

## Module : Contractual Relation and Contract Management

We shall call the group, which is involved with construction as contractor. In the civil engineering project, in a narrow sense, ideas of owners is translated into engineering. Creation by designer/architect and is given real force by contractor. We have a three party system as -

This is the simple model for the party involved in the civil engineering construction. These three bodies are having contradictory objectives, but they work in non-adversary conditions and should help each other.

In the civil engineering project, major activities are - a. Design b. Construction

All the activity and process are to help them. Thus, we can broadly say that design is (shown on the next slide ) -

c. d. Thus, the persons involved in design are involved with the mechanics and properties of materials. We shall call the group of people involved in designs as designer. A designer may be a person or a group of persons or a company.

e. Other engineering creation of designer has to translate into the real facilities. This is process of construction, which is -

f. g. Contractual Relations

h. During the life cycle of projects, various parties come together and work to fulfill objective of the project. We need to know how these parties are communicating to each other and what ways are they communicating among themselves. The first point is called delivery methods or contractual relations and the second issues are termed as type of contracts. The flow of information between various parties involved takes place in many ways. i.e . there are different approaches used to organize the project team to manage the entire design and construction process. Thus we shall discuss various delivery methods. The relations existing between various parties also vary in terms of monetary payment and goods as well as service delivery. These points we shall discuss for type of contracts.

i. The owner needs to know how to communicate with contractor or designer. Designer or contractor can direct report to him or owner can hire a person or company which can help him in fixing, communicating designer, contractor. There are other many possibility such that he can have in-house specialists who can help him in designing or supervising the work. Similarly, owner can pay the contractor or designer based on unit work of execution or percentage of the total cost based on the contractual agreements. In this chapter, we shall discuss the various arrangements between project team and contractual agreements existing between them. We shall also discuss the process of awarding contracts, documents involved.

j. Although the exact nature of arrangement in terms of reporting sub reporting getting feed-back, payments of execution is unique to the particular project, these discussions will help us in understanding particular project team arrangement. Also, we can make our own arrangement depending upon the local nature of the project.

From the degree of freedom point of view we can classify the project as a. Public project. b. Private project. Public project:

As we have discussed earlier, public project consists of primary infrastructure project. Public projects work on fixed sets of guideline fixed by particular department. For example in India, Central Public Works Departments (CPWD) works with their own rules. These are called CPWD manuals. These manuals are well documented and describe what to do when and how. Deviation from these documents needs special permission from apex body depending on the nature of change or sometimes there is almost no scope of change.

Similarly each state government maintains its own contract rules to execute the work. Like Assam public works departments has its own way of doing the things. Similarly Indian railways execute the works based on guidelines fixed by the department. Similar situation are existing in other countries. As for example, US transport department does the work according to its own document. But, there are many points common between their contractual arrangement as well as contractual agreements.

Contracts are selected based on competition bidding. In our country, public project mainly works on minimum cost bidding system. In recent year, much effort

has been paid to improve the low cost bidding system by introducing technical bidding and price bidding separately.

Private project: There are more flexibilities in the private project. Depending on the nature of the project, the owner or project manager can arrange the project team. Whom to select, how to select and what kind of information exchange systems will exist between various project team members is dependent on the owner. Due to these natures, various forms of delivery methods have developed in practice. Owner select the designer or contractor based on the quality and reputation of the contractor plus the negotiated money or competition bidding.

Contractual Relationship or Delivery methods:

We are going to talk about how different member during of project team gets organized during the life cycle of the project or in the process of design and construction in particular, or life cycle of project. The different approaches are called Delivery methods. In general, the relations existing in a particular form follows specific pattern. But we shall discuss major arrangement followed in the construction industry. The following delivery methods cover wide arrange of contractual arrangements

a. Traditional Methods b. Design- construct c. Project management method

a. Traditional Method: In this method, owner acts as overall coordinator of the project. He engages a designer or design firm to design the facilities and also prepare complete set of contract documents. With complete set of contract documents, owner employs contractor either through negotiation or competitive bid. The contractor hired is totally responsible for the delivery of the project. The designer may employ other designer to do the specific work. Such as many designer takes help of other team to do the electrical, . mechanical design in the building project and prepare the structural design in- house.

The main designer works as a coordinator of the design-process. Similarly, the contractor may subcontract out some job to subcontractor. These subcontractors will be directly reporting to the main contractor. There is no formal agreement between contractor and designer. Owner himself oversees the quality control. Sometimes designer may get involved in overseeing construction work depending upon the owner need.

Thus we can see, for large project, owner needs to maintain an engineering department to hire designer and contractor and oversees the work. There are many variations of these arrangements. Owner may have their own design group and hires only designer for specific jobs or owner can subcontract the jobs himself and oversees the project, such as award the contract of piling for one company and superstructure to other company. A typical government organization in India such as Central Public Works Department (CPWD), irrigation department works with this pattern. IIT construction work is generally carried out by this method. A typical relation is shown in the figure , on the next slide.

The ways fees are paid to contractor or designer depend up the type of contract. We shall discuss this point later on. It may be unit price, percent of cost or lump-sum etc. depending on the nature and agreement in the project. We shall now discuss the advantages and disadvantages of this contractual agreement.

Advantage:

a. As the owner receives complete set of drawing and specification of the work, he gets the fixed price of the project. He can award the contract in any type of contract; he will have good idea of the cost of project.

b. This system is followed in public sector project. Owner, designer, contractor works in the fixed frame work. They might be working many projects. Generally well-documented are available for different process. CPWD maintains well documented procedure.

c. Competitive bidding is easy to implement as complete set of contract document is available before construction starts.

d. Owner need not to worry about day to day activity of the project. He gets involved only at the specific points.

Disadvantage: a. Contractors and subcontractors have no input in the design. Material or methods specified may not be available or contractors have knowledge of efficient methods and materials.

b. It is difficult to have overlap between design and construction phase. So fast tract construction may not be possible.

c. Sometimes there may exist different interpretations of contract document by owner and contractor.

d. The change in the methods or material of construction may give rise to conflict. Unforeseen changes are difficult to implement.

#### Design-Construct

In this method of delivery, design and construction is carried out by the same company. The company may be a single unit or joint venture of two companies or more than two companies. A single company can take a job for design and construction, but the company sub-contract or contract the construction, but engaged himself in the management of construction. There are different variations available for this mode of delivery. But common point is that the same company takes the job from conceptual design phase to construction and implementation. The variations of this mode are turn-key project.

#### Design-manage

This method of delivery has been practiced in the specialized job in industrial sector. Petrochemical industry, manufacturing plants, nuclear plants, offshore oil drilling platform. In IIT Guwahati, air-conditioning was done by "Blue Star" as design-construct methods. This method has also been used in building project recently. A typical relation is shown in figure.

4. Owner is not aware of the construction and design. This lack of knowledge may be handicapped during maintenance phase.

5. In the traditional form, owner monitors the quality of conformance with the design document. But in design-construct method of delivery, there is no standard for the owner to check and monitor.

6. This arrangement doesn't guaranteed the best possible price.

#### Project Management Method

There are many variations of this mode of delivery. Some of these variations are program management; construction management, professional construction management. In this method of delivery, owner hires a construction management firm at start of the project and involves them in the project from conceptual design through implementation [start up]. The degree of involvement of the construction management firm depends upon the expertise and requirement of the owner. Owner may involve the management firm to select designer, coordinate the work between designer and contractor, monitor the constructions. A typical arrangement is shown in the figure, on the next slide.

#### Advantages :

1. It establishes the good communication between design and construction together with the owner awareness and monitoring.

2. Cooperation between different team members increases the value engineering.

3. Designer and contractor can agree on the same coordinated schedules.

4. Many a time, owner is directly involved with subcontractor, thus, getting benefit of competition in terms of price.

5. Unforeseen changes are easy to implement.

#### Disadvantages :

1. Irresponsiveness of any team member can spoil the coordination.

2. Requires owner knowledge about project management.

3. Risks involved during the execution of project is high.

#### Types of Contract

Contract is an agreement between two or than two parties in which one is agreed to provide goods and services to other for which he will get the return in the some form. The contract is legal document and binding on both the parties. The form in which return for providing goods and services is delivered, is called type of contracts. There are different types of contracts which can be employed in any of the delivery methods. Owner can pay the money to the contractor, in lump-sum, based on measured work with unit price, based on percentage plus quantity involved. In the following, we shall briefly discuss the different type of contract.

a. Lump-sum contract: This is a single fixed price contract. In this contract, contractor agrees to perform specified job for fixed sum. The owner provides the

contractor exact specification of the work. In this contract both the parties try to fix the conditions of the work as precisely as possible.

Following are the advantages of the fixed price contract.

- a. Owner is aware of the cost of the project before the project construction starts.
- b. It avoids a lot of details and accounting by both owner and contractor.
- c. Contractor gets free hand to execute the work.
- d. If this contract is used with design-construct method of delivery, contractor gets opportunity to use value engineering.

Disadvantage: a. It is very difficult to accommodate any change in design and specification.

b. This contract is as good as the accuracy of the contract document. If errors exist in the contract document, the contract need to be renegotiated and hence more risk is involved from the owner side.

c. In the case of unforeseen hazard during the construction, contractor may be put in adverse situation.

This type of construct is suited for small job, precisely specified job, low risk with construction job. This is generally suited for the job where it is easy to make the measurement. Lump-sum contract should be avoided for underground work.

