CE 633

ADVANCED BUILDING AND CONSTRUCTION MANAGEMENT TOPICS

LECTURE NOTES

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Foreword

Some parts of this lecture Notes were taken from the CE431 Lecture Notes of Civil Engineering Department, Near East University.

The remaining text is based on the education, experience and findings of the author, The text books referenced in this lecture note are;

Lecture Notes CE431, Construction Management
Author: Ata Atun
Near East University
Date: 2009

Computer Based Construction Project Management
Author: Tarek Hegazy
University of Waterloo, Ontario, Canada
Printed by Prentice Hall
Upper Saddle River, New jersey, Columbus, Ohio, USA
ISBN: 0-13-088859-1
Date: 2002

Construction Planning and Scheduling
Author: Jimmie W. Hinze
Publisher: Prentice Hall
Upper Saddle River, New jersey, Columbus, Ohio, USA
ISBN: 9780130928610
Date: August 2003

CHAPTER 1

Construction Safety Measures

Understanding Safety

Construction-related injuries are decreasing. This trend is most likely due to increased awareness of the potential risks surrounding construction jobsites. Although the concrete industry boasts one of the lower jobsite-injury rates, an understanding of the potential risks of concrete construction and proper training is necessary to limit injuries.

It is often said that everyone is a safety official—any person can call a halt to operations if conditions look unsafe. In fact, the ultimate safety of a construction project is the responsibility of everyone associated with the project. Owners are tasked with implementing a safety program and providing safety equipment; managers are responsible for conducting safety training, planning jobs according to the safety program, and ensuring employees are adhering to safety standards; superintendents and foremen must enforce the safety regulations and be prepared to halt unsafe actions; and the workers utilize safety training by recognizing hazards, wearing and using safety equipment, policing fellow workers, and reporting unsafe conditions.

Recognizing health and safety hazards is the most important element in preventing injury and death. The second element is the precaution implemented to prevent or reduce the hazard.

Health and Safety Hazards

Construction jobsites are full of hazards, and concrete construction jobsites are no exception. These hazards can be dissected into categories for better reference.

Material Hazards

Cement comprises 7 to 15 percent of total concrete volume. As an alkaline material, wet cement is caustic, and can cause severe chemical burns to exposed skin and eyes. Thus, working with fresh concrete presents an obvious risk. That's why it's so important to always wear water-proof gloves, a long-sleeved shirt, full-length trousers, and proper eye

protection. If you have to stand in wet concrete, use water-proof boots that are high enough to keep concrete from flowing into them. Wash wet concrete, mortar, cement, or cement mixtures from your skin immediately. Flush eyes with clean water immediately after contact. Indirect contact through clothing can be as serious as direct contact, so promptly rinse out wet concrete, mortar, cement or cement mixtures from clothing. And always seek immediate medical attention if you have persistent or severe discomfort.
In addition to the caustic nature of cement, 95 percent of cement particles are smaller than 45 µm.—compared to tobacco smoke of approximately 3 µm—suggesting that the danger of inhalation is possible. Workers opening bags or sacks of cement and cement products should always wear a dust mask in addition to their regular safety attire.

Machinery

Rotating machinery is always a potential source of injury on a jobsite. Early-entry saws, concrete/masonry saws, cut-off saws, and power trowels pose a threat to appendages when used improperly. In addition, any sustained or sudden noise above 85 decibels emanating from machinery can be damaging to the ear.

Hydraulic jacks used in shoring, compressed air and hydraulic concrete pumps, belt conveyors, welding equipment, post-tensioning jacks, demolition devices, and other equipment also create potential hazards on a concrete construction site.

Tools

Besides the mechanized saws and power trowels listed above, sharp-edged trowels, hammers, chisels, utility knives, etc. can be dangerous if used carelessly or incorrectly. Long-handled bullfloats, when used near utility wires, can also be dangerous.

Height

The number-one leading cause of construction-related injuries and fatalities is attributed to falls from height. Sources of height associated with concrete construction include but are not limited to scaffolding, ladders, bucket-trucks, catwalks, elevated or wall forms, and elevated floors. Owners, managers, contractors, and laborers should be aware of specific height sources on a project as they are virtually unavoidable in construction.

Construction Practices
As a practice, concrete placement and finishing is one of the most benign forms of construction. However, certain practices associated with concrete construction contribute to risks. The use of cranes for lifting and placing concrete buckets, for tilt-up concrete panels, and for lifting precast members present hazards to the finishers and erectors. Concrete pumping, hydro-demolition, or shotcreting operations where high pressures are generated in hoses prompt safety concerns for the nozzle men. Reinforcement construction can demand heavy materials, protruding steel, oxyacetylene torches or welding equipment, and height sources, each of which introduces a safety hazard either singularly or in any combination. Post-tensioning operations impart stresses nearly equal to the yield strength of prestressing tendons – which can be 17,600 kg/cm^2. Such forces are dangerous to jack-operators or on-looking personnel. Precast plants with heavy table forms, consolidation equipment, and curing rooms must follow safety procedures.

Jobsite Conditions

The general condition of the jobsite can also be hazardous. Cramped, confined projects or sections of a project affect operations and safety. Locations exposed to traffic, utility wires, excavations, or hazardous materials can produce unsafe conditions. Even weather (i.e.: snow, ice, rain, standing water, heat) can result directly in injury or combine with another risk to inflict injury to workers.

Prevention
When potential hazards are considered and combined with preventive measures, the occurrence of work-related injuries and death can be significantly reduced.

Personal Protection
In general, hardhats and hearing protection are always necessary on a construction site when overhead hazards and loud or sustained noise is present. When working with cement, sand, or any other fine material, the use of a respirator is necessary.

Equipment Protection

All equipment should be properly maintained and equipped with manufacturer-recommended safety devices. Disabling or removing safety devices is dangerous and should be avoided. All unsafe or inoperable

equipment should be marked as such to prevent further use of the equipment.
All workers should be trained and tested by the manager or superintendent before operating any equipment (from drills to backhoes). Knowledge of the hazards associated with specific equipment is the first line of defense against injury.

Jobsite Protection
Although anyone may recognize a safety hazard, it is the responsibility of the manager to provide a safe jobsite for workers. As such, the manager or superintendent should ensure that potential hazards at the project site are identified and corrected or, at minimum, made known to employees. This preparation should be directed to the categories of safety hazards listed above.

SAFETY ON VARIOUS JOBS

Construction

Nearly thousands of people work at approximately hundreds of construction sites across the nation on any given day. The fatal injury rate for the construction industry is higher than the national average in this category for all industries.

Potential hazards for workers in construction include:
- Falls (from heights);
- Trench collapse;
- Scaffold collapse;
- Electric shock and arc flash/arc blast;
- Failure to use proper personal protective equipment; and
- Repetitive motion injuries.

Hazards & Solutions

For construction, the precautions should be taken in the following areas:
1. Scaffolding
2. Fall protection (scope, application, definitions)
3. Excavations (general requirements)
4. Ladders
5. Head protection
6. Excavations (requirements for protective systems)

7. Hazard communication
8. Fall protection (training requirements)
9. Construction (general safety and health provisions)
10. Electrical (wiring methods, design and protection)

Scaffolding Hazard

When scaffolds are not erected or used properly, fall hazards can occur. Around one third of the construction workers work on scaffolds. Protecting these workers from scaffold-related accidents would prevent a notable number of injuries and fatalities each year.

Solutions:

- Scaffold must be sound, rigid and sufficient to carry its own weight plus four times the maximum intended load without settling or displacement. It must be erected on solid footing.
- Unstable objects, such as barrels, boxes, loose bricks or concrete blocks must not be used to support scaffolds or planks.
- Scaffold must not be erected, moved, dismantled or altered except under the supervision of a competent person.

- Scaffold must be equipped with guardrails, midrails and toeboards.
- Scaffold accessories such as braces, brackets, trusses, screw legs or ladders that are damaged or weakened from any cause must be immediately repaired or replaced.
- Scaffold platforms must be tightly planked with scaffold plank grade material or equivalent.
- A "competent person" must inspect the scaffolding and, at designated intervals, reinspect it.
- Rigging on suspension scaffolds must be inspected by a competent person before each shift and after any occurrence that could affect structural integrity to ensure that all connections are tight and that no damage to the rigging has occurred since its last use.
- Synthetic and natural rope used in suspension scaffolding must be protected from heat-producing sources.
- Employees must be instructed about the hazards of using diagonal braces as fall protection.
- Scaffold can be accessed by using ladders and stairwells.
- Scaffolds must be at least 10 feet from electric power lines at all times.

Fall Protection

Each year, falls consistently account for the greatest number of fatalities in the construction industry. A number of factors are often involved in falls, including unstable working surfaces, misuse or failure to use fall protection equipment and human error. Studies have shown that using guardrails, fall arrest systems, safety nets, covers and restraint systems can prevent many deaths and injuries from falls.

Solutions:

- Consider using aerial lifts or elevated platforms to provide safer elevated working surfaces;
- Erect guardrail systems with toeboards and warning lines or install control line systems to protect workers near the edges of floors and roofs;
- Cover floor holes; and/or
- Use safety net systems or personal fall arrest systems (body harnesses).

Ladders

Ladders and stairways are another source of injuries and fatalities among construction workers. The injuries due to falls on stairways and ladders used in construction forms the majority of the accidents and nearly half of these injuries were serious enough to require time off the job.

Solutions:

- Use the correct ladder for the task.
- Have a competent person visually inspect a ladder before use for any defects such as:
  - Structural damage, split/bent side rails, broken or missing rungs/steps/cleats and missing or damaged safety devices;
  - Grease, dirt or other contaminants that could cause slips or falls;
  - Paint or stickers (except warning labels) that could hide possible defects.
- Make sure that ladders are long enough to safely reach the work area.
- Mark or tag ("Do Not Use") damaged or defective ladders for repair or replacement, or destroy them immediately.
- Never load ladders beyond the maximum intended load or beyond the manufacturer's rated capacity.
- Be sure the load rating can support the weight of the user, including materials and tools.

- Avoid using ladders with metallic components near electrical work and overhead power lines.

Stairways

Slips, trips and falls on stairways are a major source of injuries and fatalities among construction workers.

Solutions:

- Stairway treads and walkways must be free of dangerous objects, debris and materials.
- Slippery conditions on stairways and walkways must be corrected immediately.
- Make sure that treads cover the entire step and landing.
- Stairways having four or more risers or rising more than 30 inches must have at least one handrail.

Trenching

Trench collapses, especially on basement excavations cause dozens of fatalities and hundreds of injuries each year.

Solutions:

- Never enter an unprotected trench.
- Always use a protective system for trenches feet deep or greater.
- Employ a registered professional engineer to design a protective system for trenches 20 feet deep or greater.
- Protective Systems:
  - Sloping to protect workers by cutting back the trench wall at an angle inclined away from the excavation not steeper than a height/depth ratio of 5.5:1, according to the sloping requirements for the type of soil.
  - Shoring to protect workers by installing supports to prevent soil movement for trenches that do not exceed 6.00 m. in depth.
  - Shielding to protect workers by using trench boxes or other types of supports to prevent soil cave-ins.

- Always provide a way to exit a trench--such as a ladder, stairway or ramp--no more than 7.50 m. of lateral travel for employees in the trench.
- Keep spoils at least two feet back from the edge of a trench.
- Make sure that trenches are inspected by a competent person prior to entry and after any hazard-increasing event such as a rainstorm, vibrations or excessive surcharge loads.

SLOPING.

Maximum allowable slopes for excavations less than 6.00 m based on soil type and angle to the horizontal are as follows:

TABLE V:2-1. ALLOWABLE SLOPES

Soil type	Height/Depth ratio	Slope angle
Stable Rock (granite or sandstone)	Vertical	90°
Type A (clay)	0.75 :1	53°
Type B (gravel, silt)	1:1	45°
Type C (sand)	5.5 :1	34°
Type A (short-term) (For a max.excavation depth of 3.60 m.)	0.5 :1	63°

Cranes

Significant and serious injuries may occur if cranes are not inspected before use and if they are not used properly. Often these injuries occur when a worker is struck by an overhead load or caught within the crane's swing radius. Many crane fatalities occur when the boom of a crane or its load line contact an overhead power line.

Solutions:

- Check all crane controls to insure proper operation before use.
- Inspect wire rope, chains and hook for any damage.
- Know the weight of the load that the crane is to lift.
- Ensure that the load does not exceed the crane's rated capacity.
- Raise the load a few inches to verify balance and the effectiveness of the brake system.

- Check all rigging prior to use; do not wrap hoist ropes or chains around the load.
- Fully extend outriggers.
- Do not move a load over workers.
- Barricade accessible areas within the crane's swing radius.
- Watch for overhead electrical distribution and transmission lines and maintain a safe working clearance of at least 3.00 m. from energized electrical lines.

Chemicals

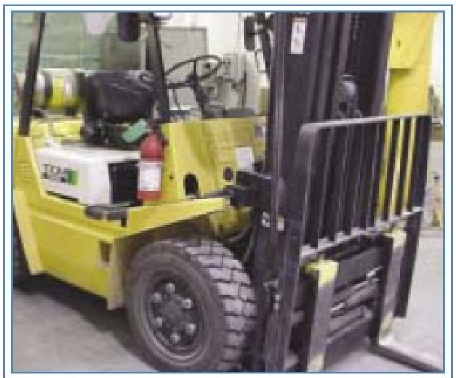
Failure to recognize the hazards associated with chemicals can cause chemical burns, respiratory problems, fires and explosions.

Solutions:

- Maintain a "Material Safety Data Sheet" (MSDS) from the local authorities for each chemical in the facility.
- Make this information accessible to employees at all times in a language or formats that are clearly understood by all affected personnel.
- Train employees on how to read and use the MSDS.
- Follow manufacturer's MSDS instructions for handling hazardous chemicals.
- Train employees about the risks of each hazardous chemical being used.
- Provide spill clean-up kits in areas where chemicals are stored.
- Have a written spill control plan.
- Train employees to clean up spills, protect themselves and properly dispose of used materials.
- Provide proper personal protective equipment and enforce its use.
- Store chemicals safely and securely.

Forklifts

Employees are fatally injured every year while operating powered industrial trucks. Forklift turnover accounts for a significant number of these fatalities.



Solutions:

- Train and certify all operators to ensure that they operate forklifts safely.
- Do not allow any employee under 18 years old to operate a forklift.

- Properly maintain haulage equipment, including tires.
- Do not modify or make attachments that affect the capacity and safe operation of the forklift without written approval from the forklift's manufacturer.
- Examine forklift truck for defects before using.
- Follow safe operating procedures for picking up, moving, putting down and stacking loads.
- Drive safely--never exceed 8 km/h and slow down in congested or slippery surface areas.
- Prohibit stunt driving and horseplay.
- Do not handle loads that are heavier than the capacity of the industrial truck.
- Remove unsafe or defective forklift trucks from service.
- Operators shall always wear seatbelts.
- Avoid traveling with elevated loads.
- Assure that rollover protective structure is in place.
- Make certain that the reverse signal alarm is operational and audible above the surrounding noise level.

Head Protection

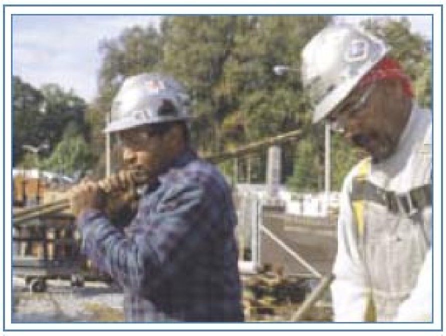
Serious head injuries can result from blows to the head.

Solution:
- Be sure that workers wear hard hats where there is a potential for objects falling from above, bumps to their heads from fixed objects, or accidental head contact with electrical hazards.

Safety Checklists

The following checklists may help you take steps to avoid hazards that cause injuries, illnesses and fatalities. As always, be cautious and seek help if you are concerned about a potential hazard.

Personal Protective Equipment (PPE)



Eye and Face Protection
- Safety glasses or face shields are worn anytime work operations can cause foreign objects getting into the eye such as during welding, cutting, grinding, nailing (or when working with concrete and/or harmful chemicals or when exposed to flying particles).
- Eye and face protectors are selected based on anticipated hazards.

- Safety glasses or face shields are worn when exposed to any electrical hazards including work on energized electrical systems.

Foot Protection

- Construction workers should wear work shoes or boots with slip-resistant and puncture-resistant soles.
- Safety-toed footwear is worn to prevent crushed toes when working around heavy equipment or falling objects.

Hand Protection

- Gloves should fit snugly.
- Workers wear the right gloves for the job (for example, heavy-duty rubber gloves for concrete work, welding gloves for welding, insulated gloves and sleeves when exposed to electrical hazards).

Head Protection

- Workers shall wear hard hats where there is a potential for objects falling from above, bumps to their heads from fixed objects, or of accidental head contact with electrical hazards.
- Hard hats are routinely inspected for dents, cracks or deterioration.
- Hard hats are replaced after a heavy blow or electrical shock.
- Hard hats are maintained in good condition.

Scaffolding

- Scaffolds should be set on sound footing.
- Damaged parts that affect the strength of the scaffold are taken out of service.
- Scaffolds are not altered.
- All scaffolds should be fully planked.
- Scaffolds are not moved horizontally while workers are on them unless they are designed to be mobile and workers have been trained in the proper procedures.
- Employees are not permitted to work on scaffolds when covered with snow, ice, or other slippery materials.
- Scaffolds are not erected or moved within 3.00 m. of power lines.
- Employees are not permitted to work on scaffolds in bad weather or high winds unless a competent person has determined that it is safe to do so.
- Ladders, boxes, barrels, buckets or other makeshift platforms are not used to raise work height.
- Extra material is not allowed to build up on scaffold platforms.
- Scaffolds should not be loaded with more weight than they were designed to support.

Electrical Safety

- Work on new and existing energized (hot) electrical circuits is prohibited until all power is shut off and grounds are attached.
- An effective Lockout/Tagout system is in place.

- Frayed, damaged or worn electrical cords or cables are promptly replaced.
- All extension cords have grounding prongs.
- Protect flexible cords and cables from damage. Sharp corners and projections should be avoided.
- Use extension cord sets used with portable electric tools and appliances that are the three-wire type and designed for hard or extra-hard service. *(Look for some of the following letters imprinted on the casing: CE, TSE, BS.)*
- All electrical tools and equipment are maintained in safe condition and checked regularly for defects and taken out of service if a defect is found.
- Do not bypass any protective system or device designed to protect employees from contact with electrical energy.
- Overhead electrical power lines are located and identified.
- Ensure that ladders, scaffolds, equipment or materials never come within 3.00 m. of electrical power lines.
- All electrical tools must be properly grounded unless they are of the double insulated type.
- Multiple plug adapters are prohibited.

Floor and Wall Openings

- Floor openings (30 cm. or more) are guarded by a secured cover, a guardrail or equivalent on all sides (except at entrances to stairways).
- Toeboards are installed around the edges of permanent floor openings (where persons may pass below the opening).

Elevated Surfaces

- Signs are posted, when appropriate, showing the elevated surface load capacity.
- Surfaces elevated more than 1.20 m. above the floor or ground have standard guardrails.
- All elevated surfaces (*beneath which people or machinery could be exposed to falling objects*) have standard 10 cm. toeboards.
- A permanent means of entry and exit with handrails is provided to elevated storage and work surfaces.
- Material is piled, stacked or racked in a way that prevents it from tipping, falling, collapsing, rolling or spreading.

Hazard Communication

- A list of hazardous substances used in the workplace is maintained and readily available at the worksite.
- There is a written hazard communication program addressing Material Safety Data Sheets (MSDS), labeling and employee training.
- Each container of a hazardous substance (vats, bottles, storage tanks) is labeled with product identity and a hazard warning(s) (*communicating the specific health hazards and physical hazards*).

- Material Safety Data Sheets are readily available at all times for each hazardous substance used.
- There is an effective employee training program for hazardous substances.

Crane Safety

- Cranes and derricks are restricted from operating within 3.00 m. of any electrical power line.
- The upper rotating structure supporting the boom and materials being handled is provided with an electrical ground while working near energized transmitter towers.
- Rated load capacities, operating speed and instructions are posted and visible to the operator.
- Cranes are equipped with a load chart.
- The operator understands and uses the load chart.
- The operator can determine the angle and length of the crane boom at all times.
- Crane machinery and other rigging equipment is inspected daily prior to use to make sure that it is in good condition.
- Accessible areas within the crane's swing radius are barricaded.
- Tag lines are used to prevent dangerous swing or spin of materials when raised or lowered by a crane or derrick.
- Illustrations of hand signals to crane and derrick operators are posted on the job site.
- The signal person uses correct signals for the crane operator to follow.
- Crane outriggers are extended when required.
- Crane platforms and walkways have antiskid surfaces.
- Broken, worn or damaged wire rope is removed from service.
- Guardrails, hand holds and steps are provided for safe and easy access to and from all areas of the crane.
- Load testing reports/certifications are available.
- Tower crane mast bolts are properly torqued to the manufacturer's specifications.
- Overload limits are tested and correctly set.
- The maximum acceptable load and the last test results are posted on the crane.
- Initial and annual inspections of all hoisting and rigging equipment are performed and reports are maintained.
- Only properly trained and qualified operators are allowed to work with hoisting and rigging equipment.

Forklifts

- Forklift truck operators are competent to operate these vehicles safely as demonstrated by their successful completion of training and evaluation.
- No employee under 18 years old is allowed to operate a forklift.
- Forklifts are inspected daily for proper condition of brakes, horns, steering, forks and tires.

- Powered industrial trucks (forklifts) meet the design and construction requirements established in American National Standards Institute (ANSI) for Powered Industrial Trucks, Part II ANSI B56.1-1969.
- Written approval from the truck manufacturer is obtained for any modification or additions which affect capacity and safe operation of the vehicle.
- Capacity, operation and maintenance instruction plates, tags or decals are changed to indicate any modifications or additions to the vehicle.
- Battery charging is conducted in areas specifically designated for that purpose.
- Material handling equipment is provided for handling batteries, including conveyors, overhead hoists or equivalent devices.
- Reinstalled batteries are properly positioned and secured in the truck.
- Smoking is prohibited in battery charging areas.
- Precautions are taken to prevent open flames, sparks or electric arcs in battery charging areas.
- Refresher training is provided and an evaluation is conducted whenever a forklift operator has been observed operating the vehicle in an unsafe manner and when an operator is assigned to drive a different type of truck.
- Load and forks are fully lowered, controls neutralized, power shut off and brakes set when a powered industrial truck is left unattended.
- There is sufficient headroom for the forklift and operator under overhead installations, lights, pipes, sprinkler systems, etc.
- Overhead guards are in place to protect the operator against falling objects.
- Trucks are operated at a safe speed.
- All loads are kept stable, safely arranged and fit within the rated capacity of the truck.
- Unsafe and defective trucks are removed from service.

Five Safety Measures Every Construction Worker Must Take

Regarded as one of the most dangerous occupations, construction work can be considered anything but fully safe. Heights, large and mobile equipment, edges, deep holes, and wobbling stairs are a reality in many construction sites, no matter how modern or careful the contractors claim them to be. Obviously, the employers do need to take care of the safety and security of the workers, but the workers need to keep in mind a lot of precautions themselves when working in such hazardous conditions.

Double-Check Your Work Areas

Scaffolds are an integral part of most construction sites and are associated with a high number of injuries. So when you are going to be working on them, you must ensure your safety first. Check with your supervisor or find out yourself whether the scaffold has been inspected by a professional or a competent person. Never work on an incomplete scaffold which does not have a strong platform or base.

Ladders are other essential construction site tools with a high potential for danger. Check the ladder thoroughly before using it. If you find any part of the ladder wobbly, do not us it. A ladder should be of proper strength and of a height that always keeps it at least one meter above the landing. All of the steps or slabs of the ladder must be secured properly. The upper and lower end of the ladder should preferably be fastened or secured properly. If not, ensure there is someone manually keeping it secure in order to prevent a fall from height.

Be Vigilant with Electricity and Equipment

Construction sites require a lot of electrical installations. Lifting equipment mostly involves electricity and weights. When working with such equipment, you need to be extra cautious to see there is no wear and tear in the machine and also to follow the safety precautions listed for the equipment. If you do not know them, seek help and instructions from a site supervisor or co-worker who has worked with the equipment before.

If you are using plugged-in portable devices, such as grinders or drills, you should always check that the cables are protected, the metal casing is grounded, and the power supply is provided with an earth leakage circuit breaker. Never allow the electrical tools to come in contact with water.

Never stand or work immediately below a heavy suspended load. And always check that you are not exceeding the permissible levels of load.

You'll need proper training before operating some equipment, including a material hoist and a crane. Ensure the hoist is operated only after the gates are locked properly. Know the working load limits of a hoist and never exceed those limits. Most importantly, when using material hoists, make sure the communication between you and the operator are clearly understood. Any error here can cause a major accident on the site.

