UNIT 14 GROUND WATER PROBLEMS AND CONSTRUCTION TECHNIQUES

Structure

14.1 INTRODUCTION

Ground water is usually regarded as one of the major problems in excavation work. Heavy and continuous pumping is required from excavations to dewater the area and the continual flow from the surrounding ground may cause settlement of adjacent structures. Heavy inflow of water is liable to cause erosion or collapse of the sides of open excavations. In certain situations, there can be instability of the base due to upward seepage towards the pumping sump. However, through the knowledge of the soil strata, the ground water conditions and an understanding of the laws of hydraulic flow, it is possible to adopt methods of ground water control. This ensures a safe and economical construction. In this unit several such methods have been discussed which encompass deep excavation in water-logged soils, ground water flow reduction by grouting, sheet piling and diaphragm wall construction.

Objectives

At the end of this unit, you should be able to :

* describe methods of ground water control,
* discriminate between different methods of grouting,
* distinguish between single sheet and double sheet pile construction, and
* describe the diaphragm wall construction.

14.2 DEEP EXCAVATION IN WATER-LOGGED SOILS

It is essential that all the necessary information about the water-logged soil is available at the site investigation stage where deep excavations in particular are involved. This enables the executive to adopt the correct method of ground water control. The methods which can be used are :

a) Pumping from Open Sumps

b) Pumping from Well Points

c) Pumping from Bored Wells

d) Ground dewatering by Electro-osmosis

The choice of the method depends greatly on site conditions and soil characteristic like particle size distribution of the soil. Let us now examine these methods one by one.

14.2.1 Open Sump Method

This method is the most widely used method of ground water lowering. It can be used in most soil and rock conditions and the installation and maintenance costs are comparatively low.

This method essentially consists of providing a sump below the general level of the excavations at one or more corners or sides. A small ditch is cut around the bottom of the excavation, with its slope towards the sump. In large excavations which have to remain open for a longtime, special attention should be paid to the design of these drainage ditches. The ditches should be sufficiently wide to keep the velocity of ground water low enough so as to prevent erosion. Additional safeguards against erosion can be in the form of check weirs, stone or concrete paving or by laying open - jointed pipes surrounded by graded stone or graded filter material. If the ground water is present in a permeable stratum overlying a clay stratum and the excavation is to be taken down into clay, then it is preferable to have the pumping sump at the base of the permeable stratum. This type of drain is called Garland Drain. This practice reduces the pumping head and avoids softening of the clay at the base of the excavation. Some typical details of a garland drain for (a) open excavation over a timbered excavation (b) a wholly timbered excavation and (c) in rock excavation are shown in Figure 14.1.

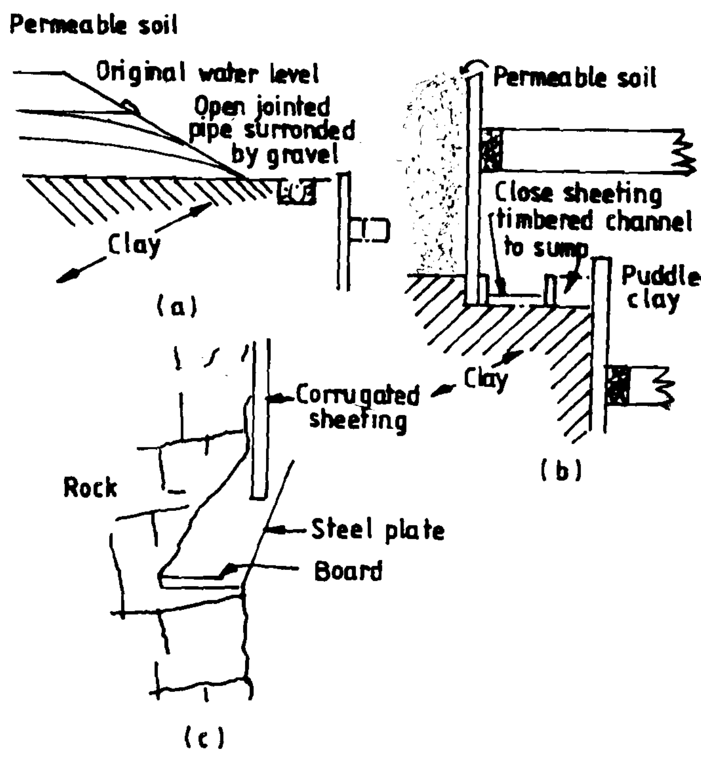


Figure 14.1 : Types of Garland Drain

Depending upon the type and efficiency of the pump, the greatest depth to which the water table may be lowered by the open sump method is not much more than 8 metres below the pump. For deeper excavation it is necessary to reinstall the pump at a lower level or to use a submersible deep well pump suspended by chains and lowered into timbered shaft or perforated tube.

Gravel filter material can be packed behind the timbers of the shaft if excessive fine material is washed through. This method ensures dry working conditions for the subsequent bulk excavation and it also provides an exploratory shaft for obtaining information on ground conditions to supplement that obtained from borings.

