The Project for
Capacity Development of Road and Bridge Technology
in the Republic of the Union of Myanmar (2016-2019)

QUALITY CONTROL MANUAL FOR BRIDGE FOUNDATION

(1st Edition)

April 2019

Ministry of Construction, the Republic of the Union of Myanmar

Japan International Cooperation Agency

PREFACE

In the exercise of its primary mandate as the construction arm of the government, the Ministry of Construction endeavors to keep abreast with systematic quality control and the latest construction techniques, with the ultimate objective of being at par with the more advanced countries in ASEAN.

This quintessential goal cannot be achieved without having to adopt clear-cut, uniform, systematic and definitive procedures on Construction Supervision on Quality/Safety Control in the first place. It is a given prerequisite that Quality Infrastructure must be a direct result of good management and project implementation.

This manual, which was jointly prepared by the MOC Engineering Staff and the Experts assigned for the Project for Capacity Development of Road and Bridge Technology in the Republic of the Union of Myanmar (2016-2019) under the Japan International Cooperation Agency (JICA), serves an effective reference material to field engineers of road and bridge construction, instrumental in our pursuit of the aforementioned ambitious objective.

With this manual, the field engineers should become familiar with and knowledgeable of the overall process in Quality Control and Safety Control, thus making them more competent in constructing government projects that are in accordance with and in strict compliance to the specification/contract requirements of the project.

April 2019

U Han Zaw
Union Minister
Ministry of Construction,
the Republic of the Union of Myanmar

INTRODUCTION

BACKGROUND

The bridge construction technology has maintained in certain technological level since "Bridge Engineering Training Center (BETC) Project (1979-1985: JICA), however, new technology has not been transferred and bridge types that can be constructed in Myanmar are still limited. Besides, insufficient training for national engineers has hampered sustainable transfer of technology in bridge engineering. In this context, the Government of Myanmar requested "the Project for Capacity Development of Road and Bridge Technology" (hereinafter referred to as "the Project") to the Government of Japan. Through series of discussion, Ministry of Construction (MOC) and JICA concluded the Record of Discussion (R/D) in January 2016 to implement the Project focusing on capacity development on construction supervision of bridges and concrete structures.

The Project was implemented for 3 years since 2016 in corroboration with MOC staff officer and JICA Experts aiming at improvement of quality as well as safety in construction of bridges and concrete structures. As the achievement of the Project, the Manuals on Quality and Safety Control for Bridge and Concrete Structure were developed in 2019 after several workshop and discussion.

REFERENCES

Following technical documents were referred as references.

1) Specification for Highway Bridges (2012, Japan Road Association, Japan)

2) Standard Specifications for Concrete Structures (2012, Japan Society of Civil Engineering)

3) Manual for Construction of Bridge Foundation (2015, Japan Road Association)

4) AASHTO LRFD Bridge Construction Specifications (3rd Edition, 2010)

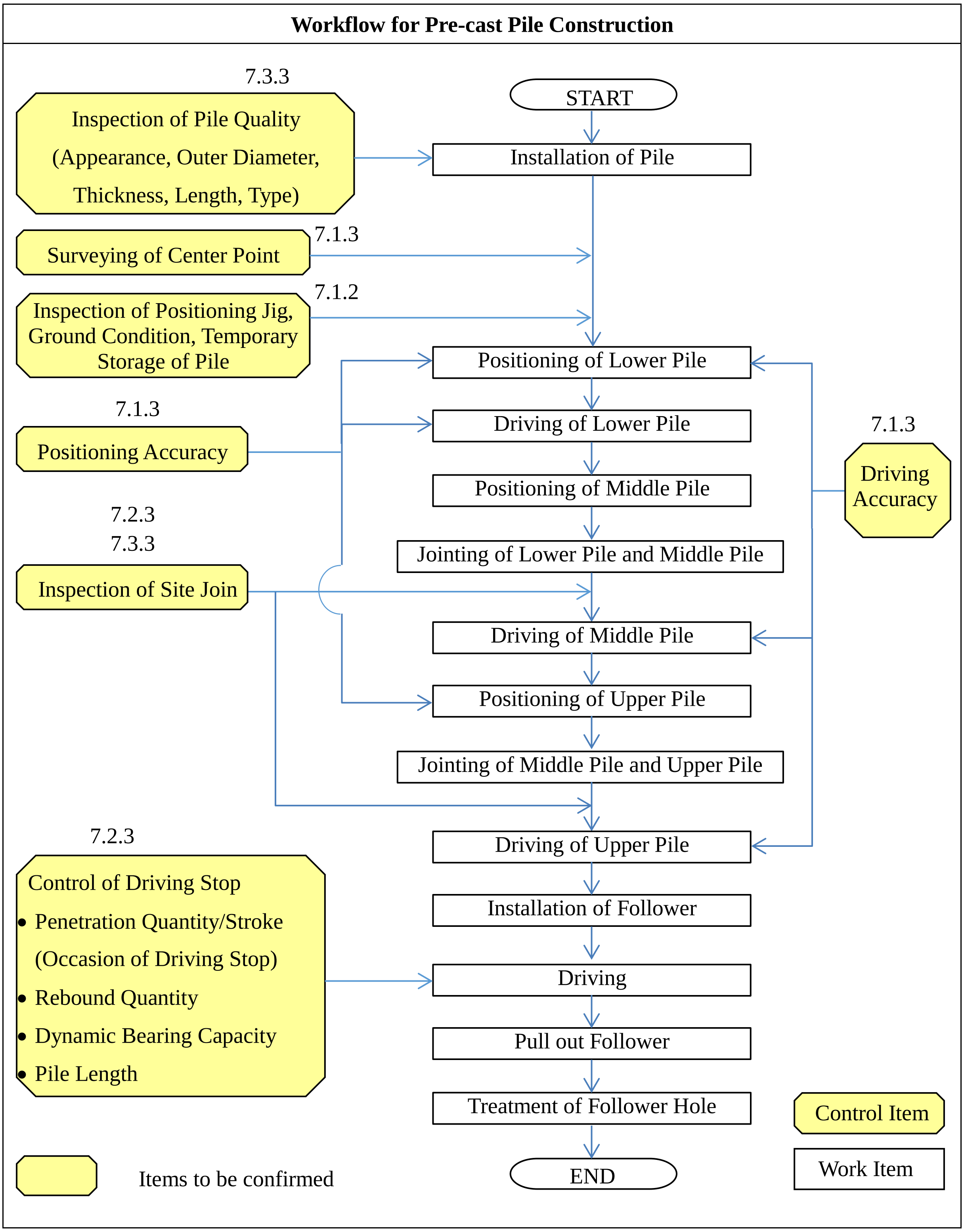
5) The Guidance for the Management of Safety for Construction Works in Japanese ODA Projects (2014, JICA)

6) Manual for Construction Supervision of Concrete Works. (2016, NEXCO)

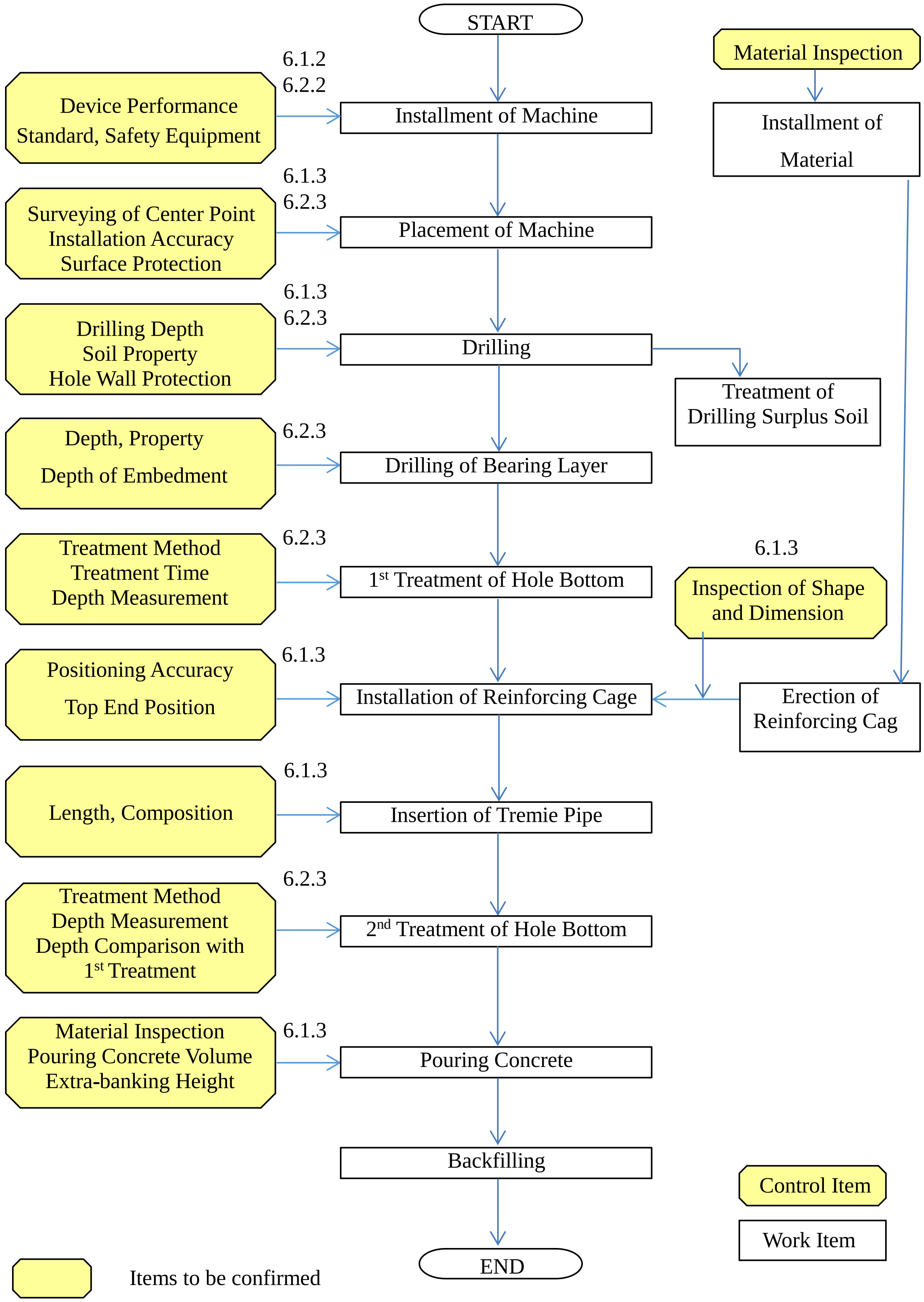
7) Manual for Construction Supervision of Road and Bridge Structures. (2016, NEXCO)

8) Construction Contract MDB Harmonized Edition (Version 3, 2010 Harmonized Red Book)

FLOWCHART OF QUALITY CONTROL FOR BRIDGE FOUNDATION



Workflow for Cast-in-situ (Bored) Pile Construction



QUALITY CONTROL MANUAL FOR BRIDGE FOUNDATION

TABLE OF CONTENT

ABBREVIATIONS

AASHTO:	American Association of State Highway and Transportation Officials
ASTM:	American Society for Testing and Materials
CPT:	Cone Penetration Test
JIS:	Japanese Industrial Standards Committee
PHC Pile:	Pre-stressed High-strength Concrete Pile
RC Pile:	Reinforced Concrete Pile
RQD	Rock Quality Designation
SC Pile:	Steel Composite Concrete Pile
SIT	Sonic Integrity Test
SPT	Standard Penetration Test

CHAPTER 1. GENERAL

1.1 Description

Foundation is the component which transfers loads from the substructure to the bearing layer. Depending on the geotechnical properties of the bearing layer, shallow or deep foundations are adopted. Usually, piles and wall foundations are adopted for bridge foundations.

The foundation constructed sufficiently below ground level such as piles, walls etc., at their base are called deep foundations.

Deep foundations are the one which are used to transmit the load to a deeper layer. The load transfer in this type of foundation is either by end bearing, friction or in combinations of both.

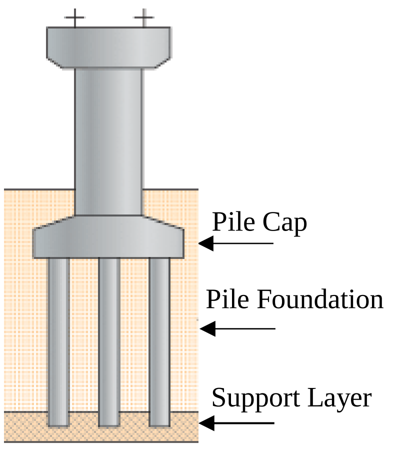


Figure 1.1-1 Bridge Foundation

1.2 Pile Foundation

Piles are used to transfer the loads from the superstructure to a competent sub-surface layer, where the required bearing capacity is available.

1.2.1. Usage of Pile Foundation

The selection of type of pile foundation is based on site investigation report. Site investigation report suggests the need of pile foundation, type of pile foundation to be used, depth of pile foundation to be provided.

Unless the ground condition is rocks, for heavy construction and multi-storey buildings, the bearing capacity of soil at shallow depth may not be satisfactory for the loads on the foundation. In such cases, pile foundation has to be provided. The number of piles in a required pile group is calculated from the pile capacity of single pile and the loads on the foundation. Piles are a convenient method of foundation for works over water, such as jetties or bridge piers.

Generally, piles are used, if the soil at shallow depth does not have adequate bearing capacity and when the estimated settlement values are greater than the allowable limits. Pile foundations are also preferred where expansive and collapsible soils are found.

1.2.2. Types of Pile Foundation

Types of pile foundation can be classified under various heads. In this discussion we limit ourselves under the following listed categories.

1) Materials Used

2) Construction Method

3) Installation Type

4) Load Transmission and Functional Behavior

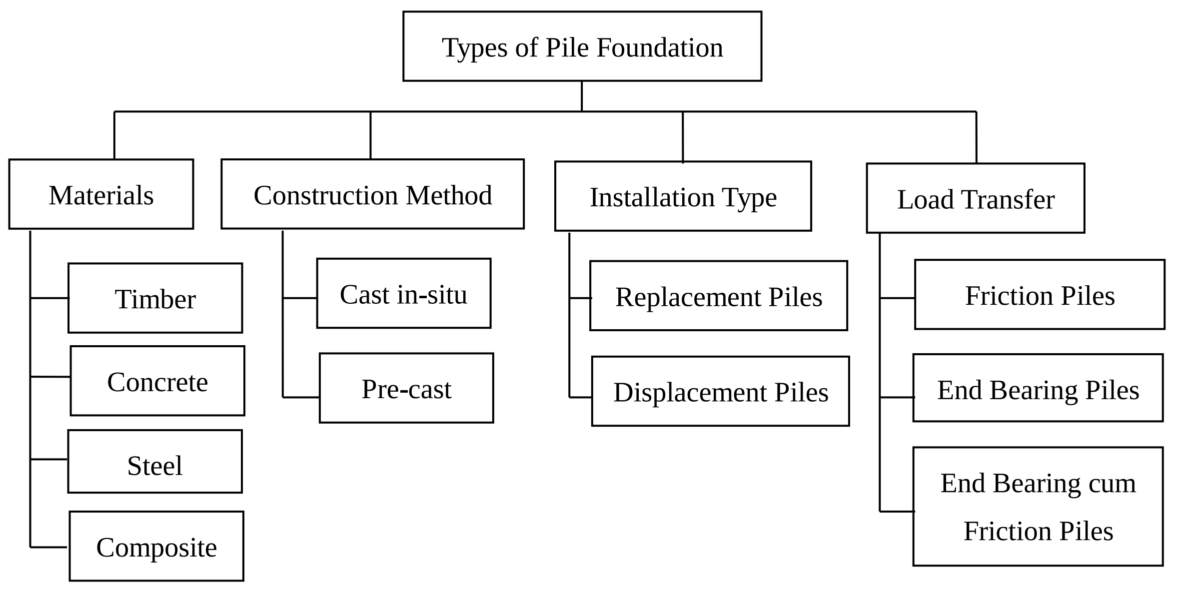


Figure 1.2-1 Types of Pile Foundation

1.2.3. Materials Used

(1) Timber Piles

Timber piles are widely used for compaction of soils and for the construction of temporary structures. They are also used in the protecting water- front structure.

The main advantages of timber piles are, they are easy to handle, low initial cost, durable in non-fluctuating weather conditions. Disadvantages include proper treatment of piles against termites and fluctuating weather conditions, difficulty in splicing and cautious driving methods to avoid to pile head damage.

Figure 1.2-2 Timber Pile Foundation

Figure 1.2-3 Timber Pile Construction

(2) Concrete Piles

Concrete piles are the widely used for heavily loaded structures. Concrete piles can be pre-cast or cast in-situ piles. The precast piles may use ordinary reinforcing bars or pre-stressed bars depending on the usage and the loading conditions. The main advantage is the higher loading capacity and ease in construction. Disadvantages include high initial cost, requirement of treatment when used in corrosive areas, marine environment and splicing in case of pre-stressed piles.

Figure 1.2-4 Pre-cast Pile

Figure 1.2-5 Cast-in-situ

(3) Steel Piles

Steel piles of various cross sections such as Hollow steel tubes, Box sections, H-sections, built -up sections are available and have to be chosen carefully according to the site conditions. Steel piles are easy to splice, handle and install where deep penetrations are required. They can withstand high driving forces and any damage to the pile head can be rectified by trimming them and splicing with a newer section. Steel piles are best suited where ground heave and lateral displacements are to be avoided. In case of corrosive environment and marine structures, the steel piles will require treatment.

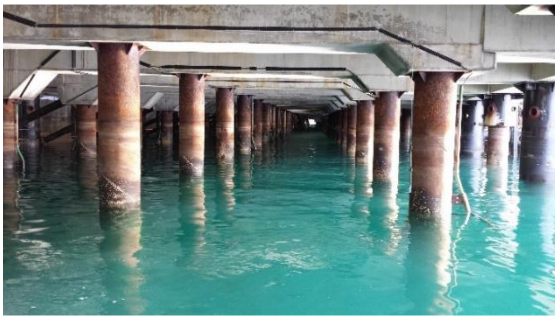


Figure 1.2-6 Steel Pile Construction	Figure 1.2-7 Steel Pile on River

(4) Composite Piles

Composite piles are generally employed under special conditions. They are generally made of two or more different type of pile materials or pile types. One such case is, concrete pile can be spliced with a timber or steel pile in marine environment. The timber or steel piles will be used far below the splash zone to avoid damage due to alternate corrosive environment with a concrete pile being spliced above.

