EQUIPMENT SCHEDULING

CONSTRUCTION PROJECTS

- **1. Use of 3-D Modelling:** A 3-D model defines and communicates the architect's design vision to the various stakeholders and is a unique digital document that can be used for all phases of design, procurement, construction, and operation.
- It **can be used** for design, analysis, and fabrication, and can help detect conflicts, interferences, and incompatibilities, achieve improved tolerances and quality, and reduce change orders and rework.

- **2. Use of 4-D Models:** The 4-D software generates a sequence of configurations of the project representing its status through time, as determined from the schedule and the 3-D model, thus creating an animation of the construction process.
- **4-D modelling allows** communicating actual construction sequences and can help detect constructability problems, interferences among trades or subcontractors, and interference between moving equipment and on-going activities.

- **3. Web-based Project Management Systems:** It use project collaboration software to provide access for all parties (design consultants, contractors, subcontractors, managers, and others) on a large construction project in order to conduct all daily project management and administrative activities.

- **The main benefits of such systems** are increased productivity, reduced cycle time, and elimination of multiple iterations of the work process for project management, invoice submittal processing, and payment operations by allowing the members of a geographically distributed group to interact as.

- **4. Aesthetics:** Aesthetic enhancement of projects increases their attractiveness and desirability, can serve to establish the identity of a district or city, and represent a statement of its spirit.
- Furthermore, much of the aesthetics features of most projects can be enjoyed by the general public, and aesthetics thus contributes to the quality of life.

- **5. Marketing and Communications:** The success of many projects depends on funding and public support, which in turn often depends on how communication with the public, elected officials, decision makers, and the media is handled.
- **Successful communication techniques** stress the need for establishing and maintaining credibility, communicating the value of the project, ensuring that media coverage is more help than hindrance, avoiding mission expansion, and **building a sense of pride and ownership.**

- **6. Early Contractor Involvement:** A contractor brought on the project team early in the process can assist in suggesting and evaluating design, finish, and construction process alternatives, and in reviewing the design for constructability and completeness.
- **The project also benefits from the contractor's knowledge** of current and projected market and pricing conditions, including labour, material, and equipment availability.

- **7. Innovation, Risk, and Reward:**
- **For the risk of introducing an innovation to be taken, it is necessary that a potential reward, of sufficient value, exist.**
- **8. Process Flexibility and Opportunity for Innovation:**
- **For innovation to be considered, it is necessary that the contracting and procurement rules provide sufficient flexibility.**

- **9. Ownership of Process - Roles and Responsibilities:**
- **All the members of the project team have the opportunity throughout the life of the project to provide input, suggest improvements, introduce innovations, and contribute to the solution of unanticipated problems.**
- **Each team member has a stake in the successful completion of the project.**
- **These factors lead to the creation of a sense of commitment to, and pride in the project, of accomplishment, and of ownership of the process.**

- **10. Project Management and Project Delivery Systems:**
- **Project delivery systems, which enhances cooperation among the project team members and tends to foster innovation, cost effective solutions, and speedy project delivery.**
- **This provides better management continuity and knowledge of the project, including decisions and commitments.**
- **Such teams often use the most advanced project management techniques and risk management concepts to benefit the project.**

- **11. Removing Barriers to Innovation:**
- **Barriers to innovation are numerous.**
- **They include the distrust that may exist between the contractor and owner's representative, concerns for the safety of the public and for potential liability, the lengthy process of proving the safety of a proposed innovation, resistance to change, and the fear of taking risks.**
- **To foster innovation, a change is required in the prevailing attitude of risk avoidance.**

- **12. Streamlining:**
- **Streamlining in the areas of construction-ready design documents, commissioning, and all-inclusive insurance policies may lead to substantial cost and schedule reductions, and quality enhancements.**
- **13. Procurement Methods:**
- **Design/Build and other alternate project delivery systems can deliver compelling and substantial benefits.**

- **14. Life-cycle Considerations:**
- **The durability and long-term viability of building projects is extremely important to owners.**
- **For widespread acceptance of life-cycle cost innovations, it is imperative to establish a sound economic rationale for decision-making, and to define and place realistic costs on indirect, but very real, costs such as user delays, traffic interruption, accidents on detours, and the like.**

- **15. Insurance:**
- **Insurance coverage and loss control activities are planned and pre-selected elements of risk mitigation.**
- **"Wrap up" insurance or an owner-controlled insurance program may provide cost savings, and remove a potential barrier to collaboration, especially during the planning and design phases.**

HORIZONTAL CONSTRUCTION PROJECTS

- Water & Sewer
- Storm Water Drainage & Detention
- Roadway & Street Design
- Paving & Grading
- Storm Water Pollution Prevention
- Storm Water Quality Management
- Runways
- Highway and Road Construction

- **Excavation Work**
- **Site work**
- **Aggregate Crushing and Hauling**
- **Potable Water Distribution Systems**

VERTICAL CONSTRUCTION PROJECTS

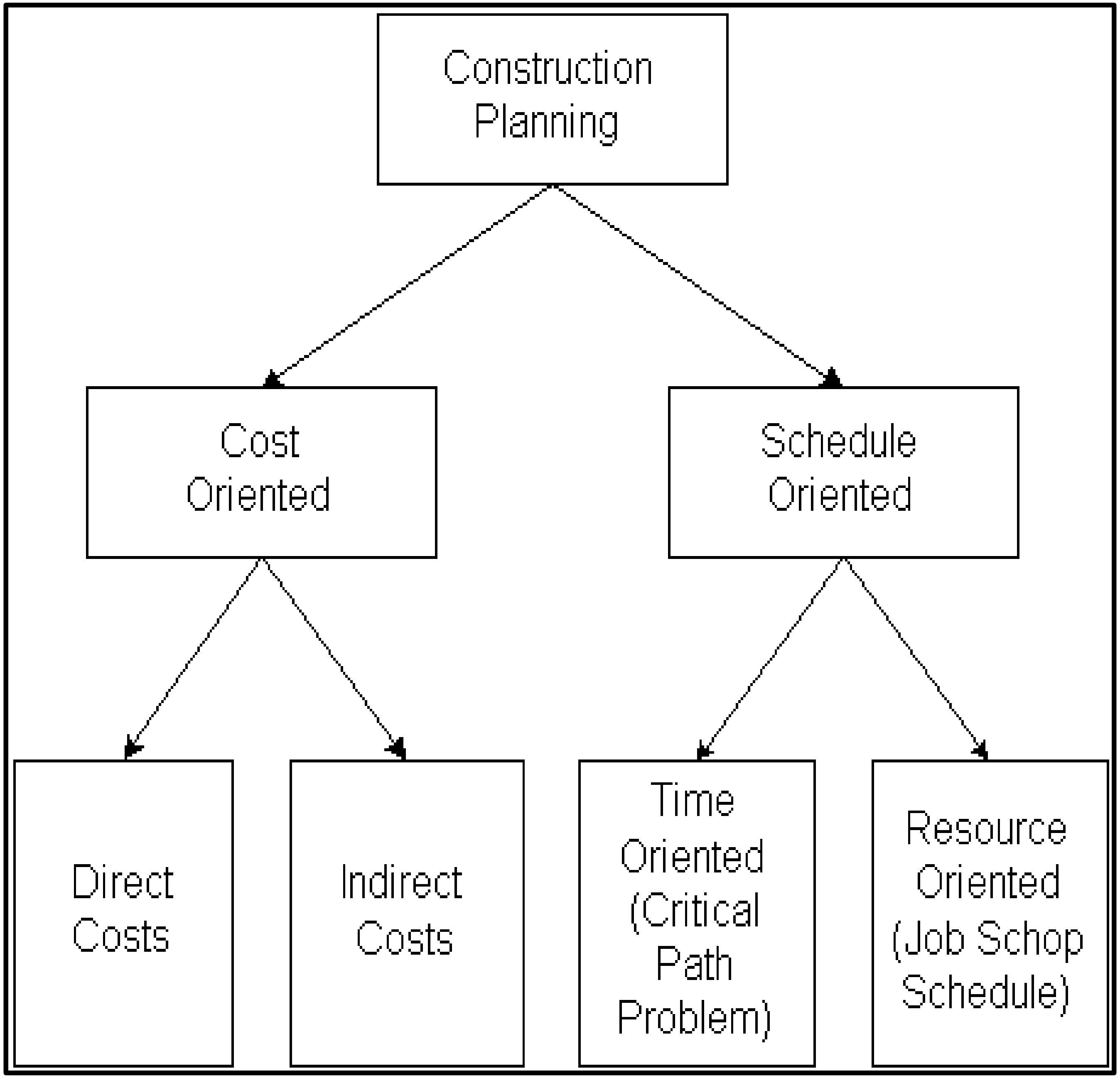
- Guard towers
- Pre-Engineered buildings
- Wash huts & Metal siding works
- Fence installation and site preparation
- Roads & Bridges
- Parking lots
- Underground utilities (water distribution, sanitary sewer system etc.)
- Runways
- Medical facilities / Housing and dining facilities etc.

Basic Concepts in the Development of Construction Plans:

- **Construction planning** is a fundamental and challenging activity in the management and execution of construction projects.
- It involves **the choice of technology**, the definition of work tasks, **the estimation of the required resources** and durations for individual tasks, and the identification of any interactions among the different work tasks.
- A good construction plan is the basis for **developing the budget and the schedule.**

- **Developing the construction plan is a critical task in the management of construction.**
- **In addition to these technical aspects of construction planning, it may also be necessary to make organizational decisions about the relationships between project participants and which organizations to include in a project.**
- **For example, the extent to which sub-contractors will be used on a project is often determined during construction planning.**

- Essential aspects of construction planning include the generation of required activities, analysis of the implications of these activities, and choice among the various alternative means of performing activities.
- In developing a construction plan, it is common to adopt a primary emphasis on either cost control or on schedule control as illustrated in Fig.



Emphases in Construction Planning

- **Traditional scheduling procedures emphasize the maintenance of task precedence (resulting in critical path scheduling procedures) or efficient use of resources over time (resulting in job shop scheduling procedures).**
- **Finally, most complex projects require consideration of both cost and scheduling over time, so that planning, monitoring and record keeping must consider both dimensions.**

Choice of Technology and Construction Method:

- **As in the development of appropriate alternatives for facility design, choices of appropriate technology and methods for construction are often ill-structured yet critical ingredients in the success of the project.**
- **For example, a decision whether to pump or to transport concrete in buckets will directly affect the cost and duration of tasks involved in building construction.**

- A decision between these two alternatives should consider the relative costs, reliabilities, and availability of equipment for the two transport methods.
- Unfortunately, the exact implications of different methods depend upon numerous considerations for which information may be sketchy during the planning phase, such as the experience and expertise of workers or the particular underground condition at a site.

- **It may be necessary to formulate a number of construction plans based on alternative methods or assumptions.**
- **Once the full plan is available, then the cost, time and reliability impacts of the alternative approaches can be reviewed.**
- **This examination of several alternatives is often made explicit in bidding competitions in which several alternative designs may be proposed or value engineering for construction methods may be permitted.**

- In forming a construction plan, a useful approach is to simulate the construction process either in the imagination of the planner or with a formal computer based simulation technique.
- By observing the result, comparisons among different plans or problems with the existing plan can be identified.
- For example, a decision to use a particular piece of equipment for an operation immediately leads to the question of whether or not there is sufficient access.

Fundamental Scheduling Procedures

Relevance of Construction Schedules:

- **Good scheduling** can eliminate problems due to production, facilitate the timely procurement of necessary materials, and otherwise insure the completion of a project as soon as possible.
- In contrast, **poor scheduling** can result in considerable waste as labourers and equipment wait for the availability of needed resources or the completion of preceding tasks.

- **Many owners require detailed construction schedules** to be submitted by contractors as a means of monitoring the work progress.
- **Progressive construction firms use formal scheduling procedures** whenever the complexity of work tasks is high and the coordination of different workers is required.
- **Sharing schedule information via the Internet** has also provided a greater incentive to use formal scheduling methods.

- **A basic distinction exists between resource oriented and time oriented scheduling techniques.**
- **For resource oriented scheduling, the focus is on using and scheduling particular resources in an effective fashion.**
- **For example, on a high-rise building site might be to insure that cranes are used effectively for moving materials; without effective scheduling in this case, delivery trucks might queue on the ground and workers wait for deliveries on upper floors.**

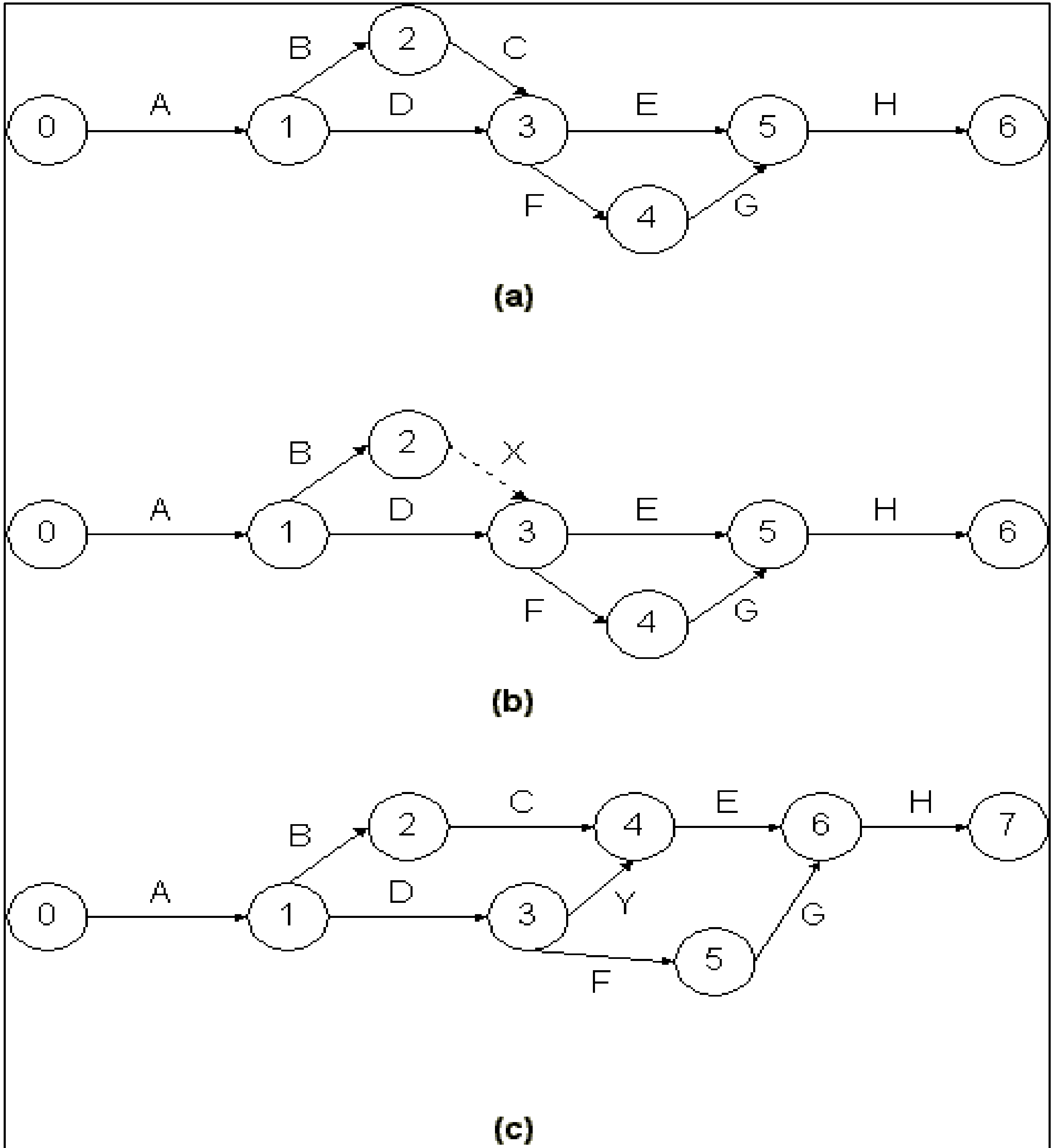
- **For time oriented scheduling**, the emphasis is on determining the completion time of the project given the necessary precedence relationships among activities.
- **Hybrid techniques for resource levelling** or resource constrained scheduling in the presence of precedence relationships also exist.
- **Most scheduling software is time-oriented**, although virtually all of the programs have the capability to introduce resource constraints.

The Critical Path Method:

- The most widely used scheduling technique is the critical path method (CPM) for scheduling, often referred to as **critical path scheduling.**
- This method calculates **the minimum completion time** for a project along with the possible **start and finish times for the project activities.**
- The critical path itself represents the set or sequence of **predecessor/successor** activities which will take the longest time to complete.

- **The duration of the critical path is the sum of the activities' durations along the path.**
- **Thus, the critical path can be defined as the longest possible path through the "network" of project activities.**
- **Formally, critical path scheduling assumes that a project has been divided into activities of fixed duration and well defined predecessor relationships.**
- **A predecessor relationship implies that one activity must come before another in the schedule.**

- To use critical path scheduling in practice, construction planners often represent a resource constraint by a precedence relation.
- A constraint is simply a restriction on the options available to a manager, and a resource constraint is a constraint deriving from the limited availability of some resource of equipment, material, space or labour.
- For example, one of two activities requiring the same piece of equipment.



Activities in a Project Network

Presenting Project Schedules:

- Communicating the project schedule is a vital ingredient in successful project management.
- A good presentation will greatly ease the manager's problem of understanding the multitude of activities and their inter-relationships.
- Graphical presentations of project schedules are particularly useful since it is much easier to comprehend a graphical display of numerous pieces of information than to sift through a large table of numbers.

- **A useful variation on project network diagrams is to draw a *time-scaled* network.**
- **In time-scaled network diagrams, activities on the network are plotted on a horizontal axis measuring the time since project commencement.**
- **The following Figure gives an example of a time-scaled activity-on-branch diagram.**
- **In this time-scaled diagram, each node is shown at its earliest possible time.**

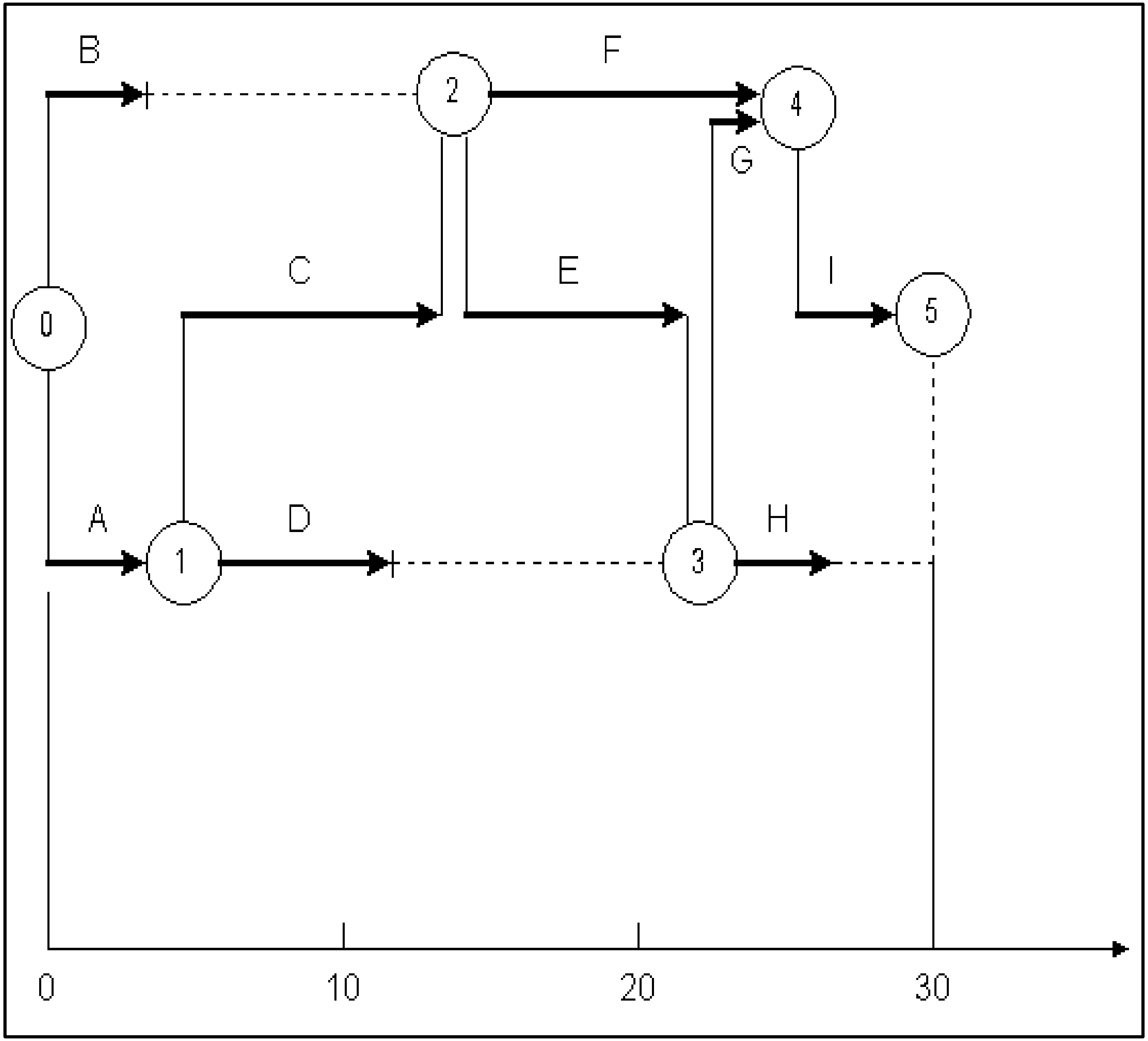
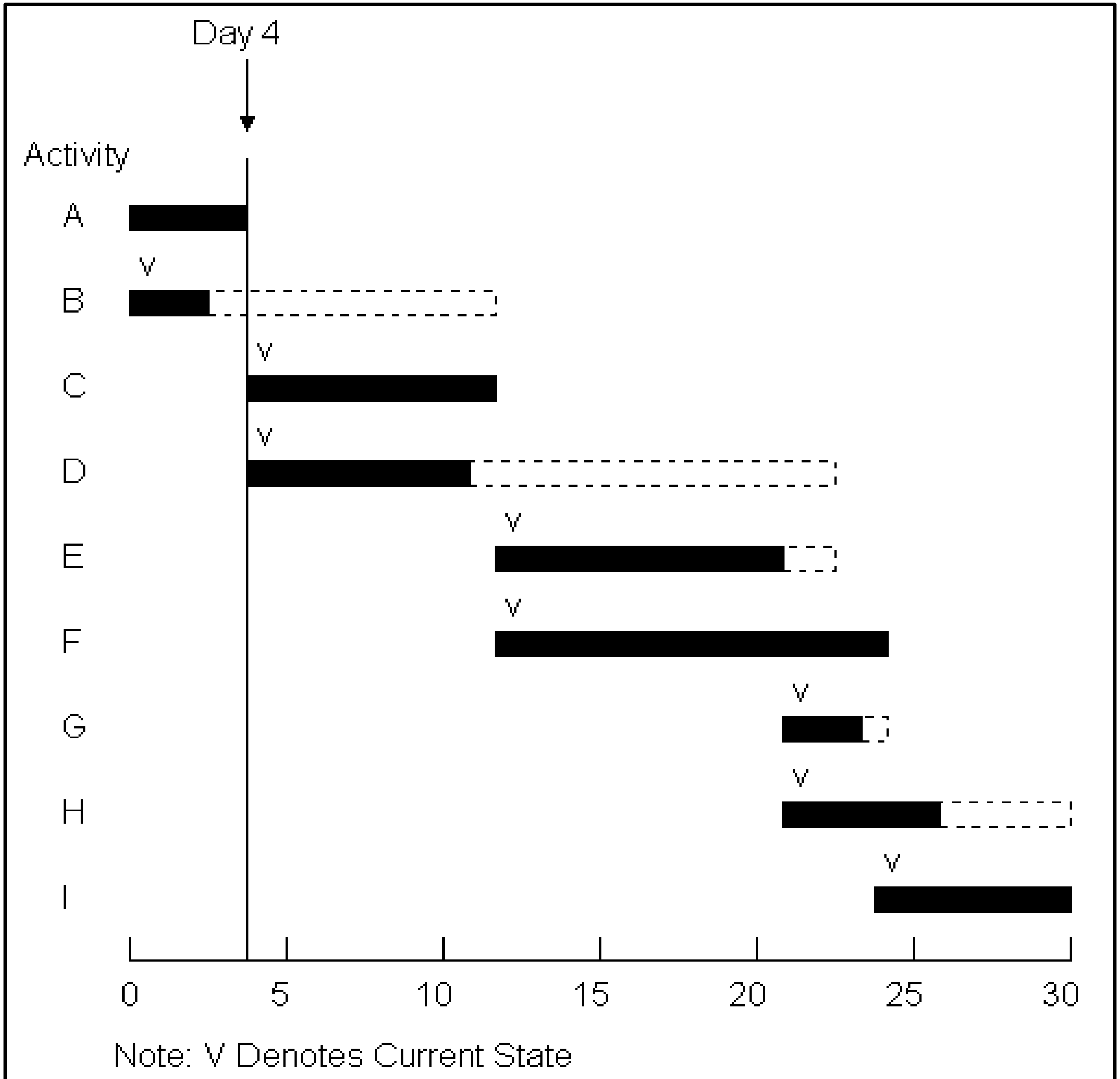


Illustration of a Time Scaled Network Diagram

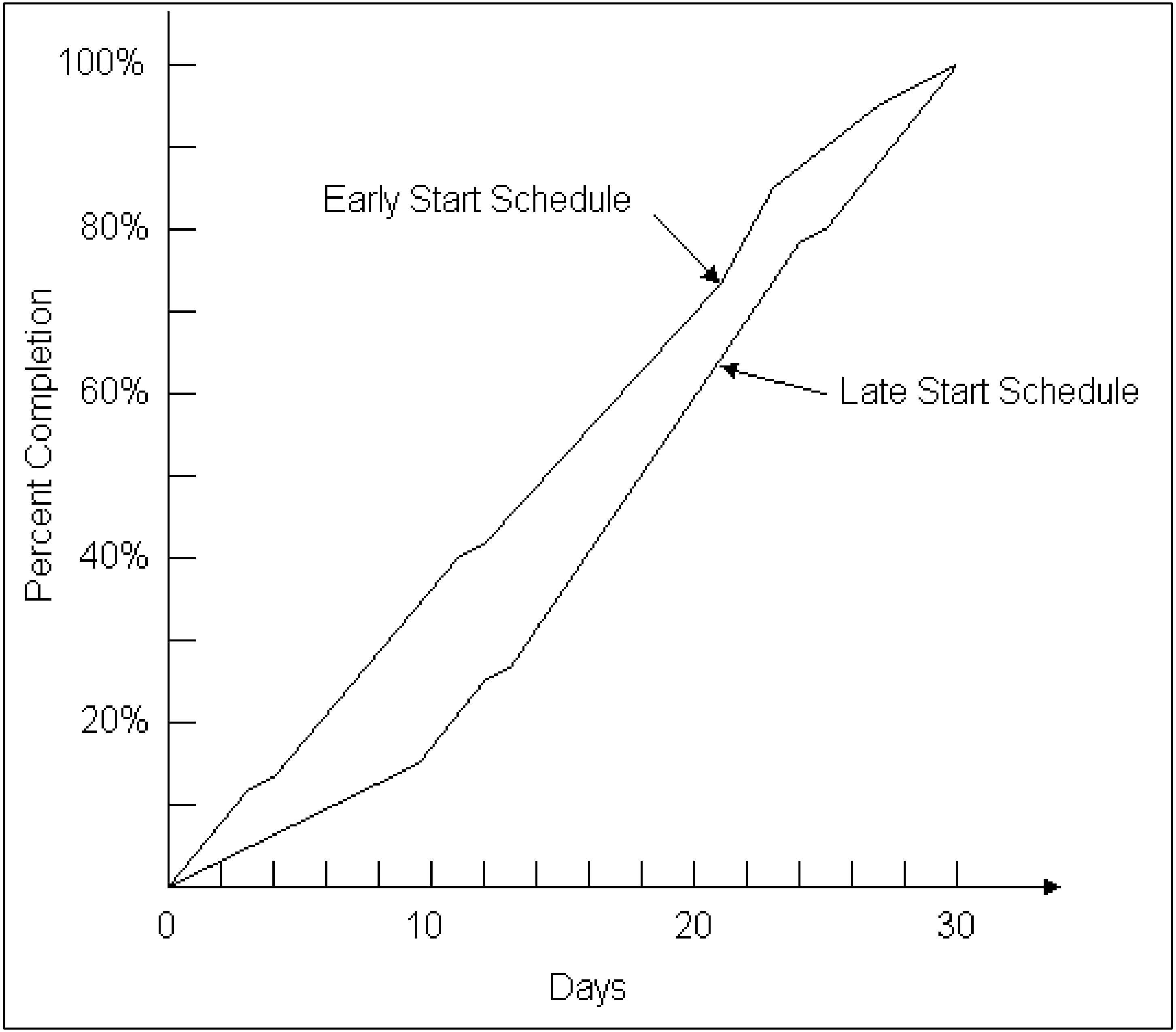
- Another useful graphical representation tool is a bar or Gantt chart illustrating the scheduled time for each activity.
- The bar chart lists activities and shows their scheduled start, finish and duration.
- Activities are listed in the vertical axis, while time project commencement is shown along the horizontal axis.
- During the course of *monitoring* a project, useful additions to the basic bar chart include a vertical line to indicate the current time plus small marks v to indicate the current state of work on each activity.



