CE 431

CONSTRUCTION MANAGEMENT

LECTURE NOTES

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Foreword

Some parts of this Lecture Notes in Chapter 1, 2 and 3 were taken from the work of Master student Yousef Baalousha.

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

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:

INTRODUCTION TO MANAGING CONSTRUCTION PROJECTS

1.1. GENERAL

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 (1).

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 1.1.

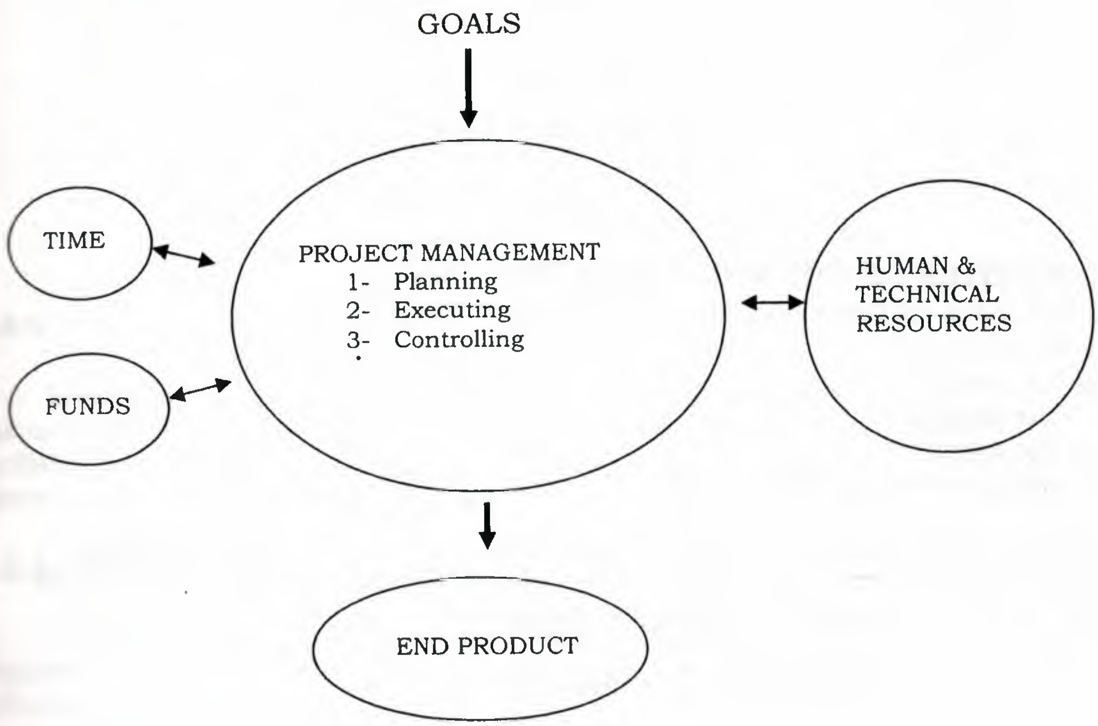
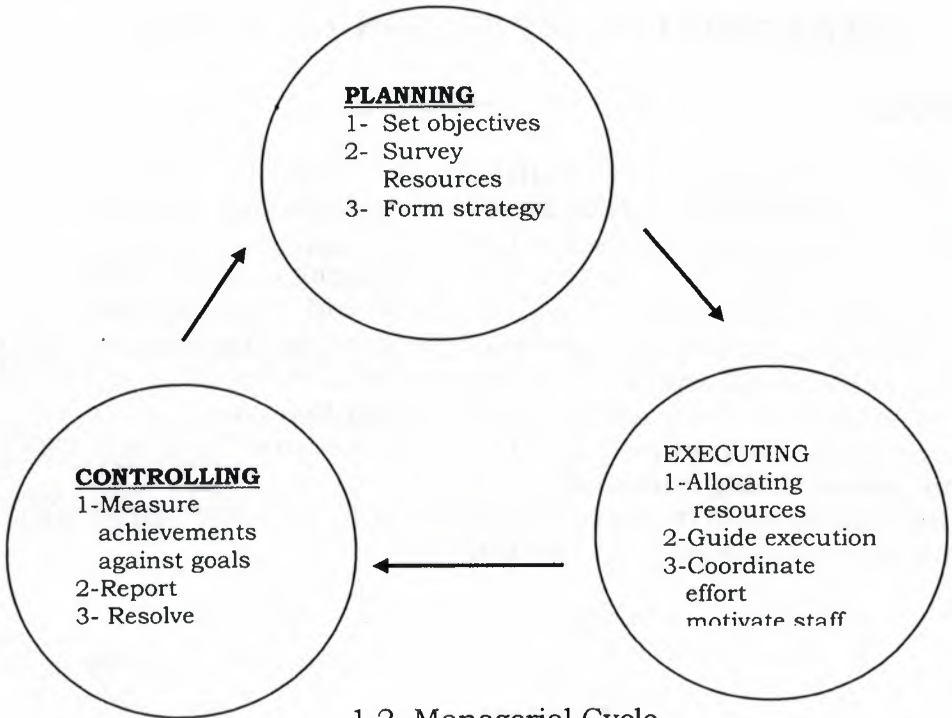


Fig. 1.1. Elements of Management

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 1.2. Since changes often unforeseen, occur during the lifetime of a project, figure 1.2 represents a continuous action aimed at achieving the best possible result.



1.2. 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 1.3.

1.2.1. 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.

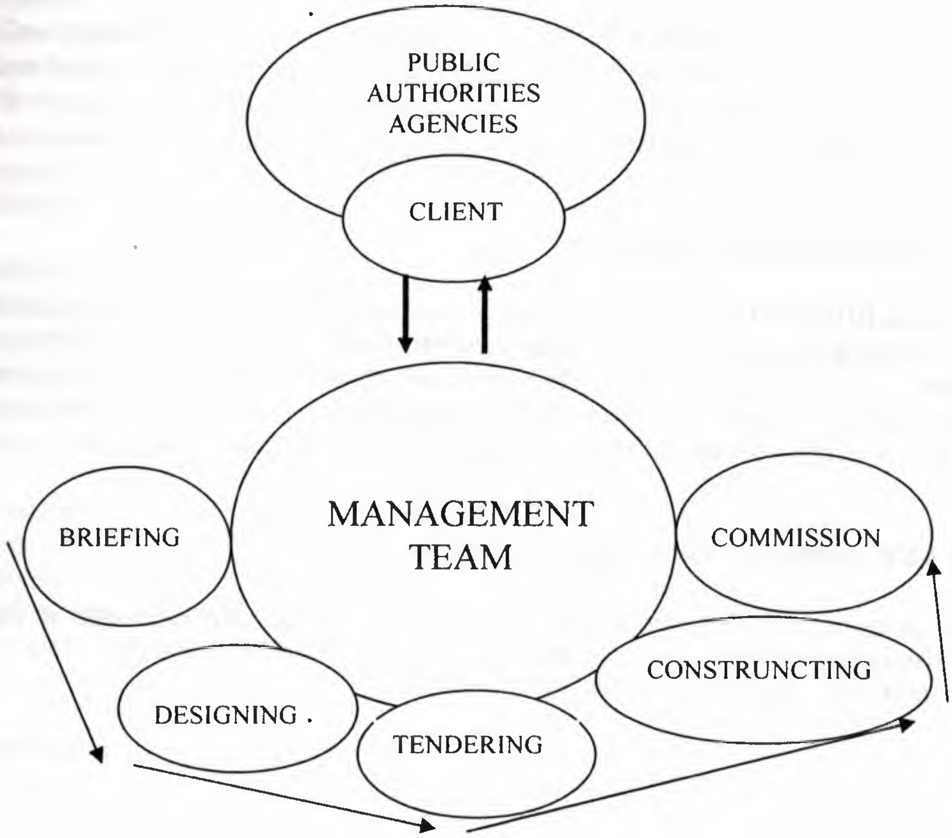


Fig. 1.3. Project Management Team

1.2.2. 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.

1.2.3. 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.

1.2.4. 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 organisations which actually build.

1.2.5. Public Authorities and Agencies

All buildings must fulfil statutory requirements regarding construction standards and safety. For example, roofs must be able to withstand specified wind loadings and fire requlations 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.

1.3. 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

1.3.1. 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

1.3.2. 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.

1.3.3. 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 time-consuming

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.

1.3.4. 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.

1.3.5. 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 2

ORGANISATIONS

2.1. PROJECT MANAGEMENT TEAM

The team of specialists such as planners administrators and supervisors, working under the direction of a project manager, which is responsible for managing the project.

Objectives of Management Team:
The main objectives of the project management team should include:
i) The production of construction works which satisfy the clients functional requirements,
ii) The completion of the project within specified time-limits
iii) The completion of the project within specified cost-limits,
iv) Construction to specified standards
v) The preservation of the health and safety of the people involved.

2.1.1. Team Functions

In order to achieve the objectives given above, the management team must exercise the functions of planning, procuring and controlling. These functions will exist through all stages of the project. They are described in detail in later chapters.

2.1.2. Team Organization

a) Project Manager
He is the person with authority and responsibility to manage the project according the requirements.
The first important management decision to be taken by a client is the appointment of a project manager. When appointing a project manager, the client should consider the following factors:

i) The qualifications and experience required
ii) The person or persons to whom he is responsible
iii) His terms of reference
iv) The limits of his authority
v) His personal qualities, including leadership skills.

b) Steering Committee
In government projects particularly, a client ministry or department may have difficulty in fitting a project manager into its organization. A solution may be to set up a steering committee representing the various parties involved. This committee will normally have a chairman, a senior official of the client ministry, the project manager should be a member of the committee, from which he will derive his authority.

The functions of this committee include,
i) Determining the terms of reference for the project management team,
ii) Approving the project management team

iii) Monitoring progress of the project
iv) Removing obstacles to progress of the project.

c) Assistants of the Project Manager

The composition of the team will change as~ the project progresses through its various stages. The minimum continuous requirement through the life of the project is the project manager, and secretary. For large projects, there may be full-time specialist assistance to the project manager. For example, a planning engineer, a quantity surveyor, etc.

d) The Reality of Management

Projects are managed by people who have to make decisions and enforce procedures that affect other people. Project management must be seen as a dynamic, difficult and often abrasive art, based on well-proven principles, but not solely devoted to their slavish or rigorous application.

2.2. SITE INSTALLATION

The aspects should be taken into consideration while installing a new construction site are as follow:

a) Site layout
b) Site access
c) Storage
d) Plant
e) Site huts
f) Temporary services
g) Fencing

a) Site Layout:

Every site has a different shape, nature and environment. The construction methods will also be different. Therefore, there is no a single pattern that can be recommended for every site.

However, in preparing a site layout, the important considerations are:

i) Analyze the contract drawings and documents in detail,
ii) Find out the restrictions on the use of the site by the permanent structures,
iii) Analyze the construction methods to obtain the required space to be kept clear,
iv) Then, workout the area of the site which is left for temporary buildings, storage, etc.
v) Site layout plan is especially important on sites in towns where the space is very limited.

A typical construction site layout is given in fig.2.1

b) Site Access:

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.

The position of the main access to the site must be practical and sensible but not just the most convenient-All the arrangements should be approved by the police and the local Highway Authority. If the site requires a permanent access, this could well as a temporary access also. Any access should have good visibility and clear of obstructions. Direction signs, and warning signs assist the smooth flow of vehicles. The width of the access should be fixed considering the largest size of vehicle likely to visit the site. Details of the site access should be given to the emergency services.

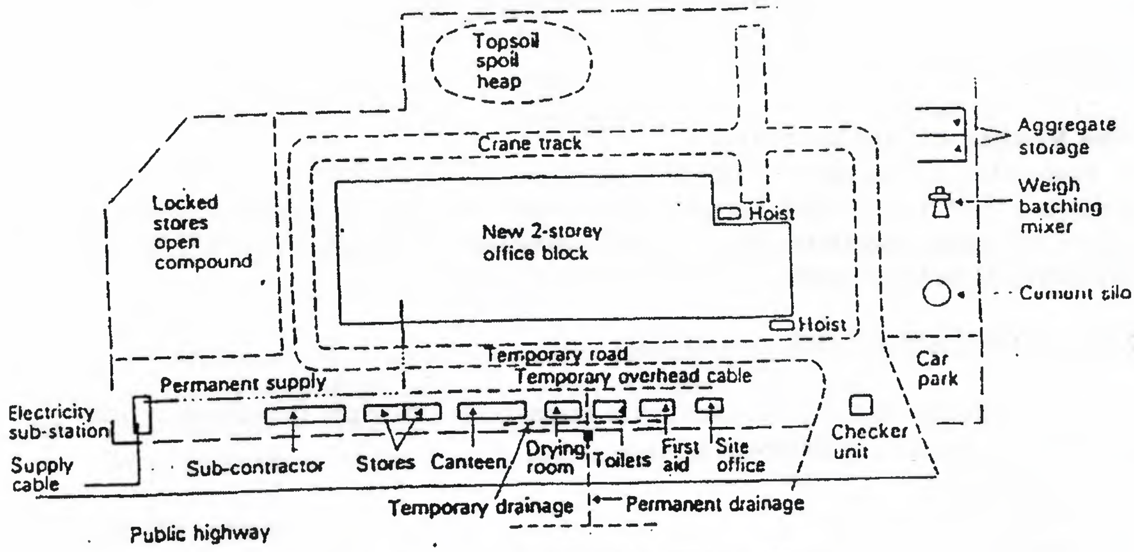


Fig.2.1 : Construction site layout

Access within the site should be convenient for loading and unloading materials in storage points or work areas. If the site is big enough an internal roadway on a one-way system is desirable. 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. The access and roadway should be made up with suitable materials to avoid vehicle getting stuck. The access should be drained to avoid standing water. If the site is big enough, a car park should be provided for small vehicles and vehicles not in use-.

The need to store materials on the site is due to:

i) Have enough materials in stock for work in hand and immediate period ahead.
ii) Have economic buying with bulk buying
iii) Expected changes in manufacturer's production
iv) Late deliveries
v) Limited availability.

Storing materials on the site is costly and therefore requires a good judgment. A careful timing of deliveries can reduce the quantities stored. Valuable materials are stored in a locked room. All materials should be stored in the correct way. For example, aggregates should be stored on a clean, firm base, preferably concrete, and no dirt or access of water allowed. Different sizes must be stored separately and near to the mixer. Bagged cement, or lime should be kept in a dry, draught-free hut, and not allowed to come in contact with moisture or moist air.

d) Plant:

The choice of plant depends primarily on the work to be done, but a secondary consideration is the size and nature of the site. Adequate roadway is required within the site. Plant should be maintained regularly for high efficiency.

All necessary records must be kept and vehicle or item of plant used on the public road as well as the site must be licensed and registered.

For static plant, such as tower crane, care must be taken to choose a correct sitting to suit the constructions and this does not clash with mobile plant.

e) Site huts:

Site huts are temporary buildings erected for the duration of the construction work. They could be timber sectional huts or mobile huts or caravans. Huts are used for administrative purposes, storage, workshops and operatives. For administrative purposes a minimum of one hut is necessary to be used as site office by the site engineer.

Normally telephone is also installed into this hut and, the hut is placed somewhere near the site entrance. In this way, the visitors will not wander about the site, and watch can be kept on persons or vehicles entering or leaving the site.

The number of huts for operatives depends on the number of employees. These huts are used as toilets, changing rooms, drying wet clothes etc.

These huts should normally be kept in groups according to their purpose. Those needing drainage, electricity, and water supply should naturally be together and near to the temporary services. If possible they will be kept away from the actual construction areas to reduce the level of dust, noise and fumes.

f) Temporary Services:

As soon as the site is set up and before actual construction starts, temporary electricity, water, telephone and drainage facility will be needed.

g) Fencing:

Fencing is needed for the protection of the public and a joining premises as well as security. However, the advantages of fencing a site should be compared against the cost implications.

2.3. CONSTRUCTOR'S SITE ORGANISATION

2.3.1. 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.

2.3.2. 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 2.2. (Job magnitude £1,100,000 -2,000,000)

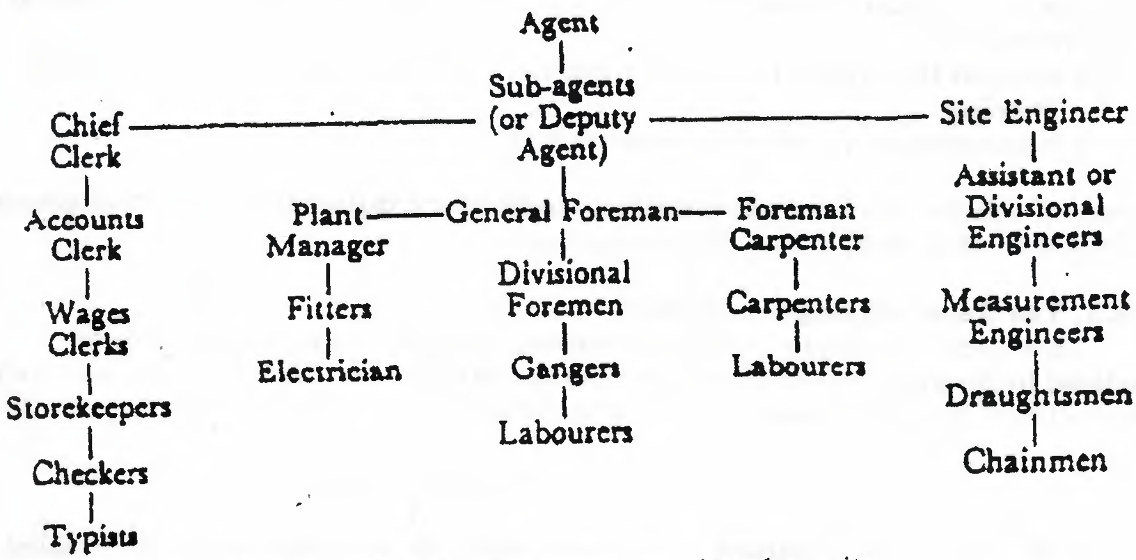


Fig 2.2. : The key personnel employed on site

2.4. THE ENGINEER'S SITE ORGANISATION

2.4.1. 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.

2.4.2. 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 io 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.

2.4.3. 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.

