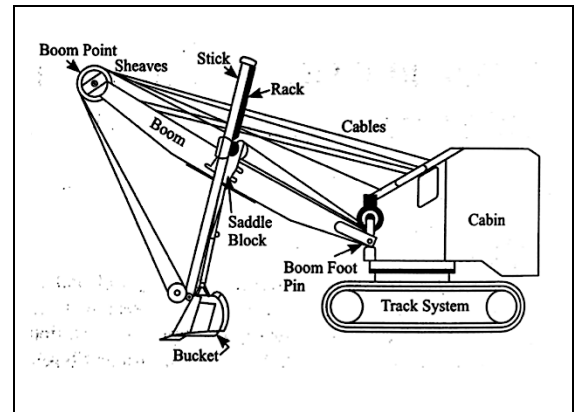


1. Types of excavating equipment

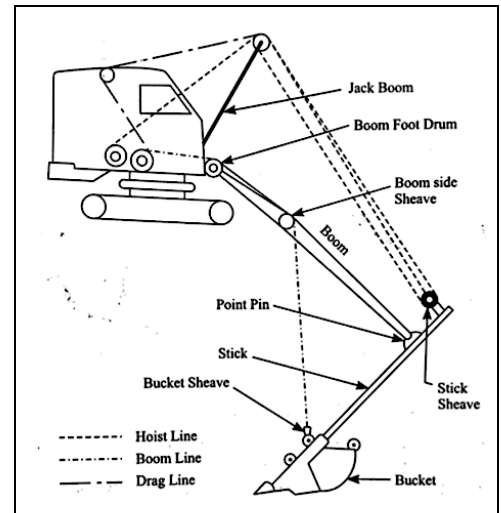
a) Power shovel

- These are used to excavate earth and load trucks, it is capable of excavating all types of earth except hard rocks.
- It is suitable for close range of work, and is capable of digging very hard materials.
- It can remove boulders and is used in various types of jobs such as digging in gravel banks, clay pits, digging cuts in road works, road side berms etc.
- It operates from a flat surface, producing up-ward digging action, excavating & filling the bucket as it climbs. After the bucket is filled, its upper part swings to the dumping position. After that, it returns to its original position & the cycle is complete.



b) Back hoe

- Also known as hoe, back shovel and pull shovel.
- It is used to extract below the natural surface on which it rests. It is similar to shovel, except it makes inward strokes while digging.
- Generally used to extract trenches, pits for basements and also for grading works, which requires precise control of depth.
- It is the most suitable machine for digging below the machine level, such as trenches, footings, basements etc.
- It can be efficiently used to dress or trim the surface avoiding the use of manual effort for dressing the excavated surface.



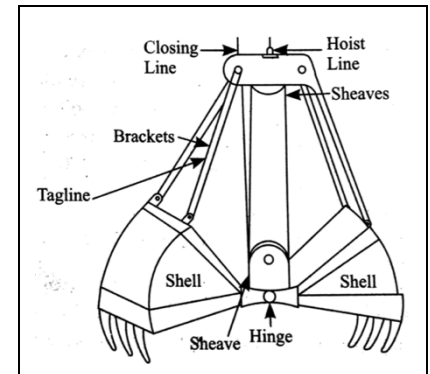
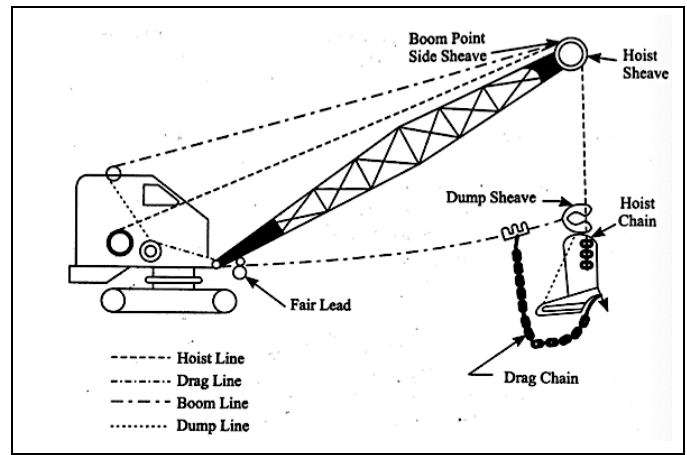
c) Dragline