An Example Bar Chart

Other graphical representations are also useful in project monitoring:

- **Time and activity graphs are extremely useful in portraying the current status of a project as well as the existence of activity float.**
- **For example, the following Figure shows two possible schedules for the project.**
- **The first schedule would occur if each activity was scheduled at its earliest start time, ES(i,j) consistent with completion of the project in the minimum possible time.**



Example of Percentage Completion versus Time

- **With this schedule, Figure shows the per-cent of project activity completed versus time.**
- **The second schedule in Figure is based on latest possible start times for each activity, LS(i,j).**
- **The horizontal time difference between the two feasible schedules gives an indication of the extent of possible float.**
- **Time versus completion curves are also useful in project monitoring.**

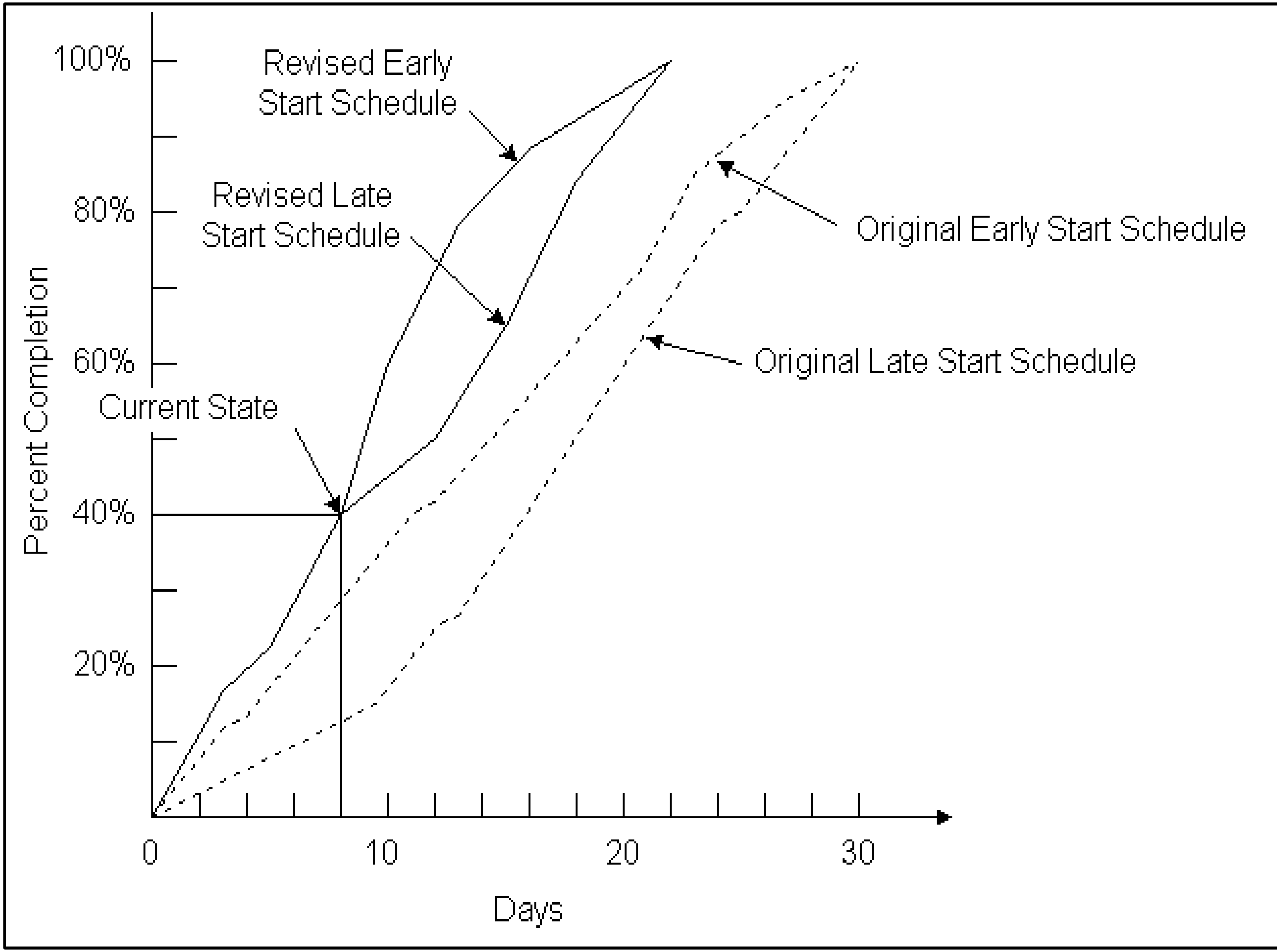
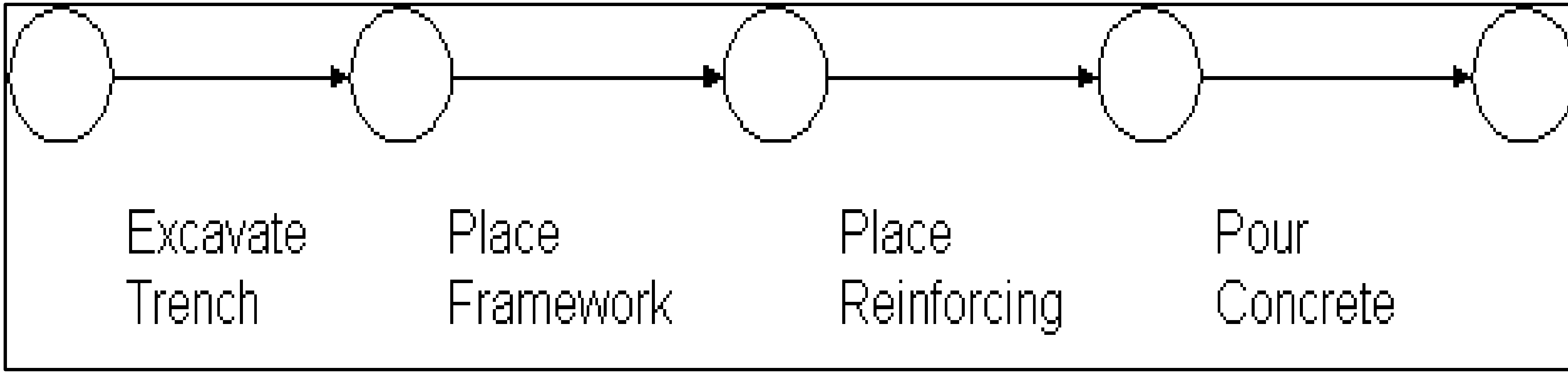


Illustration of Actual Percentage Completion versus Time

Defining Precedence Relationships Among Activities:

- **Once work activities have been defined, the relationships among the activities can be specified.**
- ***Precedence* relations between activities signify that the activities must take place in a particular sequence.**
- **Numerous natural sequences exist for construction activities due to requirements for structural integrity, regulations, and other technical requirements.**

- For example, design drawings cannot be checked before they are drawn.
- Diagrammatically, precedence relationships can be illustrated by a *network* or *graph* in which the activities are represented by arrows as in Figure are called *branches* or *links* in the *activity network*, while the circles marking the beginning or end of each arrow are called *nodes* or *events*.
- In this figure, links represent particular activities, while the nodes represent milestone events.



Illustrative Set of Four Activities with Precedence

- For example, one activity might not be able to start for several days after the completion of another activity.
- As a common example, concrete might have to cure (or set) for several days before formwork is removed.
- This restriction on the removal of forms activity is called a *lag* between the completion of one activity (i.e., pouring concrete in this case) and the start of another activity (i.e., removing formwork in this case).
- Many computer based scheduling programs permit the use of a variety of precedence relationships.

- Finally, it is important to realize that different types of precedence relationships can be defined and that each has different implications for the schedule of activities:
- Some activities have a necessary technical or physical relationship that cannot be superseded.
- For example, concrete pours cannot proceed before formwork and reinforcement are in place.

- **Some activities have a necessary precedence relationship over a continuous space rather than as discrete work task relationships.**
- **For example, formwork may be placed in the first part of an excavation trench even as the excavation equipment continues to work further along in the trench.**
- **Formwork placement cannot proceed further than the excavation, but the two activities can be started and stopped independently within this constraint.**

- **Some "precedence relationships" are not technically necessary but are imposed due to implicit decisions within the construction plan.**
- **For example, two activities may require the same piece of equipment so a precedence relationship might be defined between the two to insure that they are not scheduled for the same time period.**
- **As a second example, reversing the sequence of two activities may be technically possible but more expensive.**

Precedence Definition for Site Preparation and Foundation Work:

- Suppose that a site preparation and concrete slab foundation construction project consists of nine different activities:
- A. Site clearing (of brush and minor debris),
  B. Removal of trees,
  C. General excavation,
  D. Grading general area,
  E. Excavation for utility trenches,
  F. Placing formwork and reinforcement for concrete,
  G. Installing sewer lines,
  H. Installing other utilities,
  I. Pouring concrete.

Estimating Activity Durations:

- In most scheduling procedures, each work activity has an associated time duration.
- These durations are used extensively in preparing a schedule.
- For example, suppose that the durations shown in Table were estimated.
- The entire set of activities would then require at least 3 days, since the activities follow one another directly and require a total of 1.0 + 0.5 + 0.5 + 1.0 = 3 days.

Durations and Predecessors for a Four Activity Project Illustration

Activity	Predecessor	Duration (Days)
Excavate trench	---	1.0
Place formwork	Excavate trench	0.5
Place reinforcing	Place formwork	0.5
Pour concrete	Place reinforcing	1.0

- **If another activity proceeded in *parallel* with this sequence, the 3 day minimum duration of these four activities is unaffected.**
- **More than 3 days would be required for the sequence if there was a delay or a lag between the completion of one activity and the start of another.**
- **All formal scheduling procedures rely upon estimates of the durations of the various project activities as well as the definitions of the predecessor relationships among tasks.**

- **For example,** the duration of an activity D_{ij} such as concrete formwork assembly might be estimated as:

$$D_{ij} = \frac{A_{ij}}{P_{ij} N_{ij}}$$

where A_{ij} is the required formwork area to assemble (in square yards), P_{ij} is the average productivity of a standard crew in this task (measured in square yards per hour), and N_{ij} is the number of crews assigned to the task.

- **Linear Scheduling Method (LSM) is a graphical scheduling method focusing on continuous resource utilization in repetitive activities.**
- **It is believed that it originally adopted the idea of Line-Of-Balance method.**
- **The Linear Scheduling Method is a graphical scheduling method that focuses on continuous use of resources, in a repetitive manner, along both a time and a distance axis, along the optimal Right of Way (ROW.)**

- **LSM is used mainly in the construction industry to schedule resources in repetitive activities commonly found in highway, pipeline, high-rise building and rail construction projects.**
- **These projects are called repetitive or linear projects.**
- **The main advantages of LSM over Critical Path Method (CPM) is its underlying idea of keeping resources continuously at work.**

- In other words, it schedules activities in such a way that:
  - resource utilization is maximized;
  - interruption in on-going process is minimized, including hiring-and-firing; and
  - the effect of the learning curve phenomenon is maximized

Vertical Mast lifts

Vertical Wheel Loaders

Vertical Hoist

Crane in Construction

Horizontal Construction Equipment's

Horizontal Underground Equipment's

Horizontal Navigators

Horizontal Grinders & Pavers

EQUIPMENT FOR OTHER WORKS - II

- Concrete construction equipment is very important for the construction companies.
- With good quality concrete construction equipment, a construction company can get quality construction work done in lesser amount of time.
- It can therefore cut down on its labour costs and increase profits by giving the quality construction services to its clients in a faster way.

- **With advancement in technologies, today a number of concrete construction equipment's have come up for the use of construction companies for improved construction processes.**
- **Some of the basic and most important types of concrete construction equipment widely used in construction processes are:**
- **Concrete Batching Plant**
- **Concrete Mixer**
- **Concrete Pumps**
- **Shot-Crete Machine**

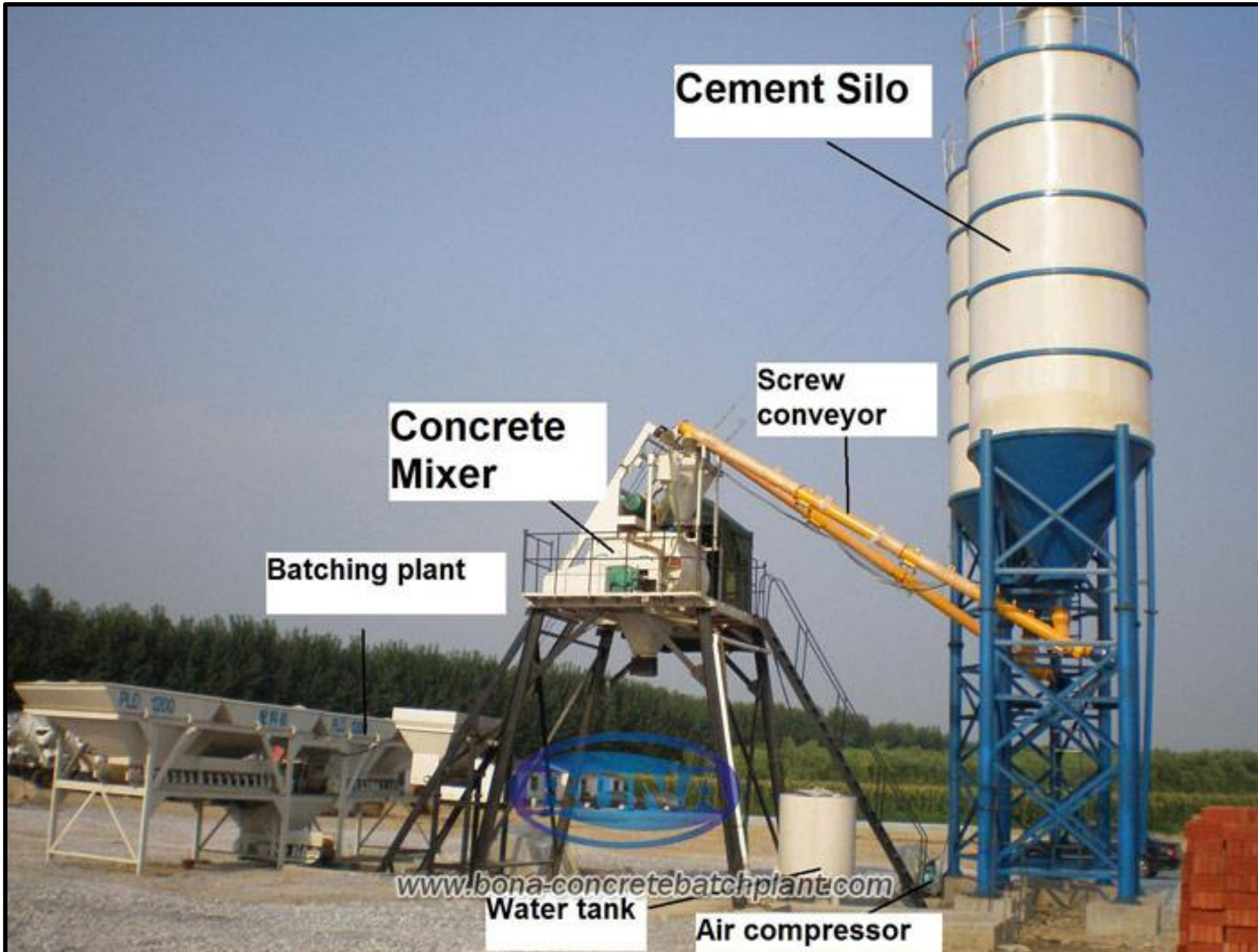
- Concrete Batching Plant
- A concrete plant or batching plant is very important equipment for the concrete construction.
- With the help of concrete batching plant, concrete is produced by proper mixing of all the ingredients like sand, gravel, water and cement and then transported to concrete construction site ready to be poured for use.

- The main advantage of using concrete batching plant is that it reduces the problems of inefficiency and wastage happening during the concrete production at construction sites.
- The batching plants can be of two forms either the stationary heavy production units or the famous mobile batching plants which can be used to produce and transport the concrete mix from site to site.

- Concrete Mixer
- Concrete mixers used at the construction sites are the mechanical devices that homogeneously combine cement, sand, gravel and water to form a fine concrete mixture.
- These help in delivery of ready-to-pour concrete to the construction jobs where large pour volumes are required.
- Different types of concrete mixers are used at the construction sites which include transit mixer, self loading concrete transit mixers, hand fed types of concrete mixer etc.

- Concrete Pumps
- A concrete pump is a kind of equipment used for transferring liquid concrete by pumping at construction sites.
- Concrete pumps help in placing concrete faster and more accurately with less labour than any other method.
- By employing on-site concrete pumps for placing of concrete at construction site will be handled by concrete pump.

- Concrete pump can be a truck mounted or trailer mounted concrete pump.
- Both of them provide flexibility on a job site allowing the constructors to have easy access to areas that are not accessible without a pump.
- So, for faster concrete placing work at construction sites, concrete pumps are the best devices to be employed.


Cement Silo
Screw conveyor
Concrete Mixer
Batching plant
www.bona-concretebatchplant.com
Water tank
Air compressor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CONCRETE PUMPING
CONCRETE PUMPING

Construction Equipments for Successful Concrete Handling


Apollo
STP-4500


Apollo


Apollo

- **Shot-Crete Machine**
- **Shot-Crete machines are used for concrete spraying applications at the construction sites.**
- **These are usually employed for wet and dry concrete spraying applications.**
- **Because of their compact designs, these are useful at locations where space is at premium.**

- **Lining of water tanks, mines, swimming pools and backfilling of tunnel construction are some applications where these shot-Crete machines are used.**
- **All these types of concrete construction equipment's are very helpful for the construction tasks and therefore it is very important that a construction company should possess them in best form for quality applications.**

What is Guniting

- The guniting is the most effective process of repairing concrete work which has been damaged due to inferior work or other reasons. It is also used for providing an impervious layer.
- The gunite is a mixture of cement and sand, the usual proportion being 1:3. A cement gun is used to deposit this mixture on the concrete surface under a pressure of about 20 to 30 N/cm^2.

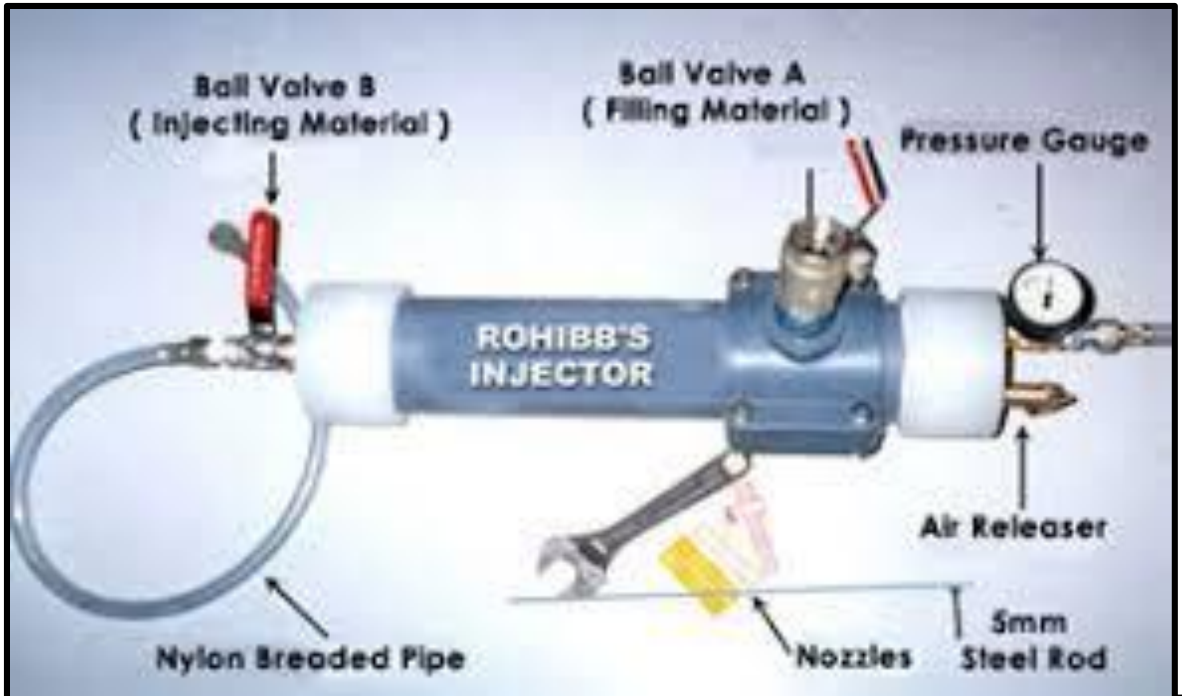
Guniting in tunnel

Guniting in wall

A guniting machine

EQUIPMENT FOR REPAIR & REHABILITATION

- RESIN INJECTED
- SAND BLASTED
- BONDED
- COATED
- GROUTED
- COMPRESSORS
- CLEANERS


Ball Valve B
(Injecting Material)
Ball Valve A
(Filling Material)
Pressure Gauge
ROHIBB'S
INJECTOR
Air Releaser
5mm
Steel Rod
Nozzles
Nylon Breaded Pipe

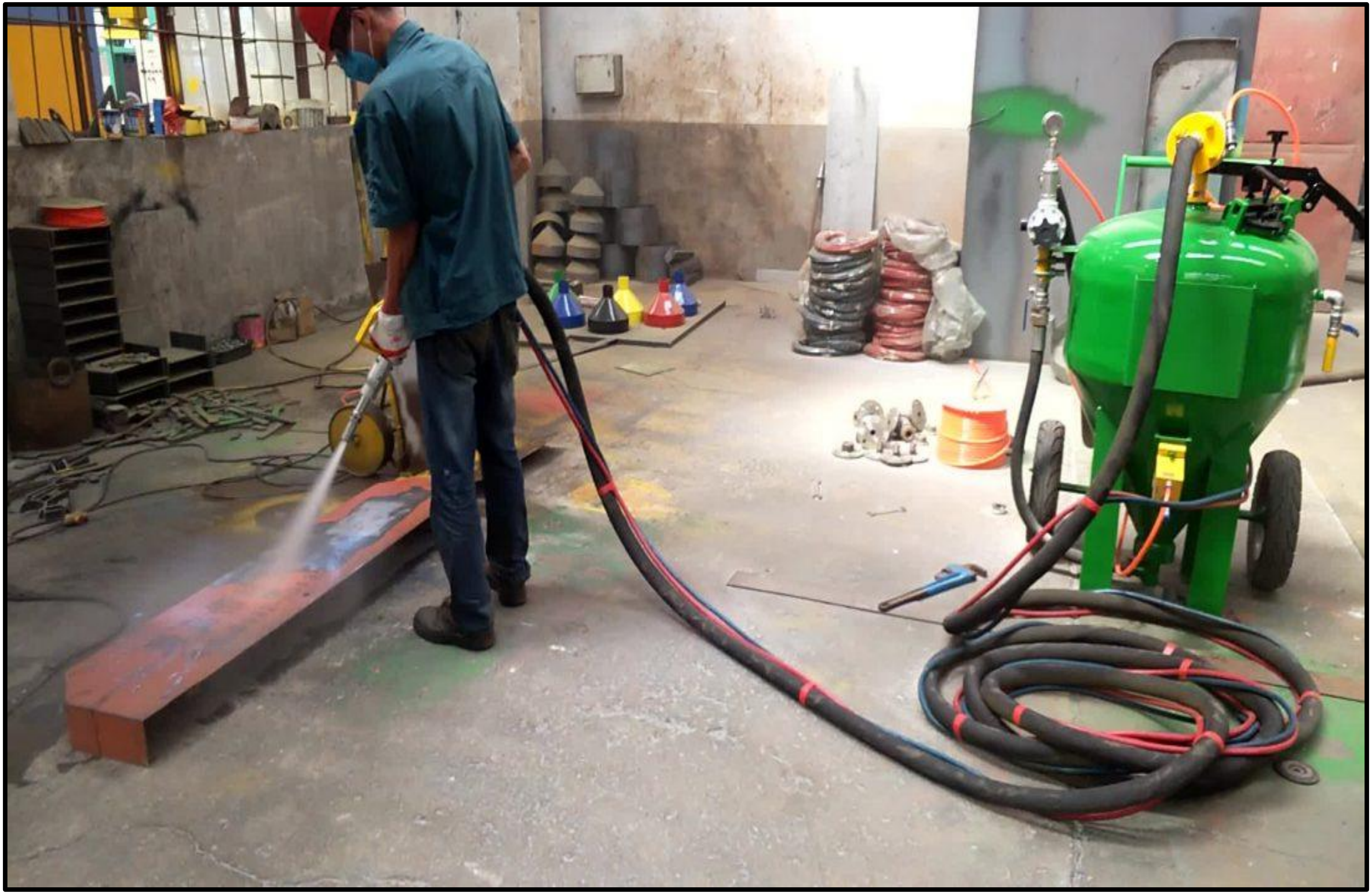

HITACHI


LEC GROUTING EQUIPMENT

Tile & Grout Cleaning Spinner Tools

- Turboforce
- Hydroforce
- Mytee
- Rotovac

& More!



BULK SANDBLASTING POTS

Rent a bulk sandblast pot for those big jobs where multiple operators are necessary.

Rented by: Week / Month

Related Rentals / Consumables:
Air Hose, Blast Hose, Blast Nozzles, Respirator Package, Air Dryer, Air Compressor, Abrasive, Bulk Bag Rack, Abrasive Storage Hopper.

Available for rent, abrasive storage hoppers allow for fast loading of bulk abrasive.


AH251
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942

SAFETY TIPS

- Awareness
- Training
- Communication
- Documentation
- Proper equipment
- Supervision
- Innovation
- Transparency

TUNNELLING EQUIPMENT

- **Crawler Excavators**
- **Tunnel excavators are special machines which can be used in all conventional types of tunnelling applications:**
- **Tunnel drilling machines have been used to create cross-tunnels, when explosives are being used for secondary profiling, and, of course, for direct excavator tunnelling.**
- **Particular features of these machines are their economic operation, high performance, and reliability.**

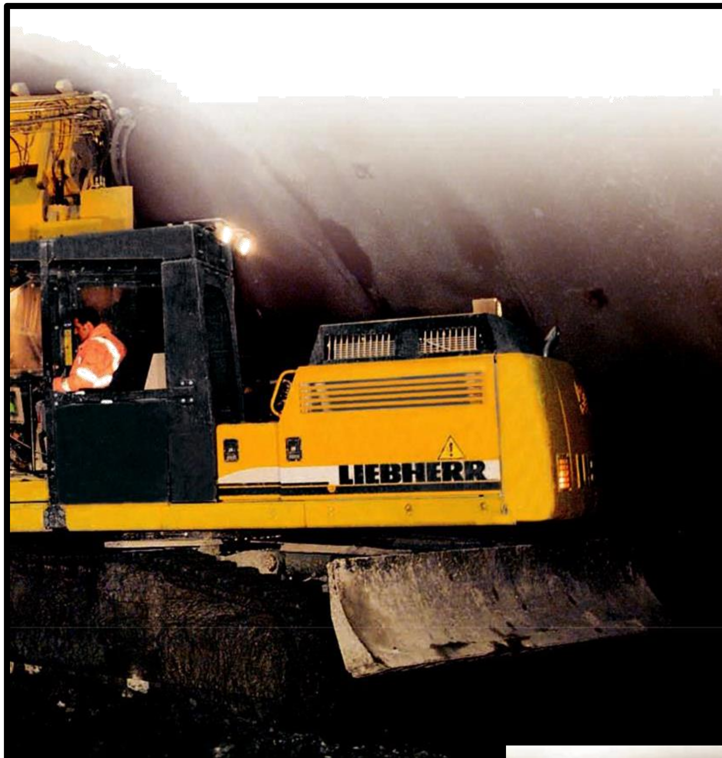
- Economy with High Performance
- The operation of a tunnel excavator becomes efficient when the machine can cut out the tunnel profile required in economical fashion.
- Tunnel excavator must produce a high hydraulic capacity and be provided with operational fittings which are tailored to the particular application.

- **Tunnel excavators meet all the high demands imposed in tunnel construction in every respect, and consistently designed to achieve real economical performance.**
- **Reliability**
- **The mechanical quick coupling system is provided with a reinforced locking unit and a wear protection element on the hook side. The sophisticated concept and the tried and trusted quality make tunnel excavators the absolute standard for reliability.**

- **Safety & Comfort**
- **To prevent damage from falling rocks, all the hoses in exposed locations on the equipment fittings are additionally secured by protection plates. The bucket cylinder is also attached in a lower position, and a cover fitted to both the lifting rams protects the hoses running between them.**

- **The windows on the right and at the rear are fitted with polycarbonate panes, resistant to scratches and impacts, and feature extremely good visibility properties.**

- **WHEEL LOADERS**
- **In comparison with conventional drive systems, the hydrostatic drive used by wheel loaders allows for a reduction in fuel consumption of up to 25%.**
- **This cuts operating costs and reduces burden on the environment.**
- **At the same time, the use of the hydrostatic drive means that the Diesel engine can be in-stalled in a special position, lengthwise at the rear, with the output shaft pointing backwards.**
- **This leads to a noticeably lighter operating weight with a higher tipping load and greater production capacity per operating hour.**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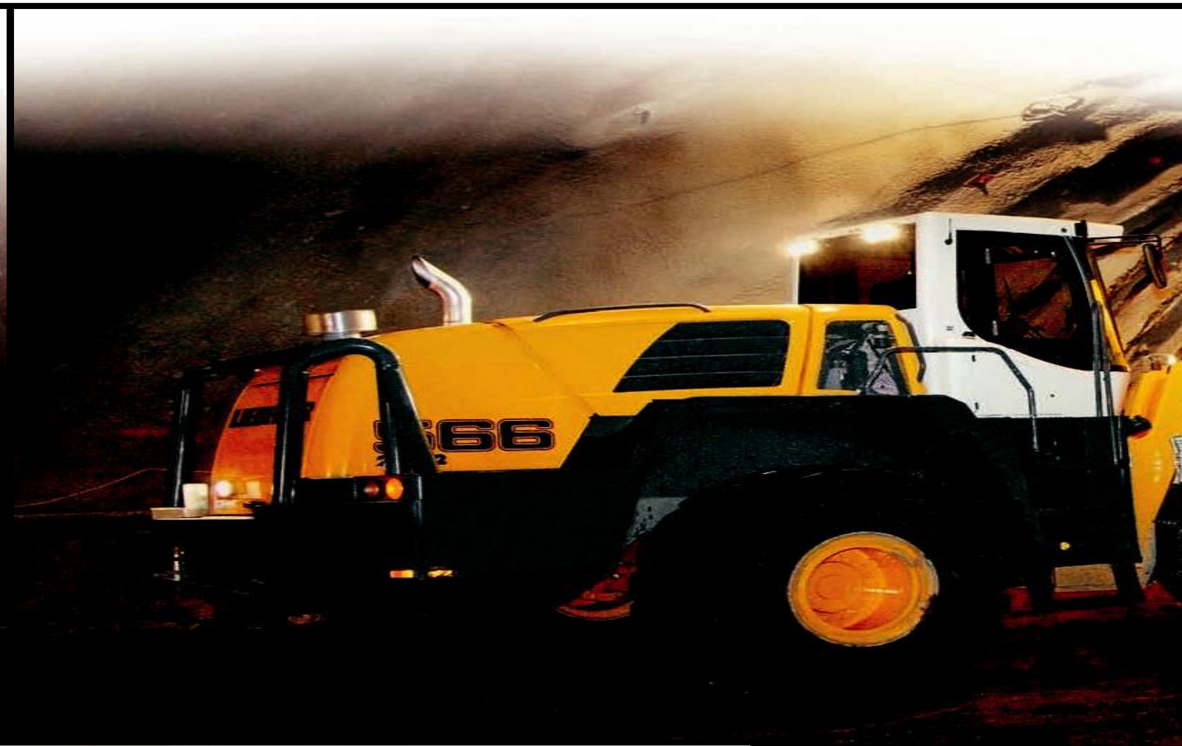

LIEBHERR

- Crawler Loaders provide impressive performance in tunnel operations by their superb production capacity.
- This is the result of unbeatable short cycle times, and a high bucket filling factor.
- Hydrostatic travel drive, the full thrust capacity can be applied to both tracks without interruption, therefore ensuring excellent handling performance under load.
- Crawler loaders are powered by economical Diesel engines running at a constant engine speed-another bonus for the economic success of tunnel construction projects.