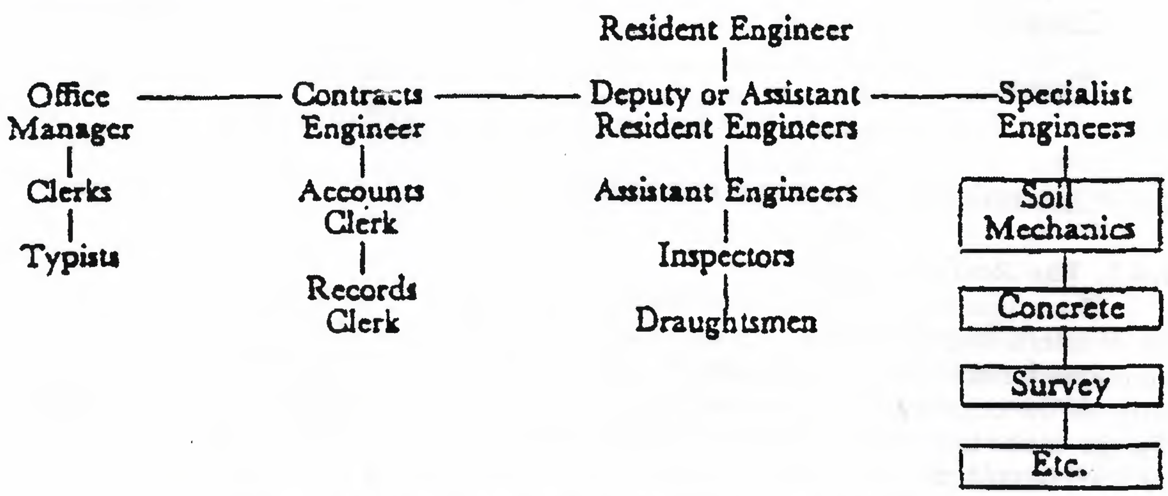


Fig 2.3 : Staff of a several million pounds project

2.4.4. 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.

2.4.5. 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 3

CONSTRUCTION CONTRACTS AND THEIR DOCUMENTS

3.1. Generally

Standardization of construction contracts is quite hard, since the variety of conditions and demands in construction industry is very wide. However, the Contracts in construction industry may be grouped in two categories.

A) Competitive bid contracts .
B) Negotiated contracts

3.2 Competitive Bid Contracts

3.2.1. Unit Price Contracts

The bid is based on the price per unit of work on of material.
Total cost (=Estimated quantity *x* Unit price in the bid).

Estimated quantity is taken from prepared bill of quantities, where measured from the contract drawings. When the work is completed, the quantities are replaced by the measurements of the actual quantity of the work the contractor carried out.

Advantages:

i) The payment to the contractor can be calculated easily according to the amount of work he did.
ii) The method gives freedom to alter the work of construction
iii) All tenderers price on exactly the same basis and their tenders may be closely with one another,
iv) Plans and specifications do not need to be completed in detail.

But this method has a disadvantage which is the employer doesn't know the exact cost of the work until it is completed.

3.2.2 Lump-Sum Contracts:

Bidding is done on a total amount of the works and services required by the plans and specifications. To avoid later trouble, the specification and drawings need to be completed in every detail before a lump-sum offer is called for. A bill of quantities may even be provided, not for pricing, but to list out every operation he must do, thus assisting him to calculate his tender.

Advantages:

i) Avoid a lot of detailed accounting and measuring work
ii) Owner does know the exact cost of the work to him.
iii) The work is a straightforward job for the contractor and he will try to complete it as early as possible in order to increase his profit.

Disadvantages:

i) Alteration of design or addition during construction by employer or engineer causes troubles,

ii) Plans and specifications must be comprehensive and must show complete details which require a lot of lime and money,
iii) Contractor has interested to use cheaper labour and materials.

But again Lump-Sum contracts work quite well when:
- The job is not very large.
- The work required can be precisely described in all details. *
- There is no great risk attached to its construction (unforeseen troubles)
- No large or numerous alterations are called for during construction.

Sometimes, Combination of both unit price contract and Lump-sum contract may be used in one work. The substructure of a large work may be based on unit price contract where as the superstructure of the same work may be based on -Lump-sum contracts.

3.3. Negotiated Contracts (Cost + Contracts)

Price of the work is not definitely fixed.
Price = cost + profit
Here profit is a professional fee and is subjected to negotiation and bidding.

They are used in such cases where
- The complete plans and specifications are not available
- There is uncertainty to exact cost of the construction
- There are possible wishes to change the work during the construction
- Work efficiency is required in the case of emergency or in war.

3.3.1. Types of Negotiated Contracts

a. Cost + Percentage of Cost:

It is forbidden in some countries, because has great disadvantages such as;
- Contractor will tend to pull up the cost of the work in order to get more money from the same work.
- Owner has a great risk.

b. Cost + Fixed Fee Contract:

To avoid the disadvantage of cost + percentage of cost contract this type a contract is used.

It is used in war and in private building constructions; for which an accurate bidding estimate is difficult to be prepared.

Disadvantages:
- Owner has the risk of the construction
- Contract has not any incentive for the contractor to minimize the cost.

c. The cost + Fixed Fee + Contract with a Profit-Sharing Clause:

There is increase in the contractor's profit if the contractor decreases the cost of the construction. Contractor may get 25 to 50% of the saving he makes.

d. Contracts Based on Cost + Sliding Scales of Fees:

Contractor's fee changes proportionally to the actual cost of the work in accordance with a sliding scale of fixed fee. He gets increasing fee with decreasing of construction costs and vice versa. A minimum fee is guaranteed to him.

Construction Cost	Contractor Fee
6.0×10^6 YTL	200,000.- YTL
5.5×10^6 YTL	220,000.- YTL
5.0×10^6 YTL	240,000.- YTL

Here the normal cost is estimated as 6×10^6 YTL and a fixed fee 200,000.- YTL will be paid to the contractor. But if however he decreases the cost to 5.5×10^6 YTL he will get this time 220,000.- YTL as profit, etc.

e. Cost + Guaranteed Ceiling Price Contract:

The contractor guaranties that the construction will not exceed a certain maximum. He can not receive the compensation for the exceeding amount. These contracts require exact plans and specifications for the establishment of a reasonable ceiling prices.

3.3.2. Sources of Controversy in (Cost+) Contracts

In (cost+) contracts, the contractor overhead (expenses) and the depreciation of contractor's equipment are sources of disagreement. It is always tried to get them counted as parts of the costs by the contractor. In reality they are to be paid by the contractor as the costs of doing his business and should be included in contract documents.

3.4. DOCUMENTS OF HE CONTRACT

A contract describes comprehensively what the works are and how payment is to be made. The works are often quite complex, involving the contractor in thousands of different operations and requiring him to buy hundreds of different manufactured items and materials and to employ a wide variety of men and machinery.

The construction contracts binds the contractor to construct the work and the employer to pay to the contractor for them. Hence the contract itself comprises a number of documents as follows.

a) Contract drawing:

Which pictorially shows the works to be built, their dimensions and level, etc.

b) Specification:

Describes in words the work to be built, the quality of materials, workmanship to be used and method of testing etc.

c) Bill of quantities:

Gives the expected measure of each operation of construction as calculated from the drawings and classified according to trade or location within the proposed works.

d) General conditions of Contract:

Define the liabilities, responsibilities, and powers of the employer, contractor and engineer. And also cover the method of payments, insurance, liability of parties to the contract.

e) Tender:

Tender is the signed financial offer of the contractor to construct the works according with (a, b, c, d) above

f) Letters of Explanation:

They cover the matters which are agreed between the parties of the contract to elucidate their intentions.

g) Legal Agreements:

Which are signed by parties, owner and contractor, confirming their intentions as defined by all foregoing documents.

3.5. FORMS OF CONSTRUCTION CONTRACTS

3.5.1 Competitive Bid Contracts:

There is no any standard type of contract for all phase of engineering work. But certain articles can be more or less standardized.

All contracts contain:

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.

3.5.2. Negotiated Contracts Selecting the Contractor:

Here the contractor is an agent of the owner and there is a confidential relation between them. Therefore, the selection of the contractor is very important. Those characteristics must be observed during the selection of the contractor.

a) Previous experience in the particular type of work.
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

3.5.3. 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

3.6. SPECIFICATIONS; (Definition of the work in words)

While the drawings show extend and quantity of the work, the specifications defines the quality and standards of it.

Specifications are prepared by an engineer while contracts are prepared by lawyers. Specifications are supposed to be specific and not general

In a satisfactory specification, following characteristics should be covered.

a) Balanced Composition:
The specification should contain all the requirements consistent with the result desired.

b) Definite requirements:
There must be directions, not suggestions that may lead to uncertainty. Do not use indefinite expressions like "Reasonable" or "Best Quality" and define the days as "working days" or "calendar days". *Everything has to be specified.*

c) Accuracy:
Non-accurate and misleading information will not take place in the specifications. Repetitions in text are sources of error.

d) Practicability:
Use standard sizes and patterns as much as possible. The impracticable requirements let the contractor to add an extra safety factor to protect him.

e) Preventation of conflicting requirements:
They are sources of error.

f) Fairness:
Do not impose the contractor harsh and unfair conditions and do not cancel difficulties from him. The risks increase the cost of the construction.

The specifications are divided into,
1- General provisions "or conditions"
2- Technical provisions "or conditions",

3.6.1. General Provisions

They related to the whole work, to the standardized materials, the control of the work and references to contract drawings.

Such as;

(a) **Drawings:**
If the contractor will prepare the drawings they must be_exact and suitable to the drawing techniques.
Details on large scale must be prepared. The contractor should check all dimensions. He has the responsibility of for all discrepancies.

(b) **The sequence of the work:**
The sequence of the work should be determined by the contractor. But when the owner or public interests indicate the necessity for a definite sequence of operations, details should be given in specifications. When necessary the sequence of operation can be changed

c) **The progress schedule:**
Periodical reports to the engineer provide the means for direct control and coordination of the whole work. A new schedule is required the construction time is extended.

d) **Control of materials:**
The contractor is required to furnish alL samples and bear all expenses for their sampling, transportation and testing.

e) **Spacer:**
In specifications, the space for construction operations aid storage of materials should be written explicitly.

f) **Information:**
Information on water, light sources and costs of installation should be given and also the expenses for their use must be written.

g) **Facilities to the engineer:**
The contractor will be required to furnish at his own expense the facilities necessary for the engineer (field office etc.) and it must be given in how many weeks after commencing of work those facilities should be prepared.

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:**
The owner; right to use completed portions of the work should be stated. Such portions will be accepted by the owner and the contractor will be relieved from his responsibility for maintaining them.

3.6.2. Technical Provisions

Contains the service and quality requirements of the work and technical requirements for inspection and test during the construction. Sections are divided to different works, equipment and materials following the order of the practicable sequence of the construction operations. Technical provisions are divided as:

a. Specifications for materials
b. Specifications for workmanship
c. Specifications for performance

a. Specifications for Materials:

After an examination of their suitability and costs, the material should be specified by their properties which are capable to be tested (Physical and chemical properties). The type of the tests must be specified (standard test if possible). The tests may be omitted if the qualities of the materials are easily determined.

b. Specifications for Workmanship:

Result will be specified and not the methods (the latter will be selected by the contractor). The normal procedure is,

a) Specifications of the results, tolerance
b) Construction methods or procedure necessary for particular purposes.
c) Limitations or restrictions on the contractor's method in interest of the coordination of the work.
d) Precautions to protect the work or adjacent property.
e) Methods of inspection and test.

c. Specifications for Performance:

The desired operating- characteristics and the working conditions are specified and provisions are made for tests, inspections and warranties to guarantee durability and avoid defects.

3.7. Bill Of Quantities

Bill of quantities is a contract document to define the quantities of work to be done in each type of the activity of the contract. The quantities are not approximate; they are exact being measured as accurately as possible from the drawings. When the work is constructed the quantities are replaced by the measurement of the actual quantity of work the contractor carries out under each item. Again this must be an accurate calculation.

3.7.1. Items

For large works it may be necessary to divide bills of quantities into separate groups relating to separate parts of the job, each group being subdivided into its various trades as listed in some standards or perhaps as listed below:

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

Brickwork, Masonry, Water proofing work, Steelwork and iron work, Roofing and carpentry, Joinery, Flooring, Plastering, Glazing, Electrical, Plumbing Painting, Fencing.

The order given is not strict, it may be changed as seems reasonable. Besides, some of the trades listed above may not exist in a particular contract. So it is a usual practice to divide the job into its main sections.

-For example, the main bill sections for a bridge might consist of:

i) piers
ii) abutments
iii) superstructure
iv) approach roads and surfacing
v) miscellaneous

Within each section the items would be taken in order grouped under trades -excavation, compacting bottom soil, reinforcement, shuttering concreting etc. A sense of proportion must be retained when billing quantities. If, for example, a main civil engineering work for a bridge is likely to cost ten billion TL, it is a waste of everyone's time to bill every little quantity involved in constructing a few ancillary roadside manholes on the approach roads. (Such as excavation for manholes; concreting to manholes bases; brickwork to walls of manholes; providing and setting manholes covers). However, if these manholes are more or less similar they should be specified comprehensively in the specification and shown on the drawings, and can then be billed in a single item: "Construct manholes as specified on the drawings."

3.7.2. Numbering of Items

The engineer who prepares the bill may find that an item or two has been missed out. Even if his work is perfect, others may ask amendments involving addition to the quantities. If the items have been numbered right through from beginning to end it is then difficult to add a further item which has been forgotten at the proof stage of producing the bill of quantities because this would involve renumbering all items subsequent to the insertion and checking to see that all cross-references are corrected.

The only possible way to avoid this difficulty is to insert the forgotten items as an "A" item, e.g. Item 38 A or to collect these as "Late Items" at the end of a bill.

A useful way of numbering the original bill items is to use a letter prefix to each number, using different letter for each section of the bill.

Thus;

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

Hence if, before the bill is printed, additions have to be made to it the additional items can at least be added at the end of their correct section without disturbing the numbering.

The pages in a bill of quantities are divided, into columns, The descriptions of the work are printed clearly to enable the contractor to price every item.

Each priced page in totaled and carried to a "collection", and all the collections relating to a section of the work is carried to a "summary". Finally all the summaries are collected at the back of the bills of quantities under a heading of "General Summary".

3.8. Costing

Accurate costing of civil engineering construction work is very difficult to carry out. By "costing" is meant finding the cost of undertaking separate classes of work such as concreting, bricklaying, shuttering etc; or finding out the cost of undertaking separate portions of the work-such as the cost of access roads, subsidiary building, main buildings installation of machinery etc.

Costing involves finding charges for labor, material, plant and overheads. To apportion labor charges it is necessary for the workmen, or the section foreman acting on behalf of the men in his team, 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.

Difficulties arise in dealing with:

1) Over time and other miscellaneous wage payments, and
2) 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.

Decisions have to be made (in advance of setting up the costing system) as to how such men's time sheets are to be allocated. They may be separated out into different categories, or they may all be put under the heading “site on-costs”.

The allocation of charges for materials presents further difficulties, since the paper work on site is usually concerned only with checking the inflow of materials against the suppliers' invoices, and none of the basic records may show where the materials have been used in the separate parts of the job. The bi1 1-of-quantities measurements can be of assistance for calculating quantities (and therefore price) of materials used in the permanent works, 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”.

Provided the plant-hire charges are known, the allocation of plant charges is relatively easy on the basis of the daily returns of plant usage provided by the plant foreman.

In addition to the items already mentioned, it is necessary to add in the various site administration charges to the account for site on costs, -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.,

The result of all this is that a heavy proportion of the total cost virtually cannot be analyzed and has to be put under the general heading of “site on-costs”. A further difficulty then reveals itself, namely that the ratio of these site on-costs to the direct charges varies from week to week of the job according to the output, amount of overtime worked, amount of temporary works being built at any one time, and so on.

On-cost expenditure at the beginning of a job may be several times the cost of the direct (or productive) expenditure because of the large proportion of labor and materials used on preliminary works, such as access roads, power and water supply, etc., etc. When productive effort is in full swing the on-cost drop to their lowest,-but they tend to rise again towards the end of the job as productive work tails off and site clearance, removing sheds, transporting plant off the site, etc., takes place.

The reader will not be surprised to learn that in consequence few, if any, contractors cost works in the manner outlined above. The actual cost of a portion of a job, or of a particular operation, is never known. What is known is the estimated charge as set out in the bill of quantities according to the quantity of work actually-done and measured.

It is only possible to find out the 'cost' of separate parts of operations on a job by using the estimator's figures put in the bill of quantities, and the only way these estimated figures can be checked against the real figures of actual expenditure is by comparing the total estimate against the total expenditure.

Of course, the direct costs involved in any particular operation can be ascertained without difficulty. The number of men and the hours they spend on that operation, together with the materials and plant they have used, can be carefully noted down and priced according to the prices for labor, material, and plant that apply; but the indirect costs, representing a heavy percentage addition, can never be exactly apportioned out; they can only be applied as a general percentage added to all the operations. Hence contractors, if they do costing at all, carry it out on a different basis from what the layout of a bill of quantities seems to imply.

The practicable headings under which a contractor can expect to analyze his expenditure are more likely to be: gross wages paid, transport of men, 'non-productive' hours (i.e. plus rates for overtime), cost of wet-time; materials used in permanent works, materials used in temporary works, materials used in shuttering; equipment, scaffolding, small stores; fuel and power; plant hire, plant repairs; temporary offices and services; site staff and administration expenses.

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 undertaken as outlined above.

Thus, the prices submitted individually in a bill-of-quantities contract may not represent the actual separate cost to the contractor of each such item, but they should in total represent the total expenditure to be incurred, including an allowance for profit.

CHAPTER 4

ESTIMATING AND TENDERING

4.1. INTRODUCTION

Clients or promoters of the construction rely on competitive tendering to justify the Awarding of contracts. Most construction contracts are awarded after a number of contractors have submitted a tender. Constructor contractors base these tenders on an estimate of the cost to the contractor, of executing the work described in the contract documents. The estimating department is therefore of central importance to the commercial success of the contracting organization.

4.2. PARTIES INVOLVED IN ESTIMATING AND TENDERING

The parties involved in estimating and tendering can be divided into three classes:

a) The client's staff or their professional representative
b) The construction contractor's personnel including senior management, estimators, planners, buyers, plant managers, temporary works designers and site management staff.
c) The external organizations such as material suppliers, plant hire companies and sub-contractors?