- It is so named because of its prominent operation of dragging the bucket against the material to be dug.
- Unlike the shovel, it has a **long light crane boom** and bucket is loosely attached to the boom through cables. Because of this construction, a dragline **can dig and dump over large distances** than a shovel can do.
- It is useful for digging below its track level and **handling softer materials**.
- It is very useful for excavating trenches when the sides are permitted to establish their angle of repose without shoring.
- It is mostly used in the excavation of canals and depositing on the embankments without hauling units.
- A dragline excavator is especially useful *when there is need for extended reach in excavating or when material must be excavated from underwater*.
- Clamshell excavators provide the means to excavate vertically to considerable depths.
- The greatest advantage of a dragline over other machines *is its long reach for digging and dumping. The dragline is designed to excavate below the level of the machine.*
- The clamshell bucket is designed to excavate material in a vertical direction. It works like an inverted jaw with a biting motion. The clamshell is capable of working at, above, and below ground level.
- Output of dragline = Ideal output × Depth & swing factor × Operating factor

- Depth and swing correction factor: taken from a standard table based on angle of swing
- Efficiency or operating factor: actual operating time per hour

d) Clam shell or Grab

- This is so named due to its resemblance of its bucket to a clam which is like a shell-fish with hinged double shell.
- The front end is essentially a crane boom with a specially designed bucket loosely attached at the end through cables as in drag line. The depth of excavation can be roughly taken as one third of the boom length.
- The capacity of a clam shell bucket is usually given in cubic meters.
- It is used for handling loose material such as crushed stone, sand, gravel, coal etc.
- Main feature is vertical lifting of material from one location to another. Mainly used for removing material from coffer dam, sewer main holes, well foundations etc.



2. Excavation and earth moving equipment

a) Volumetric measurement basics

- The volume of material changes with respect to activities performed.
- The same weight will occupy different volumes in different handling stages.
- Bank unit weight: (γ_b) the unit weight of the soil as it lies in the natural state.
- Loose unit weight: (γ_l) the unit weight of material after it has been disturbed by the loading process.
- Compacted unit weight: (γ_c) the unit weight when placed in the compacted state in place.

Shrinkage factor = $\frac{\gamma_c}{\gamma_b}$	Shrinkage percent = $\frac{\gamma_c - \gamma_b}{\gamma_c} \times 100$
Swell factor = $\frac{\gamma_l}{\gamma_b}$	Swell factor = $\frac{\gamma_b - \gamma_l}{\gamma_l} \times 100$

b) Motor graders

- They may be either towed or motorized. Usually self-propulsive. Finishing equipment.
- They are used for creating flat surface, snow/land clearance, bank cutting, and base course spreading.

c) Scraper

- It is a unique machine for digging and long-distance hauling of ploughable materials.
- It is a self-operating machine. It is not dependent on other equipment. Wheel of machine cause some compaction.
- Crawler tractor pulled and wheel tractor pulled.
- The loading operation is done by lowering the front end of the bowl till the cutting edge enters the ground. Simultaneously, the front apron is raised to provide open slot through which the earth flows into the bowl. As the scraper moves forward, the earth is forced into the bowl. The cutting edge is raised and the apron is lowered to prevent spillage during hauling.

d) Bull dozer

- These are versatile equipment which has, a heavy blade attached in front of the tractor which pushes the material from one place to another.

- The tractor can be of crawler or wheel type.
- Bull dozers can have blades perpendicular to the direction of movement or at an angle to the direction of movement.
- They are used for spreading the earth fill, for opening up pilot roads through mountainous and rocky terrains, clearing construction sites, maintaining haul roads, clearing land from trees and stumps, backfilling trenches at construction sites.
- Movement of blades of dozer are
 - Tilt: This movement is within the vertical plane of the blade. Tilting permits concentration of dozer driving power on a limited portion of the blade's length.
 - Pitch: This is a pivotal movement about the point of connection between the dozer and blade.
 - Angling: Turning the blade so that it is not perpendicular to the direction of the dozer's travel is known as angling.
- Output of a bulldozer
 - Output of bulldozer in bank measure volume (cum/h)
 - $$= \frac{\text{rated mould board capacity in loose volume}}{\text{swell factor}} \times \frac{\text{actual operating time in min/h}}{\text{time required per trip in min}}$$