Lump-sum contract with design construct method of delivery is often called turn key contract. Payment by the owner can be carried out in lump-sum contract as total amount at time or percentage of total cost after finishing certain amount of work. For example suppose a water tank was awarded as lump-sum contract. It can be said that 15% of amount will be paid after construction of foundation 50 % of total amount will be paid after construction of staging and 80% of the total amount will be after the construction of the tank. Rest will be paid only when the tank becomes operational. Lump-sum contract is often used in sub-contracting for labour contract. In our country many laborers for excavation, plastering work with this method.

b. Unit price contract: In this type of contract, the price is paid per unit of the work carried out. There are different variations of this type of contract. Some of them are mentioned below.

Bill of quantities contract: In this type of contract owner provide the drawing, quantities of work to be done and specification. The contractor bid based on the unit cost of the items of construction. The contractor overhead, profit and other expenses can be included in the unit cost of the item of work. Sometimes contractor quotes the unit price of the work and lump-sum amount separately as profit overhead. The estimated quantities of the work to be done called Bill of the quantities is fixed. Minor variation in the quantities is admissible in this type of contract. The drawing of the work is not suppose to change. Although change and deviations from original drawing could be accepted during construction but even then unit price does not change.

This type of construction is usually followed in government sector for large infrastructure construction. This type of contract provides owner a competitive bid. Disadvantage of the methods are:

a. Owner needs to measure the quantity of work done in the field, hence requires owner presence at the site.

b. Final price of the construction is not known precisely until last price of work is completed. If there is significant difference between the estimated quantities and the reality of the situation, owner is put in adverse situation. Mistaken quantities is called unbalanced bid . Significant unbalanced bid now considered as unethical.

Schedule of rate contract: Many a time, the quantity of work to be executed is not known before. Contract is signed based on the unit cost of the item of work. Generally more items are inserted in the contract than to be executed because it becomes sometimes difficult to exactly specify all the items. There is no guarantee that all the items mentioned will be used in the construction. This type of contract are widely used in underground work, flood control and road constructions. Advantages and disadvantages of this type of contract in the same as the bill qualities contract. There are other variations of schedule of rate contract where unit price plus profit is charged as the cost which we shall

discuss next.

c. Cost plus contract: In this contract, the payment is made based on the work carried out plus the fee which includes overhead, profit etc. Sometimes a cap is put on the type of contract by provided maximum and minimum cost limit such as guaranteed maximum cost contract. If project cost exceed this limit, contractor is responsible for that.

Sometimes incentive clause is also included if the contractor bring the project before certain specified limit.

The advantage of this type of contract is that considerable overlap is provide between design and construction. Hence the project can be executed in the fast-track basis. This contract is suitable for the work where it is difficult to define the task to be done before the awarding the contract.

#### Stages of awarding contract

The stage of awarding construction contract is dependent of the methods of delivery of the project. In the tradition way of delivery, contract documents are prepared after the completion of design. Generally designer helps the owner to prepare estimate of the project. If owner maintains an engineering department, an estimate is prepared by the engineering department. Specification of the items used for construction is very important from point of view of quality of design and quality of construction. Specification is generally prepared by the designers. During the design, designer may take owner advice in preparing specification of the items. The drawing and specification prepared by designer form the basis for the awarding contract.

A tender notice is advertised in the news paper depending upon the type of work. It may be in nation newspaper or local news paper. In a large project, tenders are invited from person/company from any country called the global tendering . A typical tender notice is given in the table. Sometime this process is carried out in two stages. In the first stage the aim is to select the contractor who has good experience of executing the similar kind of job and have required technical competence. The process is called "pre qualification". The contract documents are sold to these pre qualified contractors. Many a time designer himself identifying the competent contractor based on his experience.

The contract document is bought by the contract or by paying some fees.

Contractor prepares their offer and submit to the owner. The offer by contractor to the owner is called Tender and process is called submitting tender. Sometime owner ask to submit the tender in two separate documents. The first offer provides the specification of the item to be used. This is called "technical bid ". And price offer is given separate which is "price-bid".

After getting the tender, owner studies the tender documents, does comparatives studies and awards the contract to the lowest quoted contractor or who has given better technical deal. Sometimes contractor quotes the specifications which are higher or lower than the owner specifications. To get competitive bid, owner may provide this specification to other contractor and ask them to go for price bid. There is scope of using value engineering in this process also.

Thus the complete process of awarding contract can be summarized as follows.

1. Preparation of contract document. 2. Advertising the tender, tender notice.

3. Submitting Tender by contractor. 4. Study of the tender by owner 5.

Clarification regarding conditions or specifications 6. Preparing comparative list 7. Awarding contact

#### Contract documents

Documents related to awarding contract are called contract documents, generally it contains following

i. drawing ii. specification of items iii. general conditions of contract  
iv. general explanation

A tender is the offer by the contractor to the owner to construct and the execute the work according to the drawing, specification (provided by owner or changed by contractor) and general condition of controls.

Finally all the parties involved in the project (owner and contract) sign the legal agreement with respect to well defined intentions. If bidding is carried out with internationally, contract document consists of general conditions of

site, its location local laws regarding labor etc., general condition for execution of the work etc. Missing

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#### Disputes And Arbitration

During the performance of the contract, disputes may arise between the employer, engineer and contractor for various reasons of default in performance, progress payment, rates, time, etc. Negotiated amicable settlement is the endurable, quick solution, which requires mutual trust, cooperation, give and take policy, flexibility instead of rigidity of one's view, and vision for future relations. Unresolved disputes can conveniently be resolved through arbitration, which bears the stamps of law of natural justice, than resolution in court. Again, arbitration cannot succeed unless there is cooperation between contractor, client and arbitrator(s). Many times, when the award received is not palatable to either of the contesting parties, the unhappy party tries to drag on further in court to set aside the award. This defeats the very purpose of the arbitration process. The court does not set aside the award on flimsy ground or sits again for the judgment but on specific grounds. The court may even ask the arbitrator to review his award if any item is omitted. The responsibility imposed on the arbitrator is conduct the proceedings with prudence and diligence and not arbitrarily or whimsically and discharge his responsibilities in a cordial manner. The reasons for setting aside the award has been set out in Arbitration Act, 1940, which has since been modified in Arbitration & Conciliation Act 1996. As per the new Act, the award itself is considered as a decree and it need not be filed in the court. It is final and binding on both parties unless disputed by either party. The tendency to challenge the award should vanish, instead the aim should be to reach a negotiated, agreed, amicable and early settlement. It is hoped that better awareness and acceptance of this method fructifies in future.

Why does disputes arise?

1. There are errors, ambiguities and omissions in the drawing and specification. Also, there is lack of proper coordination during construction.

2. Not complying with the intent of the contract or not adhering to the standards in the performance of work (Quality of conformance problem).

3. Incomplete, delayed, inaccurate response to the question by any of the party in the contract.

4. Unforeseen changes in sub surface conditions.

5. If site condition differs from those described in contract documents.

6. Extra work or changed work order

7. Not meeting schedule by the contractor.

8. Inadequate financial strength on the part of the owner, contractor or subcontractor.

#### Origin of Arbitration

Resolution of disputes through arbitration is an accepted method from time immemorial. China, India and Italy are the first few countries that used this method. British India, from the 18 th century, had regulations on arbitration in Bengal, Bombay, Madras, etc. The first Indian Act of Arbitration was enacted in 1899; The next was the Arbitration Act 1940; The recent one is Arbitration and Conciliation Act of 1996.

#### Arbitration Acts

The arbitration Act, 1940 has been repealed under Section 85 of Arbitration and Conciliation Act 1996. Notwithstanding such repeal, the provisions of the Arbitration Act 1940 still apply to arbitral proceedings which commenced before this Act came into force unless otherwise agreed by the parties, but the Arbitration Act 1996 applies to arbitral proceedings which commenced on or after

the Act came into force.

**Principal Differences In Implementation Of Award**      The principal differences between the Indian Arbitration Act 1940 on the one hand and the 1996 Act on the other regarding the courts powers regarding an award are as shown in Table-1.

Table 1: Principal Differences In Indian Arbitration Act 1940 and Arbitration Act and Conciliation Act 1996	Indian Arbitration Act 1940	Arbitration Act and Conciliation Act 1996
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Power to modify an award if it is on matter not referred to arbitration [S.15 (a)].

Power to modify and award if it contains an obvious error, which can be amended without affecting such decisions [S.15 (c)].

Power to remit the award when the award has left undermined any of the matter referred to Arbitration [S.16 (a)].

Power to remit an award where it discloses error of law apparent upon its face [S.16 (c)].

Power to set aside the award for misconduct, both legal and personal [S.30].

Power to decide the existence and the validity of arbitration agreement [S.33].

Under S.32 (2)(a)(iv), the court has the power to set aside an award which deals with a dispute not falling within the terms of the submission to arbitration;

Power to arbitrator for correction of computation, clerical or typographical errors only.

No power to remit the award the act provides no remedy in case of an arbitrator not deciding a dispute referred to him;

No power to remit the award. No power to set aside.

No power to set aside the award on the ground of misconduct.

Power to decide the existence limited to the question whether the award decides a dispute not contemplated by the parties.

No power to decide if the omission by the arbitrator to decide a dispute which fell within his jurisdiction is valid or not.

Power to decide the validity of the arbitration agreement.

