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 criterion.

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
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-

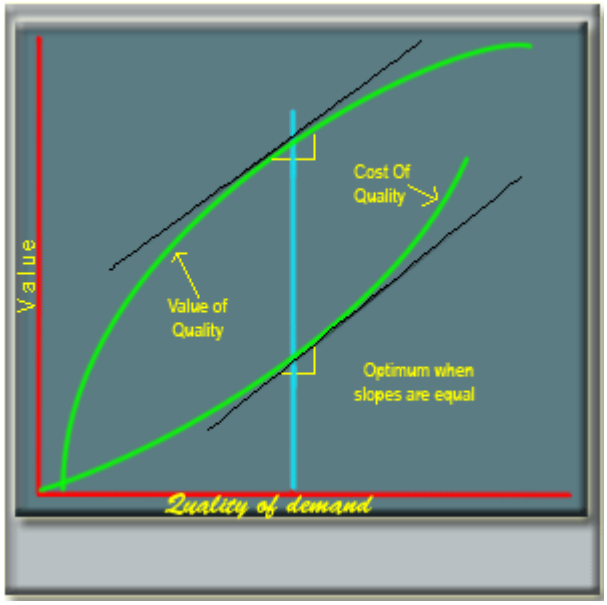
ii. field construction methodology
iii. Supervision
iv. Inspection

Economics of Quality of design

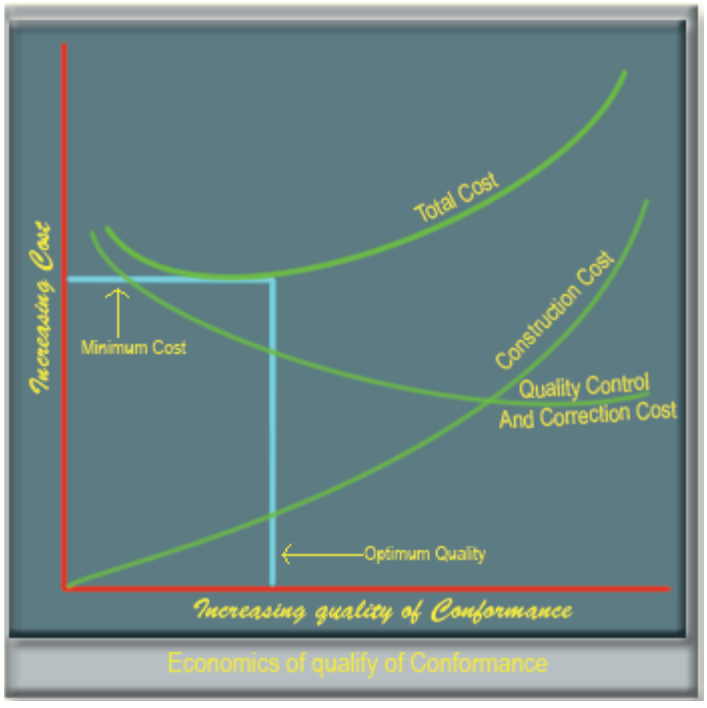
Quality of design is generally evaluated based on economics of quality. There are two aspects of economics of quality design

a. value addition of quality
b. cost of quality

With the increase of quality of design, dost 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.



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

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 hr 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.

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^3	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 3 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.

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 makes 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 equiptments. 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 safely constraints are for their betterment. A company can develop it 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.
8. Contract Requirement
9. The role of the owner in the safety management is vital. The cost and time is also dependent on the safely management. In India, large infrastructure construction is carried out by the government agencies. Safely 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 safely 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.

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 safely 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 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 contractor’s 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 are an investment.

c. Legal aspect of accident: In India, there is not a separate law regarding the safety of construction workers. But it falls under the labor 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.

EARTHWORK

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 . The 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 , tha 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, an 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 bowel attached with the cutter at the bottom, which is molded on the wheel. It is 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, and 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 bucked 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 bucked 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 requirement 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 quality of earthwork which is loaded manually. Tippers generally unload by rear-tipping. Dumper is basically a truck with large size with self unloading mechanisms via hydraulic pump. Conveyers are used in the terrain where transportation is a problem .But it has larger installation cost and generally is used in the place where large quantity of soil has to be hauled. A Grader is a wheel mounted tractor unit used to spread, trim and level soil with very high precision. This is widely used in road construction for 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. 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 find 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 wreaks equipment with protruded cylindrical projection of 20-25cm. They are suitable for compacting fine grained material, but generally are not suited for cohesion less granular material. They compact the soil kneading type of action. These rollers are helpful in breaking the lumps or clods

present in the soil. These rollers aerate 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.

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.