3. Hauling Equipment

- Hauling is defined as movement of material from one place to another. Equipment used for hauling are called as hauling equipment.
- Dump trucks:
 - Selection of type of dump trucks depend on soil condition.
 - Side or rear dump trucks:
 - These are heavy duty trucks with strongly built body which is hinged on the truck chassis at the rear end, and can be lifted using hydraulic jacks.
 - These are suitable for hauling wet clay, sand, gravel, quarry rocks etc.
 - Bottom dump trucks:
 - Bottom has two longitudinal gates.
 - These are used for hauling free flowing material such as sand gravel, dry earth, hard clay.
- Dumpers
 - These are high speed pneumatic wheeled trucks, having short chassis and strong bodies.
 - Loading, hauling and dumping can be done very fast as compared to other equipment.
 - These are suitable for short hauls on rough roads and specially where a shuttle movement is required.

4. Hoisting equipment

- Introduction
 - Hoisting is the operation of lifting a weight from one location and moving it to another location which is at a reasonable distance and then dumping it.
 - Big projects such as construction of dams, industrial buildings etc. require such equipment.
 - Hoisting equipment includes jacks, winches, chain hoists and cranes. As a hoisting equipment, crane is the only single machine which as a single piece, is capable of providing three dimensional movement of weight.
 - It does hoisting operation speedily with safety and precision.
- Stationary or **derrick cranes**
 - It consists of a mast, a boom and a bull wheel on which the boom rotates about a vertical axis and guys or supporting members.
 - The boom can revolve through 360°, this crane is used for heavy loads up to 200 tons.
 - They are either electrically operated or diesel operated or both.
 - They are used for loading and unloading cargoes at ports. Used in erection of structures.
- Mobile cranes
 - These cranes are mounted on mobile units which is either crawler type or wheel type.

- Truck cranes have high mobility while the crawler mounted cranes move slowly.
 - Crawler type cranes are capable of moving on rough terrain.
 - Mobile cranes are used for transportation of loads to short distances.
- d) Overhead or gantry cranes
- Widely used in erection, foundry, steel plants, storage yards and different types of industrial works due to large service area, free from floor obstructions and three way mobility.
- e) Traveller cranes
- Travelling or bridge cranes have their crabs moving on girders which are supported on legs instead of on overhead gantry track as used in overhead cranes.
 - The legs are capable of moving on tracks laid on the floor.
- f) Tower cranes
- Tower cranes are actually a derrick crane mounted on a steel tower.
 - They are usually used for industrial and residential high-rise buildings.
 - They are commonly used for assembly of industrial plants with steel structures.

5. Compacting equipment

- a) Smooth wheel rollers:
- These are plain steel rollers, effective in compacting granular soils, such as gravel and crushed stone.
 - These are self-propelled having weight 5 to 25 tonnes.
 - No deep compaction is achieved, as compaction is only by static weight.
- b) Sheep foot rollers:
- Hollow steel drum with projected feet mounted at 100 to 200 mm c-c.
 - It is used for compacting earth works in embankments and canals.
 - Gives best result for cohesive soils.
 - Feet produce **kneading action** and a pressure to mix and compact the soil from bottom to top layer.
- c) Pneumatic tyre roller:
- It is most suitable for compacting fine-grained soil and well graded sands.
 - Major advantages are the ability to control the ground contact pressure by altering the weight of machines, increasing the number of wheels, increasing tyre width.

6. Conveying equipment

- a) Introduction
- These equipment are used for transporting material from one place to another over a stationary structure.
 - These carries material in continuous stream with its distinct feature such as endless chain or belt.
 - When the equipment does horizontal conveying. It is known as conveyor
 - and when it does vertical, it is known as elevator.
 - They are usually used in mining construction and in some industries. Some of the popular conveyors are:
- b) Belt conveyor:
- Used when large quantities of materials have to be conveyed over long distances at fast speed.
 - It can handle light as well as heavy materials, dry or wet, fine or coarse etc. discharge can be controlled by controlling the speed of the belt.
- c) Screw conveyor:
- It is widely used for handling granular or pulverised material.
 - The quantity of material conveyed is less compared to belt conveyor but at the same time the cost is less.
- d) Bucket conveyor:
- It has buckets in shape of V which are open at the top. They may be feeder loaded or may drag in a vertical movement along an incline.

