INSTALLATION OF DRILLED PIERS

By
Dawn C. Tattle,
Anchor Shoring & Caissons Ltd., Toronto

1 INTRODUCTION

A drilled pier is commonly referred to as a caisson or drilled shaft. Shafts typically range in diameter from 30″ (750 mm) up to 120″ (3040 mm). Caissons may be reinforced or unreinforced depending on the loading conditions. After cleaning and inspection the shaft is filled with concrete.

2 CAISSON TYPES

2.1 Straight Shaft Caissons

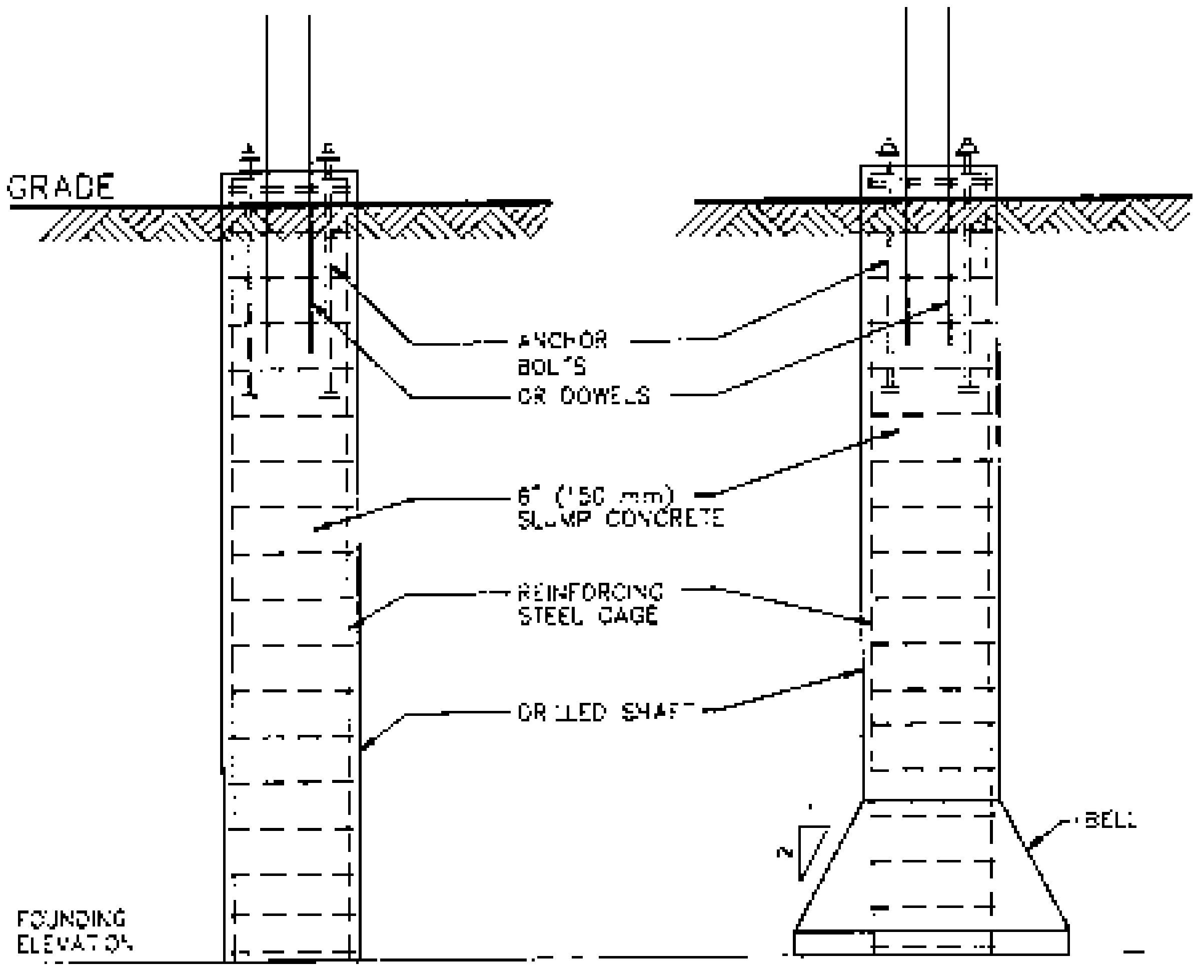
The caisson shaft is cylindrical in shape (figure 1). The hole is drilled to a suitable bearing stratum or to a length as required to develop sufficient skin friction along the sides of the hole.