- **Reliability**
- **All components used feature extremely long service life even under the toughest conditions encountered in a tunnel. Maintenance-free components, such as tracks and hinge pins, and lengthy maintenance intervals ensure that effort and expenditure on servicing and maintenance can be kept to a minimum.**
- **Safety & Comfort**
- **The front window can be fitted with a grille to provide protection against falling rock fragments. By way of a display in the cab, this provides a better view to the rear, and therefore provides greater safety for personnel who are within the working area of the machine.**

- **Depending on the application demands, travel speed forwards and backwards can be programmed from 0 – 10 km/h. In addition, the float position, automatic bucket positioner, and automatic lift kick out deactivation can be easily pre-selected in the operational controls.**


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Machines, Equipment's and Systems for Tunnel Construction

Concrete delivery into the ring space -- World-record for high-rise pumping – 532 m in Italy

CONCRETE PUMPS

Transfer of muck in a shaft, construction site

Auger conveyor with two muck pumps

Decompression pump, directly flanged at the earth pressure-balanced tunnel boring machine

Transfer of muck to the pump feeding device

- The wet spraying method is becoming more and more popular in tunnel construction
- The specific benefits of the wet-spraying concreting process are demonstrated in tunnelling: less spray mist, little rebound, low energy requirements and comparatively low installation effort.
- During the wet-spraying process, the accelerator and compressed air are regulated, combined with the pumping concrete and sprayed. The upper limit for the grain size of the concrete lies at approx. 8 mm.

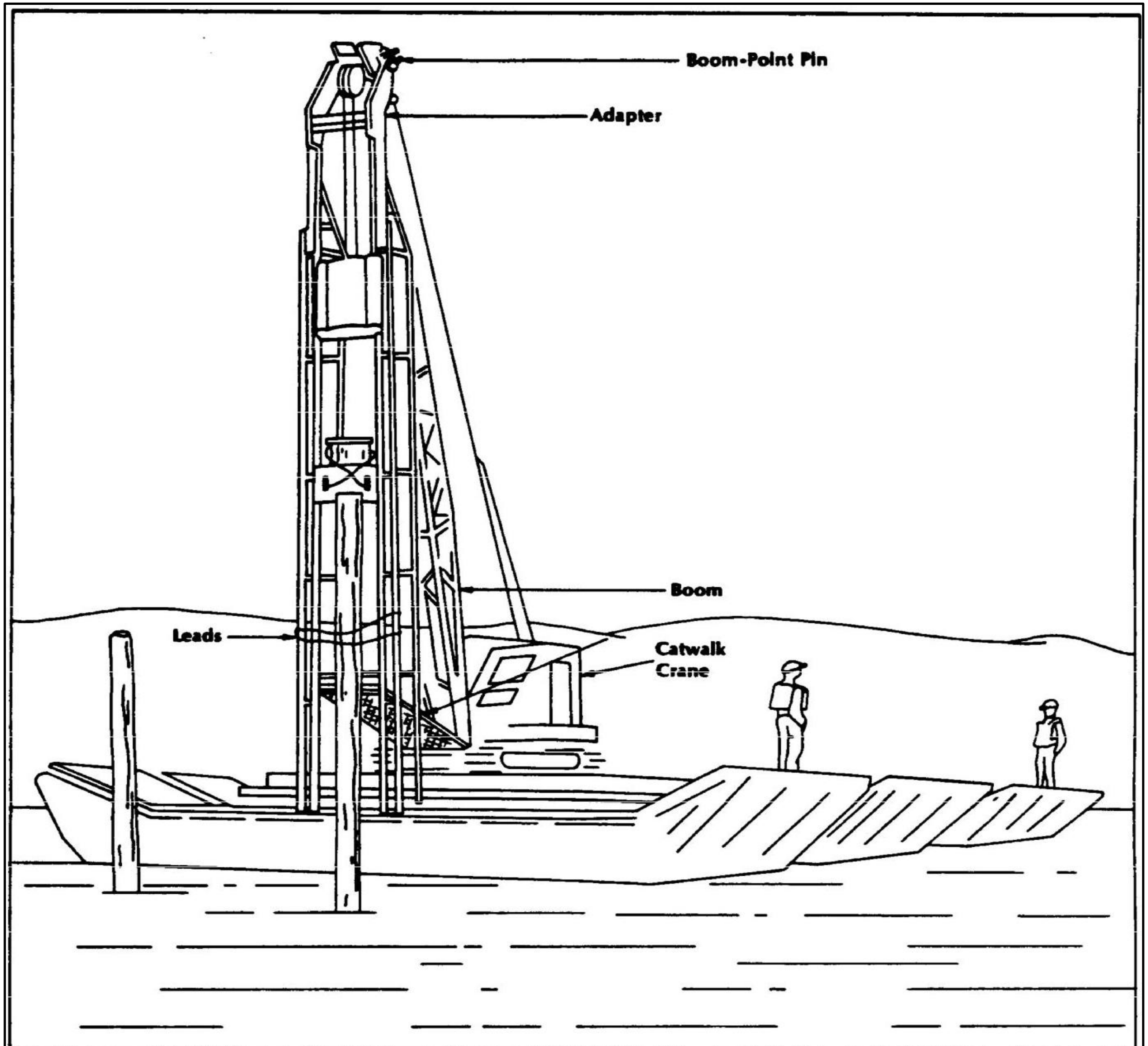
Concrete spraying made simple, secure and convenient with the high performance manipulator

Experts on Sprayed Concrete

PILE-DRIVING EQUIPMENT

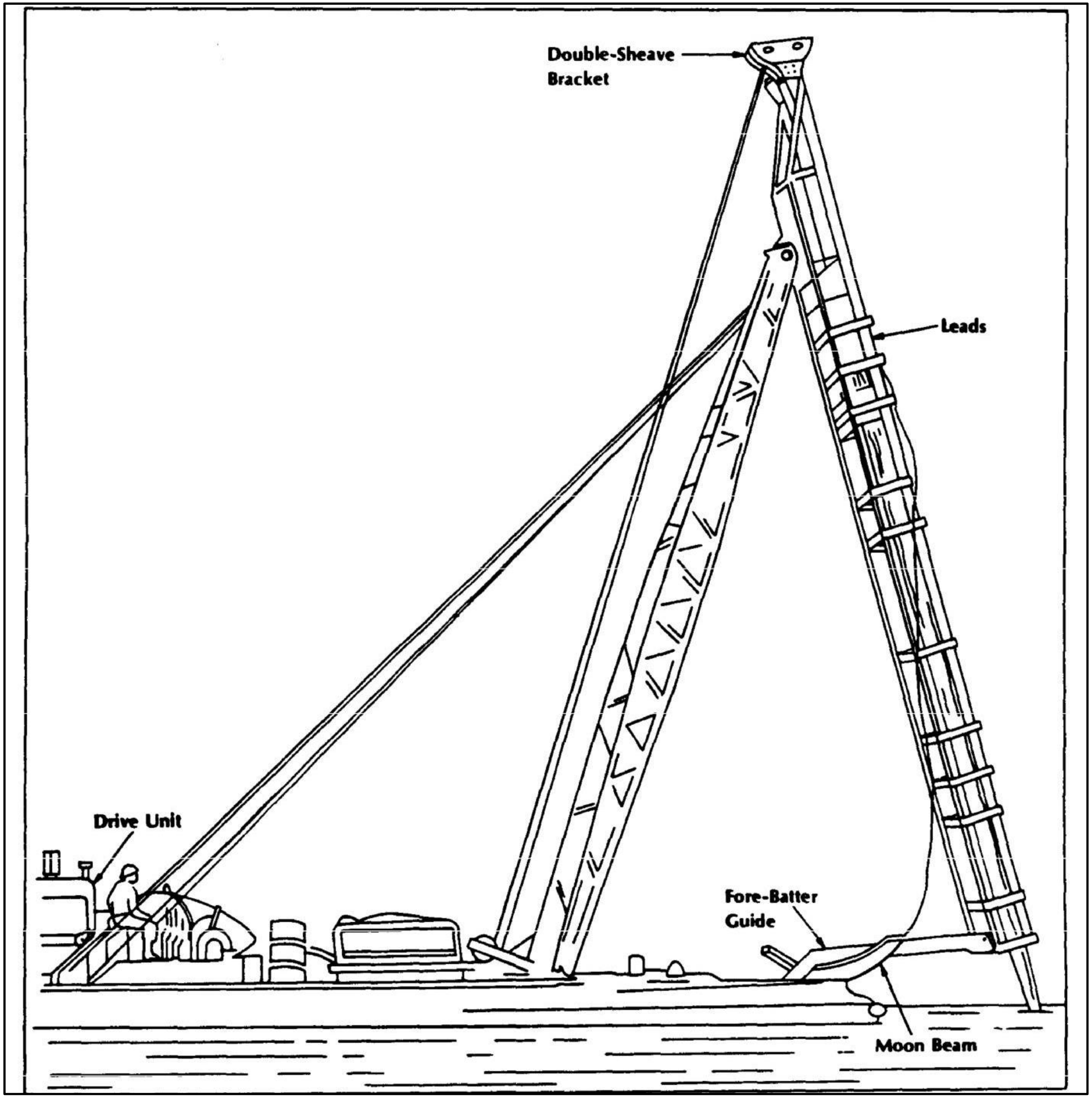
- Basic driving and installing methods
- Piles are installed or driven into the ground by a rig which supports the leads, raises the pile, and operates the hammer.
- Rigs are usually manufactured, but in the field they may be expedient, that is, constructed with available materials.
- Modern commercial rigs use vibratory drivers while most older and expedient rigs use impact hammers.
- The intent is the same, that is to drive the pile into the ground (strata).

- Rig Mounting and Attachments
- Pile-driving rigs are mounted in different ways, depending on their use.
- Most pile driving is performed using a steel-frame, skid-mounted pile driver or power cranes, crawlers, or truck-mounted units, with standard pile-driving attachment.
- The attachments include adapters used to connect the leads to the top of the crane boom leads and a catwalk or lead braces used to connect the foot of the leads to the base of the boom.



Crane with Standard Pile Driving Attachments

- Steel-frame, skid-mounted pile drivers
- Steel-frame, skid-mounted pile driver with a gasoline-driven engine is a class IV item in the following figure.
- This pile driver may be used on the ground or on any permanent structure or sturdy transport.
- It can drive vertical or batter piles.
- The reach from the base of the boom to the front of the leads depends upon the weight of the hammer and power units.
- Reach may be increased by ballasting the back of the skid frame, or by securing it to the deck on which it rests to counterbalance the weight of the equipment.



Steel frame, skid mounted Pile Driver

- **The skid-mounted pile driver consists of the following components:**
- **a. Skid frame**
- **b. Boom**
- **c. Leads**
- **d. Guides**
- **e. Drive unit**
- **f. Hammer**

- Driving devices (hammer and vibratory driver)
- There are three impact hammers used for pile-driving: the drop hammer, the pneumatic or steam hammer, and the diesel hammer.
- Drop hammers and diesel hammers are standard engineering equipment.
- Vibratory drivers/extractors are not classified as hammers and do not require pile caps for protection against impact stresses.
- They are clamped to the pile to vibrate as a unit.

- **Drop hammers:** The drop hammer is a simple pile-driving hammer consisting of a block of metal raised in the leads by the drive unit, then permitted to drop, striking the pile cap.
- Drop hammers are cumbersome, and their driving action is slow compared to other hammers.
- Velocities at impact are high and damage the top of a pile.
- For most efficient driving, the weight of a hammer twice that of the pile will give the best results.
- Drop hammers should be used only in remote sites or for a small number of pilings.

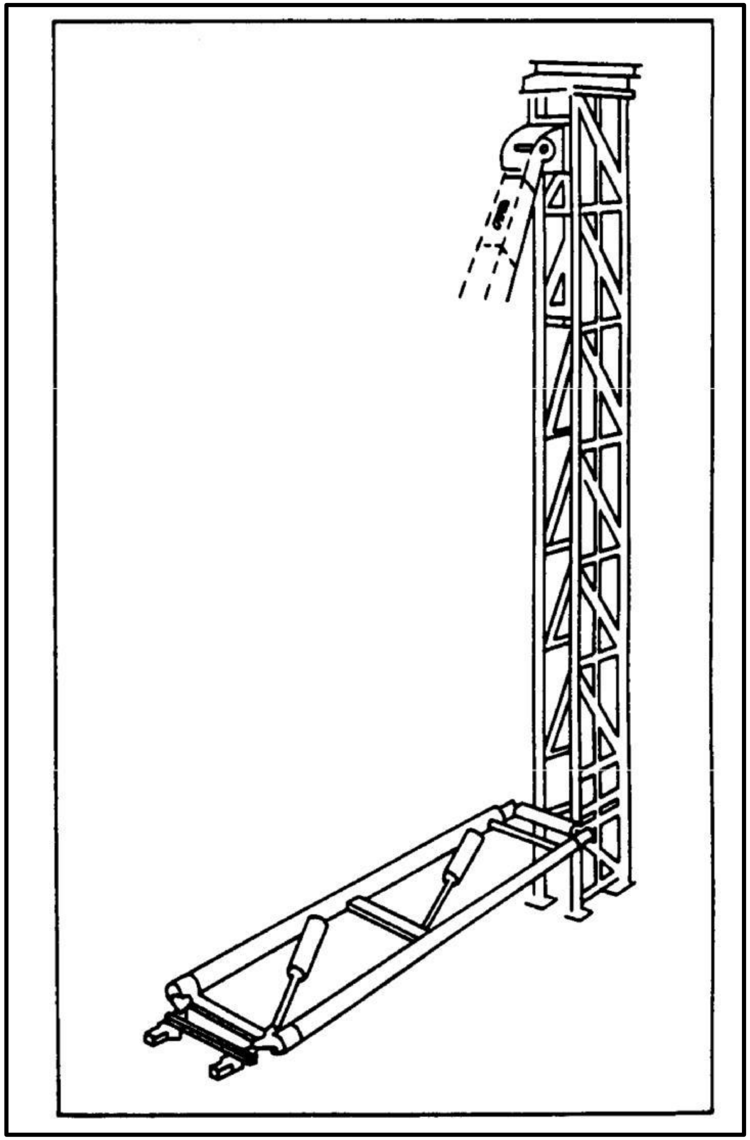
- **Air or steam hammers:** The air or steam hammers consist of stationary cylinders and moving rams which include a piston and a striking head.
- The piston is raised by compressed air or steam pressure.
- In double-acting hammers, the air or steam pressure works on the upstroke and down stroke.
- Because they provide a high rate of blows (90 to 150 blows per minute), they keep the pile moving and prevent the building of friction thus enabling faster driving.

- Diesel hammers: Diesel hammers are self-contained and need no air or steam lines.
- Fuel tanks are a part of the rig.
- Diesel hammers are well suited for military operations.
- Heavier hammers are more suitable for use with 30-ton to 40-ton cranes.
- Diesel hammers may be either open-ended or closed-ended.

- **Vibratory drivers/extractors:** Vibratory drivers are a recent development in pile-driving equipment.
- They are used in commercial pile construction, especially in driving sheet piling.
- Vibratory drivers usually require either an auxiliary hydraulic or electric power supply.
- They consist of the vibrating unit which includes the rotating eccentric weights, the suspension system that isolates the vibratory forces from the lifting device, and the clamping system which connects the vibratory driver to the pile.

- **Caps and Cushions:**
- **Caps and cushions protect the top of the pile and reduce the damage caused by the impact of the hammer.**
- **Although they serve the same purpose, they vary for different types of hammers.**

- **Pile-driving leads:**
- **Pile-driving leads are tracks for sliding the hammer and guides to position and steady the pile during the first part of the driving.**
- **Standard steel leads are supplied in l-foot and 15-foot lengths. The 15 -foot length is the top section.**
- **Leads must be approximately 20 feet longer than the pile to provide space for the hammer and accessories. There are three types of leads.**



1. Swinging leads
2. Fixed, under-hung leads
3. Fixed, extended leads

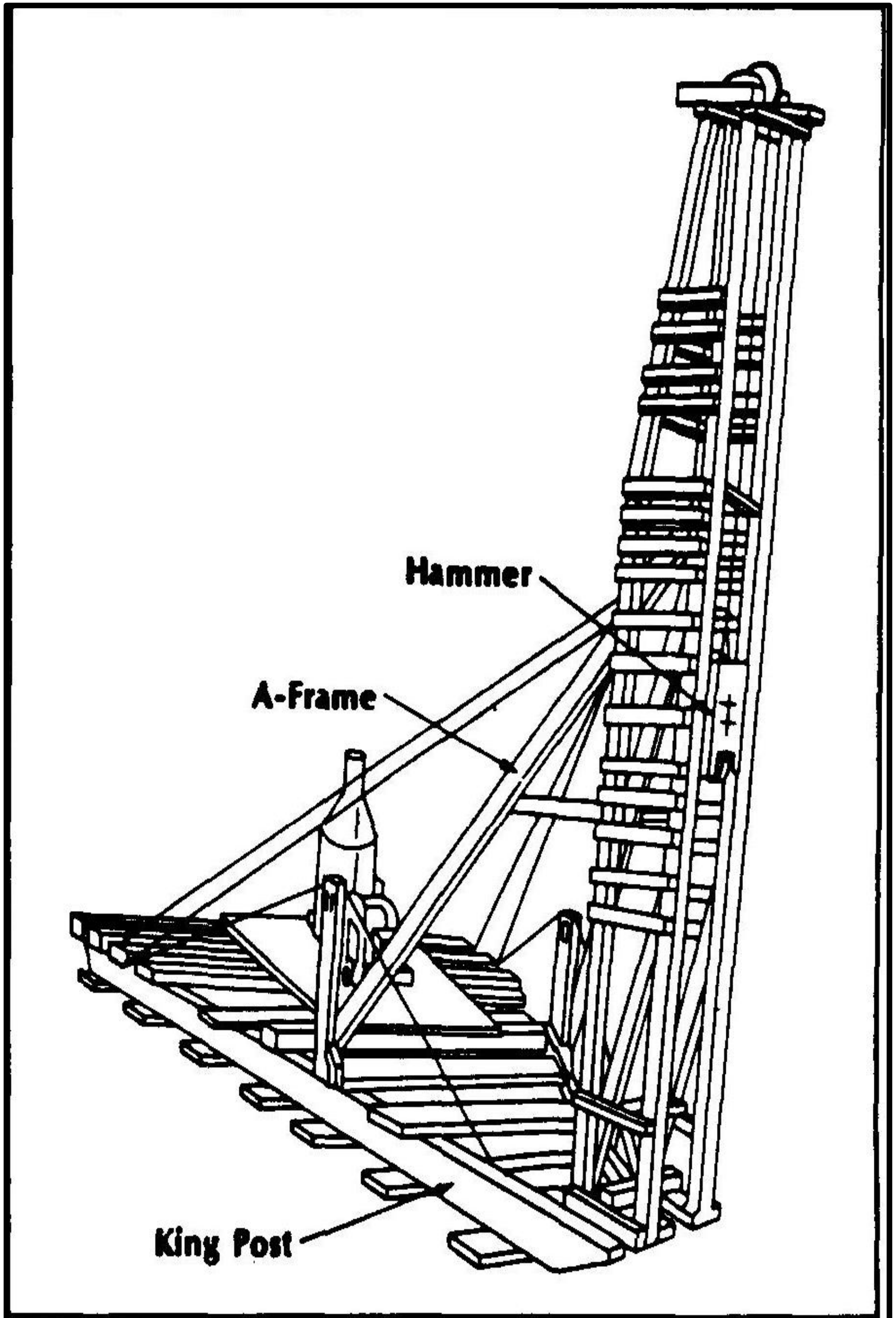
Pile Driving Leads with Bottom Brace

- Spotters and lead braces:
- The spotter connects the bottom of fixed leads (under-hung or extended) to the front of the crane.
- With standard leads used with a crane, the catwalk connects between the bottom of the leads and the front of the crane's revolving upper machinery deck.
- The front of the spotter is moved for and aft for batter piles, and side to side to plumb piles either hydraulically or manually.
- Special bottom braces are available which permit this operation.

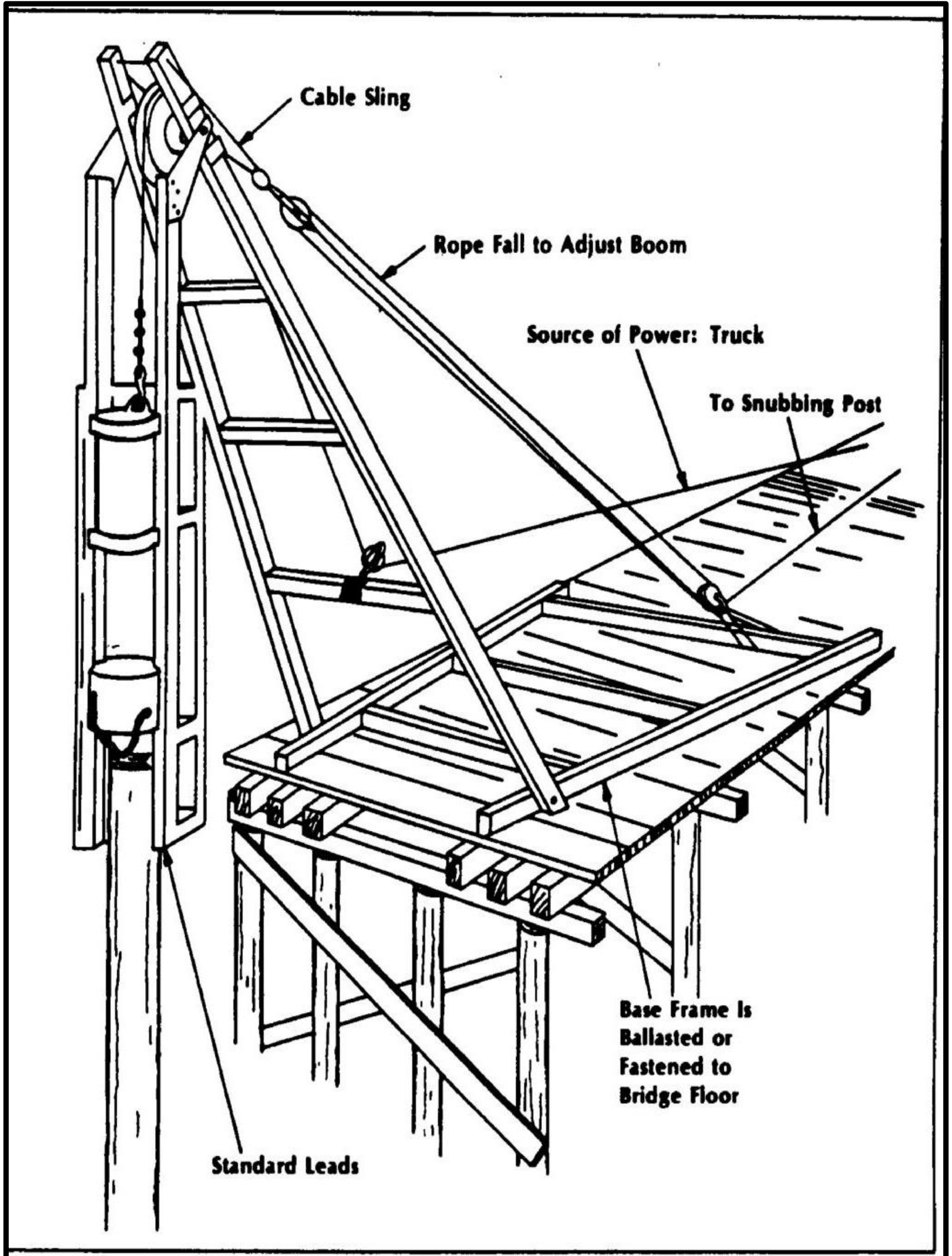
- **Followers:** Followers are fabricated pile extensions placed between the top of a pile and the hammer.
- They are used when driving piling **below the water surface,** especially with a drop hammer (which operates with reduced efficiency underwater) and with the diesel hammer (which cannot operate underwater).
- Followers are **used under fixed or swinging leads and in tight spaces** where there is no room for the leads and the hammer, as in a close pile grouping.
- Followers must be rugged and constructed to transmit the full impact of the hammer and **to hold the hammer and the pile in positive alignment.**
- Followers can be fabricated for timber, steel, and sheet piling.

EXPEDIENT AND FLOATING PILE-DRIVING EQUIPMENT

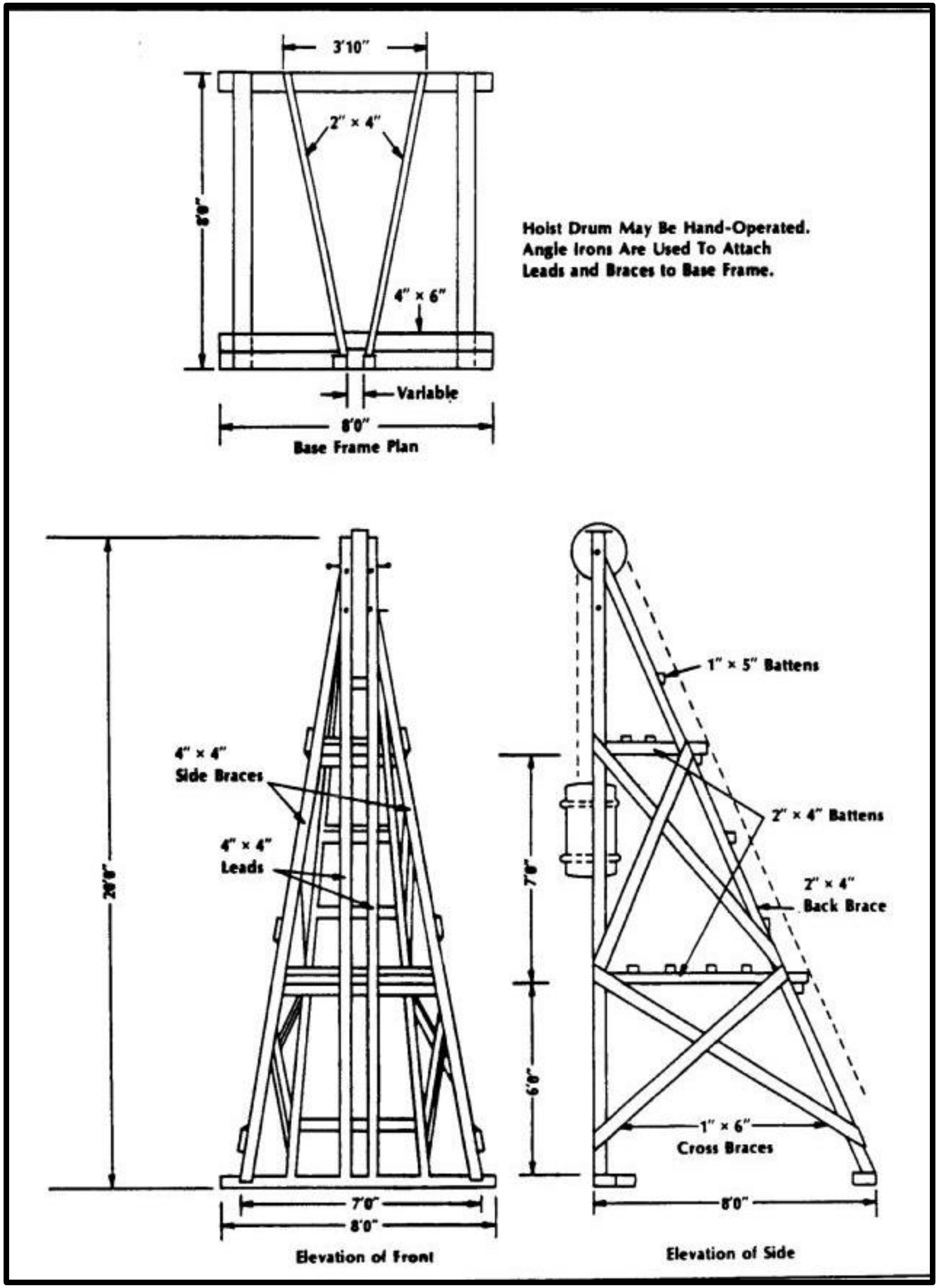
- **Expedient pile drivers**: When standard pile drivers are not available, expedient pile drivers may be constructed.
  - Wood-frame, skid-mounted pile driver
  - Timber pile driver
  - Tripod pile driver
  - Welded-angle construction pile driver



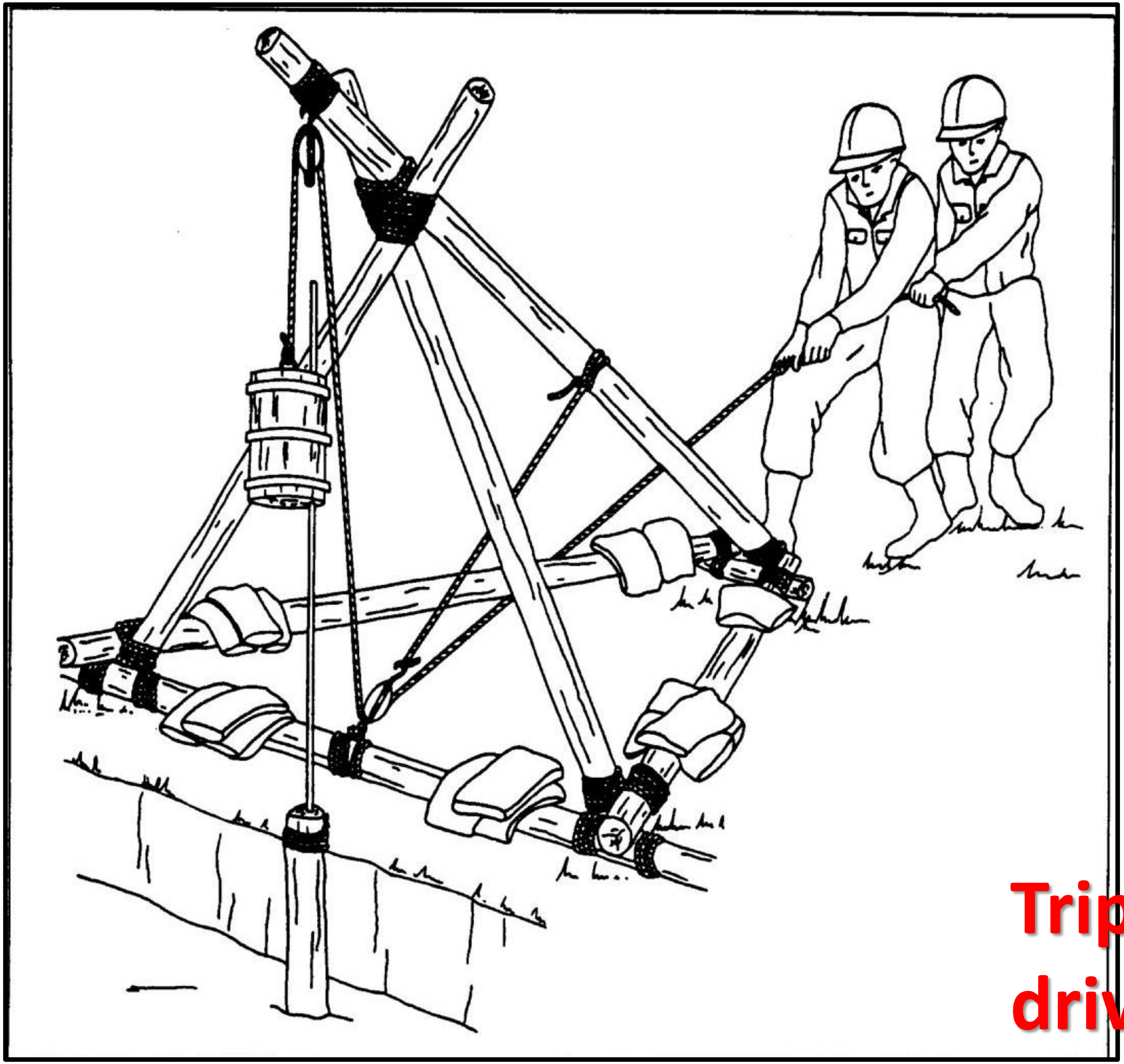
Expedient Wood-frame, skid-mounted pile driver



