BOX JACKING EXPLANATION

•It is the 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 a aqueduct or a underground structure is to be constructed.

•It enables the traffic flow without disruption.

METHODS OF BOX JACKING

Box Jacking

Non –intrusive method beneath existing surface infrastructure

Frequently used where an existing road or rail tracks is an embankment and space exists for the structure to be cast at the side

Enables traffic flows to be maintained disruption

Procedure

It involves the advancement of a site-cast rectangular or other shaped box using high capacity hydraulic jacks.

An open ended reinforced concrete box is cast on a jacking base.

A purpose designed tunneling shield is provided at its leading end and thrust jacks are provided at its rear end reacting against a jacking slab

The box is then jacked carefully through the ground

Excavation and jacking take place in small increments of advance.

Measure are taken to ensure stability of the tunnel face and to prevent the ground from being dragged forward by the advancing box

When the box has reached its final position the shield and jacking equipment are removed.

R.C.C box jacking

Is adopted where it is not possible to constructed in situ R.C.C boxes

These boxes are used for canal siphon, road under bridge and culvert for conveying water/service pipes

The box is provided with a shield in front in front called "Front shield"

Which pierces through the soil by cutting

R.C.C BOX JACKING

•First the box section is designed and cast at the site or can be transported to the site according to the requirement.

•The foundation boxes are jacked into the ground designed to carry the dead and the live loads.

•Then the high capacity jacks are placed at the back and it pushes the box into the ground.

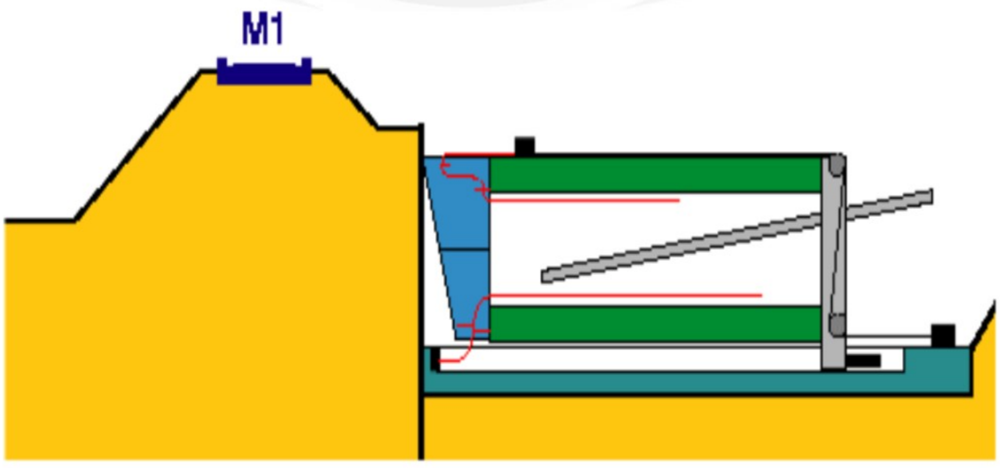
•A purpose designed tunneling shield is provided in the front end.

•Then the box is jacked carefully through the earth.

•Excavation and jacking are done in small increments in advance.

•Measures should be taken to prevent the soil being dragged towards the box.

R.C.C BOX JACKING



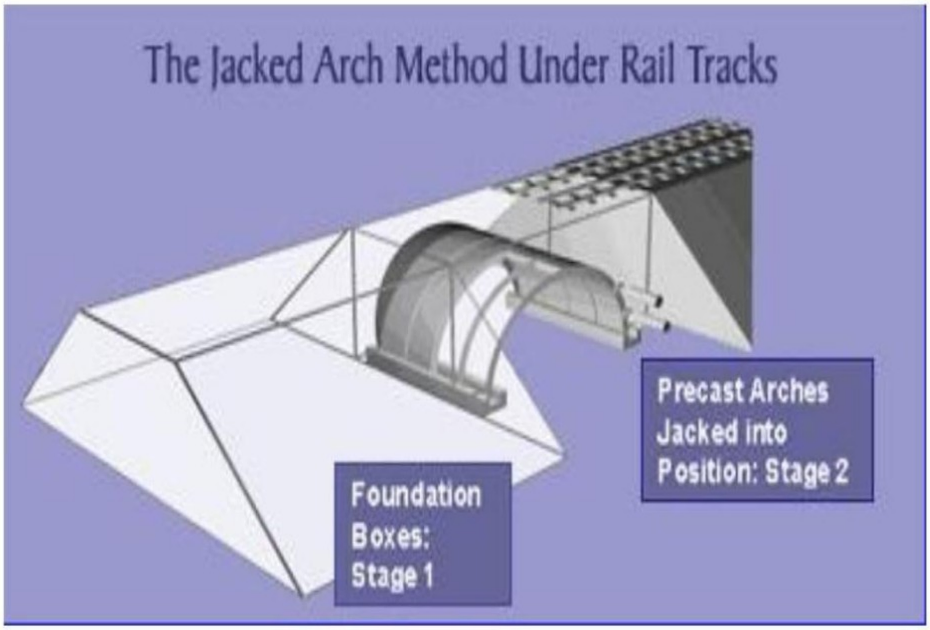
Throustboring method

Is a process of simultaneously jacking pipe through the earth while removing the soil inside the encasement by means of a rotating auger.

In unstable soil conditions, the end of the auger is kept retracted back inside the encasement so as not to cause voids.

In stable conditions, the auger can be successfully extended beyond the end of the encasement.

ARCHED JACKING



THRUST BORING METHOD

•It is a process of simultaneously jacking the pipe through the earth while removing the earth inside the box by means of a rotating auger.

•Unstable conditions- the end of auger is kept retracted inside the encasement so as not to cause voids.

•Stable conditions- the auger can be successfully extended beyond the encasement.

•This can be successfully used in any kind of soil conditions.

PROBLEMS ENCOUNTERED IN JACKING

•Settlement of the above ground.

•Seepage of ground water.

•Caving in of soil etc.

FREEZING OF GROUN

•This method is used when we encounter the problem of ground water seepage and settlement of ground.

•In this method a brine solution is continuously passed through the pipes fixed in the soil.

•The temperature of the brine would be -30°c.

•So when this brine solution is circulated through these pipes it freezes the ground and the ground behaves like an ice block.

•The spacing of the freezing pipes will vary according to the type of soil, its permeability and other factors.

•Generally it is kept at a spacing of 1.2 m

PROBLEMS IN FREEZING

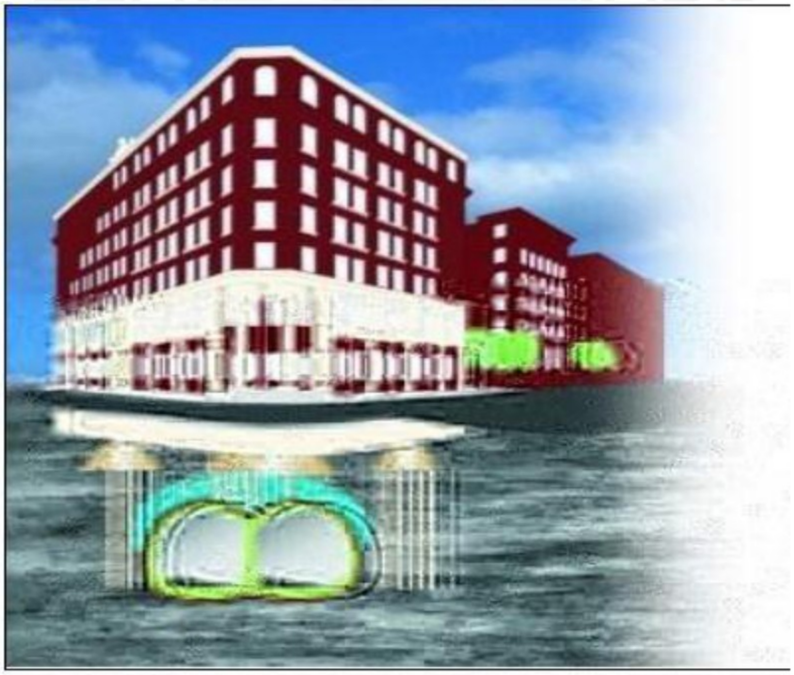
•The main problem in the freezing method is the UPHEAVING of the above ground.

•To avoid the upheavement problem we should be careful in the ground freezing process and the temperature of the brine solution.

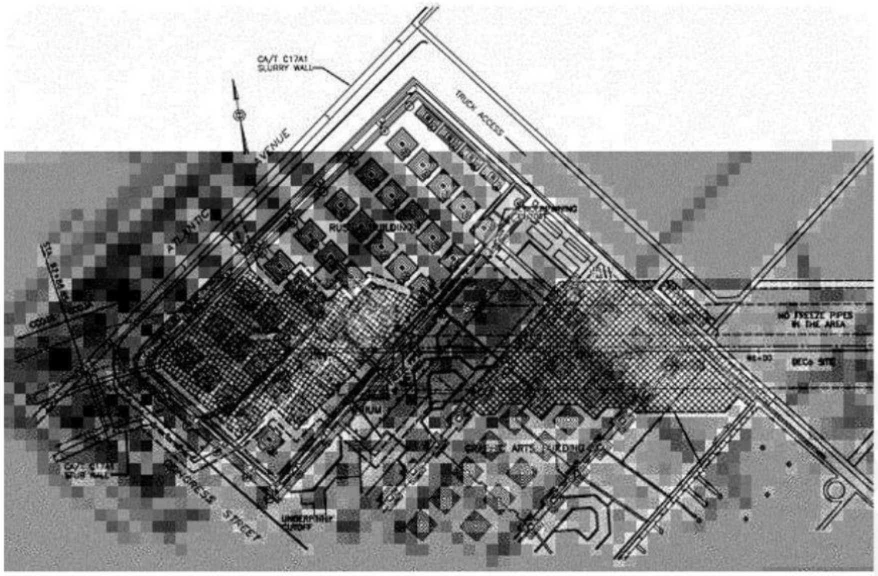
CASE STUDY - SOUTHERN BOSTON PIERS TRANSIT WAY

•The carriageway has to go beneath – a Russian building,100 year old •2m thick soil was frozen.

•Under pinning was also done using mini piles.



PLAN OF THE RUSSIAN BUILDING



ADVANTAGES

•Timely completion of project.

•No disruption of traffic.

•No need to divert the traffic.

DISADVANTAGES

•Cost of project increases.

•Skilled personnel required.

•Safety precautions to be done properly.

PIPE JACKING

ABOUT THE TECHNIQUE

•It is generally referred as "Micro tunneling"

•Pipes are pushed through the ground behind the shield using powerful jacks.

•Simultaneously excavation takes place within the shield.

•This process is continued until the pipeline is completed.

•The method provides a flexible, structural, watertight, finished pipeline as the tunnel is excavated.

•No theoretical limit to the length of individual pipelines.

•Pipes range from 150mm to 3000mm diameter can be installed in straight line or in curvature.

•Thrust wall is provided for the reaction of the jacks.

•In case of poor soil, the thrust wall may punch inside the soil. •Then piles or ground anchoring methods can be used.

PROCEDURE

•The thrust pit and the reception pit are excavated at the required places.

•Then the thrust wall is set up in the thrust pit according to the requirement.

•In case of mechanized excavations, a very large pit is required.

•But in case of manual excavation, a small pit is enough.

•Thrust ring is provided to ensure the even distribution of stress along the circumference of the pipe.

•The number of jacks vary upon the frictional resistance of the soil, strength of pipes etc.,

•The size of the reception pit is to be big enough to receive the jacking shield.

•To maintain the accuracy of alignment a steer able shield is used during the pipe jacking.

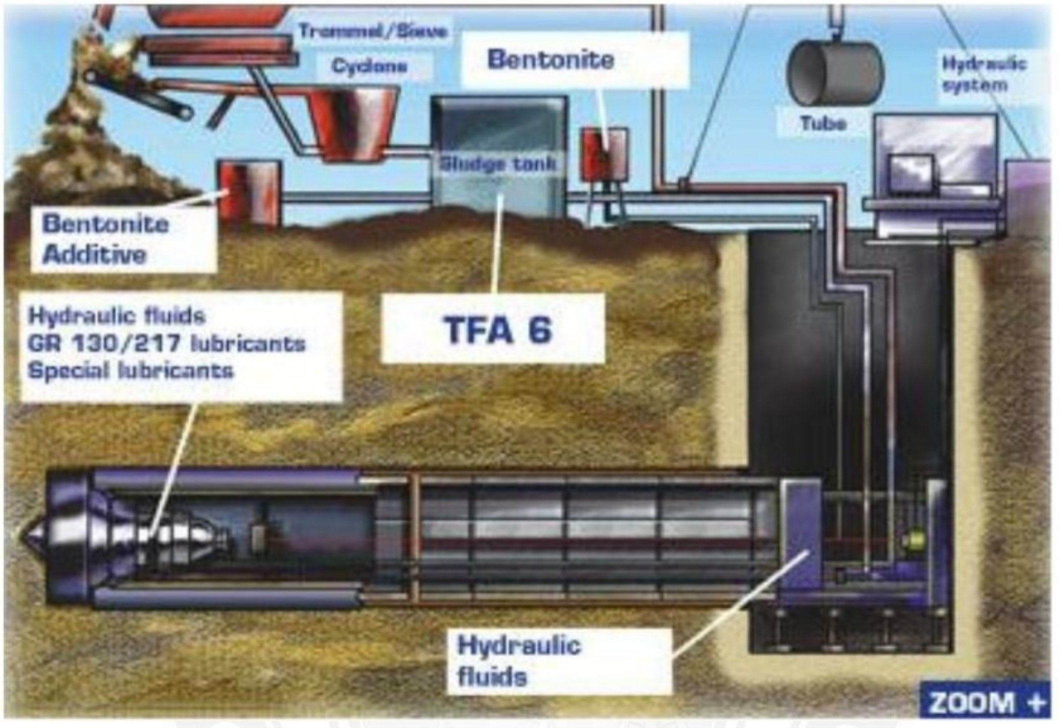
•In case of small and short distance excavations, ordinary survey method is sufficient.

•But in case of long excavations, remote sensing and other techniques can be used.

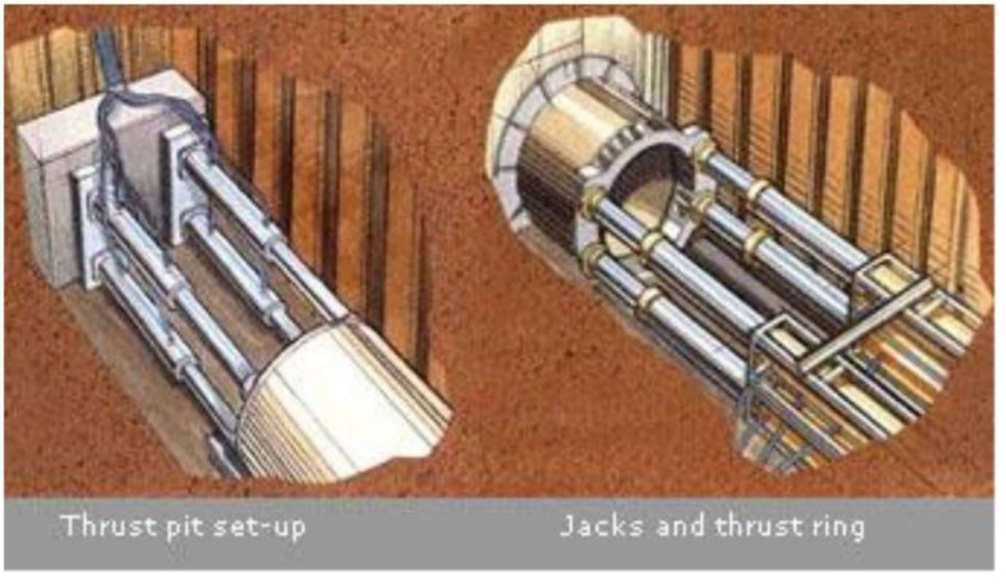
GENERAL ARRANGEMENTS

General arrangements of pipe jacking and microtunelling systems

PIPE JACKING SETUP



THRUST SETUP



COMPUTER GUIDANCE SYSTEM

•The computer system enables us to control the work remotely.

Computer guidance system for microtunnelling

ADVANTAGES

•It avoids the excavation of trenches. So it is also called as "Trench less Technique".

•There won't be any leak problems in the future. •Timely finish of projects.

DISADVANTAGES

•Very costly method.

•Skilled personnel is required.

3.2 DIAPHRAGM WALL

Diaphragm wall are structure elements, which are constructed underground to prevent the seepage into the excavated area

Various methods adopted to construct a diaphragm wall

Slurry trench technique

1. Soil mixing method
2. RC continuous diaphragm wall
3. Precast diaphragm wall
4. Glass diaphragm walls

Slurry trench technique

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 performed in all types of soil even below ground water table

Soil mixing method

This is the method used to make continuous walls by churning up piled soil using an auger, pouring in cement milk and marking soil mortar columns in the ground using the soil as aggregate

This is an in situ mixing and churning method

In the method after completing excavation of the groove wall using an excavator, soil cement is produced by mixing and churning excavated soil

The excavated soil is classified and graded with cement milk after being put through a termite

Then the soil cement is poured into the groove wall, after which the steel material is built as the core material

RC continuous diaphragm wall

This method of building a very long continuous diaphragm wall

Excavate a given groove between the surface and underground using a stabilizing liquid

Insert a given steel bar pour in concrete, thereby building a reinforced concrete wall underground.

Precast diaphragm wall

With this method, a continuous trench or longer panels are excavated under self- hardening cement- bentonite (CB) slurry.

The precast concrete wall sections are lifted and positioned by a crane The CB slurry sets to form the final composite wall

The trench is excavated under bentonite slurry, which is then displaced with CB slurry.

Glass diaphragm walls

For contained enclosure, a diaphragm wall system consisting of special glass panels with a sealing made out of glass are used.

The panels are 50cm wide and up to 15cm long

Common uses of diaphragm wall walls

- To provide structural support for the construction
- To provide retaining wall
- To provide deep diaphragms

Applications of diaphragm wall

As permanent and temporary foundation wall foundation walls for deep foundation for deep basements

In earth retention schemes for highway and tunnel projects As permanent walls for deep shafts for tunnel access

As permanent cut - off walls through the core of earth dams

In congested areas for retention systems and permanent foundation walls Deep groundwater barriers through and under dams

3.3 TUNNEL BORING MACHINE

Tunnel boring machine (TBM) as mole recent developments in the tunnel driving technique. The function of TBM is to loosen the earth or break the rock continuously in the entire section of the tunnel, in to cuttings and convey to the rear of the machine, where it can be loaded into muck cars or dumpers or on to conveyor belts for the transportation to the ultimate disposal site.

Working principle and construction features of TBM

These machines perform the boring operation through rotation of the front head against the rock face. The mole has circular cutter head in the front provided with fixed cutters of desired shape. The cutter head while rotating is pressed against the rock to cut or pulverize it. The cuttings while failing down is collected in the buckets provided around the cutter head periphery. These buckets discharge the muck into a hopper to feed it into the belt conveyor leading to the rear of the machine. This conveyor then discharges the muck either into the mine car or to another belt conveyor leading to the portal of the tunnel. The muck of cuttings can also be disposed off by using the slurry pipelines after mixing the fine muck into water to form slurry.

For driving through full- face on full-face TRMs number of cutter heads is mounted on a drum. The drum when rotates in one direction, the individually driven cutter heads having projected Tungsten carbide tipped tools can be rotated in another direction and the drum advances into the tunnel face, by providing a thrust with the help of hydraulic systems. The tips of the tools when worn out can be easily replaced. The tips are kept cooled by spraying a mixture of water and compressed air into the cutting area. This also suppress the dust formed during cutting.

Advantages of tunnel boring machines

- There is very less danger of fall outs in machine bored tunnels, since adjacent or surrounding rocks are undistributed as no blasting is done.
- Mucking is also safe and convenient, since muck is conveyed from the face to the rear of the machine and is loaded automatically by means to the rear of the machine and is loaded automatically by means of belt conveyors.
- Higher speed of excavation.
- Reduction in the tunnel supports requirement.
- Less manpower requirement.

Various types of tunneling technique

Tunneling techniques are

1. Drilling
2. Drilling jumbo
3. Loading and firing

Drill jumbo

Drill jumbos used in tunnels are also known as tunnel jumbos. A drill jumbo is a portable carriage having one 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. These platforms have arrangement for the supporting the compressed air pipes, water pipes. The booms are operated by hydraulic fluid or air and support the drifters, and are equipped with control enabling the operator to spot a drill in any desired position conforming to the drilling pattern. The platforms are constructed as per the size of tunnel and can be raised or lowered so as to allow mockers or hauling equipment to pass under the jumbo several drill can be operated from each platform for speedy excavation

The jumbos either on rails on pneumatic tyres depending upon the type of work. The jumbo can be equipped with electricity feeding cables, pneumatic concrete placers etc. Mobile jumbos of modern design with four wheels drive and centrally articulated steering speeds production and reduce tunneling costs

Loading and firing

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. Explosive selected for working in tunnels should have low fumes characteristics. Ammonium nitrate explosives are therefore preferred over dynamics due to less toxic fumes

Drilling

For driving a tunnel number 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 cuttings from the holes instead of compressed air to reduced the amount of dust in the air. Holes are drilled slightly deeper than the advance per round to taken care of loss in depth during blasting. Depth advanced due to drilling and blasting operation is called as one round. Types of well point systems

1. Pumping from open sumps
2. Pumping from well points

Well point systems are installed in two ways:

a) Line system

b) Ring system

3. Pumping from bored wells

Types of piles

(a) Driven piles – Timber, recast concrete, Prestressed concrete , steel H-section, Box and tube

(b) Driven and cast-in place piles

(c) Bored piles

(d) Composite piles

Use of H-piles

H-Piles are used in construction of bridges where they can be driven through existing construction in small spaces they are used useful for driving close to existing structures since they cause little displacement of soil. It can be withstand large lateral forces. They require less space for shipping and storing than wood, pipe or precast concrete

They not require special slings or special care in handling.

DEEP EXCAVATIONS

Problems normally developed during deep excavations

To prevent the collapsing of sides of the trenches

To prevent water oozing or coming out from the sides and bottom of the trenches

The remedial measures to avoid the problems deep excavation

Providing shoring for the trenches

Dewatering of the trenches

Line system

This system is employed when excavation area is long. The header is laid out along the sides of the excavation, and the pumping is continuously in progress in one length as further points are jetted ahead of the pumped down section and pulled up from the completed and back filled lengths and repeated till entire length is completed. For narrow excavation, like trenches, header is laid only on one laid, while for wide excavations, the header are required to be placed on both sides of the area.