Dr. A.S. Anand, the Hon'ble Chief Justice of India, while addressing a conference on the dispute resolution for Alternative dispute resolution organized by the International Centre for Alternative Dispute Resolution, on 12.12.98, stressed the need to give the Panchayats more powers to set up family courts and conciliation centers in all the districts which will be able to dispense justice quickly and at less expenses to litigants. He maintained that the administrative institutions had failed to monitor the status, substance and pace of litigation in courts. "We have not so far succeeded in developing any effective mechanism for the pretrial settlement of legal dispute with the result that there is a heavy inflow of all sorts of civil, commercial and criminal matters into courts", the Chief Justice said. Sharing the same concern, it is considered that award made under the Arbitration Act 1940 should also be given the same treatment for enforcement as under the Arbitration and Conciliation Act 1996.

#### Module : Estimation and Rate

Analysis(Estimation)

Estimation

General

During construction project planning and implementation, we need to know the quantities and costs of various items required to meet the objective of the project. That is, construction project manager has to anticipate the cost of project. The process of calculation of quantities and costs of various items in connection with the construction project is called an "estimate".

An estimate is prepared by first obtaining the quantity of the items required to complete the project and multiplied by unit cost of the items. Details of the estimate depend upon the purpose of carrying out estimate.

The preliminary estimate should be accurate enough to produce the cost of the project within 10% to 15% variations.

During the life cycle of a project, different parties for various reasons require an estimate. The details and method of estimations depend upon the needs and level of management decisions.

Suppose a philanthropic organization wants to start an academic institute. The organization is interested in knowing how much money is required to be spent. It

can be just calculated from the experience with previous project of similar kind. Such as, 20 thousand money per student has to be invested. If academic institute is to be planned for one thousand students, 20 x 1000 thousand is required. Next level of details may be required is how much money is to be invested on different subheads, equipment, laboratories, hostels etc. Suppose a philanthropic organization wants to start an academic institute. The organization is interested in knowing how much money is required to be spent. It can be just calculated from the experience with previous project of similar kind. Such as, 20 thousand money per student has to be invested. If academic institute is to be planned for one thousand students, 20 x 1000 thousand is required. Next level of details may be required is how much money is to be invested on different subheads, equipment, laboratories, hostels etc. These can be calculated based on knowing the area of construction and cost of construction per unit area. But suppose hostel has to be built based on specific drawing and specification. Now an estimate will be prepared from the drawing and specification using specified rules. This estimates form the basis for contract evaluation by the client.

Similarly when contractor is bidding for the hostel, he will prepare his own estimate such that he can buy the contract, also gets profit from the execution of the project. But during construction period the construction, company has to prepare an estimate for order and supply of the material, also for resource planning.

Thus we have seen from the above example that the estimate of same item of works differs in details based as need of the project implementation. Also the level of accuracy needed for the estimate is dependent on the purpose of estimate. Like estimate for material supply has to be very accurate because storage of material will be the burden for the project. But the accuracy of the estimate to know the total cost to study the feasibility of the project will not be very high.

Different body involved in preparation of estimate can be grouped into following three classes.

1. The owner or owner's staff such as project manager.
2. Contractor's personnel such as senior manager, planner, site management staffs etc.
3. Materials suppliers and contractors

The owner generally employs a project manager/engineer, who helps him in preparation of contract documents. The contract documents require the bill of quantities. Also, owner should be aware of the cost to sell the contract. Thus an estimate is required of various quantities. The owner's project manager prepares these estimates. Tender for the contract in a construction company is prepared by higher management. These management are helped by estimators, site engineers and material supplier to prepare the estimate of the job.

**Challenges in Estimating :** The job of an estimator is not only to calculate the quantity and cost of the material, but to co-ordinate different parties involved in the project or construction in particular. An estimator of the construction company has to get involved with the site engineer, material supplier, instrument (plant) manager and senior management staff to obtain the various details of the cost and explaining the calculation to higher management. An estimator has to understand the project details, study drawing and specification, obtain working conditions, labour and equipment productivity and collecting other data from the site. An estimate also assesses the temporary work at the site such as formwork for concreting, temporary plant for the storage of materials. Virtually, an estimator has to build the project on paper to obtain the right guess.

In the organization, background work for estimation is carried out by higher management and organizations keeps the details regarding unit cost of the items called schedule of rate, productivity, and guideline for basic calculation. The basic calculation is carried out by junior level engineers or assistants.

In preparing detailed estimate, we need to know the following two things

1. Quantities of the items involved.
2. Obtaining cost of the items involved.

Methods of obtaining quantities of the items involved is called quantity



estimate and method obtaining unit cost of the items involved is called rate analysis.

Types of Estimate:

Based on the rigor with which an estimate is prepared, the estimate can be classified as

1. Preliminary estimate.
2. Detailed estimate.

Requirements of preliminary and detailed estimate:

To prepare a preliminary estimate, quantity of work to be planned is measured in terms of unit of person, built up area, extent of work in kilometer such as a preliminary estimate of housing can be calculated based on type of house and number of house to be built. Similar preliminary estimate of highway can be calculated by knowing the type of road in terms of lane or pavement and length of the road.

Preliminary Estimate

Different methods of preliminary estimate can be grouped into the following categories – Time referenced cost estimate    Cost capacity factor    Component ratio/installation cost ratio    Parameter cost

The preliminary estimate is obtained during early phases of project. As the project progresses, an estimate keeps on getting refined and lastly we get definitive estimate.

i. Time referenced cost estimate – If the cost of construction of facilities is known at a certain time, the present cost can be estimated by multiplying it with the cost index, with reference to that time. Generally government finance department publishes cost index based on depreciation, etc. But this cost index is very crude. Construction department keeps the cost index based on the items and method of construction used. There are some limitations of such method. During the time, technology changes; productivity of various equipment may change; degree of competition may be different. One should be aware of all these factors while using the cost index to estimate the constructed facilities.

ii. Cost capacity factor – This factor refers to the change in cost of built-up facilities with the change in size of the project of similar type. If  $C_1$  and  $C_2$  be the cost of facilities to be built and old facilities. Let their size be  $Q_1$  and  $Q_2$ . We can calculate the cost of the new facility as

Where  $x$  is called the capacity factor. Many organizations publish the value of capacity factor. It is reasonable to consider cost capacity factor between 0.6 to 0.8.

The capacity factor method and time reference method can be combined.

iii. Installation cost ratio – In the industrial project, the equipment to be installed is known quite earlier to the details for their installation. In such situations, an estimate is prepared based on the ratio or percentage of the cost incurred as the installation cost. The organization generally maintains this type of data. Example- The cost of an equipment is Rs10,00,000, and its installation cost, including accessories is 50%. Thus the estimated cost is  $10,00,000 + (0.5 \times 10,00,000) = 15,00,000$

We can consider the equipment in component wise and calculate the installation cost individually. This approach will require detailed information, but will be more accurate.

iv. Unit Parameter cost – In many of the projects, it is possible to obtain the cost of unit parameter of construction. These parameters may be unit area, unit volume, etc. This type of procedures are used in building construction.

Residential apartment in our country are generally estimated using this method. There are different variations of the method. Some of them widely used are as follows – Residential buildings are generally estimated using this method.

Requirement for detailed estimate: To calculate the detailed estimate, complete structural drawing of the facilities to be built up and specification of the items are necessary. We also need to know the rate of each of the items, which includes profit of the contractor.

Revised Estimate:

Due to change in the rate of material or change in specification of materials, an estimate is often required to be modified. Thus, we prepare revised estimate against the original estimate. In the preparation of revised estimate, original estimate is also provided such that comparison can be made. There is no change in structural drawing and additional items are not added in the revised estimate.

Revised estimate is a detailed estimate. It is also accompanied by the original estimate for comparative purpose. While submitting the revised estimate, the reason for revision should also be stated.

Supplementary estimate: During the execution of project, structural modification are required or addition work is added for construction. The estimate for additional work is called supplementary estimate. Supplementary estimate is also required to be prepared when some of the items are overlooked. In preparing the supplementary estimate reason for preparing the estimate would be clearly stated.

Example: Additional partition can be planned in the building. The estimate is prepared for partitioning as supplementary estimate. Structural / architectural changes are prerequisite for supplementary estimate.