And now a few words about the "Pumping Plant". If you consider that flooding of the excavation can cause damage to partly constructed works or where pumps have been installed below ground water level, it is important to provide standby pumping plant of a capacity at least 100 per cent of the steady pumping rate. You will often notice that the pumping capacity required to lower the ground water is greater than the capacity required to hold it down at a steady rate of pumping depending upon the time allowed in the construction programme. Further, if the main pumps are electrically driven, it is advantageous to have the standby pumps driven by diesel or steam engines in case of failure of main electric supply. The common type of pump is a self contained pump and electrically driven motor unit capable of working below water and discharging through a flexible armoured hose upto ground surface. The open sump method suffers from the disadvantage that the ground water flows toward the excavation. If the head is high or steep slopes are there, there is a risk of collapse of the sides.

14.2.2 Well Point System

This system comprises installation of a number of filter wells, usually 1 metre long around the excavation. These are connected by vertical riser pipes to a header main at ground level which is under vacuum from a pumping unit. The ground water flows by gravity to the filter well and is drawn up by the vacuum to the header main and is discharged through the pump. The filter wells or well points (Figure 14.2) usually consist of a 1 m long and 60 to 75 mm diameter gauze screen surrounding a central riser pipe. Where well points are required to remain in the ground for a long time like in drydock excavation, then it may be economical to use disposable plastic well points. This type of well point consists a nylon mesh screen wrapped around a flexible plastic riser pipe. The well points are installed by jetting them into the ground, when the jetting water flows freely from the serrated nozzle. The discharge capacity of a single well point with a 50 mm riser is about 10 litres per minute. In fine to coarse sands or sandy gravels a spacing of 0.75 to 1 m is satisfactory, but in silty sands of fairly low permeability a 1.5 m spacing will be satisfactory. However, in permeable coarse gravels, the spacing could be just 30 centimetres. Normally, a set of well point system equipment, comprises 50 to 60 well points to a single 150 or 200 mm pump with a separate 100 mm jetting pump. The well point pump has an air / water separator, a vacuum pump as well as the conventional centrifugal pump.

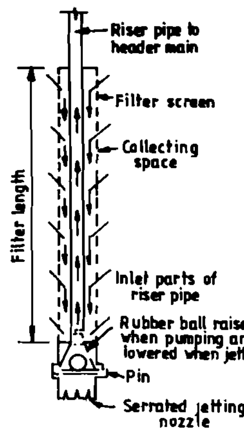


Figure 14.2 : Diagrammatic Arrangement of a Wellpoint

Systems

Normally, well points are installed in the "progressive" or "ring" systems. The "**Progressive system**" is used for excavation of trenches. The header is laid out along the sides of the excavation and pumping is continuously in progress in one length as further well points are jetted ahead of the pumped down section and pulled up from the completed and back filled lengths. One such system is shown in Figure 14.3.

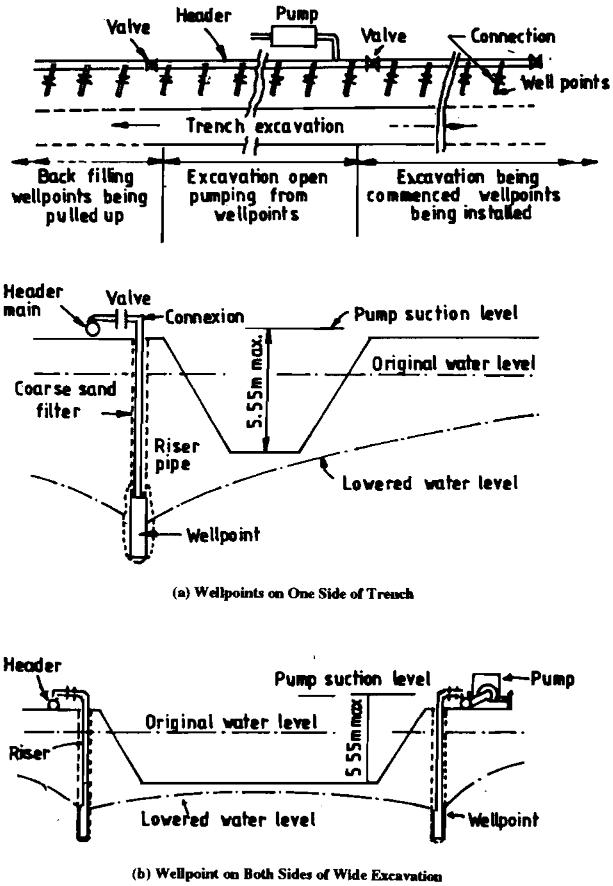
In the "**Ring System**" the header main surrounds the excavation completely and is useful for rectangular excavations like piers or basements. One such system is shown Figure 14.4.

If deeper excavation, that is more than 5 to 5.5 metre below standing water is required then a second or successive stages of well points must be installed. There is no limit to the depth of drawdown in this system, but the overall width of excavation at ground level becomes very large.

14.2.3 Bored Well System

In this system pumping from wells can be undertaken by surface pumps with their suction pipes installed in bored wells. The depth of drawdown by this method is not more than 8 metres generally. The main uses of pumping from bored wells are when a great depth of water lowering is required or where an artesian head must be lowered in permeable strata at a considerable depth below the excavation level. The cost of deep well system being high it is generally restricted to jobs which have long construction periods such as dry docks or access shafts for long sub-aqueous tunnels.