The contribution of each of these is described below.

a) The Client's Staff or Professional Representative:

The contract documents prepared by the professional representatives of clients include drawings, bill of quantities, specifications and other documents. These are the main sources of information to the estimators who prepare the cost estimates and tenders.

b) The Constructions Contractor's Personnel

i) **Senior Management** is usually involved in the decision wether or not to tender for a particular contract and in the decision on what tender to submit. Here he considers the estimate of cost and resources involved as produced by estimators.
ii) **Estimators** are employed in the estimating department. He is responsible of producing estimates.
iii) **Planners** are employed to produce construction plans or programmes. The estimators are usually concerned, with a pre-tender plan which may not be as detailed as one produced for site use. However it will provide the overall - duration of the project, the duration and sequence of the key activities, and approximate resource total's for labor and plant.
iv) **Buyers** are usually responsible for purchasing materials and placing orders with plant hire companies and sub-contractors. They provide quotations for materials, plant hire and sub-contractors.
v) **Plant Managers** are responsible for the company's plant department and supply estimators with current internal hire rates and advice availability of company owned-plant.
vi) **Temporary works designers** are responsible for designs of major temporary

works such as bridge, false work etc. Estimators would take advice on the nature of the temporary works.

vii) **Site Management** is the personnel who are employed to take responsibility for the execution of projects on site. This expression covers agents works managers, engineers and surveyors. The contribution of site management to estimating is to provide advice to the estimators on methods of construction.

c) External Organizations:

Material suppliers, plant hire companies and sub-contractors all get involved in the estimating process. They receive and respond to enquiries for quotations from contractors.

4.3. THE ESTIMATING PROCESS

The basic steps of estimates are:

a) Decision to tender
b) Programming the estimate
c) Collection and calculation of cost information
d) Project study
e) Preparing the estimate
f) Site overheads
g) Estimator's reports

a) Decision to Tender:

The decision to tender for a particular contract is mainly the responsibility of senior-management. The decision to tender is based on such factors as:

i) the company's current workload, turnover and recovery of overheads
ii) the company's financial resources
iii) the availability of resources to undertake the work
iv) the type of work
v) the location of the contract
vi) the identity of the client or promoters and his representatives
vii) a detailed examination of the contract documents

b) Programming the Estimate:

The two tasks that can take place in th is stage are:

i) collection and calculation of the cost information
ii) a study of the project to gain the required appreciation

c) Collection of Cost Information:

The cost information required by the estimator for, labor, plant, materials and subcontractor.

d) Project Study:

To gain an appreciation of the project the estimator will undertake the following tasks:

i) a study of the drawings
ii) a site visits and meeting with the clients or promoter's representative .
iii) the preparation of a method statement determining how the project will be constructed.

e) Preparing the Estimate:

The estimator is required to establish the direct cost rates for each item in the bill of quantities. A direct cost rate is a rate for the labour, plant, materials and sub-contractors but exclusive of additions for site overhead, head office overhead and profit. This will be assessed and included later.

f) Site Overheads:

The estimator assesses the site overheads based on requirements such as:

i) Site staff
ii) Clearing site
iii) Site transport facilities
iv) mechanical plant not previously included in the item rates
v) scaffolding and gantries
vi) site accommodation
vii) small plant
viii) temporary services
ix) welfare, first aid and safety provisions
x) final clearance -and handover
xi) defects liability
xii) transport of men to site
xiii) abnormal overtime
xiv) risk

g) Estimator's Reports

On completion of the estimate the estimators prepare a set of reports for consideration by the senior management. These reports contain,

i) a brief description of the project
ii) a description of the method of construction
iii) notes of any unusual risks which are not covered by the condition of contract or bills of quantities.
iv) any unresolved or contractual problem
v) an assessment of the state of the design proves and the possible financial consequences thereof
vi) notes of any major assumptions made in the preparation of the estimate
vii) assessment of the profitability of the project
viii) any pertinent information concerning market and industrial conditions

4.4. TENDERING ADJUSTMENTS:

A tender adjudicating panel is formed by the staff involved in estimating and representatives of senior management. It is the responsibility of this panel to satisfy themselves that the estimate-is adequate.

Additions for “mark-up” includes the allowances for:

i) "risk" if the chance or profitability of making a loss is assessed
ii) "Company overheads" to cover the central head office costs which are involved in administrating at the contract.
iii) the "profit" considered to be possible in the existing market conditions.

4.5 Calling for Tenders:

An employer may publicly advertise (by press) that he is open to receive tenders. It is usual for the engineer to draft this notice so that it contains a brief but adequate description of the proposed works and their location, so that contractor can judge whether they are interested in tendering. It is also usual to state that no expenses incurred in tendering will be reimbursed and that the employer does not bind himself to accept the lowest, or any tender. Contractors are normally required to pay a deposit, before they get a set of tender file.

An alternative procedure to public advertisement of tender is to invite certain contractors only to submit tenders. Probably the best way to do this is to advertise that contractors may if they send in their qualifications and experience, apply to be placed on a list of "selected tenders". This is called pre-qualification, and it saves time for both contractors and the engineer and employer. Thus, for the construction of a bridge, a public advertisement might be issued inviting contractors, experienced in bridge building to apply to be placed on the list of selected tenderers. Applications would be asked to provide details of their past experience, present labor force, plant, and equipment, and to give the names of previous employers they have-worked for.

However, sometimes the engineer may himself draw up a list of selected tenders in consultation with the employer, without resorting a public advertisement. But this may not be fair to certain contractors.

4.6 Comparing Tenders:

It is the engineer's job to recommend to the employer which contractor's offer should be accepted. It should be noticed that, the engineer does not accept the offer, nor does he make the final decision. The engineer recommends, the employer decides and acts.

The first criterion is of course, the sum total offer made by each contractor. It is important to see whether each contractor is, in fact offering the same thing. Some tenders may be submitted with certain reservations which are contrary or additional to the conditions in the tender documents. Some tenders may have misspellings or mistakes of interpretation of the documents. All these matters are listed side by side and where necessary, adjustments made to the total sums offered. After this comparison, 3 or 4, offer are selected and examined in detail.

If the tenders are based on bills of quantities, the detailed prices submitted by different contractors for the same portions of the work are compared. This will reveal relatively high or low unit prices for certain types of work, so that the engineer can decide what trouble could be in certain parts of the work. The engineer will not like a contractor making high profit from some part of the work and high loss from the other part of the work.

4.7 Choosing a Tender:

With the completion of the close check, and comparison, the engineer may invite one or two of the lowest tenderers to his office, to discuss certain points of their offer: Principally he may wish to be provided with further evidence from a tenderer, such as, proposed methods of construction, and his proposed program. The engineer will not of course reveal to any contractor the prices offered by others. Meantime, the engineer may made private contact with the referees named by the contractors. Then the decision is made as to which tender should be recommended for acceptance.

4.8 Those who can't take part in Bidding Committee

1- Member of the bidding commission
2- Employees linked to the bidding or bidding commission (secretary, etc.)
3- Highest ranking of civil and military official
4- Fathers, mothers, brothers, children, wives, husbands, sons in law, father in law of items 1,2 and 3 above.
5- These not allowed to take part in biddings, (as penalty)

4.9 Documents that a bidder should submit:

1- Registration
2- Bonds
3- Contractor ship license
4- Permission to take part in biddings
5- Documents show that the company is active
6- List of signatures

4.10 Bonds: (for defaults or damages of contractor as security of owner)

a) Bid bond
b) Performance bond

a) Bid Bond:

Amount of bid bond is normally about *5%* of the tender. At the end of the bidding if a company doesn't win, the bid bond is paid back to him. But if a company wins the bidding and then gives up, the bid bond is not given back to him.

These are accepted as Bid Bonds:

1- Money
2- Bank guarantee letter
3- National bonds
4- Shares of companies
5- First rate of mortgage

b) Performance Bonds:

The amount of performance bond is normally about 10% of estimate cost. But when a company signs a contract, the bid bond is transferred as performance bond, which is 5% of tender where it is half of the performance bond. The rest of the performance bond is cut from the payments. At each payment, %10 of the payment is cut and transferred to performance bond.

Example:

Tender: 10,000,000.- YTL
Bid Bond: 10,000,000 x 5% = 500,000.- YTL
Performance bond:. 10,000,000 x 10% = 1,000,000. - YTL

Although bid bond is transferred to performance bond, to complete performance bond another 500,000.- TL is necessary. And that amount will be cut from payments as 10% of the payment.

Suppose:
1st payment 1,750,000.- YTL
As performance bond 1,750,000.- YTL x 0,1 = **175,000.- YTL** is cut

2nd payment = 2,500,000.- YTL
2,500,000.- YTL x 0,1 = **250,000.- YTL** is cut

Total amount cut: **425,000.- YTL**

To complete the performance bond further 75,000.- YTL (500,000 - 425,000 = 75,000.- YTL) must be cut from the 3rd payment.

.•. 1st payment: 1,750,000 - 175,000 = 1,575,000.- YTL
.•. 2nd payment: 2,500,000 - 250,000 = 2,250,000.- YTL
.•. 3rd payment: 3,000,000 - 75,000 = 2,925,000.- YTL

From the rest of the payments no money will be cut as performance bond.
The contractor can take back his performance bond if:
- The permanent acceptance of the work is done
- The contractor brings a certificate from social Insurance office to rove that all the insurances of the labors are paid.

4.11 Types of Bidding:

a- Closed bidding
b- Open bidding
c- Limited bidding
d- Bargaining.

a) Closed Bidding:

There are two envelopes one inside the other one. First envelope (outer one) contains, name, address of company, and other documents of bidding. If there are any missing among them the second envelope is not opened, and the company is asked to complete. Otherwise the second envelope is opened and the signed tender is read. This bidding is used specially for large jobs.

b) Open Bidding:

There is only one envelope, and every documents and signed tender are in that envelope. It is used for small jobs.

c) Limited Bidding

If the job requires a certain quality, the tender of all contractor companies are not accepted and a limitation is required. It may be open or closed bidding.

d) Bargaining:

It is used for;
i) Small, urgent job
ii) Jobs that can be carried out by only one company.
iii) Under forced conditions (such as eartquake, flood war etc.
iv) Jobs not planned but urgent
v) Bids with no offer or offers above expected value.

CHAPTER 5

INTRODUCTION TO EARTHMOVING

The Earthmoving Process

Earthmoving (Figure 5.1) 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.

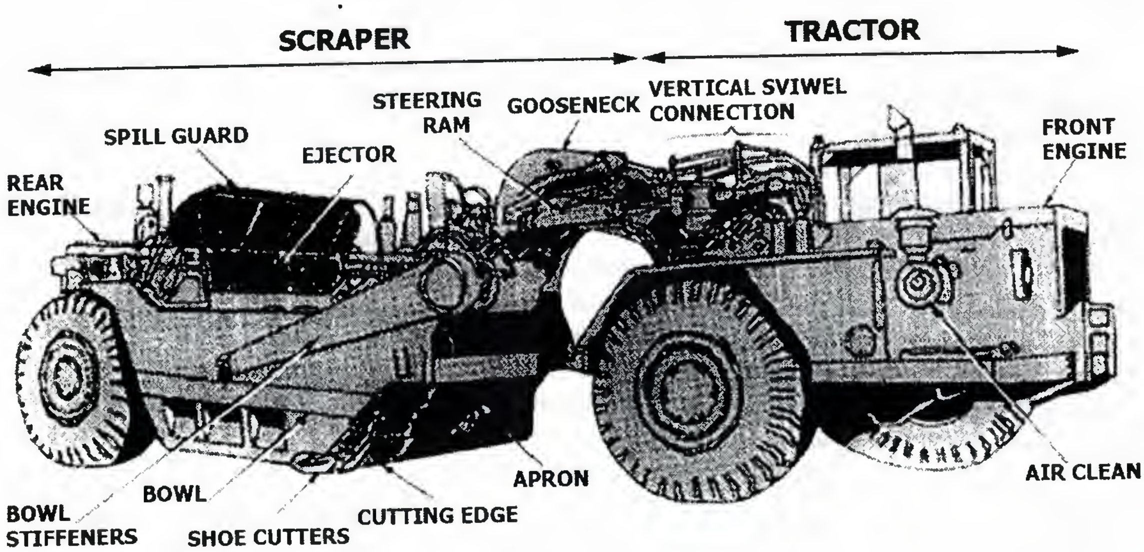


Figure 5.1 : Scraper

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. (Chapter 16 provides a discussion o 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 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 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:

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

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:

$$\text{Moisture content} = \frac{120 - 100}{100} \times 100 = 20\%$$

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 ya'd {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:

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

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/m³ in its natural state and 3500 kg/m³ 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.

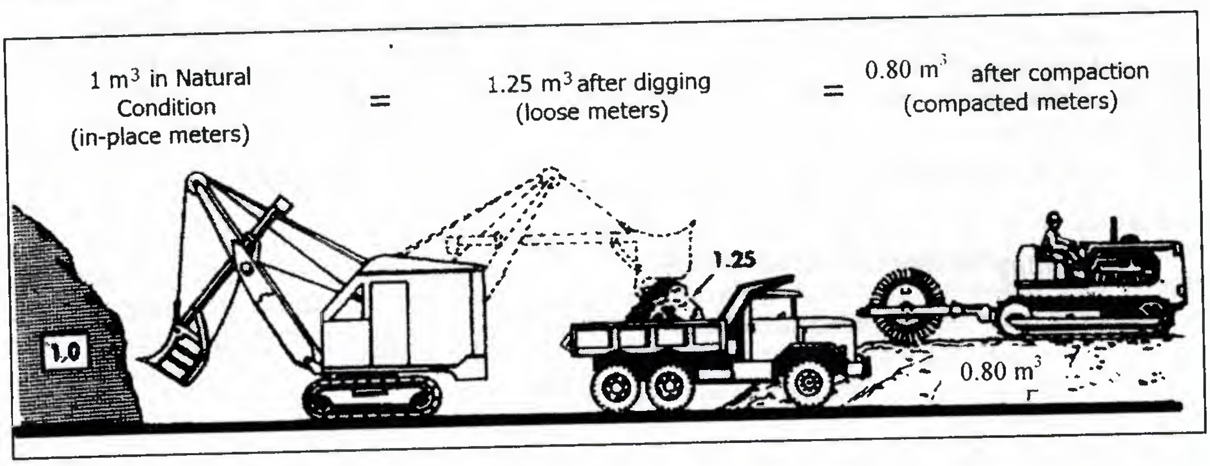


Figure 5.2 : Typical soil volume change during earth moving

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.

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

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

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

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

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/m³			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.

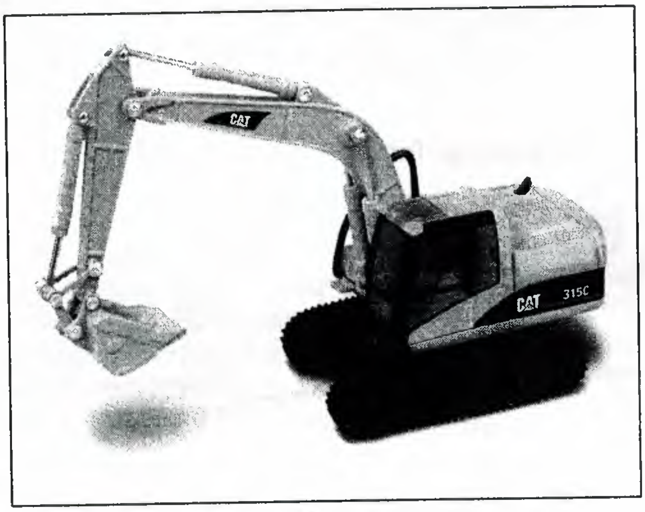


Figure 5.3 : Hydraulic Excavator

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.

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: 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 m³ bucket would be assumed to actually hold 5 bank m³ 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.

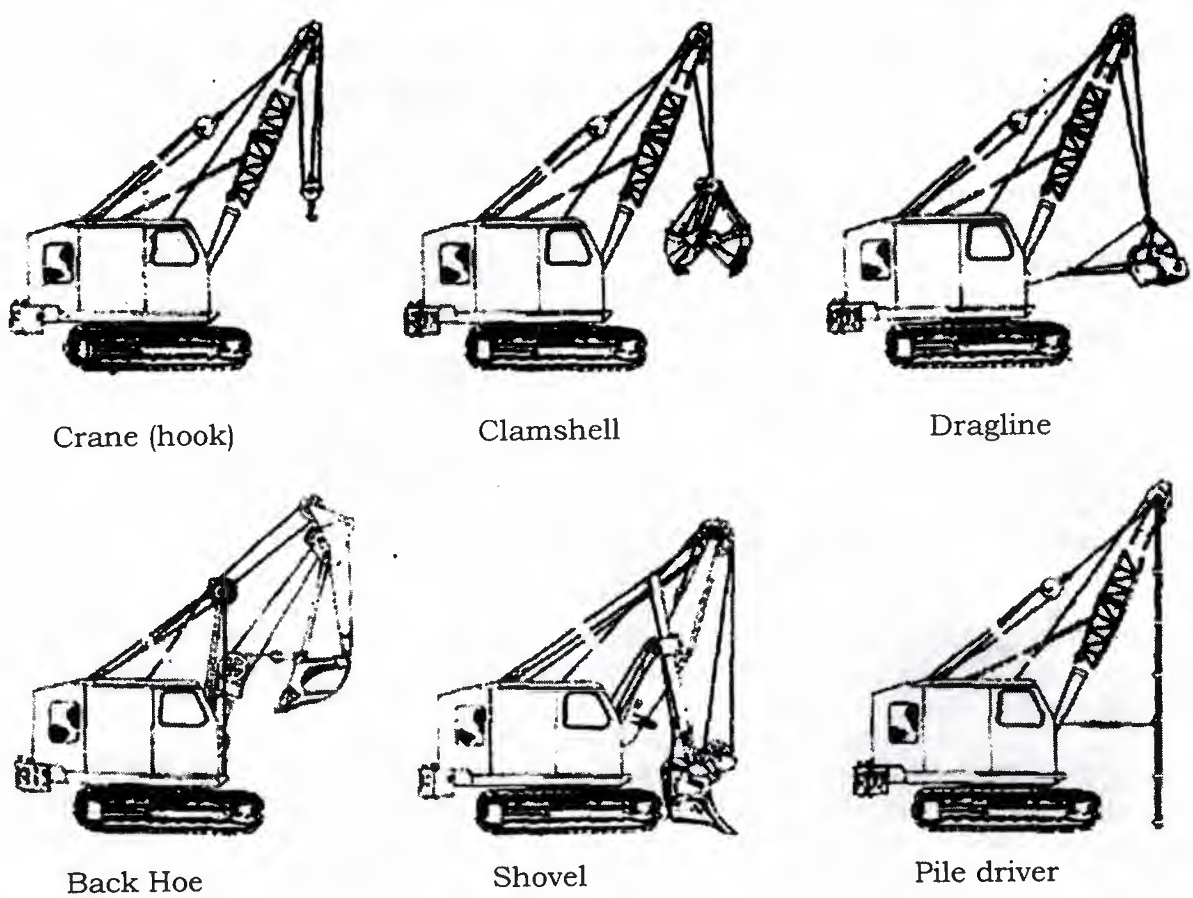


Figure 5.4: Members of the cable operated crane shovel family

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 5.5. The crawler mounting provides excellent on-site mobility and its low ground pressure enables it to operate in areas of low trafficability.