Figure 1.2-8 Composites Pile

1.2.4. Construction Method

(1) Cast in-situ Piles

Cast in-situ piles can be either driven or bored. Driven cast in-situ piles are economical for light to moderate loading conditions. Driven cast in-situ piles are difficult to use for deep penetrations and grounds having boulders and other major obstructions.

Bored cast in-situ piles are the cheapest type formed by drilling holes with or without liners. If the liners are left permanently, they are termed as cased pile and as uncased pile if the liners are removed. Suitable for very high working loads and where ground heave conditions are to be avoided. Bentonite slurry is also used in case of collapsible soils. The main concern in using these piles will be the disposal of the augured earth materials especially in case of contaminated soils.

(2) Pre-cast Piles

Since these are pre-cast piles, required quality of concrete can be assured and hence a higher working load can be assumed compared to cast in-situ piles. These pre-cast piles can also be prestressed and hence will have a higher load capacity. The main advantages of pre- cast pile are they can be used under high loading conditions and with minimum construction time at site.

Disadvantages in case of pre-cast piles are additional reinforcements have to be provided for taking care of handling stresses and the required length may not exactly match with the available pre-cast pile length.

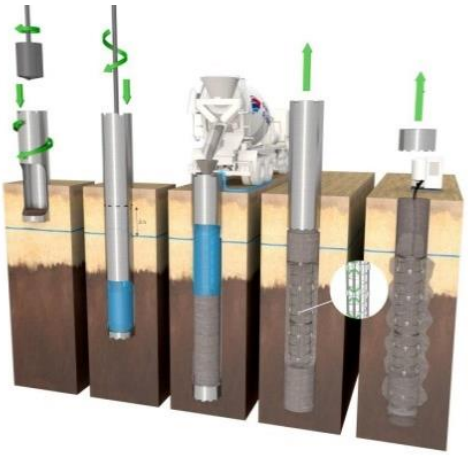


Figure 1.2-9 Cast in-situ Construction

Figure 1.2-10 Pre-cast Pile Construction

1.2.5. Installation Type

(1) Replacement Piles

These piles are either bored and cast in-situ piles or drilled-in tubular piles. In both the cases, the earth is removed where the pile has to be installed and is then filled with reinforced concrete or precast sections are erected. Steel liners, bentonite slurry may also be used according the prevalent soil condition in the site. These replacement piles do not provide any additional consolidation or displace the surrounding soil and hence ground heaving is avoided.

(2) Displacement Piles

Displacement piles are either solid sections or hollow sections with a closed end driven into the soil, thus displacing the soil around them. They are mainly used where there are no restrictions on ground heaving and lateral displacement of soil. Displacement piles are mainly preferred in marine structures.

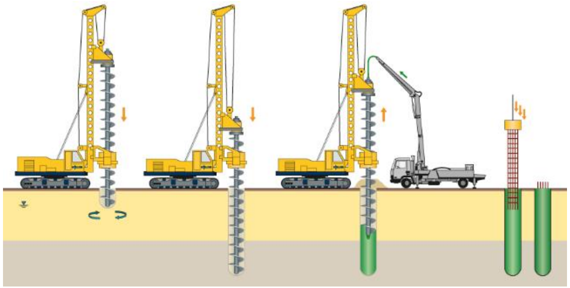
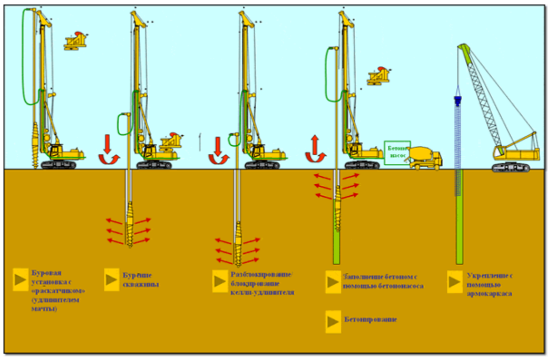
	

Figure 1.2-11 Replacement Pile	**Figure 1.2-12 Displacement Piles**

1.2.6. Load Transfer Method

(1) End Bearing Pile

If the pile transmits the load from the structure to a considerable strong stratum mainly through the resistance developed at the bottom or tip of the pile, then it is called as end bearing pile.

(2) Friction Piles

If the prominent load transfer is primarily by friction along the surface of the piles, then they are termed as frictional piles. Friction piles are generally used in low to medium dense sand and where hard strata are not available at reasonable depth.

(3) End Bearing cum Frictional Piles

In few cases, the load transfer will be a combination of both ends bearing and frictional resistance.

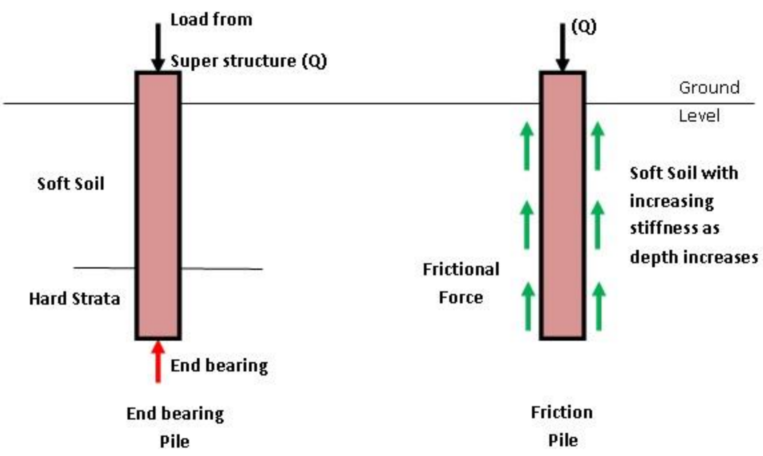


Figure 1.2-13 End Bearing Pile and Friction Pile

CHAPTER 2. SURVEY

2.1 Purpose of Surveys

A survey shall be performed to obtain the information required to design and construct foundations.

2.2 Types of Surveys

2.2.1. Types of Surveys

The following surveys shall be performed for the design and construction of bridge foundation:

1) Geotechnical investigations

2) Surveys of construction conditions

Table 2.2-1 shows the contents of survey types.

For design stage survey, it is necessary to perform surveys of the construction conditions. At the construction stage, supplementary surveys of the construction should be implemented, as needed, only after fully understanding the results of the surveys obtained at the design stage.

Table 2.2-1 Survey Item

Survey	**Principal**	**Survey Items**
1) Geotechnical Investigations		
Survey of Ground	Overview of ground, structures and properties of soil layers and General study of design and construction	a) Survey of geography and geology b) Boring, c) Sampling, d) Sounding, e) Laboratory Testing, f) Rock Testing
Survey of Groundwater	Study of construction methods and working procedures etc.	a) Underground water level, b) Water quality test, c) Pore-water pressures
Survey of Toxic Gas and Oxygen-Short Air	Study of construction methods	a) Type of gas, and its emission, b) Emission of oxygen-short air
2) Survey of Construction Conditions		
Survey of Existing Information	General reference material for design and construction of substructures	a) Design documents and construction records from typical construction examples b) Records of experiences from persons concerned and opinions of experts
Survey of Surrounding Environment	Study of the effects of construction works on environment	a) Present buildings, noise levels, vibration levels, ground movement, water level and quality in wells, traffic conditions, etc. b) Existence of special environments including forests, riverheads and hot springs
Survey of Working Environments	Understanding various restrictions and conditions on construction works	a) Working area; working space; width, alignment, and traffic restrictions on access roads b) Locations, amounts, and procedures for disposal of excavated soil and stabilizers c) Location and availability of electricity, water supply, sewerage, etc. d) Location, type, and scale of adjacent structures, buried structures, cables, etc.

2.2.2. Surveys for Specific Case

(1) Survey of Soft Ground

When designing and constructing structures on the soft ground, detailed investigations of consolidation settlement, negative skin friction, lateral ground movement and the stability of retaining and cofferdam walls are needed. As a result of these studies, it is important to evaluate the appropriate geotechnical parameters.

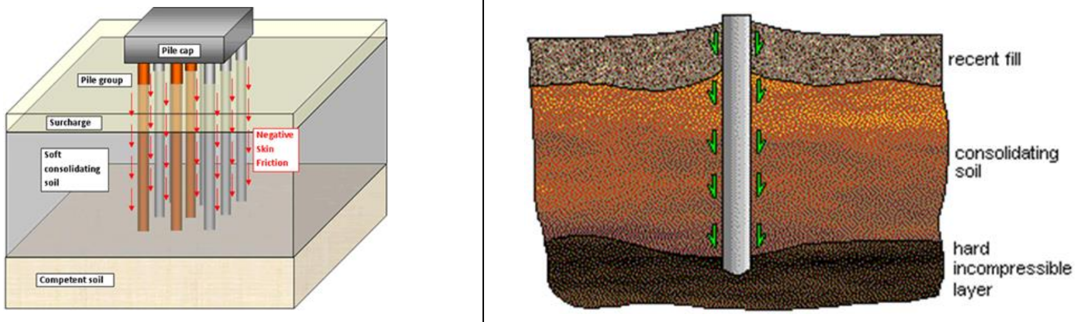


Figure 2.2-1 Negative Friction caused by Consolidation

(2) Survey of Ground Likely to become Unstable during an Earthquake

(i) Liquefaction Assessment

A liquefaction assessment is needed for saturated sandy ground where soil liquefaction is likely to occur during an earthquake. As a rough estimation, the classification of the grounds shown in Table 2.2-2 or historical records of the occurrence of soil liquefaction should be referred.

Table 2.2-2 Geographical Ground Conditions in terms of Probability of Occurrence of Liquefaction

Probability	Geographical Ground Conditions
(A) High	Active riverbeds, Dry Riverbeds, Areas Filled or Reclaimed at Coastal Areas, Lakes, Marshes and Rice Paddies
(B) Moderate	Alluvial Lowlands and Tablelands with Shallow Ground Water Tables
(C) Low	Plateaus, Hills, and Mountainous Lands

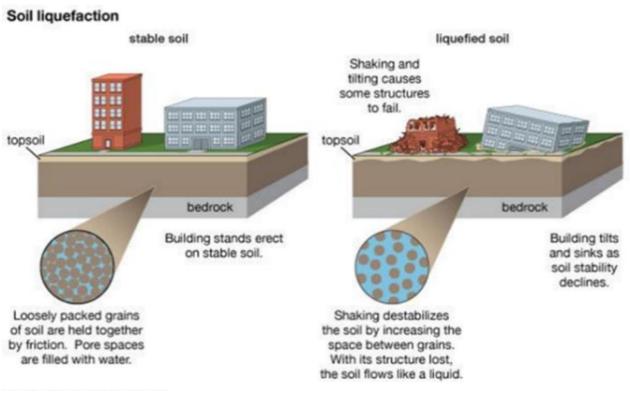


Figure 2.2-2 Liquefaction Image

Figure 2.2-3 Damages caused by Liquefaction

(3) Other Specific Case

(i) Mountain Areas

When landslides, slope failures, and debris flows are likely to occur, existing information focusing on the results of geological surveys should be collected as needed. Furthermore, with reference to past disasters that occurred nearby, substructure types, construction methods, and subsidiary construction methods shall be examined.

Figure 2.2-4 Rocky Ground

Figure 2.2-5 Landslide

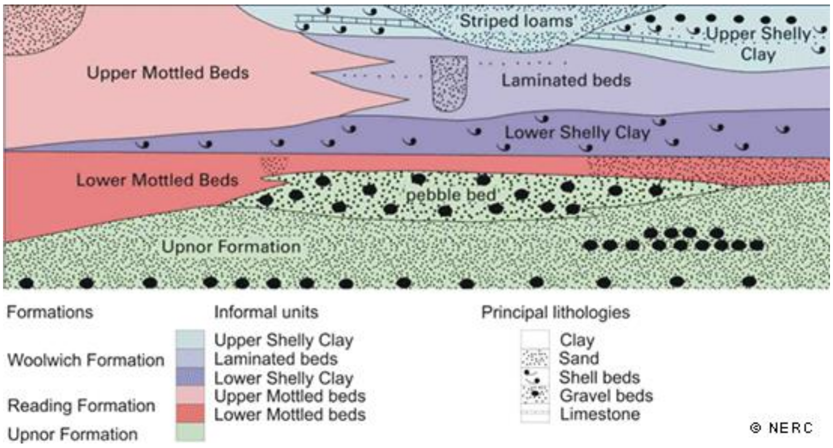


Figure 2.2-6 Geotechnical Fearers on Mountain Areas

(ii) Survey of Areas Prone to Landslide

When a bridge construction site is located in an area prone to landslides, or when the possibility of the occurrence of a landslide needs to be examined at the construction site, the following surveys shall be performed:

Figure 2.2-7 Landslide

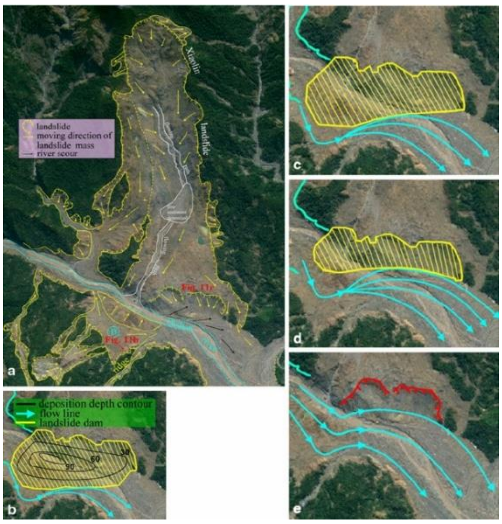


Figure 2.2-8 Aerial Photographs

CHAPTER 3. GEOTECHNICAL INVESTIGATION

3.1 General

The results from geotechnical investigations are key factors for determining overall bridge types.

Two geotechnical investigations, a preliminary survey and a principal survey, shall be performed in accordance with the design process.

3.2 Preliminary Surveys

In order to understand the approximate properties of the soil layers at the bridge site, and to obtain information necessary for selecting foundation type and conducting a preliminary design and principal survey plan, the following surveys shall be performed.

3.2.1. Survey of Existing Geotechnical Materials

Surveys of existing information are conducted to comprehend the outline of the geographical and geotechnical features at the site through existing geotechnical investigation data, geographical maps, and aerial photographs.

- Design drawings from any previous structure at the site.
- Previous site investigation reports, borehole logs, penetrometer results and construction experience.
- Geological maps, acid sulphate soils risk maps, survey data and records.
- Hydrological data.
- Aerial photographs.
- Existing traffic data.
- Local knowledge and resources.

3.2.2. Site Reconnaissance

Site reconnaissance is used to evaluate subsurface geology from the properties of rocks and soils observed at the surface. In other words, geological plans are prepared by combining sectional geological maps made from rock outcrops and other properties along rivers and roads in the survey area. Legal and physical aspects of access to site, for example, access for drilling rigs, backhoe, etc.

- Availability of any services or supplies of water, electricity, earthworks plant.
- Buried or overhead services.
- Photographs of surface conditions.
- Traffic control requirements.
- Possible effects of the investigation techniques on the environment (for example - ground disturbance, water discharge, vegetation removal, noise etc.)
- On-ground survey details.

- Tide, river level or other natural constraints.
- Record the type of vegetation in the area (for example - certain type of vegetation indicates shallow groundwater table)
- Notes on any exposed geology, for example - the presence of boulders, bedrock exposure, swamps etc.

3.3 Principal Surveys

The principal survey to identify ground conditions, construction conditions, and geotechnical parameters for the detailed design of foundations shall generally consist of the following:

(1) Boring

(2) Sampling

(3) Sounding

(4) Laboratory test

(5) Rock tests

(6) Underground water survey

(7) Loading tests

(8) Geophysical exploration and geophysical prospecting

(9) Survey of toxic gas and anoxia air

An example of a flowchart for planning principal surveys is shown in Figure 3.3-1. An overview of the stages is as follows.

A. Scheme of Surveys:
The extent and test procedures (test procedures and conditions) should be decided in view of various factors including bridge type, construction procedures, field conditions, design calculations, and characters of surveys.

↓

B. Implementation of Surveys: ← Additional surveys should be conducted, if necessary.

↓

C. Review of Survey Results:
- Examination and modification of measured values
- Evaluation of groundwater, ground layers, and geotechnical properties, and review of foundation types and design calculation procedures, when necessary.

→ Additional surveys should be conducted, if necessary.

↓

D. Evaluation of Geotechnical Parameters for Design

Figure 3.3-1 Flowchart for Planning Principal Surveys

3.3.1. Boring and Sounding (Standard Penetration Tests)

Boring is performed to understand geological formations and to measure groundwater tables. Accordingly, it is necessary to select adequate boring methods and bore diameters in accordance with appropriate sampling methods and in-situ testing methods. Therefore, rotary boring is normally employed in view of the above-mentioned survey techniques.

It is important to carefully select bore sites, numbers, and depths required for the ground survey. Standard penetration tests (SPT) are often employed in conjunction with boring. Following is a procedure of Standard penetration tests (SPT).

Figure 3.3-2 Boring Survey

1) Driven into the ground at the bottom of a borehole by blows from a slide hammer with a mass of 63.5 kg (140 lb.) falling through a distance of 760 mm (30 in).

2) Sum of the number of blows required for the second and third 6 in. of penetration is termed the "standard penetration resistance" or the "N-value".

3) In cases where 50 blows are insufficient to advance it through a 150 mm (6 in) interval the penetration after 50 blows is recorded.

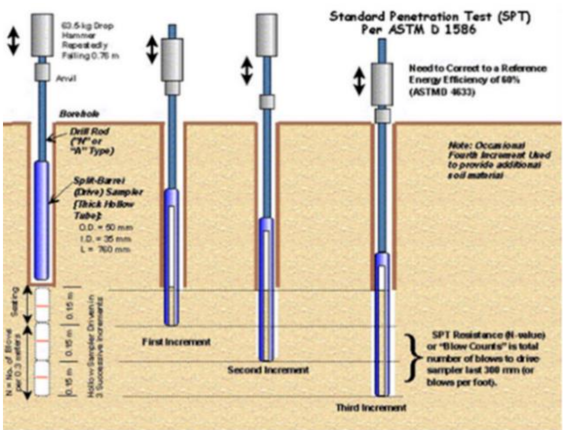


Figure 3.3-3 Standard Penetration Test

In cases of gravel layers, the SPT tends to take high values due to the inevitable impacts with individual stones. In such cases, the N values should be modified by carefully reviewing a relation between blow count and penetration.