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 piles
b. Bored cast in piles
c. Pre-cast driven piles

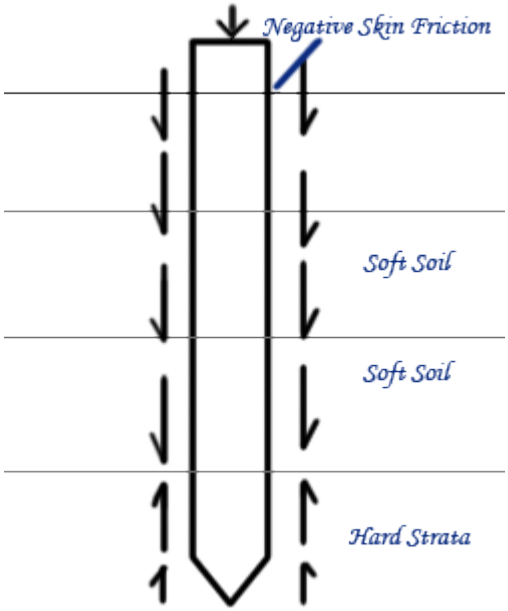
d. Pre-cast driven in pre-bored piles

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-case) is faster than bored pile.
f. If 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.
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-molded 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

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 dolley.
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 file should penetrate.

- How to maintain nominal cover in concrete piles
- How to construct a bored pile
- Concreting by tremie.

FORM WORK

Formwork in concrete construction is used as a mould for a structure in which fresh concrete is poured only to harden subsequently. Types of formwork for concrete construction depends on formwork material and type of structural element.

Formworks can also be named based on the type of structural member construction such as slab formwork for use in slab, beam formwork, column formwork for use in beams and columns respectively etc.

The construction of formwork takes time and involves expenditure upto 20 to 25% of the cost of the structure or even more. Design of these temporary structures are made to economic expenditure. The operation of removing the formwork is known as stripping. Stripped formwork can be reused. Reusable forms are known as panel forms and non-usable are called stationary forms.

Timber is the most common material used for formwork. The disadvantage with timber formwork is that it will warp, swell and shrink. Application of water impermeable cost to the surface of wood mitigates these defects.

A good formwork should satisfy the following requirements:

1. It should be strong enough to withstand all types of dead and live loads.
2. It should be rigidly constructed and efficiently propped and braced both horizontally and vertically, so as to retain its shape.
3. The joints in the formwork should be tight against leakage of cement grout.
4. Construction of formwork should permit removal of various parts in desired sequences without damage to the concrete.
5. The material of the formwork should be cheap, easily available and should be suitable for reuse.
6. The formwork should be set accurately to the desired line and levels should have plane surface.
7. It should be as light as possible.
8. The material of the formwork should not warp or get distorted when exposed to the elements.
9. It should rest on firm base.

Types of Formwork (Shuttering) for Concrete Construction:

Timber Formwork:

Timber for formwork should satisfy the following requirement:

It should be

1. well seasoned
2. light in weight
3. easily workable with nails without splitting
4. free from loose knots

Timber used for shuttering for exposed concrete work should have smooth and even surface on all faces which come in contact with concrete.

Plywood Formwork

Resin bonded plywood sheets are attached to timber frames to make up panels of required sizes. The cost of plywood formwork compares favorably with that of timber shuttering and it may even prove cheaper in certain cases in view of the following considerations:

1. It is possible to have smooth finish in which case on cost in surface finishing is there.
2. By use of large size panels it is possible to effect saving in the labor cost of fixing and dismantling.
3. Number of reuses is more as compared with timber shuttering. For estimation purpose, number of reuses can be taken as 20 to 25.

Steel Formwork

This consists of panels fabricated out of thin steel plates stiffened along the edges by small steel angles. The panel units can be held together through the use of suitable clamps or bolts and nuts. The panels can be fabricated in large number in any desired modular shape or size. Steel forms are largely used in large projects or in situation where large number reuses of the shuttering is possible. This type of shuttering is considered most suitable for circular or curved structures.

Steel forms compared with timber formwork:

1. Steel forms are stronger, durable and have longer life than timber formwork and their reuses are more in number.
2. Steel forms can be installed and dismantled with greater ease and speed.
3. The quality of exposed concrete surface by using steel forms is good and such surfaces need no further treatment.
4. Steel formwork does not absorb moisture from concrete.
5. Steel formwork does not shrink or warp.

Construction of Concrete formwork:

This normally involves the following operations:

1. Propping and centering
2. Shuttering
3. Provision of camber
4. Cleaning and surface treatment

Order and method of removing formwork:

The sequence of orders and method of removal of formwork are as follows:

1. Shuttering forming the vertical faces of walls, beams and column sides should be removed first as they bear no load but only retain the concrete.
2. Shuttering forming soffit of slabs should be removed next.
3. Shuttering forming soffit of beams, girders or other heavily loaded shuttering should be removed in the end.

Rapid hardening cement, warm weather and light loading conditions allow early removal of formwork. The formwork should under no circumstances be allowed to be removed until all the concrete reaches strength of at least twice the stresses to which the concrete may be subjected at the time of removal of formwork. All formworks should be eased gradually and carefully in order to prevent the load being suddenly transferred to concrete.

S. No.	Description of structural member	Period of time
1	Walls, columns and vertical sides of beams	1 to 2 days
2	Slabs (props left under)	3 days
3	Beam soffits (props left under)	7 days
4	Removal of props to slabs	
	(a) For slabs spanning upto 4.5 m	7 days
	(b) For slabs spanning over 4.5 m	14 days
5	Removal of props to beams and arches	
	(a) Spanning upto 6 m	14 days
	(b) spanning over 6 m	21 days