The basic procedure consists of first sinking a cased borehole having a diameter of about 200 to 300 mm larger than the inner well casing. After completion of the borehole, inner well casing is inserted, which has perforated screen over the length where dewatering of the soil is required. It terminates in a 3 to 5 metre length of unperforated pipe to act as a sump to collect any fine material which may be drawn through the filter mesh. After the well casing is installed, graded gravel filter material is placed between it and the outer borehole casing over the length to be dewatered. The outer casing is withdrawn in stages as the filter



(a) Wellpoints on One Side of Trench

(b) Wellpoint on Both Sides of Wide Excavation

Figure 14.3 : Single-stage Wellpoint Installation by the Progressive System

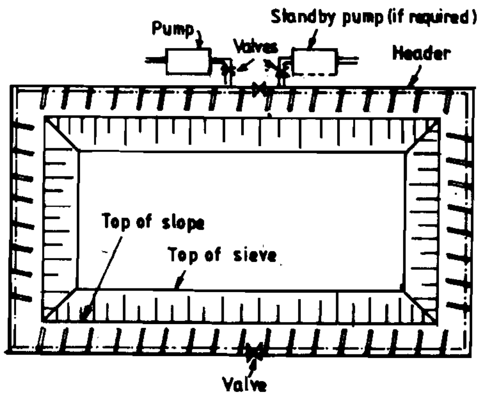


Figure 14.4 : Single-stage Wellpoint Installation by the Ring System

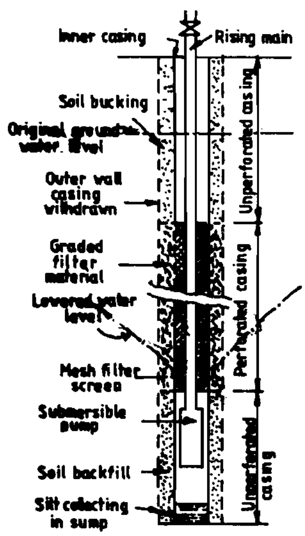


Figure 14.5 : Bored Well Installation

material is placed. The remaining space above the screen is filled with any available material. The water in the well is then surged by a boring tool to promote flow through filter. Now, the submersible pump is installed. The complete installation is shown in Figure 14.5.

Bored wells can be spaced at much larger intervals than well points, since the pumps can be installed at greater depths below excavation level, thus giving a wide area of draw down for each well. However the spacing of the wells should not be so far apart that shutting an individual well for repairs to the pump, may cause the water level to rise above the excavation level. A typical spacing of Bored Wells is shown in Figure 14.6.

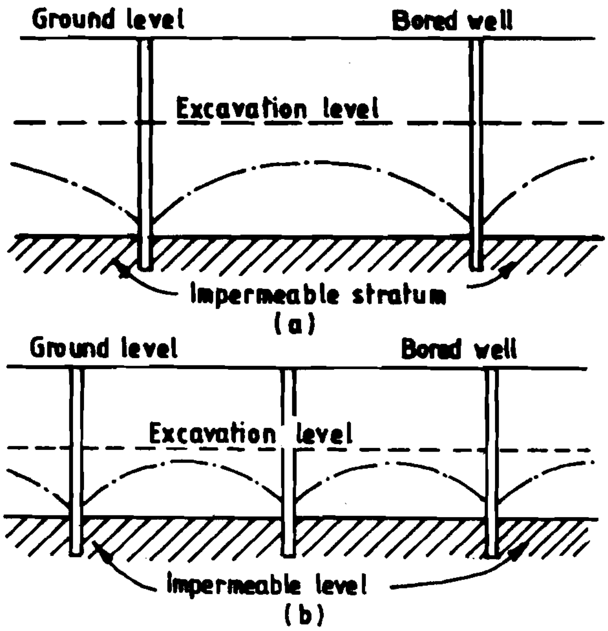


Figure 14.6 : Spacing of Bored Wells

14.2.4 Ground Dewatering by Electro-Osmosis

The methods described under 14.2.1, 14.2.2 and 14.2.3 are mainly used for gravel and sandy soils, i.e. for highly permeable soils. But if soils of finer particle size like silts and clays are encountered then electro-osmosis system could be used effectively. In the electro-osmosis system direct current is made to flow from anodes (which are steel rods driven into the soil) to filter well which form cathodes. The positively charged particles of water flow through the pores in the soil and collect at the filter well (cathodes) from where they are pumped to the surface. A typical layout is shown in Figure 14.7.

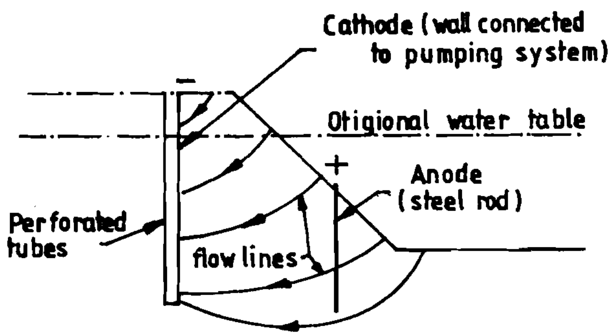


Figure 14.7 : Electro-Osmosis Installation

Generally electro-osmosis is used only when other methods have failed. Its main drawback is its high installation and initial running costs. However the power consumption and hence the running costs decrease considerably after the ground gets stabilized.