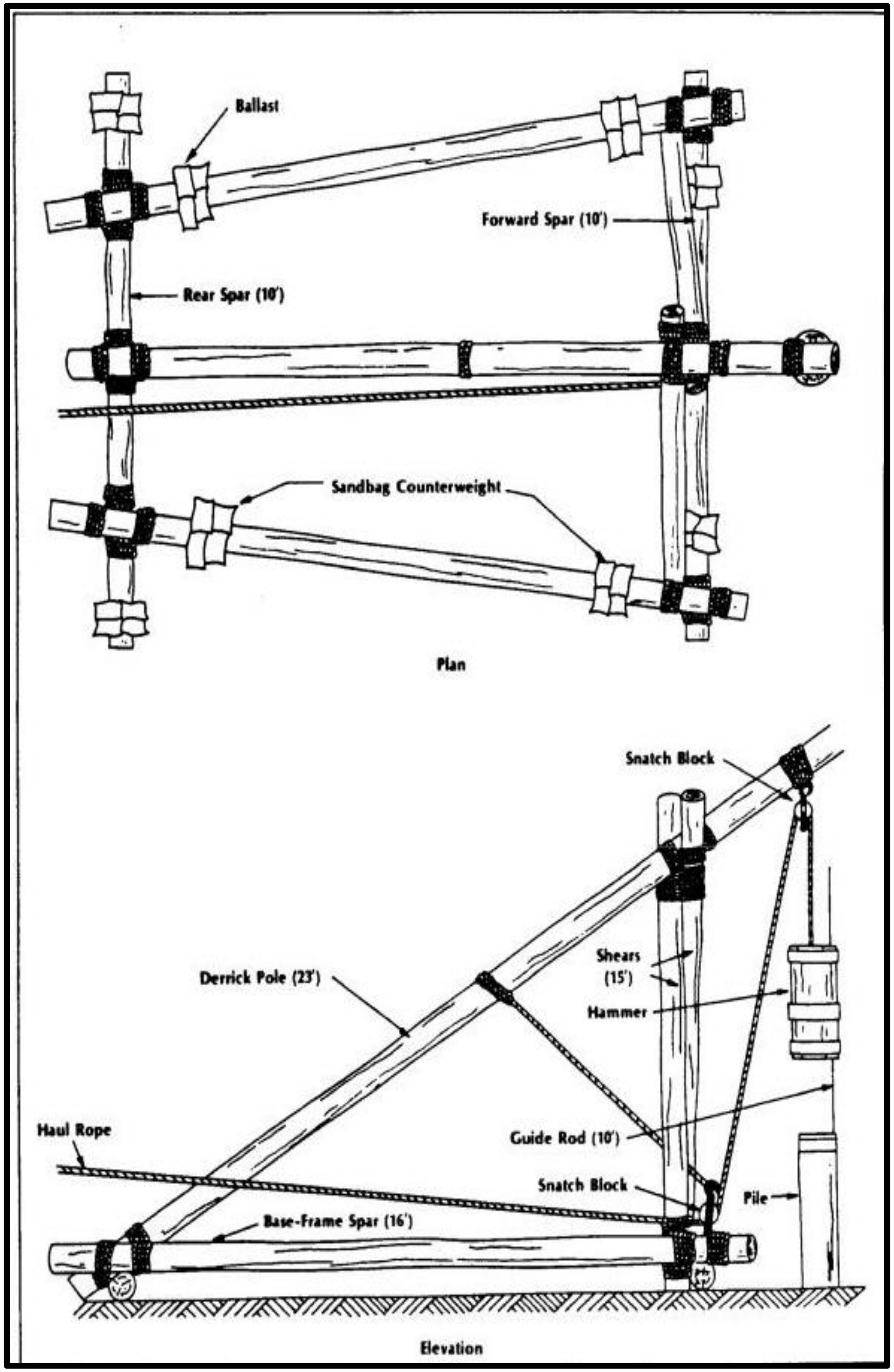
Expedient Wood-frame, skid-mounted pile driver using standard leads



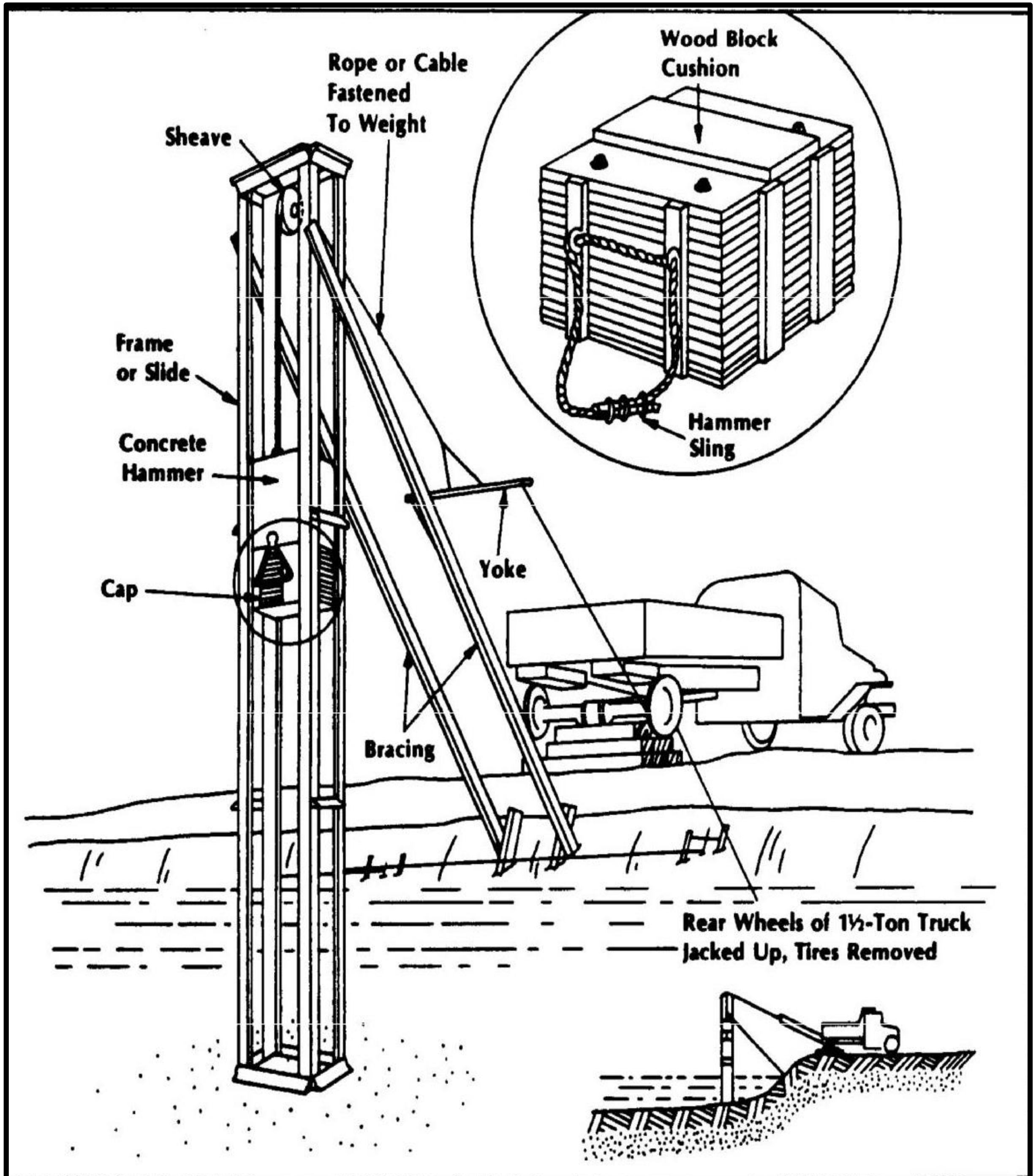
Timber pile driver



Tripod pile driver



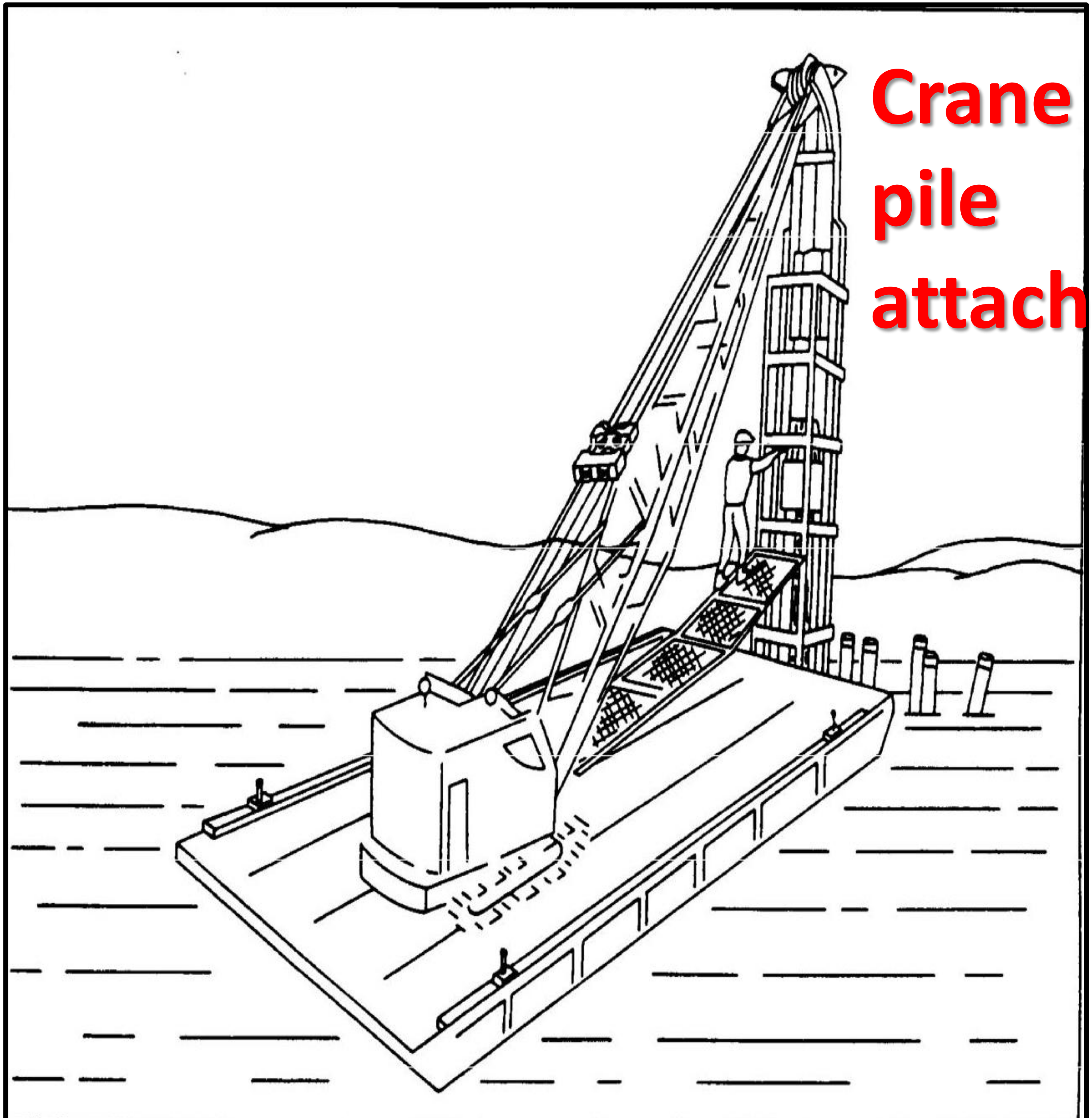
Features of Tripod pile driver



Welded-angle construction pile driver

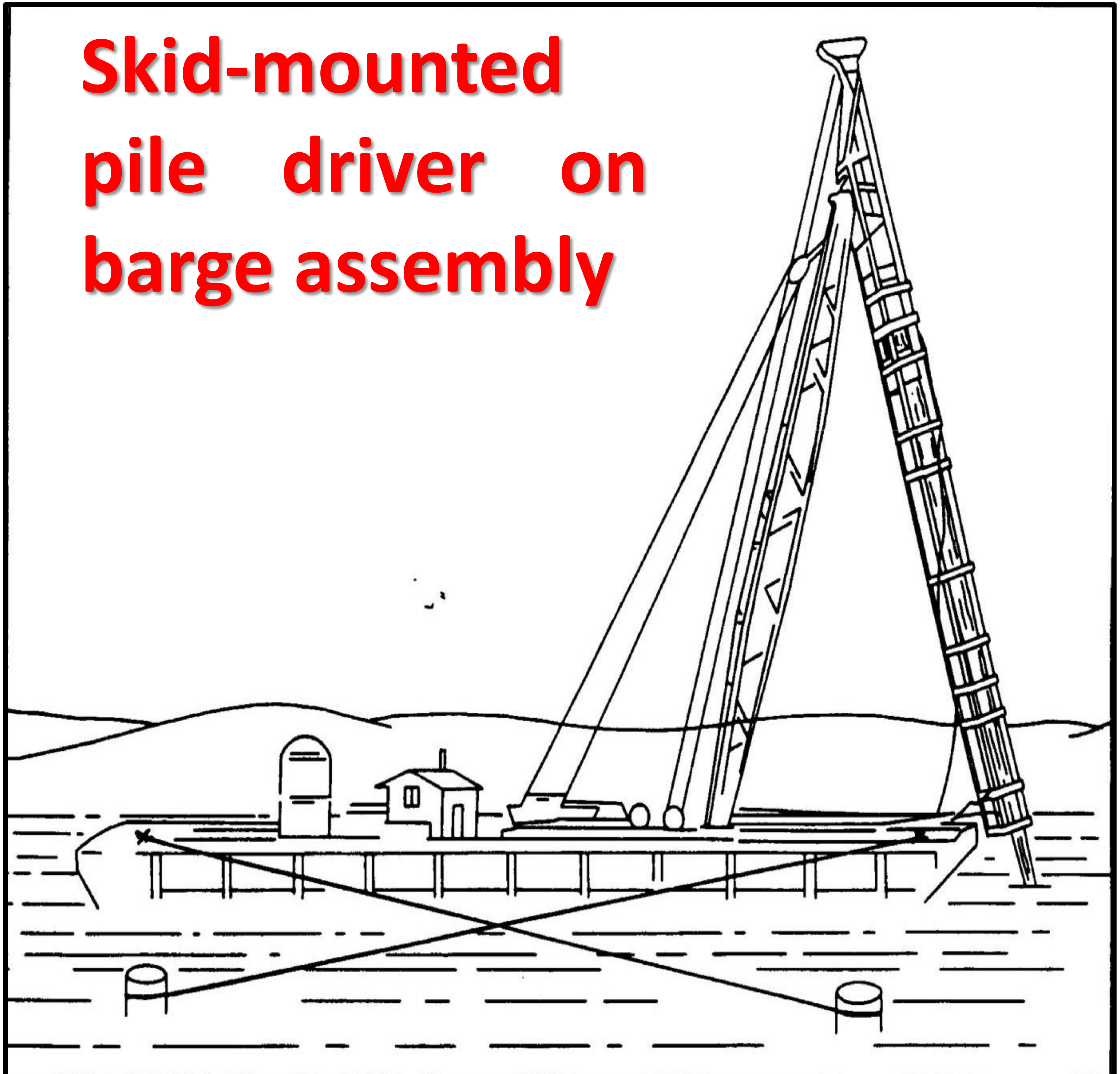
- Power for expedient pile drivers
- To raise the pile into position and operate the hammer in driving the pile, power is required.
- When available, the power unit for a standard skid-mounted pile driver should be used.
- In other cases a truck, truck motor, or manpower can be used.

- Floating pile drivers:
  - Floating cranes
  - Barges or rafts
  - Pneumatic floats
  - Anchoring of rafts



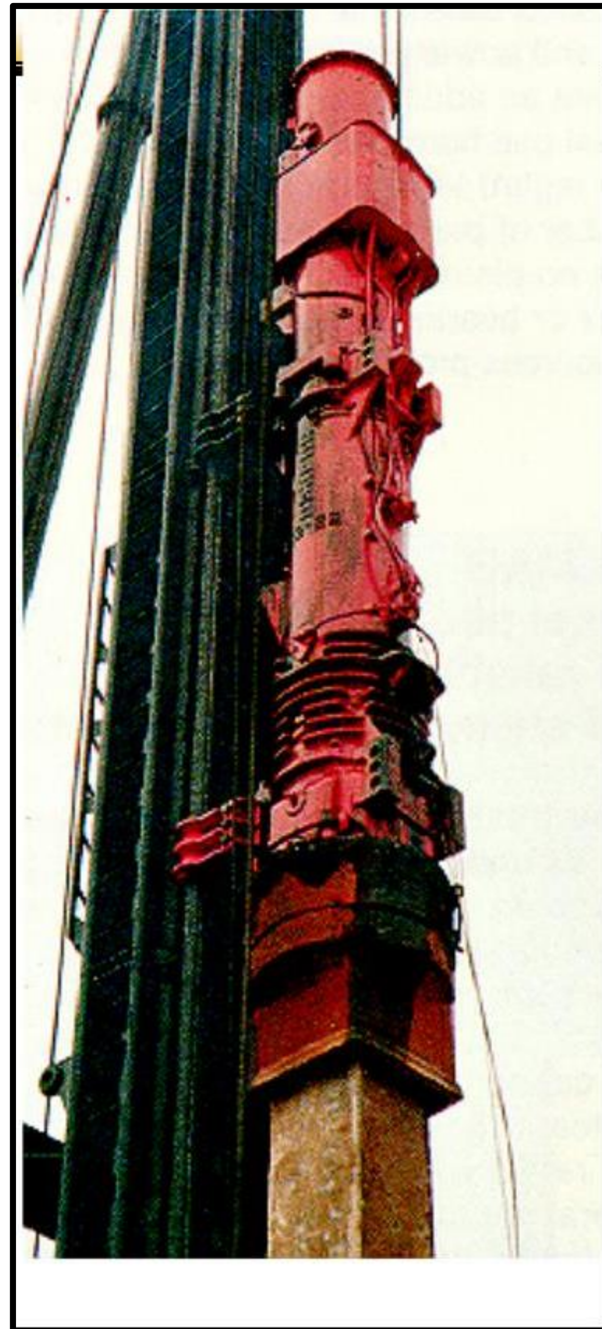
Crane shovel with pile driving attachments

Skid-mounted pile driver on barge assembly



- Accessory equipment's:
- a. Support equipment - Equipment must be available for handling stockpiled piling and for straightening, cutting, splicing, capping, and bracing piles.
- Jetting equipment- Jetting is a method of forcing water around and under a pile to loosen and displace the surrounding soils.
- The equipment consists of steel pipes, pipe fittings, water hoses, and couplings.
- The pipes and fittings are made into a jetting assembly used to connect to a water pump.

- **Equipment assembly:**
- **Skill and caution are required in the erection of pile-driving equipment.**
- **For comprehensive assembly instructions, consult the operator's manual for the pile-driving equipment to be used.**

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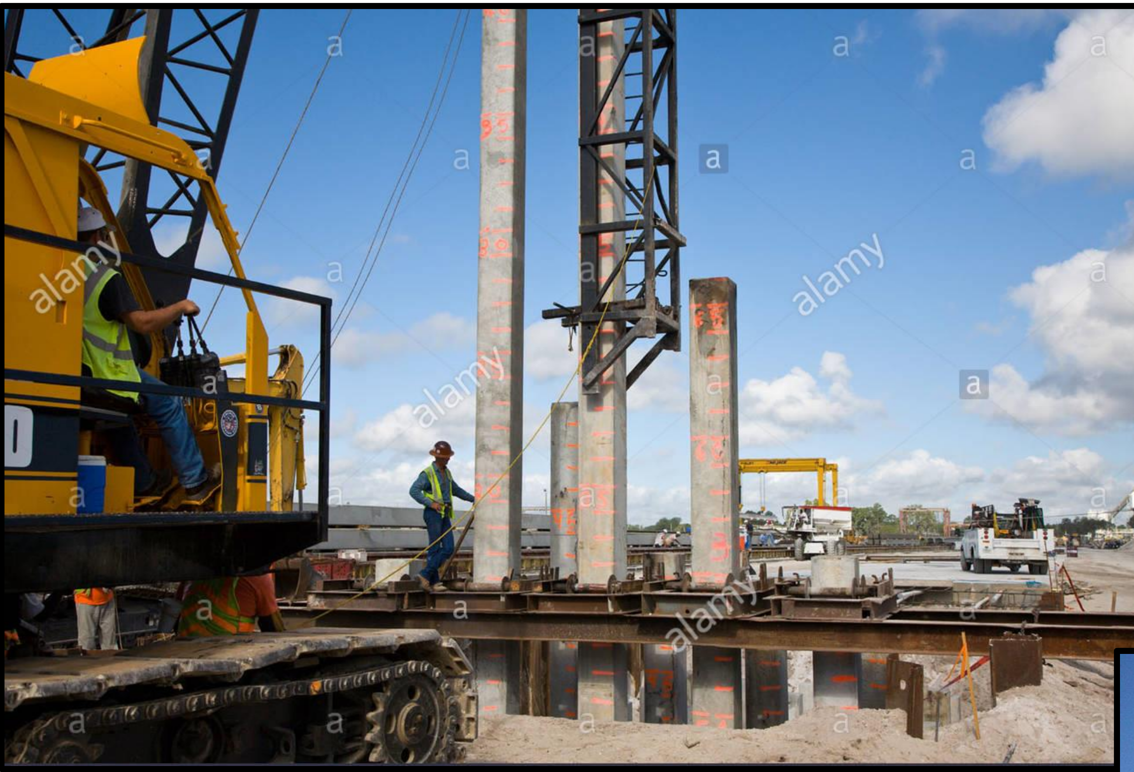



SAMSUNG

EQUIPMENT FOR OTHER WORKS - I

PRODUCTION OF AGGREGATES

- **Extraction**
  - **Stripping**
  - **Drilling and Blasting**
  - **Shot Rock or Gravel Bank**

- **EXTRACTION**
- **With the exception of slag and other manufactured aggregates most materials for aggregate production come from bedrock or unconsolidated deposits.**
- **The vast majority of materials used in the mineral aggregate industry are obtained from surface-mined stone quarries or from sand and gravel pits.**
- **How materials are extracted influences their quality.**

Extraction Influences on Quality

- Stripping
  - Not clean enough
  - Spillage over mining face
- Drilling and Blasting
  - Hole size, Depth and Spacing
  - Blast delay sequence
  - Blast intensity or charge

- **Shot Rock or Gravel Bank**
  - **Non-uniform load-out**
  - **Equipment changes**
  - **Geologic variability**
  - **Moisture variability in shot rock**
  - **Above/below water gravel deposits**

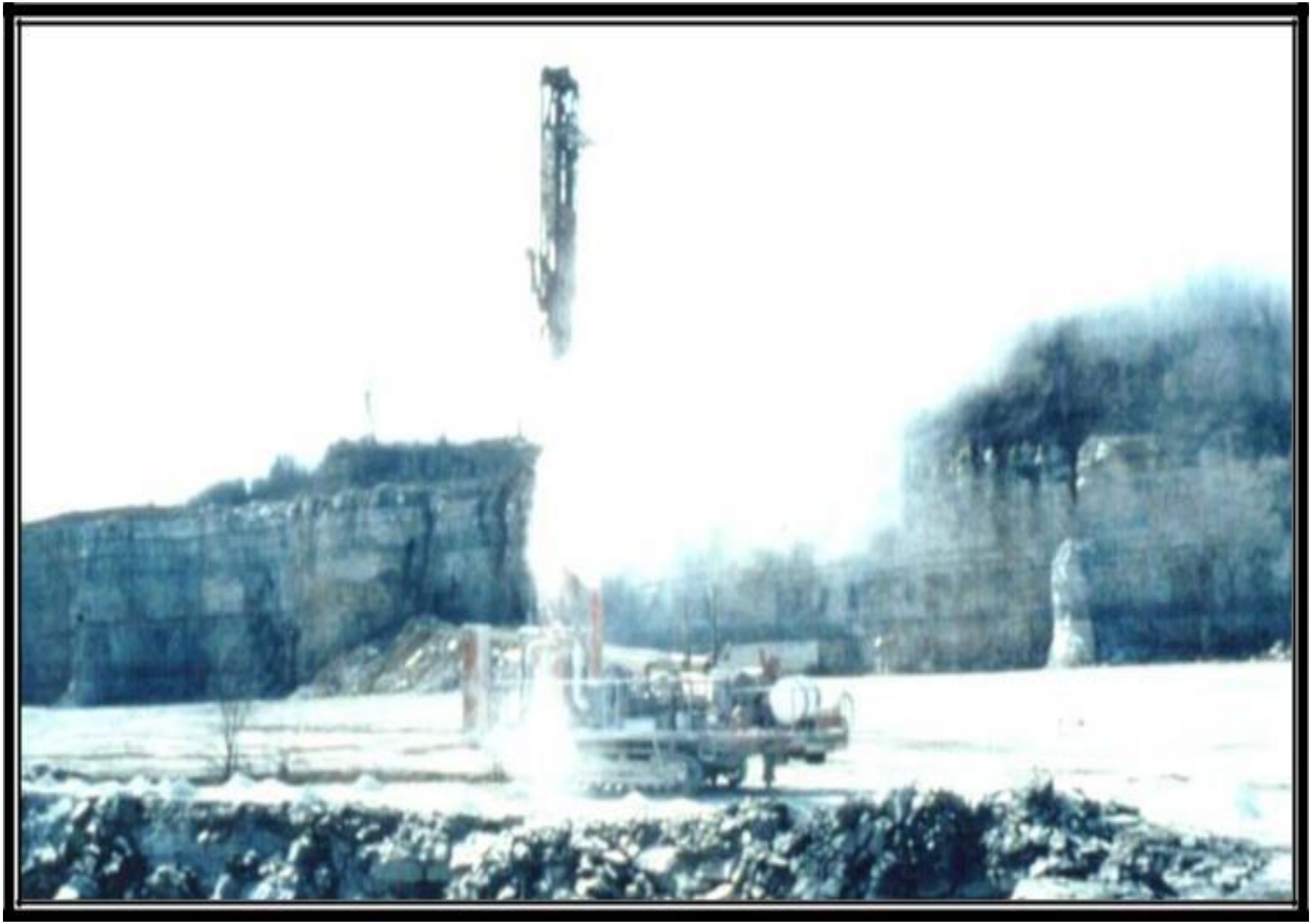
- STRIPPING
- As a first step, a Producer is required to designate a detailed stripping procedure (Figure) for each and every deposit that is mined.
- This phase often is overlooked, yet has a great influence on the quality and variability of the product.
- Inadequate removal of overburden from the mineral deposit often may be the source of excessive variation in minus No. 200 material and may even have a deleterious affect on nearby vegetation and other aspects of the mine.

- For example, excessive knobs and depressions on the surface of a stone deposit may necessitate the use of smaller equipment or special techniques to clean the stone.
- Inexperienced equipment operators may easily corrupt good stripping practices.
- Spillage over the working face and other sloppy practices can also affect the cleaning process.