### Rate Analysis

At various stages in the project management, we need to know how much is cost of executing unit amount of the work how many equipment or labour are required to execute unit amount of an item of work. These things are required for the purpose of eliminating cost of construction, material planning, labour and equipment allocation in the scheduling etc. Obtaining the cost of unit amount of an item is called rate analysis. To obtain the rate of an item, generally following cost are considered.  
cost of material    cost of labour    cost of equipments, plant tools etc.  
overhead cost    profit

The costs of these components are determined from the area survey, schedule of rates published by central and state government; transportation charges based on the location of the area. Also we need to know how much is required for execution of the work. Similarly number of labour and equipment. These things are based on both the heuristics and engineering design. Not only specification is important for obtaining the cost of the work, but one has also to include quality mentioned during construction we shall discuss this pointing detail through case study.

a. Cost of material – To obtain the cost of material in the unit amount of an item, first specification is studied carefully. Quantity of material required is calculated and multiplied by the cost to obtain the unit cost. Cost includes freight, transportation, sales tax, insurance, as well as profit. An estimator has to do his market survey and the area survey before calculating the unit cost of the material.

b. Cost of labour – Productivity of the labour is very important aspect in calculation of labour cost. Productivity of the labour depends upon the type of work, training imparted to the labourer, nature of work, time schedule of the work, etc. For example, a mason can do more plastering standing on the floor than working at a height on the scaffolding. Initially, it takes time to learn the work and gradually productivity increases, which is shown by the learning curve as follows –

For specific works, different types of labourers, such as skilled and unskilled labour, mason, carpenter, mazdoor, etc are required to execute the work. Unit amount of work is obtained based on experience; and their cost is obtained from the local survey or government wage rules.

c. Cost of equipment - Calculation of work-hour used for equipment is dependent upon the type of equipment utility. Some equipments are used for specific purpose where as some of it are used for different work simultaneously. Generally equipment used individually is calculated for each item of work. For these equipments, it is not possible to calculate the cost; the equipment charge can be added as overhead. For example, installation of a batching plant requires

special effort and it is not easy to distribute its initial cost on the concreting. We can incorporate such kind of work as establishment charges or overhead.

d. Overhead cost – During the period of construction, a company has to maintain an office or depreciation of its equipments may take place. This is usually taken as 2-5% of unit rate.

Part of the overhead is directly related to the construction of an item of work. Such expenses include –

- i. Repair and depreciation of tool and plants
- ii. Salaries of supervisors, etc; who are indirectly involved in the work
- iii. Temporary godown and sheds to store the material at the site
- iv. Lighting arrangements
- v. Labour welfare
- vi. Safety scheme
- vii.

Small tools used for work

Such expenses are incurred only when work is under execution. If there is no work, no expense is required.

Other parts of overhead are permanent in nature. These expenses are throughout the year. These expenses include –

- i. Salaries of office staff,
- ii. Printing and stationary charges,
- iii. Electricity and rental charges,
- iv. Communication expenses such as telephone, e-mail, etc,
- v. Traveling, etc.

In bigger companies, these expenses are higher compared to smaller contractors.

#### Measurement In Civil Engineering

Measurement of civil Engineering work executed in the field is carried out based on thumb rule. Indian standards provide the approximate rules to measure the quality in the field. They are comprehensive and follows almost all areas.

Following are the list of Indian Standards –

Indian standards

Standard Description

IS 1200 : Part 1 : 1992 Methods of measurement of building and civil engineering works: Part 1 Earthwork

#### Measurement Book

Measurement is entered in the table. Every department maintains its measurement book. A typical page of measurement book is shown on the next slide –

#### Project Planning

In the process of planning , alternatives are examined and the best alternative is chosen. The goal of planning is to minimize resource use (cost) while satisfactorily completing the task . Efficient use of equipments , material , labor and ensuring coordinated effort are the basic aim . The outcome of planning is predetermined course of action. Thus, the planning creates an orderly sequence of events, defines strategies to be followed in carrying forth the plan and describes ultimate disposition of the result. Putting the various activity of the project in the sequence on the time frame is the process of scheduling . Scheduling is required for continuous checking of the project (control), for resource mobilization , to minimize the cost and use of resources optimally. Various scheduling techniques have been employed to plan the activity in sequence in project management . In construction project , bar chart and critical path method (CPM) have been widely used . During the planning process , a manager builds the facilities on paper , thus identifies each of the various tasks and time . During construction , these predetermined course of action form the basis for monitoring and the checking the progress of the work . Following steps are followed during planning , scheduling and control .

- a. Identifying and defining activity,
- b. Defining activity interdependence ,
- c. Estimate time and resources for each activity ,
- d. Constructing the network,

- e. Calculations on network for project time , earliest start and finish of activity, resource requirement, etc,
- f. Project control and project review .

a. Identifying the activity : Activity is well defined task which consumes time and resources . The identification of activity depends upon the level of details and the requirement of management . Different levels of leaders requires different detail in the project planning . For example , the cost of beam can be an activity in building construction or it can be further split into different

activities such as bar scheduling , making form work , concrete mixing and casting , curing the beam etc . Generally tasks to be performed in break down using ①Top-Bottom Design② . The work break down structure (WBS) forms the useful tool to identify the activity . The outcome of this phase is the complete list of activity to perform the project .

b. Defining activity interdependence : In this step , each of the activity is considered . It is argued which activity will succeed the activity under consideration. Thus, we obtain the immediate succeeding activity or immediate successor . This way of thinking is called forward planning. We can also think which activity will precede the activity under consideration and similar manner we can prepare immediate precedence list. This way of thinking is called Backward Planning Outcome of this step is list of activity together with immediate preceding or succeeding activity.

This step is carried out by most knowledgeable persons of the team . Generally these steps are carried at the senior/experience persons in the department or contractor's company .

In this condition, cost of the activity generally goes up. The relation between cost and the duration is given as follows -

Many a time the base curve approximate as linear as shown below -

These time-estimates are used in the time-cost optimization , in the critical path method . We have specified the relations between resource as cost which can be worked out separately .

i. PERT time estimate : In this technique , it is assumed that the activity durations follow a stochastic duration . Generally , - distribution is assumed in the model . To specify the procedure , following three activity durations are chosen -

a. Most likely time,    b. Most optimistic time, c. Most pessimistic time.

d. Most likely time : This time is the time when activity has more probability to occur than any other activity . This is the tallest pick in the probability distribution, i.e. mode .

e. Most optimistic time : This time has 95% fastest occurrence than the occurrence of any other activity. This is the shortest duration assumed .We mean here is that optimistic time has 19 times fastest in every 20-occurrence time.

f. Most pessimistic time :This time has 95% slowest occurrence than the occurrence of any other activity . This is the longest duration assumed .We mean here is that pessimistic time has 19 times slowest in every 20-occurrence time. Based on the above time estimate, the average time taken for the completion of the activity or job is called expected time. Taking weighted average, we can obtain the expected time as -

This result has been derived considering - distribution and weighted average as one .

The expected time of an activity in series can be summed to calculate the total time as -

Frequency distribution of activities -

Estimation of resources : In order to estimate the resources , the project manager must consider the efficiency of the machine , productivity of labour , learning process , site conditions , impact of weather . For example , person at floor level can do more plastering than standing on the scaffolding . Similarly a person's efficiency is less at the start of the work and increases slowly and reaches the saturation level following the learning curve as shown -

The above curve is called the learning curve . All these points should be taken into account while planning resources .

d. Construction the network : In the critical path method , network is a directed graph . A directed graph is a structure formulated by nodes , which are tied by directed arrow .

Let be the set of nodes , and be the directed arrow

The graph of the activity network is represented mathematically by the symbol  $[N, P]$  .

There are two logic diagramming formats used in CPM - i. Activity on the arrow (AOA) ii. Activity on the node (AON)

iii. Activity on the arrow (AOA) : In this format , activity is denoted by the arrow and nodes merely serve as connecting points for the activity . We often require to use activity with zero time called dummy activity to retain the logic and grammatical rules of the network . The network is constructed on the logic that an activity leaving a node cannot begin until all the activity heading into that node have been completed . This diagramming format has widely been used .

ii. Activity on the node (AON) : Now-a-days , CPM users employ activity on node format and many of the softwares also use this diagramming format . This format is also referred to as "Precedence Diagramming" . In this format , logic in the network is represented by node and precedence arrow . The precedence arrows show the order sequence and relationship between activities . The logic behind the network diagram is that an activity cannot start until all preceding activities are complete .

The logic network simply represents the relationship between the activities , provides project understanding and improves communications . The network is constructed without considering the activity duration or the resource requirement of the activity .

With the advent of computers , this stage has lost its earlier significance . Now there are many softwares available , which provide the network if succeeding activity/preceding activity lists are fed .

f. Calculation on Network : In this stage , the earliest start , the earliest finish time , latest start time , latest finish time , critical activity , optimization for time-cost , resource planning through the network , etc , are carried out . We shall illustrate these calculations through examples .

Examples to be given

Project Control and project review : The planning is pre-construction activity . The schedule of the project tells the project manager how to arrange the various activities and what resources will be required at a particular instant of time , and how much progress is to be expected . During the construction phase , the schedule serves as the yard-stick to check whether the project may be ahead of plan or behind the plan . If it is behind , then network schedule also helps for further resource mobilization .

Activity Time In the network, it is important to know the criticality of the activity, time available to perform the activity provided date of completion of a project. In the previous section we have already talked about various method of obtaining activity duration. We shall be interested in the question that

1. How early we can start the activity. 2. How much we can delay the activity such that target date of completion of project is not affected

3. What the time available to perform the activity.

To answer the above question we shall associate (define) following time with an activity

a) Early start time b) Early finish time c) Latest start time  
d) Latest finish time

a) Early start time: - It is the earliest time by which an activity can started.