Maintain Fencing and Prevent Fires

Notice the number of fatal injuries and falls that happen in areas where there is no fencing. Dangerous areas that you see without fencing or with broken and damaged fencing should be avoided until they are completely repaired or a proper fencing is in place. If this is not happening in time, inform your site supervisor immediately.

With the machinery that is present, along with combustible chemicals and welding operations, there is always a possibility of fire on a construction site. Be alert and take some measures to prevent them. Open flames should be kept away from construction sites because of the presence of flammable materials (especially on oil rig sites).

All workers should know the escape or exit route if a fire occurs. Knowing where the fire extinguishers are and how to use them may prove to be very advantageous in many situations and is therefore highly recommended. Employers should train workers to use this emergency equipment.

Protective Apparel and PPE

Employers are supposed to provide their workers with proper protective gear and clothing. If you as a worker do not have them, demand them from your employer and wear them correctly.

Well-fitted helmets and protective eyewear are a must. Ear plugs or muffs for working in noisy areas and protective gloves when dealing with toxic chemicals should be worn. Anti-slip footwear and protective apparel are necessary for those working in toxic or dusty environments. Make sure you wear them. Fall harnesses are very important for every construction worker. Ensure your harness is sturdy and secured to a strong anchorage point when you are working at heights.

At sites where there is a lot of movement of heavy vehicles, workers should wear highly visible clothing so that they can be located and seen easily. Because construction workers have to be working outdoors regardless of weather conditions, they also should have some climate protective gear and clothing.

Keep First Aid Close

While it may not be possible for workers to carry first aid supplies with them all the time, both the site supervisor and contractor should ensure that first aid is always accessible to the workers.

If as a worker you find that first aid you will need is not around, inform your supervisor immediately. Basic first aid for minor burns, cuts, and falls should be available on site so that the required medical assistance can be provided to the workers immediately. This is beneficial to the employer, as well, because this ensures that after resting for some time, the worker can return to his work as soon as possible. Some injuries when treated immediately helps in limiting the damage immensely and prevents infections from spreading.

Final Thoughts

A construction worker needs to be careful at all times. Areas that are not properly lit must be avoided until proper lighting is provided.

You should also avoid playing with work equipment. Always follow instructions during an emergency; if you notice any unsafe condition, such as a floor opening that is uncovered or not fenced, inform your co-workers and supervisor immediately. Construction workers play one of the most important roles in our modern society. It's their job to provide safe buildings, bridges, and many other assets for society; the workers owe it to themselves and their employers to work safely.

NINE IMPORTANT STEPS TO SECURE SAFETY ON SITE

Step 1: Perform a thorough walk through of the site.

Identify and assess any workplace hazards and write down anything that may be considered unsafe. Notify your managers of possible dangers that he/she should know about.

Step 2

Train all personnel in work-site safety and operating procedure either on-site or at a training facility.

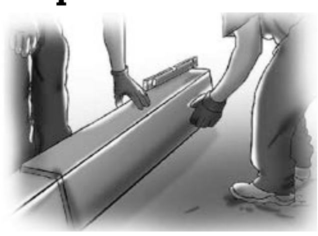
Search the Internet to see if online instruction is available. Training should include proper lifting techniques to help reduce common back injuries sustained on the job.

Step 3

Identify and mark any hazardous materials. Determine any risk involved to personnel.

Label and store any materials deemed hazardous in proper containers and secure them in a safe location. Post precautions for handling nearby. Make sure there is an MSDS (Material Safety Data Sheet) for all potentially hazardous chemicals/materials.

Step 4



Inspect equipment to be sure it is working properly. Be on the lookout for unusual noises and jerky movements. Report any problems immediately and do not operate the machinery until repairs have been made.

Step 5

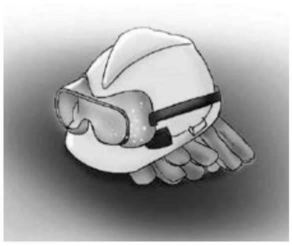
Use harnesses and other safety equipment when performing roof work or working on scaffolds. Standard "Personal Fall Arrest Systems" (PFAS) incorporate three primary components, commonly referred to as the ABC's of fall protection. These include: the anchorage connector, body support and connecting device.

Step 6

Provide personal protective equipment to all employees, including hard hats, safety goggles and boots, work gloves, ear plugs (or another form of protection) and face masks.

Step 7

Be sure Local Safety and Health Administration standards are met. Follow all recommendations and mandates from safety rules and inspectors. If you work for a private company, ask managers whether they've hired or contracted a health and safety inspector.



Step 8

Prepare for emergencies. Operators and site workers should know what to do in case of electrical, mechanical, power failures, or injuries.

Step 9
Protect the public by barricading the construction site during work hours. After working hours, lock all points of entry.

CHAPTER 2

CONCRETE CONSTRUCTION PRACTICES

Concreting Operations

Like concrete paving, structural concrete construction involves concrete hatching, mixing, transporting, placing, consolidating, finishing, and curing. The equipment, methods, and recommended practices for each of these phases of concrete construction are explained in other lectures. Special considerations for performing structural concrete operations for pouring concrete during extremely hot or cold weather are described in the remainder of this section.

Hot-Weather Concreting

The rate of hardening of concrete is greatly accelerated when concrete temperature is appreciably higher than the optimum temperature of 10 to 15.5°C.

Thirty two degrees Celsius (32 ° C) is considered a reasonable upper limit for concreting operations. In addition to reducing setting time, higher temperatures reduce the -amount of slump for a given mix.

If additional water is added to obtain the desired slump, additional cement must also be added or the water-cement ratio will be increased with corresponding strength reduction. High temperatures, especially when accompanied by winds and low humidity, greatly increase the shrinkage of concrete and often lead to surface cracking of the concrete.

Several steps may be taken to reduce the effect of high temperature on concreting operation.

The temperature of the plastic concrete may be lowered by cooling the mixing water and/or aggregates before mixing. Heat gain during hydration may be reduced by using Type IV (low-heat) cement or by adding retarder.

Air-entraining agents, water-reducing agents, or workability agents may be used to increase the workability of the mix without changing water/cement ratios. It is also advisable to reduce the maximum time before discharge of ready-mixed concrete from the normal 1.5 to 1 hour or less.
The use of shades or covers will be helpful in controlling the temperature of concrete after placement. Moist curing should start immediately after finishing and continue for at least 24 h.

Table 2.1: Typical slump ranges for various types of construction

	Slump (cm)	
Type of Construction	Maximum	Minimum
Reinforced foundation walls and footings	7.5	2.5
Unreinforced footings, caissons, and substructure walls	7.5	2.5
Reinforced slabs, beams, and walls	10.0	2.5
Building columns	10.0	2.5
Bridge decks	7.5	5.0
Pavements	5.0	2.5
Sidewalks, driveways, and slabs on ground	10.0	5.0
Heavy mass construction	5.0	2.5

* *When high-frequency vibrators are not used, the values may be increased by about 50%, but in no case should the slump exceed 15 cm.*

Cold-Weather Concreting

The problems of cold-weather concreting are essentially opposite to those of hot-weather concreting.

Concrete must not be allowed to freeze during the first 24 h after placing to avoid permanent damage and loss of strength. Specifications frequently require that when air temperature is 5 °C or less, concrete be placed at a minimum temperature of 10 °C and that this temperature be maintained for at least 3 days after placing.

Type III (high early strength) cement or an accelerator may be used to reduce concrete setting time during low temperatures.

Mix water and/or aggregates may be heated prior to mixing to raise the temperature of the plastic concrete.

The use of unvented heaters inside an enclosure during the first 36 h after placing concrete may cause the concrete surface to dust after hardening. To avoid this problem, any fuel-burning heaters used during this period must be properly vented. When heat is used for curing, the concrete must be allowed to cool gradually at the end of the heating period or cracking may result.

Cast-in-Place Concrete

Concrete structural members have traditionally been built in-place by placing the plastic concrete into, forms and allowing it to harden. The forms are removed after the concrete has developed sufficient strength to support its own weight and the weight of any construction loads.

Typical shapes and types of concrete structural members are described in the following paragraphs. The construction and use of concrete forms are described in preceding sections.

WALLS AND WALL FOOTINGS

Although almost any type of concrete wall may be cast in-place, this method of construction is now used primarily for foundation walls, retaining walls, tank walls, and walls for special-purpose structures such as nuclear reactor containment structures. High-rise concrete structures often use a concrete column and beam framework with curtain wall panels inserted between these members to form the exterior walls. Columns are normally of either circular or rectangular cross section.

Some typical cast-in-place wall and column shapes are illustrated in Figure 2.1.

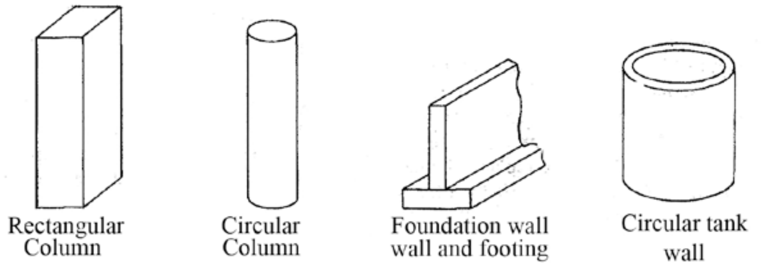


Figure 2.1: Typical cast-in-place column and wall shapes

In placing concrete into wall and column forms, care must be taken to avoid segregation of aggregate and paste that may result from excessive free-fall distances.
Another problem frequently encountered in wall construction is the formation of void spaces in the concrete under blockouts for windows, pipe chases, and so on.

This can be prevented by using concrete with adequate workability accompanied by careful tamping or vibration of the concrete in these areas during placing.
The relatively new technique of pumping concrete into vertical forms through the bottom of the form may also be used to eliminate the formation of voids in the concrete.

FLOORS AND ROOFS

There are a number of different types of structural systems used for concrete floors and roofs. Such systems may be classified as one-way or two-way slabs. When the floor slab is principally supported in one direction (i.e. at each end) this is referred to as a one-way slab.

Two-way slabs provide support in two perpendicular directions. Flat slabs are supported directly by columns without edge support.

One-Way Slabs

Supporting beams, girders, and slabs may be cast at one time (monolithically), as illustrated in Figure 2.2.

However, columns are usually constructed prior to casting the girders, beams, and slab to eliminate the effect of shrinkage of column concrete on the other members.

This type of construction is referred to as *beam-and-slab* or as *slab-beam-and-girder* construction.

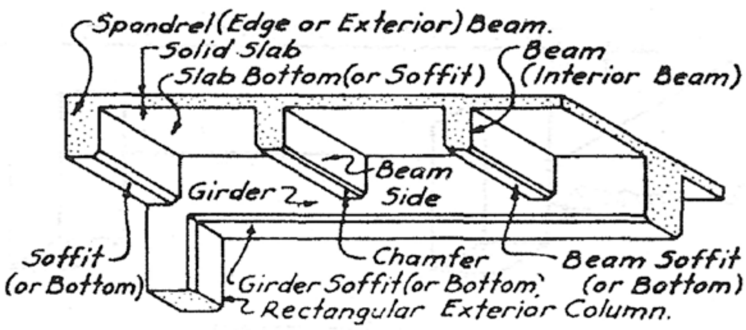


Figure 2.2: Slab-Beam and Girder floor

Notice that the outside beam is referred to as a spandrel beam. When beams are replaced by more closely spaced joists, the type of construction illustrated in Figure 2-3 results.

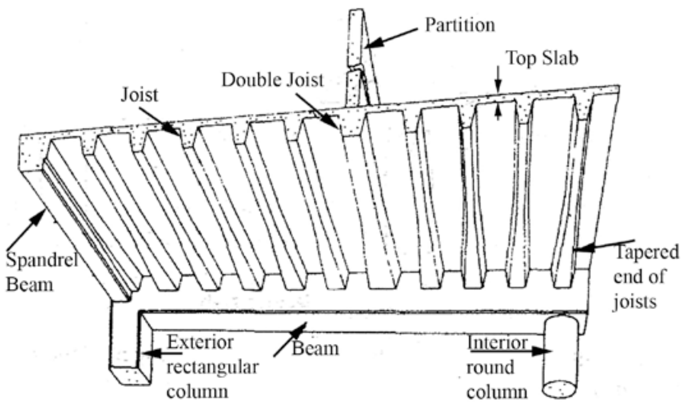


Figure 2.3: Concrete Joist Floor

Joists may be either straight or tapered, as shown. The double joist in the illustration is used to carry the additional load imposed by the partition above it.
Slabs may also be supported by nonintegral beams. Such supporting beams may be made of precast or cast-in-place concrete, timber, steel, or other materials. This ty'pe of construction is referred to as *solid slab construction.*

Two-Way Slabs

The principal type of two-way slab is the waffle slab, illustrated in Figure 2-4. Notice that this is basically a joist slab with joists running in two perpendicular directions.

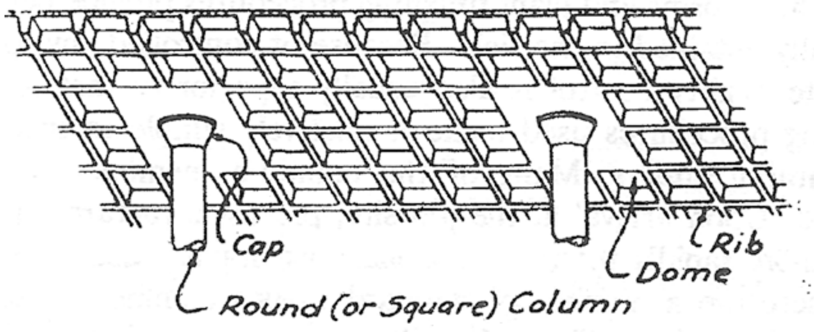


Figure 2.4: Waffle Slab

Flat Slabs

Slabs may be supported directly by columns without the use of beams or joists. Such slabs are referred to as flat slabs or flat plate slabs.

A flat plate slab is illustrated in Figure 2-5a. A flat slab is illustrated in Figure 2-5b. Note that the flat slab uses column capitals to distribute the column reaction over a larger area of slab, while the drop panels serve to strengthen the slab in this area of increased stress.

Both of these measures reduce the danger of the column punching through the slab, when the slab is loaded.

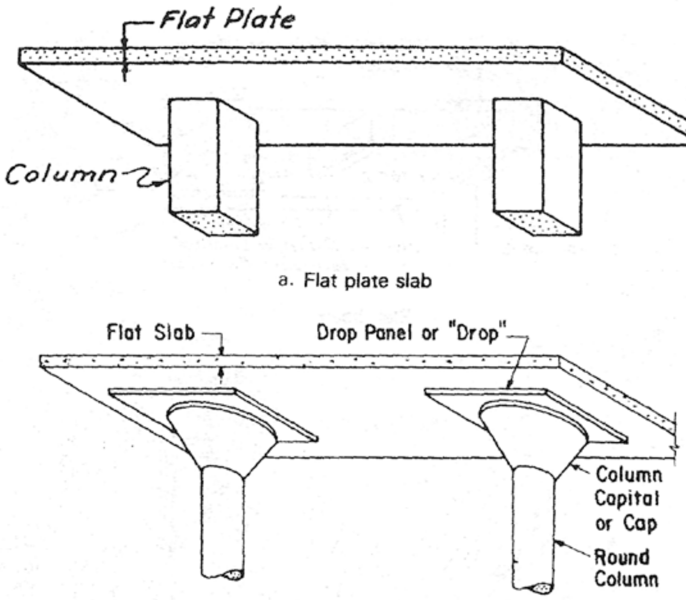


Figure 2.5: Flat Slab and flat plate slab

CONCRETE FORMWORK

General Requirements for Formwork

The principal requirements for concrete formwork are that it be safe, produce the desired shape and surface texture, and be economical. Procedures for designing formwork that will be safe under the loads imposed by plastic concrete, workers and other live loads, and external forces (such as wind loads) are explained in other relevant subjects.

Construction procedures relating to formwork safety are discussed later in this section. Requirements for the shape (including deflection limitations) and surface texture of the finished concrete are normally contained in the construction plans and specifications. Since the cost of concrete formwork often exceeds the cost of the concrete itself, the necessity for economy in formwork is readily apparent.

Typical Formwork

A typical *wall form* with its components is illustrated in Figure 6-6. Sheathing may be either plywood or lumber. Double wales are often used as illustrated so that form ties may be inserted between, the two wales. With a single wale it would be necessary to drill the wales for tie insertion.

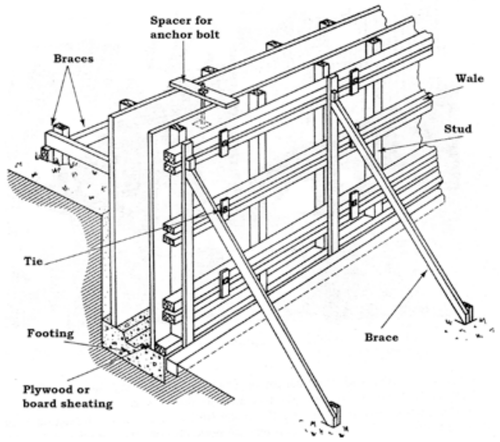


Figure 2.6: Typical Wall Form

While the pressure of the plastic concrete is resisted by form ties, bracing must be used to prevent form movement and to provide support against wind loads or other lateral loads.

Typical form ties are illustrated in Figure 2-7. Form ties may incorporate a spreader device to maintain proper spacing between form walls until the concrete is placed.
Otherwise, a removable spreader bar must be used for this purpose.

Ties are of two principal types, continuous single-member and internally disconnecting.

Continuous-single-member ties may be pulled out after the concrete has hardened or they may be broken off at a weakened point just below the surface after forms are removed.

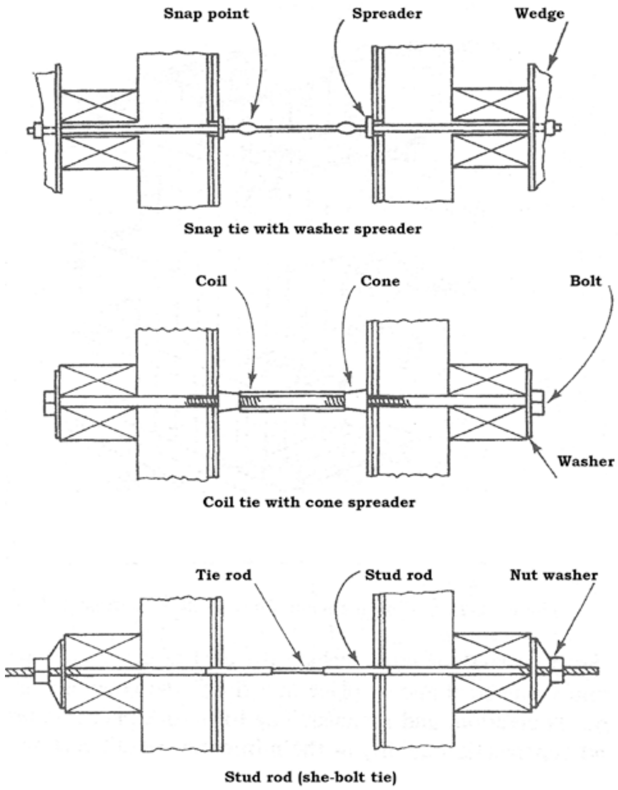


Figure 2.7: Typical form ties

Common types of *internally disconnecting ties* include the coil tie and stud rod (or she-bolt) tie.
With internally disconnecting ties, the ends are unscrewed to permit form removal with the internal section left embedded in the concrete. The holes

remaining in the concrete surface after the ends of the ties are removed are later plugged or grouted.

Column forms are similar to wall forms except that studs and wales are replaced by column clamps or yokes that resist the internal concrete pressure.

A typical column form is shown in Figure 2-8. Yokes may be fabricated of wood, wood and bolts (as shown), or of metal.

Commercial column clamps (usually of metal) are available in a wide range of sizes. Round columns are formed with ready-made fiber tubes or steel reinforced fiberglass forms.

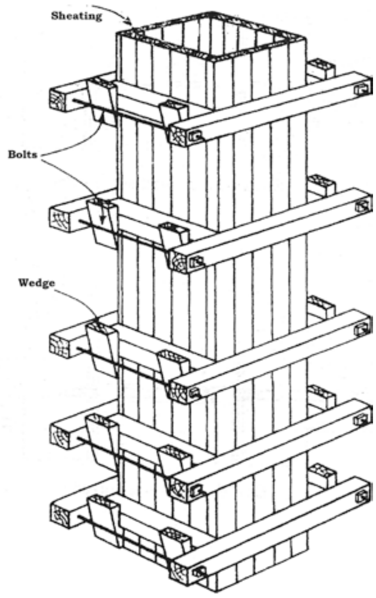


Figure 2.8: Typical wooden column form

Openings or "windows" may be provided at several elevations in high, narrow forms to facilitate placement of concrete.
Special fittings may also be inserted near the bottom of vertical forms to permit pumping concrete into the form from the bottom**.**

Figure 2-9 illustrates a typical elevated floor or desk slab form with its components identified.

Forming for a slab with an integral beam is illustrated in figure 2-10.

Forming for the one-way and two-way slabs is usually accomplished using commercial pan forms.

Figure 2-11 illustrates the use of long pans for a one-way joist slab.

Figure 2-12 shows a waffle slab formed with dome pans. Such pan forms may be made of metal or plastic.

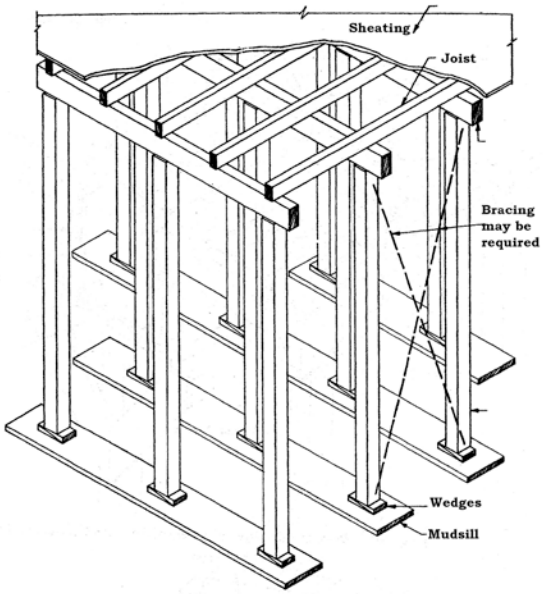


Figure 2.9: Wooden form of elevated slab

Wooden stairway forms suitable for constructing stairways up to 1.00 m. wide are illustrated in Figure 2-13

Minimizing Cost of Formwork

Since formwork may account for 40 to 60% of the cost of concrete construction, it is essential that the formwork plan be carefully developed and thoroughly evaluated. A cost comparison should be made of all feasible forming systems and methods of operation.

Such an analysis must include the cost of equipment and labor required to install reinforcing steel and to place and finish the concrete, as well as the cost of formwork, its erection, and removal. The formwork plan that provides the required safety and construction quality at the minimum overall cost should be selected for implementation**.**

In general, lower formwork cost will result from repetitive use of forms. Multiple use forms may be either standard commercial types or custom-made by the contractor. Contractor-fabricated forms should be constructed using assembly line techniques whenever possible.

Flying forms, large sections of formwork moved by crane from one position to another, are often economical in repetitive types of concrete construction. Where appropriate, the use of slip forms and the tilt-up construction techniques described earlier can greatly reduce forming costs.

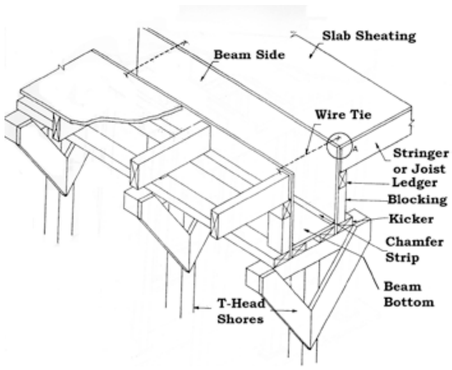


Figure 2.10: Wooden beam and slab form

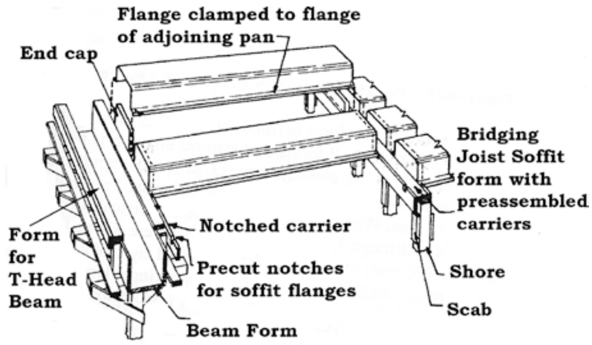


Figure 2.11: One-way slab form

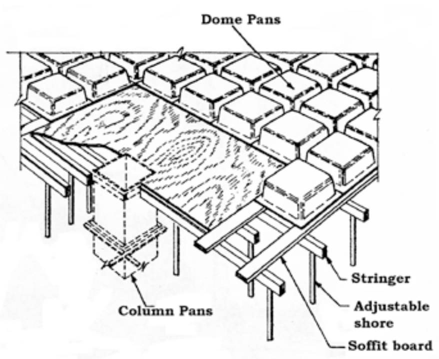


Figure 2.12: Two-way slab form

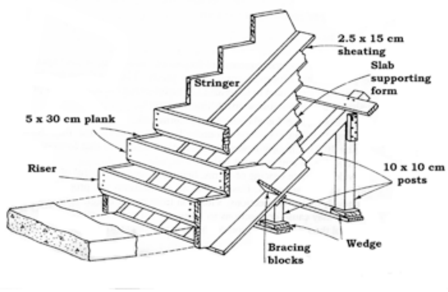


Figure 2.13: Wood form for stairway

Construction Practices

Forms must be constructed with tight joints to prevent the loss of cement paste, which may result in honeycombing. Before Concrete is placed, forms must be aligned both horizontally and vertically to remain in alignment. Form alignment should be continuously monitored during concrete placement and adjustments made if necessary. When a vertical form is wider at the bottom than at the top, an uplift force will be created as the form is filled. Such forms must be anchored against uplift.