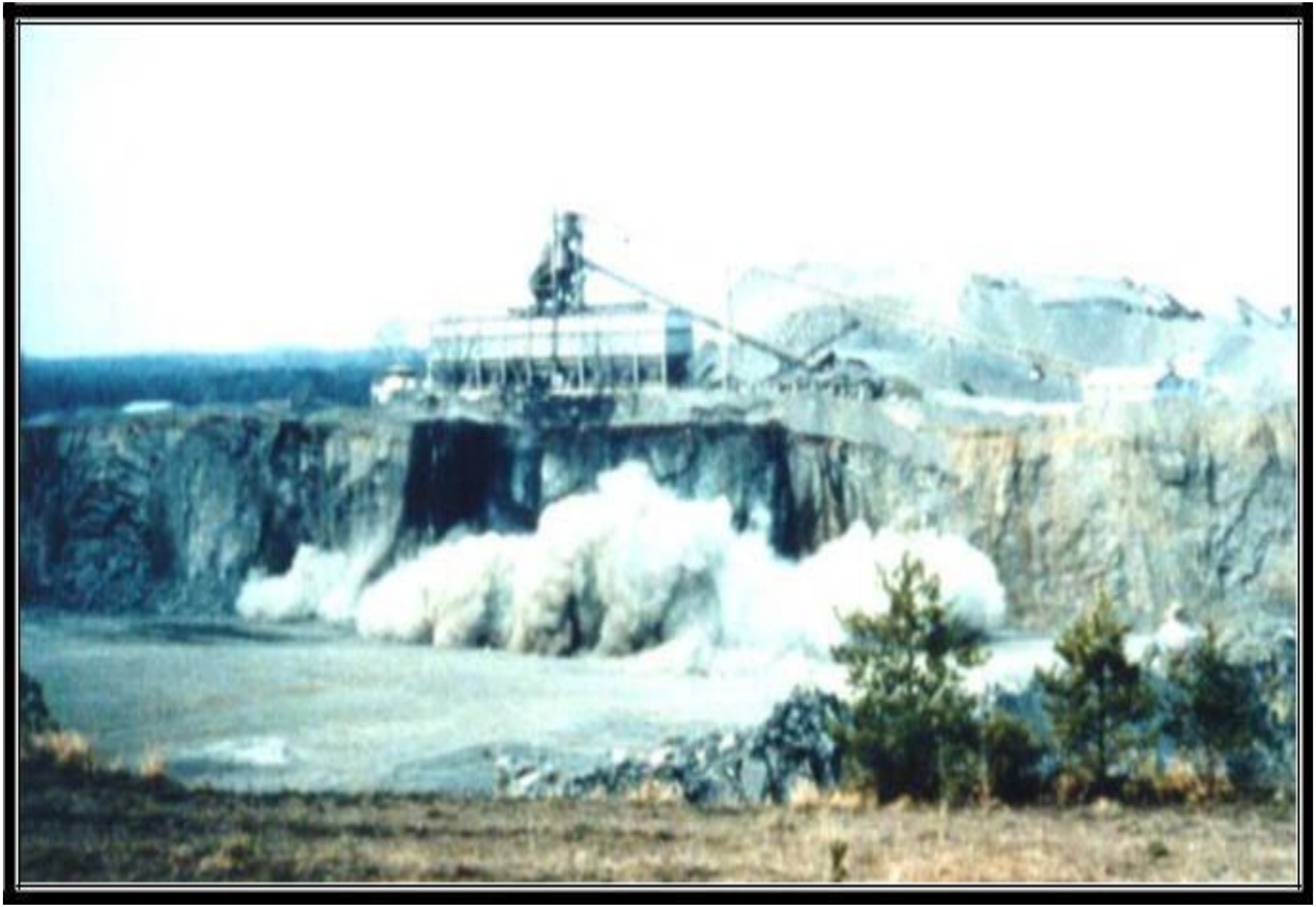
Stripping Process

Stripping

- **DRILLING AND BLASTING**
- **Quarry operators commonly design fragmentation shots for safety, economy, ease of use at the primary crusher.**
- **The shot layout is required to be properly engineered, documented, and adhered to for maximum consistency.**
- **Varying the shot pattern may mean changes in product size throughout the operation.**



Drilling Process



Blast or Shot Process

Drilling Process

Drilling Process

Drilling Process

Blasting Process

Blasting Process

- **SHOT ROCK OR GRAVEL BANK**
- **A constant problem of gravel pit and quarry operators is the difficulty in maintaining uniform load-out from either the shot rock pile or the gravel bank.**
- **Even the best shot has some variation from side to side and from front to back.**
- **Only experienced and well-trained equipment operators may accomplish the mixing from around the shot for the most uniform feed to the processing plant.**

Loading Quarry Truck

Sand and Gravel Excavation

Shot Rock Process

Gravel Banks

- Crushing
    - Scalping
    - Primary Crushing
    - Secondary and Tertiary Crushing
    - Impact Crushing
- The first step of processing begins after the extraction from quarry or pit.
- The first stage in most operations is the reduction and sizing by crushing.

- **SCALPING**
- **Scalping most often is used to divert fines at a jaw primary crusher in order to improve crusher efficiency.**
- **In this way the very coarse portion is crushed and then recombined with the portion of crusher-run material before further processing.**
- **This first step may, however, be an excellent time to improve a deleterious problem.**

Scalper Aggregate Processer

Scalper Aggregate Processer

- **PRIMARY CRUSHING**
- **In stone quarries or in very "boney" gravel pits, large material usually is reduced in size by either a jaw or a gyratory crusher. Both types are compression crushers.**
- **In some operations impact crushers are used for primary crushing, but they may have a slightly higher cost per ton.**
- **Impact crushers may upgrade poor-quality aggregate and increase separation, such as removal of rebar from concrete in recycling operations.**

- **SECONDARY AND TERTIARY CRUSHING**
- **Secondary and tertiary crushing are the final steps in reducing the material to a desired product size.**
- **Historically, cone and roll crushers were the most common choice crushers, but in recent years impact crushers are more widely used.**
- **These crushers also are sometimes used as primary crushers for fine-grained gravel deposits**

- **After primary crushing/reduction the resulting aggregate generally is placed in a large "surge" pile where the aggregate may be fed into the secondary operation whenever convenient.**
- **Care is always taken when building up and loading out surge piles, as this step may be a major source of segregation of material going to the secondary plant.**
- **Variation at this point may affect both mineral quality and gradation.**

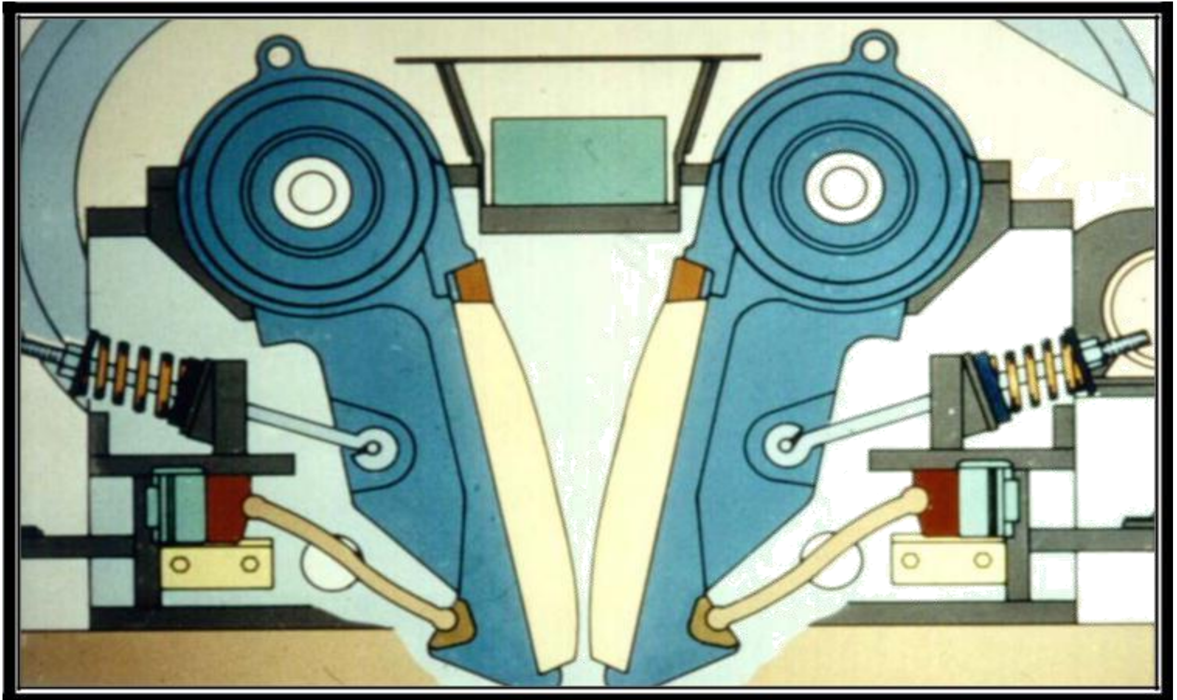
Roller Crusher

Impact Crusher

Conical Jaw Impact Crusher

Primary Crusher

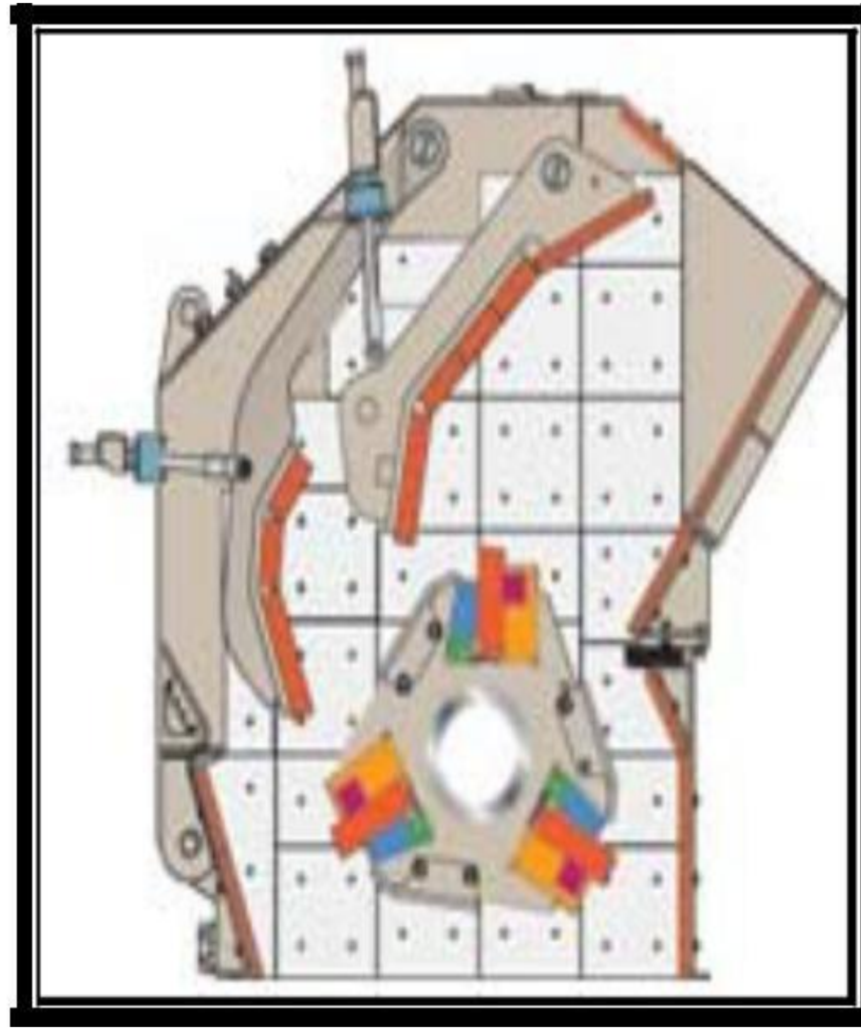
Primary Impact Crusher



Jaw Crusher

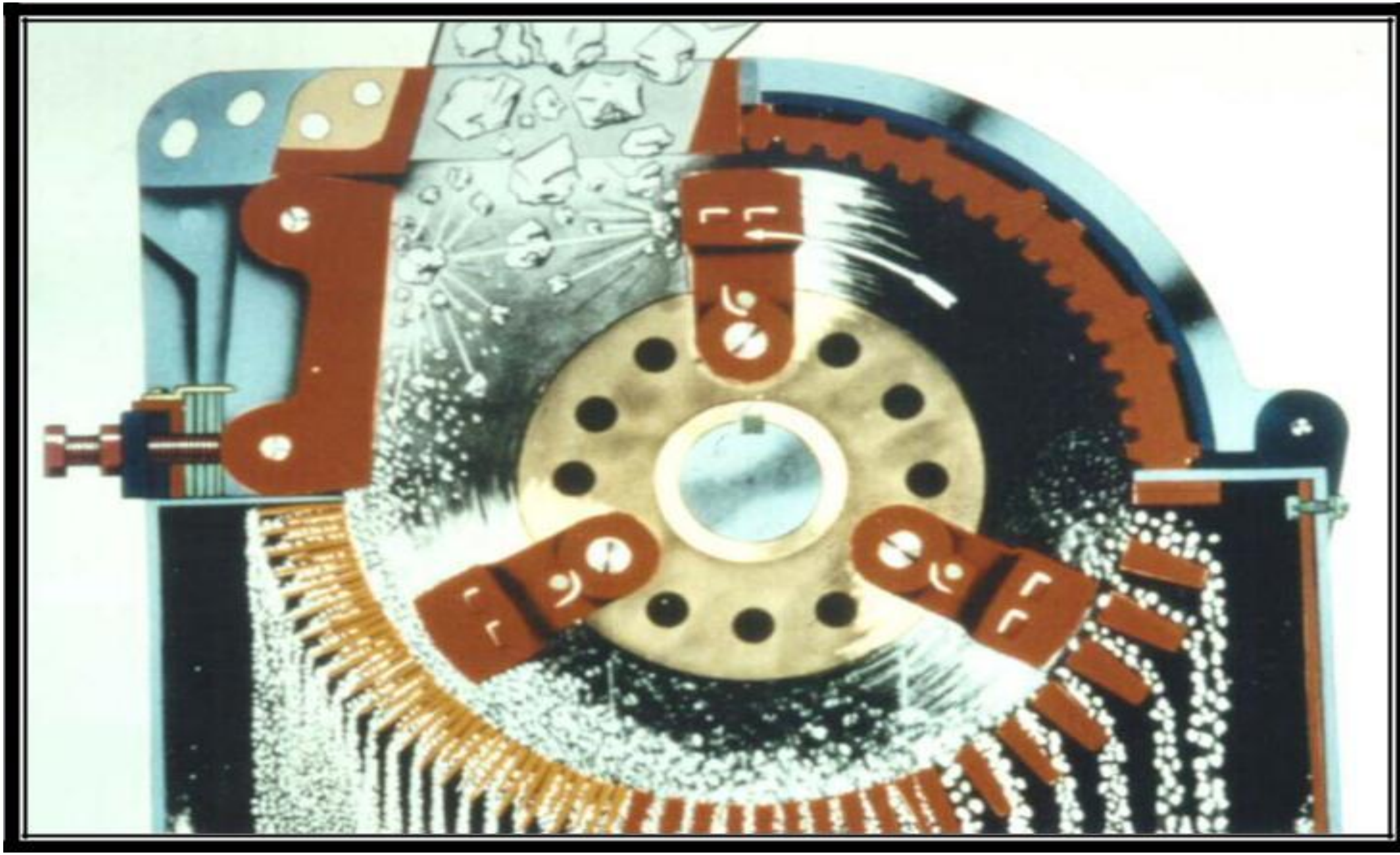
Surge Pile

- IMPACT CRUSHING
- Impact crushers may be used as primary, secondary, or tertiary crushers.
- Impact crushers usually will benefit the aggregate better than compression crushers, and they may generate more fines.
- Common types are the horizontal shaft, vertical shaft, and hammer mill im-pactors.



Horizontal Shaft Impactor

Vertical Shaft Impactor



Hammer mill Impactor


CAT
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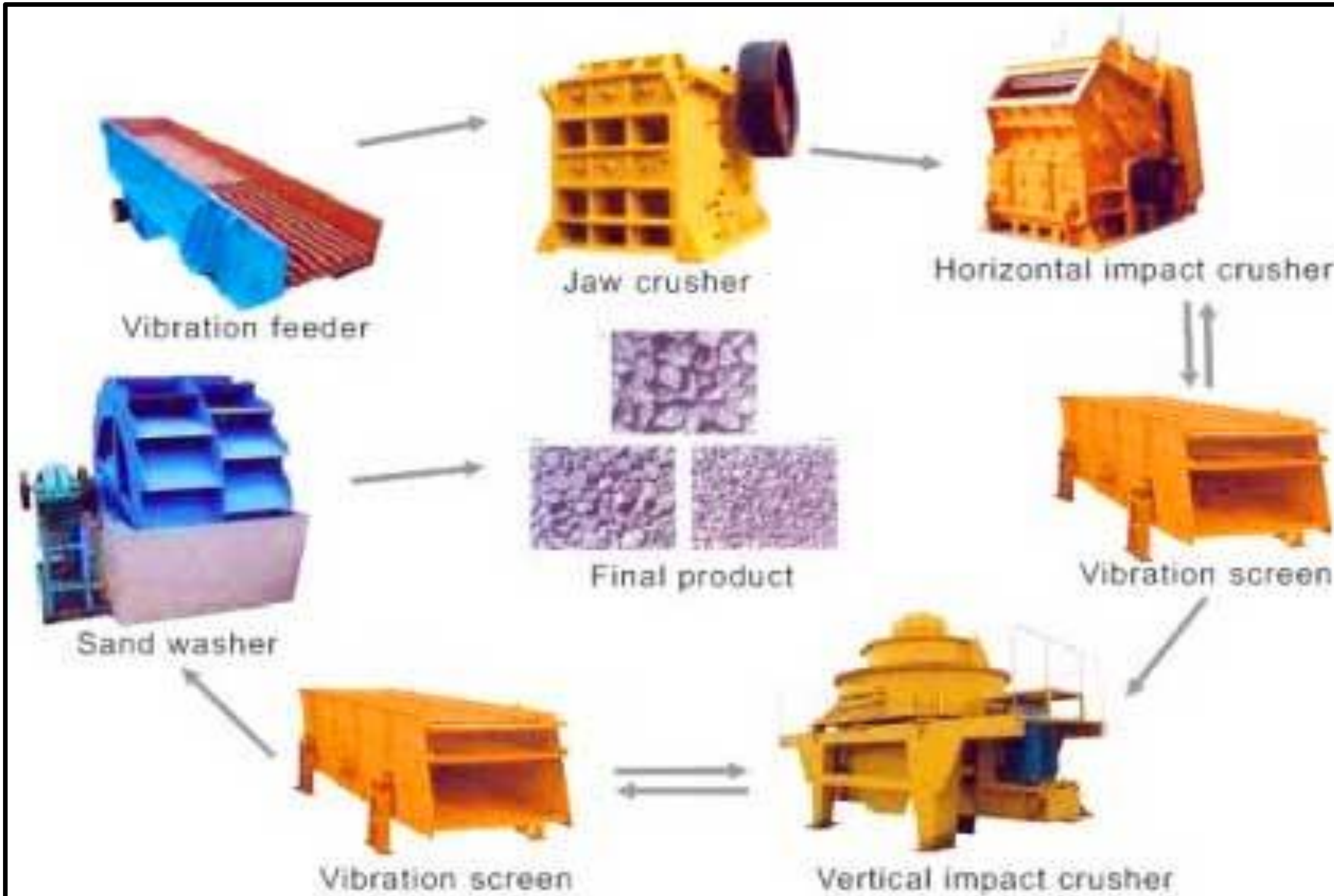
Aggregate Production Process

Crusher Feed System



Aggregate Production Equipment's

- **OTHER BENEFACTION**
- **Other forms of benefaction for quality are available to the Producer.**
- **These include the log washer, heavy media separator, and attrition mill.**
- **The log washer commonly is used in wet operations to agitate and scrub clay and other objectionable fines from coarse aggregate.**

- Heavy media separation is somewhat costly, but may be the only practical way for a Producer to meet quality requirements.
- This method works only when the undesirable material has a different specific gravity than the desirable material.
- The deleterious material is discarded after the media is separated for recycling.
- Attrition mills are seldom used but remain an option when the deleterious particles are uniformly softer than the non-deleterious particles.

Log Washer

Heavy Media Separators

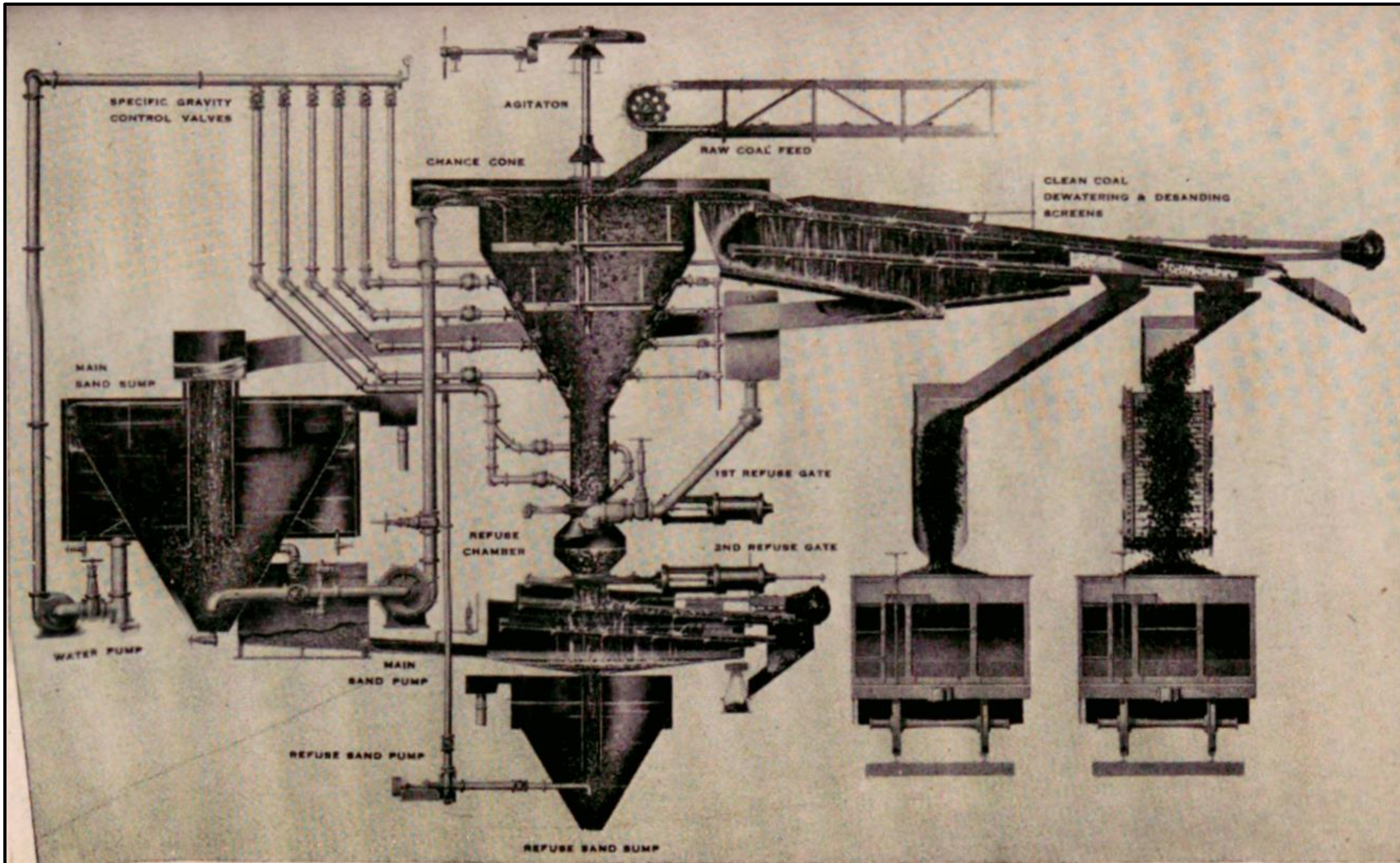


FIG. 128.—Chance sand-flotation process. (*United Engineers & Constructors, Inc.*)

Heavy Media Separators

Attrition Mill

- SCREENING
    - Product Quality
    - Gradation Control
- Product Quality
- The rinse screen is also commonly used. By processing the material over a screen that retains all of the product, the clay and deleterious fines may be rinsed away to make the product acceptable.

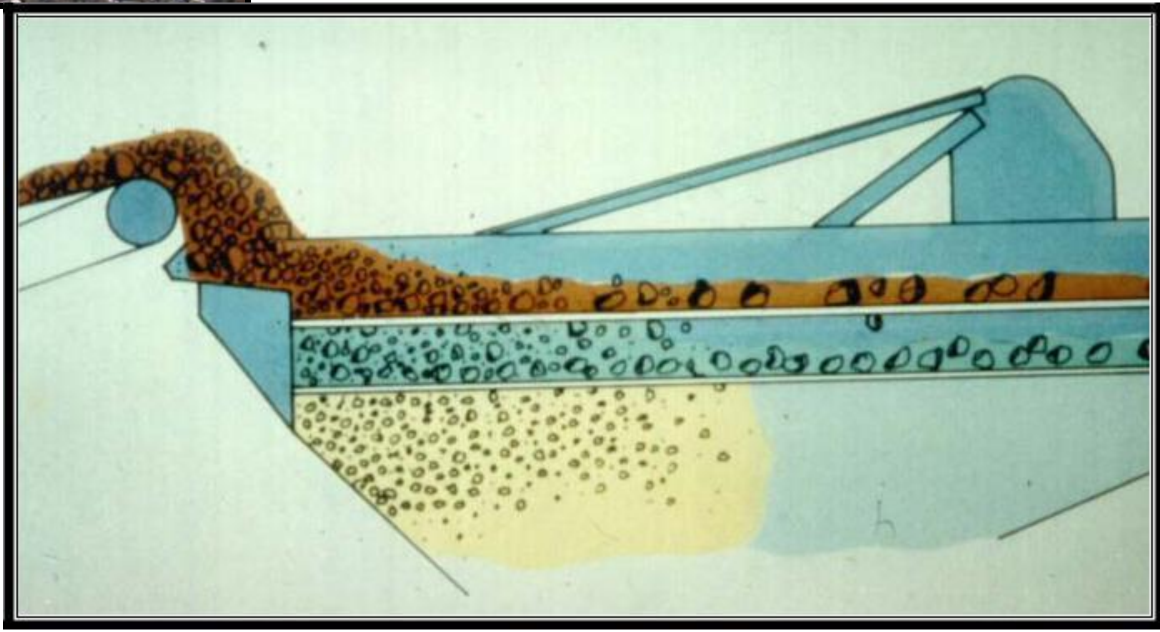
- **Gradation Control**
- **The best technique for gradation control is screening. Screening may be done wet or dry, depending on the type of aggregate being processed and the degree of consistency required for each product.**
- **Frequent sampling, testing, and control charting are necessary for monitoring because aggregate gradation is subject to so many variables.**

Rinse Screens

Screens

Dry Screens

Wet Screens



SAND PRODUCTION

- Sand plays a critical role as a construction aggregate and deserves special attention when considering the means of process control.
- Here various types of crushers may be used to upgrade mineral quality, and sizing.
- These techniques are called particle exclusion.

- **NATURAL SAND**
- **Good quality natural sand is readily available in many areas and may be easy to obtain and process.**
- **As with the gravels that they often accompany, the sand deposits may not have been laid uniformly, meaning a potential change in quality and size is possible.**
- **In some deposits, sand found below the water table differs in fines content and quality from that found above the water table.**

- Subsurface drilling, sampling, and testing is necessary to know to what degree and where these differences occur.
- Standard operating procedures in the Quality Control Plan should address the process if differences in size and quality are encountered, as a uniformly graded product of predictable quality is required to be maintained.

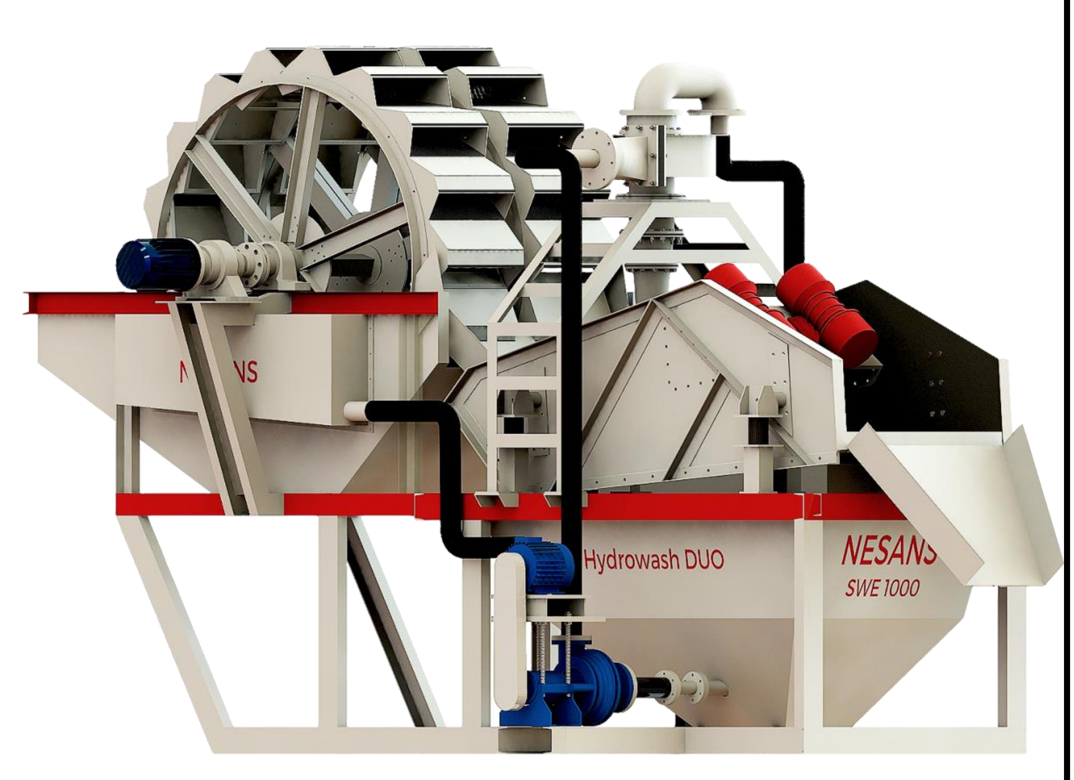
- **MANUFACTURED SAND**
- **Because of the angularity, manufactured sand is very beneficial for use in hot mix asphalt where stability is critical.**
- **Care is required to be taken to select the appropriate classification equipment that removes the necessary amount of minus No. 200, yet retains other fractions of the sand gradation that are needed.**

- Particle shape is set primarily by the crushing operation for the coarse aggregate.
- Any changes in crushers or crushing techniques may affect the properties of the manufactured sand product and therefore affect the customer's use of the product.

- PROCESSING
- Most sands are produced with wash water and water classification.
- Inadequate water supply and poor maintenance are the two most common reasons for inconsistent sand gradations.
- The most common water classifier is a simple dewatering screw which may make a single "cut" in gradation and float out a certain amount of fines.

Dewatering Screws

- The dewatering wheel device is capable only of making a cut in the feed stock but may be more finely tuned and may be the better choice when trying to retain as much No. 50 and No. 100 material as possible.
- An even more sensitive method of cutting out fines is the wet cyclone.
- The sand slurry in the cyclone is spun at a prescribed velocity. Centrifugal force separates the coarser fraction from the water and fines which exit to the pond.