The in-situ vane shear test is a method to directly obtain the shear strength (mainly cohesion) of a soil in-situ.

The portable cone penetration test, double-tube electric cone penetration test, and Swedish sounding are used to examine the hardness and density of soils. These methods are often combined with other methods. The locations, depths, and number of tests should be determined in view of the purpose.

<u>Procedure of SPT</u>

3.3.2. Sampling

Sampling is performed to prepare specimens for observation and various laboratory tests. Specimens can be classified as either "disturbed" or "undisturbed" and used for the laboratory tests shown in Figure 3.3-4 & Figure 3.3-5.

The sampling locations shall conform to the descriptions in below.

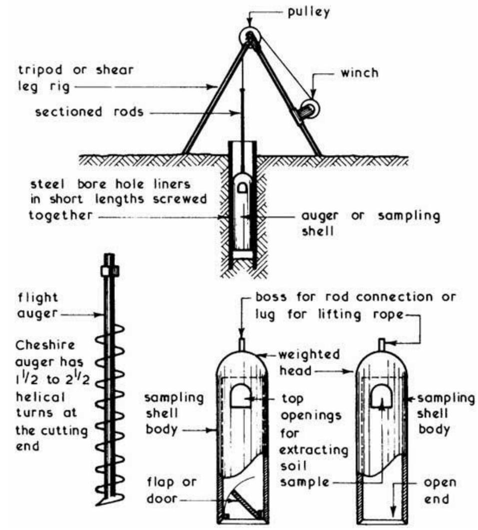


Figure 3.3-4 Samples	Figure 3.3-5 Sampling

3.3.3. Laboratory Test

Soil tests consist of tests to obtain the physical properties of soils and tests to obtain the mechanical properties of soils. The physical properties of soils include the density of the soil particles, the water content, grain size, unit weight, void ratio, etc.

(1) Unconfined Compression Test

The unconfined compression test can be employed as a simple test for clay soils in place of an undrained tri-axial compression test. However, the strengths obtained for hard clay soils or clay soils with a high sand content may be lower than the actual values due to the effects of disturbance and brittle failure of the specimens during sampling. In addition, the strength of clay soils with a high sand content may be underestimated due to the fact that the loading conditions that may not be appropriate for the undrained conditions. Therefore, in such cases, the test results should be modified in view of the plastic index of the soils or the results of other tests such as tri-axial compression tests.

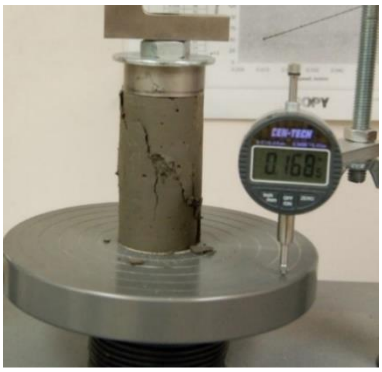


Figure 3.3-6 Unconfined Compression Test

(2) Tri-axial Compression Test

When performing tri-axial compression tests, the drainage conditions should be measured in view of the soil properties and time-dependent loading properties. Further, consolidation conditions during the test should be measured appropriately. Even when increases in ground strength after the construction of a bridge can be expected due to consolidation of the ground under the foundations, the original strength of the ground is often used. Confining pressures during a test should be appropriate because high confining pressures may result in excessive strength estimates.

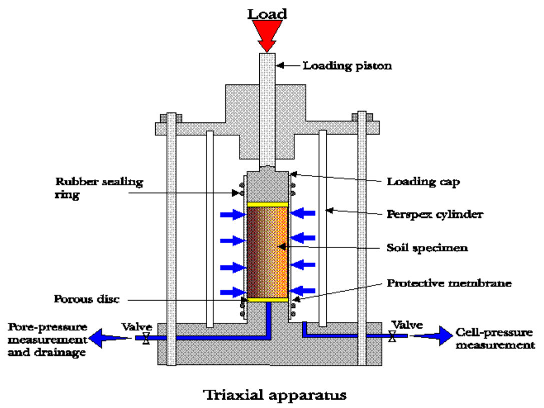


Figure 3.3-7 Tri-axial Compression Test

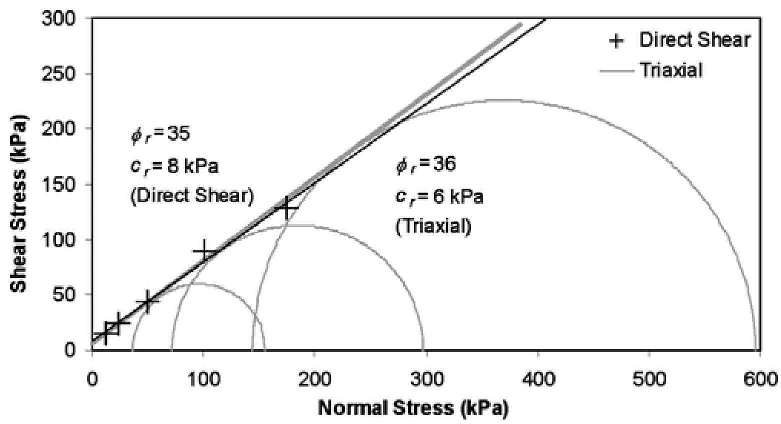


Figure 3.3-8 Mohr's Circle

3.3.4. Groundwater Survey

Groundwater surveys can be classified into surveys on the groundwater itself and surveys on aquifers as shown in Table 3.3-1, which shows the major items of groundwater surveys.

Table 3.3-1 Groundwater Survey

	Survey Items	Survey Methods
Survey on Groundwater	Measurement of groundwater table	Groundwater table measurement using wells and boring
	Measurement of pore-water pressure	Pore-water pressure measurement
	Measurement of flow direction and velocity	Water temperature, specific resistivity, tracer measurement and velocity measurement
	Water quality analysis	Hardness, specific resistivity, various chemical analyses, pH
Survey on Aquifers	Distribution area and thickness	Boring, electric prospecting, electric logging, groundwater logging
	Permeability	Pump test, permeability test
	Physical properties	Grain-size test, measurement of void ratio, electric logging

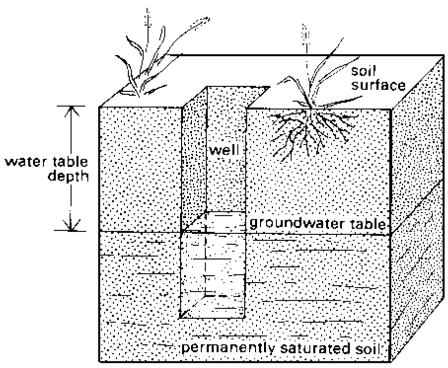


Figure 3.3-9 Groundwater Survey

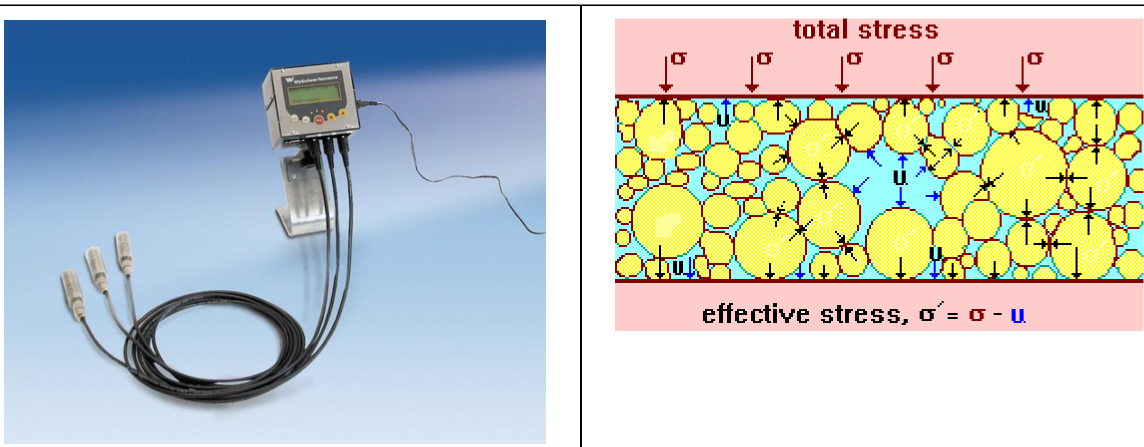


Figure 3.3-10 Measurement of Pore-water Pressure

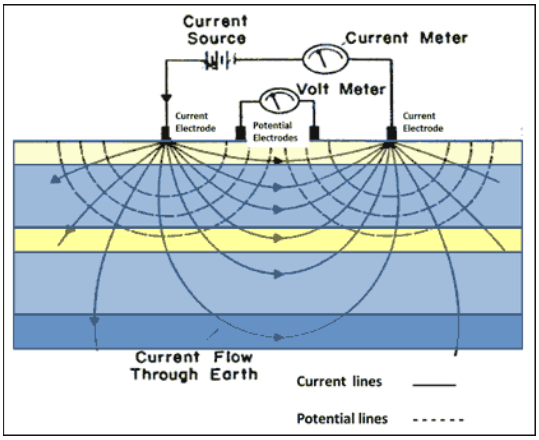


Figure 3.3-11 Electric Logging

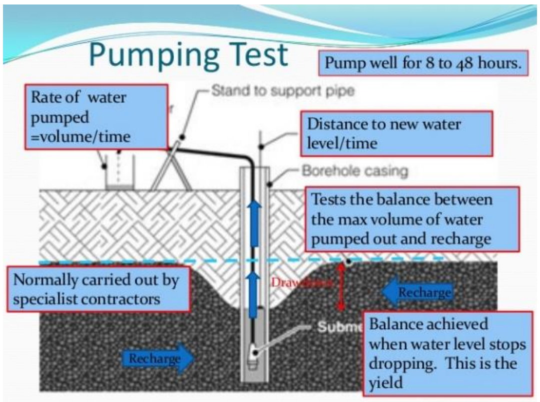


Figure 3.3-12 Pumping Test

3.3.5. Loading Test

Loading tests are used to determine the bearing capacities, subgrade reactions, and spring constants of grounds and piles by direct loading and consists of plate bearing tests, bore-hole loading tests, and vertical or horizontal loading tests of piles. A block shear test is used for rocky ground.

Ground bearing capacities and other values should be determined from the results of not only loading tests, but also those of soundings, soil tests, and examination of the geological structure.

As the coefficient of subgrade reactions and spring constants determined from loading tests may vary according to the soil type, loading conditions, size and shape of loading area, pile length, loading pattern, and construction method, they should be determined according to the purpose.

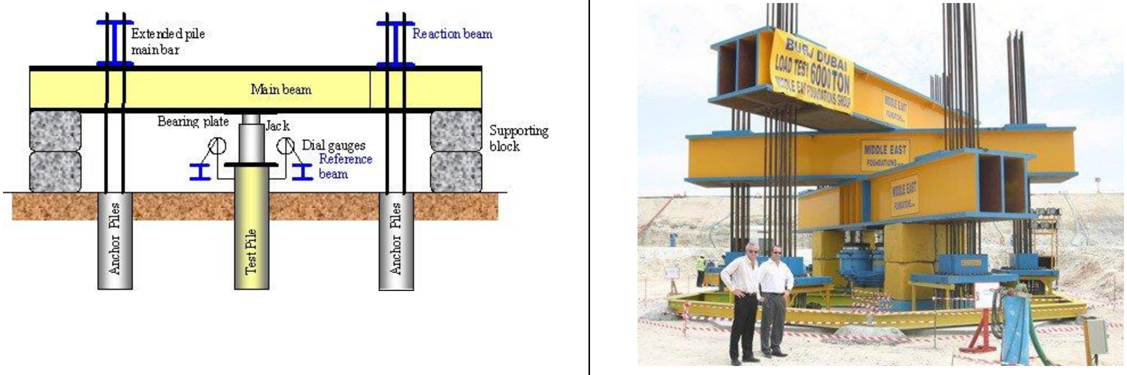


Figure 3.3-13 Loading Test

3.3.6. Survey of Toxic Gas and Anoxia Air

Various hazardous substances, mostly gaseous, may sometimes accumulate in the ground. Toxic gas may be released during the construction of bridge substructures. Further, some soil layers with a high mineral content may cause anoxia, because of its considerable deoxidizing properties. The existence of toxic gas and anoxia air is a critical problem affecting the selection of substructure design and construction methods.

Inappropriate selection may result in serious accidents during construction. Accordingly, when the existence of such gases in a soil layer is estimated during boring, the characteristics of the layer should be fully examined by taking additional specimens. In cases when these may affect the selection of substructure type and construction methods, detailed surveys should be performed at the location and depth of the gas.

Table 3.3-2 Laboratory Tests

Survey Methods	Types of Survey Methods	Soil Types	Samples	Survey Locations	Survey Items
1. Boring	1. Rotary boring 2. Auger boring 3. Wash boring	All types Clayey soil, sandy soil Soft clayey soil, soft sandy soil		In situ	1. Soil properties, strata, thickness and depth, groundwater table
2. Sampling	1. Core tube sampling 2. Fixed piston types thin walled sampling 3. Denison sampling 4. Sand sampling 5. Foil sampling 6. Triple tube type sampling 7. Block sampling	All types Soft clay soil, sandy soil Hard clayey soil Sandy soil Clayey soil, rock	Disturbed(D) Undisturbed(U) U U U U U	In situ	1. Sampling, RQD (Rock quality Designation) (rock) 2. Sampling 3. Sampling 4. Sampling 5. Sampling 6. Sampling 7. Sampling
3. Sounding	1. Standard penetration test (SPT) 2. Vane shear test 3. Static cone penetration test (CPT) 4. Swedish sounding	Sandy soil, clayey soil, soft rock Soft clayey soil Sandy soil, clayey soil Sandy soil, clayey soil	D	In situ	1. N value, sampling 2. Shear strength 3. Cone bearing capacity 4. Penetration resistance

Survey Methods	Types of Survey Methods	Soil Types	Samples	Survey Locations	Survey Items
4. Soil and rock test	1. Geophysical property test 2. Unconfined compression test 3. Tri-axial compression test (including measurement of strains on specimen's side) 4. Direct shear test 5. Consolidation test 6. Supersonic propagation test 7. Creep test 8. Wetted decay test 9. Cycle tri-axial shear test	All types Clayey soil, rock All types Sandy soil, clayey soil Clayey soil Rock Rock Rock Rock	U, D U U U U U U U U	Laboratory	1. Grain-size, consistency, density, water content 2. Unconfined shear strength, modules of deformation 3. Cohesion, angle of shear resistance, modules of deformation (Capable of measuring small strain on specimen's side) 4. Angle of shear resistance, modules of deformation 5. Compression index, coefficient of consolidation, yield stress of consolidation 6. Supersonic propagation velocity 7. Creep coefficient 8. Degree of wetted decay 9. Shear modules, strain-dependent, damping ratio, dynamic Poisson's ratio, cyclic shear strength ratio
5. Groundwater survey	1. Measurement of ground water table 2. Measurement of pore-water pressure 3. Measurement of flow direction and velocity 4. Permeability test	All types		In situ	1. Ground water table 2. Pore-water pressure 3. Flow direction and velocity 4. Coefficient of permeability

Survey Methods	Types of Survey Methods	Soil Types	Samples	Survey Locations	Survey Items
6. Loading test	1. Plate bearing test 2. Horizontal loading test in bore 3. Shear friction test in bore 4. Vertical loading test of piles 5. Horizontal loading test of piles 6. Pile pill-put test 7. Block shear test 8. Quick loading test of piles	All types		In situ	1. Vertical bearing capacity, coefficient of subgrade reaction 2. Modules of deformation 3. Modules of deformation, cohesion, angle of shear resistance 4. Vertical bearing capacity, axial spring constant of piles 5. Coefficient of subgrade reaction 6. Pull-out resistance (or Tensile bearing capacity) 7. Cohesion, angle of shear resistance 8. Vertical bearing capacity, axial spring constant of piles

CHAPTER 4. POINT OF CONSIDERATION FOR CONSTRUCTION

4.1 Checking and Confirmation for Design Calculation

Before construction, it is important to understand design concept. Moreover, also, checking and confirmation of accuracy of calculation and premise is essential.

Sometimes, the situation assumed at design stage is not same as the situation of construction stage. If necessary, the design concept should be changed and adapted to the situation of construction.

For instance, if it is appeared that the difference of support layer depth between design concept and the result of test pile or additional boring at the site, the design for foundation pile have to be changed based on the result of test pile and additional boring. Therefore, site engineer required to understand design concept and be able to discuss with design engineer.