Ring system

When excavation is done in area of appreciable width, line system is inadequate. The ring system is used in such condition and the header main surrounds the excavations completely. This system is used for rectangular excavations such as for piers or basements.

3.4 CAISSON

Caisson has come to mean a box like structure, round or rectangular, which is suck from the surface of either land or water to some desired depth. Caissons are of three types:

(a) Box caisson

(b) open caisson

(c) Pneumatic caissons

Box caisson

A box caisson is open at top and closed at the bottom and is made of timber, reinforced concrete or steel. This caisson is built on land, then launched and floated to pier site where is suck in position. Such a type of caisson is used where bearing stratum is available at shallow depth, and where loads are not very heavy.

Open caisson

A small cofferdam that is set in place, pumped dry, and filled with concrete to form a foundation (as for a pier)

Pneumatic caisson

A caisson in which air pressure is used to keep out the water a pneumatic caisson is a watertight box or cylinder-like structure that is closed at the top and open at the bottom, resting on the bed of the water body. They are used for underwater construction of foundations for bridge piers, abutments in rivers, and foundations for large multi-story buildings. They are designed to keep water out of the construction zone and act as a seal that keeps the inside of the caisson dry for workers to carry out work safely.

The inside of the caisson is kept dry by using compressed air to force water out of the structure. This process creates an airtight working chamber where construction activities, such as excavations, can be carried out safely. Pneumatic caissons are ideal for challenging situations where it is not possible to carry out wet ground excavations in the open. However, this method is complex, time-consuming, and relatively expensive when compared to other types of caissons.

SHEET PILES

Sheet piles are thin piles, made of plates of concrete, timber or steel, driven into the ground for either separating members or for stopping seepage of water. They are not meant for carrying any vertical load. They are driven into ground with help of suitable pile driving equipment, and their height is increased while driving, by means of addition of successive installments of sheets.

Functions of sheet piles

1. To enclose a site or part thereof to prevent the escape of loose subsoil, such as sand, and to safeguard against settlement.
2. To retain the sides of the trenches and general excavation.
3. To protect river banks.
4. To protect the foundations from scouring actions of nearby river, stream etc.
5. To construct costal defense works

3.5 COFFERDAM

Types of cofferdam

1. Cantilever sheet pile cofferdam
2. Braced cofferdam
3. Embankment protected cofferdam
4. Double wall cofferdam
5. Cellular cofferdam

Grout anchors used in constructions

In most cases, however anchorages may be embedded below ground level, with backstays connecting them to adjacent towers, or they may constitute the end abutments of the end spans. In addition to stability sliding, the anchorage structure must also be checked for stability against tilting and overturning.

Methods o f ground water control

Following methods of ground water control are adopted

1. Pumping from open sumps
2. pumping from well points
3. Pumping from bored wells

(1) Pumping from open sumps

This method is most commonly used where area is large enough for allowing excavation to be cut back to stable slopes and where there are no important structures close to the excavation to effect their stability by settlement resulting from erosion due to water flowing towards the sump. This method is also applicable for rock excavations.

This method costs comparatively low for installation and maintenance. In this method one or more sumps are made below the general level of the excavation. In order to keep the excavator area clear of standing water, a small grip or ditch is cut around the bottom of the excavation failing towards the sump. For grater depths of excavation the pump is used or submersible deep well pump suspended by chains and progressively lowered down. Pumps suitable for operating from open sumps are:

- Pneumatic sump pumps
- Self-priming centrifugal pumps
- Mono pump sinking pumps

Pumping is simple and less expansive, but has serious limitations. When fine sand or cohesion less soil lie below the water, this type of pumping removes the fine material from the surrounding soil and results in settlement of adjacent structures. To product it sumps lined with gravel filter are sometimes used.

(2) Pumping from well points

This system comprises the installation of a number of filter wells generally 1m long, around the excavation. These filter wells are conducted by vertical riser pipes to a large dia header main at ground level which is under vacuum from a pumping unit. The water flows to the filter well by gravity and then drawn by the vacuum up to the header main and discharged through the pump. This system has the advantage that the water is filleted as it removed from the ground and carries almost no soil with it once steady discharge conditions are attained. This system has the limitation of limited suction lift. Therefore for deeper excavations the well points are installed in two or more stages.

The filter wells or well points are usually 1m long and 60 to 75mm diameter gauge screen surrounding a central riser pipe. The capacity of a single we;; point with 50mm raiser is about 10 lit/min. Spacing between two well points depends on the permeability of the soil and on the time available to effect the drawdown. In fine coarse sand or sandy gravels a spacing of 0.75 to 1m is required, while in silty sands of low permeability a 1.5m spacing is sufficient .In permeable course gravels spacing should be as low as only 0.3m.A normal set of well point system comprises 50 to 60 points to a single 150 or 200mm pump with a separate 100mm jetting pump.

(3) Pumping from bored wells

Pumping from wells, for draw-down depth of than the meters can be under taken by surface pumps with their suction pipes installed in bored wells. When dewatering is required to be undertaken from a considerable depth, electrify driven submersible pumps are installed in deep bore holes with rising main to the surface. Since heavy boring equipment is used, installation of wells can be done in all ground conditions including boulders and rocks. Due to higher costs of installation, this method is adopted where construction period is long and other methods of dewatering are not possible. Installation of bore well consists of sinking of a casting having a dia of about 20-30 cm larger than the inner well casting. The dia of inner well casting depends on the size of submersible pump. This inner well casing is inserted after complete sinking of borehole screen over the length where dewatering of the soil is required and it terminates in a 3-5 m length of unperformed pipe to act as a sump to collect any fine material which may be drawn through the filter mesh. Screen having slots are preferable to holes, since there is less risk of blockage from round stones.

Component parts of pipe jacking

Pipe jacking is specialist tunneling method for installing underground pipelines by assembling the pipes at the foot of an access shaft and pushing them through the ground with the minimum of surface disruption

Component parts of jacking systems

The pump unit has two distinct hydraulic systems

A high pressure systems supplies oil for the main jacking cylinders and till intermediate jacking stations

A low pressure system supplies oil, via hydraulic lines, for the boring head and conveyor. An auxiliary power pack may be easily installed to double the low pressure hydraulic flow. This may be necessary for larger and more powerful boring heads

Thrust yoke

The yoke is the frame that the main cylinders push against to advance the boring head and pipe. The ring provides a 360 degree surface against the pipe to minimize point pressure and reduce the chance of breakage.

Skid base

The skid base is the foundation of the pump unit and yoke. It also acts as a guide for launching the boring head and pipe into the ground.

Power packs

Power packs with high and low pressure systems typically are matched with the multiple cylinder system.

When tunneling, a lower pressure power pack may be selected to supply oil for the tunnel boring machine (TBM)

Power required depend on the size and features of the boring head

A mobile electric power pack may be positioned in the boring head/ TBM

Intermediate jacking stations

Installing intermediate jacking stations is a simple economical way of adding and distributing thrust for pipe jacking

The size and joint of the pipe, cost, length of push and versatility are important considerations that configure intermediate stations

Most popular design is effective with a variety of pipe sizes and design. Each design consists of ram segments. Each segment has 5 rams. All stations are supplied oil by one set of lines from the power pack and operated from one point in the jacking shaft.

Methods of providing shoring for the trenches

Methods for providing shoring for the trenches

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

(1) Stay bracing

Carried out in moderately firm ground

It is adopted when the depth does not exceed 2m

The vertical sheets are placed opposite each other against the sides of the trench

The vertical sheets are held in position by one or two rows of struts

The sheets are placed at an interval of 3 to 4m and they extend to full depth of the excavation

The normal sizes of

- Polling boreds 200*40&200*50mm

- Struts 100*100mm (For trench width upto 2m)
- Structs 200*200 (For trench width more 2m)

2. Box sheeting

Carried out in loose soil

It is used when depth of excavation does not exceed 4m

A box like structure is formed by providing sheeting, walls, structs and bracing

In this arrangement, the vertical sheets are placed nearer and touching each other

The sheets are kept in position by longitudinal rows of Wales, usually two and then, structs are provided across the wales

3. Vertical sheeting

Carried out in soft ground

Adopted when the depth is about 10m

This 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, wales, structs and braces are provided as usual

The offset is provided at a depth of 3 to 4m and it various from 30 to 60cm per stages

Suitable for laying sewers or water pipes at considerable depths

4. Runners

Carried out in extremely loose and soft ground which requires immediate support as the excavation progresses

The runners which are long thick wooden sheets or planks are used in this arrangement

These are driven by hammering about 30cm

The wales and struts are provided as usual

5. Sheet piling

provided when large area is to be excavated for a depth greater than 10m

Used when the soil is soft or loose

Provided when the width of the trench is large

It is also provided when the subsoil water is present

Large reservoir construction with membranes and earth system

The main problem in reservoirs is the loss of water due to seepage

So even if the capacity of the reservoir is large much water by lost due to it

It can be made impermeable by construction of impervious membranes on the embankment

The impervious membrane can be placed on

1. The upstream face of the dam
2. Core inside the embankment

Most of the major earth dams constructed before 1925 were provided with central concrete core walls or concrete slabs on the upstream face

The impervious advantages for the impervious membrane placement in the upstream side or core of the embankment

Concrete slab

Concrete slab can be used successfully up to a height of 150ft

The performance of concrete slab will directly on the quality of concrete

Even though the earth earth embankment is not required to act as a water barrier, it should be well compacted in order to minimize post-construction settlement of the upstream

slope

When single reinforced slab is adopted, some leakage will occur due to the hairline cracks so drains should be provided.

Steel plates

Steel plate can be used where reinforced concrete is used

The life is approximately the same as that of concrete

It can be directly placed on the soil containing appreciable percentage of silt or clay

It is expansive but it has two

advantages It is watertight

It is more flexible and can adapt to differential settlement in a better manner

Asphaltic concrete

They are less costly than concrete or steel

They are more flexible than reinforced concrete and can adapt to differential settlement better

They can be constructed quickly

Under certain circumstances the leaks development are self-sea line

The portion above the reservoir level are easy to repair than either concrete or steel

Advantages of upstream membrane

When the membrane is on the upstream side optimum stability condition are produced ,so the volume of embankment can be reduced

Since the upstream slab is exposed ,damage can be inspected and repaired easily

The upstream membrane can be built after the embankment is completed

Foundation grouting can be carried out while the dam is being built

The membrane can serve a secondary function as wave protection

Internal impervious membrane

Concrete is used mostly for internal membrane steel is used rarely

Since it is not exposed for investigation very little reliable performance is available

It is less influenced by embankment settlement and less likely to crack as a result

Advantages of internal membranes

The area of the membrane is smaller than that of an upstream facing, so less material is required

The surrounding embankment protects the internal membrane

The core can be made almost watertight even if cracking develops, by placing thin layer of clay upstream

A vertical extension of the core membrane below the base of the dam can be used through soil deposits in the foundation

The length of the grout curtain in is shorter.

Well sinking operation procedures

1. **Laying the well curb**

If the river bed is dry, lying of well curb presents no difficulty. In such a case, excavation up to half a meter above subsoil water level is carried out and the well curb is laid. If, however, there is water in the river, suitable

cofferdams are constructed around the site of the. Well and is lands are made. The sizes of the island should be such to allow free working space necessary to operate tools and plane for movement of labour etc. When the island is made, the center point of the well is accurately marked and the cutting edge is placed in a level plane. It is desirable to insert wooden sleepers below the cutting edge at regular intervals so as to distribute the load and avoid setting of the cutting edge unevenly during concrete.

2. Masonry in well staining

The well staining should be built in initial short height of about 2m only. It is absolutely essential that the well staining is built in one straight line from the bottom to top. To ensure this staining must be built with straight edges preferably of angle iron. The lower portions of the straight edges must be kept butted with the masonry of the lower stage throughout the building of the fresh masonry. In no case should a plumb bob be used to build more than 5m at a time. The well masonry is fully cured for at least 48 hours before starting the loading or sinking operations.

3. Sinking operations

A well is ready to be set in after having cast the curb and having built first short stage of masonry over it. The well is suck by excavating material from inside under the curb. In the initial stage of sinking, the well is unsuitable and progress can be very rapid with only little material being excavated out. Great care should therefore be exercised during this stage, to see the well sinks to true position. To sink the well straight it should never be allowed to go out of plumb.

Excavation and scooping out of the soil inside the well can be done by sending down workers inside the well till such a stage that the depth of water inside becomes about 1m.As the well sinks deeper, the skin friction on the sides progressively increases. To overcome the increased skin friction and the loss in weight of the well due to buoyancy, additional loading known as Kent edge is applied on the well.

Pumping out the water from inside the well is effective in sinking of well under certain conditions. Pumping should be discouraged in the initial stage. Unless the well has gone deep enough or has passed through a ring of clayey strata so that chances of tilts and shifts are minimized during this process. Complete dewatering should not be allowed when the well has been sunk to about 10m depth.

4. Tilts and shifts

The primary aim in well sinking is to sink them straight and at the correct position. Suitable precautions should be taken to avoid tilts and shifts. The precautions to avoid tilts and shifts are as follows

1. The outer surface of the well curb and staining's should be as regular and smooth as possible.
2. The radius of the curb should be kept 2 to 4 cm larger than outside of well staining
3. The cutting edge of the curb should be of uniform thickness and sharpness since the sharper edge has a greater tendency of sinking than a blunt edge.
4. As soon as tilt exceeds 1 in 200, the sinking should be supervised with special care and rectifying measures should be immediately taken.

5. Completion of well

When the well bottom has reached the desired strata, further sinking of the well stopped .A concrete seal is provided at the bottom. The bottom plug is made bowl shaped so as to have inverted arch action. As generally under watering concerting as to done, no reinforcement can be provided. Under watering concreting is done the help of tremie. However, if it is possible to dewater the well successfully, the concrete can be placed dry also.

well is capped at its top, with help of reinforced concrete slab. If however sand has been filled inside, top plug of lean concrete is interposed between the wall cap and sand filling.

COFFERDAM

Types of cofferdam

1. Cantilever sheet pile cofferdam
2. Braced cofferdam
3. Embankment protected cofferdam
4. Double wall cofferdam
5. Cellular cofferdam

Grout anchors used in constructions

In most cases, however anchorages may be embedded below ground level, with backstays connecting them to adjacent towers, or they may constitute the end abutments of the end spans. In addition to stability sliding, the anchorage structure must also be checked for stability against tilting and overturning.

Methods o f ground water control

Following methods of ground water control are adopted

1. Pumping from open sumps
2. pumping from well points
3. Pumping from bored wells

(1) Pumping from open sumps

This method is most commonly used where area is large enough for allowing excavation to be cut back to stable slopes and where there are no important structures close to the excavation to effect their stability by settlement resulting from erosion due to water flowing towards the sump. This method is also applicable for rock excavations.

This method costs comparatively low for installation and maintenance.In this method one or more sumps are made below the general level of the excavation.In order to keep the excavator area clear of standing water, a small grip or ditch is cut around the bottom of the excavation failing towards the sump.

For grater depths of excavation the pump is used or submersible deepwell pump suspended by chains and progressively lowered down.Pumps suitable for operating from open sumps are:

- Pneumatic sump pumps
- Self priming centrifugal pumps
- Monopump sinking pumps

Pumping is simple and less expansive, but has serious limitations. When fine sand or cohesion less soil lie below the water, this type of pumping removes the fine material from the surrounding soil and results in settlement of adjacent structures. To product it sumps lined with gravel filter are sometimes used.

(2) Pumping from wellpoints

This system comprises the installation of a number of filter wells generally 1m long, around the excavation. These filter wells are conducted by vertical riser pipes to a large dia header main at ground level which is under vacuum from a pumping unit. The water flows to the filter well by gravity and then drawn by the vacuum upto the header main and discharged through the pump. This system has the advantage that the water is filleted as it removed from the ground and carries almost no soil with it once steady discharge conditions are attained. This system has the limitation of limited suction lift. Therefore for deeper excavations the well points are installed in two or more stages.

The filter wells or well points are usually 1m long and 60 to 75mm diameter gauge screen surrounding a central riser pipe. The capacity of a single we;; point with 50mm raiser is about 10 lit/min. Spacing between two well points depends on the permeability of the soil and on the time available to effect the drawdown. In fine coarse sand or sandy gravels a spacing of 0.75 to 1m is required, while in silty sands of low permeability a 1.5m spacing is sufficient .In permeable course gravels spacing should be as low as only 0.3m.A normal set of wellpoint system comprises 50 to 60 points to a single 150 or 200mm pump with a separate 100mm jetting pump.

(3) Pumping from bored wells

Pumping from wells, for draw-down depth of than the meters can be under taken by surface pumps with their suction pipes installed in bored wells. When dewatering is required to be undertaken from a considerable depth,electrity driven submersible pumps are installed in deep bore holes with rising main to the surface. Since heavy boring equipment is used, installation of wells can be done in all ground conditions including boulders and rocks. Due to higher costs of installation, this method is adopted where construction period is long and other methods of dewatering are not possible.Installation of bore well consists of sinking of a casting having a dia of about 20-30 cm larger than the inner well casting. The dia of inner well casting depends on the size of submersible pump. This inner well casing is inserted after complete sinking of borehole screen over the length where dewatering of the soil is required and it terminates in a 3-5 m length of unperforted pipe to act as a sump to collect any fine material which may be drawn through the filter mesh. Screen having slots are preferable to holes, since there is less risk of blockage from round stones.

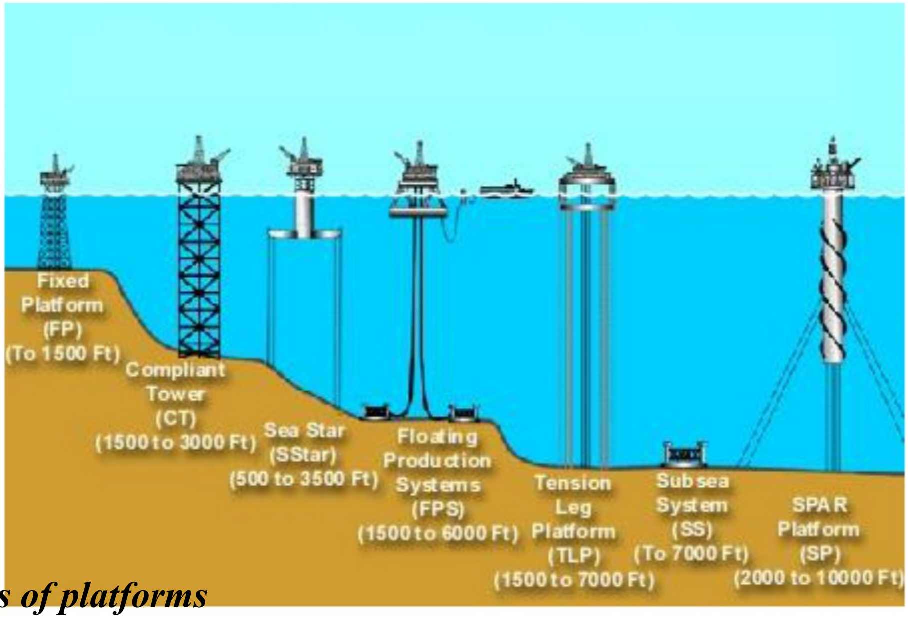
Component parts of pipe jacking

Pipe jacking is specialist tunneling method for installing underground pipelines by assembling the pipes at the foot of an access shaft and pushing them through the ground with the minimum of surface disruption Component parts of jacking systems The pump unit has two distinct hydraulic systems A high pressure systems supplies oil for the main jacking cylinders and till intermediate jacking stations A low pressure system supplies oil, via hydraulic lines, for the boring head and conveyor. An auxiliary power pack may be easily installed to double the low pressure hydraulic flow. This may be necessary for larger and more powerful boring heads

Thrust yoke The yoke is the frame that the main cylinders push against to advance the boring head and pipe. The ring provides a 360 degree surface against the pipe to minimize point pressure and reduce the chance of breakage. Skid base The skid base is the foundation of the pump unit and yoke. It also acts as a guide for launching the boring head and pipe into the ground. Power packs Power packs with high and low pressure systems typically are matched with the multiple cylinder system. When tunneling, a lower pressure power pack may be selected to supply oil for the tunnel boring machine (TBM) Power required depend on the size and features of the boring head A mobile electric power pack may be positioned in the boring head/ TBM Intermediate jacking stations Installing intermediate jacking stations is a simple economical way of adding and distributing thrust for pipe jacking

OFFSHORE PLATFORM

Offshore platforms, also referred to as oil platforms, are huge structures equipped with resources to drill wells and extract oil and gas deep inside the ocean. They boast storage facilities for crude and gas till they are transported to refineries, and sometimes may also have facilities to provide accommodation to the workforce. Depending on the requirements, an **oil platform** may be **floating** or **fixed** to the ocean floor.



Different types of platforms

Remote subsea wells can also be connected to a platform by pipelines. Offshore platforms are strongly built and are designed to last decades in the harsh environment. These platforms are usually build onshore and then transported to the drilling site.

Offshore platforms were first used in 1891 to drill submerged oil wells in the Grand Lake St. Mary's in Ohio.

Oil wells in the Grand Lake St. Marys

Main types of offshore platforms include

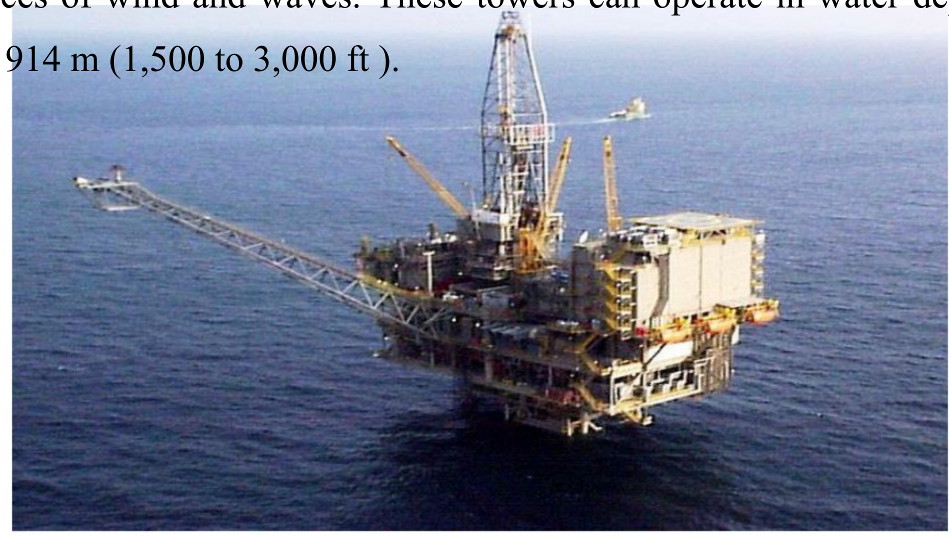
Fixed Platform

Fixed platforms are built on large steel or concrete legs that are fitted directly onto the seabed. They boast space for drilling rigs and production facilities, as well offer accommodation facilities for crew. This type of platform is extremely stable and is designed to last for a very long term. Normally, they can be installed in water depths up to 520 m (1,700 ft), as depths greater than this become impractical due to higher costs.