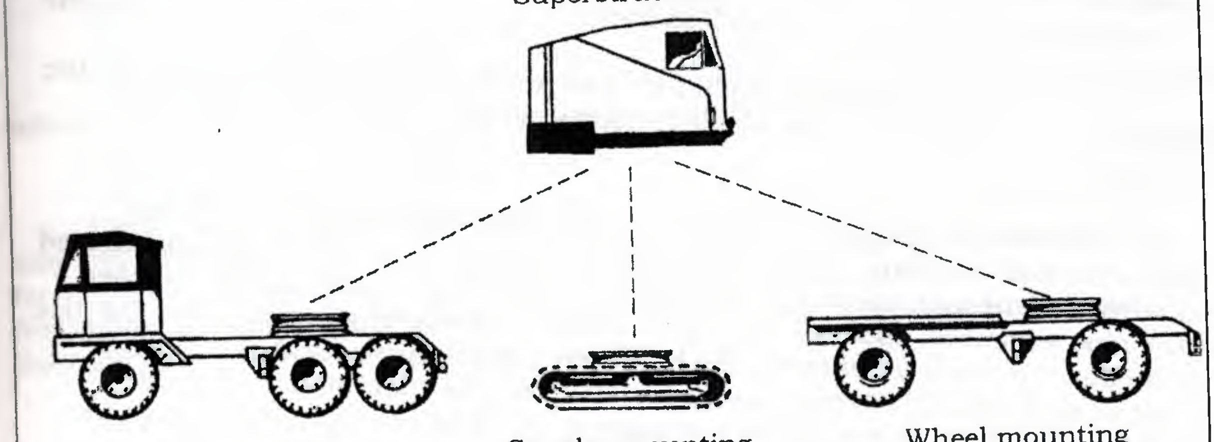


Figure 5.5: Crane-shovel mountings and revolving superstructure

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 5.6) 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.

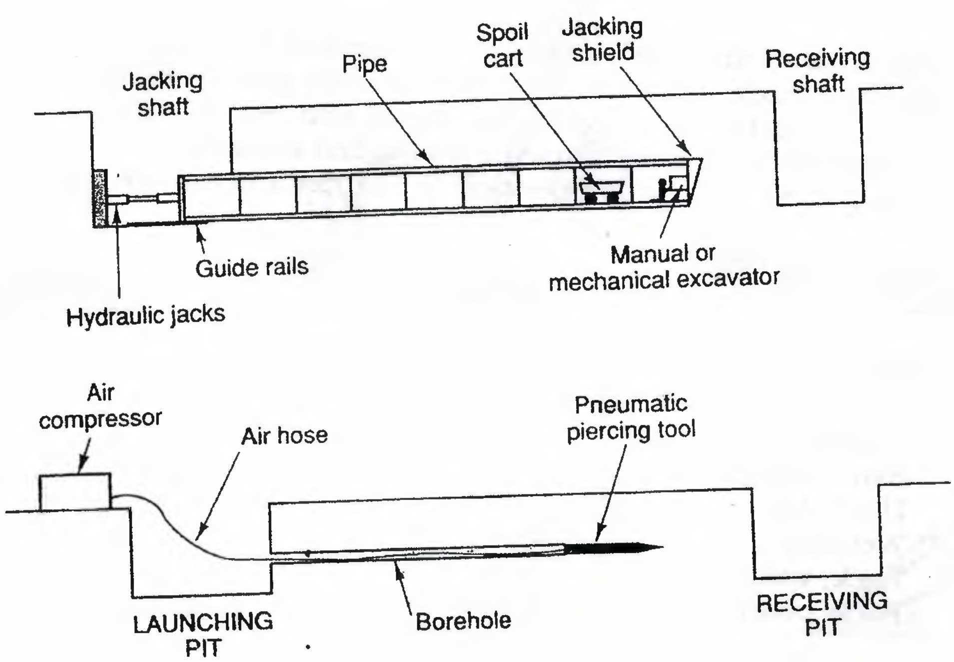


Figure 5.6: Installing a utility line by pipe jacking (upper picture) and by horizontal earth boring (lower picture)

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 5.7 is also called a *front shovel* or *hydraulic excavator-front shovel.*

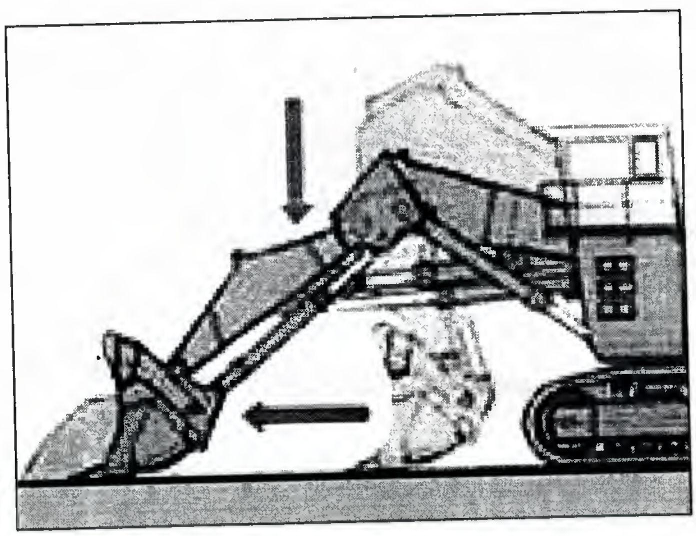


Figure 5.7: Hydraulic shovel

The major components are identified below in Figure 5.8.

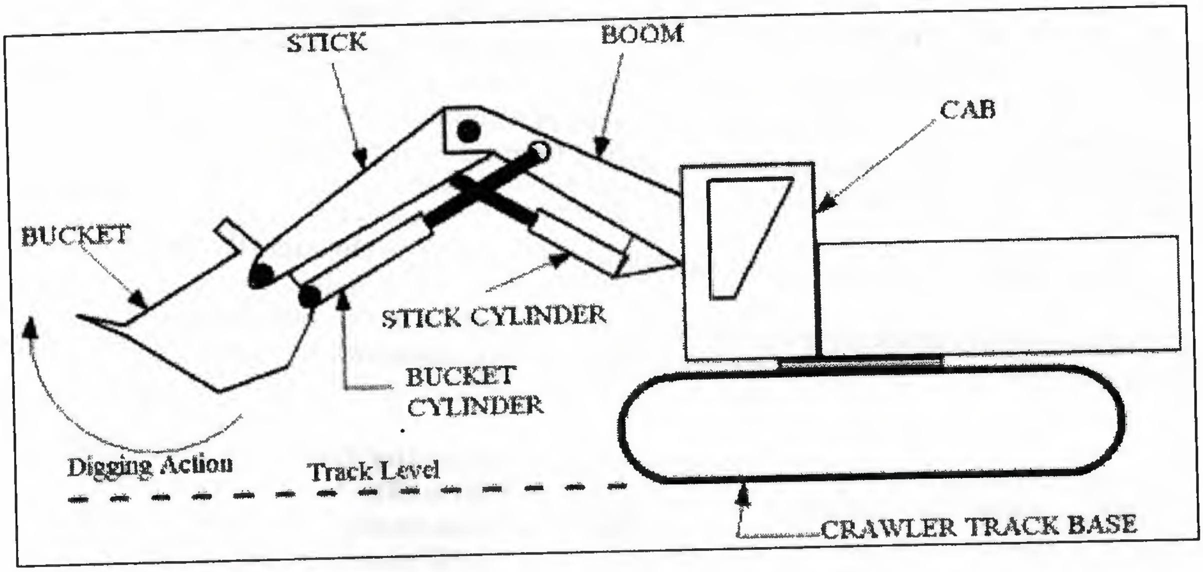


Figure 5.8: The major components of a Hydraulic Shovel

The hydraulic shovel digs with a combination of crowding force and breakout (or prying) force as illustrated in Figure 5.9.

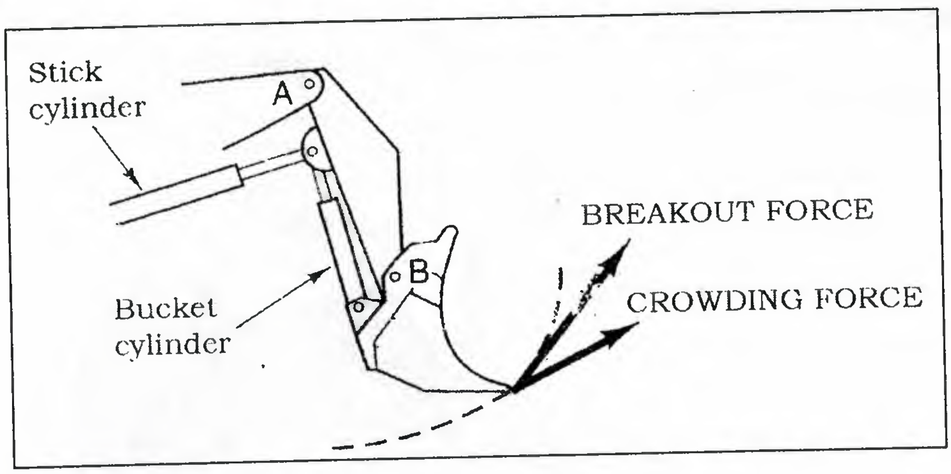


Figure 5.9: Digging action of a hydraulic shovel

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-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 5.10.

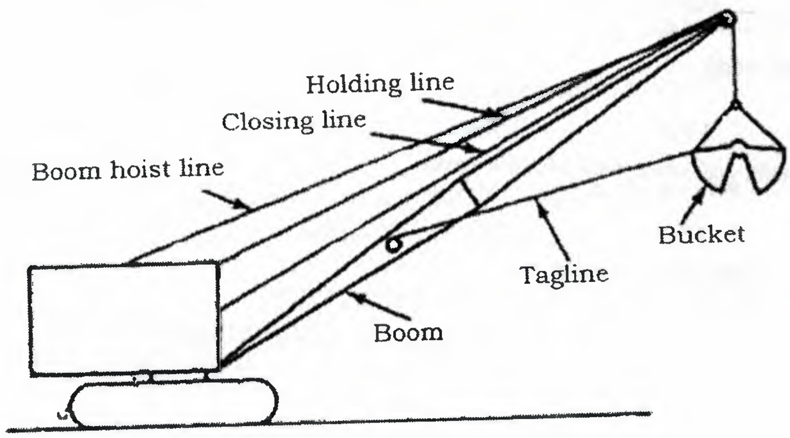


Figure 5.10: Clamshell and its components

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

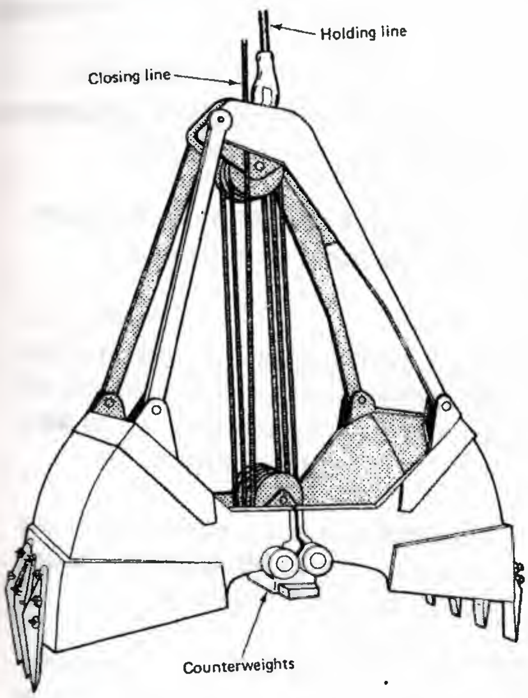


Figure 5.11: Clamshell bucket

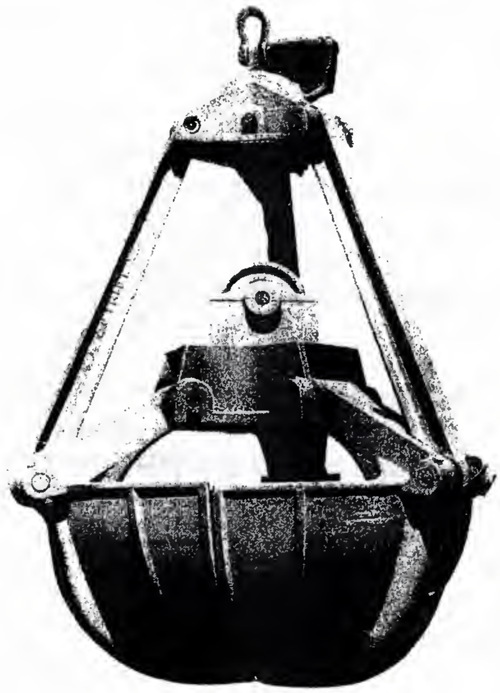


Figure 5.12: Orange peel bucket

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 5.11. 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 5.12 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 m³).

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

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

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.

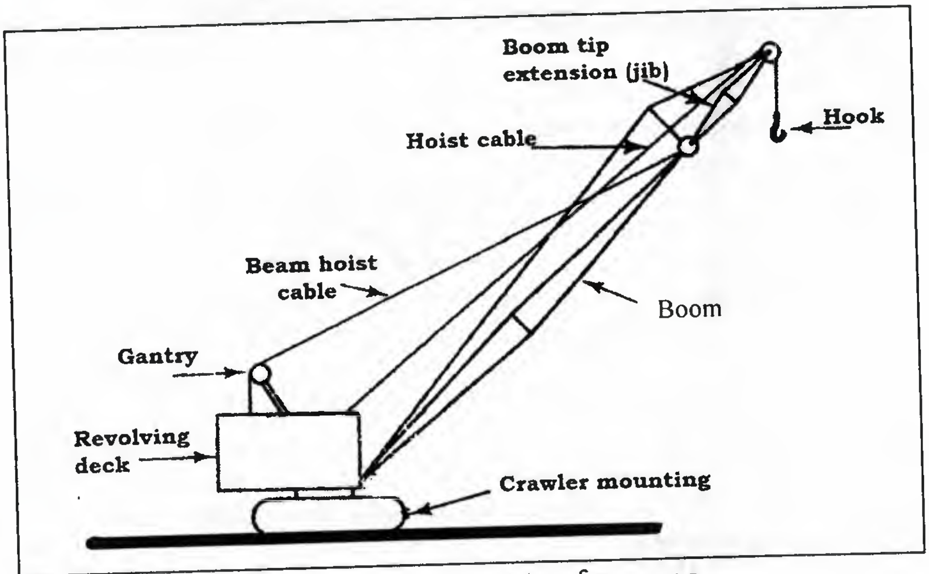


Figure 5.13: Components of a crane

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

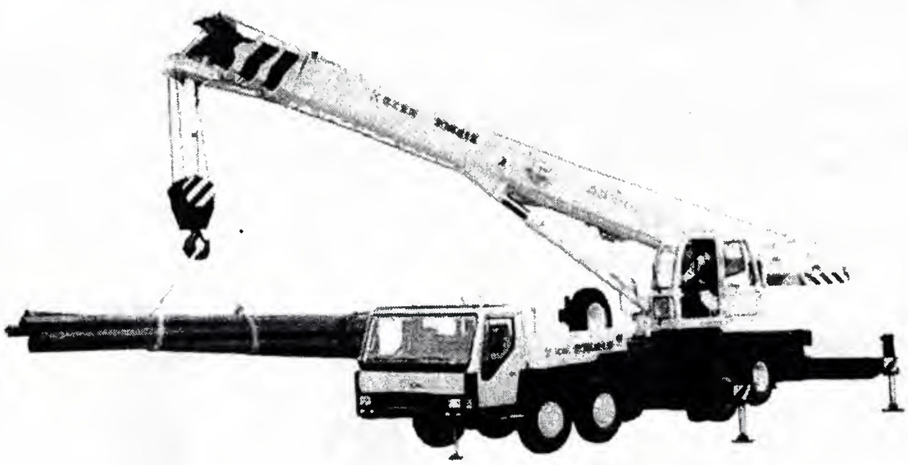


Figure 5.14: Hydraulic mobile telescoping boom crane

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

The mobile telescoping-boom crane shown in Figure 5.14 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 5.15.

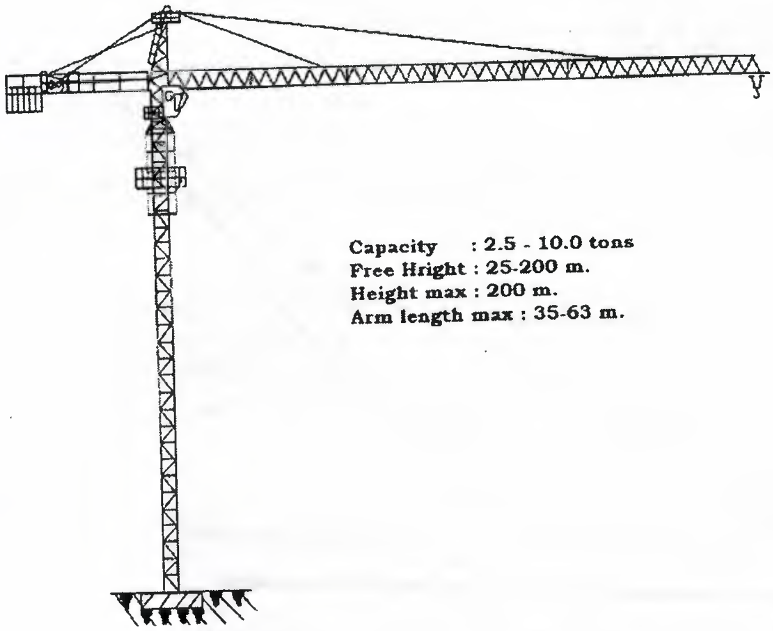


Figure 5.15 : Tower Crane

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 5.15.

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.

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 5.16).

The crane lifts an additional tower section together with a monorail beam and trolley (A).

