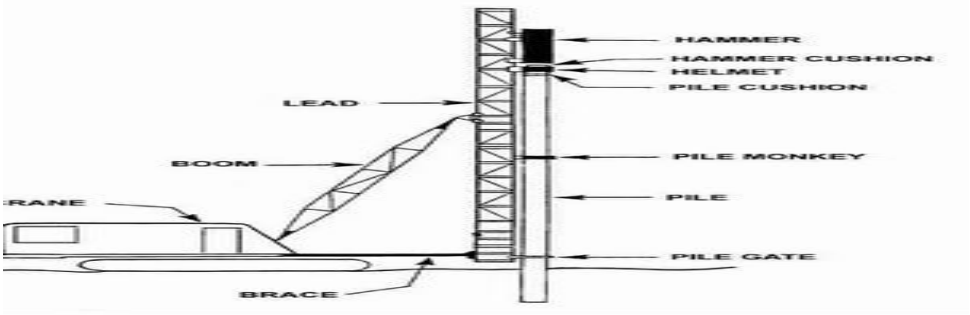

Figure 1-15 Hydraulic impact pile hammers drive

- **Bore piling machine**: used to boring

Figure 1-16 Bore pile

- **Piling rig**: used to drive piles into the soil to provide foundation support for buildings, bridges and other structures

Figure 1-17 Piling rig

- **A pile driver**: is a heavy-duty tool used to drive piles into soil to build piers, bridges

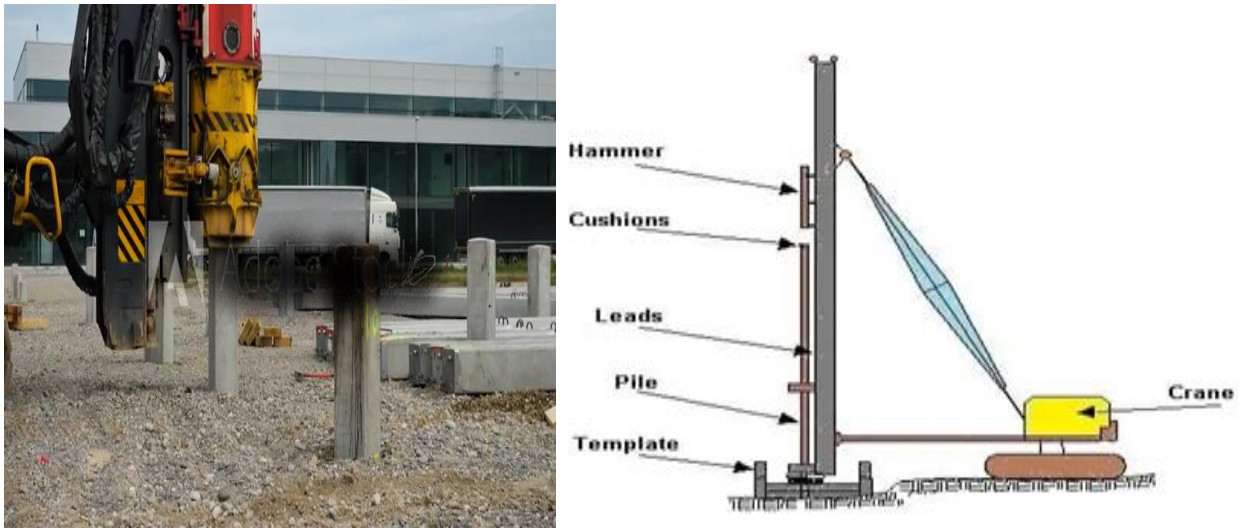

Figure 1-18 Pile driving equipment

1.5. Environmental Protection Requirements

A project's environmental management plan (EMP) consists of the set of mitigation, monitoring, and institutional measures to be taken during implementation and operation to eliminate adverse environmental and social impacts, offset them, or reduce them to acceptable levels.

i. **Waste management**: A waste management system or waste disposal is a streamlined process that organizations use to dispose of, reduce, reuse, and prevent waste. It is also an approach where companies implement comprehensive strategies to efficiently manage wastes from their origin until their final disposal. Includes the processes and actions required to manage waste from its inception to its final disposal. This includes the collection, transport, treatment, and disposal of waste, together with monitoring and regulation of the waste management process and waste-related laws, technologies, and economic mechanisms.

ii. **Water quality protection**: Water quality describes the condition of the water, including chemical, physical, and biological characteristics, usually with respect to its suitability for a particular purpose such as drinking or swimming. These include temperature, acidity (pH), dissolved solids (specific conductance), particulate matter (turbidity), dissolved oxygen, hardness and suspended sediment.

iii. **Noise:** is the propagation of noise or sound with ranging impacts on the activity of human or animal life, most of which are harmful to a degree. The source of outdoor noise worldwide is mainly caused by machines, transport and propagation systems. Protectors to the noisy tasks and jobs in a working day are suitable for the working

iv. **Vibration**: periodic back-and-forth motion of the particles of an elastic body or medium, commonly resulting when almost any physical system is displaced from its equilibrium condition and allowed to respond to the forces that tend to restore equilibrium or a mechanical phenomenon whereby oscillations occur about an equilibrium point. The oscillations may be periodic, such as the motion of a pendulum, or random, such as the movement of a tire on a gravel road.

v. **Dust and clean-up management**: is important to understand how construction activities can generate dust, as it risks harming people and the environment.it is the system implemented to reduce or eliminate dust emissions from the activities that generate airborne and fugitive dust and cause erosion. The amount of dust generated depends on several factors, including the nature of the surface, to what degree the surface is disturbed and climactic conditions.

Self-Check 1

Part I: True or False question

I. Instruction: Say true if the statement is correct and false if the statement is incorrect.

1. The function of a plumb bob in construction is to find a vertical reference line.
2. Piling rig used to drive piles into the soil to provide foundation support for buildings, bridges and other structures
3. Construction of piles doesn't have adverse impacts on environment

II. Choose the best answer

1. What is the function of a spirit level and plumb bob in construction?
   A. To set up level points and check elevations
   B. To measure horizontal levels and vertical alignment
   C. To transfer loads from the structure to the ground
   D. To dig straight-edged holes or trenches
2. What is the purpose of shovels in construction?
   A. To indicate how parallel a surface is
   B. To dig and move materials
   C. To support a work crew and materials
   D. To reduce the volume of gas or air
3. Which of the following is a benefit of scaffolding in construction?
   A. To transfer loads from the structure to the ground
   B. To provide a safe working platform
   C. To dig straight-edged holes or trenches
   D. To measure horizontal levels and vertical alignment
4. What is the purpose of augers in construction?
   A. To construct piles by drilling into the ground
   B. To reduce the volume of gas or air
   C. To indicate how parallel a surface is
   D. To support a work crew and materials

5. What is the function of a concrete vibrator in construction?
    A. To remove air bubbles and consolidate concrete
    B. To dig straight-edged holes or trenches
    C. To set up level points and check elevations
    D. To transfer loads from the structure to the ground
6. What is the use of compressors in various applications?
    A. To inject grout into the ground
    B. To support a work crew and materials
    C. To indicate how parallel a surface is
    D. To reduce the volume of gas or air
7. What is the purpose of shovels, crow bars, and hammers in construction?
    A. To transfer loads from the structure to the ground
    B. To remove nails or prise two materials apart
    C. To dig straight-edged holes or trenches
    D. To set up level points and check elevations
8. What is the purpose of piling in construction?
    A. To dig straight-edged holes or trenches
    B. To set up level points and check elevations
    C. To support a work crew and materials
    D. To transfer loads from the structure to the ground
9. Which of the following is a common type of piling equipment?
    A. Concrete vibrators
    B. High pressure hoses
    C. Scaffolding
    D. Measuring tapes

Part III: Short Answer Questions

Instructions: Answer all the following questions accordingly.

1. In what ways is leveling equipment utilized in construction?
2. What are the purposes and functions of various construction tools such as shovels, lifting equipment, crow bars, hammers, scaffolding, augers, spirit levels, plumb bobs, compressors, and concrete vibrators?
3. What are the advantages and disadvantages of using auger cast piles in construction?
4. Recognize common types of piling equipment and their uses
5. Identify the process and purpose of piling in construction

Unit Two: pile positioning

This learning unit is developed to provide the trainees the necessary information regarding the following content coverage and topics:

- Establish location, position for pile and plant
- Boring hole.
- Caisson pile construction
- Placing concrete and vibrating

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Interpret how to establish, location, position for pile and plant with related equipment
- Introduce boring hole.
- Check, install and prepare caisson.
- Explain place concrete and vibrating

2.1. Establish location, position for pile and plant

The most important step for carrying out piling is setting out. Setting out is done to locate the position of the structural parts as in the detailed drawing with geometrical construction. The setting out is done to locate pile position, pile cap, column position, beam bottoms and slab boundary in the site.

Before starting excavation at the pile position the following steps are taken:

- Survey and record the existing ground level at the pile position
- Set out the pile location from the reference points and in order to monitor the position of the steel casing, control pins are usually established at two orthogonal positions, offset from the center of the pile.

The positions of the pile are produced as-built drawings showing the position of all the piles constructed or installed. Generally a licensed Surveyor hired by the contractor will set up the positions of the piles which are shown in the pile layout plans of the detailed designs showing the Northing and Easting of the center of each pile along with diameters. The positions set out by the surveyor are secured and preserved by pegs. The surveyor will be checking the correct position and verticality of the pile foundation. Mostly the verticality of the finished pile from the vertical at any level is given tolerance of 1 in 150.

Reference points shall be marked/fixed at a suitable distance from pile points to cross-check the pile's center during the drilling operation and done with the reference to grid lines by a technique Suring angles or distances. In the absence of any kind of grid lines detail first the location is at the site. In site the base line has marked in the side of the Moors road and all grid lines are marked on around of the boundary wall.

Steps to set out pile

- Set out pile points accurately based on the design drawings. For instance, According to IS adapted from BS, the largest allowable tolerance for 60cm pile diameter or more is the greater of 75mm or D/2. For piles with diameter up to 600mm, the tolerance limit is 50mm.

- Mark set out points properly so as the points are clear and fix to avoid detrimental effect of other activities around the area.
- Use total Station or theodolite to set out pile position. Make sure to recheck these points before starting the piling activity. Establish temporary reference points (TR) for this purpose

Importance of setting out

Setting out is providing pegs, levels, profiles and other information necessary for carrying out construction works. Setting out should always have independent checks for readily detecting any errors and well recorded methodical approach for future reference.

The basic requirements for setting out are the measurement of

- Distance,
- angles and
- The establishment of levels.