Fixed platform

Compliant Towers

These towers function on the basic idea of fixed platforms. But they use narrower towers of concrete and steel. They are flexible in design to sway and move laterally with the forces of wind and waves. These towers can operate in water depths ranging from 457 to 914 m (1,500 to 3,000 ft).



Compliant tower

Floating Production Systems

FPSO (floating production, storage, and offloading system) are the major floating production system. They can be used either as floating semi-submersible platforms or drillships as per the requirements. They are mainly used for processing and storage of oil and gas, and can operate in water depths up to 1,829 m (6,000 ft).

FPSO

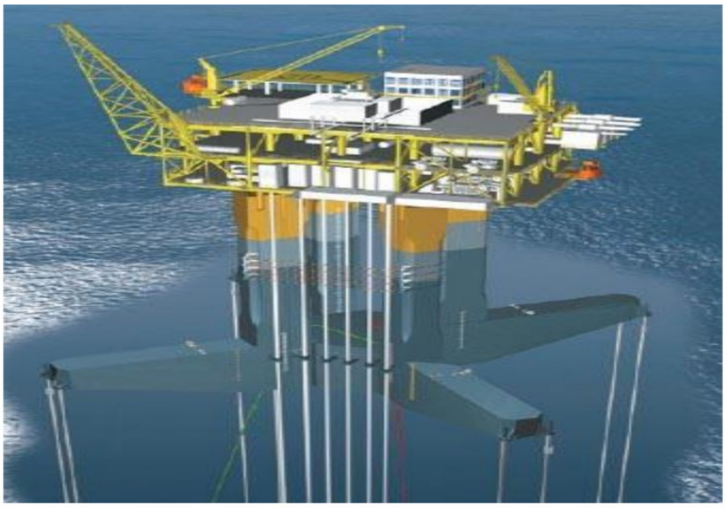
Semi-submersible Platform

As the name suggests, these are semi-submerged platforms that can be moved from one place to another whenever required. They work on the principal of dynamic positioning with giant anchors holding their places. These types of platforms can operate in water depths ranging from 60 to 3,000 m (200 to 10,000 feet).

Semi-submersible Platform

Sea Star Platform

These platforms are a larger version of semi-submersible design. But instead of anchors, they are connected to the ocean bed by flexible steel legs. These platforms usually operate in water depths ranging from 152 to 1,067 meters (500 to 3,500 feet).



Sea Star Platform

Tension Leg Platforms

They are floating platforms, usually the giant version of the Sea Star platforms, except the tension legs extend from the ocean floor to the platform itself. This type of platforms can operate in water depths up to 2,134 m (7,000 ft).

Tension Leg Platforms

Spar Platforms

In this type of platform design, the platform is placed atop a huge hollow cylindrical hull with other end of cylinder descending to a water depth of about 213 m (700 ft). Despite the fact that the cylinder stops far above the ocean bed, the platform stays in place due to the cylinder's weight. These types of platforms can operate in water depths up to 3,048 m (10,000 ft).

SPAR platform

Drillships

Drillships are marine ships fitted with drilling equipment and the dynamic positioning system, which maintains their positions over oil well. They are primarily used for exploratory drilling and can operate in water depths up to 3,700 m (12,000 ft).

Drillship

4.2 Thin shell

A thin shell is defined as a shell with a thickness which is small compared to its other dimensions and in which deformations are not large compared to thickness. A primary difference between a shell structure and a plate structure is that, in the unstressed state, the shell structure has curvature as opposed to the plate's structure which is flat. Membrane action in a shell is primarily caused by in-plane forces (plane stress), but there may be secondary forces resulting from flexural deformations. Where a flat plate acts similar to a beam with bending and shear stresses, shells are analogous to a cable which resists loads through tensile stresses. The ideal thin shell must be capable of developing both tension and compression.[

Types

The most popular types of thin-shell structures are:

Concrete shell structures, often cast as a monolithic dome or stressed ribbon bridge or saddle roof Lattice shell structures, also called grid shell structures, often in the form of a geodesic dome or a hyperboloid structure Membrane structures, which include fabric structures and other tensile structures, cable domes, and pneumatic structures.

Types of Heavy Construction Equipment

Different types of heavy equipment commonly used in the construction are as follows:

- Excavators
- Pile Boring Machine
- Pile Driving Machine
- Backhoe
- Dragline Excavator
- Bulldozers
- Graders
- Wheel Tractor Scraper
- Trenchers
- Loaders
- Tower Cranes
- Pavers
- Compactors
- Telehandlers
- Dump Trucks
- Feller Bunchers

Excavators

Excavators are important and widely used equipment in construction industry. Their general purpose is to excavation but other than that they are also used for many purposes like heavy lifting, demolition, river dredging, cutting of trees etc. Excavators contain a long arm and a cabinet. At the end of long arm digging bucket is provided and cabinet is the place provided for machine operator. This whole cabin arrangement can be rotatable up to 360o which eases the operation. Excavators are available in both wheeled and tracked forms of vehicles.

Backhoe

Backhoe is widely used equipment which is suitable for multiple purposes. The name itself telling that the hoe arrangement is provided on the back side of vehicle while loading bucket is provided in the front.

This is well useful for excavating trenches below the machine level and using front bucket loading, unloading and lifting of materials can be done.

Dragline

Dragline excavator is another heavy equipment used in construction which is generally used for larger depth excavations. It consists a long length boom and digging bucket is suspended from the top of the boom using cable.

For the construction of ports, for excavations under water, sediment removal in water bodies etc. can be done by dragline excavator

Bulldozer

Bulldozers are another type of soil excavating equipment which is used to remove the topsoil layer up to particular depth. The removal of soil is done by the sharp edged wide metal plate provided at its front. This plate can be lowered and raised using hydraulic pistons. These are widely used for the removal of weak soil or rock strata, lifting of soil etc.

Graders

Graders also called as motor graders are another type of equipment used in construction especially for the construction of roads. It is mainly used to level the soil surface. It contains a horizontal blade in between front and rear wheels and this blade is lowered in to the ground while working. Operating cabin is provided on the top of rear axle arrangement.

Motor Graders are also used to remove snow or dirt from the roads, to flatten the surface of soil before laying asphalt layer, to remove unnecessary soil layer from the ground etc

Wheel Tractor Scrapers

Wheel Tractor Scrapers are earth moving equipment used to provide flatten soil surface through scrapping. Front part contains wheeled tractor vehicle and rear part contain a scrapping arrangement such as horizontal front blade, conveyor belt and soil collecting hopper. When the front blade is lowered onto the ground and vehicle is moved, the blade starts digging the soil above the blade level and the soil excavated is collected in hopper through conveyor belt. When the hopper is full, the rear part is raised from the ground and hopper is unloaded at soil dump yard

Trenchers

Trenchers or Trenching machines are used to excavate trenches in soil. These trenches are generally used for pipeline laying, cable laying, drainage purposes etc. Trenching machines are available in two types namely chain trenchers and wheeled trenchers.

Chain trenchers contain a fixed long arm around which digging chain is provided. Wheeled trenchers contain a metal wheel with digging tooth around it. To excavate hard soil layers, wheeled trenchers are more suitable. Both types of trenchers are available in tracked as well as wheeled vehicle forms.

Loaders

Loaders are used in construction site to load the material onto dumpers, trucks etc. The materials may be excavated soil, demolition waste, raw materials, etc. A loader contains large sized bucket at its front with shorter moving arm. Loader may be either tracked or wheeled. Wheeled loaders are widely used in sites while tracked or crawled loaders are used in sites where wheeled vehicles cannot reach.

Tower cranes

Tower cranes are fixed cranes which are used for hoisting purposes in construction of tall structures. Heavy materials like pre-stressed concrete blocks, steel trusses, frames etc. can be easily lifted to required height using this type of equipment.

They consists mast which is the vertical supporting tower, Jib which is operating arm of crane, counter jib which is the other arm carries counter weight on rear side of crane and an operator cabin from which the crane can be operated

Paver

Paver or Asphalt paver is pavement laying equipment which is used in road construction. Paver contains a feeding bucket in which asphalt is continuously loaded by the dump truck and paver distributes the asphalt evenly on the road surface with slight compaction. However, a roller is required after laying asphalt layer for perfect compaction

Compactors

Compactors or Rollers are used to compact the material or earth surface. Different types of compactors are available for different compacting purposes.

Smooth wheel rollers are used for compacting shallow layers of soil or asphalt etc. sheep-foot rollers are used for deep compaction purposes. Pneumatic tyred rollers are used for compacting fine grained soils, asphalt layers etc.

Telehandler

Telehandlers are hoisting equipment used in construction to lift heavy materials up to required height or to provide construction platform for workers at greater heights etc. It contains a long telescopic boom which can be raised or lowered or forwarded. Different types of arrangements like forklifts, buckets, cabin, lifting jibs etc. can be attached to the end of telescopic boom based on the requirement of job

Feller buncher

Feller buncher is tree cutting heavy equipment used to remove large trees in the construction field. They cut the tree and grab it without felling, likewise gathers all the cut down trees at one place which makes job easier for loaders and dump trucks

Dump trucks

Dump trucks are used in construction sites to carry the material in larger quantities from one site to another site or to the dump yard. Generally, in big construction site, off-road dump trucks are used. These off-road dump trucks contains large wheels with huge space for materials which enables them to carry huge quantity of material in any type of ground conditions

Pile boring equipment

Pile boring equipment is used to make bore holes in the construction site to install precast piles.

Pile driving equipment

Heavy equipment used in construction site is pile driving equipment in case of pile foundation construction. This equipment lifts the pile and holds it in proper position and drives into the ground up to required depth. Different types of pile driving equipment are available namely, piling rigs, piling hammer, hammer guides etc. in any case the pile is driven into the ground by hammering the pile top which is done hydraulically or by dropping

4.4 DOME

A **dome** (from Latin: *domus*) is an architectural element similar to the hollow upper half of a sphere; there is significant overlap with the term cupola, which may also refer to a dome or a structure on top of a dome. The precise definition of a dome has been a matter of controversy and there are a wide variety of forms and specialized terms to describe them. A dome can rest directly upon a rotunda wall, a drum, or a system of squinches or pendentives used to accommodate the transition in shape from a rectangular or square space to the round or polygonal base of the dome. A dome's apex may be closed or may be open in the form of an oculus, which may itself be covered with a roof lantern and cupola.

Domes have a long architectural lineage that extends back into prehistory. Domes were built in ancient Mesopotamia, and they have been found in Persian, Hellenistic, Roman, and Chinese architecture in the ancient world, as well as among a number of indigenous building traditions throughout the world. Dome structures were common in both Byzantine architecture and Sasanian architecture, which influenced that of the rest of Europe and Islam, respectively, in the Middle Ages. The domes of European Renaissance architecture spread from Italy in the early modern period, while domes were frequently employed in Ottoman architecture at the same time. Baroque and Neoclassical architecture took inspiration from Roman domes.

Advancements in mathematics, materials, and production techniques resulted in new dome types. Domes have been constructed over the centuries from mud, snow, stone, wood, brick, concrete, metal, glass, and plastic. The symbolism associated with domes includes mortuary, celestial, and governmental traditions that have likewise altered over time. The domes of the modern world can be found over religious buildings, legislative chambers, sports stadiums, and a variety of functional structures.

The English word "dome" ultimately derives from the ancient Greek and Latin *domus* ("house"), which, up through the Renaissance, labeled a revered house, such as a *Domus Dei*, or "House of God", regardless of the shape of its roof. This is reflected in the uses of the Italian word *duomo*, the German/Icelandic/Danish word *dom* ("cathedral"), and the English word *dome* as late as 1656, when it meant a "Town-House, Guild-Hall, State-House, and Meeting-House in a city." The French word *dosme* came to acquire the meaning of a cupola vault, specifically, by 1660. This French definition gradually became the standard usage of the English *dome* in the eighteenth century as many of the most impressive Houses of God were built with monumental domes, and in response to the scientific need for more technical terms.[1][a]

Definitions

Across the ancient world, curved-roof structures that would today be called domes had a number of different names reflecting a variety of shapes, traditions, and symbolic associations. The shapes were derived from traditions of pre-historic shelters made from various impermanent pliable materials and were only later reproduced as vaulting in more durable materials. The hemispherical shape often associated with domes today derives from Greek geometry and Roman standardization, but other shapes persisted, including a pointed and bulbous tradition inherited by some early Islamic mosques.

Modern academic study of the topic has been controversial and confused by inconsistent definitions, such as those for cloister vaults and domical vaults. Dictionary definitions of the term "dome" are often general and imprecise. Generally-speaking, it "is non-specific, a blanket-word to describe an hemispherical or similar spanning element." Published definitions include: hemispherical roofs alone; revolved arches; and vaults on a circular base alone, circular or polygonal base, circular, elliptical, or polygonal base, or an undefined area. Definitions specifying vertical sections include: semicircular, pointed, or bulbous; semicircular, segmental or pointed; semicircular, segmental, pointed, or bulbous; semicircular, segmental, elliptical, or bulbous; and high profile, hemispherical, or flattened.

Comparison of a generic "true" arch (left) and a corbel arch (right)

Sometimes called "false" domes, corbel domes achieve their shape by extending each horizontal layer of stones inward slightly farther than the lower one until they meet at the top. A "false" dome may also refer to a wooden dome. The Italian use of the term *finto*, meaning "false", can be traced back to the 17th century in the use of vaulting made of reed mats and gypsum mortar. "True" domes are said to be those whose structure is in a state of compression, with constituent elements of wedge-shaped voussoirs, the joints of which align with a central point. The validity of this is unclear, as domes built underground with corbelled stone layers are in compression from the surrounding earth.

The precise definition of "pendentive" has also been a source of academic contention, such as whether or not corbelling is permitted under the definition and whether or not the lower portions of a sail vault should be considered pendentives. Domes with pendentives can be divided into two kinds: *simple* and *compound*. In the case of the *simple dome*, the pendentives are part of the same sphere as the dome itself; however, such domes are rare. In the case of the more common *compound dome*, the pendentives are part of the surface of a larger sphere below that of the dome itself and form a circular base for either the dome or a drum section.

The fields of engineering and architecture have lacked common language for domes, with engineering focused on structural behavior and architecture focused on form and symbolism. Additionally, new materials and structural systems in the 20th century have allowed for large dome-shaped structures that deviate from the traditional compressive structural behavior of masonry domes and popular usage of the term has expanded to mean "almost any long-span roofing system".

Materials

The earliest domes in the Middle East were built with mud-brick and, eventually, with baked brick and stone. Domes of wood allowed for wide spans due to the relatively light and flexible nature of the material and were the normal method for domed churches by the 7th century, although most domes were built with the other less flexible materials. Wooden domes were protected from the weather by roofing, such as copper or lead sheeting. Domes of cut stone were more expensive and never as large, and timber was used for large spans where brick was unavailable.

Roman concrete used an aggregate of stone with a powerful mortar. The aggregate transitioned over the centuries to pieces of fired clay, then to Roman bricks. By the sixth century, bricks with large amounts of mortar were the principle vaulting materials. Pozzolana appears to have only been used in central Italy. Brick domes were the favored choice for large-space monumental coverings until the Industrial Age, due to their convenience and dependability. Ties and chains of iron or wood could be used to resist stresses.

The new building materials of the 19th century and a better understanding of the forces within structures from the 20th century opened up new possibilities. Iron and steel beams, steel cables, and pre-stressed concrete eliminated the need for external buttressing and enabled much thinner domes. Whereas earlier masonry domes may have had a radius to thickness ratio of 50, the ratio for modern domes can be in excess of 800. The lighter weight of these domes not only permitted far greater spans, but also allowed for the creation of large movable domes over modern sports stadiums.

Experimental rammed earth domes were made as part of work on sustainable architecture at the University of Kassel in 1983.

Shapes and internal forces

A masonry dome produces thrusts downward and outward. They are thought of in terms of two kinds of forces at right angles from one another: meridional forces (like the meridians, or lines of longitude, on a globe) are compressive only, and increase towards the base, while hoop forces (like the lines of latitude on a globe) are in compression at the top and tension at the base, with the transition in a hemispherical dome occurring at an angle of 51.8 degrees from the top. The thrusts generated by a dome are directly proportional to the weight of its materials. Grounded hemispherical domes generate significant horizontal thrusts at their haunches.

The outward thrusts in the lower portion of a hemispherical masonry dome can be counteracted with the use of chains incorporated around the circumference or with external buttressing, although cracking along the meridians is natural. For small or tall domes with less horizontal thrust, the thickness of the supporting arches or walls can be enough to resist deformation, which is why drums tend to be much thicker than the domes they support.

Unlike voussoir arches, which require support for each element until the keystone is in place, domes are stable during construction as each level is made a complete and self-supporting ring. The upper portion of a masonry dome is always in compression and is supported laterally, so it does not collapse except as a whole unit and a range of deviations from the ideal in this shallow upper cap are equally stable. Because voussoir domes have lateral support, they can be made much thinner than corresponding arches of the same span. For example, a hemispherical dome can be 2.5 times thinner than a semicircular arch, and a dome with the profile of an equilateral arch can be thinner still.

The optimal shape for a masonry dome of equal thickness provides for perfect compression, with none of the tension or bending forces against which masonry is weak. For a particular material, the optimal dome geometry is called the funicular surface, the comparable shape in three dimensions to a catenary curve for a two-dimensional arch. Adding a weight to the top of a pointed dome, such as the heavy cupola at the top of Florence Cathedral, changes the optimal shape to more closely match the actual pointed shape of the dome. The pointed profiles of many Gothic domes more closely approximate the optimal dome shape than do hemispheres, which were favored by Roman and Byzantine architects due to the circle being considered the most perfect of forms.

Types

Beehive dome

Also called a *corbelled dome*, or *false dome*, these are different from a 'true dome' in that they consist of purely horizontal layers. As the layers get higher, each is slightly cantilevered, or corbeled, toward the center until meeting at the top. A monumental example is the Mycenaean Treasury of Atreus from the late Bronze Age.

Braced dome

A single or double layer space frame in the form of a dome, a *braced dome* is a generic term that includes *ribbed*, *Schwedler*, *three-way grid*, *lamella* or *Kiewitt*, *lattice*, and *geodesic domes*. The different terms reflect different arrangements in the surface members. Braced domes often have a very low weight and are usually used to cover spans of up to 150 meters. Often prefabricated, their component members can either lie on the dome's surface of revolution, or be straight lengths with the connecting points or nodes lying upon the surface of revolution. Single-layer structures are called *frame* or *skeleton* types and double-layer structures are *truss* types, which are used for large spans. When the covering also forms part of the structural system, it is called a *stressed skin* type. The *formed surface* type consists of sheets joined together at bent edges to form the structure.

Cloister vault

Also called *domical vaults* (a term sometimes also applied to sail vaults), *polygonal domes*, *coved domes*, *gored domes*,[*segmental domes* (a term sometimes also used for saucer domes), *paneled vaults*, or *pavilion vaults*, these are domes that maintain a polygonal shape in their horizontal cross section. The earliest known examples date to the first century BC, such as the Tabularium of Rome from 78 BC. Others include the Baths of Antoninus in Carthage (145–160) and the Palatine Chapel at Aachen (13th – 14th century). The most famous example is the Renaissance octagonal dome of Filippo Brunelleschi over the Florence Cathedral. Thomas Jefferson, the third president of the United States, installed an octagonal dome above the West front of his plantation house, Monticello.

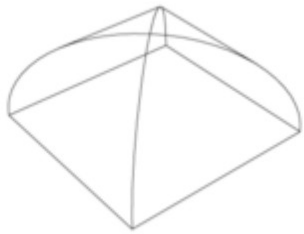
Compound dome

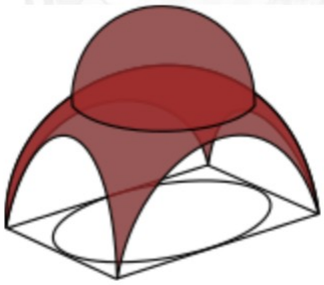
Also called *domes on pendentives* or *pendentive domes* (a term also applied to sail vaults), compound domes have pendentives that support a smaller diameter dome immediately above them, as in the Hagia Sophia, or a drum and dome, as in many Renaissance and post-Renaissance domes, with both forms resulting in greater height.

Crossed-arch dome

One of the earliest types of ribbed vault, the first known examples are found in the Great Mosque of Córdoba in the 10th century. Rather than meeting in the center of the dome, the ribs characteristically intersect one another off-center, forming an empty polygonal space in the center. Geometry is a key element of the designs, with the octagon being perhaps the most popular shape used. Whether the arches are structural or purely decorative remains a matter of debate. The type may have an eastern origin, although the issue is also unsettled. Examples are found in Spain, North Africa, Armenia, Iran, France, and Italy.

A corbel dome A domical vault A compound dome





Ellipsoidal dome

The ellipsoidal dome is a surface formed by the rotation around a vertical axis of a semi-ellipse. Like other "rotational domes" formed by the rotation of a curve around a vertical axis, ellipsoidal domes have circular bases and horizontal sections and are a type of "circular dome" for that reason.

Geodesic dome

Geodesic domes are the upper portion of geodesic spheres. They are composed of a framework of triangles in a polyhedron pattern. The structures are named for geodesics and are based upon geometric shapes such as icosahedrons, octahedrons or tetrahedrons. Such domes can be created using a limited number of simple elements and joints and efficiently resolve a dome's internal forces. Their efficiency is said to increase with size. Although not first invented by Buckminster Fuller, they are associated with him because he designed many geodesic domes and patented them in the United States.

Hemispherical dome

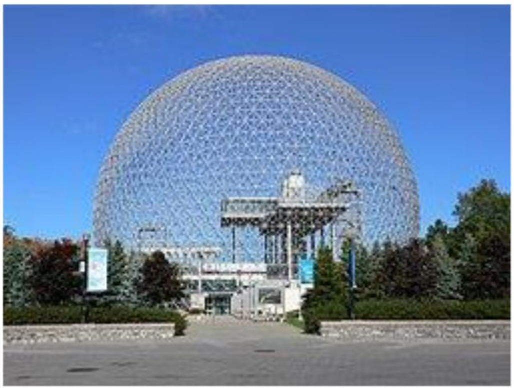
The *hemispherical dome* is a surface formed by the rotation around a vertical axis of a semicircle. Like other "rotational domes" formed by the rotation of a curve around a vertical axis, hemispherical domes have circular bases and horizontal sections and are a type of "circular dome" for that reason. They experience vertical compression along their meridians, but horizontally experience compression only in the portion above 51.8 degrees from the top. Below this point, hemispherical domes experience tension horizontally, and usually requires buttressing to counteract it. According to E. Baldwin Smith, it was a shape likely known to the Assyrians, defined by Greek theoretical mathematicians, and standardized by Roman builders.

