JP College of Engineering
Run by DMI Sisters
Affiliated to Anna University, Chennai & Approved by AICTE, New Delhi,
ISO 9001:2015 Certified
Ayikudy-627852, Tenkasi (Dist), Tamil Nadu, India.

CE 3013 ADVANCED CONSTRUCTION TECHNIQUES

Lecture Notes

Regulation 2021

G. BASKAR SINGH

INSTITUTE VISION, MISSION AND QUALITY POLICY

INSTITUTE VISION:

To evolve as Centre of Excellence in Teaching, Innovative Research and consultation in Engineering and Technology and to empower the rural youth with technical knowledge and professional competence thereby transposing them as globally competitive and self-disciplined technocrats.

INSTITUTE MISSION:

To inculcate technical knowledge and soft skills among rural students through student-centric learning process and make them as competent engineers with professional ethics to face the global challenges, thus bridging the 'rural-urban divide'.

INSTITUTE QUALITY POLICY

To develop the college into a global institute of Learning.

- Research and consultation in Engineering and Technology with high standard of academic excellence.
- To serve the institute with total commitment, dedication, team spirit and quality conscious in teaching and training the students.
- To empower the rural youth with technical knowledge and professional competence and thereby bridging the barrier between rural and urban
- To mould the students as citizens with moral, ethical and social values so as to fulfill their obligations to the society and nation at large.

DEPARTMENT OF CIVIL ENGINEERING

DEPARTMENT VISION & MISSION STATEMENT

VISION:

To build young Technocrats by imparting their technical knowledge in the field of Civil Engineering, by laying the foundation for future engineers, who can meet the demands of industry and community effectively in all part of civil works and to make significant contribution in the economic development of the state, region and nation.

MISION:

M1: To adopt valuable teaching methods and implement high quality education to maximize Engineering knowledge for students.

M2: To promote innovative and original thoughts in the minds of civil engineers.

M3: To provide facilities to the students and faculty members to enhance the understanding and implementation of recent trends in the Civil Engineering field.

M4: To produce Civil Engineering graduates with good ethical skills and managerial skills to become as successful professionals and entrepreneurs.

M5: To promote advanced technology, Industry Institute interaction, research and consultancy in Civil Engineering department with global linkages.

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)

Graduates of the programme B E Civil Engineering will

PEO I. Gain knowledge and skills in Civil engineering which will enable them to have a career and professional accomplishment in the public or private sector organizations

PEO II. Become consultants on complex real life Civil Engineering problems related to Infrastructure development especially housing, construction, water supply, sewerage, transport, spatial planning.

PE0 III. Become entrepreneurs and develop processes and technologies to meet desired infrastructure needs of society and formulate solutions that are technically sound, Economically feasible, and socially acceptable.

PEO IV. Perform investigation for solving Civil Engineering problems by conducting research using modern equipment and software tools.

PEO V. Function in multi-disciplinary teams and advocate policies, systems, processes and equipment to support civil engineering

PROGRAM OUTCOMES (POs)

PO# Graduate Attribute

1 **Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

2 **Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of Mathematics, natural sciences, and engineering sciences.

3 **Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

4 **Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

5 **Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

6 **The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

7 **Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

8 **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

9 **Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

10 **Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

11 **Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

12 **Life-long Learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

PROGRAM SPECIFIC OUTCOMES (PSOs)

PSO1 Knowledge of Civil Engineering discipline

Demonstrate in-depth knowledge of Civil Engineering discipline, with an ability to evaluate, analyze and synthesize existing and new knowledge.

PSO2 Critical analysis of Civil Engineering problems and innovation

Critically analyze complex Civil Engineering problems, apply independent judgment for synthesizing information and make innovative advances in a theoretical, practical and policy context.

PSO3 Conceptualization and evaluation of engineering solutions to Civil Engineering

Issues Conceptualize and solve Civil Engineering problems, evaluate potential solutions and arrive at technically feasible, economically viable and environmentally sound solutions with due consideration of health, safety, and socio cultural factors

Syllabus:

CE3013 ADVANCED CONSTRUCTION TECHNIQUES L T P C 3 0 0 3

COURSE OBJECTIVE:

To study and understand the latest construction techniques applied to engineering construction for sub structure, super structure, special structures, rehabilitation and strengthening techniques and demolition techniques.

UNIT I SUB STRUCTURE CONSTRUCTION 9

Construction Methodology - Box jacking - Pipe jacking - Under water construction of diaphragm walls and basement - Tunneling techniques - Piling techniques - Driving well and caisson - sinking cofferdam - cable anchoring and grouting - Driving diaphragm walls, Sheet piles - Laying operations for built up offshore system - Shoring for deep cutting - Large reservoir construction - well points - Dewatering for underground open excavation.

UNIT II SUPER STRUCTURE CONSTRUCTION FOR BUILDINGS 9

Vacuum dewatering of concrete flooring – Concrete paving technology – Techniques of construction for continuous concreting operation in tall buildings of various shapes and varying sections – Erection techniques of tall structures, Large span structures – launching techniques for heavy decks – in-situ prestressing in high rise structures, Post tensioning of slab- aerial transporting – Handling and erecting lightweight components on tall structures.

UNIT III CONSTRUCTION OF SPECIAL STRUCTURES 9

Erection of lattice towers - Rigging of transmission line structures – Construction sequence in cooling towers, Silos, chimney, sky scrapers - Bow string bridges, Cable stayed bridges – Launching and pushing of box decks – Construction of jetties and break water structures – Construction sequence and methods in domes – Support structure for heavy equipment and machinery in heavy industries – Erection of articulated structures and space decks.

UNIT IV REHABILITATION AND STRENGTHENING TECHNIQUES 9

Seismic retrofitting - Strengthening of beams - Strengthening of columns - Strengthening of slab - Strengthening of masonry wall, Protection methods of structures, Mud jacking and grouting for foundation – Micro piling and underpinning for strengthening floor and shallow profile - Sub grade water proofing, Soil Stabilization techniques.

UNIT V DEMOLITION 9

Demolition Techniques, Demolition by Machines, Demolition by Explosives, Advanced techniques using Robotic Machines, Demolition Sequence, Dismantling Techniques, Safety precaution in Demolition and Dismantling.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

On completion of the course, the student is expected to be able to

CO1 Understand the modern construction techniques used in the sub structure construction.

CO2 Demonstrate knowledge and understanding of the principles and concepts relevant to super structure construction for buildings

CO3 Understand the concepts used in the construction of special structures

CO4 Knowledge on Various strengthening and repair methods for different cases.

CO5 Identify the suitable demolition technique for demolishing a building.

REFERENCES:

1. Jerry Irvine, Advanced Construction Techniques, CA Rocket, 1984

2. Patrick Powers. J., Construction Dewatering: New Methods and Applications, John Wiley & Sons, 1992.

3. Peter H.Emmons, “Concrete repair and maintenance illustrated”, Galgotia Publications Pvt. Ltd., 2001.Press, 2008.

4. Robertwade Brown, Practical foundation engineering hand book, McGraw Hill Publications, 1995.

5. Sankar, S.K. and Saraswati, S., Construction Technology, Oxford University, New Delhi, 2008.

UNIT I

SUB STRUCTURE CONSTRUCTION

Construction Methodology - Box jacking - Pipe jacking - Under water construction of diaphragm walls and basement - Tunneling techniques - Piling techniques - Driving well and caisson - sinking cofferdam - cable anchoring and grouting - Driving diaphragm walls, Sheet piles - Laying operations for built up offshore system - Shoring for deep cutting - Large reservoir construction - well points - Dewatering for underground open excavation.

1. CONSTRUCTION METHODOLOGY

Jacking is the process of creating an underpass below a railway track or road without destruction.

1.1. TYPES OF STRUCTURES UNDER JACKING

- Box jacking
- Arch jacking
- Pipe jacking

2. BOX JACKING

Box Jacking Technique is the tunneling process in which a pre-cast R.C.C box (or a rigid box) is pushed into the soil with the help of hydraulic jacks. It is non intrusive method beneath the existing surface.

It is more often used when a subway or an aqueduct or an underground structure is to be constructed. It enables the traffic flow without disruption.

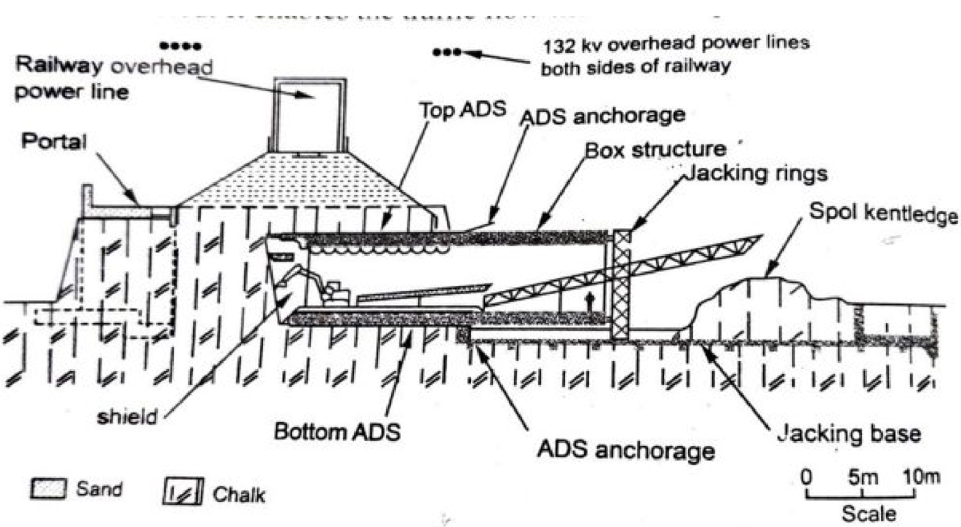


Fig. 3.1.Box Jacking

3. PIPE JACKING

Pipe jacking is a tunneling method for installing underground pipelines with the minimum surface disruption, primarily used for new sewer construction. It is also used for sewer replacement and re-aligning, gas and water mains, oil pipelines, electricity and telecommunication installations, culverts and subways.

It is generally referred as **Micro tunneling**. Powerful hydraulic jacks are used to push specially designed pipes through the ground behind a shield at the same time as excavation is taking place within the shield. The method provides a flexible, structural, watertight, finished pipeline as the tunnel is excavated.

In order to install a pipeline using this technique, thrust and reception pits are constructed, usually at manhole positions. The dimensions and construction of a thrust pit vary according to the specific requirements of any drive, in which economics being a key factor. Pit sizes vary according to the excavation methods employed, although these can be reduced if required, in special circumstances.

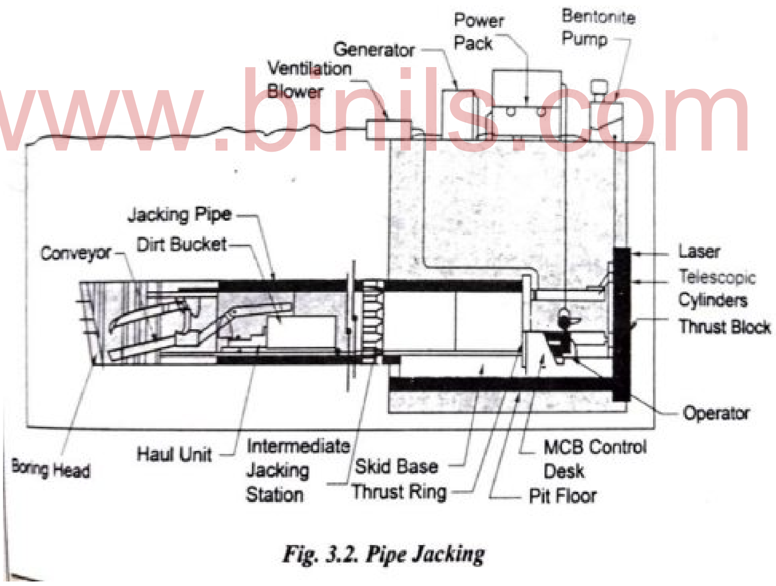


Fig. 3.2. Pipe Jacking

4. UNDER WATER CONSTRUCTION OF DIAPHRAGM WALLS AND BASEMENT

Diaphragm walls are underground structural elements ***commonly used for permanent foundation walls and retention systems.*** Diaphragm walls provide a water tight barrier and are constructed with a minimum back slope subsidence. They are formed from reinforced concrete and are constructed as normal cast-in- place walls with support, which become a part of the main structure. They can also be used as **deep groundwater barriers**.

Diaphragm wall is generally reinforced concrete wall constructed in the ground using ***under slurry trench technique*** which was developed in Europe. The technique involves excavating a narrow trench that is kept full of an engineered fluid of slurry. **Walls of thickness between 300 and 1200 mm can be formed in this way up to a depth of 45 m.**

Diaphragm wall construction is based on the **Slurry Trench Method**, which involves the excavation of alternating panels along the proposed wall, using Bentonite slurry to prevent the sides of the excavation from collapsing.

The slurry trench technique was developed in Europe and has been used in the United States since the 1940's. The technique involves excavating a narrow trench that is kept full of an engineered fluid or slurry. The slurry exerts hydraulic pressure against the trench walls and acts as shoring to prevent collapse. Slurry trench excavations can be constructed in all types of soil, even below the ground water table.

I. Parts of a Diaphragm Wall

- Membrane (used as a shear panel to carry in-plane shear)
- Drag Strut Member (used to transfer the load to the shear walls or frames)
- Chord (used to resist the tension and compression forces that develop in the diaphragm)

II. Functions of diaphragm walls

The functions of diaphragm walls are as follows.

i. To retain soils during the construction of underground structures.

ii. To control the movement of ground during construction.

iii. To take up high vertical loads from above ground structures during construction.

4.1. <u>CONSTRUCTION METHODS</u>

Following are the two methods adopted in the construction of diaphragm

- ✓ Cast-in-place Method
- ✓ Pre-cast Method

a. Construction of Cast-In-Place Diaphragm Walls

Following procedure is adopted in the construction of cast-in-place diaphragm walls.

1. The trench is being excavated in discontinuous sections or panels. The panel dimensions of 50 to 100 cm thick and 7m height is extending to the excavation bottom.

2. Stop-end pipes are placed vertically at each end of the primary panel to form joints for adjacent secondary panels.
3. The steel reinforcement cage is then placed in the centre of the panel.
4. Concrete is poured in one continuous operation through one or more Tremie pipes that extend to the bottom of the trench.
5. The Tremie pipes are extracted as the concrete rises
6. The slurry that is displaced by the concrete is saved and for subsequent panel excavations.
7. As the concrete sets, the end pipes are withdrawn.
8. The finished wall may be cantilever or require anchors or props for lateral support.

b. Construction of Pre-cast Diaphragm Walls

Following procedure is adopted in the construction of pre-cast diaphragm walls.

1. A continuous trench or longer panel is excavated under self-hardening cement-**Bentonite** slurry.

2. The slurry is retarded to remain fluid during construction.
3. After a sufficient length of excavation is complete, a crane lifts the precast wall section into the trench.
4. The cement Bentonite slurry sets to form the final composite wall.
5. Alternatively, the trench is excavated under Bentonite slurry, which is then displaced with `cement Bentonite slurry.

4.2. ADVANTAGES, DISADVANTAGES AND APPLICATION OF DIAPHRAGM WALL

I. Advantages of Diaphragm Walls

Following are the advantages of Diaphragm Walls

- Commonly used in congested areas.
- Can be installed in close proximity to existing structure
- Practically suited for deep basements

II. **Disadvantages of Diaphragm Walls**

Following are the disadvantages of Diaphragm Walls.

- They are relatively costly.
- They are also unsuited to strong soils conditions where penetration is slow and difficult due to the use of the slurry trench method.

III. **Applications**

Following are the applications of Diaphragm Walls.

- Permanent and temporary foundation walls for deep basements.
- Earth retention structures for highway and tunnel projects
- Permanent walls for deep shafts for tunnel access.
- Permanent cut-off walls through the core of earth dams.
- In congested areas for retention systems and permanent foundation walls.
- Deep ground water barriers through and under dams.

4.3. BASEMENTS

Basements are defined as the underground structures that are linked to the superstructure and functionally form an integral whole.

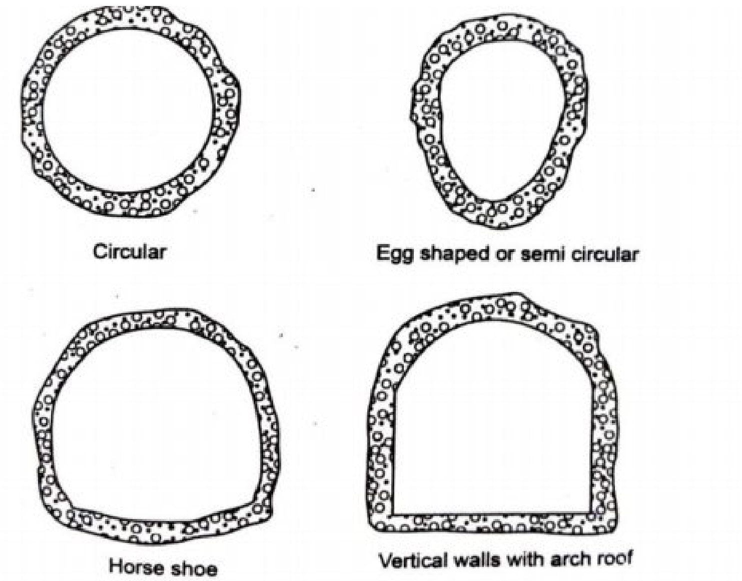
Methods:

Following are the construction methods

1. Open excavation with sloped sides.
2. Vertical cuts supported by temporary supports such as sheet piles or timber.
3. Vertical cuts supported by diaphragm walls, along with intermediate piles and floor slabs which permit top-down construction.
4. Vertical cuts supported by diaphragm walls which become a part of the final basement structure.
5. Prefabrication of the basement structure above the ground and sinking it into the soil.

5. TUNNELING TECHNIQUES

Tunneling is the process involved in underground works. **A tunnel** is defined as an underground passage for transport of passengers, water, sewage, mineral, gas.



Shape of tunnel

Tunneling is required for the following purpose

- ✓ Underground traffic
- ✓ Water conduits
- ✓ Vertical or inclined shafts
- ✓ Covers
- ✓ Accesses to mines Conduits for utility services (electric cables etc.)
- ✓ Subways, underground parking etc.

Shape of tunnel depends on the purpose for which it is constructed and on the ground pressure. In solid rock, any shape of the tunnel can be selected depending upon the purpose i.e. circular or elliptical for water and sewage conduits, while semi-circular arch with vertical side walls for vehicular traffic tunnels.

5.1. OBJECTIVES OF TUNNELING TECHNIQUES

Following are the various objectives of tunneling techniques.

1. To meet the requirements of rapid transportation in big cities
2. To connect by shortest route, two terminals separated by mountain
3. To reduce very steep grades

4. To avoid the excessive cost of maintenance of an open cut subjected to land slides or snow drifts
5. To avoid the expensive acquisition of valuable built up land, tearing up pavements and holding up traffic for long periods in large cities
6. When the depth of ordinary cutting exceeds 20m and the ground rise rapidly for a considerable distance after wards

5.2. METHODS OF TUNNEL DRIVING

Following are the various methods used for driving a tunnel.

a. Full Face Heading
b. Heading and Benching method
c. Drifts method
d. Pilots tunnel method

a. Full Face heading

When the entire face of the tunnel is attacked at the same time, then the method of tunneling is defined **full face method**. Various techniques of this method are,

a. Conventional method (of drill and shoot)
b. Mole tunneling (by tunnel boring equipment)

b. Heading and Benching method

If the top portion of the tunnel is first drilled and blasted ahead of the bottom portion, then the method is called **Heading and benching method**.

The upper portion of the tunnel is called heading and lower portion of the tunnel is called **bench.**

c. Drifts method

If, it is not possible to drive the full face of the tunnel in weak rock, a small tunnel (called **drift**) is driven for a portion of tunnel length (or sometimes for full length). The method of driving a tunnel by pre-driving a drift is called **drift method**. This method provides the ventilation while driving the main tunnel. It also reduces the consumption of explosives. However drift requires more mucking and drilling costs.

D. Pilots tunneling

A small rectangular tunnel located at the centre of the proposed tunnel is called **pilot tunnel**, and from which the section is enlarged by drilling holes along a ring, each such ring is spaced about **1m to 1.2m apart**. This method can be used for inclined portions of the penstock tunnels, since in this case, full face drilling is now possible.

I. Tunnel construction using drill and blast

Tunnel construction is carried out in a well-planned sequence of operations. A particular operation may vary with the size and type of the tunnel, method adopted for excavation and the characteristics of the formation encountered.

Following sequence of operations are generally adopted for driving the tunnel through rock

1. Setting up and drilling
2. Loading the holes with explosives and firing.
3. Ventilating and removing the dust resulted by explosion.
4. Loading and hauling the muck.
5. Removing groundwater from the tunnel, if necessary.
6. Erection of supports for the roof and sides, if necessary. This includes rock-bolting or steel supports.
7. Placing reinforcement.
8. Placing the concrete lining.
9. Curing and shuttering removal.

Drilling

For driving a tunnel, numbers of holes are drilled as per drilling pattern in size and depth as decided depending upon the size of the tunnel and its formation. Drifters are generally used for drilling in the tunnels where in water is used to remove the cutting from holes instead of compressed air to reduce the amount of dust in the air. The modern equipment used for drilling blast holes in tunnels is "drill jumbo and is being discussed in following paragraph. Holes are drilled slightly deeper than the advance per round to take case of loss in depth during blasting. Depth attained due to drilling and blasting operation is called as 'one around' or 'pull." and depends upon length of holes, type of explosive, number of holes charged and pattern of holes.

Drill jumbo

Drill jumbos used in tunnels are also known as tunnel jumbos. A drill jumbo is a portable carriage having one or more carriage having one or more working platforms equipped with columns, bars or booms to support and guide the drills, enabling the drills to perform drilling operation at any desired pattern..

Loading and firing

In tunneling the holes should be fired in the sequence as given in the drilling pattern. Drilling pattern when followed produces most economical and efficient breakage of rock for a given tunnel, and is determined by conducting tests using different patterns. Electronic detonators are used and supplied with built-in fuses and with leads of varying lengths to suit the length of holes in use in the particular tunnel.

Ventilating and removing the dust

Main objects of ventilation system in a tunnel are,

1. To provide fresh air for workers.
2. To remove poisonous gases and fumes produced by explosion.
3. To remove the dust caused by drilling, blasting, mucking and operations performed in the tunnel.

If a pilot or drift is driven in the tunnel from portal to portal, sufficient natural ventilation shall be available. When natural ventilation is not adequate, mechanical ventilation is provided by one or more electric-motor-driven fans, which may blow fresh air in the tunnel or exhaust the dust and foul gases from the tunnel.

Dust Control

Dust is created by drilling, blasting, loading the muck and is serious health hazard to the workers, hence it is necessary to control the amount of dust in the air in a tunnel. Some of the steps which can reduce the dust are listed below.

1. Water should be used while drilling for removing the cuttings from drilling holes instead of using air.
2. Muck pile should be kept wet while loading.

3. After each round of blasting, complete ventilation of the space near the face, preferably by exhaust method, should be carried out.
4. Vacuum hood should be fitted around the drill steel at the rock face to collect the dust coming out from the hole while drilling.

Muck Loading (Mucking)

Mucking is the operation of loading the broken rock or earth for removal from a tunnel. Mucking is done by hand in small tunnels and drifts. For larger tunnels, mucking operations can be performed by power shovels, tractor loader, mucking machines, etc.

Ground water in a tunnel construction is controlled in two phases namely,

1. Preventing the excess water entering the tunnel
2. Removing the water which has entered the tunnel.

Auxiliary equipment

During tunnel construction it is necessary to make arrangements for the supply of water, compressed air and electricity.

Tunnel construction requires certain additional auxiliary equipment, welding sets, reinforcement bar bending, bit repair, field repair and servicing equipment's. Tunnels also require a telephone communication system.

II. Methods of Tunneling through soft ground

The various methods of tunneling through the soft ground are,

- ✓ Fore piling method
- ✓ Needle beam method
- ✓ Five piece set method

6. <u>PILE FOUNDATION AND PILING TECHNIQUES</u>

6.1. PILE FOUNDATION

Pile foundations are defined as deep foundations, in which piles are used to transmit the load of the structure to the soil. (Pile is a long cylinder of a strong material) (such as concrete) that is pushed into the ground to act as a steady support for structures built on top of it. **Piling technique** is a process, in which a pile is forced in to the ground without excavating the soil.

The use of pile foundations is increasing day by day due to non-availability of land for construction. Heavy multi-storeyed buildings are being constructed, and load from these structures cannot be directly transferred to ground due to low bearing capacity of soil and stability of building during lateral load application. Hence, demand for use of pile foundations are increasing day by day. Due to this demand for piles, there have been many improvements in piles and pile driving technology and systems. Today there are many advanced techniques of pile installation.

Pile foundation is required when the soil bearing capacity is not sufficient for the structure to withstand. This is due to the soil condition or the order of bottom layers, type of loads on foundations, conditions at site and operational conditions. The centre to centre distance of the successive pile in the group of piles is called **pile spacing**.

Pile foundations are used in the following situations.

1. When there is a layer of weak soil at the surface. (This layer cannot support the weight of the building, so the loads of the building have to bypass this layer and be transferred to the layer of stronger soil or rock that is below the weak layer)
2. When a building has very heavy, concentrated loads, such as in a high rise structure, bridge, or water tank.

Pile foundation are capable of taking higher loads than spread footing

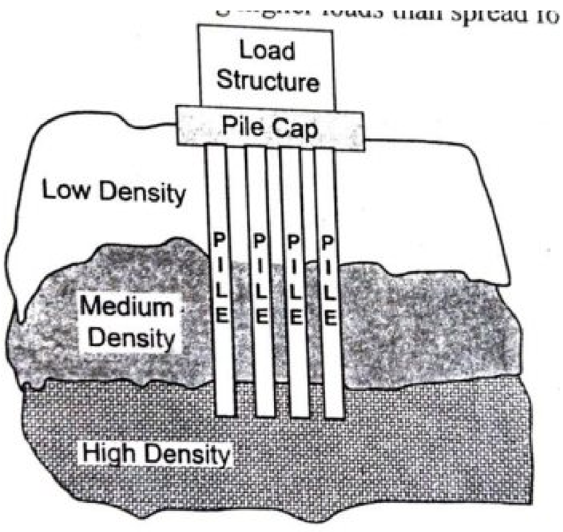


Fig. 3.4. Pile or Deep foundation

Many factors prevent the selection of surface foundation as a suitable foundation such as the nature of soil and intensity of loads, the piles are used when the soil have low bearing capacity or in building in water like bridges and dams.

A pile foundation consists of two components.

- ✓ Pile cap
- ✓ Single Pile or Group of piles.

Piles transfer the loads from structures to the hard strata, rocks or soil with his bearing capacity. These are long and slender members whose length can be more than 15m. Piles can be made from concrete, wood or steel depending on requirements. These piles are then driven, drilled or jacked into the ground a connected to pile caps.

6.2. FUNCTIONS AND ADVANTAGES OF PILE FOUNDATION

Following are the various functions and advantages of pile foundations.

1. Piles or Pile Foundations are used to transfer the vertical or inclined structural loads to foundation and soil layers.
2. It is used to install loose cohesionless soil through displacement and vibration.
3. It controls the settlements.
4. It increases the factor of safety for heavy loads.
5. It evenly distributes the load.
6. It is very useful and less cost than the raft or grillage foundations.
7. It is suitable where timbering is difficult to process.
8. It is adopted where canals, deep drainage lines, etc are to be constructed in near future.
9. It is also used as an anchor.
10. It is used in the construction of docks, marine structures as Fender piles.

6.3. TYPES OF PILES

I. Types of Piles based on Load Bearing Characteristics

There are two types of piles, Load bearing and Non-load bearing piles.

i. Load bearing piles

Piles, taking or bearing the load from the structure are called **Load bearing** or **Batter piles**. These are classified into **End bearing piles** and **Friction piles**.

ii. Non-load bearing piles

Piles which are not designed to carry any vertical load and used to separate the members below ground level and designed to carry the horizontal earth pressure are called **Non-load bearing piles** or **Sheet piles.**

II. Load bearing piles

a. End Bearing Piles

If the load may be taken directly by resting the pile on a firm stratum, it is called **End Bearing Piles**. In end bearing piles, the bottom end of the pile rests on a layer of especially strong soil or rock. The load of the building is transferred through the pile to the strong layer. That is, this pile acts like a column: The important principle is that the bottom end rests on the surface, which is the intersection of a weak and strong layer. Hence, the load bypasses the weak layer and is safely transferred to the strong layer.

b. Friction Piles

If the load may be taken by friction developed at the piles sides, it is called **Friction Piles**. In friction piles, the pile transfers the load of the building to the soil across the full height of the pile, by friction. In other words, the entire surface of the pile, which is cylindrical in shape, works to transfer the forces to the soil.

The total frictional resistance of the piles is obtained by multiplying the frictional resistance of the soil with the area of the pile in contact with the soil. Area of the pile in contact can be obtained by multiplying the circumference of pile with depth of penetration of pile on soil.

The total frictional resistance can be increased by,

1. By increasing the diameter of the pile
2. By driving the pile to greater depth
3. By making the surface of the pile rough
4. By placing the pile closely
5. By grouping the piles

c. Other Piles

Composite piles

A composite pile is formed when it is a combination either of a board pile and a driven pile or of driven piles of two different materials.

Screw piles

A Screw pile consists of a hallow cast iron or steel cylinder with one or more blades at the bottom.

III. Classification of Pile foundation

Pile foundations are classified based on,

- ✓ Material of the Pile
- ✓ Type of Soil
- ✓ Construction Method
- ✓ Load Transmitting Characteristic of pile

Timber piles, steel piles and concrete piles are commonly used materials. With the change in technology and industrial revolution, many advance systems have been developed for pile driving from the invention of steam and diesel pile driving machines.

Selection of Pile Foundation

Pile foundation selection depends on the soil data received from soil exploration bore holes at different depths. It depends on following conditions.

- ✓ Soil conditions
- ✓ Loads from structures
- ✓ Nature of loads
- ✓ Number of piles to be used
- ✓ Cost of construction

There are three types of pile foundation based on load transfer mechanism.

- ➢ End bearing piles
- ➢ Friction bearing piles
- ➢ Combination of end bearing and friction bearing piles.

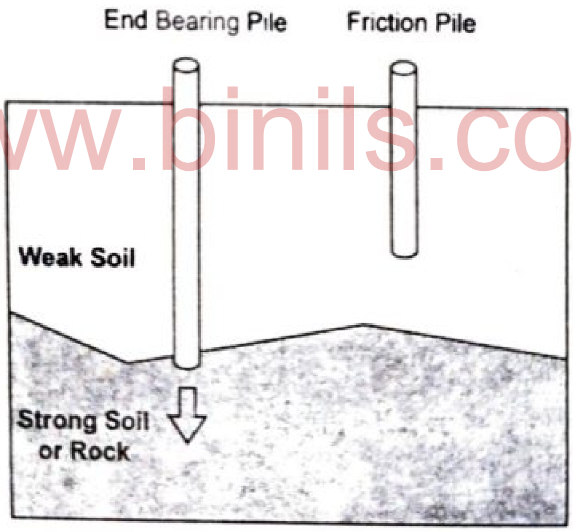
a. Selection of End Bearing Pile Foundation

End bearing piles also called as point-bearing piles are selected when the depth of hard soil strata or bedrock at site is within reasonable depth. The length of pile to be used can easily be computed based on bedrock depth obtained from soil exploration borehole records. In this case, the loads from structures are directly transferred the hard soil through bearing action of pile bottom tip and it does not require the use of skin friction to resist loads.

b. Selection of Friction Pile Foundation

Friction piles resist the loads from structures due its skin friction with soil. This type of pile foundation is selected when a hard stratum is available at large depth and construction of end bearing pile becomes uneconomical.

Then number of piles in a group is selected to resist the load from structure through its skin friction. This type of pile foundation also resists loads due to end bearing however its value is small, thus it is neglected in calculation.



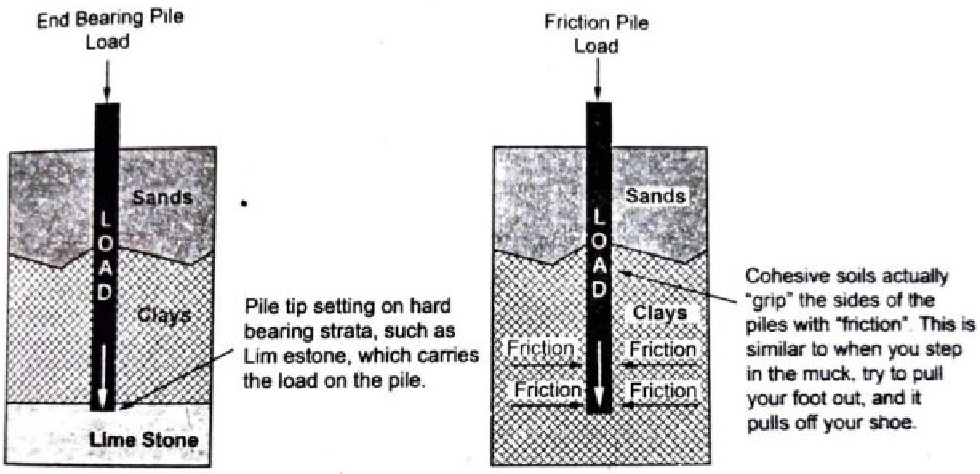


Fig.3.5. Types of piles

c. Combined End Bearing and Friction Pile Foundation:

This type of pile foundation is mostly used in construction. The advantage of using this pile is that it can resist loads from structures through both end bearing and friction resistance. This pile has high piling (or loading) capacity and is economical

This pile is used when the soil exploration results shows hard bedrock or fairly compacted soils at reasonable depth and soil above bed rock supports skin friction resistance.

IV. Selection of Type of Pile Foundation

The selection of type of pile foundation is based on site investigation report. Site investigation report suggests the need of pile foundation, type of pile foundation to be used and depth of pile foundation to be provided. The cost analysis of various options for use of pile foundation should be carried out before selection of pile foundation types. Unless the ground condition is rocks, for heavy construction and multi-storied buildings, the bearing capacity of soil at shallow depth may not be satisfactory for the loads on the foundation. In such cases, pile foundation has to be provided.

The number of piles in a pile groups required is calculated from the pile capacity of single pile and the loads on the foundation. Piles are a convenient method of foundation for works over water, such as jetties or bridge piers.

V. Classification of Pile foundation based on Construction Method

There are three types of pile foundations according to their construction methods.

a. Driven piles

b. Cast-in-situ piles

c. Driven and cast-in-situ piles

a. Driven Pile Foundations

Driven pile foundations can be made from precast concrete, steel or timber These piles are prefabricated before placing at the construction site. These piles are driven using a pile hammer. When these piles are driven into the granular soils, they displace the equal volume of soil. This helps in compaction of soil around the sides of piles and results in the densification of soil. The piles which compact the soil adjacent to it is also called as compaction pile.

b. Cast-in-situ Pile Foundations

Cast-in-situ piles are concrete pile. These piles are constructed by drilling holes in the ground to the required depth and then filling the hole with concrete. Reinforcements are also used in the concrete as per the requirements. These piles are of small diameter compared to drilled piers. Cast-in-situ piles are straight bored les or with one or more bulbs at intervals are casted. The piles with one or more bulbs are called as under-reamed piles.

c. Driven and Cast-in-situ Piles

Driven and cast-in-situ piles have the advantages of both driven and cast-in-situ piles.

VI. Sheet Piles

Piles which are not designed to carry any vertical load and used to separate the members below ground level and designed to carry the horizontal earth pressure are called Non-load bearing piles or Sheet piles. Following are the objectives of sheet piles.

1. To isolate the foundations from the adjacent soil (to prevent the escape of soil and passage of shocks, vibrations etc.)
2. To prevent the underground movement of water.
3. To prevent the transfer of machine vibrations to the adjacent structures.
4. To construct retaining walls in docks etc.
5. To protect the river banks
6. To retain the sides of foundation trenches.
7. To work as cutoff walls under dams.
8. To construct the caissons for water-intake supplies
9. To confine the soil and thereby increasing the bearing capacity.

10. To protect the foundations of a structure from erosion by nearby stream, river, sea etc.

Sheet piles may be of either concrete or steel or timber.

a. Concrete Sheet Piles

These piles are always pre-cast and the reinforcement is provided as per design. The piles are square or rectangular in cross-section and they are driven side by side 500 mm to 600 mm and thickness varies about 20 mm to 60 mm. The so as to form a continuous wall The width of the pre-cast concrete pile varies from reinforcement is in the form of vertical bars and hoops.

b. Steel Sheet Piles

Steel Sheet piles walls are constructed by driving steel sheets into a slope or excavation They are considered to be most economical, where retention of higher earth pressures of soft soil is required. Their most common use is in temporary deep excavations. It consists of small sheet sections of steel that are 10 to 15 mm thick. They are driven into the soil to provide support during excavation Each sheet is joined to the adjacent sheet by means of an interlocking joint.

c. Timber Sheet Piles

The wooden sheet piles are commonly used for the temporary works as cofferdams. They usually consist of wooden boards 80 mm to 150 mm thick, 200 mm to 300 mm wide and 2 m to 4 m long.

VII. Pile Driving and Pile Driving Equipment's - Pile Hammers

The process of forcing a pile into the ground without excavation is called pile driving. The piles should be installed vertically. However a tolerance of 2% of the pile length is permissible. The eccentricity is measured by using plumb bob by extending the exposed section of solid pile or inside the casing of a hollow pile. A pile is supposed to reach a hard stratum when it does not settle more than 10 mm with 10 blows of a 30kN hammer falling through a height of 800 mm. The equipment's used to drive the pile are,

1. Pile frames
2. Pile hammers
3. Leads
4. Winches, etc.

1. **Pile frames**

Pile frames are the steel frames of about 20m height made of steel, used for pile driving process. It consists of a working platform for supporting drivers, engines, winches etc. It is available in various forms and designs.

2. **Pile Hammers**

Piles are installed by a special pile driving device known as **Pile hammer**. The hammer may be suspended from the boom of a crawler crane, supported on a large frame called a **Pile Driver** or carried on a barge for construction in water. In all cases, the hammer is guided between two parallel steel members called leads. The leads may be adjusted at various angles for driving vertical and batter piles.

Types of Hammer

Various types of hammers used are,

a. **Drop hammer**

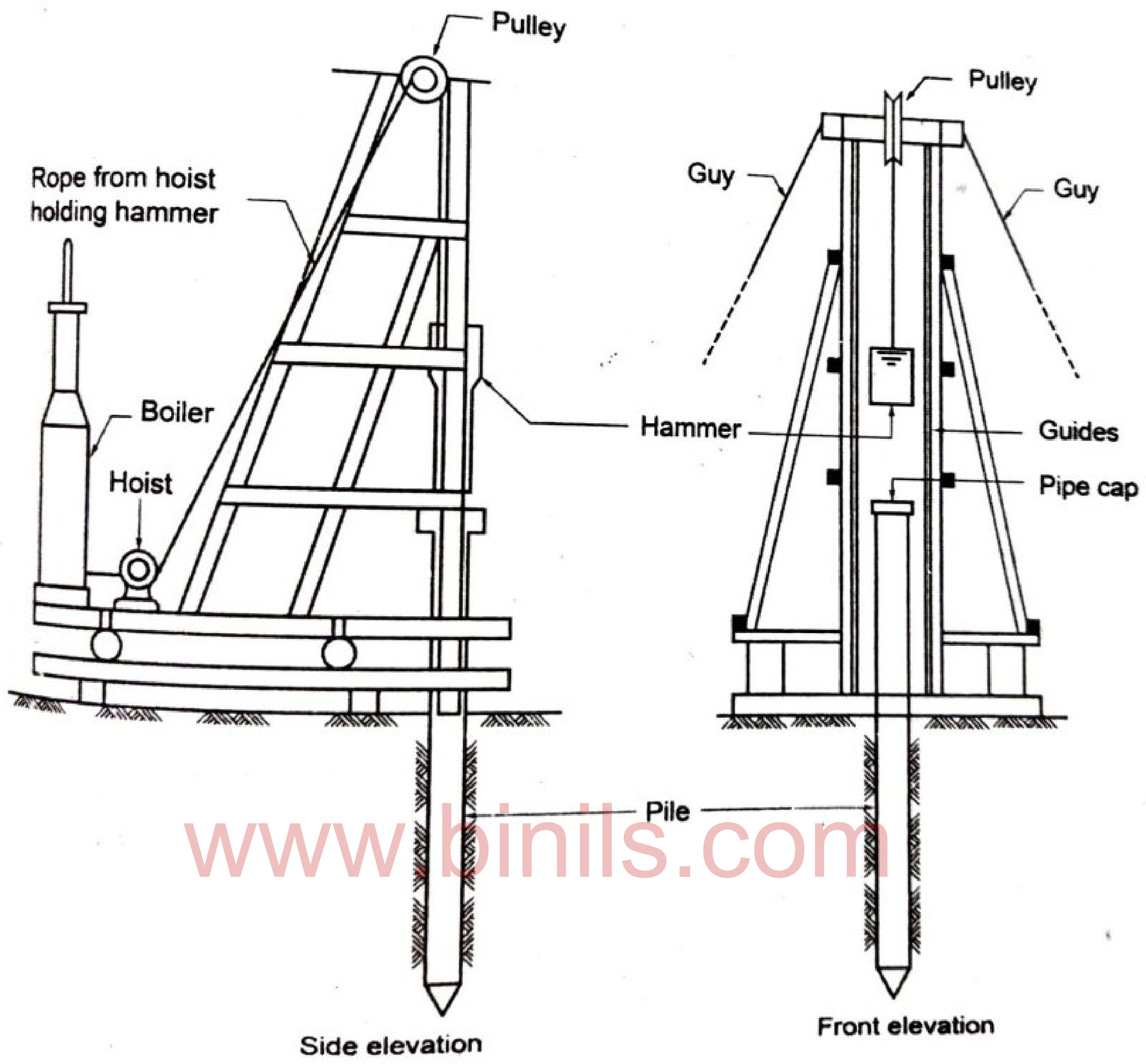


Fig. 3.6. Pile Driving With Drop Hammer

The drop hammer in the pile driving equipment consists of a heavy ram in between the leads. The ram is lifted up to a certain height and released to drop on the pile. This type is slow and therefore not in common use. It is used in the cases where only a small number of piles are driven.

b. Single acting hammer

In a single acting hammer a heavy ram is lifted up by steam or compressed air but dropped by its own weight. The energy of a single acting hammer is equal to the weight of the ram times the height of fall.

c. Double-acting hammer

The double-acting hammer employs steam or air for lifting the ram and for accelerating the downward stroke. The energy of a double-acting hammer is equal to the (weight of the ram I mean effective pressure I the effective area of ram) 1 times the height of fall.

d. Diesel Hammer

The diesel hammer is a small, lightweight and highly mobile. They use gasoline for fuel. To start the operation, the ram is raised, and the fuel is injected. As the ram is released, the ram falls and compresses air and fuel. The air and fuel becomes hot because of the compression and the air-fuel mixture is ignited. The resulting explosion,

- ✓ Advances the pile and
- ✓ Lifts the ram.

e. Vibratory Hammer

The principle of the vibratory driver is two counter-rotating eccentric weights The driving unit vibrates at high frequency and provides two vertical impulses one up and one down. The downward pulse acts with the pile weight to increase the apparent gravity force. These hummers have reduced driving vibrations reduced noise, and great speed of penetration.

3. Leads

Leads are employed to guide the hammer and pile and these are called leaders. For drop hammers, fixed leads are used.

4. Winches

These are required to lift the hammer and pile. They may be of light type with a single drum or of heavy type with double or triple drums.

6.4. PILE DRIVING

The installation process and method of installations are important factors as of the design process of pile foundations. Pile installation methods are installation by pile hammer and boring by mechanical auger.

To avoid damages to the piles, during driving, installation methods and installation equipment should be carefully selected. If installation is to be carried out using pile-hammer, then the following factors should be taken in to consideration:

- ✓ Size and the weight of the pile
- ✓ Driving resistance which has to be overcome to achieve the design penetration

- ✓ Available space and head room on the site
- ✓ Availability of cranes
- ✓ Noise restrictions which may be in force in the locality

There are basically two types of piling.

1. Piling for Displacement piles

- ➢ Bottom driven permanently cased piles
- ➢ Top driven concrete or timber piles
- ➢ Top driven or vibrated sheet piles

2. Piling for Replacement piles

- ➢ Rotary bored piles with temporary casing
- ➢ Rotary bored piles without temporary casing
- ➢ Continuous flight auger

I. Pile Driving Methods (Displacement piles)

Following are the methods of pile driving.

1. Dropping weight
2. Explosion
3. Vibration
4. Jacking (Restricted to Micro-pilling)
5. Jetting

a. Pile Driving by Dropping weight

Various hammers (Drop hammers etc.) are used for this method and are explained in this unit in various sections.

b. Pile Driving by Vibrating

Vibratory hammers are usually electrically powered or hydraulically powered and consists of contra-rotating eccentric masses within a housing attaching to the pile head. The amplitude of the vibration is sufficient to break down the skin friction on the sides of the pile. Vibratory methods are best suited to sandy or gravelly soil.

c. Jetting

In order to aid the penetration of piles in to sand or sandy gravel, water jetting may be employed. However, the method has very limited effect in firm to stiff clays or any soil containing much coarse gravel, cobbles or boulders.

II. Boring Methods (Replacement Piles)

a. Continuous Flight Auger (CFA)

Equipment comprises of a mobile base carrier fitted with a hollow-stemmed night auger which is rotated into the ground to required depth of piling. To form the pile, concrete is placed through the flight auger as it is withdrawn from the ground.

The auger is fitted with protective cap on the outlet at the base of the central rube and is rotated into the ground by the top mounted rotary hydraulic motor which runs on a carrier attached to the mast. On reaching the required depth, highly workable concrete is pumped through the hollow stem of the auger, and under the pressure of the concrete the protective cap is detached.

While rotating the auger in the same direction as during the boring stage, the spoil is expelled vertically as the auger is withdrawn and the pile is formed by filling with concrete. In this process, it is important that rotation of the auger and flow of concrete is matched that collapse of sides of the hole above concrete on lower flight of auger is avoided. This may lead to voids in filled with soil in concrete.

The method is especially effective on soft ground and enables to install a variety of bored piles of various diameters that are able to penetrate a multitude of soil conditions. However, for successful operation of rotary auger the soil must be reasonably free of tree roots, cobbles, and boulders, and it must be self-supporting

During operation little soil is brought upwards by the auger that lateral stresses are maintained in the soil and voiding or excessive loosening of the soil is minimized. However, if the rotation of the auger and the advance of the auger are not matched, resulting in removal of soil during drilling-possibly leading to collapse of the side of the hole.

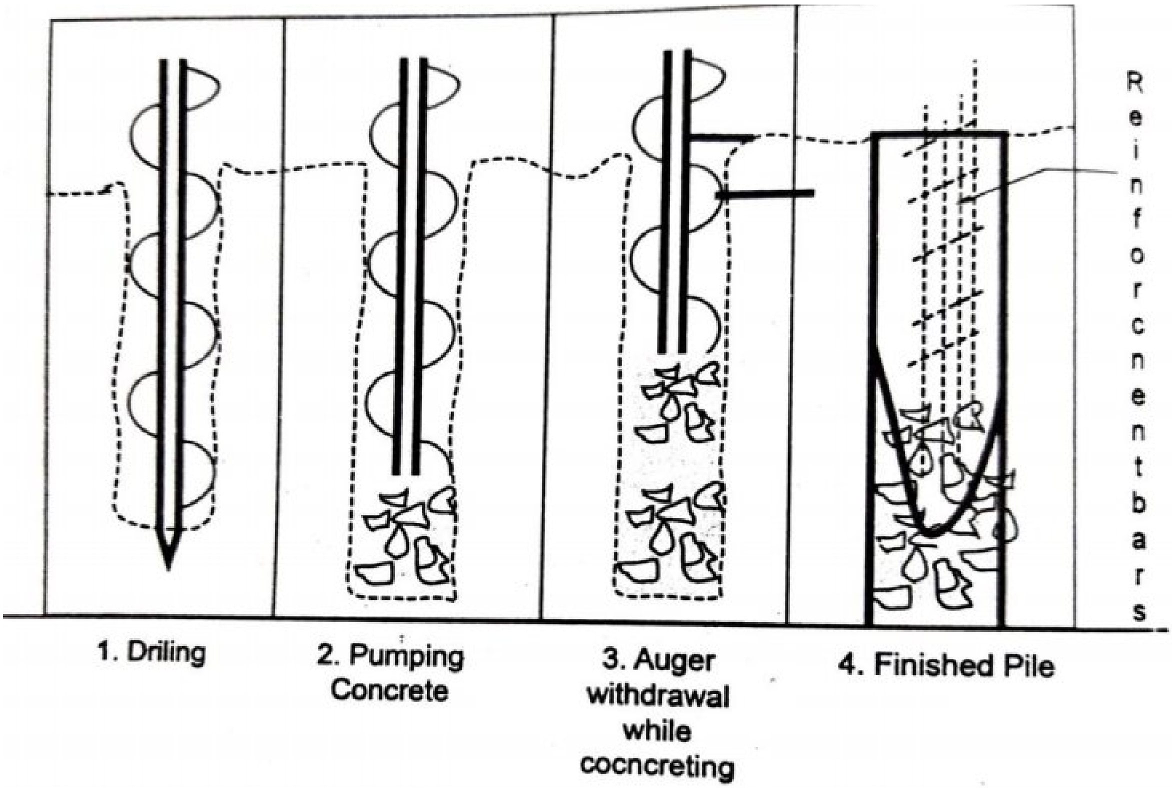


Fig. 3.7. Pile Driving

Underreaming

A special feature of auger bored piles which is sometimes used to enable to exploit the bearing capacity of suitable strata by providing an enlarged base. The soil has to be capable of standing open unsupported to employ this technique.

Stiff and to hard clays, such as the London clay, are ideal. In its closed position, the underreaming tool is fitted inside the straight section of a pile shaft, and then expanded at the bottom of the pile to produce the underream.

Normally, after installation and before concrete is casted, a man carrying cage is lowered and the shaft and the underream of the pile is inspected.

7. <u>WELL AND CAISSON FOUNDATION</u>

Caisson is a structure (or member), used for the purpose of placing a foundation in correct position under water. It is a member with hollow portion, which after installing in place by means is filled with concrete or other material. Caisson is suitable for sandy soils. Well foundation is the foundation method, structured when the good soil is available at nearly 3m below the bed level and bed consists of sand. A caisson differs from a pile in size and in method of construction. Caisson is sometimes referred as **well foundation**.

The main difference between the cofferdam and a caisson is given below.

1. Cofferdam is a temporary structure where as a caisson is the part of permanent work.
2. When the (plan) area of the foundation is very small as compared to the depth of water, a cofferdam becomes uneconomical and a caisson is a more economical structure.
3. Caisson structure is more suitable for the places where dewatering is to be done.
4. Foundation at more water depths (of about 15m), caissons are more suitable than the cofferdams.

The common materials used for the construction of a caisson are as follows.

1. Steel
2. Timber
3. Cast-iron
4. R.C.C.

7.1. CLASSIFICATION OF CAISSON

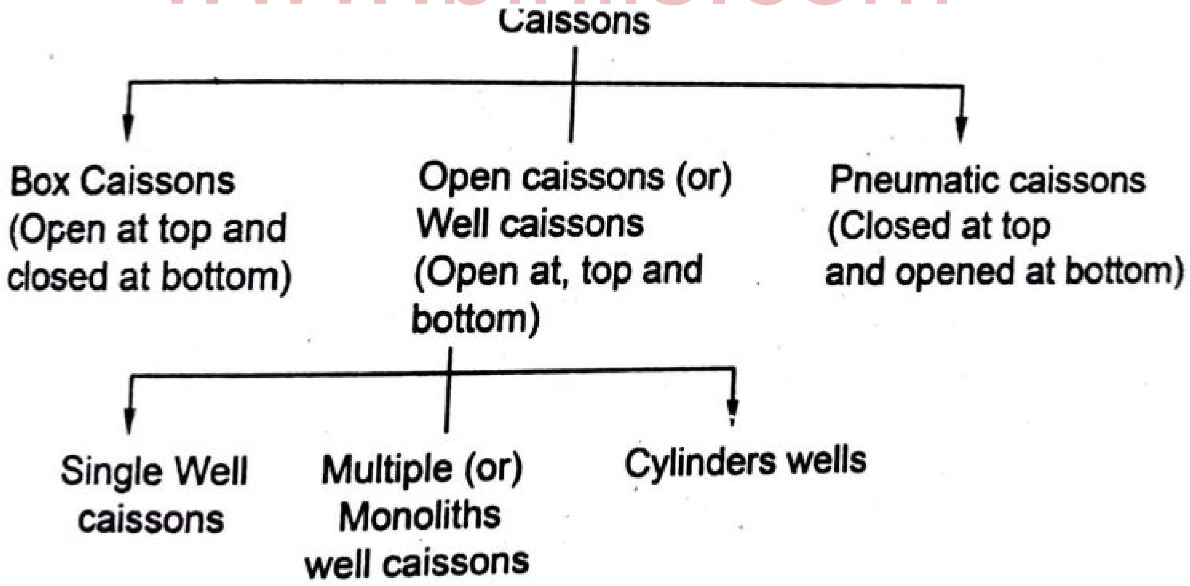


Fig. 3.8. Classification of Caisson

Caissons are classified as follows.

a. Box Caisson
b. Open or Well Caisson
   - Single well Caisson

- Multi-Well Caisson
- Cylinder well Caisson

c. Pneumatic Caisson

a. Box Caisson

Box Caisson is defined as the caisson opened at top and closed at bottom, made up of either RCC or timber or steel. It is merely a variation of the suspended type cofferdam.

Box caisson is suitable where bearing stratum is available at shallow depth and where loads are not heavy. Following procedure is adopted.

1. A level bearing surface is prepared to receive the bottom of the box. This can be done either by dredging or by drivers. If the caisson is rest on pipes. the group of piles is brought to the required height.
2. The caisson is constructed on shore, launched and floated to the site of work.
3. The box is then filled with suitable material to effect further sinking, if necessary.
4. The top is then sealed and further foundation work is started above the water surface.

b. Well Caisson (Open Caissons)

Depending upon their shape, open caissons can be further classified as,

i. Single wall open caisson

ii. Cylindrical open caisson

iii. Open caisson with dredging wells.

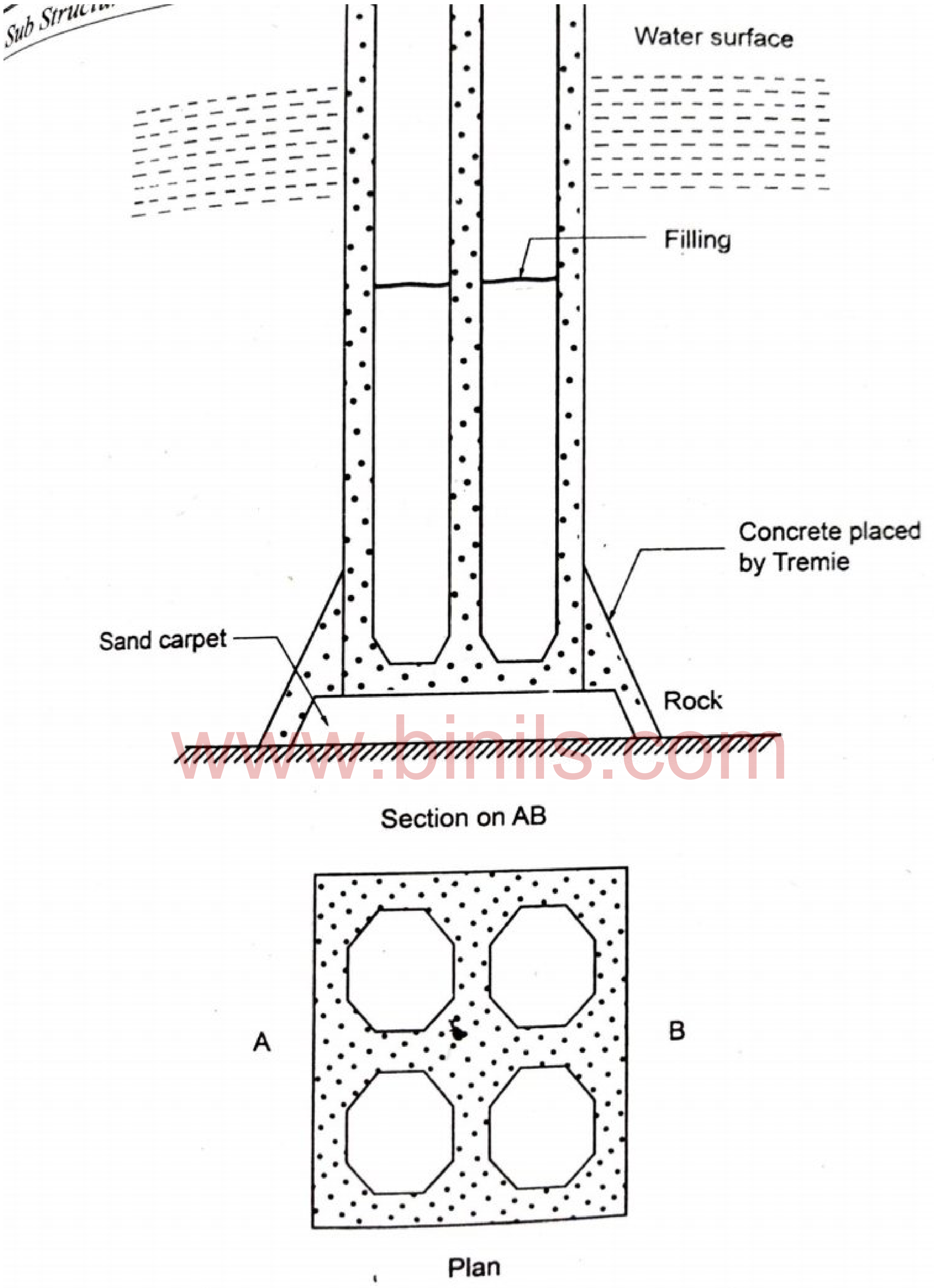


Fig. 3.9. Box caisson of concrete

i. Single wall open caisson

This is a box type structure without top or bottom (during construction) and mainly consists of vertical walls. The method of construction of a typical single wall open caisson is described below.

1. Wherever necessary, the site is made dry by dewatering the area by adopting suitable method (By constructing cofferdam, sheet piling etc).
2. A pit of suitable size and about 3 to 4 meter deep is excavated at the site where the caisson is to be sunk.
3. The cutting edge is then placed at the bottom of the pit. Above the cutting edge, the wall reinforcements are suitably tied up and the shuttering for casting the concrete wall is erected.
4. The caisson walls are then concreted in lifts to a suitable height. When the freshly laid concrete has gained sufficient strength, sinking operation is started. The caisson sinks due to its own weight when the soil from the space inside is removed by use of clamshell or any other method. As sinking proceeds, additional sections of the caisson walls are successively cast.
5. Sinking is stopped when each section is concreted and it is resumed only after the concreted section has gained sufficient strength. When the caisson is sunk to the required depth, its base is plugged by providing 15m to 45 m thick layer of concrete (concrete seal).
6. The concrete for the seal is placed by use of a Tremie pipe or by a bottom dump bucket. After the concrete seal has set, the water inside the caisson is pumped out and the empty space is filled with sand, gravel or concrete.

The rate of sinking of the caisson is always slow because the downward movement of the caisson is resisted by the skin friction of the ground on its walls. At times the skin friction becomes so great that the caisson does not sink even after all the earth has been dredged out from the inside clean down to the cutting edge. In such situations, sinking is resorted to by loading the caisson with additional weights in the form of rails, ingots etc. which are removed afterwards.

ii. Cylindrical Open Caisson

This may be defined as a cylindrical shell made up of timber, masonry, steel or reinforced concrete with a cutting edge and which is sunk by excavating the soil within the shell. The thickness of the caisson wall must be adequate so that when the inside soil is dredged out, it sinks under its own weight. To facilitate sinking of the caisson water jets are sometimes used around the sides which decrease the skin friction. Cylindrical open caisson is also known as well caisson. This type of caisson is similar in all respect to the single wall open caisson except that its wall is circular in plan. The method of construction of well caisson is exactly similar to that of a single wall open caisson described earlier.

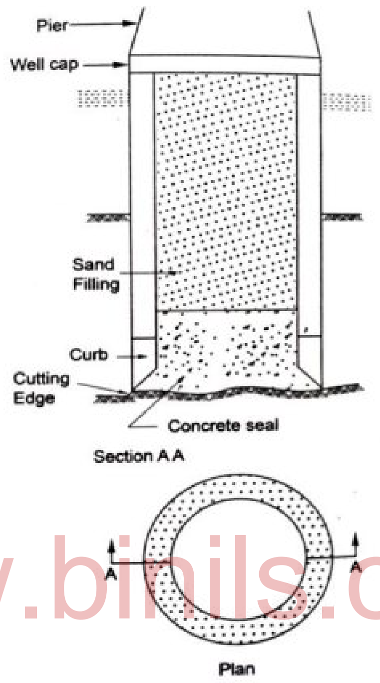


Fig. 3.10. Cylindrical Open

After the well is sunk to the desired depth its bottom is sealed with concrete. This type of caisson is commonly adopted for providing foundation for bridges and other structures to be built in rivers and waterways.

iii. Open caisson with dredging wells

This type of caisson has the distinction of being employed for the deepest foundation for, bridge piers, abutments and other similar structures. The caisson in this case is rectangular or square in plan and is further sub-divided into smaller sections from inside forming open walls. The outside walls as well as the inside divider walls are normally made up of reinforced concrete. The caisson is sunk by excavating soil through the wells by means of dredges. After the caisson is sunk to the required depth, its base is plugged with a concrete seal and the walls are filled with sand or concrete. From the point of view of control during sinking, this type of caisson has definite advantage over the other types described earlier.

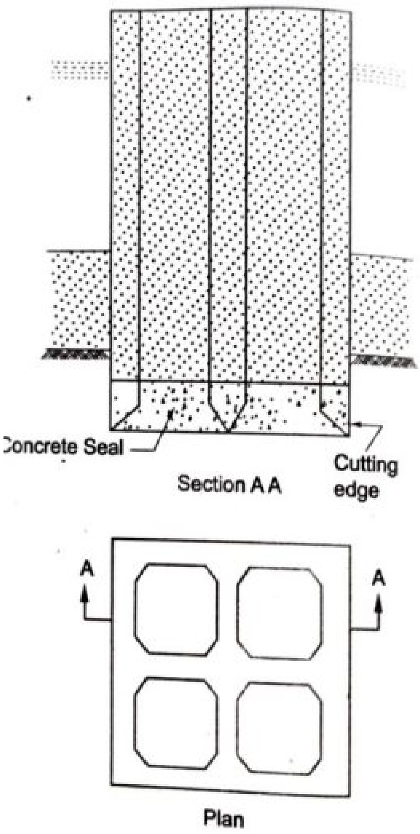


Fig. 3.11. Open Caisson with dredging wells

In this case, any tendency of the caisson to tilt or to drift from its position during the process of sinking, can be checked by dredging the soil from the appropriate wells.

c. Pneumatic Caisson

Caisson, closed at top and open (during construction) at the bottom is called **Pheumatic Caisson.** In this, water is removed from the caisson chamber by means of compressed air. The construction of the pneumatic caisson is similar to the other types, except that, the working chamber and shaft are made air-tight. In order that the workmen may carry out excavation work underneath the caisson and the water may not find its way inside from below, the pressure of the compressed air in the shaft is kept just higher than that of the water at that depth.

Each caisson has two air locks. Workers go down for working through one air lock while, excavated material is taken out through the other] An air lock essentially consists of a steel chamber having two air-tight doors One door of this chamber serves as an entry for men and material from outside into the steel chamber and the other door leads to the air shaft. When a workman enters the airlock from outside, the pressure inside the airlock is the same as that of outside atmosphere.

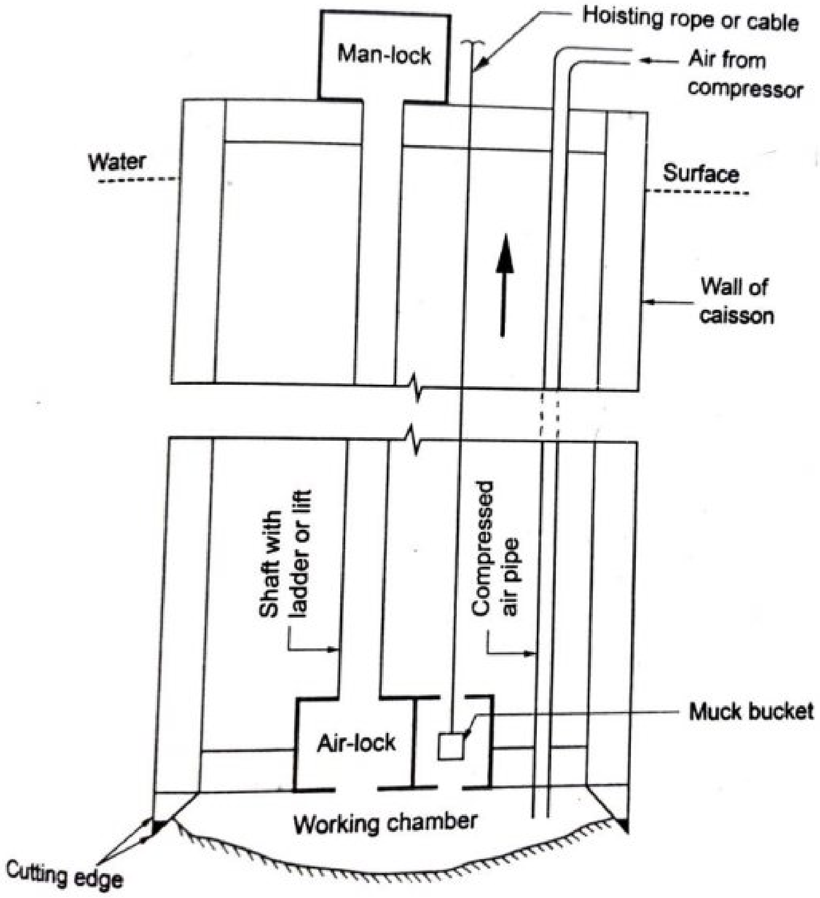


Fig. 3.12. Section of Pneumatic Caisson

Thereafter the outside door is closed and the pressure inside the airlock is raised slowly When the pressure inside the airlock becomes equal to the pressure in the caisson, the door of the airlock which leads to the air shaft is opened and the workman goes down the air-shaft with the help of a ladder installed therein. Exactly reverse procedure is followed when the workman comes out of the caisson Air-shaft provides means of access for the worker from airlock down to the working chamber.

a. Advantages of Pneumatic Caisson

Following are the advantages of pneumatic caisson.

1. Suitable for higher water depths
2. Suitable for soils with varying properties
3. Simple inspection of the work.
4. Removal of obstructions is simple
5. Concreting for foundation is a simple process
6. Reliable quality of work
7. Easy checking of vertically of pneumatic caisson

b. Disadvantages of Pneumatic Caisson

Following are the disadvantages of pneumatic caisson.

1. High Construction cost
2. High degree of skill is required in sinking
3. Proper health controls are necessary for the laborer's.
4. Depth of penetration below water is limited to 35 m.

c. Caisson Sickness

In pneumatic caissons, the workers often working in the compressed air suffered a certain type of disease when they returned to atmospheric pressure, after working in the compressed air is called **Caisson Sickness or compressed air sickness**.

The main symptoms of the disease were dizziness, double vision, headache, trouble to speaking, pain in legs, etc. The disease resulted in the loss of consciousness, paralysis or sometimes even death.

Causes of Caisson Disease

When a person is subjected to the compressed air, the nitrogen is also absorbed along with oxygen by tissue fluids of the person. The oxygen is dissolved by blood while nitrogen is kept in suspension, as it is not soluble in blood. When the pressure of the air is reduced, the tissue-fluids give up the nitrogen content at a certain rate. If the reduction of pressure is not uniform, the nitrogen will not able to come out in the form of gas. It will form bubbles within the tissue-fluids. These bubbles caught up in the different parts of our body will give rise to the caisson sickness.

Precautions to be taken to avoid Caisson Disease

1. By introducing the shift method for workers
2. By providing interval between working periods
3. By maintaining the temperature of about 25°C
4. Physical examination of the workers
5. By using Man-locks
6. By arranging clear and properly lighted passages.

7. By maintaining the first minute pressure is increased about 35 kN/m² and the rate of compression is increased to about 70 kN/m².
8. By providing recompression or medical chamber etc.

8. SINKING COFFERDAM (OR) COFFERDAM

Cofferdam is defined as the temporary structure, constructed to remove the water and soil from an area and make it possible to carry on the construction work.

Cofferdams are used to project dams, locks and bridge construction, piers and abutments.

Following are the requirement of a cofferdam.

1. It should be reasonably watertight.
2. The design and layout of a cofferdam should have a minimum cost for construction and the pumping should be minimum.
3. It should be designed for M.W.L. and other destructive forces.
4. It should be generally constructed at the site of work.

It is constructed with advantages where, a larger area of site is to be enclosed and the hard bed is at a reasonable depth. The materials used in the construction of a cofferdam are earth, timber, steel and concrete.

8.1. OBJECTIVES AND USES OF COFFERDAM

The cofferdams are used,

1. To place grillage and raft foundation
2. To facilitate pile driving operations
3. To enclose a space for the removal of sunken vessels.
4. To provide a working platform for the foundations
5. To construct foundations for piers and abutments of bridges, dams, docks etc.
6. To provide a space for carrying out the foundation work without disturbing or damaging the adjoining structures such as buildings etc.

8.2. TYPES OF COFFERDAM

Cofferdams are classified according to the type of construction. The type o construction is dependent upon the depth, soil conditions, fluctuations in the water level, availability of material etc. Following are some of the common types of of cofferdams.

1. Earth fill Cofferdam
2. Rock fill Cofferdam
3. Single Wall Cofferdam
4. Double Wall Cofferdam
5. Concrete Cofferdam
6. Cellular Cofferdam
7. Suspended Cofferdam

1. Earth fill Cofferdam

Earth fill cofferdam is an embankment of earth and it is the simplest form of cofferdam. Its uses are limited to shallow depth of water i.e., 1200mm to 1500 mm with low velocity of flow.

As a precautionary measure, the earth bank is carried about one metre above the water level. The top width of the bank should not be less than 1 m and the side slopes vary from 1: 1 to 1:2. The earth embankment should be built from a mixture of either clay and sand or clay and gravel.

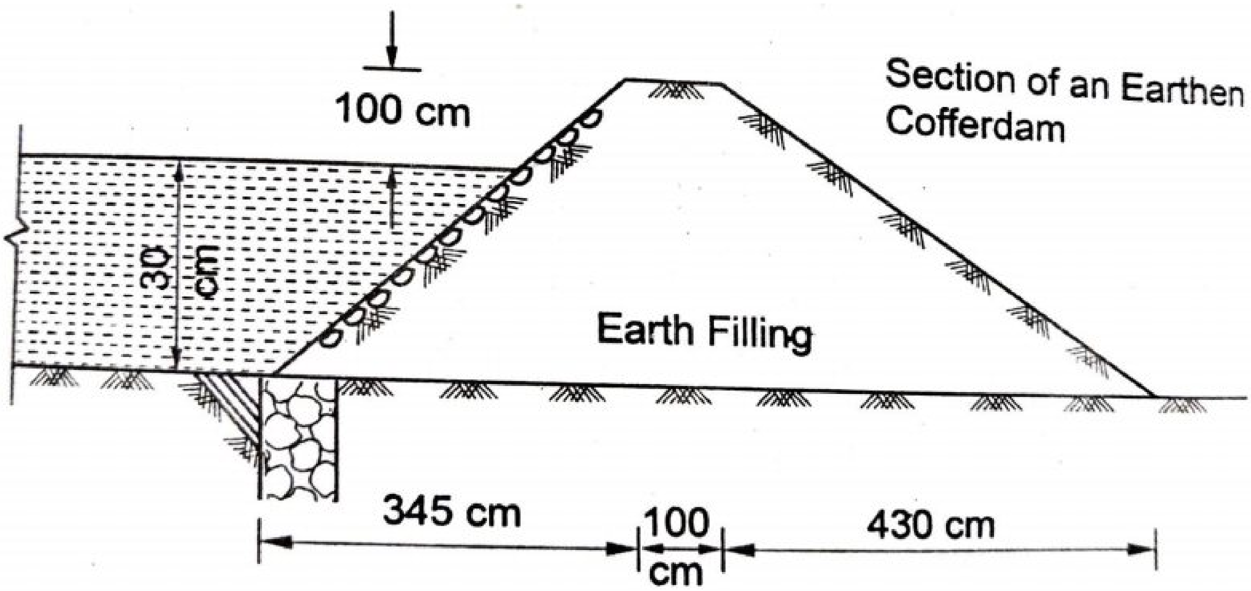


Fig. 3.13. Earth fill Cofferdam

If sufficient quantity of clay is not easily available, the banks inay be constructed with a central clay wall with slopes of sand on either side. In order to prevent the embankment from scouring due to the action of water, side slopes of the bank on water side should be pitched with rubble boulders. If the current of water is such that there is a danger of the earthen embankment getting washed away, canvas bags half filled with material of embankment (mixture of clay, sand or gravel) are stacked one over the other to form the embankment. After the work of construction of cofferdam is over, the water from the enclosed area is pumped out so as to leave a dry surface inside. Excavations can then be performed to the required depth and the work of construction of foundations carried out.

2. **Rock fill Cofferdam**

The rocks dikes or rock fill cofferdams are similar in construction to the earth dikes. They can be used for depths of water up to 3m and are suitable even in case of swift water.

It is economical at places where, rock is available in plenty. The only disadvantage of this type of cofferdam is that it is not impervious. The methods employed to make such type of cofferdams fairly watertight are suggested in fig.3.14. A properly constructed rock fill cofferdam can withstand the over tapping of water without any serious danger.

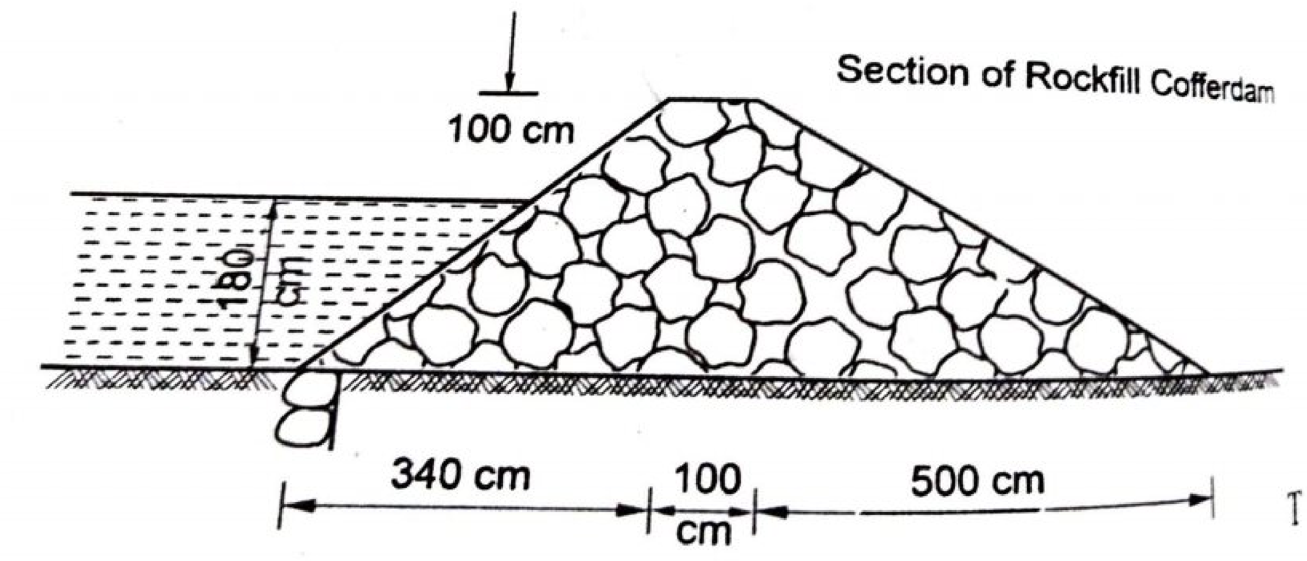


Fig. 3.14. Rock fill Cofferdam

3. **Single Wall Cofferdam**

This type of cofferdam is used in places where the area to be enclosed is very small and the depth of water is more, say 4.5 to 6 m. Timber piles (called Guide piles) are first driven deep into the firm ground below the river bed. Depending upon the velocity of the current of the water in the river, the centre to centre spacing of the piles may vary between 1.8 to 4 m.

Longitudinal runners (called **Wales**) are then bolted to the guide piles at suitable distance apart. Steel or wooden sheet piles are then driven into the river bed along the wales and are secured to the wales by bolts. The sheets on the two faces are braced by trussed arrangement of struts.

This helps in increasing the stability of walls against the water pressure. Half-filled bags of sand stacked on the inside and the outside faces of the sheets help in increasing the stability of cofferdam. After the **cofferdam** is constructed, the water in the enclosed area is pumped out and the construction work is taken up.