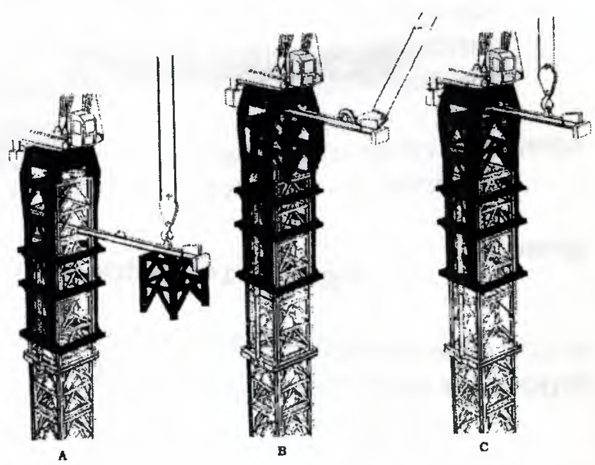


Figure 5.16: Self raising mast

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 PCSA Bureau of the Construction Industry Manufacturers Association. Under this system, a nominal capacity rating is assigned which indicates the safe load capacity (with outriggers set) for a specified operating radius [usually 12 ft (3.6 m) in the direction of least stability].

The PCSA class number following 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 hundreds of pounds (45.40 kg) at a 40-ft (12.2-m) operating radius using a 50-ft (15.2-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 5.17.

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.

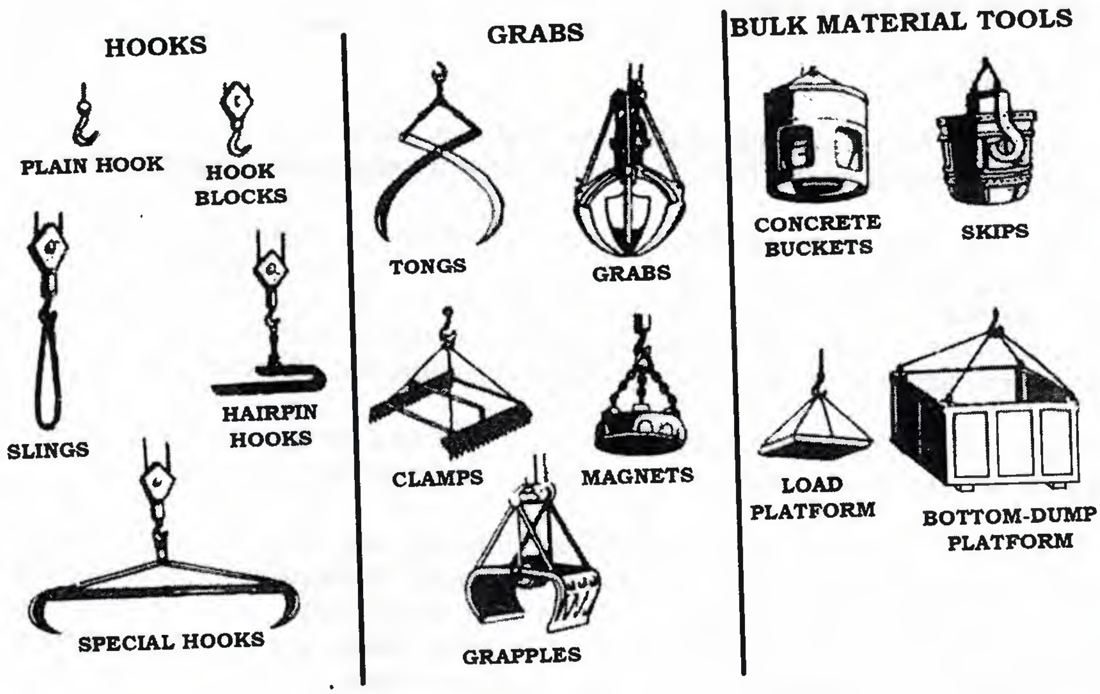


Figure 5.17: Lifting attachments for the crane

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 5.18

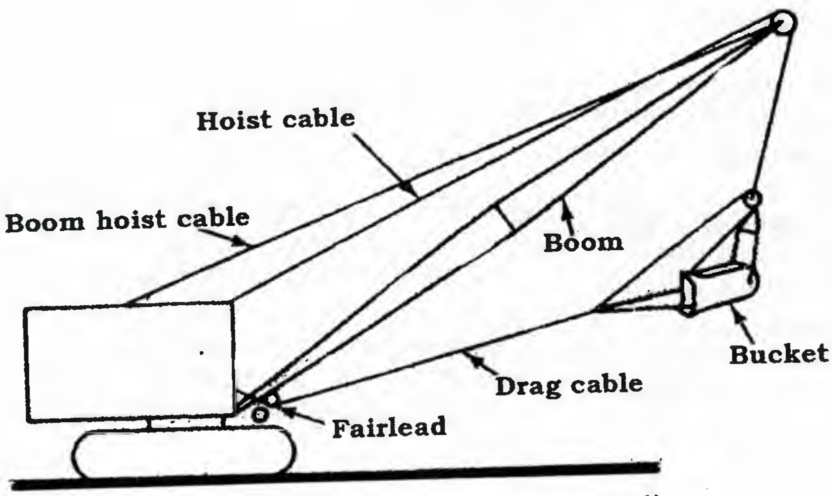


Figure 5.18: Components of a dragline

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 5.19).

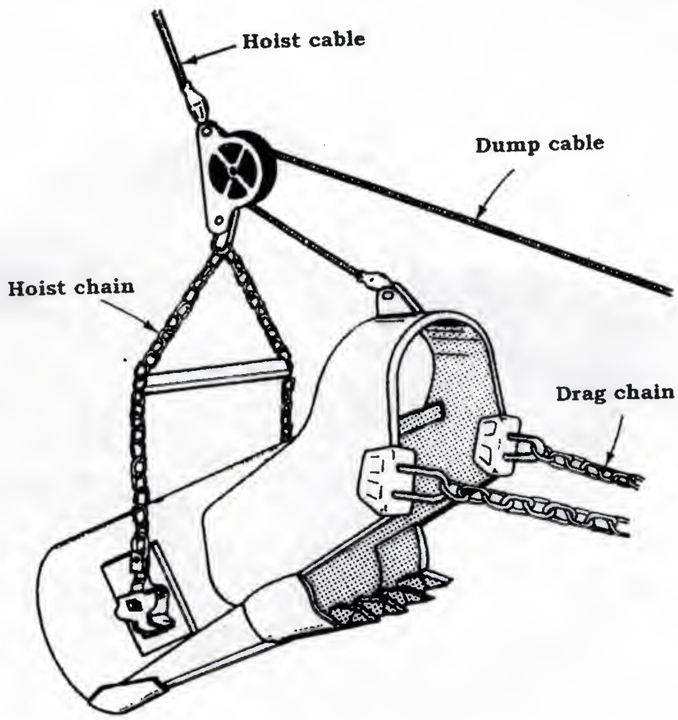


Figure 5.19: Dragline bucket

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 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*.

Figure 5.20: Crawler Dozer

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. 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 5.20) 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 transmiss*ions. 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 5.21.

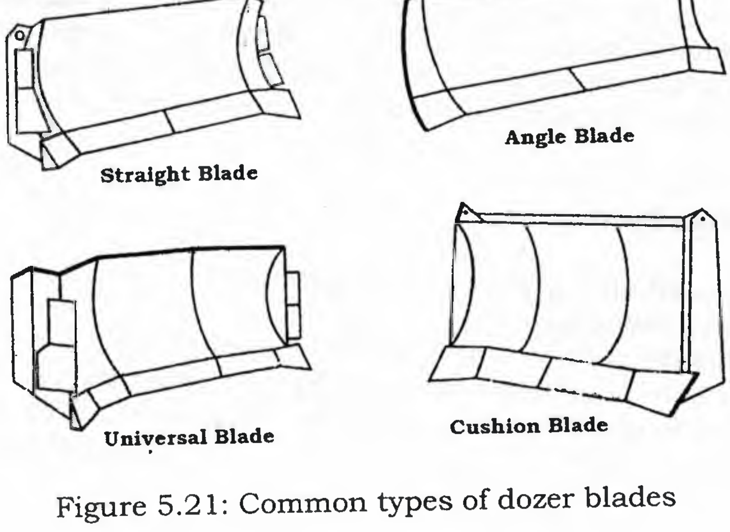


Figure 5.21: Common types of dozer blades

The three types of adjustments that may be made to dozer blades are illustrated in Figure 5.22.

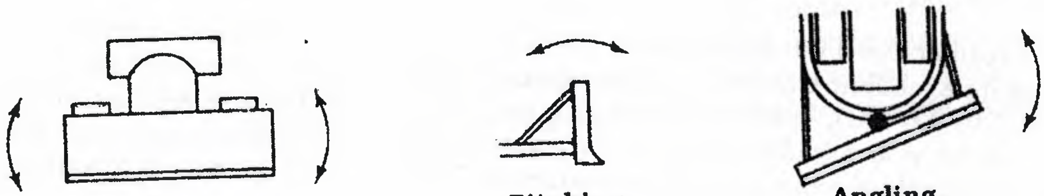


Figure 5.22: Dozer blade adjustments

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 5.21 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 5.21) 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 (Lm³) = 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. *Fixed cycle time* represents the time required to maneuver, change gears, start loadings and dump. Table 6 may-be used to estimate dozer fixed cycle time.

Table 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 7 provides typical operating speeds for dozing and return. Some manufacturers provide dozer production estimating charts for their equipment.

Table 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)

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

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

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

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

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.*

Figure 5.23: Wheel Loader

Both wheel loaders (Figure 5.23) and track loaders (Figure 5.24) 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.

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 provide greater maneuverability.

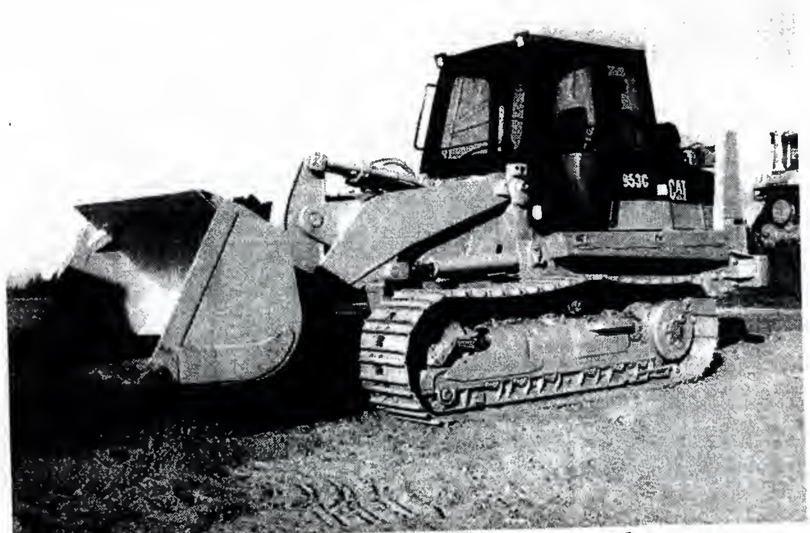


Figure 5.24: Track (crawler) Loader

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 8: Basic Loader cycle time

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

Table 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 25.

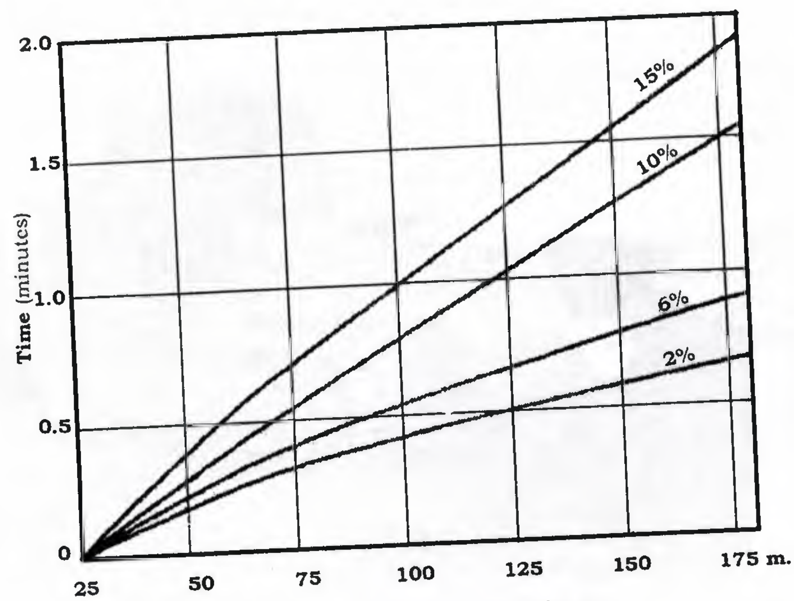


Figure 25: One way haul distance

Federal Highway Administration (FHWA) 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

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

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-1 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.

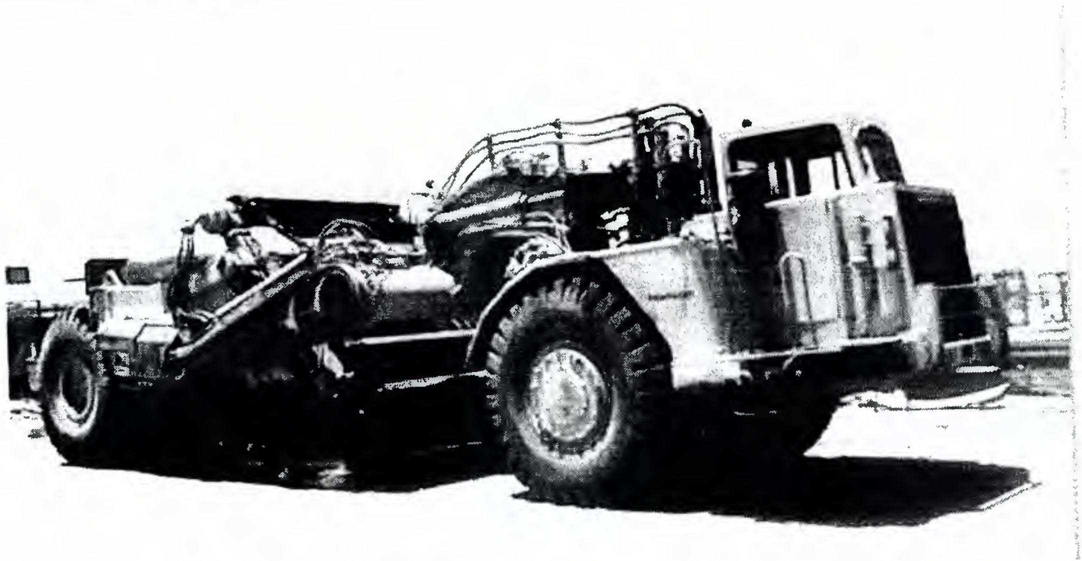


Figure 5.26: Scraper

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 5.27 shows a 40 ton rear-dump truck.

Figure 5.27: 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.

Figure 5.28: All wheel Rear Dump Truck

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 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.

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

$$\text{Load time} = \text{Number of bucket loads} \; x \; \text{Excavator cycle time} \qquad \text{(Eq.13)}$$

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)

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

$$\text{Truck cycle time} = 0.5 + 0.054 = 0.554 \text{ h}$$

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

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

(b) With nine trucks available,

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

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.

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.

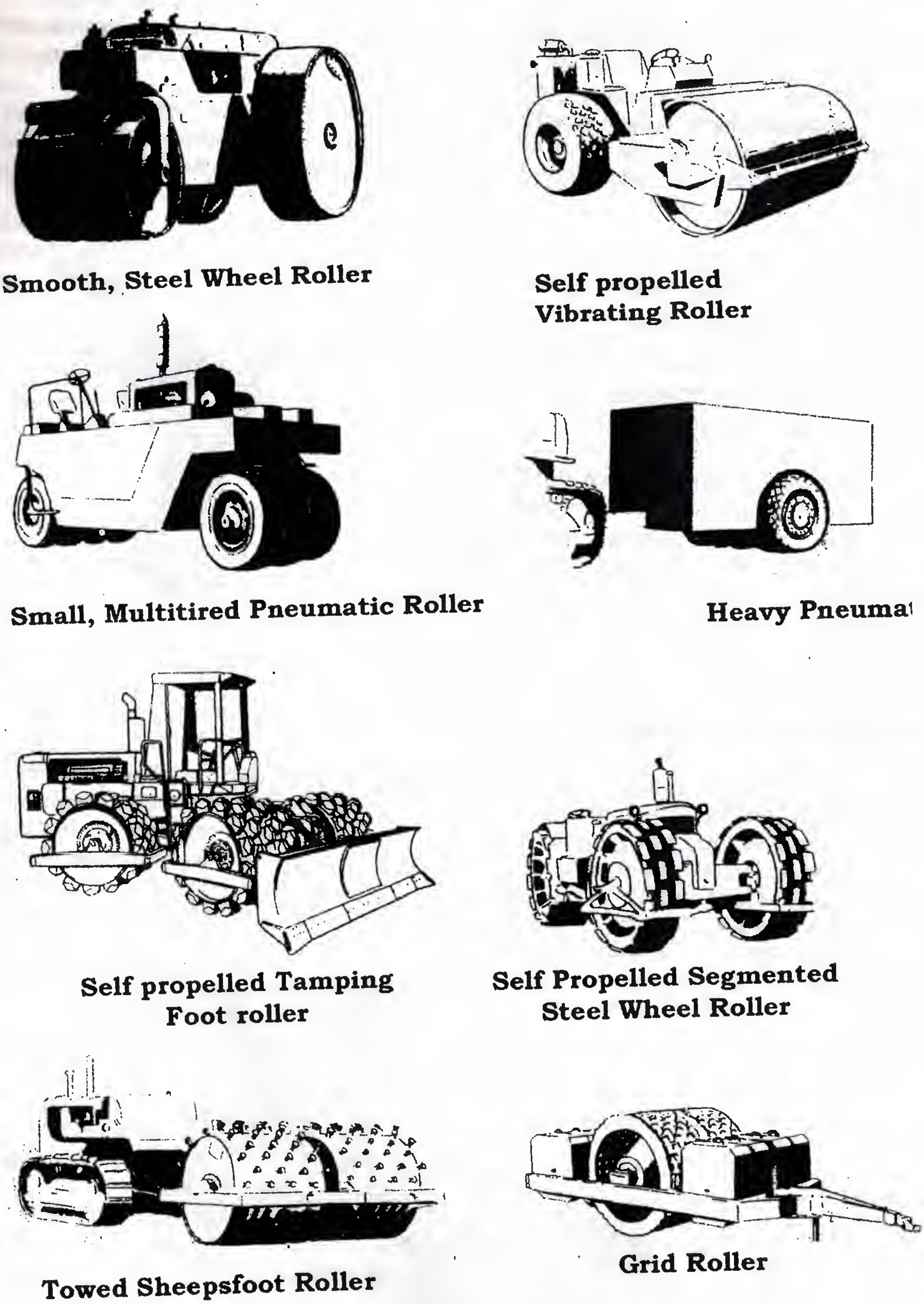


Figure 5.29: Major types of compaction equipment

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 5.30: 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 5.31).