Inspect the interior of all forms and remove any debris before placing concrete. Use drop chutes or rubber elephant trunks to avoid segregation of aggregate and paste when placing concrete into high vertical forms. Free-fall distance should, he limited to 1.5 m. or less.

When vibrating concrete in vertical forms, allow the vibrator head to penetrate through the freshly placed concrete about 2.5 cm but not more than 20 cm into the previously placed layer of concrete.
It is possible to bulge or rupture any wall or column form by inserting a large vibrator deep into previously placed, partially set concrete. However, revibration of previously compacted concrete is not harmful to the concrete as long as it becomes plastic when vibrated. When pumping forms from the bottom, it is important to fill the forms rapidly so that the concrete does not start to set up before filling is completed.

If the pump rate is so low that setting begins, excessive pressure will be produced inside the form, resulting in bulging or rupturing of the form.

Framework Safety

The frequency and serious consequences of formwork failure require that special attention be paid to this aspect of construction safety. The requirements for safe formwork design are explained relevant subjects. The following are some safety precautions that should be observed in constructing formwork.

1. Provide adequate foundations for all formwork. Place mudsills under all shoring that that rests on the ground.

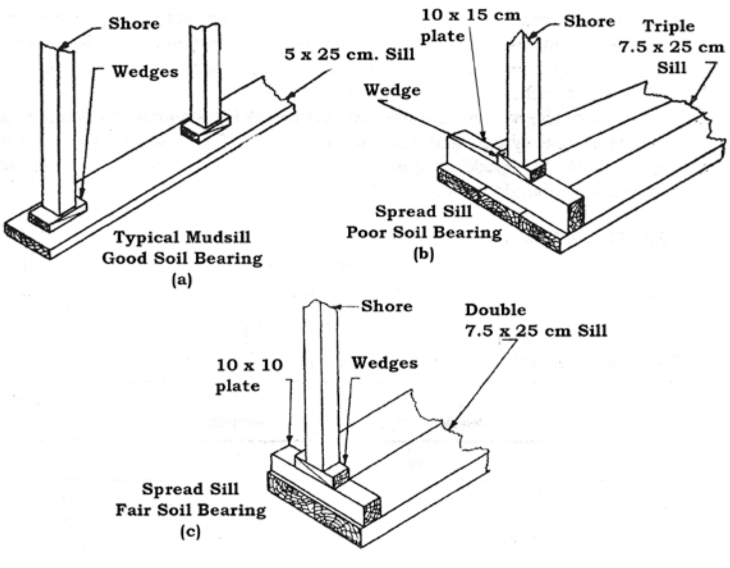


Figure 2.14: Mudsills

Typical mudsills are illustrated in Figure 2-14. Check surrounding excavations to ensure that formwork does not fail due to embankment failure.

2. Provide adequate bracing of forms, being particularly careful of shores and other vertical supports. Ensure that all connections are properly secured especially nailed connections. Vibration from power buggies or concrete vibrators may cause connections to loosen or supports to move.
3. Control the rate and location of concrete placement so that design loads are not exceeded.
4. Ensure that forms and supports are not removed before the concrete has developed the required strength. The process of placing temporary shores under slabs or structural members after forms have been stripped is called reshoring. Reshoring is a critical operation that must be carried out exactly as specified by the designer. Only a limited area should be stripped and reshored at one time. No construction loads should be allowed on the partially hardened concrete while reshoring is under way. Adequate bracing must be provided for reshoring.
5. When placing prefabricated form sections in windy weather, care must be taken to avoid injury due to swinging of the form caused by wind forces.
6. Protruding nails are a major source of injury on concrete construction sites. As forms are stripped, form lumber must be promptly removed to a safe location and nails pulled.

QUALITY CONTROL

Common Deficiencies in Concrete Construction

Adequate quality control must be exercised over concrete operations if concrete of the required strength, durability, and appearance is to be obtained. Quality control deficiencies in concrete construction practice may usually be traced to inadequate supervision of construction operations.

Below is the list of repetitive deficiencies observed in concrete construction.

STRUCTURAL CONCRETE

1. Unstable form bracing and poor form alignment evidenced by form bulging, spreading, or inaccurately aligned members.
2. Poor alignment of reinforcing steel and exceeding prescribed tolerances.
3. Obvious cold joints in walls.
4. Excessively honeycombed wall areas.
5. Belated form tie removal, form stripping, and patching.
6. Inadequate compaction (mechanical vibration, rodding, or spading).

CONCRETE SLABS ON GRADE

1. Poor compaction of subgrade evidenced by slab settlement.
2. Saturation and damage to subgrade caused by water standing around foundation walls and/or inadequate storm drainage.

3. Uneven floor slab finishes.
4. Inadequate curing of floor slabs.

Inspection and Testing

The inspection and testing associated with concrete quality control may be grouped into five phases. These include mix design; concrete materials quality; batching, mixing, and transporting concrete; concrete placing, vibrating, finishing, and curing; and testing of fresh and hardened concrete at the job site.

Mix design includes the quantity of each component in the mix, the type and gradation of aggregates, the type of cement, and so on.
Aggregate testing includes tests for organic impurities and excessive fines, gradation, resistance to abrasion, and aggregate moisture.

Control of concrete production includes accuracy of batching and the mixing procedures used. With modern concrete production equipment, the producer's quality control procedures and his certification that specifications have been met may be all that is required in the way of production quality control.

Transporting, placing, finishing, and curing procedures should be checked for compliance with specifications and with the general principles are explained in relevant subjects.

Testing of concrete delivered to the job site involves testing of plastic concrete and performing strength tests on hardened concrete. The principal tests performed on plastic concrete include the slump test and tests for air and cement content.

The temperature of plastic concrete should be checked for hot or cold weather concreting. The strength of hardened concrete is determined by compression tests on cylinder samples, by tensile splitting tests, or by flexure tests.

Such tests are usually made after 7 and 28 days of curing.

Standard cylinders used for compression tests are 15.2 cm (6 in.) in diameter by 30.5 cm (12 in.) high.

Beam samples for flexure tests are usually 15.2 cm (6 in.) square by 50.8 cm (20 in.) long.

A procedure for evaluating compression tests results which is recommended by TSE are in TS500 and by the American Concrete Institute is contained in ACI 214.

CHAPTER 3

INTRODUCTION TO EARTHMOVING

The Earthmoving Process

Earthmoving (Figure 3.1) 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 earth-moving process requires accurate estimating of work quantities and job conditions, proper selection of equipment, and competent job management.

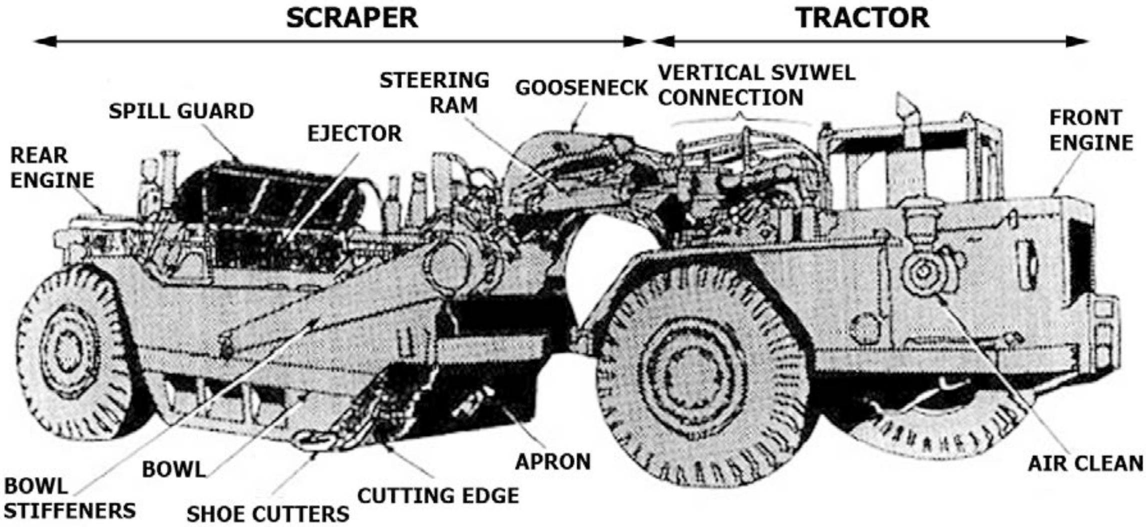


Figure 3.1 : Scraper

Equipment Selection

The choice of equipment to be used on a construction project has a major influence on the efficiency and profitability of the construction operation. Although there are a number of factors that should be considered in selecting equipment for a project, the most important criterion is the ability of the equipment to perform the required work. Among those items of equipment capable of performing the job, the principal criterion for selection should be maximizing the profit or return on the investment produced by the equipment. Usually, but not always, profit is maximized when the lowest cost per unit of production is achieved. (Further chapters provides a discussion on construction economics.)

Other factors that should be considered when selecting equipment for a project include possible future use of the equipment, its availability the availability of parts and service, and the effect of equipment downtime on other construction equipment and operations.

After the equipment has been selected for a project, a plan must be developed for efficient utilization of the equipment. The final phase of the process is, of course competent job management to assure compliance with the operating plan and to make adjustments for unexpected conditions.

Production of Earthmoving Equipment

The basic relationship for estimating the production of all earthmoving equipment is:

Production = Volume per cycle *x* Cycles per hour (Eq.1)

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 Construction Industry Manufacturers Association has developed standard production tables for shovels and draglines which may be used instead of Equation 1 for estimating the production of shovels and draglines. Manufacturers may also provide charts or tables for estimating the production of their equipment. The cost per unit of production may be calculated as follows:

$$\text{Cost per unit of production} = \frac{\text{Equipment cost per hour}}{\text{Equipment production per hour}} \quad \text{Eq.2}$$

Methods for determining the hourly cost of equipment operation are explained in proceeding chapters.

There are two principal approaches to estimating job efficiency in determining the number of cycles per hour to be used in Equation 1. 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. A table of efficiency factors based on a combination of job conditions and management conditions is presented in Table 3.1. Both methods are illustrated in the example problems.

EARTHMOVING MATERIALS

Soil and Rock

Soil and rock are the materials that make up the crust of the earth and are, therefore, the materials of interest to the constructor.

In the remainder of this chapter, we will consider those characteristics of soil and rock that affect their construction use, including their volume-change characteristics, methods of classification, and field identification.

Table 3.1 Job efficiency factors for earthmoving operations

	*Management Conditions**			
*Job Conditions***	*Excellent*	*Good*	*Fair*	*Poor*
Excellent	0.84	0.81	0.76	0.70
Good	0.78	0.75	0.71	0.65
Fair	0.72	0.69	0.65	0.60
Poor	0.63	0.61	0.57	0.52

* *Management conditions include:*
Skill, training, and motivation of workers.
Selection, operation, and maintenance of equipment.
Planning, job layout, supervision, and coordination of work.

** *Job conditions are the physical conditions of a job that affect the production rate (not including the type of material involved).*
They include:
Topography and work dimensions.
Surface and weather conditions.
Specification requirements for work methods or sequence.

General Soil Characteristics

Several terms relating to a soil's behavior in the construction environment should be understood.

Trafficability is the ability of a soil to support the weight of vehicles under repeated traffic.

In construction, trafficability controls the amount and type of traffic that can use unimproved access roads, as well as the operation of earth-moving equipment within the construction area.

Trafficability is usually expressed qualitatively, although devices are available for quantitative measurement. Trafficability is primarily a function of soil type and moisture conditions. Drainage, stabilization of haul routes, or the use of low-ground-pressure construction equipment may be required when poor trafficability conditions exist.

Soil drainage characteristics, are important to trafficability and affect the ease with which soils may be dried out.

Loadability 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 loadability.

Unit soil weight is normally expressed in pounds per cubic yard or kilograms per cubic meter. 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.

In their natural state, all soils contain some moisture. 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:

$$\text{Moisture content (\%)} = \frac{\text{Moist weight — Dry weight}}{\text{Dry weight}} \; x \, 100 \qquad \text{Eq.3}$$

If, for example, a soil sample weighed 120 kg in the natural state and 100 kg after drying, the weight of water in the sample would be 20 kg and the soil moisture content would be 20%.

Using Equation 3, this is calculated as follows:

$$\text{Moisture content} = \frac{120 - 100}{100} \; x \, 100 = 20\%$$

SOIL VOLUME-CHANGE CHARACTERISTICS

Soil Conditions

There are three principal conditions or states in which earthmoving material may exist: bank, loose, and compacted.

The meanings of these terms are as follows:

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* (Bm^3).

Loose: Material that has been excavated or loaded.
A unit volume is identified as a *Loose Cubic Yard* (LCY) or *Loose Cubic Meter* (Lm^3)
Compacted: Material after compaction.
A unit volume is identified as a *Compacted Cubic Yard* (CCY) or *Compacted Cubic Meter* (Cm^3).

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.*

Swell may be calculated as follows:

$$\text{Swell (\%)} = \left(\frac{\text{Weight of Bank volume}}{\text{Weight of Loose volume}} - 1 \right) x\ 100 \qquad \text{Eq.4}$$

Example problem :

Find the swell of a soil that weighs 2800 kg/m^3 in its natural state and 2000 kg/m^3 after excavation.

Solution :

$$\text{Swell} = \left(\frac{2800}{2000} - 1 \right) x100 = 40\%$$

That is, 1 bank cubic meter of material will expand to 1.4 loose cubic meters after excavation.

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.*
The value of shrinkage may be determined as follows:

$$\text{Shrinkage (\%)} = \left(1 - \frac{\text{Weight of bank volume}}{\text{Weight of compacted volume}} \right) x\ 100 \qquad \text{Eq.5}$$

Soil volume change due to excavation and compaction is illustrated in Figure 5.2. Note that both swell and shrinkage are calculated from the bank (or natural) condition.
Example problem:
Find the shrinkage of a soil that weighs 2800 kg/m^3 in its natural state and 3500 kg/m^3 after compaction.

Solution :

$$\text{Shrinkage} = \left(1 - \frac{2800}{3500} \right) x\ 100 = 20\%$$

Hence 1 bank cubic meter of material will shrink to 0.8 compacted cubic meter as a result of compaction.

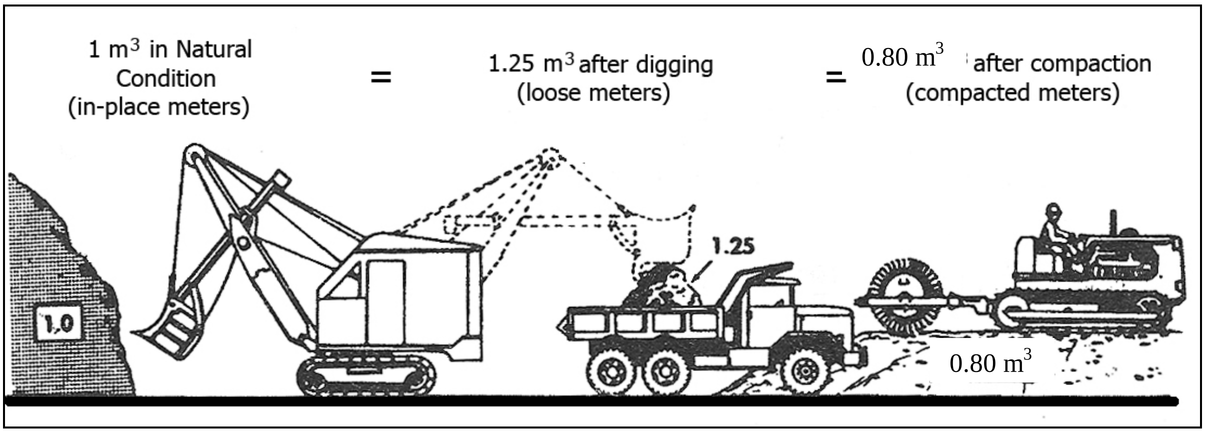


Figure 3.2 : Typical soil volume change during earth moving

Load and Shrinkage Factors

In performing earthmoving calculations, it is important to convert all material volumes to a common unit of measure. Although the bank cubic meter (or yard) is most commonly used for this purpose, any of the three volume units may be used.

A *pay meter* (or *yard*) is the volume unit specified as the basis for payment in an earth-moving contract. It may be any of the three volume units.

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 soil's load factor may be calculated by use of Equation 6 or Equation 7.

Loose volume is multiplied by the load factor to obtain bank volume.

$$\text{Load} = \frac{\text{Weight of loose unit volume}}{\text{Weight of bank unit volume}} \qquad \text{Eq.6}$$

$$\text{Load factor} = \frac{1}{1 + \text{swell}} \qquad \text{Eq.7}$$

A factor used for the conversion of bank volume to compacted volume is sometimes referred to as a *shrinkage factor.* The shrinkage factor may be calculated by use of Equation 8 or Equation 9.

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.

$$\text{Shrinkage factor} = \frac{\text{Weight of bank unit volume}}{\text{Weight of compacted unit volume}} \qquad \text{Eq.8}$$

or

$$\text{Shrinkage factor} = 1 - \text{shrinkage} \qquad \text{Eq.9}$$

Example problem :

A soil weighs 1163 kg/Lm^3 , 1661 kg/Lm^3 and 2077 kg/Lm^3.
a) Find the load factor and shrinkage factor for the soil
b) How many cubic meters (Bm^3) and compacted cubic meters (Cm^3) are contained in 593,000 Lm^3 (loose cubic meters) of this soil.

Solution :

a) $$\text{Load factor} = \frac{1163}{1661} = 0.70$$

$$\text{Shrinkage factor} = \frac{1661}{2077} = 0.80$$

b) Bank volume = 593,000 x 0.70 = 415,310 Bm^3

Compacted volume = 415,310 x 0.80 = 332,248 Cm^3

Table 2: Typical soil weight and volume change characteristics

	Unit weight kg/m^3			Swell	Shrinkage	Load	Shrinkage
	Loose	Bank	Compacted	%	%	factor	factor
Clay	1370	1780	2225	30	20	0.77	0.80
Common earth	1471	1839	2047	25	10	0.80	0.90
Rock (blasted)	1815	2729	2106	50	-30	0.67	1.30
Sand and gravel	1697	1899	2166	12	12	0.89	0.88

Excavating and Lifting Equipment

An *excavator* is defined as a power-driven digging machine.

The major types of excavators used in earthmoving operations include hydraulic excavators and the members of the cable-operated crane-shovel family (shovels, draglines, hoes, and clamshells).

Dozers, loaders, and scrapers can also serve as excavators.

In this chapter we focus on hydraulic excavators and the members of the crane-shovel family used for excavating and lifting operations.

Hydraulic Excavators

The *hydraulic excavator,* illustrated in Figure 5.3 with a backhoe front end, is a hydraulically powered machine that has largely replaced the cable-operated backhoe and shovel of the crane-shovel family.
Figure 5.3 : Hydraulic Excavator
Hydraulic excavators have a number of advantages over cable-operated excavators, including, faster cycle time, higher bucket penetrating force, more precise digging and easier operator control.

In addition to backhoe and shovel front ends, there are a number of attachments available for hydraulic excavators. Among these are clamshells, augers, vibratory plate compactors, and hammers. Most of these attachments are designed to fit the backhoe front end.

Excavator Production

To utilize Equation 1 for estimating the production of an excavator, it is necessary to know the volume of material actually contained in one bucket load.
The methods by which excavator bucket and dozer blade capacity are rated are given in Table 3.

Plate line capacity is the bucket volume contained within the bucket when following the, outline of the bucket sides.

Struck capacity is the bucket capacity when the load is struck off flush with the bucket sides.

Water line capacity assumes a level of material flush with the lowest edge of the bucket (i.e., the material level corresponds to the water level that would result if the bucket were filled with water).

Heaped volume is the maximum volume that can be placed in the bucket without spillage based on a specified angle of repose for the material in the bucket.

Table 3.3: Bucket-capacity rating methods

Machine	*Rated Bucket Capacity*
Backhoe and shovel	
a) Cable	Struck volume
b) Hydraulic	Heaped volume at 1:1 angle of repose
Clamshell	Plate line or water line volume
Dragline	90% of struck volume
Loader	Heaped volume at 2:1 angle of repose

Since bucket ratings for the cable shovel, dragline, and cable backhoe are based on struck volume, it is often assumed that the heaping of the buckets will compensate for swell of the soil.
That is a 5 m^3 bucket would be assumed to actually hold 5 bank m^3 of material. A better estimate of the volume of material in one -bucket load will be obtained if the nominal bucket volume is multiplied by a *bucket fill factor* or bucket efficiency factor.
Suggested values of bucket fill factor for common soils are given in Table 4.
The most accurate estimate of bucket load is obtained by multiplying the heaped bucket volume (loose measure) by the bucket fill factor.
If desired, the bucket load may be converted to bank volume by multiplying its loose volume by the soil's load factor.

This procedure is illustrated in example below.

Example

Estimate the actual bucket load in bank cubic meters for a loader bucket whose heaped capacity is 3.82 m^3. The soil's bucket fill factor is 0.90 and its load factor is 0.80.

Solution:

Bucket load = 3.82 *x* 0.90 = 3.44 Lm^3 *x* 0.80 = 2.75 Bm^3

Tie Crane-Shovel Family

In 1836, William S. Otis developed a machine that mechanically duplicated the motion of a man digging with a hand shovel. From this machine evolved the family of construction machines known as the *crane-shovel.*

Members of this family include the mobile crane, shovel, dragline, backhoe, clamshell, and pile driver, shown in Figure 5.4.

Crane (hook)

Clamshell

Dragline

Back Hoe

Shovel

Pile driver

Figure 3.4: Members of the cable operated crane shovel family

The crane-shovel consists of three major assemblies: a carrier or mounting, a revolving superstructure containing the power and control units (also called the revolving deck or turntable), and a front-end attachment.

Carriers available include crawler, truck, and wheel mountings, as shown in Figure 3.5. The crawler mounting provides excellent on-site mobility and its low ground pressure enables it to operate in areas of low trafficability.

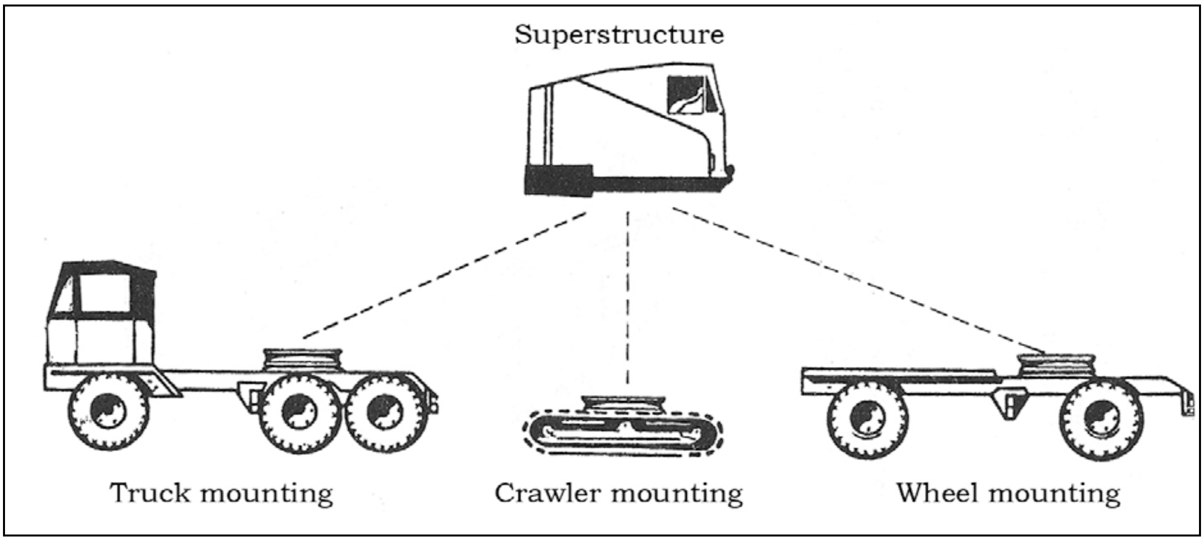


Figure 3.5: Crane-shovel mountings and revolving superstructure

Crawler mountings are widely used for drainage and trenching work as well as for rock excavation. Truck and wheel mountings provide greater mobility between job sites but are less stable than crawler mountings and require better surfaces over which to operate. Truck mountings use a modified truck chassis as a carrier and thus have separate stations for operating the carrier and the revolving superstructure.