- This type of conveyor is mainly used in coal handling where bucket elevator carry the material vertically.
- e) Aerial conveyor:
 - Aerial transportation through cableways, rope-ways and tram ways often used with advantage for transportation of material in hilly regions.

7. Types of mixers

- a) **Freefall mixer** are those where concrete is mixed by lifting the ingredients with the help of rotating blades inside a rotating drum, which free fall by overcoming friction.
 - **Tilting mixer**
 - These are commonly trailer mounted, small to midsize, used as main concrete mixing equipment on small sites.
 - The drum has two axes: one around which the drum rotates and other that serves to change from loading and mixing position to discharging position.
 - This position change is done manually by a dump wheel, while drum rotation is gasoline or diesel powered.
 - Material is loaded manually, directly into the drum.
 - As per IS 1791, mixers have been designated as
 - ◆ 100T, 140T, 200T (T: tilting, Numbers represents the nominal volume of mixed concrete in litres.)
 - **Reversible mixer**
 - Drum has one horizontal axis around which it rotates.
 - There are two opening, one at each end of the drum: one for feeding the ingredients, the other for discharging the mixture.
 - In mixing position, the drum rotates in one direction, while for discharging rotation is reversed. The mixture is equipped with tilting hopper.
- b) **Power mixers** also called paddle mixers, blend concrete by rapid rotating motion of paddles inside the mixing drum
 - **Pan mixers**
 - The paddles are connected to a vertical shaft inside the pan-shaped drum.
 - There are various models in which; drum and paddle can remain stationary, move in same direction and opposite direction.
 - Vertical shaft may be concentric or eccentrically located, with bottom opening for discharge.
 - They are generally not mobile and is used as a central mixing plant on a large concrete project or at a precast factory.
 - They are efficient with stiff and cohesive mixes.
 - **Trough mixers:**
 - These are power mixers that have a trough-shaped drum.
 - The single shaft mixture has a horizontal shaft onto which the paddles are connected in spiral-like arrangement; in some models wave shaped mixing arms replace paddles.
 - The combination of radial and axial movements obtained produces a three dimensional circulation path that further increases mixing intensity and therefore results in shortened mixing times.

8. Concrete compaction equipment

- a) Introduction
 - Compaction can be done manually (using tamping rods), mechanical means (using vibrators) and special means (vibro-processing, shock, centrifugation and air jets)
- b) Manual hand compaction
 - Rodding: poking with 2m long, 16mm dia rod with sharp corners and edges. The thickness of layers is 15 to 20 cm.

- Ramming: generally used for compaction on ground in plain concrete. It is not used either in RCC or on upper floors.
- Tamping: top surface is beaten by wooden cross beam of cross section 10x10cm. both compaction and levelling are achieved simultaneously. It is mainly used for roof slab and road pavement.

c) Mechanical compaction

- Internal vibrator:
 - These are most common type of vibrator used, also called as *needle vibrator*, *immersion vibrator*, *poker vibrator*. It consists for a power unit, a flexible shaft and a needle.
 - They are immersed into the concrete for action.
 - Can be powered by gasoline, electric or compressed air.
 - Frequency is from 10,000 to 15,000 vibrations per minute.
 - They are portable and can be used in mass concreting.
 - These are essentially efficient since all the work is done directly on the concrete unlike other vibrators.
- External vibrator:
 - also called form vibrators, as attached to the formwork from outside.
 - These are more often used in column, thin walls, pre-cast plants and tunnelling.
 - This method of vibrating concrete is particularly useful and adopted where reinforcement, lateral ties and spacers interfere too much with the internal vibrator. This gives a good finish to the concrete surface.
 - Since the vibration is given to the concrete indirectly through the formwork, these consume more power and the efficiency of external vibrator is lower than the efficiency of an internal vibrator.
- Table vibrator:
 - These are special kind of form vibrator, where the vibrator is clamped to the table.
 - They are commonly used for vibrating concrete cubes.
 - This is adopted mostly in the laboratories and in making small but precise prefabricated RCC members.
 - They are very efficient in compacting stiff and harsh concrete mixes required for manufacture of precast elements.
- Platform vibrator:
 - It is larger kind of table vibrator, used in the manufacturing of large prefabricated concrete elements such as electric poles, railway sleepers.
 - Sometimes, the platform vibrator is also coupled with jerking or shock giving arrangements such that a through compaction is given to the concrete.
- Surface vibrator:
 - Also called *screeds*.
 - A small vibrator is placed on the levelling of thin concrete members such as floor slabs, roof slabs and road surface.
 - Mostly, floor slabs and roof slabs are so thin that internal vibrator or any other type of vibrator cannot be easily employed. In such cases, the surface vibrator can be effectively used.
 - Surface vibrators exert their effects at the top surface of the concrete and consolidate the concrete from the top down.
 - In general, surface vibrators are not effective beyond about 15 cm. In the modern construction practices like vacuum dewatering technique or slip form paving technique, the use of screed board vibrator is a common feature.