Drilling for caissons is normally done with an auger (figure 3). There is a cutting edge at the base of the auger. As the auger is turned the cutting edge breaks the soil and the drill spoil travels up the auger flights. After the soil fills the flights the auger is removed from the hole and is emptied by spinning. Auger design and construction varies depending on the drilling conditions it is to be used for.

Core barrels are used when it is necessary to penetrate through concrete, hard layers of rock, or obstructions. The core barrel is a cylindrical tube with hard metal teeth welded along the bottom of the tool (figure 4). As the core barrel is turned the teeth cut evenly to penetrate the layer.

It is not possible to describe all the tooling available as contractors may develop or modify tools to suit a particular task or soils condition.

The tooling for caissons is typically based on 6″ (150 mm) increments. This size restriction should be considered during the design stage, as alternate sizes are not readily available.



TYPICAL STRAIGHT SHAFT CAISSON

FIGURE 1

TYPICAL BELLED CAISSON

FIGURE 2

Figure 3: Worker Changing Teeth on Auger

Figure 4: Corebarrel

The base of end bearing caissons should be cleaned of loose material using a mechanical tool such as a twist bucket. This tool resembles a steel bucket with a blade at the base. The tool is lowered to the base of the caisson with the drill rig. When the twist bucket is turned the blade of the tool scrapes the loose soil off the caisson base and into a slot in the bucket.

Hand cleaning of caisson bases is often specified in cases where the design is based on high end bearing values. Handcleaning requires that a worker be lowered into the caisson. The minimum diameter for handcleaning of caissons is 30” (750mm). Smaller sizes can be specified for auger cleaned caissons.

If handcleaning of a caisson is required a temporary steel safety liner must be installed in the shaft prior to lowering a worker into the caisson. The caisson must also be tested for the presence of toxic, explosive and combustible gases. It is important that both the inspectors and workers are aware of the potential hazards associated with caisson entry and ensure that these tests are completed. If these gases are detected no person shall be lowered into the caisson for cleaning or inspection.

2.2 Belled Caissons

In cohesive soils the shaft bottom can be enlarged by a process known as belling (figure 2). The bell is constructed after the straight shaft portion of the caisson has been drilled to the required founding elevation. A mechanical belling tool is attached to the base of the drill rig Kelly bar (figure 6). The wings of the tool are forced open as the bar of the drill rig is turned. This process forms the bell. When the belling tool is extracted from the hole the wings retract which traps the excavated soil inside (figure 5). Belling results in a substantial increase in bearing capacity while minimizing the quantity of concrete required for the caisson. The potential concrete savings are more significant in caissons with long shafts.

Before specifying belling it is important to study the soil conditions in the area of the belled portion of the caisson. It is not possible to line the belled portion of the caisson against caving. Therefore, this type of caisson is susceptible to caving especially in ground containing wet sand or silt layers either above or within the belled portions of the shaft. Bells should not be specified in these soil conditions. Specifying a small differential between the bell and shaft diameters can minimize the impact of wet layers on belling.

Normally it is necessary to handclean belled caissons which have been designed for end bearing. Prior to lowering a worker into the caisson to clean the base a safety liner is installed to the top of the bell. However, it is necessary for the worker to work beyond the limits of the liner to clean the unlined portions of the bell. This operation increases the length of time that a bell must stand open before concrete can be poured. The safety of the worker is paramount when making a decision regarding whether belling should be attempted. If there is any doubt regarding the stability of a bell a straight shaft caisson should be used.

All of the above factors must be considered before specifying bells as a design solution. In some cases it may be difficult to make a final decision based on borehole information alone and it may make financial sense to install a test caisson before starting the foundation design.