Leveling

A temporary bench mark is established at the site for the datum of all the leveling work of the building. But in site for the easiness the 1000 mm off line of ground floor finishing level is marked on all around the land boundary wall. It can be get anywhere in site as close reference level. The ground floor finishing level is ± 0.00 in all drawings levels are given from the ground floor finishing level.

All the excavation work has to be done according to the levels given in the drawing. By tightening and losing the support jacks the correct levels can be achieved since middle part of the slab can be sag due to the weight of the concrete, levels of the middle part of the slab were established 5 mm higher.

Setting out of a column

In column setting out first the corner columns are aligned using plum bob and according to the dimension of the column sections and the centerlines are marked.After locating the centers the centerlines are marked on a cement grout base to avoid disappearance of the marks. Then kickering is done at column section dimension to locate formwork of the column.

But if there are any reinforcement bars, edge lines are marked instead of centerlines. It must be carefully noted that, the dimension is half of the linear face dimension lesser than the center to center dimension.

Marking column centers

- First the theodolite is stout over a base point and bisects a target set or another base point and clamped.
- Then nails are driven at different locations along the line which is described by the vertical cross hair of the telescope, to obtain the grid line on the floor.
- Then the line is marked using an inked thread holding between nails the lines perpendicular to the base line is also marked as required.
- The distances to the center of each column from two perpendicular grid lines are calculated and noted down.
- Finally, by direct measurements from grid lines are marked to give the column center.

The accuracy of setting out is depending on the usage and for which the structure is used. The method of setting out is depend considering the accuracy required and the measuring instruments availability, there are two types of measuring instruments one is measuring angles and other is by length the whole setting out work.it is done either by measuring angles or by measuring lengths or by measuring both. Setting out of a pile position and foundation is very important and the accuracy of the whole structure is depending on it.

2.2. Boring of Holes

Boring enables us to extract continues or discrete samples for visual inspection and testing to determine properties of soil. Selecting the method of drilling or boring the hole will depend on soil and groundwater conditions. Bored piles are drilled using buckets and/or augers driven by percussion boring (vibratory hammers) or through rotary boring (twisting in place).

Methods of boring can be:

i. Test Pits
ii. Borehole

i. **Test Pits**: Simplest, cheapest, man-made method of Wide /shallow Usual size is 2m X 2m and 5m deep investigation. It provide clear picture of stratification. Weak lenses and pockets can be identified with test pit. Block samples can be easily extracted from which undisturbed samples are obtained – called chunk sampling. If GWT is encountered near the ground surface, bore holes are preferred. Pits cannot be dug in silts or sands below the water table or in soft clays because the sides will collapse, endangering the excavation machine & its operator.

Test pit is commonly uneconomical to go deeper than 5m. It is easier to take good undisturbed soil samples from a trial pit than a bore hole; to carry out in-situ tests (such as SPT & vane shear test.

Figure 2-1 Pit Excavation

ii. **Bore Holes**:

Usual size is 30 cm diameter and 50 m deep or more. Most common for deep investigation, Mostly done by power driven machines, can be used in any type of soil, expensive and less convenient, harder to determine exact stratification of the ground.

Figure 2-2 Borehole

Borehole drilling methods include:

- **Auger boring**: boring a hole using augers operated either by hand or machine. The hand operated augers (Figure 2-3) may be helical types or post-hole auger and be used for depths up to 3 to 5m. The hand operated augers are generally used for making subsoil explorations for high ways, runways, railways etc. where the explorations are generally confined to depths of about 5m or so. Diameter of holes varies from 5 to 20cm. Generally suitable for all types of soils above water table but suitable only below water table in clay soils. Soils with boulders & cobbles are difficult to investigate using augers. Also limited use in sandy soils because they do not stick to the auger.

Machine operated augers are suitable in all types of soils and can go to deeper depths. The hollow stem can be used for sampling or conducting SPT test and plugged when not in use. They are capable of penetrating up to 50m.

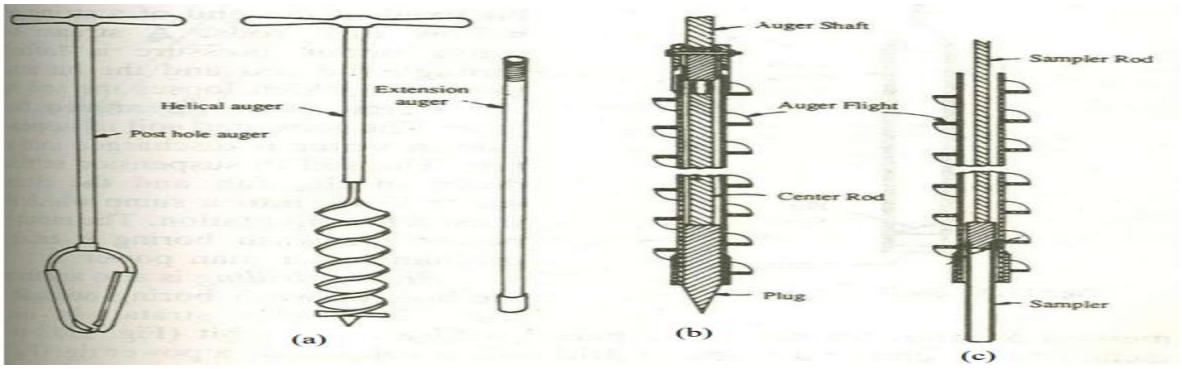

Figure 2-3. **Augers** (a) Hand Augers (b) Hollow-stem auger plugged while advancing the auger (c) Hollow-stem auger plug removed and sampler inserted to sample soil below auger

- **Wash boring**: Is machine operated boring and involves pushing or driving of casings ahead of boring operation and drilling is facilitated through by means of a chopping bit attached at the bottom of flight of hollow drilling rod (Figure 2-4). Water is pumped which helps in disintegration and facilitates loosening of the soil. Slurry rises up, screened in to soil solids and water. The method is rapid except in hard strata and soils with boulders. The machine is light so that it can be easily transported to relatively in

accessible areas. It causes not so much disturbance to underlying material. Undisturbed samples can be extracted easily by pushing thin walled sampler (split spoon sampler). However the effect of water must be taken in to consideration.

Disadvantages **of Wash boring** may be undetected thin layer and high alteration of moisture content.

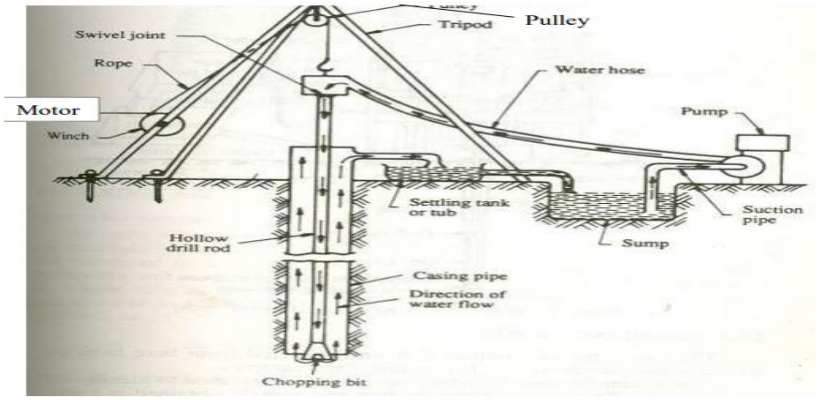

Figure 2-4 Wash boring

- **Rotary Drilling**: is generally trailer mounted or lorry mounted. Bore hole is advanced by power rotated drilling (cutting) bit with simultaneous application of pressure. The drilling bit is carbide or diamond and is attached to the drilling rods. Most rapid method in almost all soils. Fluid usually water is used to cool the edges and reduce friction. Undisturbed sample can be obtained by attaching special sampler usually split spoon sampler. Disadvantage **of Rotary Drilling** not suitable for highly fissured rocks (gravelly soils), as gravels do not break easily, but rotate beneath the bit, expensive
- **Percussion Drilling;** Involves alternately rising and falling of a heavy chisel-like bit. The drilling activity disintegrates the material below in to the sand silt size. Water is added to loosen soil and chiseler chisels and the loose material (slurry) is scooped out by a bailer. The bailer is generally attached to the boring rod after removing the tool bit at intervals, and then lowered to the hole. It has a non-returning valve. It can be adopted in almost all types of soils, and is particularly useful in very hard soils or soft rocks. Disadvantage of Percussion Drilling **is** impossible to detect thin compressible layers, high disturbance of soil, expensive in all types of drilling used in soft soils that may cave in, casing is used.

Drilling mud usually bentonite clay may also be used to stabilize the soil instead of casing.

Table 2-1 Types of strata with corresponding plant used

Type of Strata	**Plant Used or Borehole drilling methods**	**Rate (m/hr)**
Top soft deposits of site fill	Percussive / Rotary	10.00
Grade V/IV rock deposits	Wash Boring	3.15
	Triple Tube Sampling	0.75
Grade III/II rock deposits	Rotary	0.50
	Triple Tube Sampling	0.50

Pile Boring Operation:

- Once the temporary casing has been installed, excavation for the foundation pile shall be carried out using hydraulic rigs.The Boring bucket with the cutting tool will have an external diameter equal to the diameter of the pile, less 25-30mm or specified by the bucket manufacturer. For example, for a pile diameter of 1200 mm, the tool diameter shall be 1125 mm.
- During boring operation, pile borehole is filled with bentonite slurry, fed from bentonite storage tank. A proper bentonite pipeline shall be installed between the storage tank and the pile bore for the continuous supply of fresh bentonite to the borehole.
- Bentonite powder shall be mixed with fresh water at least 24 hours before, and it will ensure that bentonite is completely dispersed in the water and attain the required density to stabilize the sides of the borehole during drilling.
- It will be crucial to maintain the quality of bentonite shall be carefully controlled at stages of mixing, supply to the borehole and immediately before concrete is placed.

- Bentonite slurry is pumped by a high-pressure 15 to 20 HP reciprocating pump/vertical pump into the borehole through the pipeline. Bentonite slurry level under the borehole to be maintained throughout the boring operation.
- Each time the drilling tool is filled with boring muck, it is taken out and unloaded on the ground at a specified location. Then the tool is again lowered into the borehole, and boring is continued.
- The telescopic arrangement of the piling rig lowers the bucket further deep. Though the verticality of the pile being bored mainly depends upon the operator's skill. Verticality shall be checked periodically by checking the verticality of the rig mast.
- The verticality of the pile can also be ensured by incorporating the changes in the design of Kelly, like increasing the overlap of the Kelly assembly pieces, hence reducing the play in joints, thereby reducing the possibility of deviation in verticality.
- Some advanced tests like Ultrasonic Echo Sounding Test may ensure the verticality of the pile borehole. Specialized equipment such as 'High Precision Bore-hole Inclinometer' or 'Sonicaliper', a device which gives 3D images of bore area profile, may also be used in the construction of pile foundation to control and ensure the verticality of the pile borehole but shall be an expensive option.
- On reaching the foundation level, the depth of the borehole shall be measured by taking sounding, and the exact depth shall be measured and recorded. Measurements for pile length shall be certified by the Engineer and secured clearance for cage lowering and concreting

The following limits shall be remembered during the construction of pile to maintain the borehole stability.

