3.1 Bearing Piles - General

Piles are slender underground columns, generally placed in a group and sometimes with the top portion projecting as an unsupported column to a pier cap. They are designed to support their loads through bearing at the tip, friction along the sides, adhesion to the soil, or a combination of these means.

- Piles are used when other foundation types are impractical.
- Piles can penetrate weak soils and transmit their loads to underground strata with higher bearing capacities.
- Piles can also distribute loads over a sufficiently large vertical area of weaker soil to enable them to carry the designed loads safely.
- Piles are classified as either end bearing or friction piles, or both.

3.2 Environmental Constraints

Alberta Environment's Code of Practice is to be followed for all projects involving a stream or river crossing. Be aware of the environmental constraints when installing pier piles that encroach on the stream channel.

- The Bridge Inspector should be cognizant about noise generated by the hammer and work should not be permitted late at night in or near a populated area.

3.3 Safety

Refer to Alberta's Occupational Health and Safety Regulation, General Safety Requirements (to replace the existing General Safety Regulation) for specific approved safety requirements.

- Part 7 Cranes and Hoists
- Part 11 Fire and Explosion Hazards
- Part 15 Personal Protective Equipment
- Part 16 Powered Mobile Equipment
- All site personnel must wear a hard hat and safety boots when working with, near or around pile driving hammer, as falling objects from the hammer will create a dangerous situation.

- It is advisable to wear ear protection to minimize the noise generated from the driving hammer.

- Ensure that proper fall protection is in place when climbing pile driver leads.

- It is not advisable to allow personnel to stand underneath a pile during the pile set-up operation as a pile may fall if the cable holding the pile fails.

- A timber pile may fail without warning during driving; resulting in many pieces of timber "splintering" out from the pile, creating a very dangerous situation.

- Ensure that the pile driving procedures does not interfere with any utility lines.

3.4 Bridge Inspector's Record

The Bridge Inspector must observe and record the results of all pile driving operations and must ensure that all conditions of the Contract are met.

- Based on initial data, pile requirements may have to be modified.

- General comments pertaining to the performance and break down of the hammer should be recorded.

- A careful record of pile length driven must be recorded.

- Payment for driving piles is made at the unit price bid for the metres of piling acceptably driven and used in the completed structure.

- The length of pile is the actual length from tip to cut-off.

- It is essential that the Bridge Inspector monitor the entire driving operation so he can confirm that the length of driven piling to be paid for is correct.

- The number of set-ups and splices must be recorded.

- Any pile "set" values or negative friction should be recorded.

- Survey check of the installed pile alignment and elevations should be recorded.

3.5 Soil

Pile driving usually affects the properties of the soil through which the pile is being driven. When piles are driven in the ground, they displace soil. The soil can be pushed down, up, or sideways or a combination of these.

- The information provided by the soil log and the test pile data should assist in anticipating the degree of driving difficulties and the penetration of the piles.
- Be aware that approach fills may include soils with large boulders, stones, broken concrete slabs or old asphalt pavement, which will create difficulty in the pile driving operation.
- Vibrations from the driving effort tend to consolidate granular soils and unsaturated clays.
- Displacement of the soil by piling, such as steel pipe, steel “H” or timber piles can also increase compaction of the granular materials.
- In some over consolidated materials and saturated clays, soil displacement may cause heaving of the surrounding soil, which can lift previously driven piles and push them out of alignment.

3.5.1 Pile “Set”

Some weaker clays or silty soils offer relatively little resistance to penetration of a pile while it is being driven, but “tighten up” and grip the pile securely after the driving disturbance ceases. This is called pile “set” and can be a concern if driving is stopped for any length of time before the pile has reached the required penetration. It is sometimes difficult to get the pile moving again once pile “set” has occurred.

- The weight of the added fill material may cause underlying strata to consolidate. As the soil consolidates downward, upper layers that have gripped the pile will tend to “hang-up” on the pile and transfer their weight to the piles as additional loading.
- Where piles are driven through fills which are expected to settle or consolidate in the future, they may be installed in holes pre-bored through the fill layer or coated with a bond breaking material which will reduce or eliminate the gripping effect on the pile of the upper layers.

3.6 Equipment

- The installation of a pile involves a variety of choices of equipment.