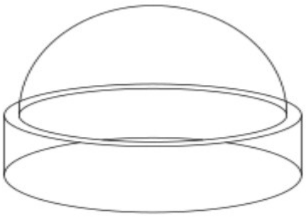
Onion dome

Bulbous domes bulge out beyond their base diameters, offering a profile greater than a hemisphere. An *onion dome* is a greater than hemispherical dome with a pointed top in an ogee profile. They are found in the Near East, Middle East, Persia, and India and may not have had a single point of origin. Their appearance in northern Russian architecture predates the Tatar occupation of Russia and so is not easily explained as the result of that influence. They became popular in the second half of the 15th century in the Low Countries of Northern Europe, possibly inspired by the finials of minarets in Egypt and Syria, and developed in the 16th and 17th centuries in the Netherlands before spreading to Germany, becoming a popular element of the baroque architecture of Central Europe. German bulbous domes were also influenced by Russian and Eastern European domes. The examples found in various European architectural styles are typically wooden. Examples include Kazan Church in Kolomenskoye and the Brighton Pavilion by John Nash. In Islamic architecture, they are typically made of masonry, rather than timber, with the thick and heavy bulging portion serving to buttress against the tendency of masonry domes to spread at their bases. The Taj Mahal is a famous example.

Oval dome

An *oval dome* is a dome of oval shape in plan, profile, or both. The term comes from the Latin *ovum*, meaning "egg". The earliest oval domes were used by convenience in corbelled stone huts as rounded but geometrically undefined coverings, and the first examples in Asia Minor date to around 4000 B.C. The geometry was eventually defined using combinations of circular arcs, transitioning at points of tangency. If the Romans created oval domes, it was only in exceptional circumstances. The Roman foundations of the oval plan Church of St. Gereon in Cologne point to a possible example. Domes in the Middle Ages also tended to be circular, though the church of Santo Tomás de las Ollas in Spain has an oval dome over its oval plan. Other examples of medieval oval domes can be found covering rectangular bays in churches. Oval plan churches became a type in the Renaissance and popular in the Baroque style. The dome built for the basilica of Vicoforte by Francesco Gallo was one of the largest and most complex ever made. Although the ellipse was known, in practice, domes of this shape were created by combining segments of circles. Popular in the 16th and 17th centuries, oval and elliptical plan domes can vary their dimensions in three axes or two axes. A sub-type with the long axis having a semicircular section is called a Murcia dome, as in the Chapel of the Junterones at Murcia Cathedral. When the short axis has a semicircular section, it is called a Melon dome.





A geodesic dome A hemispherical dome

An oval dome

Paraboloid dome

A paraboloid dome is a surface formed by the rotation around a vertical axis of a sector of a parabola. Like other "rotational domes" formed by the rotation of a curve around a vertical axis, paraboloid domes have circular bases and horizontal sections and are a type of "circular dome" for that reason. Because of their shape, paraboloid domes experience only compression, both radially and horizontally.

Sail dome

Also called *sail vaults*, *handkerchief vaults*, *domical vaults* (a term sometimes also applied to cloister vaults), *pendentive domes* (a term that has also been applied to compound domes), *Bohemian vaults*, or *Byzantine domes*, this type can be thought of as pendentives that, rather than merely touching each other to form a circular base for a drum or compound dome, smoothly continue their curvature to form the dome itself. The dome gives the impression of a square sail pinned down at each corner and billowing upward. These can also be thought of as saucer domes upon pendentives. Sail domes are based upon the shape of a hemisphere and are not to be confused with elliptic parabolic vaults, which appear similar but have different characteristics. In addition to semicircular sail vaults there are variations in geometry such as a low rise to span ratio or covering a rectangular plan. Sail vaults of all types have a variety of thrust conditions along their borders, which can cause problems, but have been widely used from at least the sixteenth century. The second floor of the Llotja de la Seda is covered by a series of nine meter wide sail vaults.

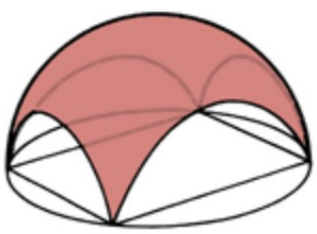
Saucer dome

Also called *segmental domes* (a term sometimes also used for cloister vaults), or *calottes*, these have profiles of less than half a circle. Because they reduce the portion of the dome in tension, these domes are strong but have increased radial thrust. Many of the largest existing domes are of this shape.

Masonry saucer domes, because they exist entirely in compression, can be built much thinner than other dome shapes without becoming unstable. The trade-off between the proportionately increased horizontal thrust at their abutments and their decreased weight and quantity of materials may make them more economical, but they are more vulnerable to damage from movement in their supports.

Umbrella dome

Also called *gadrooned*, *fluted*, *organpiped*, *pumpkin*, *melon*, *ribbed*, *parachute*, *scalloped*, or *lobed* domes, these are a type of dome divided at the base into curved segments, which follow the curve of the elevation. "Fluted" may refer specifically to this pattern as an external feature, such as was common in Mamluk Egypt. The "ribs" of a dome are the radial lines of masonry that extend from the crown down to the springing. The central dome of the Hagia Sophia uses the ribbed method, which accommodates a ring of windows between the ribs at the base of the dome. The central dome of St. Peter's Basilica also uses this method.



A sail vault

A saucer dome

An umbrella dome

PRESTRESSING METHOD IN MULTI-STORIED BUILDING FRAME

History of Pre-stressing

The art of pre-stressing concrete evolved over many decades and from many sources, but we can point to a few select instances in history that brought about this technology.

In the United States, engineer John Roebling established a factory in 1841 for making rope out of iron wire, which he initially sold to replace the hempen rope used for hoisting cars over the portage railway in central Pennsylvania. Later, Roebling used wire ropes as suspension cables for bridges, and he developed the technique for spinning the cables in place.

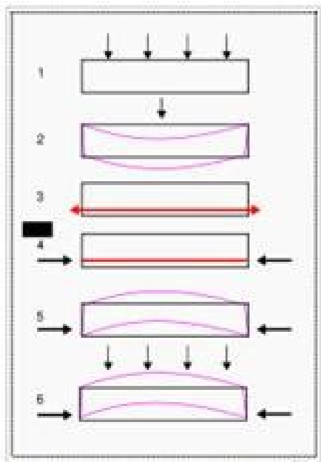
During the 19th century, low-cost production of iron and steel, when added to the invention of portland cement in 1824, led to the development of reinforced concrete. In 1867, Joseph Monier, a French gardener, patented a method of strengthening thin concrete flowerpots by embedding iron wire mesh into the concrete. Monier later applied his ideas to patents for buildings and bridges.

Swiss engineer Robert Maillart's use of reinforced concrete, beginning in 1901, effected a revolution in structural art. Maillart, all of whose main bridges are located in Switzerland , was the first designer to break completely with the masonry tradition by putting concrete into forms technically appropriate to its properties – yet visually surprising. His radical use of reinforced concrete revolutionized masonry arch bridge design.

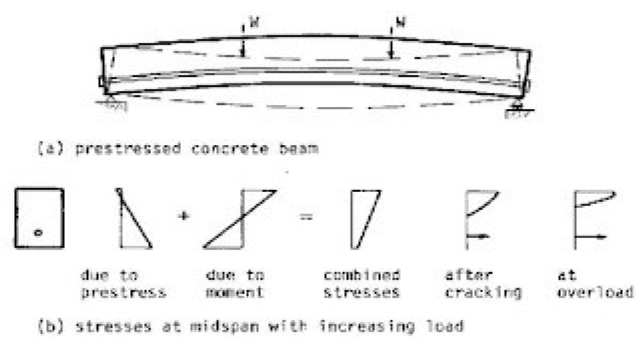
PRE-STRESSED CONCRETE

Pre stressed concrete, like reinforced concrete, is a composite material which uses to advantage the compressive strength of concrete, whilst circumventing its weakness in tension. Pre stressed concrete is made from structural concrete, usually of high strength, and high strength steel tendons which may or may not be grouped together. Prior to external loading the tendons are tensioned in one of two ways. With pretensioning the tendon are tensioned prior to the casting of the concrete and using post tensioning techniques the tendons are tensioned after the concrete has hardened. Some ordinary reinforcing steel is also often included both as subsidiary longitudinal reinforcement and as transverse stirrups to resist shear.

Pre-stressed concrete is a method for overcoming concrete's natural weakness in tension. It can be used to produce beams, floors or bridges with a longer span than is practical with ordinary reinforced concrete. Pre-stressing tendons (generally of high tensile steel cable or rods) are used to provide a clamping load which produces a compressive stress that offsets the tensile stress that the concrete compression member would otherwise experience due to a bending load. Traditional reinforced concrete is based on the use of steel reinforcement bars, inside poured concrete. The basic purpose of pre-stressing is to improve the performance of concrete members and this is achieved by inducing in the beam initial deformation and stresses which tend to counteract those produced by the service loads.



Prestressed concrete diagram



Since concrete is weak in tension in normal reinforced concrete construction cracks develop in the tension zone at working loads and therefore all concrete in tension is ignored in design.

Pre-stressing involves inducing compressive stresses in the zone, which will tend to become tensile under external loads. This compressive stress neutralizes the tensile stress so that no resultant tension exists, (or only very small values, within the tensile strength of the concrete). Cracking is therefore eliminated under working load and all of the concrete may be assumed effective in carrying load. Therefore lighter sections may be used to carry a given bending moment, and pre-stressed concrete may be used for longer span than reinforced concrete.

The pre-stressing force also reduces the magnitude of the principal tensile stress in the web so that thin-webbed I - sections may be used without the risk of diagonal tension failures and with further savings in self-weight.

The pre-stressing force has to be produced by a high tensile steel, and it is necessary to use high quality concrete to resist the higher compressive stresses that are developed. As the name itself suggests pre-stressing is the technique of stressing a structural member prior to loading to resist excessive tensile stresses.

The advantages of pre-stressed concrete as a construction material in multi storied frame can be listed as follows:

- Maximum utilization of provided section of the member.
- Provision of slender member for long span beams as compared to RCC.
- Use of high strength materials contribute to the durability of the structure.
- Pre-stresses concrete has considerable resilience and impact resistance.
- Proves to be economical only in long span beam-column frames compared to other materials.
- The intermediate distance between the columns can be in increased by using pre-stressed concrete as compared to reinforced cement concrete.
- Architectural design provisions and specifications can be achieved using pre-stressed concrete.
- Dead weight of concrete is reduced to a higher rate using pre-stressed concrete.

PRINCIPLE OF PRESTRESSING

The function of pre-stressing is to place the concrete structure under compression in those regions where load causes tensile stress. Tension caused by the load will first have to cancel the compression induced by the pre-stressing before it can crack the concrete. Figure (a) shows a plainly reinforced concrete simple-span beam and fixed cantilever beam cracked under applied load. Figure (b) shows the same unloaded beams with pre-stressing forces applied by stressing high strength tendons. By placing the pre-stressing low in the simple-span beam and high in the cantilever beam, compression is induced in the tension zones; creating upward camber.

Figure (c) shows the two pre-stressed beams after loads have been applied. The loads cause both the simple-span beam and cantilever beam to deflect down, creating tensile stresses in the bottom of the simple-span beam and top of the cantilever beam. The structural Designer balances the effects of load and pre-stressing in such a way that tension from the loading is compensated by compression induced by the pre-stressing. Tension is eliminated under the combination of the two and tension cracks are prevented. Also, construction materials (concrete and steel) are used more efficiently; optimizing materials, construction effort and cost.

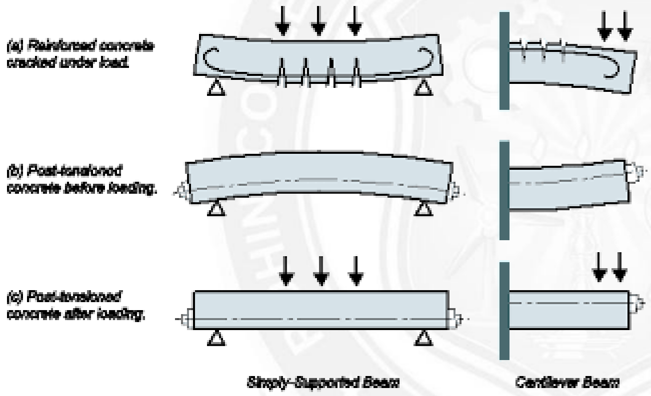


Fig 1. - Comparison of Reinforced and Prestressed Concrete Beams

Pre-stressing can be applied to concrete members in two ways, by pre-tensioning or post-tensioning. In pre-tensioned members the pre-stressing strands are tensioned against restraining bulkheads before the concrete is cast. After the concrete has been placed, allowed to harden and attain sufficient strength, the strands are released and their force is transferred to the concrete member. Pre-stressing by post-tensioning involves installing and stressing pre-stressing strand or bar tendons only after the concrete has been placed, hardened and attained a minimum compressive strength for that transfer.

METHODS AND SYSTEM OF PRE-STRESSING

There are two methods of pre-stressing concrete: -

1) Pre-cast Pre-tensioned

2) Pre-cast Post-tensioned

Both methods involve tensioning cables inside a concrete beam and then anchoring the stressed cables to the concrete.

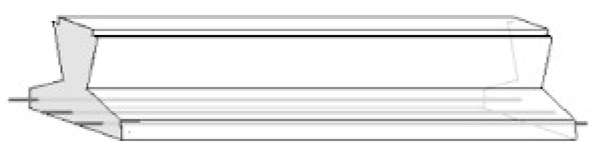
Pre-cast Pre-tensioned: -

Pre-tensioning is a method of pre-stressing in which the steel tendons are tensioned before the casting of the member. In this method the tendons are tensioned using hydraulic jacks, which bear on strong abutments between which the moulds are placed. After the concrete attains full strength the tendons are released and the stress is transferred to the concrete by bond action.

Procedure of precast pre-tensioned concreting

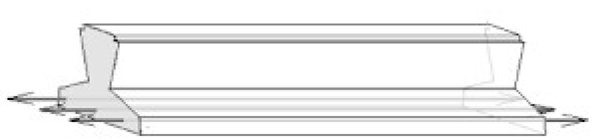
Stage 1

Tendons and reinforcement are positioned in the beam mould.



Stage 1

Stage 2
Tendons are stressed to about 70% of their ultimate strength.

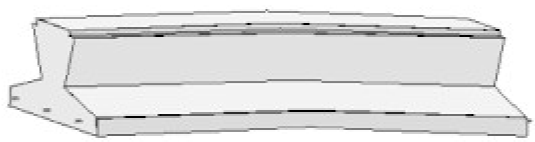


Stage 2

Stage 3
Concrete is cast into the beam mould and allowed to cure to the required initial strength.

Stage 3

Stage 4
When the concrete has cured the stressing force is released and the tendons anchor themselves in the concrete.



Stage 4

Pre-cast Post-tensioned: -

Post-tensioning is a method of pre-stressing in which the steel tendons are tensioned after the casting of the member. In this method ducts or sheaths are placed in the required profile in the mould and the tendons are passed through the ducts. After the concrete had attained sufficient strength the tendons are tensioned using hydraulic jacks which bear on the member itself. The stress is transferred to the concrete by bearing action of tendons which are anchored using suitable anchorages. Finally the ducts are grouted and the anchor plates concealed by cement mortar.

Procedure of precast post-tensioned concreting

Stage 1
Cable ducts and reinforcement are positioned in the beam mould. The ducts are usually raised towards the neutral axis at the ends to reduce the eccentricity of the stressing force.

Stage 1

Stage 2
Concrete is cast into the beam mould and allowed to cure to the required initial strength.

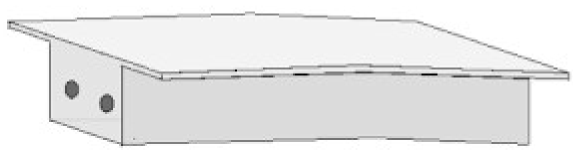

Stage 2

Stage 3
Tendons are threaded through the cable ducts and tensioned to about 70% of their ultimate strength.


Stage 3

Stage 4

Wedges are inserted into the end anchorages and the tensioning force on the tendons is released. Grout is then pumped into the ducts to protect the tendons.


Stage 4

ERECTION OF LATICE TOWERS

here are four main methods of the erection of steel transmission towers which are described below:

1. Build-up method or Piecemeal method.
2. Section method.
3. Ground assembly method.
4. Helicopter method.

Build Up Method of Transmission Tower Erection

This method is most commonly used in India for the erection of 6.6 kV, 132 kV, 220 kV, and 400 kV transmission line towers due to the following advantages :

1. Tower materials can be supplied to the site in a knocked down conditions which facilitates easier and cheaper transportation.
2. It does not require any heavy machinery such as cranes etc.
3. Tower erection activity can be done in any kind of terrain and mostly throughout the year.
4. Availability of workmen at cheap rates.

This method consists of erecting the towers, member by member. The tower members are kept on the ground serially according to the erection sequence to avoid search or time loss. The erection progresses from the bottom upwards.

The four main corner leg members of the first section of the tower are first erected and guard

off. Sometimes more than one contiguous leg section of each corner leg is bolted together at the ground and erected.

The cross braces of the first section which are already assembled on the ground are raised one by one as a unit and bolted to the already erected corner leg angles. First section of the lower thus built and horizontal struts (belt members) if any, are bolted in position. For assembling the second section of the tower, two gin poles are placed one each on the top of diagonally opposite corner legs.

These two poles are used, for raising parts of the second section. The leg members and braces of this section are then hoisted and assembled. The gin poles are then shifted to the corner leg members on the top of the second section to raise the parts of the third section of the lower in position for assembly. Gin poles are thus moved up as the tower grows.

This process is continued until the complete tower is erected. Cross-arm members are assembled on the ground and raised up and fixed to the main body of the tower. For heavier towers, a small boom is rigged on one of the tower legs for hoistin

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COOLING TOWER

Cooling towers are a very important part of many chemical plants. The primary task of a cooling tower is to reject heat into the atmosphere. They represent a relatively inexpensive and dependable means of removing low-grade heat from cooling water. The make-up water source is used to replenish water lost to evaporation. Hot water from heat exchangers is sent to the cooling tower. The water exits the cooling tower and is sent back to the exchangers or to other units for further cooling. Typical closed loop cooling tower system is shown in Figure 7.1.

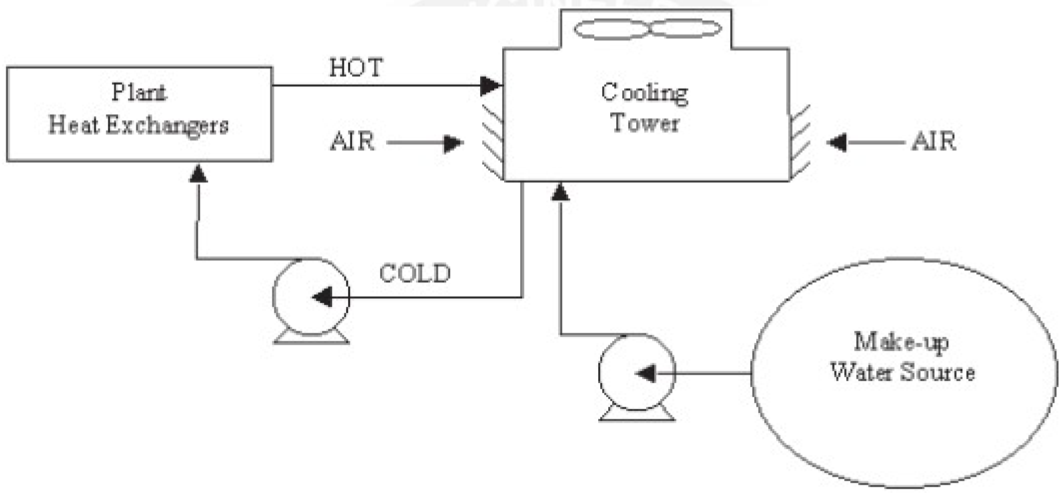
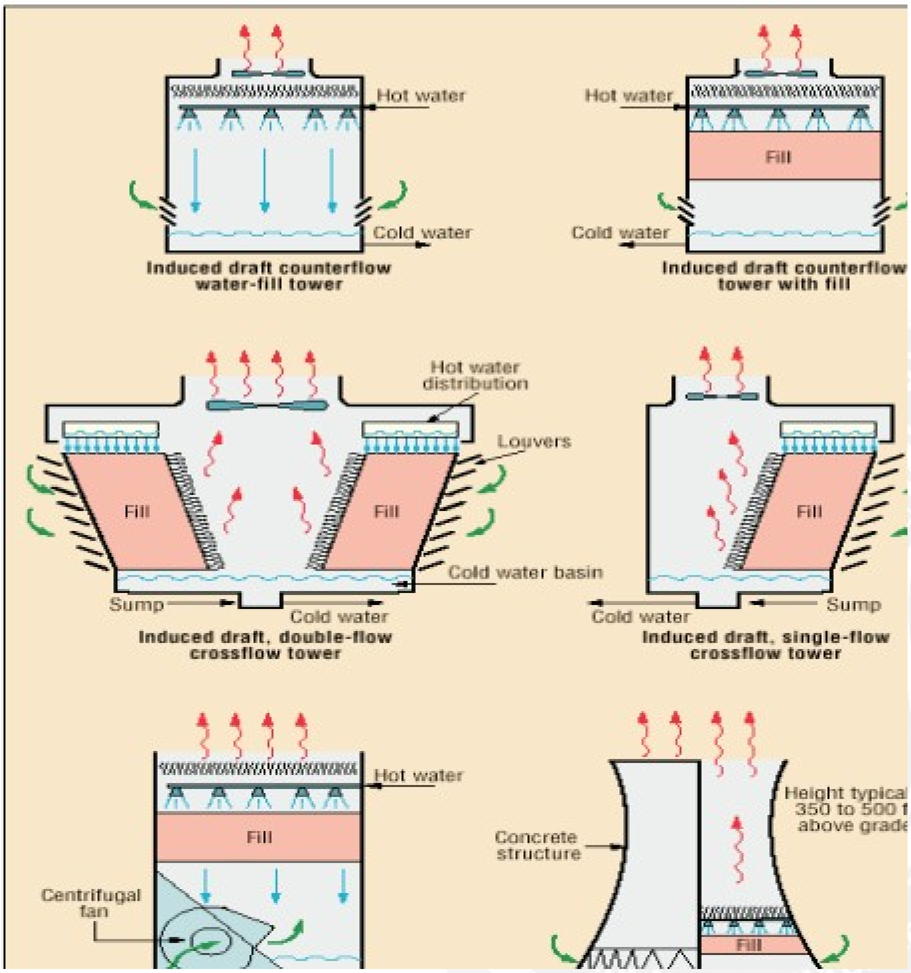


Figure 7.1 Cooling Water System

Cooling Tower Types Cooling towers fall into two main categories: Natural draft and Mechanical draft. Natural draft towers use very large concrete chimneys to introduce air through the media. Due to the large size of these towers, they are generally used for water flow rates above 45,000 m3 /hr. These types of towers are used only by utility power stations. Mechanical draft towers utilize large fans to force or suck air through circulated water. The water falls downward over fill surfaces, which help increase the contact time between the water and the air - this helps maximise heat transfer between the two. Cooling rates of Mechanical draft towers depend upon their fan diameter and speed of operation. Since, the mechanical draft cooling towers are much more widely used, the focus is on them in this chapter.