- The density of bentonites suspension from 1.05 gm/cc to 1.10 gm/cc
- The marsh cone viscosity for the construction of pile is between 30 to 40sec
- The pH value is between 9.5 to 12
- The silt content for the construction of pile is less than 1% for fresh bentonite slurry
- The liquid limit for the construction of pile is not less than 400%

2.3. Caisson pile construction

Caisson is watertight foundation used for laying foundation under water. It is the shape of hollow prismatic box, which is built above the ground and then sunk to the required depth as a single unit.

Caisson piles shall consist of concrete pipe piles that are socketed into rock and constructed with steel reinforcement, and in which the socket is observed before the concrete is poured. Steel reinforcement shall be covered with at least $1^1/_2$ inches (38 mm) of concrete. The minimum diameter of caisson piles shall be 7 inches (178 mm). A suitable steel driving shoe shall be welded to the bottom of each caisson pile. The center-to-center spacing of caisson sockets shall be at least two and one-half times the outside diameter of the shell but not less than 4 feet (1219 mm).

Classifications of Caisson foundation

Caissons may be classified into the following three categories:

- **Box caissons**: Allow construction activities to be carried out on water or in wet environments.
- **Open caissons**: used for soft soil
- **Pneumatic caissons;** having a working chamber (watertight box) inside at the lower part

Advantages and Disadvantages of Caissons

Advantages

- Economics
- Minimizes pile cap needs
- Slightly less noise and reduced vibrations
- Easily adaptable to varying site conditions

Disadvantages

- Extremely sensitive to construction procedures
- Not good for contaminated sites
- Lack of construction expertise
- Lack of Qualified inspector

Checking *caisson*

All rock sockets shall be inspected to verify rock quality. Inspection may be accomplished by direct observation or by video methods or by a core boring performed prior to the drilling of the

socket. Dimensions and required bearing strata or elevations, sidewall stability during drilling, spaced should be checked during excavate.

Main points to check caisson for conformity

- Caisson drilling equipment shall have the minimum torque capacity and downward force capacity for the contract site conditions
- Bottoms of caissons shall be cleaned of loose or soft materials and leveled. If bottoms are sloping rock, excavate to a level plane or step with maximum step height less than 1/4 the width or diameter of the bearing area
- All material removed from the caisson holes shall be removed from the ground around the casing before concrete placement is started and shall be disposed of by the Contractor off site in areas submitted to and approved by the Engineer
- Excavations for utilities, support of excavations, or other purposes shall be kept a minimum distance of two shaft diameters away from the outer edge of
- Stages of concrete pile construction,
    - Marking.
    - Inserting the casing.
    - Drilling of bore.
    - Clearing the bottom.
    - Inserting the reinforcement cage.
    - Concreting.
    - Chipping off.
    - Leveling.

For each caisson placed and before superstructure framing is placed, submit to Resident Engineer for approval certified report recording following information prepared by Registered Professional Land Surveyor or Registered Civil Engineer.

- Caisson number, length, and bearing material.
- Location.
- Concrete and steel reinforcement properties.

- Plumbness.
- Dates:
  - Excavation completed.
  - Concrete placed.
- Diameters:
  - Top of shaft.
  - Bottom of shaft.
  - Bell.
- Elevations:
  - Top of ground.
  - Top of concrete.
  - Top of rock.
  - Bottom of caisson.

A pier and caisson differ basically only in the method of construction. The caissons, has action similar to pile foundations, but are high capacity **cast-in-situ** foundations. It resists loads from structure through shaft resistance, toe resistance and / or combination of both of these.

Table 2-2 Comparison of piles based on method of construction

Pile foundation	Pier foundation	Caisson
Pile foundation is a type of deep foundation, in which the loads are taken to a low level by means of vertical timber-concrete or steel.	Pire foundation is a type of deep foundation, which consists of a cylindrical column of large diameter to support and transfer large superimposed loads to firm strata below.	Caissons are watertight structures made up of wood steel or reinforced concrete built above the ground level and then sunken into the ground.
The type of pile foundation are end-bearing piles, friction piles, compaction piles, anchor piles	The types of pier foundations are masonry or concrete piers and drilled	The types of Caissons foundations are open, box, pneumatic monolithic floating

,tension or uplift piles, sheet and batter piles etc.	caissons.	excavated etc.
Pile is a column of material driven by a pile driver. it can also cast in place	Pier insert down to the bedrock.	Caisson is putting a box underwater and pouring it with concrete.
Pile has not a footing	Pier has a footing	caisson doesn't have a footing
Piles are driven in to surface condition	Pier is typically dug out and cast in place using forms.	Caisson are driven in to surface condition

Drilled-in-caisson piles are installed by

- Driving a heavy-wall open-end pipe to bedrock,
- Cleaning out the inside of the pipe by coring or jetting,
- Drilling a socket into the bedrock, and
- Filling the entire socket and pipe with concrete. This is suitable as a high-capacity pile to bedrock

Caisson Construction Process

- After some initial form work and concrete pours, the **cutting edge** is floated to the breakwater by towboat and fastened to the **caisson** guide. Concrete is placed (poured) into steel forms built up along the perimeter of the box. With every concrete placement, the box becomes heavier and sinks into the water along the caisson guide.
- Forms are also built inside the box around the **air domes** and concrete is placed in between. The resulting open tubes above the air domes are called **dredge wells.**
- When the caisson finally touches the river bottom, the air domes are removed and earth is excavated through the long dredge well tubes, as shown in the animation below. The caisson sinks into the river bottom. Excavation continues until the caisson sinks to its predetermined depth.
- As a final step, concrete is placed (poured) into the bottom 30 feet of the hollow dredge wells and the tops are sealed.

Steps could be followed to build a caisson.

- Must set the place first for the establishment of the caisson.
- Then the first up to 5m of Caisson is pre-casted.
- Next, with the help of towboat, the caisson is floated to its location by and ties it to the caisson guide.
- After that, concrete is poured using slip forming and as concrete goes, the box becomes heavier and sinks into the water along with the caisson guide.
- Mooring cables are used to hold the caissons in place.
- When the caisson finally touches the river bottom, the mooring cables are removed.
- Finally, the cap is poured.

Before placing concrete, the tip of the caisson shall be observed and approved by a qualified testing agency registered and licensed in the state. The testing agency shall be retained by the Contractor and approved by the Resident Engineer. The shaft shall be inspected, cleared of mud, water, loose material and debris.

2.4. Placing concrete and vibrating

2.4.1. Place concrete

Concrete placement is the final step in caisson installation and involves pouring concrete into the caisson shaft and allowing it to harden and bond with the surrounding soil or rock.Proper handling of concrete during placement should minimize segregation of coarse aggregates. Basically, concrete should be placed by a vertical drop, however, the material should not be allowed to free fall for long distances.

The tremie method of concrete placement is used for the concrete pouring of the pile foundation. This method uses a vertical pipe, through which concrete is placed by gravity feed blow water level. The lower end of the tremie pipe is kept immersed in fresh concrete so that concrete rising from the bottom displaces the underground water. The diameter of the tremie pipe varies from 20 to 30 cm.

Pile concreting is carried out under water by "tremie" techniques maintaining the water or bentonite head inside the casing at or above existing ground water level. The tremie tube (250mm) is withdrawn as concreting proceeds ensuring a minimum concrete head of 2 meters above the top of the tremie tube.

Placing concrete performed as follow:

- Place concrete using a down pipe to direct flow of concrete. Except in presence of water, concrete may fall freely up to a maximum height of 9.14 meters (30 feet) provided the concrete does not hit the sides of the caisson. Use tremie pipe or pump if distance is greater than 9.14 meters (30 feet).
- Withdraw casings, as concrete is deposited, maintaining top surface of concrete constantly at least 1800 mm (6 feet) above lower end of casings. Place concrete to form a monolithic cylindrical shaft having full lateral support from surrounding undisturbed materials. Strike finished top surface of concrete to true plane at required elevation.
- Concrete placement in each caisson shall be one continuous operation. If placing operation has to be stopped, leave surface approximately level. If concrete has hardened, clean surface and slush with a 1 to 1 cement-sand grout before placing operation is resumed. Concrete pours shall not begin within one hour of darkness. In the event that this type of continuous sequential operation cannot be performed, the Contractor shall submit for approval by the Resident Engineer a method of securing the open excavation. The Contractor shall not leave excavations open overnight without receiving prior written approval from the Resident Engineer.
- When water is present, control water level to within 50 mm (2 inches) of bottom of the caisson by pumping. If impossible or impractical to control water, secure written permission from Resident Engineer to place concrete through water by means of a watertight tremie.

- When placing concrete under water, discharge end of tremie shall be submerged in fresh concrete and shaft of tremie maintained full of concrete to point above water level.
- Increase cement content of concrete required to be placed in water by one sack per cubic yard of concrete

2.4.2. Vibrate concrete.

Vibrating concrete is critical because by removing air pockets & packing the aggregate particles together, it increases the density and strength of the concrete. Tightly packed particles will result in a stronger, more durable concrete structure.

The air voids are caused by air trapped between the mold surface and the concrete. In low slump concrete and can be found underneath irregular (non-spherical) shaped pieces of crushed aggregate. This is a result of having too little mortar to fill the spaces around the aggregate.

Vibrated concrete with a lower slump built up higher strength, which was explained by a resulting additional consolidation, whereas vibrated concrete with a higher slump developed lower strength, probably due to segregation

Compaction or consolidation is a technique, which has the effect of fluidifying the mortar component of the concrete mix so that internal friction reduces and packing of coarse aggregates take place. The technique eliminates most of the entrapped air bubbles from the fresh concrete

Techniques used during vibration can eliminate most surface voids. Vibrating both the outside and inside of your mold will draw most air and water bubbles away from the surface of the concrete. Hammering the mold can eliminate any residual void.