- Selecting the most suitable equipment for each pile application is very important.

3.6.1 Drop Hammer

A gravity or drop hammer pile driver consists of a weight, guides or leads, a supporting framework and a means for raising and dropping the weight, usually a crane. The weight is raised along the leads to a desired height above the pile top, then released and allowed to drop onto the pile.

- The specifications require the Contractor to provide of the mass of the hammer being used.
- The available impact energy delivered per blow by a drop hammer is calculated by multiplying the weight of the hammer times its effective height of fall.
- The maximum allowable height of fall is limited to 4.5 metres to avoid damage to the pile.
- The leads should be marked in a manner that allows the easy determination of the distance that the hammer falls.
- The pile cap should contain a cushion block to serve as a “shock” absorber.
- Drop hammers are generally more time consuming than other types of hammers, however they can provide a fast driving rate in soft soils where high drops can be used.
- In hard soil formations, where the drop has to be reduced to avoid overstressing the pile, driving can be slow. One of the greatest risks in using a drop hammer is overstressing and damaging the pile.
- The gravity hammer is generally not efficient for driving permanent foundation structural piles and should be discouraged.
- A gravity hammer could be utilized for setting up piles, i.e. to drive the first section of a pile or driving timber piles in a soil that has a minimal amount of resistance.

3.6.2 Vibratory Pile Driver/Extractor

The vibratory pile driver drives a pile by being rigidly connected to the pile usually by clamps, and advances the pile through the soil by vibration. Vibratory pile drivers are effective for advancing piles in granular soil conditions and especially in sandy material.

- Vibratory drivers are not rated by ram (eccentric) weights or by impact energies delivered per blow. Vibratory pile drivers are classified as the driving force deliver to the pile.

- The driving force of a vibratory driver is the product of the eccentric moment of the eccentrics in the machine and the steady-state frequency at which the eccentrics can be rotated when loaded with an oscillating pile.

- The operation, maintenance and repair of vibratory pile drivers are more complex than other pile installation equipment.

- Vibratory pile drivers are efficient for driving sheet piles for cofferdams.

- Vibratory pile drivers can also be used to extract piles.

- At the site, care must be taken when swinging the vibratory hammer, clamping it properly to the pile and inspecting the connecting electric cable or hydraulic hose bundles.

3.6.3 Diesel Hammer

A diesel hammer can be a single or double acting hammer. The diesel hammer is a precision pile hammer and has a high-energy rating. The diesel hammer is efficient and compact as it carries its own fuel from which it generates its power internally.

- Diesel hammers use rapid combustion of fuel to directly drive the pile down and the ram up. The unit contains a fuel-injection system, ram, anvil, and vertical cylinder.

- To start the hammer, a cable lifts the ram and a trip drops it. As it falls, it actuates a fuel pump to inject fuel between the ram and the anvil. The compression on impact ignites the fuel, and the explosion drives the pile down and the ram up for another blow.

- In the case of double acting diesel hammers fuel is injected at the top of the ram travel and the resulting explosion also drives the ram downward giving additional energy to the ram weight as it falls. A lighter ram weight is used, but more blows per minute are achieved.

3.6.3.1 Efficiency Factor

Energy determination is important with diesel hammers. The number of blows the hammer produces per minute must be recorded so the hammer can be properly rated. For some hammers, the operator can vary the fuel supply, which directly effects the energy output. The Bridge Inspector must be aware of the operating characteristics and rated energy output of the specific hammer as provided in the manufacturer's manual supplied by the Contractor.

- Length of stroke varies with pile resistance.

- The performance of a specific hammer is evaluated, realizing that the relationship between the number of blows per minute and the efficiency of the hammer is not a linear relationship.

- Pile-driving leads facilitate proper pile positioning.

3.6.3.2 Bearing Values

Piles are usually required to be driven to the estimated pile tip elevations shown on the drawings. The indicated elevations have been determined by the designers to provide sufficient length for friction to develop the capacity and fixity of the pile, or for the tip to be properly embedded in a bearing stratum. In some cases, the minimum tip elevation is governed by scour considerations.

- The pile capacity is determined through use of a bearing formula.

- Using a bearing formula, the Bridge Inspector must calculate the number of blows per ¼ metre required to obtain the design bearing value.