Dewatering Wheel Devices

Wet Cyclone Process

Wet Cyclone Process

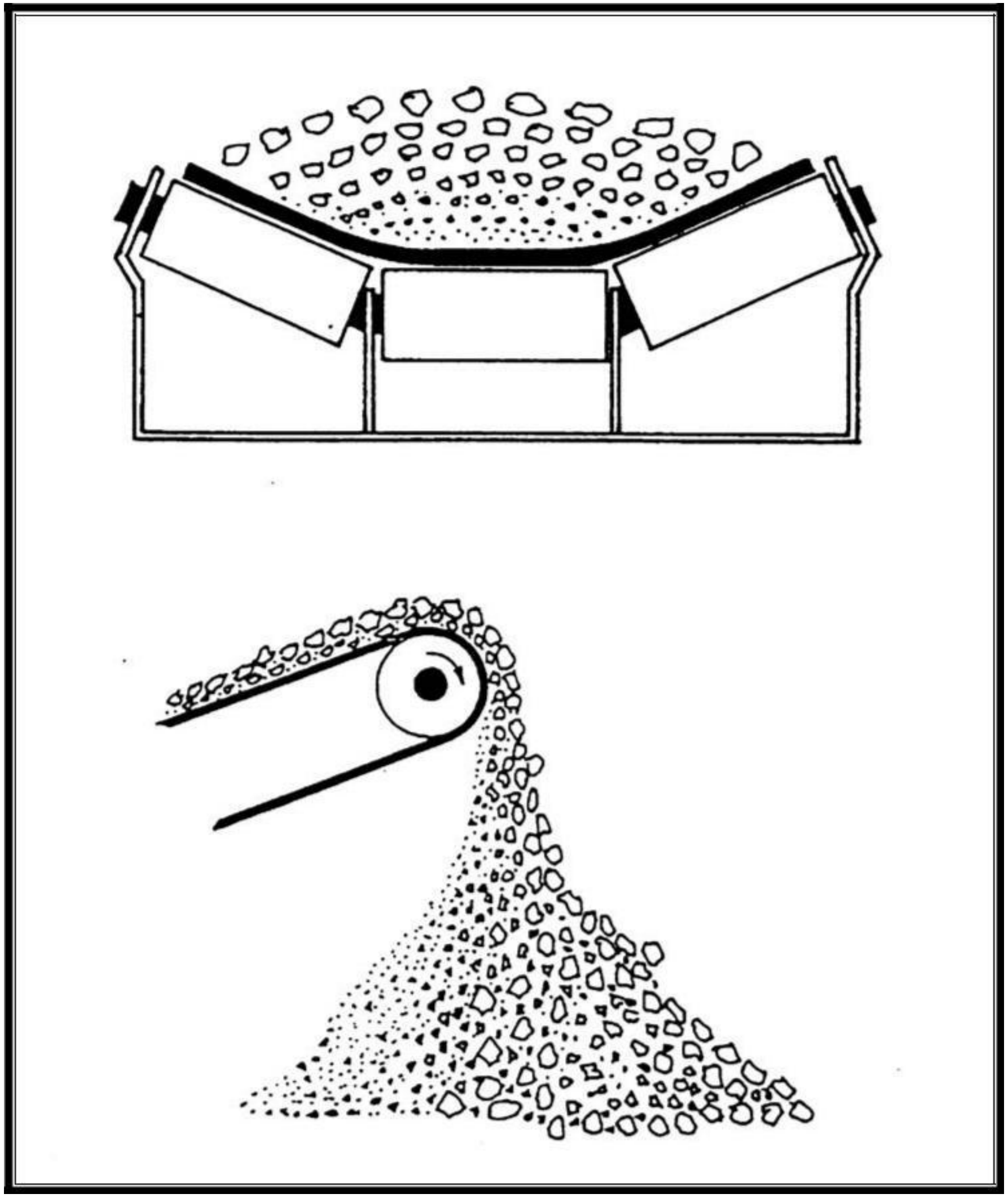
- A simpler and probably more cost effective way to control a sand gradation on multiple sieves is the rising current, multiple cell classifier.
- This equipment has numerous cells, each having varying water pressures that for different sizes of material.
- Any number of cells may then be combined to create the final product.
- With this type of system a high degree of process control is possible.

Multiple Cell Classifiers

SEGREGATION

- Product conformity and uniformity may be predicted if all of the inputs into the plant are measured, evaluated, and controlled.
- Segregation begins on the belt where fines vibrate to the bottom and coarse aggregate remains on the top as the material bounces across the idlers.
- At the end of the belt, if left un-deflected, the coarse particles are thrown out and away.
- Fine particles, tend to drop down or if wet even follow back underneath the conveyor.

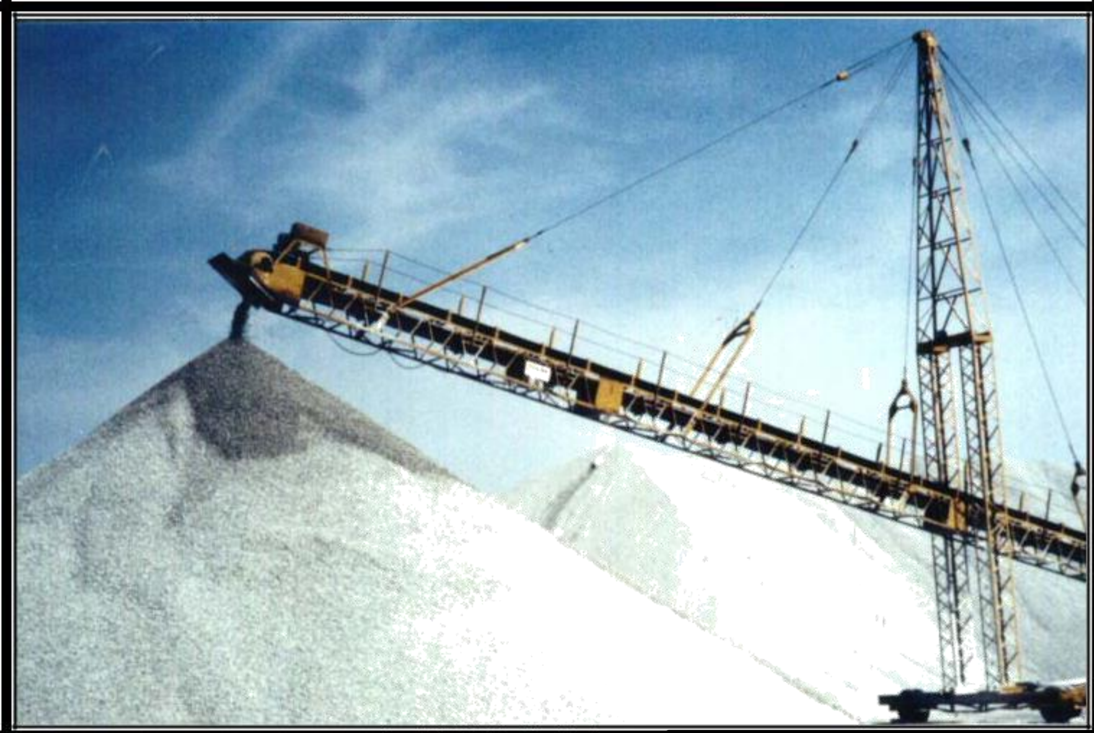
- The greater the speed of the belt, the worse the segregation problem is.
- This is known as front-to-back segregation and may be addressed by the following methods:
  - Belt wipers underneath the head pulley that reduce carry back
  - Movable stackers kept near the top of the pile to reduce the spread
  - Mixing paddles or deflectors at the head pulley to keep the material together
  - Wider belts at lower velocities to prevent segregation

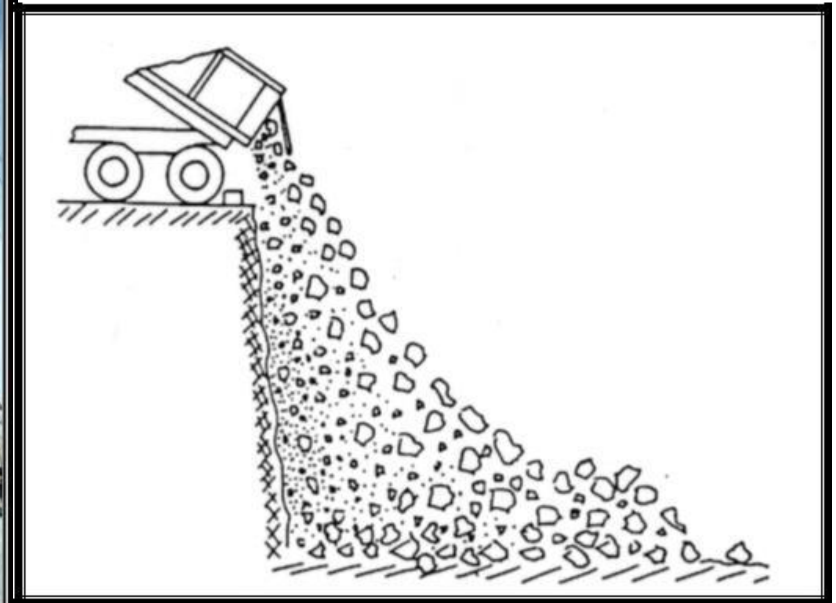


Belt Segregation

Segregation Process

- A second common type of segregation is "roll down," which occurs any time aggregate is piled so that large particles roll down the sloped side of the pile.
- The higher the pile, the worse this problem is.
- This type of segregation is very obvious in operations with high conical stockpiles, but also occurs in improperly loaded trucks.
- Keeping storage bins over half-full whenever possible improves the situation.





Segregation

- Stockpiling and Handling
    - Cone Stockpiles
    - Radial Stockpiles
    - Truck-Built Stockpiles
    - Layered Stockpiles
    - Stockpiling - General

STOCKPILING AND HANDLING

- **Segregation** is probably the **greatest problem** that occurs because of **stockpiling and handling**, but certainly other problems such as **degradation and contamination** may adversely **affect product quality.**
- Every possible precaution is required to be taken **to protect the product quality** from the point of manufacture to the point where the **aggregate leaves the Producer's control.**

- CONE STOCKPILES
- Although the cone stockpile is very common in the aggregate industry, two stockpile procedures may easily reduce product integrity.
- Roll-down segregation obviously occurs in full circle around the pile, and very high piles are difficult to adequately remix before shipping.
- These piles usually are being replenished with fresh material as old and new material is being removed, which keeps the product size in a state of continual change.

Material Added to Cone

- In some cases the "front-to-back" segregation adds extra coarse material thrown forward and extra fines carried back for even greater variability.
- In addition, some piles are not fully retrieved for several years and the new product that is added to the old pile may even have different production targets.
- Situations like these add up to serious problems for predicting gradation uniformity in the retrieved product.

Comingled Cone Piles

- **The final element of a cone pile that adds to the effects of both the roll-down and front-to-back phenomena is an excessively high drop from the end of a fixed conveyor to the top of the pile.**
- **Use of cone stockpiles should be kept to a minimum and used with extreme caution.**

High Conveyor Drop

- **RADIAL STOCKPILES**
- **A radial stacker is a compromise solution for conveyor-built stockpiles, especially if kept less than 20 ft.**
- **The proper technique is to keep the end of the movable conveyor less than a meter from the top of the pile and raise the conveyor with the pile to the full height.**
- **Then the conveyor is moved horizontally with the pile in small increments.**
- **In this manner the pile is constructed at one end while the products are retrieved at the other end.**

Radial Stacker

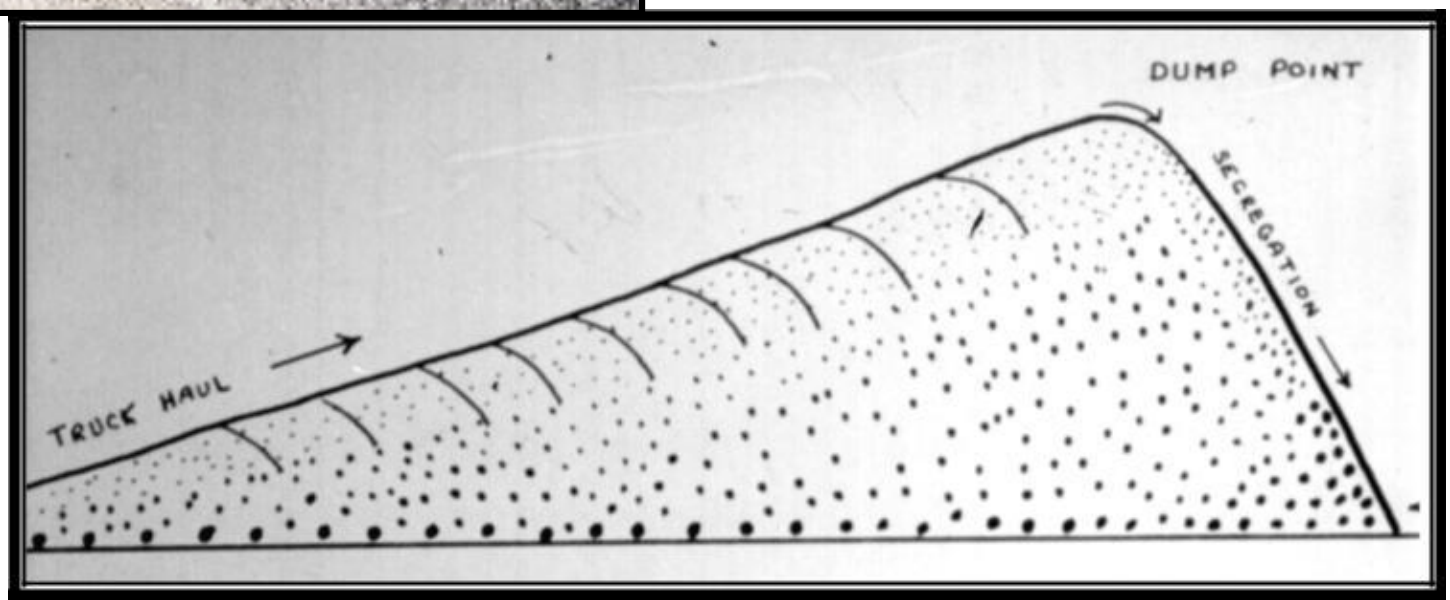
- **TRUCK BUILT STOCKPILES**
- **If piles from the end of the product belts are thoroughly remixed then truck-built stockpiles are capable of greatly minimizing segregation, if the trucks are loaded properly.**
- **The best truck-built stockpiles are those that are constructed one dump high with each dump placed against previously dumped material.**
- **Because of the low profile, reduces roll-down segregation and allows remixing during load out.**
- **However, these stockpiles require more space than the others mentioned.**

Truck Built Stockpiles

- **LAYERED STOCKPILES**
- **A layered stockpile, if built correctly, may also greatly minimize segregation.**
- **Unfortunately these types of stockpiles are very difficult to build properly.**
- **Each layer is placed uniformly across the top of the pile in thin horizontal lifts.**
- **Care is required to be taken to keep the edge of each new lift set back from the edge of each previous lift so as not to create long sloped edges.**

- This is best done with a large clam shell crane, which is slow and tedious, or with specially made equipment that may place the layers without being on the pile.
- A compromise is to allow hauling equipment on top of the pile; however, this procedure causes degradation of the product, and the pushing equipment may move the material over the edges causing severe segregation.
- Generally, these activities are poorly managed, and the stockpile takes on the shape of a ramp and spills over.
- These situations are very detrimental to product quality.

Ramp and End Dump



Ramp and End Dump

Asphalt Pavements

Asphalt Mixing Plant

Asphalt Surface Treatments

ESTIMATING EARTHWORK VOLUME

- When planning or estimating an earthmoving project it is often necessary to estimate the volume of material to be excavated or placed as fill.
- The procedures to be followed can be divided into three principal categories:
- pit excavations (small, relatively deep excavations such as those required for basements and foundations),
- trench excavation for utility lines, and
- excavating or grading relatively large areas

- The estimation of the earthwork volume involved in the construction of roads and airfields is customarily performed by the design engineer.
- The usual method is to calculate the cross-sectional area of cut or fill at regular intervals along the centreline.
- The volume of cut or fill between stations is then calculated, accumulated, and plotted as a mass diagram.

- When making earthwork volume calculations, keep in mind that cut volume is normally calculated in bank measure while the volume of compacted fill is calculated in compacted measure.
- Both cut and fill must be expressed in the same volume units before being added.
- Pit Excavations: For these cases simply multiply the horizontal area of excavation by the average depth of excavation.
- Volume = Horizontal area × Average depth

- First divide the horizontal area into a convenient set of rectangles, triangles, or circular segments.
- After the area of each segment has been calculated, the total area is found as the sum of the segment areas.
- The average depth is then calculated.
- For simple rectangular excavations, the average depth can be taken as simply the average of the four corner depths.
- For more complex areas, measure the depth at additional points along the perimeter of the excavation and average all depths.

Trench Excavations:

- The volume of excavation required for a trench can be calculated as the product of the trench cross-sectional area and the linear distance along the trench line.
- Volume = Cross-sectional area × Length
- For rectangular trench sections where the trench depth and width are relatively constant, trench volume can be found as simply the product of trench width, depth, and length.

- **When trench sides are sloped and vary in width and/or depth, cross sections should be taken at frequent linear intervals and the volumes between locations computed.**
- **These volumes are then added to find total trench volume.**

Large Areas:

- To estimate the earthwork volume involved in large or complex areas, one method is to divide the area into a grid indicating the depth of excavation or fill at each grid intersection.
- Assign the depth at each corner or segment intersection a weight according to its location (number of segment lines intersecting at the point).

- **Thus, interior points (intersection of four segments) are assigned a weight of four, exterior points at the intersection of two segments are assigned a weight of two, and corner points are assigned a weight of one.**
- **Average depth =(Sum of products of depth × weight) / Sum of weights**

CONSTRUCTION USE OF THE MASS DIAGRAM

- A mass diagram is a continuous curve representing the accumulated volume of earthwork plotted against the linear profile of a roadway or airfield.
- Mass diagrams are prepared by highway and airfield designers to assist in selecting an alignment which minimizes the earthwork required to construct the facility while meeting established limits of roadway grade and curvature.

- Since the mass diagram is intended as a design aid, it is not normally provided to contractors as part of a construction bid package.
- However, the mass diagram can provide very useful information to the construction manager and it is usually available to the contractor upon request.

Characteristics of a Mass Diagram:

- The vertical coordinate of the mass diagram corresponding to any location on the roadway profile represents the cumulative earthwork volume from the origin to that point.

Some of the principal characteristics of a mass diagram include the following:

- **The vertical coordinate of the mass diagram corresponding to any location on the roadway profile represents the cumulative earthwork volume from the origin to that point.**
- **Within a cut, the curve rises from left to right.**
- **Within a fill, the curve falls from left to right.**

- A peak on the curve represents a point where the earthwork changes from cut to fill.
- A valley (low point) on the curve represents a point where the earthwork changes from fill to cut.
- When a horizontal line intersects the curve at two or more points, the accumulated volumes at these points are equal.
- Thus, such a line represents a balance line on the diagram.

CONSTRUCTION USE OF THE MASS DIAGRAM

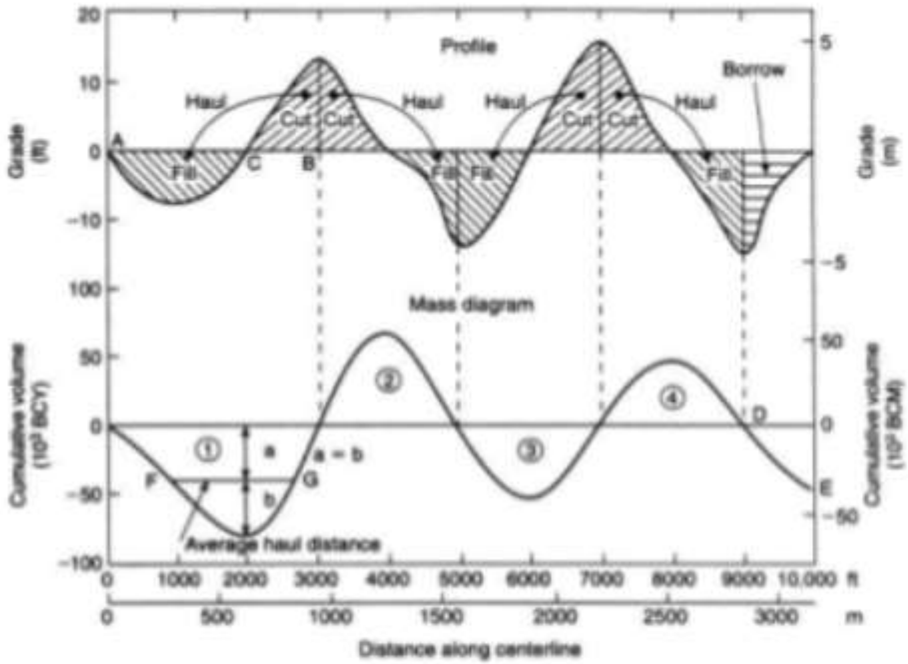


FIGURE 2-6. Construction use of a mass diagram.

CONSTRUCTION USE OF THE MASS DIAGRAM

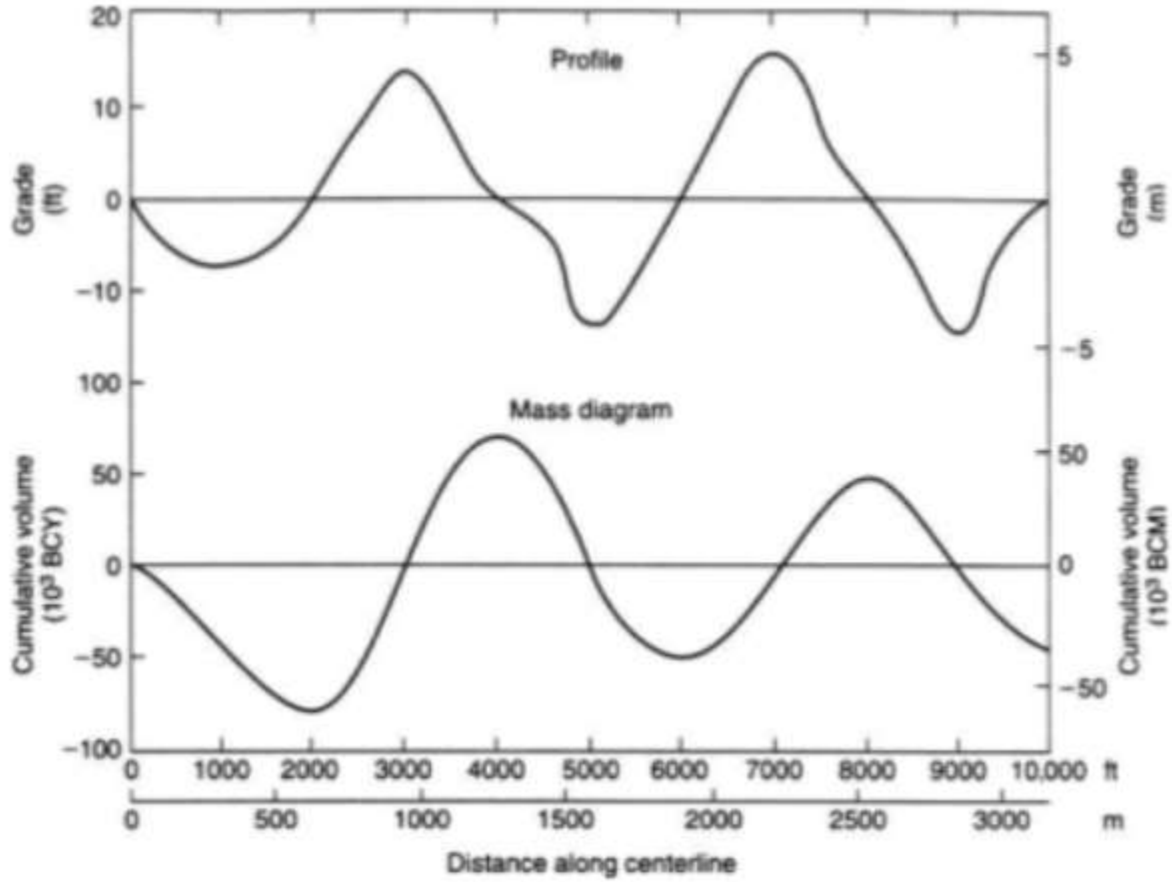
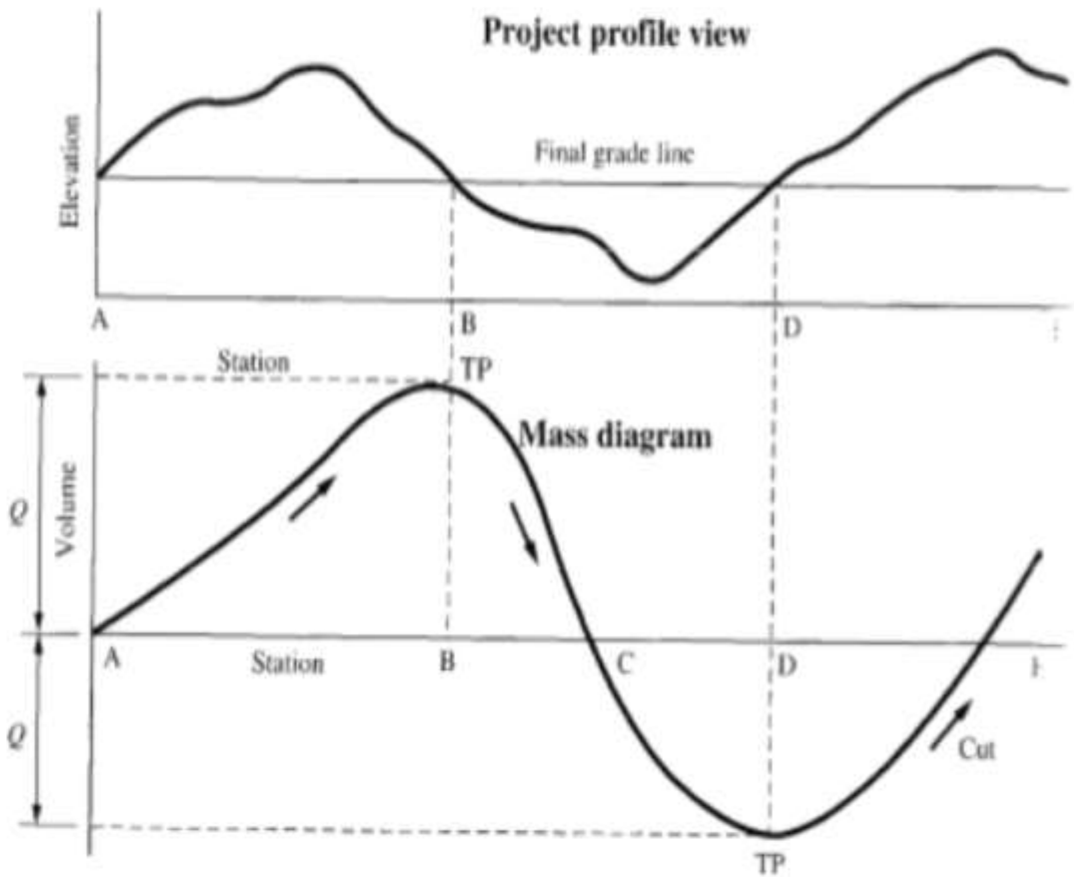


FIGURE 2-5. A mass diagram.

Properties of a Mass Diagram



Compaction

- After excavated, soil has been transported and spread at the desired places, it is compacted to obtain the desired density.
- The optimum density is obtained on a certain moisture content of the soil.
- Generally, the right amount of water is mixed before compaction the soil.
- For different types of soil, different compaction equipment's are used.

- A single equipment is not effective for all types of soil .
- A roller compacts the –
    - Pressure
    - Kneading
    - Vibration
    - Impact

Various compaction equipment's are -

- Smooth wheel roller
- Pneumatic tired roller
- Sheep foot roller
- Vibratory roller equipment –
  - Dropping weight type
  - Pulsating hydraulic type

Smooth wheel roller –

- Smooth wheel roller compacts the soil by applying pressure on it.
- It is used for coarse grained soil and spread in thin layer.
- For find grained soil , they are not effective.
- These rollers are only useful in smoothing the upper layer, whereas bottom layer normally remains loose.

Pneumatic tired roller –

- Pneumatic tired roller used the principle of action to effect the compaction below the surface .
- They are generally self – propelled .
- The rear tires are spaced in such a way they travel over the surfaces between the front tires . Thus the roller produces compaction of the whole surface.

- **The parameters which determine the compacting ability of pneumatic rollers are:**
- **Wheel load - Tire size - Tire ply - Inflation pressure**
- **Initial compaction is carried out with low pressure.**
- **The roller increased its tire pressure in subsequent operations.**
- **They are used for fine grained soil.**

- Sheep foot roller –
- Sheep foot rollers are steel wreaks equipment with protruded cylindrical projection of 20-25cm.
- They are suitable for compacting fine grained material, but generally is not suited for cohesion less granular material.
- They compact the soil kneading type of action.

- These rollers are helpful in breaking the lumps or clods present in the soil.
- These rollers aerates the soil during compaction.
- Thus , they are suitable for compaction soil heavy in moisture content above the optimum level .

Vibratory Compaction equipment's –

- Vibratory rollers compact the soil through impact forces.
- These forces result in compaction greater than the equivalent static load.
- Vibratory rollers are suitable for coarse grained soil.
- These rollers may be pulsating weight type.

- Plate compactors are widely used in the building construction for compacting soil in the room.
- Power tamper is a drop weight type vibrating compactor.
- Vibratory roller can be pad tool type.
- Vibratory rollers can be used for all types of soil except for plastic clays .

- There are many variations of the compacting equipment's; A construction engineer needs to know the suitability for a particular type of soil.
- The following parameters help him in the selection of the proper compacting equipment
  - Capacity of the roller
  - Efficiency of the various rollers

Soil Compaction Equipment's

The soil compaction equipment's can be divided into two groups:

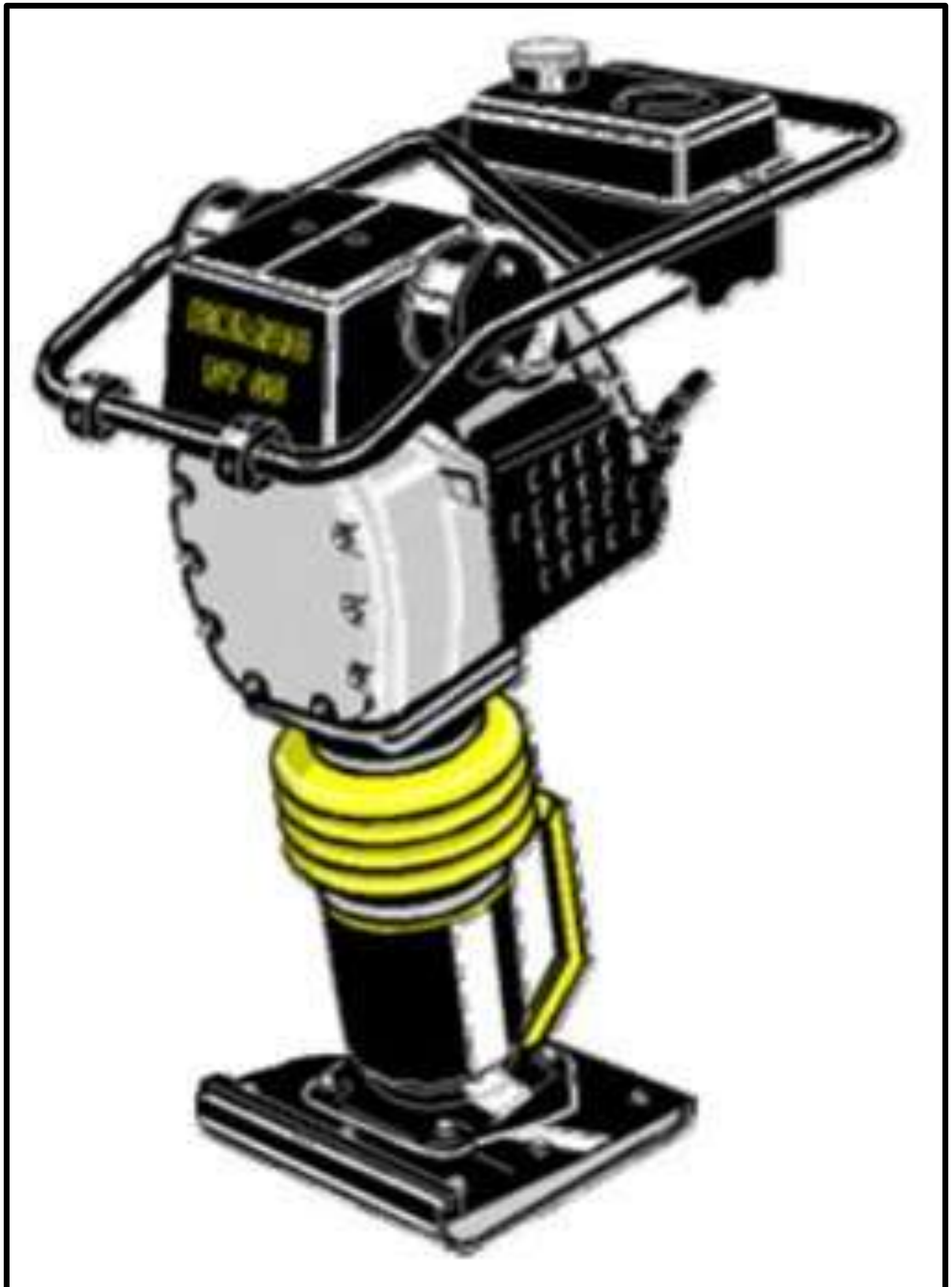
- Light soil compacting equipment's
- Heavy soil compacting equipment's

Light Soil Compacting Equipment's:

(soil compacting of small areas only and where the compacting effort needed is less)

(i) Rammers:

- Rammers are used for compacting small areas by providing impact load to the soil.
- This equipment is light and can be hand or machine operated.
- The base size of rammers can be 15cm x 15cm or 20cm x 20cm or more.