Mechanical draft towers Mechanical draft towers are available in the following airflow arrangements: 1. Counter flows induced draft. 2. Counter flow forced draft. 3. Cross flow induced draft. In the counter flow induced draft design, hot water enters at the top, while the air is introduced at the bottom and exits at the top. Both forced and induced draft fans are used. In cross flow induced draft towers, the water enters at the top and passes over the fill. The air, however, is introduced at the side either on one side (single-flow tower) or opposite sides (double-flow tower). An induced draft fan draws the air across the wetted fill and expels it through the top of the structure. The Figure 7.2 illustrates various cooling tower types. Mechanical draft towers are available in a large range of capacities. Normal capacities range from approximately 10 tons, 2.5 m3 /hr flow to several thousand tons and m3 /hr. Towers can be either factory built or field erected - for example concrete towers are only field erected. Many towers are constructed so that they can be grouped together to achieve the desired capacity. Thus, many cooling towers are assemblies of two or more individual cooling towers or "cells." The number of cells they have, e.g., an eight-cell tower, often refers to such towers. Multiple-cell towers can be lineal, square, or round depending upon the shape of the individual cells and whether the air inlets are located on the sides or bottoms of the cells. Components of Cooling Tower The basic components of an evaporative tower are: Frame and casing, fill, cold water basin, drift eliminators, air inlet, louvers, nozzles and fans. Frame and casing: Most towers have structural frames that support the exterior enclosures (casings), motors, fans, and other components. With some smaller designs, such as some glass fiber units, the casing may essentially be the frame. Fill: Most towers employ fills (made of plastic or wood) to facilitate heat transfer by maximising water and air contact. Fill can either be splash or film type. With splash fill, water falls over successive layers of horizontal splash bars, continuously breaking into smaller droplets, while also wetting the fill surface. Plastic splash fill promotes better heat transfer than the wood splash fill. Film fill consists of thin, closely spaced plastic surfaces over which the water spreads, forming a thin film in contact with the air. These surfaces may be flat, corrugated, honeycombed, or other patterns. The film type of fill is the more efficient and provides same heat transfer in a smaller volume than the splash fill. Cold water basin: The cold water basin, located at or near the bottom of the tower, receives the cooled water that flows down through the tower and fill. The basin usually has a sump or low point for the cold water discharge connection. In many tower designs, the cold water basin is beneath the entire fill. Drift eliminators: These capture water droplets entrapped in the air stream that otherwise would be lost to the atmosphere. Air inlet: This is the point of entry for the air entering a tower. The inlet may take up an entire side of a tower–cross flow design– or be located low on the side or the bottom of counter flow designs. Louvers: Generally, cross-flow towers have inlet louvers. The purpose of louvers is to equalize air flow into the fill and retain the water within the tower. Many counter flow tower designs do not require louvers. Nozzles: These provide the water sprays to wet the fill. Uniform water distribution at the top of the fill is essential to achieve proper wetting of the entire fill surface. Nozzles can either be fixed in place and have either round or square spray patterns or can be part of a rotating assembly as found in some circular cross-section towers. Fans: Both axial (propeller type) and centrifugal fans are used in towers. Generally, propeller fans are used in induced draft towers and both propeller and centrifugal fans are found in forced draft towers. Depending upon their size, propeller fans can either be fixed or variable pitch. A fan having non-automatic adjustable pitch blades permits the same fan to be used over a wide range of kW with the fan adjusted to deliver the desired air flow at the lowest power consumption. Automatic variable pitch blades can vary air flow in response to changing load conditions. Tower Materials In the early days of cooling tower manufacture, towers were constructed primarily of wood. Wooden components included the frame, casing, louvers, fill, and often the cold water basin. If the basin was not of wood, it likely was of concrete. Today, tower manufacturers fabricate towers and tower components from a variety of materials. Often several materials are used to enhance corrosion resistance, reduce maintenance, and promote reliability and long service life. Galvanized steel, various grades of stainless steel, glass fiber, and concrete are widely used in tower construction as well as aluminum and various types of plastics for some components. Wood towers are still available, but they have glass fiber rather than wood panels (casing) over the wood framework. The inlet air louvers may be glass fiber, the fill may be plastic, and the cold water basin may be steel. Larger towers sometimes are made of concrete. Many towers–casings and basins–are constructed of galvanized steel or, where a corrosive atmosphere is a problem, stainless steel. Sometimes a galvanized tower has a stainless steel basin. Glass fiber is also widely used for cooling tower casings and basins, giving long life and protection from the harmful effects of many chemicals. Plastics are widely used for fill, including

PVC, polypropylene, and other polymers. Treated wood splash fill is still specified for wood towers, but plastic splash fill is also widely used when water conditions mandate the use of splash fill. Film fill, because it offers greater heat transfer efficiency, is the fill of choice for applications where the circulating water is generally free of debris that could plug the fill passageways.



CABLE STAYED BRIDGE BY CANTILEVER METHOD.

he cantilever method is normally adopted for the construction of long-span cable-stayed bridges. Here the towers are built first. Each new segment is built at site or installed with precast segment, and then supported by one new cable or a pair of new cables which balances its weight.

The stresses in the girder and the towers are related to the cable tensions. Since the geometric profile of the girder or elevation of the bridge segments is mainly controlled by the cable lengths, the cable length should be set appropriately at the erection of each segment. During construction, monitoring and adjustment of the cable tension and geometric profile require special attention.

A notable example of the construction of a major cable-stayed bridge by the cantilever method is the Yangpu bridge in Shanghai, China, built in 1994 with a main span of 602 m. The composite girders of this bridge consisted of prefabricated, wholly welded steel girders and precast reinforced concrete deck slabs.

Depending on the bridge site, cable-stayed bridges can have any one of four general layouts of spans :

(a) Cable stayed bridges with one eccentric tower, eccentric with respect to the gap to be bridged, e.g. Severin's bridge;

(b) Symmetrical two-span cable stayed bridges, e.g. Akkar bridge :

(c) Three-span cable stayed bridges, e.g. Second Hooghly bridge, Stromsund bridge :

(d) Multi-span cable stayed bridges, e.g. Millau viaduct. Of these, the most common type is the three-span cable stayed bridge, consisting of the central main span and the two side spans. Temporary stability during construction is a major problem, particularly just prior to closure at midspan. The structure must be able to withstand the effects due to wind and accidental loads due to mishaps during erection. When intermediate piers are provided in the side spans, the stability is very much enhanced, In this case, the side spans are built first on the intermediate supports, and later the long cantilevers in the main span.

Discuss the Detail of Cable used in Cable Stayed Bridge.

The stay cables constitute critical components of a cable stayed bridge, as they carry the load of the deck and transfer it to the tower and the backstay cable anchorage. So the cables should be selected with utmost care. The main requirements of stay cables are :

(a) High load carrying capacity :

(b) High and stable Young's modulus of elasticity :

(c) Compact cross-section ;

(d) High fatigue resistance ;

(e) Ease in corrosion protection ;

(f) Handling convenience; and

(g) Low cost. The ultimate tensile strength of wire is of the order of 1600 MPa. While locked coil stands have been used in early bridges (e.g. Stromsund bridge), the recent preference is towards the use of cables with bundles of parallel wires or parallel long lay stands. The sizes of cables are selected to facilitate a reasonable spacing at the deck anchorages. Parallel wire cables using 7 mm wires of high tensile steel have been adopted in the Second Hooghly bridge. Corrosion protection of the cables is of paramount importance. For this purpose, the steel may be housed inside a polyethylene (PE) tube which is tightly connected to the anchorages. The cables are anchored at the deck and at the tower. The anchorage at the deck is fixed and has a provision for a neoprene pad damper to damp oscillations. The length adjustment is done at the tower end.

The cables are prestressed by introducing additional tensile force in the cables in order to improve the stress in the main girder and tower at the completion stage, to prevent the lowering of rigidity due to sagging of cable, and to optimize the cable condition for the erection. The magnitude of the prestress is determined by taking into consideration the following factors :

(i) the horizontal component there is no in-plane bending of the tower due to unbalanced horizontal fore due to dead load at the completion stage; and

(ii) the net force on the main girder member at the connection of the cable at the completion stage be zero.

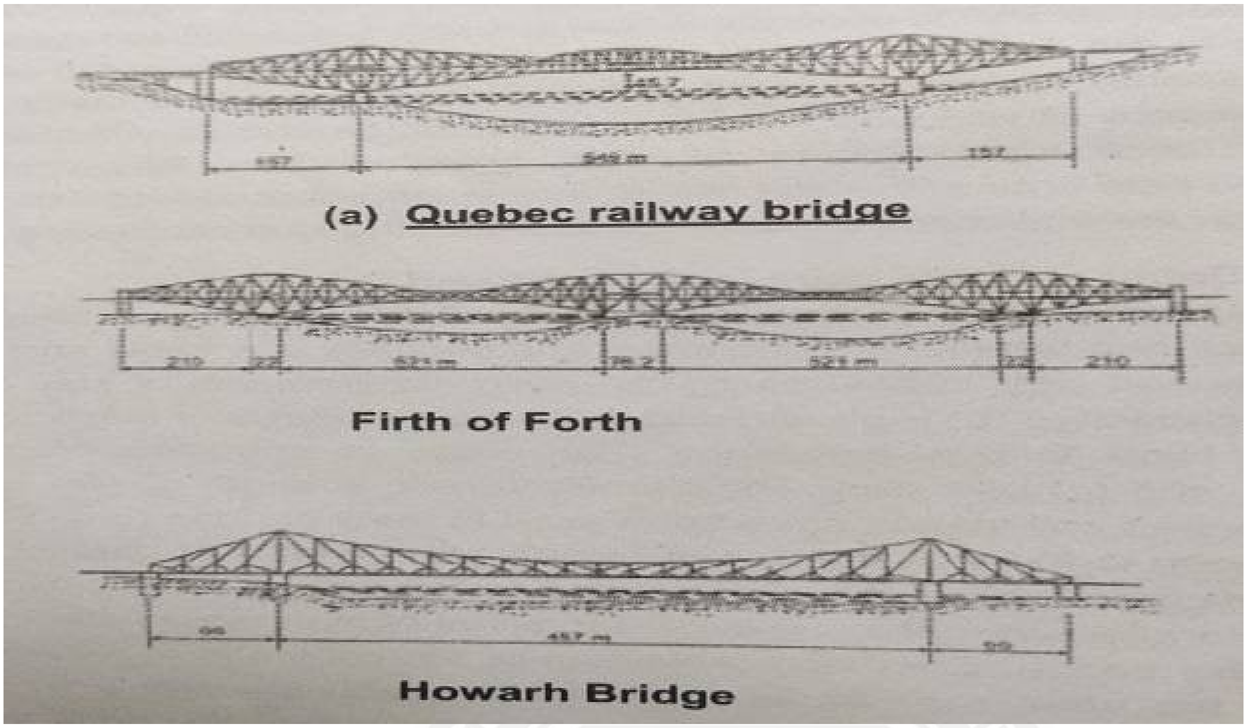
Currently, the steel used for cables have ultimate tensile strength (UTS) of the order of 1600 MPa. Carbon fiber cables having UTS of about 3300 MPa are under development. The latter cables are claimed to have negligible corrosion and to possess high fatigue resistance. However, carbon fiber cables are presently very expensive.

What are Cantilever Bridges? Explain in detail using examples.

A cantilever bride with a single main span consists of an anchor arm at either end between the abutment and the pier, a cantilever arm from either pier to the end of the suspended span, and a suspended span. Such an arrangement permits a long clear span for navigation and also facilitates the erection of steelwork without the need for supporting centering from below.

Steel cantilever bridges came into general use for long-span railway bridges, because of their greater rigidity compared with suspension bridges. Three well-known examples are shown in Figure 2.6. The Firth of Forth bridge with two main spans of 521 m each became a milestone in bridge construction on its completion in 1889.

The designers, John Fowler and Benjamin Baker used tubular members of fairly large size with riveted construction for the arch ribs to withstand wind pressures of 2.68 KN/m”. Though the tubes were large in size, the weight per linear meter of the bridge was still less than that of the Quebec bridge.



Howarth bridges

The design of the Quebec bridge was first entrusted to Theodore Cooper, who was then well known for his specifications on railway bridges. The plan envisaged a main span of 549 m with anchor spans of 157 m each, making this bridge the longest span in the world. The first attempt to construct the bridge ended in the complete collapse of the south arm killing 75 men (1907). The failure was due to miscalculation of dead load and wrong design of compression members, which errors were not noticed in time. The design was revised by H.A. Voutelet and the structure was reconstructed in 1917 with the same main span.

Howrah bridge with a main span of 457 m was the third-longest span cantilever bridge in the world at the time of its construction (1943). The bridge was erected by commencing at the two anchor spans and advancing towards the center with the use of creeper cranes moving along the upper chord. The closure at the middle was obtained by means of sixteen hydraulic jacks of 800 t capacity each, The construction was successfully completed with very close precision.

Osaka Port bridge was completed in 1974 with a clear span of 510 m. The bridge is double-decked and is currently the world's third-largest span cantilever bridge. The construction has been achieved without accidents and with great precision, testifying to the great advance in technology in bridge construction.

The weight of the structure and the labour involved in the construction of a cantilever bridge are large compared with a cable stayed bride of the same clear span. Hence the cantilever bridge is not very popular at present.

ERUCTION OF ARTICULATED STRUCTURS

It is the process of assembling the prefabrication element in the search direction and the portion according to the drawing. The following tasks must be carried out in the construction of prefabricated elements.

Launch of prefabricated elements

- The fastening of the mounting earrings is attached to the mounting hooks.
- Cleaning of the elements and the erection site.
- Cleaning of steel inserts before incorporation into lifting joints
- Set the elements to correct the position.
- Adjustments to obtain the stipulated level line and plumb line.
- Deats welding.
- Change of erection rigs.
- Placement and removal of the necessary scaffolding/supports.
- Welding of insortslalaying the reinforced in joints.
- The assembly work in several constructions works by using different prefabricated elements with risk conditions, therefore, skilled workers to be employed at work

Equipment required for erection

The equipment required for prefabrication elements in the industry can be classified as,

- Machinery necessary for extraction, of course, and fine aggregates.
- Transport equipment, such as conveyors, chain conveyors, etc.
- Concrete mixers
- Vibrators
- Assembly equipment such as cranes, cranes, pulleys, etc.
- Transport machines
- Workshop of machinery for the manufacture and repair of steel.
- Machines for stretching, bending and welding bars
- Tools and smaller sockets, such as wheel bars, concrete hubs, etc.
- Steam Generation a plant for accelerated curing
- Planning Coordination
- It is important that the installer/installer and the precaster builder work together to achieve the best performance.

Site access and storage

- Verify site accessibility and delivery of prefabricated panels to the site, especially low platform trailers.
- Check if there is adequate space for temporary storage before installation and ground conditions.
- Irregular terrain will cause overload and crack the panels.
- Crane Arrangement Planning
- Plan the capacity of the crane and lifting gears according to
- The higher weight of prefabricated panels
- Elevation of heights.
- Working radius
- Crane position in relation to the final location of the panel
- Plan another team
- Boom lift and scissor lift to unhook installed panels.
- Lifting gears
- Qualified staff
- Competent crane operators
- Rigging equipment
- Signal equipment
- General considerations for crane selection
- Total lifting weight
- Crane model
- The safe work load for crane
- Lifting capacity must be 1.5 times the total weight
- Lifting and balancing radius
- Crane counterweight

- The length of the crane boom is related to the vertical and horizontal separation of the building.

CONSTRUCTION OF JETTIES AND BREAK WATER STRUCTURES

Jetties are generally constructed with the following procedure:

1. **Site selection and survey:** The location for the jetty is chosen and surveyed in order to gather necessary information—including the soil conditions, tide levels, and wave patterns throughout the area.
2. **Design and planning:** Engineers and architects design the jetty based on the site survey, as well as the intended application of the jetty.
3. **Permitting:** To ensure that the jetty complies with all local and national regulations, the construction project must go through various permitting processes, including environmental impact assessments.
4. **Excavation and dredging:** In order to create a stable foundation for the jetty, the seafloor is excavated and dredged.
5. **Piling and foundation work:** Continuing the creation of a strong foundation, piles are driven into the seabed.
6. **Decking and superstructure:** The deck of the jetty is constructed—as well as any additional structures, including walkway and railings.
7. **Accessories:** Any necessary accessories are applied, including lighting and signs.

Keep in mind that this is the general process for constructing a jetty. Of course, the construction process can vary by project.

Maintaining, Repairing, and Ensuring the Longevity of Jetties

Considering that jetties are exposed to extreme forces of nature—like waves, currents, storms, and erosion—proper maintenance of jetties is essential. These environmental factors pose serious risks for safety, as jetties can lose their structural integrity and be less effective in protecting the coast.

Here are some of the best practices to ensure the longevity of jetties:

- **Monitoring:** Monitoring the jetty's condition—including measuring the water level and wave patterns—can help identify any potential issues that may need to be addressed.
- **Regular inspections:** Regular inspections are crucial to identify any potential issues—such as cracks, erosion, or damage caused by boats. A lack of regular inspections can lead to more serious, costly issues.
- **Regular cleaning:** Regular cleaning of the jetty—including removing debris and sediment—can prevent build-up and erosion that can cause damage to the jetty over a period of time.
- **Regular maintenance:** Regular maintenance such as repainting, replacing worn or damaged materials, and restoring the jetty's structural integrity can help extend both the life and aesthetics of the jetty.

breakwater, artificial offshore structure protecting a harbour, anchorage, or marina basin from water waves. Breakwaters intercept longshore currents and tend to prevent beach erosion. Over the long term, however, the processes of erosion and sedimentation cannot be effectively overcome by interfering with currents and the supply of sediment. Deposition of sediment at one site will be compensated for by erosion elsewhere; this phenomenon occurs whether one breakwater or a series of such structures is erected. *Compare* jetty.

SEISMIC RETROFITTING

Seismic Retrofitting Techniques for Concrete Structures:
Seismic Retrofitting Techniques are required for concrete constructions which are vulnerable to damage and failures by seismic forces. In the past thirty years, moderate to severe earthquakes occurs around the world every year. Such events lead to damage to the concrete structures as well as failures. Thus the aim is to Focus on a few specific procedures which may improve the practice for the evaluation of seismic vulnerability of existing reinforced concrete buildings of more importance and for their seismic retrofitting by means of various innovative techniques such as base isolation and mass reduction. So Seismic Retrofitting is a collection of mitigation technique for Earthquake engineering. It is of utmost importance for historic monuments, areas prone to severe earthquakes and tall or expensive structures. **Keywords:** Retrofitting, Base Isolation, Retrofitting Techniques, Jacketing, Earthquake Resistance

1. Introduction to Seismic Retrofitting Techniques:

- Earthquake creates great devastation in terms of life, money and failures of structures.
- Upgrading of certain building systems (existing structures) to make them more resistant to seismic activity (earthquake resistance) is really of more importance.
- Structures can be (a) Earthquake damaged, (b) Earthquake vulnerable
- Retrofitting proves to be a better economic consideration and immediate shelter to problems rather than replacement of building

1.1 Seismic Retrofitting of Concrete Structures:
Definition: It is the modification of existing structures to make them more resistant to seismic activity, ground motion, or soil failure due to earthquakes. The retrofit techniques are also applicable for other natural hazards such as tropical cyclones, tornadoes, and severe winds from thunderstorms.