14.3 GROUND WATER FLOW REDUCTION BY GROUTING

In highly permeable soils, well pointing or bored wells may need to be of very high pumping capacity to be effective, and therefore become costly. In such situations, other solutions are required for control of ground water. One such solution is to reduce permeability of soil by injecting fine suspensions or fluids into the pore spaces, cavities or fissures existing in the soil strata or rock. Such a process is called grouting. We will discuss three types of grouting namely cement grouting, clay grouting and chemical grouting.

14.3.1 Cement Grouting

The cement grouting is suitable in situations where strengthening is required in addition to reduction in the permeability of soil or rock strata. The effectiveness of cement grouting increases if the soil has a very coarse grading. This grouting is generally ineffective in sands, except for its consolidating or compacting effort achieved by injecting at close intervals. In coarse materials or rocks the excavation is surrounded by a "grout - curtain" consisting of two rows of primary injection holes spaced at 2.5 m to 5 m centre to centre in both directions, with secondary holes spread between them as shown in Figure 14.8.

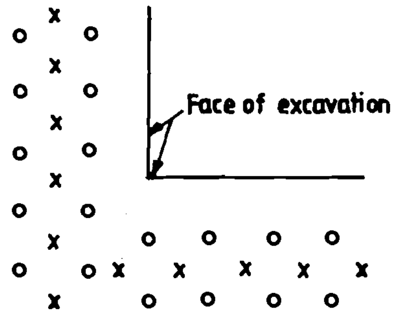


Figure 14.8 : Layout Plan of Grout Injection Holes to Form 'Grout Curtain' Around Excavation. 0, Primary Injection Holes; *x*, Secondary Injection Holes.

Cement grouting has been used for excavation of foundation, one such case being extension to the North Point Generating Station at Hong Kong. Here in order to avoid pumping large quantities of water from the shafts, a cement grout curtain was formed. A single row of 9 metre deep holes was drilled at 3.7 metres centres to form the curtain. In all 150 tons of cement was used. In order to economize, a sanded grout consisting of three parts of cement to one part of sand was used. The effectiveness of this cement grouting can be judged from the fact that only two 150 mm pumps were required to dewater the shafts nearest to the harbour.

14.3.2 Clay Grouting

In situations where soil grading is too fine for cement grouting or in gravels where no strengthening is required, the grouting has been done by injecting bituminous emulsion or clay or bentonite slurries. Sometimes chemicals are added to aid dispersion and suspension of these grouting materials. Chemically-treated bentonite clay slurry grouting has been used extensively for creating impermeable cut-offs in alluvial strata beneath dam foundations and to create impermeable curtains around excavations in water-bearing alluvial strata. The underlying principle is to use bentonite clay in combination with cement, soluble silicates and other agents in varying proportions, so as to produce a grout which can suit the ground requirements. First, the larger voids are filled with clay-cement grout and then clay-chemical grouting is done to fill the spaces in the finer materials.

14.3.3 Chemical Grouting

The chemical grouting is suitable for sandy gravels and all types of sands except the finest gradings. The most commonly used chemical is "Sodium Silicate", which in conjunction with other chemicals forms a fairly hard and insoluble silica-gel.

In the 'Two-shot' process, pipes are driven into the ground at about half metre spacing. Calcium chloride and Sodium silicate are injected into first and second pipe respectively as the pipes are slowly withdrawn in stages.

The 'Two-shot' process has been generally superseded by the 'one-shot' technique in which all chemicals are mixed together just before injecting them. The grout is formulated such that the gel formation is delayed for sufficient time to allow for complete penetration of the ground.

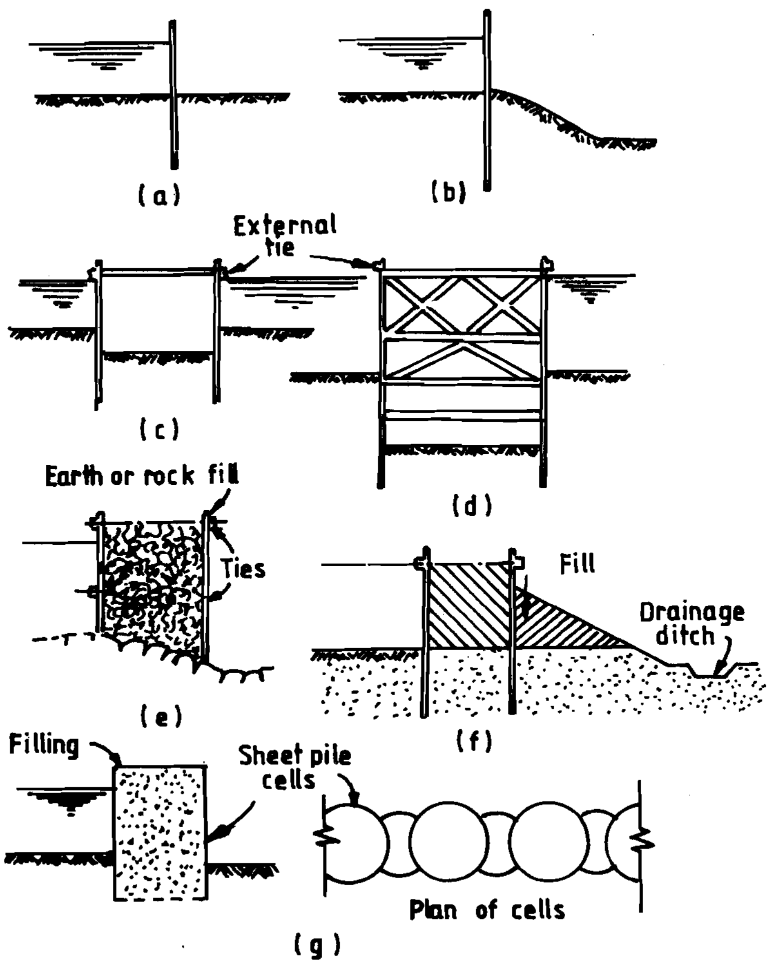
There are other chemical processes which are based on 'One-shot' principle in which the aim is to obtain a very low viscosity at the time of injection with a gradual and slow increase in viscosity until gel formation occurs. This ensures maximum penetration. These chemicals include acrylic polymers, resins and lignins. Chemical grouting has several applications in underpinning work.