Vibrating Plate Compactors:

- Vibrating plate compactors are used for compaction of coarse soils with 4 to 8% fines.
- These equipment's are used for small areas.
- The usual weights of these machines vary from 100 kg to 2 tonne with plate areas between 0.16 m^2 and 1.6 m^2.

Vibro-Tampers:

- **Vibro-tampers is used for compaction of small areas in confined space.**
- **This machine is suitable for compaction of all types of soil by vibrations set up in a base plate through a spring activated by an engine driven reciprocating mechanism.**
- **They are usually manually guided and weigh between 50 and 100 kg (100 to 220 lbs).**


BT60
BOMAG
BT65
BOMAG
BVT65
BOMAG

Heavy Soil Compaction Equipment's:

- These are selected based on moisture content of soil and types of soil.
- I) Smooth Wheeled Rollers:
  - Static smooth wheeled rollers
  - Vibrating smooth wheeled rollers
- The most suitable soils for these roller type are well graded sand, gravel, crushed rock, asphalt etc. where crushing is required.

Vibrating smooth wheeled rollers:

- In case of vibrating smooth wheeled rollers, the drums are made to vibrate by employing rotating or reciprocating mass.
- These rollers are helpful from several considerations like:
- (i) Higher compaction level can be achieved with maximum work
- (ii) Compaction can be done up to greater depths
- (iii) Output is many times more than conventional rollers


KORMAX

- **(ii) Sheepsfoot Roller:**
- Sheepsfoot rollers are used for compacting fine grained soils such as heavy clays and silt clays.
- Sheepsfoot rollers are used for compaction of soils in dams, embankments, subgrade layers in pavements and rail road construction projects.
- Sheepsfoot rollers are of static and vibratory types.
- Vibratory types rollers are used for compaction of all fine grained soils and also soil with sand-gravel mixes.
- Generally this roller is used for compaction of subgrade layers in road and rail projects.

- **(iii) Pneumatic Tyred Rollers:**
- **Pneumatic tyre rollers are also called as rubber tyred rollers.**
- **These rollers are used for compaction of coarse grained soils with some fines.**
- **These rollers are least suitable for uniform coarse soils and rocks.**
- **Generally pneumatic tyred rollers are used in pavement subgrade works both earthwork and bituminous works.**

- **(iv) Grid Rollers:**
- **Grid rollers are used for compaction of weathered rocks, well graded coarse soils.**
- **These rollers are not suitable for clayey soils, silt clays and uniform soils.**
- **The main use of these rollers are in subgrade and sub-base in road constructions.**

- (v) Pad Foot / Tamping Rollers:
- These rollers are similar to sheepsfoot rollers with lugs of larger area than sheepsfoot rollers.
- The static pad foot rollers also called tamping rollers have static weights in the range of 15 to 40 tonnes and their static linear drum loads are between 30 and 80 kg/cm.
- These rollers are more preferable than sheepsfoot roller due to their high production capacity, and they are replacing sheepsfoot rollers.

EQUIPMENT FOR EARTHWORK

EARTHWORKS

- **The disturbance of soil or earth by any means including excavation (including subsurface), tunnelling, drilling, infilling, land rehabilitation or restoration, stockpiling, dumping of soil or sand, and the construction/reconstruction of any track, embankment, or drainage channel.**

- **Soil is one of major construction materials used for the construction of road, embankment , earthen dam.**
- **To construct the infrastructural facilities on the soil.**
- **Construction engineer has to involve with soil with various object.**
- **The process of excavating the soil, transport to the other place and placing it is called Earthwork.**

- Quantities of Earthwork varies from millions of cubic meters to 100 cubic meter.
- Like in the excavation of open mines to obtain coal require the removal of 200 m to 800 m of soil from the top which is a gigantic amount whereas construction of building with spread footing requires few cubic meter of soil.

Earthwork primarily involved the following process:

- **Excavation of soil or shifting of the soil.**
- **Loading, transportation and unloading of soil.**
- **Placing and compacting of the soil.**
- **Depending upon the quantity of work, site conditions availability of recourses these works are carried out by various method and equipment's.**

Excavation

- Soils are required to be excavated at site for various purposes . Some of the purposes of soil excavations are:
- Removal of soil to level the ground. Example , cutting of hill .
- For filling the ground at other places – making embankments .
- For making structures such as footing or laying pipes , etc.

- **Depending on the type of soil, different techniques are used for the excavation.**
- **In India, small earthwork excavation such as for building work, canal embankment, repair and construction; excavation is carried out manually.**
- **For infrastructural project such as construction of road, dams, embankment for flood control and irrigation, large volume of earthwork is involved.**

- These constructions are carried out using large scale equipment's .They are heavy equipment's.

Commonly used equipment's are:

- Bulldozers
- Power Shovels
- Scrapers
- Dragline
- Clamshell
- Backhoe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Bulldozers:

- A dozer which is popularly called bulldozer is a self contained tractor power unit with a blade attached to its front .
- They are used for pushing the materials, land clearing, striping, towing other pieces of constructions, assisting in loading side hill cutting, backfilling & spreading, etc.
- Dozers can be classified as: Crawler type
  - Wheel type

DOZERS

They are used for moving earth up to a distance of about 100m and act as a towing tractor and pusher to scraper machines. They can be track-mounted or wheel-mounted.

Power shovels:

- Power shovels are the hydraulic excavator.
- A excavation bucket is attached to the hydraulically controlled boom & stick.
- The bucket moves in a forward and upward direction.
- The bucket can be swung around depending upon the type of the shovel and load the soil in the truck.

- **The shovels may be either crawler or rubber tire carrier mounted .**
- **Its capacity is dependent upon the manufacturer specifications .**
- **A construction engineer needs to enquire about the bucket capacity, cutting height, output, etc. to plan the construction work .**

FRONT SHOVEL

Front shovel are mainly used for excavation purposes above its own track or wheel level.
They are suitable for heavy positive cutting in all types of dry soils.

Scrapers:

- Scrapers is a large steel bowel attached with the cutter at the bottom, which is moulded on the wheel.
- It is a multipurpose equipment which is used for excavation the soil, transporting it and spreading it at the other place.
- The basic operating parts of the scrapers are bowl, apron, ejector.
- During excavation, the cutting edge is lowered to scrape the soil and the cutting edge is raised when the bowl is filled.

- **The material is spread after transporting a short distance.**
- **There are various types of scrapers, such as pusher loaded, self loading, etc.**
- **Scrapers can be used for a haulage distance of 100m to 1500m.**
- **Scrapers are not suited for hard rock, muddy soil and certain types of sands which does not pile up in the scrapers.**

SCRAPER

They are used for site levelling, loading, hauling over distances varying between 150m-900m. They may be towed, two-axle or three-axle type.

Dragline:

- In a dragline, a bucket is connected to a cable, which is attached to a long - crane.
- The soil is excavated by dragging this bucket against the soil to be excavated.
- In dragline, bucket falls under the gravity load which loosens the soil.
- It is used for excavation as well as loading the material in the truck.
- Dragline can also be used for underwater excavation.

DRAGLINE

They are used for bulk excavation below its track level in loose soils, marshy land and areas containing water.

Clamshell:

- This bucket is designed to excavate the soil in vertical direction.
- The bucked is like an inverted jaw, having a biting motion.
- It is used for excavating soft soil and stockpiling it.
- The bucket can be opened and closed with the help of a cable or by hydraulic control.

- It is designed that it is half opened when dropped and gets closed when the bucket is filled.
- It can stock pile the soil up to 20 - 30m of height and at a diameter up to 60m .
- It is often used in mining industry .

CLAMSHELL

It consists of a hydraulically controlled bucket suspended from a lifting arm. It is mainly used for deep confined cutting in pits and trenches.

Backhoe:

- Backhoe is a hydraulic excavator with a bucket attached to hydraulic controlled boom and stick.
- In backhoe, the excavation bucket moves in downward and backward direction during excavation.
- The difference between power shovel and backhoe is the movement of bucket.

- Backhoe may be crawler or rubber wheel mounted.
- Backhoe is more suited for the excavation below the ground, such as excavation for basements in building construction or trenches for laying sewer lines.
- The learning requirements for backhoe is same as power shovel .

BACKHOE

Backhoes are mainly used to clean up construction areas, to dig holes in the ground, to smooth uneven ground, to make trenches, ditches and to help remove deep roots from trees.

Transportation

- Some of the equipment's used for excavation are also used for transporting for a distance, depending upon ground conditions.
- Many a time, the soil needs to be transported to other places which are not adjacent to the excavation site.
- The equipment used for transportation is also called haulers.

Various equipment's used for transportation are:

- **Belt conveyers**
- **Tippers**
- **Truck**
- **Dumpers**
- **Graders**

- **Trucks are used for small quality of earthwork which is loaded manually.**
- **Tippers generally unload by rear-tipping.**

- **Dumper** is basically a truck with large size with self unloading mechanisms via hydraulic pump.
- **Conveyers** are used in the terrain where transportation is a problem.
- But it has larger installation cost and generally is used in the place where large quantity of soil has to be hauled.
- **A Grader** is a wheel mounted tractor unit used to spread, trim and level soil with very high precision.
- This is widely used in road construction for levelling and maintaining the grade.

DUMPER

It is used for horizontal transportation of materials on and off sites. Large capacity dumpers are used in mines and quarries.

GRADER

It is used for grading and finishing the upper surface of the earthern formations and embankments. They usually operate in the forward direction.

DUMP TRUCKS OR DUMPERS


ROAD LORRIES
Military-Today.com

CONVEYERS

BOOM HOIST

Boom hoists are used to lift weights on the hooks that are attached to the special metal ropes designed to bear maximum loads.

Boom hoist is mostly used as industrial machine where it loads the weight on containers.

CHAIN HOIST

Chain hoists are quite common example of hoist system and it can be seen at most of the construction and industrial purposes. Basically, chain hoist consists of chain rope and pulley that is used to move the load from up to down.

ELECTRIC HOIST

Electric hoist is modernized form of chain and boom hoist mostly used in the industries for fast working.

It is very much popular in material handling industries because it saves labor costs by handling maximum loads at a time with no damage threats.

TRACTOR HOIST

Tractor hoist consist of a boom that is attached with base of tractor and a hook with rope is installed on this boom that can operated through driver controls.

Mobile Cranes

TOWER CRANES

DERRICK CRANES

- Grab consists of a cable or hydraulically controlled bottom-opening bucket suspended from a crane or a lifting arm.
- The bucket is opened and dropped on to a material to be removed.
- It is then closed and the material caught between the jaws lifted in the grab bucket and discharged onto stockpiles or into waiting haulage vehicles.
- Grabs are typically used for the excavation of pits or trenches and loading to and from stockpiles.

GRAB

During earthwork following volume measurements are used:

- Bank measure volume
- Loose measure volume
- Compacted volume

- Bank measure volume – the volume of earth measured prior to excavation is called bank measure volume .
- Loose measure volume – This is the volume of excavated soil . This volume is useful for transportation payment .

- Compacted volume – This is the volume of earth after the compaction .
- Suppose certain areas are to be filled up, we have to specify the compacted density. This volume will be useful in this payment .

The Earthmoving Process

- Earthmoving is the process of moving soil or rock from one location to another and processing it so that it meets construction requirements of location, elevation, density, moisture content, and so on.
- Activities involved in this process include : excavating, loading, hauling, placing (dumping and spreading), compacting, grading, and finishing.

- **Efficient management of the earthmoving process requires: accurate estimating of work quantities and job conditions, proper selection of equipment, and competent job management.**
- **Production of Earthmoving Equipment: The basic relationship for estimating the production of all earthmoving equipment is;**
- **Production = Volume per cycle × Cycles per hour**

- The term "volume per cycle" should represent the average volume of material moved per equipment cycle.
- Thus the nominal capacity of the excavator or haul unit must be modified by an appropriate fill factor based on the type of material and equipment involved.
- The term "cycles per hour" must include any appropriate efficiency factors, so that it represents the number of cycles actually achieved (or expected to be achieved) per hour.

The cost per unit of production may be calculated as follows:

- **Cost per unit of production = Equipment cost per hour ÷ Equipment production per hour.**
- **There are two principal approaches to estimating job efficiency in determining the number of cycles per hour to be used.**

- One method is to use the number of effective working minutes per hour to calculate the number of cycles achieved per hour.
- This is equivalent to using an efficiency factor equal to the number of working minutes per hour divided by 60.
- The other approach is to multiply the number of theoretical cycles per 60-min hour by a numerical efficiency factor.

EARTHMOVING MATERIALS

General Soil Characteristics

- Soil and rock are the materials that make up the crust of the earth and are the materials of interest to the constructor.
- Characteristics of soil and rock that affect their construction including: their volume-change characteristics, methods of classification, and field identification.

- Several terms relating to a soil's behaviour in the construction environment should be understood. **Traffic-ability & Load-ability**
- **Traffic-ability** is the ability of a soil to support the **weight of vehicles** under **repeated traffic.**
- In construction, traffic-ability **controls** the **amount and type of traffic** that can use unimproved access roads, as well as the operation of **earthmoving equipment** within the construction area.

- Traffic-ability is usually expressed qualitatively, although devices are available for quantitative measurement.
- Traffic-ability is primarily a function of soil type and moisture conditions.
- when poor traffic-ability conditions exist, the following may be required: Drainage, stabilization of haul routes, or the use of low ground pressure construction equipment.
- Soil drainage characteristics are important to traffic-ability and affect the ease with which soils may be dried out.

- Load-ability: It is a measure of the difficulty in excavating and loading a soil.
- Loose granular soils are highly loadable, whereas compacted cohesive soils and rock have low load-ability.
- Unit weight of soil is normally expressed in lb/yd3 or km/m3.
- Unit weight depends on : soil type, moisture content, and degree of compaction.

- **For a specific soil, there is a relationship between the soil's unit weight and its bearing capacity.**
- **Thus soil unit weight is commonly used as a measure of compaction.**
- **Soil unit weight is also a factor in determining the capacity of a haul unit.**
- **The moisture content of a soil is expressed as a percentage that represents the weight of water in the soil divided by the dry weight of the soil.**

SOIL IDENTIFICATION AND CLASSIFICATION

Soil is considered to consist of five fundamental material types: gravel, sand, silt, clay, and organic material.

- **Gravel is composed of individual particles larger than about ¼ in. (6 mm) in diameter but smaller than 3 in. (76 mm) in diameter.**
- **Rock particles larger than 3 in. (76 mm) in diameter are called cobbles or boulders.**

- **Sand** is material smaller than gravel but larger than the No. 200 sieve opening (0.7mm).
- **Silt particles** pass the No. 200 sieve but are larger than mm.
- **Clay** is composed of particles less than mm in diameter.
- **Organic soils** contain partially decomposed vegetable matter. **Peat** is a highly organic soil having a **fibrous texture**. It is normally readily identified by its **dark colour, odour, and spongy feel.** It is generally considered to be unsuitable for any construction use.

Soil Classification Systems:

- There are two principal soil classification systems used for design and construction in the United States. Unified System and the AASHTO [American Association of State Highway and Transportation Officials, formerly known as the American Association of State Highway Officials (AASHO)] System.
- In both systems soil particles 3 in. or larger in diameter are removed before performing classification tests.

- **The liquid limit (LL)** of a soil is the water content (expressed in percentage of dry weight) at which the soil will just start to flow when subjected to a standard shaking test.
- **The plastic limit (PL)** of a soil is the moisture content in percentage at which the soil just begins to crumble when rolled into a thread ⅛ in. (0.3 cm) in diameter.
- **The plasticity index (PI)** is the numerical difference between the liquid and plastic limits and represents the range in moisture content over which the soil remains plastic.

Field Identification of Soil (Unified System):

- When identifying soil in connection with construction operations, adequate time and laboratory facilities are frequently not available for complete soil classification.
- All particles over 3 in. (76 mm) in diameter are first removed.
- The soil particles are then separated visually at the No. 200 sieve size: this corresponds to the smallest particles that can be seen by the naked eye.

- If more than 50% of the soil by weight is larger than the No. 200 sieve, it is a coarse-grained soil.
- The coarse particles are then divided into particles larger and smaller than ¼ in. (6 mm) in diameter.
- If over 50% of the coarse fraction (by weight) is larger than ¼ in. (6 mm) in diameter, the soil is classified as gravel; otherwise, it is sand.
- If less than 10% by weight of the total sample is smaller than the No. 200 sieve, the second test is assigned based on grain size distribution.

- **If the sample is fine-grained (more than 50% by weight smaller than the No. 200 sieve), classification is based on dry strength and shaking tests of the material smaller than 1/64 in. (0.4 mm) in diameter.**

CONSTRUCTION CHARACTERISTICS OF SOILS

Soil Volume-change Characteristics:

Soil Conditions – Swell – Shrinkage - Load and Shrinkage Factors

- **Soil Conditions**: There are three principal conditions or states in which earthmoving material may exist: bank, loose, and compacted.
- **Bank:** Material in its natural state before disturbance. Often referred to as "in-place" or "in situ.“ A unit volume is identified as a bank cubic yard (BCY) or a bank cubic meter (BCM).

Loose:

- **Material that has been excavated or loaded. A unit volume is identified as a loose cubic yard (LCY) or loose cubic meter (LCM).**

Compacted:

- **Material after compaction. A unit volume is identified as a compacted cubic yard (CCY) or compacted cubic meter (CCM).**

Swell:

- A soil increases in volume when it is excavated because the soil grains are loosened during excavation and air fills the void spaces created.
- As a result, a unit volume of soil in the bank condition will occupy more than one unit volume after excavation.
- This phenomenon is called swell.

Shrinkage:

- When a soil is compacted, some of the air is forced out of the soil's void spaces.
- As a result, the soil will occupy less volume than it did under either the bank or loose conditions.
- This phenomenon, which is the reverse of the swell phenomenon, is called shrinkage.

Load and Shrinkage Factors:

- In performing earthmoving calculations, it is important to convert all material volumes to a common unit of measure.
- Because haul unit and spoil bank volume are commonly expressed in loose measure, it is convenient to have a conversion factor to simplify the conversion of loose volume to bank volume.
- The factor used for this purpose is called a load factor.

- **A factor used for the conversion of bank volume to compacted volume is sometimes referred to as a shrinkage.**
- **Bank volume may be multiplied by the shrinkage factor to obtain compacted volume or compacted volume may be divided by the shrinkage factor to obtain bank volume.**

SPOIL BANKS:

- **When planning and estimating earthwork, it is frequently necessary to determine the size of the pile of material that will be created by the material removed from the excavation.**
- **If the pile of material is long in relation to its width, it is referred to as a spoil bank.**
- **Spoil banks are characterized by a triangular cross section.**

- **If the material is dumped from a fixed position, a spoil pile is created which has a conical shape.**
- **To determine the dimensions of spoil banks or piles, it is first necessary to convert the volume of excavation from in-place conditions (BCY or BCM) to loose conditions (LCY or LCM).**

- A soil's angle of repose is the angle that the sides of a spoil bank or pile naturally form with the horizontal when the excavated soil is dumped onto the pile.
- The angle of repose (which represents the equilibrium position of the soil) varies with the soil's physical characteristics and its moisture content.

CONSTRUCTION EQUIPMENT MANAGEMENT

- **Construction equipment management refers to continuous evaluation of the construction equipment fleet and its cost while at the same time considering the projects at hand.**
- **The process of balancing the expense and use of the construction equipment against the timelines and income from the projects can be called construction equipment management.**

- A construction equipment manager needs to be able to take practical decisions with regards to management of the construction equipment to ensure maximum benefits with minimal expenses for the company.
- Construction equipment should ideally pay for themselves by helping the owner earn more than it costs to own, operate, maintain, store and use the machine.

- **Operation costs are a recurring expense based on frequency of use.**
- **Construction fleets should be evaluated continuously to determine whether**
- **New equipment need to be added to the fleet.**
- **Equipment or any of its parts need to be replaced.**
- **If and when underutilised or damaged machines need to be discarded and at what cost.**

- The choice of construction equipment for a job site is a key factor to be considered for timely completion of the project within the stipulated budget.
- The construction equipment managers thoroughly understand the tasks that need to be completed, the machines that need to be used, the budget and time constraints for the same for flawless execution of the construction project.

- Construction equipment management can either be taken up project wise or for the company as a whole.
- Cost-effectiveness is a major criterion of construction equipment management.
- Following are the things to be considered for effective construction equipment management:

1. The choice of construction equipment and the number in which each of the equipment is required for a certain project or projects.

2. Whether it makes more sense to own, lease or rent the equipment and its effect on the bottom line of the balance sheet.

3. Planning which equipment will be working on which job site at what time and for how long.

4. Considering the transportation and operating costs when dealing with multiple projects and their time lines.

5. How to make the most of the construction equipment at hand.

6. Another major aspect of effective construction equipment management is preventive maintenance of the construction equipment which can help save a lot of down time, money and reduce delays in the project.

Acquiring Construction Equipment

- Many companies and contractors in need of acquiring new or used construction equipment often don't have the financial resources needed to buy the construction equipment outright, unless it is a large corporation or some branch of the government.
- This is when the option of renting or leasing construction equipment comes into play.

- Deciding to rent or lease often depends on what the contractor or business manager feels most comfortable doing from a financial perspective after evaluating the many possibilities and deciding what suits their need from long term leasing to short term renting.
- The construction equipment rentals has met a positive growth since 2004, where nearly 50% of construction equipment dealers' are offering heavy equipment rentals as part of their operation.

- There are two ways most companies acquire their construction equipment, renting or leasing.
- Many contractors or business managers viewed renting or leasing as an opportunity to test out construction equipment at no extra cost.
- Most often the rental would be converted into a purchase to avoid losing the invested equity.

- **Most buyers would also take into account whether their business is flourishing or floundering, before committing to buying any construction equipment.**
- **In a case where a business has an uncertain future, the potential buyers may deem renting as the best way economically and then return the construction equipment to its owner when the job is done.**

- The Association of Equipment Manufacturers (AEM) is the international trade and business development resource for companies that manufacture equipment, products and services used worldwide in the construction, agricultural, mining, forestry, and utility fields.
- The AEM has conducted a survey that predicted that in the near future, more construction equipment buyers will turn to the Internet for product purchases; as construction equipment buyers increasingly turn to the Internet for transactions, information and support.

- **Consequently, the rise of on-line auctions, sales, renting and leasing are made available by a variety of merchants who cater to the needs of companies and contractors worldwide.**
- **On-line merchants such as: Machine Mart, Rock & Dirt, Machinery Trader, Iron Planet, Contractors Hotline, etc. are only a few of the leading markets**

- where companies and contractors alike can find nearly every piece of construction equipment they are looking for, from the top manufacturers such as Caterpillar and John Deere to many more.
- Many of these merchants offer the options of buying, selling, renting and leasing of new and used construction equipment to parts service and repair and machine maintenance.

THE 4 METHODS OF EQUIPMENT ACQUISITION

- **BENEFITS OF BUYING**
- **Buying a machine basically means converting cash to an asset on balance sheet.**
- **This can be a good decision if company has a healthy amount of cash and is looking to add to their assets.**
- **In owning an asset, the machine is always available with and are able to do with it which gives great flexibility.**

- **In terms of overall cost, purchasing for cash with be the lowest cost of acquisition because don't have to pay any interest and can extend depreciation schedule to whatever.**
- **If don't plan to use the machine very often and can spread this cost out over a longer period of time.**
- **Another benefit to a cash purchase is the ability to customize the machine to own unique needs.**

- **The specifications can be adjusted for own application and once on site, free to customize the machine however feel.**
- **Want to add a rock in' stereo and a paint job? No problem, the equipment is yours to do as you please.**

- **DOWNFALLS TO BUYING**
- **First off, in many cases it requires a large capital investment which is going to reduce the available cash flow.**
- **If planning on a major expansion or another acquisition in the near future, this could potentially limit the ability to do so.**

- This method also means entirely responsible for the equipment including any maintenance, repairs, liabilities, and management which can be time consuming.
- Setting a depreciation schedule is great when extend it, but what happens it's still sitting on your books at a high cost?
- Needs of a business may also change as well and it's difficult to change equipment when you have a lot invested into it.

- BENEFITS OF LEASING
- Leasing is a good option when you're looking to keep the equipment long term but you also want to conserve cash flow.
- Leasing is typically used as a form of financing by providing a small buyout at the end of the term and offers a lower monthly rate than a rental options.

- **Leasing offers the lowest monthly rate of any method of acquisition.**
- **Operating leases can be offered under certain circumstances and can be tax deductible.**
- **Leasing makes acquiring new, more expensive equipment available to more companies, especially when cash is tight and allows to run higher quality equipment which will be less likely to require repair.**

- **DOWNFALL TO LEASING**
- **In some cases, the terms will not be favourable given a high interest rate or significant down payment.**
- **Leasing also requires commitment to a set term with limited to no options of early cancellation or pay-out.**
- **This can make changing out equipment difficult in business requirements change and new variables are added.**

- While leasing offers the lowest monthly cost when compared to the next 2 methods, there is still a cost to borrowing money.
- If times are tough and business is slow, the lease rate continues on at the same rate no matter how much revenue are bringing in.

- **BENEFITS OF RENTING**
- **When have got short term equipment requirements and need flexibility, renting is the way to go.**
- **If needs on the job change, can call off the rental or change to a different machine usually within a day or two.**
- **The machines are typically available on short notice and don't have to worry about any storage or warehousing costs while the equipment isn't being used.**

- Most rental machines include planned maintenance if are working on a local site.
- This reduces maintenance costs and eliminates one component need to plan for.
- Renting allows to cut capital costs and instead, operate equipment as a monthly expense.
- This not only increases cash flow, but can also have significant tax benefits at the end of the year.

- **DOWNFALL TO RENTING**
- **Convenience comes at a cost; this is why a short term rental is typically the most expensive option over time.**
- **This can be reduced when renting over a longer period of time, but it won't come close to a capital lease when looking at a longer term.**
- **The monthly rental payment also builds no equity so, while taking advantage of the tax benefits, balance sheet's asset value will not improve.**

- **BENEFITS OF FLEET MANAGEMENT**
- **Fleet management offers the tax benefits of renting, with the customization capabilities of buying or leasing.**
- **This method has been developed by Leavitt Machinery as a comprehensive way to reduce total operating costs and is tailored specifically to each customer's application.**

- With this program, the responsibility to manage the equipment is on us and in return, pay on monthly payment for easy budgeting.
- This also eliminates the risk of unforeseen costs such as improper depreciation, major component failure, lost productivity, and unexpected maintenance repairs on old equipment.

- Similar to renting, fleet management is a fully tax deductible operating expense however; this method can accommodate specialty equipment required for unique or specialized situations.
- Cash flow is conserved, and are able to operate the latest technology without any carrying costs for equipment.

- The rates are typically less than renting as they are adjusted to meet specific usage and can also accommodate a number of different options.
- Some of these items include equipment maintenance, annual non-destructive testing (NDT), tire replacement, battery replacement, extended warranties, and even custom attachments for machine.

- **DOWNFALL TO FLEET MANAGEMENT**
- **This is usually determined with the help of an account manager by determining the optimal turnout time for each specific piece of equipment.**
- **In an application where the machines experience a higher utilization, the term will be shortened and thus a higher monthly rate will be applied.**

- With this method don’t build equity in to the machine, similar to renting.
- To reduce the total operating costs of an equipment by taking into account the cost of buying, depreciation, maintenance, and intangible costs.
- Total costs will be decreased over time and won’t need to dish out the capital for equipment every year.

- **WHICH OPTION IS BEST FOR YOU?**
- **The fact is the right method will ultimately depend on your own unique situation.**
- **When deciding on a method, dig deep and ask yourself questions to find the best fit:**
- **Are needs constantly changing?**
- **Could be better use capital towards other projects?**
- **How long will need the equipment?**
- **Is equipment meeting my needs?**
- **Do value convenience over cost?**

- These are just a few questions to ask but they will help drill down and determine which method is the best fit.
- A customer in a highly volatile and unpredictable business might prefer short term rentals whereas a company with strong mechanical abilities and a healthy cash flow will prefer buying. In the end, it all depends on situation.

- **When to buy or rent heavy equipment – five factors to consider.**


OVERSIZE LOAD
MACK

- **1. Current financial situation**
- **We can reduce the initial financial impact of buying a piece of equipment in many different ways:**
- **Buy good quality used equipment**
- **Finance your equipment purchase**
- **2. Cost of ownership vs cost of renting**
- **3. Length of project or job frequency**
- **4. Equipment availability & usage**
- **5. Fleet management and inventory control**

ELC – Equipment Life Cycle

- **The equipment lifecycle begins from the time equipment is requested through its retirement from service and typically consist of three phases:**
- **Acquisition, Use, and Retirement**

- **What is Equipment Life Cycle (ELC)?**
- **In working with utility customers, we have seen that most often, Data pertaining to their distribution assets (such as street lights, poles, night guards) are maintained within various applications or Databases.**
- **Unfortunately, this Data is not often integrated with the Distribution Network Model**

- **Faced with having to train clerical staff on full Geographical Information Systems (GIS), most utility companies choose to support this information in simple Databases or spread sheets that are not at all synchronized with the GIS.**
- **This result in numerous separate Data sources that often contain conflicting information, are not up-to-date and require time-consuming maintenance.**

- **ELC is a standalone Viewport with built-in search capabilities that connects to the Distribution Network Model Database (Oracle Data Centre).**
- **It provides users with a single Data Centre for all facility information, thereby eliminating source Data conflicts and multiple Data maintenance issues.**

Efficient access to accurate Data improves equipment lifecycle management and in this case, could provide the Foam Unit with helpful information in a timely manner.