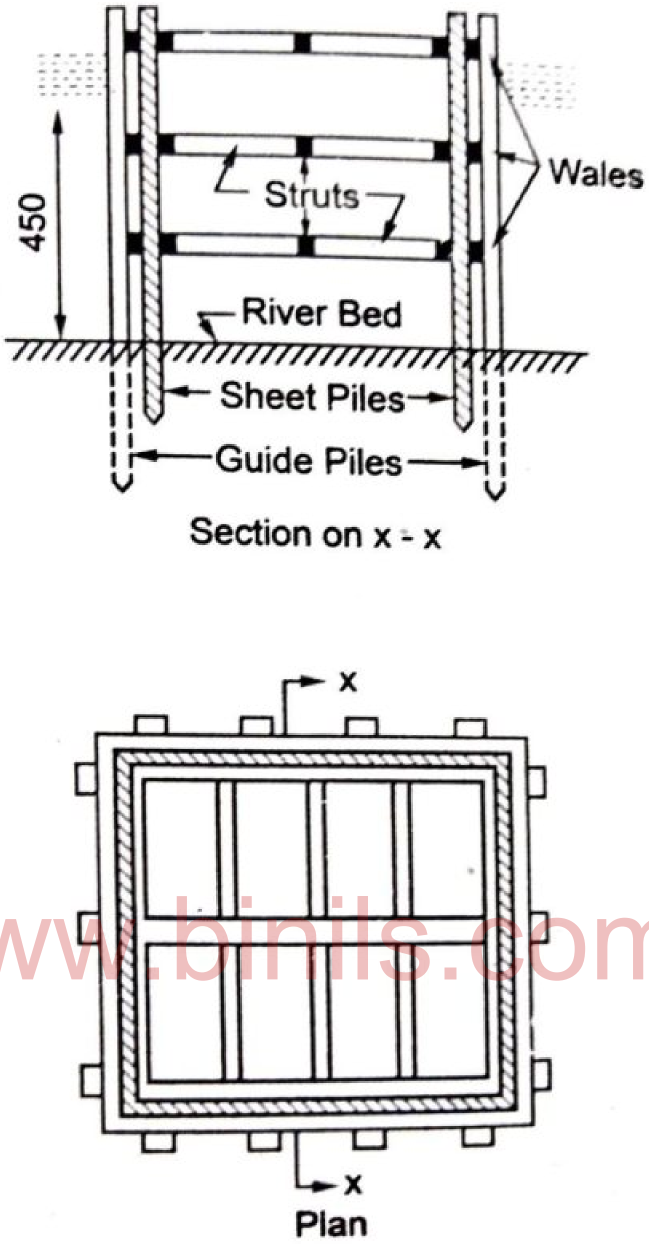


Fig. 3.15. Single Wall Cofferdam

4. Double Wall Cofferdam

Larger sections of trussed struts would be necessary to resist the water pressure, single wall type becomes uneconomical. Hence, in order to enclose larger areas in deep water, **Double-walled** cofferdam is required. Its construction is essentially the same as that of a single-walled cofferdam except that in place of one wall, a pair of walls with a gap in between is used all along the boundary of the space to be enclosed.

This type of cofferdam can be used in depth of water up to 12 m. As the depth of water increases, the wall should be made wider in order to make it stable against overturning and sliding. The distance between the two walls depends upon the depth of water. The thickness of wall should be equal to the depth of water up to 3m. For greater depths of water, the thickness of wall should be 3 m. plus %½ the depth of water in excess of 3 m. At their top, the two faces of the walls are connected by steel rods spaced at close intervals. To prevent the leakage from the ground below, the sheet piles are driven to a good depth in the bed.

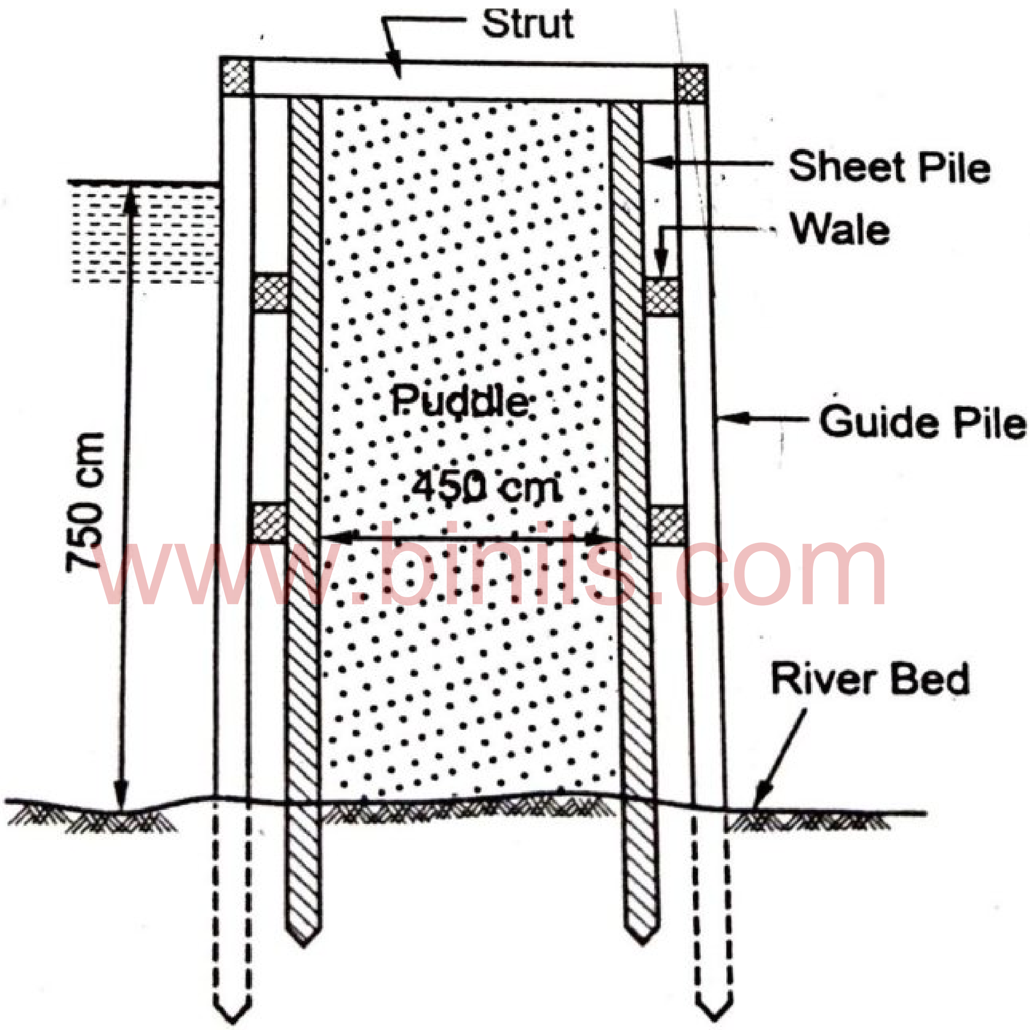


Fig. 3.16. Double Wall Cofferdam

5. Cellular Cofferdam

This type of cofferdam is mostly used for de-watering large areas in places where, the depth of water varies about 18 to 21 m. Cellular cofferdams are mostly used during the construction of marine structures like dams, locks, whares etc. Cellular cofferdam is made by driving straight web steel sheet piles, arranged to form a series of inter-connected cells. The cells are constructed in various shapes and styles to suit the requirements of site.

Finally the cells are filled with clay, sand or gravel to make them stable against the various forces to which they are likely to be subjected to.

The two common shapes of the cellular cofferdam are,

i. Circular type

ii. Diaphragm type

The circular type of cellular cofferdam has the advantage that, each cell may be filled completely to the top before starting the construction of the next cell without causing any distortion to the cofferdam's shell. Diaphragm type cellular cofferdam consists of a series of diaphragm of steel sheet piles connected as shown in the image below. The straight diaphragm walls are connected to each other by steel piles arranged in the form of arches on either sides. The radius of the connecting ares is generally made equal to the distance between the straight diaphragm walls.

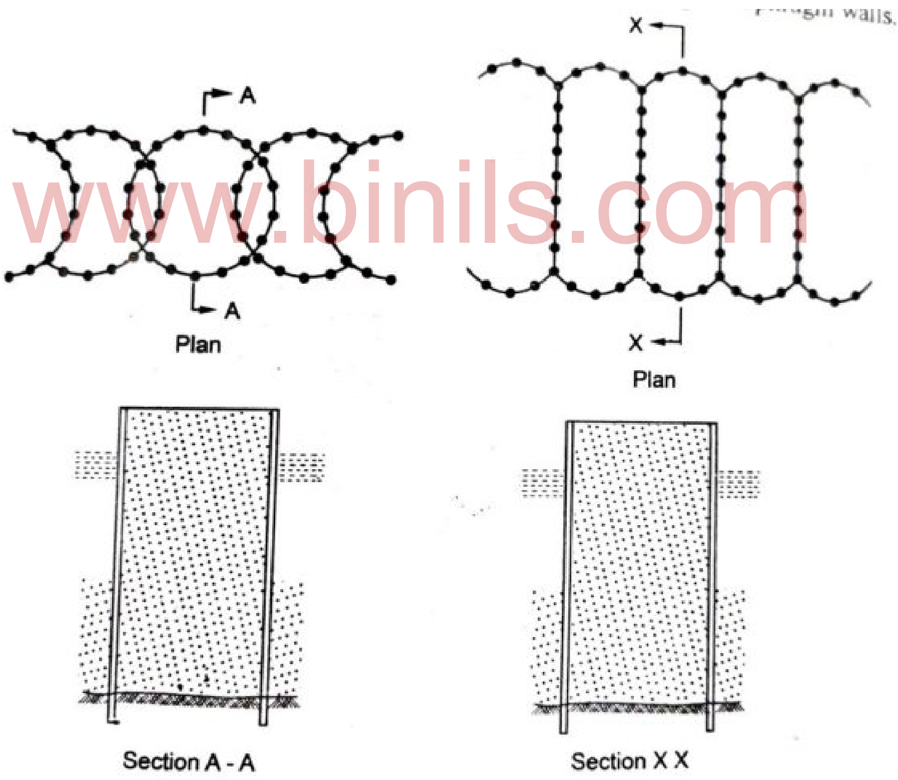


Fig. 3.17. Cellular Cofferdam

9. CABLE ANCHORING AND GROUTING

9.1. CABLE ANCHORING

Excavations and other engineering processes in the ground are common to ma civil and mining projects. Ground reinforcement includes the techniques of ground anchoring, cable bolting and rock bolting. **Ground anchoring** tends to be long with higher capacity, and is usually associated with civil infrastructure projects.

Anchors are constructed at locations around each caisson. At anchor location soil bearing was carried out by using rotary percussion type drilling equipment The required depth of bearing near the caisson location was achieved by using a standard size of casing pipes of dia 135 mm, length 1500 mm and having thread both ends and soil drilling was done by rotary percussion type drilling equipment.

Ground anchoring is carried out for three different conditions.

- Anchors in Rocks
- Anchors in Clay
- Anchors in Granular Materials

9.2. GROUTING

Grouting is a process of ground improvement, by injecting fluid like mater into subsurface soil or rock. It is used to fill the cracks and seams of the rock voids in the soil.

Grouting is an engineering and art combined to fill up the voids or cavities i rock or soil masses with fluid that will increase the overall strength impermeability of the mass. Portland cement grout is useful for crack upto 1.6 mm width only.

I. Purpose of Grouting

- It strengthens and makes the rock or soil water tight and monolithic.
- It has been successfully used in stopping the leakage from rocks.

II. Types of Grouting

- Chemical Grouting
- Cement Grouting
- Jet Grouting

Chemical Grouting

In this, a concentrated solution of sodium silicon and calcium chloride act as electrolyte. There are two types of chemical grouts.

- Inorganic chemicals

- Organic chemicals

Cement Grouting

It is the process of filling the holes in the ground by cement grout under pressure. **Cement grout** is the mixture of cement, sand and water, which is applied with pressure, for various filling applications.

- This process is carried out by making number of holes in the ground and filled by cement grout. This is continued till no grout is coming up through the hole.
- There is no specification for number of holes created in the ground and it depends on the nature of the ground.

Jet Grouting

It is a technology in which high-pressure jets of cement grout are discharged sideways into the borehole wall to simultaneously excavate and then mix with the soil. The outstanding feature of jet grouting is the ability to treat a whole range of Jet grouting can be performed in soils with a wide range of granulometries and soils, from silty sands to cohesive deposits, by means of simple cement grouts. permeabilities.

III. Characteristics of Grouting Materials

The characteristics of grouting materials are,

- The grouting material has high permeability.
- No vibrations are used.
- Application requires no additional structure used.

10. <u>SHORING FOR DEEP CUTTING</u>

Shoring is defined as the process of providing temporary support to produce adequate stability of the structure due to unequal settlement of foundations or due to removal of adjacent building or due to other reasons.

Shoring is carried out under the following conditions.

To increase the stability of the structures in which,

i. The stability may be affected due to the unequal settlement of the foundation, or due to the removal of adjacent buildings, or due to the defective or bad workmanship or due to any other reason.

ii. When certain alterations are required to be done in the structure itself (such as re-modeling of walls, etc.) or during the alterations of adjacent buildings such as underpinning of (the adjacent building) foundations, dismantling of adjacent building, etc.

The following points should be noted while installing shores.

i. Shoring may be done externally or internally and in certain cases they may be provided from both sides of the wall to produce additional stability. However, before the installation of shores, the necessary permission from the local authority should be obtained.

ii. It is essential that the lines of action of the overturning forces in floors and roofs, the forces in walls and the reaction of the shores must meet at a single point to maintain the equilibriums. (The over-turning forces must be resisted by the supporting shores)

iii. Shoring should be strong enough to resist the acting forces, consistent with economy.

iv. Shoring should be provided to unsafe structures till such times as they have been made stable.

10.1. TYPES OF SHORING

Shoring is classified into the following three classes either on the basis of their supporting characteristics or their position in the space:

1. Raking or Inclined Shores
2. Flying or Horizontal Shores
3. Dead or vertical shores.

1. Raking Shores or Inclined Shores

Raking shores is a system of giving temporary support to an unsafe wall. The construction of raking shores varies with the conditions of site. In all cases, wall plate of 230mm x 50mm to 230mm x760mm size is fixed against the unsafe wall with hooks. The wall-plate is further secured to the wall by means of needles.

The needles of 100mm x 760mm in section penetrate inside the wall for a distance of about 100 mm. The needles are strengthened by providing wooden cleats. The top end of the inclined rakers rests against the needles.

At their base the racers are supported by a sole piece bedded in an inclined position in the ground. The rakers are secured to the sole piece by cleats and dogs. in soft ground the area of the sole piece is increased so as to distribute the pressure over large area. In places where more rakers are provided, they are bound together by means of hoop iron or braces

250mm thick and 150mm wide. The inclination of the outer raker to the ground should very between 60° to 75°. The sets of shores should be usually placed at 30mm to 460mm centre to centre along the wall length.

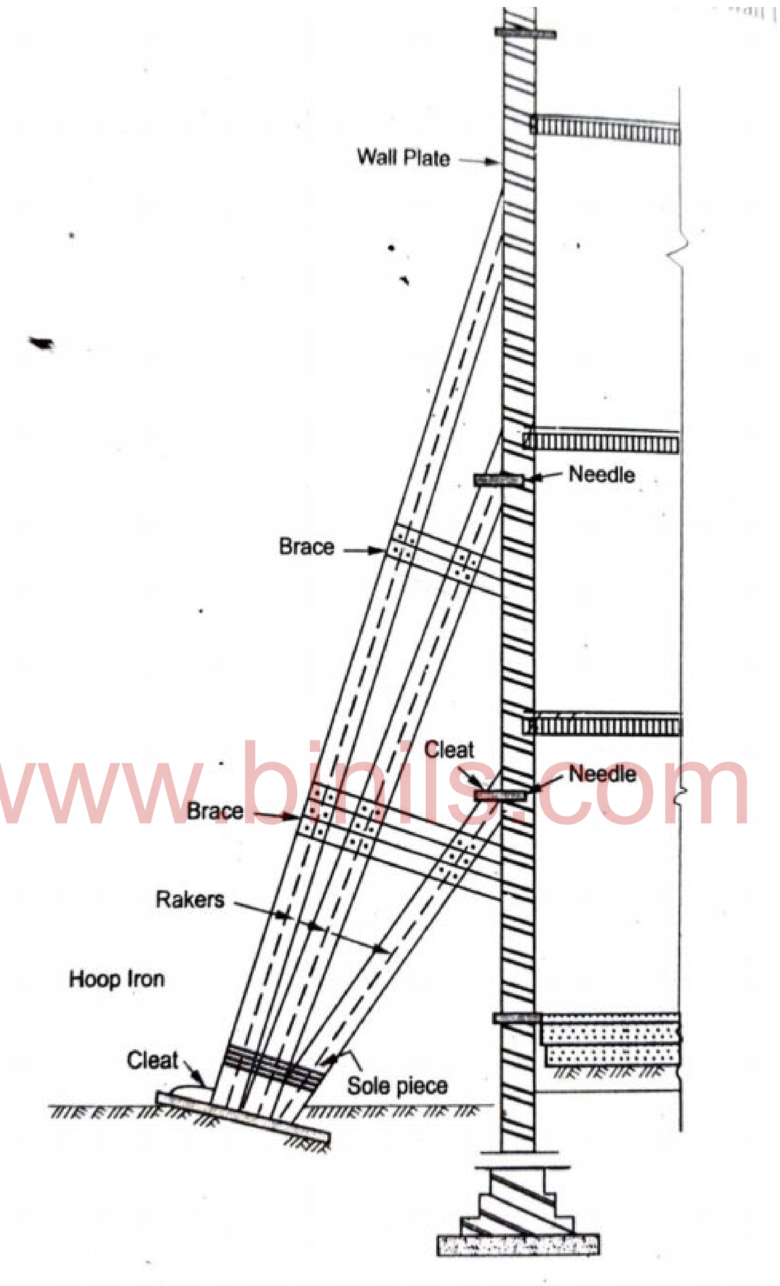


Fig. 3.18. Raking Shores

b. Flying or Horizontal Shores

Flying or Horizontal Shores are horizontal type supports, provided for supporting temporarily the parallel walls of the two adjacent buildings, which may tend to collapse or damage when one of the intermediate buildings has to be pulled down and rebuilt.

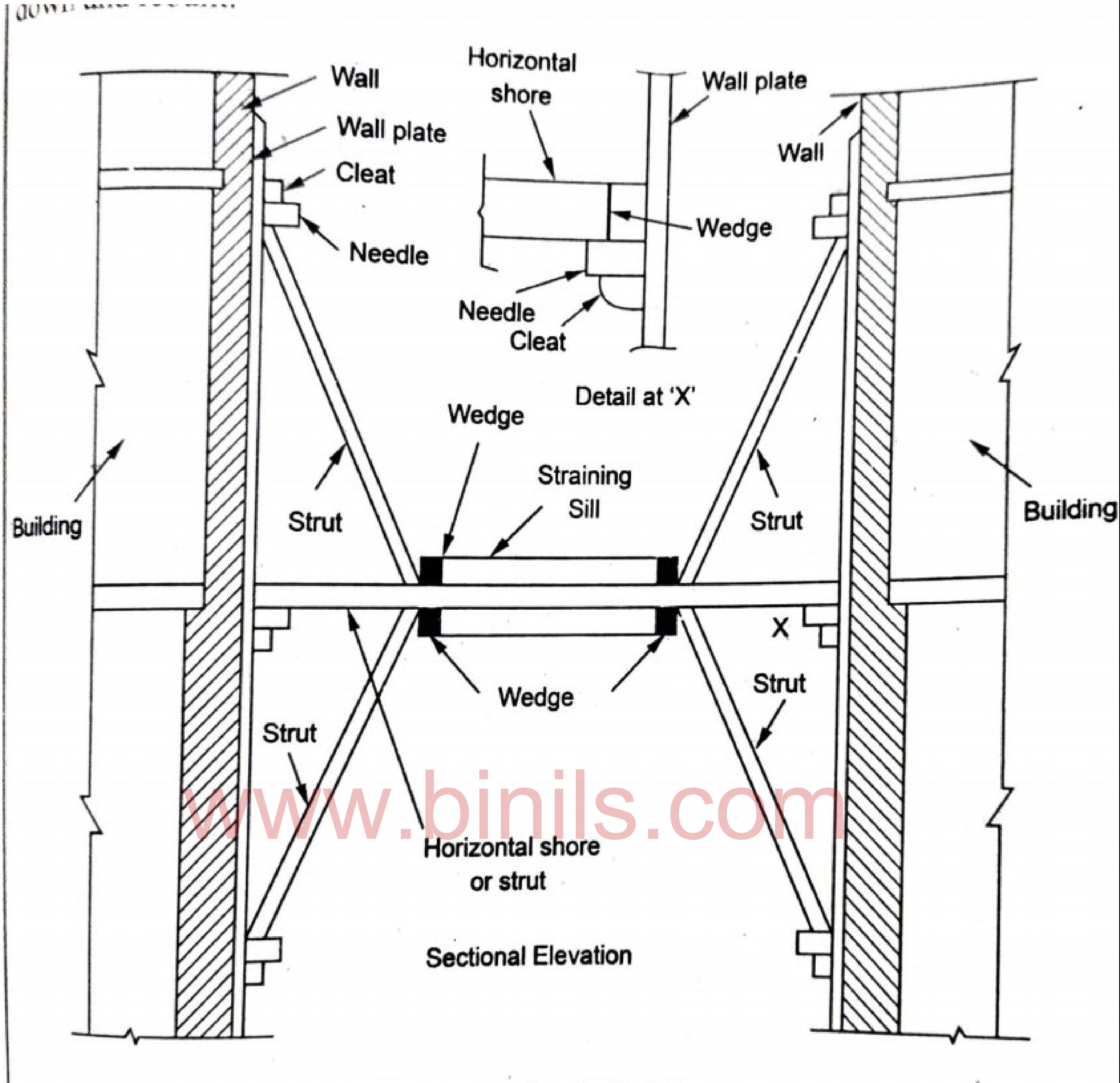


Fig. 3.19. Details of a single flying shore

Such conditions occasionally arise when one of the intermediate buildings from a series of buildings standing side by side is either required to be reconstructed or has collapsed due to some reason.

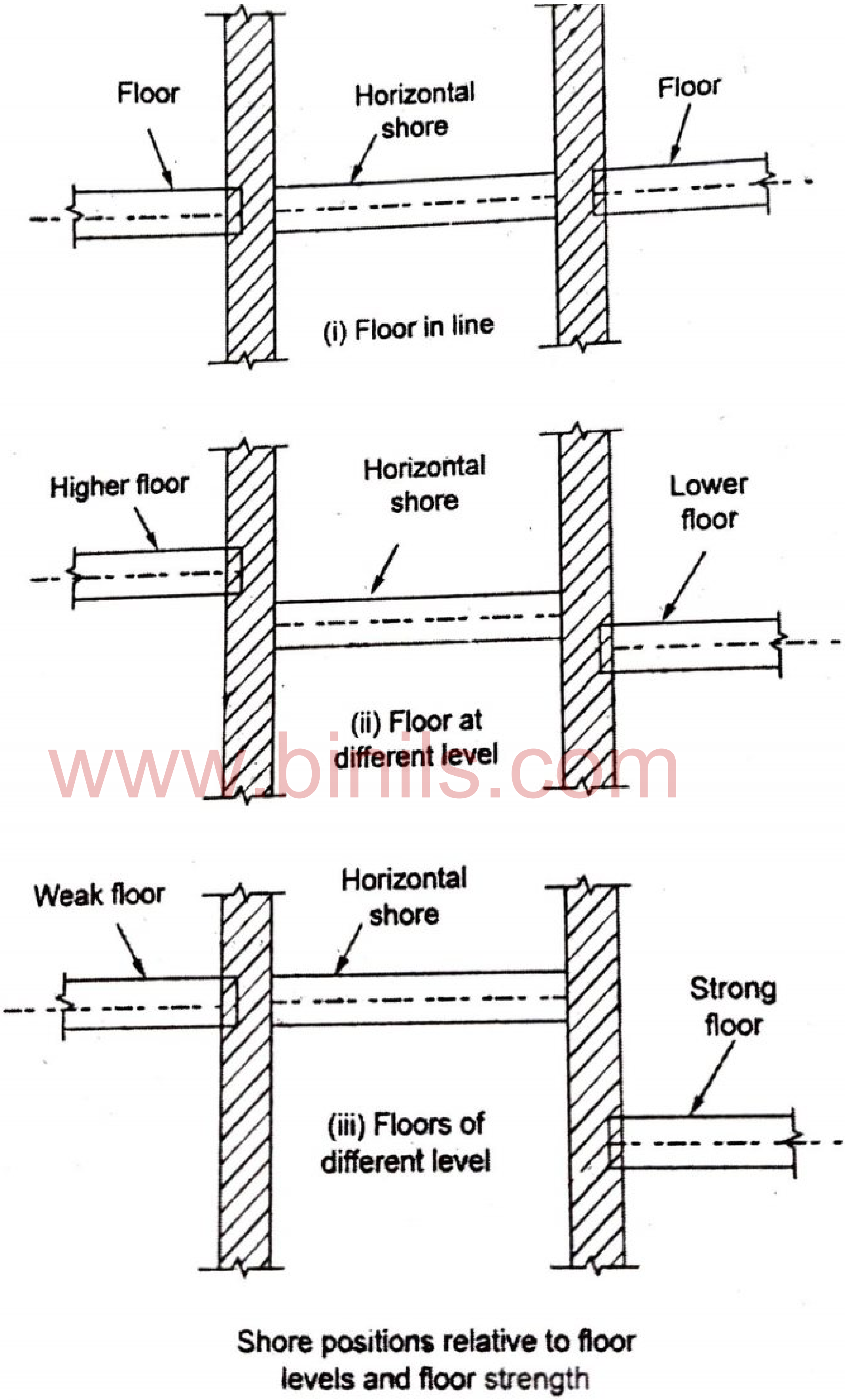


Fig. 3.20. Shore positions relative to floor levels and floor strength

A single flying shore consists of wall plates, struts, straining pieces, horizontal shore (or horizontal strut), needles, cleats and wedges, as shown in the above image. Like inclined shores, in this system also, the wall plates are secured against the walls by means of needles and cleats. The horizontal shore is held in position by wedges, needles and cleats to the wall plate as shown at section (x).

The inclined struts are supported by the needles at their one end and straining sill at the other end. Straining Sill, in turn, is spiked to the horizontal shore.

The details of a simple raking shore (with three rakers, known as **treble** raking shore) are shown which can be employed up to 3-storey heights.

i. During reconstruction of the intermediate building, the flying shores temporarily take up the position of the dismantled building.
ii. The centre-lines of **flying shores** and **struts**: and flying shore and walls, should meet at the floor levels. If the floor levels of two buildings are different or their strengths are different, then shore positions should be provided as shown in the below image.

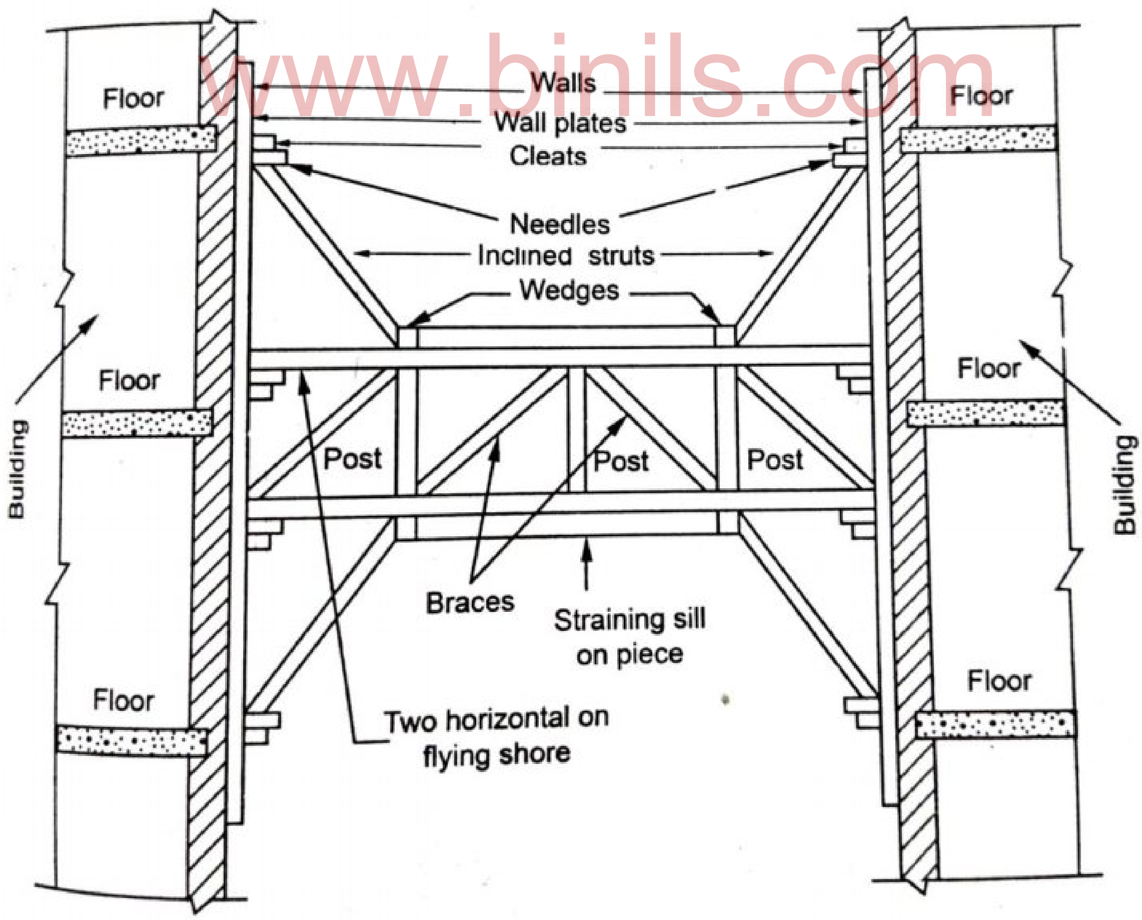


Fig. 3.21. Details of double flying shore or horizontal shore

iii. The maximum distance of about 10m between the parallel walls can be supported by single flying shore. For a distance more than 10m, a double flying shore, is having a trussed form work as shown in Fig.3.21, is employed.

iv. The flying shores are kept in position so long as the adjacent buildings are made stable by constructing the building to a sufficient height.

v. Unlike the inclined shoring in this type, only one set of shoring is employed to strengthen the two adjacent walls.

vi. A larger factor of safety should be adopted in design analysis of flying shores because of uncertainty of actual loads. For shores to be more effective, the struts should be inclined at 45°, if possible.

c. Dead Shores or Vertical Shores

Dead Shores are the vertical members used to support temporarily the walls, roofs, floors, etc., by providing horizontal members (known as needles). Following are the objectives of dead or vertical shores

i. To rebuild the lower part of a defective load bearing wall

ii. To replace or deepen the existing foundations, for strengthening or for carrying heavier loads

iii. To provide large openings in the existing walls such as doors, windows, shop fronts or garages at a lower level.

In the fig 3.22, the arrangement is shown to meet first two objectives. In this system, wooden needles consisting of thick sections, used to transfer the overhead loads to the properly braced vertical shores. These vertical or dead shores transfer those loads to the ground on firm foundations below. The other details regarding introducing of rolled steel joists for supporting, strutting of floors by props, use of wedges, sole pieces is self-explanatory.

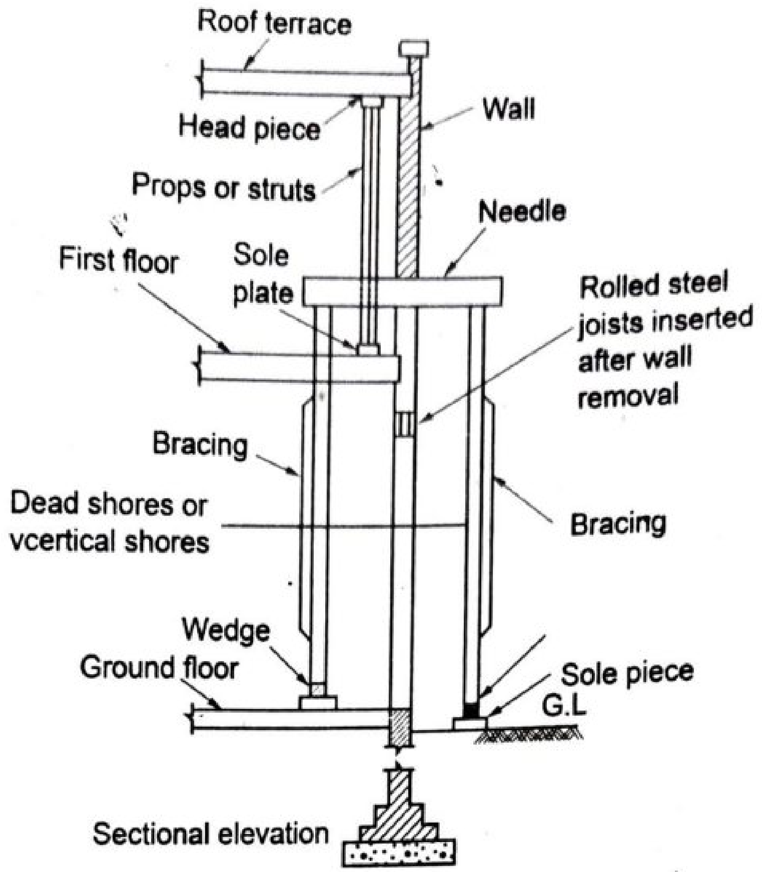


Fig. 3.22. Dead Shores

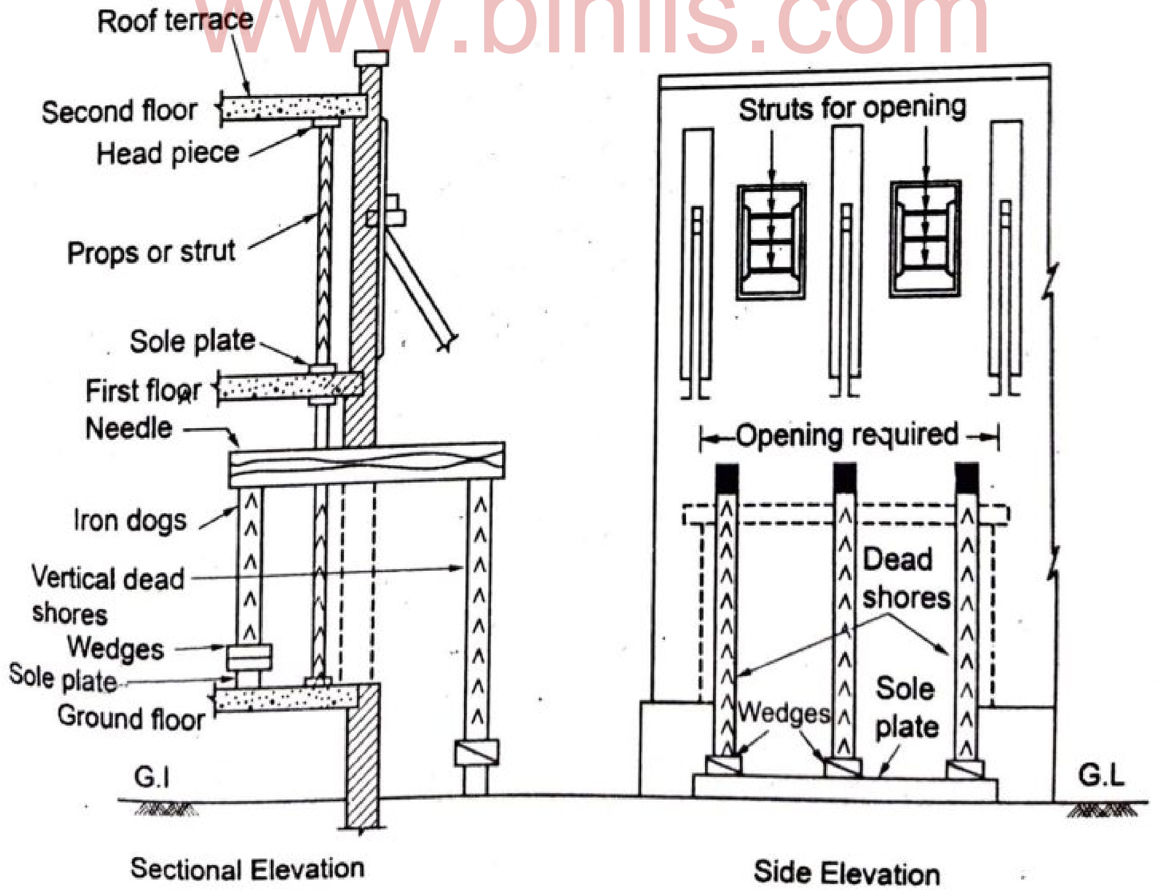


Fig. 3.23. Use of dead shores in making an opening in the existing wall

In the fig 3.23, the arrangement is shown to meet the third objective, ie, providing a large opening in an existing wall. To meet this objective following procedure is adopted.

i. Before providing shores to a building, all door and window openings properly strutted to resist any possible deformation and then inside floors of the building are also strutted by props or vertical posts. At the top and bottom of these vertical struts or posts, timber heads and sole pieces are provided to distribute the load more effectively; wedges are also used at the bottom or foot of prop for tightening purpose.

ii. Holes are than cut in the wall by crow bar at points above the required opening, at a distance of 1 m to 2.5 m depending upon the weight of structure above.

iii. Through these holes, timber or steel horizontal beams, called needles, are inserted and projected at right angles on each side of the wall. The projected ends of needle beams are supported on heavy transfer the loads to the ground and hence are made to rest on a sole plate, firmly bedded on the ground.

iv. The shores are removed only after the new construction work has attained sufficient strength and this period of removal usually is not less than 7 days.

v. The sequence of removal of shoring system should be needles first and then strutting from openings and floor strutting inside the building.

Sometimes, raking shores are provided to support the wall from above the proposed opening to safeguard against shocks and vibrations during wall cutting. If raking shores are used, they should be removed after the whole dead-shore system is removed.

11. LARGE RESERVOIR CONSTRUCTION

- When there is topography consisting of U-Shaped valley with very little overburden, then RCC gravity dam is mostly recommended.
- RCC dam is a solid structure made of concrete and steel reinforcement and constructed across the river so as to develop the reservoir on its upstream side.
- RCC dam are strong, durable and having the maximum reservoir capacity. Dead load of dam is distributed in such way that the entire section resists the pressure of water on the upstream side.
- RCC dam can sustain the various types of loads like:

  i. Weight of the dam

  ii. Water pressure on upstream side

iii. Wave pressure

iv. Uplift pressure

v. Pore pressure

vi. Slit pressure

vii. Wind pressure

viii. Earthquake pressure or seismic load

- Initial cost of construction of RCC dam is high but long term cost is minimum.
- The fig shows the section of RCC dam subjected to various types of loads or pressures.

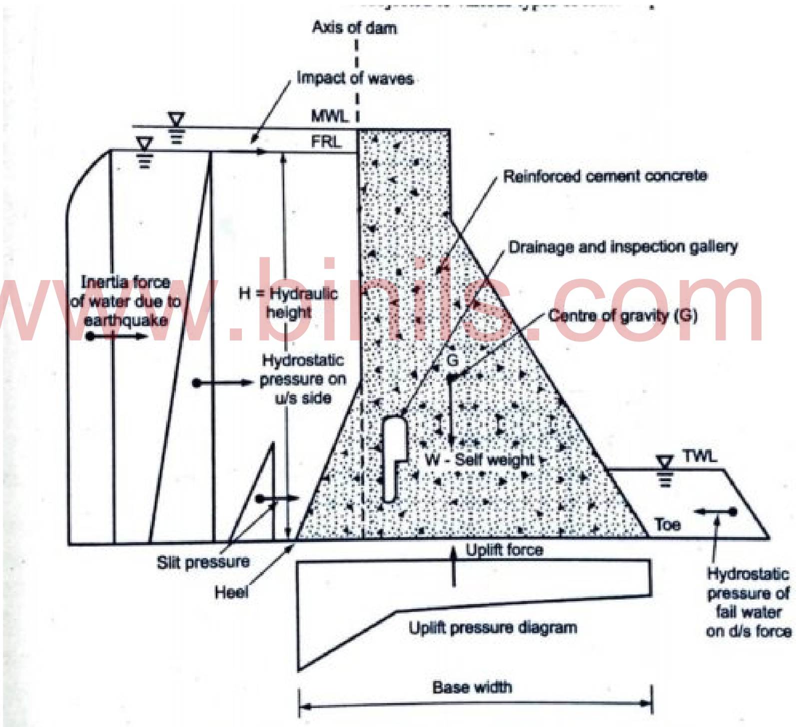


Fig. 1.3.10 : Section of R.C.C dam subjected to various types of forces

- The section of RCC dam is so proportional that all the disturbing forces are resisted by its own weight.
- It consists of two section namely:

i. Non-overflow section ii. Overflow section i.e. Spillway

- The non-overflow section is approximately triangular in shape with apex at the top and maximum width at the bottom.
- The overflow section is generally of reversed "S" shape or ogee type.

- RCC dam is provided with various instrument so as to measure uplift pressure, temperature of the interior of dam, displacement, intensity of earthquake load etc. and also provided with the drainage and inspection gallery.

11.1. Various stages in the construction of Large Reservoir

Following are the various stage in construction of gravity dam:

1. **Diversion problem in dams construction**

   Before construction of gravity dam, initially the water of the river should be temporarily diverted.

   Diversion can be done by two ways:

   (i) Provision of a diversion tunnel.

   (ii) By constructing the dam in two stages.

2. **Construction of Galleries in gravity dam**

   Two types of galleries are to be constructed:

   (i) Foundation galleries

   (ii) Inspection galleries.

   Rectangular, circular and oval-shaped are the common shapes of dam galleries.

3. Use of special measures to avoid cracking of concrete. Due to temperature difference between temperature of concrete when sets and atmospheric temperature, temperature stresses are developed and due to shrinkage of concrete as it cools, the shrinkage stresses are developed. This stresses will cause the concrete to crack. Hence various measures generally adopted in the construction of dam to avoid cracking.

   Following measures are to be adopted to avoid cracking:

   i. Low lifts of concrete at the time of pouring. Generally 1.5 m lifts is used in modern dam.

   ii. By providing suitably spaced construction joints.

   iii. Use of special low heat cement.

   iv. Cooling of material before mixing

4. Construction of joints in a gravity dam. Construction joints; contraction joints and expansions joints are provided. Shear keys or key ways: water stops are also provided.

5. Installation of water stops.

6. Foundation treatment for gravity dam. It is done by preparing the surface and grouting the foundation.

12. WELL POINTS

12.1. Well Points

- This method is based on gravity flow. It consists of a perforated pipe about 0.5 to 1 m long and 5 to 8 cm in diameter.
- This perforated pipe is covered by cylindrical wire gauge screen.
- The suction pump has a capacity to bring water to the surface from a maximum depth of about 6m.

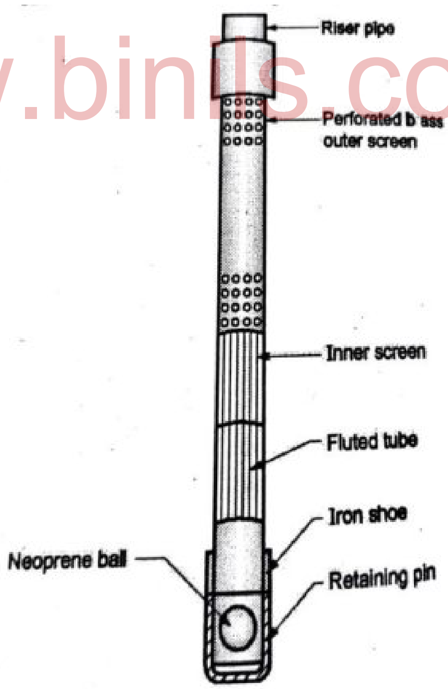


Fig. 1.3.11 : Well point

- The well points are spaced between 1 to 2 m. if the dewatering excavation is more than 6 m below the water table, then a multistage well point system is preferably adopted. Refer 1.3.11 and 1.3.13 for better understanding.

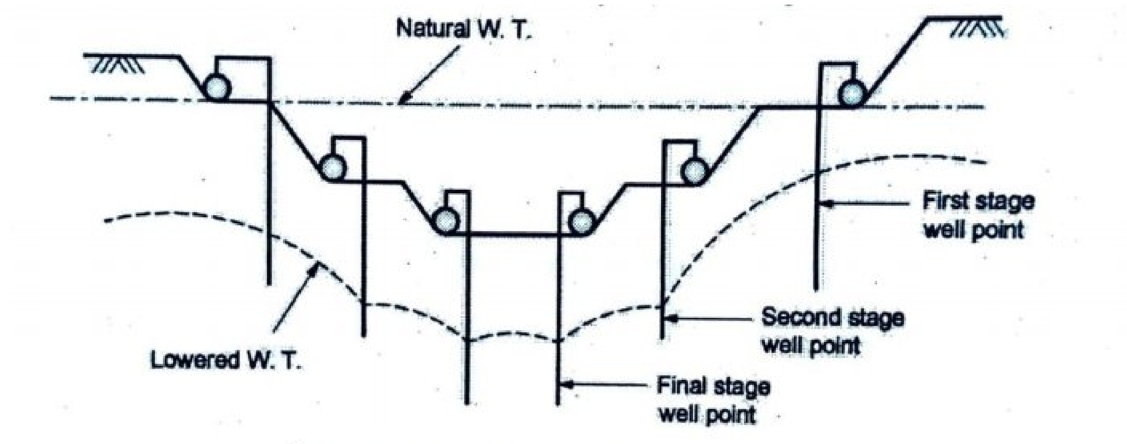


Fig. 1.3.12 : Multi-stage well point system

Fig 1.3.13 shows lowering the water table (W.T) by well point system.

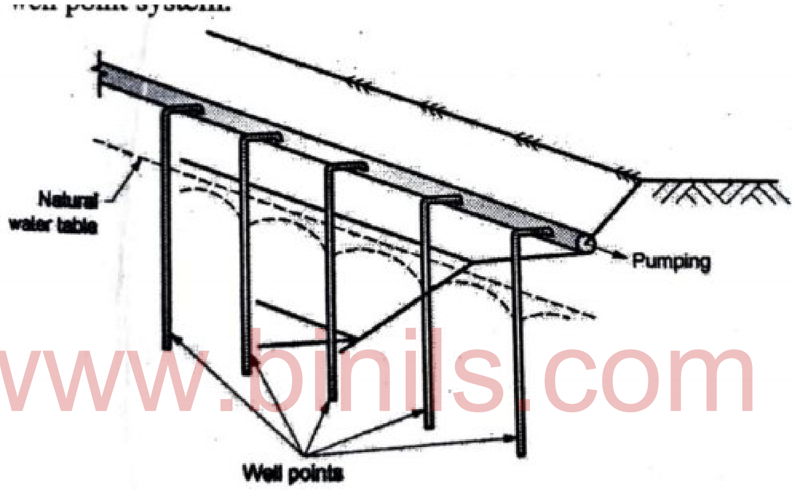


Fig. 1.3.13 : Lowering of W. T. by well point system

- In this method, conical steel drive point is provided at the lower end of the pipe. A ball valve is also fitted to the lower end of pipe so as to permit jetting of water for the purpose of driving it.
- Well points are arranged in a row or ring and riser pipes are fitted to a special well point pump with a common header pipe or manifold. Water is pumped down the well point under pressure for inserting the well point into ground by jetting. The jet flow displace the surrounding soil and the well point can be lowered to the required depth. Jetting of water emerging under pressure also washes away the soil fines accumulated around the well point and coarser material is settle down forming a natural filter around the well point.
- Because of jetting water, the hole is formed around the riser pipe and the well point. This hole is filled with coarse sand which also helps in directing drainage to the well point.

- When the suction is started, the ball valve get closed and the water comes in the well point only through the surrounding screen. Thus the ground water table is lowered by the suction at the very bottom of the well point. In the well point system, capacity of suction pump to bring the water on the surface is upto minimum depth of about 6m.

13. DEWATERING AND STAND BY PLANT EQUIPMENT FOR UNDER- GROUND OPEN EXCAVATION

13.1. DEEP EXCAVATION

Deep excavation is defined as the process of excavating the soil for foundation for a depth of about 1.5m or above. In deep excavations, supports are required to support the sides of trenches and water may be met with during the process of excavation. Hence, it is very essential in the deep excavation to stop the water oozing out and to prevent the collapsing of sides of trench.

The prevention of collapsing the sides of the trench is achieved by **timbering** and the prevention of oozing out water is carried out by **dewatering**.

13.2. TIMBERING AND ITS METHODS

Timbering is defined as the process of providing the additional lateral support the sides of trenches, in deep excavation.

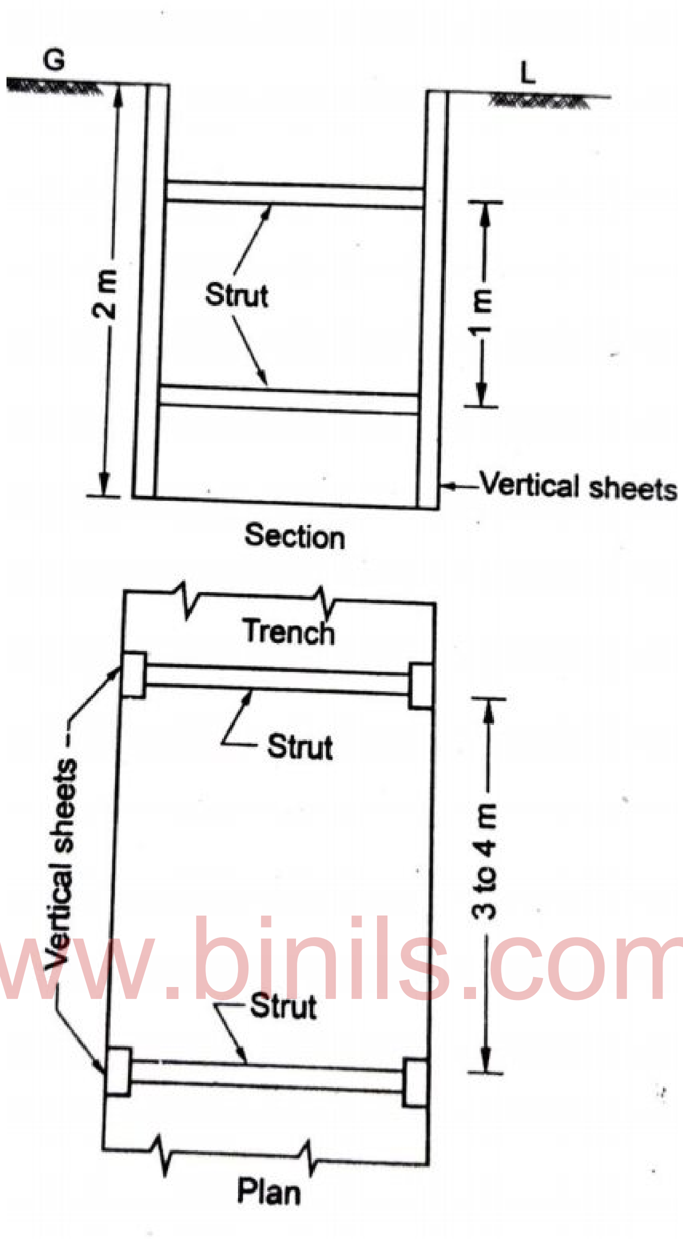


Fig. 3.24. Stay bracing

Following are the various methods of timbering.

1. Stay bracing
2. Box sheeting
3. Vertical sheeting
4. Runners sheeting
5. Sheet piling

1. **Stay bracing**

This arrangement is used when the depth exceeds 2m and carried out in moderately firm ground. The vertical sheets or poling boards are placed opposite each other against the walls of the trench and they are held in position by one or two rows of struts. The sheets are placed at an interval of 3m to 4m and generally they may be extended upto the depth of excavation

2. **Box Sheeting**

It is used when excavation is to be carried out in loose soil and when the depth not exceeds 4m. A box like structure is formed by providing sheeting, wales, struts, bracings etc.

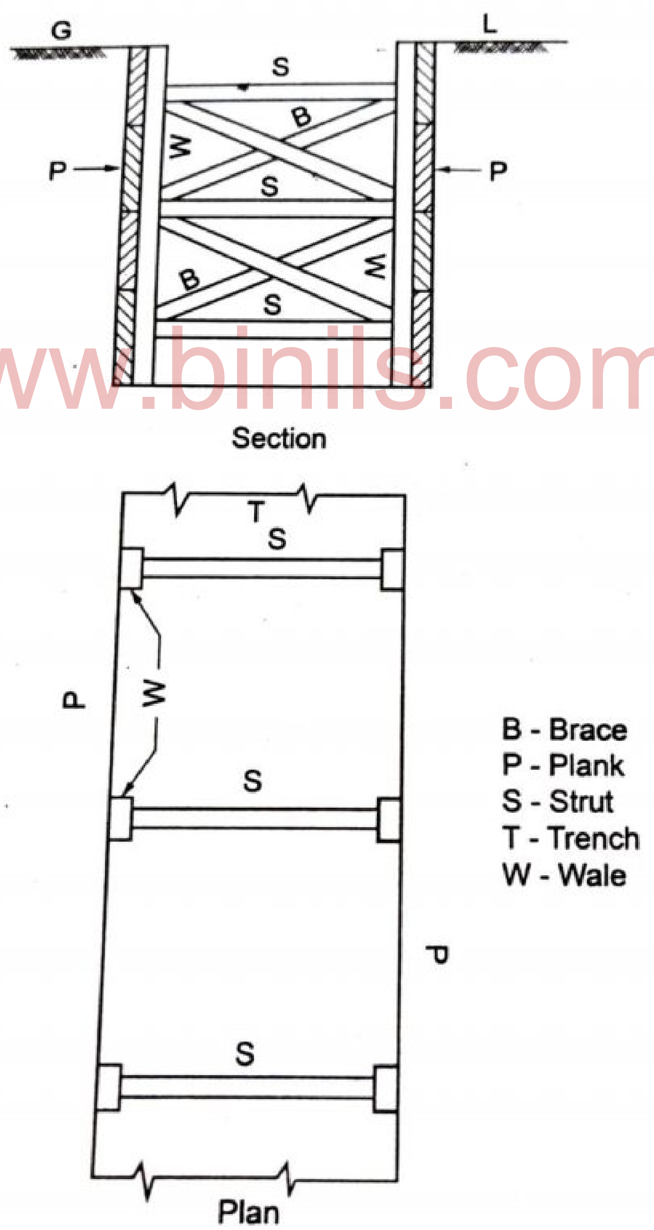


Fig. 3.25. Box sheeting

3. Vertical Sheeting

Vertical sheeting is used when the depth of foundation exceeds 10m in soft ground. This method is similar to box sheeting except that the work is carried out in stages and at each stage, an offset is provided. For each stage, vertical sheets, horizontal wales, struts and braces are provided as usual. The offset is provided at a depth of 3m to 4m and its value varies from 300mm to 600mm per stage.

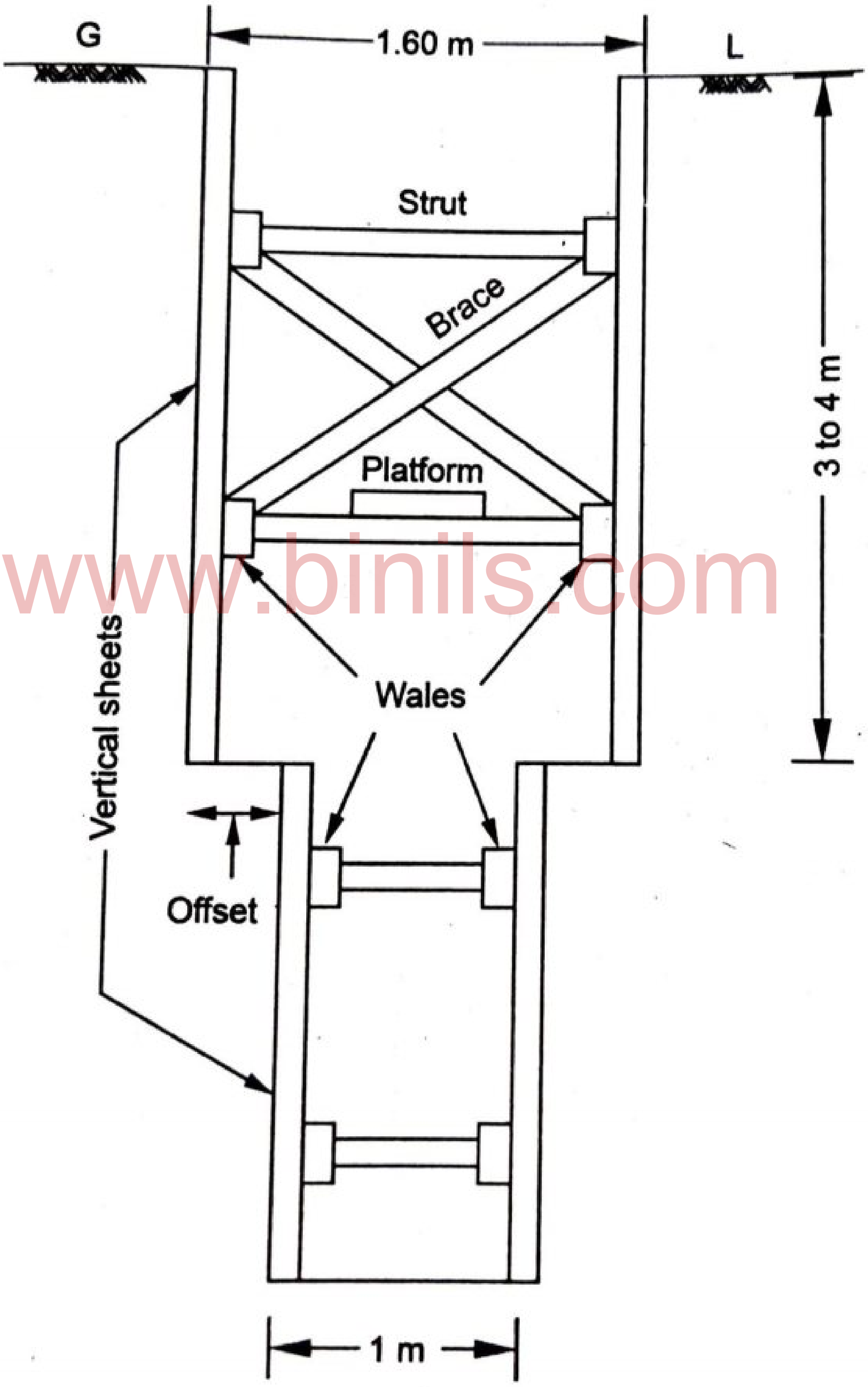


Fig. 3.26. Vertical sheeting

4. Runners

Runners are the immediate support as excavation progresses, in case of extremely loose and soft ground. The runners are long thick wooden sheets or planks, arranged to form timbering. One end of the runner is made of iron shoe. The runners are driven by hammering about 300mm in advance of the progress of the work.

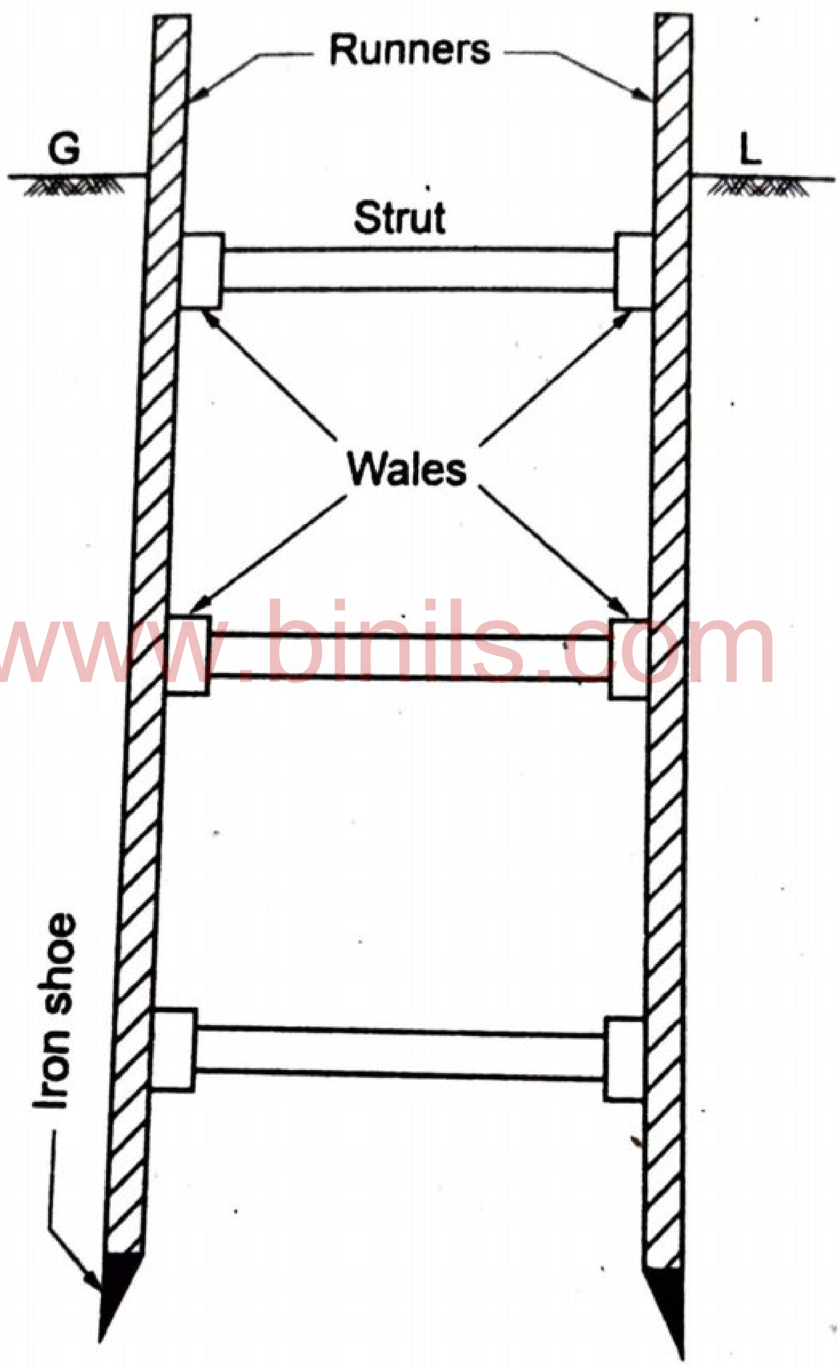


Fig. 3.27. Runners

5. Sheet Piling

This method of timbering is adopted when,

i. large area is to be excavated for a depth more than 10m

ii. loose soil is to be excavated for a depth more than 10m

iii. width of the trench is large excavated for a depth more than 10m

iv. sub-soil water is exist

13.3. DEWATERING INTRODUCTION

Dewatering of foundation trenches is carried out for deep excavations or deep foundations. Shallow foundations generally not require the dewatering process. Dewatering is carried out to prevent the water oozing (or coming) out from the sides or bottom of the trench.

13.4. METHODS OF DEWATERING TRENCHES

Following are the methods adopted for dewatering the trenches for deep foundations.

- ✓ Pumping

- ✓ Sumps and side drains method
- ✓ Cement grouting
- ✓ Well-point system
- ✓ Chemical process or chemical grouting
- ✓ Freezing process
- ✓ Electro-osmosis process

1. Pumping

Pumping is the important and usual method of dewatering, in which pumps are installed along the foundation trenches at suitable points and the water-gaining access to the trench is pumped out.

Following are to be considered while pumping of trenches

1. The pump should be portable (to use wherever required)
2. The pump should pump out water with impurities.
3. The strength and reliability should be considered.

Centrifugal pump fulfills the above requirement completely and hence it is applied for dewatering the trenches.

2. Sumps and side drains method

In this method, semi-circular side drains are constructed along the bottom of the trench and sumps are constructed at a distance of about 50m, to collect the water from these drains.

The size of the sump is about 1m x 1m x 1m and the dia of the semi-circular drains varies about 200mm or so.

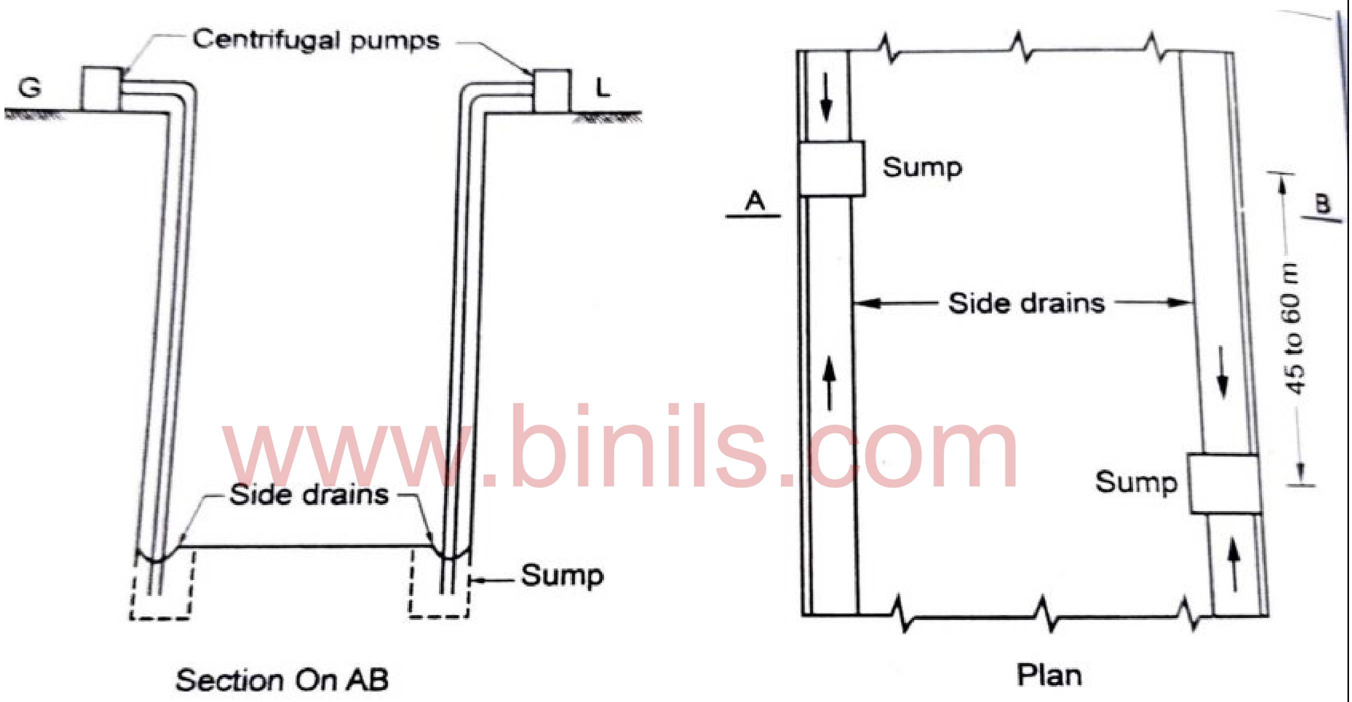


Fig. 3.28. Sumps and Side drains Method of Dewatering

3. Cement grouting

Cement grouting is the process of filling the holes in the ground by cement grout under pressure. **Cement grout** is the mixture of cement, sand and water, which is applied with pressure, for various filling applications.

This process is carried out by making number of holes in the ground and filled by cement grout. This is continued till no grout is coming up through the hole. There is no specification for number of holes created in the ground and it depends on the nature of the ground.

4. Well-Point System

A **well point** is defined as the perforated pipe of 50mm to 80mm diameter with Im long covered by a cylindrical wire gauge called **strainer**.

At the bottom of the well-point, the arrangement of the valve is made in such a way that it opens when the water is pumped down the pipe and it closes when suction is applied to the pipe.

5. Chemical process or chemical grouting

Chemical grouting solidifies and strengths the formation to increase its load carrying capacity. It also reduces or eliminates the flow of water through the formation. It also reduces the hydrostatic up-lift pressure.

In chemical process, chemicals in the liquid form can be pumped into and through very small openings, which other grouts cannot penetrate.

The chemicals form a barrier to flow of water through a formation by changing from a liquid to gel, at a pre-determined time after it enters the formation. The gel time may be varied from 3 seconds to several hours, depend upon the type of chemical used.

In this method, a concentrate solution of sodium silicate and calcium chloride is used. An aqueous solution of two acrylic monomers and catalyst di-methyl-amino- nitrite mixed with an aqueous solution of catalyst ammonium sulphate has been used, just before it is pumped into the ground.

6. Freezing Process

In this method, the area surrounding the excavation is frozen and thus a solid wall of frozen earth is formed. The concept of ground freezing is the use of refrigeration to convert in-situ pore water to ice. This ice becomes a bonding agent and it fuses with the adjacent particles of soil or blocks of rock to increase their combined strength and make them impervious. The freezing does not affect the existing water table. It thus eliminates the concern for adjacent water wells. It is the best suited method, where other methods may be difficult or impossible. This method does not require any shoring and can be used for even loose soils. Freezing process is an expansive technique and hence it is used for only exceptional situations.

7. Electric-Osmosis Process

This method holds the advantages of both electric properties of soil particles and the water stored in the void spaces of soil particles. The positive and negative electrodes are in the saturated soil and a DC is passed between the electrodes. The water contained in soil is repelled by positive electrode (i.e. anode) and is attracted by the negative electrode (cathode). If the cathode is provided in a well, the water can be collected in it and then it can be pumped out.

This method can be used for dewatering the extremely fine grained soil such as silts, clayey silts and fine clayey silty sands. The removal of water increases the stability of side slope and the shear strength of the soil.

14. WELL-POINT SYSTEM

A **well point** is defined as the perforated pipe of 50mm to 80mm diameter with 1 m long covered by a cylindrical wire gauge called strainer. At the bottom of the well-point, the arrangement of the valve is made in such a way that it opens when the water is pumped down the pipe and it closes when suction is applied to the pipe.

A well point system consists of the following parts.

- Well-point
- Riser
- Swinger arm
- Header

Riser is a vertical pipe having a dia of about 50mm, ground and the well point is provide at the bottom end of the riser.

The pipe connecting the riser with the header is called **swinger arm**.

The header is the pipe to which all the swinger arms of different well points are attached. The header is laid on the ground and its diameter varies from 150mm 10 250mm.

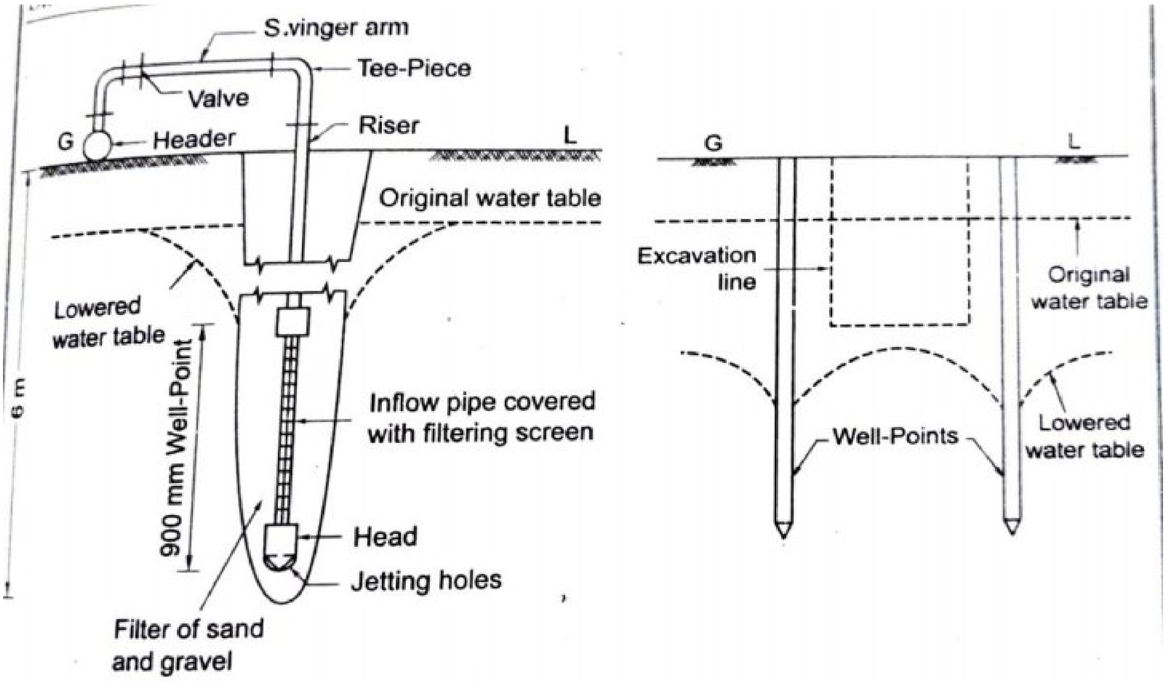


Fig. 3.29. Well-Point System

14.1. WORKING SYSTEM

1. In this method, number of well points at suitable intervals are provided on the trenches, where the dewatering is to be done.
2. The water is then forced down at the rate of 20 to 25 litres per second and thus the well point is jetted down into the ground without the driving process. After the reaching of well-points at the desired depth, the water is still kept flowing, and the water is rising up, it creates an annular space around the well point.
3. In the annular space, a filter media of sand and gravel is provide (called Stainer) to prevent the entry of sand and grit
4. The forcing of water down the pipe is stopped and the suction is then applied.
5. The water starts coming out from the ground and thus the level of original water table is lowered.
6. Then the excavation is started.
7. When the excavation is completed, the suction is stopped and the water is forced down the pipe. This makes the well-point loose in the ground and it is recovered simply by withdrawing.

Well point system is classified based on the no. of stages and as follows.

- ✓ Single-stage system
- ✓ Multi-stage system
- ✓ Vacuum system.

14.2. PRECAUTIONS TO BE TAKEN IN WELL-POINT SYSTEM

Following precautions are to be taken in the well point system.

1. The rate of pumping should exceed the rate of inflow of water from the surrounding water table, to bring down the water table.
2. All the connections of Well-point system should be air-tight.
3. To avoid air locks, all the pipelines should be laid in such a way that they rise towards the pumps.
4. When instability of side slope is expected to happen, the deep well pumps should be used, in the case of multi-stage Well-point system.

5. Deep jetted wells are constructed to release the artesian pressure, if any.

TWO MARKS QUESTIONS AND ANSWERS

1. State the uses of Box jacking. (May/June 2012)

It is more often used when a subway or an aqueduct or an underground structure is to be constructed. It enables the traffic flow without disruption.

2. Define Box jacking and Pipe jacking. (May/June 2014)

Box Jacking Technique is the tunneling process in which a pre-cast R.C.C box (or a rigid box) is pushed into the soil with the help of hydraulic jacks Pipe jacking is a tunneling method for installing underground pipelines with the minimum surface disruption, primarily used for new sewer construction.

3. Mention the uses of pipe jacking. (Nov/Dec 2014)

- ✓ Used for new sewer construction.
- ✓ Also used for sewer replacement and re-aligning, gas and water mains. oil pipelines,
- ✓ Electricity and telecommunication installations, culverts and subways.

4. What do you understand about diaphragm walls? (Nov/Dec 2009)

Diaphragm walls are underground structural elements commonly used for permanent foundation walls and retention systems. Diaphragm walls provide a water tight barrier and are constructed with a minimum back slope subsidence.

5. Define Tunneling.

Tunneling is the process involved in underground works. A tunnel is defined as an underground passage for transport of passengers, water, sewage, minerals, gas, etc.

6. What is pile foundation?

Pile foundations are defined as deep foundations, in which piles are used to transmit the load of the structure to the soil. Pile is a long cylinder of a strong material (such as concrete) that is pushed into the ground to act as a steady support for structures built on top of it.

7. How will you increase the frictional resistance of piles? (Nov/Dec-2011)

1. By increasing the diameter of the pile

2. By driving the pile to greater depth
3. By making the surface of the pile rough
4. By placing the pile closely
5. By grouping the piles

8. Give the names of any four types of piling technique. (Nov/Dec 2010)

1. Dropping weight
2. Explosion
3. Vibration
4. Jacking (Restricted to Micro-pilling)
5. Jetting

9. What are sheet piles? (May/June 2012) (Nov/Dec 2015)

Piles which are not designed to carry any vertical load and used to separate the members below ground level and designed to carry the horizontal earth pressure are called Non-load bearing piles or Sheet piles.

10. What are the uses of sheet piles? (Nov/Dec-2011)

Sheet piles are used,

1. To prevent the underground movement of water.
2. To retain the sides of foundation trenches.
3. To protect the river banks
4. To construct retaining walls in docks etc.

11. What are the different types of hammers used in pile driving? (Nov/Dec-2011)

- Drop hammer
- Single acting hammer
- Double-acting hammer
- Diesel Hammer
- Vibratory Hammer

12. Define well foundation and caisson foundation.(Now/Dec 2012) (May/June 2014)

Caisson is a structure (or member), used for the purpose of placing a foundation in correct position under water. It is a member with hollow portion, which after installing in place by means is filled with concrete or other material. Caisson is suitable for sandy soils.

Well foundation is the foundation method, structured when the good soil is available at nearly 3m below the bed level and bed consists of sand. A caisson differs from a pile in size and in method of construction. Caisson is sometimes referred as well foundation.

13. What is a box caisson? Where do we use it? (April/May 2010)

Box Caisson is defined as the caisson opened at top and closed at bottom, made up of either RCC or timber or steel. It is merely a variation of the suspended type cofferdam. Box caisson is suitable where bearing stratum is available at shallow depth and where loads are not heavy.

14. Differentiate cofferdam from caisson (Nov/Dec 2009)

1. Cofferdam is a temporary structure where as a caisson is the part of permanent work.
2. When the (plan) area of the foundation is very small as compared to the depth of water, a cofferdam becomes uneconomical and a caisson is a more economical structure,
3. Caisson structure is more suitable for the places where dewatering is to be done.
4. Foundation at more water depths (of about 15m), caissons are more suitable than the cofferdams.