Let  $t_{ij}$  be the activity between events  $i$  and  $j$ . Let  $T E i$  is the earliest expected time of the event  $i$  then

Earliest start time is equal is to  $EST = T E i$

b) Earliest finish time: The earliest finish time of an activity is the time by which an activity can be finished earliest. The earliest finish time of an activity is earliest start time plus activity duration.  $EFT = EST + \text{activity duration}$

c) Latest finish time: The latest finish time is the time by which an activity must be finished such that completion of the project is not delayed the latest finish time of an activity between events  $i$  and  $j$  is the latest allowable event time of  $LFT = T L j$

d) Latest start Time: The latest start time is the time by which an activity must start such that completion of project is not delayed. The latest start time of an activity between events i and j is latest finish time minus activity duration.  $LST = LFT - \text{activity duration}$

Float: In the last reading we have discussed that in the project with art interested in time available to execute particular task(activity) during the project period. We shall introduce the concept float which tells us how much an activity can fluctuate without affecting the completion of a project. We shall introduce following float

a) Total float. b) Free float. c) Independent float. d) Interfering float. a) Total float is the maximum time available during which an activity can fluctuate. It is maximum time available minus activity duration. The maximum time available in the difference between latest finish time minus earliest start time. Maximum time available to execute the work =  $LFT - EST$

Hence

total float = maximum time available - activity duration

$$= LFT - EST - t_{ij} = LST - EST$$

b) Free float: - Free float is the time available to fluctuate the activity without affecting the succeeding activity. The mean of without affecting succeeding activity is that the activity must finish before the earliest occurrence of the head event.

Time available =  $T E i - EST$  Free float = Time available - activity duration =  $T E i - EST - T E ij$

Free float =  $T E i - EFT$

c) Independent float: - It is the time available to fluctuate if the preceding activities get completed as late as possible and succeeding activities get started as early as possible.

$$\text{Hence time available} = T E i - T Li$$

This is the minimum time available to execute

Independent float = Minimum time available - activity duration =  $T E i - T Li - T E ij$

d) Interfering float is defined as difference between total float and free float.

## Event

Event is the important point (mile stone) during execution of particular work or task. Many a time we only are concerned about commencement or completion of the task. Event is defined as start or end of an activity or activities. Thus, event is followed by more than one activity. In this case event is marked by completion of all activities or start of any one of the activity.

Example: -

1. Start of plastering is an event. 2. Completion of excavation for piping layout is an event.

3. Start of floor tiles is an event. 4. Giving power supply to fan and light.

Event is characterized by completion and start of an activity. We can defined

a) An event is said to occur if all the activity leading to it has been completed.

b) An event is said to occur if any of the activity has started.

During a project, project manager needs to know following two questions

a. How easily he can start any particular activity? b. How late he can delay such that project does not delayed?

We shall define following two times associated with an event.

a. Earliest expected time. b. Latest allowable occurrence time.

Earliest expect time: The earliest expected time of an event is time which tells the event can not occur earlier than this time.

If is the expected occurrences time of an activity between event i and j and and is the earliest occurrence time of the occurrence of this event then earliest occurrence time of occurrence of the event j is related to that of event i as = +

If there are many activities leading to the event j then earliest expected time of j is  $=\max( + )$  for all i

The latest allowable occurrence time is the late occurrence of the event such that schedule of the project is not disturbed. The time tells us how much the event can be delayed such that project will be completed on time. Let us consider an event i and j connected through activity i-j as

Let and be the latest allowable occurrence time of event i and j. is the expected time of activity i-j. Then the latest occurrence time of i is related to the latest occurrence time of j as

= -

Thus we can see that latest allowable occurrence time of an event has to be calculated starting from completion event of the project in backward direction. This is called Backpass.

If suppose a number of activity starts from an event then the latest allowable occurrence time is the minimum of the time calculated from all the path. Earliest occurrence time and latest occurrence time is shown in the following figure-

Let completion time of project is 32 days. The latest allowable occurrence time is shown in box

The earliest expected time of an event is shown in box

### Solved problems

#### Quality in Construction

Quality in construction is defined as 'meeting or exceeding the requirement of client/owners. In construction industry, quality is used in different every than the product industry. In the product industry, quality of some product is better than the other, but we can not say that one grade of concrete. Quality in construction is employed with conformity with which specifications are met. Designer specifies the grade of concrete to be used and contractor has to use the in gradients of concrete such that desired grade of concrete is obtained.

Quality in construction is related to

satisfying the specification mentioned in the contract completing the project time. Fulfilling the owner's requirement within budget

Avoiding disputes claims and Ensuring the faculties performs its intended purpose.

We use certain product in the construction industry such as tiles, brick.

Quality of these products can be partially related with the general connotation of quality. Other aspect in quality has slightly different meaning at various stages of life cycle of product such as at design stage or construction stage.

Quality schemes involve economic studies of selection of types of material and methods to be included in design, ensuring that this design is in accordance with all applicable codes and regulation and controlling the construction on the project to be sure that the work is performed according to the standards specified in the contract documents. Method to be adopted may vary from the automated documented through computer to statistical quality control in the field.

#### Quality Assurance

Quality assurance is referred as a scheme adopted by a construction company to maintain the standard or quality consistent. It is primarily an internal management system of a construction company. Generally a company maintains a quality assurance chart by specify various checks at different levels as well as constantly improving its attributes. A quality assurance program may include Arranging periodical training for its worker

a good safety Programme a sound procurement system to get best quality material and suppliers A reward scheme for innovative work and competitive career progress scheme

If a company is involved in repetitive work, then implementations of statistical control of the process. Such as in concreting, regular sampling scheme control the production of concrete. Similarly in asphalt work, regular satisfied

quality control is carried out.

#### Quality Control

Quality control is the periodic inspection to ensure that the constructed facilities meet the standard specified in the contract. It is usually carried by team of owners engineers or its morning. As for example, in a high way project, engineers check that compaction of soil is carried out properly by measuring its density; workability of concrete is checked by employing slump test etc. or checking compressive strength of concrete at periodical level.

Quality assurance is good management scheme whereas quality control is an inspection or sampling process.

Government works is generally carried out using lowest bid system. In lowest bid system, high quality work carried out by contractor does not play a major role rather price quoted by them is an important criteria.

The procedure for selection of contractor affects the quality control in the construction. Low bid system hardly provides any incentive to high quality work carried out by the contractor. Government organizations are highly their hard to improve the low bid system.

Quality control includes

- a. Setting up specific standard for construction from the standard
- b. Checking the deviation from the standard
- c. Taking action to correct or minimize the variation
- d. Improvement of the standard.

#### Quality Standardization

ISO 9000 standards fix the standard for quality. ISO stands for International organization for standardization. This organization founded in Switzerland in 1947. Similar standards for Indian context are IS 14000 - 04.

ISO 9000 series of standard are quality assurance standard that assures client that the organization having obtained the certification works according to specified requirement.

It stands for system standardization and certification. Emphasis is given to defining and laying down the procedure, process etc in the form of documents. ISO is important because it offers an internationally recognized systematic approach, coupled with institutionalization of the institutes, policies, procedures, record keeping, technologies and resources for managing quality work.

Basic principles advocated by ISO are -

- a. Focus on customer
  - b. Provide leadership
  - c. Involve your people
  - d. Use a process approach
  - e. Take a systematic approach
  - f. Encourage continual improvement
  - g. Get the facts before you decide
  - h. Work with your supplier
- ISO 9000 series standards are - ISO 9000 ISO 9001 ISO 9002 ISO 9003 ISO 9004

#### Elements of Quality

The basic element of quality in construction is

- a) Quality characteristics
- b) Quality of design
- c) Quality of conformance

a) Quality characteristics is related to the parameters with respect to which quality - control processes are judged. Quality characteristic includes strength, colors, texture, dimension, height etc. Example in compressive strength of concrete, usability of concrete in slump , etc.

b) Quality of design:- It refers to the quality with which the design is carried out. It primarily related to meeting the requirement of the standard, functionally efficient system and economical maintainable system.

c) Quality of conformance:- It is referred to the degree to which the constructed facility conformed the design and specification. Quality of conformance is affected by-

- i. field construction methodology
- ii. Supervision
- iii. Inspection

#### Economics of Quality of design

Quality of design is generally evaluated based on economics of quality. There are two aspects of economics of quality design

- a. value addition of quality
- b. cost of quality



With the increase of quality of design, cost increase is exponential but value addition initially increases, but starts saturating at of some point. Hence the optimum cost is arrived when slope of both the curves is same .

The economics of quality conformance is shown in the figure. One can note that with the increase of quality of construction, cost of quality control gets saturated. Thus we can arrive at optimum quality for minimum cost from total cost of the construction. This has been shown in the figure .

IS Code provision for quality control of concrete IS 456 provides the schemes for quality control and quality assurance of concrete , we have reproduced the clauses – Clause 10.1 Quality Assurance Measures  
Clause 10.1.1 In order that the properties of the completed structure be consistent with the requirements and the assumptions made during the planning and the design, adequate quality assurance measures shall be taken. The construction should result in satisfactory strength, serviceability and long term durability so as to lower the overall life-cycle cost. Quality assurance in construction activity relates to proper design, use of adequate materials and components to be supplied by the producers, proper workmanship in the execution of works by the contractor and ultimately proper care during the use of structure including timely maintenance and repair by the owner.

Clause 10.1.2 Quality assurance measures are both technical and organizational. Some common cases should be specified in a general Quality Assurance Plan which shall identify the key elements necessary to provide fitness of the structure and the means by which they are to be provided and measured with the overall purpose to provide confidence that the realized project will work satisfactorily in service fulfilling intended needs. The job of quality control and quality assurance would involve quality audit of both the inputs as well as the outputs. Inputs are in the form of materials for concrete; workmanship in all stages of batching, mixing, transportation, placing, compaction and curing; and the related plant, machinery and equipments ; resulting in the output in the form of concrete in place. To ensure proper performance, it is necessary that each step in concreting, which will be covered, by the next step is inspected as the work proceeds (see also 17).