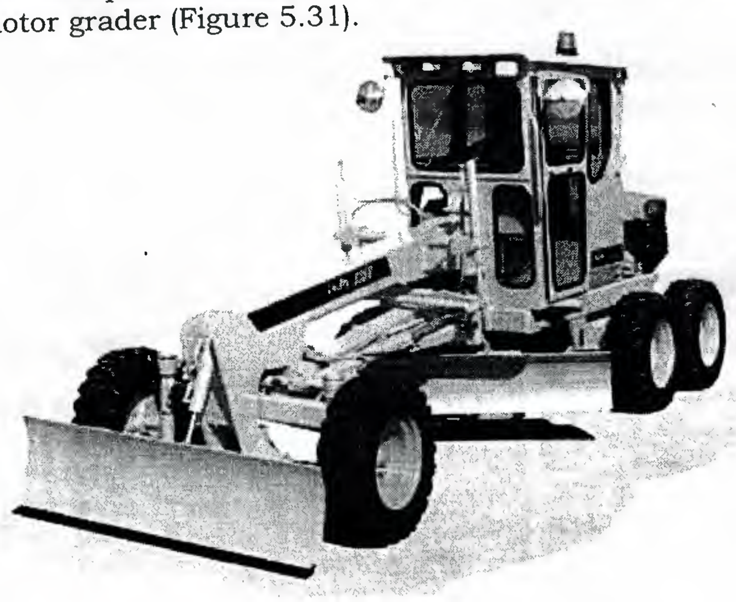


Figure 5.31: Motor grader

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 5.32.

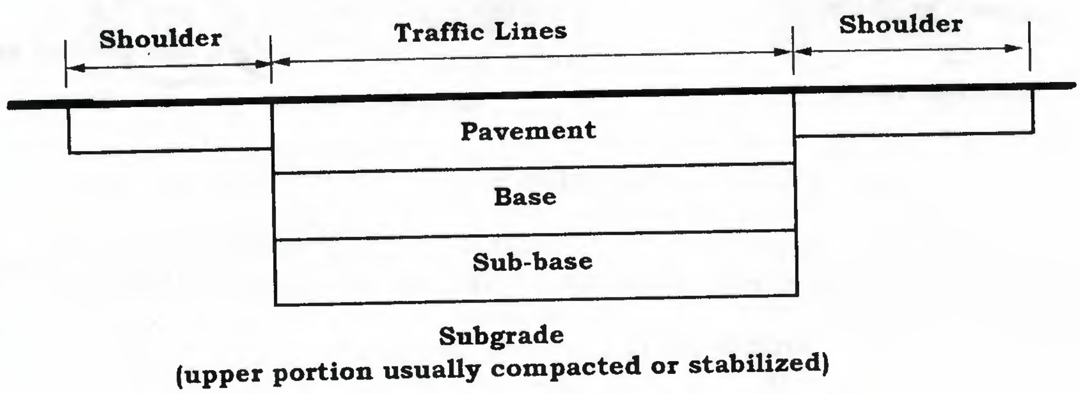


Figure 5.32: Typical Roadway Components

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 5.33.

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.

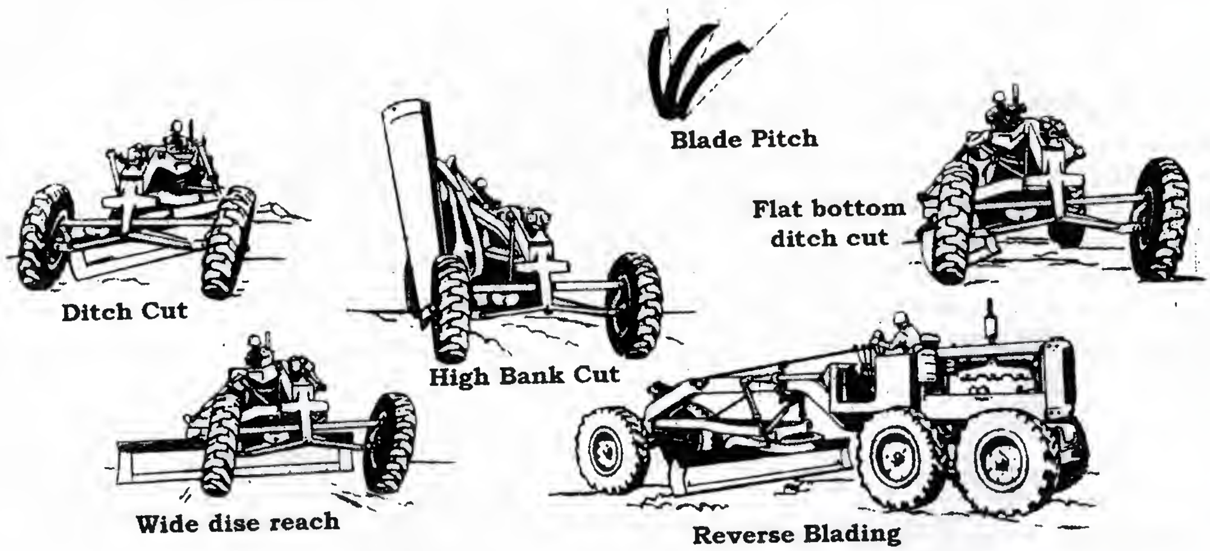


Figure 5.33: Blade positions for the Motor Blade

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.

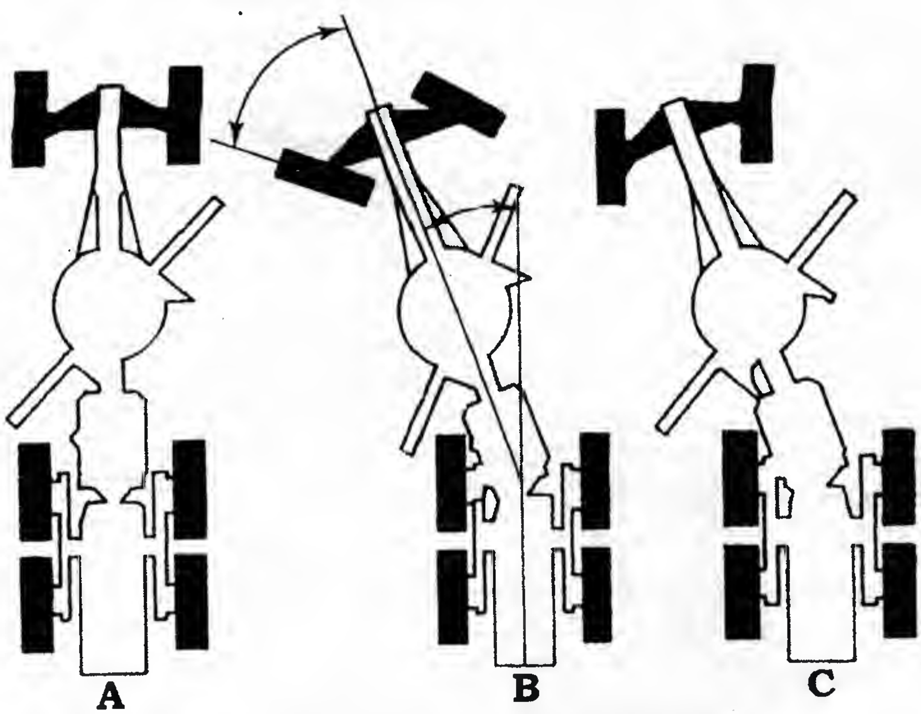


Figure 5.34: Articulated Grader Positions

The machine may operate in the conventional manner when in the straight mode (Figure 5.34A).

The articulated mode (Figure 5.34B) allows the machine to turn in a short radius.

Use of the crab mode (Figure 5.34C) 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 5.35 is also capable of compacting base material, laying asphalt, or acting as a slipform power.

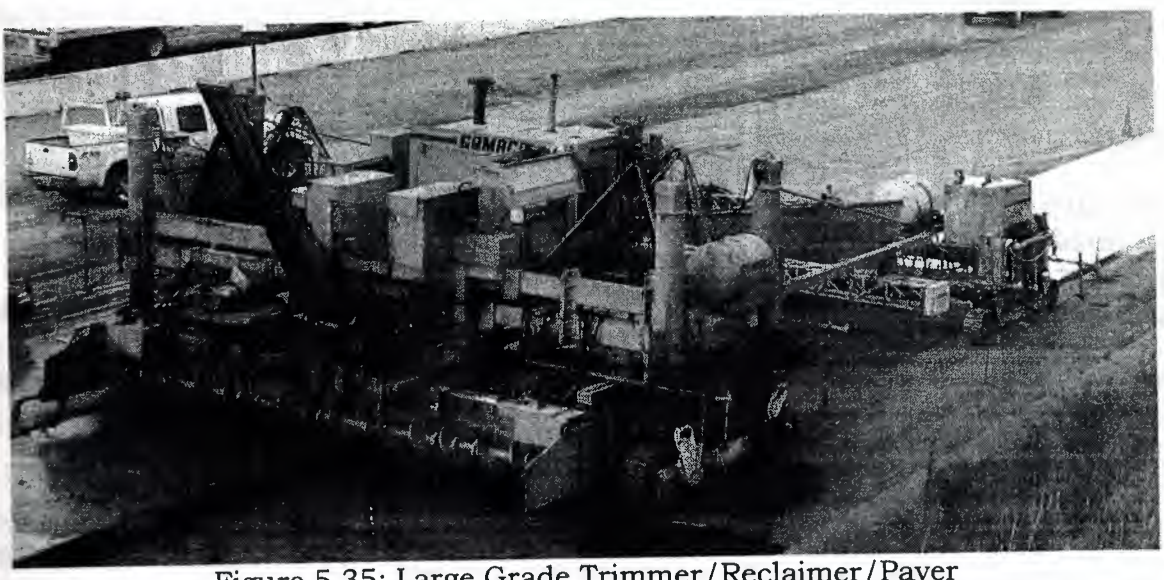


Figure 5.35: Large Grade Trimmer/Reclaimer/Paver

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:

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

Average speed will depend on operator skill, machine characteristics, and job conditions. Typical grader speeds for various types of operations are given in Table 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 6

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.

Table 10-2 Typical slump ranges for various types of construction

Type of Construction	Slump (cm 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.

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.

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 6.1.

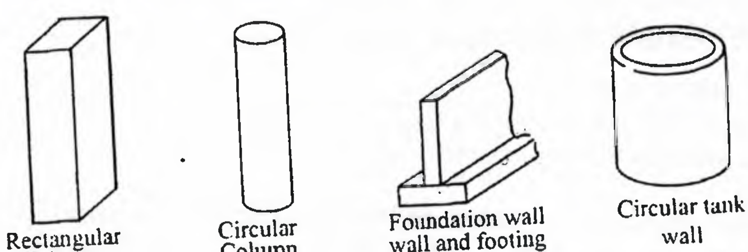


Figure 6.1: Typical cast-in-place column and wall shapes

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 6.2.

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.

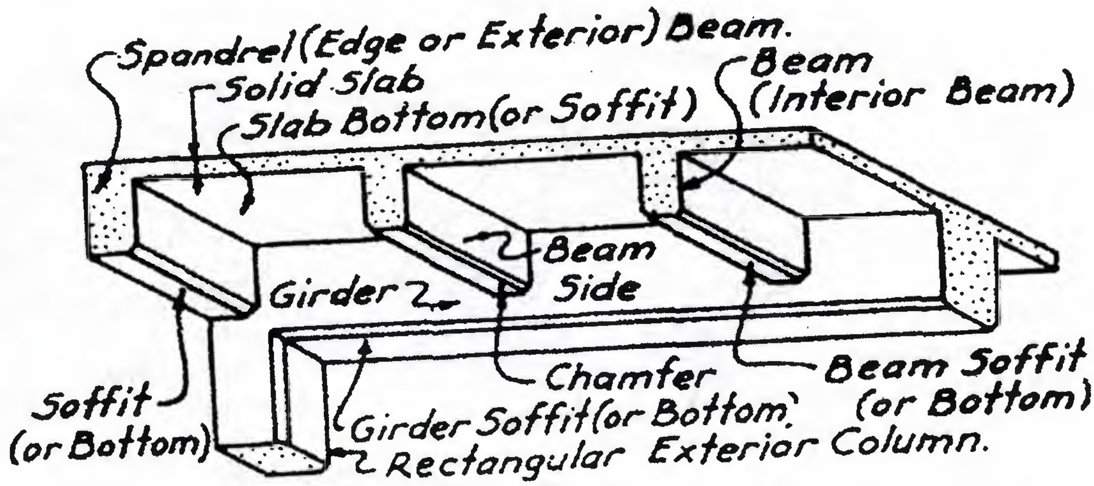


Figure 6.2: Slab-Beam and Girder floor

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 6-3 results.

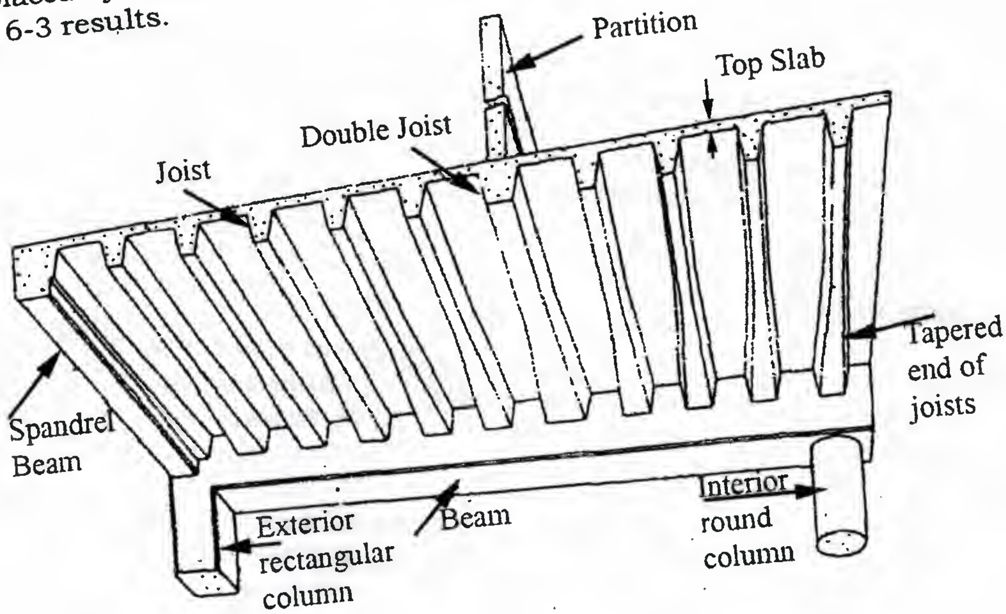


Figure 6.3: Concrete Joist Floor

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 6-4. Notice that this is basically a joist slab with joists running in two perpendicular directions.

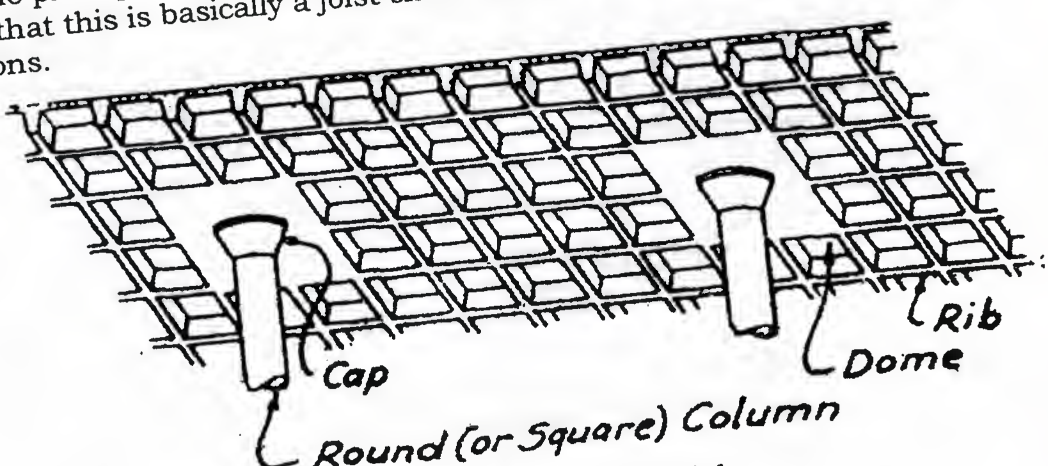


Figure 6.4: Waffle Slab

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 6-5a. A flat slab is illustrated in Figure 6-5b. 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.

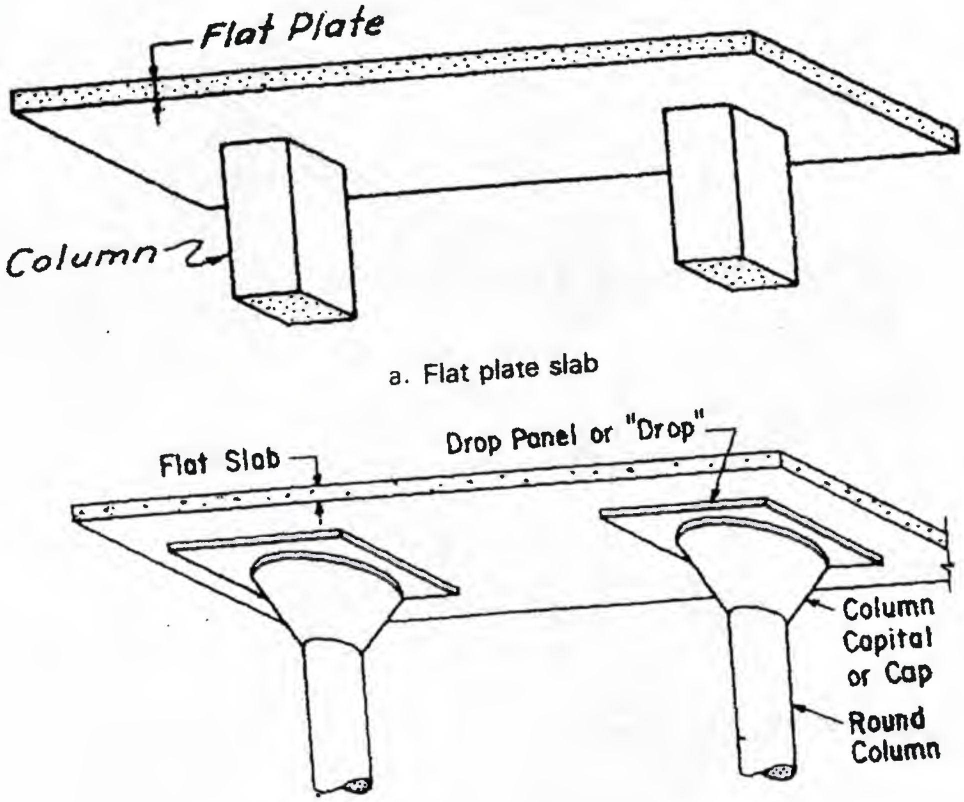


Figure 6.5: Flat Slab and flat plate slab

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.