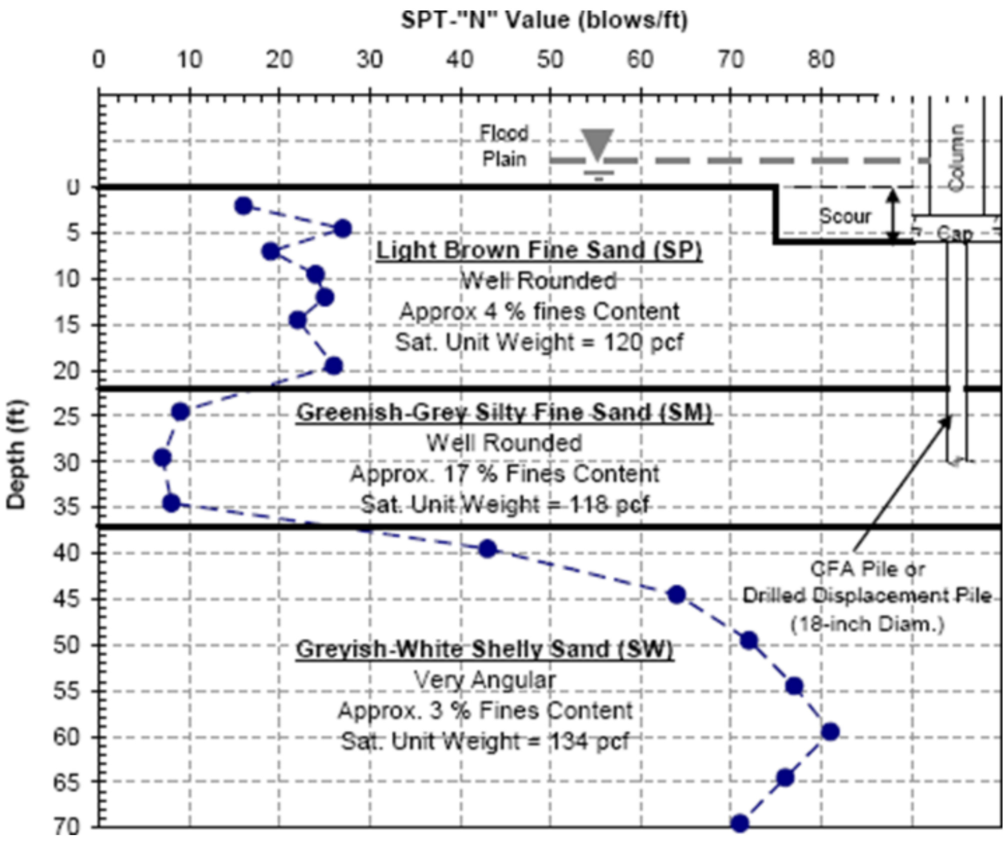


Figure 4.1-1 Geographical Investigation

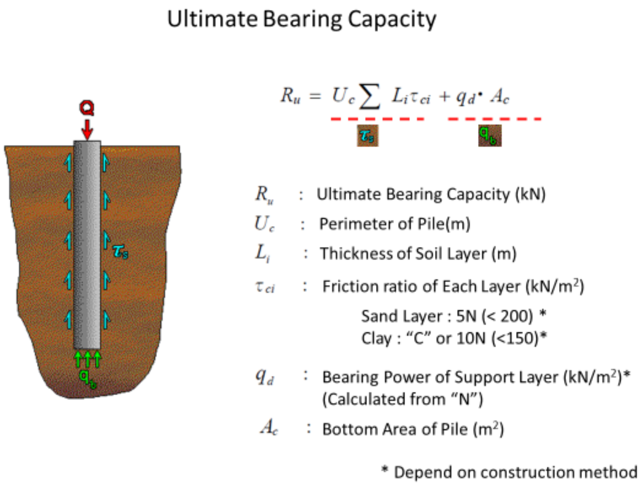


Figure 4.1-2 Calculation of Bearing Capacity

4.2 Survey for Construction

4.2.1. Survey for Soil and Groundwater Condition

Basically, detailed survey might be conducted in advance of design stage. However, actual condition of construction site might be different from designed. If needed, additional survey should be conducted at construction stage, boring test, ground water survey or other.

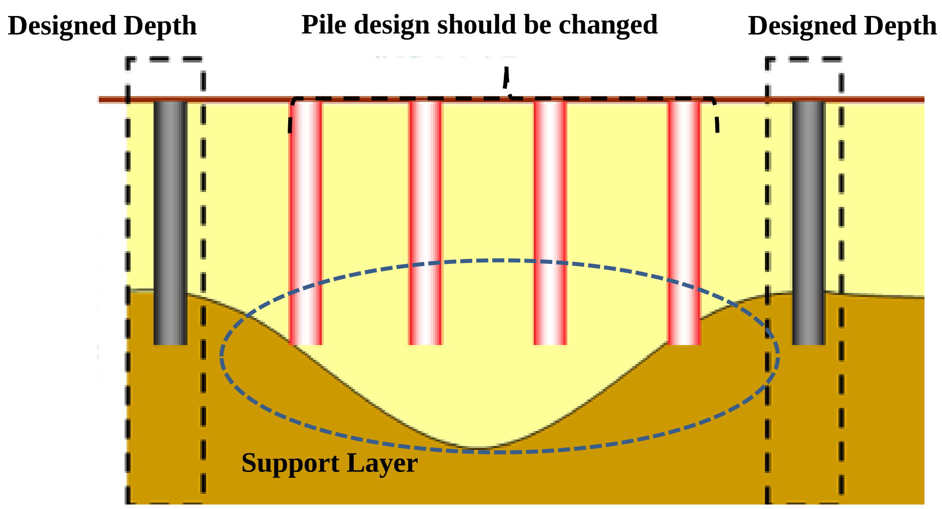


Figure 4.2-1 Difference between Geographical Investigation and Actual Site Condition

4.2.2. Inspection for Construction Situation and Environment

If construction work could influence nearby, it is necessary to consider effect such as noise, vibration, geotechnical movement, etc.

Prior to constructing a substructure, surveys shall be carried out which are necessary for preparing construction plans and controlling the construction work.

(1) Surveying Soil Property and Groundwater

It is common practice to make close survey of soil property and groundwater conditions at a designing stage by means of boring and other tests. However, properties of soil layers and groundwater at a construction site are one of the vital factors that will affect success, easiness, and reliability of a foundation construction work. Hence, it is necessary to fully review results of soil property surveys which are conducted at a designing stage, and if a foundation type of that substructure and/or soil layer conditions so require, a move vigilant survey should be carried out by means of additional series of boring and other tests.

(2) Surveys during Construction Work

When implementing a construction work, environmental changes which may affect conditions surrounding the work site should be checked, if necessary, by measuring noises, vibrations, well water levels and quality, and land subsidence and by observing behaviors of adjacent structures.

Whether or not harmful gases or irrespirable atmosphere are produced at a construction site is a vital factor which affects life of workers: they should be fully checked during as well as before the work. Especially when conducting a foundation work by employing compressed air near the work site where a pneumatic caisson or a cast-in-place pile is being installed, it is feared that the compressed air may lose oxygen initially contained in it while it passes through gravel layers and then it may flow to the installation site. Hence, due care should be always taken to assure safety in the work by constantly checking oxygen content in the atmosphere together with full coordination with persons in charge of the foundation work.

CHAPTER 5. CONSTRUCTION PLANNING

5.1 Execution Program

An execution program shall be prepared for performing the actual construction work, by which it can be confirmed that the construction will be conducted satisfying the various conditions taken as premises in the design.

Construction of substructures depends greatly on execution of field work and is composed of a combination of diversified jobs. Regarding a construction method, different measures are taken against different types of soil layers and different constructing conditions. Functions of completed foundations are greatly affected by whether or not the construction method is appropriate, whether or not techniques used are superior, and whether or not the execution program was closely reviewed when formulating it. Therefore, it is important to know well beforehand the various conditions taken as premises in the design, fully examine the various matters involved in the construction to make it possible to confirm that the construction will be performed satisfying these conditions, and plan to satisfy the dimensions and functions given to the foundation throughout the entire process and make safe construction possible.

The execution program should contain such main items as mentioned below:

5.1.1. Process Chart

The process chart should be composed of a construction work process of each substructure, an execution process of the whole work including temporary facilities, and, if constructing more than one foundation, a plan view describing order of construction procedures.

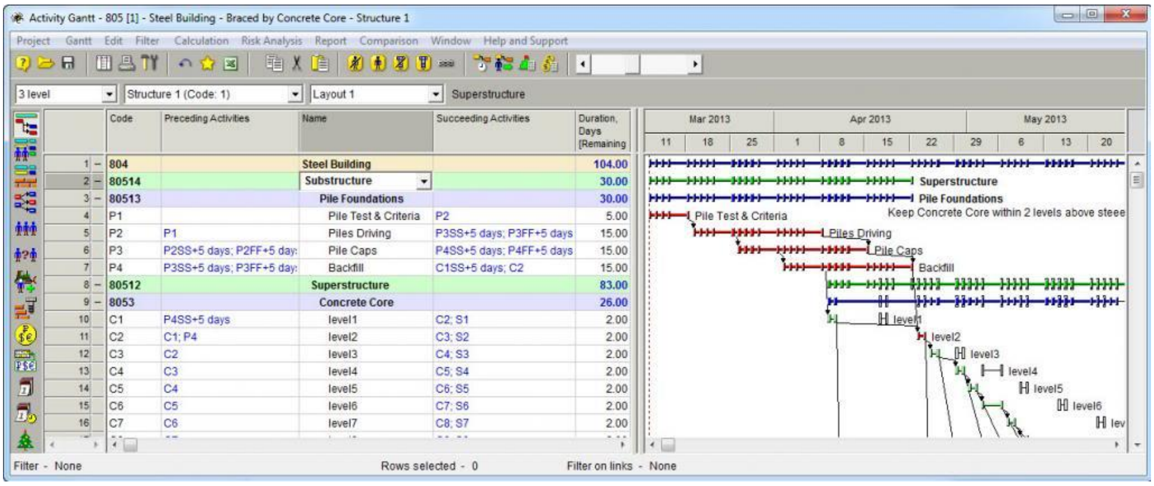


Figure 5.1-1 Process Chart Example (1)

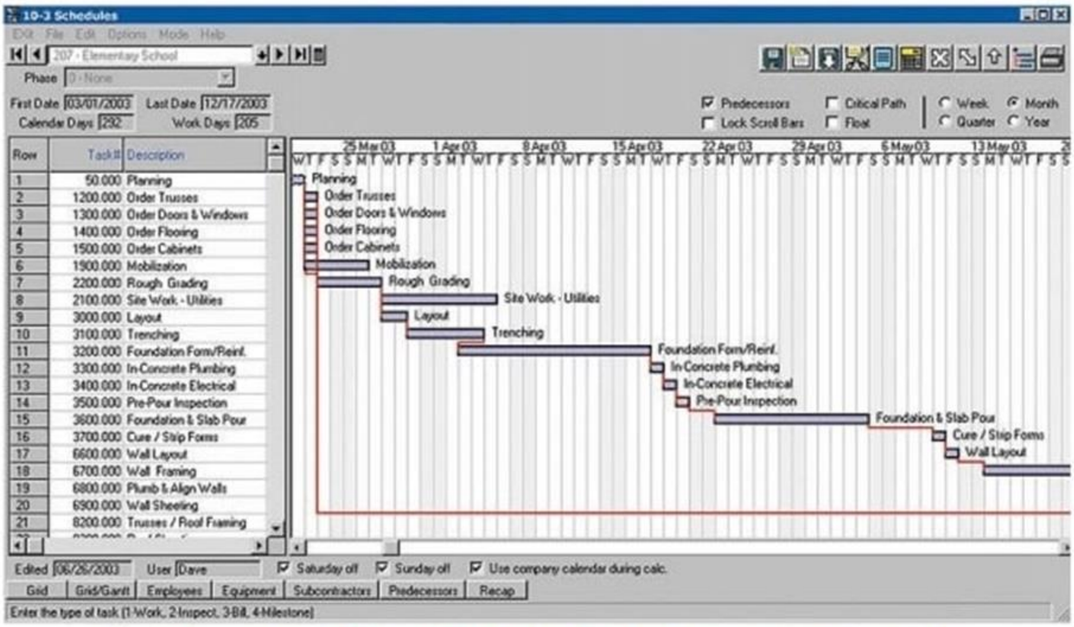


Figure 5.1-2 Process Chart Example (2)

5.1.2. Construction Procedures

The construction procedures should clarify basic contents of the construction plan for both temporary facilities and main structures. Here, the various conditions taken as premises in the design, etc. should be clarified.

5.1.3. Construction machinery and instruments and temporary facilities including their arrangement

Planned composition and arrangement should be clarified as to construction machinery and instruments and temporary facilities to be used.

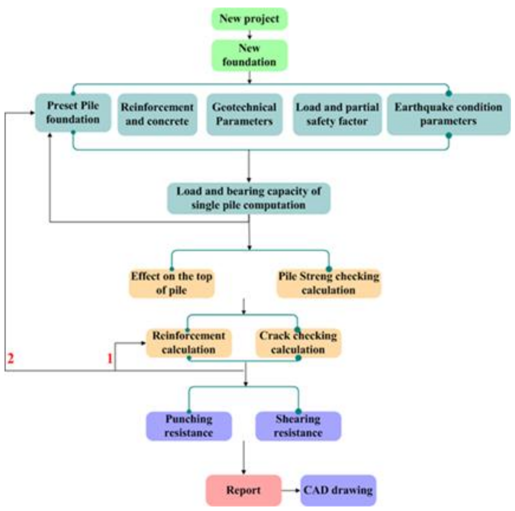


Figure 5.1-3 Construction Procedures

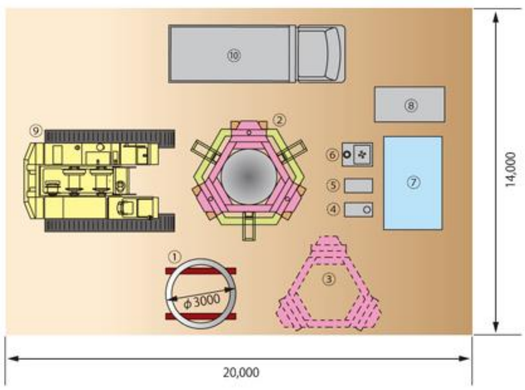


Figure 5.1-4 Machinery Arrangement

5.1.4. Work-recording Methods

Work records must be prepared in a manner to include records for respective working days and to allow situations of the whole work of respective foundations to be easily understood. When keeping the records, consideration should be taken to offer reference data to engineers who will engage in a similar work in the future as well as those who are presently engaged in the work.

Table 5.1-1 Items for Execution Program

Items	**Contents**
Survey for construction planning	- Confirmation of design books - Legislation - Geotechnical condition - Survey for situation of construction - Existing structures
Scheduling	Manpower allocation
	Temporary facilities
	Material supply plan
	Transportation plan
	Scheduling for details
Quality control plan	- Organization - Requirement for quality - Systems for confirmation for quality - Planning for test pile
Safety plan	- Safety control plan - Organization for Safety control
Environmental consideration	- Vibration, Noise, Waste - Groundwater pollution
Other	- Gas emission, etc.

5.2 Work Record

Since the overall work record about the construction will serve as important data in the construction of superstructure and maintenance of the foundation, the following shall be recorded and kept as a work record:

(1) Name and location of works; names of implementing party and constructor; processes to be implemented

(2) Specifications arrangement diagrams, and structural drawings of substructures, and outlines of soil layers

(3) Arrangement and capabilities of temporary facilities, construction methods, and machines and instruments used

(4) Construction control

(5) Environmental measures and safety measures

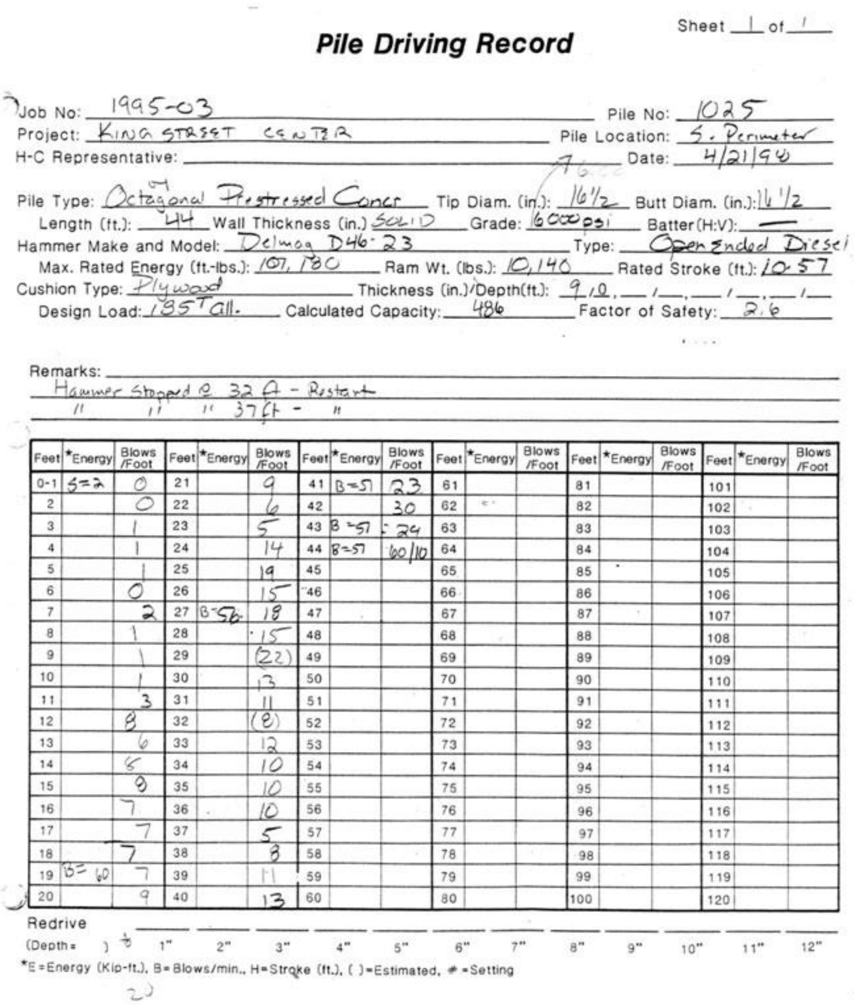
(6) Special situations happened during the work and countermeasures taken

(7) Work records of respective processes

(8) Record of surveys and tests performed in the work

(9) Other matters to be carried over to the subsequent work and maintenance.

To have correct knowledge of situations at each stage of a construction work by preparing a comprehensive record during and after construction is helpful to prevention of erroneous recording and gives great effects to subsequent work to be conducted at the same site. Accumulation of such data is important for the future maintenance. Therefore, when constructing a substructure, the work records as given in the article should be written down and kept without fail after completion of the work. When conducting a test using a test pile as well, not only the items in (3) to (8), but also its measures and evaluation results must be recorded.