## 15 SAMPLING AND STRENGTH OF DESIGNED CONCRETE MIX

### 15.1 General

Samples from fresh concrete shall be taken as per IS 1199 and cubes shall be made, cured and tested at 28 days in accordance with IS 516.

15.1.1 In order to get a relatively quicker idea of the quality of concrete, optional tests on beams for modulus of rupture at 72 + 2 h or at 7 days, or compressive strength tests at 7 days may be carried out in addition to 28 days compressive strength test.

For this purpose the values should be arrived at based on actual testing. In all cases, the 28 days compressive strength specified in Table 2 shall alone be the criterion for acceptance or rejection of the concrete.

### 15.2 Frequency of Sampling

#### 15.2.1 Sampling Procedure

A random sampling procedure shall be adopted to ensure that each concrete batch shall have a reasonable chance of being tested that is, the sampling should be spread over the entire period of concreting and cover all mixing units.

#### 15.2.2 Frequency

The minimum frequency of sampling of concrete of each grade shall be in accordance with the following:

Quantity of Concrete in the Number of Samples

Quantity of Concrete in the work , m<sup>3</sup> No of samples

1-5 1 6-15 2 16-30 3 31-50 4 51 and above 4 plus one additional sample for each additional 50 m<sup>3</sup> or part thereof

NOTE - At least one sample shall be taken from each shift where concrete is produced at continuous production unit, such as ready-mixed concrete plant, suppliers and purchasers may agree upon frequency of sampling mutually by suppliers and purchasers.

### 15.3 Test Specimen

Three test specimens shall be made for each sample

IS 456 : 2000

for testing at 28 days. Additional samples may be required for various purposes such as to determine the strength of concrete at 7 days or at the time of striking the formwork, or to determine the duration of curing, or to check the testing error. Additional samples may also be required for testing samples cured by accelerated methods as described in IS 9103. The specimen shall be tested as described in IS 516.

### 15.4 Test Results of Sample

The test results of the sample shall be the average of the strength of three specimens. The individual variation should not be more than +15 percent of the average. If more, the test results of the sample are invalid.

**Total Quality Management ( TQM )** Total quality management(TQM) is a system of continuously improving goods or services . The philosophy was promoted by W. Edwards Deming . A TQM approach is considered as essential to long term survival of the business , such as construction . In the TQM philosophy , everyone in the company should feel involved and committed for quality of products , from top to bottom of the organization . Total quality management provides principles , tools and techniques for cultural changes and continuous improvement . Quality assurance can be considered as part of Total Quality Management . Basically quality assurance is a system of approach which is related to attitudes and working environment of the company . Deming has suggested 14 points for total quality management which are -

1. create constant commitment to the employee for aim and purpose of the company and improvement .
2. Adopt new philosophy to avoid defects .
3. Use statistical quality control and understand purpose of inspection .
4. Practice of business should be based on statistical evidence rather than price tag alone .
5. Improve constantly and forever production and services .
6. Employee training .
7. Teach and institute leadership .
8. Encourage communication and productivity .
9. Encourage teamwork, to work in group .
10. Eliminate posters or slogans with specific improvement methods .
11. Use statistical methods to continuously improve quality and productivity .
12. Remove barriers that rob people of pride of workmanship.
13. Provide education and self improvement for everybody .
14. Define top management commitment for quality .

The basic foundation for total quality management is -

Everyone in the company should understand the mission and vision of the business .

Total management should be highly committed to quality . Continuous training is required .

### Safety Management

Safety is one of the vital issues in the success of the project . Safety programme ensures the worker to be mentally and physically prepared to execute a job quickly , fearlessly and efficiently . Safety is a way of life . It must be part of every individual at every time during performance of any activity .

Working in a fearless protected environment makes the team to be more productive and efficient . Safety is an important parameter to measure a project , as cost of implementation and time of completion of the project . Although every manager , supervisor , worker accept their safety requirement , but it is by-passed by just lip service . Construction is highly accident prone industry .

In India , construction industry is labour intensive , with unskilled and untrained worker . Fatal accidents and minor accidents are very frequent . For example , it has been reported that more than two people died in the construction of dam like Bhakhara-Nangal project .

In out country , in construction work , a large number of inexperienced laborers are employed . They are unaware of the hazard during their work and generally the company hardly make an effort to explain this worker's inherent risk

involved with the job . Medical check-up of the workers is not carried out before engaging them in the construction work . Also , many accidents occur due to the use of improper tools and equipments . Improper methods and processes are used to cut the time of execution. Such as scaffoldings are not properly made , ladders are not checked properly . Many a time poor quality of safety belts are used , which gets broken during accident .

The major causes of accidents in construction industry are due to -

1. fall from high elevation .
2. electrocution .
3. being struck by equipment .
4. being caught by equipment .
5. trench excavation , cave-in .
6. drowning ( bridge and offshore construction ) .
7. Overexertion .

It has been found that more than 40-50% of accidents due to fall from height or fall of an object .

#### Salient Points of Safety Management

It is the responsibility of the construction manager to create safety programs that will prevent these accidents .

The philosophy of the company must be that all accidents are prevented and the actions expected to accomplish that goal must be clearly stated to the employees.

Without a safety plan , a project cannot be described as a successful construction project . The safety should be the highest priority of the company . The company must be committed to the improvement of safety . The safety code of conduct should be communicated to the employees in the company , who should also be made aware of the pros and cons of the accidents. A company with a better culture of safety attracts the right kinds of employees and builds a good , consistent safety record .

During the project planning in the beginning of the work , a unique job-specific safety plan must be developed .

Task specific hazard should be addressed daily .

#### Safety Programs

Safety program should be developed as a culture of the company . It should be at all times , at all places and all types of work . Every employee of the company should think and work about safety . Supervisors and managers play a very important role in safety management . The workers should feel that the safety constraints are for their betterment . A company can develop its own plan and culture .

Some of the major components of a company safety plan should be -

1. First aid equipment should be available and known to the employee .
2. Every employee's need requires personal safety equipment .
3. Formal training program for each employee should be mandatory .
4. Procedures for emergency evacuation of injured employees should be clearly explained and employees should be trained for such situations .
5. Safety record and accident report of the company should be honestly examined .
6. Site visit requirement for supervisory personnel plays a very important role in safety management .
7. Training for all supervisors and the managers should be mandatory .

#### Contract Requirement

The role of the owner in the safety management is vital . The cost and time is also dependent on the safety management . In India , large infrastructure construction is carried out by the government agencies . Safety should be included in the contracts and pre-qualification . It has been observed that construction is carried out by many small constructors , and they do not follow the safety rules properly . That is why the owner and the government agencies can enforce the safety . Their safety plan should be included in the contract i.e. it is a part of the contract and safety performance should be measured against the owner's plan . \

#### Safety guidelines for Personnel Conduct

1. Employees should always wear hard hats , safety shoes , eye protection , ear protection , in noisy areas .

2. Equipment operator should have the license and training with the equipment operation and safety norms .      3. Stay out of dangerous places .

4. One should not work alone on the site , when other employees are not on the site.

5. New employees should make themselves conversant with safety norms from senior persons of the department .

# Safety and health management , are as much a part of an efficient project planning and management as the minimizing the cost of project , completing the project on schedule and maintaining the high quality of construction . Safety and health , cost of the project , schedule and quality are interrelated . They are an integral part of effective project management .

#### Reasons for safety management

a. Humanitarian side : Construction industry in any country is comparatively highly accident prone . The number of fatal accidents , as well as injuries in which workers become disabled or reduced in efficiency , is higher as compared to other industries . The death of a worker , creates a vacuum in the family earning as well as psychological and emotional disruption of the family .

The main purpose of improved safety is to minimize human pain and suffering , to the worker's family or to the worker , that results due to accident or work induced illness .

Loss of a skilled worker is a damage to the construction industry . Skilled workers are scarce and considerable time as well as money is spent on their training .

b. Economics of safety : The premiums for insurance for equipments and manpower depends upon the past safety record of the company . If the accident rate is high , the insurance company has more risk . Thus , there will be higher premiums . If a good safety record is maintained , less premiums has to be paid .

Second point is regarding compensation , to the family of the worker or to the worker himself . If the accident rate is higher , the company has to pay more money .

In advanced countries , the owner also looks into the contractors insurance costs and safety record .

When the indirect as well as the direct costs of accidents and illness are examined , costs associated with insurance premiums and claims settlements are only a small part of the whole . Indirect and impact costs resulting from disrupted production , reduced morale of employee , lower productivity or worker and ripple effects on the interrupted project schedule can be several times the direct costs associated with hospitalization , disability pay , spoiled materials and damaged equipment .

An improved safety management plan reduces these direct and indirect costs incurred due to accidents . It has been pointed out that the expenses in improved safety and health is an investment .

c. Legal aspect of accident : In India , there is not a no separate law regarding the safety of construction workers . But it falls under the labour laws and criminal laws . After accidents , it is reported to the concerned police station . There are a lot of problems due to investigation , regarding the cause of accident , and the compensation demanded to the contractor , owner and even co-workers .

d. Organization problems : Past safety records of the construction company plays a very important role in the employment of workers , getting contracts , pride among peers . It inculcates high productivity , high morale and stronger loyalty of the worker to the organization .

e. Health hazards : Health hazards include those activities which cause problems to life , in long such - head radiation , noise , dust , shocks and vibrations , toxic chemical .