Table 4: Bucket fill factors for excavators

Material	*Bucket Fill Factor*
Common earth, loam	0.80-1.10
Sand and gravel	0.90-1.00
Hard clay	0.65-0.95
Wet clay	0.50-0.90
Rock, well blasted	0.70-0.90
Rock, poorly blasted	0.40-0.70

Wheel mountings, on the other hand, use a single operator's station to control both the carrier and the crane-shovel mechanism.
Truck mountings are capable of highway travel speeds of 80 km/h or more, whereas wheel mountings are usually limited to 50 km/h or less.
The name of a particular member of the crane-shovel family is determined by the front-end attachment used. Thus a crane-shovel with a shovel attachment is referred to simply as a shovel.

In this chapter we discuss the principles of operation, methods of employment, and techniques for estimating production of all members of the crane-shovel family except for the pile driver.

Trenchless Excavation

There is a growing demand for methods of installing utility systems below ground with minimum open excavation. Such construction is often called *trenchless excavation.*
Trenchless excavation is much less disruptive to urban areas than are conventional trenching methods.
While a number of different techniques are used for trenchless excavation, the principal categories include pipe jacking, horizontal earth boring, and utility tunneling.

The process of *pipe jacking* (Figure 3.6) involves forcing pipe horizontally through the soil. Working from a vertical shaft, a section of pipe is carefully aligned and advanced through the soil by hydraulic jacks braced against the shaft sides. As the pipe advances, spoil is removed through the inside of the pipe. After the pipe section has advanced far enough, the hydraulic rams are retracted and another section of pipe placed into position for installation. The excavation and spoil removal process can be manual or mechanical. The process requires workers to enter the pipe sections during the pipe jacking operation.

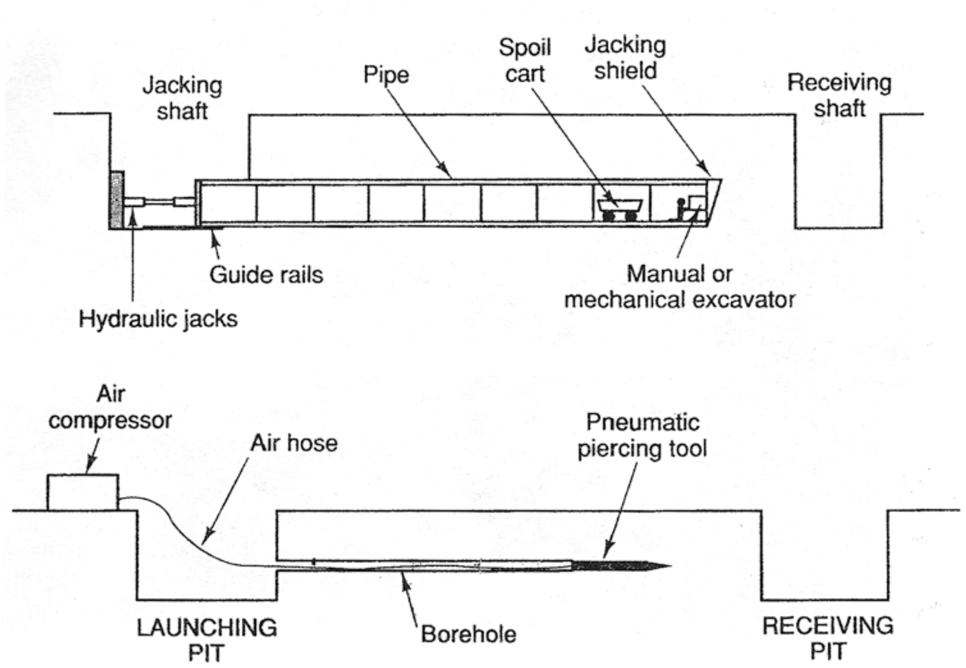


Figure 3.6: Installing a utility line by pipe jacking (upper picture) and by horizontal earth boring (lower picture)

In *horizontal earth boring* a horizontal hole is created mechanically or hydraulically with the pipe to be installed serving as the casing for the hole. Some of the many installation methods include auger boring, rod pushing (thrust boring), rotational compaction boring, impact piercing, horizontal (directional) drilling, fluid boring and microtunneling.

Many of these techniques utilize lasers and television cameras for hole alignment and boring control. The use of a pneumatic piercing tool to create a borehole for a utility line is illustrated in Figure 6 (lower picture).
After the bore has been completed, several methods are available to place pipe into the borehole. In one method, pipe is pulled through the bore using the tool's air hose or a steel cable pulled by the air hose.

Another method uses the piercing tool to push the pipe through the borehole.

A third method uses a pipe pulling adapter attached to the piercing tool to advance the pipe at the same time as the piercing tool advances the bore.

Utility tunneling is similar to the conventional tunneling except for the tunnel size and use, Since the tunnels are used as conduit for utility systems rather than for vehicle passage, they are normally smaller than road or rail tunnels. They differ from other trenchless excavation methods in their use of a conventional tunnel liner instead of using the pipe itself as a liner.

SHOVELS

Operation and Employment

The *hydraulic shovel* illustrated in Figure 3.7 is also called a *front shovel* or *hydraulic excavator-front shovel.*

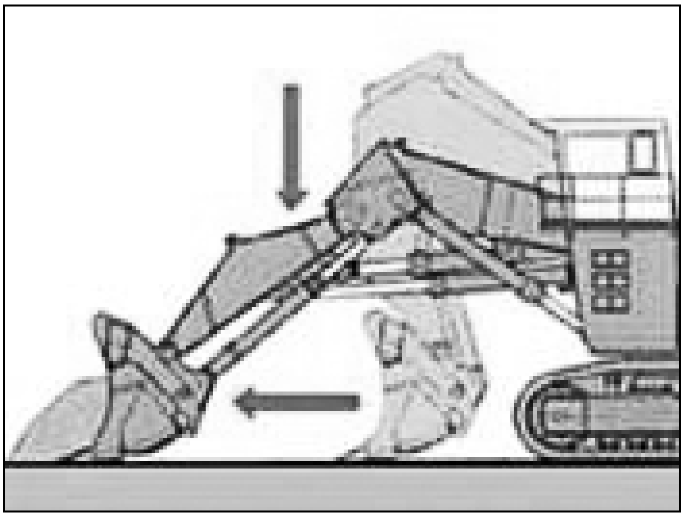


Figure 3.7: Hydraulic shovel

The major components are identified below in Figure 3.8.

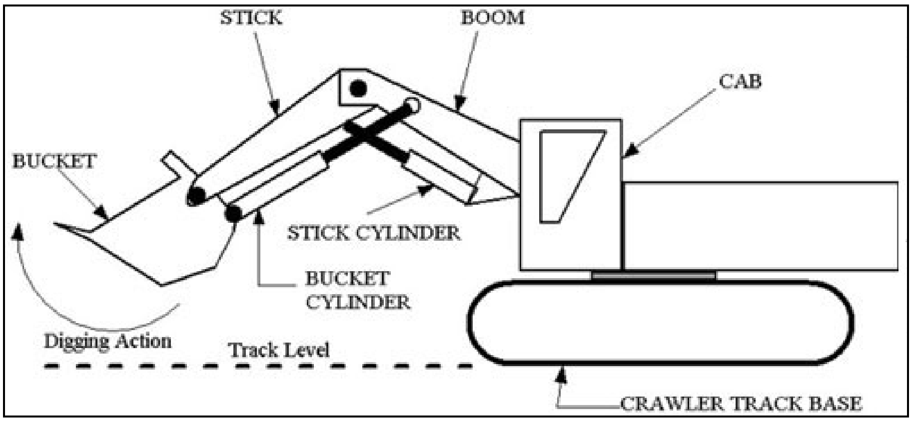


Figure 3.8: The major components of a Hydraulic Shovel

The hydraulic shovel digs with a combination of crowding force and breakout (or prying) force as illustrated in Figure 3.9.

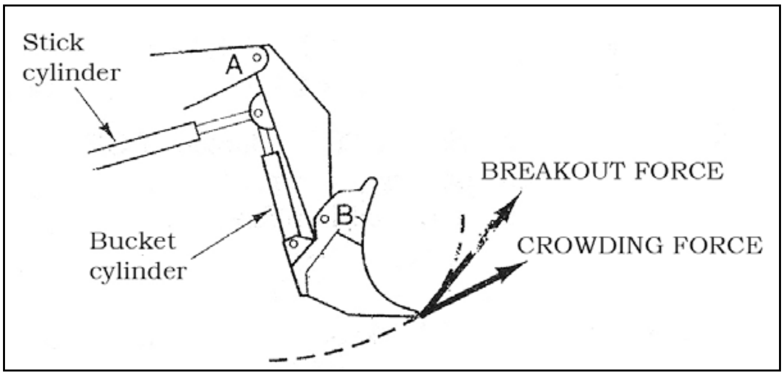


Figure 3.9: Digging action of a hydraulic shovel

Crowding force is generated by the stick cylinder and acts at the bucket edge on a tangent to the arc of the radius from point *A*.

Breakout force is generated by the bucket cylinder and acts at the bucket edge on a tangent to the arc of the radius through point B. After the bucket has penetrated and filled with material, it is rolled up to reduce spillage during the swing cycle.

Both front-dump and bottom-dump buckets are available for hydraulic shovels.

Bottom dump-buckets are more versatile, provide greater reach and dump clearance and produce less spillage. However, they are heavier than front-dump buckets of equal capacity, resulting in a lower bucket capacity for equal bucket weight. Hence front-dump buckets usually have a slight production advantage. In addition, front-dump buckets cost less and require less maintenance.

Although the shovel has a limited ability to dig below track level, it is most efficient when digging above track level. The shovel should have a vertical face to dig against for most effective digging. This surface, known as the *digging face,* is easily formed when excavating a bank or hillside. Thus embankment digging with the material dumped to one side (sidecast) or loaded into haul units provides the best application of the shovel. The ability of the shovel to form its own roadway as it advances is a- major advantage. Other possible applications of the shovel include dressing slopes, loading hoppers, and digging shallow trenches.

Production Estimating

Production for hydraulic shovels may be estimated using Equation 10 together with table 5, which has been prepared from manufacturers', data.

Production (Lm^3/h) = C *x* S *x* V *x* B *x* E Eq. 10

where C = cycles/h (Table 5)
S = swing factor (Table 5)
V = heaped bucket volume (Lm^3)
B = bucket fill factor (Table 4)
E = job efficiency

Table-3.5 Standard cycles per hour for hydraulic shovels

	Machine Size					
	Small under 3.8 m^3		Medium 3.8 – 7.6 m^3		Large over 7.6 m^3	
	Bottom Dump	Front Dump	Bottom Dump	Front Dump	Bottom Dump	Front Dump
Soft (*sand, gravel, coal*)	190	170	180	160	150	135
Average (*common earth, soft clay, well blasted rock*)	170	150	160	145	145	130
Hard (*tough clay, poorly blasted rock*)	150	135	140	130	135	125

	Adjustment for Swing Angle					
	Angle of swing (degrees)					
	45	60	75	90	120	180
Adjustment factor	1.16	1.10	1.05	1.00	0.94	0.83

Example *:*

Find the expected production in loose cubic meters (Lm^3) per hour of a 2.3 m^3 hydraulic shovel equipped with a front-dump bucket. The material is common earth with a bucket fill factor of 1.0. The average angle of swing is 75° and job efficiency is 0.80.

Solution

Standard cycles = 150/60 min (Table 5)
Swing factor = 1.05 (Table 5)
Bucket volume = 2.3 Lm^3
Bucket fill factor = 1.0
Job efficiency = 0.80
Production = 150 *x* 1.05 *x* 2.3 *x* 1.0 *x* 0.80 = 290 Lm^3/h

Job Management

The two major factors controlling shovel production are the swing angle and lost time during the production cycle. Therefore, the angle of swing between digging and dumping positions should always be kept to a minimum. Haul units must be positioned to minimize the time lost as units enter and leave the loading position.

When only a single loading position is available, the shovel operator should utilize the time between the departure of one haul unit and the arrival of the next to move up to the digging face and to smooth the excavation area. The floor of the cut should be kept smooth to provide an even footing for the shovel and to facilitate movement in the cur area. The shovel should be moved up frequently to keep it an optimum distance from the working face. Keeping dipper teeth sharp will also increase production.

CLAMSHELLS

When the crane-shovel is equipped with a crane boom and clamshell bucket, it becomes an excavator known as a *clamshell.* The components of a cable-operated clamshell are identified in Figure 3.10.

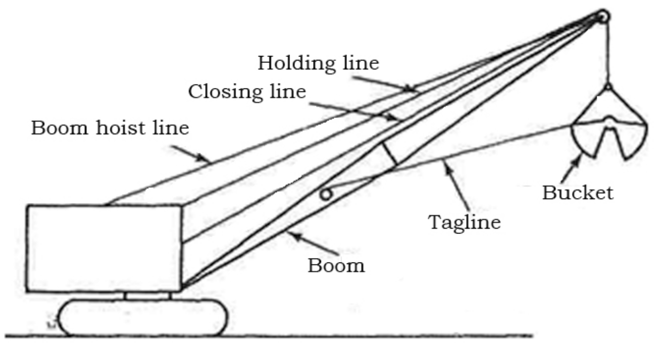


Figure 3.10: Clamshell and its components

The clamshell is capable of excavating to great depths but lacks the positive digging action and precise lateral control of the shovel and backhoe.

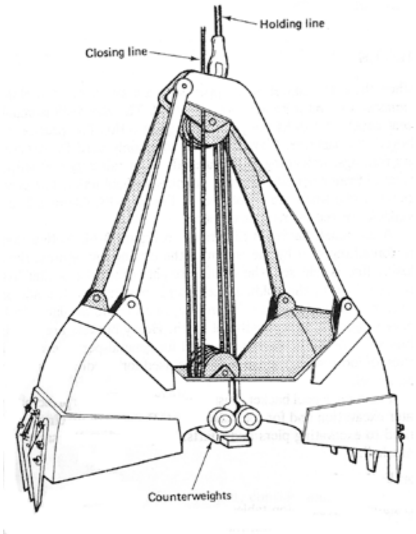


Figure 3.11: Clamshell bucket

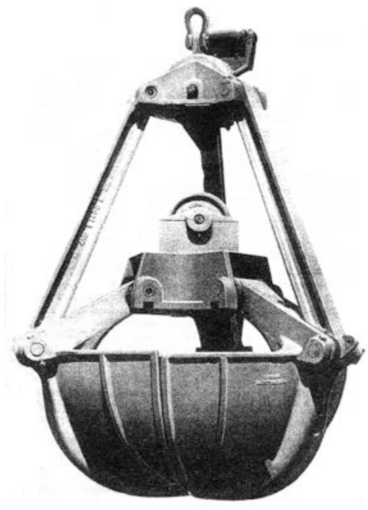


Figure 3.12: Orange peel bucket

Clamshells are commonly used for excavating vertical shafts and footings, unloading bulk materials from rail cars and ships, and moving bulk material from stockpiles to bins, hoppers, or haul units.

Clamshell attachments are also available for the hydraulic excavator.

A clamshell bucket is illustrated in Figure 3.11. Notice that the bucket halves are forced together by the action of the closing line against the sheaves.

When the closing line is released, the counterweights cause the bucket halves to open as the bucket is held by the holding line.

Bucket penetration depends on bucket weight assisted by the bucket teeth. Therefore, buckets are available in light, medium, and heavy weights, with and without teeth.

Heavy buckets are suitable for digging medium soils. Medium buckets are used for general-purpose work, including the excavation of loose soils. Light buckets are used for handling bulk materials such as sand and gravel.

The orange peel bucket illustrated in Figure 3.12 is principally utilized for underwater excavation and for rock placement. Because of its circular shape, it is also well suited to excavating piers and shafts. It operates on the same principle as does the clamshell.

Production Estimating

No standard production tables are available for the clamshell. Thus production estimation should be based on the use of Equation 1. The procedure is illustrated in the Example below.

Example

Estimate the production in loose cubic meters per hour for a medium-weight clamshell excavating loose earth. Heaped bucket capacity is 0.75 m^3).

The soil is common earth with a bucket fill factor of 0.95.
Estimated cycle time is 40 s.
Job efficiency estimated at 50 min/hour.

Solution

$$\text{Production} = \frac{3600}{40} \; x \; 0.75 \; x \; 0.95 \; x \frac{50}{60} = 53 \text{ Lm}^3/\text{h}$$

Job Management

The maximum allowable load (bucket weight plus soil weight) on a clamshell should be obtained from the manufacturer's clamshell loading chart for continuous operation.

If a clamshell loading chart is not available, limit the load to 80% of the safe lifting capacity given by the crane capacity chart for rubber-tired equipment or 90% for crawler-mounted equipment.

Since the machine load includes the weight of the bucket as well as its load, use of the lightest bucket capable of digging the material will enable a larger bucket to be used and will usually increase production. Tests may be necessary to determine the size of bucket that yields maximum production in a particular situation.

Cycle time is reduced by organizing the job so that the dumping radius is the same as the digging radius.

Keep machine level to avoid swinging uphill or downhill. Nonlevel swinging is hard on the machine and usually increases cycle time.

CRANES

Operation and Employment

Cranes are used primarily for lifting, lowering, and transporting loads. They move loads horizontally by swinging or traveling.

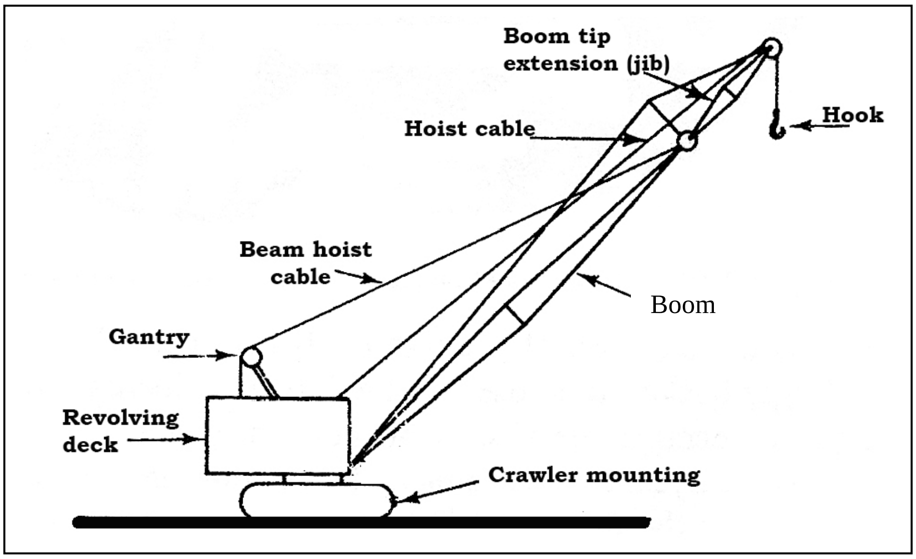


Figure 3.13: Components of a crane

Most mobile cranes consist of a crane-shovel carrier and superstructure equipped with a boom and hook as illustrated in Figure 5.13.

Figure 3.14: Hydraulic mobile telescoping boom crane

The current trend toward the use of hydraulically operated equipment includes hydraulically powered telescoping boom cranes.

The mobile telescoping-boom crane shown in Figure 3.14 is capable of lifting loads to the top of a 24-story building.

Some mobile cranes are intended to be used only as cranes and do not have the capability of using the crane-shovel front-end attachments described earlier.

Another special type of crane is the *tower crane,* illustrated in Figure 3.15.

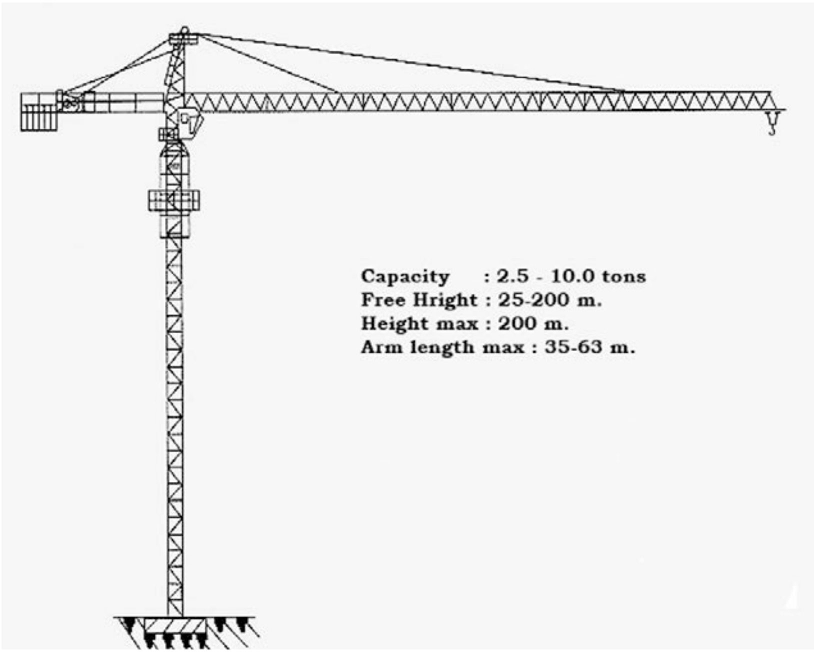


Figure 3.15 : Tower Crane

The tower crane is widely used on building construction projects because of its wide operating radius and almost unlimited height capability. The majority of tower cranes are of the saddle-jib or horizontal boom type shown in Figure 3.15.

However, luffing jib (inclined boom) are available which have the ability to operate in areas of restricted horizontal clearance not suitable for conventional tower cranes with their fixed jibs and counterweights.

Types of tower crane by method of mounting include static (fixed mount) tower cranes, rail-mounted tower cranes, mobile tower cranes, and climbing cranes.

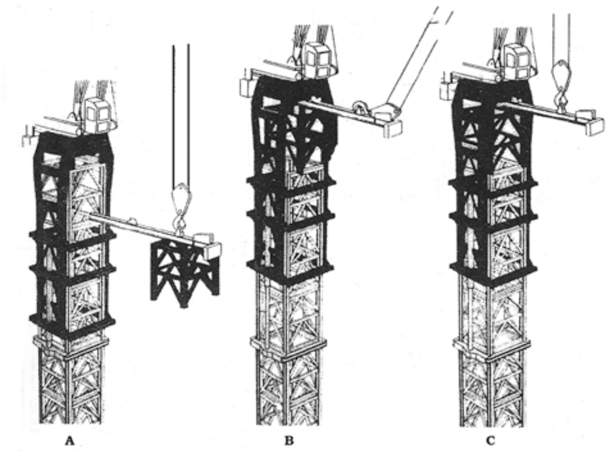


Figure 5.16: Self raising mast

Climbing cranes are supported by completed building floors and are capable of raising themselves from floor to floor as the building is erected. Most tower cranes incorporate self-raising masts. That is, they can raise themselves section by section until the mast or tower reaches the desired height. A typical procedure is as follows (refer to Figure 3.16).

The crane lifts an additional tower section together with a monorail beam and trolley (A).
The monorail beam is fastened to the crane's turntable base and the new section is trolleyed close to the tower.
The turntable base is unbolted from the tower.
The climbing frame's hydraulic cylinders lift the climbing frame and the new section is inserted into the climbing frame using the monorail beam trolley (B).
The climbing frame is then lowered and the new section is bolted to the tower and the turntable base (C).

The major factor controlling the load that may safely be lifted by a crane is its *operating radius* (horizontal distance from the center of rotation to the hook).

For other than horizontal boom tower cranes, this is a function of boom length and boom angle above the horizontal. Some of the other factors influencing a crane's safe lifting capacity include the position of the boom in relation to the carrier, whether or not *outriggers* (beams that widen the effective base of a crane) are used, the amount of counterweight, and the condition of the supporting surface.

Safety regulations limit maximum crane load to a percentage of the *tipping load* (load that will cause the crane to actually begin to tip).

Crane manufacturers provide charts giving the safe load capacity of the machine under various conditions. Notice that hook blocks and other load-handling devices are considered part of the load and their weight must be included in the maximum safe load capacity calculation. Electronic load indicators are available that measure the actual load on the crane and provide a warning if the safe load is being exceeded.

A standard method of rating the capacity of mobile cranes has been adopted by the relevant governmental department. Under this system, a nominal capacity rating is assigned which indicates the safe load capacity (with outriggers set) for a specified operating radius [usually 3.60 m. in the direction of least stability].

The nominal rating consists of two number symbols. The first number indicates the operating radius for the nominal capacity. The second number gives the rated load in 45.40 kg at a 12.2-m. operating radius using a 15.20 m. boom.