Pile Driving Record

Sheet 1 of 1

Job No: 1995-03 Pile No: 1025
Project: KING STREET CENTER Pile Location: S. Perimeter
H-C Representative: Date: 4/21/98

Pile Type: Octagonal Prestressed Concr Tip Diam. (in.): 16 1/2 Butt Diam. (in.): 16 1/2
Length (ft.): 44 Wall Thickness (in.) SOLID Grade: 6000 psi Batter (H:V): —
Hammer Make and Model: Delmag D46-23 Type: Open Ended Diesel
Max. Rated Energy (ft.-lbs.): 107,180 Ram Wt. (lbs.): 10,140 Rated Stroke (ft.): 10.57
Cushion Type: Plywood Thickness (in.)/Depth(ft.): 9 / 0 , / , / , /
Design Load: 185T all. Calculated Capacity: 486 Factor of Safety: 2.6

Remarks:
Hammer Stopped @ 32 ft - Restart
" " " 37 ft - "

Feet	*Energy	Blows /Foot	Feet	*Energy	Blows /Foot	Feet	*Energy	Blows /Foot	Feet	*Energy	Blows /Foot	Feet	*Energy	Blows /Foot	Feet	*Energy	Blows /Foot
0-1	S=2	0	21		9	41	B=51	23	61			81			101		
2		0	22		6	42		30	62			82			102		
3		1	23		5	43	B=57	24	63			83			103		
4		1	24		14	44	B=57	60/10	64			84			104		
5		1	25		19	45			65			85			105		
6		0	26		15	46			66			86			106		
7		2	27	B=56	18	47			67			87			107		
8		1	28		15	48			68			88			108		
9		1	29		(22)	49			69			89			109		
10		1	30		13	50			70			90			110		
11		3	31		11	51			71			91			111		
12		8	32		(8)	52			72			92			112		
13		6	33		12	53			73			93			113		
14		8	34		10	54			74			94			114		
15		8	35		10	55			75			95			115		
16		7	36		10	56			76			96			116		
17		7	37		5	57			77			97			117		
18		7	38		8	58			78			98			118		
19	B=60	7	39		11	59			79			99			119		
20		9	40		13	60			80			100			120		

Redrive
(Depth =) 1" 2" 3" 4" 5" 6" 7" 8" 9" 10" 11" 12"
*E = Energy (Kip-ft.), B = Blows/min., H = Stroke (ft.), ( ) = Estimated, # = Setting

Figure 5.2-1 Pile Driving Record

5.3 Quality Control Plan

5.3.1. Static Load Test

Static loading test was operated as a repetitive loading test referring to ASTM standard.

1) Set the load jack and the test beam on the test pile.
2) Make possible to load by hydraulic jack connecting the reaction anchor and test beam.
3) Install the strain gauge on the two-way to measure the settlement of the load.
4) Practice the load test maintaining the load regularly by using the load cell.

Figure 5.3-1 View of Static Loading Test	Figure 5.3-2 View of Static Loading Test

A typical load test arrangement is shown in Figure 5.3-3. Reaction to the jack load is provided by a steel frame that is attached to an array of steel H-piles located at least 3 m away from the test pile. Pile head deflections were measured relative to a fixed reference beam using dial gauges. Telltale measurements were made in reference to the pile head or the reference beam using dial gauges. Pile head and telltale deflection data were recorded for each loading increment.

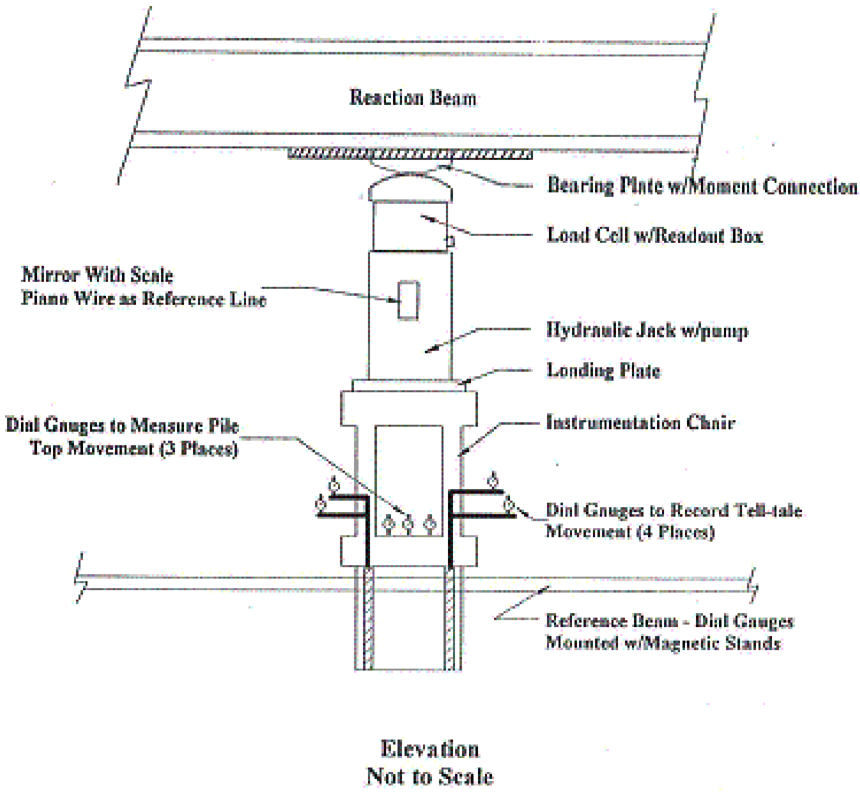


Figure 5.3-3 Static Load Test

(1) Reaction Frame

Install two or more reaction piles, or anchors, for the reaction frame (Figure 5.3-2) after the installation of the test pile. For driven piles, locate these reaction piles not less than 10 ft. (3 m) or the sum of 5 reaction pile diameters and 5 test pile diameters (whichever of the two criteria is the greater distance) from the test pile or reference beam supports. For drilled shafts or micro-piles, locate these reaction piles not less than 10 ft. (3 m) or 5 reaction pile diameters (whichever of the two criteria is the greater distance) from the test pile or reference beam supports. These distances are measured between the faces of the test pile and reaction piles. Anchors, if used, must be designed with sufficient free length so as not to interfere with the load test pile or the reference system.

Design the reaction frame and reaction piles to resist four times the pile design load indicated in the contract documents without undergoing a magnitude of deflection exceeding 75 percent of maximum travel of the jack.

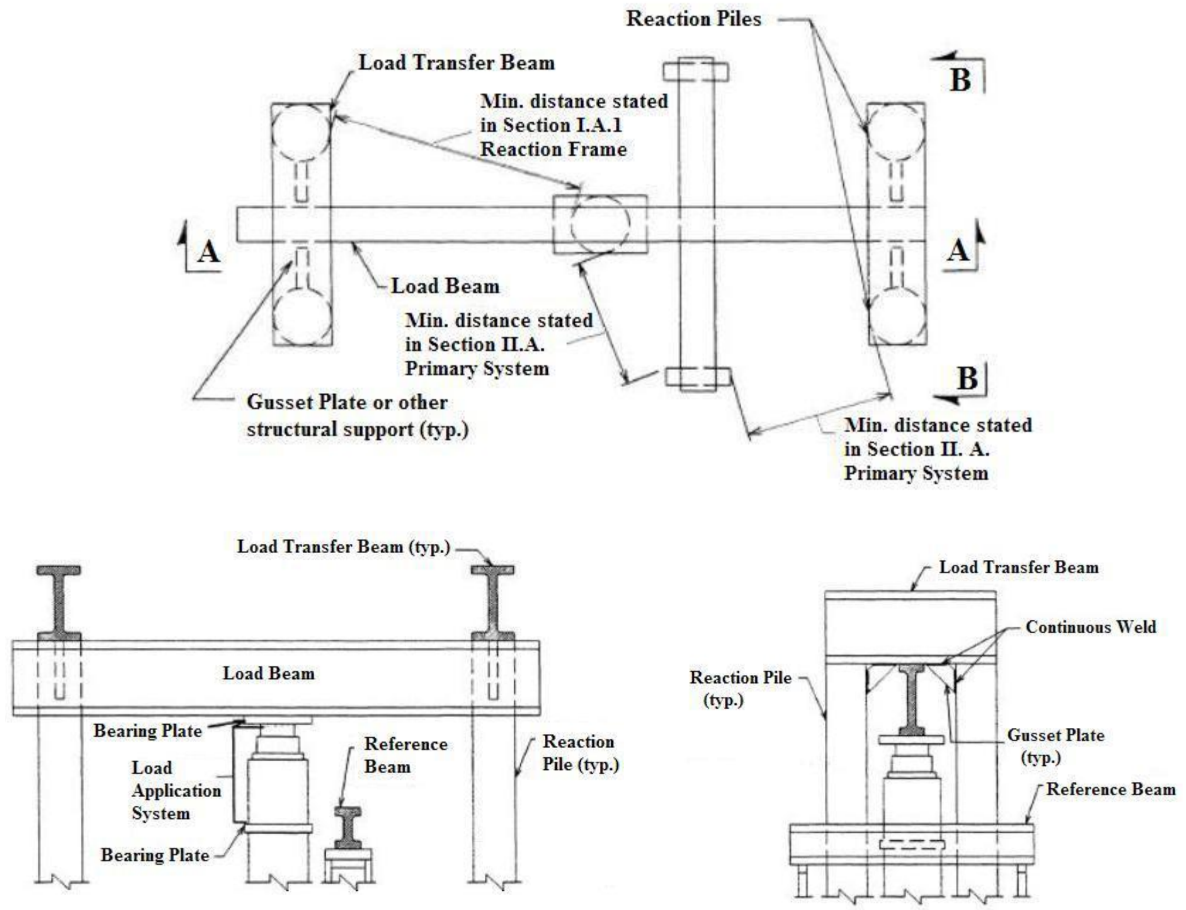


Figure 5.3-4 Typical Setup for a Reaction Frame

(2) Weighted Box or Platform.

Construct a weighted box or platform (Figure 5.3-5) over the test pile, supported on cribbing or on other piles installed after the test pile.

(i) Cribbing Support:

For driven piles, drilled shafts or micro-piles, locate the nearest face of the cribbing support not less than 10 ft. (3 m) or 5 test pile diameters (whichever of the two criteria is the greater distance) from the test pile or reference beam supports. Measure these distances between the test pile face and the nearest face of the cribbing supports. A greater spacing between the cribbing supports and test pile or reference system may be required to prevent foundation stresses caused by the cribbing from affecting the test.

(ii) Pile Support:

For driven piles, locate these support piles not less than 10 ft. (3 m) or the sum of 5 support pile diameters and 5 test pile diameters (whichever of the two criteria is the greater distance) from the test pile or reference beam supports. For drilled shafts or micro-piles, locate these support piles not less than 10 ft. (3 m) or 5 reaction pile diameters (whichever of the two criteria is the greater distance) from the test pile or reference beam supports. Measure these distances between the test pile face and the nearest face of the pile supports.

Design the load beam and transfer beam to resist four times the pile design load indicated in the contract documents, without undergoing a magnitude of deflection exceeding 75 percent of maximum travel of the jack. Load the weighted box or platform with earth, sand, concrete, water, pig iron, or other suitable material to obtain a total weight of at least four times the pile design load indicated in the contract documents.

The load beam for a reaction frame may bear on the load transfer beam with no connections. The load beam may need stiffeners at the points of bearing. The beam may need truss work, not shown in the figure, to prevent excessive bending and resulting ram extension in excess of the seventy-five percent (75%) of the maximum travel of the jack.

The pressure intensity exerted on the ground surface from any cribbing must not exceed the bearing capacity of the soil or cause settlement of the test pile and/or measurement system.

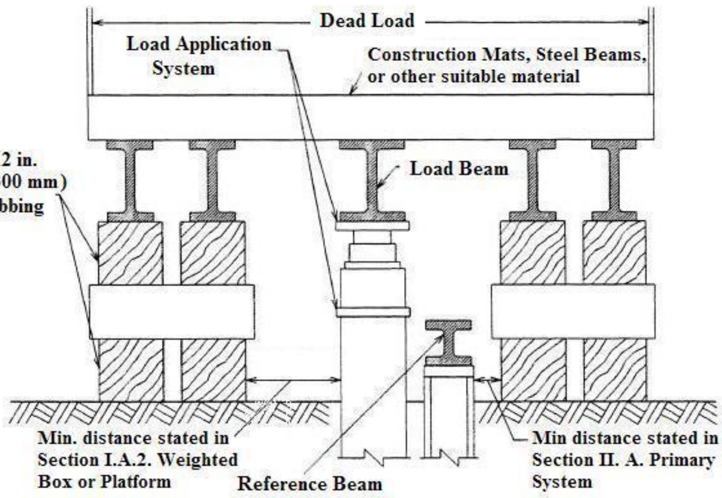


Figure 5.3-5 Typical Setup for a Weighted Box or Platform

An excerpt from the loading procedures for short-duration load test is given below:

1) Apply 25 percent of the allowable design load every one-half hour up to the greater of the following: [two alternatives are described; the most general is 200 percent of the design load]. Longer time increments may be used, but each time increment should be the same. At 100 percent of the design load, unload to zero and hold for one-half hour; then reload to 100 percent and continue 25 percent incremental loads. At 150 percent, unload to zero and hold for one-half hour; then reload to 150 percent and continue 25 percent incremental loads. In no case shall the load be changed if the rate of settlement is not decreasing with time.

2) At the maximum applied load, maintain the load for a minimum of one hour and until the settlement (measured at the lowest point of the pile at which measurements are made) over a one-hour period is not greater than 0.254 mm (0.01 inch).

3) Remove 25 percent of the load every 15 minutes until zero load is reached. Longer time increments may be used, but each shall be the same.

4) Measure rebound at zero load for a minimum of one hour.

5) After 200 percent of the load has been applied and removed, and the test has shown that the pile has additional capacity, i.e., it has not reached ultimate capacity, continue testing as follows. Reload the test pile to the 200 percent design load level in increments of 50 percent of the allowable design load, allowing 20 minutes between increments. Then increase the load in increments of 10 percent until either the pile or the frame reaches their allowable structural capacity, or the pile can no longer support the added load. If failure at maximum load does not

occur, hold load for one hour. At maximum achieved load, remove the load in four equal decrements, allowing 15 minutes between decrements.

(3) Load Test Example

Generally, load of test is planned on the basis of 200% of design load. In this test, however, we arranged the load 5,000kN to analyze the maximum bearing capacity of the pile from yield and ultimate load of the pile.

Example of the test results are summarized in Table 5.3-1 Load Test Result.

In general, two types of load deflection behavior were observed in the static load tests Figure 5.3-6 through Figure 5.3-11).

Table 5.3-1 Load Test Result

Test Pile No.	Time after Pile Installation (days)	Maximum Applied Load (KN)	Maximum Pile Head Displacement (cm)
1	13	3,122	1.7
2	20	3,558	2.4
3	15	3,447	1.6
4	33	3,447	2.4
5	23	3,781	1.6
6	6	3,105	2.2
7	30	1,512	1.4
8	24	1,014	0.5
9	17	3,612	2.6
10	6	3,558	1.7
11	9	3,959	2.4
12	10	3,167	2.0
13	84	2,384	1.3
14	10	2,891	4.1
15	30	2,535	1.3

Test pile No.7 (Figure 5.3-6) represents a condition where the axial deflection of the pile is less than the theoretical elastic compression (assuming zero shaft friction). This pile was loaded to 1,557 kN in five steps and at no point during the loading did the deflection exceed the estimated elastic compression of the pile. This behavior is attributed to shaft friction, which reduces the compressive forces in the pile and limits the settlement. The significant contribution of shaft friction is also apparent in the load distribution curve shown in Figure 5.3-7, which shows the load in the pile decreasing with depth. This behavior is typical of test piles No.1, No.2, No.5, No.7, No.8, No.10, and No.11.

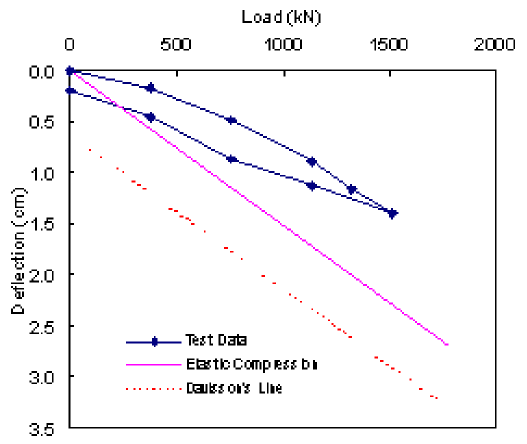


Figure 5.3-6 Deflection of Pile Head during Static Load Testing of Pile No.7.

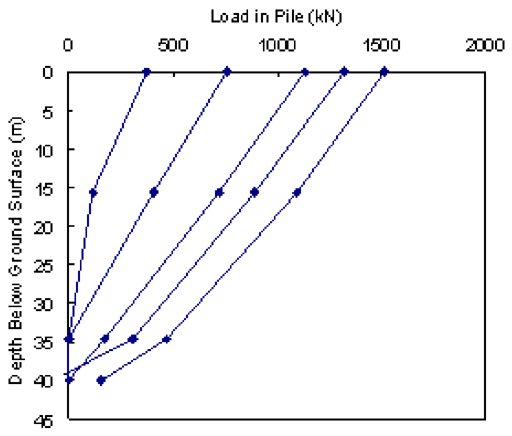


Figure 5.3-7 Distribution of Load in PileNo.7.

Test pile No.6 (Figure 5.3-8) represents a condition where the axial deflection is approximately equal to the theoretical elastic compression. This suggests that more of the applied loads are being distributed to the toe of the pile with less relative contribution of shaft friction. This is apparent in Figure 5.3-9, which shows negligible changes in the load within the pile with depth. This behavior is typical of test piles No.3, No.4, No.6, No.9, No.12, No.13, and No.14.

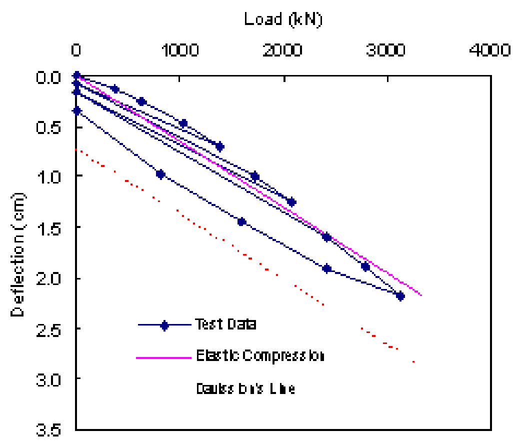


Figure 5.3-8 Deflection of Pile Head during Static Load Testing of Pile No.6.

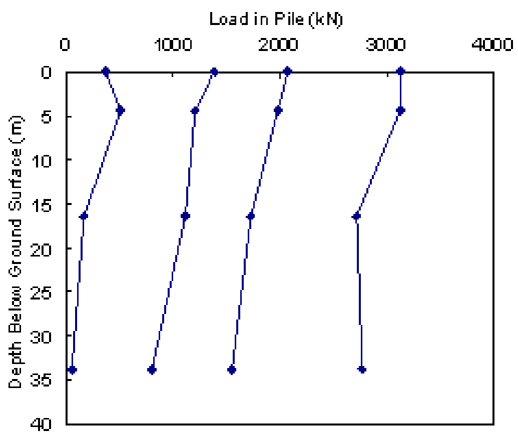


Figure 5.3-9 Distribution of Load in Pile No.6.