Figure 5: Wings of belling tool in closed position. Hatch at base is in open position to allow excavated soil to be removed from inside of the tool.

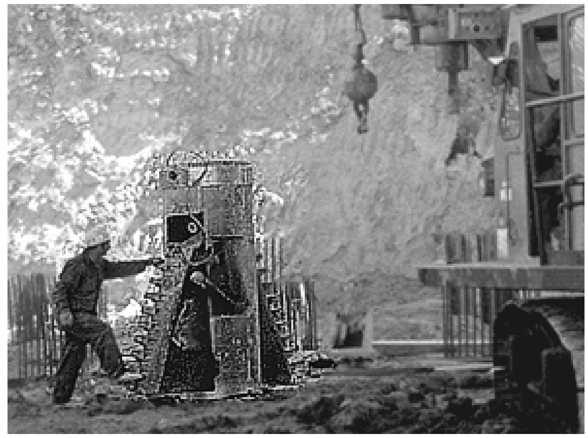


Figure 6: Wings of Belling Tool Fully Extended.

3 CAISSON DRILLING EQUIPMENT

Drilled shafts are normally constructed using rotary drilling equipment. The three most common types of drill rigs used in Canada are truck mounted, track mounted and crane mounted. There are various manufacturers that construct each of these types.

3.1 Truck Mounted Drill Rigs

Truck mounted drill rigs are economical to move between sites as they can be driven on the road. They do not require floats for transportation to the site and set up time upon arrival is minimal. The working surface must be firm and level for this machine to be used efficiently.

3.2 Track Mounted Drill Rigs

Track mounted drill rigs are moved between sites on a single float (figure 7). There is minimal set up of the machine required when it arrives at the site. This rig is an excellent choice on sites with difficult or tight access. It is very compact. Soft working platforms are less of a problem for this machine than the other two rig types.

3.3 Crane Mounted Drill Rigs

These machines consist of a drill attachment mounted on a crane (figure 8). The various components are moved to the site using several floats and trailers. These rigs also require considerably more set up time then the other two alternatives. Due to the size of a crane mount a larger work area is also required. One advantage of a crane mounted drill rig is that it is capable of drilling large diameter holes. It is also able to lift and place liners to case its’ own drill holes. The track and truck drills often require a separate service crane to handle liners.

Figure 7: Track Mounted Drill Rig

Figure 8: Crane Mounted Drill Rig

4 INSTALLATION METHODS

The installation methods used are primarily dependent upon the soil conditions. It is very important to the structural engineers and caisson contractors that a complete geotechnical investigation is completed prior to design and tendering. This will allow development of the most cost effective design and installation solution.

4.1 Open Hole Drilling

The simplest method of caisson construction occurs in dry cohesive soil conditions. In this situation it is possible to drill an open hole to the required depth without use of a liner or slurry to stabilize the hole. If the base of the hole is to be hand cleaned and inspected a temporary steel safety liner is installed to within 4 feet (1200 mm) of the base after completion of drilling. The purpose of this liner is to allow a worker to be lowered to the bottom of the caisson to remove any loose material that may remain at the base after augering is complete. After the caisson is cleaned and inspected the liner is removed.

4.2 Lined or Cased Holes

Temporary steel liners are typically installed to stabilize the sides of holes which must be drilled through non-cohesive or caving materials. The hole is drilled without lining until the wet or non-cohesive layer is encountered. If the layer is relatively thin and is underlain by a cohesive layer the drill rig will push an oversized liner through the wet layer and into the cohesive layer below to provide a seal. If the layer is too thick to allow the liner to be advanced in this manner then other methods must be used to stabilize the sides of the shaft. These methods are described briefly in the following sections.

4.2.1 Vibratory Equipment

A vibratory hammer is mounted on a service crane. The vibratory hammer is connected to the top of the steel liner with “steel jaws”. This temporary liner is vibrated through the non-cohesive material into a cohesive soil below to provide a seal. The larger hammers are capable of advancing liners into weathered shale or dense tills.

Once the liner has been installed the soil within the liner is removed by augering. The rebar and concrete are placed in the hole and the temporary liner is extracted using the vibratory hammer.