Comparison of Grouting Methods

Complete cut-off of ground water by chemical grouting or clay injection can only be obtained by repeated injections at close spacing over a considerable width of treated ground. The process works out to be very costly and generally a 80 to 95 per cent cut off is considered sufficient. Clay grouting is considered cheaper than cement grouting particularly if locally excavated clay can be used. Whereas, chemical grouting such as resin and acrylic polymer grouting may be 10 to 20 times as costly compared to cement grouting per cubic metre of treated ground.

14.4 SHEET PILING

Steel sheet piling driven by drop hammer or double acting hammer enables much deeper settings. Particularly in favourable ground conditions, sheet piles can be driven as much as 15 metres ahead of the excavation. The use of sheet piles also permits a much wider spacing of bracing frames. Steel sheet piling is widely used for cofferdams, because of its structural strength, the watertightness given by its interlocking sections and its ability for deep penetration. Various types of sheet piles cofferdams are shown in Figure 14.9.



(a) Single Wall (b) Single Wall with Earth Bank (c) With Single Top Frame
(d) With Multiple Frames (e) Double Wall (f) Double Wall on Permeable Soil (g) Cellular

Figure 14.9 : Types of Sheet Pile Cofferdam

14.4.1 Single Wall Sheet Pile Cofferdams

For low heads of water and shallow excavations, the cofferdam can consist of a single wall which is self supporting by the cantilever action of the piling. Single wall construction can also be used where it is possible to strut across the excavation. Higher heads can be withstood if a bank of earth is left on the inside face. For low heads, a single top frame can be used; but for high heads or deep land cofferdams it becomes necessary to provide multiple frames.

Sheet piles should be driven through guides to ensure verticality in pitching piles. In the case of land cofferdams the guides are provided by a lower pair of guide wailings at ground level and an upper pair at the highest level permitted by the position of hammer on completion of the first stage of driving. These guide wailings are supported at one end by bolts through the partly driven piling and by cross members at the other end (Figure 14.10). Where sheet piles are driven by a frame, there it is sufficient to provide guide wailings at the lower level. The upper part of the piles is kept in the vertical position by a toggle bolt passing through the leaders of the pile frame.

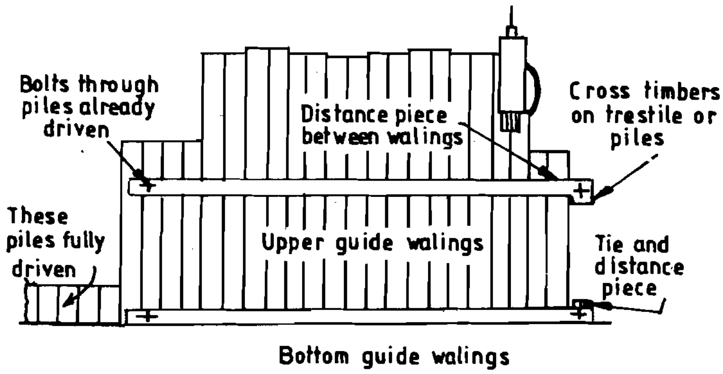


Figure 14.10 : Guide Wallings for Driving Sheet Piles

Piles are usually driven in pairs. Sheet piles may be driven by drop hammer or single acting hammer. Double acting hammers are generally preferred for speed and efficiency. It also functions well in most ground conditions, particularly in sandy and gravelly soils. On the other hand single acting hammers are preferable for driving in heavy clays.

It is also important to protect the heads of the sheet piles during driving. For driving with single-acting or drop hammer, a single or double cast steel driving cap can be used together with a hardwood or plastic dolly. A double anvil block is supplied with double acting hammers for driving piles singly or in pairs. Long length of sheet piles are driven in "two stages". In the first stage the piles are pitched by long jib derrick or crawler crane and driven partly by a light or medium weight hammer. In the second stage, a heavy hammer, suspended from a truck mounted crane is used to complete the driving. Another method to accomplish two-stage driving is with two pile frames, one of which is tall and light while the second is short and sturdy. A typical "two-stage" pile driving is shown in Figure 14.11.