15. Define Caisson Sickness.

In pneumatic caissons, the workers often working in the compressed air suffered a certain type of disease when they returned to atmospheric pressure, after working in the compressed air is called Caisson Sickness or compressed air sickness.

16. What are coffer dams or sinking coffer dams? (Nov/Dec 2010) (Nov/Dec 2013) (Nov/Dec 2015) (May/June 2016)

Cofferdam is defined as the temporary structure, constructed to remove the water and soil from an area and make it possible to carry on the construction work.

17. Define shoring for deep excavation. (May/June 2013) (May/June 2015)

Shoring is defined as the process of providing temporary support to produce adequate stability of the structure due to unequal settlement of foundations or due to removal of adjacent building or due to other reasons.

18. Name some equipment used for underground open excavation. (April/May 2010)

1. Drillers and other Drilling Equipments
2. TBM and other Tunnelling Equipments
3. Excavators
4. Handling Equipments

19. Enlist different de-watering techniques. (April/May-2011) (Now Dec 2013) (Nov/Dec 2015)

- Pumping
- Sumps and side drains method
- Cement grouting
- Well-point system
- Chemical process or chemical grouting
- Freezing process
- Electro-osmosis process

20. Define well point. (May/June 2015)

A well point is defined as the perforated pipe of 50mm to 80mm diameter with 1 m long covered by a cylindrical wire gauge called strainer. It is used for de-watering of deep excavations.

REVIEW QUESTIONS

1. Draw and explain the various operations of pipe or box jacking under water construction of a bridge**.(Nov/Dec-2011)**
2. Write the operation procedure pipe jacking **(May/June 2015)**
3. Describe the procedure involved in under water construction of diaphragm walls and basement. **(May/June 2012) (May/June 2016)**

4. Explain the construction techniques involved in underwater construction with neat sketches. **(Nov/Dec 2014) (Nov/Dec 2015)**

5. Describe the procedure involved in Tunneling techniques? **(Nov/Dec-2010)**

6. Explain with neat sketches techniques for box jacking, pipe jacking and tunneling **(Nov/Dec 2012)**

7. What are all the pile driving techniques available in the field and explain any one technique with neat sketches. **(Nov/Dec 2012)**

8. Brief about different types of pilling techniques applied in the sub surface construction. **(Nov/Dec 2013)**

9. Describe with neat sketch about the technique of pile driving. (16) (May/June 2013) **(May/June 2014) (May/June 2015)**

10. Brief about types of pilling techniques applied in the sub surface construction. (Nov/Dec **2013) (May/June 2016)**

11. Explain about the advantages of Pile foundations**.(Nov/Dec-2011)**

12. Explain the construction techniques applied for driving diaphragm walls and sheet piles with neat sketches. **(Nov/Dec 2014) (Nov/Dec 2015)**

13. What is meant by well foundation and Caisson foundation and explain in detail about the construction of well foundation and Caisson foundation? (16) **(May/June 2014)**

14. What is pneumatic caisson? Where is it adopted? How is it constructed? **(Nov/Dec 2009)**

15. What are caissons and cofferdams? Explain the methods of sinking cofferdams with sketches.**(May/June 2012)**

16. What is called Cofferdams? Explain the types of cofferdams in detail. **(April/May 2010) (April/May-2011) (Nov/Dec-2011) (May/June 2013)**

17. Explain the types of shores in detail. (16) **(April/May 2010)**

18. Describe with neat sketch about the underground open excavation. **(Nov/Dec 2013) (May/June 2016)**

19. Explain the process of dewatering and the uses of stand by plant equipment for underground open excavation. **(Nov/Dec-2010) (Nov/Dec 2015)**

20. Explain the methods of dewatering the foundation trenches**(Nov/Dec 2009)**

21. Discuss the various methods of dewatering techniques and explain some of dewatering equipment's used in the field. **(Nov/Dec-2011)**

22. What is dewatering? And briefly explain the various dewatering techniques. (**May/June 2016)**

23. Explain with sketches.

i. Sheet piles (8) **(April/May-2011)**

ii. Well points . (8) **(April/May-2011)**

Previous Year Anna University Question Analysis

PART A

1. What is meant by coffer dam? **May/June 16**
2. What is meant by pipe jacking? **May/June 16**
3. Write a note on offshore platform **May/June 16**
4. What is meant by micro piling? **Apr/May 17**
5. Define Shoring. **Apr/May 17 Nov/Dec 19**
6. List out the various methods tunnelling in soft soil. **Nov/Dec 17**
7. Write any two functions of sheet piles. **Nov/Dec 17**
8. Why are caissons used? **Apr/May 18**
9. What is shoring in construction? **Apr/May 18**
10. What is shoring and state its components? **Nov/Dec 18**
11. State the various methods of dewatering a basement excavation **Nov/Dec 17**
12. List out the various methods tunnelling in soft soil. **Apr/May 19**
13. Write any two functions of sheet piles **Apr/May 19**
14. What is an under reamed pile? **Nov/Dec 19**
15. Write the various operations involved in the construction of off shore platforms. **Nov/Dec 19**
16. What is the purpose of using sheet piles ? **Nov/Dec 20**
17. What are the dewatering techniques used in underground open excavation? **Nov/Dec 20**
18. Name the different tunneling techniques **Nov/Dec 20**

PART B

1. Describe the procedure involved in underwater construction of diphragm walls and basement **May/June 16, Nov/Dec 19**
2. What is dewatering? And briefly explain the various dewatering techniques. **May/June 16, Nov/Dec 17**
3. Explain the various equipment's for pile driving **May/June 16**
4. Explain in detail about the underwater construction methods. **Apr/May 17**
5. Define tunneling. Explain in detail about the different tunnelling methods. **Apr/May 17**
6. Explain in details about the various methods of dewatering process with neat sketch **Nov/Dec 17**
7. Define piles and explain about various types of pile driving techniques. **Nov/Dec 17**
8. **i.** Describe the term jacking (6) **Apr/May 18**

   ii. Explain the types of hammers using in pile driving (7) **Apr/May 18**
9. i. Explain types of sheet pile and list its functions.(10) **Apr/May 18**

   ii.What is well pointing and how does dewatering work? (3) **Apr/May 18**

   iii. What are the uses of offshore platform? **Apr/May 18**
10. Explain construction of sheet pile wall **Nov/Dec 18**
11. Explain the process of transporting and installation of fixed offshore jacket platform **Nov/Dec 18**
12. Explain the various types of sheet piles **Apr/May 19**
13. Explain the detail about tunneling techniques. **Apr/May 19**
14. Explain in detail the different piling techniques. **Nov/Dec 20**
15. Explain the construction sequence of box jacking process with neat sketches **Nov/Dec 20**

Part C

1. What is coffer dam? With the help of sketches explain various types of coffer dam. **Nov/Dec 17 , Apr/May 19**
2. In which situation pile foundation is adopted? Explained various types of pile foundation with neat sketch **Nov/Dec 17 , Apr/May 19**

3. Explain the construction sequence of constructing diaphragm wall **Nov/Dec 18**
4. Explain the construction of under ground train tunnel using tunnel boring machine **Nov/Dec 18**
5. Explain in detail about the caissons and cofferdam **Nov/Dec 19**
6. Suppose you want to construction a large reservoir, explain with neat sketches the construction sequence and the techniques used for dewatering and concreting **Nov/Dec 20**

Assignment Topics

1. Case study of a box or pipe jacking project
2. Comparison of box and pipe jacking methods.
3. Construction of Foundation & Sub-Structure of Bogibeel Rail-Cum Road Bridge Over River Brahmaputra – Case Study
4. Construction dewatering for underground station in urban environment-Case Study
5. Modern Sub structures construction techniques

UNIT II

SUPER STRUCTURE CONSTRUCTION FOR BUILDINGS

Vacuum dewatering of concrete flooring – Concrete paving technology – Techniques of construction for continuous concreting operation in tall buildings of various shapes and varying sections – Erection techniques of tall structures, Large span structures – launching techniques for heavy decks – in-situ prestressing in high rise structures, Post tensioning of slab- aerial transporting – Handling and erecting lightweight components on tall structures.

2.1. VACCUM DEWATERING OF CONCRETE FLOORING

2.1.1. Definition

Method of removal of surplus water from the concrete maintain optimum water/content ratio by vacuum system so as to increase impact strength or toughness and abrasion due of wearing course of concrete.

2.1.2. Equipment's used to Tre mix concreting

1. Vacuum pump
2. A top cover
3. Filter pads
4. Power trowel

2.1.3. Procedure of Tremix concreting or Vacuum Dewatering Concreting.

- The tremix equipment for dewatering of concrete consist of a vacuum pump P 4001, Small, powerful that makes it possible to be work with tow suction mats 6m x 7m. The pump is self discharging and can be run continuously which runs on electric motor or petrol engine.
- The pump is fitted with a ring liquid pump. The tank is provided with two removable lids, bottom lids is useful for cleaning purpose. A complete suction mat consist of one top cover and 1 to 6 filter pads depending on width of top cover. Two persons can easily move the top Cover.
- Top cover is available in standard widths from 3m to 7m in intervals of 1m. The standard length is 6m. Number of filter pads depends on size of top cover. Normally 6 pads are required for each standard top cover.

- The filter pads must overlap each other by 20-30 cm. The top cover must be placed so that it seals against fresh concrete all around.
- This whole assembly plays roll in dewatering. In the sucking operation, filter pads restricks the particles in concrete to enter in pump.
- Immediately after vacuum dewatering the flatness of concrete surface is checked and adjusted with a control tool and finishing operation with a power trowel can start.
- Power trowel may be of rotating blades and guiding ring which gives a smooth top layer of concrete.

2.1.4. Uses of Vacuum Dewatering Concreting / Tremix Flooring

1. As tremix concrete is strong and durable it is used in industrial flooring.
2. Used in parking decks.
3. Used in bridges.
4. Places, where the surface is in contact with impact loading.
5. Tremix concrete can be produced with acceptable cost.

2.1.5. Tremix Floor as an Example of Tremix Concrete

- For making tremix floor, the tremix vacuum system is used.
- The tremix vacuum system is a method for laying high- quality concrete floors at an acceptable cost.
- The key of the method is dewatering concrete by the vacuum process.
- Through vacuum dewatering, the surplus water is removed from the concrete, which means that the water/cement ratio automatically leads to a noticeable improvement of almost each of the concrete properties.
- These improvements are particularly noticeable on the top surface i.e. the most vital part of a floor.
- Immediately after vacuum dewatering the flatness of the concrete surface is checked and adjusted with a control tool, and the finishing operation with a power- trowel can start.
- The tremix equipment for dewatering of concrete by the vacuum process consists of a vacuum pump P 4001. a top cover and filter pads.

- The top cover is made of special reinforced, airtight plastic sheet, with a suction channel on the bottom side. It is provided with two lifting tubes which makes it easier to unroll the top cover to the required length.
- The filter pad is made of perforated plastic sheet with distance cushions on the top side. It acts as a filter between the fresh concrete and the top cover.

Tremix vacuum system has following salient features

1. Reduction of the water content in concrete by 20-25%.
2. Increased compression and wear resistance.
3. Reduced risk of shrinkage in concrete.
4. Finishing possible immediately after vacuum dewatering.
5. In making tremix floor, the tremix vacuum pump is used.
6. The tremix vacuum pump P 4001 is a small, powerful pump that makes it possible to work with two suction mats of 6 x7 m = 42 m2 simultaneously.
7. The pump is self discharging and can be run continuously. It is provided with an electric motor or a petrol engine.
8. Standard voltage 400 V.
9. The tremix vacuum pump P 4001 is fitted with a ring liquid pump. The tank is provided with two easily removable lids, one of which is positioned on the bottom of the tank for efficient cleaning.
10. The suction hoses consist of a helical hose of durable reinforced plastic diameter 1 1/2", standard length 15 m.
11. The hoses are provided with either a quick-coupling. type fire-hose, or conical couplings for connection to different types of suction hoses.
12. The tremix top cover and filter pads are connected to the vacuum pump. A complete suction mat consists of 1 top cover and 1 to 6 filter pads depending on the width of the top cover. Two person can easily move the top cover.
13. The top cover is available in standard widths from 3 m to 7 m in intervals of Im. The standard length is 6 m. Special lengths and widths to order.

Fig 2.1.1. Process of Tremix floor

14. The standard width of the pads is 1.2 m. Standard lengths: 2.8-6.8 m in intervals of 1 m. The pad is also available in a roll of 30 m.

15. The number of the pads depends on the size of the top cover. Normally, 6 pads are required for each standard top cover.

- The pads must overlap each other by 20-30 cm. The top cover must be placed so that it seals against fresh concrete all around.
- The Fig. 2.1.1 shows the process work for tremix floor.
- In above Fig. 2.1.1, the top cover is connected to the suction hose of the vacuum pump. Thereafter it is important to check that the top cover seals against the fresh concrete outside the filter pads.

Uses of tremix floor

1. Tremix products are successfully used in the construction industry and in civil engineering projects.
2. Tremix system is used for the production of strong and durable concrete for industrial floors, parking decks, bridges etc

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2.1.6. Performance of Vacuum Dewatering System

- A high quality concrete floor or pavement requires not only to be level but it should also have high wear resistance, high compressive strength, reduced shrinkage and minimum water permeability.
- The TREMIX method, pioneered by TREMIX AB, SWEDEN and introduced by Aquarius in India in 1987, is a system for laying high quality concrete floors with superior cost-effectiveness. Aquarius subsequently entered into a technical collaboration with TREMIX AB, in 1991 to start production of Vacuum System in India.
- The key to the use of this method is the dewatering of concrete by vacuum process. Surplus water from the concrete is removed immediately after placing and vibration, reducing the water / cement ratio to an optimum level. Therefore, adopting the TREMIX method facilitates use of concrete with better workability than what is normally possible.
- A lowered water / cement ratio automatically leads to a noticeable improvement in almost each of the concrete properties.

The operation

- In order to obtain a high quality concepts floor using the method, it is essential to follow the various operations in the correct sequence. Initially, power vibration is essential, especially at the panel edges. This results in proper compaction of the concrete and hence elimination of voids and entrapped air.
- Poker vibration never really gives a levelled surface. It is therefore essential to combine this vibration with surface vibration (screeding), in order to obtain a vibrated concrete with a levelled surface. Two passes with surface vibrator are normally recommended.
- The surface vibrator is guided by two men, standing on either side of the panel.
- Vacuum dewatering process removes surplus water always present in the concrete. This is done using the vacuum equipment comprising of suction mat top cover, Filter pads and vacuum pump. The process starts immediately after surface vibration.
- Filter pads are placed on the fresh concrete leaving about 4 inches of fresh concrete exposed on all sides. The top cover is then placed on the filter pads and rolled out till it covers the strips of exposed concrete on all sides. The top cover is then connected to the vacuum pump through a suction hose and the pump is started.

- Vacuum is immediately created between the filter pads and the top cover. Atmospheric pressure compresses the concrete and the surplus water is squeezed out. This process lowers the water content in the concrete by 15-25%
- The dewatering operation takes approx 1.5-2 minutes per centimeter thickness of the floor. The dewatered concrete is compacted and dried to such an extent that it is possible to walk on it without leaving any footprints. This is the indication of concrete being properly dewatered and ready for finishing.
- The finishing operations Floating and trowelling takes place right after dewatering. Floating operations is done with floating disc. This ensures after mixing of sand and cement particles, further compaction and closing the pores on the surface. Floating operation generates skid-free finish.
- Trowelling is done with trowelling blades in order to further improve the wear resistance, minimize dusting and obtain smoother finish. Repeated passes with disc and blades improve the wear resistance substantially.
- Suction mat of special grade multilayered polymer sheets along with reinforced distance cushions on the filter pads ensure sufficient cross-sectional area to squeeze out and remove excess water from the concrete. This design is a prerequisite for effective dewatering.
- Performance of vacuum dewatering system is shown graphically.

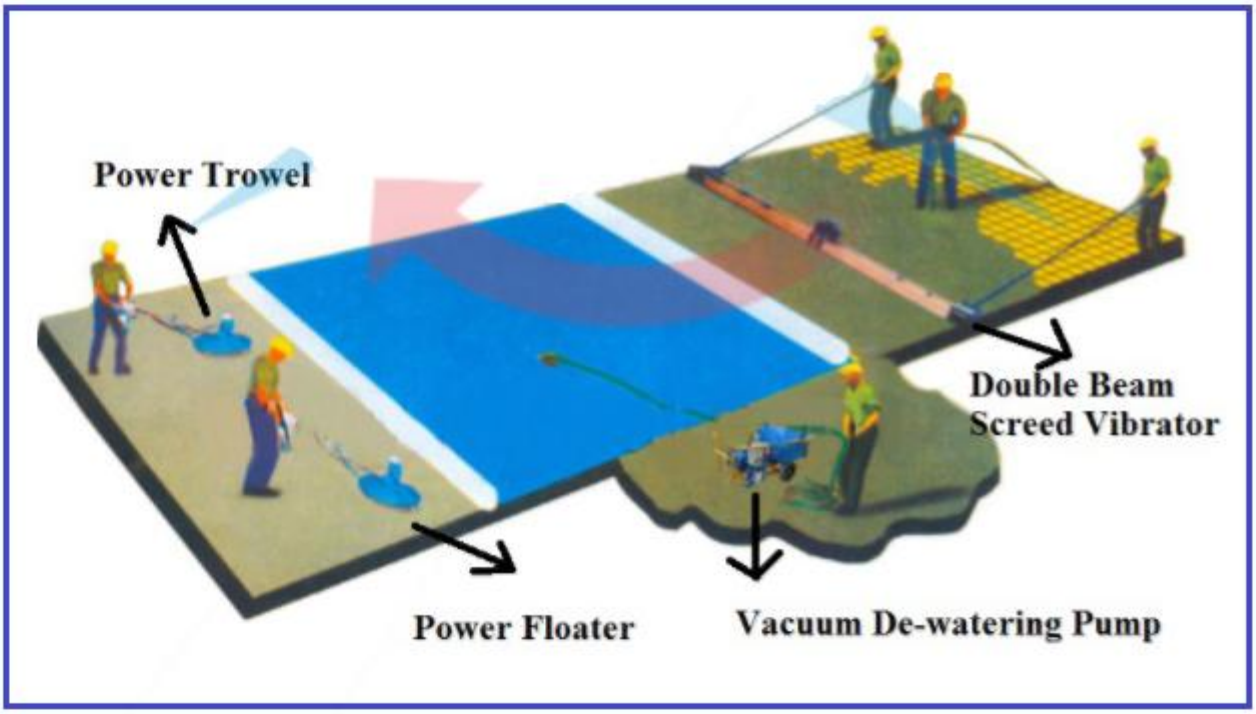


Fig.2.1.2:Various operation of vacuum dewatering system

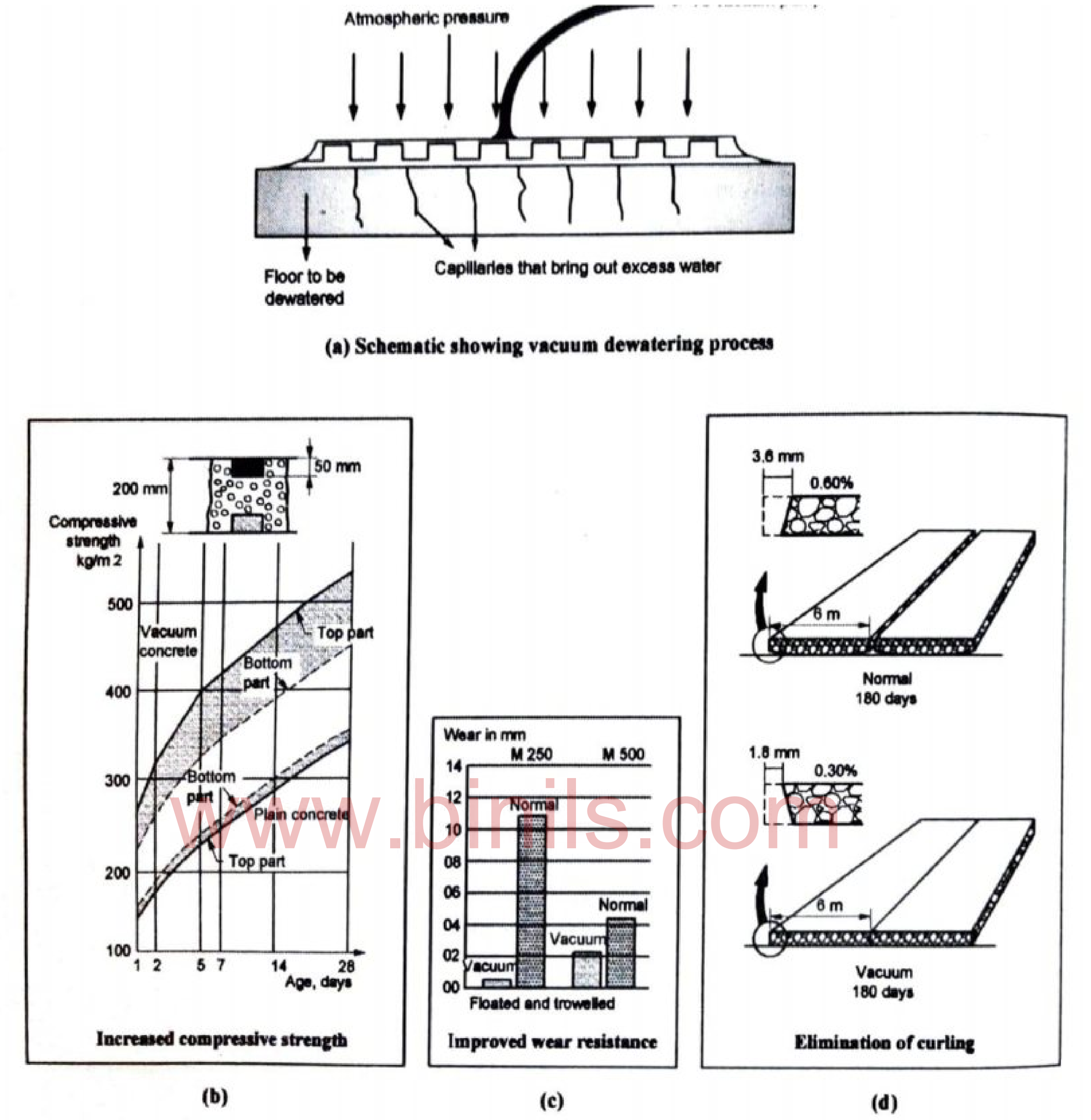


Fig. 2.1.3

2.2. CONCRETE PAVING TECHNOLOGY

Following are the various properties of solid concrete blocks:

(1) It is more cost effective as compared to other traditional walling system.

(2) It has high quality, high strength and uniform size and shape.

(3) It is energy efficient and hence it does not require any non-renewable resources for production.

(4) It is environmental friendly (in short eco-friendly) and hence utilizes wastes and local resources.

(5) Structural performance can be engineered as per application.

(6) Decentralize production allows both factory and on-site production.

(7) Semi-mechanized process produces high quality material and provide adequate working opportunities.

2.2.1. Pavement Blocks

- Paver blocks are also called as interlocking concrete pavement blocks. Paver blocks are made from a special dry mix pre-cast piece of concrete commonly used in exterior hardscaping pavement applications.
- Interlocking paving blocks are installed over a compacted sub-base and a levelling bed of sand.
- Standard thickness of paving blocks are 60 mm for light traffic, 80 mm for heavy traffic and 50 mm for general work.
- Interlocking concrete pavers are now an efficient and economical choice in various areas of building construction.

2.2.2. Manufacturing of Paver Blocks

- Paver blocks consist of both fine and coarsely grained aggregates along with cement compounds taken in appropriate proportions.
- Ingredients are put through pressure and vibration courses, which produces a strong, durable concrete which can then be moulded into various shapes and design.

Process diagram

Manufacturing of paver blocks

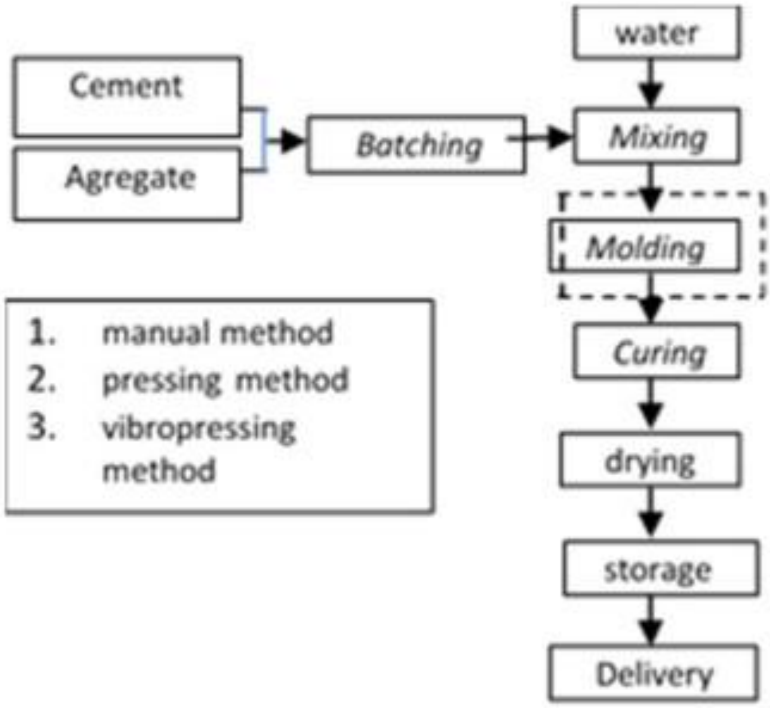


Fig.2.2.2: Process Diagram

2.2.3. Uses of Paver Blocks

Following are the various uses of paver blocks:

(1) Paver blocks are commonly used for walkways.

(2) These blocks are also used for pool desks, patios, driveways, airports or loading docks etc.

(3) These blocks are commonly used now-a-days in parking areas, garden areas, kids playground, etc.

(4) Hexagonal paving blocks used for external floor are in great demand.

(5) Paver blocks used for external floors are commonly used in today's building due to their beauty, durability and economy.

(6) Paver blocks are increasingly used not only in walkways and jogging tracks but also in entire building compounds, storage yard, petrol pumps stations, swimming pool decks, parking lots and other landscaping areas.

2.2.4. Properties of Paver Blocks

Following are the various properties of paver blocks:

(1) It has good dimensional stability .

(2) It has non-skid surface.

(3) It has good compressive strength. It sustain the compressive strength from 20 N to 50N/mm².

(4) Its water absorption is very low and about 5%.

(5) It has good transverse strength (3 N/mm2 and above).

(6) Its dimensional tolerance is 2 mm length and width 3 mm for height.

(7) Its average abrasion is 3 mm.

2.2.5. Advantages of Paver Blocks

Following are the various advantages of paver blocks:

(1) Paver blocks have beautiful appearance.

(2) These blocks are durable and economical.

(3) These blocks are easily installed over the sand base compacted surface.

(4) It require less quantity of cement mortar and concrete for installation.

(5) These blocks can be made in any design and shape desired.

(6) The paving blocks of medium duty and heavy duty can be laid on sand base over stone soling over compacted earth to 90% of proctor density with adequate slope for drainage.

(7) These blocks are highly wear-resistant in nature, make them long term than ordinary P.C.C. done in external areas.

(8) Paver blocks are available in different patterns, designs, shape and colour schemes.

2.3. TECHNIQUES OF CONSTRUCTION FOR CONTINUOUS CONCRETING OPERATION IN TALL BUILDING OF VARIOUS SHAPES AND VARYING SECTION

- Tall structures can be classified according to their utility or purpose as follows:

(1) Multistoreyed residential buildings. Multistoreyed commercial buildings. Multistoreyed administrative buildings.

(2) Tall transmission towers cooling towers.

(3) High rise elevated service reservoirs.

(4) Tall chimneys in industries.

- Now-a-days, lots of buildings structure especially in metro cities are high rise building structures or tall structure. Wherever the area of the land is a problem, in this case the tall structures are best suitable.
- Hence area optimization of the land can suitably be done by constructing the tall building structure or high rise building structures.
- Now-a-days, horizontal expansion of the building is almost over in the areas having more population and vertical expansion of the building is preferably taken place.

Definition of tall structure

- A skyscraper is a tall structure continuously habitable building. There is no official definition or height above which a building may clearly be classified as a tall structure or a skyscraper most cities define the term empirically, ***even a building of 80 metres may be considered as a tall structure or a skyscraper*** if it produces above its built environment and changes the overall skyline.
- From the structural engineer's point of view, a tall building or tall structure may be defined as one that, because of its height it is affected by lateral forces due to wind force or earthquake action to an extent that these action play a vital role in its structural design.
- However the tallness of a building is a matter of a person's or community's circumstances and their consequent perception and hence a measurable definition of a tall structure cannot be universally applied and a matter of fact that tall structures cannot be defined in specific terms related only to its height or to the number of floors.
- Note that in the design process the influence of actions caused by lateral forces due to wind and earthquakes should be considered so as to make it more stable and durable.

2.3.1. Techniques of Construction for Continuous Concrete Operation in Tall Building

Continuous concrete operation in tall building is specially done as follows,

(1) Use of RMC (Ready Mix Concrete)

(2) Transportation of RMC by Transit mixer.

(3) Placing of concrete by pump to desired place of formwork at various floor level of tall building

- In case of tall building, the concrete is pumped up to the require point of placement with the help of a pump. usually diesel powered or electric power.
- The pipe through which concrete to be pumped must be cleaned after each use. As the building goes higher with floor level, pipe is added for pumping process.
- Placement of pumped concrete is usually carried out at the point of placement by an articulated boom with a flexible hose at the end. There are usually two operators, one on the ground to control the pump mounted on transit mixer, and other one on top of the building to operate the boom. There should be proper coordination between these two operators.
- Depending upon the height of casting site of tall building, a pump of proper capacity is selected. The pumping process is operated on a reciprocating principle
- It is noted that the concrete usually losses some slump when carrying by pump, hence concrete mixes for pumping are carefully chosen to survive the pumping process with sufficient workability and the desired strength.
- When concrete is pumped to large heights in case of tall building, segregation of concrete is possible which can be overcome by staged pumping.
- There are various possibilities that the pipe can clog or burst, the pump or articulated boom can fail, or air in the line can cause the boom to operate. Hence placing of concrete with a crane bucket is possible, but slow under the best of circumstances which shows the another techniques for continuous concrete operation in tall building.
- Therefore, there are three techniques such as

(i) concrete operation by staged pumping

(ii) concrete operation with a crane bucket

(iii) Slip forming

- **Slip forming:** It is a technique in which concrete is poured into a continuously moving form. Slip forming, continuous poured, continuously formed, or slip form construction is a techniques of construction for continuous concrete operation in tall building.
- Slip forming is used for tall structures like bridges, towers, tall buildings, and dams and for horizontal structures such as roadways highways.
- Slip forming makes possible the continuous, non- interrupted, cast-in-place no joints concrete structures. Slip forming relies on the quick-setting properties of concrete and requires a balance between quick-setting capacity and workability.
- There are two types of slip forming namely,

(1) vertical slip forming

(2) horizontal slip forming

(3) vertical slip forming

- The concrete form can be surrounded by a platform on which workers stand, placing steel reinforcing rods into the concrete and ensuring a smooth pour in vertical slip forming.

(1) The concrete form and working platform are raised with the help of hydraulic jacks together.

(2) horizontal slip forming

- Horizontal slip forming is best suitable for pavement and traffic separation walls in which concrete is laid down, vibrated, worked, and settled in place while the form itself slowly moves ahead.

2.3.1.1. Slip Formwork

GQ. What is slip formwork?

- Slip form construction is a advanced method for building the large towers or bridges. The name refers to the moving from the concrete is poured into, which moves along the project as the previously poured concrete hardens behind it.
- he technique of slip form construction has also been applied to road construction.
- The slip form technique e was in use by the early 20 century for building silos and grain elevators.

- A notable use of the method was the 'Skylon Tower' in Niagara falls, Ontario which was completed in 1965. The technique was soon utilized to construct the "Inco Superstack' in Sudbury, Ontario and the CN Tower in Toronto.
- It is the most common method for construction of all buildings in Australia.

Use: Slip formwork is widely used for constructing the large towers or bridges. It is also used for constructing the silos and grain elevators.

2.3.1.2. Process of Concreting with Slip Formwork

There are mainly four types of system of slip form by which process of concreting work can be done.

Types of slip form systems

1. Vertical slip forms system
2. Cantilever jump form methods
3. Egg shape slip form system
4. Conical formwork system

1. Vertical slip forms system

- Vertical slip form relies on the quick setting properties of concrete requiring between early strength gain and workability.
- Concrete needs to be workable enough to be placed to the formwork and strong enough to develop early strength such that the form can slip upwards without any disturbance to the freshly placed concrete.
- When the concreting process goes on, hydraulic lifters raise the formwork for the entire horizontal projection of a given structure in upward direction in continuous sliding motion.
- Work platforms are permanently attached to the top of the vertical slip form. Work platforms which suspended from on the inside and outside of slip form are light in weight.
- The main important advantage of vertical slip form is that, no need to erect and dismantle the expensive scaffolding.
- **Vertical slip form has the following two limitations:**

(i) The walls have to be vertical.

(ii) The walls have to trace an unchanging horizontal projection.

- Because of these two limitations, conical formwork method is developed. See the fig 2.3.1. for better understanding

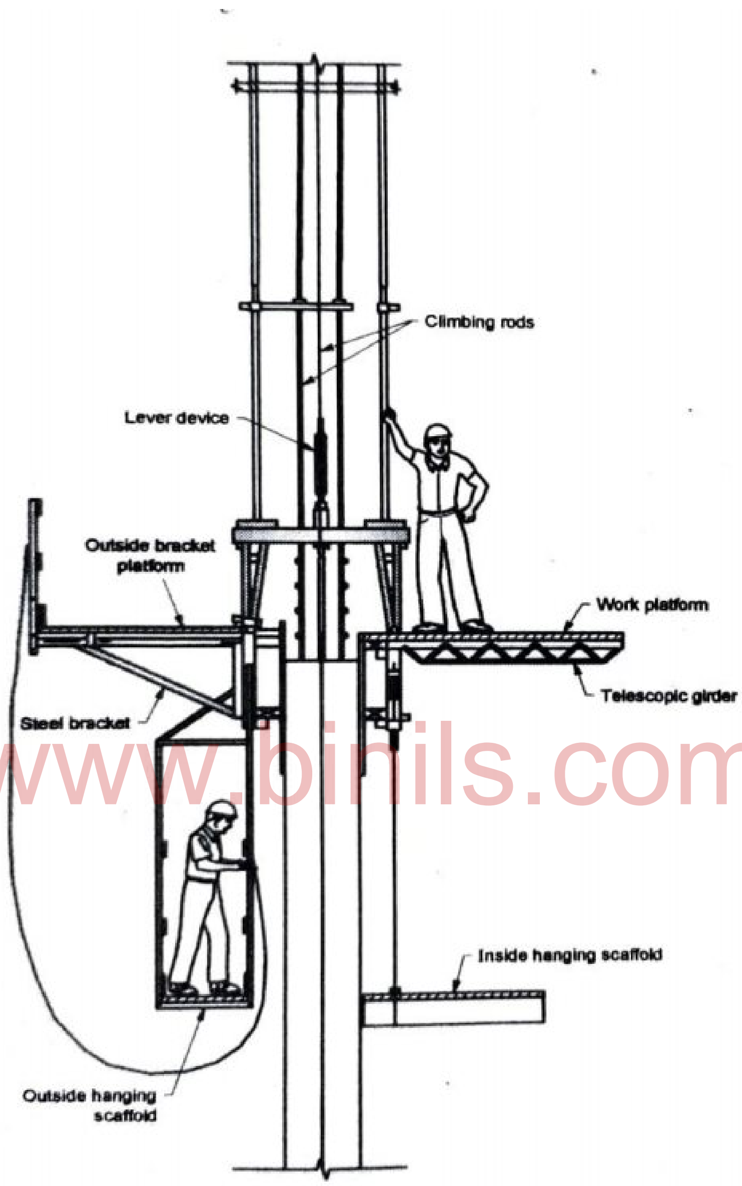


Fig. 2.3.1 : Vertical slip form method

2. Cantilever jump form method (Self-climbing)

- In cantilever jump form method, the lifting device is synchronously driven by electric motors. The main advantage of this system is that the climbers are independent of the crane and attached to the large area formwork at storey height.
- In this system, the shuttering can be fixed to the already completed part of the structure between the individual levels of the climber.

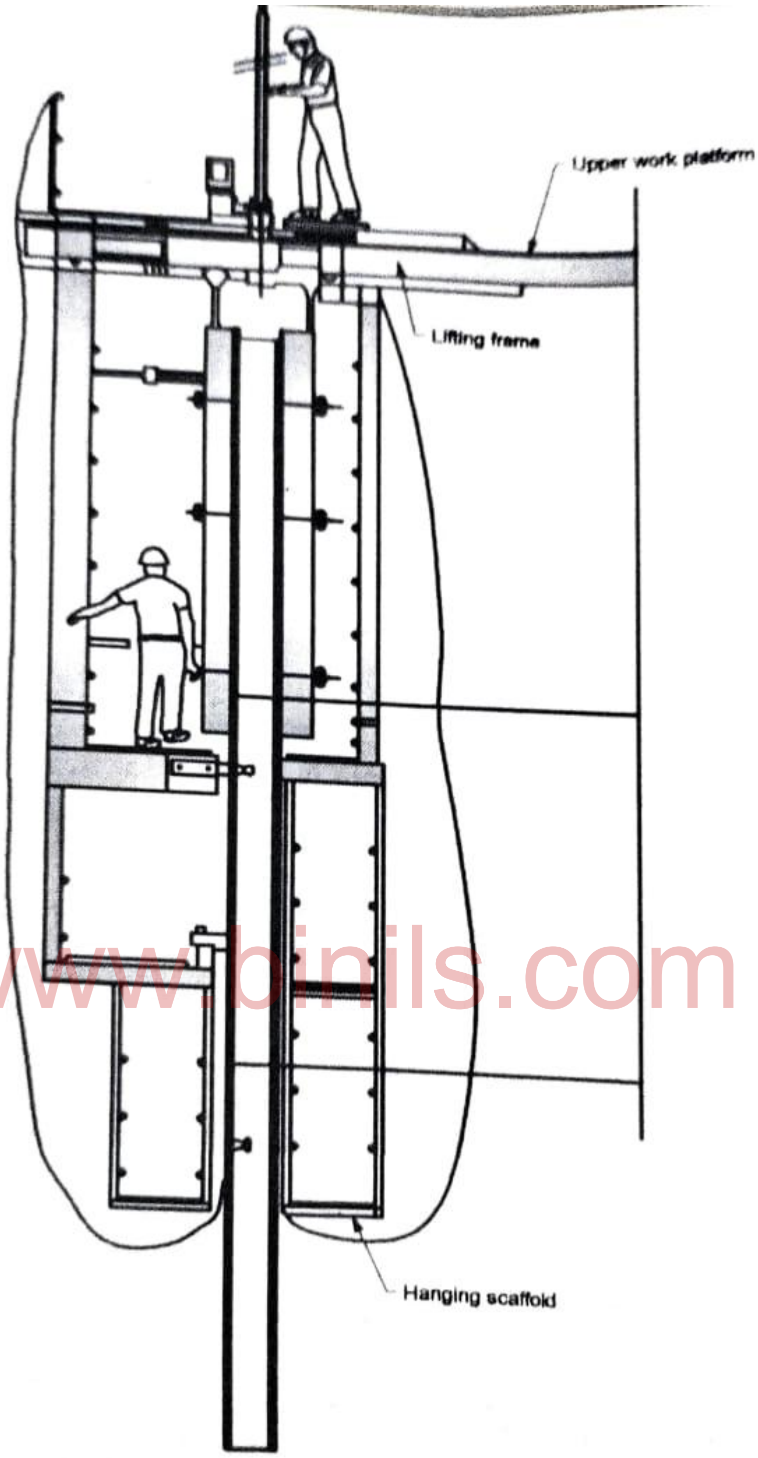


Fig. 2.3.2 : Cantilever jump formwork system

- Cantilever jump form system gives the maximum safety. It provides complete self-climbing formwork system which is independent of crane for walls, columns, supports and floor bearers.
- For precast floors, cantilever supports are easy to install.
- Lecesses and built-in elements can be placed accurately. Upper gridwork system provides a work deck for material handling and concreting. It is fully enclosed system

which provides to proceed the work of concreting safely and with great comfort and protected from inclement weather.

- Any erection and dismantlisation work of expensive scaffolding is completely eliminated. The great advantage of slip form construction is that, it provides a monolithically cast structure which is free from ties and cold joints. See the Fig. 2.3.2 for better understanding.

3. Egg shape slip form system

- The egg-shape slip form system is based on the jump form principle which can be adapted to any geometrical shape.
- See the Fig. 2.3.3 for understanding its use.
- In this system, when the circumference of the egg shape varies, the cantilevered plates on the periphen are removed or extended and the individual curvature adjustments can be achieved by adjusting the spindle and the vertical peripheral slope.

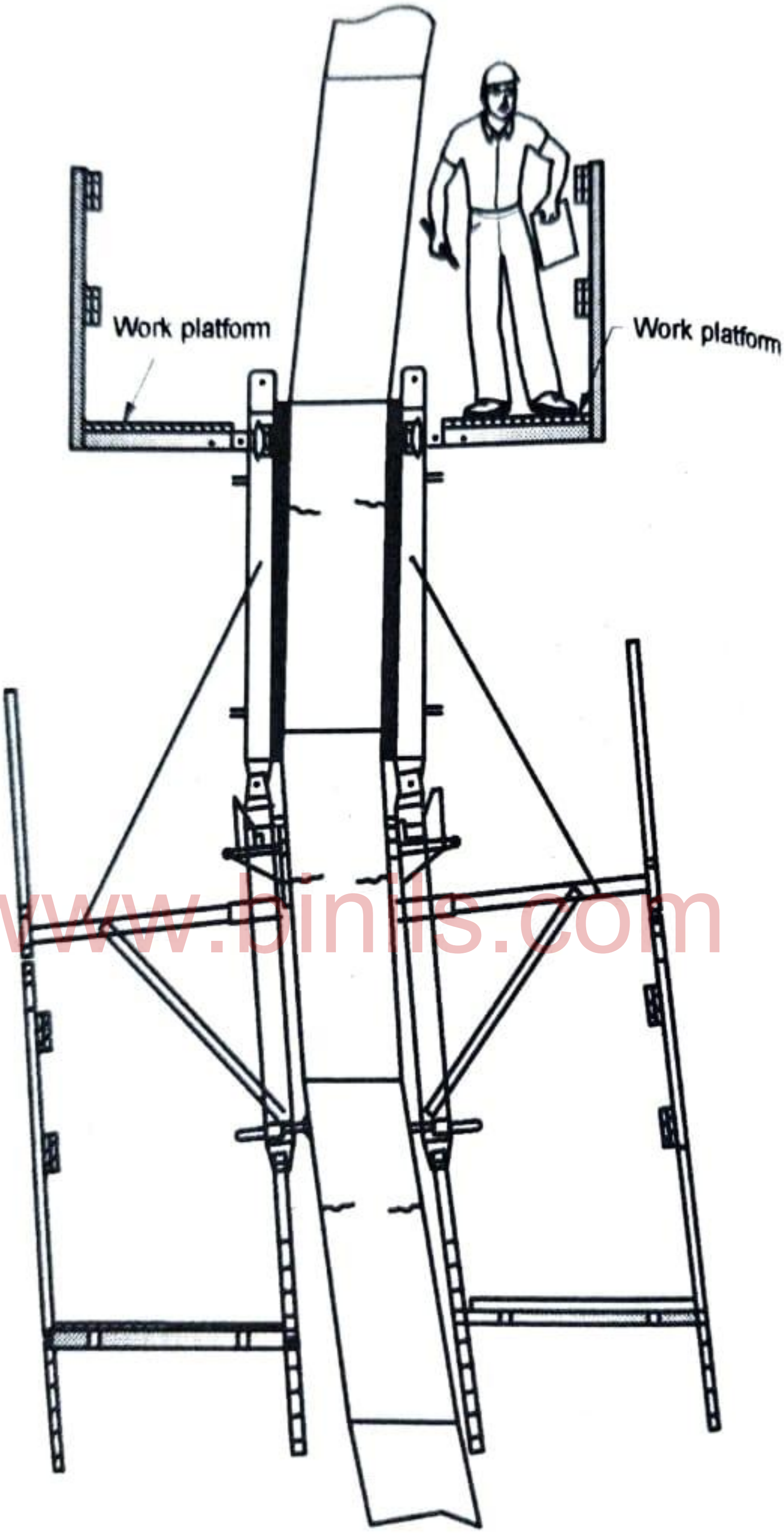


Fig. 2.3.3 : Egg shape slip form system

- From the Fig. 2.3.3, it has been observed that both the sides of the formwork are independent of each other, which shows the main advantage of the egg shape slip form system.
- This system can be adjusted independently on each side of the wall and also produces optimal working conditions. It also shows an apparent saving in time and personnel costs.

4. Conical formwork system

- Conical formwork is a system by which it is made possible to construct the structures of varying wall thickness and tapering walls. It is also possible to construct the structures whose formwork geometrically changes from angular to circular.
- See the Fig. 2.3.4 for understanding its use.

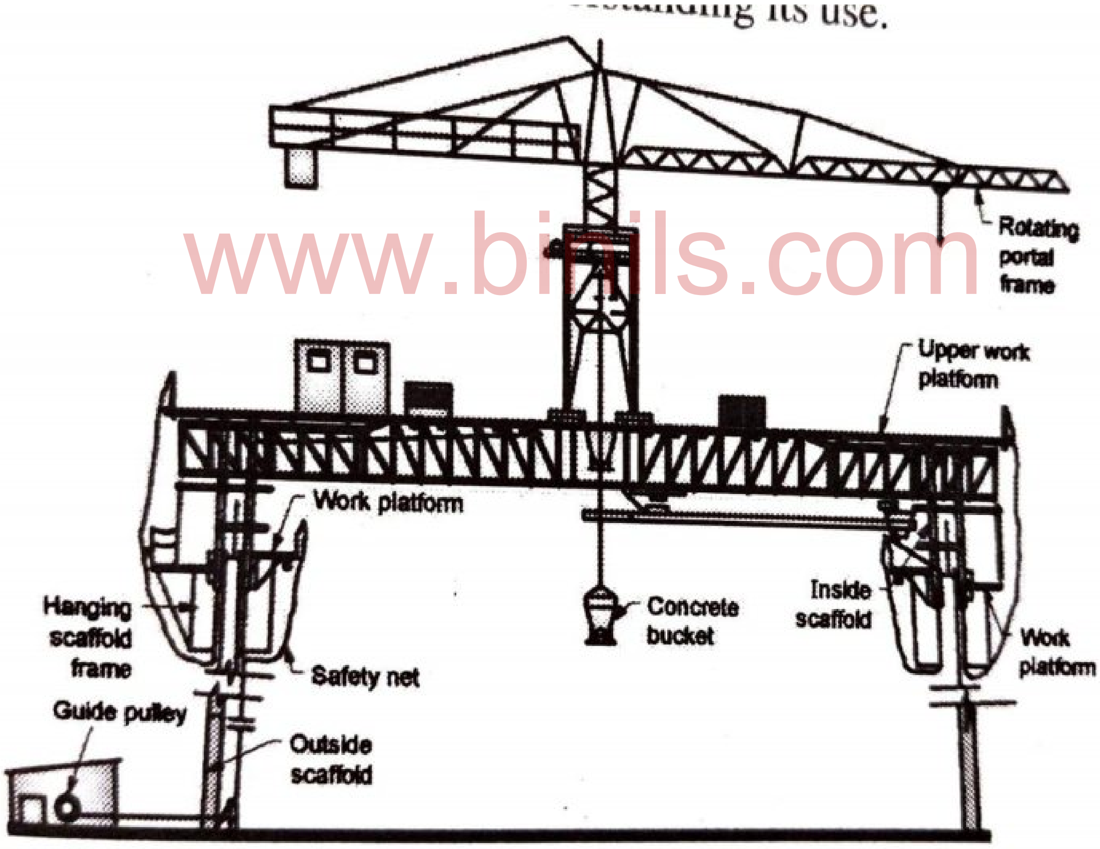


Fig. 2.3.4 : Conical formwork

- Conical formwork is made up of cantilevered plates and overlapping plates which are fastened to the steel yoke frames. The cantilevered plates and overlapping plates automatically adjust the formwork geometry.

- It shows the integrated scaffolding system which includes horizontal work platforms which provide an optimal and safe working area for labour, engineers and supervisors.

2.3.1.3. Pumped Concrete

- The method in which the fresh concrete is pumped to the area where the concreting work to be done is called as pumped concrete. For small work; concreting can manually be done, but for large scale work, concreting is efficiently done by pumping.
- Concrete pumps are generally mounted on a truck or on a trailer. Pumps can be operated by electric power or diesel. Pipeline pumping system has a diameter between 100 mm to 180 mm. Diameter size of 125 mm is must probably adopted for pumping the concrete.
- Modern and advanced handy or portable concrete pumps have more power, high capacity and absolutely reliable hydraulic system and these pumps can take the fresh concrete to a height near about 600 m and also can take the concrete in horizontal distance near about 2200 m.
- Pumps have fully hydraulic, compact and dirt resistance control system. Hydraulic pump is output regulated and hence require less power utilization at an ideal speed and pressure.
- Taper and a clamping device is provided to the outlet portion of the pump so as to connect the pipeline. The outlet portion is easy to clean and also has a simple side swing. The agitator maintain the concrete in an agitated form in between two batches of concrete fed into the hopper.
- The concrete pump unit is mounted on the chassis of a truck and drive of the hydraulic pump is driven from the engine of truck directly. Water pump is joined to the water tank and it is driven hydraulically.
- The pump capacity is in m /hr and it depends on a distance of pumping the concrete, diameter of delivery line and the maximum line pressure.
- Concrete pumping capacity depends upon the following factors:
    - (i) Horizontal pipe length through which concrete can be pumped.
    - (ii) Vertical pipe length through which concrete can be pumped.
    - (iii) Number of bends in pipe line.

- (iv) Diameter of delivery pipe line.
- (v) Length of flexible hose pipe.
- (vi) Number of reducers in the pipe line.
- (vii) Workability of concrete and cohesiveness concrete of the
- (viii) Type and size of aggregates used in the concrete.
- (ix) Proportion of ingradients in the concrete.

2.3.1.4. Advantages of Pumped Concrete

Following are the advantages of pumping the concrete for casting the various member of the structures:

(1) Concrete can be moved horizontally as well as vertically at a time.

(2) It provides a good quality control.

(3) Concreting by pumping is the most effective and sensitive method because any variation in concrete mix can be easily rectified at the pumping point by observing the pumping pressures and hence there is a proper control on consistency and workability of concrete.

(4) It refuses to handle any concrete which is unduly harsh. non-cohesive, consistency. inadequately mixed, improper

(5) No wastage of concrete if casting work done by pumping, but there is more wastage if concrete if casting work done manually.

(6) Pumped concrete has high workability and good cohesion which provides good finish and ultimate strength.

(7) By pumping system, concrete can be placed in inaccessible areas.

(8) Mass concreting work can be carried out in a limited time with high speed without cold joints.

(9) For high rise building, pumped concrete method is best suitable, economical and faster.

(10) Pipeline for delivery of the concrete require a very less space and can be easily extended to the desired height and can be easily removed.

(11) The total unit of pumped concrete helps to complete the contracts within the prescribed time given in agreement. It also reduces the site-overheads.

Use of concrete pump

- Because it is a fluid, concrete can be pumped to where it is needed. Here, a concrete transport truck is feeding concrete to a concrete pumper, which is pumping it to where a slab is being poured.
- A concrete pump is a tool for transferring liquid concrete by pumping. There are two main classifications of concrete pumps.
- The first type of concrete pump is attached to a truck. It is known as a truck-mounted boom pump because it uses a remote-controlled articulating robotic arm (called a boom) to place concrete with pinpoint accuracy.
- Boom pumps are used on most of the larger construction projects as they are capable of pumping at very high volumes and because of the labor saving nature of the robotic arm.
- The second main type of concrete pump is mounted on a trailer, and it is commonly referred to as a trailer pump or line pump. This pump requires steel or rubber concrete placing hoses to be manually attached to the outlet of the machine. Those hoses are linked together and lead to wherever the concrete needs to be placed. Trailer pumps normally pump concrete at lower volumes than boom pumps and are used for smaller volume concrete placing applications such as swimming pools, sidewalks and single family home concrete slabs.
- There are also skid-mounted and rail mounted concrete pumps, but these are uncommon and only used on specialized jobsites such as mines and tunnels.
- When space for movement of workers is less and when the construction is huge and high rise then concrete pumps are commonly used for casting the various members of the structure in cast-in-situ work.
- With the help of concrete pump, the volume of concrete can be transported and placed in the required area to be casted.
- Rigid or flexible pipes are most suitable and economical for pumping the concrete in high rise building, tunnels, deck slab of long span bridges.
- Concrete mix of 8 m'/hr to 80 m'/hr can be pumped horizontally for a range of 90 m to 300 m and vertically for a range of 30 m to 90 m.

Types of Concrete Pump

There are mainly three types of concrete pumps used in the building construction work for concreting.

1. Pneumatic pump
2. Piston pump
3. Squeeze type of concrete pump

2.3.2. Need of Tall Structures

(i) The actual growth of tall building structure in modern construction is began in 1880, which has been largely for commercial and residential purposes. Tall commercial structures are mainly a response to the demand by business activity to be as close to each other and especially to the city centre area as possible and hence concentrating more attention and pressure on the available land space in the city centre areas. Also tall buildings or tall structure makes distinctive land marks and hence tall commercial buildings are frequently developed in city centres as corporate organisations.

(ii) The business and tourist community with its increasing mobility has considered the preferable need for more frequently high rise, and city centre hotel accommodations.

(iii) The rapid growth of the urban population and the consequent pressure and attention on limited space have considerably influenced the city residential development.

2.3.3. Factors Affecting Growth, Height and Structural Form of Tall Structure

Following are the various factors affecting the growth, height and structural changes of tall buildings:

(1) The feasibility and desirability of tall building structures depends upon the following factors:

i. Availability of material.

ii. The level of construction technology.

iii. State of development of the services necessary for the use of the building.

(2) Significant advances and changes have occurred launched from time to time with advance technology and new trends of a new material, construction facility or form of service.

(3) Development of higher strength and structurally more efficient materials, wrought iron and subsequently steel and the introduction of the elevator are also the important factors

(4) The new material allowed the development of lightweight framework or skeletal structures, permitting building of greater height and with larger interior open spaces and windows.

(5) The first tall building structure totally supported by a metal frame was of 11-storied building. Then due to introduction of diagonal bracing, the height was raised upto 20-story. It was then appreciated that at that wind forces were an important design parameter has to consider in the design of tall structure. Improved design methods and construction techniques allowed the maximum height of steel frame structure so as to increase steadily reaching a height of 60-stories with the construction of 'Woolworth building in New York in 1913.

(6) Floor space arrangement led to the provision of large column-free open areas to allow flexibility in planning.

(7) Improved levels of services have frequently add the new technology and trends in the development of high- rise structures.

(8) The earlier heavy internal partitions and masonry cladding with their contribution to the reserve of stiffness and strength have largely given way to light demountable partition and glass curtain walls, forcing the basic structure alone to provide the required strength and stiffness against both vertical and lateral loads.

(9) The trends to exposed structure and architectural cutouts and the provision of setbacks at the upper levels to meet daylight requirements have also been features of modern architecture.

(10) Speed of erection is also a important factor in obtaining a return on the investment involved in such large-scale projects.

(11) Progress in the ability to build tall structure has gone hand to hand with the development of more efficient equipment and improved methods of construction such as slip and flying formwork, concrete pumping and the use of tower, climbing and large mobile cranes.

2.3.4. Basic Design Concept of Tall Structures

- Once the functional layout of the structure by the architect has been decided. Then next process is a structural design which can be done by structural engineer.
- Preliminary member sizes are usually based on gravity loading augmented by an arbitrary increment account for wind forces.
- The main emphasis of static linear analysis is applied to both components and assemblies found in tall building structures, ranging from the primary rigid frames braced and in filled frames and shear walls, to the more efficient composite system which consist of coupled shear wall, wall-frame and framed-tube structures, shear cores and outrigger braced structures.
- Tall building structures are designed mainly to employ the needs of an intended occupancy whether residential, commercial or a combination of this two.
- It is essential for the architect to fulfil or to satisfy the client's expectations concerning the aesthetic qualities of the exterior of the building. The main design criteria are architectural and it is within these that the structural engineer is usually constrained to fit his structure.
- The basic layout will be contained within a structural mesh or skelton which must be less obtrusive to the various functional requirements of the buildings.
- At the same time, there should be an integration of the building structure with the various service systems like heating, ventilating, air-conditioning, water supply, waste disposal, electric supply and vertical transporation which are extensive and more complex and become a major part of the cost of a tall building.
- Once the functional layout is prepared, then structural engineer must develop the structural system which will satisfy established design criteria as efficiently and economically as possible,
- The important structural criteria are an adequate reserve strength against failure, adequate lateral stiffness and an efficient performance during the service life of a building.
- Two fundamental types of limit state should be considered as a limiting design conditions.

(i) The ultimate limit state that corresponding to the loads to cause failure including instability, since events associated with collapse, endangering lives and causing serious financial losses and the probability of failure must be very low.

(ii) The serviceability limit state which involve the criteria governing service life of the building.

(1) Loading consideration in the design of tall structure

- The tall structure should be designed so as to resist the gravitational and lateral forces, both permanent and transient, that it will be called on to sustain during its construction and subsequent service life.
- These forces depends on :

(a) Shape and size of the building.

(b) Geographic location of building.

(c) Maximum probable values which must be determined before design can proceed.

- The probable accuracy of finding the dead load and live loads and the probability of the simultaneous occurance of different combinations of gravity loading both dead and live with either wind forces or earthquake forces is included in limit state design through the use of prescribed factors.
- After completion of building, the loads such as live load, dead load, wind load or seismic loading which are applied over the entire structure. For such loading, the structural analysis is independent of the construction sequence.
- For dead loads, however, which are applied to the building frame when the construction is going on, the effects of sequential loading must be considered to assess the worst but possible conditions to which any component may be subjected.

(2) Strength and stability

- Design the tall structure in such way that, for the ultimate limit state, the main design requirement is that, the building structure should have sufficient and adequate strength to resist.
- Any worst probable loads action which can occur during the lifetime of building and also the building structure should remain stable under any worst probable loads application during the lifetime of building including the period of construction.
- A check should be made on the most fundamental condition of equilibrium to establish that the applied lateral forces will not cause the complete building structure to topple as a rigid body about one edge of the base.

- Hence resisting moment about one edge of the dead weight of the building should be greater than overturning moment for stability by an acceptable factor of safety.

(3) Stiffness and drift limitations

- So as to have adequate stiffness, particularly lateral stiffness is the major consideration in the design of tall building structure for many important reasons.
- The stiffness of joint particularly in the design process of precast or prefabricated structure, should be given special concentration to develop adequate lateral stiffness of the structure and to avoid any possible progressive failure.
- The drift criteria apply essentially to quasistatic conditions. When extreme force condition are possible. then a more sophisticated approach involving a dynamic analysis should be needed.
- In excessive conditions, the drift of the structure can be reduced by changing the geometric configuration so as to alter the mode of lateral load resistance and hence increasing the handing stiffness of horizontal members.

(4) Creep, shrinkage and temperature effects

- The cumulative vertical movement because of creep and shrinkage can be sufficiently large causing distress in non-structural elements and inducing significant structural actions in the horizontal elements especially in the upper part of the building in case of tall building structures.
- In tall buildings provided with partially or fully exposed exterior columns, significant temperature differences may between the exterior columns and interior columns and it induces stresses in the members.
- Hence analysis of such action caused by the temperature differences need a knowledge of the differential temperature which are likely to occur between the building and its exterior and the temperature gradient through the members. Hence using a standard elastic analysis, the resulting thermal stresses and deformation may be determined.
- Differential movements caused by creep and shrinkage should be well considered structurally and accommodated as far as possible in the architectural details at the design stage.

(5) Foundation settlement and soil-structure interaction

- In tall building structures, the gravity forces and lateral forces acting on the building are transmitted to the earth strata through the foundation system provided.
- Structural engineer should consider the influence of any foundation deformation on the building's structural behaviour and on the soil-structure interactive force in the design of tall structures.
- In areas in which soil conditions are poor, loadings on foundation elements should be limited to avoid shearing failure or excessive differential settlements.

(6) Various types of loading considered in tall structure design

- Note that loading on tall building structures differs from loading on low-rise building in its accumulation into much larger structural forces, in the increased significance of wind load and in the greater importance of dynamic effects.
- Wind load on a tall building acts not only over a very large building surface but also with greater intensity at the greater heights and with a larger moment arm about the base which is not occured in case of low-rise building

- Following are the various loads to be considered in the proper design of tall building structures:

(i) Gravity loading i.e. live load and dead load.

(ii) Wind loading

(iii) Earthquake loading.

(iv) Combinations of loading

(7) Floor system in tall structures

- Following floor system in reinforced concrete is basically adopted in the design of tall structures in R.C.C.:

(i) One-way slabs on beams or walls

(ii) One-way pan joists and beams

(iii) One-way slab on beams and girders

(iv) Two-way flat plate

(v) Two-way flat slab

(vi) Waffle flat slab

(vii) Two-way slab and beam

Following floor system in steel framing is basically adopted in tall structures:

(i) One-way beam system

(ii) Two-way beam system

(iii) Three-way beam system

(iv) Composite steel-concrete floor system

2.3.5. Structural Form

- There are various types of structural form which are probably adopted in the design of tall structures. Some of them are mentioned as below:

(i) Braced-frame structure

(ii) Rigid-frame structure

(iii) Shear wall structure

(iv) Flat plate and flat slab structures

(v) Infilled-frame structures

(vi) Wall frame structure

(vii) Core structures

(viii) Framed-tube structures

(ix) Suspended structures

(x) Hybrid structures

(xi) Space structures

(xii) Outrigger-braced structures

- The structural engineer designs the form of structure for tall buildings or high-rise buildings, which involves only the selection and arrangements of the major structural elements to resist most efficiently the various combinations of gravity and horizontal loading. Fig. 2.3.9 shows the braced frame showing different types of bracing.

- In this type of frames, the lateral resistance of the structure is provided by diagonal members which together with the girder, form the web of the vertical truss with column acting as the chords as shown in Fig. 2.3.9.

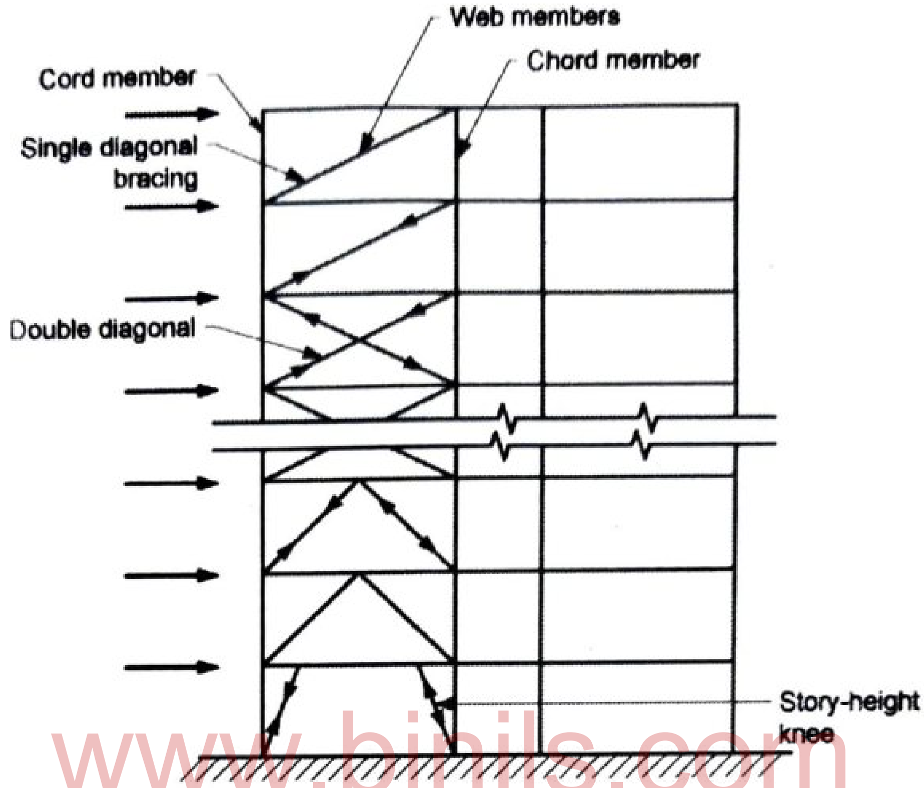


Fig. 2.3.9 : Braced frame

Fig. 2.3.10 shows a rigid frame.

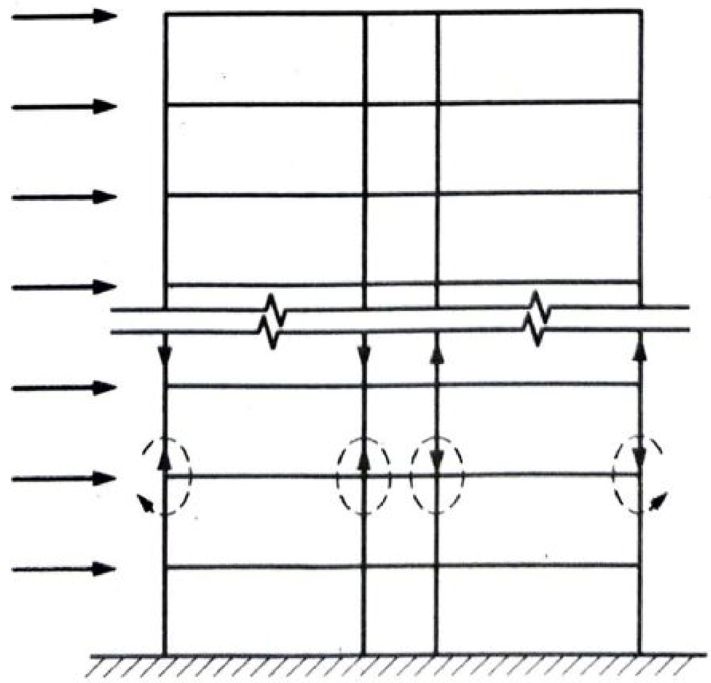


Fig. 2.3.10 : Rigid frame

- This type of rigid frame structures consists of columns and girders joined by moment-resistant connections.
- Fig. 2.3.11 shows infilled frame.
- In infilled frame structure, column and girder framing of reinforced.
- Concrete or sometimes steel, is infilled by panels of brickwork, blockwork or cast-in-place concrete. Tall building of such form occurs upto 30 stories in height.

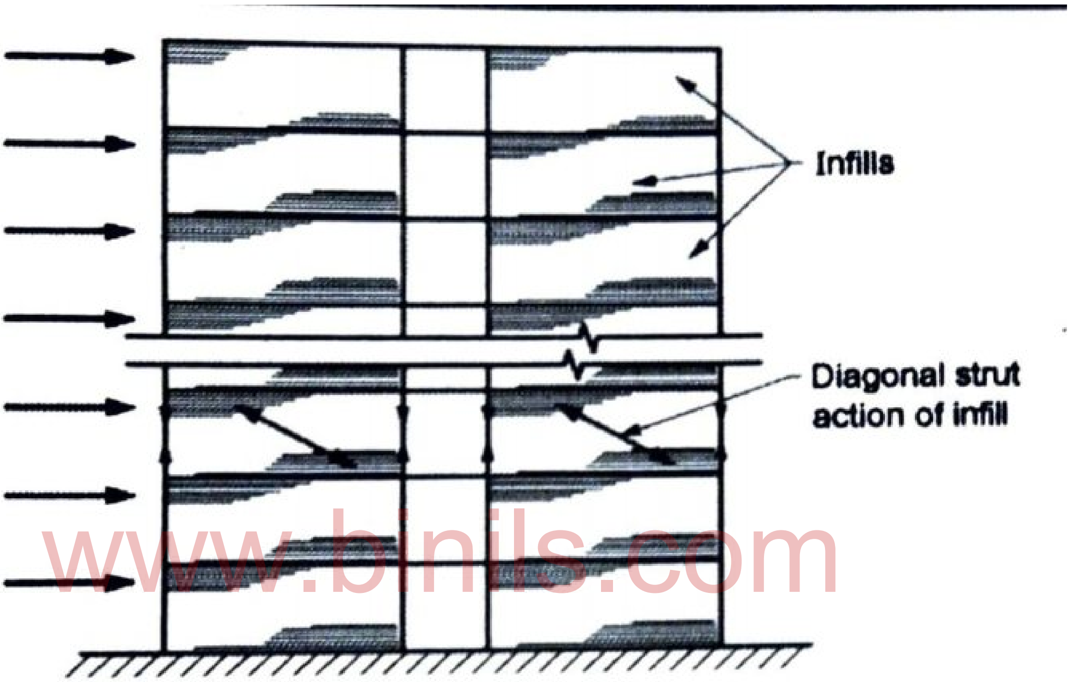


Fig. 2.3.11 : Infilled frame

- Fig. 2.3.12 shows shear wall structure.
- In shear wall structure, concrete or masonry continuous vertical wall serve both the purposes architecturally as partitions and structurally to carry gravity and lateral loading. In a shear wall structure, such walls are totally responsible for the lateral load resistance of the building.
- Fig. 2.3.13 shows wall frame structure.
- In wall frame structure, the walls and frame interact horizontally especially at the top so as to produce a structure stiffer and stronger. It has a range upto 40 to 60 story.

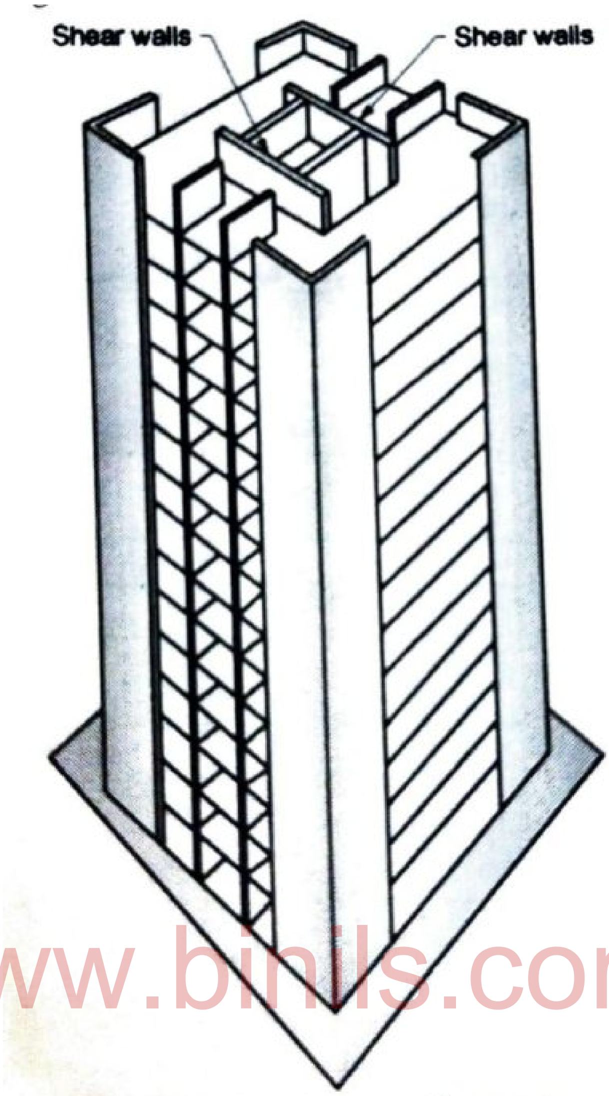


Fig. 2.3.12 : Shear wall structure

- Fig. 2.3.14 shows framed tube structure. In framed-tube structure, the lateral resistance is provided by very stiff moment resisting frames which makes a tube around the perimeter of building. The frame consist of closely spaced column (2m to 4m in height) between centers joined by deep spandrel girders.
- Fig. 2.3.15 shows tube-in-tube structure.
- Tube-in-tube structure is also termed as Hull-core structures.
- This type of structure consist an outer framed tube, the "hull" together with an internal elevator and service core. In this structure, the core and hull which acts jointly and resisting gravity loading as well as lateral loading.

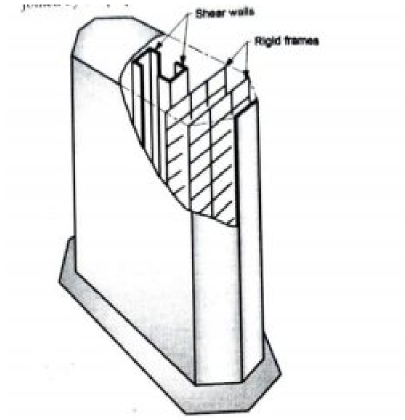


Fig. 2.3.13 : Wall frame structure

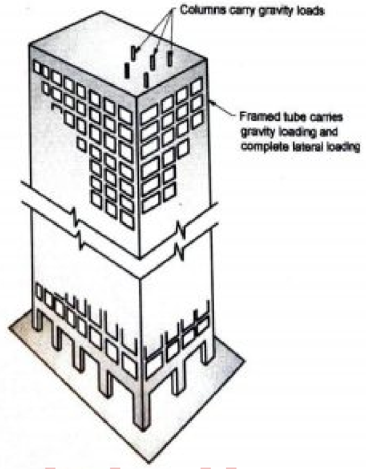


Fig. 2.3.14 : Framed tube structure

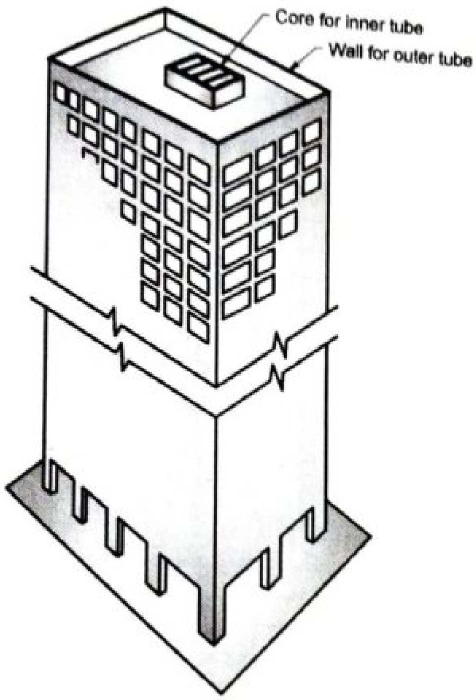


Fig. 2.3.15 : Tube-in-tube structure

Fig. 2.3.16 : Steel-braced tube structure

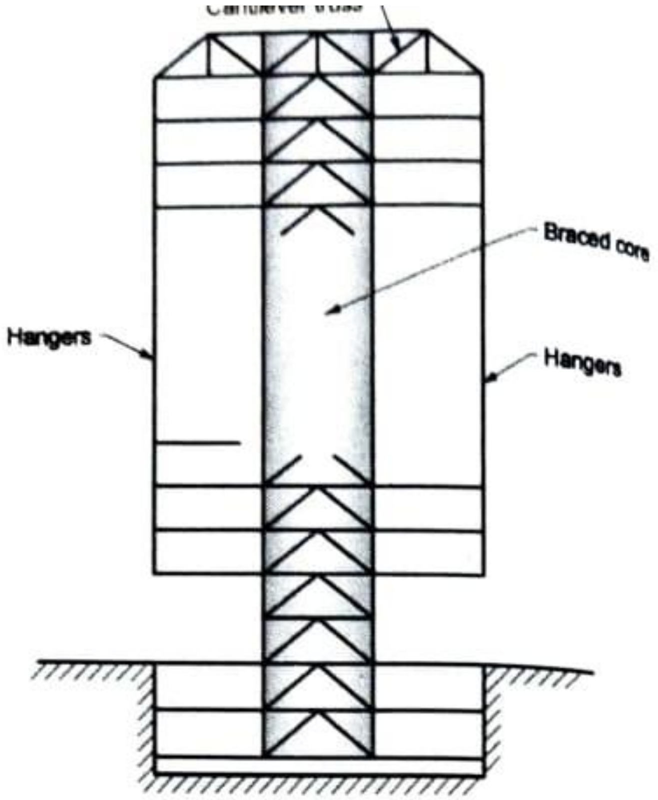
- Fig. 2.3.16 and Fig. 2.3.17 shows the braced-tube structures. Braced-tube structure has two types viz,

(i) Steel-braced structure and

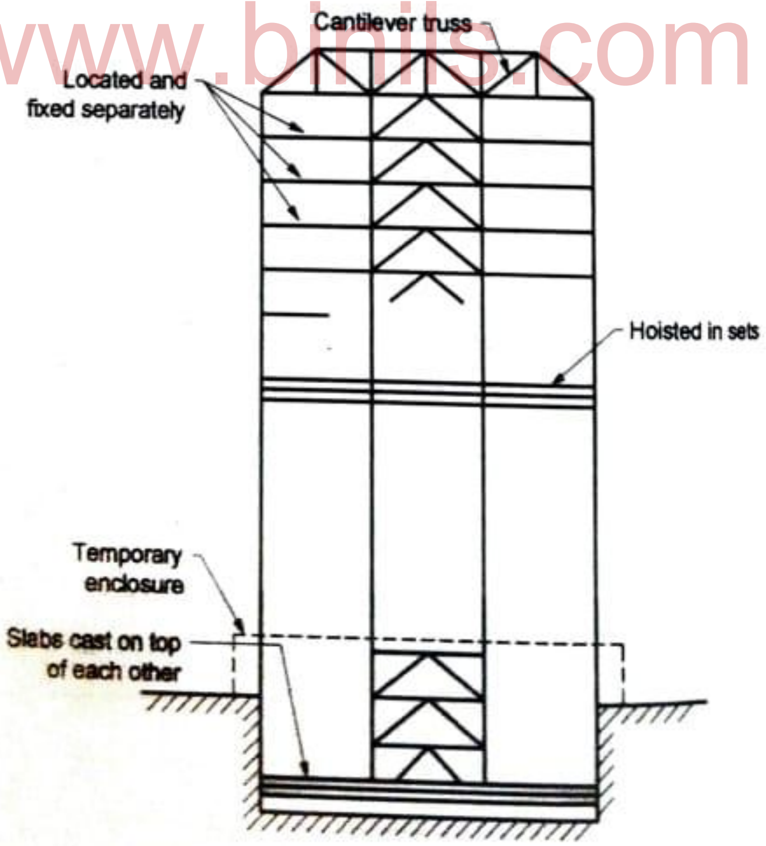
(ii) Concrete-braced structure

- Efficiency of the framed tube can be increased by adding diagonal bracing to the faces of the tubes. Steel-braced tube structure was first used in Chicago's John Hancock building in 1969 as shown in Fig. 2.3.16 and concrete-braced tube structure was first used in a reinforced concrete structure in New York's 780. Third avenue building shown in Fig. 2.3.17.
- Fig. 2.3.17 Shows concrete-braced tube structure.
- Fig. 2.3.18 shows outrigger-braced structure. This tube of structural form consist of a central core, comprising either braced frames or shear walls with horizontal cantilever "outrigger" trusses or girders connecting the core to the outer column as shown in Fig. 2.3.18.
- Fig. 2.3.19 shows suspended structure. This type of suspended structure consists of a central core or cores with horizontal cantilevers at roof level to which vertical hangers of steel cables, rod or plate are attached.