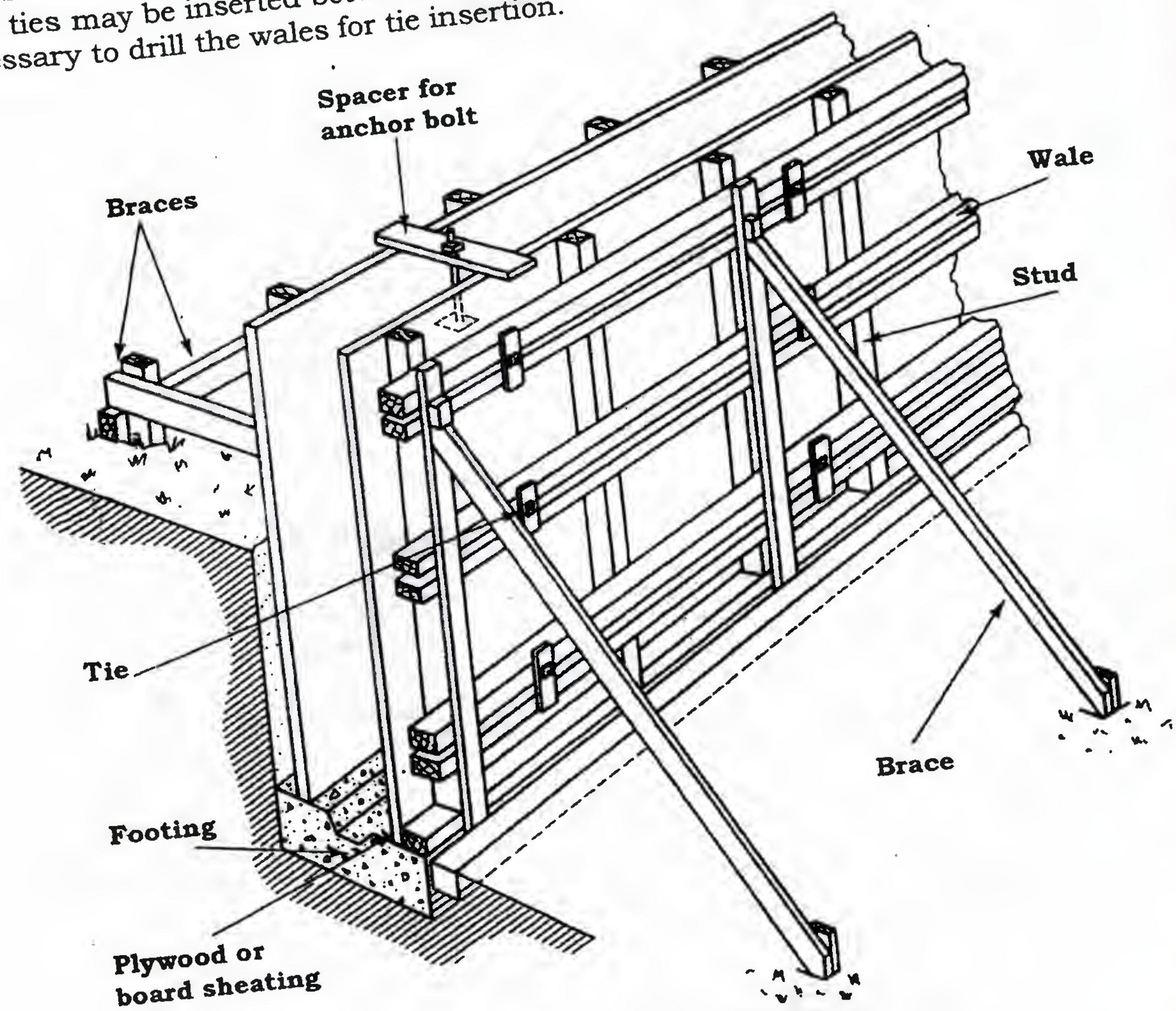


Figure 6.6: Typical Wall Form

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 6-7. 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.

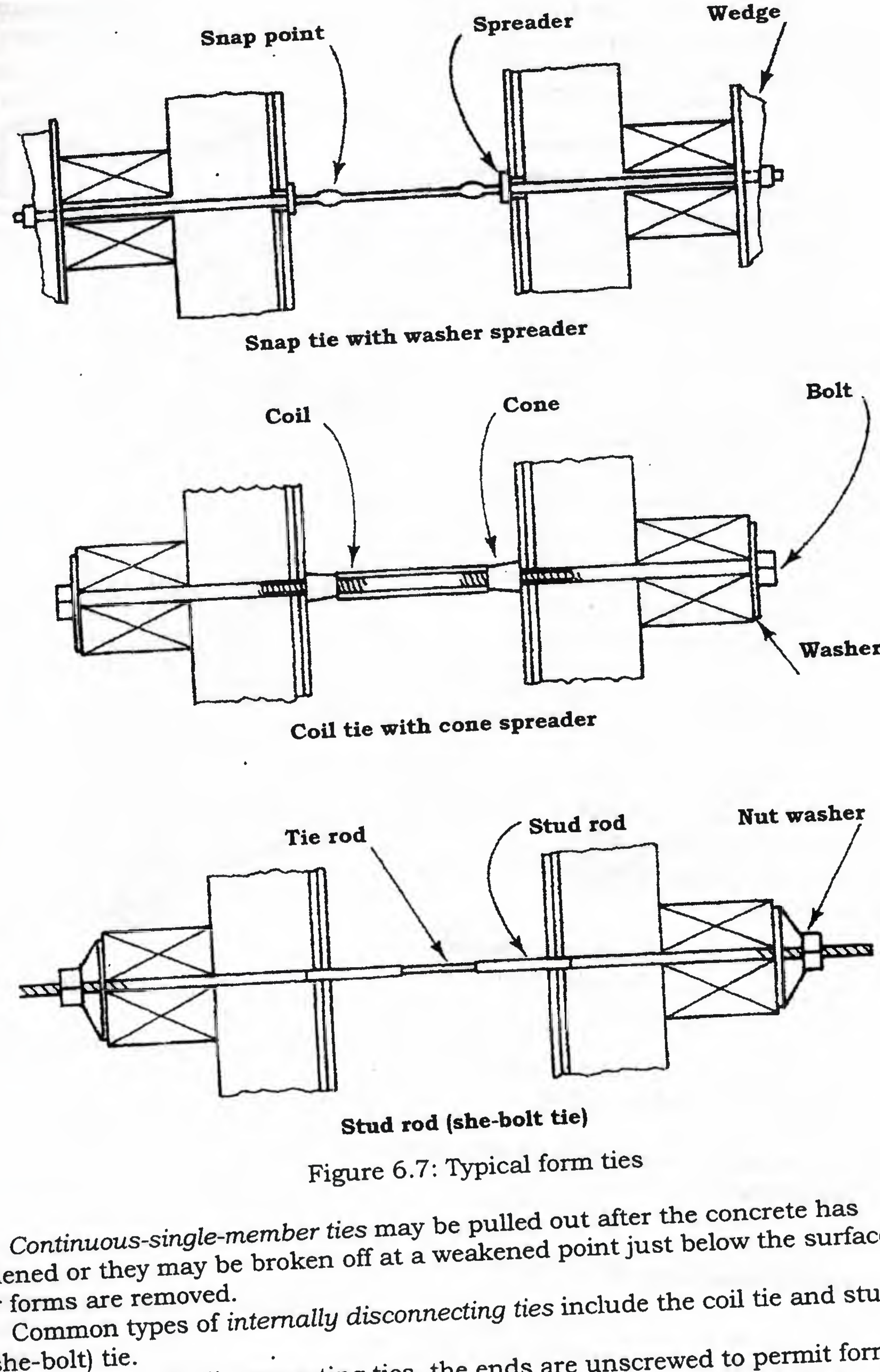


Figure 6.7: Typical form ties

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.

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 6-8. 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. 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 6-9 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 6-10.

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

Figure 6-11 illustrates the use of long pans for a one-way joist slab.

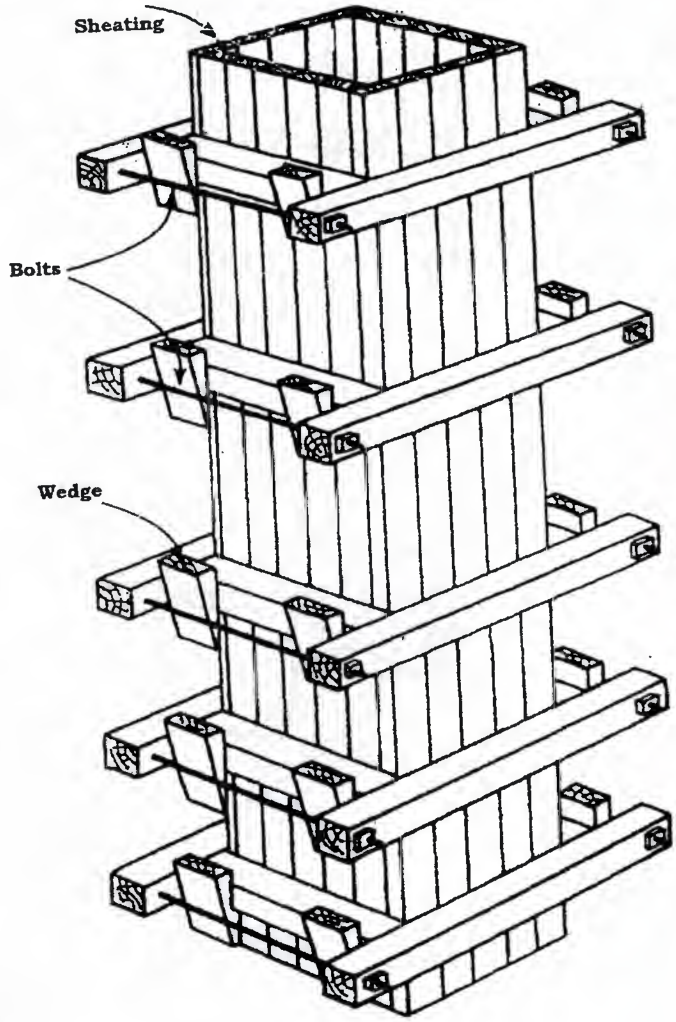


Figure 6.8: Typical wooden column form

Figure 6-12 shows a waffle slab formed with dome pans. Such pan forms may be made of metal or plastic.

Wooden stairway forms suitable for constructing stairways up to 1.00 m. wide are illustrated in Figure 6-13

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.

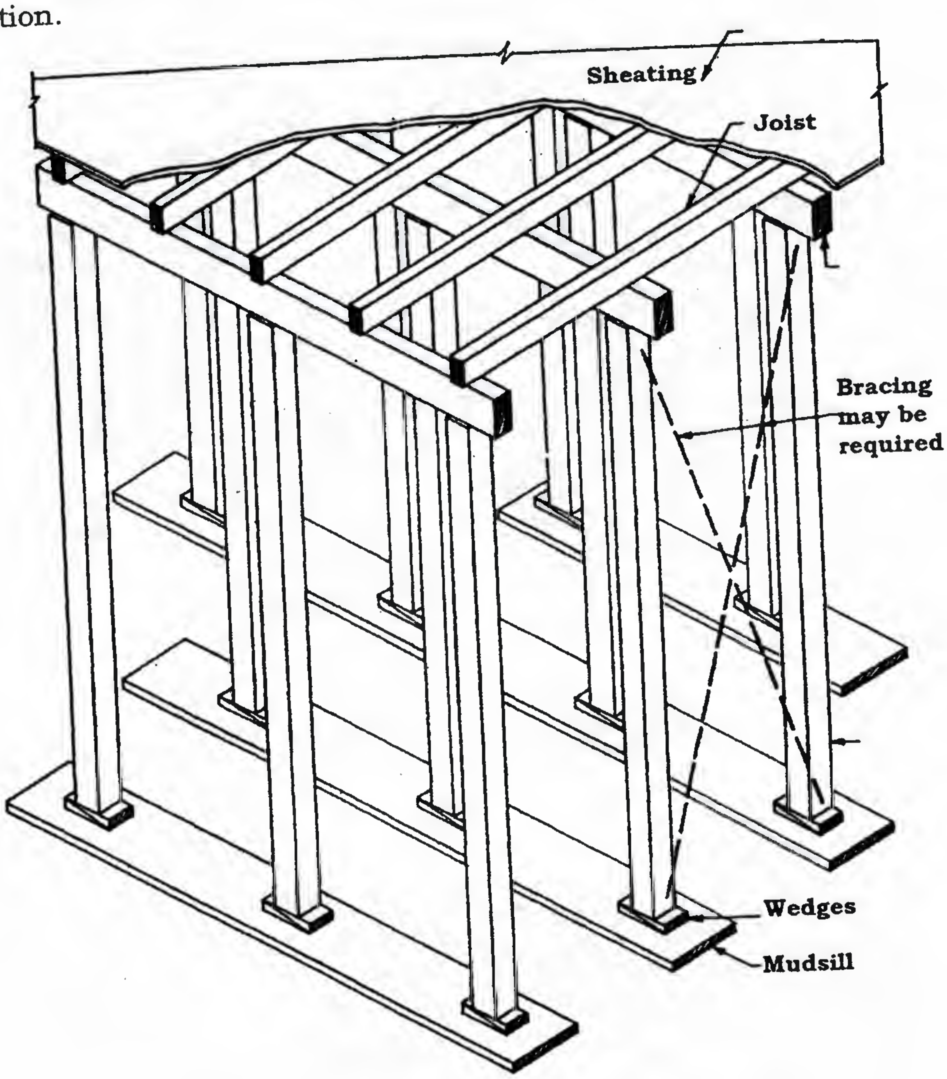


Figure 6.9: Wooden form of elevated slab

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.