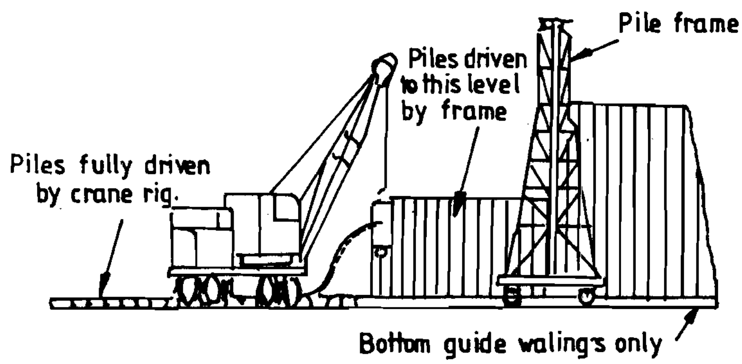


Figure 14.11 : Typical Two-stage Pile Driving

14.4.2 Double Wall Sheet Pile Cofferdams

The Double-wall sheet pile cofferdams are basically free standing walls which are used for broad excavations, where cross-bracing is uneconomical. Double wall sheet pile cofferdams consist of two lines of steel sheet piling driven into the ground and tied together at the top by wailings and tie bolts. The space between the piling is filled with sand, gravel, crushed rock or broken brick bats. The depth of penetration is decided by the pressure exerted by the filling and by the need to prevent horizontal sliding. Where cofferdams are constructed on permeable soils, the depth of penetration is also governed by considerations of piping. In case double wall sheet pile cofferdams are constructed on unstable soils, it is necessary to excavate the space between the sheet piles to remove soft material before placing the filling material.

SAQ 1

a) What methods are available for ground water control ?

b) What generally is the spacing of well points in different soils ?

c) What are the main disadvantages of dewatering by Electro-osmosis method ?

d) In which situations you would prefer cement grouting ?

e) What is "Two Stage" sheet pile driving system ?

14.5 DIAPHRAGM WALL CONSTRUCTION

Construction of diaphragm walls is an advanced development on construction of contiguous (touching) bored piles. Bored piles are being constructed in India from 1950 onwards basically by using casings. However, in 1965, sodium based bentonite with liquid limit more than 300 was used in construction of bored piles. Thus, casinge were eliminated, except provision of a guide casing on the top and it was possible to construct piles of larger diameter. One of the first major projects where large diameter (1 m) bored piles, drilled using bentonite slurry, were used in India, was Fertilizer Berth at Visakhapatnam. The maximum length of the pile constructed here was around 58 m.

In case of contiguous bored pile walls, the piles are cast touching each other to form a continuous wall. However, in case of diaphragm wall construction, the length of each diaphragm panel is kept at least about 3.5 m with the result the vertical joints between two consecutive panels are reduced.

Diaphragm walls have been used very extensively in this country and some of the major applications are as follows :

1) Basement of multistoreyed buildings.
2) Cutoff wall for dams.
3) For underground structures, such as pump houses, atomic reactor foundations etc.
4) For marine structures, such as wharves, wet basins.
5) Underground railway project, especially at Calcutta.
6) Miscellaneous applications, such as bridge foundation, load bearing walls as piles and for closing gaps between adjacent monoliths.

14.5.1 Equipment

Equipment used on site for the construction of diaphragm wall can be grouped/listed as below :

Excavation equipment

For excavation of 17 m deep panels, mechanical grab is used. Mechanical grab is mounted on a pulley with four legs and again legs are mounted on a platform. This platform moves on rails with a prime mover. On this platform, double drum winch is mounted. One cable of double drum winch is used to take loads up and down and other cable is used to open and close the mechanical grab for excavation of soil. This whole equipment is called special tripod. Mechanical grab cuts the earth and the bored muck is unloaded in tipping wagon. Tipping wagon moves on rails and pulled/pushed manually. The bored muck is dumped at a distance with the help of tipping wagon, to keep the site clear of muck. Chiesel is also used to cut any hard strata.

14.5.2 Bentonite Slurry Installation

For preparing bentonite slurry, sodium based bentonite powder is mixed in fresh water. Mixing installation consists of a steel tank, a powerful pump which runs with 20 HP Electric motor, a funnel and a venturi tube. Bentonite powder is added in funnel and it mixes with water at venturi tube and goes to steel tank at bottom. From top of the tank, the slurry is recirculated by the pump till the time the gel like solution is formed and it is then allowed to swell for 24 hrs. From the steel tank, the arrangement of valves and pipes is made in such a way that the bentonite slurry is either taken to storage tanks or to the trench/pit, the diaphragm wall. Arrangement of vertical pumps, pipes and valves is also made in such a way, that bentonite slurry can be circulated either to trench/pit from the storage tank or vice-versa.