- What are the Benefits of Using ELC?
- Manipulate all facility attribution using a search function that references a unified Data Centre.
- Evaluate the status of the equipment (or classes of equipment) in order to assume the most appropriate course of action (collect more Data, conduct tests, call for an inspection, schedule maintenance, verify warrantees, notify other departments or agencies, replace, relocate, refurbish or retire equipment).

- **User interface is intuitive, simple to use and designed for tabular Data-entry, so there is no specialized user training required.**
- **Expand on preventive and predictive maintenance measures with augmented Data.**
- **Reporting tools (QUE) may now be configured to leverage the ELC Data Centre to automatically generate reports.**

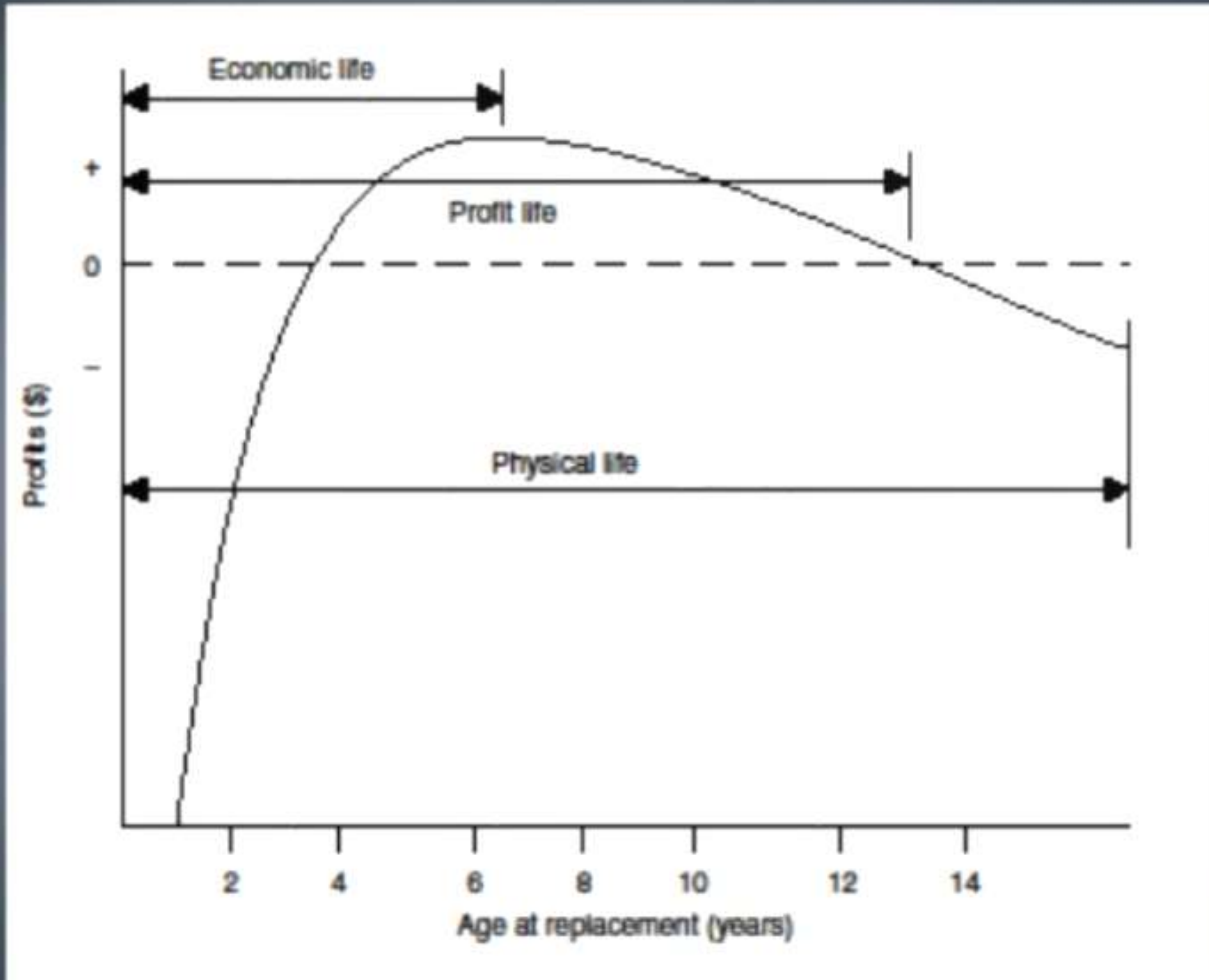
- Network visualization tools (Fusion/Viewer) may be used together with ELC to geographically locate equipment in the field.
- Data Exchange mechanisms (Data Port) allow for the Data updated in ELC to be shared with GIS, OMS, CIS, ERP or any database-driven system.
- Mobile dispatch applications (JOBS) may be configured to leverage ELC Data to assign field inspections or specialized tasks for mobile crews.

EQUIPMENT LIFE AND REPLACEMENT PROCEDURES

- **Equipment Life**
- **Before 2000, most of the roadway construction projects were delivered through traditional low Equipment life can be mathematically defined in three different ways: Physical Life, Profit Life and Economic Life.**

- **Physical and economic life both must be defined and calculated when considering equipment life because they provide two important means to approach replacement analysis and to ultimately make an equipment replacement decision.**

- The concepts of depreciation, inflation, investment, maintenance and repairs, downtime, and obsolescence are all integral to replacement analysis and make reasonable equipment replacement decisions.



Economic life
Profit life
Physical life
+
0
–
Profits ($)
2
4
6
8
10
12
14
Age at replacement (years)

- Physical life of equipment will be identified as the service life.
- This stage is greatly impacted by the repair and maintenance attention that the machine has been provided over its lifespan.
- A piece of equipment that has not been given adequate maintenance throughout its lifespan will deteriorate at a faster rate than a machine that was been given substantial preventative maintenance.

- **Profit life** is the time period where equipment is generating a profit.
- This is the **most desired stage** of the equipment life because after this point in time the **equipment will operate with a loss**.
- This is a **critical stage** in the equipment life to maximize on **profitability and efficiencies**.
- The equipment **fleet manager** must be able to determine this time period to implement a **replacement plan** for a new machine while the components are useful.

- **Economic life** is based on decreasing ownership costs with the increase in operating costs.
- The time period that these **costs are equivalent** is called the economic life.
- When the **operating costs exceed the ownership costs** a piece of equipment is costing more to operate rather than own.
- Thus, to maximize profits **the replacement** of a piece of equipment should occur before the economic life is reached.
- "The proper timing of equipment replacement **prevents an erosion of profitability** by the increased cost of maintenance and operation as the equipment ages beyond its economic life".

- **Equipment Replacement Procedures**
- **Once a piece of equipment is purchased and used, it eventually begins to wear out and suffer mechanical problems.**
- **At some point, it reaches the end of its useful life and must be replaced.**
- **Thus, a major element of profitable equipment fleet management is the process of making the equipment replacement decision.**

- **This decision essentially involves determining when it is longer economically feasible to repair a broken piece of machinery.**
- **Thus, the three components of equipment management economic decision-making include:**
- **Equipment life: Determining the economic useful life for a given piece of equipment.**

- **Replacement analysis:** Analytic tools to compare alternatives to replace a piece of equipment that has reached the end of its useful life.
- **Replacement equipment selection:** Methods to make a logical decision as to which alternative furnishes the most promising solution to the equipment replacement decision

- **The economic life, alternative selection and replacement timing of equipment can be determined using replacement analysis.**
- **The methods can be categorized as either theoretical replacement methods or practical replacement methods.**
- **The theoretical replacement methods include:**

- **Intuitive method** that can be used by owners of small equipment fleets.
- **Minimum cost method** that can be used by public agencies with large equipment fleets.
- **Maximum profit method** that can be used by construction contractors and other that own large equipment fleets.
- **Payback period method**, which is based in engineering economics and can be generally applied.

- **Mathematical modelling method which furnishes a theoretical basis for developing the some of the equipment cost input for computer simulations used to optimize equipment fleet size and composition.**
- **Determining the appropriate timing to replace a piece of equipment requires that its owner include not only ownership costs and operating costs, but also other costs that are associated with owning and operating the given piece of equipment.**
- **These include depreciation, inflation, investment, maintenance, repair, downtime, and obsolescence costs.**

- **Inflation:** Like all everything, equipment replacement costs are affected by **economic and industry inflation.**
- **Economic inflation** is defined as the loss in buying power of the national currency, and industry inflation is the change in construction costs due to long and short-term fluctuations in commodity pricing.

- **Downtime:** Downtime is the time that equipment does not work due to repairs or mechanical adjustments.
- Downtime tends to increase as equipment usage increases.
- The downtime cost includes the ownership cost, operating cost, operator cost, and productivity loss caused by the loss of equipment availability.
- **Productivity** is a measure of the equipment's ability at the original rate.

- **Obsolescence:** Obsolescence is the reduction in value and marketability due to competition from newer or more productive models.
- Obsolescence can be subdivided into two types: technological and market preference.
- Technological obsolescence can be measured in terms of productivity.
- Market preference obsolescence occurs as a function of customers' taste.

- **Replacement Analysis**
- **Replacement analysis is a tool with which equipment owners time the equipment replacement decision.**
- **Through this analysis, the cost of owning the present equipment is compared with the cost of owning potential alternatives for replacing it.**
- **Dr. James Douglas, Professor Emeritus at Stanford University, wrote in 1975 book Construction Equipment Policy.**

- **Intuitive method** is perhaps the most prevalent one for making replacement decisions due to its simplicity and reliance on **individual judgment.**
- **This method mainly depends on professional judgment or an apparent feeling of correctness to make replacement decisions.**
- **Equipment is often replaced when it requires a major overhaul or at times at the beginning of a new equipment-intensive job.**
- **In this case, it is clearly seen that long-term maintenance and operating cost is overlooked by "professional judgment".**

- **Minimum Cost Method:** Minimizing equipment costs is always an important goal for equipment owners.
- However, it is a paramount to public agencies that own large and small fleets of construction equipment, as they have no mechanism to generate revenue to offset their costs.
- To achieve this goal, the minimum cost method focuses on minimizing equipment costs based on not only cost to operate and maintain (O&M costs) a piece of equipment but also the decline in its book value due to depreciation.

Maximum Profit Method:

- This method is based on maximizing equipment profit.
- The method should be used by organizations that are able to generate revenue and hence profits from their equipment.
- If the profits associated with a given piece of equipment can be isolated and clearly defined.
- For this method, the economic life of equipment is the year in which the average annual cumulative profit is maximized.

Payback Period Method:

- The payback period is the time required for a piece of equipment to return its original investment by generating profit .
- This method is useful when it is hard to forecast equipment cash flow due to market instability, inherent uncertainty, and technological changes.
- This method springs from classical engineering economic theory and thus does not seek to identify the economic life of the equipment.

Mathematical Modelling Method

- **Utilizing a computer model to furnish output to assist in making the all-important equipment replacement timing and selection decision allows for more than technical accuracy to be achieved.**
- **It also creates a continuity of institutional equipment management policy that can be carried from one manager to the next without a loss.**

A mathematical model is a function or group of functions comprising a system. It include the following factors:

- Time value of money
- Technological advances in equipment
- Effect of taxes
- Influence of inflation, investment credit, gain on sale

- Increased cost of borrowing money
- Continuing replacements in the future
- Increased cost of future machines
- Effect of periodic overhaul costs and reduced availability

Additionally, in this model revenues and costs may be classified as follows:

- Revenues from the service of the machines
- Maintenance and operating costs, including annual fixed costs, penalties, and overhead
- Capital costs, including interest on investment, depreciation charges, and interest on borrowed funds

- **Discrete costs such as engine, track, and final drive overhauls**
- **Income and corporation taxes, considering depreciation method, recapture of income on sale, and investment credit.**

M.E CONSTRUCTION ENGINEERING AND MANAGEMENT (SECOND SEMESTER)

CEMC 202: CONSTRUCTION EQUIPMENT AND MANAGEMENT

- CONSTRUCTION EQUIPMENT COST
- CONSTRUCTION EQUIPMENT MANAGEMENT
- EQUIPMENT FOR EARTHWORK
- EQUIPMENT FOR OTHER WORKS
- EQUIPMENT SCHEDULING


THE ROLE OF CONSTRUCTION EQUIPMENT
IN CIVIL ENGINEERING
Infra Bazaar
Trust for Value

- **With government rolling out new policies frequently, it is clear that civil engineering will be a predominant requisite for smooth change and development.**
- **It covers a wide field from designing and construction of heavy structures to soil and rock mechanics, surveying, material science and environmental science.**
- **It would need better construction equipment, better construction material and more advanced heavy equipment.**

- The construction industry today is greatly different from the one of the past.
- In the inevitable scenario of infrastructure development, labour shortage and non-availability of skilled manpower, mechanization of construction activity plays vital role.
- Another area gaining popularity is the mechanisation in respect of vertical transportation of men and material.

- Today's tools and equipment have allowed construction worker to eliminate a lot of imperfect mechanisms in construction.
- Mastery over tools and equipment’s has definitely increased man's overall productivity.
- Innovations in the field of construction equipment have reached new heights and equipment’s are being designed considering reduced carbon footprint, air and noise pollution.

CONSTRUCTION EQUIPMENT COST

- **The activities involved in Construction Projects where the magnitude of the work is on a large scale, Speedy Work and Timely Completion of Work with Quality Control are very vital.**
- **In order to achieve this, Mechanization of Work has to be done, where Construction Machinery & Equipment play a pivotal role.**

The need for Mechanization arises due to the following reasons:

- **Magnitude & Complexity of the Project**
- **Projects involving large quantities of material handling**
- **Complexity of Projects using high grade materials**
- **High quality standards**
- **Importance of keeping the Time Schedules**
- **Optimum use of Material, Manpower and Finance**
- **Shortage of skilled and efficient Manpower**

Equipment Selection

- One of the most important tasks in the pre-construction planning process is equipment selection.
- There are many variables to consider when selecting equipment.
- Following factors should be considered at the time of Selecting Construction Equipment:

1. The Equipment should be Standard Equipment if possible.

2. It should give the best service at low cost.

3. Its unit cost of production should be moderate.

4. It should be easily repairable with low shutdown period

5. It should be easily disposed off.

6. It should suit the majority of the requirements of the job.

7. It should be capable of doing more than one function.

8. It should be of moderate size, as they have fewer moving parts and have low working cost.

Classification of Construction Equipment's

- **The basic operations involved in the construction of any Project are Excavation, Digging of large quantities of earth, Moving them to fairly long distances, Placement, Compacting, Levelling, Dozing, Grading, Hauling, etc.**
- **Construction Equipment can be classified as under:**

- 1. Excavating Equipment
-     a.Power Shovel
-     b.Dragline
-     c.Hoe
- 2. Earthmoving Equipment
- 3. Hauling Equipment
- 4. Conveying Equipment
- 5. Dredging Equipment

- 6. Hoisting Equipment
- a. Tower Cranes
- b. Mobile Cranes
- c. Crawler Mounted Cranes
- d. Builders Hoist
- e. Passenger Hoist
- 7. Pumping Equipment
- 8. Compacting Equipment
- 9. Pile Driving Equipment

- 10. Drilling Equipment
- 11. Equipment's used for the Production of Aggregate
- 12. Equipment's used in Hot Mix Batch Plant
- 13. Equipment's used for Concrete Works
- 14. Material Testing Equipment's

Equipment Cost

- Depending on the size of the project, the constructor can either lease/rent the equipment or own the equipment. In case of leasing option, following are to be examined and considered.
- Time factor- whether the rate quoted is for one shift or two shifts or per month etc.
- Cost of Repairs-Clear understanding to be arrived at in respect of repairs, maintenance, consumables etc.

- **Operator**-Usually accompanies the equipment.
- **Fuel and Lubricants**- usually Lessee's responsibility
- **Freight Charges**- Whether delivery at site or transportation extra
- **Insurance**-It is standard practice for the lessee to furnish the lessor a certificate of insurance prior to the delivery.

- For construction firms, it is important to accurately estimate the equipment cost as part of the total cost of the construction project.
- The total cost of a piece of construction equipment consists of two components namely ownership cost and operating cost.
- This is also referred as O&O cost of the construction equipment.

- **Ownership cost:** It is the total cost associated with the construction equipment for owning it irrespective of the equipment is employed or not in the project. The ownership cost consists of the following:
- a) Initial cost b) Salvage value c) Interest cost or cost of capital investment d) Taxes e) Insurance cost and f) Storage cost

a) Initial cost

- Initial cost is the capital investment required to own the equipment.
- It includes purchase cost, sales tax, transportation cost (or freight charges) and cost of assembly and installation of the equipment.
- If the equipment is mounted on rubber tires (pneumatic tires), then the tire cost is deducted from the initial cost for calculating ownership cost.

- **Cost of tires is considered as a part of operating cost of the equipment.**
- **The total amount of depreciation for the construction equipment over the useful life is equal to the initial cost less the estimated salvage value.**

b) Salvage value

- **Salvage value represents expected cash inflow that will be received by disposing of equipment at the end of its useful life.**
- **The estimation of expected salvage value of the equipment can be carried out by referring to the data obtained from past projects wherein same (or similar) equipment was used or information obtained from other relevant sources.**

c) Interest cost or cost of capital investment

- **It is the annual cost of interest charged on the borrowed money or that of capital investment to acquire the ownership of the equipment.**
- **If the equipment is purchased by borrowing money from a lender, then interest cost is the interest charged (at interest rate charged by lender) on the borrowed amount.**

- On the other hand if the equipment is purchased using construction firm's own funds, then cost of capital investment is the interest charged on capital investment at interest rate equal to construction firm's rate of return.
- Even though the construction firm uses its own funds to purchase the equipment, cost of capital investment is charged as part of the ownership cost because the construction firm could have invested the funds elsewhere to earn the return instead of purchasing the equipment.

- The interest cost on borrowed money or cost of capital investment can be exactly calculated by considering time value of money and using appropriate compound interest factors.
- However the interest cost or cost of capital investment can also be calculated approximately as percentage of constant average annual investment (cost) over the useful life of the equipment.

- The annual interest rate or the rate of return is multiplied to the average annual investment to find out the annual interest cost or cost of capital investment.
- The average annual investment can be calculated by finding out the average value of the equipment over the useful life of the equipment.
- It may be noted here that the value of the equipment depreciates with time.

- **The expression for constant annual depreciation from straight-line method is given as follows:**

$$D_m = \frac{P - SV}{n}$$

- **Where, *P* is the initial cost of equipment, *n* is the useful life and *SV* is the estimated salvage value of the equipment.**

d) Taxes

- It represents the property taxes to be paid to the state or central government.
- It depends on the value of the equipment owned and the applicable tax rate for a given location.
- The property tax can be calculated as a percentage of the average annual investment or a percentage of the book value in a given year.
- Generally it ranges from 2 to 5% of the average annual investment or book value of equipment.

e) Insurance cost

- It represents the annual premium to be paid to insurance companies to cover the cost incurred due to accident, fire, theft etc. for the construction equipment.
- The insurance cost can be calculated as a percentage of the average annual investment or the book value in a given year.
- It is generally about 1 to 3% of the average annual investment or book value of equipment.

f) Storage cost

- It is the cost of keeping the equipment in storage yards when it is not operating at the work site.
- Storage cost includes the rental and maintenance charge for storage yards, wages of security guards and wages of workers employed for bringing in and out of the storage yards.
- It is around 0.5 to 1.5% of the average annual investment or book value of equipment.
- The annual storage cost can be calculated for the entire fleet of equipment.

- However the actual rates will vary depending on the type and size of equipment, place of purchase, location of project site etc.
- The total annual ownership cost of the construction equipment is calculated by summing up depreciation cost, investment (or interest) cost, tax, insurance and storage costs.
- Then the hourly cost of ownership can be calculated by dividing the annual ownership cost by the number of operating hours the equipment will operate annually.

Operating Cost

Operating cost is incurred only when the equipment is operated.

The operating cost of the equipment is influenced by various parameters namely number of operating hours, location of job site, operating conditions, category of equipment etc.

The operating cost consists of the following;

a) Repair and maintenance cost,

b) Fuel cost,

c) Cost of lubricating oil, filter and grease,

d) Tire cost

e) Equipment operator wages,

f) Cost of replacing high-wear items and

g) Cost of mobilization, demobilization and assembly

a) Repair and maintenance cost

- **Repair and maintenance cost is incurred as the construction equipment is subjected to wear and tear due to the operations it performs.**
- **It includes the cost of replacement parts, labour charges and the cost of setting up and operating facilities to carry out major repair and maintenance operations.**

- **It varies from one year to another over the service life of the equipment, however it increases with age of the equipment. This cost contributes a substantial portion of the operating cost.**
- **The increase in service life and decrease in repair and maintenance cost of construction equipment can be achieved by carrying out timely recommended maintenance and repair operations.**

- **The minor repairs can be carried out at the job site where the equipment is operating, however the major repairs can be carried out in the facilities set up by the equipment owner or in the workshop of authorized dealers for the equipment.**
- **The annual repair and maintenance cost can be calculated as a percentage of the annual depreciation cost of the equipment.**

- Past information available from company records or from other relevant sources for similar equipment under similar working conditions can be used for estimating the repair and maintenance cost.
- If this data is not available, equipment manufacturer's guidelines can be used for calculating this cost.
- The hourly repair and maintenance cost can be calculated by dividing the annual cost by the number of operating hours per year.

b) Fuel cost

- The construction equipment's are generally powered by IC engines which use either gasoline (petrol) or diesel as the fuel.
- The fuel consumption depends on the rated flywheel horsepower (fwhp) of the engine and the nature of working conditions.
- The flywheel horsepower represents the power for operating an equipment.

- **A gasoline engine consumes about 0.06 gal (gallon) of fuel per flywheel horsepower hour whereas a diesel engine consumes about 0.04 gal of fuel per flywheel horsepower hour when operating under standard conditions.**
- **Historical data about the quantity of fuel consumed by similar equipment under similar working conditions can be used to estimate the hourly fuel consumption by the equipment.**

- If these records are not available, equipment manufacturer's fuel consumption data can be used to estimate the fuel cost.
- The hourly fuel cost can be calculated by multiplying the hourly fuel consumption by its unit price.

c) Cost of lubricating oil, filter and grease

- The quantity of lubricating oil, filter and grease required depends on operating hours, frequency of changes, engine characteristics and working conditions at the job site.
- The equipment manufacturer guidelines or past data from experience of similar equipment in similar working conditions can be used to estimate of time period between the changes.

- **The quantity of lubricating oil required by engine can be calculated by using the following relationship.**

$$q_l = \frac{hp \times f \times 0.006\,lb/hp-h}{7.4\,lb/gal} + c/t$$

Where

q l **= quantity of oil required in gal/h**

hp = rated horsepower of the engine

f **= operating factor**

c **= capacity of crankcase in gallons**

t **= number of hours (i.e. duration) between the oil changes**

d) Tire cost

- The cost of pneumatic tires (rubber tires) is considered as a part of operating cost.
- The tire cost includes the tire repair and replacement charges.
- The service life of tires is generally shorter than that of the equipment as the tires wear out at a faster rate than the equipment.

- **The life of tires varies according to extent of wear it is subjected to, which depends on the job site conditions.**
- **Tire repair charges can be calculated as a certain % of tire depreciation cost.**
- **The past data from similar operating and project site conditions and tire and equipment manufacturer guidelines can be used to estimate the expected life of tires.**

- The hourly tire repair and replacement cost can be calculated by dividing the sum of the cost of a set of tires and repair charges by the life of tires in hours.

e) Equipment operator wages

- The operator cost includes the hourly wages and benefits paid by the company to the operators.

- It includes normal wages, workmen's compensation insurance premium, fringe benefits, bonus etc.
- The operator wages vary from project to project.
- The operator cost is normally calculated as a separate cost category and is added to other components of operating cost.

f) Cost of replacing high-wear items

- It represents the cost of high-wears items and these items have a shorter life as compared to the service life of the equipment.
- The high-wear items include blades, cutting edges, drill bits, bucket teeth etc.

- **The expected life of these items can be estimated from past records or from manufacture guidelines.**
- **The hourly cost can be calculated by dividing the unit cost by estimated life (in hours).**

g) Cost of mobilization, assembly and demobilization

- **This cost includes transportation charges from one project site to another, cost required for getting road permits, unloading charges, cost of assembly at the project site etc.**
- **The hourly cost can be calculated by dividing the total cost by the number of operating hours.**

Methods of Calculating Ownership and Operating Cost

The most common methods available are the Caterpillar method, Association of General Contractor method (AGC), Equipment Guide Book method (EGB), Dataquest method, Corps of Engineers method, and Peurifoy / Schexnayder method.

Caterpillar Method: (Caterpillar 1998):

1. **No prices for any items are provided.**
2. **Calculations are based on the complete machine.**
3. **The multiplier factors provided will work equally well.**
4. **Machine use, the operating conditions and applications are defined in zones.**

- **Ownership Costs:**
- **These costs are calculated for depreciation, interest, insurance, and taxes.**
- **Usually depreciation is done to zero value with the Straight Line Method, which is not based on tax consideration.**
- **Service life of equipment is given in the Caterpillar Performance Handbook.**

- **Acquisition or delivered costs should include costs due to freight, sales tax, delivery, and installation.**
- **Tire cost is subtracted from the delivered price.**
- **Insurance cost and property taxes can be calculated in one of two ways. (machine is purchased outright or financed)**

- **Operating Costs:**
- **The factors for fuel, FOG, tires and repairs costs can be obtained for each model from tables and charts given in the Caterpillar Performance Handbook (Caterpillar 1998).**
- **Repairs are estimated on the basis of a repair factor that depends on the type, employment and capital cost of the machine.**

Corps of Engineers Method:

- **This method is often considered as the most sophisticated method for calculating equipment ownership costs because it not only covers economic items but it also includes geographic conditions.**
- **This method generally provides hourly use rates for construction equipment based on a standard 40-hour workweek.**

- The total hourly use rates include all costs of owning and operating equipment except operator wages and overhead expenses.
- The ownership portion of the rate consists of allowances for depreciation and costs of facilities capital cost of money (FCCM).

- **Operating costs include allowances for fuel, filter, oil, grease, servicing the equipment, repair and maintenance, and tire wear and tire repair (US Army Corps of Engineers 2003).**

Ownership Costs:

- 1. Depreciation: It is calculated by using the straight-line method.
- The equipment cost used for depreciation calculation is subtracted by tire cost at the time the equipment was manufactured.
- Another cost that has to be subtracted is salvage value.

- **It is determined from the “Handbook of New and Used Construction Equipment Values” (Green Guide), and advertisements of used equipment for sale displayed in current engineering and construction magazines (Handler 2004).**
- **The expected life span of the equipment is designated from the manufacturers’ or equipment associations’ recommendations.**

- **2. Facilities Capital Cost of Money (FCCM),** the Department of the Treasury adjust the cost-of-money rate on or about January 1st and July 1st each year.
- This cost is computed by multiplying the cost-of-money rate, determined by the Secretary of the Treasury, **by the average value of equipment and prorating the result over the annual operating hours.**

- **It is normally presented in terms of FCCM per hour.**
- **It should be noted that licenses, taxes, storage and insurance cost are not included in this computation.**
- **Instead, they are considered as indirect costs.**

Operating Cost:

- **1. Fuel costs:** Fuel costs are calculated from records of equipment consumption, which is done in cost-per-gallon per hour. Fuel consumption varies depending on the machine's requirements. The fuel can be either gasoline or diesel.
- **2. Filter, oil, and grease (FOG):** FOG costs are usually computed as percentage of the hourly fuel costs.

- **3. Maintenance and repair costs:** These are the expenses charged for parts, labour, sale taxes, and so on. Primarily, maintenance and repair cost per hour are computed by multiplying the repair factor to the new equipment cost, which is subtracted by tire cost, and divided by the number of operating hours.

- **4. Hourly tire cost:** This is the current cost of new tires plus cost of one recapping and then divided by the expected life of new tires plus the life of recapped tires.
- It has been determined that the recapping cost is approximately 50% of the new tire cost, and that the life of a new tire plus recapping will equal approximately 1.8 times the **"useful life"** of a new tire.
- **5. Tire repair cost:** This cost is assumed to be 15% of the hourly tire wear cost.

The Associated General Contractors of America (AGC) Method:

- This method enables the owner to calculate the owning and operating costs to determine capital recovery.
- Rather than dealing with the specific makes and models of the machines, the equipment is classified according to capacity or size.

- **For example, this method computes the average annual ownership expense and the average hourly repair and maintenance expense as a percentage of the acquisition costs.**

- **Ownership Cost:** The ownership costs considered in this method are the same as described in the Caterpillar Method, however, replacement cost escalation is also considered.
- **Depreciation is calculated by the straight-line method, and includes purchase price, sales tax, freight, and erection cost, with an assumed salvage value of ten per cent.**

- **Operating Costs:** Maintenance and repair costs are calculated based on an hourly percentage rates.
- **It is a level rate regardless of the age of the machine.**
- This expense includes field and shop repairs, overhaul, and replacement of tires and tracks, etc.
- **The FOG costs and operator’s wages are not considered in this method.**

Peurifoy/Schexnayder Method:

- **R.L. Peurifoy is considered by many to be the father of modern construction engineering.**
- **His seminal work on the subject, now in its sixth edition set the standard for using rigorous engineering principles to develop rational means for developing cost estimates based on equipment fleet production rates (Peurifoy and Schexnayder 2002).**

Ownership Cost:

- This method assumes the straight-line method for depreciation.
- The value of the equipment is depreciated to zero at the end of the useful life of the equipment.
- The ownership costs are based on an average investment cost that is taken as 60 per cent of the initial cost of the equipment.

- **Usually equipment owners charge an annual fixed rate of interest against the full purchase cost of the equipment.**
- **This gives an annual interest cost, which is higher than it should be. Since the cost of depreciation has already been claimed, it is more realistic to base the annual cost of investment on the average value of equipment during its useful life.**

- **This value can be obtained by taking an average of values at the beginning of each year that the equipment will be used, and this is the major difference between the Peurifoy Method and the other methods.**
- **The cost of investment is taken as 15 per cent of the average investment.**

Operating Costs:

- **Since the tire life is different from that of the equipment, its costs are treated differently.**
- **The maintenance cost is taken as 50 per cent of the annual depreciation, the fuel and the FOG costs are included, whereas the operator wages are not included.**