Self-check 2

Part I: True or False question

I. Instruction: Say true if the statement is correct and false if the statement is incorrect.

1. The purpose of reference points and grid lines in setting out pile positions is to cross-check the pile's center during the drilling operation.
2. proper handling of concrete during placement important to prevent segregation and ensure uniformity
3. Decreasing the cement content of concrete placed in water used to compensate for the effects of water on concrete strength

II. Choose the best answer

1. What is the most important step for carrying out piling?
   A. Construction
   B. Surveying
   C. Excavation
   D. Setting out
2. What are the steps involved in setting out for piling?
   A. Measuring angles and distances
   B. Establishing levels
   C. Establishing temporary reference points
   D. All of the above
3. What technique can be used to set out pile positions in the absence of grid lines?
   A. Using theodolite
   B. Suring angles
   C. Using total station
   D. Measuring distances
4. What instrument can be used to set out pile positions?
   A. Hammer
   B. Saw
   C. Total Station
   D. Drill
5. Why is setting out important in construction works?
   A. To check the verticality of the pile foundation
   B. To locate the position of the structural parts
   C. To establish temporary reference points
   D. To monitor the position of the steel casing

6. What is the most common method for deep investigation?
   A. Test Pits
   B. Auger boring
   C. Borehole
   D. Rotary drilling
7. Why is auger boring limited in sandy soils?
   A. It is difficult to operate
   B. It is not suitable for deep investigation
   C. It is too expensive
   D. Sandy soils do not stick to the auger
8. What is the advantage of using machine operated augers for drilling?
   A. They can be easily transported to inaccessible areas
   B. They do not stick to the auger in sandy soils
   C. They are suitable for all types of soils
   D. They can penetrate up to 50m
9. What are the steps involved in concrete placement for caisson installation?
   A. Placing concrete through water, controlling water level, securing open excavations, vibrating concrete
   B. Securing open excavations, controlling water level, placing concrete through water, vibrating concrete
   C. Removing air pockets, controlling water level, securing open excavations, increasing cement content
   D. Increasing cement content, controlling water level, securing open excavations, vibrating concrete
10. What should be done if the concrete has hardened during placement?
   A. Leave the surface approximately level
   B. Clean the surface and slush with a 1 to 1 cement sand grout
   C. Withdraw casings
   D. Begin concrete pours within one hour of darkness

11. What causes air voids in concrete?
    A. Air trapped between the mold surface and the concrete
    B. Securing open excavations
    C. Increasing the cement content of concrete
    D. Controlling water level in the caisson
12. What is the purpose of vibrating concrete during placement?
    A. To pour concrete into the caisson shaft
    B. To minimize segregation of coarse aggregates
    C. To maintain the water or bentonite head inside the casing
    D. To consolidate and remove air voids from the concrete
13. What should be done if the concrete placement distance is greater than 9.14 meters?
    A. Maintain top surface of concrete at least 1800 mm above lower end of casings
    B. Strike finished top surface of concrete to true plane at required elevation
    C. Use a tremie pipe or pump
    D. Withdraw casings
14. What should be done if the concrete placement operation has to be stopped?
    A. Leave the surface approximately level
    B. Begin concrete pours within one hour of darkness
    C. Submit a method of securing the open excavation for approval
    D. Clean the surface and slush with a 1 to 1 cement sand grout
15. What is the main purpose of compaction or consolidation in concrete?
    A. To reduce internal friction and pack coarse aggregates
    B. To increase the cement content of concrete
    C. To secure open excavations
    D. To control water level in the caisson
16. What is the purpose of the tremie method of concrete placement?
    A. To maintain the water or bentonite head inside the casing
    B. To pour concrete into the caisson shaft

C. To direct flow of concrete using a down pipe

D. To minimize segregation of coarse aggregates

17. What is the tremie method of concrete placement?

A. Placing concrete through water using a watertight tube

B. Removing air pockets from concrete

C. Securing open excavations

D. Controlling water level in the caisson

18. What is the result of tightly packed particles in concrete?

A. Controlled water level in the caisson

B. A stronger and more durable concrete structure

C. Secured open excavations

D. Increased cement content of concrete

Part III: Short Answer Questions

Instructions: Answer all the following questions accordingly.

1. Identify the steps involved in setting out for piling
2. What is the purpose of setting out in piling construction?
3. What are the different methods of drilling or boring holes for soil investigation?
4. What are the advantages and disadvantages of using test pits for soil investigation?
5. What are the advantages and disadvantages of using boreholes for soil investigation?
6. How does auger boring work and what types of soils is it suitable for?
7. Recognize the steps involved in checking a caisson for conformity with design specifications
8. Identify the different types of caissons
9. Explain the tremie method of concrete placement in caissons
10. . Explain the advantages and disadvantages of caissons
11. Understand the process of concrete placement in caissons
12. How caisson foundations classified and what are their characteristics?
13. What are the benefits and drawbacks of utilizing caissons as a foundation method?

14. What inspection procedures should be followed to ensure that caissons meet design specifications?
15. What is the procedure for placing concrete in caissons and what techniques are used, such as the tremie method?

Unit Three: Boring and Piling Rig

This learning unit is developed to provide the trainees the necessary information regarding the following content coverage and topics:

- Boring and piling rig.
- Remove boring and pile rig.

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Locate boring and piling rig.
- Remove boring and pile rig.

3.1. Boring and pilling rig

3.1.1. Boring rig

Two types of drilling rigs that are used for drilling pile holes are the auger type and the rotary type. In an auger type drilling machine, boring is done by an auger of suitable capacity into soil or soft rock. In rotary rigs, fluid pressure is used to drill the hole, and the drilling fluid also comes the cuttings out of the hole. Various types of auger drilling rigs are available and manufacturer's catalogs can be obtained from major equipment suppliers. Information, such as maximum hole size and depth, driving arrangement, rig-mounting details, maximum continuous .torque, and maximum continuous downward force are the main characteristics of auger drilling rigs.

Boring enables operators to further process cast, forged, or drilled holes that exist within a work piece, enlarging them, improving their dimensional accuracy, or increasing the diameter of the hole. These processes can also increase surface smoothness and ensure the original hole axis's deviation is correct.

Main considerations during relocate boring rig to next point of installation are:

- Boring Rig tool pusher shall inspect the new rig location. Before moving to new locations confirm, leveling, dimensions, compaction, caller, access roads conditions & mud sump was done in a suitable way.
- Night tool Pusher's Make out rig layout on the new location.
- Prepare the area for drill pipe boxes.
- Cut off the conductor pipe at a suitable level above the ground.
- Check the camp location and make the footprint for caravans.

3.1.2. Piling rig

Piling rig is a large track-mounted drill used in foundation projects which require drilling into sandy soil, clay, silty clay, and similar environments. Such rigs are similar in function to oil drilling rigs, and can be equipped with a short screw (for dry soil), rotary bucket (for wet soil) or core drill (for rock), along with other options. Expressways, bridges, industrial and civil buildings, diaphragm walls, water

conservancy projects, slope protection, and seismic retrofitting are all projects which may require piling rigs.

Piling rigs are machines used for construction that are meant for piling in or making piles in foundation engineering. They help provide support for the foundation of buildings and other large structures.

Piling rigs are mainly used to drill/create piles in soil, clay, etc. It is widely used for cast-in-place piles, diaphragm walls, and foundation reinforcement. It consists of a tabular element or hard box, placed and fixed on a crane base. Piling rigs come with different features that can be utilized to dig within the earths subsurface, making of the water wells, oil wells or natural gas extraction wells, or to install sub-surface fabrications. It is designed for multipurpose use and can be equipped with special kits for different foundation and geotechnical construction methods including, drilled shafts, caissons, continuous flight auger, diaphragm walls, etc.

Piling rigs are necessary for drilling piles on surfaces like soil and clay. It comprises a rigid box placed on the base of a crane. It comes with additional features that help to dig into the ground. Relocate pilling rig new location is almost similar to boring rig.

3.2. Remove of boring and pilling rig

Resources like cranes, trailers, trucks, tools, human power can be deployed and a network plan for the movement of the boring and piling rig and drawn showing explicitly the dependency relationships among the activities during rig building. The network would help for critical path identification with for early completion. It also furnishes planning of parallel activities. The plan highlights explicitly the dependency of various departments like mechanical, electrical, transport, auto, security, civil, drilling, chemistry, etc.

3.2.1. Remove of boring rig

Drill boring rigs are differentiated from other offshore drilling unit types by their easy mobility. Operating over unstable ground represents the most hazardous aspect of moving the rig.

Planning should include consideration of mobile maintenance and refueling stations so that such operations can be brought to the rig and conducted without tracking the rig backwards and forwards to fixed maintenance or refueling points.

The rig operator moved the rig under instruction of the Supervisor. It needs

- **Communication** – The coordination arrangements were not clear or agreed at the start of the shift to the supervisor and sub-contractor with regards to the planned activities.
- **Planning** - The Work Package Plans (WPP) / Task briefing (TB) did not identify how the rig was to move from one certified platform to the next certified platform alongside the live railway with the mast of the rig erected.
- **ALO** Planning - There was a lack of understanding of the ALO constraints on site, which should have been identified and addressed in the planning, briefings etc.

Plan preparation for rig movement

- Prepare a layout that illustrates the expected path for rig movement based on the work program and the planned deployment of resources.
- The layout shall guarantee easy movement of all rigs without causing disturbances and problems to other rig operations.
- If the layout is prepared according to the above guidelines, then the team will have a clear picture on planning the work of next day.

Considering points during boring rig movement:

- Avoid moving a rig over areas where the ground is soft or un-compacted.
- Working near the edge of an excavation is typically avoided,
- The rig can also be mounted on a gantry.
- Clearing overhead obstacles is vital to rig movement, with leaders not to come within 20 feet horizontally or 10 feet vertically of high-tension lines. When overhead obstructions can't be avoided, the rig may be dismantled.
- If a rig travels on ramps, significant coordination between the supervisor and operator is necessary, as this operation is fundamentally hazardous.

- Before entering on a ramp, locks should be checked, and with the operator prepared to engage them quickly. The travel lock should be in ratchet position when going uphill, with the leaders facing uphill and the boom down if necessary. Additionally, the operator should hold the hammer on the brake so that it can be lowered to the ground to serve as an anchor.
- If it is necessary to drive piles from a ramp, wedges can be cut from heavy timbers to fit under each track. This will temporarily level the rig for driving.
- When moving the rig around the site, the supervisor should position himself in the operator's view while also being able to view the operating areas to the rear and sides.
- Only the supervisor, or a trained signalman, should sign to the operator, with standard hand signals being utilized. Additionally, the supervisor should ensure that all workers are clear before giving a signal to move, swing, pick up, or lower a load. The hoisting or swinging of loads over areas where typical work operations are conducted should be avoided.