1.2 Need for Seismic Retrofitting:

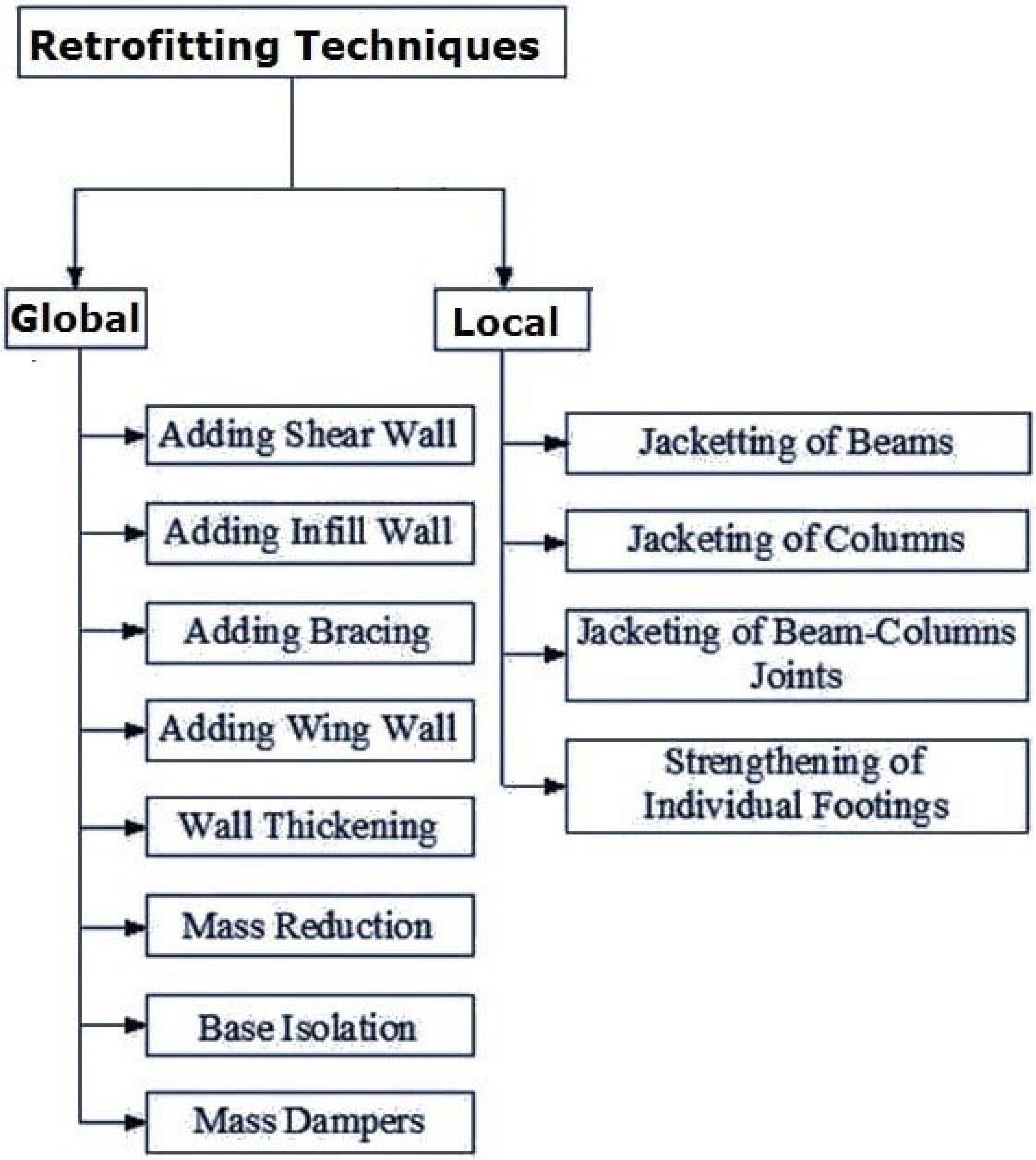
- To ensure the safety and security of a building, employees, structure functionality, machinery and inventory
- Essential to reduce hazard and losses from non-structural elements.
- predominantly concerned with structural improvement to reduce seismic hazard.
- Important buildings must be strengthened whose services are assumed to be essential just after an earthquake like hospitals.

1.3 Problems faced by Structural Engineers are:
Lack of standards for retrofitting methods – Effectiveness of each methods varies a lot depending upon parameters like type of structures, material condition, amount of damage etc.,

1.4 Basic Concept of Retrofitting:
The aim is at:

- Upgradation of lateral strength of the structure
- Increase in the ductility of the structure
- Increase in strength and ductility

2. Classification of Retrofitting Techniques



2.1 Adding New Shear Walls:

- Frequently used for retrofitting of non ductile reinforced concrete frame buildings.
- The added elements can be either cast?in?place or precast concrete elements.
- New elements preferably be placed at the exterior of the building.
- Not preferred in the interior of the structure to avoid interior mouldings.

Fig 2: Additional Shear Wall

2.2 Adding Steel Bracings

- An effective solution when large openings are required.
- Potential advantages due to higher strength and stiffness, opening for natural light can be provided, amount of work is less since foundation cost may be minimized and adds much less weight to the existing structure.

Adding STEEL Bracings:

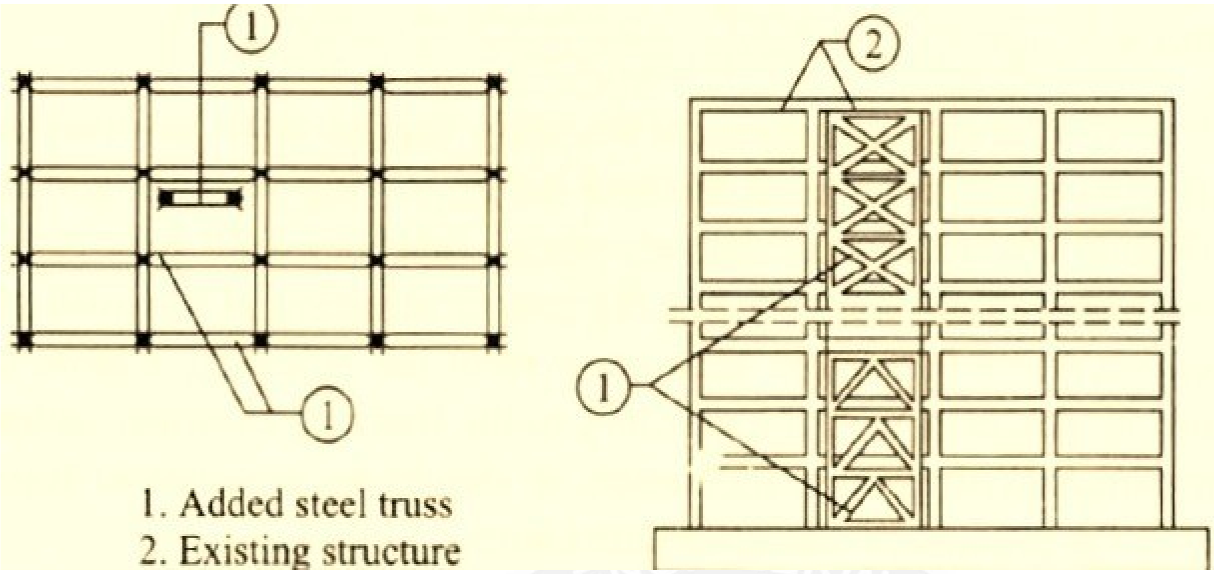


Fig 3: RC Building retrofitted by steel bracing

2.3 Jacketing (Local Retrofitting Technique):
This is the most popular method for strengthening of building columns.

Types of Jacketing:

1. 1.Steel jacket,
2. Reinforced Concrete jacket,
3. Fibre Reinforced Polymer Composite (FRPC) jacket

Purpose for jacketing:

- To increase concrete confinement
- To increase shear strength
- To increase flexural strength

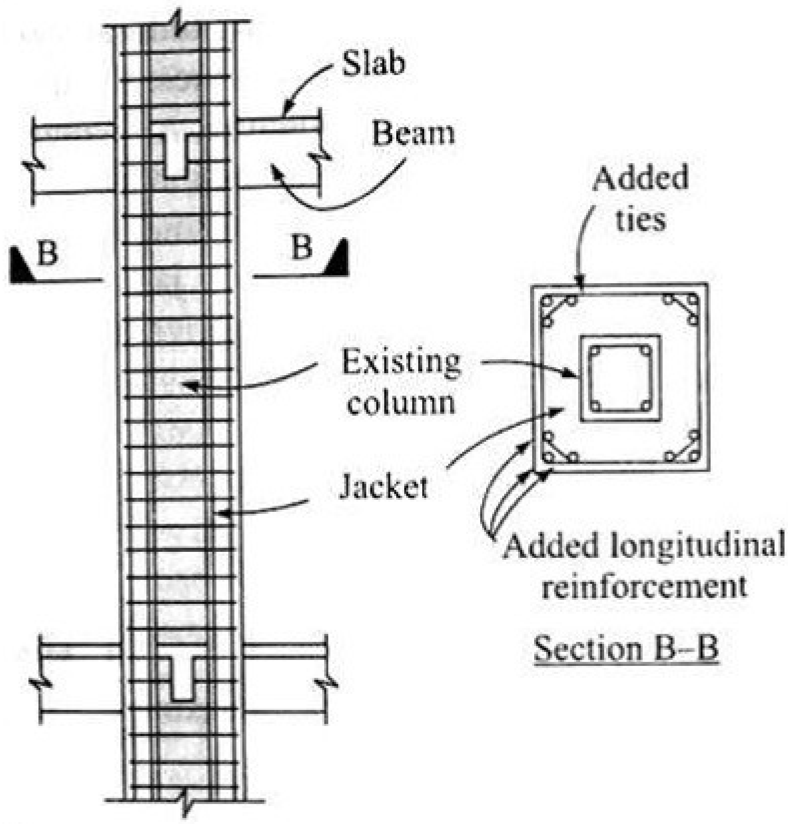


Fig 4: Column Jacketing

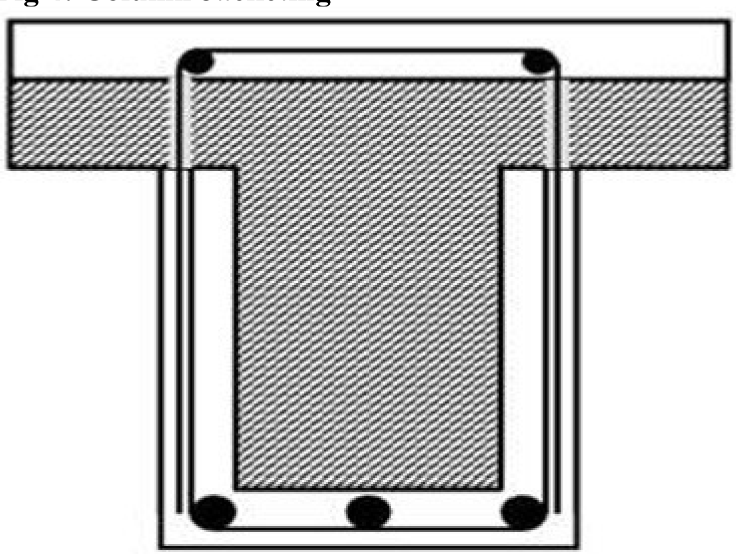


Fig 5: Beam Jacketing

2.4 Base Isolation (or Seismic Isolation):

Isolation of superstructure from the foundation is known as base isolation. It is the most powerful tool for passive structural vibration control techniques.

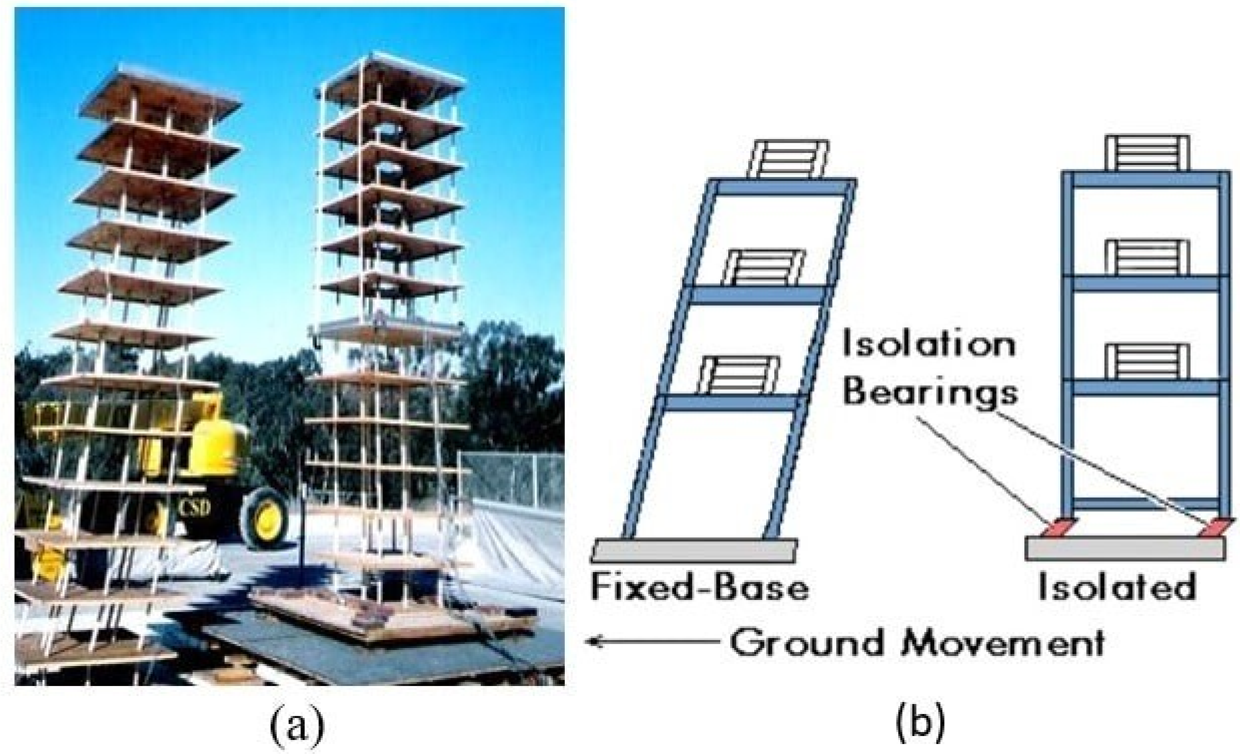


Fig 6: Base Isolated Structures (a)Model Under Test, (b) Diagrammatical Representation

2.4.1 Advantages of Base Isolation

- Isolates Building from ground motion – Lesser seismic loads, hence lesser damage to the structure, -Minimal repair of superstructure.
- Building can remain serviceable throughout construction.
- Does not involve major intrusion upon existing superstructure

2.4.2 Disadvantages of Base Isolation

- Expensive
- Cannot be applied partially to structures unlike other retrofitting
- Challenging to implement in an efficient manner

2.5 Mass Reduction Technique of Retrofitting:

This may be achieved, for instance, by removal of one or more storey's as shown in Figure. In this case it is evident that the removal of the mass will lead to a decrease in the period, which will lead to an increase in the required strength.

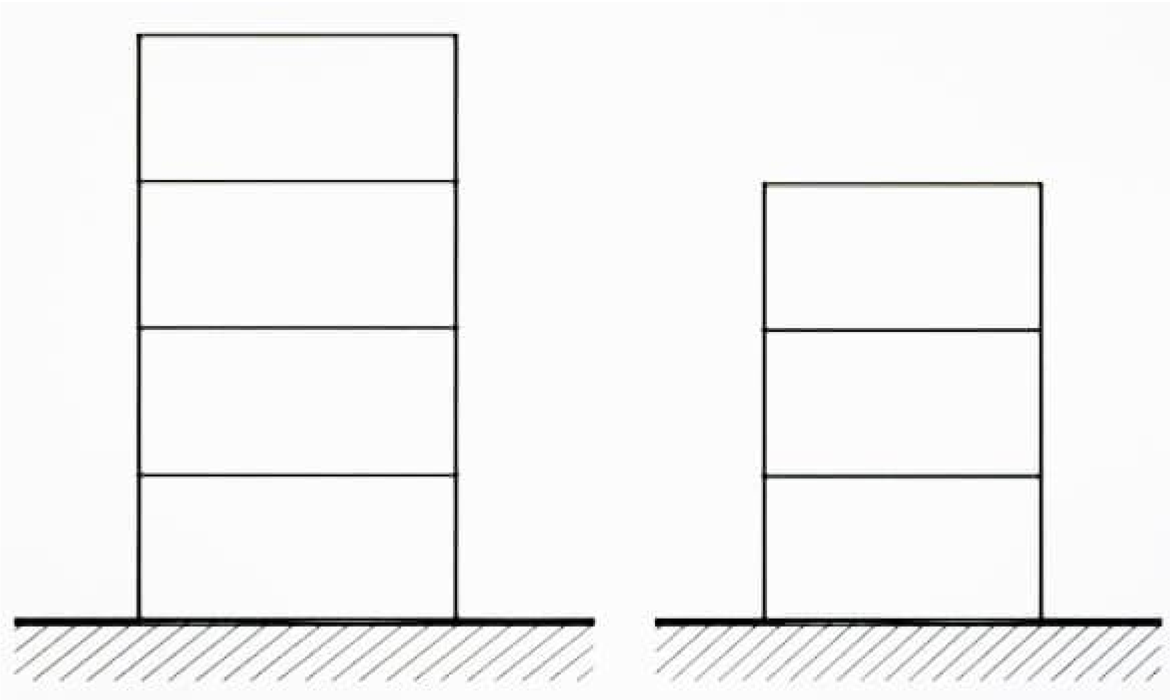


Fig 7: Seismic Retrofitting by Mass reduction (removal of Storey)

2.6 Wall Thickening Technique of Retrofitting:

The existing walls of a building are added to certain thickness by adding bricks, concrete and steel aligned at certain places as reinforcement, such that the weight of wall increases and it can bear more vertical and horizontal loads, and also it's designed under special conditions that the transverse loads does not cause sudden failure of the wall

STRENGTHENING OF BEAM COLUMN AND SLAB

Strengthening of concrete structures must be considered when the existing structure deteriorates or any alteration to the structure has to be made due to which the structure may fail to serve its purpose. Concerns must be taken to existing materials, often in deteriorated condition, loads during strengthening and to existing geometry. In some cases it can also be difficult to reach the areas that need to be strengthened. When concrete structural strengthening is to be undertaken all failure modes must be evaluated. Strengthening a structure for flexure may lead to shear failure instead of giving the desired increased load bearing capacity. It should also be noted that not only the failure mode of the strengthened member is important. If a critical member in a structure is strengthened, another member can become the critical one. Because of changed stiffness in an undetermined structural system the whole structure must be investigated. The strengthening should also designed with consideration to minimize the maintenance and repair needs. When a strengthening is designed the consequences from loss of strengthening effectiveness by fire, vandalism, collision etc. must in addition be considered.

The existing documentation of the structure is often very poor and sometimes even wrong. It might be necessary to redesign the structure with the probable former codes that were active when the structure was built. This can give enough knowledge about the structural mode of action, otherwise field investigations must be undertaken to provide an understanding of the structure. The design of a strengthening however must fulfill requirements in the codes of today. It is not only the financial and structural aspects that should form the basis for decisions of strengthening method, but environmental and aesthetic aspects must also be considered.

STRENGTHENING OF BEAMS

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. In such cases, there are different solutions that could be followed: **I-ADDING REINFORCEMENT STEEL BARS TO THE MAIN STEEL WITHOUT INCREASING THE BEAM'S CROSS SECTIONAL AREA** This solution is carried out when the reinforcing steel bars are not capable to carry the stresses applied to the beam. The following steps should be followed: 1. The concrete cover is removed for both the upper and lower steel bars. 2. The steel bars are well cleaned and coated with an appropriate material that would prevent corrosion. 3. Holes are made, in the whole span of the beam under the slab, as shown in Fig.1, 15-25cm apart, a diameter of 1.3cm and extend to the total width of the beam.

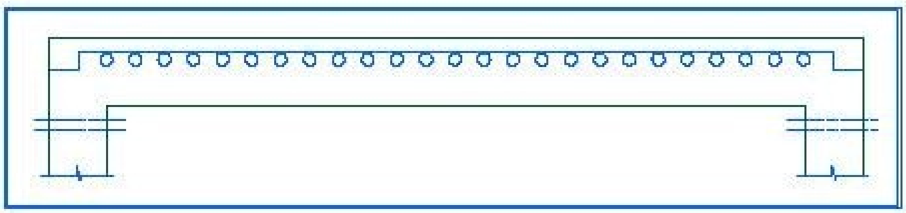


Fig.1: Holes in the span of a beam

4. The holes are filled with an epoxy material with low viscosity and installing steel connectors for fastening the new stirrups. 5. Steel connectors are installed into the columns in order to fasten the steel bars added to the beam. 6. The added stirrups are closed using steel wires and the new steel is installed into these stirrups. 7. The surface is then coated with a bonding epoxy material. 8. The concrete cover is poured over the new steel and the new stirrups. The previous steps are illustrated in Fig 2.

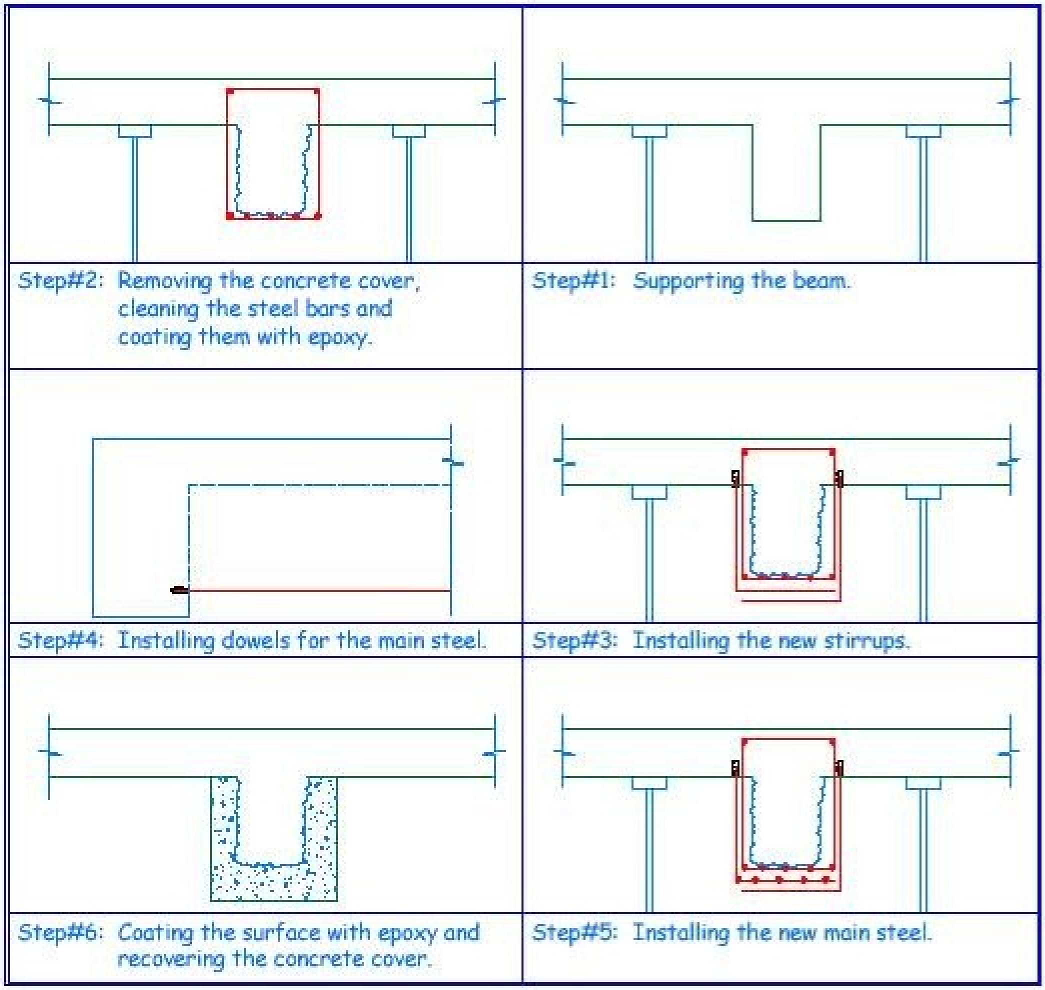


Fig.2-

Strengthening a beam without increasing cross sectional area.