Job Management

There are a number of attachments besides the basic hook available to assist the crane in lifting and transporting various types of loads. A number of these attachments are illustrated in Figure 3.17.

Among these attachments, concrete buckets, slings and special hooks are most often used in construction applications.

High-voltage lines present a major safety hazard to crane operations. TRNC Safety and Health regulations prohibit a crane or its load from approaching closer than 3.05 m. (10 ft) to a high voltage line carrying 50 kV or less. An additional 1 cm (0.4 in.) must be added for each kilovolt over 50 kV.

These safety clearances must be maintained unless the line is deenergized and visibly grounded at the work site or unless insulating barriers not attached to the crane are erected which physically prevent contact with the power line.

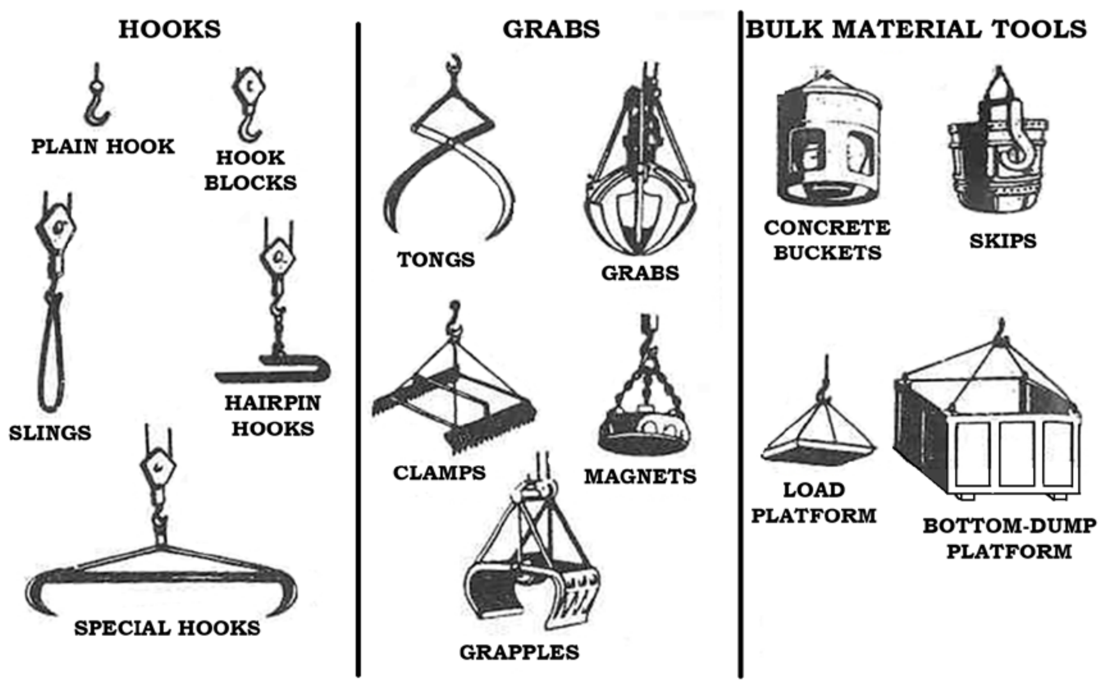


Figure 3.17: Lifting attachments for the crane

Crane accidents occur all too frequently in construction work, particularly when lifting near-capacity loads and when operating with long booms.

Some suggestions for safe crane operations include the following:

- Carefully set outriggers on firm supports.
- The crane base must be level. Safe crane capacity is reduced as much

50% when the crane is out of level by only 3° and operating with a long boom at minimum radius.

- Use a communications system or hand signals when the crane operator can not see the load. Make sure that all workers involved in the operation knows the signals to be used.
- Provide *tag lines* (restraining lines) when there is any danger due to swinging loads.
- Ensure that crane operators are well trained and know the capability o their machines.
- Check safe-lifting-capacity charts for the entire range of planned swing before starting a lift. Use a load indicator if possible.

DRAGLINES

The *dragline* is a very versatile machine that has the longest reach for digging and dumping of any member of the crane-shovel family.

It can dig from above machine level to significant depths in soft to medium-hard material. The components of a dragline are shown in Figure 3.18

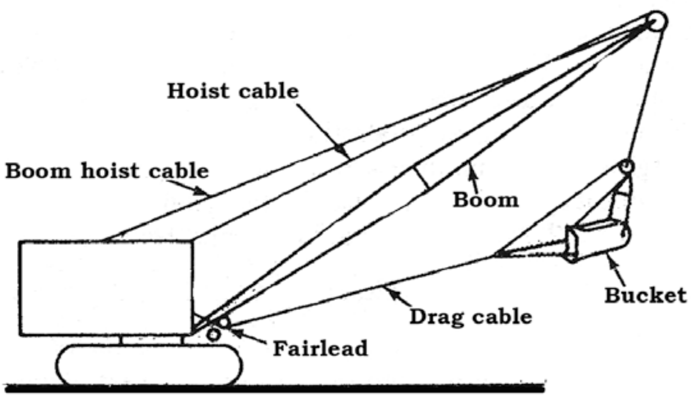


Figure 3.18: Components of a dragline

Bucket teeth and weight produce digging action as the drag cable, pulls the bucket across the ground surface.

Digging is also controlled by the position at which the drag chain is attached to the bucket (Figure 3.19).

The higher the point of attachment, the greater the angle at which the bucket enters the soil. During hoisting and swinging, material is retained in the bucket by tension on the dump cable.

When tension on the drag cable is released, tension is removed from the dump cable, allowing the bucket to dump. Buckets are available in a wide

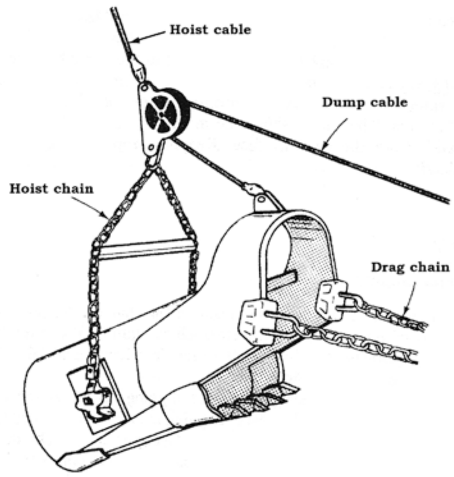


Figure 3.19: Dragline bucket

range of sizes and weights, solid and perforated. Also available are archless buckets which eliminate the front cross-member connecting the bucket sides to provide easier flow of material into and out of the bucket.

While the dragline is very versatile excavator, it does not have the positive digging action or lateral control of the shovel. Hence the bucket may bounce or move sideways during hard digging.

Also, more spillage must be expected in loading operations than would occur with a shovel. While a skilled dragline operator can overcome many of these limitations, the size of haul units used for dragline loading should be greater than that of those used with a similar-size shovel.
The maximum bucket size to be used on a dragline depends on machine power, boom length, and material weight. Therefore, use the dragline capacity chart provided by the manufacturer instead of the machine's lifting capacity chart to determine maximum allowable bucket size.

DOZERS

Tractors and Dozers

A tractor equipped with a front-mounted earthmoving blade is known as a *dozer* or *bulldozer.*

A dozer moves earth by lowering the blade and cutting until a full blade load of material is obtained. It then pushes the material across the ground surface to-the required location. The material is unloaded by pushing it over a cliff or into a hopper or by raising the blade to form a spoil pile.

Both rubber-tired (or wheel) dozers and crawler (or track) dozers are available.

Figure 3.20: Crawler Dozer

Because of its excellent traction and low ground pressure, typically 0.42 to 0.63 kg/cm^2 (0.4 to 0.6 bar), crawler dozers (Figure 3.20) are well suited for use in rough terrain or areas of low traffic-ability. Low-ground-pressure models with extra-wide tracks are available having ground pressures as low as 0.21 kg/cm^2. (0.2 bar).

Crawler dozers can operate on steeper side slopes and climb greater grades than can wheel dozers.

Wheel dozers, on the other hand, operate at higher speed than do crawlers dozers. Wheel dozers are also capable of operating on paved roads without damaging the surface. While the wheel tractor's dozing ability is limited somewhat by its lower traction and high ground pressure 1.76 to 2.46 kg/cm^2 (1.7 to 2.4 bars). Its high ground pressure makes it an effective soil compactor.
Either rubber-tired or crawler tractors may be equipped with attachments other than dozer blades. These include rakes used for gathering up brush and small fallen trees and plows, rippers and scarifiers which are used to break up hard surfaces.

Tractors are also used to tow many items of construction equipment, such as compactors, scrapers, and wagons.

Dozers may be equipped with, direct-drive, power-shift, or hydrostatic transmis*sions. Hydrostatic transmissions* utilize individual hydraulic motors to drive each track. Therefore, the speed of each track may be infinitely varied, forward or reverse. As a result, it is possible for a dozer equipped with a hydrostatic drive to turn in its own length by moving one track forward while the other track moves in reverse.

Dozer Blades

There are a number of types of dozer blades available, and the four most common types are illustrated in Figure 3.21.

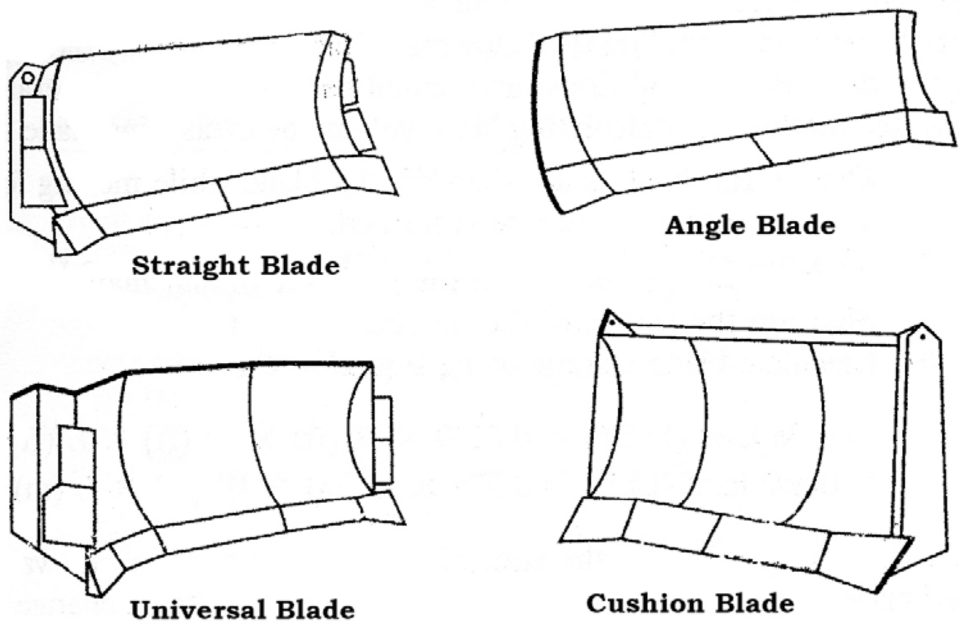


Figure 321: Common types of dozer blades

The three types of adjustments that may be made to dozer blades are illustrated in Figure 3.22.

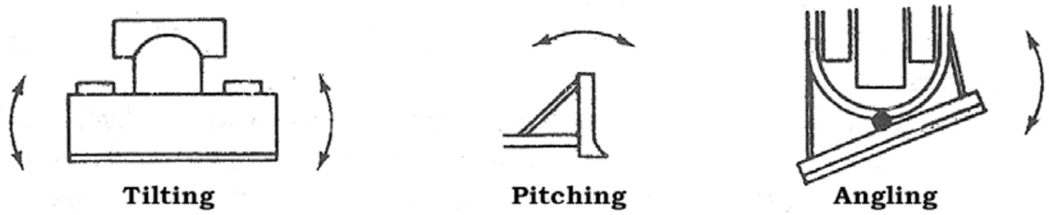


Figure 3.22: Dozer blade adjustments

Tilting the blade is useful for ditching and breaking up frozen or crusty soils. Pitching the blade forward reduces blade penetration and causes the loosened material to roll in front of the blade, whereas pitching the blade backward increases penetration. Angling the blade is helpful when side-hill cutting, ditching, and moving material laterally. All the blades shown in Figure 3.21 may be tilted except the cushion blade. However, only the angle blade may be angled.

The two indicators of potential dozer performance are based on the ratio of tractor power to blade size. These indicators are horsepower per meter of cutting edge and horsepower per loose cubic meter. A blade's *horsepower per meter of cutting edge* provides a measure of the blade's ability to penetrate hard soils. The *horsepower per loose cubic meter* rating provides an indication of the blade's ability to push material once the blade is loaded.

The wings on the universal blade (Figure 3.21) enable it to push a large volume of material over long distances. However, its low horsepower per foot of cutting edge and per cubic meter limit its ability to penetrate hard soils or to move heavy materials.

The straight blade is considered the most versatile dozer blade. Its smaller size gives it good penetrating and load pushing ability. The ability of angle blades to angle approximately 25° to either side make them very effective in side hill cutting, ditching, and backfilling. They may also be used for rough grading and for moving material laterally.

The cushion blade is reinforced and equipped with shock absorbers to enable it to push-load scrapers. It may also be used for cleanup of the loading or dumping areas and for general dozing when not push-loading scrapers.

Other available types of dozer blades include light-material U-blades, special clearing blades, and ripdozer blades (blades equipped with ripper shanks on each end).

Estimating Dozer Production

The basic earthmoving production equation (Equation 11) may be applied in estimating dozer production.
This method requires an estimate of the average blade load and the dozer cycle time. There are several methods available for estimating average blade load, including the blade manufacturer's capacity rating, previous experience under similar conditions, and actual measurement of several typical loads.

A suggested method for calculating blade volume by measuring blade load is as follows:
- Doze a full blade load, and then lift the blade while moving forward on a level surface until an even pile is formed.
- Measure the width of the pile *(W)* perpendicular to the blade and in line with the inside of each track or wheel. Average the two measurements.
- Measure the height *(H)* of the pile in a similar manner.
- Measure the length of the pile parallel to the blade.
- Calculate blade volume.

Blade load (Lm^3) = $0.375 \; x \; H$ (m) $x \; W$ (m) $x \; L$ (m) (Eq. 11)

Total dozer cycle time is the sum of its fixed cycle time and variable cycle time. F*ixed cycle time r*epresents the time required to maneuver, change gears, start loadings and dump. Table 6 may-be used to estimate dozer fixed cycle time.

Table 3.6: Typical dozer fixed cycle times.

Operating Conditions	Time (min)
Power shift transmission	0.05
Direct-drive transmission	0.10
Hard digging	0.15

Variable cycle time is the time required to doze and return. Since the haul distance is relatively short, a dozer usually returns in reverse gear.

Table 3.7 provides typical operating speeds for dozing and return. Some manufacturers provide dozer production estimating charts for their equipment.

Table 3.7: Typical dozer operating speeds

Operating Conditions	Speeds
Dozing:	
Hard materials, haul 30 m. or less	2.4 km/h
Hard materials, haul over 30 m.	3.2 km/h
Loose materials, haul 30 m. or less	3.2 km/h
Loose materials, haul over 30 m.	4.0 km/h
Return:	
30 m. or less	Max. reverse speed in second Range (power shift) or reverse Speed in gear used for dozing (direct drive).
Over 30 m.	Max. reverse speed in third Range (power shift) or highest Reverse speed (direct drive).

Example

A power-shift crawler tractor has a rated blade capacity of 7.65 Lm^3. The dozer is excavating loose common earth and pushing it a distance of 61 m. Maxi-mum reverse speed in third range is 8 km/h. Estimate the production of the dozer if job efficiency is 50 min/h.

Fixed time = 0.05 min (Table 6)
Dozing speed = 4.0 km/h) (Table 7)

$$\text{Dozing time} = \frac{61}{4 \, x \, 16.7} = 0.91 \text{ min}$$

Note: 1 km/h = 16.7 m./min.

$$\text{Return time} = \frac{61}{8 \, x \, 16.7} = 0.45 \text{ min}$$

$$\text{Production} = 7.65 \, x \, \frac{50}{1.41} = 271 \text{ Lm}^3/\text{h}$$

Job Management

Some techniques used to increase dozer production include downhill dozing, slot dozing, and blade-to-blade dozing.

By taking advantage of the force of gravity, downhill dozing enables blade load to be increased or cycle time to be reduced compared to dozing on the level. Slot dozing utilizes a shallow trench (or slot) cut between the loading and dumping areas to increase the blade capacity that can be carried on each cycle.

Under favorable conditions, slot dozing may increase dozer production as much as 50%. The slot dozing technique may be applied to the excavation of large cut areas by leaving uncut sections between slots. These uncut sections are removed after all other material has been excavated.

Blade-to-blade dozing involves two dozers operating together with their blades almost touching. This technique results in a combined blade capacity considerably greater than that of two single blades. However, the technique is not efficient for use over short dozing distances because of the extra maneuvering time required.

Mechanically coupled side-by-side (S *x* S) dozers equipped with a single large blade are available and are more productive than are blade-to-blade dozers.

LOADERS

A tractor equipped with a front-end bucket is called a *loader, front-end loader,* or *bucket loader.*

Both wheel loaders (Figure 3.23) and track loaders (Figure 3.24) are available. Loaders are used for excavating soft to medium-hard material, loading hoppers and haul units, stockpiling material, backfilling ditches, and moving concrete and other construction materials.

Figure 3.23: Wheel Loader

Wheel loaders possess excellent job mobility and are capable of over-the-road movement between jobs at speeds of 40 km/h or higher. While their ground pressure is relatively low and may be varied by the use of different-size tires and by changing inflation pressures, they do not have the all-terrain capability of track loaders. Most modern wheel loaders are *articulated.* That is, they are hinged between the front and rear axles to

Figure 3.24: Track (crawler) Loader

provide greater maneuverability.

Track loaders are capable of overcoming steeper grades and side slopes than are wheel loaders. Their low ground pressure and high tractive effort enable them to operate in all but the lowest trafficabilitv soils.
However, because of their lower speed, their production is less than that of a wheel loader over longer haul distances.
Attachments available for the loader include augers, backhoes, crane booms, dozer and snow blades, and forklifts in addition to the conventional loader bucket.

Estimating Loader Production

Loader production may be estimated as the product of average bucket load multiplied, by cycles per hour (Equation 1).

Basic cycle time for a loader includes time required for loading, dumping, making four reversals of direction, and traveling a minimum distance (5 m. or less for track loaders).

Table 3.8: Basic Loader cycle time

	Basic Cycle Time (min)	
Loading Conditions	Articulated Wheel Loader	Track Loader
Loose materials	0.35	0.30
Average materials	0.50	0.35
Hard materials	0.65	0.45

Table 3.8, presents typical values of basic cycle time for wheel and track loaders.

While manufacturers' performance curves should be used whenever possible, typical travel-time curves for wheel loaders are presented in Figure 3.25.

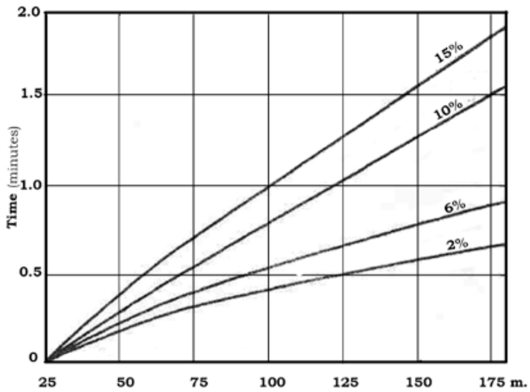


Figure 25: One way haul distance

Studies have shown little variation in basic cycle time for wheel loaders up to a distance of 25 m. between loading and dumping position. Therefore, travel time should not be added until one-way distance exceeds this distance.

Loader bucket capacity is rated in heaped (loose) volume. Bucket capacity should be adjusted by a bucket fill factor to obtain the best estimate of actual bucket volume.

Example

Estimate the hourly production in loose volume (Lm^3) of a 2.68-m^3 wheel loader excavating sand and gravel (average material) from a pit and moving it to a stockpile.
The average haul distance is 61 m, the effective grade is 6%, the bucket fill factor is 1.00, and job efficiency is 50 min/h.

Bucket volume = 2.68 x 1=2.68 Lm^3

Basic cycle time = 0.50 min (Table 8)

Travel time = 0.30 min (Figure 25)

Cycle time = 0.50 + 0.30 = 0.80 min

$$\text{Production} = 2.68\ x\ \frac{50}{0.80} = 168\ Lm^3/h$$

Job Management

Some considerations involved in choosing a loader for a project have already been presented. Cutting of tires is a major problem when loading shot rock with a, wheel loader. Type L-5 tires (rock, extra deep tread) should be used to increase tire life when loading rock. The pit must be kept well drained, because water acts as a lubricant to increase the cutting action of rock on rubber tires.

Because of tipping load limitations, the weight of the material being handled may limit the size of bucket that may be used on a loader. In selection of a loader, consideration must also be given to the clearances required during loading and dumping.

Like excavators, optimum positioning of the loader and haul units will minimize loading, maneuver, and dump times. Multisegment buckets, also called 4-in-l buckets and multipurpose buckets are capable of performing as a clamshell, dozer, or scraper, as well as a conventional loader.
Such buckets are often more effective than are conventional buckets in handling wet, sticky materials. Blasting or ripping hard materials before attempting to load them will often increase loader production in such materials.

SCRAPERS

Operation and Employment

Scrapers are capable of excavating, loading, hauling, and dumping material over medium to long haul distances.

Figure 3.26: Scraper

However, only the elevating scraper is capable of achieving high efficiency in loading without the assistance-of a pusher tractor or another scraper. Loading procedures are discussed later in this section.

The scraper excavates (or cuts) by lowering the front edge of its bowl into the soil. The bowl front edge is equipped with replaceable cutting blades, which may be straight, curved, or extended at the center (stinger arrangement). Both the stinger arrangement and curved blades provide better penetration than does a straight blade. However, straight blades are preferred for finish work.

Although there are a number of different types of scrapers, principal types include single-engine overhung (two-axle) scrapers, three-axle scrapers, twin-engine all-wheel-drive scrapers, elevating scrapers, auger scrapers, and push-pull or twin-hitch scrapers.

Two-axle or overhung scrapers utilize a tractor having only one axle. Such an arrangement has a lower rolling resistance and greater maneuverability than does a *three-axle scraper* that is pulled by a conventional four-wheel tractor. However, the additional stab of the three-axle scraper permits higher operating speeds on long, relatively flat haul roads.

All-wheel-drive scrapers, as the name implies, utilize drive wheels on both

tractor and scraper. Normally, such units are equipped with twin engines. The additional power and drive wheels give these units greater tractive effort than that of conventional scrapers.
Elevating scrapers utilize a ladder-type elevator to assist in cutting and lifting material into the scraper bowl. Elevating scrapers are not signed-to be push-loaded and may be damaged by pushing.

Auger scrapers are self loading scrapers that use a rotating auger (similar to a pesthole auger) located in the center of the scraper bowl to help lift material into the bowl.

Push-pull or *twin-hitch scrapers* are all-wheel-drive scrapers equipped with coupling devices that enable two, scrapers to assist each other in loading.

Estimating Scraper Production

Scraper cycle time is estimated as the sum of fixed cycle time and variable eye time. Fixed cycle time in this case includes spot time, load time, and maneuver and dump time.
Spot time represents the time required for a unit to position itself in the cut and begin loading, including any waiting for a pusher.

Variable cycle time, or travel time, includes haul time and return time. As usual haul and return times are estimated by the use of travel-time curves or by using the average-speed method with performance and retarder curves.

It is usually necessary to break a haul route up into sections having similar total resistance values. The total travel time required to traverse all sections is found as the sum of the section travel times.

In determining the payload per scraper cycle, it is necessary to check both the rated weight payload and the heaped volume capacity. The volume corresponding to the lesser of these two values will, of course, govern.

TRUCKS AND WAGONS

Operation and Employment

Because hauling (or the transportation of excavation) is a major earthmoving activity, there are many different types of hauling equipment available to the constructor. In addition to the dozer, loader, and scraper already described, hauling equipment includes trucks, wagons, conveyor belts, and trains. Most of the belt-type conveyors used in construction are portable units used for the movement of bulk construction materials within a small area or for placing concrete. However, conveyors are capable of moving earth: and stone relatively long distances at high speed. Their ability to move earth for highway construction has been demonstrated in Great Britain. In the United States, they have been utilized on a number of large construction projects, such as dams.

Their application is primarily limited by their large capital cost. Conventional freight trains may be used to haul earth or rock over long distances when tracks are located near the excavation and fill areas. However, most construction applications involve narrow-gauge rail lines built in the construction area. This type of equipment is often used to remove the spoil from tunneling. Special rail cars are available for hauling plastic concrete.
Although not usually thought of as a piece of earth moving equipment a dredge is capable of excavating soil and fractured rock and transporting it through pipelines in the form of a slurry.