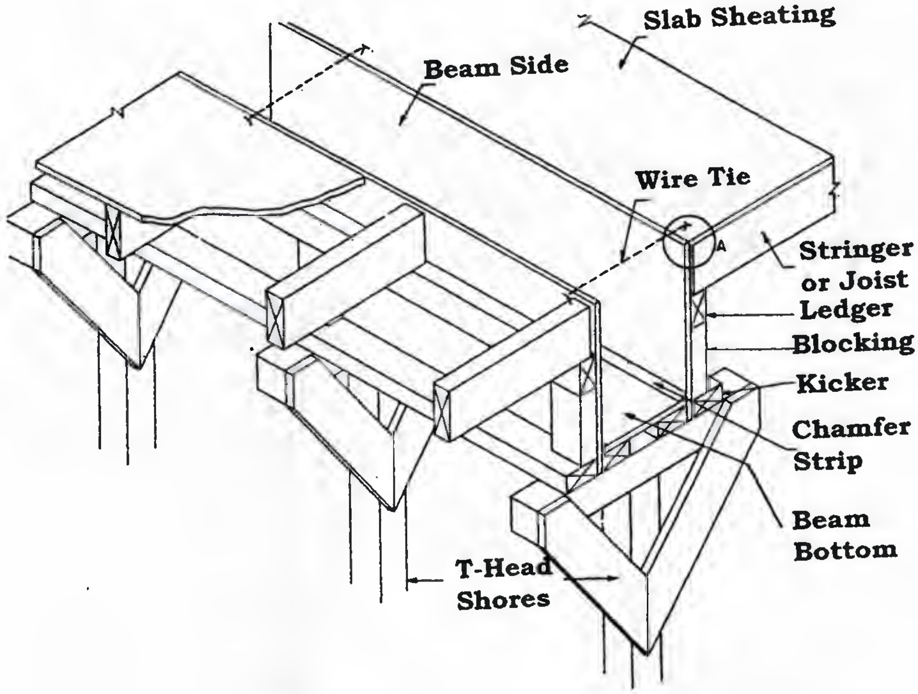


Figure 6.10: Wooden Beam and Slab form

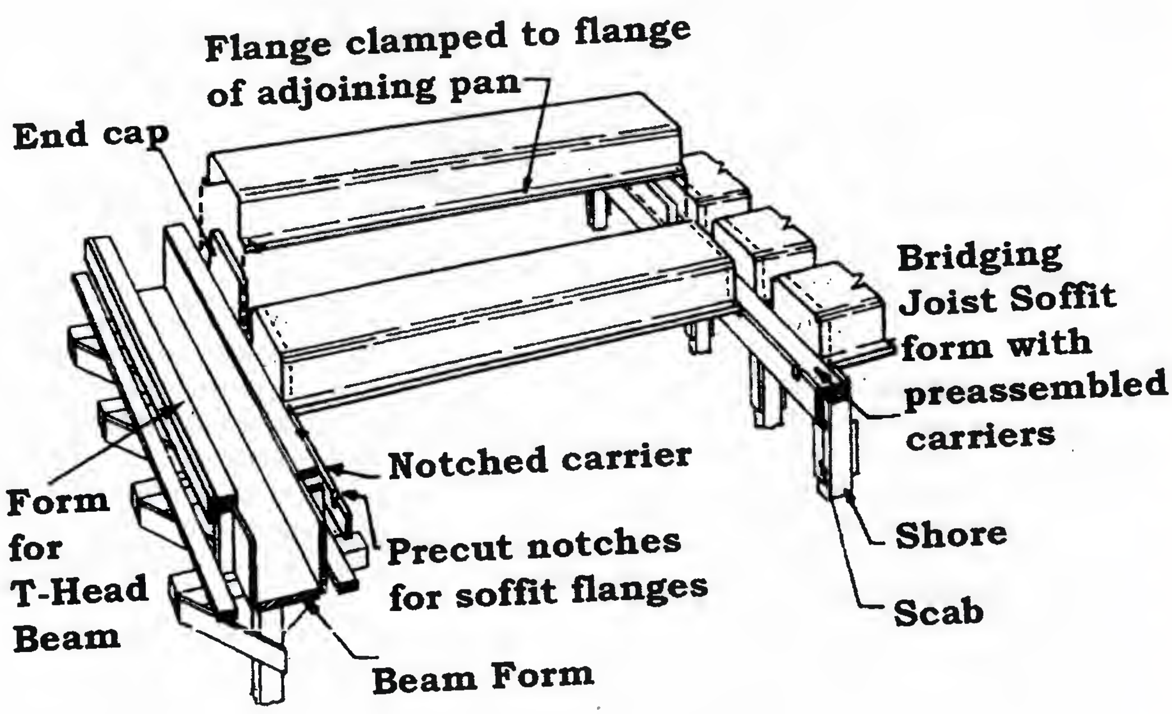


Figure 6.11: One-way slab form

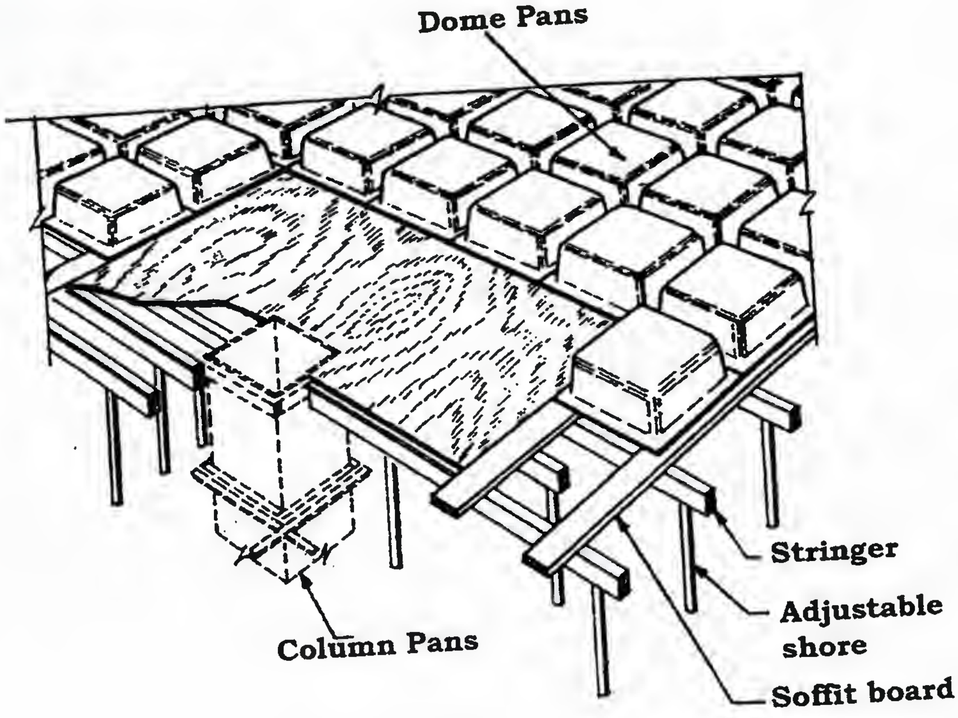


Figure 6.12: Two-way slab form

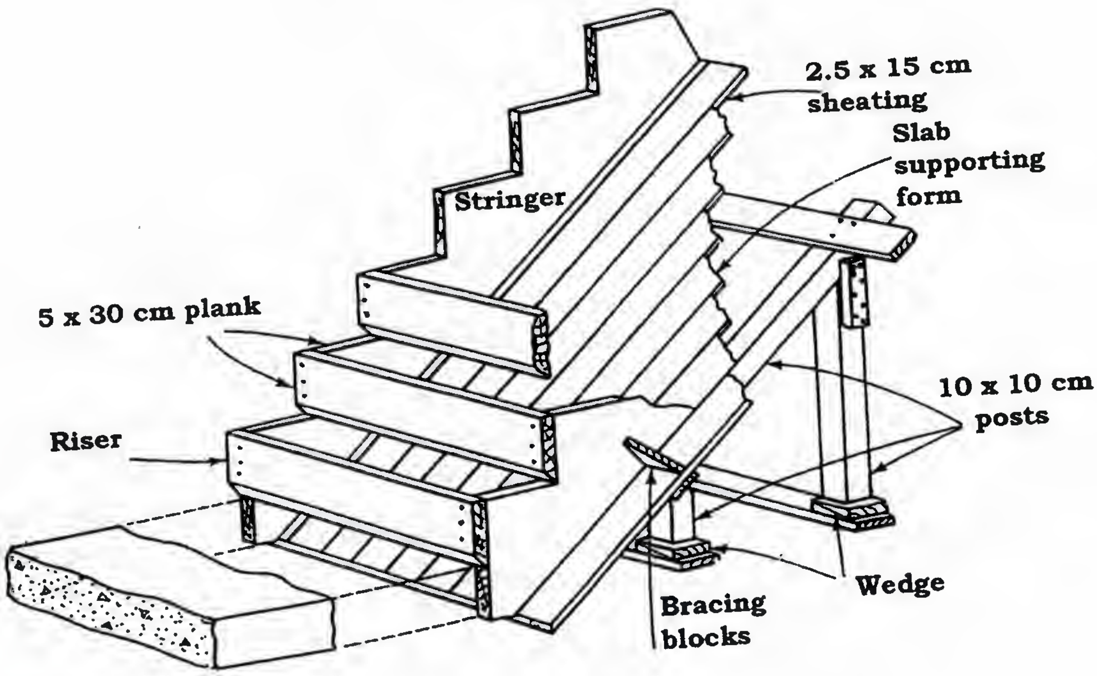


Figure 6.13: Wood form for stairway

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. Typical mudsills are illustrated in Figure 6-14. 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.

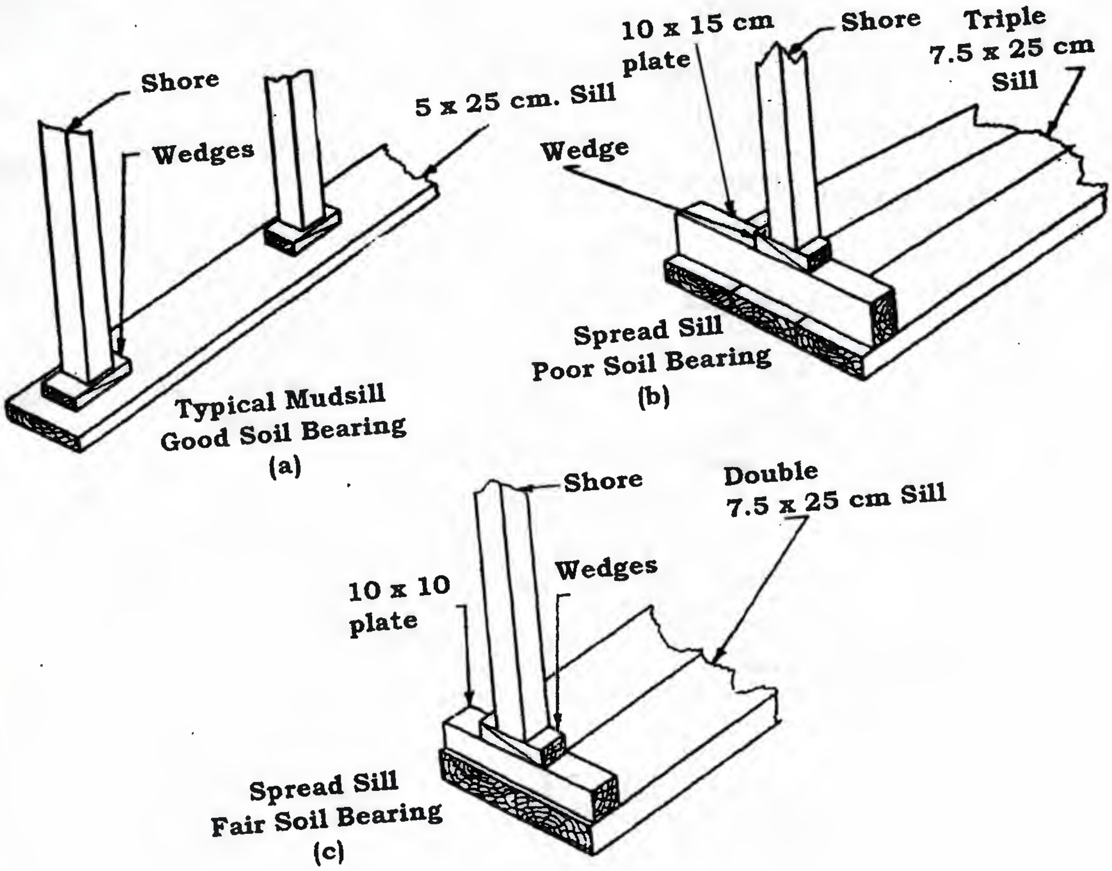


Figure 6.14: Mudsills

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 cies 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.

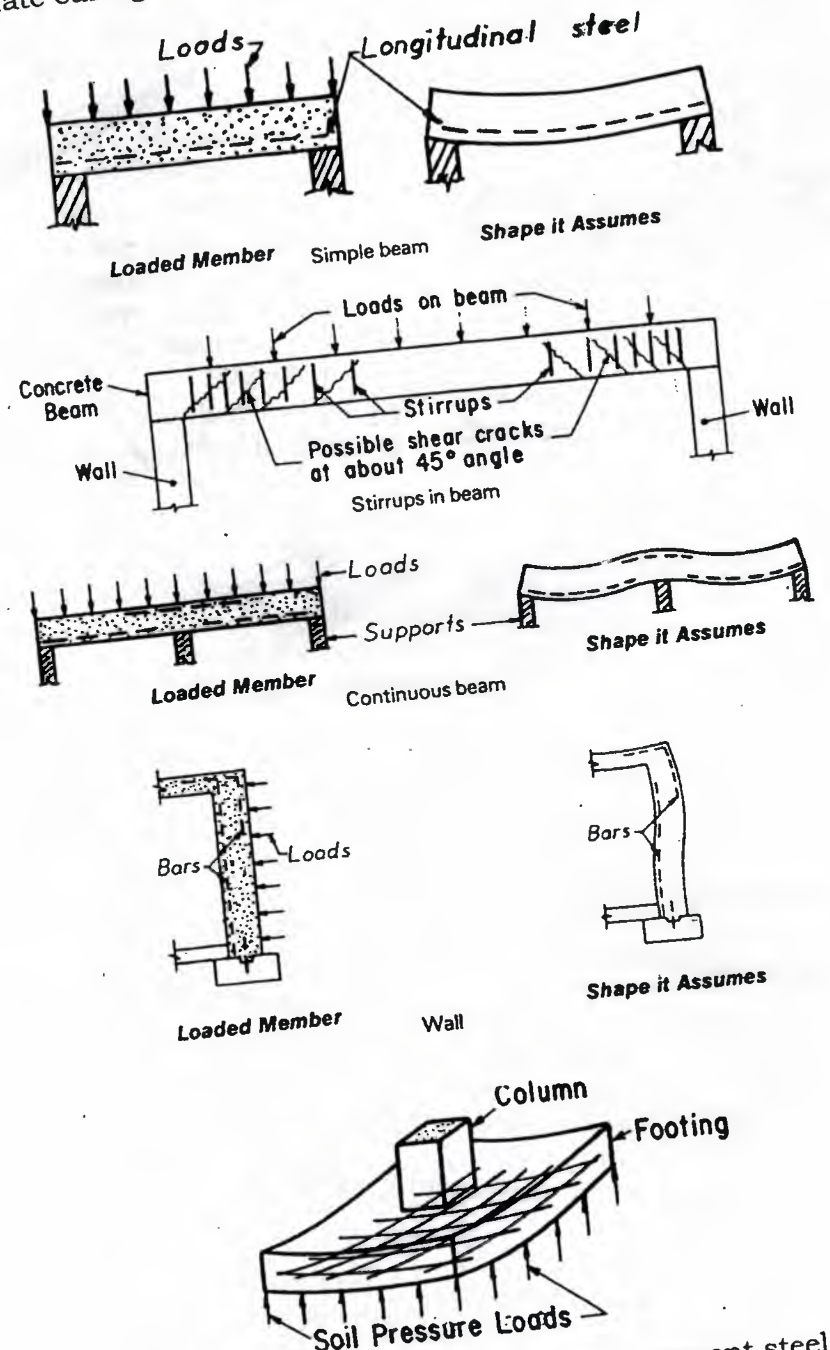
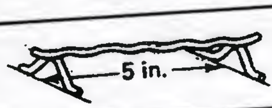
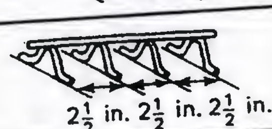
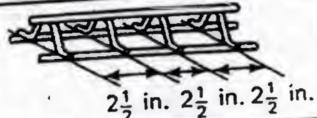
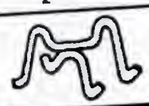
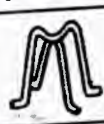
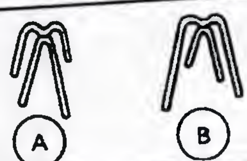
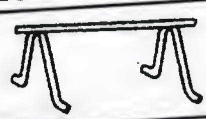
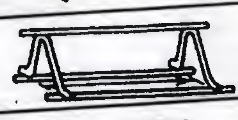
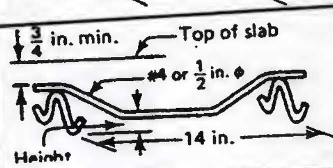


Figure 6.15: Placement of reinforcement steel

Symbol	Bar support illustration	Type of support	Standard sizes
SB		Slab bolster	20, 25, 40 and 50 mm. heights in 1.50 m. and 3.00 m. lengths.
SBU*		Slab bolster upper	Same as SB
BB		Beam bolster	20, 25, 40, and over 40 to 125 mm. height in increments of 6 mm. in lengths of 1.50 m.
BBU*		Beam bolster upper	Same as BB
BC		Individual bar chair	20, 25, 40 and 45 mm. in heights
JC		Joist chair	100, 125 and 150 mm widths and 20, 25 and 40 mm. heights.
HC		Individual high chair	50 to 380 mm. heights in increments of 6 mm.
HCM*		High chair for metal deck	50 to 380 mm. heights in increments of 6 mm.
CHC		Continuous high chair	Same as HC in 150 cm. and 300 cm. lengths.
CHCU*		Continuous high chair upper	Same as CHC
CHCM*		Continuous high chair for metal deck	Up to 12.5 cm. heights in increments of 6 mm.
JCU**		Joist chair upper	350 mm. Span Heights -25 mm. through +90 mm vary in 6 mm. increments.

* Available in Class A only, except on special order.
** Available in Class A only, with upturned or end bearing legs.

Figure 6.16: Wire bar supports

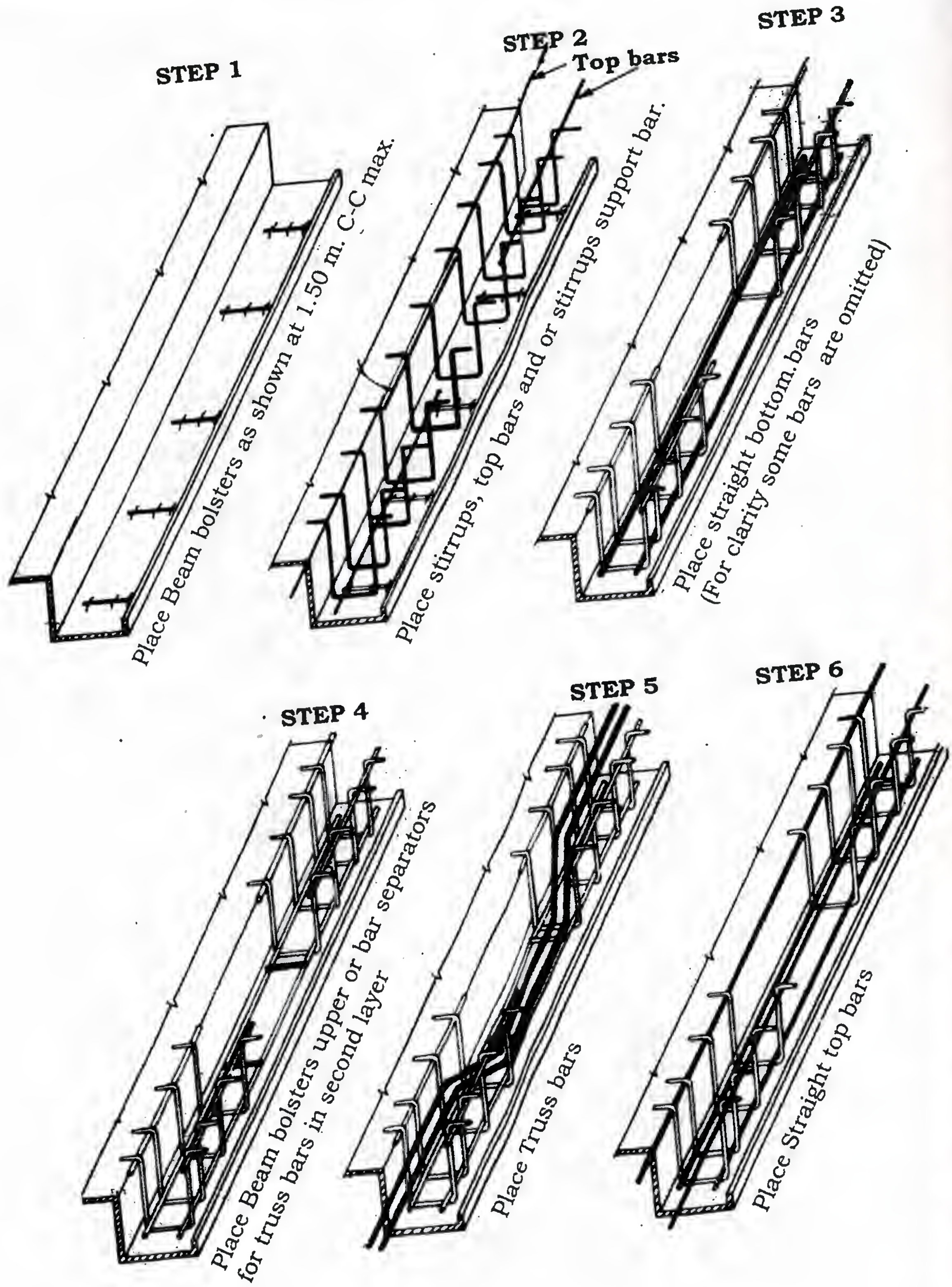


Figure 6.17: Placing reinforcing steel in a beam