- Fig. 2.3.20 shows Two-tiered suspended structure.
- Fig. 2.3.21 shows core structure.
- In core structure, a single core is capable to carry the complete gravity loading as well as horizontal loading.
- Fig. 2.3.22 shows space structure which is made of 3-dimensional triangulated frames. The 76-story Hong Kong Bank of china building is a best example of this form of space structure members of space structures helps in resisting both gravity loading as well as horizontal loading.
- Due to relatively lightweight structure with a potential, it achieves the greater heights.
- Fig. 2.3.23 also shows the space structure but in another form.
- Fig. 2.3.24 shows hybrid structure.
- Hybrid structure is a combination of two or even more of the basic structural forms used in same building structure.



(a) Suspended structure



(b) Sequence of construction - Suspended structure

Fig. 2.3.19 : Suspended structure

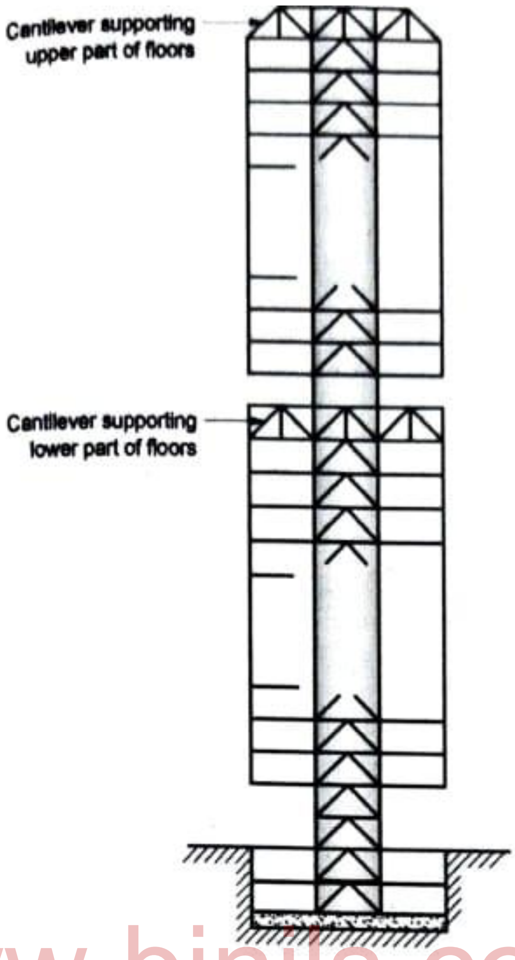


Fig. 2.3.20 : Two-tiered suspended structure

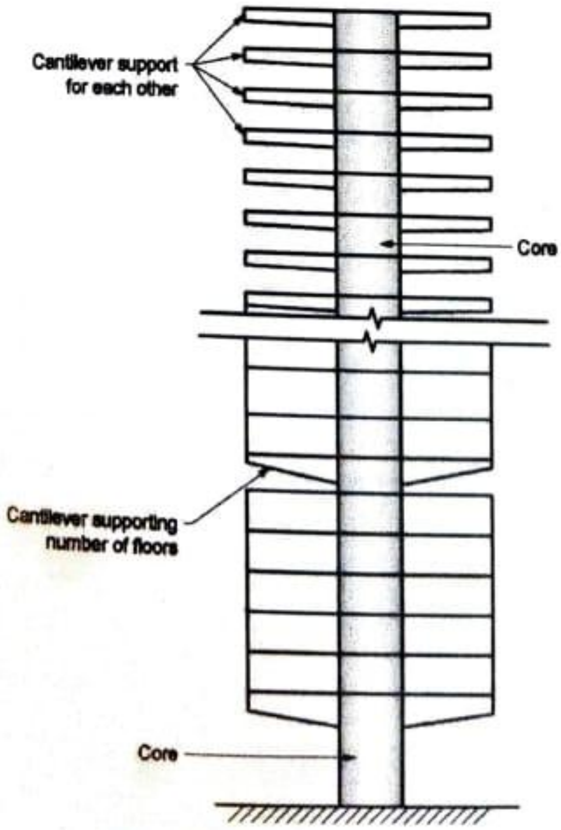


Fig. 2.3.21 : Core structure

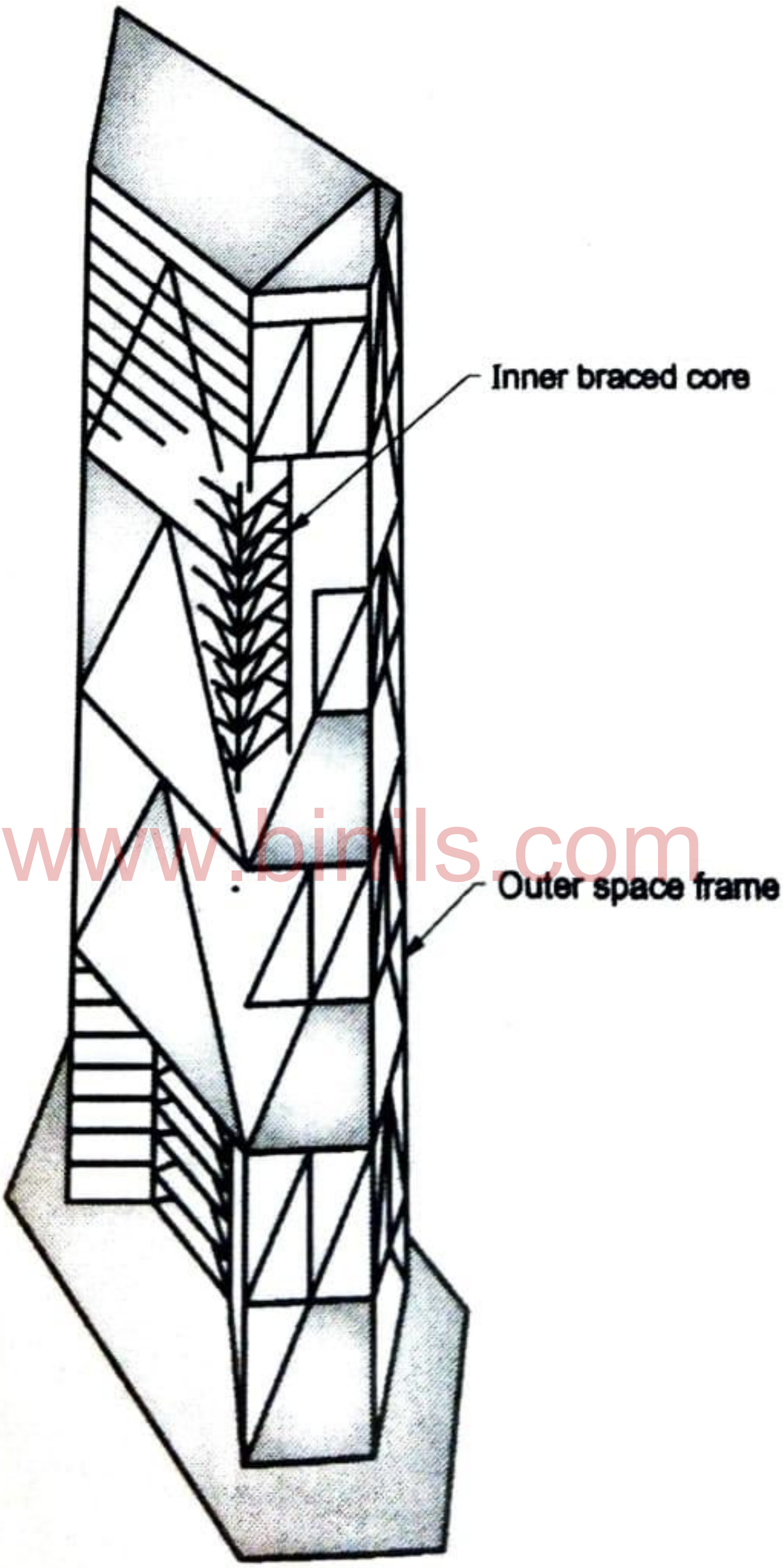


Fig. 2.3.22 : Space structure

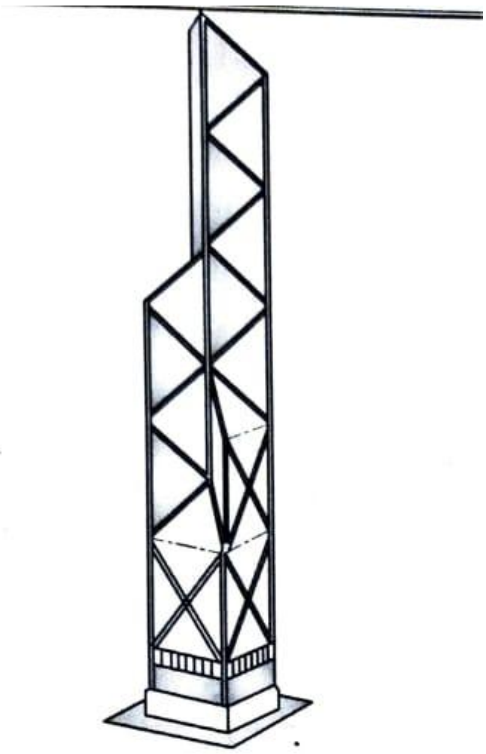


Fig. 2.3.23 : Space structure in another form

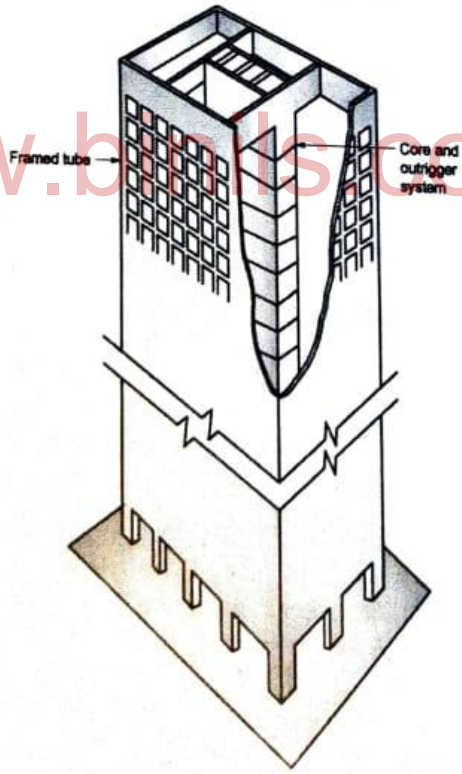


Fig. 2.3.24 : Hybrid structure

- Fig. 2.3.25 shows the combination of tube system on three faces of the building and a space frame on a faceted fourth face.
- Fig. 2.3.25 shows hybrid structure in another form.
- Fig. 2.3.26 shows hybrid structure which is combination of two basic structural form like framed tube structure and outrigger system.

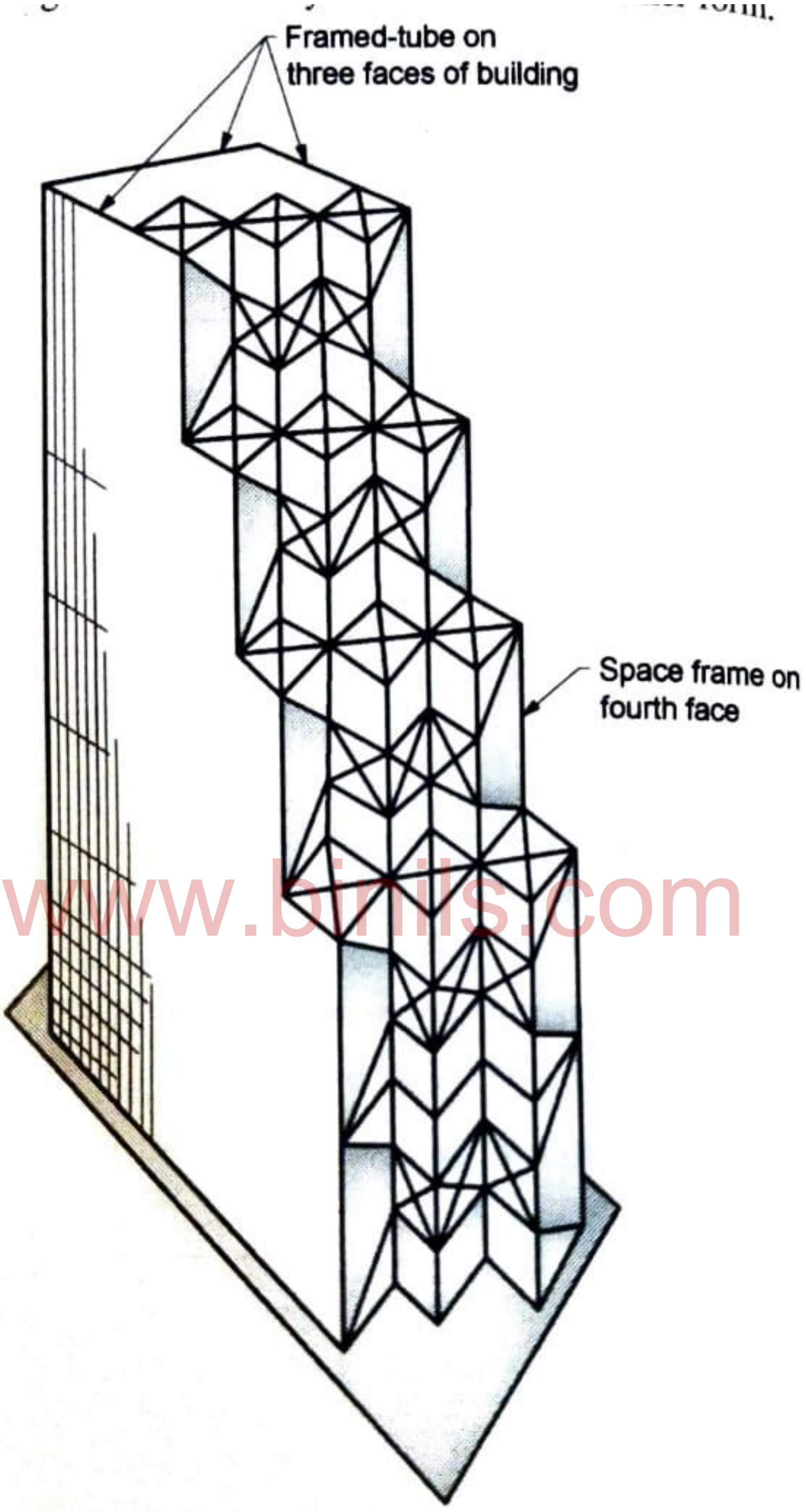


Fig. 2.3.25 : Hybrid structure in another form

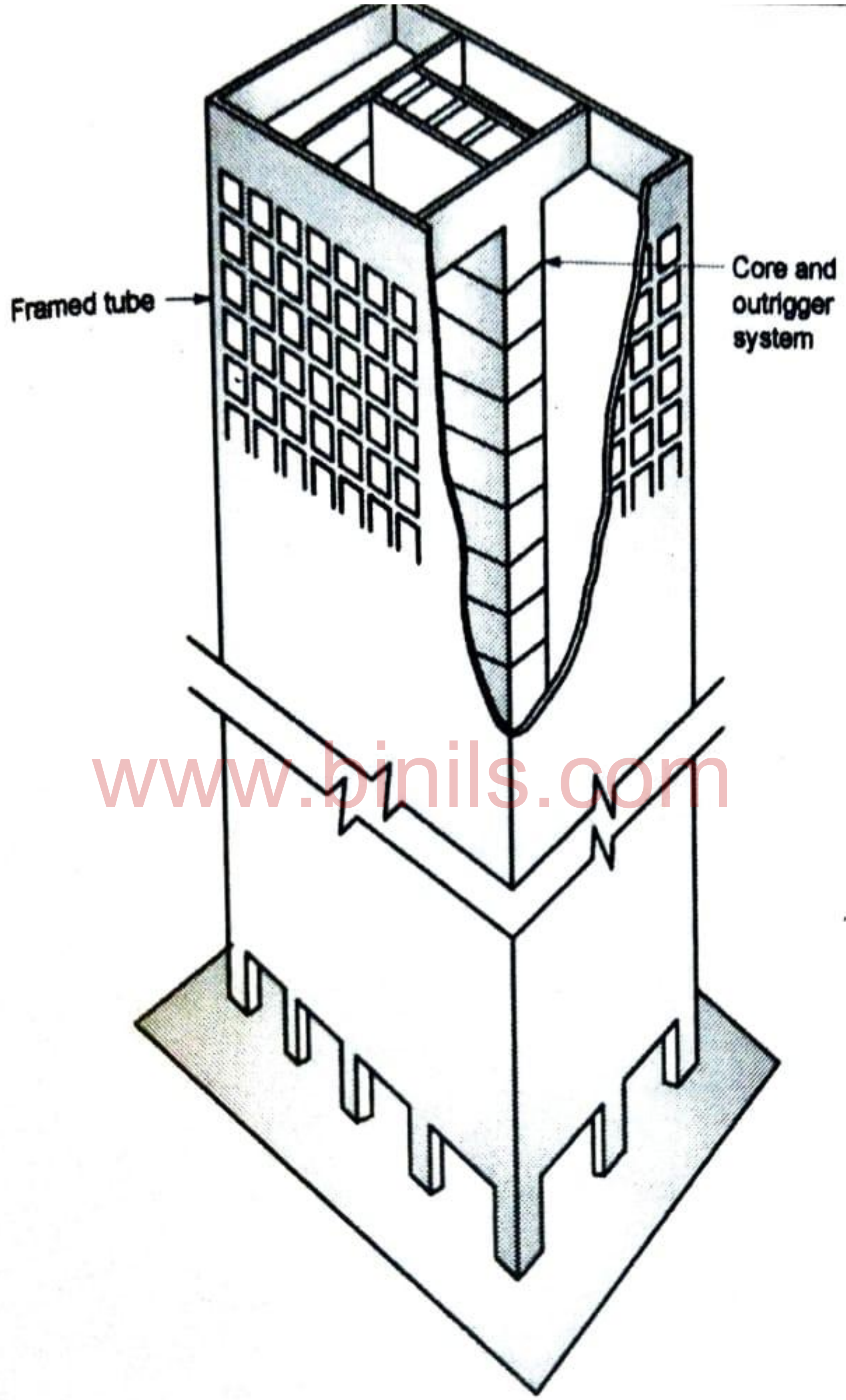


Fig. 2.3.26 : Hybrid structure (combination of framed tube and core and outrigger system)

2.4. ERECTION TECHNIQUE OF TALL STRUCTURE

- Special types of structures may require extensive planning to ensure stability of the structure during erection. For the erection various components in case of high-rise or tall buildings, the choice of formwork systems, delivery and lifting of concrete mixes, installation of reinforcement, the formation of lifting and transporting and auxiliary equipment play a vital role.
- Multi-storey structures or tall structures lie within reach and capacity limitations of cranes are usually erected with crawlercranes.
- For tall structures, a crawler crane or carry and places steel it can reach and then erects the guy derrick (or derricks), which continue process of erection. Alternatively, tower crawler cranes as shown in Fig. 2.4.1 and climbing tower cranes are used extensively for tallstructures.
- Depending on height, these cranes can erect a complete structure and allow erection to proceed vertically. completing floors or levels for other trades to work on before the structure is topped out.
- Guy derricks impart loads at guys, and at the base of the boom, a horizontal thrust that must be provided to install additional bracing or temporary erection material. Considerable temporary bracing is required in a tall structure when a climbing crane is used.
- Loads are also imposed on the structure when the crane is jumped to the next level. These cranes usually jump about 6 floors at a time.
- The sequence or order of placing the members of a tall structure is generally as columns, girders, bracing, and beams. Structural steel is erected by skill ironworkers. The sequence of erection follows pattern of columns, girder and beams or columns, trusses and purlins. Tall buildings are generally erected by cranes and beyond the reach are erected guy derricks.
- Step wise operation in tallbuilding is as follows:

  (1) Guy derrick mast is assembled on ground with its base in approximate desired location.

  (2) The mast is tipped up vertically and guys are anchored to column bases.

  (3) The boom is inserted and topping lift and load lines are served.

  (4) The derrick is ready to operate to install various components.

(5) The first-tier steel is erected

- The exact sequence depends on the erection equipment and type of framing.
- Planning must ensure that all members can be erected and that placement of one member does not prohibit erection of another. Various precautions are to be taken while erecting light weight components on tall structures listed below,

(i) Excellent coordination and site organization have to be maintained

(ii) All heavy equipments such generators, lightning system, twists, etc., are to be ensured in working Condition

- Sufficient communication facility should be coordinated between ground level, crane drivers, ship format and twist operators.

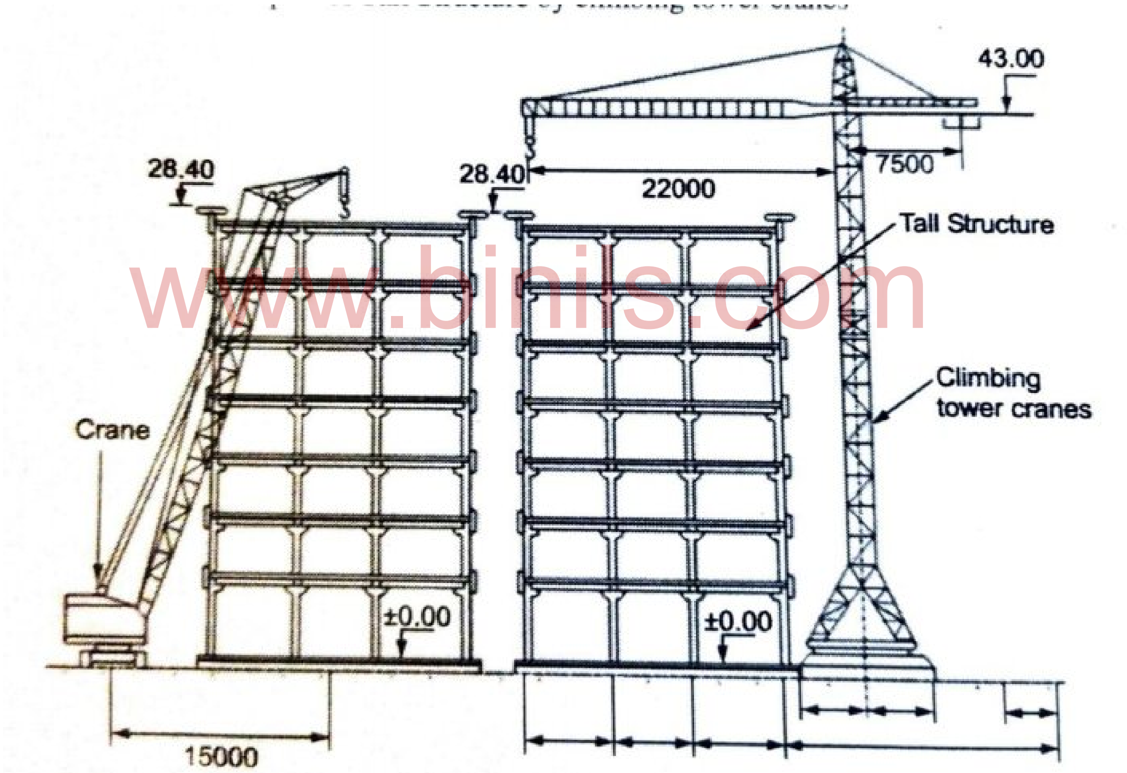


Fig 2.4.1: Erection Techniques of Tall Structures by climbing tower cranes (All Dimensions are in mm)

Construction of Multistoried Buildings

Use of Lifts

- It is defined as an appliance designed to transport persons or materials between two or more levels in vertical direction by means of a guided car or platform.

Types of lifts

(1) A passenger lift is a lift designed for the conveyance of passengers.

(2) A goods lift is a lift designed primarily for the transport of goods, but which may carry a lift attendant or other persons necessary for the loading and unloading of goods.

(3) Hydraulic elevators-generally used for low rise.

(4) Electric lifts used exclusively in tall buildings.

For designing any lift, following points are to be considered:

(1) Number of lifts, size and position of lift well.

(2) Particulars of lift well enclosure.

(3) Size, position, type and number of landing doors.

(4) Number of floors served by the lift.

(5) Height between floor levels.

(6) Total headroom.

(7) Number of entrances.

(8) Number of passengers to be handled.

Location of lifts

Investigation should be made for assessing the most suitable position for lift while planning the building. It should take into account future expansions, if any.

- Where a lift is arranged to serve two to four flats per floor, the lift may be placed adjoining a staircase, with the lift entrance serving direct on to the landings.
- Where the lift is to serve a considerable number of flats having access to balconies or corridors, it may be conveniently placed in a well ventilated tower adjoining the building.
- In case of hospitals, it is convenient to place the passenger lifts near the staircases and hospital bed lifts should be situated conveniently near the ward and operating theatre entrances.
- There shall be sufficient space near the landing door for easy movement of stretchers.

- In case of shops and departmental stores, lift shall be situated so as to ensure convenient and easy access at each floor.

Construction Lifts (Advanced Type)

- There are two types of lifts depending upon their use in various field

  (1) Lifts in general (for domestic, commercial, industrial, public)

  (2) Construction lifts (for various construction processes)

- Here, we are going to study the construction lifts used for various construction system. for various
- Now-a-days, construction lifts are commonly used for high rise building construction. If the construction height of the building is more than 100 m then it is termed as high rise buildings. For donning the various construction processes at different level, they should be comfort and safety for working.
- Following are the various types of construction lifts manufactured by a "Universal Construction Machinery Company Ltd." in India. It is the largest selling construction equipment company in India.

(1) PM lifts

(2) Hanging platform (Lifting type)

(3) Uniswift work platform (Lifting type)

1. PM lifts

- PM lifts play a vital role in construction of high rise building and multistoried building as well for lifting the construction materials at various levels of construction work. See the Fig. 2.4.2 for better understanding.

Salient features of PM lifts

Safety

- The mounting of the twin Electric brake motor drive facilitates high safety in case of failure of either motor.

User friendly control panel

- The control panel is rigid and user friendly and gives accurate control to stop the lift at the required height.

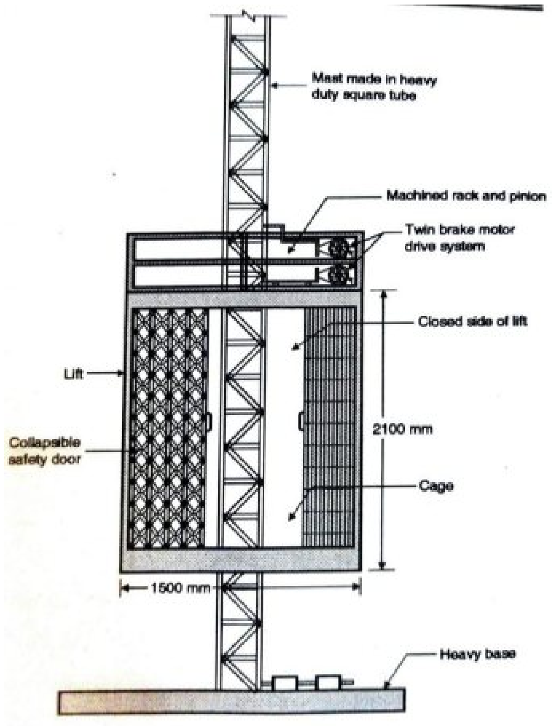


Fig. 2.4.2 : PM lift

Smooth operation

- The accurately machined Rack and Pinion gives smooth operation, which ensures safety and durability of the lift. The guide rollers maintain accurate tolerance in the movement of the lift on the mast.

Easy erection of mast

- Mast made in heavy duty square tube, provided with male and female joints.

Variable frequency drive (VFD)

- The unique feature is incorporated for jerk free and safe operation of lift. It also reduces power consumption during operation.

Fail safe brake

- The brake locks the cabin under free fall.

Safety features

(a) Approved by ARAI.

(b) Self braking electrical motors.

(c) Ascent and descent limit switch.

(d) Limit switch on cage entrance and exit doors.

(e) Manual brake release device (2-28) for emergency descent.

(f) Centrifugal brakes provided to arrest free fall.

(g) Buzzer during down travel start.

(h) Flap arrangement for safer exit.

(i) Electro mechanical lock on cage entrance and exit door.

(j) Lock and key master switch.

(k) Barricade arrangement to protect lift.

Applications of lifts.

PM lifts has following utilities at various levels of construction work at construction site:

- To carry consultants and engineers.
- To carry labours and technicians.
- To carry customers to have a look at their flat.
- To carry valuable fillings, fixtures and materials:
- Using mast cranes are more expensive but PM lifts are economical. It require less space and low maintenance.
- It is easy for erection and operation. safety features.
- It is technologically advanced with unique

(2) Hanging platform (Lifting type)

- This lift type of hanging platforms are manufactured by "Universal Construction Machinery Company" in India. These lifting type of platform is based on suspending mechanism
- These platform is suspended along the building facade by wire ropes. It moves up and down with the help of electric motor through the suspending mechanism installed at the top of building.
- Hanging platform can be used for external plastering, painting, aluminium glass cladding and glass cleaning of high rise building structure. Fig 2.4.3 shows the hanging platform
- Hanging platform is either made of steel or aluminium.

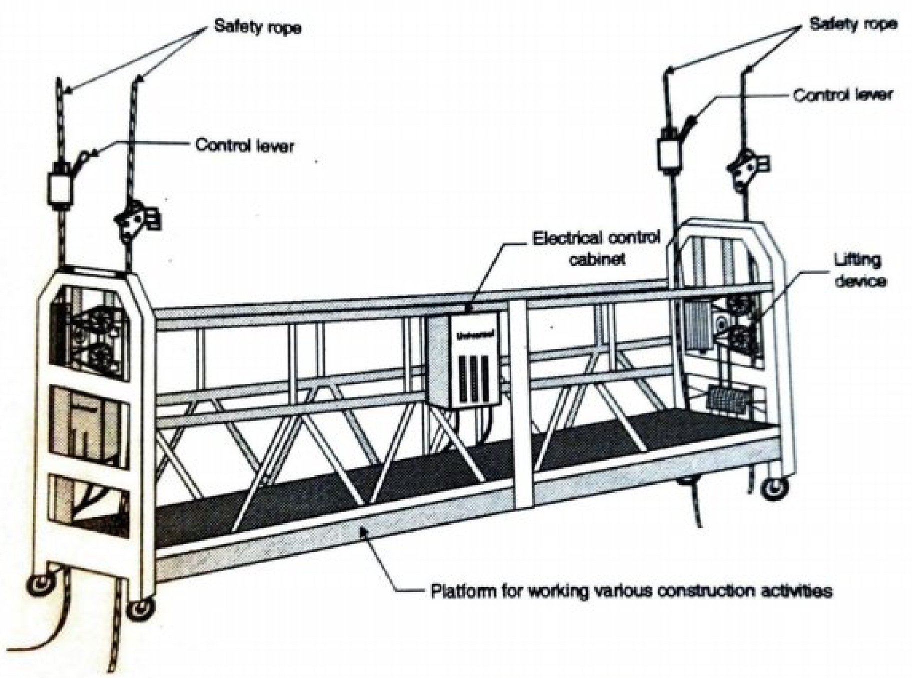


Fig. 2.4.3 : Hanging platform (Lifting type)

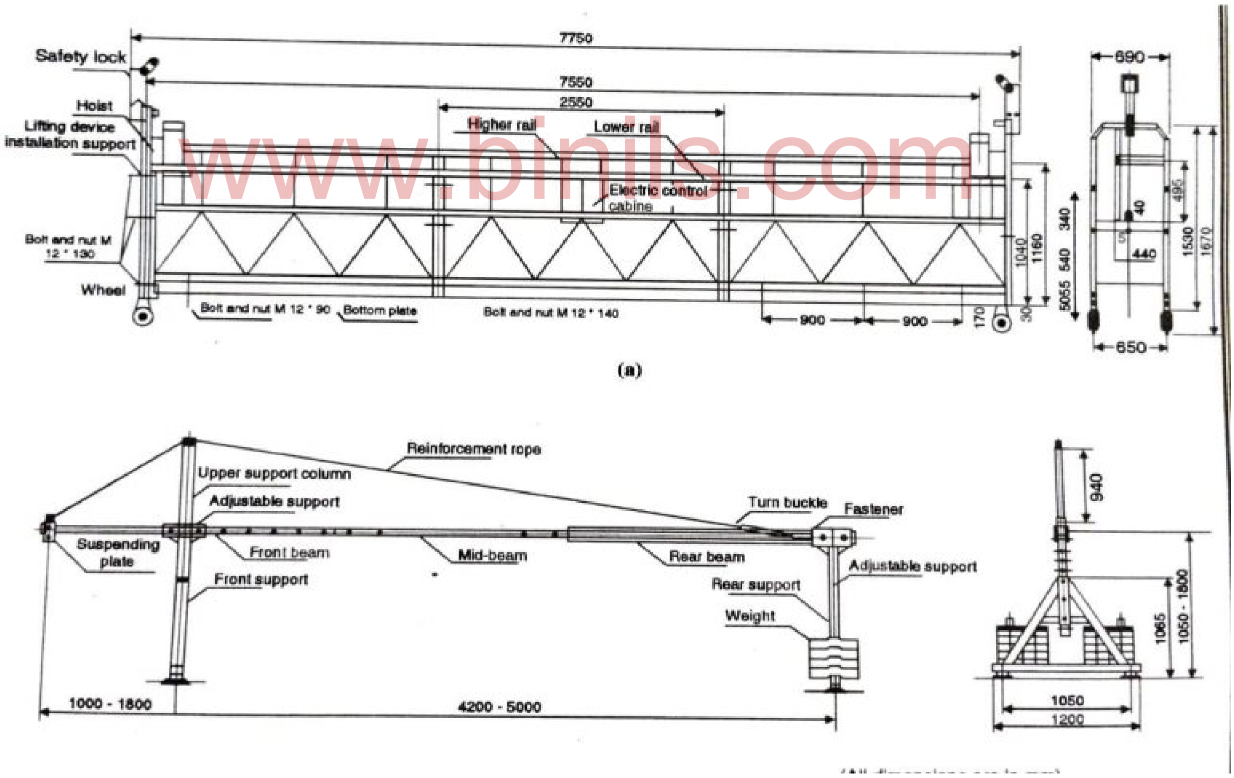


Fig 2.4.4: Line Diagram of Hanging Platform

Applications of lifting type of hanging or suspended platform

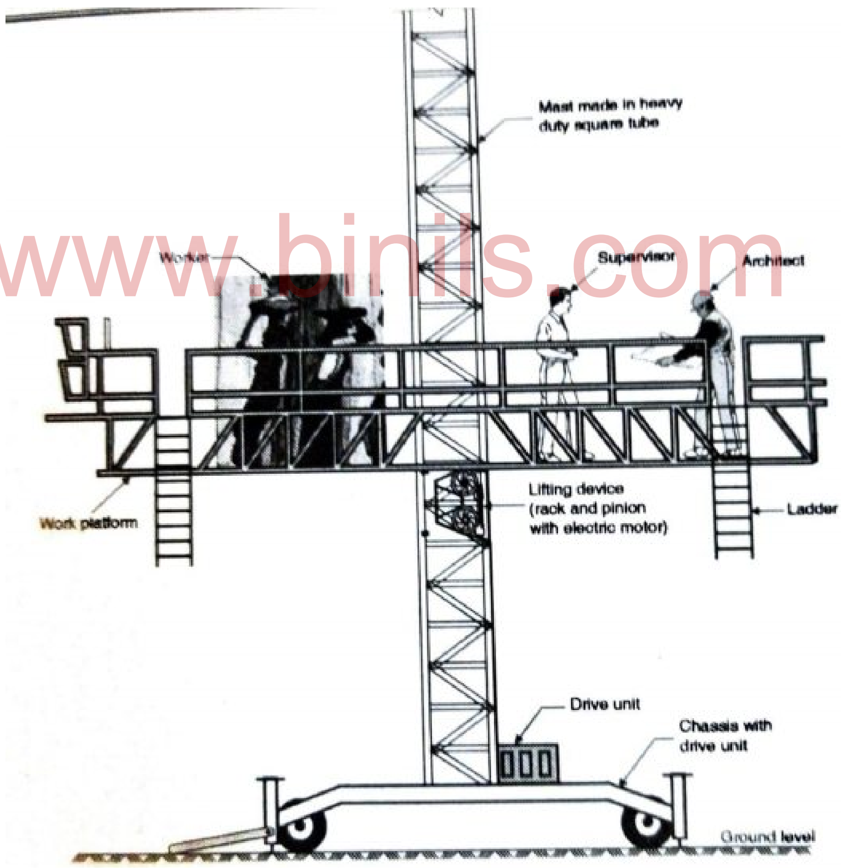
- Hanging platform is more beneficial and can be used for multipurpose in the construction work of high rise building.
- It is used for the construction processes like external plastering, external painting, external glass cleaning of high rise building. It is also used for building maintenance

work like repairing work of sanitary pipe system, cracks sealing, replastering. repainting, periodical glass cleaning etc.

- It is also used for external glass cladding work.

(3) Uniswift work platform (Lifting type)

- It is a work platform which get lifted up and down over the vertical mast made in heavy duty square tube. This platform get lifted to the desired height which faciliate to the workers for doing the various construction processes like external plastering, external painting, brick work, glass and alluminium cladding, extemal sanitary pipe fitting etc.
- Engineers, architects, supervisors, site visitors can also use this lifting type of work platform to go to any desired floor lever.



(b)

Fig. 2.4.5 : Work platform (lifting type)

Salient features

The important features of uniswift platform manufactured by Universal Construction Machinery' are as follows:

Easy erection of mast

Mast made in heavy duty square tube, provided with male and female joints.

Smooth operation

The accurately machined Rack and Pinion gives smooth operation, which ensures safety and durability of the platform.

The guide rollers maintain accurate tolerance in the movement of the platform on the mast.

Advantages of using work platform

Convenience (Time and cost saving)

Material, equipments, workers shifted at a speed of 8 Mtrs./Min giving perfect loation.

Safe working condition

Worker gets good position and ample space and safe place on work platform with railings (In case of scaffolding he has to climb up his way and also make horizontal movement on walkway).

Easy erection

Work platform can be easily erected and used upto 6 meters without support just by using jacks. Above 6 meters, anchoring has to be made at a interval of every 6 meters

Optional features

Chassis with drive unit

Heavy duty chassis with jacks felicitates free standing upto 6 meter. (also available mini chassis for narrow places).

Variable frequency drive (VFD)

This unique feature is incorporated for jerk free and safe operation of platform thus enables good control during operation.

Field applications

Following are the various field applications of uniswift work platform (lifting type and electric motor operated):

- These lifting type of work platforms are used for glass and alluminium cladding in high rise building construction.

- It is also used for external plastering, painting and brick work in case of high rise building construction work.
- It is also used in the construction of chimneys hoardings and in shipyards maintenance.
- It is also used for external sanitary fitting and any repair work in case of high rise building construction.

Belt Conveyers

- Belt conveyer is a machine by which material can be transferred continuously. The belt works under the effect of frictional force.
- It is not only the device to transfer material, but also the components to transfer the force.

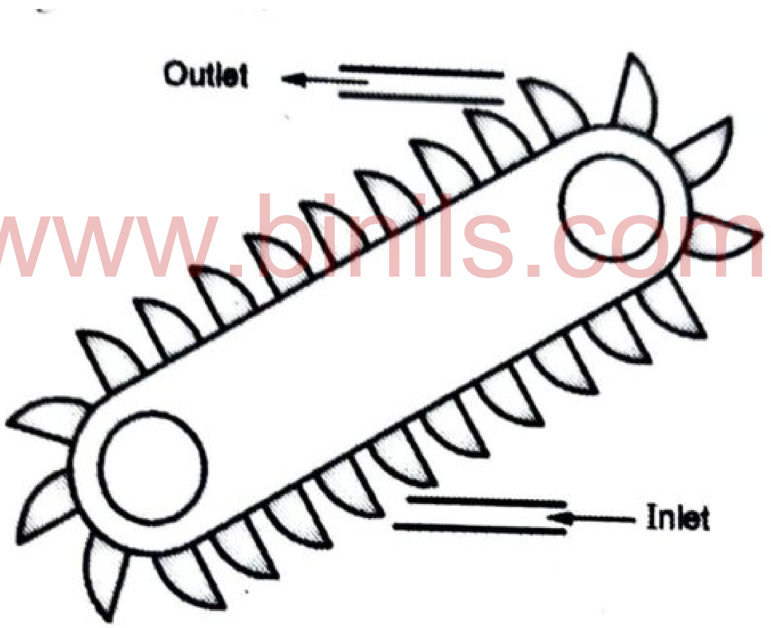


Fig. 2.4.7 : Conveyer belt

- The belt conveyer is advanced and simple in structure, easy to maintain. It has high transfer capacity and can shows great performance over long distance.
- Belt conveyers are widely used in mining, metallurgical and coal industry to transfer sandy or lump material or packaged material.
- It is also used widely in thermal power station so as to transfer the coal to the turbine unit for the formation of stream. It is also used in ceramic tiles factory and stone crushers for carrying the material from one place to another.

- According to different transferring equipment, the belt conveying system can work well by one independently or multi-conveyers or combined with other transfer equipments.
- The belt conveyer can be installed horizontally or inclined so as to meet the needs of different transfer lines.

2.4.1. Holsting and Conveying Equipment Used in Tall Structures Construction

- The equipment used for the operation of hoisting is called as hoisting equipment.
- In this operation hoists are used to lift material and to land it on ground or other place or platform In simple word, hoisting means it is an operation consisting of lifting a load from one location and transport it to required location and then loading it down. The hoists are mounted on trucks, tractors, etc.
- Hoist are classified into 3 types

(i) Jib Hoist

(ii) Tower Hoist

(iii) Mobile Hoist

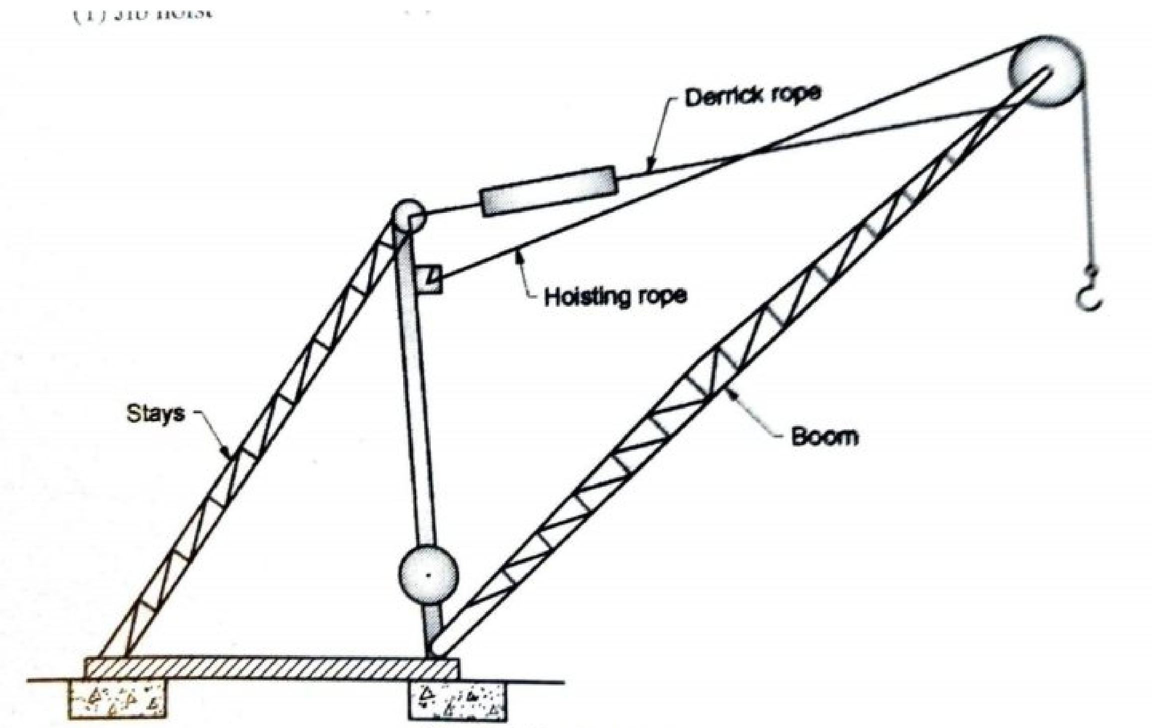


Fig. 2.4.8 : Jib hoist

2.4.2. Tower Cranes

- Normally cranes are used in building construction for lifting and erecting pre-fabricated units and for other purposes.
- Depending upon the nature of work and load to be lifted different cranes are used
- Tower cranes are the non- swinging type cranes mounted on high steel tower.
- These cranes are suitable for tall structures, high rise building construction of buildings in conjusted areas in assembling of high industrial plants.
- With the tower cranes loading and unloading of heavy structural pieces is done quite easily.
- The tower on which crane is mounted has a truss structure welded with bars and angles and channels generally jib is attached to last tower.
- The tower cranes are available in different forms with a horizontal jib carrying a saddle or trolley or alternatively with a lifting or derricking jib with lifting book at extreme end.
- The horizontal jibs can bring the load closer to tower while luffing jibs are used to clear obstruction
- The tower crane are of following types

(1) Self supporting static tower crane.

(2) Supported static tower crane.

(3) Travelling tower crane.

(4) Climbing crane.

1. Self Supporting Static Tower Crane

- The self supporting cranes have a static tower with rotating or slewing tower. The maximum height of tower in 27.4 m and the maximum height to which load is attached is 26.2 m.
- The hoisting speed of these crane is 60 m/min at its maximum radius and at minimum hoisting radius will be 1.1 rpm. the tower. The self
- The crane is operated either from ground level as well as the operator cabin provided above supporting static tower cranes are as shown in Fig. 2.4.9.

... cranes are as shown in Fig. 2.4.9.

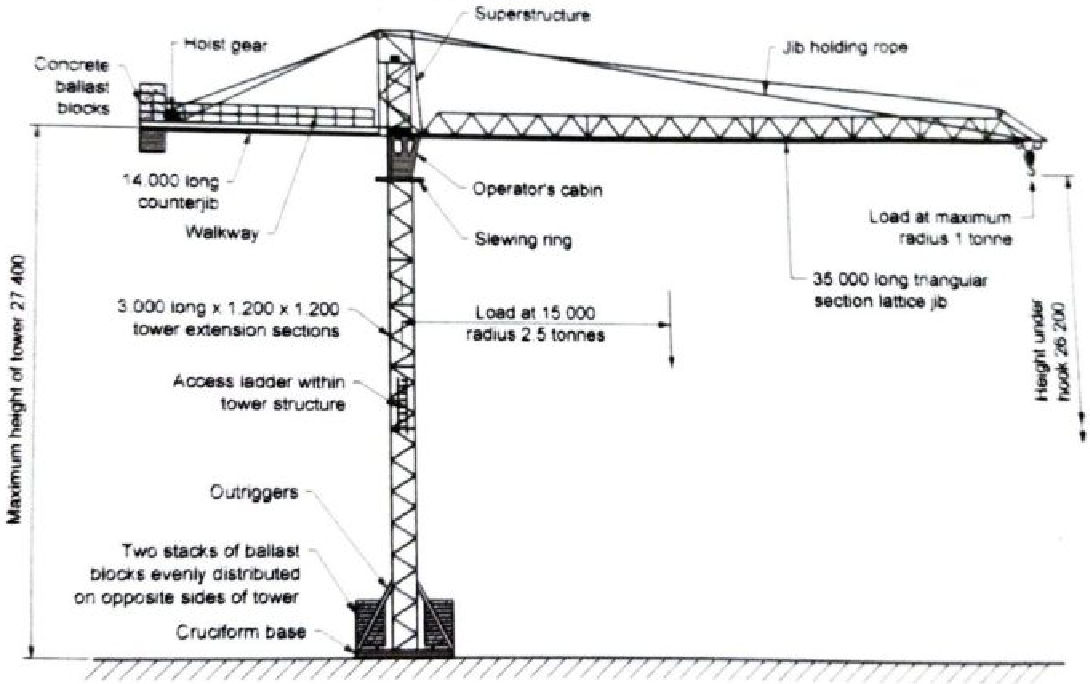


Fig. 2.4.9 : Typical Self supporting static tower crane

2. Supported Static Tower Crane

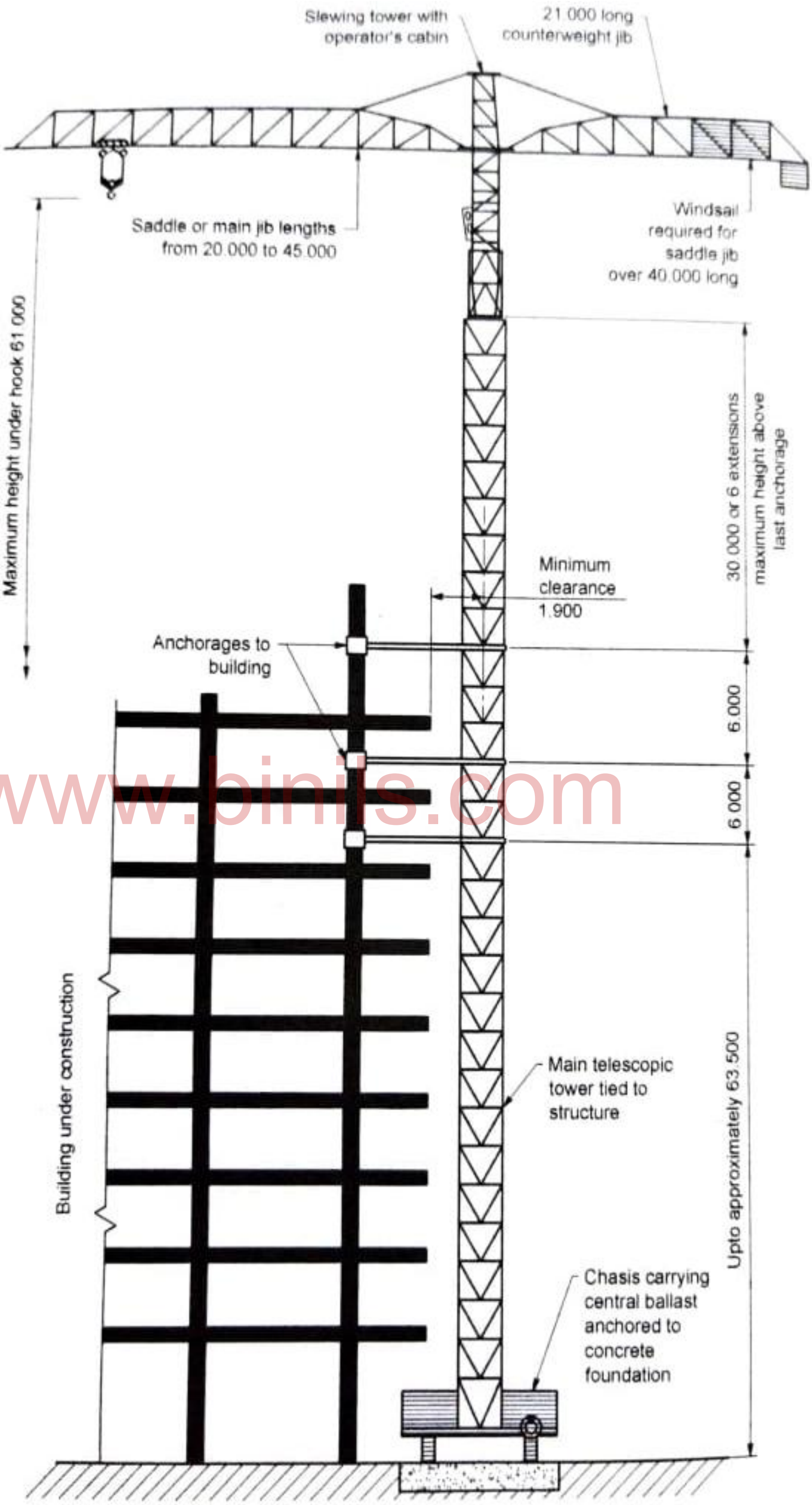


Fig. 2.4.10 : Typical supported static tower crane

- These are similar to self supporting static tower cranes. Only difference is that main telescopic tower is tied to structure. The maximum height upto which load is lifted is 63.50 m and its lifting capacity is 3.5 tonne and its lifting speed varies from 31.7 m/min to 108 m/min.
- Depending upon the loads these cranes are electricity operated.
- The care is taken while tieying the tower to building. Minimum clear distance should be kept is 1.9 m and tower is fixed or tied to the structure using single or double steel stags to provide stability.
- The typical Fig, of supported static tower crane is as shown in Fig 2.4.10.

3. Travelling Tower Crane:

- Whenever large area is to be covered then rail mounted or travelling tower cranes are used. In this, the crane travels on heavy track fixed to timber sleeper. It consists of saddle jib of triangular tubular lattice construction and having lifting capacity is I tonne at the extreme end and 3 tonnes at middle. The maximum height to which load is lifted is 36 m and these cranes are electric powered controlled from base of crane
- The travelling tower cranes are as shown in Fig 24.11.

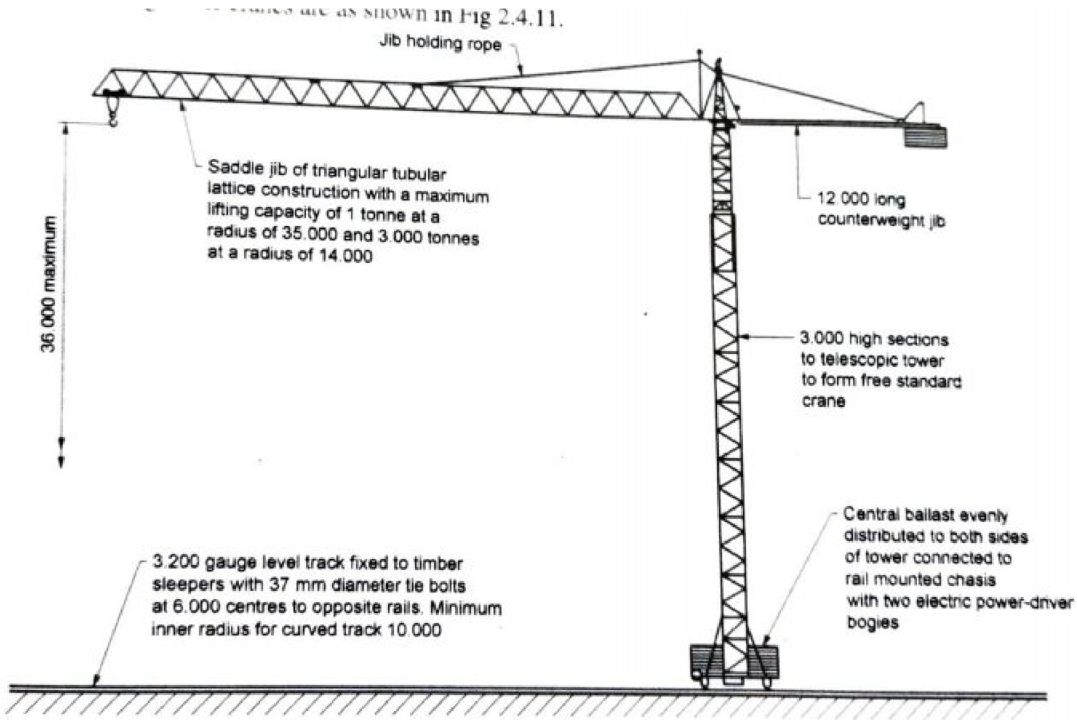


Fig. 2.4.11 : Typical travelling tower crane

4. Climbing Tower Crane

- This type of cranes required a smaller horizontal or luffing jib to cover the construction area than other types of crane. Jib is small and easy to handle sections and these are lowered down the face of building when crane is no longer required by means of special witch attached to one section.
- These are consist of 27.2 m long jib with lifting capacity of 1.25 tonnes at maximum radius and 2.5 at 14:150 radius. For 2.5 tonne load hoisting speed is 30 m/min and for 1.25 tonne 60m /min. Its slewing speed is 1.1 rpm and its trolley speed is 39.6m/min. It has 10.2 m long counter jib which is kept with concrete ballast over it.
- These can be mounted anywhere and hence are most suitable for any type of construction work.
- The typical climbing tower crane is as shown in Fig. 2.4.12.

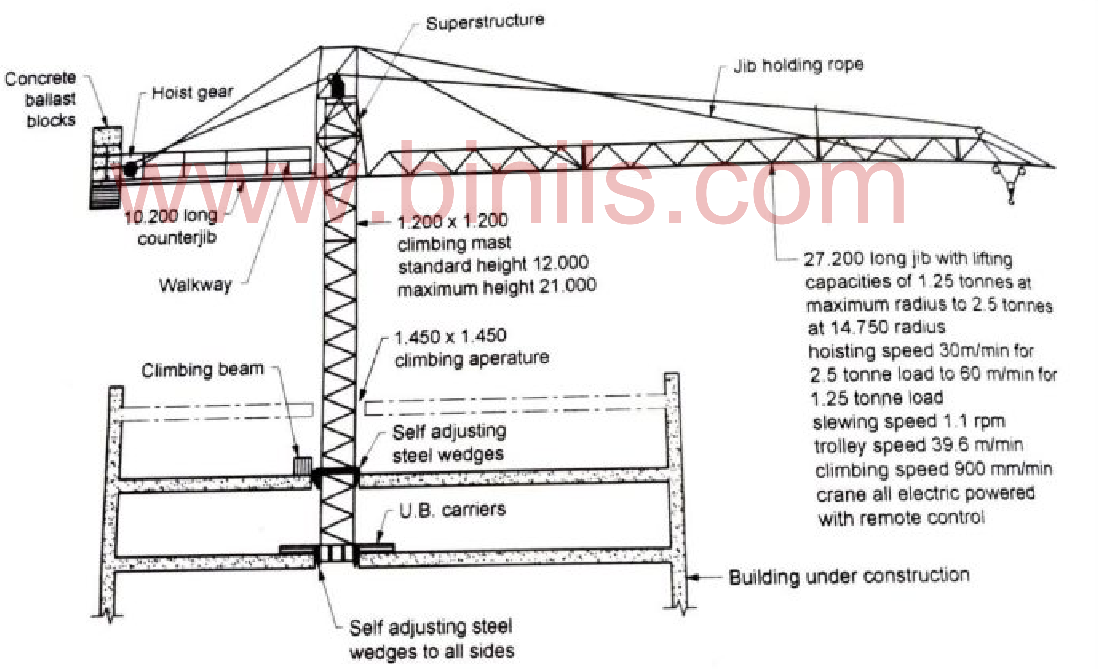


Fig. 2.4.12 : Typical climbing tower crane

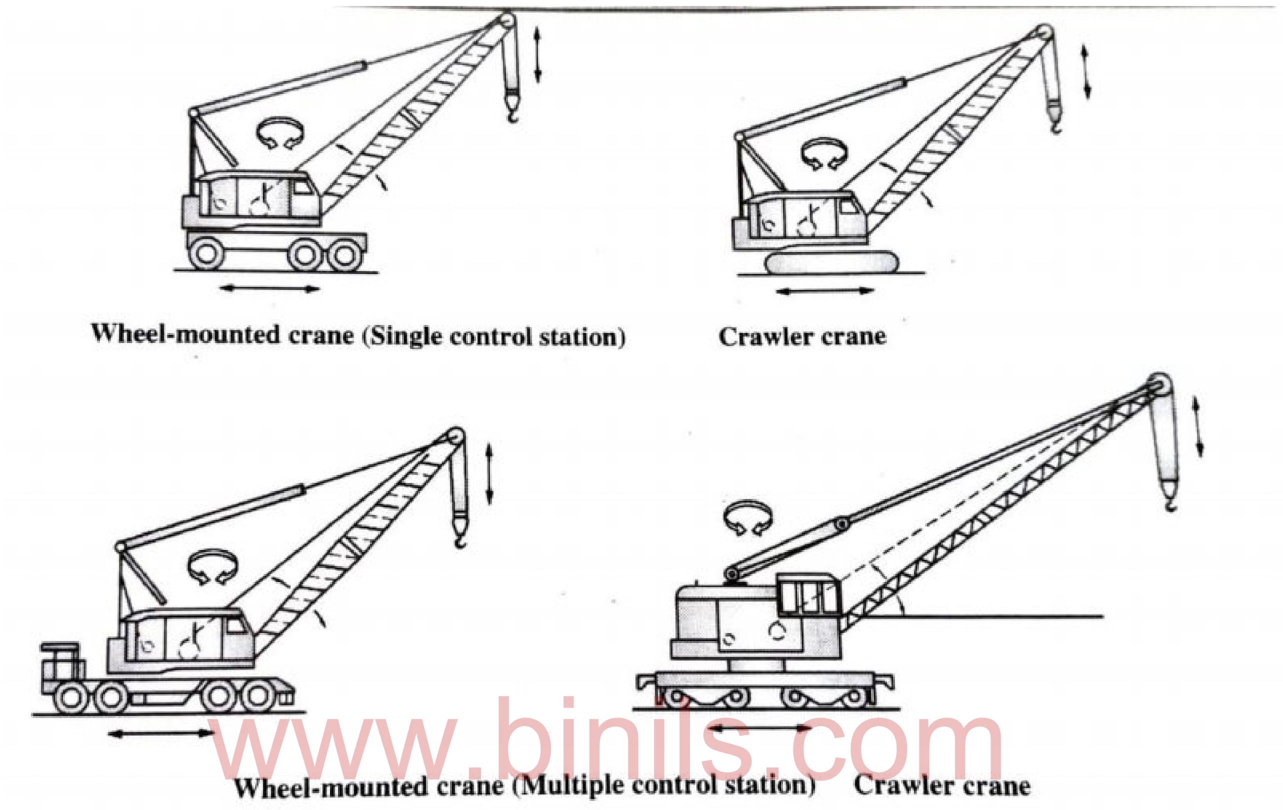
2.4.3. Mobile Cranes

- The mobile cranes are either tyre mounted or crawl mounted. These are fittend on trucks with special arrangements and facility.
- They comes under a wide variety of design and capacity, generally with 360 rotation or slewing circle a low pivot and luffing jib. The mobile cranes are classified as,

(1) Truck mounted cranes

(2) Mast crane

(3) Gantry crane



(b)

Fig. 2.4.13 : Mobile cranes

1. Truck Mounted Crane

- These are the cranes consisting of stiff chassis mounted upon two or more axle depending upon the weight the chassis incorporates a diesel engine. The transmission and out rigger the engine is used to power the vehicle for transportations
- Travelling speed of these cranes is upto 75 km/h and having capacity upto 2000 tonnes.
- In lifting section it has conventional strut boom crane super structure without crawler tracks which sits on a turntable mounted on charts.
- It comprises the counter weight, hoist and derricking drums, slewing mechanism boom and operating control.
- The typical truck mounted crane area as shown in Fig. 2.4.14.

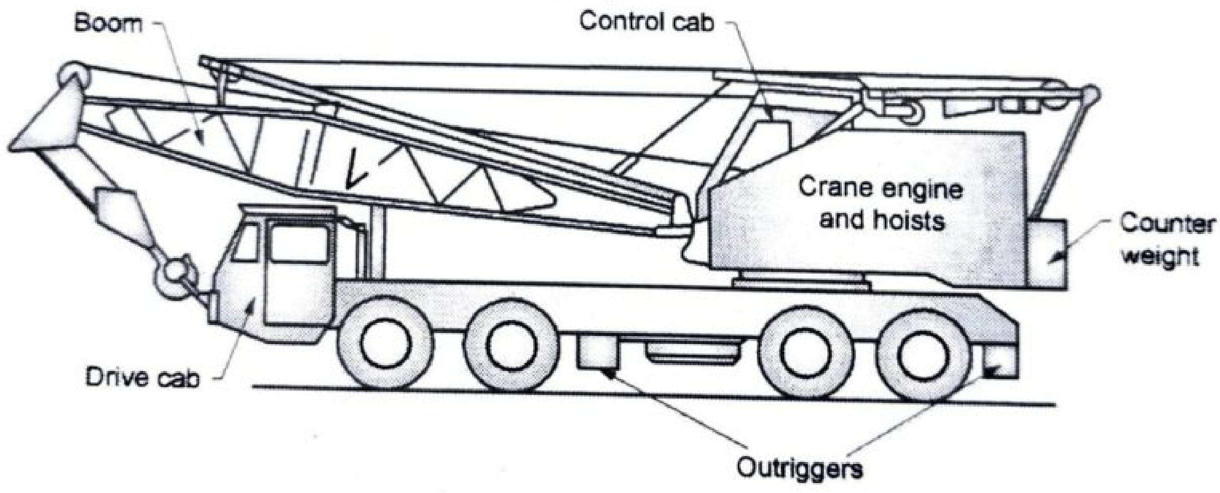


Fig. 2.4.14 : Truck mounted crane

2. Mast Crane

- These are either lorry or track mounted machines as shown in Fig. 24.15.
- It consists of 15 m long luffing jib. It has self erecting must and jib which folds onto slewing platform chassis for towing by vehicle.
- Its hoisting speed is 12 to 24 m/min and trolley speed is 33 m/min. Its slewing speed is 1.3 rpm.
- The main advantage of high pivot mast cranes is that it is less likely to foul the side of building under construction and it can approach closer to structure
- Mast is mounted on the jib pivots and held in vertical position by ties

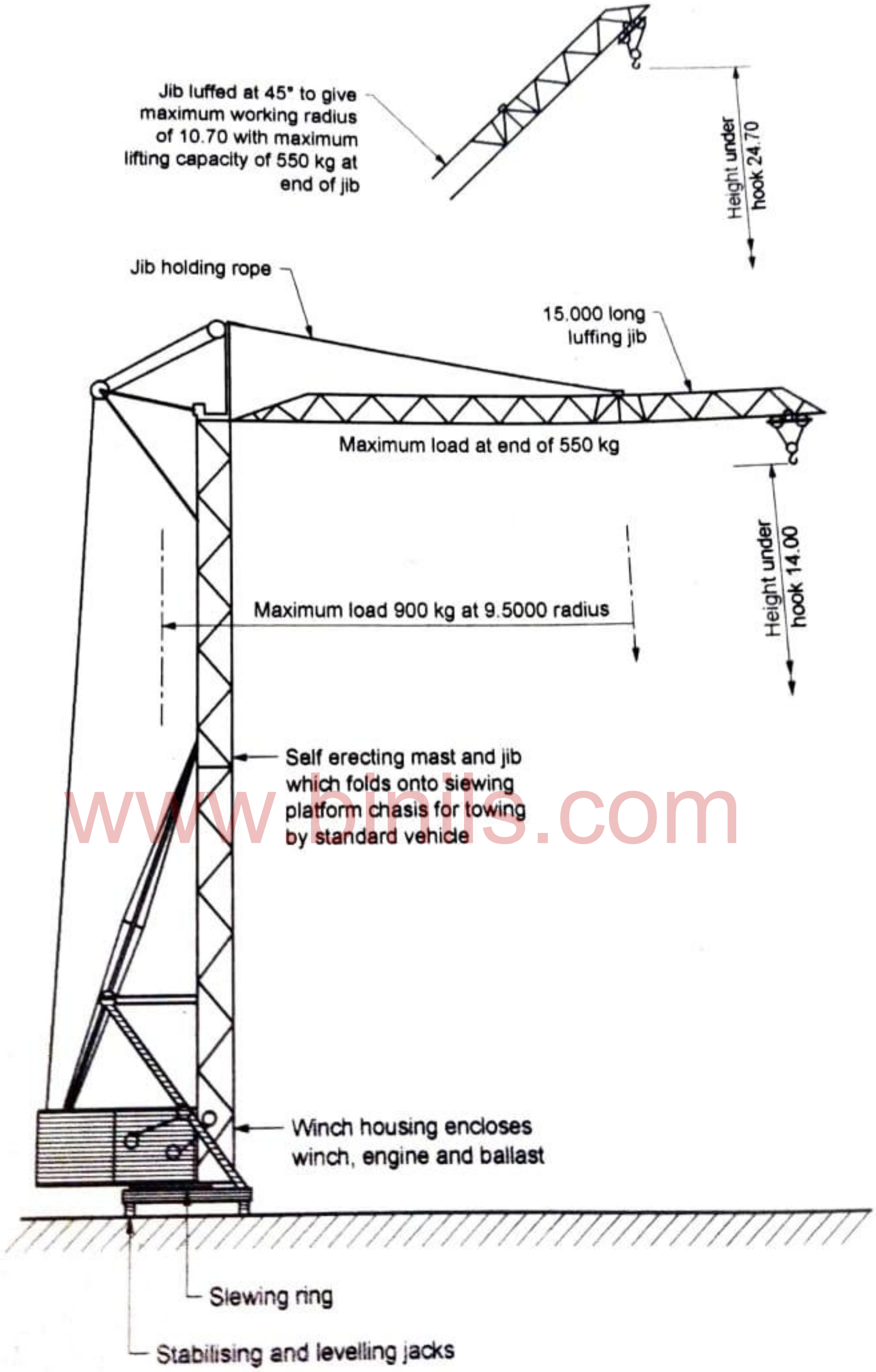


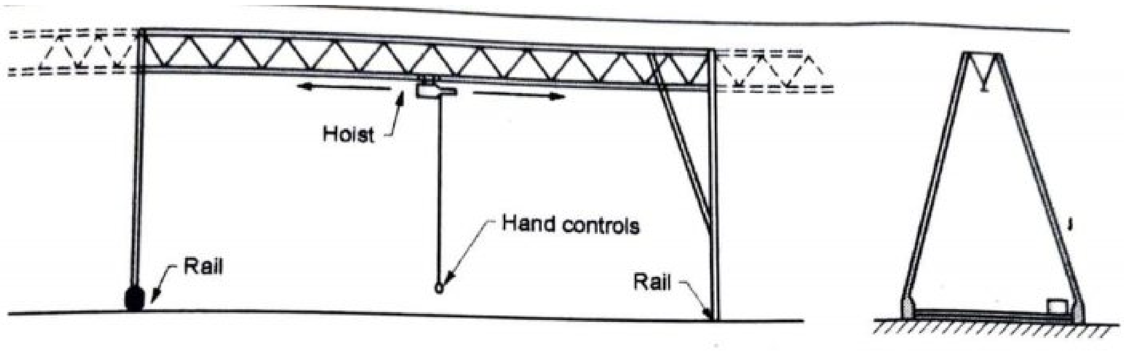
Fig. 2.4.15 : Typical mobile mast crane

3. Gantry Crane

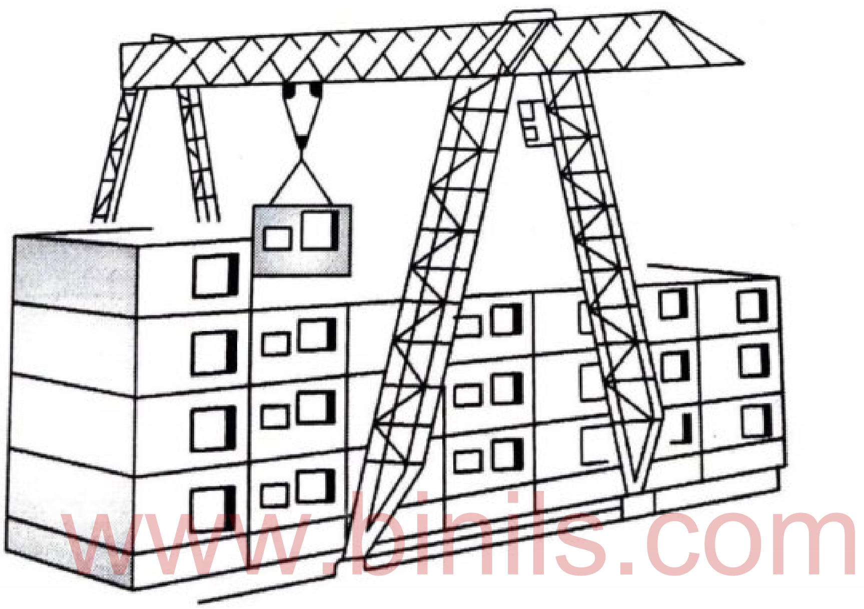
- These types of cranes are provided where lifting facilities are required to cover both the casting and storage areas for which portal structure is ideally suited.
- The portal legs are mounted on rail track and bridging beam is positioned to span upto the full widths of manufacturing stock yard area.
- These types of cranes are used for construction of precast concrete building, precast concrete manufacturing factories, large foundation of uniform shape, dry docks etc. where working space is important
- These are also called as portal crane.

4. Working of Gantry cranes

- It consists of horizontal transverse beam supported by rail mounted frames on powered bogies on both sides of the building under construction. In this crane, the driver have a very good view all-round him.
- It also allows the hook three-way movement t of in vertical, horizontal transverse deviations.
- Hand controls are sometime provided to the gantry cranes so as to move the crane to the required point.
- Fig. 2.4.16(a) shows the working of gantry crane.



(a) Gantry or portal crane



(b) Portal crane used in high rise building construction

Fig. 2.4.16 : Gantry crane

2.4.4. Derricks

- These are mounted on triangulate frame and their load carrying capacity is 5-10 MT and its jib length is 30 m. It is mainly used for factory columns, trusses, frames, etc.
- The Fig. 24:17 shows the typical details of derrick
- The Derricks are classified as

(1) The Guy derrick

(2) Scotch derrick.

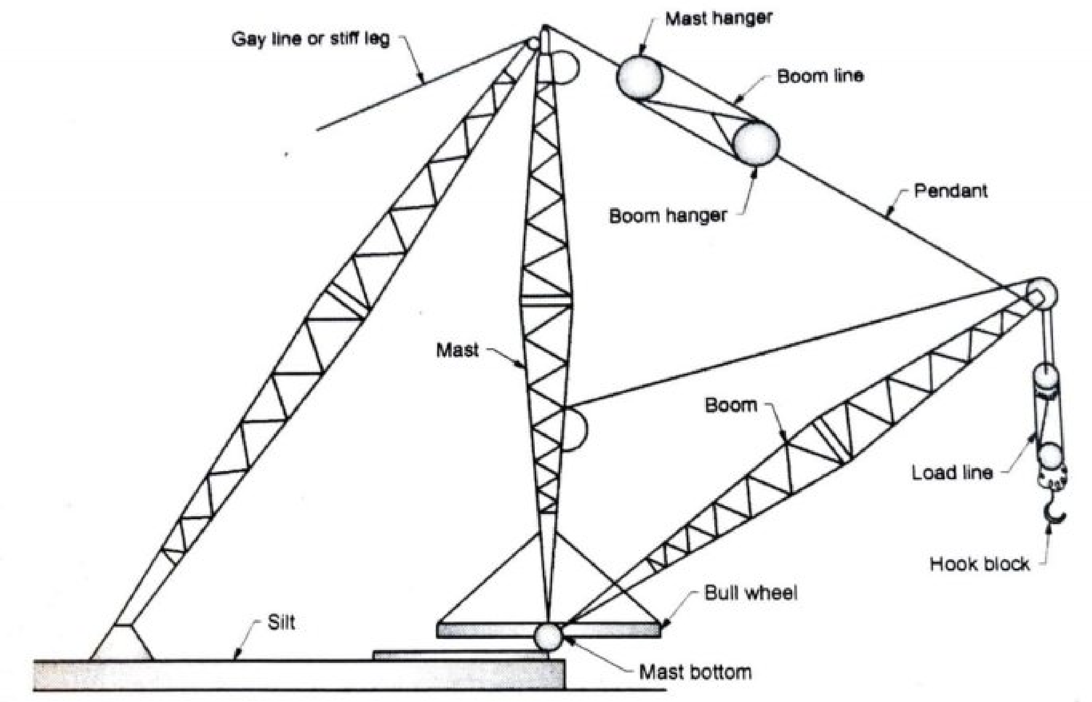


Fig. 2.4.17 : Derrick

1. **Guy Derrick**

➢ In this type of crane vertical post is longer than jib and is mounted on the basement and held by five or more anchored guy ropes. These are simple type of static crane powered by diesel engine.

➢ The shorter lib has advantage that at minimum radius it can rotate through full 360 clearing the guys by passing underneath them.