- The bearing formulas are included in the specifications along with the conditions under which they are to be used. These formulas have many limitations and should be used with caution.

- Bearing formulas should be used in conjunction with borehole information and with pile test results when available and the bearing values should be confirmed with the Bridge Project Engineer.

3.7 Piling

Essentially, piles to be installed fall into two major categories: bearing piles and retaining piles. The bearing pile category can be subdivided into end bearing and friction bearing pile. The retaining pile category can be subdivided into permanent and temporary piles.

- Commonly used piles in bridge construction include steel H-piles, steel sheet piles and pipe piles or timber piles.

- Bearing piles are slender columns, and as such they rely on the lateral support from the soil through which they are driven to prevent buckling. When piles are driven through water or in extremely weak soils special precautions to prevent buckling may be required.

- When foundations are subjected to significant lateral forces, piles may be driven battered (i.e. at an angle to the vertical) to provide a horizontal component to the load carrying capacity.

- Pile tops must be cut squarely, to accommodate a driving cap or follower which is provided to hold the pile in line with the hammer.

- To prevent damage to the pile from the impact of the hammer, a plywood or hardwood shock block is used as a cushioning material in the driving cap or follower.

- Pre-boring may be required to assist pile alignment where the ground is frozen. Approval from the Bridge Project Engineer must be obtained before pre-boring.

- The pre-bored hole could be over/under sized depending on whether side friction is a critical factor or not.

3.7.1 Timber Piles

Timber piles have been used in foundations for a long time. If the piles are installed such that they will be permanently below water level the material will not decay and untreated timber may be used. Where piles may be subject to decay, they are pressure-treated.

- Piles that are curved, cracked or contain large knots must be rejected.

- Timber piles are susceptible to damage and must be handled and driven carefully. Treated piles must not be handled with tools such as hooks, tongs, dogs and pike-poles, which will break the surface. If cuts or breaks in the surface do occur the surface is to be appropriately repaired.

- Driving operations tend to split and “broom” the tops of timber piles. The top of the pile must be protected with a collar, multiple banding, or some other approved device. Pile caps or followers used with the hammer must be such that the driving impact is distributed to the full end surface of the pile. Limitations on the weight and height of fall for drop hammers, and the energy supplied by diesel hammers must be controlled to avoid pile damage.

- No splicing is allowed on timber piles, and occasionally, metal shoes are used when driving into hard soil conditions.

- Ensure that the required elevation is maintained after any “broom”, splintered or damaged material is cut off.

3.7.2 Steel Sheet Piles

Steel sheet piles are generally utilized for cofferdam construction. As with treated timber piles, steel sheet piles cannot withstand hard driving. A vibratory hammer is most effective for driving and extracting sheet piles, especially when driving in granular material.

- It is imperative that the "starter" pile to be properly aligned and subsequent piles be properly "threaded" in order to maintain the desired alignment. At the corners of a cofferdam, appropriate "corner piles" should be employed.

- All sheet piles should be "threaded" and set-up before driving commences.

- The first sheet pile should be minimally advance with subsequent piles advanced the same amount, rotating equally from pile to pile.

- Spliced sheet piles should not be used, as the "splice" in the pile will cause problems in the "threading" process and the final alignment.

3.7.3 Steel "H" Piles

Steel H-piles are usually rolled wide flange sections varying from 250 to 360 mm. H-piles are strong and durable and can be driven into relatively difficult ground conditions. They have a small cross section, so ground displacement and heaving are minimized.

- The specifications state limitations on driving requirements.

- The specifications require that the pile head to be cut squarely and a suitable follower provided to ensure the driving force is delivered to the pile uniformly over the full cross section.

- When splicing during adverse weather conditions, the welding area must be sheltered from the wind and preheated. Splicing details are given in the specifications.

- Under difficult driving conditions, a pile "shoe" or end reinforcement may be required.

- A pile "extension" should not be allowed unless approval is obtained from the Bridge Project Engineer for unusual circumstances. Details of the proposed pile "extension" must be submitted to the Bridge Project Engineer for approval.