Of the 15 static load tests, only one test pile (No.14) was loaded to failure according to Davisson's criteria. These data are shown in Figure 5.3-10 and Figure 5.3-11. This pile showed a significant increase in the deflection at approximately 2,580 kN, subsequently crossing the Davisson's line at approximately 2,670 kN at a displacement of around 2.5 cm. The telltale data obtained near the toe of the pile indicated that the pile failed in plunging.

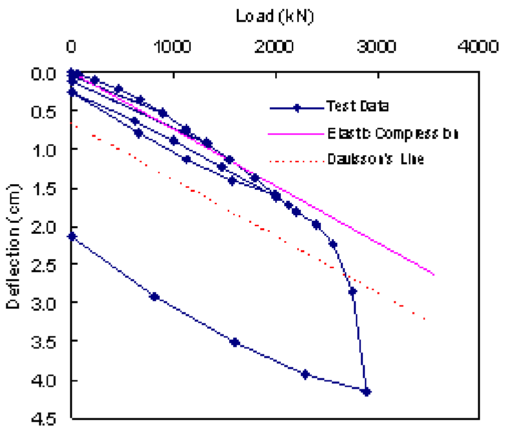


Figure 5.3-10 Deflection of Pile Head during Static Load Testing of Pile No.14.

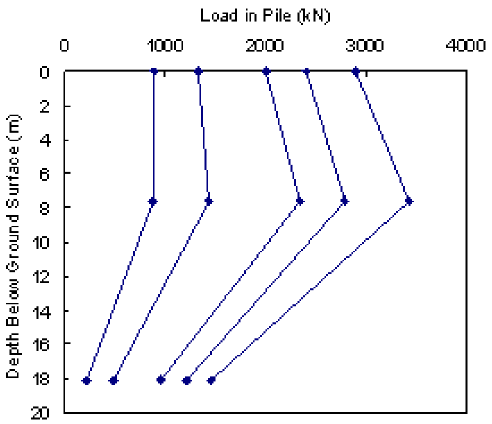


Figure 5.3-11 Distribution of Load in Pile No.14.

All test piles achieved the required ultimate capacities in the static load tests. The required ultimate capacities were determined by multiplying the allowable design capacity by a factor of safety of at least 2.0, as specified in the project specifications. A slightly higher factor of safety of 2.25 was used. Three of the 15 static tests did not demonstrate that 100 percent of the design load was transferred to the bearing soils. Two of the piles (No.7 and No.8) could not transfer the load to the bearing soils because of the high skin friction. Test pile No.10 could not demonstrate load transfer because the bottom telltale was not functioning.

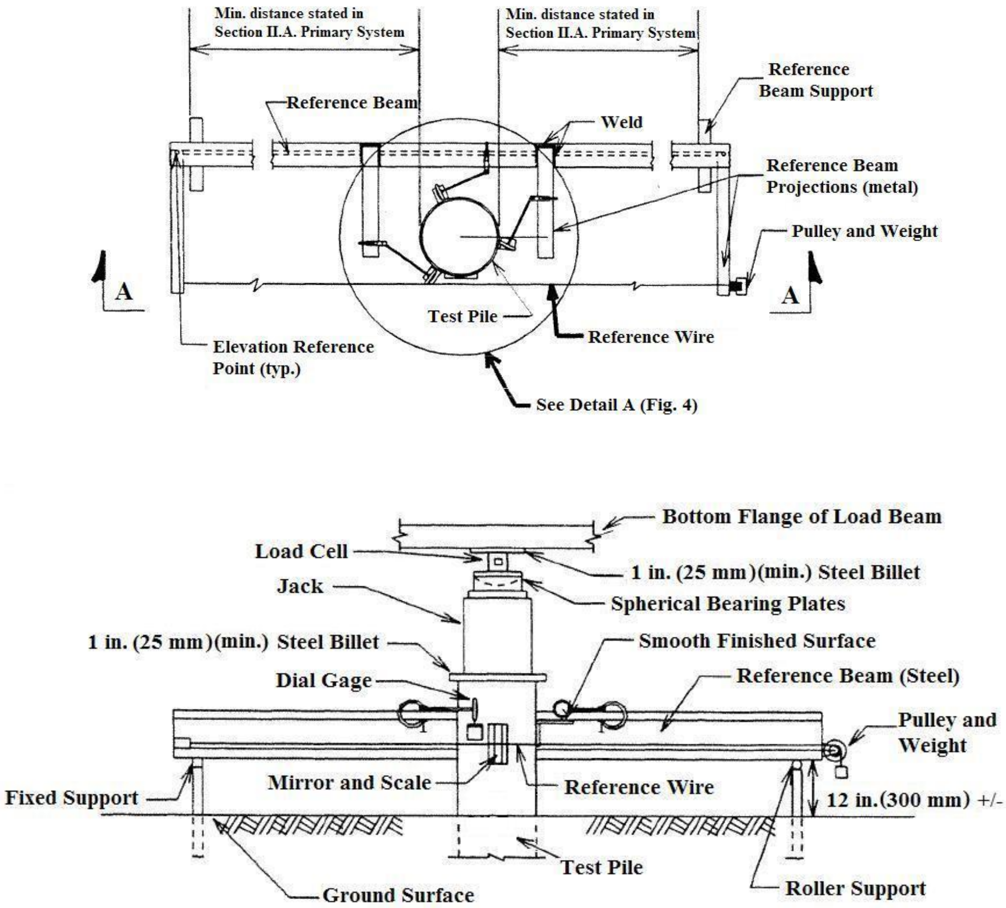


Figure 5.3-12 Distribution of Load in Pile No.14.

Figure 5.3-13 Static Load Test

Figure 5.3-14 Static Load Test

5.3.2. Test Pile

(1) Precast Pile

Test piling shall be conducted, in principle, prior to constructing a prefabricated pile. However, if the workability of piles at the construction site is fully comprehended, test pile installation may be omitted.

1) Test piling should be affected by selecting appropriate locations for each of abutment and pier foundations and using piles one to two meters longer than those which will be actually used in the construction work.
2) Finishing conditions for driving piles should be fully reviewed.
3) Should test piling results suggest necessity to modify lengths, thicknesses, and numbers of piles and their driving methods, they should be modified only after fully reviewing geologic columnar sections, soil layer conditions in design calculation, influences on superstructures, environmental problems, construction period, etc.

Table 5.3-2 Reported Items for Test Pile

Item		Contents
Preparation	General	Date, Weather, Soil condition, Pile measurement (type, size, shape)
	Machinery	Type of pile driver, Follower (size, shape), Cushion, Hammer(weight), Welding machine
Driving	General	- Construction method and procedure - Accuracy (position, inclination) - Other phenomenon during construction - Ground height
	Construction Record	- Time duration of each stage (preparation, positioning, welding, driving) - Number of times of driving - Drop height of hammer
Placement	General	- Elevation of pile top - Elevation of pile foot - Embedment depth
	Construction Record	- Operation time duration - Drop height of hammer - Rebound quantity - Dynamic bearing capacity - Number of the time of driving
Other		Construction area, Vibration level, Noise, etc.

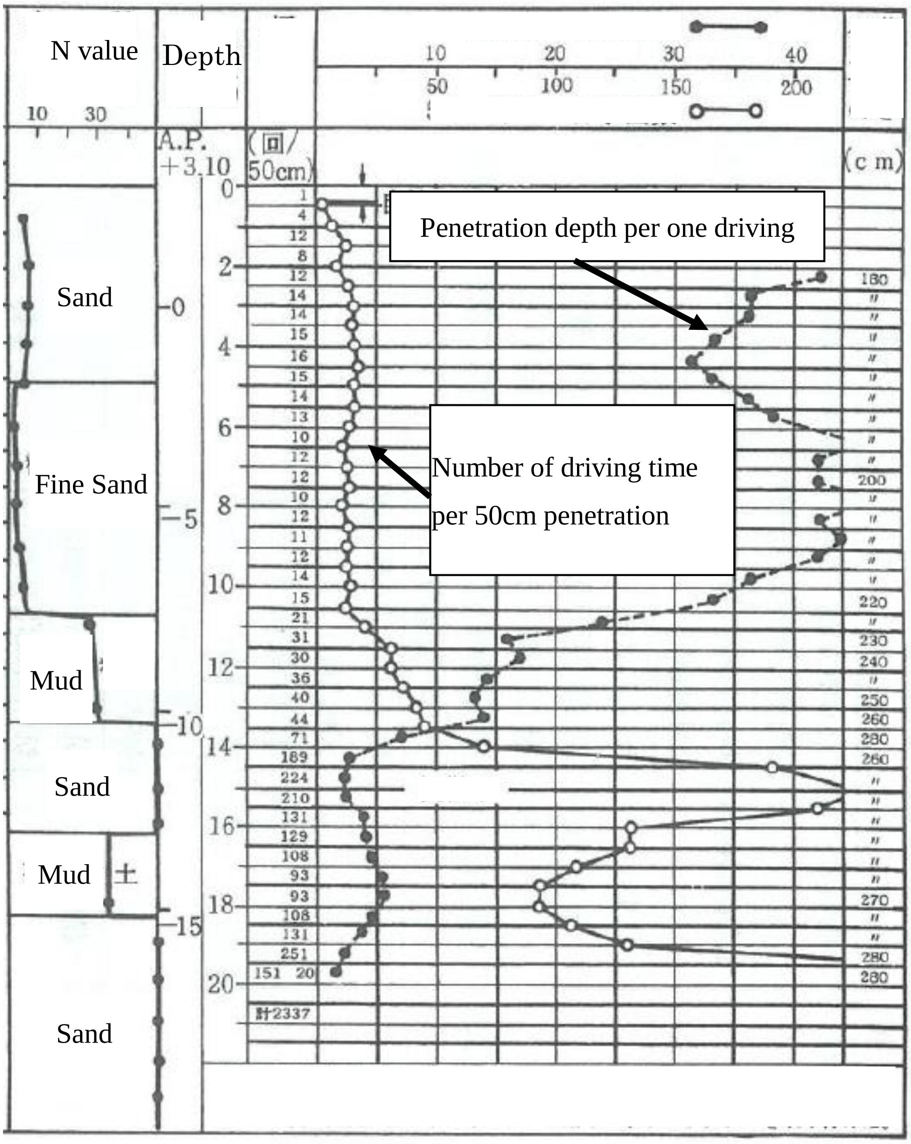


Figure 5.3-15 Test Pile Report for Driven Pile

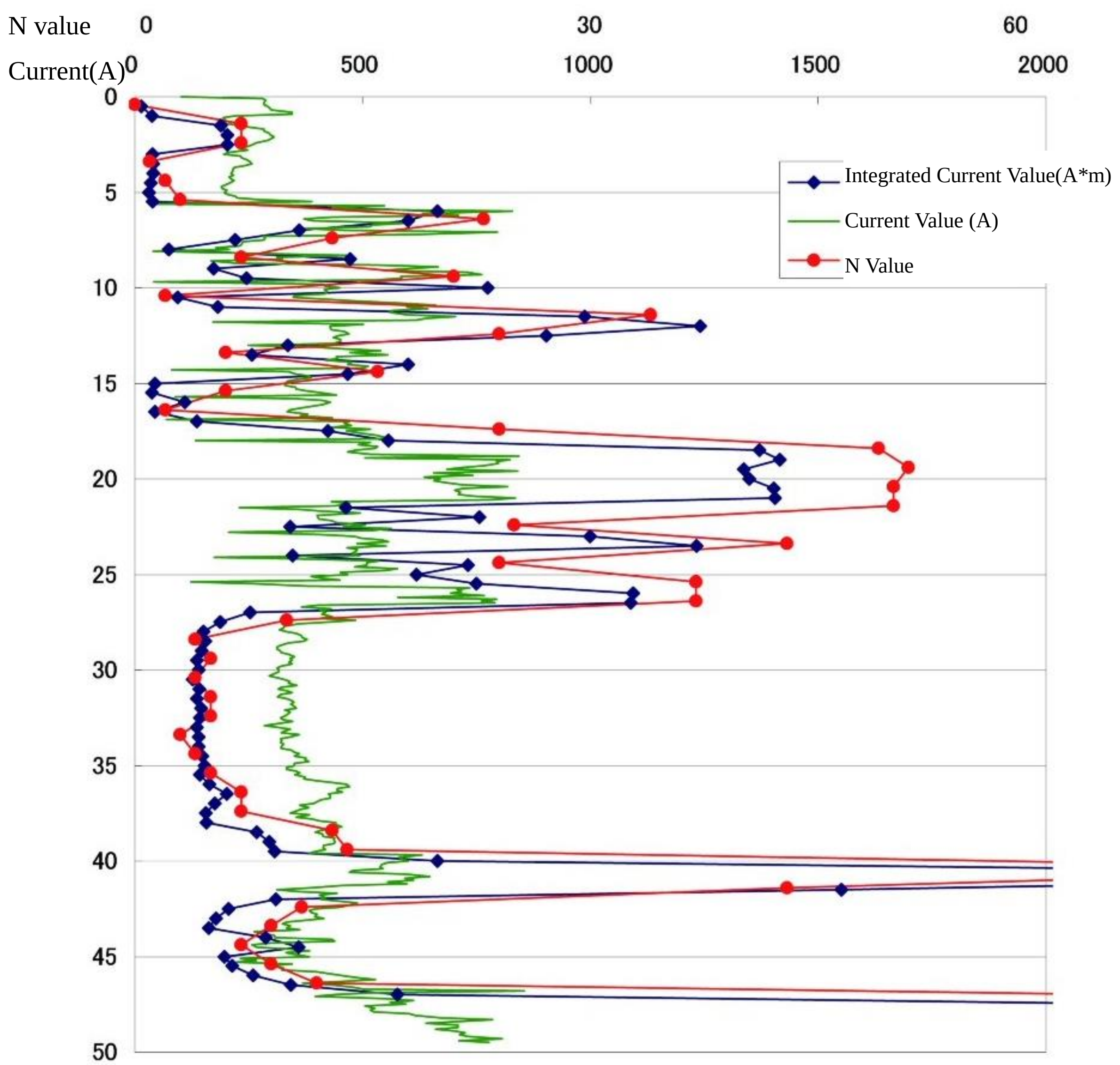


Figure 5.3-16 Test Pile Report for Driven Pile

(2) Cast-in-situ Pile

Test piling shall be conducted, in principle, prior to constructing a pile. However, it may be omitted if workability of piles at the construction site has been fully ascertained.

Because the cast-in-place pile has the following particularities, it is good to do test pile installation beforehand.

1) Since reliability of a foundation pile depends much on field work, it is indispensable to select a construction method suitable for conditions of the work site.

2) Dependable work is needed partly because design load per pile is great and partly because the piles are hardly substituted by others.

Test piling may be affected at locations where piles are to be initially cast or auxiliary ones other than the initial casting locations, by considering survey items and concrete piling procedures. The auxiliary casting locations should have soil layers which can fully satisfy the objectives of the test piling and should be such locations as do not give adverse influences on casting of regular piles and completed structures. Should extreme changes be found in conditions for constructing cast-in-place piles as a result of result of reviewing details of test piling work and should they be judged to exercise great influences on designing and constructing the piles, the construction method or its details should be modified.

Table 5.3-3 Reported Items for Test Pile

Item		**Contents**
Preparation	General	Date, Weather, Soil condition, Pile measurement (size)
	Machinery	Excavator, Casing tube, Slash tank
Excavation	General	Procedure, Accuracy, Geotechnical condition, Groundwater, Inflow water, …………etc.
	Construction Record	Operation time, excavated soil condition, gravel layer, Soil condition above support layer, Soil resistance, Depth of support layer, Ground water level, Time duration of slurry settlement ,,,,,, etc.
Placement of Rebar Cage and Concrete	General	Concrete mixture design, Structure of Tremie pipe, Structure of casing pipe, Top height of concrete, Inclination of re-bar cage, Interference between Tremie and rebar cage
	Construction Record	Operation time, Quantity of placed concrete, Placing height of concrete, Extra excavation depth, etc.
Other		Area, Vibration level, Noise, etc.