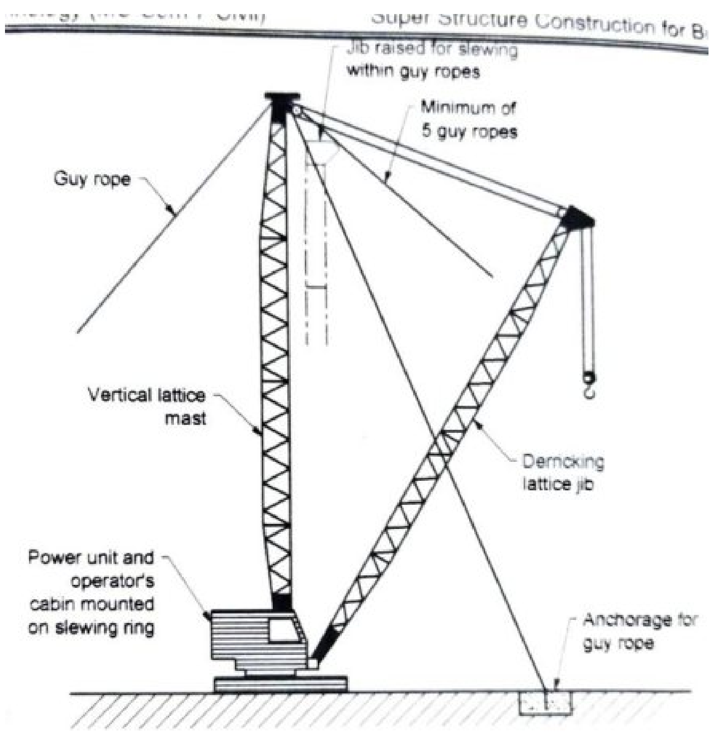


Fig. 2.4.18 : Guy Derrick

2. Scotch Derrick

➢ It has short vertical centre post and a jib is usually two times as long as centre post. These are capable of slewing 270° only as they are restricted in further rotational movement by sloping lattice guy.

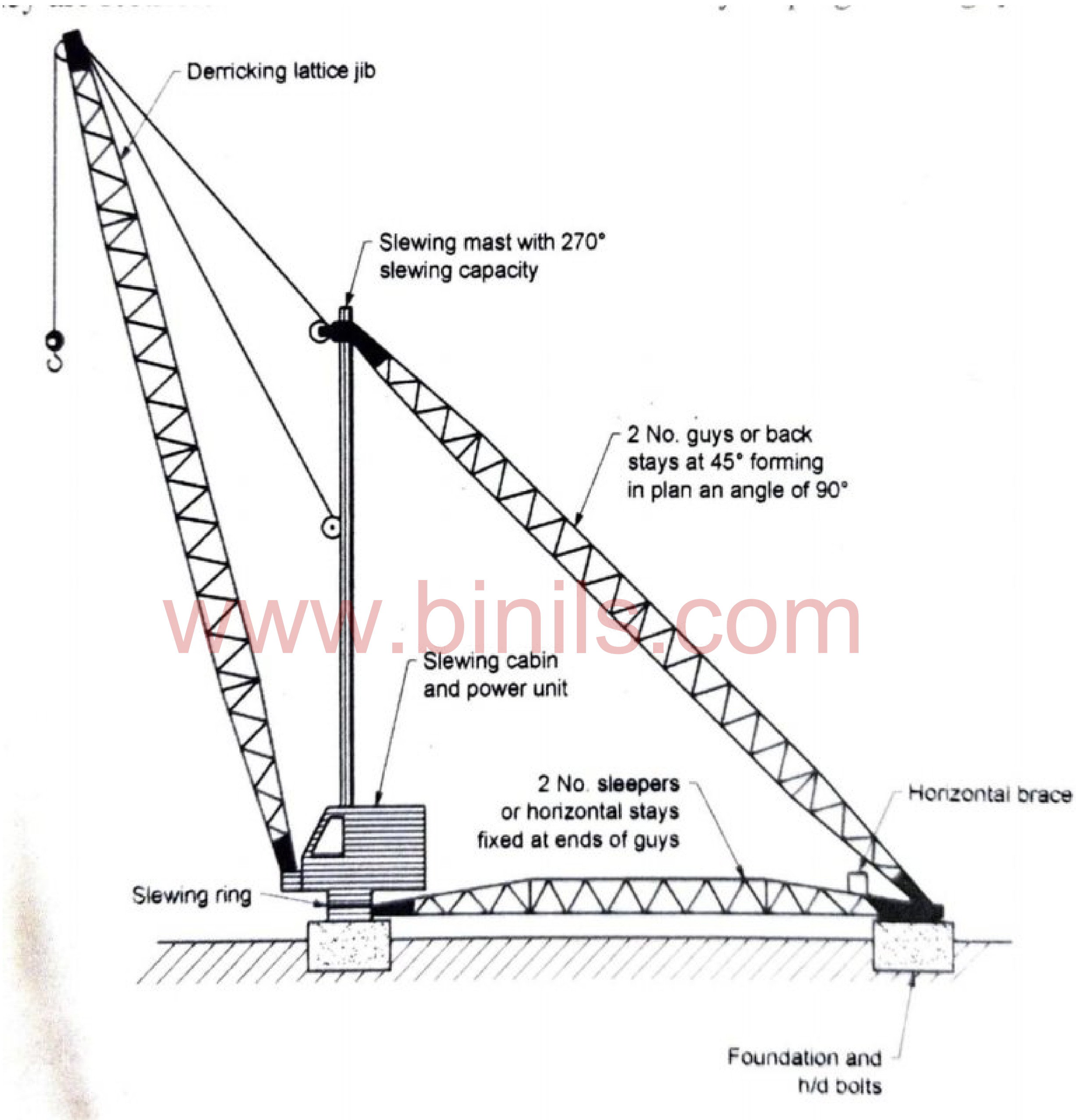


Fig. 2.4.19 : Scotch derrick

➢ The centre post carried the hoisting Mewing and luffing gears together with the operator and his cab.

➢ Most of the scotch derricks are stationary and requires firm anchorage and heavy ballasting to hold down the feet of stays and the base of the centre post. The weight on foot of each stay, should be such that it should be four times the rate of maximum lifting capacity foot derricks.

- The capacity of scotch demcks are upto 200 tonne

2.4.5. Crawler Cranes

- When work is spread over the wider area and beyond the reach of tower crane and derricks and where sites conditions are had and ground is not levelled crawler cranes proves efficient and most suited for such conditions.
- It consists of base frame, super structure and boom
- Crawler crane move slowly, but are capable to move on rough terrain and can travels with load hanging in position.
- It has an advantage that conversion from crane to grabbing crane or drag line for excavation, purpose is easily achieved.

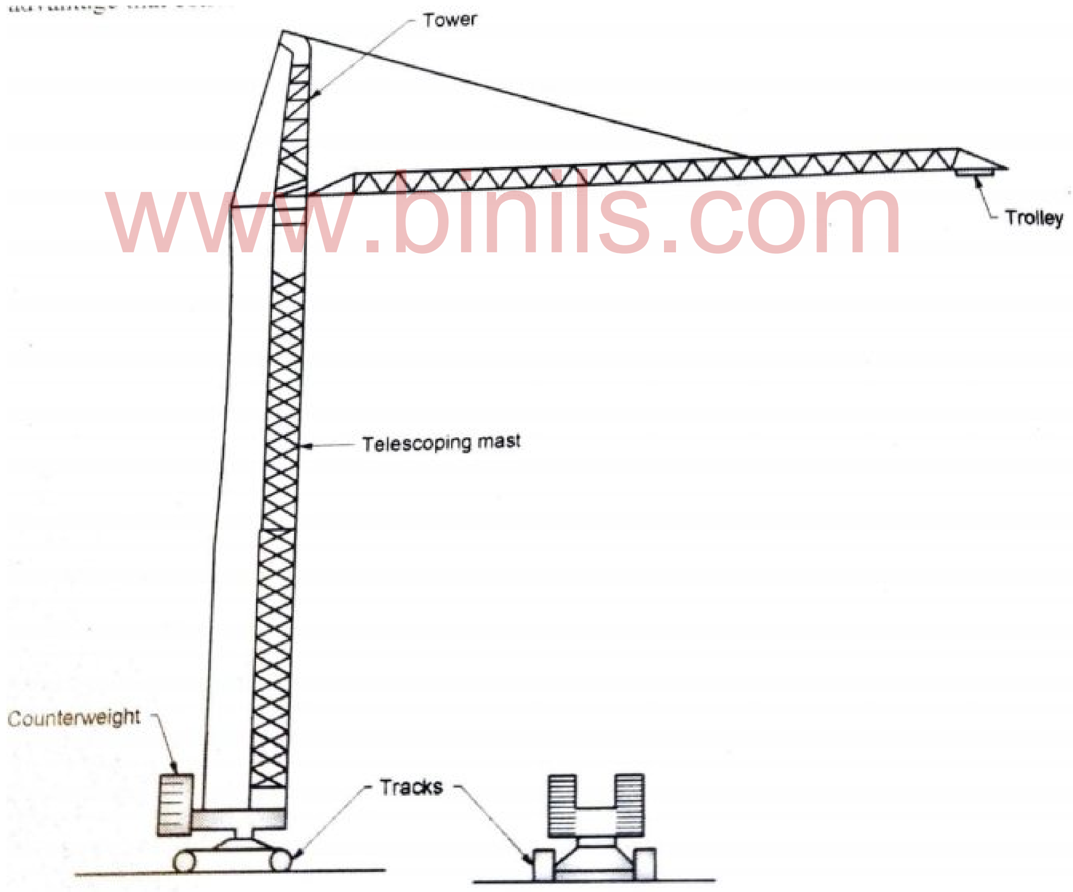


Fig. 2.4.20 : Crawler-mounted tower crane

2.4.6. Mobile Concrete Mixer or Volumetric Mixer

- Mobile concrete mixer are provided with tyres so that it is easy, suitable and convenient to move from site to site under construction.
- It is usually used to mix plastic and semi-harsh concrete.
- Mobile concrete mixer are more suitable for construction site such as road, bridge and water-power engineering. It is more convenient to change the installation site according to the requirement of construction project as compared to the stationary concrete mixers

Types of mobile concrete mixer

Following are the various types of concrete mixer:

(i) Diesel concrete mixer

(ii) Self loading concrete mixer

(iii) Electric concrete mixer

(iv) Hopper concrete mixer

(v) Mobile concrete mixer with pump

(vi) Drum mixer

(vii) Pan concrete mixer

(viii) Portable mixers

Benefits of mobile concrete mixer

Following are the various applications and uses mobile concrete mixer which are most common

1. General concrete including repairs
2. Pervious concrete
3. Flowable fill
4. Rapid setting concrete
5. Overlay concrete

(1) Mobile mixer can bring flexibility of having always fresh concrete on site when required.

(2) Materials are stored in separate bins allowing to have a fresh mix on each delivery.

(3) It is ideal for a remote location or when the batch plant cannot be installed at the site.

(4) It reduces the amount of concrete waste and minimise shortages by mixing the amount that need.

(5) Concrete is always fresh.

(6) Mobile concrete mixer trucks are available in different sizes as per the requirement and need of concrete

(7) These mixers can also be customised to add colour and admixtures to the concrete batch.

(8) Volumetric mixers can supply mortar, screed and all types of mixes and cement.

(9) It eliminate complaints about shortage and overages by mixing fresh on site in the amount required.

(10) It handle short loads, emergencies or weekend jobs with mixer which is flexible and can be used for any size job on short notice.

- Thus, a mobile concrete mixer is a batch plant mounted on a chassis usually a truck or trailer and carries unmixed materials such as cement, sand, coarse aggregate, water or other material or chemicals or admixture to a job site and mixed on a continuous or intermittent basis as required for fresh maximum strength concrete

- Mobile concrete mixers carry materials like cement, sand and course aggregates in divided bins mounted on the unit are loaded from the top and cement bin has a water tight cover. Water is also carried on the mixer unit in tanks.

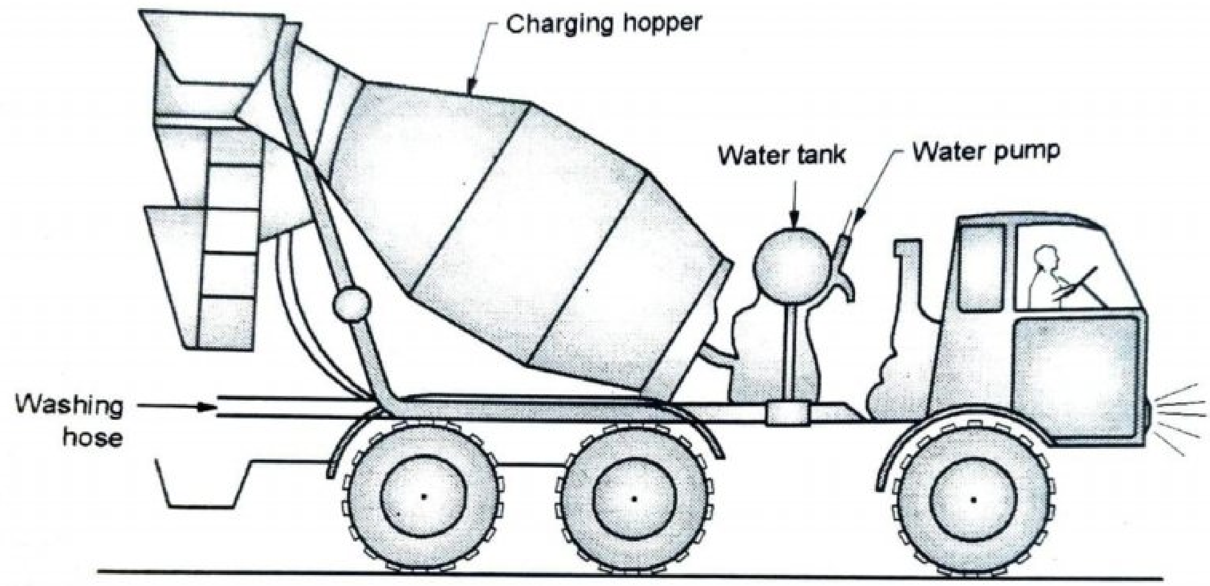


Fig. 2.4.22 : Transit mixers/Mobile concrete mixer

2.4.6.1. Transit Mixer/Mobile Concrete Mixer

- Transit mixer is a very effective and popular equipment used for transportation of concrete over long distance vitally used in RMC plants. Transit mixer is simply a truck mounted mixer having capacity 4 to 7 m.
- Functionally there are two types of transit mixers. In one type, mixed concrete is transported to the site by keeping it agitated all along at a speed of 2 to 6 revolutions per minute.
- In other type concrete is batched at plant and mixing is done in truck mixer during travel or at destination.
- For longer transportation transit mixer gives better results. This mixer contains a rotating drum rotating about central axis which is mounted on drum. Speed on rotating drum is between 4-16 revolution per minute. Revolutions are limited to 300 for mixing and agitation.
- Now a days, for effective transportation of concrete, concrete pumps are mounted on truck carrying transit mix Pressure pumps are also provided with concrete pump so that concrete discharged from mixer is pumped and placed directly in formwork of structure
- The safe time of transportation of RMC is lower value of

  1. 90 Minutes

2. Time taken for 300 revolutions of drum.

2.5. ERECTION OF TECHNIQUES OF LARGE SPAN STRUCTURE AND LAUNCHING TECHNIQUES FOR HEAVY DECKS

Erection methods employed during construction of bridges

- The method selected depends very much on the type of bridge construction, span, height above ground or water etc.

Commonly used methods for the erection of bridges.

(1) **In-situ :** assembly of bridge components on temporary false work.

(2) **Lifting:** e.g. (a) beams and trusses - placing of individual beams or a complete deck by crane (b) suspension bridges - lifting of pre-fabricated deck modules which are then hung from the deck hangers connected to the previously installed main cables, slung between the main towers and anchorages.

(3) **Launching:** sequential construction (on rollers or tracks) of a continuous deck at one end of the bridge. As each new section is added the whole deck is pushed or pulled out (usually over multiple spans).

(4) **Sliding or rolling:** construction of a complete new bridge (usually alongside a busy existing bridge) which is then jacked into place over a few hours or days, to replace the existing structure.

(5) **Cantilevering:** (a) for arches - successive construction from the two springing points which is temporarily tied back until the two halves can be joined at midspan (b) for cable-stayed bridges - successive cantilevering out from the pylons of deck units suspended from the stay cables.

2.5.1. Bridge Launching Equipment

Bridge launching equipment

- There are various launching equipments in the construction of bridges used to erect the precast members or prebuilt bridge elements or members made of prestressed concrete or steel.
- There are various equipments designed to allow the construction of the deck based on different construction methods.

Different construction methods

Method 1: Lifting and placing the precast segments

- Various types of heavy duty cranes are being used to lift and place the precast prestressed concrete long span beam on the top of the flange or on the deck in required position.

Method 2: Precast beam method

(i) Launching equipment in case of bridges are made of a single or twin supported on the deck with the help of a series of cross rail-beam supplied with sliding rollers.

(ii) Main girder is also supplied with a front and rear leg.

(iii) The equipment is completed with a couple of hoisting which trolleys so as to move along the main girder itself.

(iv) The equipment hoists each precast concrete beam at the rear locating using the winches. After this, the winch trolleys are moved forward so as to obtain the final position of beam.

(v) Once it is completed the positioning of all the precast beam composing the bridge, then the equipment is self- launched to the next span

Method 3: Balanced cantilever and span by span segments method

Balanced cantilever method

(i) In this method, launching equipment is made of main girder supported on the deck with the help of a series of cross rail beams supplied with sliding rollers. Main girder is also supplied with a front and rear leg.

(ii) The equipment is completed with a couple of hoisting winches trolleys which moves on the main girder itself.

(iii) Then once the position of the equipment is fixed onto the pier-head segments, the other precast segments of the bridge are handled and positioned alternately one at each side of the pier so as to reduce the unbalanced forces.

(iv) Once position of the precast segments composing the bridge are completed, then equipment is self-launched to the next span.

Span by span method

- It is another method. It this method the deck is erected by first hanging the all precasted segments to main girder.
- Then each precasted segments is joined to the other by using epoxy glue and post-tensioned to form the final span.
- Following are the various bridge launching equipments as shown in Fig. 2.5.1.

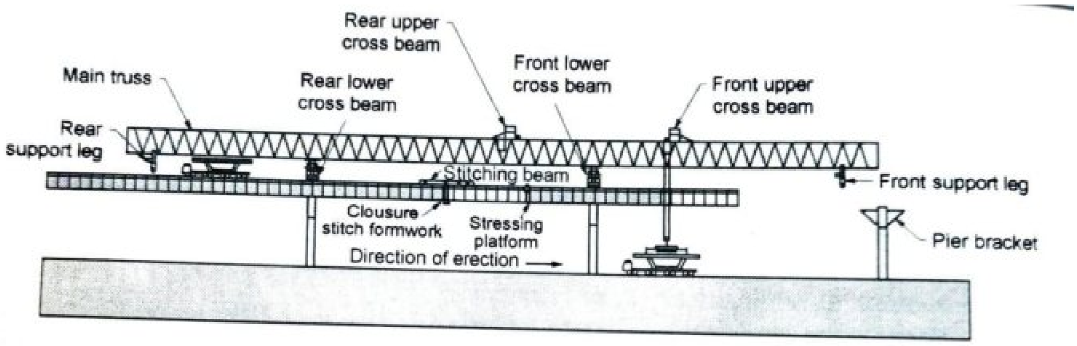


Fig. 2.5.1(b)

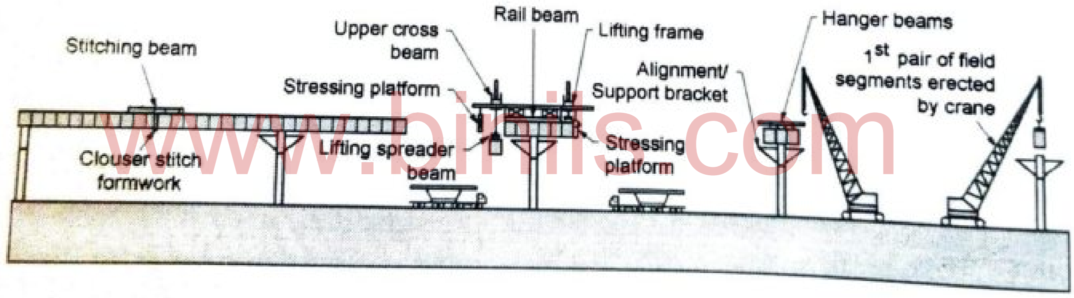


Fig. 2.5.1(c)

2.6. IN-SITU PRESTRESSING IN HIGH RISE STRUCTURE

- High tensile strength steel is used for prestressing and it have also a higher ultimate elongation.
- Various forms of steel used for prestressing are as follows:

(i) Tendons

(ii) Wire Strands or Cables

(iii) Bars

- In high rise structure, bonded post-tensioned concrete is the advanced technique for applying compression after pouring concrete and the curing process (in situ). The concrete is poured around a plastic, steel or aluminium curved duct.

- A set of tendons are inserted through the duct and then concrete is poured. When the concrete is hardened, the tendons are pulled or tensioned by hydraulic jacks.
- Once the tendons have tensioned by hydraulic jacks sufficiently with a view of the design specifications, then these tendons are wedged in position which maintain tension in tendons after the hydraulic jacks are removed from their position and transferring it to the concrete. Then the duct is grouted to protect the tendons from corrosion.
- This method is commonly used to create monolithic slabs in high rise structure. All stresses from atmospheric variation which causes expansion and contraction of the underlying soil are taken into the entire tensioned slab, which supports the building without significant flexure
- In short, in-situ pre-stressing in high rise structure is carried by following steps,

(1) A set of tendons are inserted through the duct

(2) The concrete is poured around a plastic, steel or aluminium curved duct.

(3) When the concrete is hardened, the tendons are pulled or tensioned by hydraulic jacks.

(4) Tendons are wedged in position which maintain tension in tendons after the hydraulic jacks are removed from their position and transferring it to the concrete.

(5) The duct is grouted to protect the tendons from corrosion

2.6.1. Stages of the Post-Tensioning Operation

Following are the various stages of the post- tensioning operation:

(1) In first step, there is casting of concrete.

(2) The tendons are then placed

(3) There is placement of the anchorage block and jack.

(4) Tension is applied to the tendons

(5) Seating of the wedges is then employed

(6) There is cutting of the tendons

Fig 2.6.1 Shows of post-tensioning system in-situ pre- stressing in high rise structure

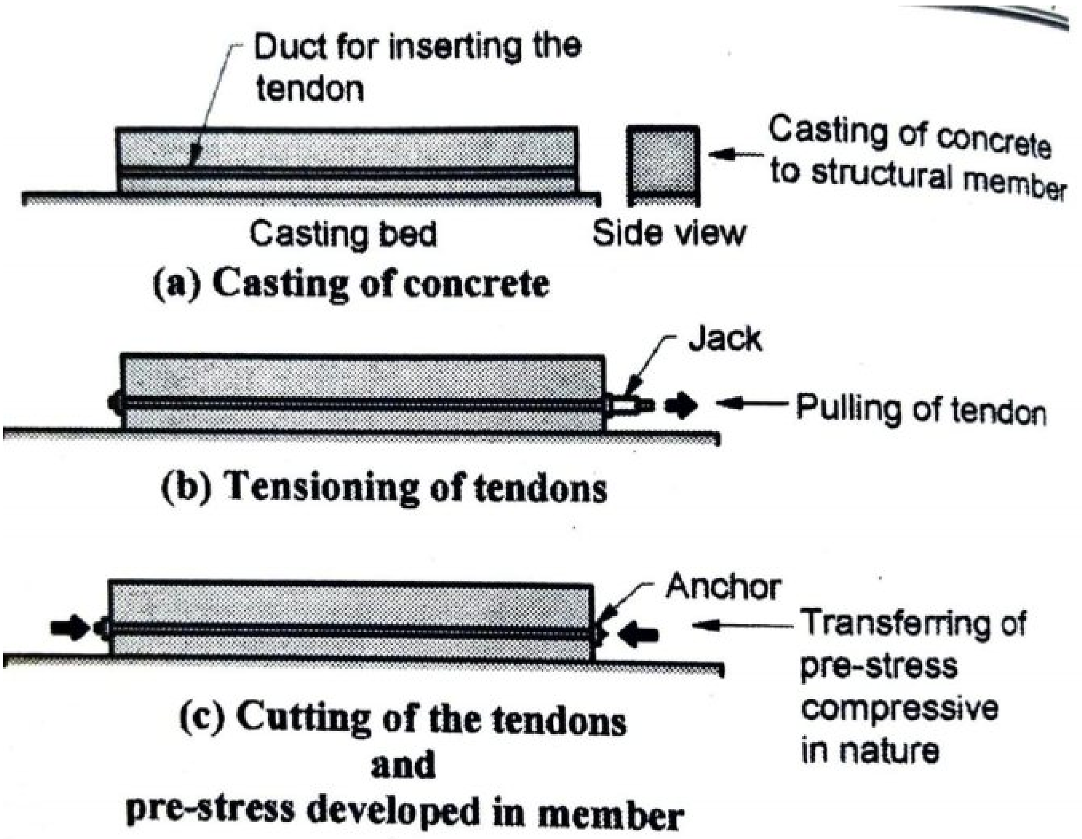


Fig. 2.6.1 : Post-Tensioning System

Following are the advantages of pre-stressed concrete as a construction material in high rise structure

(1) There is maximum utilization of provided section of the structural member

(2) Using the high strength materials makes the tall structure more durable.

(3) There is provision of slender member for long span beams as compared to reinforced cement concrete

(4) Using pre-stressed concrete reduces dead weight of concrete to a higher rate

(5) The intermediate distance between the columns can be in increased by using pre-stressed concrete as compared to RCC.

(6) It is more suitable for flat slab or beamless slab.

(7) It provide considerable resilience and impact resistance. It provide long term durability

(8) It imports better finishing of placed concrete

(9) Because of the absence of cracks prestressed concrete members are capable to take reversal of stresses, impact, vibration and shock.

(10) It needs a smaller amount of construction materials.

(11) Prestressed Concrete structures can resists stresses are higher than normal RCC structures and is free from cracks,

(12) Dead loads are neutral in a prestressed concrete beam hence it reduces reduced consumption of materials.

(13) In Prestressed Concrete structures longer span increases untroubled floor space and parking facilities.

(14) In prestressed Concrete structures, due to larger span length fewer joints are required than conventional RC structures.

(15) It provide thinner slabs in case of high rise building.

(16) Maintenance cost is also less due to fewer joints

(17) In prestressed Concrete structures, tension cracks are eliminated, which reduce the risk of corrosion of the steel components.

(18) It reduces shear stresses.

(19) The cross-section is utilized more efficiently in pre- stressed concrete as compared to reinforced concrete.

(20) Pre stressed concrete allows structures for a longer span

(21) Pre-stressed concrete members offer more resistance against shear force.

(22) There is usually low deflection in Prestressed concrete beams.

(23) Entire section of the beam is effective in taking both compression and tension

(24) It provide better corrosion resistance and shear resistance .

(25) Need less materials

(26) Use of the entire section to resist the load

(27) Very effective for deflection control.

2.7. POST-TENSIONING OF THE SLAB

- In post-tensioned slabs, there is use high-strength tensioned steel strands which compress the slabs and such way keeping the majority of the concrete in compression.

- Post-tensioned (PT) slabs are typically flat slabs, band beam and slabs or ribbed slabs. Post-tensioned slabs provide the thinnest slab type where there is no beams provided or post-tensioned system makes the structure beamless. The thinnest slab in which concrete is worked to its strengths, mostly being kept in compression
- Longer spans can be achieved because of prestress, which can also be used to counteract deflections.
- Components of post tension slab

(i) Duct

(ii) Tendons

(iii) Cables

(iv) Anchors

(i) Duct

- It is thin metal sheet pipes with claw couplings. Plastic ducts are now available which are water tight, frictionless and fatigue resistant.

(ii) Tendons

- When a group of strands or wires or high tensile steel cables are placed together or wound, then it forms a pre-stressing tendon.
- When a group of strands or wires are wound then it forms a pre-stressing units which is called as tendon. In tendons, there is a bunch of high strength tensile wires/cables which are available in various diameter from 1.5mm to 8mm
- In short, a tendon is a steel element like a wire, cable, bar, rod, or strand are placed together and used to impart pre-stress to concrete when the element is tensioned.
- The strands, cable, bar, rod are placed in a duct which may be filled with grout after the post-tensioning operation is completed.
- The following Fig. 2.7.1 shows a typical tendon in pre- stressing concrete slab.

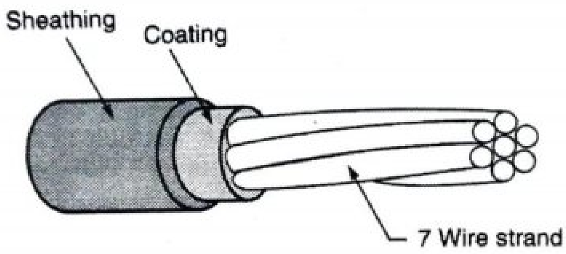


Fig. 2.7.1 : A typical tendon in pre-stressing concrete slab

(iii)Cables

- Pre-stressing cable is a twisted steel cable composed of 2, 3, 7 or 19 high strength steel wires and is stress- relieved (stabilized) for pre-stressed concrete.
- In short, Pre-stressing cable is a group of tendons. The cables are used in bridges

Fig. 2.7.2 : Twisted steel cable

(iv) Anchor

- Anchors are used to anchor tendons into concrete while ending or joining the two tendons. To transfer the stressing force to the concrete is the function of anchorage

Construction procedure of Post-Tensioning of slab (PTS)

Following is the Construction procedure of Post Tensioning of slab (PTS):

(1) Installation of form work for Post-Tensioning of slab

(2) Installation post tension duct for inserting tendons in which high tensile cables are fished

(3) Installation of reinforcements over the slabs

(4) Installation of conduits for electrical services and sleeves and opening

(5) Concreting The concrete is poured around a plastic. Steel or aluminium curved duct

(6) Tensioning the tendons When the concrete is hardened, the tendons are pulled or tensioned by hydraulic jacks

(7) Tendons are wedged in position which maintain tension in tendons after the hydraulic jacks are removed from their position and transferring it to the concrete slab

(8) Grouting: The duct is grouted to protect the tendons from corrosion

(9) Curing for getting strength.

Advantages of Post-Tensioning of slab (PTS)

Following are the various advantages of Post-Tensioning of slab (PTS):

(1) It provides fire resistance

(2) Less cost

(3) It provides speed in construction

(4) There is reduced material use

(5) It provides sound control

(6) Robustness

(7) It provides thermal resistance.

2.7.1. Application of Post-Tensioning

Following are the various applications of post- tensioning:

(1) Post-Tensioning is used extensively for slabs on grade where soils are likely to move (expansive soils).

(2) Post-Tensioning slabs is used extensively for producing crack-free tennis courts.

(3) There is a recently developed application of post- tensioning is, external post-tensioning for strengthening of existing structures, especially as an upgrade to resist seismic forces.

(4) Water tanks can be post-tensioned.

(5) Post-Tensioning can be used both for cast-in-place concrete and for precast segmental construction.

(6) Post-Tensioning allows longer spans and keeps cracks tight structures.

(7) Concrete water tanks are often post-tensioned to reduce crack width and leakage.

(8) Masonry walls can be post-tensioned. It is usually done with a solid steel bar fastened to the foundation and stressed with a nut at the wall's top.

(9) In prestressed bridge construction, post-tensioning method is generally adopted and as such only post- tensioning.

2.8. AERIAL TRANSPORTING HANDLING AND ERECTING LIGHTWEIGHT COMPONENTS OF TALL STRUCTURE

- Aerial transporting handling and erecting lightweight components of tall structure.
- When the transporting, handling and erecting lightweight components of tall structure is carried out by Aerial cable way and Helicopter, then it is called as Aerial method.
- The usage of permanent concrete form works, structural steel elements and precast element are the main lightweight components for erection on tall structures results in rapid speed of constructions.
- In advanced construction technology, for the rapid speed of constructions the aerial transporting handling and erecting the light weight components of tall structure is prefebraly used in which equipments like aerial cable way and helicopter play the important role and hence the erection of steel beams and columns and also the installation of concrete form work consumes less time.
- In short, during the construction of tall structures the following equipments are used for the aerial transporting and handling.

(i) Aerial cable way

(ii) Helicopter

- Helicopter method is used for transporting, handling and erecting various components and panels in the construction of transmission tower. The transmission tower is erected in section in the helicopter method.
- With the help of the helicopter, bottom section is first lifted on to the stubs and then the upper section is lifted and bolted to the first section and this process is repeated till the entire tower is erected.
- Helicopters method is also employed for lifting completely assembled towers with guys from fabrication yards and then transported one by one to the site locations. If

transmission tower is to be erected in dense forest, then helicopter method or drones are much suitable.

- Various building material, various components and precast components can be trasported, handled and erected by aerial cable way.
- Aerial ropeway is that cableway is a system of suspended cables from which cable cars are hung while ropeway is a system of cables, slung from towers, from which carriers are suspended for transporting, handling and erecting various components.

2.8.1. Equipment for Precast Elements

The most common equipment for production of precast elements include,

1. Reinforcing steel fabrication equipment
2. Forming equipment
3. Consolidation equipment.

1. Reinforcing steel fabrication equipment

- Reinforcing steel fabrication equipment ranges in size and cost from small portable units to fully automated machines capable of fabricating bent reinforcing ste bars. Automated cage machines are also available fo fabricating standardized reinforcing cages
- In precast concrete units, the reinforcing steel bar reinforce the precast concrete and these steel bars an formed and shaped by powerful equipment and experienced crew members.

2. Forming equipment

- In the production process of precast concrete units, the forming equipment are used for casting the concrete units

3. Consolidation equipment

- Concrete must be consolidated in order to obtain the specified strength, durability, permeability and surface finish requirements.
- Electric and pneumatic vibrators are the most widely used within the precast concrete industry.

External form vibrators

- Precast concrete industry often use external form vibrators due to typically require less time for consolidation compared with internal vibrators.

Internal vibrators

- When using internal vibrators, the frequency, amplitude and head size should be appropriate for the concrete mix design and precast concrete units.

Table and surface vibrators

- Surface vibrators are often used to efficiently consolidate concrete in thin precast concrete units with a large surface area.

4. **Tilting tables for precast walls,**
5. **Pallet circulation plants for reinforced panels**
6. **Machinery for the production of hollow core slabs**

Lifting Equipment for Site Erection of Precast Elements

Lifting Equipment

1. Shackles
2. **Lift Mandrels**: Lift mandrels must correspond to the lifting hole in the element and the element weight, and be secured so that the loop cannot slip off.
3. **Lifting Scissors and Eye Bolts**: For the fitting of hoisting bolts and permitted screws. It should be noted that the nut or bolt head provides sufficient contact surface.
4. **Lifting Yoke / Assembly Winch:** A Lifting Yoke / Assembly Winch shall be used where the fitting positions require vertical lifting.
5. **Clamping Bracket:** Clamping Brackets are used for the assembly of ceiling elements.
6. Round Slings/Lifting Slings
7. Chain Sling may be used for hoisting

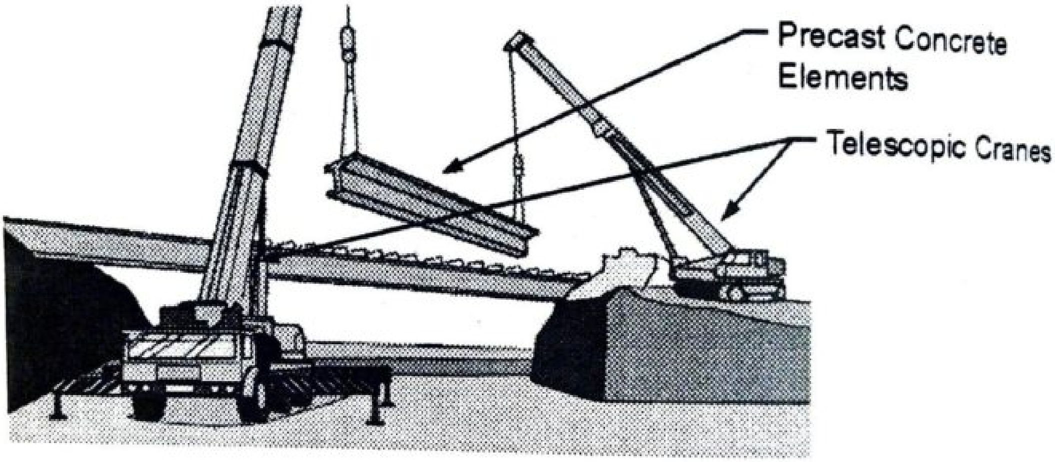


Fig. 2.8.3 : Lifting Equipment for Erection of Precast Elements at job site

Two Marks Questions and Answers

1. **What is meant by Launching girders? (May/June 2014)**

Launching girders are steel or concrete girders, used in the erection process of large beams in buildings or bridges. It is also used for placing pre-cast. post-tensioned concrete box. The balanced cantilever method is the best method of launching girders.

2. **What is the function of launching girders? (Now/Dec 2012)**

1. It is used in the erection process of large beams in buildings or bridges.
2. It is also used for placing pre-cast post-tensioned concrete box.

3. **Distinguish between space decks and bridge decks. (Nov/Dec 2009)**

Space decks are the structures used to form a double-layer roof construction, by factory-produced steel pyramid structures on-site and nodes connected with tie bars, bolted together.

Bridge decks are the bridge support structures, used to provide the support to the local vertical loads and to transmit these loads to the primary superstructure of the bridge.

4. **What is an offshore platform? (April/May 2010)**

(Or)

Write a short note on off shore platforms. (April/May-2011) (May/June 2013) (May/June 2016)

Off Shore Platforms are self-contained platforms used for the exploration of oil and gas from sea-bed with adequate facilities for drilling, electric cranes mud drilling pumping unit etc.

5. **Explain the Gravity towers. (May/June 2015)**

The offshore platforms in concrete construction, are called Gravity towers, which consist of concrete circular shafts, supporting the processing platforms.

6. **Mention the reasons for using special forms for shells. (May/June 2012) (Nov/Dec 2015)**

1. To cover a larger area without support and columns etc
2. To distribute the load in more than two directions.
3. The shell shearing stresses normal to the middle surface should be negligible.

7. What is pre-stressing? (Now/Dec-2011) (Nov/Dec 2012)

Pre-Stressing is the process of introducing the stress in a structural member before the loads are applied to it, for which it is designed.

8. Explain the merits of pre-stressed cement concrete. (May/June 2015)

1. In Pre-Stressed Concrete, the complete section is utilized for resisting the loads. This will reduce the size of the member and hence the head weight of the structure.
2. It has better resistance to fatique and impact.
3. Overall cost is reduced in many cases.
4. Pre-stressed member provides better corrosion protection for steel

9. List the different types of conveyors. (Nov/Dec 2014) (Nov/Dec 2015)

- Belt conveyor
- Roller conveyor
- Chain or cable conveyor
- Pipe line conveyor
- Screw conveyor

10. What are the precautions to be taken while erecting light weight components on tall structures? (May/June 2012) (Nov/Dec 2015)

1. All the equipment are checked for over loading and no equipment should be overloaded.
2. All bolts and splice material on lattice derricks and crane sections should be inserted.
3. The legs of brother chains are not to be opened for large angles.
4. It is to be ensured that the rings of chain slings is trigged enough for crane hook.
5. Sudden shocks are to be avoided when lifting.

11. Mention any two types of lifting and lowering devices. (Now/Dec-2011)

- Block and tackle.
- Winches
- Hoists

- Elevators
- Pillar cranes
- Overhead cranes
- Jacks
- Lifts

12. What are the three common tower crane configurations? (Nov/Dec-2011)

- Fixed Mast Crane
- Movable Mast Crane
- Telescopic Stationary Crane
- Non-Telescopic Rotating Crane
- Telescopic Travelling Crane etc

13. What is meant by articulated structures? (Nov/Dec 2009) (April/May 2010) (Nov/Dec 2013) (Now/Dec 2014) (Nov/Dec 2015)

A structure, in which relative motion is allowed to occur between parts by hinged or sliding joint or joints, is called an Articulated Structure. Articulated Structure means the structure constructed by using joints.

14. In which situations articulated structures can be adopted? (Nov/Dec 2010)

1. Articulated structures can be adopted when, temporary construction is to be made with available steel.
2. Articulated structures can be adopted when, good appearance is required.

15. Define articulated structures and space decks. (May/June 2014) (May/June 2016)

A structure, in which relative motion is allowed to occur between parts by hinged or sliding joint or joints, is called an Articulated Structure.

16. What are erection stresses? (Nov/Dec 2010)

Erection stresses are the internal forces or stress induced by applied loads on a structural member during erection or construction. Braced domes, Space decks and high rise towers are some of the Articulated Structures.

17. Define braced domes. (April/May-2011) (May/June 2016)

Braced domes are three dimensional dome structure, in which the applied load is distributed between members, and these members are located at distances from the point of application of load.

18. Write a short note on braced domes. (Nov/Dec 2013)

Domes are one of the oldest structural forms used in architecture since the earliest times, looks like the upper half of a sphere on top of a building. Braced domes are three dimensional dome structures, in which the applied load is distributed between members, and these members are located at distances from the point of application of load. Braced Domes avoid any obstruction of the inner space. It is composed of either members lying on a surface of revolution or of straight members.

<u>Question Bank</u>

1. Explain various support structures for heavy equipments and conveyors. (Nov/Dec 2009) (April/May 2010) (Nov/Dec 2011) (May/June 2012) (Nov/Dec 2015) (May/June 2016)
2. Describe the merits and demerits of various types of shells. (Nov/Dec 2009)
3. Explain the special forms for shells in detail. (16) (April/May 2010)
4. Discuss the process of in-situ pre-stressing in high rise structures. (Nov/Dec-2010) (May/June 2013) (Nov/Dec 2013) (May/June 2016)
5. Describe the procedure involved in the erection of braced and space decks. (Nov/Dec-2010) (May/June 2013) (Nov/Dec 2015) (May/June 2016)
6. What are the advantages of using belt conveyors for transporting materials?

   Describe the construction of a typical belt conveyor installation with sketches. (10+6= 16) (April/May-2011) (Nov/Dec 2015)
7. Explain (1) General requirements in launching girders. (May/June 2016) (ii) Shell roof structures.(April/May 2011)
8. Explain the method of erecting light weight components for tall structures. (16) (Nov/Dec-2011)
9. Explain about any one type of mobile crane in detail. (Nov/Dec-2011)

10. Discuss in detail the various techniques used for the construction of heavy decks. (May/June 2012) (Nov/Dec 2014) (Nov/Dec 2015)

11. What is meant by articulated structures and explain the procedure for erecting articulated structures? (Nov/Dec 2012)

12. What is the necessity for off shore platforms and how it is erected with a neat sketch showing the foundation details? (Nov/Dec 2012)

13. Write detail note on (i) Launching girders (ii) Bridge decks (iii) Off shore platform (Nov/Dec 2013)

14. Explain in detail about any four types of Bridge deck slab with a neat sketch. (May/June 2014)

15. What are the merits and demerits of shell roof construction? (May/June 2014)

16. What is meant by pre-stressed concrete and explain in detail about various methods of pre-stressing? (May/June 2014)

17. Describe the construction procedure and equipments used for erecting light weight structural components on tall structures. (Nov/Dec 2014)

18. Explain the types of bridge decks with neat sketch. Explain the erection procedure. (May/June 2015)

19. Write short notes on (i) Sky scrapers (ii) Articulated structure (iii) Space decks (iv) Support structure. (May/June 2015)

20. Describe the equipments involved in the material handling and erection of structures. (Nov/Dec 2013)

(OR)

What are the types of material handling equipments and explain with a neat sketch about any four material handling equipments? (May/June 2014)

UNIT III

CONSTRUCTION OF SPECIAL STRUCTURES

Erection of lattice towers - Rigging of transmission line structures – Construction sequence in cooling towers, Silos, chimney, sky scrapers - Bow string bridges, Cable stayed bridges – Launching and pushing of box decks – Construction of jetties and break water structures – Construction sequence and methods in domes – Support structure for heavy equipment and machinery in heavy industries – Erection of articulated structures and space decks.

3.1. Erection of Lattice Towers

A lattice tower is also termed as truss tower which involve a freestanding vertical framework. Construction of lattice towers is widely used in transmission towers carrying high voltage electric power lines, in radio masts towers which are a self- radiating tower or as a support for aerials and also in mobile towers and light house towers in docks and harbours.

It is also used in observation towers which a structure used to view events from a long distance and to create a full 360 degree range of vision to conduct long distance observations in case of military or defence border and in and light house towers in docks and harbours. Observation towers are usually at least 20 metres tall and are made from stone, iron, and wood and many modern towers are also used as TV towers, restaurants, or churches.

Lattice towers are often designed as either a space frame or a hyperboloid structure in which erection of lattice towers can be carried out using gin poles or floating derricks where crane erection is not possible. The majority of the tallest steel lattice towers in the world are actually built in water and used as oil platforms

A lattice towers are erected as per the erection drawings provided by designer to the manufacturers in order to perform propererection.

3.1.1. Rigging of Transmission Line Structures

- The process in which construction or erection of transmission line structures with help of ropes, Gin pole or Derrick is called as Rigging transmission line structures.
- A small boom is rigged on one of the tower legs for hoisting purposes for heavier towers. The members or sections of tower can be hoisted manually or by pulling with a tractor or by winch machines operated from the ground.
- Rigging of transmission line structures involve the following operations:

(i) Methodology Leg Erection

(ii) Methodology Body Erection

(iii) Cage

(iv) Cross Arm Erection

(v) Fastening

(vi) Transversal and Longitudinal Verticality Check

(vii) Tack Welding

3.1.1.1. Methods of Erection of Steel Transmission Towers or Rigging of Transmission Line Structures

Following are the methods of erection of steel towers namely:

I. Built up method

II. Method of making Section or Section Method

III. Method of ground assembly

IV. Helicopter Method or Aerial method

I. Built up method

This method is also called as piecemeal method. Built up method is most commonly used for the erection of transmission line towers, TV towers etc.

Erection process

Following are the various steps involved in Erection process of steel tower by Built up method:

1. In built up method, erection of the towers is carried with member by member.
2. Initially are first set out the tower members and all these members are kept on the ground serially according to erection.
3. The tower members are sorting out by main erection gang to maintain speed and the members are kept in correct position on the ground.
4. Those panels are assembled on the ground for to be erected as a complete unit.
5. Now there is the preparation of the main corner leg members by fitting all cleats or plates for joints and bracings and step bolts.

6. The erection process progresses from the bottom upwards in which the four main corner leg members of the first section of the tower are first erected and kept in correct position by fixing temporary ropeguys.

Fig. 3.1.1 shows Erection of Lattice Towers or Rigging of transmission line by Built up method

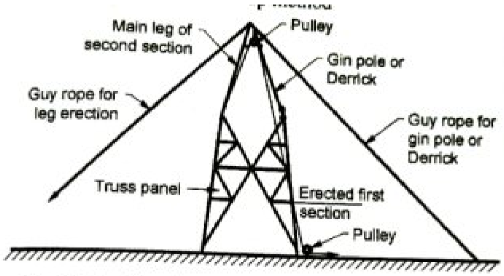


Fig. 3.1.1 : Erection of Lattice Towers or Rigging of transmission line by Built up method

Fig. 3.1.2 shows Erection of Lattice Towers or Rigging of transmission line by crane

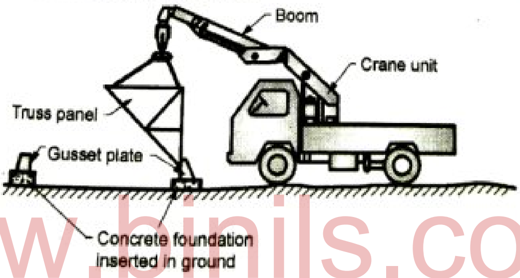


Fig. 3.1.2 : Erection of Towers transmission or Rigging of transmission line by crane

7. The cross bracings of the first section are raised one by one as a unit and bolted to the already erected corner leg angles.

8. This way, the first section of the tower is built and horizontal struts are bolted in position followed by erection other sections one by one progresses upwards till it reaches to final position or desired height.

9. Two gin poles are placed one each on the top of diagonally opposite corner legs while assembling the second section of the tower. Thus two gin poles are use for raising parts of the second section.

10. Then the gin poles are shifted to the corner leg members on the top of the second section to move up the parts of the third section of the lo assembly. This way gin poles are raised as the tower grows and This erection process is continued until the complete tower is erected to final position or desired beight or followed by erection other sections one by one progresses upwards till it reaches to final position or desired height.

Note that for smaller base towers, one derrick or gin pole is used whereas for widebased towers, two derricks or gin poles are placed which are guyed using ropes and temporary ground anchors.

A small boom is rigged on one of the tower legs for hoisting purposes in case of heavier towers. The members or sections are hoisted either manually or by winch machines operated from the ground.

Advantages of Built up method

Following are the various Advantages of Built up method:

1. This method is most commonly used for the erection of 132 kV, 220 kV and 400 kV transmission line towers.
2. Tower materials can be supplied to site in pieces which facilitates easier and cheaper transportation.
3. No need to have any heavy machinery such as cranes, etc, for Tower erection activity
4. Tower erection activity can be carried out in any kind of terrain.
5. There is availability of workmen and labour at cheaper rates.

II. Section Method

Following are the various steps involved in Erection process of steel tower by section method:

1. The section method in which major sections of the tower are assembled on the ground itself and these major sections are installed or erected as units of tower by a mobile crane or a ginpole.
2. After completion of the first section, the gin pole is set on the top of the first section and then the gin rests on a strut of the tower immediately below the leg joint and then the gin pole is to be properly guyed into position.
3. The first face of the second section is lifted up and it is essential to slide the foot of the gin on the strut of the opposite face of the tower in order to raise the second face of second section
4. The lacing on the other two sides is bolted up after the two opposite faces are lifted up. Then the last lift raises the top of the towers.

5. Whenever it is feasible then entire one face of the tower is assembled on the ground, hoisted, and supported in position.

6. In the same manner, the opposite face is assembled. hoisted and supported in position.

7. Then these two opposite faces are fitted to each other by connecting the bracing angles.

III. Method of Ground Assembly for Tower Erection

- In this method, the complete tower is assembled in a horizontal position on even ground
- In this method, the complete tower is assembled in a horizontal position on even ground and then erected it as a completeunit.
- When the assembly of entire tower is completed, then the tower is lifted up from the ground by a crane and carried to its location, and set on its foundation. This method is not suitable for the large and heavy towers.

IV. Helicopter Method or Aerial method for Tower Erection

- This method is more suitable when the tower is to be erected in dense forest but it is costlier method. In such method, the Transmission tower is erected in section by section ie one section over the other.
- Initially, the bottom section is raised on to the stubs and then the upper section is lifted and bolted to the first section and the process is continued further till the complete tower is erected to the desired height.

3.1.2. <u>Construction Sequence in Cooling Towers</u>

- The purpose of a cooling tower is to remove excess heat which is generated in large industrial and commercial units by cooling the area by lowering the temperature.
- There is a typical construction sequence in cooling towers in which such towers are often constructed as hyperboloid, doubly-curved concrete shell structures supported on a series of concrete struts.
- Cooling towers can be constructed in small-scale roof- top installations, medium-sized packaged units, or very large structures used in industrial processes or thermal power stations with their characteristic plume of water vapour in the exhaust air.

- These large cooling towers can be up to 200 m in height and 100 m in diameter hence Based on the type of application, the structure can be up to 200 m tall and 100 m. in diameter and for rectangular structures, it can be over 40 m tall.
- Fig. 3.1.3 shows the flow diagram of construction sequence in cooling towers.

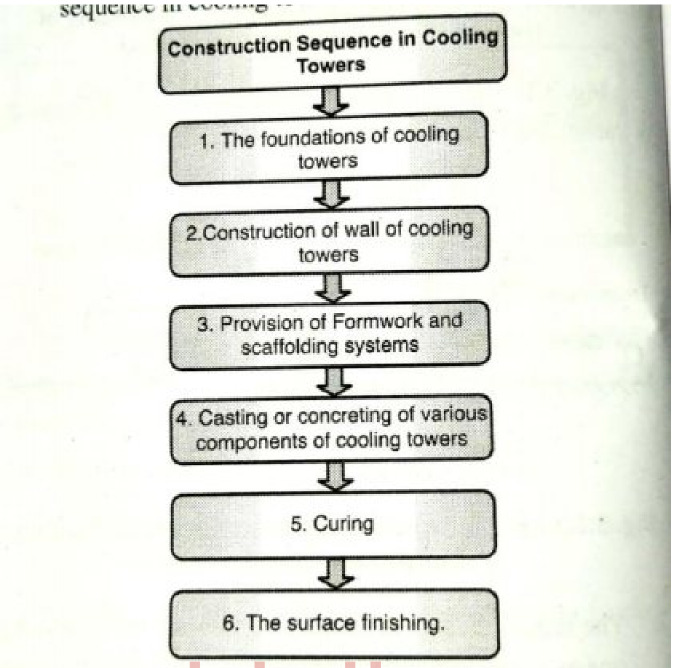


Fig. 3.1.3 : Flow diagram of Construction Sequence in Cooling Towers

Following steps shows construction sequence in cooling towers :

1. The foundations of cooling towers

- The foundations typically consist of an inclined pond wall forming a circular 'tee' beam with a wide concrete strip. The function of tee beam is to resist the lateral load of the tower's shell structure. In construction of cooling towers, the 'tee' beam and piled foundations are normally constructed in order to minimise differential settlement and reduce the risk of cracking as well. Foundation structures should also be within ±6.0 cm of the design location.
- The cooling system is housed in the base of tower typically having the bottom of 10 m. and the rest of the tower consisting of an empty shell.

2. Construction of wall of cooling towers

- It is recommended that the actual wall thickness be not less than the design thickness and exceed this thickness by not more than 10%.

- The imperfections of the shell wall middle surface should not exceed 1/2 of the wall thickness (t) or 10 cm during the construction should be corrected gradually limiting the angular change in either direction to 1.5%.
- The column heads should be either within 0.005 times the column height or ± 6.0 cm of the design position. The shell wall should be designed to resist the anchor loads of the scaffolding, based on the strength of the concrete which is expected to be available when the anchors are loaded.

3. Provision of Formwork and scaffolding systems

- Formwork and scaffolding systems are generally proprietary and are provided by the constructor.
- Formwork and scaffolding systems should be designed in such way that it should provide safety to operating personnel and to produce a sound structure as well.
- The working platforms for various construction activities should be designed for realistic loading and scaffolding systems used for continuous material transport should be designed and built such that it can sustain resulting loads.
- The connections and joints between individual scaffolding units must be designed and install to act independently in situation of collapse, due to this, there is loss of one unit can not affect the adjacent units.
- In addition to this, at least two independent safety devices should be in place to avoid possible collapse.

4. Casting or concreting of various components of cooling towers

- The concrete for cooling towers should be of high- quality approved materials including fly-ash. This concrete should have high resistance against chemical attacks, should have high early strength, should have high structural density and also should have high resistance against frost. Now-a-days, ready mixed concrete (RMC) is being used and it is pumped to the desired place of casting.
- It is essential to have continuous monitoring of the concrete strength during the climbing process and special care must be taken in order to provide a durable tower structure because cooling tower shells are subjected to a relatively severe environment attack over their lifetime.
- The tower is subjected to the weathering action produced by wind, temperature, and moisture acting on concrete and also it may be exposed to severe frost action in a

saturated state, chemical attacks, biological attacks over the lifetime of the structure, hence the concrete should be of high-quality approved IS materials including fly-ash and should be resistant to chemical attacks and frost.

5. Curing

- The methods of curing are derived from the basic principle of lowering of the surface temperatures and prevention of water evaporation in order to obtain required strength.
- Curing methods should be employed in proper way and it can only be ensured by the proper quality control and supervision. Several specialized curing techniques are employed in the modern construction work, but following are the most commonly methods of curing can be employed:

i. Ponding with water.

ii. Covering concrete with wet sand, saw dust, etc.

iii. Covering concrete with wet sand, saw dust, etc.

iv. Covering concrete with water-proof paper or polyethylene sheets and holding it in position.

v. Spraying with water and continuous sprinkling of water.

vi. Applying curing compounds.

vii. Chemical curing

viii. The intermittent spraying of water is the most common method of curing under Indian conditions.

6. The surface finishing

- The surface finishing can be done by using high quality plaster resistant to weathering action and durable. The surface should be smooth and essentially free of shrink holes.
- Air bubbles deeper than 4 mm and unintended surface irregularities at joints should be particularly prevented. The shell should be coated with a curing agent providing a high blocking effect and long durability.

3.1.3. Construction Sequence in Silos

- Silos are deep bins and a tall cylindrical structure in which the agriculture field use it to store food products, chemical industries use to store plastic resins, cement factories use to store cement, calcium oxides, and many other materials such activated carbons etc.
- The most common geometry of silos is a cylinder which has a metal support. Other than cylinder-shape, the silos can also take the shape of a rectangular or a square as per the requirement or need.
- The silos are commonly constructed in materials like wood, reinforced plastic, reinforced concrete, or stainless steel.
- The construction and design of silos are dependent on the following factors:

(i) The quantity of product to be stored

(ii) The environmental conditions

(iii) Site Conditions

- There is an opening and closing provisions in silos for loading and unloading the materials. The interior surface of the silos is made smooth and lined with special coatings in order to prevent any reaction to stored material. It is also made water tight or waterproof or damp-proof.

Types of Storage Silos based on height and diameter

Following are three main types of silos,

1. **Tower Silos:** Tower silos are commonly constructed with a diameter of 4 to 48 m and a height of 3 to 40 m. Tower silos are constructed in material like wood, steel, or concrete.
2. **Bunker Silos:** Bunker silos are trenches and are made from concrete wall. Trenches are filled and packed with the help of tractors and loaders. There is maximum use of bunker silos to store a high quantity of materials in agriculture and large manufacture industries.
3. **Bag Silos:** It is made out of plastic or hermetic bags or tubes. Bag silos are commonly constructed with a diameter of 2 to 21m and made out of plastic or hermetic bags or tubes. Bag silos are used to store grains and fodder.

Types of Storage Silos based on materials used

Following are types of silos based on materials:

(i) Concrete block silo

(ii) Reinforced concrete silos

(iii) Fibre Reinforced Polymer Silo

(iv) Prestressed concrete silos

(v) Steel silo

(vi) Masonry silos

(vii) Wooden stave silo

Construction sequence in silos

Following are main steps involved in construction sequence in silos:

1. **Foundation**: In construction of silos, it is necessarily it have raft foundation and constructed in one pair to prevent cold joint. Wooden silos are often built with foundations extending only about 600 mm below the ground surface. Concrete is the material most generally used for silo foundations. Concrete should be mixed and placed carefully

2. **Drainage:** To assist the water in getting into the drain, the foundation and floor may be placed upon a bed of gravel or cinders

3. **Floor:** Concrete floor is desirable as it is rat proof and may be cleaned without any mixing of earth with silage. A concrete floor 60 mm to 100 mm thick is sufficient.

4. **Construction of wall of silos:** Silo walls must be designed to resist the bursting pressure due to the silage. In masonry silos steel reinforcing rods are used to resist the bursting pressure

   Scaffolding: It is difficult to over estimate the advantage of a convenient, safe, and simple scaffold for any masonry construction.

   Reinforcement: The amount of circular reinforcement required for different heights and diameters. Smooth wall silos is cylindrical in shape from top to bottom.

Following are types of form work used in construction of wall of silos:

(i) Conventional method

(ii) Advanced method such as Jump form method and Slip form method for speedy rate of construction

- There are the two most common systems for constructing a concrete silo which are Jumpform and Slipform.
- Concrete storage silos from 255 mm to 1650 diameter can be constructed by using the Jumpform technique, while Slipform silos are more suitable for construction of concrete storage silos over 1650 mm in diameter. Jumpform construction is one of the most flexible silo construction methods.
- Jumpform construction is not as time sensitive as Slipform. Jumpform is completed in stages such as equipment installation, reinforcing steel assembly. rebar inspection and concrete pour to cure.
- Jumpform can be the most economical construction. The form can be set-up and can be made ready to make the first pour of concrete within a week. Concrete pour costs in case of Jumpform can be reduced by as much as 20% over Slipform because slipform construction where a continuous pour is required whereas Jumpform is poured in increments. The Jumpform sile framework is reusable.
- Slipform silo forms are an integrated form and work deck system ystem that includes an interior work deck and interior and exterior finishing scaffolding

5. **Roof**: The silo roof should be firmly fastened to the wall to prevent the roof from being damaged by wind storm. There are three types of roofs being used into practice as follows.

(i) Frame roof

(ii) Concrete roof (Dome type)

(iii) Galvanized Steel Roofs (Dome type)

- **Steel silo construction process**

Following are the step involved in steel silo construction process:

(i) The pre-embedded parts of the inspection warehouse base

(ii) The positioning of the warehouse equipment

(iii) Installation of the platform to calculate the height of a silo body volume to Im high from left and right.

(iv) Cutting on the warehouse body, then install the lower ring, to make the warehouse top a warehouse volume to the design height, to withdraw the equipment and materials, to cut down, to drop silo.

(v) Make a manhole in the silo wall, then to fix the ribs, then to remove the equipment and the running frame.

(vi) After setting the height of the silo, the first ring of reinforcing ribs is installed, and then the silo is rolled to a certain height to install the second.

(vii) The ribs are looped so that the cycle reciprocates until the requirement of height of the steel slab roll design.

- Note that, There is the roll installation of the bin which is a process of continuous control of the production.
- The construction sequence of spiral steel silo is the reverse loading sequence meaning that it is started in a order from top to bottom.

(i) Initially make a warehouse roof, a top fence, etc.

(ii) Then carry out the warehouse construction.

(iii) There is the continuous rolling of the silo body spirals upwards

(iv) To ensure the vertical force of the silos body, stiffeners are arranged step by step on the inner wall of the silo silos.

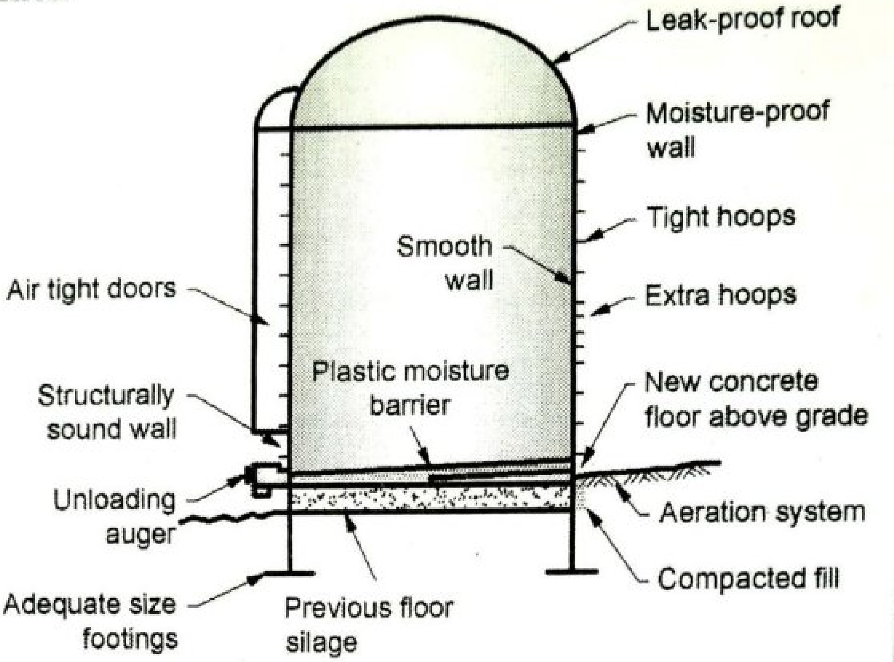


Fig . 3.1.4 : Various construction components of silos

Fig. shows 3.1.5 grain concrete silos grain concrete silos

Fig. 3.1.5 : Grain concrete silos

Fig. shows 3.1.6 steel silos used for storing cement.

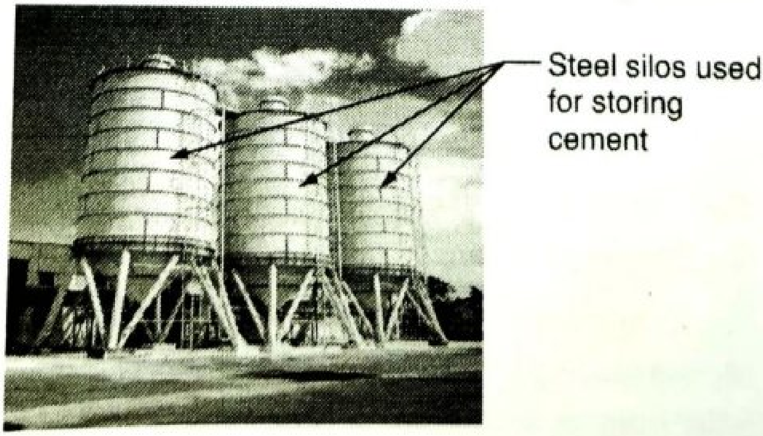


Fig. 3.1.6 : Steel silos used for storing cement

3.1.4. Construction Sequence of Chimney

Following steps shows the construction sequence of concrete chimney:

1. **Shape and type:** Shape of Chimney can be circular or square or rectangular depending upon the capacities and design. Also type can be Straight and Tapered Chimneys depending upon the height and architectural design. The height of a chimney influences its ability to transfer flue gases to the external environment via stack effect.
2. Construction of Dry and Wet Flue Gas Desulphurization Systems.
3. Construction of Chimney Liners and Ductwork and curing.
4. Construction of Concrete Foundation Slabs and Pilings and curing.
5. Heavy Lifting Systems for erection of scaffolding and various construction activities.
6. Provision of Ladders, Platforms, and Test Ports for various construction activities.
7. Construction of Expansion Joints and Drainage Systems.
8. Installation of Lightning Protection, Lighting Systems, Aviation Warning Lights.
9. Installation of Elevator.
10. Surface finishing work such as plastering and Painting.

- A chimney is an architectural ventilation structure made of masonry, clay or metal or concrete which isolates hot toxic exhaust gases or smoke produced by a boiler, stove, furnace, incinerator or fireplace from human living areas.
- Chimneys in which the gases flow smoothly, drawing air into the combustion in which is called as the stack or chimney effect.

1. Construction methods for Concrete chimneys

- Concrete chimneys can be built using one of two available forming methods such as slipform and jumpform.
- Slipform construction is more suitable to chimneys which are very tall or have very large diameters and on projects with accelerated schedules.
- In this method, concrete is continuously poured into a single form which is steadily elevated or slipped to built the concrete column. An integrated hydraulic jacking system is used to raises the formwork, controls the shell taper and wall thickness,

and uses lasers to constantly monitor alignment. The slipform method is labor intensive, with work performed on an around-the- clock basis.

- Jumpform construction relies on more traditional concrete forming techniques to build the shell on an incremental basis. We use state-of-the-art technology to make our jumpform system an extremely efficient construction method.

2. Masonry Chimney Construction

1. An adequate concrete footing is needed and can sustain the weight of the chimney or fireplace in masonry chimney foundation. To determine minimum requirements for all footings and reinforcements details should checked with local code.
2. Following are the various construction materials used in masonry chimney construction:

(i) Flue Liners (ASTM Specification C 315)

(ii) Refractory Mortar

(iii) Mortar (ASTM Specification C 270)

(iv) Concrete Block (ASTM Specification C 90 or C 129)

(v) Fire Brick (ASTM Classification C 27)

(vi) Brick (ASTM Specification C 55 or C 216, Grade SW)

(vii) Natural Stone (ASTM Test Method C 170 or C 99)

3. A chimney consists of the flue and the chimney wall. In the construction of the chimney wall, wall has to be a minimum of 102 mm of solid masonry completely surrounding the flue liner in which the flue lining extends the complete length of the chimney.

- Flue liners is require to be line up flush at the joints in order to make a smooth interior surface without ledges or other obstructions where there is the possibilities to accumulate creosote and debris.
- An air space has to be maintained between the chimney wall and the flue liner of not more than the thickness of the flue liner wall while constructing the chimney around the flue liner.
- Industrial chimneys are commonly termed as flue gas stacks and are generally external structures. Industrial chimneys are generally located adjacent to a steam-generating boiler or industrial furnace and the gases are carried with ductwork.

- In advanced construction, there is use of reinforced concrete and almost entirely replaced brick as a structural component.
- Refractory bricks are often used as a lining, particularly if the type of fuel being burned generates flue gases containing acids.

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Fig. 3.1.8 shows masonry chimney construction

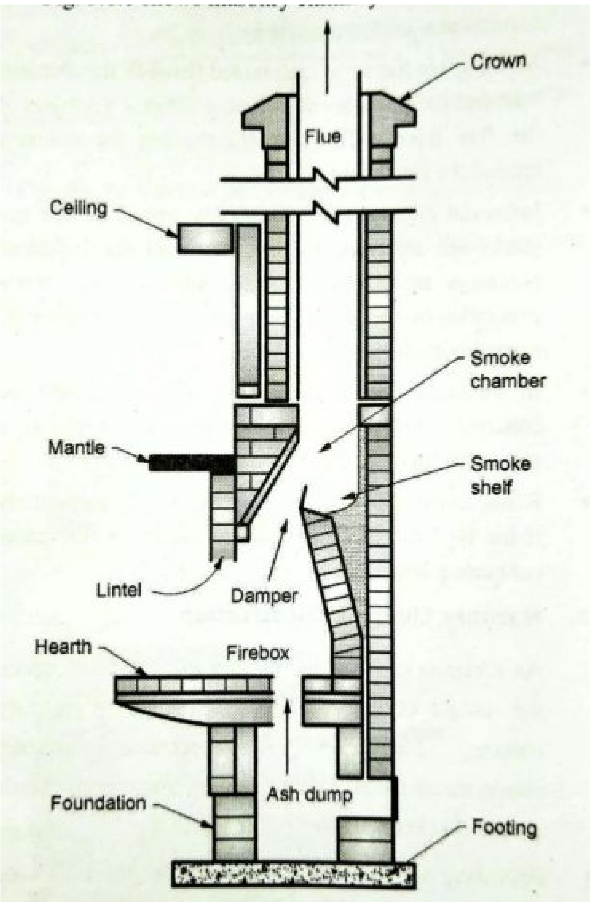


Fig. 3.1.8 : Shows masonry chimney construction

3.1.5. The Construction Sequence in Skyscrapers

Following are the various steps involved in the construction sequence in skyscrapers generally :

1. Site selection,
2. Design considerations,
3. Preparation of excavation and foundation,
4. Installing the steel or reinforced concrete frameworks
5. The exterior work of the skyscraper
6. The finishing work of the skyscraper.

1. Site selection

- Site selection is the important process in which there is detailed examination of foundation soil, performing the proper analysis of local environmental situations like rainfall and wind direction, consideration of seismic intensity in the areas, consideration of construction cost etc.

2. Design considerations

- The design and construction of skyscrapers consist of creating safe, habitable spaces in very tall buildings. The buildings should support their weight. It should resist wind and earthquakes pressure and protect occupants from fire. Design are considered among the most complex encountered given the balances required between economics, engineering, and construction management in skyscraper.
- The lateral wind load imposed on super structures of skyscrapers is generally the governing factor in the structural design. Wind pressure increases with height, so for very tall buildings, the loads associated with wind are larger than dead or live loads.

3. Preparation of excavation and foundation

- The process of site clearance and excavation are carried out simultaneously. Earthmoving work is necessary at the beginning. When the construction of the skyscraper starts, the first job is to excavate a pit to hold the whole foundation. The depth of the pit depends on many factors such as the height of the buildings and numbers of underground levels.
- The construction of a skyscrapers commence with a deep foundation, the boundaries of which are primarily supported by the installation of piles which are temporary vertical structural elements which can reach up to 30.48 m in height below the ground level.
- Once the excavation is completed, piles are replaced by stronger retaining walls usually made with a combination of steel and concrete as well as other sturdy materials to sustain excessive construction loads of the structural foundation works.

4. Installing the steel or reinforced concrete frameworks

- Steel columns are bolted or welded at the end of the beam which beam is wrapped into a special jacket for heat protection from fire. The core of the skyscraper is constructed with concrete columns by using a "slip forming" technique in order to built the column without any joints. The floors are fixed into the building core and support columns.
- Work of reinforced concrete frameworks is carried out by using advanced concreting and formwork method such as slipform work or jumpform work and any other.

- Different Types of Cranes used on construction sites for installation of various building components and materials.

5. The exterior work of the skyscraper

- When the superstructure with the core is completed, then the construction process is to build the exterior work in which the exterior walls are made of panelling which surrounds the metal or steel structure of the building.
- The most common panel material is metal, steel, glass or polished stone. Hence there is external cladding with curtain walls of glass or polished stone.

6. The finishing work of the skyscraper

- In the finishing work of the skyscraper, roof is built as a normal floor covered by waterproof layers from rubber or plastic materials. The top surface is finished by highly resistant metal or tiles in order to protect it from weathering conditions and the threat of natural disasters.
- The final finishing process in which there is many kinds of installations from telephones, electrical wires over all plumbing work, fire controls to mechanical installations such as elevators or cooling and heating systems.

Equipments

- There are various heavy equipment used in the skyscraper construction process such as heavy trucks. crawlers, excavator, loader, roller, drilling machines, recycling machines and any advanced equipments if required.
- Tallest skyscraper buildings in the Worlds
- There are three skyscraper buildings in the Worlds namely, Burj Khalifa,
- Shanghai Tower and Makkah Clock Royal Tower in which height of Burj Khalifa located in Dubai is 828 m with 163 floor, height of Shanghai Tower located in China is 631.85 m and height of Makkah Clock Royal Tower located in Saudi Arabia is 600.761 m.

3.1.6. The Construction Sequence and Methods in Domes

- Domes have been constructed over the centuries from mud, stone, wood, brick, concrete, metal, glass, and plastic.
- Domes are also used for covering large areas like assembly hall, gymnasium etc. But they are of semi- spherical or semi-elliptical shapes.

- Dome structures are generally used in monumental works or roofs of circular or hexagonal buildings.
- Dome structures have very small thickness within certain height and diameter ratio. The domes can be either smooth shell domes or ribbed domes.
- A typical spherical shaped dome is shown in Fig. 3.1.11.

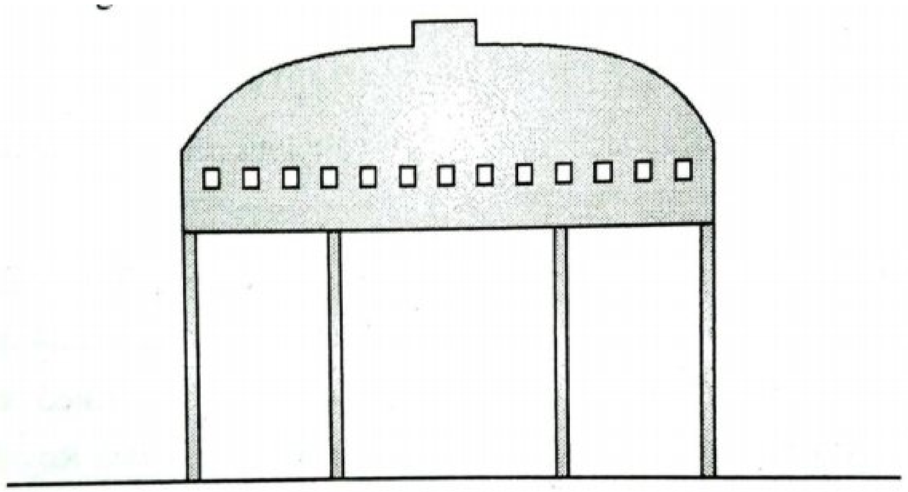


Fig. 3.1.11 : Spherical dome

Following are the various steps involved in the construction sequence in domes:

1. Construction of foundations and tunnels
2. Use of conventional fabrication and advanced fabrication i.e Airform Fabrication and Inflation
3. Steel-Reinforced Concrete Application
4. Provision of additional structures and systems
5. Polyurethane foam-insulation application

1. Construction of foundations and tunnels

- Foundations of domes depends on the nature of soil and its conditions which may require shallow foundations or deep foundations.
- There are variety of alternate options of foundations for the dome. Construction of tunnels can be speed up the project by using innovative precast concrete and also with various dome shapes and floor configurations.

2. Fabrication

- Use of conventional fabrication and advanced fabrication ie Airform Fabrication and Inflation
- Advanced fabrication: There is a use of PVC airform which acts as the air-supported structure for applying additional building layers further acts as waterproof membrane. The airform is fabricated used in the dome technology to match precise design requirements.
- Airform creates a protected environment, permitted for construction to continue inside the dome in almost any weather condition.

3. Application of Steel-Reinforced Concrete

- In steel-reinforced concrete application, the shotcrete method is employed which is the final step in constructing the dome and shows completion of the concrete dome assembly.

4. Provision of additional structures and systems

- Dome is an impressive and elegant structure. Hence industrial commercials and applications need a variety of additional features and due to this, there is a provision of additional structures and systems.

5. Polyurethane foam-insulation application

- In polyurethane foam-insulation application, polyurethane foam is used and applied to the air- supported PVC airform followed by placing the reinforcing and concrete against the foam insulation.
- The foam acts as a thermal insulator. It also protect the concrete dome structure.

3.1.6.1. Methods or Techniques for Constructing Domes

Following are the various methods or techniques for constructing domes:

1. Flattened conduit method
2. The tube and hub style method
3. The stressed skin technique
4. Beam and hub method
5. Monolithic method
6. Panellised timber frame

7. Brick and former method

1. Flattened conduit method

- In this method, there is moulding and flattening of metal tubes.
- A geodesic dome frame is flatten the end of some metal tubing bend it slightly and then drill a hole. In short, a hole is drilled on both the ends of the frames and various other tools after slightly bending the tubes.

Advantages of flattened conduit method

(i) It is simple and less time-consuming method

(ii) It is easy to build and construct.