**Implementation Guidelines** Company should prepare comprehensive guideline for different personnel and processes . Following guidelines can be prepared . Behavioral approaches to safety and health - Guidelines for top managers . Guidelines for superintendents of project . Guidelines for foreman manager . Guidelines for workers .

Physical approaches to safety and health -

Education and training in correct methods and procedures . Utilization of safety certified tools in well condition . Use of equipment for personal protection such as hard hats , seat belt , ear plugs , etc .

Good house keeping on job sites .

Frequent and thorough job site inspections by knowledgeable and objective professionals . Incorporation of safety review .

Some of the best research in the area of safety has been done by the construction industry institute at the University of Texas, Houston.

[www.construction-institute.org](http://www.construction-institute.org)

## Earthwork

Soil is one of major construction materials used for the construction of road, embankment , earthen dam. We construct the infrastructural facilities on the soil. Construction engineer has to involve with soil with various object. The process of excavating the soil, transport to the other place and placing it is called Earthwork. Quantities of Earthwork varies from millions of cubic meters to 100 cubic meter. Like in the excavation of open mines to obtain coal require the removal of 200m to 800 m of soil from the top which is a gigantic amount whereas construction of building with spread footing requires few cubic meter of soil .

Earthwork primarily involved the following process.

1. Excavation of soil or shifting of the soil. 2. Loading, transportation and unloading of soil. 3. Placing and compacting of the soil.

Depending upon the quantity of work, site conditions availability of resources these works are carried out by various method and equipments. We shall first discuss the equipments required to execute the various earthwork.

## Excavation

Soils are required to be excavated at site for various purposes . Some of the purposes of soil excavations are -

1. Removal of soil to level the ground . Example , cutting of hill . 2. For filling the ground at other places -making embankments . 3. For making structures such as footing or laying pipes , etc.

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

Commonly used equipments for the excavation are -

1. Bulldozers 2. Power Shovels 3. Scrapers 4. Dragline 5. ClamShell 6. Backhoe

1. Bulldozers - A dozer which is popularly called bulldozer is a self contained tractor power unit with a blade attached to its front . They are used for pushing the materials , land clearing , striping , towing other pieces of constructions , assisting in loading side hill cutting , backfilling & spreading , etc . The amount of material a dozer can move depends upon the size of the blade , that is the amount of material that can remain in the blade .

Dozers can be classified as -

a. Crawler type b. Wheel type

Dozers are generally used for haulage distances less than 50m .

2. Power shovels - Shovels also called power shovels are the hydraulic excavator . In the shovel , a excavation bucket is attached to the hydraulically controlled boom & stick . The bucket moves in a forward and upward direction . The bucket can be swung around depending upon the type of the shovel and load

the soil in the truck. The shovels may be either crawler or rubber tire carrier mounted . They are many variations , depending upon the manufacturers. Its capacity is dependent upon the manufacturer specifications . A construction engineer needs to enquire about the bucket capacity , cutting height , output , etc to plan the construction work .

3. Scrapers - Scrapers is a large steel bowl attached with the cutter at the bottom , which is molded on the wheel. It is a multipurpose equipment which is used for excavation the soil , transporting it and spreading it at the other place . The basic operating parts of the scrapers are bowl , apron, ejector . During excavation , the cutting edge is lowered to scrape the soil . the cutting edge is raised when the bowl is filled . The material is spread after transporting a short distance . There are various types of scrapers , such as pusher loaded , self loading , etc . Scrapers can be used for a haulage distance of 100m to 1500m . Scrapers are not suited for hard rock , muddy soil and certain types of sands which does not pile up in the scrapers .

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

5. Clamshell - Like dragline , clamshell bucket is designed to excavate the soil in vertical direction . The bucket is like an inverted jaw , having a biting motion . Generally it is used for excavating soft soil and stockpiling it . The bucket can be opened and closed with the help of a cable or by hydraulic control . It is designed in such away that it is half opened when dropped and gets closed when the bucket is filled . it can stock pile the soil up to 20-30m of height and at a diameter up to 60m . It is often used in mining industry .

6. Backhoe - Backhoe is hydraulic excavator with a bucket attached to hydraulic controlled boom and stick . In backhoe , the excavation bucket moves in downward and backward direction during excavation . The difference between power shovel and backhoe is the movement of bucket . Backhoe may be crawler or rubber wheel mounted . Backhoe is more suited for the excavation below the ground , such as excavation for basements in building construction or trenches for laying sewer lines . The learning requirements for backhoe is same as power shovel .

Transportation

We have seen that some of the equipments used for excavation are also used for transporting for a distance , depending upon ground conditions . Many a time , the soil needs to be transported to other places which are not adjacent to the excavation site. The equipment used for transportation is also called haulers .

Various equipments used for transportation are -

a. Belt conveyers b. Tippers c. Truck d. Dumpers e. Graders

Trucks are used for small quantity of earthwork which is loaded manually .

Tippers generally unload by rear-tipping . Dumper is basically a truck with large size with self unloading mechanisms via hydraulic pump . Conveyers are

used in the terrain where transportation is a problem .But it has larger installation cost and generally is used in the place where large quantity of soil has to be hauled . A Grader is a wheel mounted tractor unit used to spread , trim and level soil with very high precision . This is widely used in road construction for leveling and maintaining the grade .

Compaction

After excavated soil has been transported and spread at the desired places , it is compacted to obtain the desired density . the optimum density is obtained on a certain moisture content of the soil . Generally , the right amount of water is mixed before compaction the soil . For different types of soil , different compaction equipments are used . A single equipment is not effective for all types of soil . A roller compacts the -

Pressure Kneading Vibration

## Impact

Various compaction equipments are -

a. Smooth wheel roller    b. Pneumatic tired roller    c. Sheep foot roller    d. Vibratory roller equipment -

i. i. Dropping weight type    ii. Pulsating hydraulic type .

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

b. Pneumatic tired roller - Pneumatic tired roller used the principle of \_\_\_\_\_ action to effect the compaction below the surface . They are generally self - propelled . The rear tires are spaced in such a way they travel over the surfaces between the front tires . Thus the roller produces compaction of the whole surface . The parameters which determine the compacting ability of pneumatic rollers are -

i. Wheel load    ii. Tire size    iii. Tire ply    iv. Inflation pressure

There are pneumatic rollers which have the capacity to increase its tire pressure during compaction . Initial compaction is carried out with low pressure . The roller increased its tire pressure in subsequent operations . They are used for fine grained soil .

3. Sheep foot roller - Sheep foot rollers are steel wheels equipment with protuded cylindrical projection of 20-25cm. They are suitable for compacting fine grained material , but generally is not suited for cohesionless granular material . They compact the soil kneading type of action . These rollers are helpful in breaking the lumps or clods present in the soil . These rollers aerates the soil during compaction . Thus , they are suitable for compaction soil heavy in moisture content above the optimum level .

4. Vibratory Compaction equipments - Vibratory rollers compact the soil through impact forces . These forces result in compaction greater than the equivalent static load . Vibratory rollers are suitable for coarse grained soil . These rollers may be pulsating weight type . Plate compactors are widely used in the building construction for compacting soil in the room . Power tamper is a drop weight type vibrating compactor . Vibratory roller can be pad tool type . Vibratory rollers can be used for all types of soil except for plastic clays .

Remarks - There are many variations of the compacting equipments ; we have mentioned the important characteristics . A construction engineer needs to know the suitability for a particular type of soil

1. Capacity of the roller    2. Efficiency of the various rollers

These parameters help him in the selection of the proper compacting equipment During earthwork following volume measurements are used -

1. Bank measure volume    2. Loose measure volume    3. Compacted volume

1. Bank measure volume - the volume of earth measured prior to excavation is called bank measure volume .

2. Loose measure volume - This is the volume of excavated soil . This volume is useful for transportation payment .

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

Drilling : Making a hole in rock or earth is called drilling. It is a very ancient human construction activity. The process of a man swinging a hammer against a point drill is as old as civilization. Drilling is an important construction activity which is required for following purposes -  
To explore the types of materials to be encountered on a project usually called exploratory drilling.

For explosive charges    For grouting on rock bolt stabilization    Making bore for placing utility lines    Seep hole for drainage of water

Constructing well for water supplies    For obtaining sample of soil for testing  
Installing cast in-site piles    Driving shaft for ventilating tunnels and other underground facility    Making horizontal holes to install various utilities

Locating deposits of aggregates

Drilling is a very fundamental activity in mining and petroleum industry. We shall confine our self here to give an introductory view of drilling as used in the construction industry. Different methods and equipments are used for drilling in rock and earth drilling. The factor affecting the selection of equipment can be enumerated as -

The required depth of the holes    The size of project    The purpose of drilling  
Type of terrain    The size cores required for exploration

The nature of the formation i.e. extent to which it is broken or fractured

Drilling equipments can be categorized into the following broad groups -

a. Percussion drills      b. Rotary drills - The rotary drills can be further grouped into -

i. Pressure drilling      ii. Abrasion drilling

Also, various types of augers are used for earth drilling.

a. Percussion drilling - A percussion drill breaks rocks into pieces by the impact from repeated blows. Sometimes, compressed air or hydraulic fluid can power percussion drills. It may be combined as rotary and percussion. It generally employs a reciprocating air operated hammer with impacts a rotating bit or a spring of rotating drill with bit on its bottom.

b. Rotary drilling - In the rotary drilling, the drilling is carried by applying a down pressure and at the same time continuously rotating the bit in the hole. This type of drills can be mounted on a truck or crawler tracts. These drills are suitable for drilling soft or medium rock.