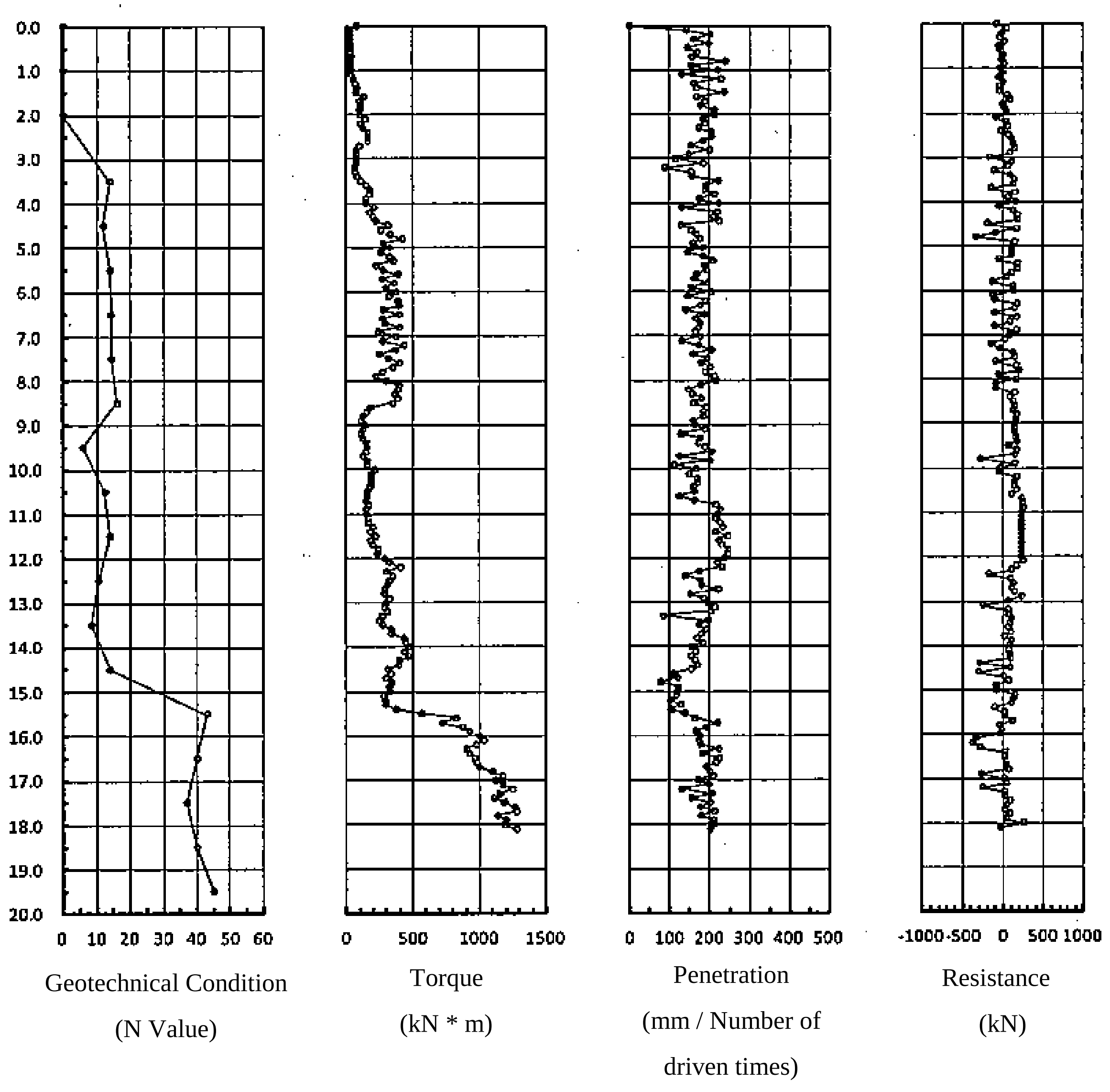


Figure 5.3-17 Test Pile Report for Cast-in-situ Pile

5.3.3. Pile Quality

Table 5.3-4 Inspection Items on Factory

	Steel Pile	Concrete Pile
Material	A Standard (Ex. JIS), Size Chemical Component etc.	A Standard (Ex. JIS), Size Performance Compressive Strength Tensile strength of PC cable Result of Bending test
Appearance	No defect	No defect
Shape	Diameter Length Thickness Curve Edge Etc.	Diameter Length Thickness etc.
Other	Nondestructive test on welded part (X ray 1 time/10 connections) Confirmation for mill sheet	Confirmation for mill sheet (cement, PC cable, etc.) Particle size distribution of aggregate

Table 5.3-5 Tolerance for Steel Pile (JIS A 5525)

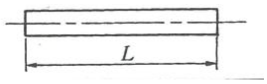
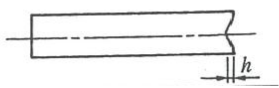
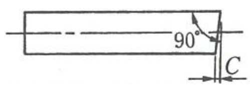
Items			Tolerance	Contents
Dimension (D)	Edge of Pile		± 0.5%	
Thickness (t)	Less than 16mm (Designed)	D < 500mm	(+) Not specified (−) 0.6mm	
		500mm ≦ D < 800mm	(+) Not specified (−) 0.7mm	
		800mm ≦ D < 2000mm	(+) Not specified (−) 0.8mm	
	More than 16mm (Designed)	D < 800mm	(+) Not specified (−) 0.8mm	
		800mm ≦ D < 2000mm	(+) Not specified (−) 1.0mm	
Length (L)			(+) Not specified (−) 50mm	
Lateral bend (M)			Less than 0.1% of Length (L)	
Flatness of edge (h)			Less than 2 mm	
Squareness (C)			Less than 0.5% of Dimension (D)	

Table 5.3-6 Tolerance for Concrete Pile (JIS A 5372, A 5373)

	Length (L)	Dimension(D)	Thickness (t)
D ≦ 600mm	± 0.3% of Length (L)	(+) 5mm (−) 2mm	(+) Not specified (−) 0mm
700mm≦D <1200mm		(+) 7mm (−) 4mm	

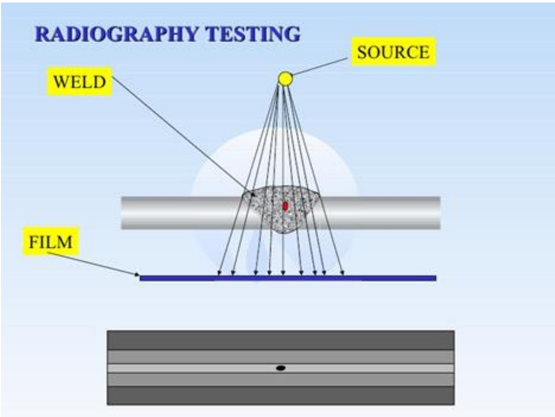


Figure 5.3-18 Nondestructive Test (X-ray Test) Image

Figure 5.3-19 Nondestructive Test (X-ray Test) on Welded Part

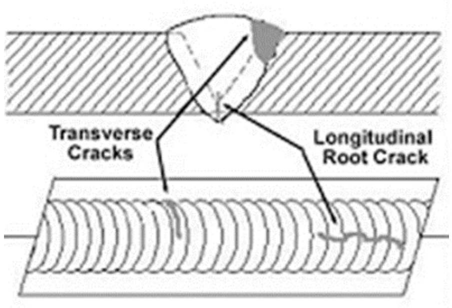


Figure 5.3-20 Defect on Welded Part

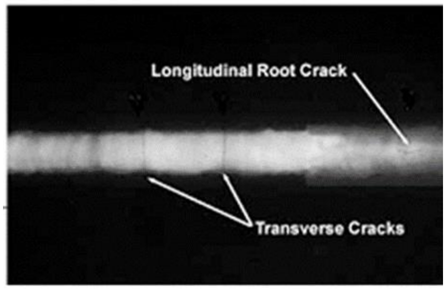


Figure 5.3-21 Result of Nondestructive Test (X-ray Test) on Welded Part

(1) Concrete

AASHTO Standard

The concrete slump shall be as follows;

Dry placement methods	6.0 – 8.0 in
Casting removal methods	8.0 – 10.0 in
Tremie placement methods	8.0 – 10.0 in

Slump loss of more than 4 in shall not be permitted during the period equal to the anticipated pour period for this time period equal to the anticipated pour period plus 2.0 h. A minimum for 6.0 in. slump shall be required for this time period. Slump life may be extended through the use of retarders and mid-range water reducers if approved by the Engineer.

Table 5.3-7 Quality Criteria for Concrete

Item	Criteria	
Unit cement quantity	More than 350 kg/m^3	
W/C	Less than 55 %	
Slump	180 – 210 mm	JIS A 1101
Nominal strength of concrete	30 N / mm^2	JIS A 1132, JIS A 1108, JIS A 5308
Air content	4.5% ± 1.5%	JIS A 1116, JIS A 1118, JIS A 1128
Chloride content	0.30 kg/m^3	JIS A 1144

Figure 5.3-22 Testing Concrete on Site

5.3.4. Construction Accuracy

Confirmation items for construction accuracy are placement of pile, inclination and diameter for cast-in-place pile. Table 5.3-8 and Table 5.3-9 are required accuracy for pre-cast pile and cast-in-situ pile construction.

Also, ground condition for pile driving machine and pile positioning are essential for accuracy. Strength of ground surface should be confirmed and baseplate should be used if necessary. In case of soft soil condition, control point for survey should be placed where not effected by soil movement caused by machinery.

Table 5.3-8 Accuracy for Pre-cast Pile

Displacement from Designed Pile Center	D/4 or Less than 100 mm (Choose Smaller)
Pile Inclination	Less than 1/100

Table 5.3-9 Accuracy for Cast-in-place Pile

Displacement from Designed Pile Center	Less than 100 mm
Pile Inclination	Less than 1/100
Excavation Diameter	More than the designed diameter

Figure 5.3-23 Measurement of Drill Core Position

Figure 5.3-24 Survey for Drill

5.3.5. Support Layer Confirmation

Confirmation of reaching support layer is essential for pile construction. Although test pile conducted in advance of construction, support layer should be confirmed each pile construction. Even, geotechnical condition for each pile could differ even for the same foundation.

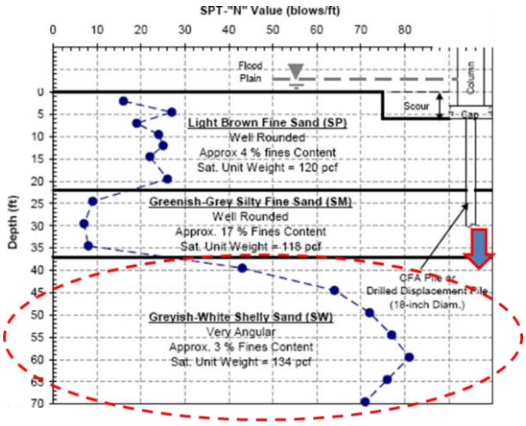


Figure 5.3-25 Support Layer depend on Geotechnical Survey

Figure 5.3-26 Excavated Soil Condition

5.3.6. Sonic Integrity Testing (SIT)

(1) Principles of Sonic Integrity Testing

A stress wave (sound wave) is introduced into the pile by means of a hammer blow on the pile head (Figure 5.3-28). This stress wave travels at the speed of sound (c) to the pile toe and reflects back to the pile head (Figure 5.3-28). The response of the pile head, as a result of the hammer blow and reflections, is measured with an acceleration transducer. The acceleration is integrated and presented as a velocity signal (v) For each pile at least 3 hammer blows are applied to the pile head and the results are presented as 3 traces in a diagram (Figure 5.3-29). To proof the quality of testing the 3 traces should be similar.

The time (T) between the start of the hammer blow and the time of arrival of the reflection from the pile toe is measured. The pile length (L) is calculated with: L = c. T/2 when the stress wave velocity (c) is known to present the measuring results the time axis (t) is scaled to a length (depth) (l) axis with L= c.t/2. Due to shaft friction the toe reflection might be of small magnitude. To make the reflection visible, the measured signal is amplified. To remove noise from the signals a filter value can be applied.

Figure 5.3-27 Sonic Integrity Test by MOC Engineers

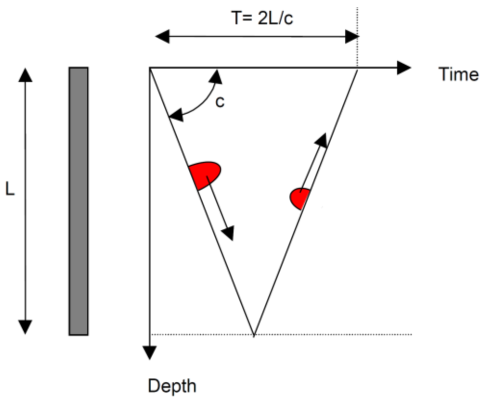


Figure 5.3-28 Stress Wave Travels

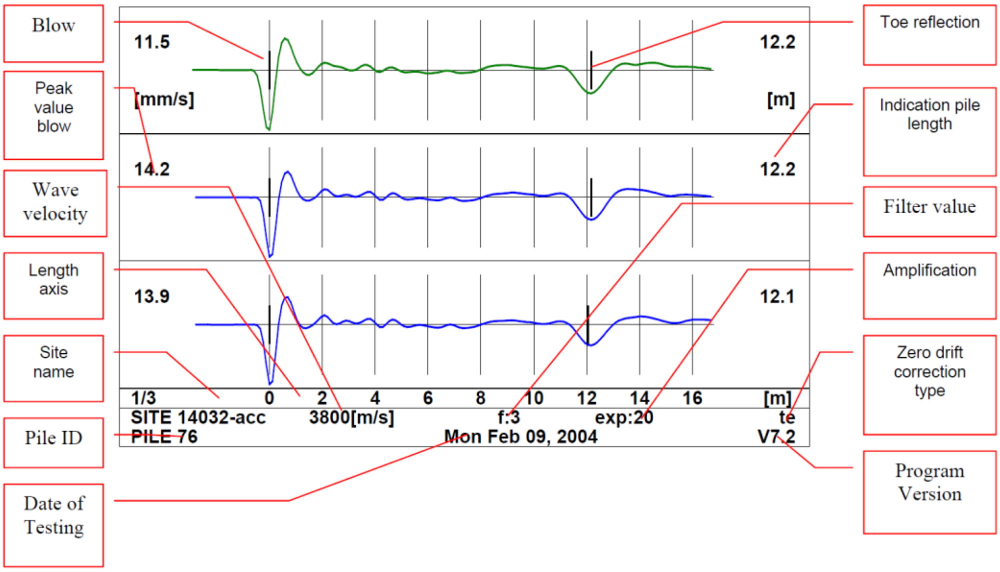


Figure 5.3-29 Result of Three Hammer Blows

Pile integrity testing analysis is based on the one-dimensional stress wave theory. Reflections generated by impedance changes (discontinuities) travel to the pile top and are recorded and analyzed. The impedance Z is defined as

$Z = A\ \sqrt{\ }\ (E.\ \rho)$

In which

A = cross sectional area

E = modulus of elasticity

ρ = density

Any change in A, E, or ρ or a combination of them will generate a reflection from an impedance change (discontinuity). Potential causes for reflections are:

- Pile toe
- Dimensional changes
- Soil inclusions
- Cracks
- Joints
- Variations in concrete quality
- Variations in soil layers
- Overlap of reinforcement (heavily reinforced piles).

`Limitations of sonic integrity testing are:

- Minor impedance changes are not detected
- Gradually increasing and decreasing pile diameters cannot be detected
- Curved pile shapes cannot be detected
- Small soil inclusions are not detected
- Local loss of reinforcement cover cannot be detected
- Thickness of debris layer at pile toe cannot be detected

(2) Discontinuities in the Pile Shaft

Reflections will occur when discontinuities in the pile cross section or pile material properties are present (Figure 5.3-30 and Figure 5.3-31). From the time of occurrence of a reflection the location of the discontinuity can be determined. The sign of the reflection indicates an increase or decrease in the pile cross section or an increase or decrease in pile material quality.

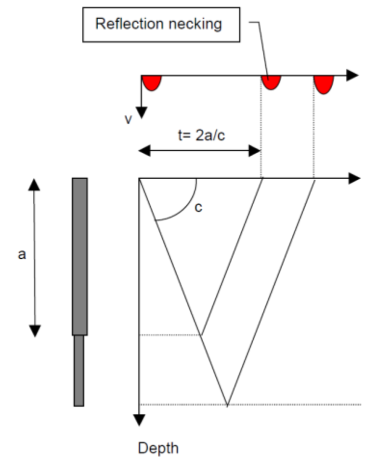


Figure 5.3-30 Reflection indicate decrease in the pile cross section

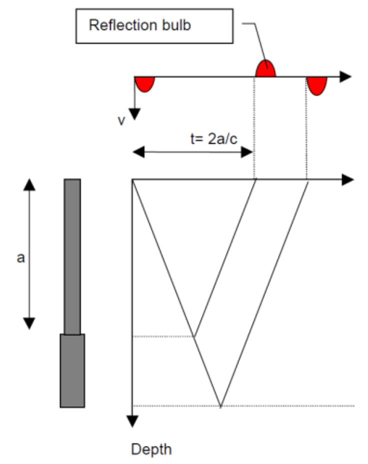


Figure 5.3-31 Reflection indicate increase in the pile cross section

(3) Signal Processing

(i) Signal Amplification

Shaft friction (see Appendix) has a strong influence on the pile integrity testing results and shall be considered. The signals measured on the pile top are amplified linearly or exponentially to overcome the reduction of the amplitude of the stress wave while traveling to the pile toe and back.

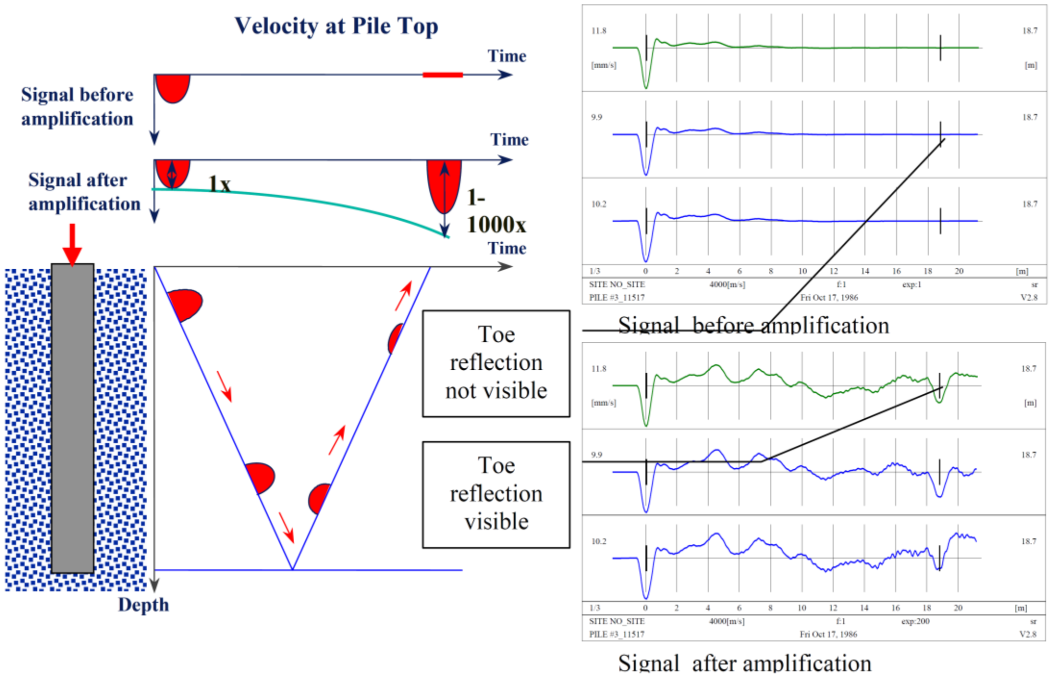


Figure 5.3-32 Signal Amplification

(ii) Signal Smoothing

Discontinuities near the pile top or extending reinforcement will generate high frequency reflections, which mask the global shape of the measured signals. To view the global shape of the signals smoothing is applied. It should be taken into account that by smoothing information about discontinuities is lost. For the final interpretation and presentation of the signals, smoothing should be reduced to a minimum.