(iii) It can be easily assembled and disassembled

(iv) Special tools is not required

Disadvantage of flattened conduit method

The structure that is formed covered with other materials and hence no fine finishing at the joints.

2. The tube and hub style method

- In tube and hub style method, there is the joining of the struts with a larger diameter pipe at the hub holes.
- Larger diameter pipe is used as a hub holes which are drilled through the hub and the struts are bolted to it.

Advantages of tube and hub style method

(i) It is a very simple, cheap, and professional method

(ii) It makes a nice neat job with all struts finishing level

Disadvantage of tube and hub style method

(i) There is no option for rectifying a damaged hard cover material.

(ii) There is no easy way to fix a hard covering material.

3. The stressed skin technique

It is a modern techniques for constructing domes in which there is use of metal or fiber glass panels which is bolted or riveted together in order to form dome

In such techniques, beams, hubs or separate support structure are required in which the stressed skin does everything.

Advantages of the stressed skin technique

(i) It is the most cost effective technique

(ii) It is the most cost efficient technique to build a dome

(iii) Simple fabrication is required which can be easily locally available

Disadvantages of the stressed skin technique

(i) Durability of the dome structure can seriously affect due to cutting holes for doors and windows

(ii) Some form of insulation has to be glued to the inside of the panels to avoid condensation forming because of metal sweats when it gets cold

4. Beam and hub method

- In beam and hub method, Wooden beams are attached to specially made hubs in order to make the dome framework.

- The angles are taken by the hubs to cut the beams to the correct length. It makes a solid permanent dome. It is more expensive to construct than a tube type framework.

Advantages of beam and hub method

(i) Dome construction system is simple that doesn't require specialist tools or knowledge to build.

(ii) No need of specialist tools

(iii) No need of knowledge to build

5. Monolithic method

A monolithic domes are constructed basically in three stages.

(i) **First stage**: An airform membrane is made from PVC and which is inflated on the site where the dome is to be construct.

(ii) **Second stage:** To insulate the structure the inside portion is sprayed with polyurethane foam. Reinforcing bar is fixed to the foam ready prepared for the last stage.

(iii) **Last stage:** In the last stage, a concrete mix is sprayed on top of the urethane to finish.

Advantages of monolithic method

(i) It provide very strong efficient structure

(ii) It needs very little in the way of heating or cooling.

Disadvantages of monolithic method

(i) The outer airform can be damaged easily which allow the entry of water into the insulation layer.

(ii) There is use of oil based chemical materials which are not that environmentally friendly.

6. Panellised timber frame method

➢ In panellised timber frame, there is use of wooden beams but no metal hubs at the joints panels.

➢ Panellised timber frame method is simple.

➢ It provide extremely fast way to build a permanent dome structure.

(i) No design choice.

(ii) Material fixed on both sides creates ventilation problems.

7. Brick and former method

➢ In brick and former method, when a wooden former is made to the required shape, then stone, brick, or concrete is placed on top of the former producing the final shape of dome.

Advantages of brick and former method

(i) It is a very strong and durable dome

(ii) It can be built using reclaimed materials.

Disadvantages of brick and former method

(i) A lot of expense is needed in making the former

(ii) Construction of very large domes is not economical using this system

3.1.7. Support Structure for Heavy Equipment and Machinery in Heavy Industries

- The best steel support structure and concrete structure offers strength and durability.
- Steel support structures help heavy loads of equipment at ground level and at heights.
- The structures usually consist of I-beams, Z- or HSS- shape beams, rods, and plates which can be used for support structure for heavy equipment and machinery in heavy industries.
- Support structures can consist of different types of steel, such as:

(i) Carbon

(ii) High strength low alloy

(iii) Corrosion resistant high strength low alloy

(iv) Quenched and tempered alloy

(v) Forged

- Industrial equipment and machinery can be elevated at various level and supported in structures or at grade on foundations depending on the type of equipment and its operations, process requirements, or construction methods.
- A support structure for heavy equipment and machinery in heavy industries is adapted to support vehicle-mounted equipment in an elevated stored state position above ground and further adapted to mount onto a bed of a vehicle to assist in loading and off- loading of equipment.
- The support types and connections for equipment can be arranged differently due to the varying operating requirements for each piece of equipment.
- Heavy equipment consists of excavators, crawler tractors, skidders, rock trucks and muskeg transporters, aerial lifts, large towable air compressors, generators and light towers, concrete saws, earth compactors and rollers, backhoes, motor graders, skid-steer loaders. bulldozers, wheel loaders, trenchers, utility tractors, excavators, forklifts, sweepers and utility vehicles and tracked equipment on an excavator type carrier.
- **Machine foundation for heavy machinery in industries**

GQ. Explain in detail the machine foundation with labelled sketch.

- Whenever any machine such as pumps, turbines, lathe or drilling machines etc are to be installed, it is obligatory on the part of the user to see that the machine is anchored on the ground where it is resting. The foundation designed for resting the machine and anchoring is called machine foundation. The machinery vibration influences adversely the foundation supporting soil by densifying it which may in turn, cause differential settlement of soil and foundation.
- The foundation block provided for the machine may vibrate in reciprocating motion or rotary motion or pulsating motion or random motion.

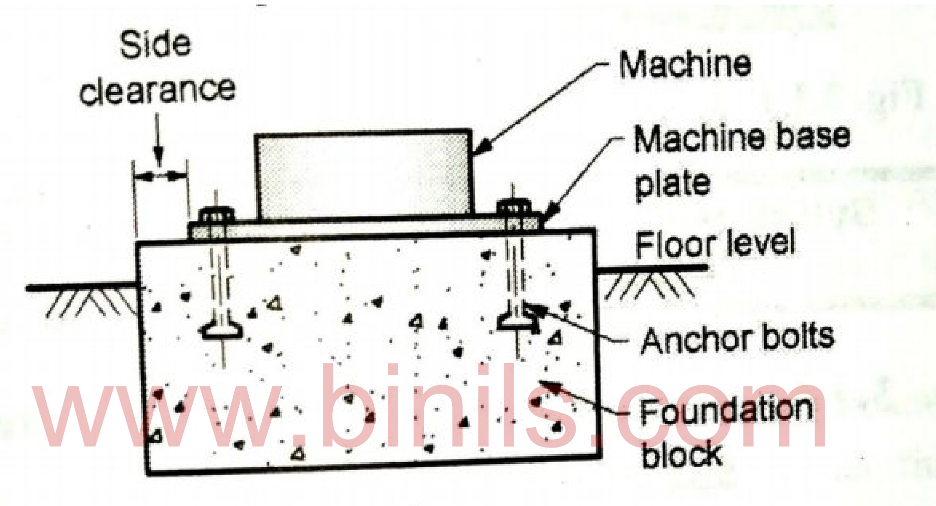


Fig. 3.1.12 : Machine foundation

1. General Design Aspects of Foundation of Industrial Machinery

A good design fulfills the following objectives

1. Machine must be free from damage
2. The excessive vibrations should not be transmitted to neighboring structures
3. There should not be any excessive settlement of the structure.
4. It should not cause excessive settlement or damage to adjoining structures.

2. Machine vibration control

GQ.Comment on machine vibration control.

To avoid damage of adjoining structures and machines, due to vibrations, isolation technique may be followed. Also, the following methods are employed

1. **Location of foundation:** The foundation is located at a greater depth because the results in greater reduction in amplitude of vibration.
2. **Mechanical Isolation:** For high frequency machines additional masses known as dampers are attached to the foundation, resulting in damping of the vibrations.
3. **Absorbers:** Use of absorbers in the form of cork, felt, steel springs etc. placed between the machine and the base of foundation may help in reducing the transfer of vibrations to the subsoil.
4. **Structural foundation:** Structural changes in foundations like increasing the difference between the natural frequency and the operating frequency of the machine can be done.

Excessive vibrations if transmitted to adjoining structure may case excessive settlement and may cause damage to adjoining structure.

Mass of foundation and the soil mass below vibrate with a frequency called as natural frequency. If this frequency is very close to operating frequency of the machine, then resonance may take place. If the soil strata underneath the foundation consists of fine saturated sand then liquefaction may take place resulting in excessive settlement and loss of strength of the soil.

Excessive vibration make it difficult for the workers to operate the machine. Also the machine itself may get damaged due to excessive vibrations.

Actions required to be taken vibration control are:

1. Increasing the weight of the foundation by 2.5 to 4 times than the weight of machine.
2. Shock absorbs can be provided below the base i.e. between the machine and the base in the form of cork or rubber padding or studs etc.
3. Vibrations can be controlled by taking the foundation deep in the soil.
4. Machine is firmly anchored in the foundation by anchor bolts. Richer mix of concrete is recommended of machine foundation.

3. Design of foundations for reciprocating type machinery

For designing reciprocating type machine foundations. the design considerations are as follows:

1. The size of foundation block in plan should be larger than base plate of machine by it 15 cm. on all sides (i.e. clearance around the machine should be 15 cm).

2. Width of foundation should be at least equal to the distance of the centre of gravity crank shaft to the bottom of the foundation in all vertical machines.
3. The stability against rotation in a vertical plane can be ensured by resting the foundation on a good bearing strata.
4. Combined centre of gravity of machine and foundation block should be well below the top at the foundation.
5. The operating frequency should be lower than the natural frequency of the foundation soil system.

4. Design of foundations for impact type Industrial machinery

GQ. Write in brief the design of foundation for impact type machine.

Design criteria for impact type machines such as hammers of drop and forge type are difference from reciprocating type of machines.

1. The centre of gravity of the anvil and the foundation block and the resultants of forces in elastic joints should coincide with the line of fall of the hammer.
2. The depth of foundation should guarantee the safety of block both in punching shear and bending.
3. The area of foundation block should be such that the safe bearing capacity of soil is never exceeded due to the operation of hammer.

Table below shows the minimum depth of foundation block to be provided for impact type foundation.

Weight of Hammer (Tonners)	**Minimum depth of foundation block**
Upto1.0	1.00 m
1.0 to 2.0	1.25 m
2.0 to 4.0	1.75 m
4.0 to 6.0	2.25 m
Above 6.0	2.50 m

4. The weight of anvil is generally kept 25 times the weight of hammer whearas the weight of the foundation block varies between 66 to 120 times weight of hammer

5. The reinforcement in the foundation block shall be designed for all the three directions. More reinforcement shall be provided at the top of the foundation block than at the other side.

3.1.8. Erection of Articulated Structure and Space Decks

- The Space Deck is modular system which is made of inverted pyramids called as half-octahedrons placed side-by-side and connected to each other. Hence a Space deck or space frame is a structure system assembled of linear elements so arranged that forces are transferred in a three-dimensional manner
- The pyramid units is built in special high accuracy jigs by welding the components to each other.
- The pyramidunits are joined to each other using tie bars and bolts. The tie bars are connected to the bosses of the units and form the bottom layer of the spatial structure. There are main and secondary tie bars.
- There are two types of tie bars used in the space deck namely main and secondary tie bars. Main type of tie bars are connected at the boss directly and the secondary members of pyramid units are placed perpendicular to them.
- The assembly of space deck system is fastened by bolting the adjacent unit trays and joining the tie bars between the bosses next to each other.
- The assembly of space deck members are generally carried out on the ground by workers and erected them using lift slab method or lift-up method

Methods for Erection of space deck

Following are the various methods used for erection of space deck:

1. Lift-up method for erection
2. Scaffold method for erection
3. High-altitude sliding method for erection
4. High-altitude bulk method for erection

1. Lift-up method for erection

- The assembly of space deck system is done at ground level prior to hoisting which provide in increased efficiency and better quality.

- The space frame structure can be hoisted up by several cranes for short and medium spans whereas temporary posts are used as the support and electric winches as the lifting power for long-span space frames.
- The entire space frame or space deck can be translated or rotated in the air and then installed in its final position. This method can be employed in all types of double-layer space frames.
- The high-altitude sliding construction method can be divided into single slip method and strip by strip accumulation slip method, and its applicability is prominent. This method can be used in parallel with other civil engineering and shorten the total construction period. Especially in the site is narrow or across other structures, equipment and cranes can not enter the more suitable. The stadium roof or theater and other large-span projects such as civil construction, decoration, and equipment installation can play an economic effect.

2. Scaffold method for erection

- This method is also called as High altitude bulk method in which individual members of space deck are assembled in place at actual elevations and joints or prefabricated sub-assembly members are assembled directly in their final position and hence full scaffoldings are usually required for such type of erection.
- Partial scaffoldings is suitable when a cantilever erection of the space frame is to be done. The platform is used for construction workers to work on the platform.

Advantage

- In this method the construction is simple and the scaffolding is removed after the high-altitude splicing and forming which can be reused.

3. High-altitude sliding method for erection

- In such method, there is use of splicing rods on the ground to form a sliding unit After preparation of sliding unit, hoisting the sliding unit is done to the set sliding track for assembly.
- This method is especially more suitable in the site which is narrow or across other structures and site where equipment and cranes can not enter and reach.

4. High-altitude bulk method for erection

- This method is suitable for screw-connected space frames and generally only suitable for the assembly of small-volume space frame structures. It does not require a lot of lifting equipment.
- In the construction process of the high-altitude bulk method, the requirement of aerial positioning of rod joints is relatively high and hence a reasonable construction sequence has to be adopted.

Fig. 3.1.14 shows erection of space deck by Lift-up method with heavy duty telescopic crane.

Fig. 3.1.14 : erection of space deck by heavy duty telescopic crane

Fig. 3.1.15 shows erection of space frame or space deck.

Fig. 3.1.15 : Erection of space frame or space deck

Fig. 3.1.16 shows erection of space frame or space deck.

Fig. 3.1.16 : Erection of space frame or space deck

Fig. 3.1.17 shows erection of space frame or space deck.

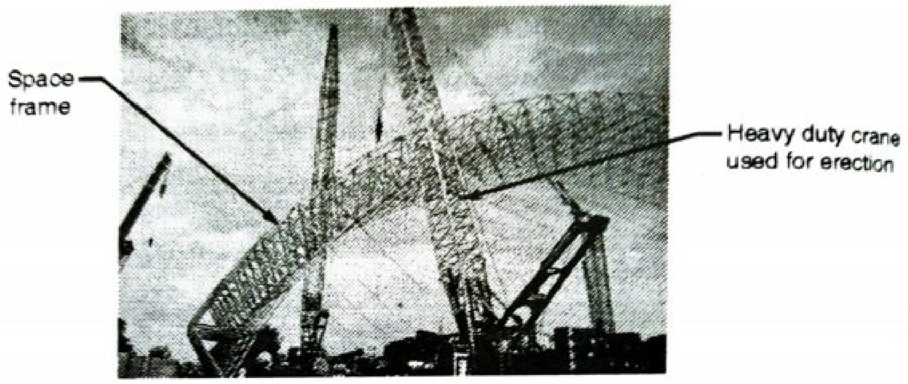


Fig. 3.1.17 : Erection of space frame or space deck

3.1.9. <u>Bow String Bridges</u>

Bowstring Bridges: Graceful Spans with Tension in their Core

Bowstring bridges, named for their resemblance to the taut string of an archer's bow, are a captivating type of bridge design. They feature an arched structure supported not by the ground itself, but by a strong, tensioned chord running beneath the deck. This creates a visually striking bridge with unique advantages and applications.

Advantages of Bowstring Bridges:

- **Lightweight and Efficient:** The use of a tensioned chord instead of massive piers or abutments makes bowstring bridges incredibly lightweight and material-efficient. This translates to lower construction costs and reduced environmental impact.

- **Long Spans Achievable:** The efficient design allows bowstring bridges to span impressive distances with minimal support. This makes them ideal for crossing valleys, rivers, or other obstacles where traditional bridge types might struggle.

- **Aerodynamic Stability:** The streamlined shape of the arch and the absence of bulky piers make bowstring bridges highly aerodynamic. This is especially beneficial in areas prone to strong winds.

- **Low Construction and Maintenance Costs**: The simple design and minimal materials required for construction contribute to lower overall costs. Additionally, the lack of exposed components like piers reduces maintenance needs.

- **Aesthetically Pleasing Appearance**: The graceful arc of the bowstring bridge, often accentuated by a slender deck, creates a visually appealing structure that can enhance the surrounding landscape.

Disadvantages of Bowstring Bridges:

- **Susceptibility to Wind and Vibration:** The lightweight nature and open design of bowstring bridges can make them more susceptible to wind and vibration compared to some other bridge types. Careful engineering and construction techniques are needed to mitigate these concerns.
- **High Initial Tension Required:** Achieving the necessary tension in the chord is crucial for the structural integrity of the bridge. This requires specialized equipment and expertise, adding to the initial construction complexity.
- Specialized Construction Techniques Needed: The unique design of bowstring bridges demands specific construction techniques that may not be readily available in all regions. This can pose challenges and increase costs.
- Limited Redundancy in Case of Failure: Unlike some other bridge types with multiple load-bearing components, bowstring bridges rely heavily on the integrity of the tensioned chord. Failure of this critical element could have catastrophic consequences.
- Not Suitable for All Bridge Types or Environments: The limitations in terms of wind and vibration sensitivity, as well as the specialized construction needs, make bowstring bridges less suitable for certain bridge types or environments.

Applications of Bowstring Bridges:

- **Pedestrian and Bicycle Bridges:** The lightweight and aesthetically pleasing nature of bowstring bridges makes them well-suited for pedestrian and bicycle paths, offering graceful crossings over waterways or other obstacles.
- **Small to Medium-Sized Vehicular Bridges:** Bowstring bridges can effectively handle the weight of cars and trucks over shorter to medium spans, making them a good choice for rural roads or urban overpasses.
- **Suspension Bridges with Long Spans:** The efficient design of bowstring trusses can be incorporated into the supporting towers of suspension bridges, allowing for longer spans and greater load capacity.

- **Temporary or Movable Bridges**: The modular nature and ease of assembly/disassembly make bowstring bridges suitable for temporary applications or movable bridges where quick deployment and retraction are needed.
- Bowstring bridges, with their elegant form and efficient design, offer a captivating solution for various bridge needs. Understanding their advantages, disadvantages, and suitable applications can help determine if they are the ideal choice for your next crossing project.

3.1.10. Cable Stayed Bridges

Cable-Stayed Bridges: Elegance and Efficiency Spanning Great Distances

Cable-stayed bridges are marvels of modern engineering, captivating the eye with their sleek silhouettes and impressive spans. They're defined by a network of cables radiating from tall pylons, directly supporting the bridge deck. This unique design approach comes with a distinct set of advantages, disadvantages, and suitable applications.

Construction Methods:

Cable-stayed bridges can be constructed using various methods, each with its own intricacies:

Incremental Launching: This method involves building the deck in segments, progressively pushing them outwards from the pylons. Each segment is anchored by temporary cables until the final connection is made.

Free Cantilever: In this method, the deck is built outwards from the pylons on either side, with the weight balanced by pre-installed stays. Once both sides meet, a closure section is added to complete the deck.

Semi-Gantry Crane Erection: This method utilizes cranes supported by temporary structures to lift and place prefabricated deck sections onto the pylons and stay cables.

The choice of method depends on factors like bridge size, site constraints, and budget. Each method requires careful planning, specialized equipment, and skilled expertise to ensure structural integrity and safety.

Advantages:

Long Spans: Cable-stayed bridges excel at covering long distances compared to traditional bridge types like beam bridges. This makes them ideal for crossing wide rivers, valleys, or other obstacles.

Efficient Design: The use of cables instead of solid support structures minimizes the amount of material needed, making construction lighter, faster, and more cost-effective.

Aesthetic Appeal: The graceful arch of the deck and the intricate network of cables create a visually striking bridge that can enhance the surrounding landscape.

Aerodynamic Stability: The streamlined design of cable-stayed bridges offers good resistance to wind loads, making them suitable for windy areas.

Low Maintenance Needs: The absence of exposed components like piers or bearings reduces the need for frequent maintenance, resulting in lower long-term costs.

Disadvantages:

Susceptibility to Vibration: The long, flexible deck of cable-stayed bridges can be susceptible to vibrations under certain load conditions or wind patterns. Careful engineering measures are needed to mitigate these vibrations.

Complex Construction and Design: The intricate cable system and precise tensioning requirements demand specialized expertise and sophisticated construction techniques, potentially increasing the cost and complexity of the project.

High Anchor Loads on Pylons: The concentrated loads transferred from the cables to the pylons require robust foundations and careful structural design to ensure stability.

Limited Redundancy: Unlike bridges with multiple load-bearing components, the structural integrity of cable-stayed bridges relies heavily on the cables. Failure of a cable could have catastrophic consequences.

Not Suitable for All Environments: The susceptibility to vibration and wind, along with the specialized construction demands, can make cable-stayed bridges less suitable for certain environments or bridge types.

Applications:

Cable-stayed bridges find diverse applications across various contexts:

Long-Span Crossings: They're often the preferred choice for bridging large rivers, gorges, or straits, especially where traditional bridge types struggle due to distance limitations.

Urban Viaducts and Overpasses: Their efficient design and aesthetically pleasing appearance make them suitable for elevated roadways within urban landscapes.

Pedestrian and Bicycle Bridges: The lightweight and visually appealing nature of cable-stayed bridges can enhance pedestrian and bicycle paths, offering elegant crossings over obstacles.

Replacement of Deteriorated Bridges: Cable-stayed bridges can be a viable option for replacing old or outdated bridges, offering improved structural integrity and aesthetic appeal.

In conclusion, cable-stayed bridges offer a captivating blend of elegance, efficiency, and impressive spanning capabilities. Understanding their advantages, disadvantages, and suitable applications equips you to appreciate their remarkable role in modern infrastructure and envision their potential for future bridge projects

3.1.11. Construction of Jetties and break water structures

Jetties and Breakwaters: Guardians of the Coast

Jetties and breakwaters are two crucial coastal structures with distinct roles in protecting shorelines and waterways. While they might seem similar at first glance, their designs and purposes differ significantly. Let's dive into their construction, advantages, disadvantages, and applications:

Jetties:

Construction: Jetties are typically elongated structures extending from the shoreline into the water. They're often built using a combination of materials like:

Rock: Large rocks piled up to form a stable and robust barrier

Concrete: Precast blocks or poured concrete sections offer a more permanent and controlled structure

Steel: Used for pile jetties, where steel piles driven into the seabed support a platform or walkway

Advantages:

Prevent shoreline erosion: Jetties deflect waves and currents, protecting the coastline from erosion and preserving valuable land.

Maintain navigable channels: By channeling water flow, jetties can deepen and stabilize navigation channels for harbors and waterways.

Create sheltered harbors: Jetties can enclose areas of water, providing calmer conditions for anchoring and protecting boats from rough seas.

Facilitate land reclamation: In some cases, jetties can aid in land reclamation by trapping sediment and promoting the growth of new land.

Disadvantages:

High construction costs: Depending on the materials and length, jetties can be expensive to build and maintain.

Impact on natural ecosystems: Jetties can alter water flow and sediment patterns, potentially affecting marine life and coastal ecosystems.

Upset the balance of erosion and deposition: Jetties can cause increased erosion on nearby beaches due to altered wave patterns.

Applications:

- Protecting harbor entrances from waves and currents.
- Deepening and stabilizing shipping channels.
- Creating sheltered areas for marinas and boatyards
- Reclaiming land for coastal development.

Breakwaters:

Construction: Breakwaters are typically detached structures built offshore, parallel to the coastline. They can be constructed using similar materials as jetties, like:

Rock: Most common material, creating a stable and absorbent barrier against waves.

Concrete: Offers greater flexibility in shaping and can withstand strong waves

Caissons: Large concrete boxes sunk into the seabed and filled with rocks or concrete, creating a stable foundation.

Advantages:

Protect harbors and coastal areas from waves and storms: Breakwaters absorb wave energy, creating calmer conditions for harbors and protecting infrastructure from storm surges.

Prevent coastal erosion: By reducing wave impact, breakwaters can shield coastlines from erosion and preserve valuable land.

Create recreational areas: Breakwaters can provide sheltered areas for swimming, snorkeling, and other water activities.

Enhance fisheries: In some cases, breakwaters can attract fish by providing shelter and habitat.

Disadvantages:

High construction costs: Similar to jetties, breakwaters can be expensive to build and maintain, especially those using large concrete structures.

Visual impact: Large breakwaters can be visually intrusive and alter the natural aesthetics of the coastline.

Impact on coastal currents and sediment transport: Breakwaters can disrupt natural sediment movement, potentially affecting beaches and nearby ecosystems.

Applications:

- Protecting harbors and marinas from waves and storms.

- Sheltering coastal areas from erosion.
- Creating recreational areas for swimming and boating.
- Providing habitat for fish and other marine life.

Remember, the choice between a jetty and a breakwater depends on the specific needs and challenges of the coastal area. Understanding their distinct roles and the potential drawbacks is crucial for choosing the most appropriate solution.

UNIT IV

REHABILITATION AND STRENGTHENING TECHNIQUES

Seismic retrofitting - Strengthening of beams - Strengthening of columns - Strengthening of slab - Strengthening of masonry wall, Protection methods of structures, Mud jacking and grouting for foundation - Micro piling and underpinning for strengthening floor and shallow profile - Sub grade water proofing, Soil Stabilization techniques.

6.1. SEISMIC RETROFITING

- The process or method used to decrease the effect of seismic intensity for building or other civil engineering structural elements is called as seismic retrofitting techniques.
- In short, Retrofitting is the techniques of adding some new provisions that were not there previously. It is the method of changing or repairing and modifying something after it has been made. Retrofitting of buildings is required for the houses that are influenced by disappointments and harmed by seismic forces.
- Seismic Retrofitting Techniques are needed for concrete constructions which are vulnerable to damage and failures by intensity of seismic forces. Hence there are various innovative techniques such as base isolation, jacketing and mass reduction used as seismic retrofitting. Therefore seismic retrofitting is a collection of mitigation technique for Earthquake engineering.
- Seismic retrofitting techniques have the great significance to protect the historic monuments, areas prone to severe earthquakes and tall or expensive structures and also save life, money and failures of structures.
- Structures can be (i) Earthquake damaged, (ii) Earthquake vulnerable, hence seismic retrofitting proves to be a better economic consideration and immediate shelter to problems rather than replacement of building.
- The retrofit techniques are also applicable for other natural hazards like tropical cyclones, tornadoes, and severe winds from thunderstorms

Purpose of seismic retrofitting

Following points shows the purpose of seismic retrofitting:

(i) To increase the ductility of the structure.

(ii) To upgrade the lateral strength of the structure.

(iii) To ensure that building have a certain energy dissipation capacity and deformation to avoid sudden brittle damage in the earthquake and fierce wind.

(iv) To increase the strength and the ductility of the structure.

(v) To contort and dissipate energy during an earthquake

(vi) To make modification of existing structures in order to make existing structures more resistant to seismic activity, ground motion, or soil failure caused by earthquakes.

(vii) To reduce hazard and losses from non-structural elements.

(viii) To make important existing buildings like hospitals to be more strengthened after an earthquake.

(ix) To ensure the safety and security of a building. employees, structure functionality, machinery and inventory by seismic retrofitting.

Following are the methods of retrofitting of structure which are commonly used into construction practice:

1. Adding steel reinforcement in beam and column and its junction
2. Adding Steel Bracing.
3. Jacketing Method.
4. External Plate Bonding.
5. Base Isolation Technique.
6. Mass Reduction Technique.
7. Wall Thickening Technique.
8. Composite of Fiber Reinforced Polymer (FRP)
9. Adding Shear Wall.
10. Epoxy Injection Method.
11. External Plate Bonding.
12. Section Enlarging Reinforcing Method

- Adding steel bracing is suitable in the retrofitting of building when it needs enormous openings

- Three types of jacketing such as (i) Reinforced Concrete Jacket, (ii) Steel Jacket, and (iii) Fiber Reinforced Polymer Composite Jacket (FRPC) can be employed in the retrofitting of building.
- Strengthening of reinforced concrete beams with external plates or strips is a methods of retrofitting which has been used for a long time in the construction practice.
- In base isolation technique, superstructure is isolated from the foundation. Base isolation technique is the most efficient method for passive structural vibrations control technique.
- In mass reduction technique of retrofitting, there is evacuation of at least one storey employed in the construction practice for the reduction in the loading.
- In Wall Thickening Technique, the existing walls of a building are added with a specific thickness by adding concrete, bricks and steel at specific weak places as reinforcement.
- A fiber reinforced polymer (FRP) is an axial strengthening technique which used to improve the capacity of reinforced concrete beams.
- Adding shear wall is a regularly retrofitting techniques which is used regularly for RCC buildings and for non- ductile reinforced concrete frame building.
- The epoxy injection techniques is utilized in retrofitting of building to repair the non-moving cracks and fill the structural failure areas.
- Section enlarging reinforcing techniques is broadly utilized in the reinforced concrete structure of the slab, beam column, etc.

Fig. 6.1.1 shows jacketing method in retrofitting of column.

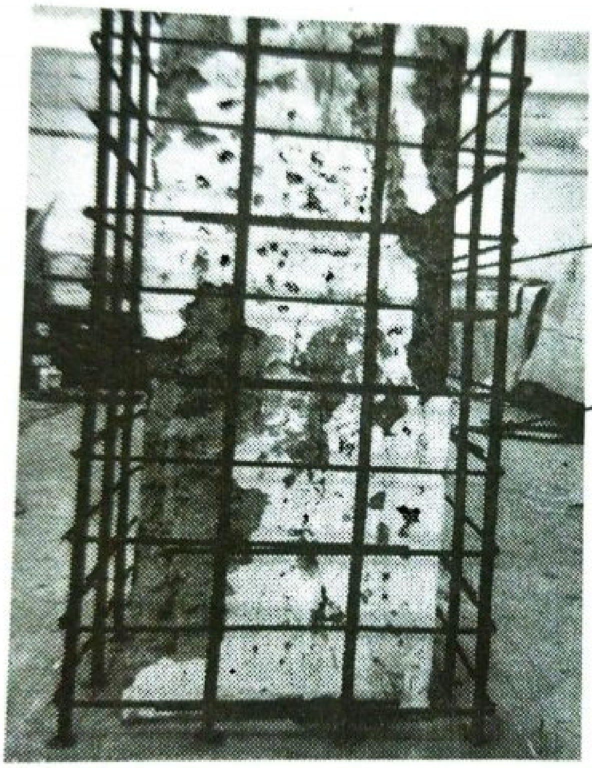


Fig. 6.1.1 : Shows external steel plate bonding method in retrofitting of RC beam and RC slab

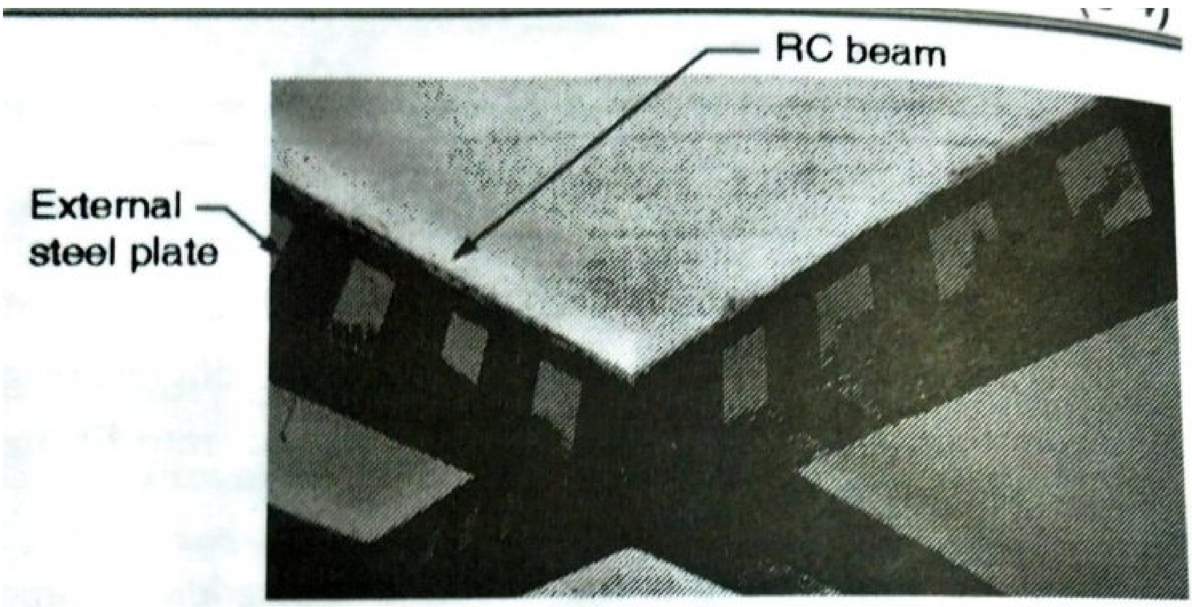


Fig. 6.1.2 : External plate bonding method in retrofitting of RC beam and RC slab

6.1.1. Strengthening of Beams

- Strengthening of beams of reinforced concrete beam (RC beams) is necessary in order to increase their flexural strength, shear strength, fatigue life, seismic resistance, and impact and blast resistance for better durability of structure.
- Reinforced concrete beams need strengthening when the existing steel bars in the beam are unsafe or insufficient, or when the loads applied to the beam are increased.
- After a certain period of loading over the structure, RC beams has to be strengthened due to structural damage or corrosion.
- In such situations, there are different treatment or solutions which can be used for strengthening of RC beams as described below.

I. In advanced technology, use of Fiber-reinforced polymer (FRP) for strengthening of RC beams give better results in various features such as noncorrosiveness; high longitudinal tensile strength, stiffness, strength-to-weight ratio, insect and fungal resistance, and chemical attack resistance; low thermal transmissibility etc.

- Hence various typical FRP materials, such as glass FRP (GFRP), carbon FRP (CFRP), aramid FRP (AFRP), and basalt FRP (BFRP) are available and play a vital role in strengthening of RC beams.
- FRP-strengthened RC beams shows enhanced ductility, flexural strength, shear and torsion capacity, seismic resistance, and durability
- FRPs are typically used to toughen RC members, to withstand increased static loading and to repair damaged members after environmental degradation, corrosion, earthquakes, or storms.
- Composite FRP in RC beams is durable under mild exposure conditions, such as moisture, acid- alkaline environments, freeze-thaw cycles, and temperature.
- FRP can fulfill the requirements for strengthening RC elements under controlled conditions.

II. In this method, the reinforcement steel bars are added to the main steel without increasing the cross-sectional area for strengthening of RC beams. The holes are filled with an epoxy material with low viscosity and installing steel connectors for fastening the new stirrups

- This type solution can be adopted when the reinforcing steel bars are not capable to carry the stresses applied to the beam.

III. In this method, the reinforcement steel bars and the cross-sectional area of concrete both are increased for strengthening of RC beams.

- This type solution can be adopted when both the steel and concrete are not able to carry the additional loads applied to the beam.

IV. In this method, steel plates are added to the beam for it's strengthening

- This type solution can be adopted when it is needed to strengthen the beam's resistance against the applied moment or shear stress. The steel plates are attached to the concrete by using bolts as shown in Fig. 6.1.3.

V. In this method, the load on the beam can be reduced by introducing steel beam on top or below the concrete beams.

Fig. 6.1.3(a) and (b) shows the steel plates are attaches to the concrete beam by using bolts.

Fig. 6.1.3(a) : The steel plates are attached to the concrete by using bolts

Fig 6.1.3(b) shows the steel plates are attached to the concrete beam by using bolts.

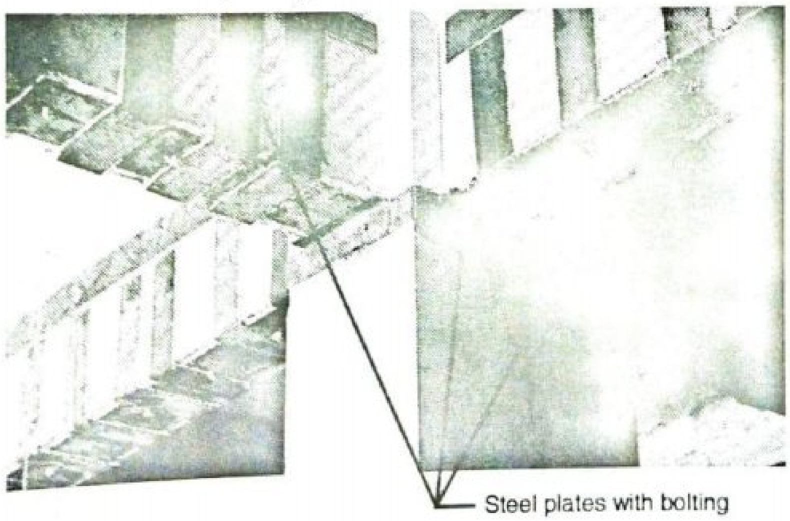


Fig. 6.1.3(b) : The steel plates are attached to the concrete by using bolts

6.1.2. Strengthening of Columns

Definition of Strengthening of columns

- The method used to add or restore ultimate load capacity of RCC columns(reinforced concrete columns) is called as column strengthening which is commonly employed into construction practices for seismic retrofitting, supporting additional live load or dead load to relieve stresses induced by design or construction errors, or to restore original load capacity to damaged structural components.

Necessity or Purpose or need for strengthening of R.C. Columns

Following are the points which shows purposes or needs for strengthening of R.C. Columns.

(i) When the load carried by the column is increased because of increasing the number of floors or because of mistakes in the design or additional load due to alterations, then strengthening of columns is necessary.

(ii) When eccentricity of column is beyound the allowable limits, then strengthening of columns is necessary.

(iii) When the crushing strength of the concrete or the percent and type of reinforcement are not as per the IS codes requirement, then strengthening of columns is necessary.

(iv) When the settlement in the foundation becomes greater than the allowable limits.

Strengthening techniques of columns

Following are techniques which are commonly used to strengthen reinforced concrete columns :

1. Reinforced concrete jacketing,
2. Steel jacketing,
3. FRP jacketing

1. **Reinforced concrete jacketing :** This method of jacketing improve or restore capacity of RCC column. The size of the jacket and the number the steel bars used in the jacketing process depend on the structural analysis of the column. Fig. 6.1.4(a) and (b) shows reinforced concrete jacketing for rectangular and circular RCC column used in RCC structural rehabilitation

2. **Steel jacketing:** When with the increase of loads over the column when, increasing the cross sectional area of the column is not permitted, then in such case method of steel jacketing can be employed in the construction practice.

3. **FRP jacketing:** FRP axial strengthening systems is one of the techniques being used to improve or enhance the capacity of reinforced concrete columns and suitable for both circular and rectangular shaped columns. FRP Confining or Jacketing increases the ultimate load carrying capacity of reinforced concrete column and also improves shear capacity of reinforced concrete element.

Fig. 6.1.4(e) shows FRP jacketing for rectangular RCC column used in RCC structural rehabilitation

- Fig. 6.1.4(a), (b) shows reinforced concrete jacketing for rectangular and circular RCC column used in RCC structural rehabilitation

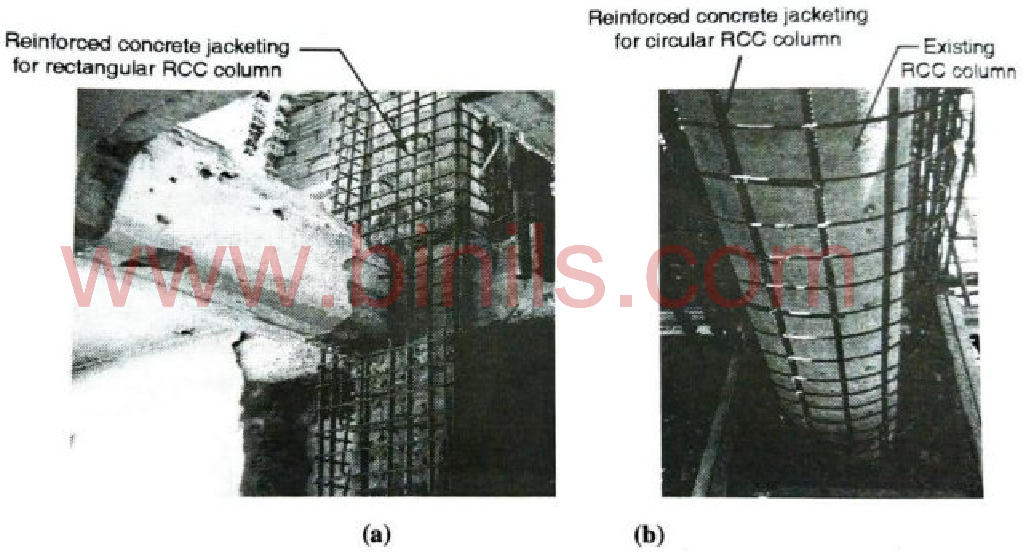


Fig. 6.1.4 : Reinforced concrete jacketing for rectangular and circular RCC column used in RCC structural rehabilitation

Fig. 6.1.4(c) shows reinforced concrete jacketing for rectangular RCC column used in RCC structural rehabilitation.

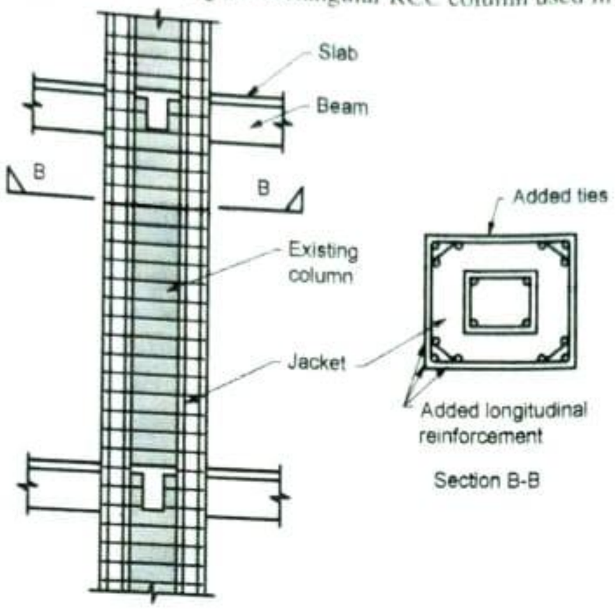


Fig. 6.1.4(c) : Shows reinforced concrete jacketing for rectangular RCC column used in RCC structural rehabilitation

Fig. 6.1.4(d) shows steel jacketing for rectangular RCC column used in RCC structural rehabilitation.

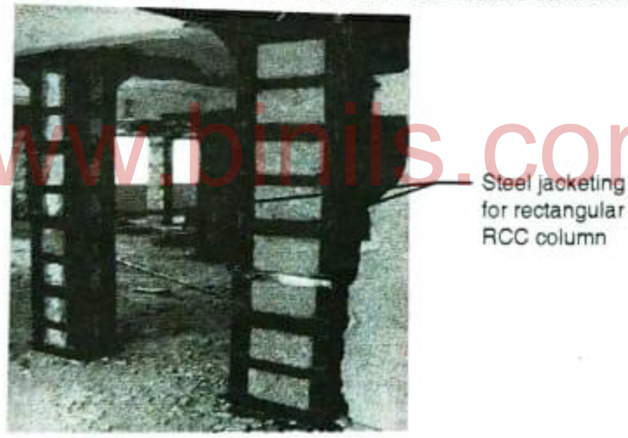


Fig. 6.1.4(d) : Shows steel jacketing for rectangular RCC column used in RCC structural rehabilitation

Fig. 6.1.4(e) shows FRP jacketing for rectangular RCC column used in RCC structural rehabilitation.

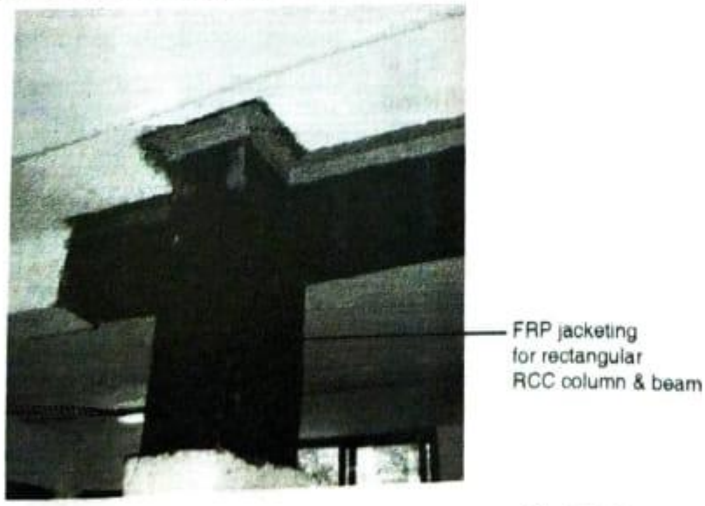


Fig. 6.1.4(e) : FRP jacketing for rectangular RCC column used in RCC structural rehabilitation

6.1.3. Strengthening of Slabs

Because of increasing the applied loads on slabs or their unsafe design, or corrosion of the reinforcing steel bars, or cracks in the slabs, strengthening of RC slab is necessary.

Factors responsible for strengthening of RC slab

Following are the various factors being responsible for strengthening of RC slab:

(i) When load increases on slab because of additional live loads, increased wheel loads, installations of heavy machinery, or vibrations, then strengthening of slabs or retrofit of slab is necessary.

(ii) Development of cracks in concrete and stress more than design stress.

(iii) When there is damage to structural parts caused by fire damage, corrosion of steel reinforcement, and impact of vehicles.

(iv) When there is the settlement in the foundation becomes more than the allowable limits, then strengthening of slabs or retrofit of slab is necessary.

(v) When there is modification of structural system because of an elimination of walls columns and openings cut through slabs, then strengthening of slabs or retrofit of slab is necessary.

(vi) Strengthening of slabs or retrofit of slab is necessary because of mistakes or unsafe design.

(vii) Strengthening of slabs or retrofit of slab is necessary because of reinforced steel corrosion or insufficient number of bars.

(viii) It needs strengthening of slabs or retrofit of slab due to errors in planning or construction due to insufficient design dimensions or provision of insufficient reinforcing steel

(ix) When the slab is unable to carry the negative moment and the lower steel is sufficient, then strengthening of slabs or retrofit of slab is necessary.

(x) When the slab is unable to carry the positive moment or when the dead load much less than the live load carried by the slab, then strengthening of slabs or retrofit of slab is necessary.

Methods of Strengthening of the RC slab

Following are the methods of strengthening the RC slab

1. Strengthening a slab by increasing its depth from top layer: When the slab is unable to carry the negative moment (hogging bending moment) and the lower steel is sufficient, then upper steel mesh bars are to be added with a new concrete layer
2. Strengthening a slab by increasing its depth from the bottom layer: When the slab is unable to carry the positive moment (sagging bending moment) or when the dead load much less than the live load carried by the slab, then lower steel mesh bars are to be added with a new concrete layer.
3. Concrete Jacketing
4. Concrete Replacement.
5. Retrofitting by Steel Materials.
6. Retrofitting using Shape Memory Alloys
7. Use of FRP Laminates
8. Bonding carbon fabric reinforcements
9. Sticking and bolting steel plate at the bottom of slab to reinforce

Steel plate reinforcement is usually made of flat steel which are glued with adhesive and bolted also.

Stepwise working procedure for strengthening of the RC slab

Following steps shows the stepwise working procedure for strengthening of the RC slab:

(i) Initially, the existing concrete layer is removed

(ii) In this steps, the reinforcing steel bars are properly cleaned by using a wire brush or a sand compressor.

(iii) Then, the existing steel bars are coated with iron oxide or an epoxy material in order to avoid possibility of corrosion.

(iv) A new steel mesh bars are then placed to the required area. A new steel mesh bars are designed according to the requirements. A new steel mesh bars are vertically fixed to the slab of the roof and horizontally to the surrounding beams by using steel dowels.

(v) In this stage, workable concrete is poured before the epoxy dries to the desired thickness.

(vi) In last stage, curing is carried out to the concreting area by suitable method for 28 days for getting the design strength.

Fig. 6.1.5 shows strengthening a slab by increasing its depth by removing the concrete from top layer and by providing upper steel mesh bars.

Fig. 6.1.5

Fig. 6.1.6 shows strengthening of a slab by increasing its depth by removing the concrete from bottom layer and by providing lower steel mesh bars.

Fig. 6.1.6 : Strengthening a slab by increasing its depth by removing the concrete from bottom layer and by providing lower steel mesh bars

Fig. 6.1.7 shows strengthening of a slab by Sticking and bolting steel plate at the bottom of slab to reinforce.

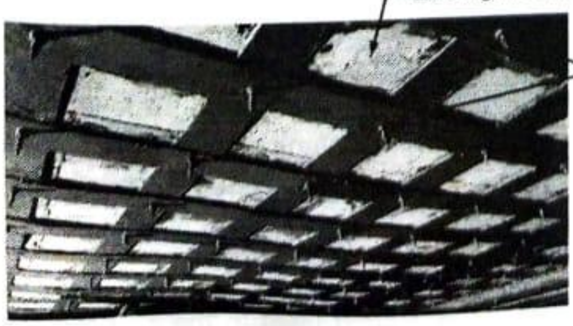


Fig. 6.1.7 : Strengthening of a slab by sticking and bolting steel plate at the bottom of slab

6.1.4. Strengthening of a Masonry Wall

Definition: Technique of applying reinforced concrete (RC) jackets for brick masonry and stone masonry walls is called as strengthening of masonry structure in which there is application of jackets on one or both sides of masonry walls. The total thickness of RC jackets generally varies from 30 mm to 100 mm. Note that the thickness depends on the method for application of concrete layers.

Use of FRP and structural repointing can also be employed for strengthening of masonry walls.

Methods

1. Technique of applying reinforced concrete (RC) jackets for brick masonry and stone masonry walls
2. Use of FRP
3. Structural repointing
4. Strengthening of wall with a provision of corner reinforcement

Stepwise procedure of applying reinforced concrete (RC) jackets

Following is the stepwise procedure of applying reinforced concrete (RC) jackets:

(i) Masonry surface to be strengthening is first cleaned.

(ii) Mortar joints between bricks or stones are properly cleaned

(iii) If any cracks is observed in masonry walls should be first grouted.

(iv) Holes are drilled in which anchor ties are inserted.

(v) The surface of drill holes is cleaned, moistured and cement slurry is spread over the masonry surface and in drills also.

(vi) Reinforcement mesh as per the design on both sides of wall is installed with steel anchors very properly. Steel anchors can be welded with the mesh or tied with steel binding wire. Thus reinforcement mesh is positioned.

(vii) Then concrete is forcely applied in two-layers with reinforcement mesh in between them.

(viii) Then curing is done for 7 days for getting required strength.

Fig. 6.1.8 shows strengthening of a brick masonry wall by applying reinforced concrete (RC) jackets.

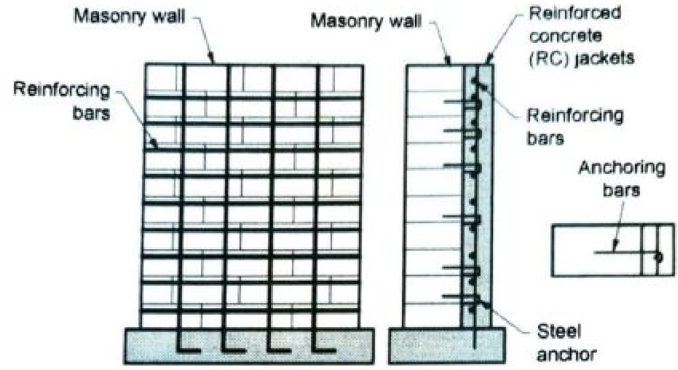


Fig. 6.1.8 : Strengthening of a brick masonry wall by applying reinforced concrete (RC) jackets

Fig. 6.1.9 shows strengthening of a brick masonry wall by applying reinforced concrete (RC) jackets.

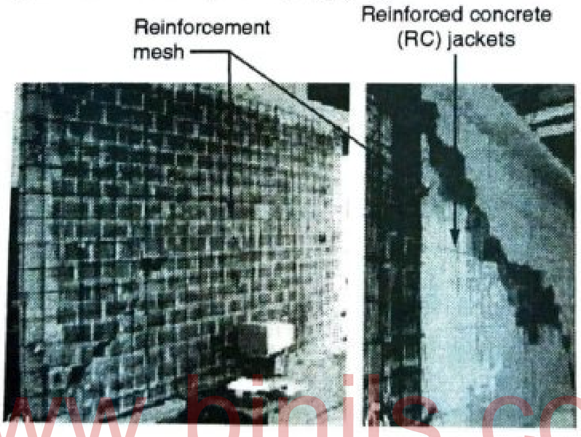


Fig. 6.1.9 : Strengthening of a brick masonry wall by applying reinforced concrete (RC) jackets

6.1.4.1. Strengthening of Wall with a provision of Corner Reinforcement

- The design and construction of masonry in general shall be governed by IS / 1905 - 1969 and IS: 2212-1962 well burnt clay bricks having a crushing strength no less than 1.5N / m * m ^ 2 shall be used in the construction of wall.
- Squared stone masonry or random rubble masonry brought to courses at not more than 600 mm intervals or hollow concrete block masonry of adequate strength may also be used.
- Well burnt bricks conforming to IS 1077 or solid concrete blocks conforming to IS 2185 (part I) shall be used. Square stone masonry, stone block masonry as per IS 1997-Part II may also be used.
- Generally random rubble masonry structures are highly susceptible to earthquake, where such structure cannot be avoided, it will be necessary to improve their resistance against by adopting suitable strengthening arrangements like a provision of corner reinforcement. Strength at the corners or junction of walls can be increased by

providing vertical as horizontal reinforcing bars which imparts the maximum resistance against earthquake shaking.

- Masonry bearing walls built-in mortar unless rationally designed as reinforced masonry shall not be built of greater total height than 15 m subject to a maximum of 4 storeys when measured from the mean ground level to the roof slab or main tie level.

- Brick masonry walls and random rubble masonry walls brought to courses not more than 600 mm apart built-in mortars shall not be adopted for more than two storeys or 8 m height whichever is less.

- For seismic strengthening arrangement, all buildings to be constructed of masonry shall be strengthened by the methods as specified by BIS for various categories of buildings. For overall strengthening arrangement to be adopted for category D (i.e. two storeys with flat roof and one storey plus attic for pitched roof) which consist of horizontal bands of reinforcement at critical levels and vertical reinforcing bars at corners and junctions of walls.

- Fig. 6.1.10 shows the overall arrangement of reinforcing low strength masonry buildings.

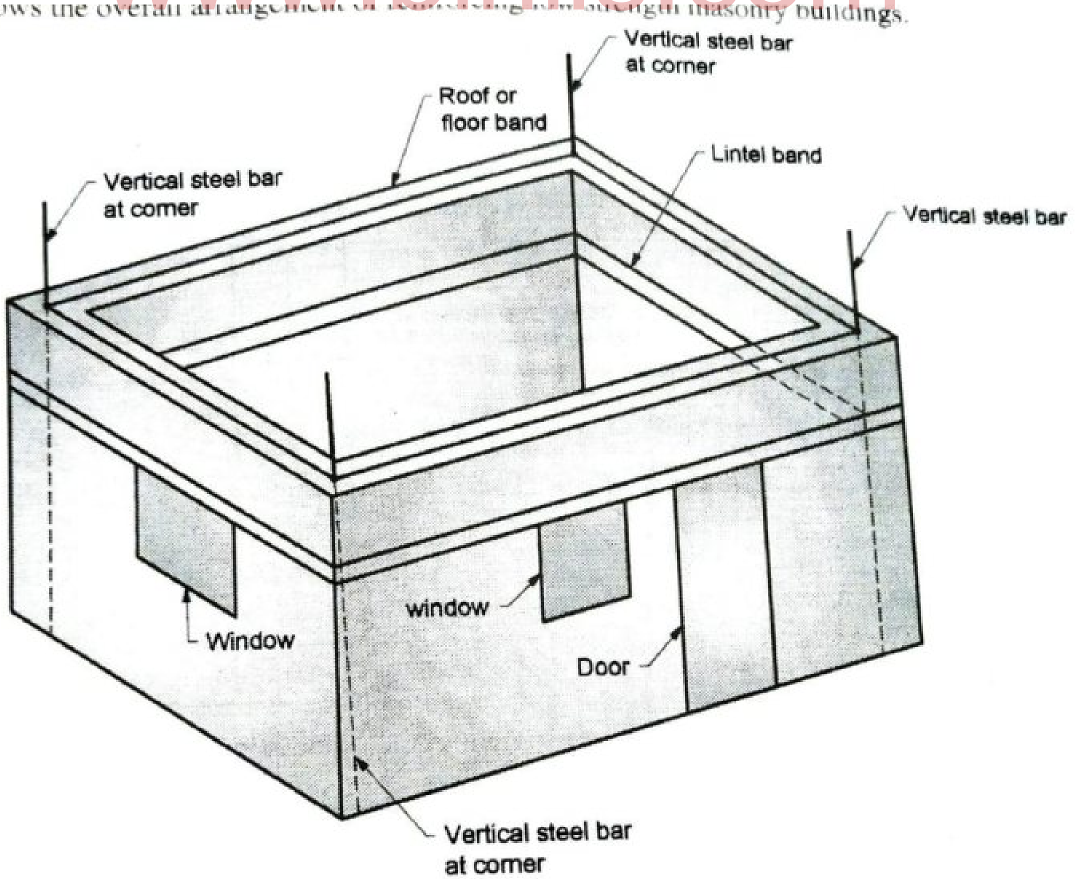


Fig. 6.1.10 : Overall arrangement of reinforcing low strength masonry buildings

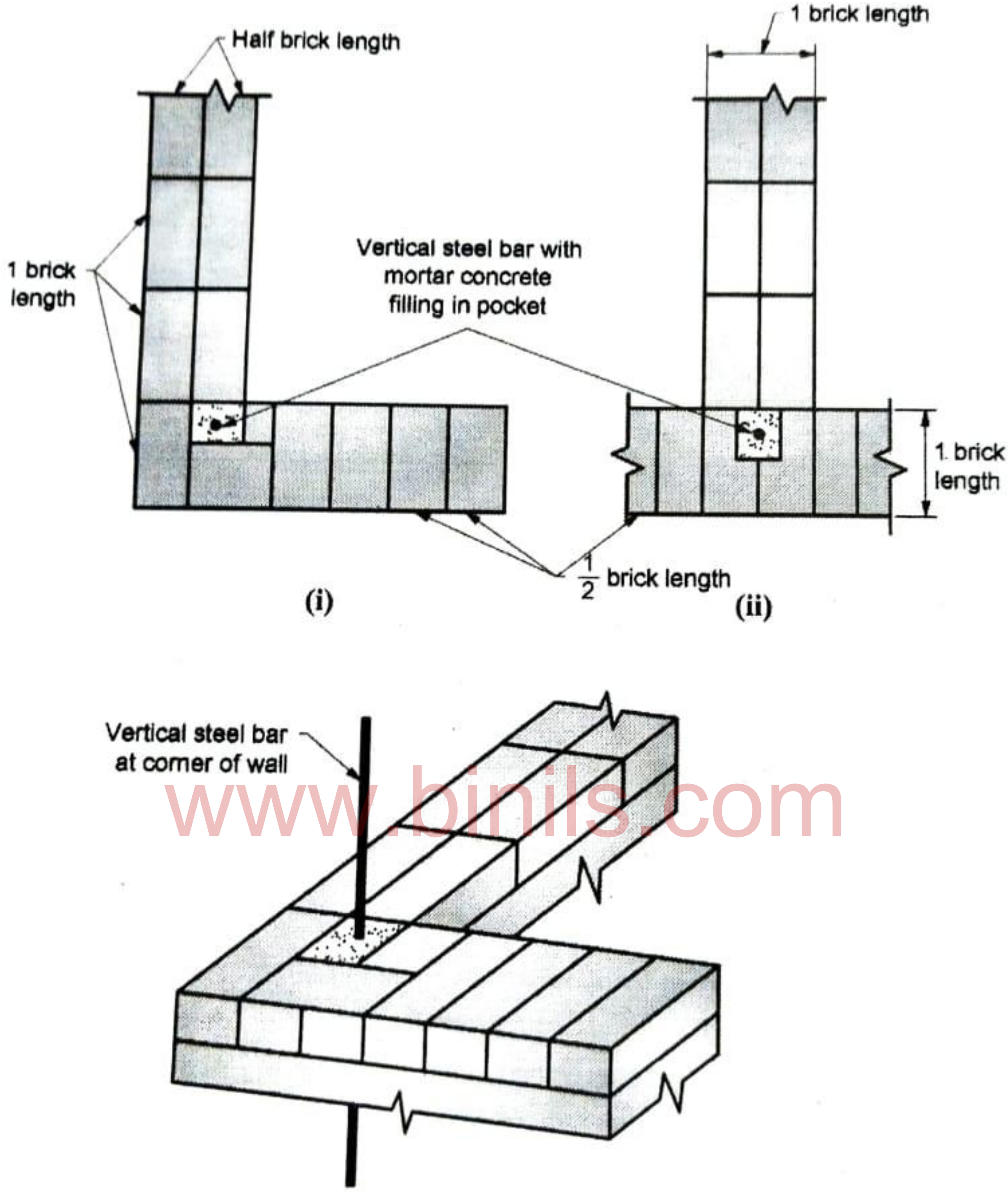
Vertical reinforcement at corner of wall

- Vertical steel bar at corners and junctions of walls which are thick upto 350mm and should be provided as specified by BIS in table 6.1.1.

Table 6.1.1. : Vertical steel reinforcement in low strength masonry walls

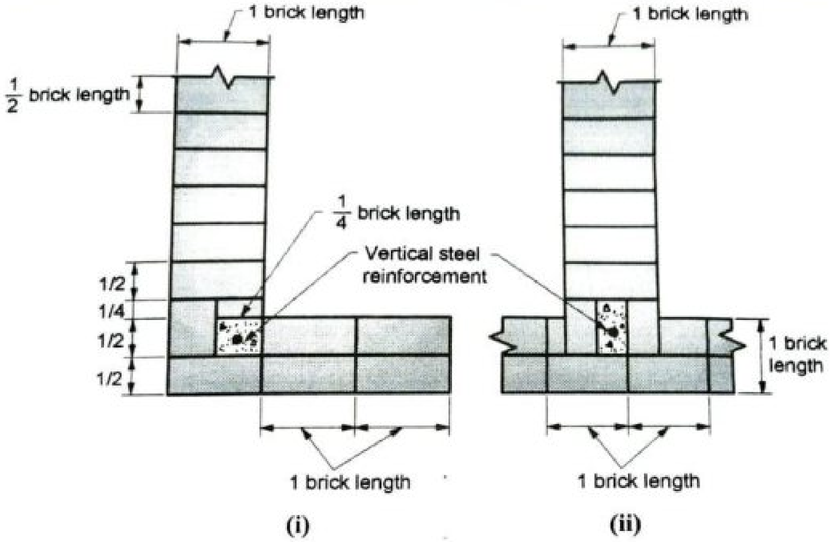
No.of. Storeys	Storey	Diameter of HSD single bar in mm, at each critical section for			
		Category A	**Category B**	**Category C**	**Category D**
One	-	NIL	NIL	NIL	10 mm
Two	Top	NIL	NIL	10 mm	10 mm
	Bottom	NIL	NIL	10 mm	12 mm
Three	Top	NIL	10 mm	10 mm	10 mm
	Middle	NIL	10 mm	10 mm	12 mm
	Bottom	NIL	12 mm	12 mm	12 mm

- The diameters mentioned in Table 6.1.1 are high strength deformed (HSD) bars with yield strength of 415/Nmm ^ 2 For mild steel plain bars, use the equivalent diameters.
- Vertical bars should be embedded in M15 grade concrete or in mortar having proportion of 1:3 i.e. 1 part of cement and 2 part of sand or fine aggregates. Concrete makes ensure the steel bars safety from corrosition and good band with masonry.
- Typical details of providing vertical bars in brickwork at corners and T-junctions are shown in Fig. 6.1.11.



(iii) 3-D view of alternate course in one brick wall with vertical steel bar at corner

Fig. 6.1.11(a) : Alternate courses in one brick wall



(b) Alternate courses in one brick wall

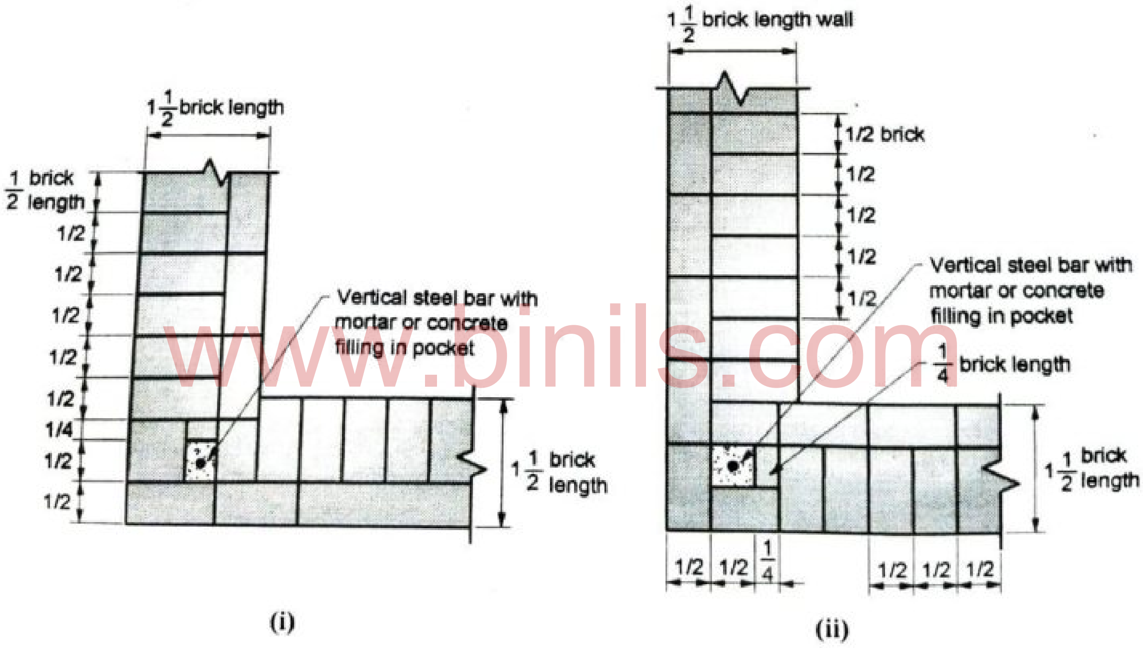
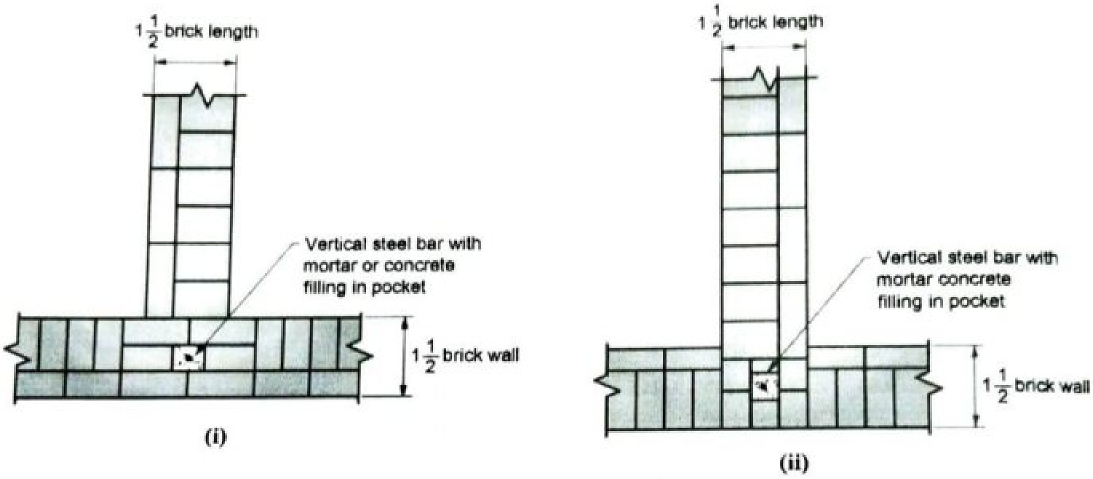


Fig. 6.1.11(c) : Alternate courses at corner junction of $1\frac{1}{2}$ brick wall



(d) Alternate courses at T-junction of $1\frac{1}{2}$ brick wall

Fig. 6.1.11 : Vertical reinforcement in brick work at corners

For providing vertical steel bar in stone masonry, the use of a casing pipe is recommended around which masonry is constructed upto a height of 600 mm as shown in Fig. 6.1.12.

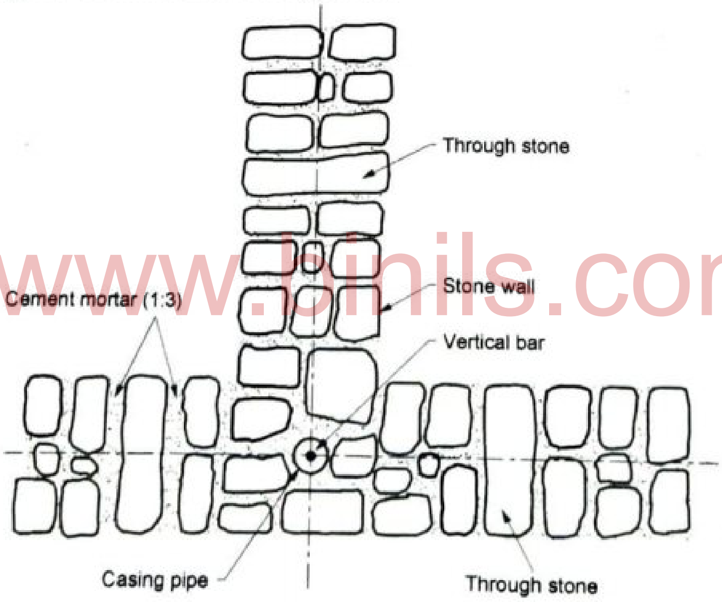


Fig. 6.1.12 : Vertical steel bar in random rubble stone masonry

- The pipe is kept loose by rotating it during masonry construction. It is then raised and the cavity below it is filled with M15 grade of concrete mix (1:2:4) and rodded it for compaction.

6.1.5. Protection Methods of Structures

- The continuing deterioration of concrete structures with time is a serious problem. Hence it is a need for certain guidelines to enable classification, testing, assessment, and ultimately restoring the structures to their original conditions.
- The reason for deterioration of concrete structures is mainly due to adverse climatic conditions such as moisture, acidity, alkalinity etc.

- There is a difference between repairing a structure and protecting it from future corrosion and adverse climatic conditions. Repair deals with identifying cracks, cavities, and filling these cavities with reinforced steel. Protection processes can involve repaired concrete structure or newly built ones, always ideals limiting the climatic factors to avoid extensive corrosion.

6.1.5.1. Protection Methods of Structures

Following are the various methods or techniques used protect building structures from damages and to deterioration:

1. Superficial protection
2. Prevention against corrosion
3. Techniques of repairing deteriorated concrete
4. Strengthening of the structure
5. Electrochemical treatment of contaminated concrete
6. Other techniques

1. Superficial protection

Superficial protection consists of the methods or techniques such as,

(i) **Impregnation :** In the impregnation system, the protection is attained through prevention of capillary absorption of water by concrete structure. Impregnations, is made of low density resins which penetrate and fill the pores of the surface of the concrete, diminishing its superficial permeability and increasing resistance. In the hydrophobic impregnation, there is a use of silans and siloxans.

(ii) **Surface coating of membranes:** Coating of membrane is a special type of surface coating, whose main feature is of very flexible and totally impermeable

(iii) **Layer of surface coating:** It consists on a layer put on top of the substrate surface, hence this technique provides superficial protection.

(iv) **Overcladding by mortar or shotcrete:** It consists on providing extra cover to reinforcement and protection to surface.

(v) Physical external protection

2. Prevention against corrosion

Prevention against corrosion consists of the methods or techniques such as,

(i) Steel protection against corrosion

(ii) Cathodic protection

3. Techniques of repairing deteriorated concrete

- Techniques of repairing deteriorated concrete consists of the methods or techniques such as,

(i) Treatment of cracks

(ii) Patching repair of deteriorated surface with mortar or concrete

- Steel becomes unprotected against corrosion due to spalling or extensive deterioration of the surface hence patching repair of deteriorated surface is done with mortar or concrete by sdding the admixtures to reduce shrinkage and increase workability.

4. Strengthening of the structure

Strengthening of the structure consists of the methods or techniques of adding or replacing steel bars, by bonding external plats such as steel or composite material or the use of internal or external prestress.

5. Electrochemical treatment of contaminated concrete

- Electrochemical treatment help to create a new protective layer for contaminated concrete.
- In another techniques electrochemical treatment, there is the use of simple installation consisting on a metal mesh outside concrete, electrically connected to reinforcement with imposed current.
- Electrochemical treatment is simple in installation non intrusive, quite effective and durable.

6. Other techniques

It consists electrochemical moisture control, replacing of deteriorated elements and limiting the oxygen content at the cathode by saturation or surface coating.

In short, there are the simple methods such as Impregnation, Hydrophobation, Painting and Coating. Sealers etc. to protect concrete structures from damages and deterioration.

6.1.6. Mud Jacking and Grouting for Foundation

Definition of Mud jacking or Slab jacking

- A method in which repairing a foundation of structure is done by stabilizing and raising concrete slabs that are settled over time is called as Mud jacking. It ia also termed as slab jacking. Hence one of the most common techniques used to repair a foundation is mud jacking
- For a successful mudjacking for slab foundations, grout consistency and its composition play avital role.
- Typical compressive strengths of grout, designed in mud jacking are 345 kpa to 690 kpa.

Process of mud jacking

- There are drilling holes in mudjacking intending to raise settled concrete slabs. A slurry made of water, soil, and cement is then injected underneath the concrete slab in order to make it more even.
- Mud jacking method is employed into the practice to lift settled or sunken concrete slabs from patios, pool decks and foundations.

- Mud jacking method provides a quick repair which can be finished in only under a few hours.

Methods of Mud jacking

There are two methods of mud jacking which can be employed as follows:

(i) Filling a Void

(ii) Raising the Floor

(i) Filling a Void

- Technique of filling a void needs two holes to be drilled through the grade beam which surrounds the house or structure.
- Cement grout and soil mixture is then pumped into the created void. Then these two drill holes are filled with a mixture of cement grout and soil. Thus a voids are created below the slab then filling of the void left is done with a mixture of cement grout and soil using the mud jacking method.

(ii) Raising the Floors

- Raising the floors technique is used in the situations where the slab have settled. Then in such case, this technique is used to lift the floors and it is done from the interior of the house.
- In this method, two holes are drilled into the slab on the area which is settled. A stiff mixture of cement grout and soil is then pumped into the foundation. This method is suitable for complex foundation problems. This technique may sound and simple but it is a delicate process, hence it should be carried out under expert supervision and guideline.

Advantages and Disadvantages of Mudjacking

1. Advantages of Mudjacking

Following are the advantages of Mudjacking:

(i) This method is relatively not expensive

(ii) It is fast method to complete

(iii) This technique is sound and simple

2. Disadvantages of Mudjacking

Following are the disadvantages of Mudjacking:

(i) It does not provide a warranty

(ii) In this method, sometimes the concrete emerges in unexpected places.

(iii) It needs expert supervision and guideline

Grouting

- Pressure grouting is the process of injecting concrete or grout into foundation, wall, or floor.
- Pressure grouting is carried out by drilling holes in specific areas identified by expert or professionals. Specialized concrete grout is pumped at high pressure until the concrete comes in contact with the existing foundation. It fill void or empty space to provide a stabilized or strengthen foundation.
- In short, pressure Grouting is a process of injecting grout under the ground and into loose soils to solidify and strengthen the existing foundation.

- The mixture of groutin can be injected as deep as 25 m or more underground.
- Pressure grouting can be used to stabilize soil or in some cases to lift structures which have settled.
- Fig. 6.1.13 shows mud jacking to stabilise a settled foundation in which concrete slurry grouting is pumped below the foundation to provide support down to the sound soil or weak soil.

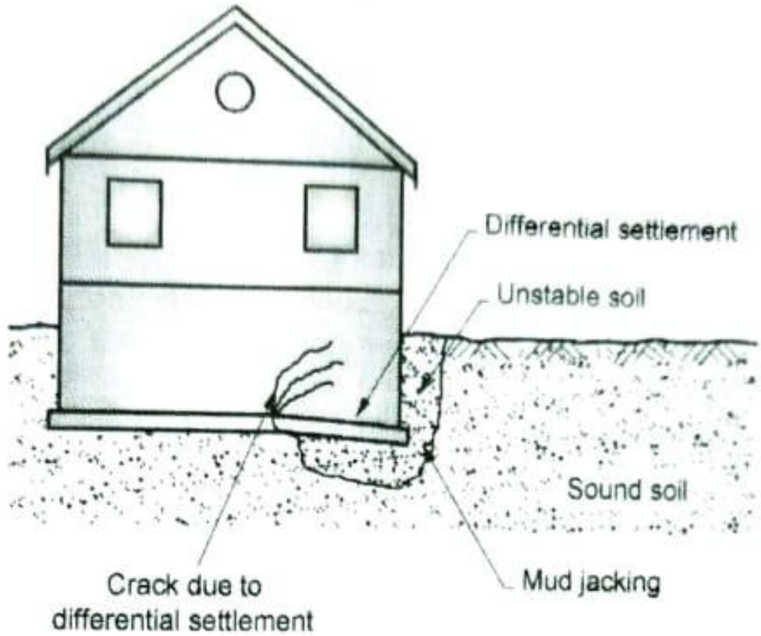
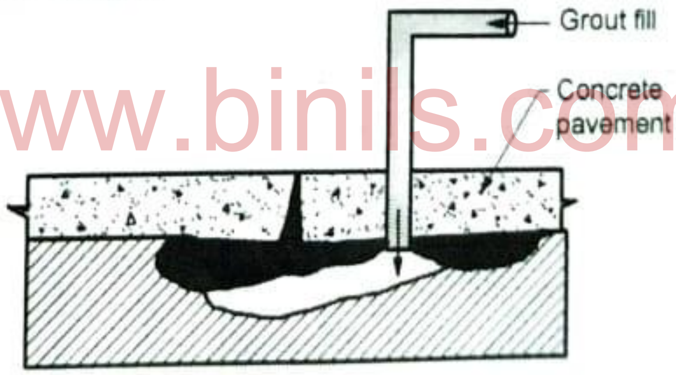
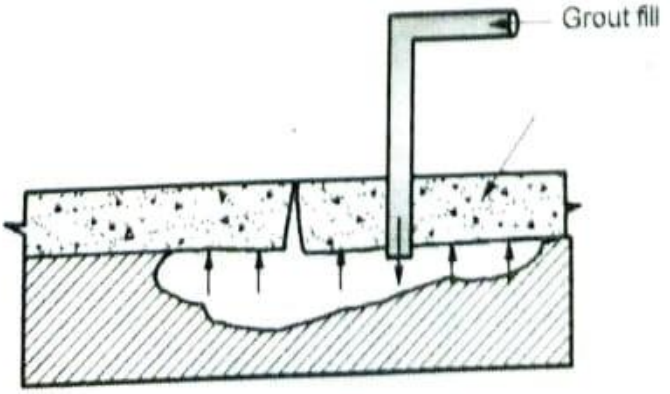


Fig. 6.1.13 : Mud jacking to stabilise a settled foundation

Fig. 6.1.14 shows grout fill the voids under pavement without lifting it.