In figure 9 a vibratory Hammer is mounted on a service crane. The hammer is clamped to the top of a temporary steel liner to advance the liner through the non-cohesive material. Two crane mounted drill rigs are visible at the rear of the photograph. These drilling rigs are augering inside liners that had been previously installed by the vibratory hammer. After a liner has been “drilled out” concrete will be placed in the steel casing using the free fall method. The casing will then be extracted using the vibratory hammer.

Figure 9: Vibratory Hammer mounted on service crane. Two crane mounted drill rigs located at rear of photograph.

4.3 Slurry Drilling

In non-cohesive soils below the water table bentonite slurry or drilling mud can be used to stabilize the sides and base of drilled shafts.

Drilling mud is composed of a stabilizing polymer and there are several manufacturers of this product. An upper liner is installed to stabilize the top of the hole. A mix of water and drilling fluid is then added to the drill hole before the hole is advanced below the water table. A sufficient head of the water/fluid mixture should be present to ensure that collapse of the sides of the hole does not occur when drilling continues below the water table. Additional water and drilling fluids should be added as the hole is advanced to maintain the balance of pressure below the water table. The drilling fluids increase the viscosity of the mixture and encapsulate the outer grains of sand or gravel to ensure clean removal from the hole. Flocculent can be added to the mixture to ensure rapid settling of fine silts if required. A similar procedure is used for shafts drilled using a bentonite slurry for stabilization.

After drilling is complete the concrete is placed in the shaft using tremie methods or by concrete pump. During pouring it is important to ensure that the base of the pipe is kept an adequate distance below the top of concrete to ensure that contamination of the concrete can not occur.

5 INSTALLATION TOLERANCES

The normal installation tolerances for caissons are maximum 3” out of location and drilled within 2 percent of plumb.

For caissons drilled in non cohesive, wet soils or with concrete cutoff elevations located well below the working platform level it is beneficial to specify a caisson cap. This is because it is extremely difficult to provide a precise concrete cutoff elevation when working under these site conditions.

6 BOULDERS AND OBSTRUCTIONS

An obstruction is defined as a cobble or boulder, or any other natural or man-made object that cannot be removed using normal drilling procedures or which interferes with progress within a drilled shaft. It is impossible to accurately quantify the number of obstructions or the time required to remove them. As a result of these unknowns it is normal industry practice to remove these obstructions on a time and material basis. Typically the owners’ site representative or the soils inspector documents this additional work in the daily reports to verify the quantities for payment. This method ensures that the owner is only charged for the actual cost of the work and that the contractor does not add a risk contingency for this item in the bid.

7 CONCRETE PLACEMENT

STS Consultants Ltd. In the United States completed a study into the effects of placing concrete in drilled shafts using the free fall method. The study concluded that placing of concrete into properly constructed, dry shafts can be performed to depths of 120 feet or greater without meaningful loss of strength or segregation of the concrete aggregate occurring. A copy of this report is available from the Association of Drilled Shaft Contractors (ADSC).

A minimum concrete slump of 6” (150 mm) is normally specified to allow extraction of the temporary liner during concreting.

8 ASSOCIATIONS

The Association of Drilled Shaft Contractors (ADSC) is a North American organization, which provides an excellent source of information for contractors and engineers. The head office is located in Dallas, Texas (phone 214-343-2091). The ADSC funds research and have also prepared design, inspection and installation information and standards for the foundation industry. The organization also provides training workshops for contractors, inspectors, and designers.

The Deep Foundations Institute (DFI) is an international organization which is dedicated to the improvement of the planning, design and construction aspects of deep foundations and deep excavations. The head office is located in New Jersey (phone 201-567-4232). They are also an excellent source of technical information.

9 CONCLUSION

Caissons provide an economical foundation system for support of a wide range of structures. They can be used on small jobs such as cellular towers which may only require a single drilled hole up to mega projects such as the new airport terminal which will require several thousand drilled shafts. The ability of specialty contractors to modify equipment and customize drilling tools to suit specific conditions make caissons a viable foundation option in virtually all types of rock and soil conditions.