9. Engineering Economy

a) Pay back period gives an estimate of liquidity.

- In declining balance, greater write-off in early year is aimed.
- Capital recovery factor = $\frac{i(1+i)^n}{(1+i)^n - 1}$
- **Sinking fund factor** = $\frac{i}{(1+i)^N - 1}$
- **Declining balance** $1 - \left(\frac{\text{salvage value}}{\text{initial value}}\right)^{\frac{1}{n}} = \text{rate of depreciation}$

10. PYQ Answers

a) PYQ

- Coordinating – The organisational setup is aided to operate efficiently with flow of information, decisions and results in all directions. It is integration of activities of different departments in efficient operational information decisions in all directions.
- Planning – Determination of course of action to achieve desired objectives. It involves translation of management policy into method of achieving the set out objectives.
- Organising – Bringing resources (men, material, money, machine) etc. together and use them properly for achieving objectives. It is a process and structure, i.e. execution of a business plan. It defines the responsibilities of each resources.
- Directing – Deals with guiding and instructing men to do work in right way by transforming information to subordinate coordinating.
- Specifications of crane are: Boom length, Swing angle, Long travel, Hoist, speed, class of duty.
- **Injury frequency rate** = $\frac{\text{number of disabling injuries}}{\text{Man hour spent}} \times 1,00,000$
- **Injury severity rate** = $\frac{\text{number of days lost}}{\text{Man hours worked}} \times 1000$
- **Injury index** = $\frac{\text{injury frequency rate} \times \text{injury severity rate}}{1000}$
- Crawler mounted: Power crane and shovel association (PCSA) standards limit the load capacity concerning tipping to 75% of maximum load.
- Truck and rough terrain mounted: PCSA standards limit the load capacity concerning tipping to 85% of maximum load whether on tires or outer rigs.

b) Factors considered in the **selection of an equipment** for a construction project.

- *Specific construction operation*: It is the first factor that must be considered in the selection of an equipment. The equipment selected must be capable of doing the work specified.
- *Condition at job site*: When there is a working space limitation, the operating dimension of equipment must be considered in order to ensure that whether there are adequate clearances, reaches and so on.
- *Location of job site*: weather condition, temperature precipitation and wind affect the performance of construction equipment and the ability of the operator to operate it.
- *Versatility and adaptability of equipment*: this factor must be considered when there are a number of operation requiring similar equipment. A versatile piece of equipment is one that can be used for several construction operations.
- *Economy*: it is one of the most important factor in consideration of equipment. The cost of production, depreciation, fuel all combinedly used to predict the future profit.
- *Project timeline considerations*: Project deadline also affect the selection of equipment. If there is a limited time available to complete a project, then companies may prefer highly advanced construction equipment that can reduce the project's completion time significantly.
- *Labour considerations*: This also highly affects the selection decision. If there is a shortage of manpower at the job site, then the companies may opt for highly automated machine. A company may or may not opt for the highly sophisticated equipment.