14.5.3 Concreting Installation

One non-tilting type concrete mixer which can give 5 cu.m./hr. concrete of M-20 grade is installed on site. Electric motor is mounted to drive this mixer. Fresh concrete is carried by a dumper to the funnel. Funnel is screwed on the tremie pipe of 20 cm internal diameter. This funnel and tremie pipe can be moved up and down with the help of special tripod. Tremie pipes are of various sizes 1.5 to 1.8 m long joined together which can be made to any length. A stop plate which fits on the opening of tremie pipe at funnel junction is also provided and is used while the first batch of concrete is to be poured in the excavated pit. This plate does not allow the concrete to be contaminated with bentonite slurry present in the tremie pipe. When the funnel is full with concrete, stop plate is removed which is tied to a wire, and thus concrete rushes in the pipe and bentonite slurry is removed from the pipe.

14.5.4 Miscellaneous Equipment

Following are the other equipments which may be used on site :

a) Electric welding set.

b) Gas cutter (Oxy-acetelene).

c) Water pumps.

d) Sounding chain for measurement of depth of pit.

e) Chiesel in case any unforeseen hard strata is encountered during excavation of pit.

f) Marsh cone for checking viscosity of bentonite slurry.

g) Hydrometer for checking density of bentonite slurry.

14.5.5 Materials

a) Bentonite Slurry

Sodium based bentonite powder which is pulverised, is used for preparation of bentonite slurry. Its liquid limit should be less than 300%. Density of slurry should be 1.05 to 1.12 depending upon site conditions. Viscosity as tested by Marsh-cone should be approximately 35 seconds. Generally 50 to 60 kg. of bentonite per cubic meter of theoretical based volume is found adequate. Records may be kept of day to day consumption of bentonite. Bentonite slurry gives a gel like solution. It does not allow the ground water to rush in the excavated pit and prevents side cavings of the pit.

b) Concrete M 20

M 20 concrete is generally used for concreting of diaphragm wall. Crushed 10 mm and 20 mm stone is used as coarse aggregates. Fine aggregate used is coarse sand. Sulphate resistant cement (SRC) may be used if sulphates are present in the sub-soil. Fineness Modulas of sand is between 2.2 to 3.2. From Inspection and Quality Control Division, an officer should be detailed to have a check on the quality of material and method of operation. Tor steel may be used as reinforcement.

14.5.6 Methods of Construction

a) Construction of Pre-trench

RCC pre-trench/guide wall of depth 1.0 M to 1.5 M maybe constructed. Pre-trench is marked and aligned accurately on the plan layout of diaphragm wall. Pre-trench consists of a wall on either side of diaphragm wall. If the diaphragm wall is 60 cm. thick, then the space in-between two walls of pre-trench is kept 70 cm. Basic function of pre-trench is to guide the tools of excavation in its required position. The top of pre-trench level is atleast 1.5 M above the water level or cut-off level of diaphragm wall, whichever is higher. M-10 concrete can be used for construction of pre-trench and nominal reinforcement is generally provided.

b) Boring Operation

Before commencement of boring, bentonite slurry in sufficient quantity is kept ready. The pre-trench is kept full with bentonite slurry. The level of bentonite slurry is kept atleast 1.5 M above the groundwater table. Before commencement of boring, lengths of the panels will be properly demarcated on the pre-trench wall. Panel boring is done by mechanical grab mounted on special tripod. During boring operations, bentonite slurry is added as and when required to maintain the level of bentonite slurry. Mechanical grab mounted on special tripod is positioned on the pre-trench markings and the excavation is started. Bored muck is dumped by grab on tipping wagons and removed to the dumping site. Boring in this manner is carried out upto the required founding level for the entire panel. The depth of the trench is determined by soundings. Before removing the equipment, the bottom of the trench is cleaned by grab. The length of diaphragm wall panel is 1.5 to 2.0 M in most of the panels. Alternate panels can be constructed as primary panels. After two primary panels on both sides have been constructed, secondary panel may be constructed after chieselling through the ends of the primary panels already constructed. One panel of 2.0 M length and 17.0 M deep takes around 26 hrs. for boring.

Reinforcement

Reinforcement particularly is very heavy. Using special tripod available on site for lowering the reinforcement in the trench, the reinforcement is divided in two parts; called upper cage and lower cage. By the time the boring of panel is completed, the reinforcement should be ready for lowering into the excavated panel. To facilitate lifting and lowering of two parts of reinforcement cages, lapping of reinforcement bars for upper and lower cages needs to be done. The laps are staggered effectively. First the lower cage is lifted and lowered into the bored trench and is kept supported on the pre-trench. Then the upper cage is lifted and aligned on to the lower cage. Individual bars are aligned, lapped and welded to other. Overlapping point is provided at a section where B.M. is zero or very small. The reinforcement being very heavy, the bars are welded to each other in order to keep the cage of reinforcement in its shape and position while handling and lowering. Insert plates are welded on the reinforcement as per drawing.

Dowels are to be provided on the main reinforcement. Dowel bars are kept folded in the reinforcement and are to be taken out of diaphragm wall face and to be strightened during construction of other components. Steel plates welded on both sides of reinforcement are called liners. The main function of liners is to provide an effective key between primary and secondary panels. Thus the male and female joint is provided by these liner plates between the adjacent panels. Width of liner plate is 70 cm. This 5 cm extra width of liner on both corners, goes into the soil and does not allow the concrete to overflow into the sides.