3.7.4 Steel Pipe Piles

Steel pipe pile may be driven with open or closed ends. All steel pipe piles should be checked for roundness and it is essential that the pile cap on the follower fit the pipe piles properly. Care should be taken so that pipe piles are not over driven to cause buckling or folding at the tip. One indication of folding is when high blow counts suddenly drop and the information provided in the soil log does not account for this sudden change.

- Steel pipe piles with closed bottom ends displace a relatively large amount of soil.

- Care must be taken during driving to ensure that pipe piles are not damaged from buckling of the pipe walls. The interior of pipe pile should be inspected by either lowering a light bulb or using a mirror to ensure that the pile is not buckled or split and allowing water seepage.

- During hard driving some local buckling of the pipe wall at the driving follower may occur requiring removal of the damaged portion.

- When splicing in cold weather, the welding area must be sheltered and the splice location pre-heated. The Contractor must use a bevelling machine to properly prepare the end of the pile for welding and use backup rings when making the weld.

- The method of "drive and drill" may be necessary to advance the piles. When this method is used, casing will be required if the sides of the holes are unstable and begin to cave. If a water seal cannot be maintained at the designed elevation, the casing will have to be further advanced to ensure a proper seal.

- The Bridge Inspector must discuss with the Bridge Project Engineer all special requirements such as cleaning out the pipe pile after driving, socketing the pile base, concreting and reinforcement.

- Tremie concrete may be employed to pour the pipe pile if approved by the Bridge Project Engineer.

- A mix design for tremie concrete must approved by the Bridge Project Engineer.

- Steel pipe piles extending above the ground or water surface are susceptible to corrosion and must be protected either by painting or by galvanizing. Sandblasting will be required to properly prepare the steel surface before field painting.

- Open steel pipe piles must be securely covered until they are filled with concrete or otherwise back filled.

3.7.5 Drilled Piles

Selection for the pile type to be incorporated into a structure is primarily dictated from economics and soil conditions. The full advantage of a drilled pile may be utilized in situations where the bed rock outcrop is close to the surface. Due to the high friction value of a drilled pile, it is advantageous in certain soil conditions to use a shorter drilled pile rather than driving a long steel pile.

- Ensure that the pile locations are correct.
- Ensure that the angle of the batter is correct. The batter angle may be checked measuring the angle of the “kelly-bar”.
- Ensure that the sides of the drilled hole have not collapsed and that free water is not in the bottom of the hole before concreting.
- Ensure that the hole is concreted as soon as the hole is satisfactory drilled.
- Ensure that the hole is drilled to the correct elevation and record it for concrete quantity calculation.

3.8 Checklist

3.8.1 Bridge Inspector’s Responsibilities

- Read the specifications and study the drawings.
- Confirm that driving equipment have been approved by the Bridge Project Engineer.
- Ensure piling material is ordered where applicable and that the Contractor has proper equipment for unloading. Ensure that Contractor have extra piles and extra splice plates, especially in remote areas.
- Check pile layout and ground elevations prior to driving. Ensure that allowances are made for the batter piles and the ground elevation.
- Check drawings to see if pre-boring is required or permitted.
- Calculate required blow count. Apply the appropriate bearing formula.
- Carefully measure and record pile lengths for payment purposes and as constructed drawings.
- Check that pile tops are square before driving and that a pile follower is used.

- Observe the driving operations from the beginning and report the results of driving the first one or two piles to the Bridge Project Engineer.
- A pile should be driven at each end of the element if possible to serve as “test” piles.
- Check the blows per minute of the hammer and compare with the manufacturer’s specifications.
- Record the blow count per ¼ metre on the pile data form.
- Check that the pile has been driven to the required depth, or that it has the required capacity as measured by a bearing value formula.
- Check that pile has been driven to refusal and has not “set” because driving was stopped.
- Check piles to see whether they are heaving and have them re-driven if necessary.
- Check pile splices for splice plates, back-up rings and proper welding.
- Ensure special precautions are taken when splicing piles in cold weather.
- Reject defective timber piles for checks, knots or bowing.
- Ensure timber piles are properly handled and that all surface breaks and cut tops are treated.
- Ensure timber pile tops are banded before driving.
- Check cut-off of pile tops for correct elevations.
- Check the pipe pile to ensure the pile is not split or buckled at any point and de-watered before concreting.
- Do quantity calculations for piling and summarize the collected data.