Before moving rig, the location following information must also be available:

- Coordinates and name of next location.
- Distance of new location from departing location.
- Names and capacity of towing boats duly inspected and approved by warranty surveyor.
- Soil data of new location expected leg penetration and punch-through possibilities.
- Report of seabed survey of the new location to ascertain that no significant debris/pipeline is present within a 100 x 100 m area in the north face of the platform and in a radius of 100 m of open location.

Drilling units/rigs are designed to move from one location to another location for undertaking drilling/work over operations after completing operations at an earlier location. As soon as the rig is released from the location, it has to be prepared for the move to a new location. The following are the steps involved:

- The cantilever and substructure are to be skidded into towing position
- Drilling string, casings, etc. are to be placed on a pipe rack and secured
- Hook, traveling block, etc. to be tied Up
- The lacing of all the loose material

- Securing all water-tight doors/hatches etc.
- All the openings or dumps must be fully closed
- Backload the material to bring variable load within permissible limits.

3.2.2. Remove of piling rig

Piling rig is a construction machine mainly used to drill/create piles in soil, clay, etc. Widely used for cast-in-place piles, diaphragm walls, and foundation reinforcement. Maximum Pile diameter typically 1.5-4m, maximum pile depth from 60-90m thus crawler chassis, box-type must, and telescopic drill pipe. Mainly used in foundation engineering of elevated roads, bridges, industrial and civil buildings, slope protection, etc.

Temporary geotechnical structures providing a stable working surface for piling rigs, mobile cranes and other heavy construction equipment. A working platform is the foundation for a piling rig which may weigh up to 200 tons.

Steps to move pilling rig:

- Dismantle all equipment Systems and load to a new location
- Pull and Haul tools and equipment from the old location to the new location
- Secure the rig and remove all insecure tools and equipment and secure loose tools
- Raise the substructure
- Raise the substructure from the front with the help of jacks
- Engage the Mack trucks and secure the wheel by bolts Insert Pins and release the rig
- Straight pull when starting to move and no direction change until the unit is moving
- The single direction of movement/positioning of the rig over the cellar
- Move the rig to the new location

Self-test 3

Part I: Say true if the statement is correct and false if the statement is incorrect

1. The new location shall be marked/staked in accordance with the layout drawing by the NTP prior to the commencement of the rig move
2. Piling rigs are mainly used to move drill equipment of piles.
3. Before moving rig, coordinates and name of next location should be fixed

II. Instruction: Chose the best answer

1. What are the two types of drilling rigs used for drilling pile holes?
   A. Auger and hydraulic
   B. Rotary and auger
   C. Rotary and hydraulic
   D. Hydraulic and mechanical
2. What is the purpose of piling rigs in foundation engineering?
   A. To ensure correct deviation of hole axis
   B. To improve dimensional accuracy of holes
   C. To increase surface smoothness
   D. All of the above
3. What are the main considerations during relocating a boring rig to a new location?
   A. Cutting off the conductor pipe at a suitable level above the ground
   B. Inspecting the new rig location and confirming leveling and dimensions
   C. Checking the camp location and making footprints for caravans
   D. All of the above
4. Who has overall responsibility for the old location during a rig move?
   A. NTP
   B. Senior Tool Pusher
   C. Truck Pusher
   D. Night Pusher
5. What is the main function of a piling rig?
   A. To check camp locations
   B. To load trucks
   C. To drill pile holes
   D. To relocate boring rigs

6. What are the main characteristics of auger drilling rigs?
   A. Driving arrangement and rig-mounting details
   B. Maximum hole size and depth
   C. Maximum continuous torque and force
   D. All of the above
7. What are the features of piling rigs?
   A. Driving arrangement and rig-mounting details
   B. Maximum hole size and depth
   C. Maximum continuous torque and force
   D. All of the above
8. What are the responsibilities during the relocation of a boring rig?
   A. Night Pusher's overall responsibility for a new location
   B. AFPC OSA/R assists with the inspection of trucks
   C. Senior Tool Pusher overall responsibility for the old location
   D. Mechanic, crane operator, and truck pusher inspect crane and trucks
9. Which projects may require the use of piling rigs?
   A. Bridge construction
   B. Road construction
   C. Building foundations
   D. All of the above

Part III: Short Answer Questions

Instructions: Answer all the following questions accordingly

1. Identify the main function and purpose of piling rigs in foundation engineering
2. Explain the projects that may require the use of piling rigs
3. Understand the responsibilities during the relocation of a boring rig
4. Recognize the main considerations during relocating a boring rig to a new location
5. Recognize the features of piling rigs
6. What is a piling rig and what is its function in foundation projects?
7. What are the main uses of piling rigs in construction?
8. What are the different features of piling rigs that allow them to dig within the earths subsurface

Unit Four: Pile positions and rig plant establishment

This learning unit is developed to provide the trainees the necessary information regarding the following content coverage and topics:

- Piles location and establishment
- Pile equipment
- Piling area

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Set out and establish location for piles.
- Prepare plant and check pile equipment
- protect piling area

4.1. Piles location and establishment

Setting out is done to locate the position of the structural parts as in the detailed drawing with geometrical construction. The setting out is also done to locate pile position, pile cap, column position, beam bottoms and slab boundary in the site. It is done with the reference to grid lines and bringing the dimensions from a plan to the real situation. The activity consists of establishing the exact location and measurements of the pile to be built.

Set out location

- To arrange or display things. It needs very well set out.
- To present ideas, facts, in an organized way, in speech or writing.

Methods of Setting out Survey

- Clear the ground of any debris, vegetation and other obstructions
- Setting out buildings by coordinates.
- Setting out with theodolite and level.
- Checking verticality.
- Setting out and alignment in steel-framed buildings.
- Alignment and verticality in formwork.
- Control and calculation for route surveying.

New Location Preparation

Rig Tool Pusher (T.P) shall inspect the new rig location. In new location, the professional should check and prepare

- Types of drilling rigs before moving to confirm leveling dimensions, compaction, caller, access roads conditions & mud sump was done in a suitable way.
- Rig layout on the new location.
- The area for drill pipe boxes. Prepare the area
- Cut off the conductor pipe at a suitable level above the ground.
- The camp location and make the footprint for caravans.

Establish location for piles from reference points and set out to requirements considered the following:

- All rig equipment shall be spotted on location in accordance with the rig layout drawing
- The new location shall be marked/staked in accordance with the layout drawing by the prior to the commencement of the rig move
- To assist with spotting rig equipment, the location is marked with guide ropes, A grid of perpendicular and parallel lines (guide ropes) is marked relative to well center, the grid shall be marked as accurately as possible and shall be checked (using the Pythagoras triangle 3/4/5) to ensure that all the lines are indeed at right angles and others at parallel positions
- Senior Tool Pusher overall responsibility for the old location
- Night Pusher's overall responsibility for a new location
- The truck pusher checks each truck before leaving the location and assures proper loading, chaining, and condition of securing tools
- The mechanic, crane operator, and truck pusher inspect crane and trucks
- Truck pusher checks the overhead electric cable height before crossing with the convoy and compares it with actual height including the truck
- AFPC OSA/R will assist with the inspection of trucks and accompany the convoy as necessary
- The road junction which has the potential to cause problems for long and wide load should be avoided and the route should be changed.
- Integrated with mechanical, electrical and hydraulic systems
- Comes with 360º camera rearview for operator efficiency
- Emergency stopping of machine possible
- Attached with Boom micro-switch for control of the stability limit
- Double-rotary interlocking kelly bars for transfer of torque and crowd force from the rotary drive to the drilling tool
- Interlocking bars with the higher pulling force for the tougher terrain
- Interlocking Kelly bars for pulling up during the extraction phase with the main winch and the rotary comes with a parallelogram for precise positioning

4.2. Pile equipment

Pile driving equipment used often varies according to conditions ranging from soil consistency to depth of piles required.

Types of Pile Driving Equipment's are

- Piling Rigs
- Rotary Drilling Rig
- Piling Winches
- Hanging Leader
- Hammer Guides
- Piling Hammer
- Hydraulic impact pile hammer
- Vibratory pile hammer
- Helmet, Driving Cap, Dolly and Packing

Piling Rigs

It composed of a series of leaders, which are consist of tabular element or hard box, placed and fixed on a crane base as it can be seen from Figure-3.Not only does the leaders support the hammer and the pile but also guide them when the pile is forced into the ground.

The leader can be sloped forward and backward using screw or hydraulic adjustment and attachment at the base of the equipment .It is possible to install a series of piles, without the need to move the equipment, through turning around base machine and positioning leaders.

Regarding pile installation in water, pile driving rig can be used to install piles in water by placing it on pontoon or leader are fixed on braced frames that mounted on pontoon

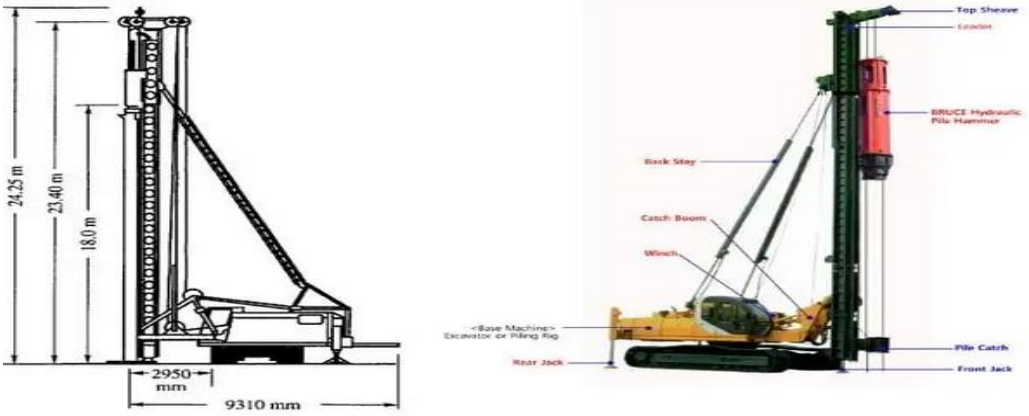

Figure 4-1 Pile Driving Rig

Piling Winches

The prime goal of piling winches is to left the hammer and piles in addition to support tools that responsible for leader raking and rotation. It functions with pile frames and different powering sources such as hydraulic power, stream; diesel; or petrol engines, and occasionally electric motors could be applied for powering winches. There are different piling winches with different capacity for instance winches with double or triple drums possess satisfactory controlling and pile driving speed whereas one drum winch does not have that advantage. So, the former type would be favored provided that handing and driving piles with great speed is required.

Hanging Leader

Hanging leaders are specifically designed to be hanged from the jib of a crane as shown in Figure 4.2 A steel strut, which its length can be varied as per requirements of construction site, provides a stiff connection from the leader foot to the machine bed frame.