- *Safety considerations*: companies may have to select equipment which ensures safety of the workers.
 - *Replacement parts*: prior to purchasing equipment, the buyer should determine whether spare parts are obtainable, otherwise the project may get delayed.
- e) Arbitration
- Arbitration is a procedure in which a dispute is submitted, by agreement of the parties, to one or more arbitrators who make a binding decision on the dispute. In choosing arbitration, the parties opt for a private dispute resolution procedure instead of going to court. Its principal characteristics are:
 - *Arbitration is consensual*: It can only take place if both parties have agreed to it. In the case of future disputes arising under a contract, the parties insert an arbitration clause in the relevant contract. In contrast to mediation, a party cannot unilaterally withdraw from arbitration.
 - *The parties choose the arbitrator*:
 - *Arbitration is neutral*: in addition to their selection of neutrals of appropriate nationality, parties are able to choose applicable law, language and venue of the arbitration.
 - *Arbitration is a confidential procedure*
 - *The decision of the arbitration tribunal is final and easy to enforce*:
- f) Force majeure
- Force majeure refers to a clause that is included in contracts to remove liability for natural and unavoidable catastrophes that interrupt the expected course of events and prevent participants from fulfilling obligations.
- g) Security deposit vs mobilisation advance
- **Security deposit** is the sum of money held in trust with the department. It is generally 10% of the tender amount. The purpose of security deposit is to guarantee that the contractor will:
 - Perform and complete the work according to the contract requirement.
 - Discharge lawful obligations and satisfied lawful claims against the contractor.
 - Insure that sub-contractors discharge their lawful obligations and satisfy lawful claims against them.
 - Mobilisation advance
 - For the activation of the contractor's physical and manpower resources; transfer to the construction site until the completion of the project in civil construction, project advance is given to the contractor known as mobilisation advance. It is normally restricted to 10 to 15% of the contract value.
 - The prerequisite for the issue of advance is that the contractor has to provide a guarantee in the shape of bank or insurance equal to the amount being issued to the contractor.
 - Mobilisation advance is deducted from the bill of the contractor in equal instalments covering the project period, on completion of a recovery guarantee provided by the contractor is released.
- h) Different types of **contracts adopted in construction**
- Various methods or alternatives that are used in the construction industry either in part or in a whole consist of different approaches to contracting for service or production or different setups created.
 - This is due to different relationship existing between the owner/ultimate user or occupant and contractor. Depending upon the size and complex nature of the job these methods may be modified to suit the requirements. Following are different types of contracts adopted in construction:
 - **Lump-sum contract**:
 - This is a traditional method in which a construction project is implemented.
 - The owner, having retained an architect/engineer has a set of definite documents consisting of design plan and specifications prepared, defining the scope of the work required.
 - The definitiveness of lump-sum contract makes it the established method of contracting in many instances and the only method utilised, because of the statutory requirements.

- **Cost plus fixed fee contract:**
 - All costs within predetermined yardstick or in accordance with the specific regulations are reimbursed by the owner to the contractor apart from the contractor is paid a fixed sum which represents profit (his fee).
- **Cost plus bid fee contract:**
 - In this method also, the cost of construction are to be reimbursed as incurred within the predetermined yardstick.
 - The fee or the profit with one contractor, and owner will issue a request for proposal to a select number of contractors, all of the whom he believes are in an equal or at least similar position to build the required facility, past experience and performance in the evaluation of the contractors from whom the successful one is selected.
- **Guaranteed maximum contract:**
 - This method is often used as either a direct substitute of a lump sum or cost plus or modification of either contracting system.
 - No owner wishes in a position to issue a blank check for building a new facility; all new building, improvements, maintenance or repairs are accomplished within pre-stabilised budget.
- **Negotiated contract (competitive and non-competitive)**
 - There are many elements common to cost plus method and this traditional method of contracting, but the negotiated contract is open classified separately.
 - The end result of negotiated contract can be any form of contracting previously described Lump-sum or cost plus.
 - It is however dependent upon plan development status or a specific owner or project requirements.
- **Unit-price contract:**
 - This type of contract is based on established quantities of items involved in the work.
 - The cost per unit of each item is bid by the contractor and the established quantities of these items are given by the owner.
- **Design build:**
 - As the term implies this approach establishes a single administrative management and professional responsibility for the two separate function of design and construction.
 - The owner enters into one agreement for both. The method of contracting can be any of the traditional method or modified previously described.
- **Turn-key contract:**
 - Turnkey contract utilises a single contract for all the functions.
 - There is one administrative, management and professional responsibility for design and construction.
 - There is a single party under contract to an owner to fulfil these functions in addition to other functions that may be necessary to implement a project.