Trucks and wagons are still the most common forms of construction hauling equipment. The heavy-duty, rear dump -truck is most widely used because of its flexibility of use and the ability of highway models to move rapidly between job sites.
There are a wide variety of types and sizes of dump truck available. Trucks may be powered by diesel or gasoline engines, have rear axle or all-wheel drive, have two or three axles, be equipped with standard or rock bodies, and so on.
Trucks used hauling on public highways are limited by transportation regulations in their maximum width, gross weight, and axle load. There is a growing trend toward the use of off-highway models that can be larger and heavier and carry payloads up to several hundred tons.

Figure 3.27: 40 ton Rear Dump Truck

Figure 3.27 shows a 40 ton rear-dump truck.

The all-wheel-drive articulated dump truck illustrated in Figure 5.28 (also called articulated hauler) is finding increasing usage because of its ability to carry large loads over low-trafficability soils.

Wagons are tractors equipped with earthmoving semitrailers. Wagons are available in end-dump and side-dump models as well as the more common bottom-dump model. Bottom-dump

Figure 3.28: All wheel Rear Dump Truck

models are preferred for moving earth and crushed rock cause of their ability to dump and spread while moving at a relatively high speed.

Determining the Number of Haul Units Needed

The components of the truck or wagon cycle are similar to those of the scraper described in the previous sections. Thus total cycle time is the sum of the fixed time (spot, load, maneuver and dump) and the variable time (haul and return).

The fixed time elements of spot, maneuver and dump may be estimated by the use of Table 9.
Loading time, however, should be calculated by the use of Equation 12 or 13.

$$\text{Load time} = \frac{\text{Haul unit capacity}}{\text{Loader production at 100\% efficiency}} \qquad \text{(Eq.12)}$$

Load time = Number of bucket loads x Excavator cycle time (Eq.13)

The reason for using an excavator loading rate based on 100% excavator efficiency in Equation 12 is that excavators have been found to operate at or near 100% efficiency when actually loading.
Thus the use of the 100% efficiency loading rate is intended to ensure that an adequate number of trucks are provided so that the excavator will not have to wait for a truck. Either bank or loose measure may be used in Equation 12, but the same unit must be used in both numerator and denominator.

The number of trucks theoretically required to keep a loader fully occupied and thus obtain the full production of the loader may be calculated by the use of Equation 14.

Table 9: Spot, maneuver and dump time for trucks and wagons (min)

	Bottom Dump	Rear Dump
Favorable	1.1	0.5
Average	1.6	1.1
Unfavorable	2.0	2.5

Although this method gives reasonable values for field use, it should be recognized that some instances of the loader waiting for haul units will occur in the field when this method is used.
This is due to the fact that some variance in loader and hauler cycle time will occur in the real-world situation.
More realistic results may be obtained by the use of computer simulation

techniques or the mathematical technique known as queueing theory.

$$\text{Number of haulers required (N)} = \frac{\text{Haul unit cycle time}}{\text{Load time}} \qquad \text{(Eq. 14)}$$

The result obtained from Equation 14 must be rounded up to the next integer.

Using this method, the expected production of the loader/hauler system is the same as though the excavator were simply excavating and stockpiling. Reviewing the procedure, system output is assumed to equal normal loader output, including the usual job efficiency factor. However, the number of haul units required is calculated using 100% loader efficiency.

If more than the theoretically required number of trucks is supplied, no increase in system production will occur, because system output is limited to excavator output. However, if less than the required number of trucks is supplied, system output will be reduced, because the excavator will at times have to wait for a haul unit.
The expected production in this situation may be calculated by the use of Equation 15. In performing this calculation, use the precise value of N, not its integer value.

$$\underset{\text{(no. units less than N)}}{\text{Expected production}} = \frac{\text{Actual number of units}}{N} \times \text{(Excavator production)} \qquad \text{(Eq. 15)}$$

Example

Given the following information on a shovel/truck operation, (a) calculate the number of trucks theoretically required and the production of this combination; (b) calculate the expected production if two trucks are removed from the fleet.

Shovel production at 100% efficiency = 283 Bm^3/h
Job efficiency = 0.75
Truck capacity = 15.3 Bm^3
Truck cycle time, excluding loading = 0.5 h

Solution

(a) $$\text{Load time} = \frac{15.3}{283} = 0.054 \text{ h}$$

Truck cycle time = 0.5 + 0.054 = 0.554 h

$$\text{Number of trucks required} = \frac{0.554}{0.054} = 10.3 = 11$$

$$\text{Expected production} = 283 \times 0.75 = 212\ Bm^3/h$$

(b) With nine trucks available,

$$\text{Expected production} = \frac{9}{10.3} \times 212 = 186\ Bm^3/h$$

Job Management

An important consideration in the selection of excavator/haul unit combinations is the effect of the size of the target that the haul unit presents to the excavator operator. If the target is too small, excessive spillage will result and excavator cycle time will be increased.

Studies have found that the resulting loss of production may range from 10 to 20%. As a rule, haul units loaded by shovels, backhoes, and loaders should have a capacity of 3 to 5 times excavator bucket capacity. Because of their less precise control, clamshells and draglines require larger targets.

A haul unit capacity of 5 to 10 times excavator bucket capacity is recommended for these excavators. Haul units that hold an integer number of bucket loads are also desirable. Using a partially filled bucket to top off a load is an inefficient operation.

Time lost in spotting haul units for loading is another major cause of inefficiency. As discussed under excavator operations, reducing the excavator swing angle between digging and loading will increase production. The use of two loading positions, one on each side of the excavator, will reduce the loss of excavator production during spotting.

When haul units are required to back into loading position, bumpers or spotting logs will assist the haul unit operator in positioning his vehicle in the minimum amount of time.

Some other techniques for maximizing haul unit production include:

- If possible, stagger starting and quitting times so that haul units do not bunch up at the beginning and end of the shift.
- Do not overload haul units. Overload results in excessive repair and maintenance.
- Maintain haul roads in good condition to reduce travel time and minimize equipment wear.
- Develop an efficient traffic pattern for loading, hauling, and dumping.

- Roads must be wide enough to permit safe travel at maximum speeds.
- Provide standby units (about 20% of fleet size) to replace units that breakdown or fail to perform adequately.
- Do not permit speeding. It is a dangerous practice; it also results in excessive equipment wear and upsets the uniform spacing of units in the haul cycle.

In unit price earthmoving contracts, payment for movement of soil or rock from cut to fill that exceeds a specified distance is termed *overhaul*. Overhaul can be minimized by selection of an optimum design surface elevation (grade) and by use of borrow and waste areas at appropriate locations.

COMPACTION EQUIPMENT AND PROCEDURES

Types of compaction Equipment

Principal types of compaction equipment include tamping foot rollers, grid or mesh rollers, vibratory compactors, smooth steel drum rollers, pneumatic rollers, segmented pad rollers, and tampers or rammers (see Figure 5.29).

Tamping foot rollers utilize a compaction drum equipped with a number of protruding feet. Tamping foot rollers are available in a variety of foot sizes and shapes, including the sheepsfoot roller.

During initial compaction, roller feet penetrate the loose material and sink to the lower portion of the lifts. As compaction proceeds, the roller rises to the surface or "walks out" of the soil. All tamping foot rollers utilize static weight and manipulation to achieve compaction. Therefore, they are most effective on cohesive soils.

While the sheepsfoot roller produces some impact force, it tends to displace and tear the soil as the feet enter and leave the soil. Newer types of tamping foot rollers utilize a foot designed to minimize displacement of soil during entry and withdrawal. These types of rollers more effectively utilize impact forces, High-speed tamping foot rollers may operate at speeds of 16 km/h or more. At these speeds they deliver impacts at a frequency approaching vibration.

Grid or mesh rollers utilize a compactor drum made up of a heavy steel mesh. Because of their design, they can operate at high speed without scattering the material being compacted. Compaction is due to static weight and impact plus limited manipulation. Grid rollers are most effective in compacting clean gravels and sands. They can also be used to break up lumps of cohesive soil. They are capable of both crushing and compacting soft rock (rock losing 20% or more in the Los Angeles Abrasion Test).

Vibratory compactors are available in a wide range of sizes and tyres. In size they range from small hand-operated compactors through towed rollers to large self-propelled rollers. By type they include plate compactors, smooth drum rollers, and tamping foot rollers. Small walk-behind vibratory plate compactors and vibratory rollers are used primarily for compacting around structures and in other confined areas.

Vibratory plate compactors are also available as attachments for hydraulic excavators. The towed and self-propelled units are utilized in general earthwork. Large self-propelled smooth drum vibratory rollers are often used for compacting bituminous bases and pavements. While vibratory compactors are most effective in compacting noncohesive soils, they may also be effective in compacting cohesive soils when operated at low frequency and high amplitude. Many vibratory compactors can be adjusted to vary both the frequency and amplitude of vibration.

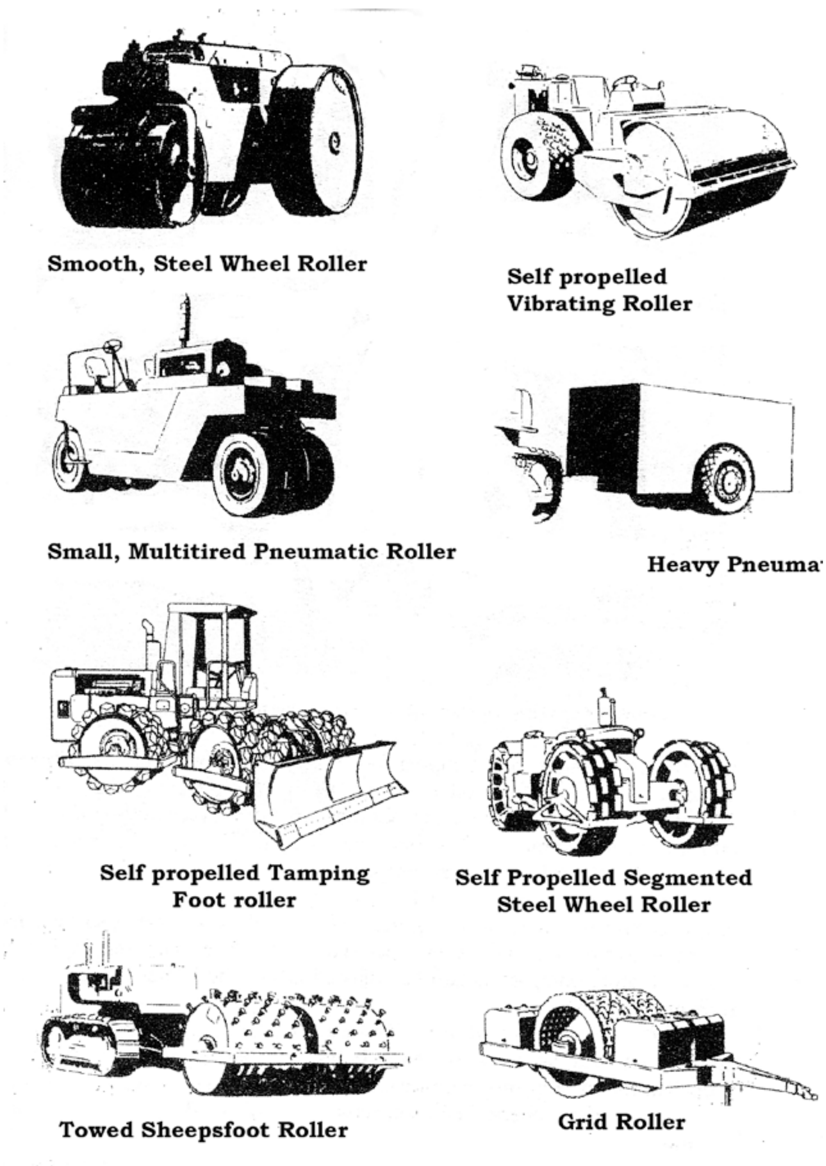


Figure 3.29: Major types of compaction equipment

Steel wheel or smooth drum rollers are used for compacting granular bases, asphaltic bases, and asphalt pavements. Types available include towed rollers and self-propelled rollers. Self-propelled rollers include three-wheel (two-axle) and two- and three-axle tandem rollers. The compactive force involved is primarily static weight.

Rubber-tired or pneumatic rollers are available as light- to medium weight multitired rollers and heavy pneumatic rollers. Wobble-wheel rollers are multi tired rollers with wheels mounted at an angle so that they appear to wobble as they travel. This imparts a kneading action to the soil.
Heavy pneumatic rollers weighing up to 200 tons are used for dam construction, compaction of thick lifts, and proof rolling. Pneumatic rollers are effective on almost all types of soils but are least effective on clean sands and gravels.
Segmented pad rollers are somewhat similar to tamping foot rollers except that they utilize pads shaped as segments of a circle instead of feet on the roller drum. As a result, they produce less surface disturbance than do tamping foot rollers. Segmented pad rollers are effective on a wide range of soil types.

Rammers or tampers are small impacts-type compactors, which are primarily used for compaction in confined areas. Some rammers, like the one shown in figure 5.30, are classified as vibratory rammers because of their operating frequency.

Figure 3.30: Small vibratory rammer

GRADING AND REFRESHING

Grading is the process of bringing earthwork to the desired shape and elevation (or grade). Finish grading, or simply finishing, involves smoothing slopes, shaping ditches, and bringing the earthwork to the elevation required by the plans and specification. Finishing usually follows closely behind excavation, compaction, and grading. Finishing, in turn, is usually followed closely by seeding or sodding to control soil erosion. The piece of equipment most widely used for grading and finishing is the motor grader (Figure 3.31).

Figure 3.31: Motor grader

Grade trimmers and excavators are frequently used on large highway and airfield projects because their operating speed is greater than that of the motor grader.

In highway construction, the process of cutting down high spots and-filling in low spots of each roadway layer is called balancing. Trimming is the process of bringing each roadway layer to its final grade.

Typical tolerances allowed for final roadway grades are 1.25 cm per 3.0 m. for subgrades and subbases and 0.3 cm per 3.0 m. for bases. Typical roadway components are illustrated in Figure 3.32.

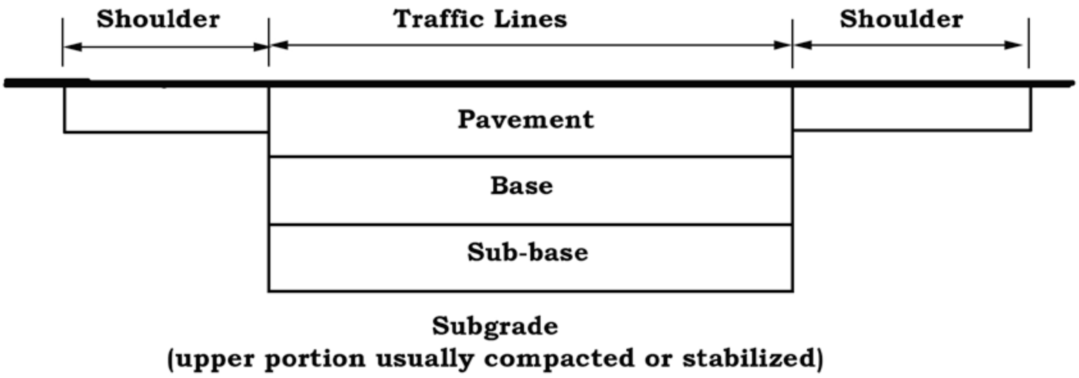


Figure 3.32: Typical Roadway Components

Finishing is seldom a pay item in a construction contract because the quantity of earthwork involved is difficult to measure. As a result, the planning of finishing operations is usually rudimentary. However, studies have shown that the careful planning and execution of finishing operations can pay large dividends.

Motor Grader

The motor grader is one of the most versatile items of earthmoving equipment. It can be used for light stripping, grading, finishing, trimming, bank sloping, ditching, backfilling, and scarifying. It is also capable of mixing and spreading soil and asphaltic mixtures. It is used on building construction projects as well as in heavy and highway construction. It is frequently used for the maintenance of highways and haul roads.

The blade of a motor grader is referred to as a *moldboard* and is equipped with replaceable cutting edges and end pieces (end bits). The wide range of possible blade positions is illustrated in Figure 3.33.

The pitch of the blade may be changed in a manner similar to dozer blades. Pitching the blade forward results in a rolling action of the excavated material and is used for finishing work and for blending materials. Pitching the blade backward increases cutting action but may allow material to spill over the top of the blade. Blade cutting edges are available in flat, curved, or serrated styles. Flat edges produce the least edge wear, but curved edges are recommended for cutting hard materials and for fine grading. Serrated edges are used for breaking up packed gravel, frozen soil, and ice.

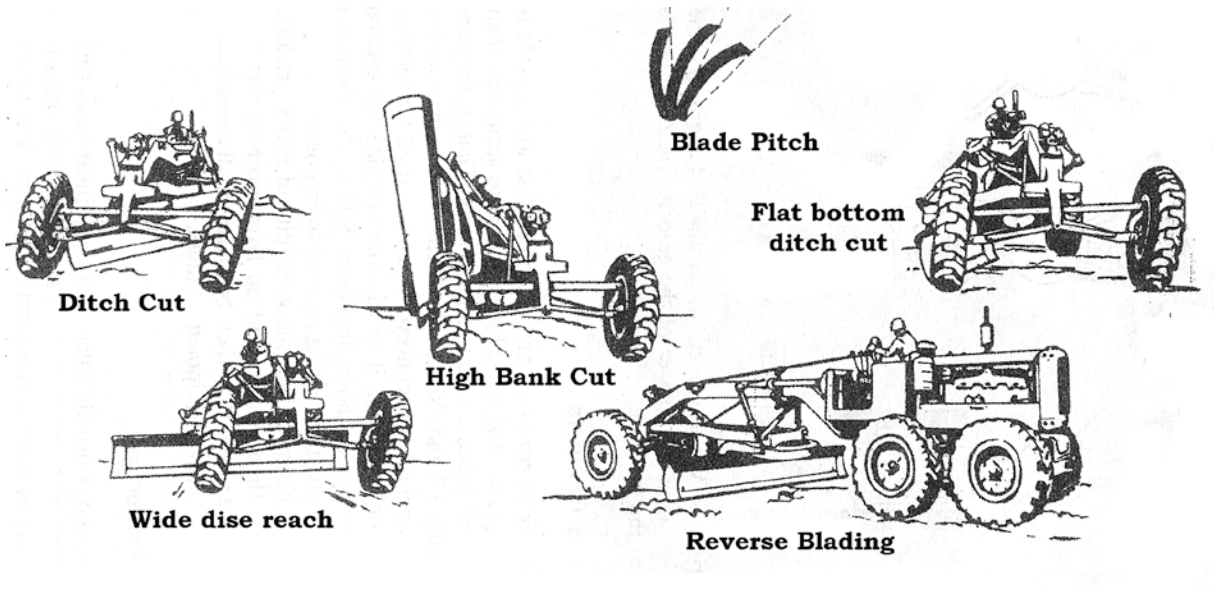


Figure 3.33: Blade positions for the Motor Blade

Motor graders are available with articulated frames that increase grader maneuverability. The three possible modes of operation for an articulated grader are illustrated in Figure 5.34.

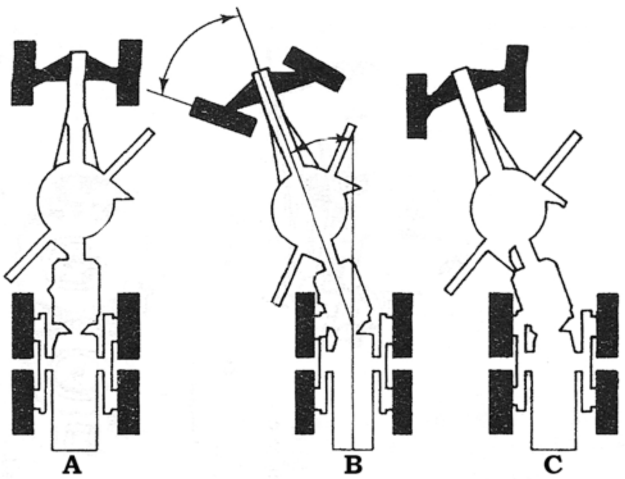


Figure 3.34: Articulated Grader Positions

The machine may operate in the conventional manner when in the straight mode (Figure 3.34A).
The articulated mode (Figure 3.34B) allows the machine to turn in a short radius.
Use of the crab mode (Figure 3.34C) permits the rear driving wheels to be offset so that they remain on firm ground while the machine cuts banks,

side slopes, or ditches. The front wheels of both conventional and articulated graders may be leaned from side to side. Wheels are leaned away from the cut to offset the side thrust produced by soil pressure against the angled blade. Wheel lean may also be used to assist in turning the grader.

Graders are available with automatic blade control systems that permit precise grade control. Such graders utilize a sensing system that follows an existing surface, string line, or laser beam to automatically raise or lower the blade as required to achieve the desired grade.
Scarifiers are used to loosen hard soils, before grading and to break up asphalt pavements and frozen soil. However, scarifiers are not intended for heavy-duty.

Grade Excavators and Trimmers

Grade excavators or *trimmers* are machines that are capable of finishing roadway and airfield subgrades and bases faster and more accurately than can motor graders. Many of these machines also act as reclaimers.
That is, they are capable of scarifying and removing soil and old asphalt pavement.
Trimmers and reclaimers are usually equipped with integral belt conveyors that are used for loading excavated material into haul units or depositing it in windrows outside the excavated area. The large grade trimmer/reclaimer shown in Figure 3.35 is also capable of compacting base material, laying asphalt, or acting as a slipform power.

Figure 3.35: Large Grade Trimmer/Reclaimer/Paver

While grade trimmers lack the versatility of motor graders, their accuracy and high speed make them very useful on large roadway and airfield projects. Their large size often requires that they be partially disassembled and transported between job sites on heavy equipment trailers.

Estimating Grader Production

Grader production is usually calculated on a linear basis kilometers completed per hour for roadway projects and on an area basis (square meters per hour) for general construction projects. The time required to complete a roadway project may be estimated as follows:

$$\text{Time (h)} = \left[\sum x \frac{\text{Number of passes } x \text{ Section length (km)}}{\text{Average speed for section (km/h)}}\right] x \frac{1}{\text{Efficiency}} \quad \text{Eq.16}$$

Average speed will depend on operator skill, machine characteristics, and job conditions. Typical grader speeds for various types of operations are given in Table 3.10.

Table 10: Typical grader operating speed

Operation	Speed (km/h)
Bank Sloping	4.0
Ditching	4.0-6.4
Finishing	6.5-14.5
Grading and road maintenance	6.4-9.7
Mixing	14.5-32.2
Snow removal	19.3-32.3
Spreading	9.7-14.5

Job Management

Careful job planning, the use of skilled operators, and competent supervision is required to maximize grader production efficiency. Use the minimum possible number of grader passes to accomplish the work. Eliminate as many turns as possible.
For working distances less than 305 m, have the grader back up rather than turn around. Grading in reverse may be used for longer distances when turning is
difficult or impossible. Several graders may work side by side if sufficient working
room is available. This technique is especially useful for grading large areas.

Example

24.1 km of gravel road require reshaping and leveling. You estimate that six passes of a motor grader will be required. Based on operator skill, machine characteristics, and job conditions, you estimate two passes at 6.4 km/h, two passes at 8.0 km/h, and two passes at 9.7 km/h. If job efficiency is 0.80, how many grader hours will be required for this job?

$$\text{Time} = \left(\frac{2 \, x \, 24.1}{6.4} + \frac{2 \, x \, 24.1}{8.0} + \frac{2 \, x \, 24.1}{9.7}\right) x \frac{1}{0.80} = 23.1 \text{ h.}$$

CHAPTER 4

INTRODUCTION TO MANAGING CONSTRUCTION PROJECTS

Genral

Good project management is essential. In many developing countries construction alone accounts for about 10 percent of gross national product, and 50 percent or more of the wealth invested in fixed assets.
Managing a project is quite different from managing a "steady-state" organization. A project has a distinct beginning and end, whereas steady-state organizations run continuously. Examples of the latter are hospitals and mass-production factories. In a hospital the basis of medical care changes slowly, despite technological advances and the administration works to a routine. In mass-production industries the routine of production proceeds continuously, except when new models are being introduced.
The elements included of project management starting from goals and ending with end-product is given in figure 4.1.