Figure 4-2 Hanging Leader

Moreover, crane or excavator winch units are utilized to left the hammer and piles using separate drums. Regarding hammer application, either drop hammer with friction winch is considered or it may be operated using stream or hydraulic power or compressed air which are provided by different units. Finally, it is substantially crucial to practice utmost precaution to hanging leader stiffness particularly in the case of long sloped pile driving since intolerable deformation would lead to eccentric hammer blow and possibly cause pile fracture.

Hammer Guides

When it is intended to remove hanging leaders or piling frames completely, rope suspended leaders which are commonly guided by timber or steel formwork, would be considered. In this technique, an independent crane needed to control the pile and establishing the guide and hammer. it is necessary to set and secure the guide properly in order to avoid movements specifically in the during raking pile installation. This is because serious fatigue stress would generate if the thrust is not centered properly and the guide might deteriorate. Finally, it is required to prevent disproportionate bending stress development in guide and piles because it leads to undesired results. for example, when heavy hammer is attached to the upper end of a long pile which is driven at flat angle of rake, excessive bending stress may be generated at support point in the guide. This problem might be tackled by providing suitable support for the pile at proper position.

Figure 4-3 Hammer Guided and Rope Suspended Leader

Piling Hammer

There are several factors that greatly influence the decision to choose suitable piling hammer. For example, pile size and weight, the resistance of the ground which should be overcame in order to obtain specified penetration, construction site space availability, noise limitation that might be imposed at certain areas, and availability of cranes. Previously, the combination of a dynamic equation result and extensive experiences were employed to select piling hammer, but this has changed nowadays and drivability analysis results, which is conducted using computer program based on Smith

wave equation, is considered for the piling hammer determination. As for input data required for drivability analysis, piling hammer producer provided necessary data about efficiency and energy feature of the piling hammer. It should be bore in mind that piling hammer efficiency is not a constant and it is affected by number of factor for example mechanical condition of the hammer and operation temperature. It should be known that the mechanical condition is not influence the efficiency of piling drop hammer. That is why dynamic pile analysis is carried out and its results would be used to assess the influence of different factor on the piling hammer efficiency.

Helmet, Driving Cap, Dolly and Packing

Helmet is a cast steel that placed over the pile to hold the dolly that placed between the pile and the hammer to avoid pile head deterioration that may cause by pile driving hammer. Dolly, which is square at the bottom and round at the top, is placed in a square recess at the top of the helmet. There are different types of dollies for example Elm dollies, hardwood like oak; greenheart and pyinkado, and their selection is dependent on the driving force. As far as packing is concerned, it is placed between pile top and the helmet in order to protect the former from the hammer blow. Different types of packing include paper sacking, thin timber sheet, coconut mapping, and sawdust in bags. Regarding driving cap, it is provided as a protection for steel bearing piles. It is necessary to place the driving cap tightly otherwise the pile cap would suffer deterioration. That is why it is fitted with a recess for hardwood or plastic dolly and with steel wedges to fix the cap tightly on its position. Lastly, serious pile head damage and hammer breakage cannot be avoided unless appropriate material and suitable thickness is selected for dollies and packing.

Pile driving preparation covers all the activity that needs to be done to the pile before the sensors and cables are installed .The inspector should check to see if the Contractor's choice of hammer will provide enough energy to drive the pile. The general principle behind the pile integrity test is relatively simple. By assuming that the stress wave travels at the speed inside the pile shaft, the pile depth can be determined by measuring the time lapse between striking pile head and receiving reflections on pile head.

A Guide preparing a Surface for Piling Foundations (For Piling Contractors)

1. Site assessment. Before any work can begin, it's essential to assess the site and understand the soil conditions.
2. Clearing and grading.
3. Excavation.
4. Compacting the surface
5. Foundations from capital piling..

The main equipment for pile is pile driver. A **pile driver** is a heavy-duty tool used to drive piles into soil to build piers, bridges, cofferdams, and other "pole" supported structures, and patterns of pilings as part of permanent deep foundations for buildings or other structures. Pilings may be made of wood, solid steel, or tubular steel (often later filled with concrete), and may be driven entirely underwater/underground, or remain partially aboveground as elements of a finished structure.

4.3. Piling area

Pile driving cause's vibrations and soil movements. Soil deformations due to pile driving, and the excess pore pressures generated due to un-drained deformation, can influence the performance of nearby foundations and may cause damage to adjacent structures. Thus protect area for pile driving and surrounding working space in accordance with safety requirements should be considered.

The following points considered to protect area for pile driving and surrounding working space

- Work areas and walkways need to be kept free of loose materials, debris, pile cut-offs, and scrap lumber.
- Platforms and walkways more than four feet off the ground, or in a hazardous location, should feature a secure handrail with a toe board.
- Properly built ladders must be maintained, with side rails extending 36" above a landing.
- Containers for oil rags, combustible materials, and trash should be provided, with unused equipment stored outside of the working area.
- drain any muddy area onsite and provide plank runways across trenches

- Slippery walkways and other areas should be sanded. In freezing weather, salting is recommended.
- Construction areas must be adequately lit if night work is to occur. Typically, temporary lights are installed, with power supplied by heavy-duty electric cords.
- Working in areas containing harmful gases, vapors, fumes, or inadequate ventilation, suitable precautions must be taken. Additionally, special care must be taken when working in potentially flammable environments.

Self-check 4

Instruction I: Say true if the statement is correct and false if the statement is incorrect

1. Setting out can be done to locate the position of the structural parts without the detailed drawing
2. pile installation in water, pile driving rig can be used to install piles in water by placing it on pontoon
3. Protect area for pile driving and surrounding working space in accordance with safety requirements should be considered in driven piles.

II Instruction: choose the best answer

1. What are the steps involved in preparing a new rig location?
    A. Avoiding road junctions
    B. Marking and staking the new location
    C. Checking the condition of the crane and trucks
    D. Inspecting trucks and securing tools
2. What is the responsibility of the Tool Pusher in the rig move process?
    A. Avoiding road junctions
    B. Inspecting trucks and securing tools
    C. Checking the condition of the crane and trucks
    D. Overall responsibility for the old location
3. What is the responsibility of the truck pusher during a rig move?
    A. Checking each truck before leaving the location
    B. Inspecting drilling rigs
    C. Marking guide ropes
    D. Cutting off the conductor pipe
4. What is the purpose of clearing the ground of debris in setting out?
    A. To arrange or display things
    B. To locate the position of structural parts
    C. To present ideas in an organized way
    D. To prepare the area for setting out

5. What are the methods of setting out in construction projects?
   A. Checking verticality
   B. Setting out with theodolite and level
   C. Clearing the ground of debris
   D. All of the above
6. What type of pile driving equipment is used for driving piles into the ground using vibration?
   A. Piling Rigs
   B. Piling Winches
   C. Rotary Drilling Rig
   D. Vibratory pile hammer
7. What steps are involved in preparing a new rig location?
   A. Inspecting drilling rigs
   B. Marking guide ropes
   C. Cutting off the conductor pipe
   D. Checking verticality
8. What type of pile driving equipment is used for transferring torque and crowd force from the rotary drive to the drilling tool?
   A. Interlocking Kelly bars
   B. Rotary Drilling Rig
   C. Piling Rigs
   D. Piling Winches
9. What is the purpose of setting out in construction projects?
   A. To present ideas in an organized way
   B. To check verticality
   C. To arrange or display things
   D. To locate the position of structural parts
10. What types of pile driving equipment are used in construction projects?
   A. Theodolite and level
   B. Guide ropes
   C. Conductor pipe
   D. Drilling rigs
11. Why is it important to mark and stake a new location in accordance with layout drawings?
   A. To present ideas in an organized way
   B. To locate the position of structural parts
   C. To arrange or display things
   D. To ensure accuracy and alignment
12. What type of pile driving equipment is used for driving piles into the ground using impact?
   A. Piling Rigs
   B. Piling Winches
   C. Rotary Drilling Rig
   D. Piling Hammer

Part III: Short Answer Questions

Instructions: Answer all the following questions accordingly

1. What is the purpose of setting out in construction?
2. What are the methods used for setting out survey?
3. What preparations are necessary for establishing a new rig location?
4. What types of pile driving equipment are commonly used in construction?
5. Recognize the steps involved in preparing a new rig location

Unit Five: Drive pile and clean-up workplace

This learning unit is developed to provide the trainees the necessary information regarding the following content coverage and topics:

- Lifting pile and maneuver
- drive pile
- splicing or jointing
- workplace and equipment cleaning

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Lift pile and maneuver
- Set up piling rig and drive pile
- Carry out splicing or jointing
- clean up workplace and equipment

5.1. Lift pile and maneuver

The most common form of pile driver uses a heavy weight situated between vertical guides placed above a pile. The weight is raised by some motive power such as hydraulics, steam, diesel, electrical motor, or manual labor. At its apex the weight is released, impacting the pile and driving it into the ground.

The code also designates three categories of lift each has a slightly different requirement in terms of the safe system of work**.**

- **Basic lift**: most common good lifting technique
- **Standard lift:** a low risk lift and use light in weight
- **Complex lift**: a non-routine crane lift requiring detailed planning and unusual or additional safety precautions

The load should always be lifted high enough that it will clear any obstructions. If it isn't lifted high enough, it could knock over other objects and cause serious damage. Make sure the load will easily clear any obstructions before move it laterally.

Lifting pile operations are high-risk operations that involve lifting equipment such as:

- Crawler cranes.
- Tower cranes.
- Lorry cranes (or lorry loaders)
- Gantry cranes.
- Overhead travelling cranes.
- Jib cranes.
- Powered hoists

Ensure the crane is as close to the load being lifted as possible and keep loads as low to the ground as is reasonably safe when performing lifts, secure the load once it has been lifted and properly stow the crane, stabilizers, winches and any other moving parts

Recommended concept during lift pile and maneuver

- Lift piles with proper slings or other equipment, with workers properly trained in their use
- Pick up piles from the side opposite of other operations
- Clear workers when piles are hoisted into the leads
- Do not undermine the rig or an adjacent structure when jetting or pre-excavating for piles
- Clean augers of clods of earth and rocks as they are hoisted out of the ground

- Holes made in advance should then be covered or barricaded to prevent a possible fall
- Instruct workers to never be under the hammer or core at any time
- Release the core sling on both sides when changing cap blocks or a hammer cushion
- Keep workers away from leads when cap blocks or a hammer cushion is being changed
- Keep the hammer under control during driving, via slight pressure on the hammer drum brake
- Shut off the hammer immediately if the pile should break or start running into the ground
- Watch the hammer hose closely when lifting the hammer at the end of driving, ensuring it does not catch
- Hold any hose loop below the leaders away from them until the hose is clear

Hug the load as close as possible to the body better than gripping it tightly with just hands. Slight bending of your back, hips and knees at the start of the lift is preferable to either fully flexing your back (stooping) or fully flexing your hips and knees.