(a) Before grouting



(b) After grouting

Fig. 6.1.14 : Grout fill the voids under pavement without lifting it

Syllabus Topic: Micro-piling and Underpinning for Strengthening Floor and Shallow Profile

6.1.7. Micro-piling and Underpinning

- A drilled and grouted non-displacement pile which is heavily reinforced and carries most of its loading on the high capacity steel reinforcement is called as micro- piling in which reinforcement and cement grout play a major role.
- In micro-piling, drilling, placing reinforcing steel and grouting play a vital role to bonds to the soil.
- In a process of micro-piling, the piles are drilled, grouted and injected using the hollow bars as drill rods and grouting ducts along with disposable special drill bits and rotary drilling methods.

Definition: When the piles are molded on the spot so as to obtain deep foundation and highly tensioned stress along the shaft, then it is called as micro-piles.

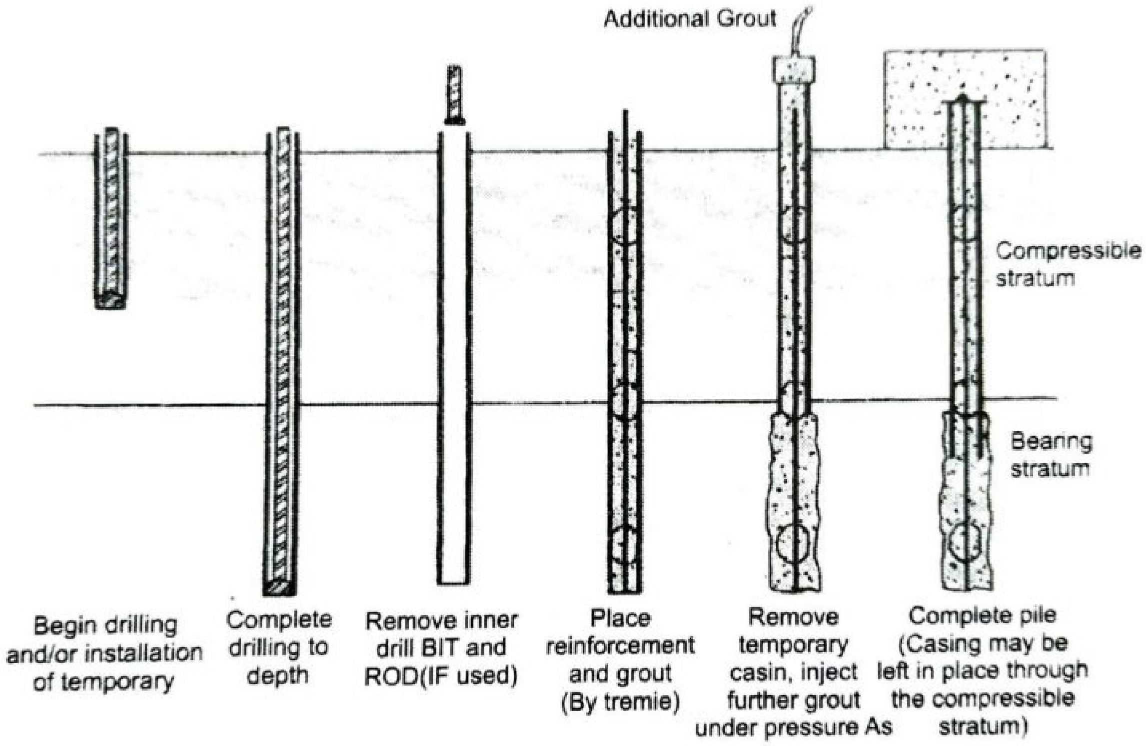
- Micro-piles are composed of sand and cement mortar and thoroughly reinforced throughout its length.
- Micro-piles are used in highly compact or consistent ground or in the ground where bedrock or rocky formation are found.
- Micro-piles are also called as pin piles, needle piles or root piles.

Advantages of micro-piles

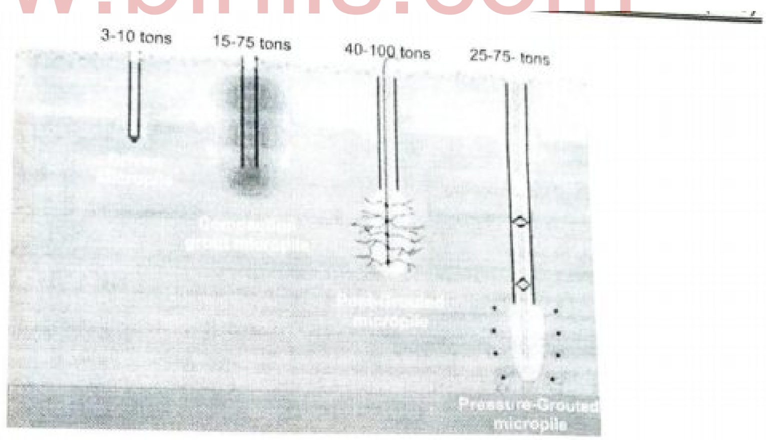
Following are the various advantages of micro-piles.

1. It provide drilling simultaneously. and grouting operation
2. It improve the ground (densification).
3. It provide fast-one-step installation.
4. It offers higher skin friction.
5. There is total single corrosion protection by design.
6. It allows the use of smaller equipment with minimum cost.
7. It allows low overhead and limited access installation.

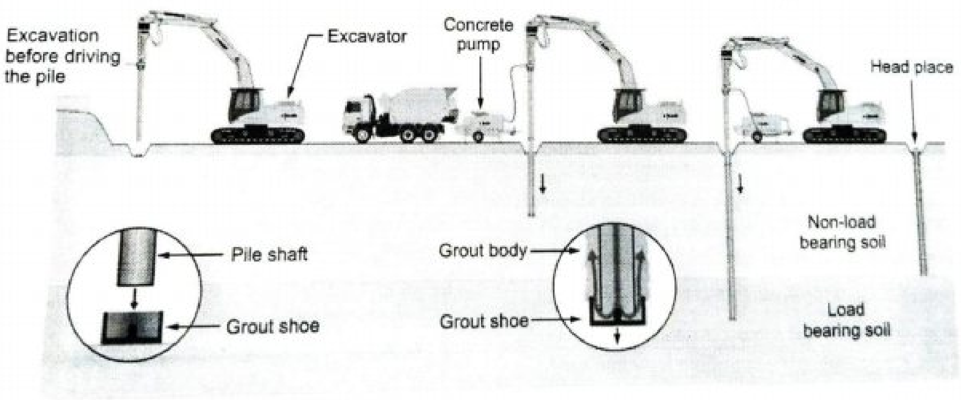
Fig. 6.1.15(a) and (b) shows micro piles.



(a) Micro-pile construction
Fig. 6.1.15



(b) Micro pile types



(c) Construction process of micro piles
Fig. 6.1.15 : Micro piles

6.1.7.1. Underpinning

Definition: Underpinning is the process of providing new foundation below the existing foundation without damaging the stability of existing structure

Underpinning may be required to meet the following requirements:

1. If deep foundation is to be construe following require providing having shallow foundation, the shallow foundation may face some problems and may need strengthening.
2. To strengthen existing foundation which has settled and caused cracks in the wall.
3. If the height of existing building is to be increased and existing foundation, if unable to bear increased load, may strengthening.
4. If basement is to be provided to the existing building and if depth and strength of existing foundation is 4. insufficient, then existing foundation may need strengthening

6.1.7.2. Methods of underpinning

Discuss the method of underpinning

Underpinning can be carried out by the following methods

Methods of underpinning

i. Pit method

ii. Pile method

1. Pit method

Types of Pit method

a) Alternate pit method

b) Cantilever needle beam method

(a) Alternate pit method

(i) Pit of size 1.2 to 1.5 m length and to a depth greater than the depth of existing foundation are excavated on either side of the existing wall.

(ii) To start with, pits are excavated at mid length of wall.

(iii) One section is taken at a time, for each section, a hole is made in the wall, above the plinth level and needle is inserted in the hole.

(iv) Needle may be either of timber or steel section.

(v) Bearing plates are placed above the needle to support the masonry above it.

(vi) Needle is supported on either side of the wall on wooden blocks and screw jacks, with this arrangement, load of wall above the needle beam is transferred on needle beam and no damage will be caused for a short period, if soil below the existing foundation is removed.

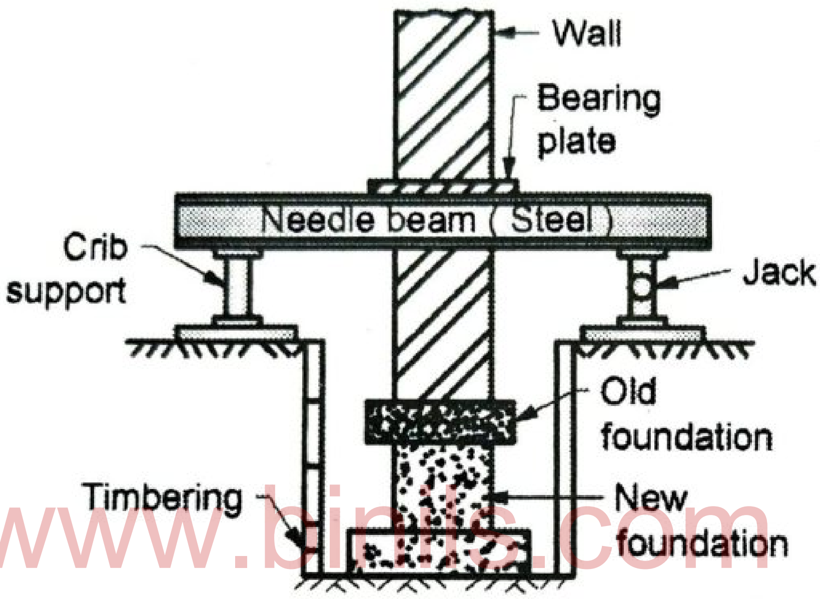


Fig. 6.1.16 : Pit method

(b) Cantiliver needle beam method

- If an interior strong column exists or if the foundation is to be extended only on one side or if sufficient space is not available to support the needle beams, outside the existing building, than cantilever needle beams may be used.
- Load is placed on the needle beam. Due to cantilever action, load of the wall is transferred on the needle beam and soil below existing foundation can be removed without causing any damage to existing building.

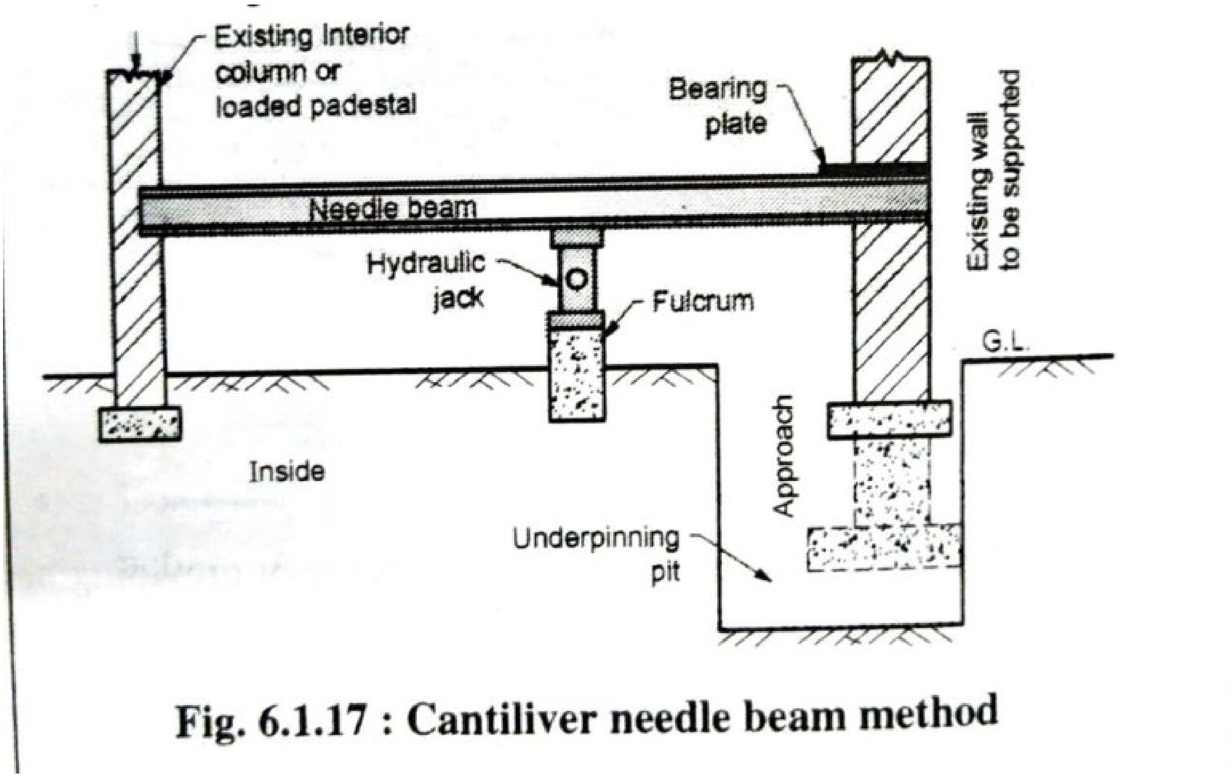


Fig. 6.1.17 : Cantiliver needle beam method

2. Pile Method

In this method

(1) Piles are driven at a regular interval along both the sides of the wall. Generally, bore hole piles or under reamed piles may be used.

(2) The piles are connected by concrete or steel needles penetrating through the wall.

(3) These beams act as pile caps also.

(4) This method is useful in clayey soil and in-water- logged areas.

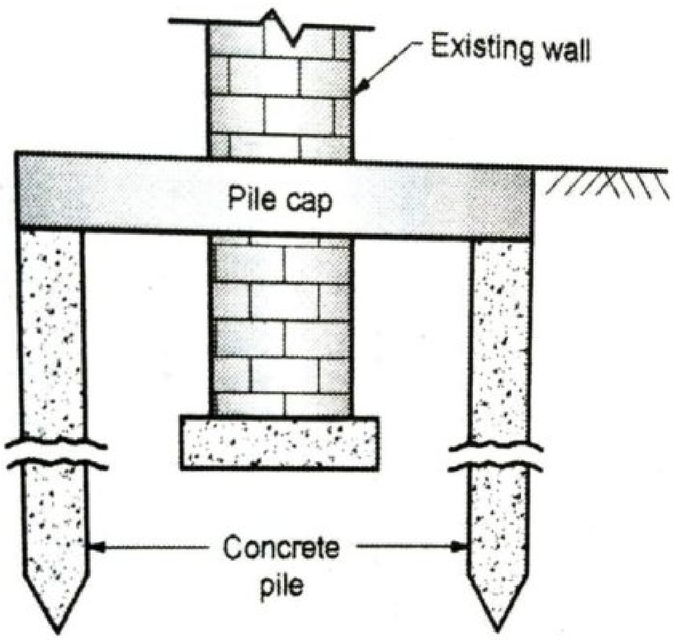


Fig. 6.1.18 : Pile method

6.1.8. Subgrade Waterproofing

- The construction practice in which the techniques of applying membranes and coatings to the foundation walls of the structure under street or ground level, as part of the building structure is called as subgrade waterproofing. It is also called as below-grade waterproofing.
- Below-ground or basement waterproofing are also the part of subgrade waterproofing.
- Effective waterproofing, water management techniques and hand-in-hand to keeping the below grade areas leak-free are the ways to protect subgrade areas such as parking, utility rooms, storage for maintenance, and tunnels for services, basement and communication conduits.
- Subgrade waterproofing design depends on various sources of information such as the soil profile of land, underground water conditions, foundation design the buildings, the ground slope around the foundation, irrigation systems used on landscaping and subgrade drain systems etc. There should be a combination of effective drainage and impervious membranes applied on the foundation during the construction resulting into a long-lasting subgrade waterproofing.
- Basement is generally an underground place constructed for many various purposes.
- Now-a-days, basement structure is generally found to be in commercial offices, factories, offices, complexes, food malls, market, buildings, multi-complexes and even

at houses because basement serves a good storage place which can be used for different purposes like;

(i) Parking areas,

(ii) Godowns,

(iii) Storage.

(iv) Security,

(v) Commercial needs, etc.

- Construction of basement should be done according to the building standards following all the norms and with all necessary precautions.

6.1.8.1. Subgrade Waterproofing Methods

Following are the various methods broadly used for subgrade waterproofing:

(1) D.P.C. for foundation

From the foundation, water may percolate from the adjacent ground and this water or moisture may rise in the wall and air drain is provided to external wall to check the moisture. The details of air drain is shown in Fig. 6.1.19.

The outer wall of the drain is kept above the ground so as to check the entry of surface water. A roof slab is provided on the top of air drain. D.P.C. is provided horizontally and vertically as shown in Fig. 6.1.19.

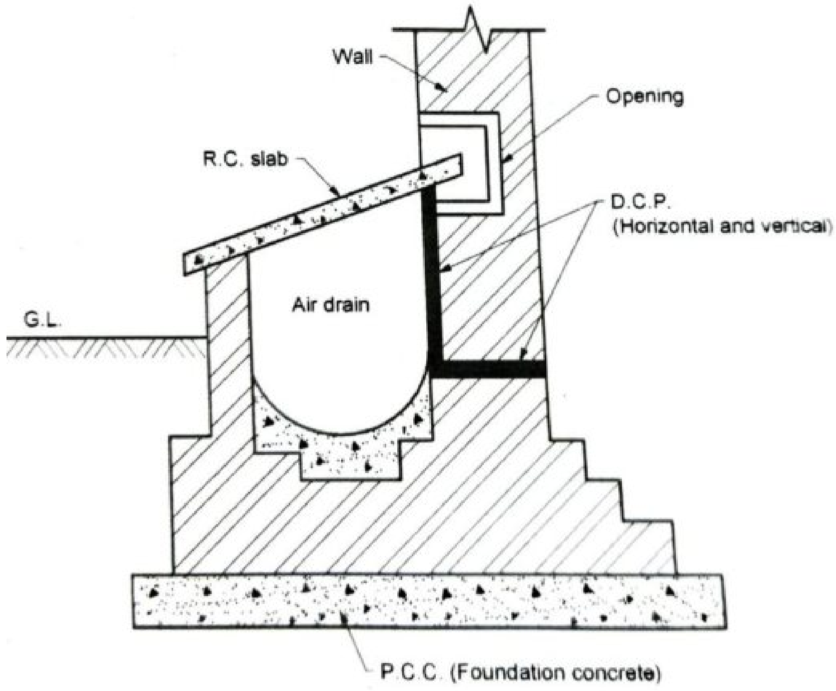


Fig. 6.1.19 : D.P.C. for foundation

(2) Need of DPC for basement

- In case of basement construction, there is more possibilities of leakage and seepage from the sides of the wall of the basement and from the foundation of basement and hence DPC treatment should be done by providing bituminous felts or mastic asphalt etc.
- Fig. 6.1.20 shows the basement construction which is more suitable under normal conditions.
- In such construction, P.C.C (Plain cement concrete) with appropriate proportion is done over the firm foundation and a coat of damp proof course (D.P.C) is applied and then bricks are placed flat or cement concrete is poured and leveled.
- Then the floor is casted in R.C.C. Then brick walls are constructed all around and one side of wall is constructed in concrete and bricks with providing the D.P.C (Damp Proof Course) throughout horizontally as well as vertically without any gap or break as shown in Fig. 6.1.20.
- D.P.C should be provided throughout without any gap so as to prevent any dampness. Any space which is remained in wall or concrete and D.P.C are grouted by cement.

cement.

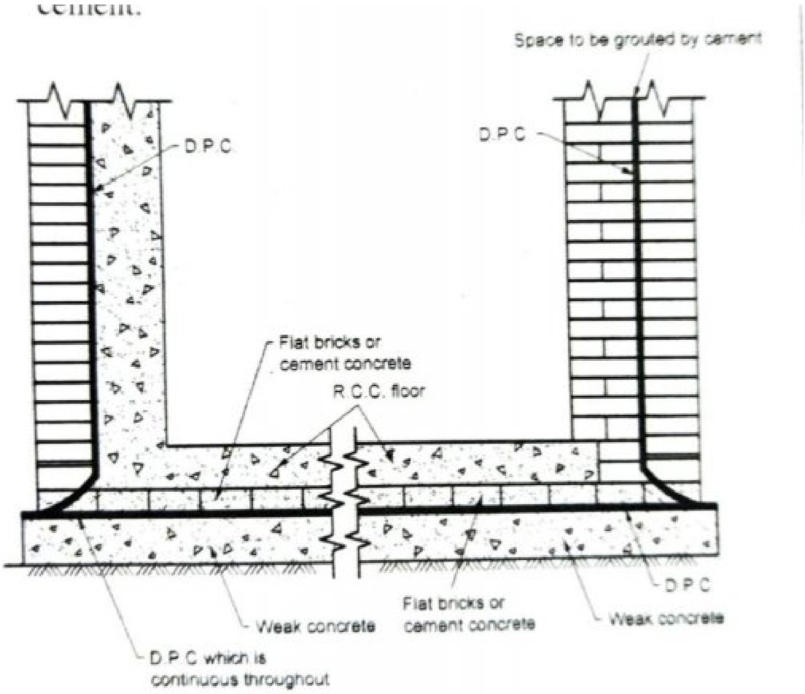


Fig. 6.1.20 : Basement construction provided by DPC

Fig 6.1.21 shows basement construction under heavy pressure

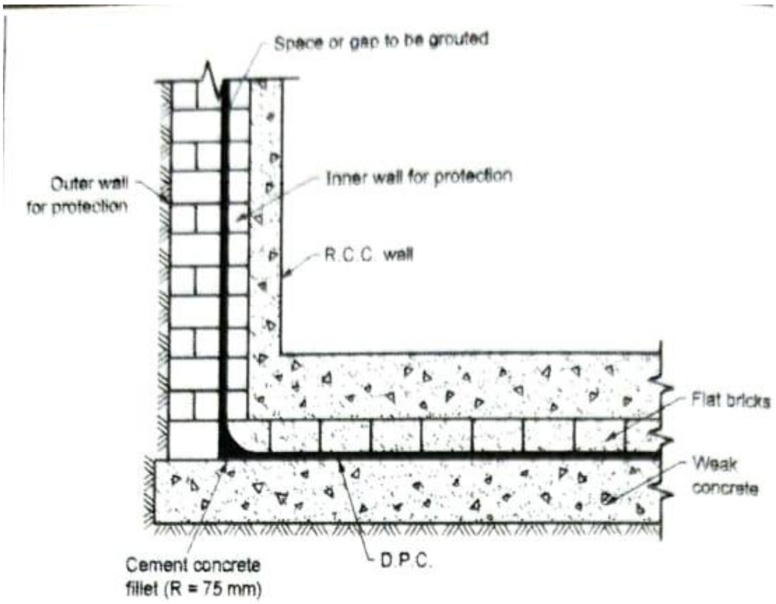


Fig. 6.1.21 : Basement construction provided by DPC under heavy pressure

Fig. 6.1.22 shows treatment given to basement with provision of inner reinforced cement concrete wall throughout.

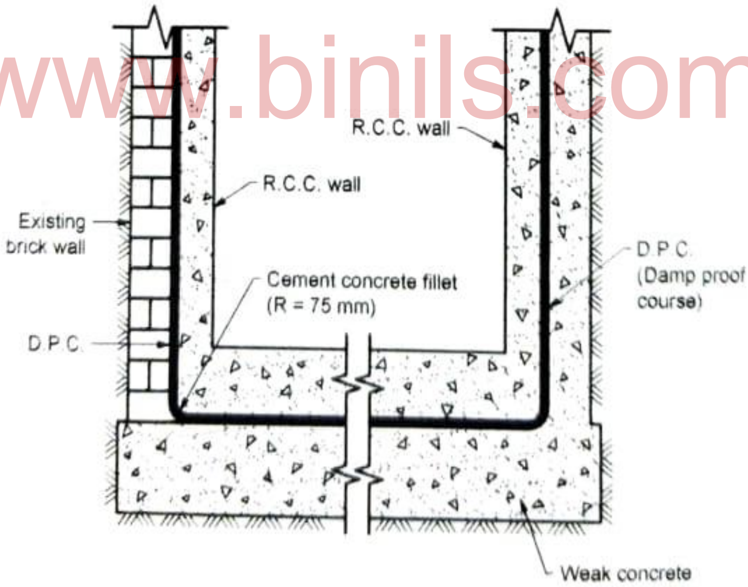


Fig. 6.1.22 : Treatment given to the existing basement

3. Positive-side waterproofing

- The positive side means the waterproofing treatment given to the outside surface of the foundation and closest to the soil. Positive-side waterproofing is generally suitable and preferred over negative-side methods since it is more effective method.
- Positive-side waterproofing consists of systems and treatments to be applied the outside surface of the foundation and closest to the soil as follows,

(i) Use of sheet systems

(ii) Fluid-applied seamless membranes

(iii) Application of bentonite clay

(iv) Use of hybrid systems combining a fluid-applied membrane in conjunction with an integral fabric.

4. Negative- side waterproofing methods

- The negative side waterproofing methods consists of applying of the coating inside of the foundation in acrylics crystalline, or latex additives or in a cement and sand mixture.
- Fig. 6.1.23 shows subgrade waterproofing for foundation.

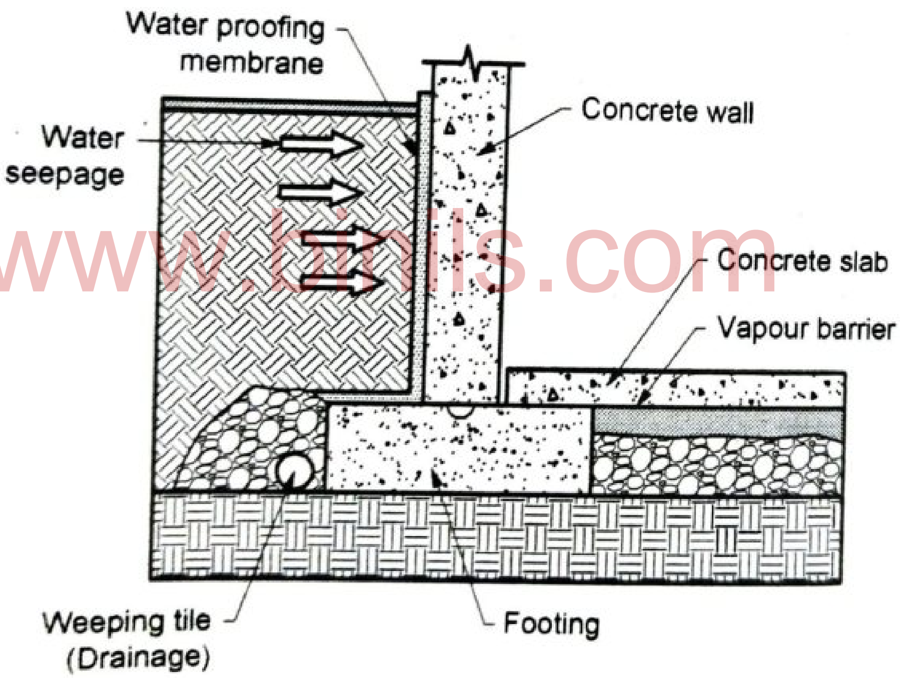


Fig. 6.1.23: Subgrade waterproofing for foundation

6.1.9. Soil Stabilisation Techniques

GQ. Define soil Stabilization.

Definition: The engineering properties of poor soils can be improved by the use of admixtures is known as soil stabilization.

The stabilized soil may form the sub grade or wearing layer of road.

GQ. Explain the concept of soil stabilization.

There are various method being used to improve or to alter the properties of a soil in order to improve the engineering performance for the foundation point of view.

Methods

(i) Properties of soil can be improved by using various types of admixtures.

(ii) Properties of soil can be improved by not using the admixtures

(iii) Combination of (i) and (ii)

- Excess water from soil can be drained and followed by the compaction is the method of not using admixtures i.e. method (i)
- Soil properties can be altered or improved by using admixture like lime, cement, fly ash, chemicals etc. i.e. method (ii).
- Addition of missing fraction of soil and then compacting it is the example of combination of method (i) and method (ii).

Syllabus Topic: Necessity of Soil Stabilization

6.1.9.1. Necessity of Soil Stabilization

GQ. State the necessity of soil stabilization.

1. To alter the properties of soil to suit the traffic requirements.
2. To increase shear strength of soil.
3. To minimize the swelling due to wetting and shrinkage bearing.
4. To increase bearing capacity of soil.
5. To prevent the crack in soil due to reduction of moisture content.
6. To increase the stability of slopes.
7. To increase strength against displacement and deformation.
8. To increase the density of soil
9. To reduce the settlement of structure
10. For improving and performance under heavy moving and impact loads in conditions such as subgrade of roads, runways in air parts.

6.1.9.2. Different Methods of Soil Stabilization

GQ. State any four methods of soil stabilization and explain any one.

GQ. Enlist the various methods of soil stabilization and explain any one

Different methods of soil Stabilization

Following are the various methods of soil Stabilization:

1. Mechanical Stabilization. stabilization or mechanical soil
2. Lime stabilization or soil-lime stabilization.
3. Cement stabilization or soil cement stabilization.
4. Bitumen stabilization or soil-Bitumen Stabilization.
5. Fly-ash stabilization or soil-fly-ash Stabilization.
6. Soil reinforcing techniques.
7. Chemical stabilisation.
8. Stabilization by grouting.
9. Stabilization by heating.

1. Mechanical stabilisation

GQ. Explain mechanical stabilisation.

- This is the most commonly used method of soil stabilization. It is simple and economical.
- Following three cases will be considered for sand-clay road where mechanical stabilization is done :

Case 1: Sandy soils i.e. when sand is present and clay is absent.

Case 2: Clayey soils i.e. when clay is present and sand is absent.

Case 3: Neither sand nor clay is present to a sufficient extent.

Case I: Sandy soil

- When the sub grade is sandy, the existing road surface is cleaned. It is shaped to require section. The top layer of sand of about 50 mm to 100 mm depth is removed.

- It is stacked on the sides. The layer of selected clay is then spread upon the surface and it is again covered by the sand which was previously removed.
- The two materials are mixed under optimum moisture condition by means of ploughs, burrows or blade graders. Mixing of material is carried out till uniformity of texture and moisture are attained. Finally the compaction is done by medium roller of sheep foot roller.
- **Case II: Clay Soil**

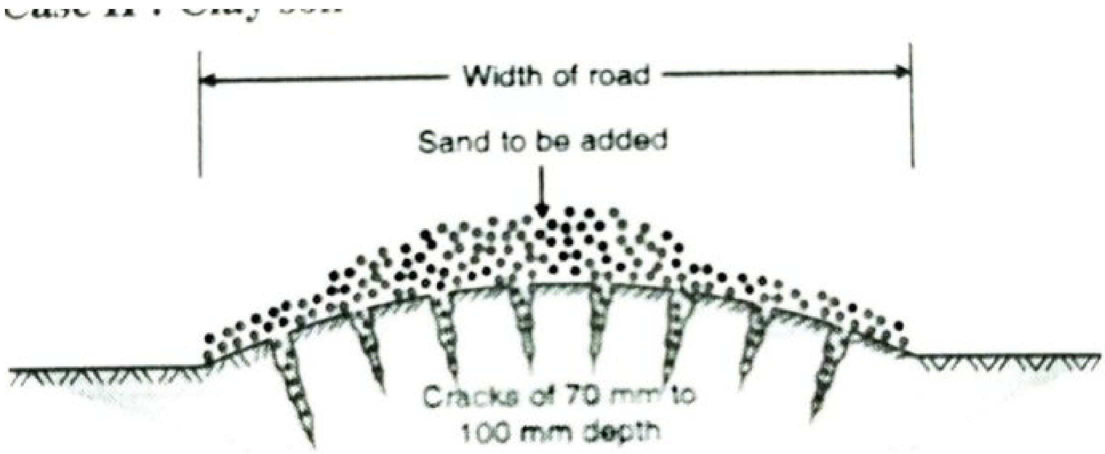


Fig. 6.1.24 : Stabilization of clayey soils

- When the sub grade contains a large amount of clay, the road surface is cleaned and it is shaped to required section.
- The top 50 mm to 100 mm thickness of clay is loosened or disturbed by means of a plough so that it contains cracks extending to a depth of about 70 mm to 100 mm as shown in Fig. 6.1.24.
- The selected sand is spread and well mixed.
- Then compaction is carried out by sheep foot roller and then medium roller.

Case III: Neither sand nor clay is present to a sufficient extent

- When the sub grade does not contain sand or clay to considerable extent.
- Materials (i.e. sand and clay) are brought to site and well mixed in required proportion.
- The mixture is spread on road surface. Then it is compacted by sheep's foot roller first and then by a medium roller.

- In all above three cases, it should be seen that the final section of the road surface has a camber of 1 in 24 to 1 in 36 to drain the surface water.

GQ. Explain the procedure of mechanical stabilization

Procedure of mechanical stabilisation

- Following points shows the stepwise procedure of mechanical soil stabilisation which can be preferred in order to obtain stabilised road:

(i) Designing of mix proportions

- There is which are further samples of really availab material which am further mixed in various proportione with different moisture content. Then several trial mixes of soil and aggregate are prepared.
- After this, there is determination of the dry density and strength of these trial mixes and then out of this, the one of the best and suitable trial mix is adopted for field work. Thus the designing of various proportions are being carried out and then selected the best one.

(ii) Collection and stacking of required material

- After designing of selected mix proportion, the required material and required quantity are brought to the road site and stacked along the sides of the proposed road.
- Various machinery or manual labour can be used for the various operation like excavation, haulage and mixing based on the type and size of the work.

(iii)Preparation of sub-grade

Then sub-grade is prepared.

(iv) Mixing of material to designed proportion

- Mixing of designed proportions of material is done and water can be added as per the requirement.
- When there is excess moisture present in the soil and the aggregates, then it is necessary to expose the mix in sun for proper drying.

(v) Spreading and compaction of wet mix

- Then there is spreading of wet mix of soil and aggregates to the required grade and thickness and it is then properly compacted by rollers.

- The process of compaction by rollers is kept continued in order to obtain the required compaction to be achieved.

(vi) Field control tests

- Field control tests are carried out before during and just after the compaction in order to determine dry density and moisture content and necessary modification is done in the field if required.

(vii) Road opened to traffic

- After hardening the compacted layer on drying, the well stabilised road is then kept opened to movement of traffic.

GQ State the advantages an machanical stabilization (4 Marka)

Advantages of mechanical stabilisation

Following are the various advantages of mechanical stabilisation

(i) It is most economical method

(ii) It is simple to carry out

(iii) Basic properties of soil are retained or not changed.

(iv) It improves the soil properties.

(v) It is rapid and construction can be immediately started

(vi) It require less time as compared to other type of stabilisation

Disadvantages of mechanical stabilisation

Following are the various disadvantages of mechanical stabilisation:

(i) It needs special equipment for various construction operation and activities.

(ii) It is not suitable for all types of soils.

(iii) It is suitable and effective upto a certain extent.

GQ. State the factors affecting the strength and stabilize of mechanical stabilization. (4 Marks)

Following are the various factors which are responsible to stabilise and strength of mechanical stabilisation:

(i) Designing of mix proportions.

(ii) Grading of materials.

(iii) Compaction of material.

(iv) Salt content in soil

(v) Properties of aggregates and soil

(vi) Special equipment.

2. Lime stabilisation

GQ. Explain lime stabilization of soil.

- This type of stabilisation is also called as soil lime stabilisation.
- Lime stabilisation is mostly suitable and effective for plastic clays
- Slaked lime chemically known as CaOH is found to be more effective in such soils.
- Lime stabilisation is generally suitable and hence used to stabilise road bases and its sub-grade
- Lime can be used alone in process of stabilisation or it can be used in combination with cement, fly ash or bitumen or tar
- For coarse grained soils, the use of lime is 2 to 8% and it is 5 to 10% in case of plastic soils
- Lime provides good cementing action and hence binds the soil particles well together.
- Lime changes the nature of adsorbed moisture layer over the particles and decreasing the plasticity index and hence resulting the increase of strength.

Advantages of lime stabilisation

GQ. State the advantages and disadvantages of lime stabilization. (4 Marks)

(i) It is cheap and hence economical.

(ii) No need of expert supervision.

(iii) There is easy availability of lime material.

(iv) It takes a good compaction and provide a good stabilised road.

Disadvantages

(i) Such type of stabilization is only suitable and effective for plastic clays.

(ii) There is no drastic alterations in soil properties.

Factors affecting the lime stabilisation

GQ. Enlist the various factors affecting the lime stabilization. (4 Marks)

Following are the various factors broadly responsible the lime stabilisation:

(i) It depends upon the type of soil.

(ii) It depends upon the lime control.

(iii) Amount of compaction.

(iv) Process of curing

(v) Addition of additives

Stepwise procedure of lime stabilisation

GQ. Describe the stepwise procedure of lime stabilisation(6 Marks)

Following points shows the stepwise procedure of lime stabilisation

(i) Preparation of trial mixes for best mix design

- There are several trial mixes required to be prepared and then amount of lime water of compaction required to obtain the best soil time stabilisation is found. Thus the best and selected mix design is adopted for soil- lime stabilisation.

(ii) Preparation of sub-grade

- The surface of road is properly cleaned and excavated and then sub-grade is prepared to desired shape and size.

(iii)Mixing of lime material and soil

- The mixing of soil to be stabilised and lime is carried out with water at required quantities.

(iv) Pre-conditioning and Remix

- Wet mix is kept for 24 hours for pre-conditioning. There is remix of soil with addition of more lime if necessary and desired.

- There is addition of additive such as fly-ash, pozzolana, surkhi etc being carried out in required amount and then mixed properly with soil and lime.

(v) Spreading and compaction of wet mix

- The wet mix is properly spread on sub-grade to the required gradient and thickness followed by proper compaction with rollers.

3. Cement stabilisation or soil-cement stabilisation

GQ. Explain cement stabilization method of soil stabilisation.

Cement stabilisation

- When the soil is stabilised with binding material like cement, then it is called as cement stabilisation. Hence, it is also called as soil-cement stabilisation.
- There is chemical reaction of the cement with silicon present in soil during the hydration process. Such type of chemical action due to cement can be possible in non-cohesive and coarse-grained soils.
- Note that there is very few particles causing the cement bond with fine-grained cohesive soil.
- Method of cement stabilisation is almost suitable for all inorganic soils excluding the black cotton soils:
- It is important to mention that if organic matter and sodium sulphate ($NaSO_2$) are present in soil, then it provides the difficulties for cement stabilisation.
- Well graded soils consisting of fine fraction lesser than 50% and plasticity index I, less than 20 providing the best results in case of cement stabilisation.
- Note that there is a requirement of 5 to 15% of cement for the dry weight of soil, however, actual requirement can be found by trial and error or by taking a number of trial mixes.
- Cement having the compressive strength of 2.5 to 3 N/mm^2 (or 25 to 30 kg/cm^2) is sufficient or adequate for stabilisation for tropical climate such as India, etc.
- For good and proper stabilisation, gravels of 5 to 10%, sands of 7 to 12%, silts of 12 to 15% and clays of 12 to 20% are required.

- When there is mixing of soil, cement and water thoroughly, then it provides a better soil cement, but when the process of hydration is started, then mixing should not be continued or should be discontinued.
- For getting the appropriate strength due to hydration reaction, there should be curing (i.e, keeping the mix moist) at least for 7 days.
- In order to reduce the consumption of cement or in order to enhance the stabilisation, some type of admixtures can be used.
- Lime and calcium carbonate ($CaCO_3$) are being used along with cement in case of clays and soils containing the organic matter.
- For various different and practical situations, fly ash, sodium carbonate ($NaCO_3$) and sodium sulphate ($NaSO_1$) are also mixed with the cement.

Advantages

GQ. Write the various advantages and disadvantages cement stabilization. (4 Marks)

Following are the various advantages of semant stabilisation

(i) It provides permanent solution.

(ii) It provides a large and better strength

(iii) It is suitable for loose soils and non-obestve soils,

Disadvantages

Following are the various disadvantages of cement stabilisation

(i) Cement stabilisation is costly and hence it is not economical

(ii) It consist of complicated procedure

(iii) It is not suitable for clays, expansive soils like black cotton soil and organic soils

Factors affecting the cement stabilisation

GQ. State the factors affecting the cement stabilization (4 Marks)

Following are the various factors on which the cement stabilisation depends:

(i) Nature and type of soil

(ii) Amount of cement used

(iii) Mixing of various ingredient

(iv) Amount of compaction

(v) Curing,

(vi) admixture

(i) Procedure of soil-cement stabilisation

GQ. Write the procedure of cement stabilization.(6 Marks)

Following points shows the stepwise procedure of soil- cement stabilisation:

(i) **Preparation of mix design of trial mixes**: There are a number of trial mixes being prepared, tested and compacted in order to obtain the best mix for soil- cement stabilisation. It is also termed as mix design for soil-cement stabilisation.

(ii) **Preparation of sub-grade:** The road surface to be stabilised is cleaned, excavated and sub-grade is prepared to the desired shape; size and thickness.

(iii) **Pulverslation:** The soil is pulverised and dry mixed with cement

(iv) **Mixing**: There is proper mixing of soil, cement and water in required quantity.

(v) **Spreading of wet mix and compaction**: The wet mix is spread on sub-grade to required grade and thickness and it is compacted by rollers.

(vi) **Curing:** The compacted layers are cured properly. Moist curing is preferred by covering with moist soil.

(vii) **Wearing surface:** It is provided in order to protect the base course from abrasion.

(viii) When the wearing surface of road hardens, then the road is opened to the movement of traffic.

4. Bitumen stabilisation

GQ. How bitumen is useful in stabilization of soil ? Explain?

- Bitumen stabilisation is best suited for pavement construction. The tar and asphalt are the main component and hence used in this method.
- Bituminous material with a very high viscosity is properly mixed with soil. The viscosity of bitumen can be decreased by heating, emulsifying or by cut back process.
- Bituminous material are added in order to provide a better cohesion and to reduce water absorption. Bituminous material provide a better binding action with soil as well as water proofing action and thus increases the strength.

- Following are the various types of biumen stabilisation:

(i) Sand bitumen

(ii) Water proof mechanical stabilisation

(iii) Soil bitumen

(iv) Oiled earth

Advantages

GQ. Write the advantages and disadvantages of bitumen stabilization.(4 Marks):

Following are the various advantages of bitumen stabilisation:

(i) It is durable

(ii) It is cheaper than that of soil-cement stabilisation

(iii) It is suitable for roads, sub-grade and water proof structure.

Disadvantages

Following are the various disadvantages of bitumen stabilisation:

(i) It is not suitable for foundation.

(ii) It is suitable for only some of the types of soil

(iii) It provides the strength rather than water proofing

Factors affecting soll-bitumen stabilisation

GQ. Enlist the factors affecting bitumen stabilization.(2 Marks)

Following are the various factors responsible for soil- bitumen stabilization:

(i) Nature, type of soil and structure of soil

(ii) Mixing of material,

(iii) Amount of bitumen to be used

(iv) Compaction

(v) Curing

(vi) Addition of admixtures

5. Fly ash stabilisation

GQ. Explain the fly-ash stabilisation?(4 Marks):

- Fly-ash is the bye-product generated from thermal power station. It is formed due to the combustion of mineral coal.
- There is much difficulty for its disposal and hence if it is used in the process of stabilisation, the question of its disposal is automatically solved.
- When fly-ash is used in soil stabilization, it performs the actions of filler or pozzolane material and it hydrates by forming the cement like gel.
- Note that, the fly-ash is rarely or not commonly used in soil stabilisation, but it can be used in combination with other methods of soil stabilisation. Thus it performs the role of admixture to enhance the stabilisation.

Advantages

GQ. State the advantages and disadvantages of fly-ash stabilization.(4 Marks)

Following are the various advantages of fly-ash stabilisation :

(i) It is cheap and hence economical.

(ii) It can be recycled.

(iii) It is eco-friendly.

(iv) It is simple to use.

(v) It is rapid in the process of stabillisation.

Disadvantages of the fly-ash stabilisation

Following are the various disadvantages of fly-ash stabilisation :

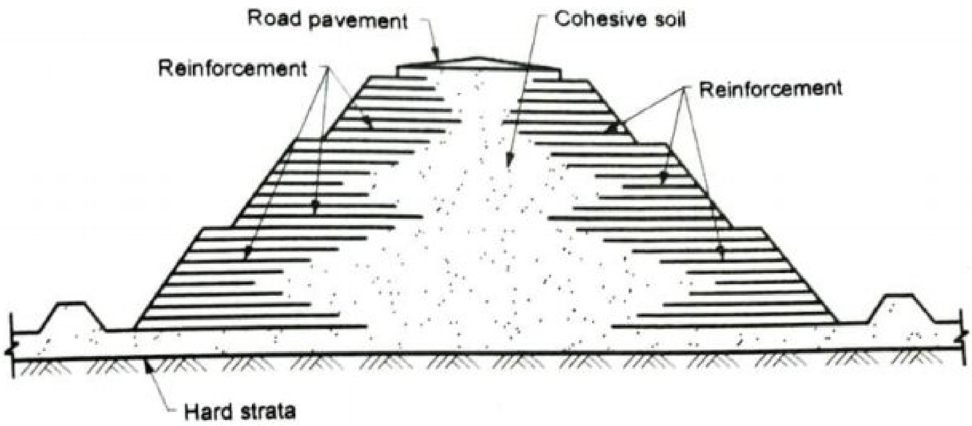
(i) Its enhancement is not substantial.

(ii) It is not always available as like cement.

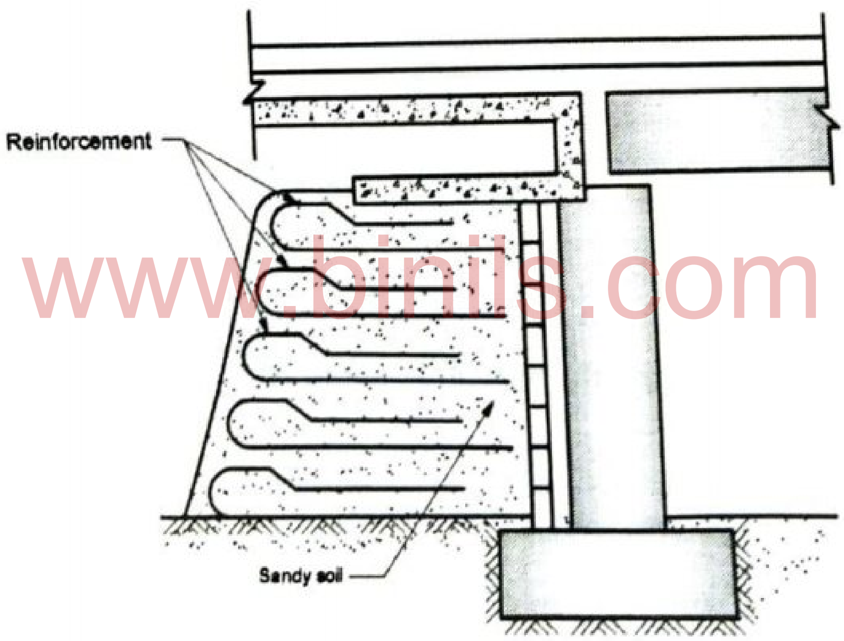
6. Soil Reinforcing Techniques

- When the soil is loaded by the structure, then soil is not able to transfer all the forces arising in a structure, since the soil have relatively low tensile strength. Hence it is essential and necessary to make the soil reinforced by geosynthetic materials like geogrids, geotextiles or geocomposites, wire mesh rod of metals, wire grid, horizontal strip of metal which increases the tensile strength of soil.

- The geosynthetics products used as a reinforcing element in soil reinforcing techniques, hence term used for such soil is reinforced soil.



(a) Soil reinforcement techniques used in road embankment



(b) Soil reinforcement in bridge abutment

Fig. 6.1.25 : Soil reinforcing techniques

- To ensure the satisfactory performance of the reinforcement, a low elongation under stress and a proper design with respect to the type of soil which to be reinforced is necessary.
- Geogrids are more suitable for non-cohesive soil like sand or fine aggregates and grainy soil containing gravels
- Geotextiles or reinforcing geocomposites are more suitable for cohesive ie, clay and fine-grained soils Le loess. See the Fig. 6.1.25 for better understanding of soil reinforcing techniques in road embankment and bridge abutment.

- The main object to provide the soil reinforcing techniques is to increase tensile strength in the earth mass in locations where the shear stresses are developed and finally it increases the stability of the structure

- A geotextile also acts as a filter in the earth dam. Fig. 6.1.26 shows a typical example of filtration function of geotextiles.

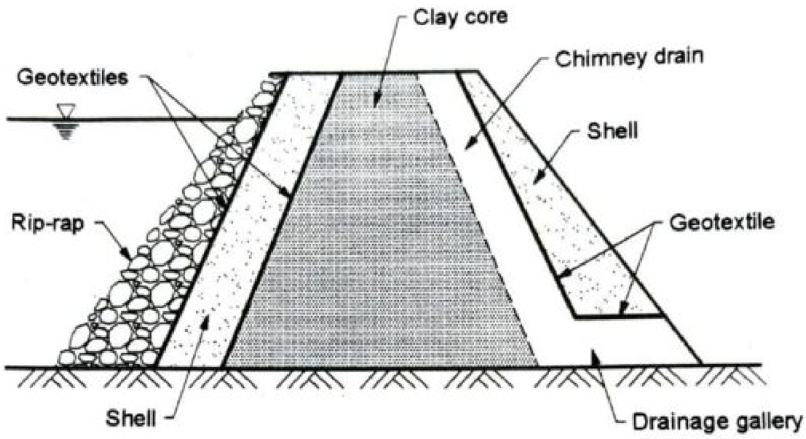


Fig. 6.1.26 : Filtration function of geotextiles

Fig. 6.1.27 shows the soil reinforcement technique below road pavement in hilly areas.

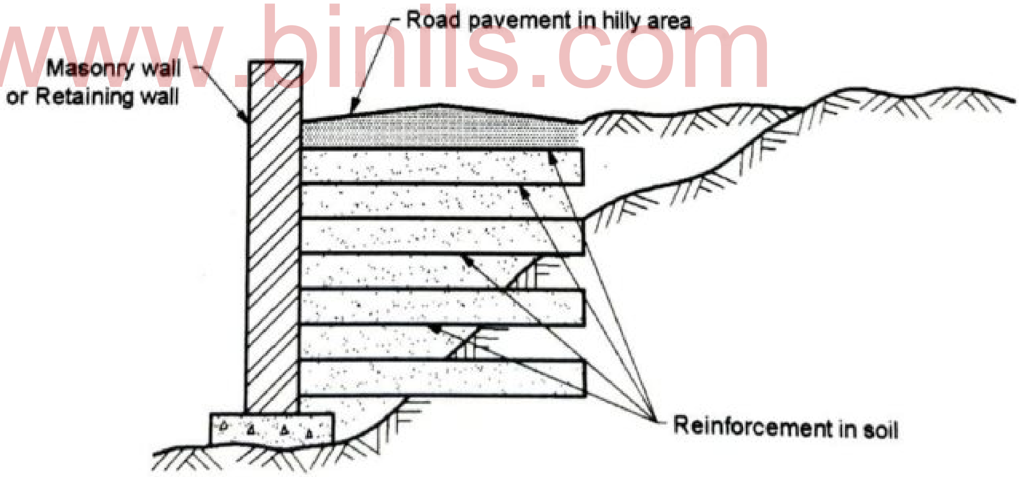


Fig. 6.1.27 : Soil reinforcement technique in hilly areas

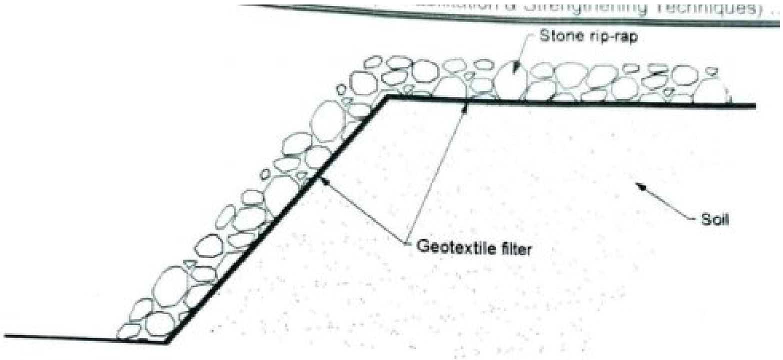


Fig. 6.1.28 : Geotextile for erosion control

- Fig. 6.1.29 shows the fabric reinforced wall which increases the stability of retaining wall.

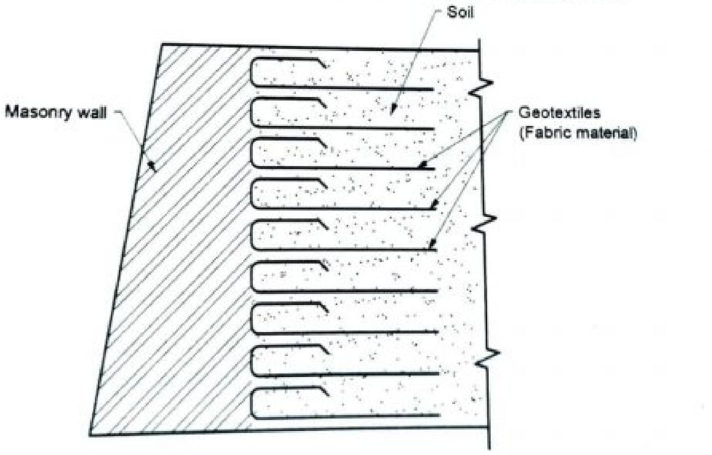


Fig. 6.1.29 : Retaining wall with fabric reinforced material

UNIT V

DEMOLITION

Demolition Techniques, Demolition by Machines, Demolition by Explosives, Advanced techniques using Robotic Machines, Demolition Sequence, Dismantling Techniques, Safety precaution in Demolition and Dismantling

5.1. <u>ENGINEERED DEMOLITION TECHNIQUES</u>

5.1.1. DEMOLITION

- Demolition means dismantling, razing, destroying or wrecking any building or structure or any part there of pre-planned and controlled methods.
- For any demolition of building, detailed survey and assessment of building is required.
- Demolition plan must be prepared based upon the inspection and it should be submitted to local authority.
- Plan must be prepared based upon the noise, vibrations and dust creation during the demolition process.

5.1.2. SURVEY OF BUILDING OR STRUCTURES

- The survey of building or structures includes following surveys:

❖ **Building survey - includes following details:**

- Drawing records
- Material survey
- Hazardous material

❖ **Structural survey-consists of data as follows:**

- Drawing records
- Special structure
- Behavior

5.1.3. DEMOLITION PLAN

Demolition plan should include the followings:

- A plan showing the location of building to be demolished
- Detailed topography of structure and its surround with contours

- Layout plan
- Structural transferring system
- A plan showing all the precautionary measures
- A plan showing the procedure for the demolition of each particular area
- If mechanical machinery is used then route of movement of machinery should be included.
- A plan for handling and disposal of debris

5.1.4. PRINCIPLES OF DISMANTLING

Primary Dismantling

- To break up the structure with an aim to reduce the height and size of the elements
- To break the structural elements into handle able pieces for immediate removal from on-site location

Secondary Dismantling

- To reduce the size of demolished debris for disposal, salvage of swap or processing.

5.1.5. DISMANTLING METHODS

Primary dismantling methods

Some of the primary dismantling methods are:

- Splitters
- Non explosive cracking agent
- Controlled demolition
- Thermal lancing
- Crane and ball method
- Diamond sawing
- Robotic machines

Secondary dismantling methods

The following methods are secondary dismantling methods:

- Rock breaker

- Jack hammers
- Concrete pulverizes
- Hand held clippers
- Hydro demolition

5.1.6. FACTORS AFFECTING THE SELECTION TECHNIQUES OF DEMOLITION

- The following are the some of the factors affecting the selection of demolition techniques:
- **Type of structure** - demolition technique depends upon the type of structure or load transferring system like load bearing masonry wall, reinforced concrete frame structure, steel structure, etc.
- **Size**-size of structure affect the demolition process. If the size of structure is small no need of special methods. It can be demolished by common methods.
- **Duration** - limitation time period affect the selection of demolition technique
- **Location of structure** - based upon the location of structure (city, town or village) demolition methods are selected
- **Limitation of noise, dust and vibration**
- **Availability of equipment's**
- **Skill of labors**
- **Safety**
- **Behavior of structure**
- **Foundation support**
- **Adjacent structure**

5.1.7. DEMOLITION TECHNIQUES

★ The various demolition techniques are described below:

❖ **Top-Down Demolition by Manual**

- By the name it indicates the method that proceeds from top to bottom that is from roof to ground.
- For reinforced concrete buildings, jack hammers are used for break down the concrete.

- Oxy-acetylene torch used for cutting the reinforcement The reinforcement shall remain until all the concrete connecting by the reinforcement is broken away.

Top-down demolition by manual follows the order:

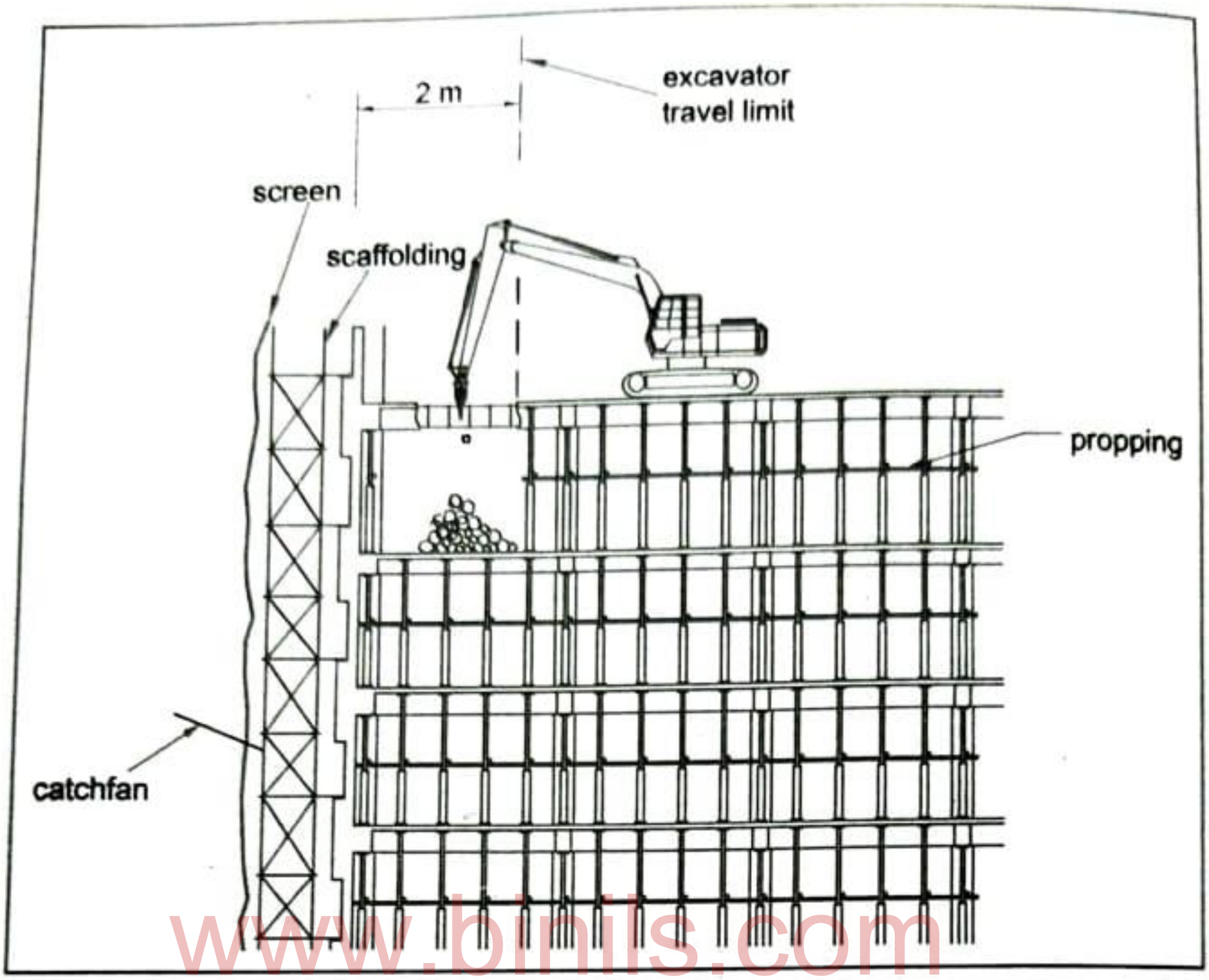
- All cantilevered structures shall first be demolished.
- When demolishing roof structure, all water tanks and lift machine rooms shall be demolished in top - down sequence
- Demolition of the floor slab shall begin at mid span and work towards the supporting beams.
- Demolition of floor beams in the order as cantilever beams, secondary beams, primary beams.
- Non-load bearing walls shall be removed prior to demolition process.
- Columns and load bearing walls shall be demolished after removal of beans on top.

Top-Down Demolition by Machines

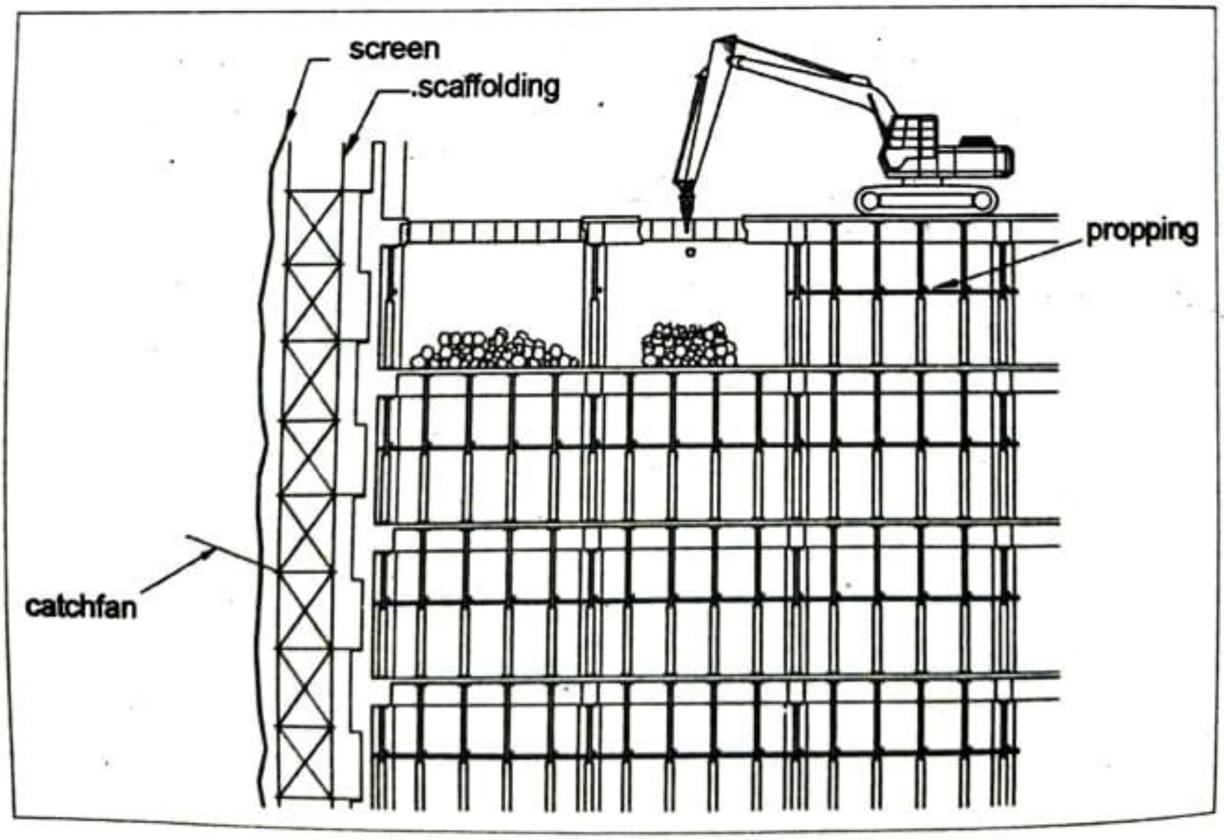
- The demolition of structure starts with the lifting of mechanical machine on the building top floor.
- When rope or tie wire is used to pulling the workers stay away from the process.
- The capacity or strength of wire shall be at least 4 times the anticipated load.

Top-down demolition by machine follows the order:

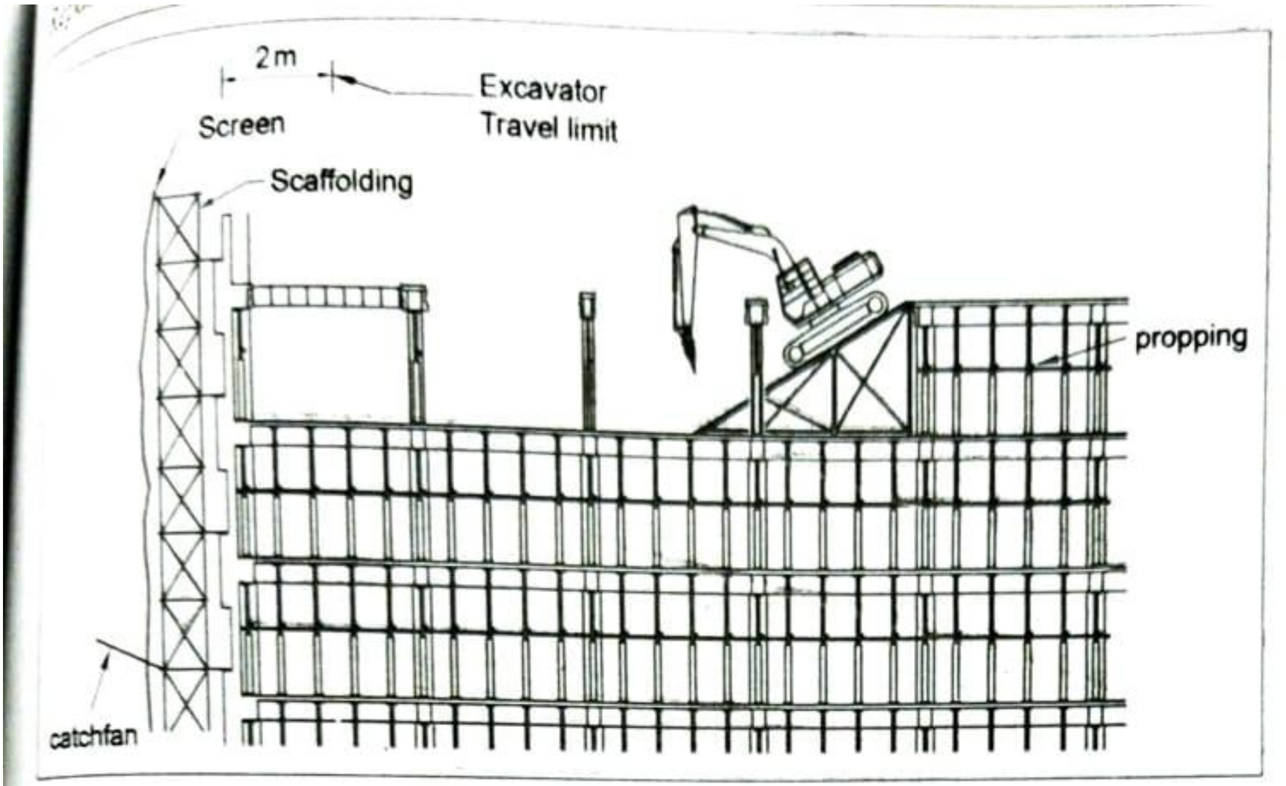
- Prior to demolition all cantilever members, and internal floor shall be first demolished.
- Sequence of structural elements will be as slab, secondary beams, primary or main beams.
- Mechanical plant shall be descending from the floor with temporary access ramp.
- When a mechanical plant has just demolished above floor, the structure member may be demolished by mechanical plant, simultaneously.
- The wall panel and column shall be demolished by gradually breaking down or by pulling down in controlled manner.



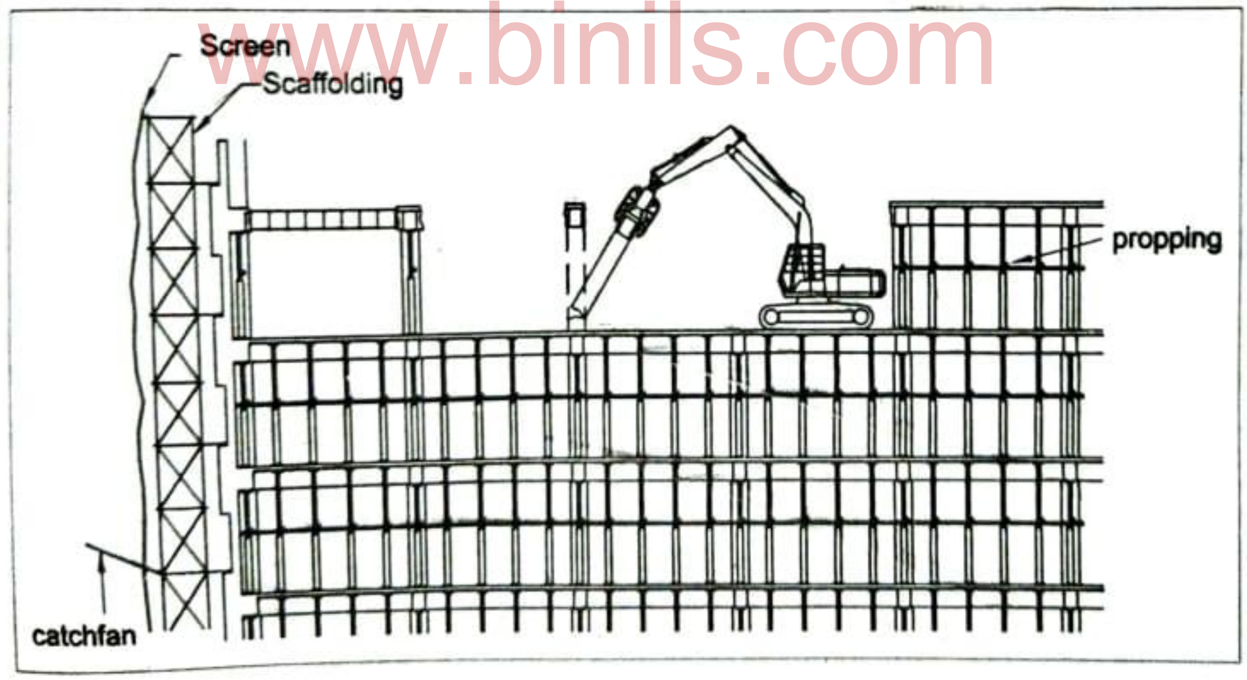
1. Demolition of Slabs and Beams



2. Continue Demolition of Slabs and Beams



3. An access ramp of steel structural frame to allow machinery to climb down to the next floor below



4. Demolition of interior column may be needed to create access and working room for exterior wall demolition. To demolish column by first pre-weakening the bottom, then dismantled by machine in fully controlled motion

Fig. 5.18. Steps in top – down demolition by machines

❖ **Hydraulic crusher**

- Equipment can be operated from the ground outside the building.
- This method is suitable for silos, chimney, dangerous building.
- Minimum clear space of half of building height as a safety zone for falling debris as shown in the Fig. 5.19.
- To minimize dust, the structure shall be presoaked with water before the demolition started.

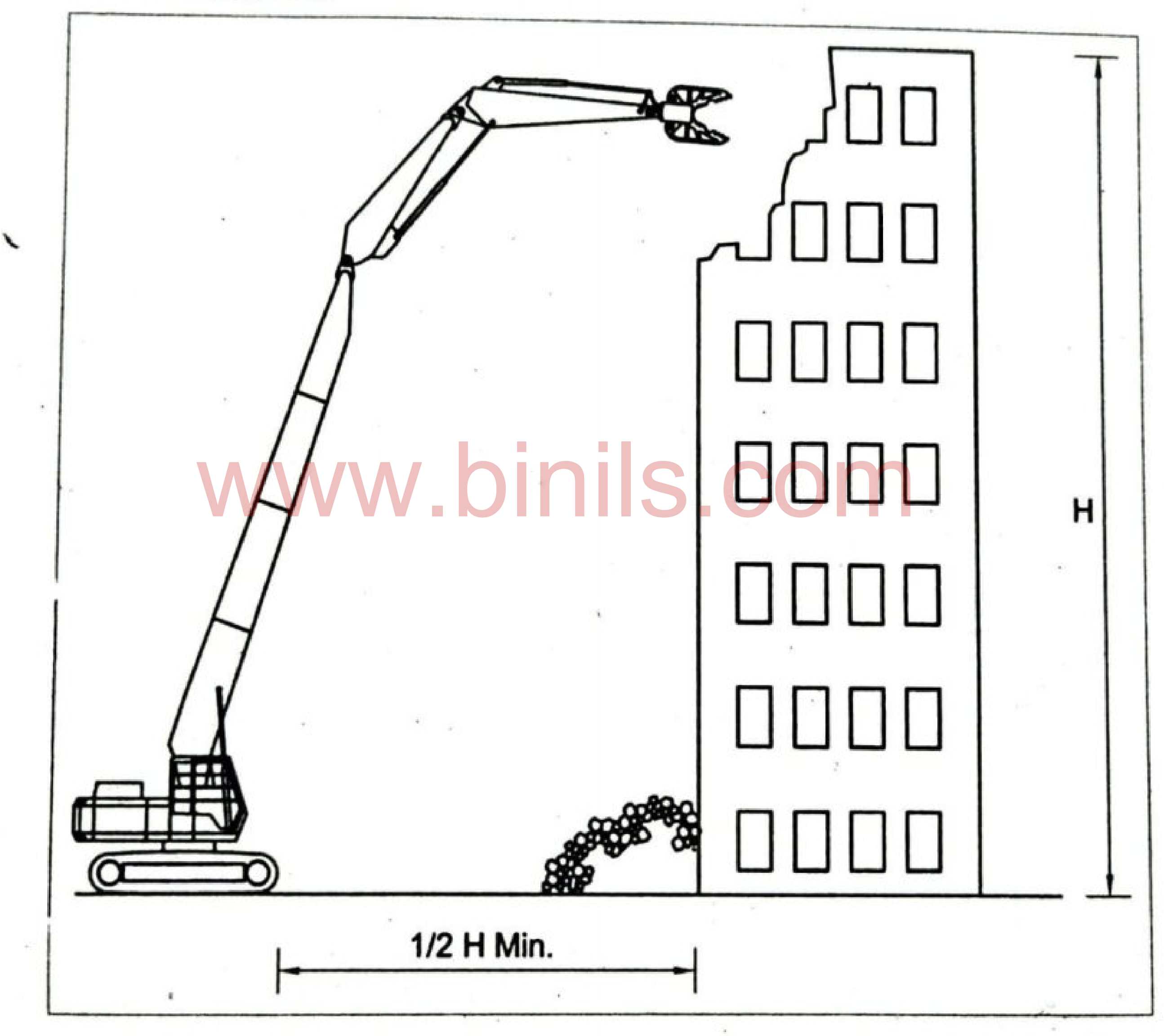


Fig. 5.19. Hydraulic crusher

❖ **Wrecking ball**

- The wrecking ball application consists of a crane equipped with a steel ball.
- The destruction of the building is by the impact energy of the steel ball suspended from the crawler crane.
- The operation requires clear space as one-half of the building.

- This method also demands high level skill operator and labor.
- The following are the recommended techniques for the wrecking ball operation as shown in Fig. 5.20 and Fig. 5.21.
  - Vertical drop - free falling of the wrecking ball onto the structure
  - Swing in line-swinging of the ball in-line with the jib
- The jib or boom shall be operated with no less than 3 m above the portion of the structure being demolished.
- The demolition ball shall be connected with swivel type anti-spin device to prevent twisting and tangling of the wire during operation.
- The wire and boom of the machine used for balling shall have a rated capacity, at the working radius, of at least 5 times the weight of the ball.