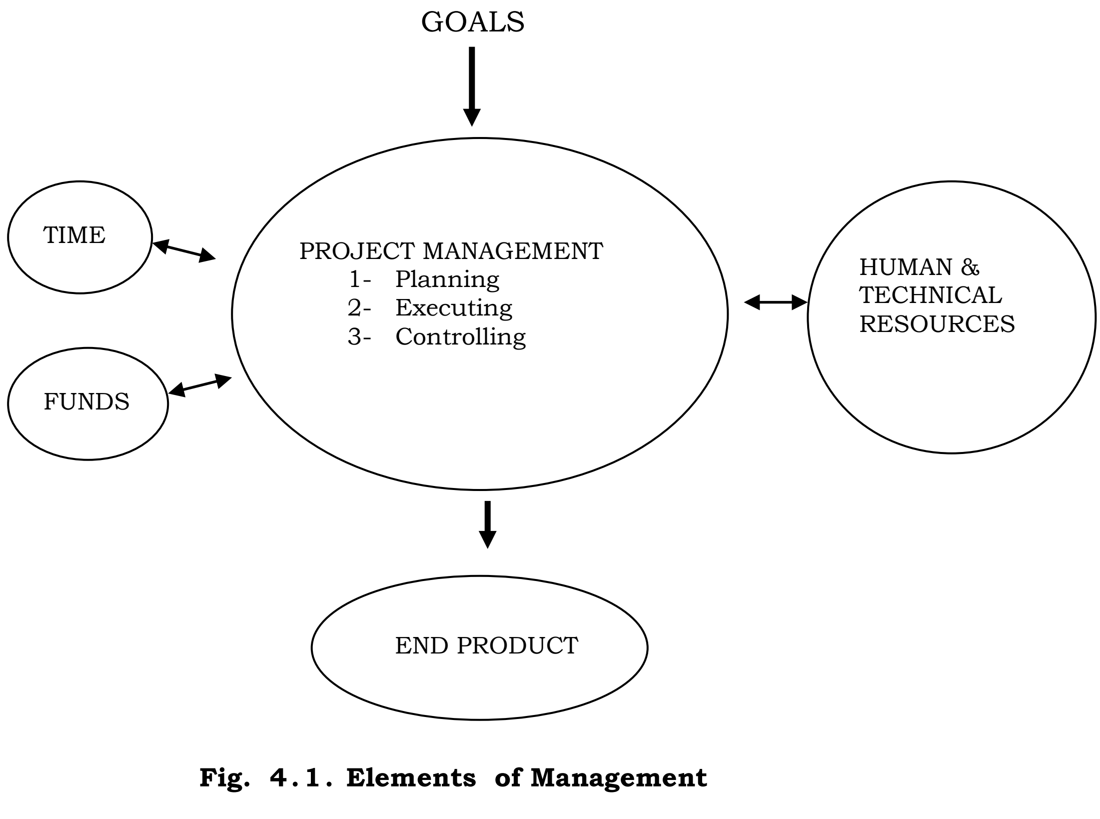


Fig. 4.1. Elements of Management

Construction industry supplies the basic requirements of shelter, water, sanitation, roads, schools and hospitals. Therefore, performance of construction industry has a marked effect both on the economy and on social conditions. This is especially true in developing countries, where much of this infrastructure is lacking. It follows that the efficient management of construction project is vital if scarce resources are not to be wasted. A proper construction management should provide the cycle of activities to achieve the project goals.

The managerial cycle is shown in figure 4.2. Since changes often unforeseen, occur during the lifetime of a project, figure 4.2 represents a continuous action aimed at achieving the best possible result.

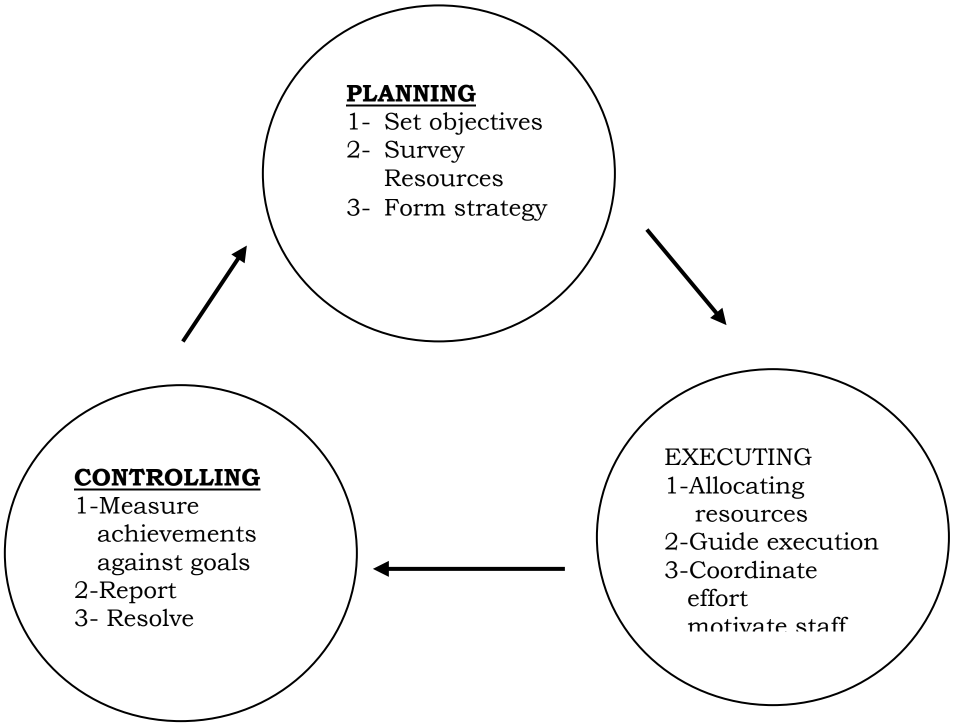


Figure 4.2: Managerial Cycle

4- 1.2. PARTIES OF CONSTRUCTION PROJECT

The main parties involved in a construction project are:

i) the client
ii) the users
iii) the designers
iv) the executors
v) public authorities and agencies.

The link between them is often provided by a project management team created for the duration of the project. The team is normally headed by a project manager, who is responsible to the client for the execution of the project.

The project management team is shown in figure 4.3.

The Client

The client may be an individual, such as someone wishing to build a house. The word is more generally used for the organization which needs the end product and has the authority (and the money) to order and approve it. For government projects, the client is usually a ministry or department.

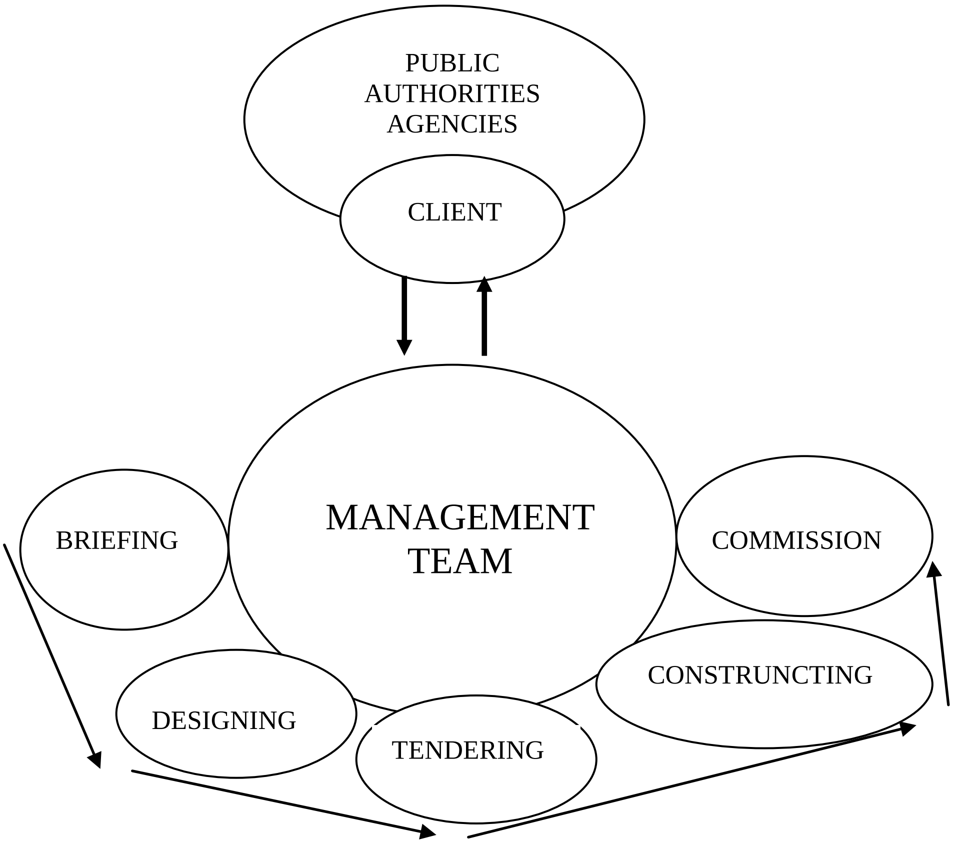


Figure 4.3: Project Management Team

The Users

In many respects the users are the most important party, yet often they are the most neglected. They are the people who must operate and maintain the facilities which have been provided. Although the same organization may be both client and user, the individuals involved may be different.

The Designers

These are the architects and specialists responsible for translating the client's requirements into reality. In a building project, the architect works with the following people:

i) structural engineers in the design of the structure,
ii) draughtsman to produce working drawings from the sketches,
iii) electrical engineers in the design of power and lighting supplies
iv) civil engineers in the design of access roads, earthworks,
v) Water supply quantity surveyors in the preparation of estimates and tender documents

Not every project requires all these people. On the other hand, large and complex projects may require additional specialists, for example, for heating and cooling, health and safety.

The Executors

These are the people who undertake the physical construction, who in many cases-will be private contractors. Some ministries have their own labour forces and works carried out in this way is said to be done by "direct labour", or "force account". For simplicity the word "contractor" is used and is deemed to include all organizations which actually build.

Public Authorities and Agencies

All buildings must fulfill statutory requirements regarding construction standards and safety. For example, roofs must be able to withstand specified wind loadings and fire regulations must be observed. The health and safety of people who work or dwell in a building are usually safe guarded by legal regulations. So they must have a substantial effect on the shape of the building and the facilities provided.

STAGES AND ASPECTS OF CONSTRUCTION

A construction project includes five stages from the time when the decision is made to implement the construction project untill the project becomes a reality. The stages of a construction project are:
i) Briefing
ii) Designing
iii) Tendering
iv) Constructing
v) Commissioning

Briefing Stage

a) Purpose:
To enable the client to specify project functions and permissible costs, so that the architects, engineers quantity surveyors and other members of the design team can correctly interpret his wishes and provide cost estimates.

b) Activities:
i) Set up a work plan and appoint designers and specialists
ii) Consider user requirements locations and site conditions, planning designing, estimated costs, quality requirements.
iii) Ensure the preparation of
- Sketches at scale 1/100, 1/1000, 1/3500
- Cost estimates and implications
- A plan for implementation

- The department data programme

c) Participants:
i) Architect
ii) Structural, electrical, mechanical engineers
iii) Quantity surveyor
iv) Specialists such as health or school planner
v) User representative

Designing Stage

a) Purpose
To complete the project brief and determine the layout, design, methods of construction and estimate costs, in order to obtain the necessary approvals from the client and authorities involved.

To prepare the necessary production information, including working drawings and specifications and to complete all arrangements for obtaining tenders.

b) Activities
Activities at this stage include
i) developing the project brief to final completion
ii) investigating technical problems
iii) obtaining the client final approval of the brief
iv) preparing

- a scheme design, including cost estimates
- a detail design
- working drawings, specifications and schedules
- bill of quantities
- a final cost estimates
- a preliminary production programme, including time-schedule.

c) Participants
Depending on the nature and the complexity of the project, the design team should include the following:
i) project manager
ii) architect (buildings)
iii) quantity surveyor
iv) Structural, mechanical and electrical engineers
v) Some specialists such as health and safety officials, organizational planners etc.

Tendering Stage

a) Purpose

To appoint a contractor or a number of contractors who will undertake the site construction works.

b) Activities

To obtain tenders from contractors: for the construction of the building and to award the contract.

Government tendering procedures are particularly closely controlled to ensure that national contracts are awarded in an equitable and uniform way. In many cases tendering is the responsibility of a central Tendering Board which is independent of either the client or the executing agency. Members of the project management team may be required to provide the basic documentation to the central "Tendering Board" and generally to provide technical assistance.

c) Pre-Qualification

To increase the probability that the client will get what is required, it is usual to introduce some procedure to ensure that only experience and competent contractors are allowed to tender. This procedure known as "pre-qualification", involves an investigation to the potential contractor's financial, managerial and physical resources and of his experience of similar projects and an assessment of the firm's integrity.

d) Contract Documents

The contract itself will be defined in a legal document which describes the duties and responsibilities of the parties to it. For construction work, standard forms of contract have evolved in most countries and it is usual for the central Tender Board to require the use of one of these standard forms with perhaps minor modifications to suit the circumstances of a particular project.

Other contract documents *are* those necessary to define in detail the construction required by the client: drawings, specifications, schedules, bill of quantities, time-scale. These documents will have been prepared during the design stage.

Standard Forms of Contract:

The use of standard forms of contract is recommended because:

i) their contents will be well known and understood by the parties involved,

ii) their wording embodies much experience in resolving difficulties of interpretation and enforcement.

iii) they will usually *have* been tested in law,

iv) the preparation of new forms of contract is expensive and timeconsuming

e) Participants

In the case of government projects, the project management teams may be expected to give technical support by:

i) providing the necessary contract documents
ii) providing a basis for pre-qualification of tenderers,
iii) checking that the tenders are arithmetically correct and conform to tender requirements.

Government Tender Boards usually award the contract to the lowest bidder. In the case of private projects, the final choice of contractor rests with the client, acting on the advice of the project management team.

Constructing Stage

a) Purpose
To construct the structure within the agreed limits of cost and time and to specified quality.

b) Activities
To plan, co-ordinate and control site operations. Production planning includes the formulation of:

i) time-schedules,
ii) site organization,
iii) a manpower plan,
iv) a plant and equipment plan
v) a materials delivery plan

Site operations include:

i) all temporary and permanent construction works and the supply of all built-in furniture and equipment.
ii) the co-ordination of subcontractors,
iii) general supervision.

The construction stage consists of a number interrelated a activities. The failure of one activity can disrupt the entire production schedule. Therefore, careful production planning is important.

d) Participants
The main participants are the project management team and the contractor. Normally, direct responsibility rests with the contractor. The project manager and his team must arrange for adequate supervision of the work to ensure requirements.

Commissioning Stage

a) Purpose
To ensure that the building (structure) has been completed as specified in the contract documents, and that all the facilities work properly.
To provide a record of the actual construction, together with operating instructions.
To train staff in the use of the facilities provided.

b) Records
During construction, difficulties may arise which result in changes to the original design. Records of these changes will be kept during construction, mainly for financial reasons.

c) Activities

i) prepare "as built" records,
ii) inspect the construction thoroughly and have defects remedied,
iii) start up, test and adjust all services,
iv) prepare operating instructions and maintenance manuals
v) train staff

The commissioning stage is the transition period between the construction and the occupation and use of the building (structure).

d) Participants

i) project management team
ii) operating staff
iii) designers and specifications,
iv) building services suppliers staff
v) the contractor

CHAPTER 5

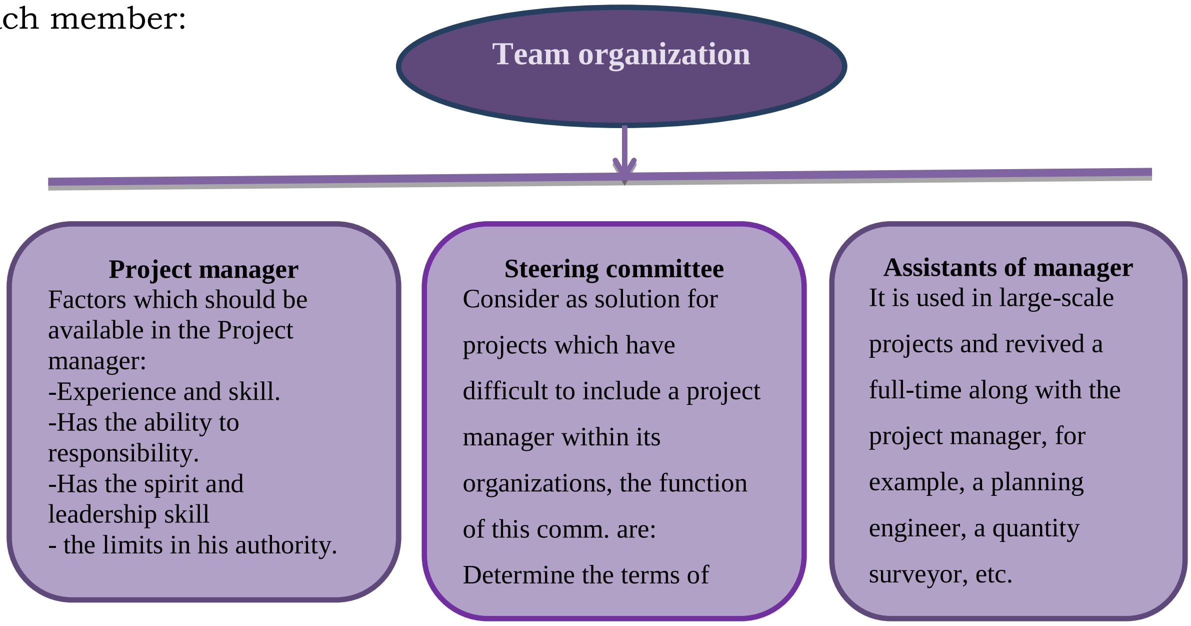
ORGANISATIONS

The management of construction projects requires knowledge of modern management as well as an understanding of the design and construction process. Construction projects have a specific set of objectives and constraints such as a required time frame for completion, the completion of the project with in cost-limits, and a project within the standard specifications for construction.

A project manager, which is responsible for managing the project and conceder main supervisor of the team and all planners administrators and supervisors, working under his direction. The management team must exercise the functions of planning, procuring and controlling which will exist through all stages of the project, where be difficult for government projects which have a special structure into its organization, in order to solve this problem is createda steering committee representing the various parties involved, and who is team leader of one of its members, and which carries out the administration of his powers.

The good contractor shall use the official type of people within his team and giving them the freedom to act when necessary in order to minimize the economic construction.The people involved are: the agent, site engineer, office manager, general foreman, foreman, and for very large project contract manager.

Team Organization:
Team Organization depends on the people, both according to the tasks assigned to it and the hard facts in each project where the difference is simple and is controlled by the size and nature of the project. According to what has been mentioned in the below chart shows the tasks assigned to each member:



Site Installation:
There are aspects should be taken into consideration when install a new construction site, these aspects are as follows:

Site layout
The construction methods has a various pattern for every site,and its different according to a shape of sit, its nature, and environment. So there are important considerations to be taken when preparing the layout of the site, are:

1. Detailed analysis of the work contract drawings and documents
2. In order to use the permanent structures on the site must discover the restrictions that prevent it to be removed

3. Appointment of space required for the implementation of using methods of analyzing construction
4. The rest of the abandoned spaces used for storage, for temporary buildings, etc.
5. Site layout plan is the most important in the implementation sites within cities that relatively limited spaces

Site Access

Per site should be available paths for the passage of an external one to enter the site and secondary access within the same site. Access has two separate aspects, the actual entrance from the public highway to the site, and the access within the site. For both, the vehicles and plant entering or leaving the site or using the site should be considered.

Any access should have good visibility and clear of obstructions. To ensure the proper passage of vehicles within the site. Must be given all the details of traffic to the site to emergency services. Possible use two-way internal road if the site is large enough. If there are any overhead cables, then a temporary checker unit should be erected on either side to stop any vehicle that is too high. On-site storage of materials are relatively expensive Therefore, to ensure the desired arrival time reduces the cost. In special cases, there will be a need for storage but appropriate means must be taken to preserve it from damage.

Plant

There are two directions to choose the plant, the first the nature of the work and the second port the nature and size of the work site.Plant should be maintained regularly for high efficiency. Must be all vehicles or item of plant registered and licensed for use on public roads. As for the static plant (tower crane) taking into account the suitability of the nature of the construction and that do not conflict with the mobile station.

Site huts

Is a temporary building Placed during the period of the implementation of the project and can be timber sectional huts or mobile huts or caravans. Must be on-site at least one hut used as an office by the site engineer to complete administrative purposes. And must be at the entrance to the site and installing the telephone line into it, and should be available where electricity and water sources, sanitation and all-purpose necessary for staff. . If possible they will be kept away from the actual construction areas to reduce the level of dust, noise and fumes.

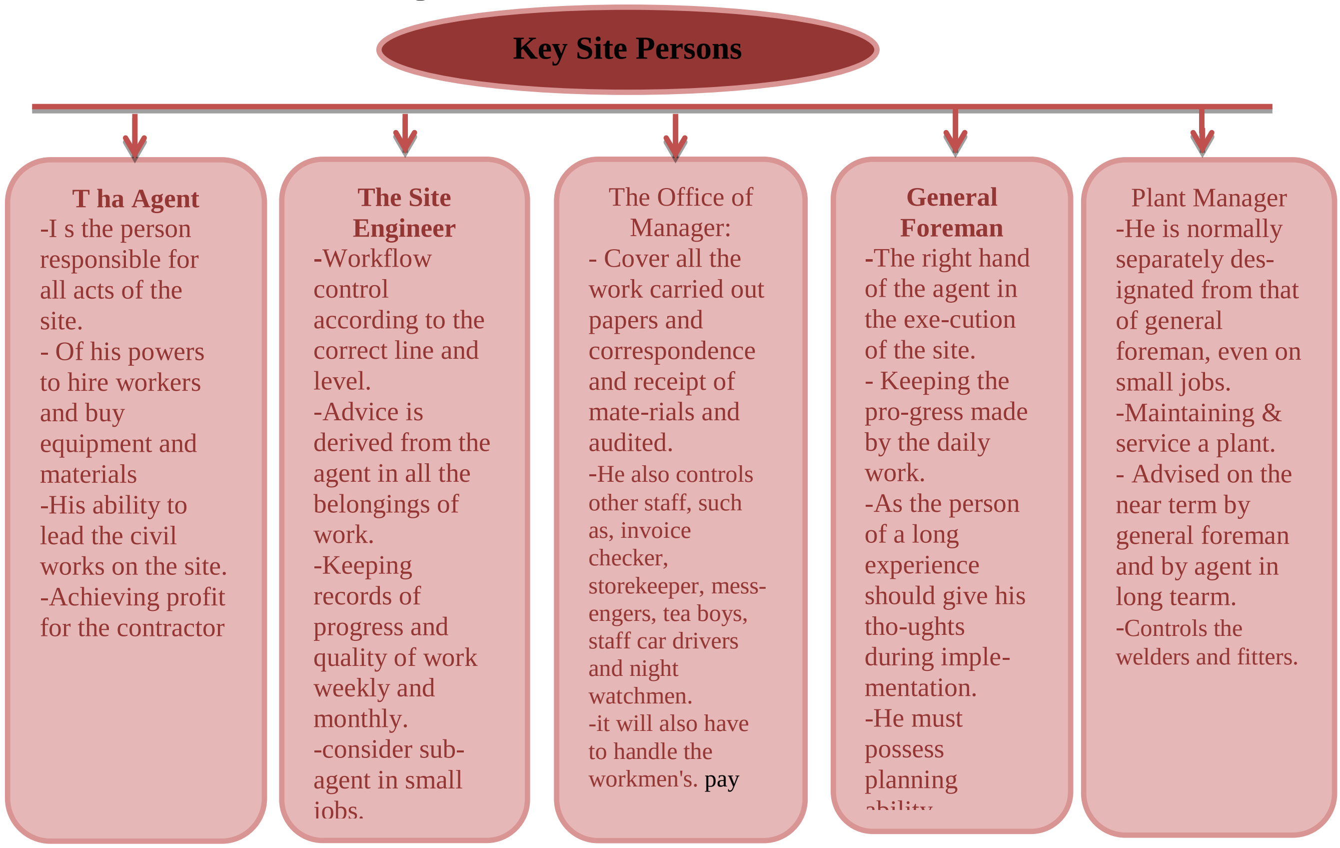
Temporary Services

Must provide all the necessary basic service requirements at the site before the actual construction start such as, temporary electricity, water, telephone, and drainage facility.

Fencing
One considers ways to protect the public and although it must take into account the cost against the cost implications.

Constructor's site Organization
The successful contractor to choose the right people within the team and give them the freedom to act and responsibility where this leads to reduce the number of employees and reduce the cost accordingly

Key Site Personnel for Contractor
There are five persons in the site organization of a contractor, the chart below shows the tasks assigned to each one of them:



The Engineer's Site Organization

The Resident Engineer
- The CEO of the work site so he is the person opposite to the agent, and consider as chief responsible person on site.
- His job monitoring the implementation of the work in accordance with the designs and instructions (Must be the absolute loyalty to engineer designer) to be followed and whether the contractor has completed all its obligations stipulated in the contract.
- The lead manager for the management contract between the contractor and the employer.

Duties of the Resident Engineer

The duties of Resident Engineer according to requested of him by the engineer:

1. Coordination of work between contractors assigned to them different work and make sure that all the instructions properly implemented.
2. Confirm receipt of the necessary materials on the site in a timely manner and checking permits.
3. Ensure that all materials that have been assembled by contractors in accordance with the required specifications for issuing instructions to resolve any defect exists.
4. Planning my work for the structure and design compared with drawings to make sure the suitability.
5. Make sure the full implementation of finished work and free from defects.
6. Prepare detailed reports for each of the above-mentioned work for submission to the engineer.