5.2. Drive pile

Driven piles can be made of timber, pre-cast concrete, steel H-piles, steel sheet piles, or pipe piles. Piles can be installed as a single length or spliced for extremely deep piles.

Driven piles are broadly classified as

- Steel Driven pile
- Precast Concrete Driven pile
- Timber pile
- Composite driven pile

Classified based on load transfer.

- End-bearing piles
- Friction piles
- Friction and end-bearing piles

Classified based on their construction method

- Driven piles

- Cast in-situ piles
- Driven and cast in-situ piles

Figure 5-1 Driven Pile

Pile driving is a task where piles are driven into, jacked, screwed, or removed from the ground. Piles are used to support foundations or secure excavations. Piles are usually driven into position by a crane with a mounted pile hammer.

Driven piles are the most commonly used deep foundation system for transportation projects. Piles are typically installed in groups using an impact pile driving hammer. Multiple pile types with various section properties are available to resist almost any load demand. Pile lengths for some pile types can be easily adjusted and spliced in the field to accommodate variations in subsurface conditions.

Temporary sheet piles are used in cofferdams and other temporary works to enable deep excavations to facilitate construction below ground and water level. After completion of construction the sheet piles are usually extracted for reuse

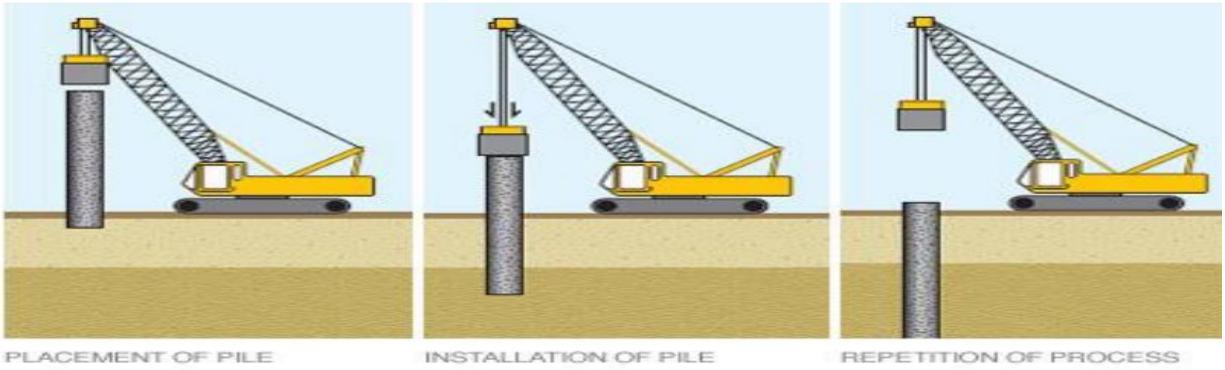

Figure 5-2 process of driven piles

Driven Precast Concrete Piling

Precast concrete piles are installed in the ground by using pile driving equipment. Due to the possibility of carrying vertical and horizontal loads as well as bending moments, precast piles are used for the foundation of all sorts of engineering structures under virtually every soil conditions. Piles can be a single section, or several sections can be jointed to provide longer piles for deeper ground conditions.

A driven precast concrete pile

- Usually of square section
- produced in short lengths in one meter intervals between 3 and 14 meters
- They can be easily connected together in order to reach their required length.
- This will not decrease the design load capacity.
- Reinforcement is necessary within the pile to help withstand both handling and driving stresses.

Driven precast concrete piles generate no spoil or arising's from the installation and removes the need for additional traffic movements in and out of the site. Piles can be provided in various sizes, formed in high strength concrete, with varying reinforcement. They are particularly useful where there is a need for very deep piles, typically up to 40 meters, in soft ground or in aggressive or contaminated soils.

Generally ,Driven piles are performed by hammered, jacked or vibrated into the ground using a percussion hammer, hydraulic driver or rams (typically used for sheet piles), or diesel-powered

vibratory drivers used to reduce surrounding ground resistance and allow the pile to slide into the ground.

Pile Driving Methods (Displacement Piles) categorized as

- Dropping weight
- Explosion
- Vibration
- Jacking (restricted to micro-piling)
- Jetting

There are three driving systems that are applicable to both retaining and bearing piles:

- impact driving
- vibro driving
- pressing

Impact driving

The most common form of impact driving is the drop hammer, which uses a falling weight to create the impact, spread to the top of the pile by a driving cap. The most common form of drop hammer in current use is the hydraulic hammer. Historically, air hammers and diesel hammers were used, which utilise an explosive force to drive the hammer, however, as the newer hydraulic hammers operate at significantly higher efficiencies and are far less noisy than older diesel hammers, the latter are now less frequently used.

Vibro driving

An oscillating driver is clamped to the top of the pile, to induce vibrations in the pile and reduce friction along the sides of the pile, thus allowing the pile to be inserted into the ground with little extra application of force.

Pressing (Jacking)

Pressing methods operate by jacking the piles into the ground, using the adjacent piles for reaction. This is a low noise and low vibration method, which makes it good for sensitive sites.

The panel driving/pressing rigs are suited mainly to installation in heavy clays and require a crane to move the rams from pile to pile. With older multi-ram presses it was also necessary to bolt plates to each pile; however recent advances have eliminated this requirement.

Driving assistance methods

Driving assistance methods can significantly improve the constructability of a sheet pile wall. Jetting and pre-auguring are the main methods.

- Jetting involves delivering a water jet to the soil at the toe of the sheet pile, reducing friction.
- Pre-auguring refers to the use of a continuous flight auger to penetrate the ground along the pile line in advance of the sheet pile installation. Soil should only be loosened along the line and not removed when using this technique.
- Both methods change the in situ soil properties around the sheet piles and the impact of their use needs to be considered during design. The acceptability of these methods for other reasons, including ground movement and creation of flow paths for contamination will also need to be taken into account.

Sheet pile installation methods

There are two basic driving methods for sheet pile installation, 'pitch and drive' and 'panel driving'.

Pitch and drive

The pitch and drive method installs the piles one by one. This can lead to forward lean and out of tolerance piling, unless verticality is strictly controlled. Better control of this is available with more modern equipment. Rotation of the pile about its vertical axis is also a risk, as it is supported on only one interlock during driving. Pitch and drive methods are best suited to short piles

Panel driving

With panel driving, it is much easier to control verticality, as a number of piles are threaded together before driving. The panel of piles is supported in a guide frame and then driven sequentially in stages. The method can achieve installations of longer piles in more difficult ground than the pitch and drive method. Recent developments in multi-ram presses have improved the availability of panel driving by the pressing method.

Bearing pile installation methods: The installation of bearing piles is a specialist activity, calling for considerable knowledge and experience of handling piles and operating hammers to achieve an acceptable placement within specified tolerances of position and level..

The same installation methods as for sheet piles described above can be used for bearing piles.

The requirement further states that the minimum diameter for the longitudinal bars should not be less than 16 mm. Piles should have at least 6 longitudinal bars and the clear distance between bars should not exceed 200 mm measured along the periphery of the pile

For piles founded on rock, the minimum center-to-center spacing is an optimum spacing of 3 times the diameter of the pile is often used. This allows both adequate room for driving and economical design of the pile cap or 1.75 times the diagonal dimension of the pile cross section, but not less than 24 inches. An optimum spacing of 3 times the diameter of the pile is often used.

The lateral resistance of pile groups is greatly affected by the pile spacing. The presence of neighboring piles at close spacing results in a reduction in the lateral capacity of each pile in the group due to the greater interaction between the piles.

In conclusion, the minimum center to center spacing of friction piles of diameter (D) as per British BIS code is 3 D for cohesive soils and 2.5 D to 3 D for cohesion less soils. The spacing between piles should be greater than or equal to the diameter of the pile to avoid overlap between the piles.

5.3. Splicing or jointing

Splicing is called for when pile lengths required are too long for trucking or driving in one piece with the available equipment, or if there is a headroom restriction. A pile may have one or more splices. The splice should be capable of resisting stresses induced by driving, and service loads and conditions.

Pile splice joins two segments of a driven pile using either welding (common for H-beams), grouting or mechanical means (common for precast concrete piles). Pile splices allow the use of shorter segments to drive piles in low headroom situations such as under bridges or inside buildings. Reducing the length of the pile segment to less than approximately 165cm means that the trailer that carries the pile segment to the site will be within state length limits.

Pipe piles can most conveniently be extended with a splicer. This is designed with a taper for a drive fit without welding so no advance preparation is required or a slip on splice requiring welding. If water is a problem, roofing mastic swabbed around the joint probably will be adequate.

For piles where the joint is not embedded well into firm soil or where uplift is expected the splice can be supplied without a taper. It can be slipped on a pile section while horizontal and a weld made in convenient position as the pipe is rolled. This joint has substantial lateral resistance and tension value. Driving can be done on the splicer; the next section is set into it and a quick down hand weld made to complete the joint. Do not bevel pipe to be used with the splicer. It bears on a square ledge.

A method of coaxially splicing a pair of tubular foundation piles in an end-to-end relationship includes the step of constructing a tubular splice from a resilient material, the tubular splice having the same outer diameter as the pair of foundation piles and being shaped to define a longitudinal slit which extends the entirety of its length. A strap is cinched tightly around the splice which renders its outer diameter less than the inner diameter of the pair of foundation piles. Each end of the compressed splice is then inserted into an adhesive coated end of a corresponding foundation pile. With the pair of foundation piles telescoping mounted over the compressed splice, the cinched strap is removed which causes the splice to resiliently expand radially outward and thinly spread the adhesive. The foundation piles are then preferably drawn together and the adhesive is allowed to cure.

A pile joint is a connecting device for precast concrete pile segments. It is used to connect additional segments of precast reinforced concrete piles, during pile driving to depths greater than the length of a single segment**.**

The Pile joint for precast concrete piles is made of steel sheet, steel bar and steel reinforcement bar, see in figure 5.3 Different grades of steel are used for the various components of the pile joint as clarified.