Blasting

The operation to break rocks such that it can be quarried for processing aggregate production or to excavate a right-of-way is called blasting. Blasting is carried out by discharging an explosive in the borehole or any other confined manner carries out blasting. There are various types of commercially available explosives. They can be -

i. Dynamite    ii. Slurries    iii. ANFO, or    iv. Two components explosive

The various issues involved in the blasting can be listed as follows -

a. A site engineer should understand the process of blasting. Depending on the type of explosives, the blasting process has been developed. A site engineer should understand different components in the blasting process.

b. The understanding of the nature of explosive is very important. He has to know the various materials available in the market. Economy and suitability of the explosive for the particular site condition plays an important role.

c. The site engineer should make safety plan during blasting. Each member of his team should understand the safety requirements.

d. Transportation and storage of explosives is very dangerous. The explosive should be transported and stored with high safety.

e. The schedule of blasting should be intimated to the local people residing in the areas near to the site.

Tunneling

Tunnels are horizontal underground passages generally used for transporting men and materials. Making caves and tunnels is a very old activity of mankind, which even dates back to 4000 B.C. In the present day, tunnels are used for the following purposes -

Underground traffic

Diversion of river water

Water supply and drainage      Excavation of precious materials such as coal, iron, gold.

Military purposes like underground fortification

Underground power plant, warehouse      For underground parking places

Subways and express ways



Tunnels are generally of a few metres to several kilometers. Its diameter ranges from that of less than a metre to 16-17metres. It may be near to the ground or may be at large depths below the ground surface, such as those tunnels in mountains. Before starting the tunneling work (process of making a tunnel), following investigations should be carried out meticulously - a. Hydrological survey b. Geological survey and exploration c. Rock temperature and gases d. Factor influencing the depth of the tunnel below the ground level e. Factor affecting the diameter of the tunnel f. Geological features along the axis of the tunnel

The above factors are important for arriving at the design of the tunnel, but a site engineer has to investigate the parameters before design. Also, a construction engineer should always verify the available data for design. If there is any discrepancy in the existing profile with the coordination during design of a tunnel, modifications are needed.

Tunneling is carried out by -

a. Cut and cover tunneling b. Bored tunneling  
a. Cut and cover tunneling - Generally, cut and cover tunneling is carried out at the shallow depths. In this process ground is excavated and a concrete box is casted, and then it is covered with the soil. The process of cut and cover tunneling is shown in the figures on the next slides -

b. Bored tunneling - In the case of soft soil, a shield is used before excavating the soil. In rocks, rocks are drilled and blasted. Depending on the method used, the tunneling process can be described as-

i. Full face heading ii. Heading and bench method iii. Ring Drilling method iv. Groove method v. Side Drift method

In the full-face heading, the entire face is drilled and blasted in one operation. This method is economical, speedy and most widely used. In the heading and bench method, the top portion is blasted after drilling and loading. Lower portion is treated as one or more benches and drilled as well or blasted horizontally or vertically.

There are various shield mechanisms, which are used. Some of them are illustrated in the following slides -

## Piling

Depending upon the purpose for which piles are used, they can be grouped as -

a. Load bearing pile b. Sheet pile

Load bearing piles are used to transfer the load of super structures to ground whereas sheet piles are lateral support of earth during excavation. We shall talk about the various issues related to the construction of piles. We shall confine ourselves to only the popularly used piles and construction methods. Indian Standard IS 2911 specifies the following four types of piles -

a. Driven cast-in place pile b. Bored cast in piles c. Pre-cast driven piles d. Pre-cast driven in pre-bored piles

The Indian standard IS 2911 also gives the specification for Timber piles and under reamed piles. The driven piles are displacements piles whereas bored piles are non-displacement piles. Depending upon the diameter of the piles, they are -

a. Large diameter piles - greater than 600mm b. Small diameter piles - 300mm to 600mm c. Mini piles - 150mm to 250mm d. Micro piles - less than 150mm

During the installation of piles, the construction engineers have to keep in mind the following points -

a. Pile driving causes disturbances to the surrounding areas. The noise of hammering is very troublesome.

b. When pre-cast or cast-in-place piles are driven in soil, a volume equal to the volume of penetration of the pile is displaced. If the pore water pressure is not dissipated, then ground heave takes place because there will not be a volume change.

c. If the pre-cast driven pile is installed in the hard soil, it tends to set damage due to driving stresses and at the top due to lack of strength or lack of proper equipments.

d. Bored piles require proper washing of the base of the pile. It depends upon the availability of proper equipment, workmen and experienced contractors.

- e. Generally, time taken for installation of driven pile (both cast-in-place and pre-cast) is faster than bored pile.
- f. It has been found to be difficult to pull out the casing after concreting while using driven cast-in-place pile in pure sand deposits.
- g. Dumping of concrete from large height in cast-in-place pile particularly in driven piles cause segregation of concrete. A special care is needed to avoid them.
- h. The ground surface should be made such that the equipment should be able to move freely. After the piling, driven piles remain projected above the ground level. This may cause inconvenience in the movement of equipment backwards.

i. The bituminous coatings on the surface of pre-cast piles reduce the negative skin friction.

c. If the pre-cast driven pile is installed in the hard soil, it tends to get damaged due to driving stresses and at the top due to lack of strength or lack of proper equipments.

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j. According to the Indian Standard IS 2911 (Part 1 Section 3), negative skin friction developed as in the following cases. Special care is needed.

i. For Pile in clay strata which is subjected to shrinkage settlement

ii. Lower of ground table causes settlement of ground causing negative skin friction.

iii. Fill ground undergoes consolidation which causes negative skin friction.

iv. Negative skin friction develops if soil sets re-moulded or disturbed due to the pile installation

v. If pile is installed in clayey soil with surcharge loading, negative skin friction may develop.

Whenever there is a chance of settlement of soil and clay soft layer is encountered, negative skin friction may get developed. It is required to take special care whenever there is a chance of development of negative skin friction.

#### Pile Driving Equipments

Pre-cast pile driving equipments consist of -

1. Pile frame      2. Pile hammer      3. Helmet      4. Follower

1. Pile frame - Pile frame is a frame mounted on crawlers or trucks having arrangement of lifting, aligning and driving the pile.

#### Figure To Be Given

2. Pile hammer - There are different types of hammers used which are - i. Prop hammer ii. Vibratory hammer iii. Single action hammer iv. Double action hammer v. Diesel hammer

In India, drop hammers are widely used.

3. Helmet - It is assembly to avoid damage of the pile from hammer. Helmet consists of cushion, steel cap and dolly.

4. Follower - Follower is generally used when pile is out of reach of hammer. It is the extension, which transmits hammer blows to the piles.

#### Selection of pile hammers

The following pile hammers are more efficient than the drop hammers

- a. Single acting steam or compressed air hammer
- b. Double acting steam or compressed air hammer
- c. Diesel hammer - Diesel hammer is used when hard driving is required.

The capacity of hammer is calculated based on the depth to which the pile should penetrate.

How to maintain nominal cover in concrete piles      How to construct a bored pile

#### Dewatering

There are many situations when construction is to be carried out below the ground water table. In such circumstances, excavation becomes very difficult. Either seeped water has to be pumped or the water table has to be lowered. The process of lowering the water table is called dewatering. Sometimes, we use the term pumping and dewatering together. There are many ways that the dewatering can be carried out. These can be classified as -

- a. By pumping the collected water in the sump      b. By pumping water from suitably arranged well points

c. By pumping water from suitable arranged bored wells

a. By pumping the collected water in the sump - This method is commonly used in the construction where there aren't any important structures close to the excavated area and enough area is available to maintain a stable slope. In this method, one or more sumps are made at the outer boundary of the excavated site and cutting ditches around the bottom of the excavation collects water. This open sump method is generally used for construction not more than 6-7m below the water table. This method is less costly, but there are limitations. If there is fine sand lying below the water table, they get removed in seeping and causes settlement of the surrounding area. The process of open sump pumping is illustrated for foundation.

5. Excavate the soil above the water table and make the ditch and sump, in a similar manner as in step-3 and pump the water. Repeat this process till excavation is complete up to desirable depth.

Note: Sand gravel layer is provided at the base which acts as a filter and keep the working area dry.

b. Suitably arranging the well point- In this method, the concept of lowering of the water table surrounding the well point is used to lower the water at the construction site. The figure (a) and (b) show the draw down curve for single and multiple well points.

Fig(a)

Fig(b)

Well points are arranged around the area for construction at a distance of 1 to 4m. These well points can be arranged in single stage as shown in figure (c) or double stage as shown in figure (d).

c. Suitably arranging the bored wells - Bored wells are generally used when the water table has to be lowered beyond 15m. In this method, well is bored in the ground at a distance of 5m to 40m, depending upon the soil condition. Pumps are installed at this water table level. A typical well is shown in the figure.

This method also works in a similar way as well points. Bored well are arranged around the excavated site, in a single chain, similar to single stage well points.

Commonly used pumps in construction industry are-

- i. Reciprocating pump      ii. Diaphragm pump      iii. Conventional centrifugal pump
- iv. Self primary centrifugal pump      v. Air operated centrifugal pump