II-INCREASING BOTH THE REINFORCING STEEL BARS AND THE CROSS - SECTIONAL AREA OF CONCRETE This solution is chosen when both the steel and concrete are not able to carry the additional loads applied to the beam. In such cases the following steps should be followed as in *Fig 3*. 1. Removing the concrete cover, roughing the beams surface, cleaning the reinforcement steel bars and coating them with an appropriate material that would prevent corrosion. 2. Making holes in the whole span and width of the beam under the slab at 15-25cm. 3. Filling the holes with cement mortar with low viscosity and installing steel connectors for fastening the new stirrups. 4. Installing the steel connectors into the columns in order to fasten the steel bars added to the beam. 5. Closing the added stirrups using steel wires and the new steel is installed into these stirrups. 6. Coating the concrete surface with an appropriate epoxy material that would guarantee the bond between the old and new concrete, exactly before pouring the concrete. 7. Pouring the concrete jacket using low shrinkage concrete.

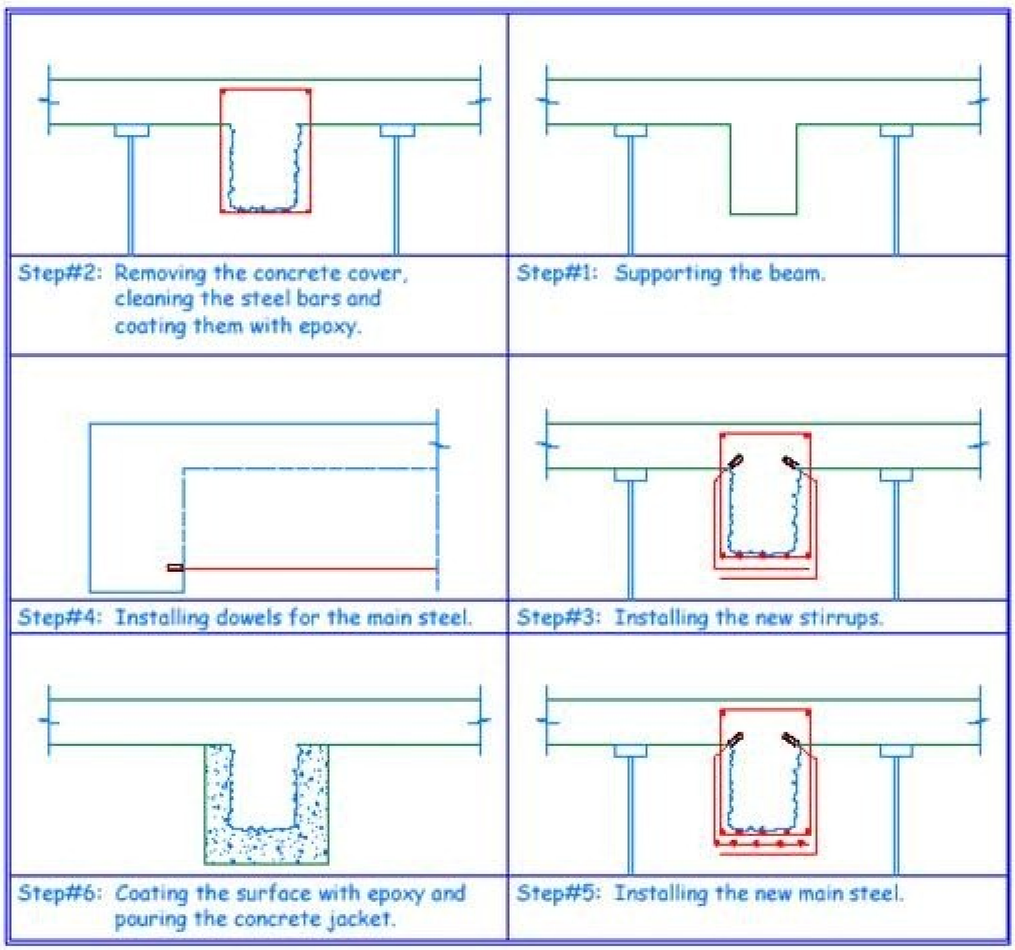


Fig.3:

Strengthening of beam by increasing the cross-sectional area and bars

III-ADDING STEEL PLATES TO THE BEAM When it is required to strengthen the beam's resistance against the applied moment or shear stress, steel plates are designed with the appropriate size and thickness. Then those plates are attached to the beam as follows: 1. Roughing and cleaning the concrete surfaces where the plates will be attached. 2. Coating the concrete surfaces with a bonding epoxy material. 3. Making holes in the concrete surfaces and plates. 4. Putting a layer of epoxy mortar on top of the plates with a 5mm thickness. 5. Attaching the steel plates to the concrete using bolts. The previous steps are illustrated in Fig 4.

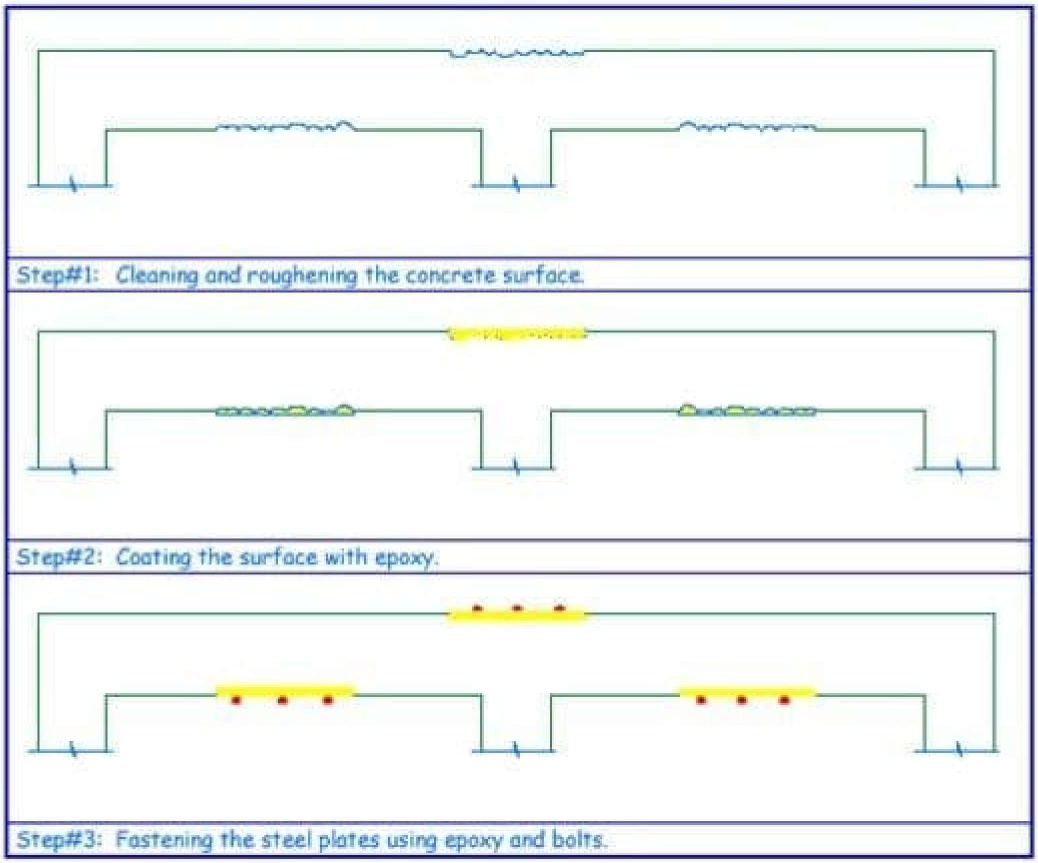


Fig.4: Strengthening of Beam by adding steel plates

In some cases, it is needed to reduce the load on the beam that needs strengthening before implementing the previous steps, either partial or complete unloading. This is made by putting steel beams on top or below the concrete beams, as shown in *Fig5*.

Fig.5: Reducing the load on the beam using steel beam.

The following photos were taken during strengthening an existing building; they present the practical method of implementing some strengthening techniques.

Strengthening a beam , slab and column.

Strengthening a beam and Slab.

Jacketing a beam by increasing bars and cross section.

Strengthening by steel plates.

Column strengthening is a process used to add or restore ultimate load capacity of reinforced concrete columns. It is used for seismic retrofitting, supporting additional live load or dead load that not included in the original design, to relieve stresses generated by design or construction errors, or to restore original load capacity to damaged structural elements. There are several techniques which are used to strengthen reinforced concrete columns like reinforced concrete jacketing, steel jacketing, and FRP confining or jacketing.

When strengthening of R.C. Column is needed?

1. The load carried by the column is increased due to either increasing the number of floors or due to mistakes in the design.
2. The compressive strength of the concrete or the percent and type of reinforcement are not according to the codes' requirements.
3. The inclination of the column is more than the allowable.
4. The settlement in the foundation is more than the allowable.

Strengthening Techniques for R.C. Columns

1. Reinforced Concrete Jacketing

It is one of the techniques used to improve or restore capacity of reinforced concrete column. The size of the jacket and the number and diameter of the steel bars used in the jacketing process depend on the structural analysis that was made to the column.

Reinforced Concrete Jacketing Process

1. Initially, reduce or eliminate loads on columns temporarily if it is required. This is done by putting mechanical jacks and additional props between floors.
2. After that, if it is found out that reinforcements are corroded, the remove the concrete cover and clean the steel bars using a wire brush or sand compressor.
3. Then, coat the steel bars with an epoxy material that would prevent corrosion.
4. If reducing loads and cleaning reinforcement is not needed, the jacketing process begin by adding steel connectors into the existing column.
5. The steel connectors are added into the column by making holes 3-4mm larger than the diameter of the used steel connectors and 10-15cm depth.
6. The spacing of new stirrups of the jacket in both the vertical and horizontal directions should not be more than 50cm.
7. Filling the holes with an appropriate epoxy material then inserting the connectors into the holes.
8. Adding vertical steel connectors to fasten the vertical steel bars of the jacket following the same procedure in step 5 and 6.
9. Installing the new vertical steel bars and stirrups of the jacket according to the designed dimensions and diameters.
10. Coating the existing column with an appropriate epoxy material that would guarantee the bond between the old and new concrete.
11. Pouring the concrete of the jacket before the epoxy material dries. The concrete used should be of low shrinkage and consists of small aggregates, sand, cement and additional materials to prevent shrinkage. Steps of reinforced concrete jacketing are illustrated in Fig. 1.

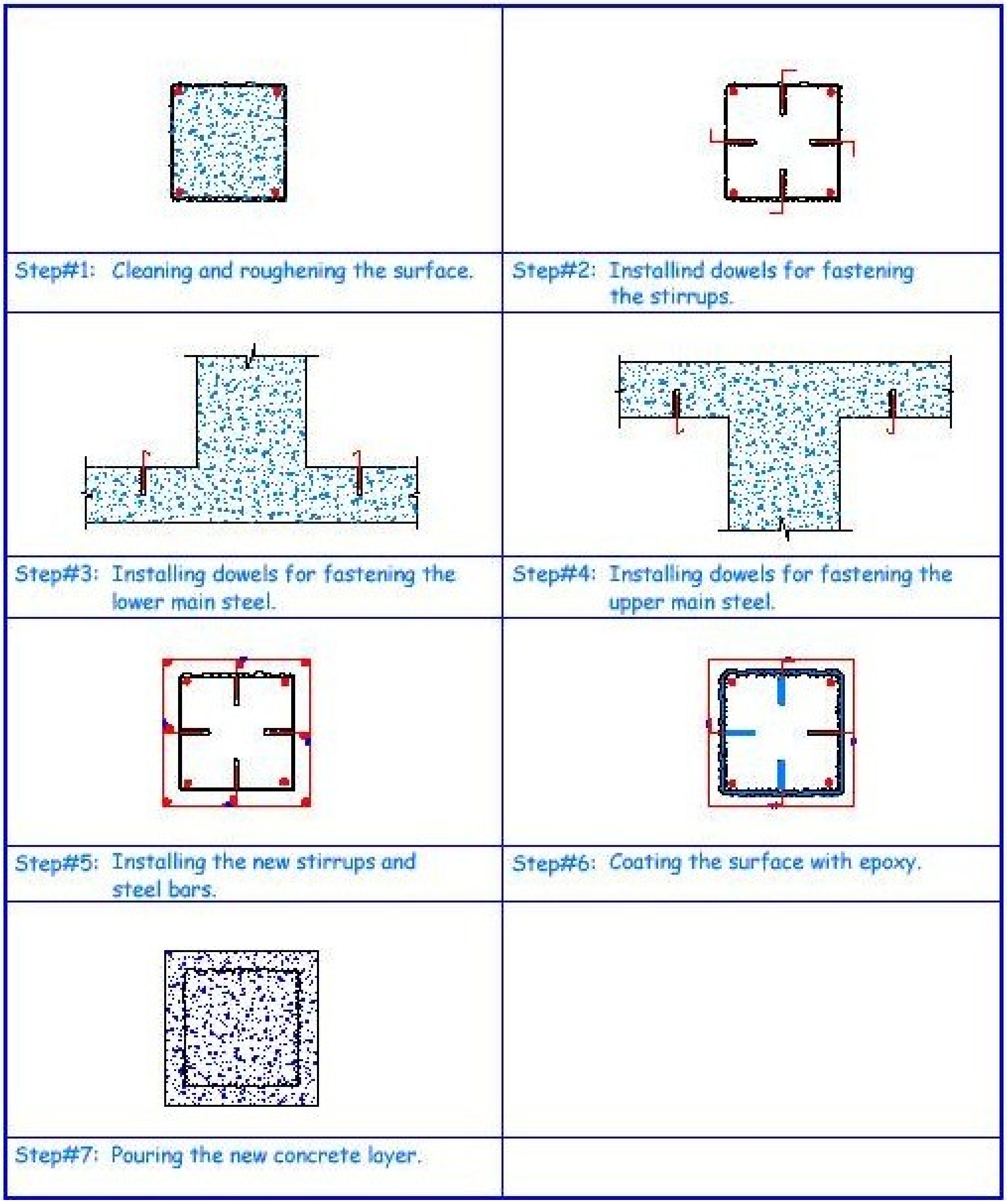


Fig. 1: Increasing the Cross-sectional Area of Column by RC Jacketing

2. Steel Jacketing

This technique is chosen when the loads applied to the column will be increased, and at the same time, increasing the cross sectional area of the column is not permitted.

Steel Jacketing Process

1. Removing the concrete cover.
2. Cleaning the reinforcement steel bars using a wire brush or a sand compressor.
3. Coating the steel bars with an epoxy material that would prevent corrosion.

4. Installing the steel jacket with the required size and thickness, according to the design, and making openings to pour through them the epoxy material that would guarantee the needed bond between the concrete column and the steel jacket.
5. Filling the space between the concrete column and the steel jacket with an appropriate epoxy material.

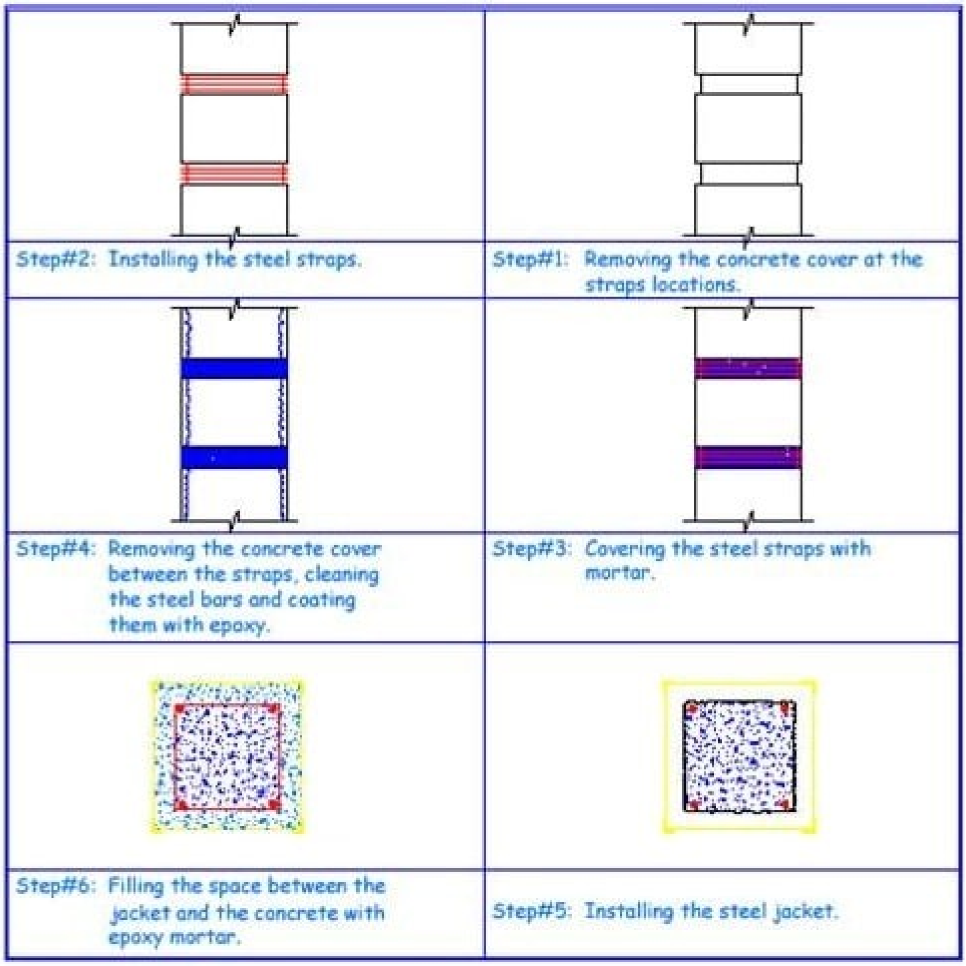


Fig. 2: Increasing the cross-sectional area of column by steel jacketing

In some cases, where the column is needed to carry bending moment and transfer it successfully through the floors, one should install a steel collar at the neck of the column by means of bolts or a suitable bonding material.

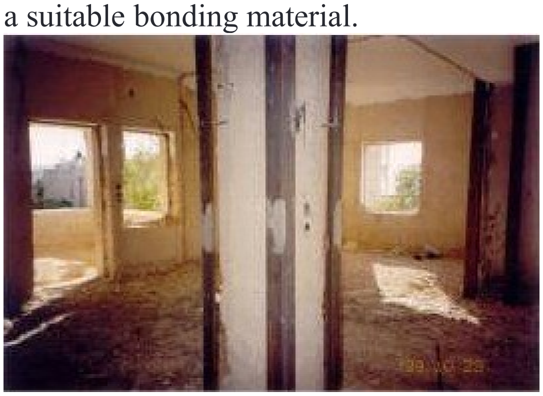


Fig. 3: Column strengthened with steel angles

Fig. 4: Welding steel jacket

Fig. 5: Welding process

Placement of Steel Jacket After Welding process ended

STRENGTHENING OF MASONRY WALLS

Strengthening of masonry walls is required to prevent failure and collapse during major earthquake or addition of extra load on buildings. Strengthening of masonry walls also may be required during rehabilitation of buildings. Unreinforced masonry walls have good compressive strength, but they are brittle and very weak under the action of lateral loads which causes tension in walls. Whenever tension forces acts on a masonry wall, it tends to crack. Cracking of masonry walls may occur due to settlement of foundation, during earthquakes, application of lateral loads. There can be several causes for masonry wall cracks, but occurrence these cracks may lead to complete collapse of wall. Some of the failures of masonry walls are shown in images below:

Fig: Corner Failure of Masonry Wall

Fig: Vertical Cracks in Masonry Walls

Fig: Roof Collapse due to Removal of Wall

In a load bearing masonry buildings, loads from the building is transferred through walls and failure and collapse of such masonry walls can lead to complete collapse of the building. In case of reinforced concrete framed structures, although loads are transferred through columns, but in the event of an earthquake, these walls are more susceptible to develop cracks and fail. Uses of half brick thick masonry walls are common as partitions in the interior of RC framed buildings. These half brick masonry walls are unsafe under the action of lateral forces during earthquake. Out of plane strengthening of partitions can be clubbed together with lateral strengthening of building by providing reinforced concrete jackets to the partitions. To prevent the collapse of masonry walls during earthquake, it is advisable to use reinforced brick masonry walls in new construction. Existing masonry walls can also be strengthened by providing reinforced concrete jackets on one or both sides of the walls.

Methods of Masonry Wall Strengthening

Masonry walls can be strengthened by following methods: 1. Providing reinforced concrete jackets on one or both faces of walls. 2. Use of FRP Structural Repointing for strengthening of masonry walls (Source: Strengthening of Masonry Walls by FRP Structural Repointing by Gustavo Tumialan, Pei-Chang Huang, Antonio Nanni, Pedro Silva)

Masonry wall Strengthening using RC Jackets:

Reinforced concrete (RC) jackets technique for strengthening of masonry structure consists of application of jackets on one or both sides of masonry walls. This method is used for brick masonry as well as for stone masonry walls. For using reinforcement jackets, first the plaster is removed from the walls. Mortar joints between bricks are cleaned. In case of any cracks in masonry walls, those are first grouted. Anchor ties are are inserted in pre-drilled holes. The surface of drill is cleaned, moistened, and cement slurry is spread on the masonry surface and in drills. The concrete is applied in two-layers with reinforcement mesh in between them. The reinforcing mesh on both sides of wall is connected with the help of steel anchors. These anchors are welded with the mesh or tied using tying wire. The usual total thickness of RC jackets varies from 30mm to 100mm. The thickness depends on the method for application of concrete layers. **Rules for Strengthening of Masonry Walls by Reinforced Concrete Jacketing:**

- The minimum horizontal and vertical reinforcement should be 0.25% of the jacket section.
- The minimum reinforcement with which the ends of the wall are strengthened should be 0.25% of jacket section.
- The diameter of the ties at the well ends should not be less than 8 mm with a maximum spacing of 150 mm.
- The jacket must be anchored to the old concrete with dowels spaced at no more than 600 mm in both directions.