3.8.2 Bridge Project Engineer’s Responsibilities

- Discuss site soil conditions with the Bridge Inspector, to anticipate possible problems and to provide possible solution for such.
- Discuss with the Bridge Inspector all operating aspects and potential problems pertaining to hammer efficiency, acceptable pile penetration and pile bearing values.

- Discuss with the Bridge Inspector, the possible occurrence of a "set" condition of the soil, and the possible occurrence of a negative friction force enacting on the piles.

- Discuss with the Design Engineer, the acceptable blow counts for the first one or two piles to determine the final acceptable pile penetration.

SECTION 3

BEARING PILES

Drop Hammer

3-1 Drop hammer driving sheet piles

Vibratory Pile Driver/Extractor

3-2 Advancing sheet piles with vibro hammer

3-3 Vibratory Pile Driver for advancing pipe piles

3-4 Advancing pier pipe pile caissons

SECTION 3

BEARING PILES

Diesel Hammer

3-5 Bermingham B-3505 diesel hammer driving sheet piles

3-6 Bermingham B-4505 diesel hammer driving H-piles

3-7 Delmag D19-32 diesel hammer driving first length of H-Piles at abutment

3-8 Delmag D30-32 diesel hammer driving H-pile to final set

3-9 Diesel hammer driving pier pipe piles first and then driving abutment H-Piles

Steel Sheet Piles

3-10 Two sheet pile driving frames were used to ensure sheet pile alignment

3-13 The first sheet pile for a cofferdam should be advanced one metre

3-11 Setting up sheet piles

3-14 Subsequent piles advanced the same amount rotating equally from pile to pile

3-12 Thread sheet piles prior to driving

3-15 Subsequent piles advanced the same amount

SECTION 3

BEARING PILES

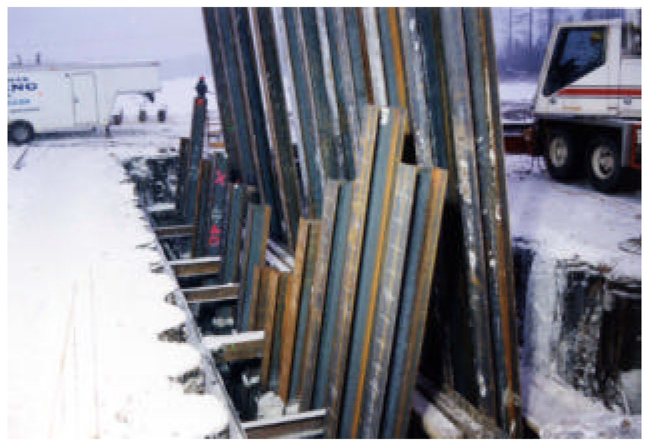
Steel "H" Piles

3-16 Pre-fabricated splice detail

3-17 Field splice preparation

3-18 Field splice detail

3-19 Pile driving frame at pier



3-20 Piles driven battered are to provide a horizontal component to the load carrying capacity

3-21 Driving H-Piles at pier - Cofferdam full of water to reduce pressure differential on the cofferdam walls

SECTION 3

BEARING PILES

Steel Pipe Piles

3-22 Typical closed end detail

3-23 Galvanized pipe sections spliced onto plain pipe sections

3-24 Galvanized pipe piles

3-25 Pipe piles at pier

3-26 Pipe piles at abutment

SECTION 3

BEARING PILES

Drilled Piles

3-27 Pipe pile caissons

3-28 Pipe pile with tip reinforced

3-29 Pre-drilling for pile installation

3-30 Pipe pile driving guide

3-31 Advancing pipe pile with vibro hammer

3-32 Removing material from inside pipe pile with drill rig

SECTION 3

BEARING PILES

3-33 Material inside pipe pile being drilled out with an auger rig attachment

3-34 Examining tailings to see whether suitable bearing layer has been reached

3-35 Checking pile tip elevation

3-36 Cleaning sidewalls and bottom of drilled hole with wire brush/bucket drill rig attachment

3-37 Placing reinforcing steel cage after hole has been satisfactory cleaned and inspected

3-38 Pouring pile concrete after reinforcement has been properly placed