The Resident Engineer's Staff

Must assign the Engineer resident byinspectors and office manager and temperament to help him, even if the project is small, but for big works must provide a team of engineers and technical specialists.

Engineering Assistants

His mission to support the resident engineer at the work site and save the information and the conduct of the progress of work on a regular basis,and he will from time to time rearrange their duties so that in due course each engineer becomes familiar with all parts of the job, It should be noted that one of the most important times in the life of a professional engineer is the time spent on the site.

2.4.5. Inspectors: Entrusted with this responsibility to people with experience and high efficiency and skill in this area where they can provide advice to the resident engineer when needed and meet the accuracy of observation and judgment on the quality of the work.

CONSTRUCTOR'S SITE ORGANISATION

Introduction

A good contractor always tries to keep his site staff to a minimum for economic construction. To achieve this, the right type of men must be used, and they must be given freedom and responsibility to act on their own initiative. They must have quick communication with each other, and their areas of action must be clearly defined. A contractor cannot afford to tolerate ineffectiveness in any of these responsible positions.

Key Site Personnel for Contractor
In the site organization of a contractor, the key five persons are:

a) the agent
b) site engineer
c) office manager
d) general foreman
e) plant manager (foreman)
f) Contract manager on large jobs (Only in very large jobs)

However on small jobs, the duties of the agent and site engineer may be combined, and the general foreman may also be the plant foreman.
On large jobs, a contract manager may be appointed over the agent. His job being managerial rather than technical and executive control.

a) The Agent
The agent is responsible for directing and controlling the whole of the construction work on site, and he will have wide powers to enable him to employ men, hire machinery and equipment, purchase materials, and employ sub-contractors. His power to do these things without reference to his firm's head office will depend on the size of the job, its nature and distance from head office, the policy adopted by his firm, and of course his standing within his firm.

An agent must display a number of talents. He must be knowledgeable in the civil engineering construction, he must be able to command men and be a good organizer and administrator.
He also needs sound business sense, because his job is not only to get the work built properly to the satisfaction of the engineer, but also to make a profit for the contractor.
If things go wrong with an intended plan and this is an almost daily occurrence the agent must be informed immediately. All the information are centralized upon him. Once the agent has made up his mind to make changes, it is the office manager and sub-agent's job to see that the necessary instructions get through the right person without delay.

b) The Site Engineer
The site engineers and his staff is responsible for seeing that the works are constructed to the right lines and levels. Their responsibility will also extend to advise the agent on all design and engineering matters. Their duties will include taking site levels; lining in and leveling construction work; planning temporary access, roads and bridges; dealing with powers supply, water supply, drainage; concrete batching plant foundation and so on. They are also responsible for keeping of progress and quality records. Each engineer will, in addition, normally have a section of the work to look after, measuring up the work in his section weekly or monthly. On small jobs, the site engineer may act as sub-agent.

c) The Office Manager
Within the site office, the agents' principal administrator is the office manager. His responsibility covers carrying out most of the paper works-correspondence issuing of orders for materials, receiving and checking and checking accounts, making up pay sheets etc. Normally under him there are other persons such as, pay clerk, order clerk, correspondence secretary, and accounts clerk. He also controls other staff, such as, invoice checker, storekeeper, messengers, tea boys, staff car drivers and night watchmen. If there is no a separate site cashier, the office manager will also have to handle the workmen's pay.

d) General Foreman
The general foreman is the agent's right-hand man for the execution of the works in the field. His work is to keep the work moving ahead daily as the agent has planned it. He has to be a man of wide practical knowledge and long experience, so that he can, if needed be demonstrate personally how things should be done. He should spend alot of his time outside, visiting all parts of the work under his control. He is the one who contributes most of the changing ttejob from a set of plans into a finished structure. The foreman must be able to read engineer's drawings. He has to be boss of the workmen not in title but in an actual way. Finally a general foreman must possess foresight and planning ability.

e) Plant Manager
The position of plant engineer is normally separately designated from that of general foreman, even on small jobs. His job is to maintain and service the plant and to have it available as required. He is advised by the agent in long-term planning, and by general foreman for day to day planning. He controls the fitters and welders, and it is his job to maintain power supplies to the site- i.e. to run the site generator.

The key personnel employed on site by a contractor to take charge of the construction are shown in Fig 5.2. (Job magnitude £1,100,000 -2,000,000)

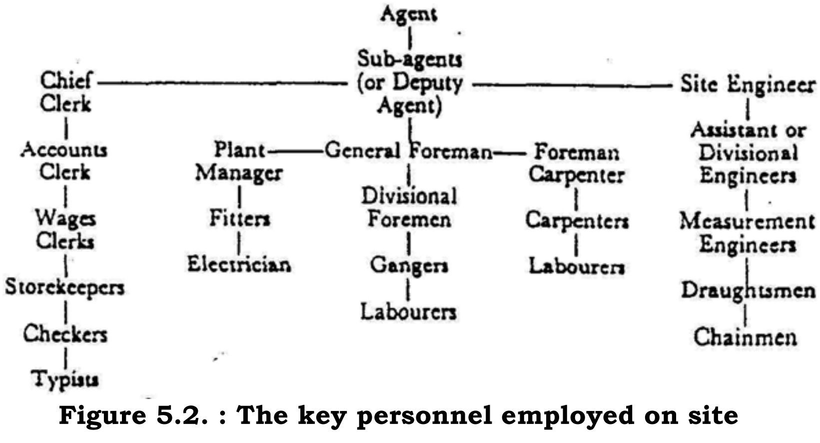


Figure 5.2. : The key personnel employed on site

THE ENGINEER'S SITE ORGANISATION

The Resident Engineer

The engineer's representative and chief responsible person on site is known as the resident engineer. He is the opposite member to the agent being the chief executive on site for the engineer. His job is primarily of seeing that the works are built as the engineer has designed and instructed they shall be built. He is also in charge to see that the contractor carries out all his obligations under the contract for the construction.

The resident engineer is responsible only to the engineer even if he is actually paid by the employer. In every circumstances his loyalty must be to the engineer who designed the works and who is responsible for administering the contract of construction entered into between employer and contractor. In all cases of doubt to correctness of his attitude, he should first report to the engineer.

Duties of the Resident Engineer

Resident engineer is expected to carry out the following activities as may be requested of him by the engineer:

1- To coordinate the work of various contractors; to agree detailed programs of works; to check that all necessary instructions have been given to contractors,
2- To check all the materials are ordered in good time and all necessary permits for them are obtained,
3- To see that the requirements of specifications in regard to materials and workmanship are compiled with the contractors.
4- To watch for faulty workmanship or material, and to issue instructions for remedying such faults.
5- To check the line and level and layout of the structure conforms with the drawings.
6- To issue further instructions and classifications of detail as are necessary,
7- To measure the amount of the work done for the purpose of payment and to calculate such payments
8- To keep records of all measurements and test, and to bring plans into conformity with the work as actually executed.
9- To act as a channel for all claims and disputes' and to provide the facts which are relevant
10- To see that the finished works are free from defects, tested and set properly functioning
11- To report regularly to the engineer on all the above matters.

However, this list does not necessarily include all the duties the resident engineer may have delegated to him by the engineer.

The Resident Engineer's Staff

Even on a small job, it will be necessary for the resident enginer to be assisted by an inspector and a typist or other office worker. On the large jobs he will need a team of engineers and other technical specialists to assist him.

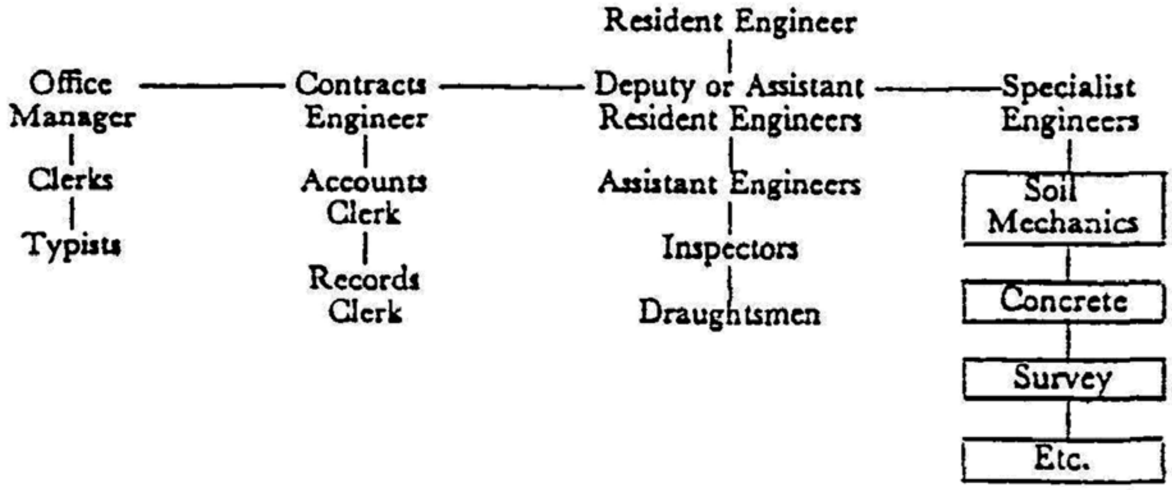


Figure 5.3 : Staff of a several million pounds project

Engineering Assistants

In general, a vice resident engineer will ensure that his engineering assistants are kept continuously informed about the progress of the job as a whole, and he will from time to time rearrange their duties so that in due course each engineer becomes familiar with all parts of the job, and has an opportunity to take part in all the aspects of engineering that the job offers.

The time an engineer spends on site is one of the most instructive periods of his career.

Inspectors

They have the task of continuously inspecting the work. They primarily work outside, but they must also book down detailed accounts of the progress of the work.

They are usually skilled tradesmen having special practical experience. They even can advise to the resident engineer when needed. They must be able to judge quality, workmanship and finish of work.

CHAPTER 6

CONSTRUCTION CONTRACTS AND THEIR DOCUMENTS

The contract is a legal document stating the duties and responsibilities of the Parties involved in it.

Standardization of construction contracts is very difficult and it is almost not possible due to lack of the possibility of unification of the conditions and requirements of each project construction. However, two models can be adopted with a few simple modifications and make it consistent with the nature and the requirements and conditions of the project.

The contract itself comprises a number of documents as: Contract drawing, Specification, Bill of quantities, General conditions of Contract, Tender, Letters of Explanation, and Legal Agreements. All the previously mentioned documents are necessary to define in detail the construction required by the client.

Competitive Bid Contracts

Unit Price Contracts

It is based on the

Total cost = Estimated quantity *x* Unit price in the bid.

Where;
Estimated quantity; measured from the contract drawings, and it will be replaced by the measurements of the actual quantity of the work after completing this work, so (*This method is not given the employer exact information about the cost of the work is done*).

Unit price; the implementation of the price of each step in construction.

the advantages of this stage that payment is made to the contractor based on the work done by him and give more flexibility in changing business, and therefore the work done is not fully match the specifications and plans.

Lump-Sum Contracts

In this way is to provide the total amount of the contract and the implementation of the acts mentioned therein in accordance with the plans and specifications, so must complete the plans and specifications in detail before submitting the tender.

To help Contractor at the expense of the overall cost of the contract is to provide him a bill of quantities to know each process must be carried out.

Advantages:

- There is no accounting or major modifications on the measurements work.
- Owner knows exactly the real cost of his work.
- Ensure the completion of works within the specified period or less, because the work directly to the contractor and this would bring him greater profits.

Disadvantages:

- Cause trouble because this method provides an opportunity for an engineer or an employer to make some changes designs.
- Uneconomical because the plans and specifications must be detailed, which consumes time and money.
- Quality of work and materials used may be not required level because it is the responsibility of the contractor who wants to achieve higher profits.

It must be noted that the previous two methods are used above at the same time, but you should be aware that big business is assigned to Lump-Sum Contracts.

Negotiated Contracts (Cost + Contracts)
Price in works is not constant that depends on two variables as shown below:

Price = cost + profit

The profit professional fee amount varies from one tender to another for the same work, and considers the extra cost by the contractor speculative added to the original cost of the implementation of the work, taking into considerations exceptional cases, such as:

- The lack of the necessary plans and specifications
- Inaccuracy of speculative construction costs
- -Efficiency in the implementation of a private business is required in cases emergency and war.

Types of Negotiated Contracts

❖ **Cost + Percentage of Cost:**
Has a significant drawback make it undesirable way in most countries, where to getmore profits tends contractor to pull equivalent to the cost of the work, and this causes damage to the owner significantly.

❖ **Cost + Fixed Fee Contract:**
This type of contract in precise estimates that have not been prepared in advance in special cases such as war and private building constructions, and used to avoid defects and the proportion of the cost of the contract.

The disadvantages of this contract that it does not give any incentive for the contractor to achieve greater profits and Owner has the risk of the construction.

❖ **The cost + Fixed Fee + Contract with a Profit-Sharing Clause:**
Contractor gets increasing convergence (25-50%) of net profit if he reduced the cost of construction.

❖ **Contracts Based on Cost + Sliding Scales of Fees:**
Contractor fee is inversely proportional to the cost of construction where increasing down the actual cost of the building, and vice versa,a minimum fee is guaranteed to him.

❖ **Cost + Guaranteed Ceiling Price Contract:**
These contracts require the preparation of plans and specifications minutes to set reasonable prices,wherea contractor guaranties that the construction will not exceed a certain maximum, and does not compensate him for costs that exceed the maximum contract.

Sources of Controversy in (Cost+) Contracts

The sources of disagreementare (cost+) contracts, the contractor overhead (expenses) and the depreciation of contractor's equipment. All that has been mentioned must be paid by the contractor as part of his business and must be included in contract documents.

Documents of the contract

Contract describes the nature of the works and how to pay between major parties (the employer and the contractor), where the implications of the contractor to do many of the operations and procurement of equipment and materials and the use of a group of employees, consistent with the nature of the project, The contract includes several documents, such as:

❖ **Contract drawing**
Shows dimensions and the level of works that will be implemented depending on pictures.

❖ **Specification**
Theory describes the quality of the materials and method used and tested experimentally etc.

❖ **Bill of quantities**
Are calculated depending on the drawings and classified according to location within the proposed works, where gives the expected measure of each operation of construction.

❖ **General conditions of Contract**
Determine the powers and obligations and responsibilities arising from the distribution of each of the employer and the contractor and engineering, in addition to the responsibilities of method of payments and insurance.

- **Tender**
  Tender is the signed financial offer of the contractor to construct the works according with (Contract drawing, Specification, Bill of quantities, General conditions of Contract).
- **Letters of Explanation**
  Showing of intent between the parties to the contract and the issues that have been agreed.
- **Legal Agreements**
  Refers to the signing of the contract between the parties and which confirms the items set forth in the documents referenced above.

Forms of construction contracts

Competitive Bid Contracts
Does not have a unified standard type of contracts for all stages of the implementation of the engineering works, but there is an increase or decrease standardized to certain articles.

Generally all contracts include:

a) **Introduction**:
Where stating date of agreement and the parties there to.

b) Articles:
Which may be written in the following order, (most of the time standardized and printed)

1- Consideration of work to be done and price
2- Time (beginning and end of the work)
3- Liquidated damages
4- Required security
5- Payment of the contractor
6- Definition of terms
7- Responsibility and right of the owner during the construction
8- Responsibility and right of the contractor during the construction
9- Duties and authority of the engineer
10- Progress and control of the work
11- Insurance, safety and sanitary requirements
12- Provision relating to subcontract
13- Changes in the work
14- Termination of the contract

c) Final concluding paragraph:
Signature of parties and witness.

Negotiated Contracts Selecting the Contractor:
Contractor is selected by the owner's agent called a confidential where the contractor is chosen according to the availability of the following characteristics:

a) He has prior experience in implementing similar type of business (Acts similar)b)
b) Reputation for fairness and excellence in performance
c) Quality and experience of personnel
d) Record in management and coordination of the work of subcontracts
e) Available working capital
f) Available plant and equipment
g) Normal volume of work per year.
h) Incomplete work in progress
i) Available work capacity.

Terms of Contract

1. Definition of the scope of the work, its estimated cost and the contractor's fee.
2. Time for completion
3. Control of the work, responsibilities of the owner, engineer and the contractor.
4. Definition of the reimbursable direct costs and overhead costs
5. Labor and material
6. Provisions for plant, rental or purchase or maintenance of equipment and the overhaul of the equipment at the end of the job.
7. Subcontractors
8. Method of compensation
9. Changes
10. Termination
11. Accounting method and control of costs

Conclusion:
Been addressed in this chapter to construction contracts and documents its own terms in the contract was initially defined as a legal document between two parties (owner + the contractor) this specifically in construction contracts, Standardization of construction contracts is very difficult due to different patterns of construction projects,However, two models can be adopted with a few simple modifications: Competitive Bid Contracts, Negotiated Contracts (Cost + Contracts), In some cases, are used together for one work, taking into account that the latter type used for large projects. As was mentioned details of the contract documents and forms.

CONSTRUCTION CONTRACTS AND THEIR DOCUMENTS

Specifications
Be prepared by engineers and be specific and non-public, while the rest of the documents such as contracts are prepared by lawyers.

It should be noted that the specifications illustrate the quality and standards of work while drawings illustrate limits and quantity of it.

To obtain the required specifications must provide the following:

1. **Balanced Composition**:
   This is achieved by consensus required specifications with the result that is obtained.
2. **Definite requirements**:
   Here error is undesirable where it should not be relied upon certain guess, but must identify trends that are at the end to reach the required certainty.
3. **Accuracy:**
   The main source of inaccuracies here repeat the text, refers inaccuracies and misleading information to a wrong way in access toSpecifications.
4. **Practicability:**
   Achieved through the use of standard sizes and styles known as much as possible, either impracticable requirements are being added by the contractor as extra safety factor for his work.
5. **Prevention of conflicting requirements:**
   They are sources of error.
6. **Fairness:**
   Means to make a balanced deal with the contractor is not the imposition of strict conditions and at the same time shall be obligated him to the implementation of the work requirements; this would reduce the likelihood of increasing the cost of construction.

The specifications are divided into,

- General provisions "or conditions"
- Technical provisions "or conditions".

General provisions

They related to the whole work, the control of the work, contract drawingsand references to standardized materials, such as:

a. Drawings:
The Contractor shall prepare the drawing with high accuracy and inclusive of all the details and must consistent with drawing techniques,where he has the responsibility of any error in implementation.

b. The sequence of the work:
A work sequence is determined by the Contractor and be subject to change sequence in certain cases, In certain cases, when the employer's desire to the presence of a specific sequence, in this case must include details of the work sequences to the specifications

c. The progress schedule:
Is to provide periodic reports to the Site Engineer include control and coordination of the work site as a whole, where you must prepare a new progress of the work table in the event of delay in the implementation of any stage of the construction and inform engineer.

d. Control of materials:
The Contractor shall provide all building materials samples and bear the costs of transport and examined.

e. **Spacer:**
   The space for construction operations, aid storage of materials should be written In specifications in detail.
f. **Information:**
   All information and expenses related by water, light sources and costs of installation should be given and must be known.
g. **Facilities to the engineer:**
   The Contractor shall provide the necessary facilities for the site engineer (field office etc.) in a few weeks to start working and be at his own expense
h. **Warranties:**
   The work must be free from defects for a special period (usually one year from the acceptance date of the work)
i. **The owners right to use:**
   If the owner accept completed portions of the work contractor will be relieved of his responsibility to maintain them.

Technical Provisions

And includes all of the functional and technical requirements and necessities of testing and inspection, and after ordering the sequence of construction work are divided into the following according to the work available to them

1. Specifications for materials.
2. Specifications for workmanship.
3. Specifications for performance.

Specifications for materials

Materials must be selected after studying the suitability and costs and checked (physically and chemically) to determine the type of test and would rather be a record in some cases, when the quality of the materials is easy selection can be dispensed.

Specifications for workmanship

Methods are determined by the contractor while the results are specific only and are not methods, and in general the usual pattern is:

1. Specifications of the results, tolerance
2. Construction methods or procedure necessary for particular purposes.
3. Limitations or restrictions on the contractor's method in interest of the coordination of the work.
4. Precautions to protect the work or adjacent property.
5. Methods of inspection and test.

Specifications for performance

To avoid defects and ensure durabilityis determined characteristics required for operating, working and provisions are made for tests.

Bill Of Quantities
Is a contract document to determine the approximate quantities of work being measured accurately by a drawing,these quantities replaced by the actual amounts required to implement each of the terms of the contract.

Items
Bill Of Quantities (BOQ) is divided into separate groups in large projects and each group is divided into different mini-groups is consistent with the work that has prepared for it, and it may be that according to certain standards or as described below:

1. Demolition work (if a major item in the contract)
2. Excavation and filling
3. Pipe-laying (if a major item in the contract)
4. Roads (if a major item in the contract)
5. Concrete- in situ
   - Reinforcement.
     Shuttering.
   - Pre-cast.
   - Pre-stressed.

The construction requirements are not standard for all types of construction contracts may include categories such as Brickwork, Masonry, Water proofing work, Steelwork and iron work, Roofing and carpentry, Joinery, Flooring, Plastering, Glazing, Electrical, Plumbing Painting, Fencing, employment contracts may include other parts of them where it depends on the nature of the work to be executed.

Numbering of Items
Engineer who is preparing a bill, even if it was done so well could be missing one or more from the outside but it can be difficult or not possible if the items numbered from start to finish as it requires re-numbering again.
The solution to this problem could be through the introduction of a forgotten item such as “A” or any other item in case forget to add a certain stage prove quantities or by placing "Late Items" at the end of a bill.

Message prefix is used in numbering the terms of the original law through using a different message (different letters) for each item of the original bill, for example:

- Excavation items are numbered A1, A2, and A3... etc.
- Concreting items, B1.B2... etc.
- Reinforcement items C1.C2... etc. and so on.

Pages are divided in BOQ to columns, writes at the end of each page the total price for the pricing of the work contained in and carry carried to a "collection” and all the collections relating to a section of the work is carried to a "summary", In the end, these summaries are collected in the rear part of the BOQ under the name of the “general summary”.

Costing
Refers to the cost required to implement each stage of the work, such as building bricks concreting etc. termination or sometimes refers to the cost needed for the separate parts to work like finding out the cost of undertaking separate portions of the work-such as the cost of access roads, subsidiary building, The accuracy of the cost of civil engineering works relatively difficult.

Cost is not limited to materials needed for the establishment, but includes manpower for the implementation of each stage of the work, machinery and expenses; it must split the work and preparation of to fill up time sheets showing the hours spent each day by each day by each man on the various type of work. The hours entered on these sheets must be priced out so that the labor cost can then be allocated under the different headings by the cost clerk.

There are some difficulties arise from dealing with

- Other miscellaneous wage payments and Over time.
- The time sheets of men such as fitters, time -checkers flag men, night-watchmen, chainmen, storekeepers, etc., whose work cannot be directly allocated to a specific site operation, can be calculated quantities of materials used in the per-moment as well as their permanent by bill-of-quantities measurements, but there are many more materials, such as timber for shuttering, scaffolding, small tolls, diesel oil and fuel oil, nuts and bolts, etc., which are not used in the measurement records. As-with wages, which cannot be directly charged to any specific operation, so materials which cannot be costed out to particular parts of the job will have to be charged as part of “site on-costs”.

In addition to everything mentioned must be allocated Miscellaneous Site Management for the management of the site, such as wages of general foreman, engineers, site clerk, wages clerk, agent and subagents, etc., together with all such other charges as telephone, water supply, messing, sanitation, insurance of works, petty cash, etc.,

large proportion of the total cost are placed under the title of “site on-costs” the difficulty of analyzing practically.

To find out the'cost' of separate parts of operations this is done through the use estimator's figures which can be checked by comparing the total estimate against the total expenditure.

To check any estimate submitted against a bill of quantities, the sum total of the tendered prices in the bill will be compared with an estimate based on the expected number of men and machines required for the job, together with a calculation of the cost of the materials to be used in the permanent works, to which are added all the other on-costs applicable, as judged from costing records of other jobs.

Prices may be not represent actual separate cost to the contractor in a bill-of-quantities contract because it provides individually, but they should in total represent the total expenditure to be incurred, including an allowance for profit.

Conclusion:

In this part of the chapter3 has been defined specification related to the quality of work and standards that are prepared by the Engineer as well as the conditions that must be covered, such as balanced Composition, definite requirements, etc., Those specifications were divided into two main parts are: general provisions, technical provisions and display it in detail.

Then touched on the bill of quantities and defined as a contract document that is able to experience the quantities of work to be done and checked for accuracy where there is no space for guess this with respect to small jobs, As for the huge works divide the bill of quantities into separate groups relating to separate parts of the job. To avoid loss of any bill must numbered it from the beginning to the end. In this case, add any addition bills is not possible and this required re-numbering again, In special cases, when forgotten the some bill can use an easy way to address this error by insert the forgotten items as an "A" item, e.g.

And finally been presented a detailed explanation of how calculate the costing of civil engineering construction work for separate work and work as a whole.