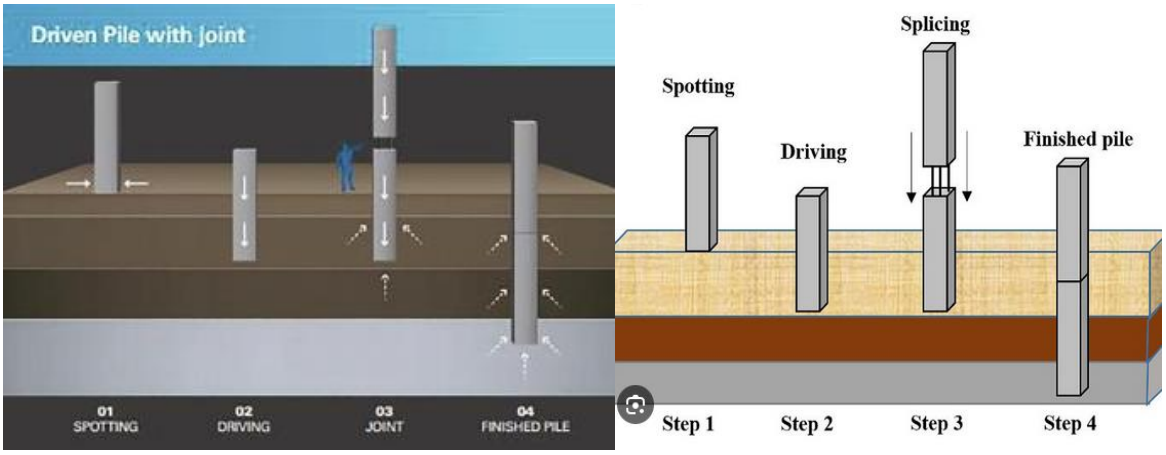

Figure 5-3drive piles with splice and joint

A pile joint is a connecting device for precast concrete pile segments. It is used to connect additional segments of precast reinforced concrete piles, during pile driving to depths greater than the length of single segment.

The pile joint is incorporated in to the precast concrete as the pile is cast, and the steel reinforcement bars bond it to the pile. By using a mould spacer device during casting, the correct position of the joint in the pile can be assured every time. During pile driving, when two concrete pile segments are jointed together and the locking dowels enter the locking blocks, the two halves of the joint in the extended concrete pile are locked securely with 4 or 8 locking pins. The locking pins are hammered in by hand or by machine. The lock mechanism for the pin (locking ring) ensures that the joint remains intact during pile driving immediately before offering a second pile segment for pile joining, the protective plugs in the locking blocks shall be removed on site and the connection surface shall be cleaned before joining of the pile segments.

5.4. Workplace and equipment cleaning

The site should be cleaned at frequent intervals and no material shall be stored on the site in a manner, which would obstruct the easy access of equipment and personnel. All debris from excavation of objectionable material, removal of obstructions, and any material not to remain as part of the construction are to be removed and disposed of by the contractor in a legal manner at no additional cost to the Owner.

An employer must ensure that workers in the area of a pile being struck by a pile driver are protected from any risk to their safety or health that may result from the pile shattering; before piles are placed in position for driving, pile heads are trimmed to fit the follower on the pile-driving cap and are free of debris; and a follower or pile-driving cap is of a size and type suitable for the type of piling to be driven.

Upon completion of practice, all tools, and equipment used in the driven and piling must be put back in their correct storage local. All tools, and equipment used in the driven and piling must be clean properly.

Take it a habit to clean tool after each use before return them to storage. Always check it, free of dust, grease and debris before put them into their proper places. This is also an opportunity to look for any damage or defects. Storing dirty tools without cleaning can cause them to deteriorate. Routine cleaning reduces the chances of rust and can reduce the rate of wear and tear. Making sure tools are dried thoroughly before storing and treating them with linseed or mineral oil are the best ways to keep tools from getting rusty.

Before you put your drive tool for the season, though, make some time for the important task of cleaning and maintaining your tools. A regular maintenance routine keeps your drive tool in good working order and helps them last longer.

General maintenance tools and equipment

- Hang simple tools rather than standing them.
- Brush off soil when you have finished.
- Allow them to dry before storing.
- Give each tool its own space.
- Use a disinfectant
- Sand and oil wooden handles.
- Tighten up loose bolts.

Self-check 5

Instruction I: Say true if the statement is correct and false if the statement is incorrect

1. The importance of lifting the load high enough is to reduce noise
2. End-bearing piles, Friction piles, Friction and end-bearing piles are the three types of piles based on load transfer
3. Steel piles, Concrete piles, Timber piles are the different types of cast in-situ piles
4. Hydraulics is the most common form of pile driver
5. A pile joint is a connecting device for precast concrete pile segments

II: Choose the best answer

1. What should be done before lifting piles with proper slings or other equipment?
   A. Undermine the rig or adjacent structure
   B. Cover or barricade holes made in advance
   C. Clear workers from the area
   D. Clean augers of clods of earth and rocks
2. What is the purpose of lifting the load high enough?
   A. To clear any obstructions
   B. To secure the load
   C. To cause serious damage
   D. To move it laterally
3. Which equipment is commonly used in lifting pile operations?
   A. Gantry cranes
   B. Overhead travelling cranes
   C. Jib cranes
   D. All of the above
4. How are piles classified based on their construction method?
   A. Driven and cast in-situ piles
   B. Cast in-situ piles
   C. Driven piles
   D. All of the above
5. How are piles typically driven into position?

A. By a bulldozer
B. By hand using a sledgehammer
C. By a hydraulic press
D. By a crane with a mounted pile hammer

6. What is the purpose of piles?
   A. To support foundations
   B. To secure excavations
   C. To provide stability to structures
   D. All of the above
7. What is the benefit of using pile splices in low headroom situations?
   A. To spread adhesive radially outward
   B. To draw foundation piles together
   C. To cure adhesive
   D. To connect additional segments of precast concrete piles
8. What is the purpose of the locking dowels in pile jointing?
   A. To spread adhesive radially outward
   B. To lock two concrete pile segments together
   C. To connect additional segments of precast concrete piles
   D. To draw foundation piles together
9. What is the purpose of cleaning and maintaining tools and equipment?
   A. To increase their resale value
   B. To prevent rust and wear and tear
   C. To make them look nice
   D. To impress coworkers
10. What should be done with tools after cleaning them?
    A. Put them in a box
    B. Throw them away
    C. Leave them on the ground
    D. Hang them up
11. What should be done with tools and equipment after they are used in driven and piling?
    A. Leave them where they are
    B. Throw them away
    C. Give them to another worker
    D. Put them back in their correct storage location
12. What should be done before storing a drive tool for the season?
    A. Give it to a coworker
    B. Leave it dirty
    C. Sell it to a pawn shop
    D. Clean and maintain it

13. What is a good practice for storing simple tools?
    A. Hang them rather than standing them
    B. Stack them on top of each other
    C. Leave them on the ground
    D. Throw them in a pile
14. What should be done with loose bolts on tools?
    A. Remove them
    B. Tighten them up
    C. Leave them loose
    D. Replace them with new bolts

Part III: Short Answer Questions

Instructions: Answer all the following questions accordingly

1. How can the load be lifted to avoid causing damage?
2. What are the different types of driven piles?
3. What are the different types of cast in-situ piles?
4. Identify different types of pile drivers and their motive power
5. Identify different types of cast in-situ piles and their construction process
6. What are the advantages and disadvantages of using welding, grouting, or mechanical means for pile splicing?
7. How does a pile joint work to connect additional segments of precast concrete piles during pile driving?
8. How should tools and equipment used in driven and piling operations be properly cleaned and stored?
9. What are some recommended maintenance practices for tools and equipment in general?

References

1. Braja M. Das, Khaled Sobhan -(2018) . Principles of Geotechnical Engineering-Cengage
2. V N S Murthy (2008)“Advanced Foundation Engineering Geotechnical Engineering Series”,
3. An-Bin Huang, Hai-Sui Yu (2018), Foundation Engineering Analysis and Design CRC Press) - libgen.lc
4. Bernard Hertlein, Allen Davis (2006) Nondestructive Testing of Deep Foundations
5. Braja M. Das & Nagaratnam Sivakuga (2019)Principles of Foundation Engineering, 9th Edition, SI Edition-Cengage Learning, Inc.
6. Carlo Viggiani_ Alessandro Mandolini_ Gianpiero Russo (2012) Piles and pile foundations-Spon Press, Taylor and Francis .
7. F. G. Bell (2019) Foundation Engineering in Difficult Ground , Butterworth-Heinemann Ltd)
8. Hsai-Yang Fang (1991) Foundation engineering handbook , Springer
9. Gunaratne Manjriker -(2006) The Foundation Engineering Handbook CRC Press Inc)
10. John D. Nelson, Kuo Chieh Chao, Daniel D. Overton, Erik J. Nelson -(2015). Foundation Engineering for Expansive Soils, Wiley
11. Joseph E. Bowles -(1995) Foundation Analysis and Design -McGraw-Hill Science_ Engineering Math
12. Lymon C. Reese, William M. Isenhower, Shin-Tower Wang (2005) - Analysis and Design of Shallow and Deep Foundations-Wiley
13. Lymon C. Reese_ William F. van Impe - (2010) Single Piles and Pile Groups Under Lateral Loading, 2nd Edition-CRC Press
14. Muni Budhu -(2008) Foundations and Earth Retaining Structures-Wiley
15. N. S. V. Kameswara Rao -(2011) Foundation Design_ Theory and Practice-John Wiley & Sons
16. Robert Day -(2010) Foundation Engineering Handbook 2 E, McGraw-Hill Professional)

DEVELOPER(S) PROFILE

Name	Qualification	Field of Study	Institute	Phone Number	Email
Ashagre Bibiso	B	Road Construction (B.Sc.)	Wolaita Sodo Polytechnic College	0912304708	ashagrebibiso@gmail.com
Bekalu Yibeltal	A	Structural Engineer (M.Sc.) Civil Engineering (B.Sc.)	FTVTI	0911271096	fikruyibetal@gmail.com
Belete Aweke	B	Road Construction (B.Sc.)	Bahir Dar Polytechnic College	0910974355	beleteyc@gmail.com
Habib Surur	B	Road Construction (B.Sc.)	Hawassa Polytechnic College	0979798778	Habibsurur0@gmail.Com
Mohammed Seid	A	Surveying (B.Sc.) Construction Technology and Management (M.Sc.)	FTVTI	0914053274	muha.seid@gmail.com
Nigussie Teshome	A	Geotechnical Engineering (M.Sc.) Civil Engineering (B.Sc.)	Arba Minch Polytechnic and Satellite Institute	0913767770	teshomeng@gmail.com
Wondwesn Girma	A	Construction Technology and Management (M.Sc.)	Harar Polytechnic College	0912778365	wondwesngirma@gmail.com

		Civil Engineering (B.Sc.)			
Zekarias Gebre	B	Civil Engineering (B.Sc.)	General Wingate Polytechnic College	0912421317	thekey1502@gmail.Com