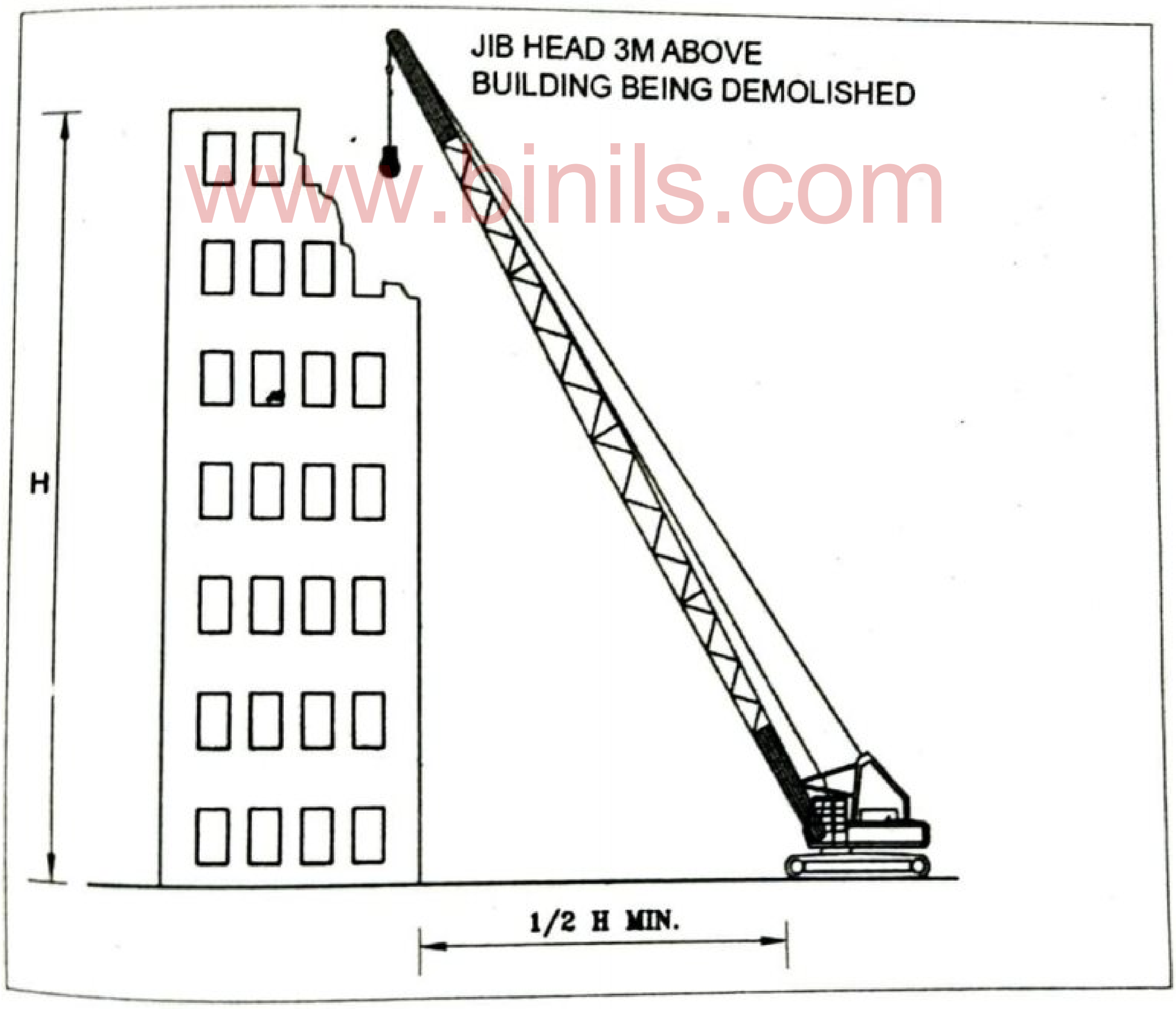


Fig. 5.20. Wrecking ball – vertical drop method

- The strength of the wire shall be at least twice the tensile strength of the nominal steel reinforcement of the floor slab and beams.
- The high strength wire allows the pullout of the wrecking ball from potential traps.
- To ensure that the crane is in good condition, the wire connecting to the ball, the boom components and connecting pins shall be inspected twice daily.
- The operation shall not be performed adjacent to overhead power lines.
- During the use of the demolition ball, except for the crane operator and the spot person, all other workers shall be kept away.

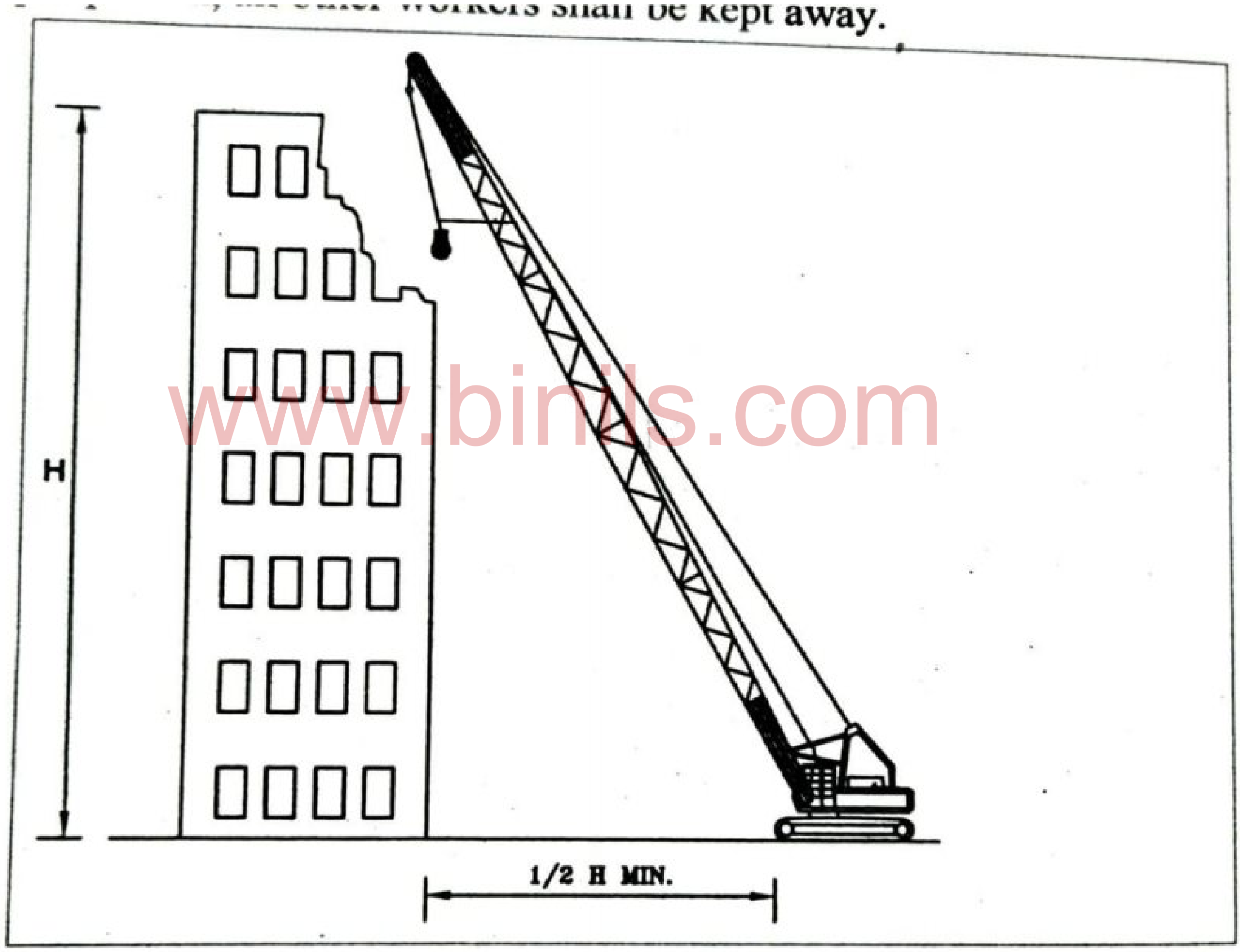


Fig. 5.21. Wrecking ball – swing in line method

❖ Thermal lance

- This method for demolition of reinforced concrete structures involves very high temperature up to 2000-4000°C.
- This high heat requires extreme special precautionary measures for safety.

- This method shall not be used unless there is no other alternative method. Unless follow the adequate protective measure provided for workers this method cannot be used.

❖ **Water Jet**

- It involves the use of water jet pumped at high pressure such as 250-300 MPa to eroding the cement matrix and wash out the aggregates.
- Area around the structural member to be cut shall be shielded to avoid damage to persons and properties.
- For the safety purpose all site personnel shall wear adequate safety cover and clothing.
- Provision shall be included to dispose used water and recycle the water for continuous operation.

❖ **Cutting and lifting**

- Cutting and lifting involve the cutting of the structure into individual many parts and then lifting that parts or pieces by crane.
- It may be applied to safety removes projection of structures like cantilever or hanging components.

❖ **Bursting**

- This method needs extra care and must be done by blasting expert.
- Building collapse itself due to gravity. Explosives are just to trigger.
- Dynamite is just absorbent stiffing soaked in a highly combustible chemical or mixture of chemicals, when the chemical is ignited; it burns quickly, applying immense outward pressure.
- Blasters cram this explosive material into narrow bore holes drilled in the concrete columns.
- When the explosive are ignited, the sudden outward pressure sends a powerful shock wave busting through the column at supersonic speed.
- Type of explosive material and amount of explosives are used upon the thickness of column and strength of column.
- The blasting speed varies from 30 m/sec to 4000-7000 m/sec.

- Blasting should be such plan that the structure shall be fall towards the centre of building or within the protected area.
- Geotechnical assessment shall be conducted in case of slopes and earth retaining walls.
- After the explosion, the expert must check that there is no unfitted explosive left on site.

❖ **Implosion**

Pre-blast Considerations

- If it is intended to blast a building structure, the Registered Specialist Contractor (Demolition) shall carry out a comprehensive Risk Assessment Report and an Environmental Assessment Report on the effect of implosion on the affected neighborhood.
- With positive results on both the risk assessment and environmental impact assessment and agreed by the relevant approval Authority, through the central processing of the Buildings Department, the Registered Specialist Contractor (Demolition) may begin studying the structure of the building and develop a blasting design.
- The design may include pre-weakening of the structure, the strategy in placement of the explosives and time delay so that the building will collapse in a safe manner.
- Pre-weakening of the structure may include cutting out a portion of the shear walls and other structural elements. A test blast may be conducted to verify the strength of the structural member and to fine tune the explosive design.
- Protection of the adjacent properties and habitats is also an important consideration.

General Concerns

General concerns and good practices in controlled demolition by blasting are discussed in the following:

- Pre-weakening of the structure shall be designed to ensure the structural stability before the implosion.

- To minimize the dispersion of building debris into adjoining land after blasting, a trench or bund wall shall be installed outside the building to contain the debris, unless a basement exists.
- A good design will cause the structure to fall towards the centre of the building and/or within the protected area.
- A good design will provide adequate and sufficient time delay to allow only one or two floors of the building debris to fall on ground level at a time in order to limit the magnitude of the impact on the ground.
- The design must also identify an exclusion zone to evacuate all residents of inhabitants during the blasting.
- The impacts of noise and dust generated during the blasting shall be considered.
- Radius of the typical exclusion zone shall not be less than 2.5 times the building height.
- If there are slopes and earth retaining walls or features, a geotechnical assessment shall be conducted to ensure that the blasting will not affect the stability of these features.
- The entire site shall be under 24-hour security from the installation of explosive until final blasting.
- Handling and storage of explosives shall be in conformance with the dangerous Goods Ordinance, any requirements of the Commissioner of Mines and other relevant regulations.
- The implosion expert shall have proven experience and track records in design and supervision of blasting similar building structures to the satisfaction of the Commissioner of Mines.
- The blasting expert shall have acquired the relevant training and practical experience in using the proposed explosives.
- The blasting expert shall obtain from the Commissioner of Mines an authorization to carry out blasting.
- All personnel must be evacuated from the site before and during blasting;
- The Registered Specialist Contractor (Demolition) must co-ordinate with the government and local community to determine the best procedures in notification, schedules for the events, traffic routing, design for the sequence of events, evacuating

residents, clear out personnel from the building and assigning responsibilities during blasting.

- For the purpose of crowd control, blasting should be carried out in the early morning of a Sunday or public holiday;
- An emergency plan shall be prepared to handle emergency situations such as premature explosion, misfire or interruption due to bad weather. including thunder and lightning:
- After the explosion, the blasting expert must check to make sure that there is no unfired explosive left on site.
- The entire area must remain clear and under security control until the unfired explosives have been detonated or safely dealt with by the blasting expert;
- As far as practicable, non-electrical initiation systems should be used to avoid the risk of pre-mature detonation by stray currents, external electro- magnetic waves or radio frequencies.
- The installation shall include a redundant system to ensure successful detonation. Nitroglycerine based explosives are not permitted to be used.
- The Registered Specialist Contractor (Demolition) must provide evidence of his capability to safely perform the demolition and shall illustrate to the approving authorities that the procedures are safe;
- The structural safety of the building to be imploded shall be checked and certified to be sound and safe at all stages prior to implosion.

5.2. ADVANCED TECHNIQUES USING ROBOTIC MACHINES

Machines have completely changed the way we work in most industries in the world, whether we are talking about utilizing a computer in an office environment or a robotic demolition machine in the construction industry. They have indeed made human life easy in most facets.

The industry where they have arguably made the most difference is the construction industry. As worldwide urbanization continues to grow in the form of new buildings, changes in infrastructure, as well as remodeling of old cities, the need for additional reliable, efficient, safe, and cost-effective construction equipment have continued to grow alongside it. Through the use of different types of machinery, human labor is not only significantly, but also safer.

Much of the development today is due to a singular machine: the robotic demolition machine. Demolition is generally one of the more dangerous work areas in construction. The new types of demolition robots have played a significant role in constructing new buildings, placing rooftops, renovating bridges and tunnels, among many more.

TYPES OF ROBOTIC DEMOLITION MACHINES

Robotic demolition machines refer to different types of heavy machinery with the sole purpose of demolishing buildings and other structural elements. Robotic demolition machines usually refer to one of two things:

- robots with hydraulic breakers; or
- **hydrodemolition robots using high-pressure water.**

BENEFITS OF ROBOTIC DEMOLITION MACHINES

Regardless of the type of demolition machine, the robotic aspect of them provides a host of advantages including:

- **Tremendous power:** One of the most evident advantages of robotic powered demolition is the increase in power and efficiency. Even though their size is much more compact than the traditional counterparts, excavators or mechanical jackhammering etc., its power is much greater. Robotic demolition machines are able to work continuously without interruption or break. A hydrodemolition robot from Conjet is, for example, 25x faster than mechanical jackhammering.
- **Remote-controlled operations:** The remote-controlled aspect of demolition robots provide an additional level of control to its features. In addition to greater flexibility and efficiency, it also ensures the safety of the operator as they can control them from a safe distance from the demolition site.
- **Environment-friendly:** Robotic demolition robots, hydrodemolition robots especially, are very environment-friendly and are a great solution to many environmental issues contractors face, such as noise and vibrations.

ROBOTIC DEMOLITION MACHINE – PRICE CONSIDERATION

Regardless of how many advantages a robotic demolition machine presents, the price will always be an important consideration – as it should be! While we can’t speak for robotic demolition machine suppliers, we know that investing in an automatic concrete removal robot from Conjet will be worth your investment in terms of efficiency, safety, and health.

These are the advantages you can expect when investing in a hydro demolition robot from Conjet:

- No micro-cracks in the remaining structure, which ensures that the repair will be long-lasting with a high quality.
- Creates no vibrations, and noise and dust are dramatically reduced.
- Allows for both selective and non-selective removal.
- Keeps the rebars clean and intact.
- Prepares a surface ideal for bonding between old and new concrete.
- 25X faster than mechanical jackhammering.

5.3. DISMANTLE TECHNIQUES

Preliminary Investigation

Demolition is a highly skilled and dangerous activity in terms of damage to life and property and there are certain basic factors to consider before a contract is placed:

- The demolition contractor should have ample experience of the type of work to be offered;
- Fully comprehensive insurance against all risks must be maintained at all times;
- An experienced supervisor should be continuously in charge of the work;
- The contract price should include all safety precautions included in the relevant building regulations;
- The completion date should be realistic, avoiding and need to take risks to achieve the date.

Preliminary Considerations

Demolition operations are the subject of strict legal controls - there is a substantial body of legislation and a great deal of case law relating to such operations. There may also be some regulations which impose additional restrictions: for example, action against nuisance such as noise and dust.

The BSI Code of Practice for Demolition BS 6187 exerts further influence, in that if the demolition contractor does not observe the recommendation of the Code, this may well influence a Court's decision as to his liability in any legal proceedings.

General Site Provisions

A. *Plant and Equipment*: Must only be operated by skilled operators and must be regularly serviced.
B. *Protective Clothing*: Buildings where chemicals have been stored or where asbestos, lead paint, dust or fumes may be present will require specialized protective clothing,

e.g. Respirators, helmets, goggles, footwear, gloves, etc. Projecting nails, pieces of metal, etc. resulting from demolition can cause accidents.

C. *Shoring and Underpinning*: The demolition contractor has a legal obligation to show technical competence when carrying out the work. When removing sections of the building which could have leave other parts unsafe, adequate temporary supports and shoring etc. must be provided.

D. *Working Areas*: These will need to be well signposted and clear warnings given that demolition work is in progress. This may include the necessity for some kind of lighting.

E. *Debris*: Sections of the building must not be overloaded with debris either on suspended floors or against party walls.

F. *Weather Conditions*: These can affect safety. Strong winds or drifting snow against unsafe walls, suspended floors etc. which are unpropped may lead to collapse.

G. *Flooding*: The build-up of water can sometimes be hazardous.

H. *Overhead Cables*: A crane heights etc. must be checked against the height of any surrounding overhead cables to avoid damage and cutting off supplies etc

I. *Scaffolding and Hoarding*: These must be constructed and illuminated to the relevant building regulations.

J. *Security*: The demolition site and any partially demolished buildings must be properly secured against entry.

K. *Dust*: Should be kept to a minimum by spraying with water when necessary.

L. *Noise*: Suppressors and silencers, particularly on compressors etc., should be used to keep noise levels to a minimum.

Supervision of Demolition Work

A method statement showing how the demolition work is to be carried out should be prepared and the contractors should appoint a "competent person" to supervise the demolition work.

Demolition Processes

As an intrinsic part of the construction process, efficient demolition of structures is an important factors deserving careful consideration in the evolution of any redevelopment project.

Modern emphasis is on reduction of construction periods to ensure economic redevelopment, coupled with increasing town centre regenerating calling for careful demolition on constructed and restricted site, have resulted in more consideration being given to demolition as part of the process of construction and redevelopment than was typical in previous times.

Developing a Demolition Strategy

The strategy will need to take into account the method of construction used for the original building and its proximity to other buildings, structures and the general public. These factors, together with location, the cost and availability of tipping and disposal and the desirability and economics of reuse, must be taken into account in the development of an appropriate strategy for the demolition of a structure.

Building Information

Information on buildings in terms of "as built" drawings and structural details may often be unavailable or unreliable, and consequently some investigative site and desk work may be necessary, both to ascertain the way in which the building was originally constructed, and to identify the stresses and strains which exist within it.

In order to plan the most efficient method of demolition, it is important to have a full understanding of the method of construction and the stress patterns imposed upon the building. Failure to do so may result in risks to the safety of both those involved in the demolition and those in close proximity to the site.

Selecting Appropriate Techniques

Majors factors to be considered in selecting an appropriate technique include:-

- Safety of personnel and public
- Working Methods
- Legislation applicable
- Insurance Cover

Preliminary Aspects Prior to Site Demolition Work

Considerations should be given to:-

- Conducting a site and building survey, with a structural bias;
- The examination of drawings and details of existing construction where available;
- The preparation of details and drawings from site survey activities where no such information is available;
- Establishing previous use of premises, especially with regard to flammable substances or substances hazardous to health or safety;
- Programming the sequence of demolition work;
- The preparation of a Method Statement.

Method statement

- A detailed health and safety method statement, produced before work starts, is essential for safe working. It should include a full risk assessment, identify problems and their solutions, and form a reference for the site supervision.
- The method statement should be easy to understand, agreed by and known to all levels of management and supervision, and should include such matters as:-
- The sequence and method of demolition or dismantling of the building or structure with details of personnel access, working platforms and machinery requirements;
- Details and design of any temporary supporting structures to be used during the demolition process;
- Specific details of any pre-weakening on structures which are to be pulled down or demolished with explosives;
- Arrangements for the protection of personnel and the public and the exclusion of unauthorized persons, with details of areas outside the site boundaries that may occasionally need to be controlled to improve safety during critical aspects of the work;
- Details of the removal or making safe of electrical, gas and other services and drains;
- Details of temporary services available or required for the contractor's use;
- Details of the methods for detailing with flammable materials and gases which may have been retained or deposited as residue in process machinery, pipework or storage;
- Details of methods to establish the presence of hidden or other substances that may be hazardous to health, the methods to be used for their disposal, and any necessary protective equipment;
- Arrangements for the control of site transport used for the removal of demolition debris.

Demolition Methods

In many circumstances, buildings and structures should be demolished in the reverse order to their erection; although where partial demolition is involved, a more careful evaluation of the nature of the effects of the demolition is necessary.

Normally, the demolition contractor is able to adopt a method of work which:-

- Gradually reduces the height of the building; or
- Arranges the deliberate controlled collapse of the building or structure so that work can be completed at ground level.

Demolition Technique Selection

The choice of demolition technique will depend on the nature of the building or structure and its environment. Risks to the public, operatives involved in the demolition process and adjacent structures and buildings should be considered.

Demolition techniques may be categorized as:-

- Piecemeal demolition, using **hand-held tools**
- **Mechanical method** by
  - Hydraulic crusher with Long Boom arm
  - Wrecking Ball
  - Pusher Arm
  - Wire Rope Pulling
  - Clam Shell
- Other Methods like
  - Non Explosive Demolition Agent
  - Explosive Demolition
  - Saw cutting
  - Cutting and Lifting
  - Water Jet

Piecemeal Demolition (Demolition by Hand):

- For demolitions of reinforced concrete buildings by hand, tools such as electric, pneumatic breakers, jack hammers etc are commonly being used.
- Oxy-acetylene torch could be used to cut the reinforcements.
- The reinforcements shall remain until all the concrete connecting to or supported by the reinforcement is broken away or when its supports are no longer required.
- Cantilever canopies, balconies and exterior walls are critical elements in building demolition.
- In congested areas, these features could critically impact on the safety of the public.
- Demolition of these features shall be performed with extreme caution.
- If rope or tie wires are used to pull down the structural elements, the pulling wire must be at least 4 times stronger than the anticipated pulling force.
- In addition, workers shall be shielded from the rope or tie wires. The rope or ties wire shall be checked at least twice per day.
- Lifting appliances may be necessary to hold larger structural members during cutting and for lowering severed structural members and other debris.
- Chutes may be used to discharge debris into a vehicle or hopper.
- Foundations would normally be grubbed up by excavation machines.

Figure : Demolition By Hand

Demolition Sequence

- Demolition sequence shall be determined according to actual site conditions, restraints, the building layout, the structural layout and its construction.
- In general, the following sequence shall apply:

(a) All cantilevered structures, canopies, verandahs and features attached to the external walls shall first be demolished prior to demolition of main building and its internal structures on each floor;

(b) When demolishing the roof structure, all lift machine rooms and water tanks at high level shall be demolished in "top down" sequence to the main roof level.

(c) Demolition of the floor slabs shall begin at mid span and work towards the supporting beams;

(d) Floor beams shall be demolished in the order as follows:

(1) cantilevered beams;

(2) Secondary beams; then

(3) Main beams.

In the case when structural stability of beams is affected, e.g., due to loss of restraints, the affected beams shall be propped prior to loss of support or restraint;

(e) Non-load bearing walls shall be removed prior to demolition of load bearing walls;

(f) Columns and load bearing walls shall be demolished after removal of beams on top;

(g) If site conditions permit, the first floor slab directly above the ground floor may be demolished by machine sitting on ground level and mounted with demolition accessories.

Mechanical Demolition:

- Mechanical demolition generally involves the use of large machinery with attachment to dismantle the building from outside.
- The common mechanical methods include the use of a **Hydraulic crusher with long Boom arm, Wrecking Ball**, **pusher arm**, **wire rope, clam shell etc..**.
- These methods shall only be applied to isolated buildings on relatively flat ground.
- If it is attached to another structure, the two properties should be separated by the use of hand methods before the main demolition process begins.
- The concerns and good practices of the mechanical demolition generally included the following:
  (1) The machine shall be operated on smooth and firm ground;
  (2) It shall also have adequate counter-weight to prevent overturning during the operation;
  (3) The equipment and accessories such as attachments and rope shall be inspected frequently and shall be repaired or replaced whenever necessary;
  (4) The impact of the collapsed structural sections on the floor or ground shall be checked to prevent the potential overloading of the suspended floor, vibration and disturbance to adjacent properties and damage to underground utilities;
  (5) The site shall have full time security to prevent unauthorized personnel entering the site. No person shall stay within the working area of the machine and the building while the machine is operating.
  (6) Sufficient water spray or other anti-dust precautions shall be provided to minimize air pollution by dust;
  (7) The cab of the machine shall be equipped with impact proofed glass and its construction shall be robust enough to protect the operator from flying debris;
  (8) A spot person shall be on site full time to provide guidance and assistance to the operator in the demolition process.

Demolition Sequence

- In general, the following sequence shall apply:
  (a) Prior to demolition of internal floors, all cantilevered slabs and beams, canopies, and verandahs shall first be demolished

(b) The structural elements, in general, shall be demolished in the following sequence:

- Slab;
- Secondary beams; then
- Main beams.

(c) Mechanical plant shall descend from the floors with temporary access ramp, or be lowered to the next floor by lifting machinery or by other appropriate means;

(d) When a mechanical plant has just descended from the floor above, the slabs and beams, in two consecutive floors may be demolished by the mechanical plant simultaneously. The mechanical plant may work on structural elements on the same floor and breaking up the slabs on the floor above;

(e) The wall panel, including beams and columns shall be demolished by gradually breaking down the concrete or by pulling them down in a controlled manner;

A. Hydraulic crusher with Long Boom arm

- The crusher attachment breaks the concrete and the reinforcement by the hydraulic thrust through the long boom arm system.
- The hydraulic crusher can be operated from the ground outside the building.
- This method is also suitable for dangerous buildings, silos and other industrial facilities.
- For environmental reason, it should be used wherever practicable because of its quietness.

Application Criteria

- The operation shall have a minimum clear space of 1/2 the building height as a safety zone for the falling debris;
- The equipment shall be inspected and maintained periodically to make sure the equipment is in good and safe condition.
- The excavator shall operate on firm ground that can support the machine during the crusher operation;
- Except for special applications, each section of the structure shall be demolished in a top down sequence to ensure stability of the structure;
- Debris may be used to build up a platform for the excavator to extend the range of reach. It is important that the debris is densely compacted to support the operation of the excavator. The platform must be flat and the slope must be stable. The height of

the build up platform shall be limited to 3 m. The side slope of the temporary platform shall not be steeper than 1:1 (horizontal to vertical) unless the condition allows a steeper slope. The slope of access ramp for the machine shall be in accordance with the manufacturer's recommendation. The width in both directions of the platform shall be at least one and one-half the length of the machine to allow safe maneuver during the demolition operation;

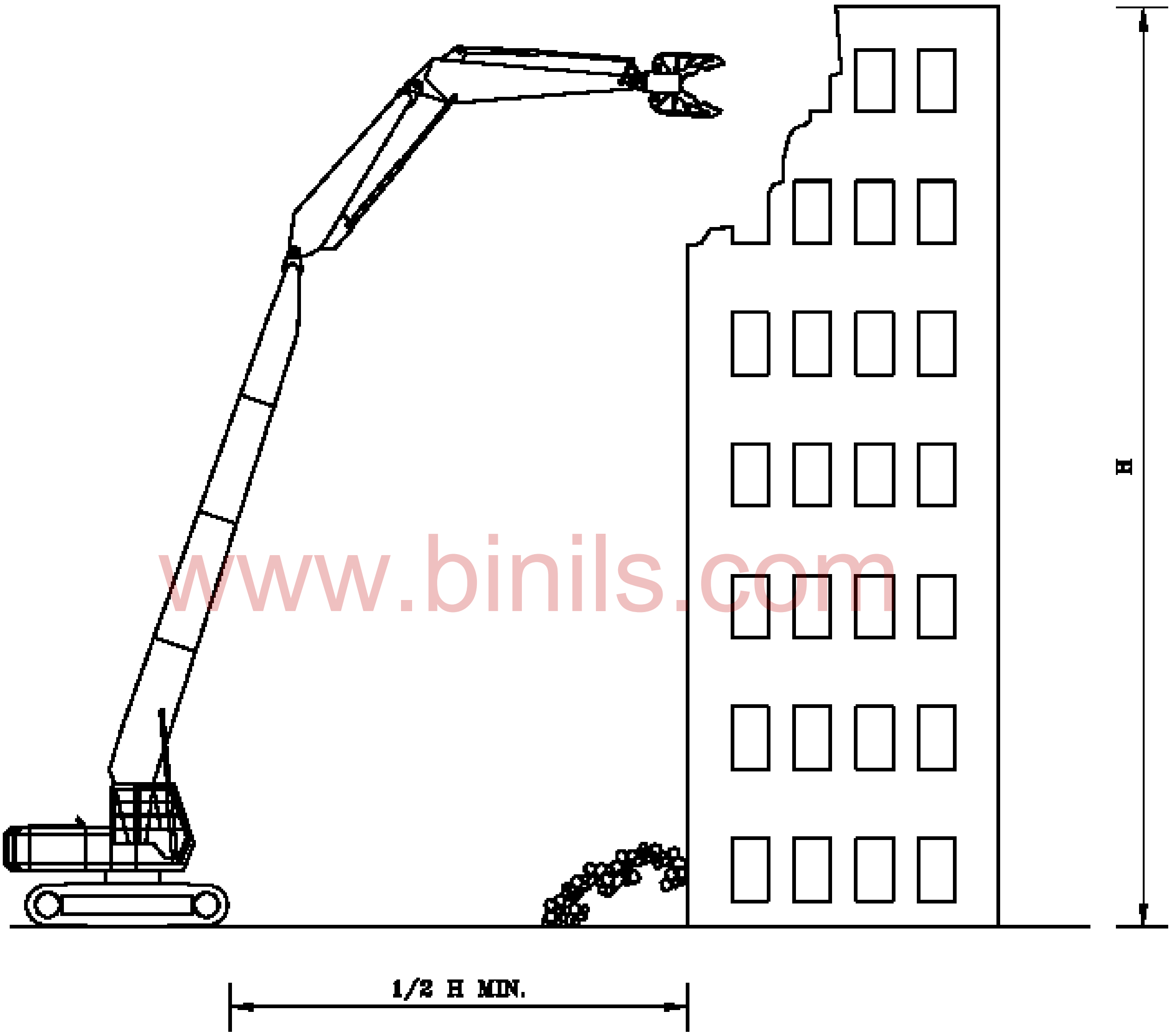


Figure 1: Demolition by Hydraulic Crusher with Long Boom Arm

- To minimize the dust impact, the structure shall be pre-soaked with water before demolition. Water shall be continuously sprayed during the crushing operation;
- Debris may fall out of the building during the demolition. The site shall be completely fenced off. There shall be 24-hour guarded security to allow only authorized personnel

for site access. During the operation of the crusher there shall be no worker within the machine operating area or inside the building;

- The crusher operator shall possess the essential skills and significant experience in the crusher operation. There shall be a spot person to assist in the operation and alert the operator of any potential problem during the operation.

B. Wrecking Ball:

- The wrecking ball application consists of a crane equipped with a steel ball.
- The destruction of the building is by the impact energy of the steel ball suspended from the crawler crane. The wrecking ball operates outside the building.
- This method is suitable for dilapidated buildings, silos and other industrial facilities.
- However, the operation requires substantial clear space.
- The application also demands high level skill operators and well-maintained equipment.

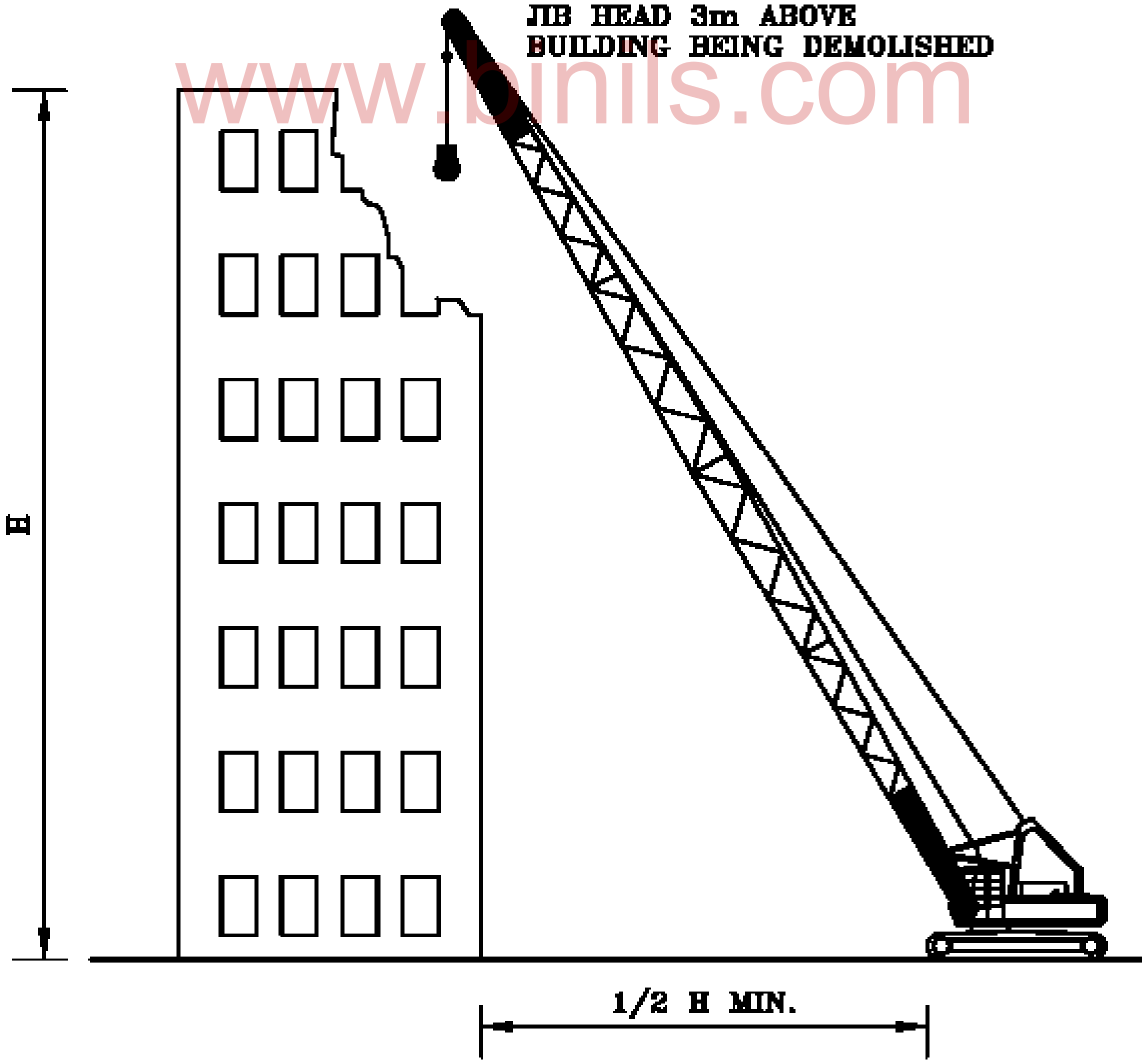


Figure 1: Vertical Drop

Application Criteria

The recommended criteria for the use of wrecking ball are presented in the following:

- Except for special application, the balling of each section of the structure shall proceed from top to bottom. Care shall be taken to maintain the stability of the structure;
- Recommended techniques for the wrecking ball operations include:
  (1) Vertical Drop - free falling of the wrecking ball onto the structure;

  (2) Swing in line - swinging of the ball in-line with the jib.
- A second dragline will normally connect to the ball horizontally to control the ball motion. The ball shall be swung into the building. The ball shall strike at the top of the member so as to avoid the member from falling outside the building.
- Slewing the jib is not recommended. The motion of the ball by slewing the jib is difficult to control. It demands expert knowledge of the machine and structure as well as operating skills to safely perform the task. Slewing can potentially induce a tremendous amount of stress on the jib, as such, its use shall be avoided;

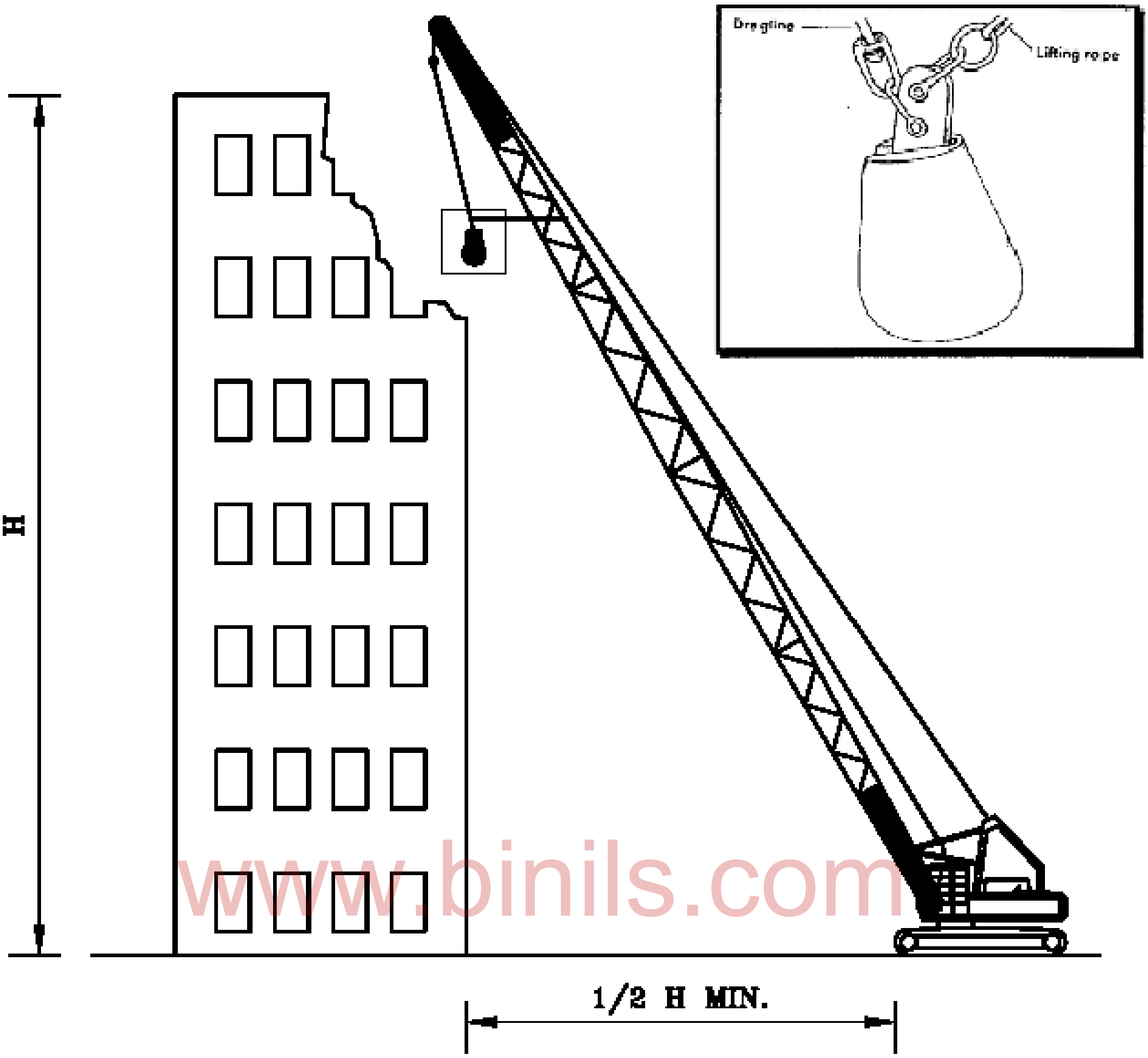


Figure 1: Swing In-Line Method

- The jib or boom shall be operated with not less than 3 m above the portion of the structure being demolished;
- Clear space for operation between the crane and the structure being demolished shall be 50% of the height of structure, the clear distance between the site boundary and the building to be demolished shall not be less than 50% of the building height plus an additional 6 m for the crane to maneuver, this criteria shall apply to all sides of the building to be demolished by wrecking ball;
- The demolition ball shall be connected with swivel type anti-spin device to prevent twisting and tangling of the wire during operation;
- The wire and boom of the machine used for balling shall have a rated capacity, at the working radius, of at least 5 times the weight of the ball;

- The strength of the wire shall be at least twice the tensile strength of the nominal steel reinforcement of the floor slab and beams. The high strength wire allows the pullout of the wrecking ball from potential traps;
- To ensure that the crane is in good condition, the wire connecting to the ball, the boom components and connecting pins shall be inspected twice daily;
- A sufficient length of the wire shall be provided to allow the ball to drop to the lowest working level plus an addition of 10% of the wire length and no less than 3 drums. For swing in-line method, there shall be sufficient length of the dragline wire to allow the ball to fall in the event that the ball is entangled with the falling debris;
- The operation shall not be performed adjacent to overhead power lines;
- The site shall be entirely fenced off to forbid public access. A 24-hour security guard shall be assigned to the site to enforce the access restriction; depending on the relative location between the fence and the building, and fence shall be designed to withstand accidental impact by the wrecking ball;
- During the use of the demolition ball, except for the crane operator and the spot person, all other workers shall be kept away from the demolition ball's working radius. No body shall stay inside the building;
- To minimize the dust impact on the surrounding area, the structure to be demolished shall be pre-soaked with water before demolition. Water spraying shall continue on the structure during demolition;
- Since the safety and success of the project depend highly on the operator and site personnel, the operator must have proven experience and skill for operating the wrecking ball to the satisfaction of the approval authority; and
- A spot person shall be on site during the operation to assist the operator and to ensure site safety. The spot person shall have extensive knowledge and experience in the use of wrecking ball. The qualification and experience of the spot person shall be equivalent to those of the wrecking ball operator.

C. Hydraulic Pusher Arm:

- Articulated, hydraulically-powered pusher-arm machines are normally mounted on a tracked or wheeled chassis, and have a toothed plate or hook for applying for applying a horizontal force to a wall.
- The machine should stand on a firm level base and apply force by a controlled movement of the pusher arm.
- Special conditions for pusher arm demolition are listed below:

(1) The pusher arm shall be constructed of steel or equivalent material and shall have adequate strength to operate on the building; a crane boom shall not be used;

(2) Minimum safety distance of 0.5 times the height of the building element being demolished shall be maintained between the machine and the building for pushing into the building;

(3) Minimum safety distance of 1.5 times the height of the building element being demolished shall be maintained if structural elements are pulling out of the building;

(4) The point of application of pushing shall not be less than 2/3 of the height and not more than 600 mm below the top of the wall; and

(5) The pusher arm method shall be limited to buildings less than 15 m high.

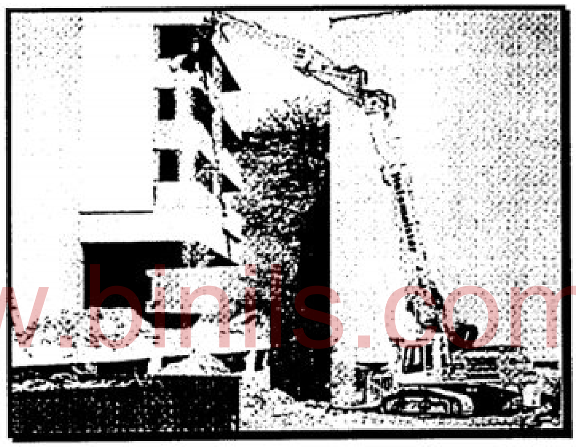


Figure 3: Hydraulic pusher arm

D. Overturning - Wire Rope Pulling

- This method is the application of a horizontal force at a high level by pulling with wire ropes attached to winches or vehicles, and allowing the impact on overturning to demolish the building or structure.
- An adequate steel cab or cage should protect the winch or the pulling vehicle and the operator.
- Building over 21m high should not normally be demolished by rope pulling.
- Special conditions for wire rope pulling are listed in the following:

(1) A safety distance of 1.5 times the height of element to be demolished shall be maintained between the machine and the building during the pulling;

(2) The machine shall always travel parallel to the line of pull during the pulling operation;

(3) In the case when pulling is done by a pulley, such a pulley device shall be securely anchored;

(4) The wire rope or chain shall be composed of steel with tensile strength not less than 4 times the theoretical force required to perform the pulling;

(5) The wire rope used for the operation shall be inspected for wear and damage at least twice daily and replaced as necessary;

(6) Any sharp edge that is to be wound by the rope shall be protected to minimize the possibility of cutting or wearing of the rope during pulling;

(7) The bottom of the wall may be pre-weakened with care and protection to ensure controlled collapse;

(8) The wire rope pulling shall be limited to buildings less than 15 m high; and

(9) All workers shall stay away from the area within reach of the rope or wire in case it breaks.

E. clam shell

- Demolition by clam shell typically involves the use of a crane equipped with a clam shell attachment which progressively bites away the structure.
- Special conditions for clam shell are listed in the following:

(1) A minimum safety distance of 0.5 times the height of the building element being demolished shall be maintained between the machine and the building during the operation;

(2) The process of biting off the structural elements shall begin from the top and progress downwards; and

(3) The clam shell shall be operated not less than 1 m above the structure being demolished.

Figure 5: Clam Shell

Other Methods of Demolition.

A. Non Explosive Demolition Agent

- **N**on **E**xplosive **D**emolition **A**gent (NEDA) is a static demolition agent.
- When the reaction takes place in a confined drill hole, the NEDA generates an expansive pressure to crack and break concrete and stone.
- The NEDA is a suitable application in a restrictive environment where noise, flying debris and vibration are less tolerated.
- A drilling pattern shall first be designed. For large projects, test breaking shall be performed.
- The NEDA shall be mixed with water to form slurry and immediately placed into the pre-drilled holes. The loading intensity and water content shall be controlled to optimize the expansive pressure and prevent blow-out of the NEDA.
- The breaking effect of NEDA is relatively small comparing to explosives. Secondary efforts are required to further break down and remove the debris by mechanical means.
- NEDA may be used on foundation works, pile caps or structures that are fully supported.
- When used in rock, NEDA should be contained within strong, flexible, impermeable bags to prevent uncontrolled entry into rock joints.

B. Saw Cutting

- Saw cutting is suitable for alteration and additional works where accuracy in the cutting is important and the tolerance to noise and vibration is very limited.

- It can be used to cut concrete slabs and wall elements into segments. An entire building may be dismantled by saw cutting.
- Saw cutting generally includes conventional disc saw and chain saw, diamond core stitch drilling and wire saw.

(1) Wire Saw Cutting

- Wire saw cutting comprises a special steel wire often impregnated with diamond beads to increase its cutting ability.
- The wire saw method is a suitable application for projects that require precision and total control of demolition work.
- A hole shall first be pre-drilled for the passage of the diamond wire, the wire cutting operation follows.
- Because of its flexibility, it may be used for “hard to reach” areas.
- A diamond wire saw may also be applied in cutting off piling of marine structures and bridges.

(2) Diamond Core Stitch Drilling

- Diamond core stitch drilling may be adopted to cut concrete elements by continuously coring a set of holes to carve up the concrete structure.
- The thickness of the concrete to be cut depends on the depth of the drilling or coring equipment.
- Diamond core stitch drilling is particularly suitable in the removal of existing pile cap for construction of large diameter bored pile foundation.

(3) Management of Process Water

- The sawing and drilling operations require large amounts of water to cool down the blade which cuts through the concrete at high speed.
- Provision shall be made to provide a water source for the operation and for the disposal of the cooling water.

C. Cutting and Lifting.

- Cutting and lifting involve the initial cutting of the structure into individual pieces or segments, and then lifting the pieces or assembly by crane onto the ground for further demolition or hauling away.
- Slabs can be cut into segments and then lifted off for further cutting into smaller pieces before disposal.
- Precast concrete structures can be cut into pieces and then lifted off as a reversal of the construction sequence.
- When the precast elements are fabricated from pieces into an assembly of structure.

- Cutting and lifting may be applied to safely remove projections such as canopies, architectural features, balconies and bay windows.
- The typical procedures for cutting and lifting are summarized in the following:

  - Prior to cutting, the structural stability of the remaining structure shall be checked;
  - The structural element to be removed shall be secured, either by temporary supports or by tie wires connected to lifting appliances. The lifting appliances must have adequate capacity to support the weight of the structural section.
  - The wire strength shall not be less than 4 times the anticipated loads;
  - The lifting appliance, cutting by disc saw, chain saw and diamond wire saw shall comply with the Factories and Industrial Undertakings Ordinance; and
  - After cutting, the structural element shall be lowered to the designated area in a controlled manner. Free falling shall be avoided.

D. Water jet

- Water jetting involves the use of a water jet stream pumped at high pressure to erode the cement matrix and wash out the aggregates.
- Abrasive compounds may be added for cutting reinforcing steel. The application of the water jetting shall be subject to the following criteria:

  (A) City water supply shall be used in water jet cutting. Provision shall be included to dispose the water used in the operation, and to recycle the water for continuous operation through local filtration and sedimentation;

  (B) The area behind the structural member to be cut shall be shielded to avoid damage to persons and properties during the cutting; and

  (C) In the case when abrasive water jets are used, further precautionary measures shall be provided in accordance with manufacturer recommendations to confine the rebound of the abrasive compounds. All site personnel shall wear adequate safety cover and clothing.

E. Explosives

If explosives are to be used for demolition, the planning and execution, include pre-weakening, should be under the control of a person competent in these techniques. For large demolition, the competent person is likely to be an experienced explosive engineer; for smaller work, a shot-firer may be sufficient.

When the use of explosives is contemplated, it is usual to employ a technique that will ensure the total demolition of the whole building by staging a controlled collapse. The explosive charges are set and fired in a sequence that will weaken the structure in such a way that the building collapses in upon itself.

Explosives are generally used for removing large volumes of concrete via insertion of explosive devices in a series of boreholes:

- *Versatile and flexible in terms of work output*
- *Vibration and air blast may damage surrounding structures*
- *Heightened safety considerations involved when compared to other demolition methods*

Although we tend to think of explosives as devices producing spectacular bomb-like explosions, the use of non-explosive "explosives" is now at an advanced stage. These non-explosive techniques are essentially expanding charges that achieve the same results as explosives but without the noise and initial devastating blast.

Demolition of structure using Implosion Technology: A case study

Introduction

An structure which is made by any material is to be demolished after its designed age is completed in order to reutilized the valuable land. Demolition was also necessary to remove danger of falling. In western railway, Mumbai division, there was a G+3 storied building numbered as 25/T. It was built in 1924, constructed by BB & CI railway as a first cement concrete residential structure in Mumbai. It was having 80 Nos. (4×20) type I Quarter with total land area about 430 Sq. m. The total height was 13.20 m. above rail level. The structure completed its designed life and existing condition of building was so deteriorated that there was no option but to demolition the same for safety of running trains and adjoining residents.

Options for Demolition (Conventional Methods)

As usual there are two methods for demolition. One by manually and other by mechanical means such as using JCB, Poclains, etc. While planning for the method to be adopted a lot of discussion was held and it was concluded that neither of above method is suitable due to existing constraints around chawl No. 25/T. These were as under.

1. There were four running lines just adjoining to structure in east side, the face of building was just 4.55m away from track centre.

2. There was a OHE Mast containing portal for five numbers OHE live conductors at a distance of 5.80 m. from face of building towards north side.

3. There was stone masonry boundary wall at a distance of 2.80 m. from face of building.

4. In addition to above as described railway's assets, there was a 40 storied structure about 100 m. away from building to be demolished and one diamond factory exists in the east side having exterior glazed building.

Due to above said constraints, manual method was not suitable as it was going to take more time and structure was very near to running track which requires continuous track protection / traffic block. Which would have resulted longer disruptions to running traffic .The mechanical method was not suitable, as there was no space to bring heavy machineries near the structure and to work at a height of 13.50 m.

It is advisable and worthy to note that railway context, Implosion method of demolishing would be proved very suitable and useful, most of railway assets i.e. building /

structure located nearby running track and in metro cities congested area which already passed their designed life.

Demolition by Implosion

When all above-mentioned methods of demolition was not found suitable, the idea of demolition by using implosion technology came to mind as it is being utilizes worldwide. Though it was not tried over Indian Railway till date. “Implosion” is a word which derived from word ‘Implode’ which means, make a building collapse down on its footprint. The basic idea of implosion is quite simple, If we remove the support of structure of a building at a certain point, the structure of a building above that point will collapse. If the upper section is heavy enough, it will collapse on the lower part of the structure with force to cause significant damage. The explosives are used in these methods are such that the whole structure should fall towards its center of its gravity by just triggering off the explosive in designed manner for demolishing the structures. The true meaning of implosion of structure is to fall on its footprints, but in some cases structures are given desired direction of fall during demolition in order to protect some important existing structures.

The advantages of implosion technology method over conventional methods are as under.

1. It is less expensive.

2. There are no ground vibrations

3. This method is quickest.

4. Suitable for multi-storeyed structures / high piers, cabins, distressed piers etc.

Important Aspect of Implosion Technology

Following are important aspects of Implosion,

Analysis of Existing structure & locating weak points. The approximate strength of left on R.C.C / PSC member worked out by taking the core of concrete, In order to decide quantity /location of explosive to be provided. In our case the structure was very much dilapidated and unsafe, there was no need to carry out such tests as weakening of strength of structure was done by making the vertical columns from adjoining partition wall, which were of RCC.

Drilling of holes for placement of explosive

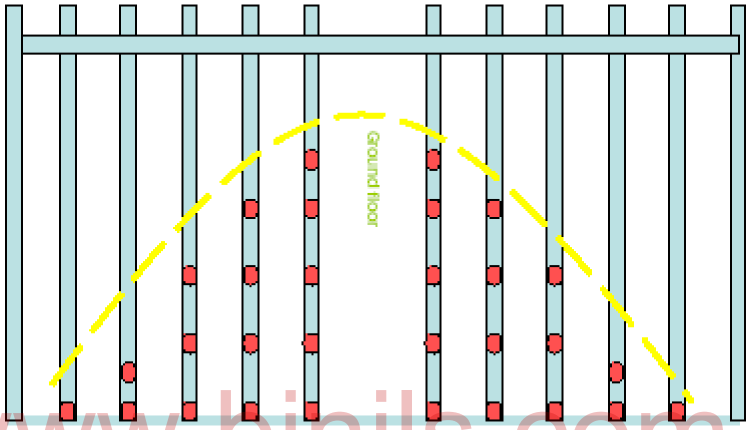
The holes were drilled of about 25 mm to 30 mm dia and about 20 to 30 cm deep depending upon quantity of explosive energy is required to break a particular support. In this case the building was planned to bring down on its footprint. We provided 20 holes of 25mm dia & 30 cm in depth central column. It was reduced to 4 holes of 25mm dia & 20cm deep (4x1) at columns away from centre.

Quantity of Explosive

The quantity of explosive to be placed depends upon the size of column and extent up to which it is to be destroyed. Depending on above requirements 250 gm of explosive in central 24 columns. & 125 gm in outer 16 columns were placed, because it was desired to destroy the central column completely. No outer column was weakened so that the building collapsed towards its centre from both side.

Type of explosive & Detonators

There are two types of explosive commonly used for implosion RDX & gelatin. In this case we used brand name 'Power Gel ' explosive, which is, ammonium nitrate based explosive which expand at very high speed and applies at a very high pressure of about 600 T/sq inch. The electronic detonators were used to ignite the explosive.



PLACEMENT OF EXPLOSIVES – CROSS SECTIONAL VIEW

Test Blast

Before carrying out the actual blasting; a test blast was done, in ordered to ascertain the efficiency of explosive &detonators and also to develop a level of confidence as this was a specialized work and executed 1st time on in Indian railway.

BEFORE

AFTER

Wrapping of holes

The wrapping of holes is done to ensure that due to explosion of charges the debris does not fly in air. For this purpose, the holes were covered with gunny bags and iron net after placement of explosive and detonators.

Ballasting

Ballasting of Charges / Explosives work are carried out in a controlled manner such that there will be a time gap of 1/100 second between two successive blasts. The trigger of charges is done in such a control manner so that the noise pollution and air pollution should be minimum. The central column is first triggered and then blast proceed towards outside to produce three way action and hence results the fall of existing structure on its footprint.

Falling of structure

Once central support/column will be destroyed and adjoining columns will be weakened, due to its gravity the entire mass will come down on its footprints. In this case after blasting within few seconds the entire structure of (g+3) storied came down on its footprint without damaging any adjoining asset.

PART A

1. **When do you demolish a building? (April/May 2015)**

Reasons for demolition of structures are:

- When structure is unsafe to perform any kind of function.
- Whenever extensive structural modifications required.
- Due to modernization old building may require demolition for new construction
- Structural failure of building and when repair works may not be possible
- When expansion or extension of building is required
- The structures severely suffered during natural hazards like earthquake, landslide, fire, cyclone, floods, etc.

2. What are the methods of demolition? (Nov/Dec. 2011)

- Pneumatic and hydraulic breakers Dismantling
- Pressure bursting.
- Explosives
- Ball and crane for demolishing masonry and concrete structures

3. State the preventive measure taken during Demolition? (April 2014)

The preventive measures taken during demolition are as follows:

- Necessary measures to prevent accidental collapse should be provided
- Materials of fragile nature like glasses should be commencement of work removed before
- To prevent harm to workmen dust should be controlled
- Proper ventilation and lightening should be provided at the working place.
- Easy emergency exit should be provided for quick evacuation of workers.
- All service connections such as electricity, system, gas and water should be . disconnected.
- No demolition work should be carried out during nights as far as possible

4. What are the preliminary investigations before demolition of a structure?

The following are the preliminary investigations before demolition of a structure are:

- The demolition contractor should have ample experience of the type of work to be offered.
- Fully comprehensive insurance against all risks must be maintained at all times.
- An experienced supervisor should be continuously in charge of the work.
- The contract price should include all safety precautions included in the relevant building regulations,

- The completion date should be realistic, avoiding and need to take risks to achieve the date.

5. What are the major factors in selecting a demolition procedure?

Major factors to be considered in selecting an appropriate demolition technique include:-

- Safety of personnel and public
- Working methods
- Legislation applicable
- Insurance cover

6. Give the categories of demolition techniques.

Demolition techniques may be categorized as:-

- Piecemeal demolition (using hand-held tools or machines) to reduce the height of the building or structure gradually.
- Deliberate controlled collapse-demolition to be completed at ground level.

7. Write short notes on demolition by hand.

- Demolition of buildings or structure by hand-held tools such as electric or pneumatic breakers, sometimes as a preliminary to using other methods, should be carried out, where practicable, in the reverse order to the original construction sequence.
- Lifting appliances may be necessary to hold larger structural members during cutting and for lowering severed structural members and other debris.

8. In what cases demolition by machine can be done? (April/May 2010)

- Simple roof structures supported on wall plates should normally be demolished to the level of wall plates by hand, but if this may involve unsafe working, then demolition totally by machine may be appropriate.

9. Write short notes on balling machine.

- Balling machines generally comprise a drag-line type crawler chassis fitted with a lattice crane jib.
- The demolition ball, with a steel anti-spin device, is suspended from the lifting rope and swung by the drag rope.

10. How are explosives used for demolition of a structure?

- If explosives are to be used for demolition, the planning and execution, include pre-weakening, should be under the control of a person competent in these techniques.
- For large demolition, the competent person is likely to be an experienced explosive engineer, for smaller work, a shot-firer may be sufficient.

11. What is a hydraulic pusher arm?

- Articulated, hydraulically-powered pusher-arm machines are normally mounted on a tracked or wheeled chassis, and have a toothed plate or hook for applying for applying a horizontal force to a wall.
- The machine should stand on a firm level base and apply force by a controlled movement of the pusher arm.

12. What is pre-weakening?

- Buildings and structures normally have structural elements designed to carry safely the loading likely to be imposed during their life.
- As a preliminary to a deliberate controlled collapse, after loads such as furnishings, plant and machinery have been removed, the demolition contractor may be able to weaken some structural elements and remove those new redundant.
- This pre-weakening is essentially a planned exercise and must be preceded by an analysis of its possible effects on the structure until it collapses, to ensure that the structural integrity of the building is not jeopardized accidentally.
- Insufficient information and planning relating to the structure may result in dangerous and unsafe work.

13. What is deliberate collapse?

- The deliberate collapse of the whole or part of a building or structure requires particularly high standards of planning, supervisions and execution, and careful consideration of its effect on other parts of the structure or on adjacent buildings or structures.
- A surrounding clear area and exclusion zone are required to protect both personnel and property from the fall of the structure itself and debris which may be thrown up by the impact.

14. How can you develop a demolition strategy?

- The strategy will need to take into account the method of construction used for the original building and its proximity to other buildings, structures and the general public.
- These factors, together with location, the cost and availability of tipping and disposal and the desirability and economics of reuse, must be taken into account in the development of an appropriate strategy for the demolition of a structure.

15. What are the considerations before demolition?

Considerations should be given to:

- Conducting a site and building survey, with a structural bias;
- The examination of drawings and details of existing construction where available;
- The preparation of details and drawings from site survey activities where no such information is available;
- Establishing previous use of premises, especially with regard to flammable substances or substances hazardous to health or safety
- Programming the sequence of demolition work;
- The preparation of a Method Statement.

PART B

1. State the various general methods of demolition
2. Discuss the case study on engineered demolition techniques for a structure using implosion technology
3. What are the techniques available to demolish the structure? Explain any one with detailed case study.
4. State the various methods/ approaches of structural strengthening that can be considered without completely demolishing/ reconstructing the member of a structure
5. Explain in detail the techniques used for dismantling
6. Explain in detail the different demolition techniques
7. Outline the advanced techniques demolition techniques by using robotic machine
8. Summarize the safety precaution before demolition and dismantling

9. What are the techniques available to demolish the structure? Extend any one case study?

10. Rephrase the procedure for demolishing main structural members like columns, beams and slabs with the help of neat sketch.

Reg No:

QUESTION PAPER CODE: JP3103

B.E / B. Tech. DEGREE EXAMINATIONS, AUGUST 2023
Fifth Semester
CIVIL ENGINEERING
CE3013 – ADVANCED CONSTRUCTION TECHNIQUES
Internal Assessment Test – I
(Regulation 2021)

Time: 01:30 Hours | Maximum: 50 Marks

Answer ALL questions
PART A – (05 X 02 = 20 Marks)

1.	List out the disadvantages of demolition using explosives	CO5	[K1]	
2.	What are the safety precautions used in demolition and dismantling?	CO5	[K1]	
3.	Differentiate dismantling and demolition	CO5	[K1]	
4.	When do you demolish a building?	CO5	[K1]	
5.	Label the methods of demolition?	CO5	[K1]	
	PART B – (02 X 13 = 26 Marks)			
6 (a)	Rephrase the procedure for demolishing main structural members like columns, beams and slabs with the help of neat sketch	CO5	[K2]	(13)
	(OR)			
(b)	Interpret in detail the techniques used for dismantling	CO5	[K2]	(13)
7 (a)	Explain the Modern advanced techniques demolition techniques by using autoboot	CO5	[K2]	(13)
	(OR)			
(b)	State the various methods/ approaches of structural strengthening that can be considered without completely demolishing/ reconstructing the member of a structure	CO5	[K2]	(13)
	PART C – (1 X 14 = 14 Marks)			
8 (a)	What are the techniques available to demolish the structure? Explain any one with detailed case study.	CO5	[K2]	(14)
	(OR)			
(b)	Discuss the case study on engineered demolition techniques for a structure using implosion technology	CO5	[K2]	(14)

Knowledge Level:
[K1] - Remember, [K2] - Understand, [K3] – Apply, [K4] – Analyze, [K5] – Evaluate & [K6] - Create
Course Outcomes:
On completion of the course, the student is expected to be able to
CO 1: Understand the modern construction techniques used in the sub structure construction.
CO 2: Demonstrate knowledge and understanding of the principles and concepts relevant to super structure construction for buildings
CO 3: Understand the concepts used in the construction of special structures.
CO 4: Knowledge on various strengthening and repair methods for different cases.
CO 5: Identify the suitable demolition techniques for demolishing a building.

Reg No:

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B.E / B. Tech. DEGREE EXAMINATIONS, AUGUST 2023
Fifth Semester
CIVIL ENGINEERING
CE3013 – ADVANCED CONSTRUCTION TECHNIQUES
Internal Assessment Test – I
(Regulation 2021)

Time: 01:30 Hours Maximum: 50 Marks

Answer ALL questions
PART A – (05 X 02 = 10 Marks)

1.	State the preventive measure taken during demolition.	CO5	[K1]	
2.	Enlist the preliminary investigation before demolition of a structure	CO5	[K1]	
3.	Name the major factors in selecting a demolition procedure	CO5	[K1]	
4.	Give the category of demolition techniques	CO5	[K1]	
5.	In what cases demolition by machine can be done?	CO5	[K1]	
	PART B – (02 X 13 = 26 Marks)			
6 (a)	Explain in detail the different demolition techniques	CO5	[K2]	(13)
	(OR)			
(b)	Interpret in detail the techniques used for dismantling	CO5	[K2]	(13)
7 (a)	Outline the advanced techniques demolition techniques by using robotic machine	CO5	[K2]	(13)
	(OR)			
(b)	Summarize the safety precaution before demolition and dismantling	CO5	[K2]	(13)
	PART C – (1 X 14 = 14 Marks)			
8 (a)	What are the techniques available to demolish the structure? Extend any one case study?	CO5	[K2]	(14)
	(OR)			
(b)	Rephrase the procedure for demolishing main structural members like columns, beams and slabs with the help of neat sketch.	CO5	[K2]	(14)

Knowledge Level:
[K1] - Remember, [K2] - Understand, [K3] – Apply, [K4] – Analyze, [K5] – Evaluate & [K6] - Create
Course Outcomes:
On completion of the course, the student is expected to be able to
CO 1: Understand the modern construction techniques used in the sub structure construction.
CO 2: Demonstrate knowledge and understanding of the principles and concepts relevant to super structure construction for buildings
CO 3: Understand the concepts used in the construction of special structures.
CO 4: Knowledge on various strengthening and repair methods for different cases.
CO 5: Identify the suitable demolition techniques for demolishing a building.

Reg No:

QUESTION PAPER CODE: JP3103

B.E / B. Tech. DEGREE EXAMINATIONS, SEP 2023
Fifth Semester
CIVIL ENGINEERING
CE3013 – ADVANCED CONSTRUCTION TECHNIQUES
Internal Assessment Test – II
(Regulation 2021)

Time: 03 Hours | Maximum: 100 Marks

Answer ALL questions

PART A – (10 X 02 = 20 Marks)

1.	List out the uses of Box jacking	CO1	[K1]	
2.	Relate Box jacking and Pipe jacking	CO1	[K2]	
3.	What do you understand about diaphragm walls?	CO1	[K1]	
4.	Solve will you increase the frictional resistance of piles?	CO1	[K3]	
5.	Show do you demolish a building?	CO5	[K2]	
6.	What are the methods of demolition?	CO5	[K3]	
7.	Summarize the preventive measure taken during Demolition	CO5	[K2]	
8.	Infer the preliminary investigations before demolition of a structure	CO5	[K2]	
9.	Outline the prestressing	CO2	[K2]	
10.	Select the merits of prestressed cement concrete	CO2	[K3]	
	PART B – (05 X 13 = 65 Marks)			
11 (a)	Recall the construction sequence of box jacking process with neat sketches	CO1	[K1]	(13)
	(OR)			
(b)	Explain the detail about tunneling techniques	CO1	[K2]	(13)
12 (a)	Utilize the process of transporting and installation of fixed offshore jacket platform	CO1	[K3]	(13)
	(OR)			
(b)	Examine in details about the various methods of dewatering process with neat sketch	CO1	[K4]	(13)
13 (a)	Show the various general methods of demolition	CO5	[K1]	(13)
	(OR)			
(b)	Outline the advanced techniques demolition techniques by using robotic machine	CO5	[K2]	(13)
14 (a)	Develop the various methods/ approaches of structural strengthening that can be considered without completely demolishing/ reconstructing the member of a structure	CO5	[K3]	(13)
	(OR)			
(b)	Dissect the case study on engineered demolition techniques for a structure using implosion technology	CO5	[K4]	(13)
15 (a)	Construct in detail the erection techniques of tall structures	CO2	[K3]	(13)
	(OR)			
(b)	Discover the in-situ prestressing done in high rise structure?	CO2	[K4]	(13)
	PART C – (1 X 15 = 15 Marks)			
16 (a)	Experiment with you want to construct a large reservoir, explain with neat sketches the construction sequence and the techniques used for dewatering and	CO1	[K3]	(15)

	concreting.			
	(OR)			
(b)	Inference the construction techniques and sequences involved in the construction of superstructure of tall buildings?	CO2	[K4]	(15)

Knowledge Level:
[K1] - Remember, [K2] - Understand, [K3] – Apply, [K4] – Analyze, [K5] – Evaluate & [K6] - Create
Course Outcomes:
On completion of the course, the student is expected to be able to CO 1: Understand the modern construction techniques used in the sub structure construction. CO 2: Demonstrate knowledge and understanding of the principles and concepts relevant to super structure construction for buildings CO 3: Understand the concepts used in the construction of special structures. CO 4: Knowledge on various strengthening and repair methods for different cases. CO 5: Identify the suitable demolition techniques for demolishing a building.

Reg No:

QUESTION PAPER CODE: JP3103

B.E / B. Tech. DEGREE EXAMINATIONS, SEP 2023
Fifth Semester
CIVIL ENGINEERING
CE3013 – ADVANCED CONSTRUCTION TECHNIQUES
Internal Assessment Test – II
(Regulation 2021)

Time: 03 Hours | Maximum: 100 Marks

Answer ALL questions
PART A – (10 X 02 = 20 Marks)

1.	Define well point	CO1	[K1]	
2.	Infer different de-watering techniques	CO1	[K2]	
3.	Select some equipment used for underground open excavation.	CO1	[K1]	
4.	Choose shoring for deep excavation	CO1	[K3]	
5.	List the categories of demolition techniques.	CO5	[K2]	
6.	Develop explosives used for demolition of a structure	CO5	[K3]	
7.	Relate a hydraulic pusher arm	CO5	[K2]	
8.	Outline the pre-weakening	CO5	[K2]	
9.	Compare the different tunneling techniques	CO2	[K2]	
10.	Plan the purpose of using slip form technique in construction	CO2	[K3]	
	PART B – (05 X 13 = 65 Marks)			
11 (a)	Recall the procedure involved in under water construction of diaphragm walls and basement	CO1	[K1]	(13)
	(OR)			
(b)	Summarize the operation procedure pipe jacking	CO1	[K2]	(13)
12 (a)	Construct by well foundation and Caisson foundation and explain in detail about the construction of well foundation and Caisson foundation?	CO1	[K3]	(13)
	(OR)			
(b)	What is called Cofferdams? Examine the types of cofferdams in detail	CO1	[K4]	(13)
13 (a)	Choose the procedure for demolishing main structural members like columns, beams and slabs with the help of neat sketch.	CO5	[K1]	(13)
	(OR)			
(b)	Summarize the safety precaution before demolition and dismantling	CO5	[K2]	(13)
14 (a)	What are the techniques available to demolish the structure? Develop any one with detailed case study.	CO5	[K3]	(13)
	(OR)			
(b)	Categorize the advanced techniques demolition techniques by using robotic machine	CO5	[K4]	(13)
15 (a)	Make use of the various steps involved in the erection of lattice towers	CO2	[K3]	(13)
	(OR)			
(b)	Discover in details erection and operation of tower cranes.	CO2	[K4]	(13)
	PART C – (1 X 15 = 15 Marks)			
16 (a)	Identify different types of tunnel boring machines with near sketches.	CO1	[K3]	(15)

(OR)				
(b)	Conclusion the sequence in demolition and dismantling of building with neat sketches.	CO5	[K4]	(15)

Knowledge Level:

[K1] - Remember, [K2] - Understand, [K3] – Apply, [K4] – Analyze, [K5] – Evaluate & [K6] - Create

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CO 4: Knowledge on various strengthening and repair methods for different cases.
CO 5: Identify the suitable demolition techniques for demolishing a building.

Faculty In-charge HOD

Reg No:

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B.E / B. Tech. DEGREE EXAMINATIONS, OCT 2023
Fifth Semester
CIVIL ENGINEERING
CE3013 – ADVANCED CONSTRUCTION TECHNIQUES
Internal Assessment Test – III
(Regulation 2021)

Time: 03 Hours | Maximum: 100 Marks

Answer ALL questions
PART A – (10 X 02 = 20 Marks)

1.	Define dewatering of concrete flooring.	CO2	[K1]	
2.	List out the properties of paver blocks.	CO2	[K1]	
3.	What is slip formwork?	CO2	[K1]	
4.	Show the all structural forms in tall structures.	CO2	[K1]	
5.	State the advantages and disadvantages of mechanical stabilization	CO4	[K1]	
6.	Outline the types of bridge maintenance	CO4	[K2]	
7.	Recall of mud jacking or slab jacking.	CO4	[K1]	
8.	Infer the requirements of to meet the underpinning	CO4	[K2]	
9.	Build the Methods of erection of steel transmission towers or rigging of transmission line structures	CO3	[K3]	
10.	Utilize types of storage silos based on height and diameter and its applications.	CO3	[K3]	
	PART B – (05 X 13 = 65 Marks)			
11 (a)	Extend about vacuum dewatering of concrete flooring and concrete paving technology with neat sketches.	CO2	[K2]	(13)
	(OR)			
(b)	Develop briefly about Erection techniques of tall structures with neat sketches	CO2	[K3]	(13)
12 (a)	Examine about Erection techniques of large span structure and launching techniques for heavy decks.	CO2	[K3]	(13)
	(OR)			
(b)	Explain about In-Situ prestressing in high rise structures with stages of operations	CO2	[K4]	(13)
13 (a)	Explain the seismic retrofitting, its purpose and how to strengthening of beams with neat sketches.	CO4	[K1]	(13)
	(OR)			
(b)	Short notes about how to strengthening of column and slab in modern techniques with neat sketches .	CO4	[K2]	(13)
14 (a)	Short notes about the protection methods of structures and explain mud jacking and grouting for foundation	CO4	[K3]	(13)
	(OR)			
(b)	Examine the micro-pilling and underpinning for strengthening floor and shallow profile with neat sketches.	CO4	[K4]	(13)
15 (a)	Explain briefly about Erection of lattice towers- rigging of transmission line structures.	CO3	[K3]	(13)
	(OR)			
(b)	Explain about construction sequence in cooling towers	CO3	[K4]	(13)
	PART C – (1 X 15 = 15 Marks)			

16 (a)	Explain about subgrade waterproofing with neat sketches.	CO3	[K3]	(15)
	(OR)			
(b)	Explain about Post-tensioning of the slab with neat sketches.	CO4	[K4]	(15)

Knowledge Level:
[K1] - Remember, [K2] - Understand, [K3] – Apply, [K4] – Analyze, [K5] – Evaluate & [K6] - Create
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B.E / B. Tech. DEGREE EXAMINATIONS, OCT 2023
Fifth Semester
CIVIL ENGINEERING
CE3013 – ADVANCED CONSTRUCTION TECHNIQUES
Internal Assessment Test – III
(Regulation 2021)

Time: 03 Hours | Maximum: 100 Marks

Answer ALL questions
PART A – (10 X 02 = 20 Marks)

1.	Tell the process of concreting the slip formwork.	CO2	[K1]	
2.	Label the advantages of pumped concrete	CO2	[K1]	
3.	Spell the benefits of mobile concrete mixer.	CO2	[K1]	
4.	Sketch the post tensioning system and mark the components.	CO2	[K1]	
5.	Infer the advantages and disadvantages of bitumen stabilization	CO4	[K2]	
6.	Classify the various factors affecting the lime stabilization	CO4	[K2]	
7.	Identify the cause of cracks in buildings	CO4	[K3]	
8.	Relate various water proofing materials of advanced technology	CO4	[K2]	
9.	Summarize the techniques for construction domes.	CO3	[K2]	
10.	Select methods of erection of steel towers	CO3	[K3]	
	PART B – (05 X 13 = 65 Marks)			
11 (a)	Explain about types of structural form adopted in the design of tall structures with neat sketches.	CO2	[K2]	(13)
	(OR)			
(b)	Rephrase about mobile concrete mixer or volumetric mixer with merits and demerits	CO2	[K2]	(13)
12 (a)	Solve the aerial transporting handling and erecting lightweight components of tall structures.	CO2	[K3]	(13)
	(OR)			
(b)	Conclusion the basic design concept of tall structures and factors affecting growth, height and structural form of tall structures.	CO2	[K4]	(13)
13 (a)	Illustrate the retrofitting in steel structures and summary about repair of bridges with neat sketches,	CO4	[K2]	(13)
	(OR)			
(b)	Explain about how to repair the building and summary about maintenance and inspection it.	CO4	[K5]	(13)
14 (a)	Discover the repair of towers by used recent trends techniques and methodology.	CO4	[K4]	(13)
	(OR)			
(b)	Inspect the repair of monuments and historical structures.	CO4	[K4]	(13)
15 (a)	Conclude briefly about construction sequence in skyscrapers.	CO3	[K5]	(13)
	(OR)			
(b)	Justify about the construction sequence in silos.	CO3	[K5]	(13)
	PART C – (1 X 15 = 15 Marks)			
16 (a)	Solution about prevention of water leakages in structures.	CO3	[K6]	(15)

(OR)				
(b)	Prioritize about the durability of repairing material.	CO4	[K5]	(15)

Knowledge Level:

[K1] - Remember, [K2] - Understand, [K3] – Apply, [K4] – Analyze, [K5] – Evaluate & [K6] - Create

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