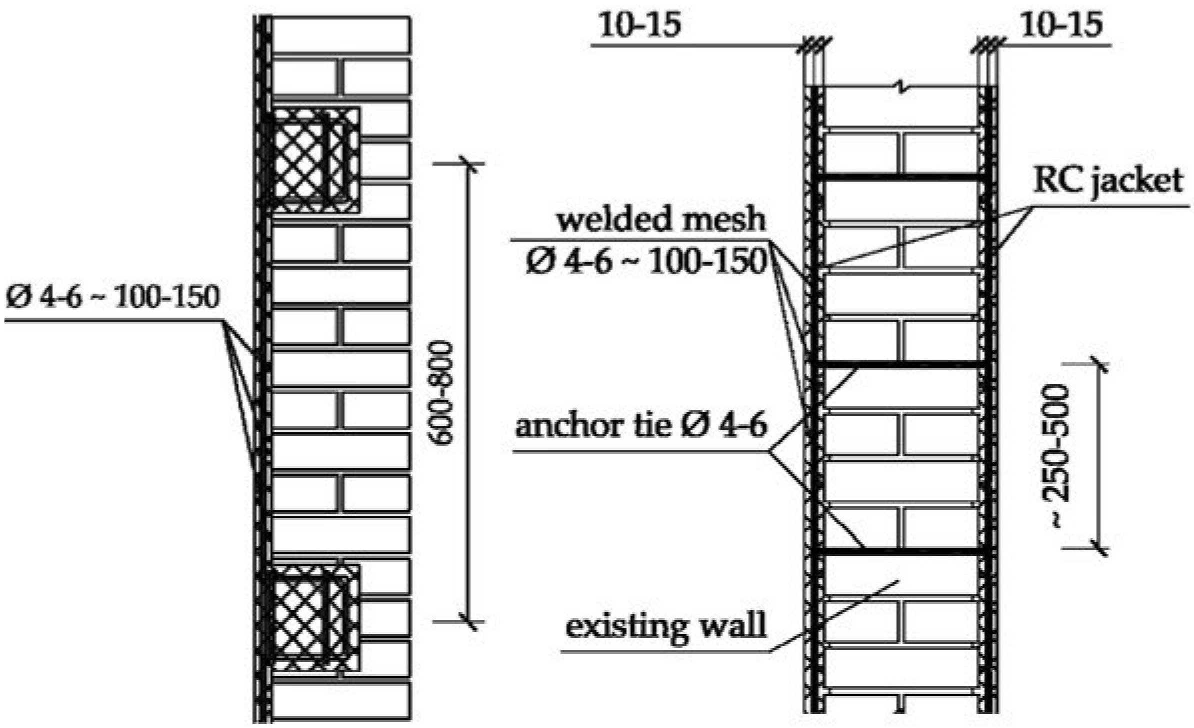


Fig: Strengthening of Masonry Walls by Application of Single and Double sided reinforced concrete (RC) jackets (source: Paper by S. Churilov & E. Dumova-Jovanoska on "Analysis of masonry walls strengthened with RC jackets" It is also important that the jacket should be able to transfer forces to slab diaphragms. This can be achieved by providing epoxy grouted anchors and diagonal connecting bars through holes made in slabs.

Strengthening of Masonry Walls by Using FRP Structural Repointing:

Structural repointing of masonry walls has advantages compared to the use of FRP laminates. This method of masonry wall strengthening is simple since the surface preparation is reduced (sandblasting and puttying) is not required. In addition the aesthetic of masonry is preserved. Following figure illustrates the strengthening procedure of masonry walls:

Fig: Strengthening of Masonry Walls using FRP Structural Repointing; (a) Grinding of masonry joints, (b) Masking of masonry to avoid staining, (c) Application of epoxy based paste to masonry joint, (d) Installation of GFRP Rod

4.5 SHORING AND UNDERPINNING

4.5.1 SHORING

The arrangement employed to prevent a damaged structure, due to either foundation settlement or other reasons from collapse, is called shoring. It is also used for providing temporary support to a structure which is being remodeled.

The shores are of types:

Racking Shores: In this type, notches are cut in the walls of the building and inclined posts are property, while demolishing the building, are called horizontal or flying shores.

Horizontal of Flying Shores: The shores, which are employed to support the walls of adjoining property while demolishing the building are called horizontal or flying shores.

Vertical Dead Shores: The vertical shores used to support walls temporally are called vertical or Dead shores.

4.5.2 UNDERPINNING

The operation of providing new permanent foundation is known as underpinning The under pining may be done by the following methods.

Pit Underpinning

In this method, a pit is dug to expose the foundation to b remodeled & the old foundation is either removed completely or strengthened suitably.

Pier Underpinning

In this method of underpinning, piers under foundations of structures are installed, filledwith concrete and wedged up to transfer the load to a new pier.

This method is most suitable in dryground. In pier underpinning, proper care must be taken to prevent loss of ground installing the sheeting, otherwise the building structure mar sink. The least size of the underpinning pits to provide working place, for workers is 1m x 1.3m. The pits are sunk to a stratum strong enough.

In this method piles are jacked into the ground with case for underpinning building, whereunderlying ground has water bearing strata.

Types of Soil Stabilization

The three basic types of soil stabilization techniques are (1) Mechanical (2) Compaction & (3) Chemical

1) Mechanical Soil Stabilization Technique:

The oldest types of soil stabilization are mechanical in nature. Mechanical solutions involve physically changing the property of the soil somehow, in order to affect its gradation, solidity, and other characteristics. Ultimately, dense and well graded material can be achieved by mixing and compacting two or more soils of different grades. Addition of a small amount of fine materials such as silts or clays enables binding of the non-cohesive soils which increases strength of the material. On the other hand, strong and angular particles of sand and gravels, impart internal friction and incompressibility to the mix and can be well stabilized with addition of clay owing to its binding properties. Factors affecting the mechanical stability of mixed soil may include:

- The mechanical strength and purity of the constituent materials
- The percentage of materials and its gradation in the mix
- The degree of soil binding taking place
- The mixing, rolling, and compaction procedures adopted in the field
- The environmental and climatic conditions

2) Compaction Soil Stabilization Technique:

Uses mechanical means for expulsion of air voids within the soil mass resulting in soil that can bear load subsequently without further immediate compression. Dynamic compaction is one of the major types of soil stabilization; in this procedure, a heavyweight is dropped repeatedly onto the ground at regular intervals to quite literally pound out deformities and ensure a uniformly packed surface. Vibratory Vibro compaction is another technique that works on similar principles, though it relies on vibration rather than deformation through kinetic force to achieve its goals.

3) Chemical Soil Stabilization Technique:

Chemical solutions are another of the major types of soil stabilization. All of these techniques rely on adding additional material to the soil that will chemically and physically interact with it and change its properties. For example cement stabilization is most effective on low cohesion soils, owing to difficulty in good distribution of the anhydrous stabilizer amongst cohesive clays and because larger granular particles can be surrounded and coated by the cement paste.

On the contrary, in cohesive soils, many particles are smaller than anhydrous cement grains and hence are more difficult to coat. There are a number of different types of soil stabilization that rely on chemical additives of one sort or another; you will frequently encounter compounds that utilize cement, lime, fly ash, or kiln dust. Most of the reactions sought are either cementitious or pozzolanic in nature, depending on the nature of the soil present at the particular site you are investigating. The chemicals present in lime for example are oxides and hydroxides of calcium and magnesium with options for commercial production through calcination of carbonate rock minerals for high calcium limes or as dolomitic limestone consisting of calcium and magnesium oxides through pressure hydration.

Polymer/Alternative Soil Stabilization Technique:

Both of the previous types have been around for hundreds of years, if not more; only in the past several decades has technology opened up new types of soil stabilization for companies to explore. Preference for polycondensation polymers over polyaddition polymers is because the former works with larger polymeric chains, polymerization stops and rarely restarts, and they are low cost and easy to prepare. Synthetic polymers such as vinyls and acrylamides coat soil grains reducing permeability and enhancing the dry strength of the fine material to hold coarser aggregate together. Polymers can be mixed with soil in the form of a liquid in order to fill the pores and harden the soil structure. The prerequisites for polymer stabilization include:

- The polymer must be adhesive to soil particles in the presence of water
- Internal cohesion of the polymer is key
- Workability at high humidity and low ambient temperatures
- Miscibility with water to produce a low viscosity liquid

Most of the newer discoveries and techniques developed thus far are polymer-based in nature, such as those developed by Global Road Technology. These new polymers and substances have a number of significant advantages over traditional mechanical and chemical solutions; they are cheaper and more effective in general than mechanical solutions, and significantly less dangerous for the environment than many chemical solutions tend to be.

All three types are still employed on construction projects all across the globe, though the polymer-based solutions offered by firms like Global Road Technology are rapidly gaining ground due to the cost savings, ease-of-use, environmental benefits, and other significant advantages they bring to the table over more traditional soil stabilization types.

What is Meant by Soil Stabilization?

Soil stabilization is a process by which the physical properties of a soil are transformed to provide permanent strength gains before construction. Stabilized soils outperform non-stabilized soils when materials, design, and construction are properly considered. When the stabilized soil layer is incorporated into the structural design of the pavement, the subsequent layers can be thinner, resulting in sizable cost savings and minimizing the need for virgin materials. In addition to adding strength, stabilized soil forms a solid monolith that decreases permeability, which in turn reduces the shrink/swell potential and the harmful effects of freeze/thaw cycles.

Soil stabilization can improve in situ, or natural state, soils eliminating the need for expensive remove-and-replace operations. Often job sites where roads, building pads, parking lots, runways or other pavement structures need to be built contain naturally wet, weak soils. Those soils can be chemically treated to add strength through stabilization and improve engineering properties including moisture content and plasticity, through modification. Ex situ, or off site, soil stabilization processes are possible but are usually reserved for environmental projects rather than typical construction operations.

hemical Stabilization of Soil

The chemical stabilization of soil is a relatively broad term that is used when chemical reagents such as quicklime, Calciment Lime Kiln Dust (LKD), cement, or other industrial co-products and bi-products are used to increase the strength of subgrade soil. Regardless of the reagent, the use of proper techniques is important. Thorough mixing ensures complete incorporation and an overall homogeneous mix. Moisture and compaction testing is important to be sure that all reactions have occurred. Each reagent must hydrate completely, and maximum density is only achievable at optimum moisture content. Regardless of the stabilizing agent used, pre project planning, including laboratory testing, is important to be certain that the proper amount of stabilizing agent is present to permanently stabilize the soil and provide the desired result.

Soil Stabilization Materials

LIME

Quicklime, often referred to simply as lime, is the chemical compound calcium oxide (CaO). Quicklime is available in two types, high calcium and dolomitic. High calcium is almost completely calcium oxide, whereas dolomitic quicklime contains a portion of magnesium oxide (MgO) along with calcium oxide. Some industrial applications such as steel need the magnesium component for certain processes. For construction purposes, high calcium and dolomitic quicklime are virtually indistinguishable. Learn more about why lime-based products are the most effective soil-drying agent and how they can improve soils through modification.

Lime will stabilize clayey soils to provide long-term, strength gains that will continue after initial application. Studies have shown that these reactions can continue for a year or more. Lime stabilization provides the calcium component and the proper chemical environment that is necessary to permanently stabilize a soil. Since lime is an alkali material, it provides the proper chemical environment by raising the soil pH to the point that naturally occurring pozzolans, such as silica and alumina, to become soluble. Once soluble, they are available to react and form cementitious bonds with the calcium from the lime. The resulting calcium-silicate-hydrates (C-S-H) and calcium-aluminate-hydrates (C-A-H) are permanent and reduce the effect of clay soil resulting in a very resilient subgrade rather than masking it as is the case with other stabilization techniques.

Soils with a plasticity index (PI) of 10 or more are generally great candidates for lime stabilization. Proper laboratory testing is important to determine soil reactivity and dosage rates necessary for proper stabilization.

CALCIMENT® LKD

Lime Kiln Dust, or LKD, is a co-product of the lime manufacturing process that contains a combination of CaO, MgO and pozzolans. Much like fly ash, the pozzolans come from the fuel used in combustion processes and are finely sized materials carried by exhaust gasses and collected by emission controls such as bag houses.

These products are a hybrid of sorts between quicklime and cement that work well in 5-35 PI soils. The presence of pozzolans enables the stabilization of more granular, sandier soils. Since Calciment LKD also contains calcium, like lime, the product can also leverage the pozzolans naturally present in clayey soils to generate cementitious bonds. Similar to fly ash, anytime the co-products are used, energy consumption and emissions are reduced. The use of virgin material and disposal to landfills is minimized, making Calciment LKD an environmentally friendly alternative to traditional reagents.

CEMENT

Cement is a widely used composite material composed mainly of calcium, silica, alumina, and iron derived from limestone, sand and clay. All are processed, fired in a kiln and pulverized to a fine powder. When cement is exposed to water, it chemically hydrates resulting in a gel that forms an interlocking matrix around soil particles. The mix hardens, or cures, very rapidly, typically within one to three hours, so the soil-cement mixture must be placed, mixed and compacted quickly. This rapid curing results in high initial strength gains that taper off rapidly.

Cement is an effective reagent for stabilizing certain types of soils. However, not all soil types are created equal and understanding the geotechnical properties of the soils for your specific application is key. Cement is a good option when working with sandy, coarse-grained soils but the effectiveness of cement decreases as clay content and plasticity increase. Cement stabilization merely masks the effect of clay and is not an economical option to stabilize fine-grained soils. Additionally, undesirable shrinkage cracking is often associated with cement-stabilized soils allowing water to penetrate and cause further damage.

Soils with a plasticity index (PI) of 10 or less are generally candidates for cement stabilization. Proper laboratory testing is important to determine the right product, and dosage rates necessary to properly stabilize the soil for your specific application.

Other Stabilization Products

BITUMEN

Bitumen is a naturally occurring organic binder that is typically obtained from petroleum distillation or refining crude oil. It is a sticky, viscous liquid that commonly holds asphalt together. When bitumen is added to a soil, it fills the voids in the soil to mechanically stabilize the soil rather than reacting with individual soil particles. Soil type is an important factor when considering bitumen for stabilization. Finely grained soils need higher dosage rates of bitumen to stabilize soil compared to sandy, coarse-grained soils. Bitumen is often one of the costliest construction materials, so dosage rates are a key factor for cost effectiveness when considering bitumen. Weather is another factor to consider as bitumen and its viscosity is very susceptible to differences in temperature. Viscosity will decrease with temperature resulting in poor mixing, an unwanted uneven mix and seemingly random stabilization in colder temperatures.

GEOTEXTILES

Geotextiles are fabrics that resist chemicals and biodegradation. Like bitumen, geotextiles mechanically interact with the soil to provide increased strength and bearing capacity. Opening size, interlocking grab strength, and puncture resistance are important factors associated with geotextiles. The increased cost of geotextiles adds to the overall cost of the project.

GROUT

Grout is a flow-able mixture of water, cement and sand that can be pumped throughout a jobsite. Slurried grout is injected at predetermined intervals to infiltrate the soil matrix. The mix cures over time adding strength and bearing capacity to the soil. Pressure grouting is only an option in granular soils as the material must be able to flow through the mass of soil. The fine particle size associated with clayey soils results in minimal to no permeation, rendering grouting ineffective.

Soil Stabilization Methods

LAB TESTING

Laboratory testing is important to determine the product type and minimum dosage rate as well as the water necessary to reach optimum moisture content. Our Innovation Center and Customer Application Specialists are available to prove out options.

TRANSPORTATION AND SPREADING

Lime typically arrives at the jobsite via pneumatic truck before being transferred into a spreader truck. Spreader trucks distribute the material on the job site at the specified dose rate. Once the chemical reagent is applied, water is usually added, and the amount is dependent on the desired results and current water content of the soil. For smaller or remote jobs, lime can be delivered in dump trucks or bulk bags.

Pneumatic Truck

Bulk Bags

MIXING

The lime and water need to be properly incorporated into the soil to achieve a homogeneous mix and help break down the soil. Reclaimers are the preferred mixing equipment for this portion of the process. However, backhoes and bulldozers work well for smaller jobs or when the initial soil bearing capacity is low, which is often the case on environmental sites involving lagoon, sludge or sediment stabilization projects.

COMPACTION AND GRADING

Both compaction and grading are important to allow free water to drain to keep the integrity of the stabilized soil. Compaction, targeting maximum dry density, can be achieved by using a number of different soil compaction methods. The compacted material is then graded to a profile and cross slope. Finally, the surface is ready for a final smooth roll to seal the soil making the subgrade ready for further construction to continue.

Step by step process

STEP 1:

Lime is transferred from Pneumatic truck to spreader truck

STEP 2:

Mintek's reagent, water and soil are mixed using a reclaimer

STEP 3:
A spreader truck then spreads product over the problematic soil

STEP 4:
A drum roller or pad foot compacts the pulverized mix

Soil Stabilization Using Cement

Cement stabilization is very similar to lime stabilization but the cement must be placed, mixed and compacted before the mix starts to cure, generally within three hours. If there is a disruption in production, reapplication and incorporation may be necessary.

5.5 DEMOLITION TECHNIQUES

General

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 control – 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 techniques 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 the 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.

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 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;

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.

5.6 ENGINEERED DEMOLITION METHODS

Mechanical method by

* Hydraulic crusher with Long Boom arm
* Non Explosive Demolition Agent
* Saw cutting
* Water jet
* Pusher Arm
* Wire Rope Pulling
* Other Methods like
* Explosive Demolition
* Cutting and Lifting
* Wrecking Ball
* Clam Shell

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.

a) 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 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:

- Slabs;
- Secondary beams; then
- Main beams

c) Mechanical plant shall descend from the floor with temporary access ramp, or be lowered to the next day 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;

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.

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;

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, expect for the crane operator and the spot person, all other workers shall be kept away from the demolition ball"s working radius. Nobody 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.

Chutes may be used to discharge debris into a vehicle or hopper.

Foundations would normally be grubbed up by excavation machines.

Explosive Demolition Method for Building Structures

Implosion Method of Building Demolition

Implosion is the process of demolition of a building using explosives. If the supports of the building are removed, the structure collapses. Using implosion technique, the main supports of the buildings such as column's, beams and slab are fixed with explosives. When these explosives are detonated, the column collapse and so is the structure. Depending how the structure falls, there are two types of implosion:

a) Falling like a tree

In this type of implosion, the building is made to fall like a tree to the sideward. This is the commonly used type of implosion. When free space is available besides the building, this type of demolition is prescribed. If the free space is available on the left side of the building, the explosives are set on the lower level of the building on the left side columns. As the explosives are detonated, the columns bursts, the building tends to falls towards the left side. Steel cables are tied to the building to control the falling direction of the building.

b) Falling into its own footprint

When the free spaces are not available around the building and the structure around the building are to be protected. This type of demolition is used. In this type of demolition, explosives are set in the floor below the middle part of the building.

These explosives are to be heavy as the explosion must demolish the building at once. If one part blast and followed by another. Then the building falls towards the first blasted part. So only less companies in the world are experienced in this type of demolition. As the explosions are detonated, the upper part of building destroys and falls upon the lower building. Due to the heavy load and force the lower part of the building also collapses and falls on its own footprint

SAFETY IN DEMOLITION DEMOLITION

Demolition or dismantling refers to breaking up of buildings , structures either fully or partially . Utmost consideration is to be given to demolition or dismantling of structures than to erection, construction and maintenance. The problems, hazards and uncertainties can be much greater in demolition and it is also carried out by the unskilled workers. The design engineers have responsibility for safety for not only for design and construction but also for the demolition of the structures at the end of its usual life. Precautions during demolition has three goals. (1) specifically aimed at safeguarding the personnel on the site. (2) safeguarding of persons not connected with demolition including the general public and (3) the protection of the property likely to be effected by demolition operation. The causes of accidents to workers involved with demolition are fall from heights, falling materials, inadequate access, over-fragile materials etc. Premature collapses due to incorrect dismantling, over loading or excessive pre- weakening feature particularly during demolition. SAFETY PRECAUTIONS : The safety precautions to be taken before demolition depends on method of demolition. Demolition methods include (1) manual demolition (2) mechanical demolition by pusher arm, demolition ball and wire rope pulling; explosives; demolition by hydraulic busters and the thermic lance. These used methods of demolition vary depending on types of buildings and structured such as houses, large buildings, bridges, arches, independent chimneys, steel and concrete structures, spires, pylons and masts, petroleum tanks etc. Any demolition work should be proceeded by (a) Site survey which should be comprehensive (b) Decide on the location and position of screens, scaffolds etc., (c) Protection of the public (d) Methods to protect surrounding buildings from the danger of collapse. (e) Electric power to all services within the structures should be shut off. Similarly all) (f) Gas, water and steam service lines should be shut off. (g) The structure to be demolish should be adequately fenced and cordoned off (h) Display boards to be displayed prominently warning the public of the danger. (i) Glass in doors and windows, loose objects and projecting parts to be removed. SAFETY MEASURES IN DEMOLITION OF THE BUILDINGS: 1. Workers should not be deployed at different levels unless adequate precautions are taken to ensure safety of them 2. Demolition work should begin at the top of the structure and proceed downwards. . 3. Masonry concrete and other dismantled materials should not be allowed to accumulate in quantities which may endanger the stability of any floor or structural support. 4. Part of the structures, where necessary should be adequately shored, braced or otherwise supported. 5. If the structure is to be demolished by explosives, all safety measures pertaining to explosives such as transport, storage, handling, loading firing etc. should be strictly adhered to. 6. Foundation walls serving as retaining walls to support of adjoining structures should not be demolish until the adjoining structure have been under pinned or braced or earth supported by sheet pilling. 7. Stairs with hand railing should be kept in place as long as practicable to provide access and egress. 8. If the work of demolition is continued in night, all passageways, stairs and other parts of the structure where the workers have to pass and also to work should be adequately lit. 9. Workers should wear strictly safety belts, safety belts, safety helmets and hand glove. 10.If the demolition is carried out by machines such as power shovels, bulldozers etc. the safety measures relevant to operation and use of such machines should be adhered to. 11.If swinging weight such as ball is used for demolition, a safety zone having a width of at least 1.50 times the height of the building or structure should be maintained. 12.Scaffolds used for demolition operations should be independent of the structure to be demolished. 13.If ladders are used for demolition, only travelling mechanical ladders should be used. 14.The hoists or chutes, whenever it is practicable, should be used to lower the materials. Materials chutes should have a gate at the bottom with suitable means for regulating the flow of materials. Safety measures in demolition of structural steel works: 1. The steel structures should be demolished from top tier by tier. 2. Removing the various members of the steel structures should be done in a planned manner. 3. All precautions should be taken to prevent danger from any sudden twist, spring or collapse of steel parts/work when it is cut or released. 4. Structural steel parts should be carefully lowered and not dropped from a height. 5.Safety precautions of gas cutting of the steel members should be adhered to. Safety measures in demolition of tall chimneys, minars, pylons etc. 1. Tall chimneys, minars, pylons, etc., should not be demolished by overturning or blasting unless a protected area of an adequate dimension in which the chimney or the structure can fall safely.. 2. If the demolition of the tall structures are done by , blasting with explosives, it should be done with the services of specialized engineers . The entire operation should be under his supervision and control. Safety measures in demolition of Industrial Structures: 1. The Safety measures in removing heavy and bulky machinery, plant and equipment should be observed in addition to some of the relevant safety measures already stated. 2. If the industrial Structure such as a nuclear power station the services of the specialist expert in the field of radio-activity and radiation should be utilized.