Care should be taken to see that tremie pipe lowered in the reinforcement cage for concreting, has sufficient space for its movement. The bars are arranged in such a way that they do not come in contact of tremie pipe.

d) Concreting

Once the reinforcement is lowered and positioned into the trench, tremie pipe is lowered into the reinforcement cage. Through this tremie pipe, bentonite slurry is flushed so that the bottom of trench is cleaned of the soil which has caved in during the process of lowering of reinforcement. After this, funnel to receive concrete is replaced on top of tremie pipe assembly. A steel circular plate, called stopper is put on top of tremie pipe or bottom of funnel. This stopper is tied with a steel wire. Concrete of M-20 grade is carried from concrete mixer to the funnel in the dumper. Once sufficient quantity of concrete is added in the funnel, stopper is removed and the concrete is rushed through the tremie pipe. This way, the bentonite slurry present in the tremie is replaced by the concrete and the tremie is free from bentonite slurry. Concrete used may have the slump of 150 mm. With this slump, concrete spreads in the trench at its own. Subsequent batches of concrete are poured. The tremie is kept atleast 1.5 m to 2.0 m inside the concrete. As the concrete is built up in the trench, tremie pipe is removed and the length of tremie is reduced. First batch of concrete, which has got contaminated with bentonite slurry is brought up above the cut-off level of the diaphragm wall. Subsequent batches of concrete are free from bentonite. Care is to be taken that proper slump of concrete is to be maintained throughout.

Alternate panel construction technique is followed here. Liner plate on sides of reinforcement of primary panels is concave in shape. So for the boring of secondary panels, the grab will be modified in such a way that the panel joints are free from any earth. After two primary panels on both sides have been concreted, secondary panel filled with bentonite slurry, should not be left as such for a very long time. After boring, reinforcement is lowered and concreting is to be started. Sulphate Resistant Cement is used here. To safeguard against any leakage of water through diaphragm wall, a water proofing coarse and protective wall may be constructed, on inside face of diaphragm wall.

e) **Circulation of Bentonite Slurry**

During the process of boring, bentonite slurry is added in the trench to maintain the required level of slurry. Whereas during concreting bentonite slurry is replaced by concrete and the excess quantity of bentonite is taken to the storage tanks. Before start of concreting, the bottom of trench is to be flushed with bentonite slurry. With this continuous process of circulation/use of bentonite slurry, some quantity of slurry is reduced. At intervals, fresh quantity of bentonite slurry is added in the circulation system. Care is to be taken that the required properties of bentonite slurry (i.e.) viscosity, liquid limit and density are maintained throughout the use of the slurry. Clay/soil mixed with slurry settles down in storage tanks and the tanks are cleaned at intervals of this clay/soil. From the storage tanks, clear bentonite is removed and the sediments are removed. Bentonite slurry should be circulated atleast at intervals of 8 to 10 hours to maintain its properties.

14.5.7 Precautions

a) Reinforcement is to be welded properly otherwise cage may collapse during lifting.

b) While boring secondary panel, joints should be free from any earth. Grab is to be suitably modified.

c) After lowering of reinforcement in the trench the depth of trench is to be checked with soundings. The liners cut the earth and generally half a meter of trench is filled with caved earth.

d) Before start of concreting, flushing of trench bottom with bentonite slurry is to be resorted to atleast for half an hour, so that the caved in soil is flushed out of the trench.

e) Role of Inspection & Quality Control Division is very important. They have to keep a sharp eye on each and every activity of construction. Diaphragm wall, being an important structure, need of quality cannot be overruled. Checking of cubes strength, sieve analysis of aggregates, slump, proper arrangement of reinforcement bars as per drawing, properties of bentonite slurry etc. are to be counter-checked by Inspection Division.

14.6 SUMMARY

Excavation in water-logged soils is possible by use of several methods which depend upon site conditions and soil characteristics. Prominent methods are open sump, well point system, bored well system and Electro-osmosis. However in highly permeable soils other solutions may have to be employed like grouting which involves injection of fine suspensions or fluids into soil pore spaces. Some methods are cement, clay and chemical grouting. Steel sheet piling is used widely for cofferdams. Various configurations can be employed, two of them being single wall sheet pile and double wall sheet pile cofferdams.

Diaphragm wall construction is an advanced development on construction of contiguous bored piles and is now being widely used in India in basements, dams, pump houses, marine structures, underground rail projects, etc.

14.7 KEY WORDS

Anode	:	positive electrode
Cathode	:	negative electrode
Grouting	:	Injecting fine suspensions or fluids into the pore spaces
Slurry	:	Thick viscous liquids

14.8 ANSWERS TO SAQs

SAQ 1

a) i) Pumping from open sumps
   ii) Pumping from Well Points
   iii) Pumping from Bored Wells
   iv) Ground dewatering by Electro-osmosis

b) Fine to coarse sands or sandy gravels = 0.75 to 1 metre

   Silty sands of fairly low permeability = 1.5 metres

   Permeable coarse gravels = 0.30 metres

c) The main drawback is its high installation and initial running costs.

d) The cement grouting is suitable in situations where strengthening is required in addition to reduction in the permeability of soil. Its effectiveness increases if the soil has a very coarse grading.

e) In "two-stage" system, in the first stage piles are pitched by long jib derrick or crawler crane and driven partly by a light or medium weight hammer. In second stage a heavy hammer is used to complete the driving.