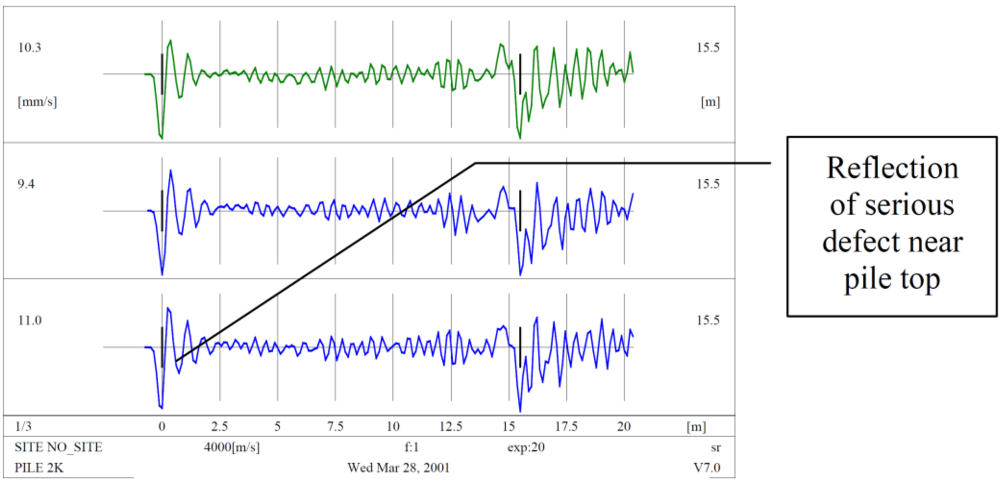


Figure 5.3-33 Unsmoothed Signal

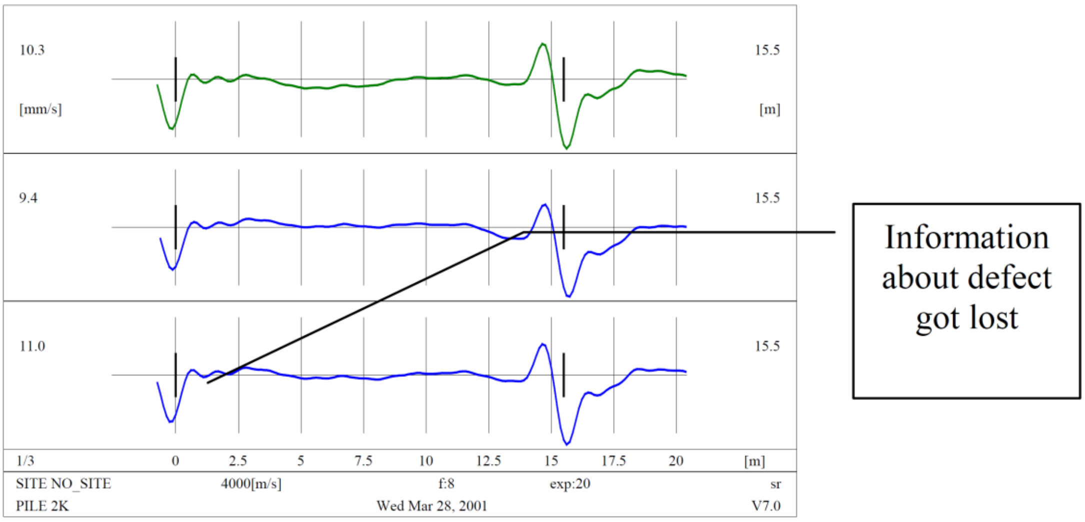


Figure 5.3-34 Smoothed Signal

(4) The Characteristic Signal

To differentiate between a change in soil resistance and a pile discontinuity, the SIT signal from a test pile is compared to a "characteristic signal" deemed to be representative of similar piles in similar soil conditions on site. (The characteristic signal can either be an average of a number of piles on site or the SIT signal of a reference pile chosen prior to testing.) If the test signal is different than the characteristic signal, then any impedance changes are due to the changing pile impedance and not characteristic of the site. Changes not found in the characteristic signal require further analysis to determine the cause.

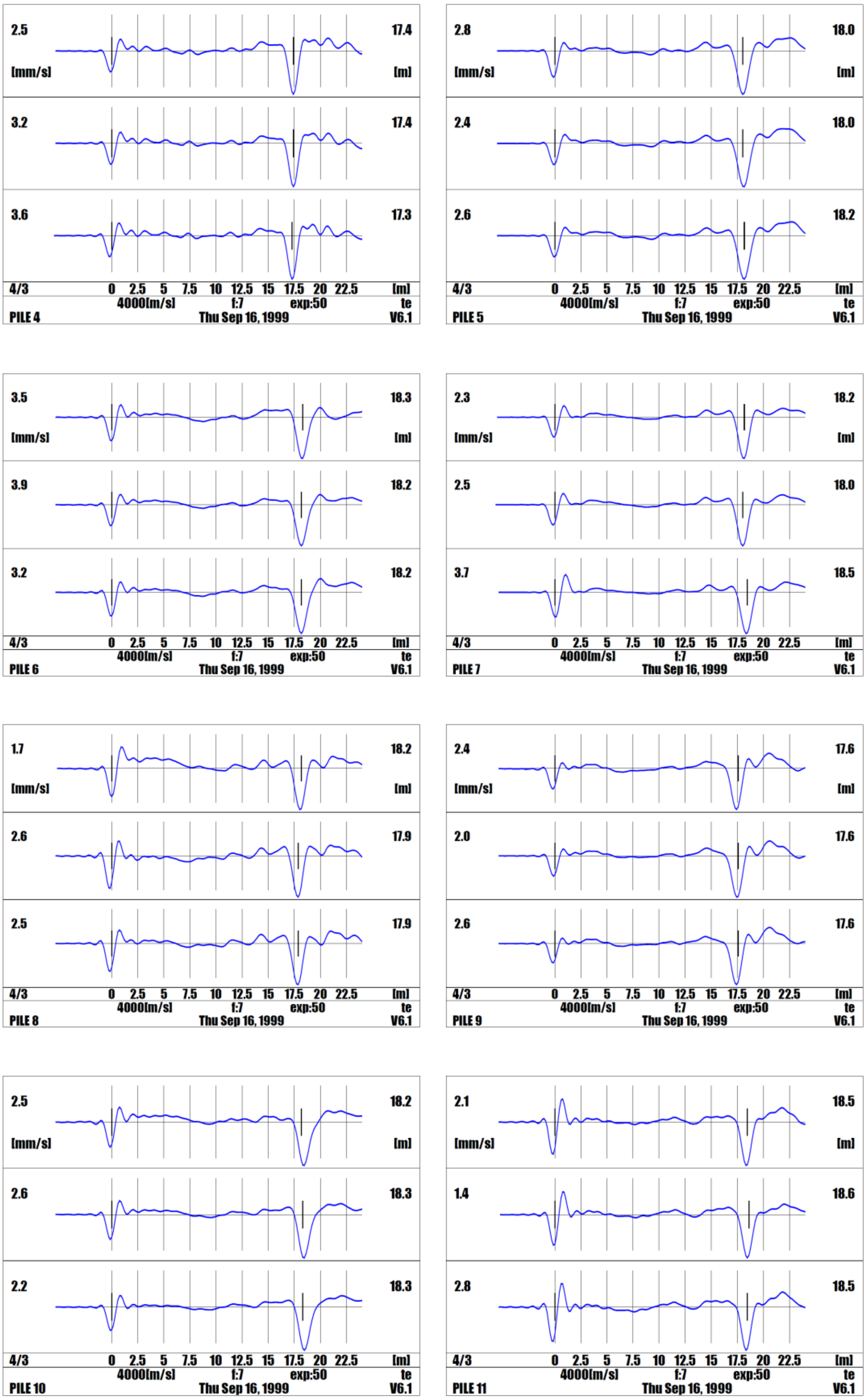


Figure 5.3-35 Example of piles constructed by a similar installation method, in the same ground conditions, of similar age and having the same length.

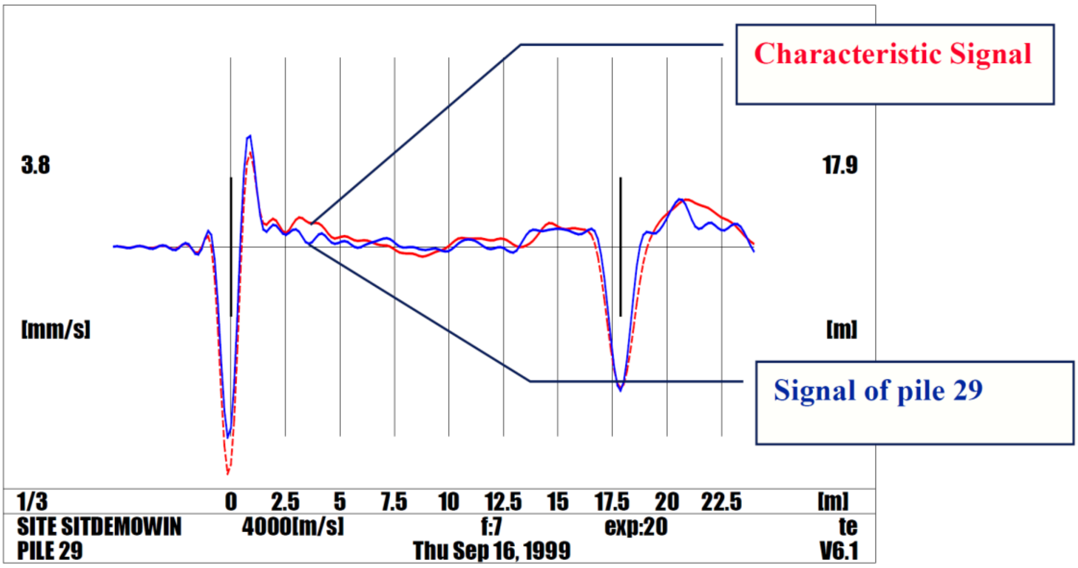


Figure 5.3-36 Example of a SIT Signal corresponding with the Characteristic Signal

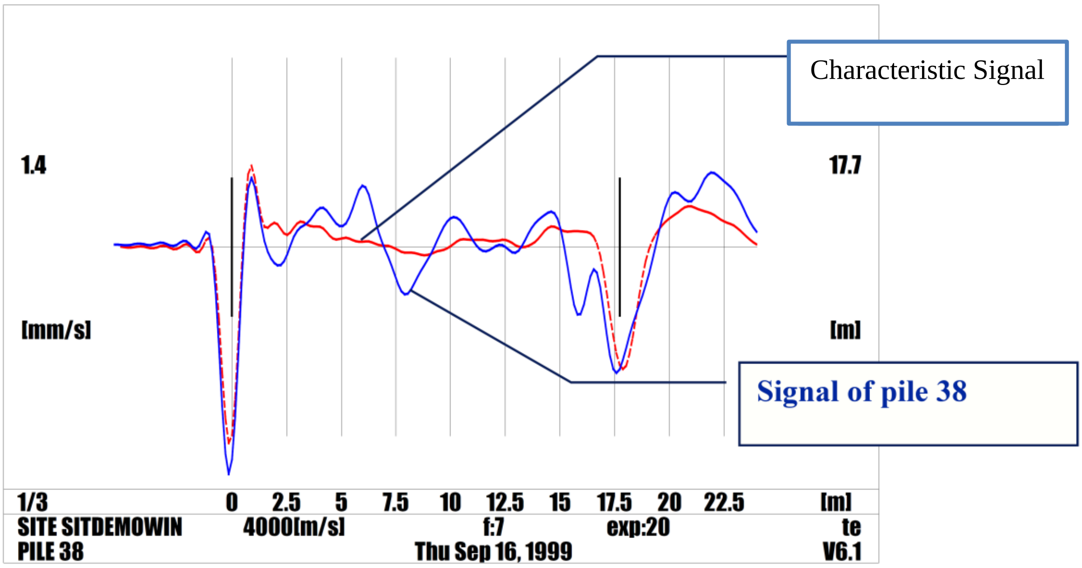


Figure 5.3-37 Example of a SIT Signal deviating from the Characteristic Signal

(5) Interpretation Guidelines

- Never be satisfied testing only piles which appear suspect.
- Determine the characteristic signal for piles of the same type on a site. The characteristic signal from the site or group average should be compatible with that for other piles of the same type and should generally correspond with the majority of piles tested on a particular site. The characteristic signal can be established intuitively or made by averaging a number of piles results together, excluding any piles which deviate from the norm.

- Compare the characteristic signal with the available soil data.
- Try to understand the causes of deviations—most often a change in pile cross section caused by soft layers, fill materials, voids in ground, old foundation bases, entry into hard layers, casing lengths, or deliberate pile base enlargements.

Note: If a pile enters a rock material, damping will be very high because of greatly increased shaft friction and this will show as an apparent increase in cross section and there will be no reaction from the pile toe.

- If possible, try to determine the pile length from the characteristic signal.
- Carry out individual pile interpretation using all individual signals.
- Flag as "suspect" signals with important deviations from normal.
- Determine the level and type of deviation from normal and physically examine the pile.

Note: Be aware that three dimensional effects will influence the signals for pile diameters larger than 0.4m.

(6) Interpretation

For interpretation six classes are distinguished

Class 1, Pile OK

Class 2, Pile head problem

Class 3, Discontinuity reducing the nominal impedance of the pile shaft

(The nominal impedance represents normally the impedance at the pile top)

Class 4, Pile seems too short

Class 5, Pile seems too long

Class 6, Deviating or no pile toe reflection

Examples of results for each class are presented below.

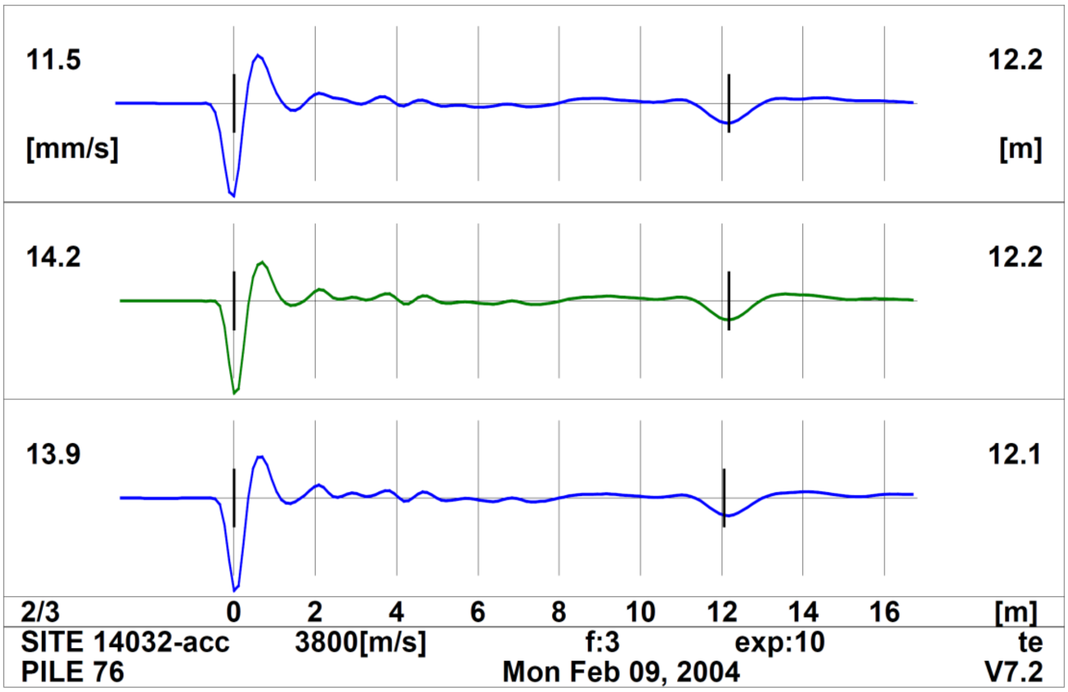


Figure 5.3-38 Class.1 Pile Good, Length OK,

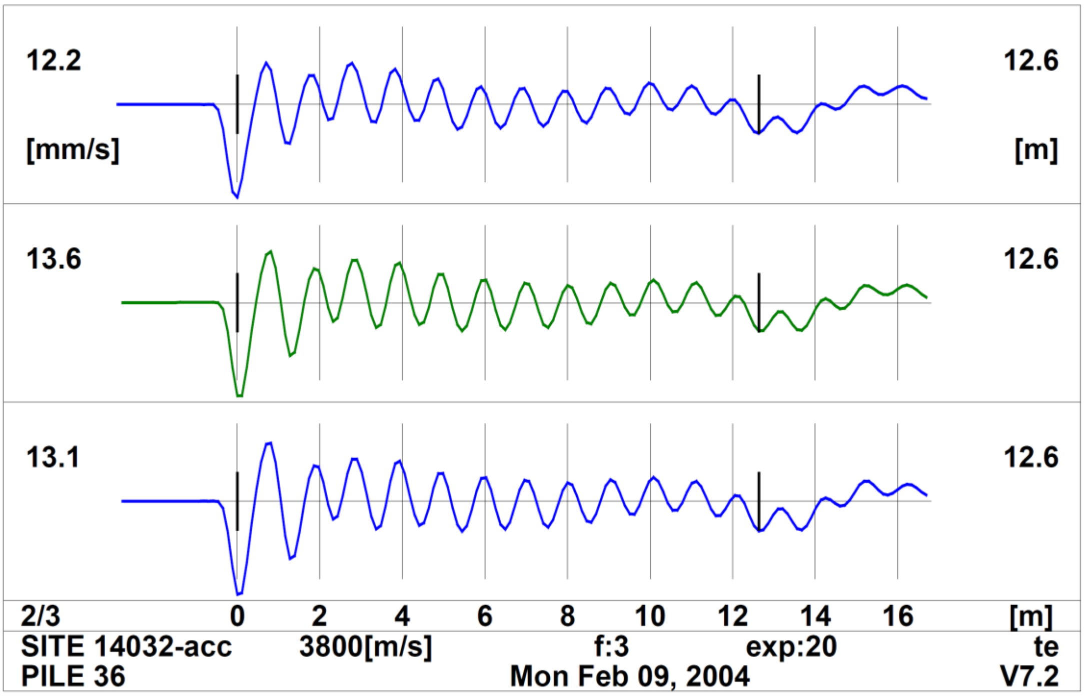


Figure 5.3-39 Class .2 Pile head problem,

Class 2 Possible reason, crack, necking, low material quality.

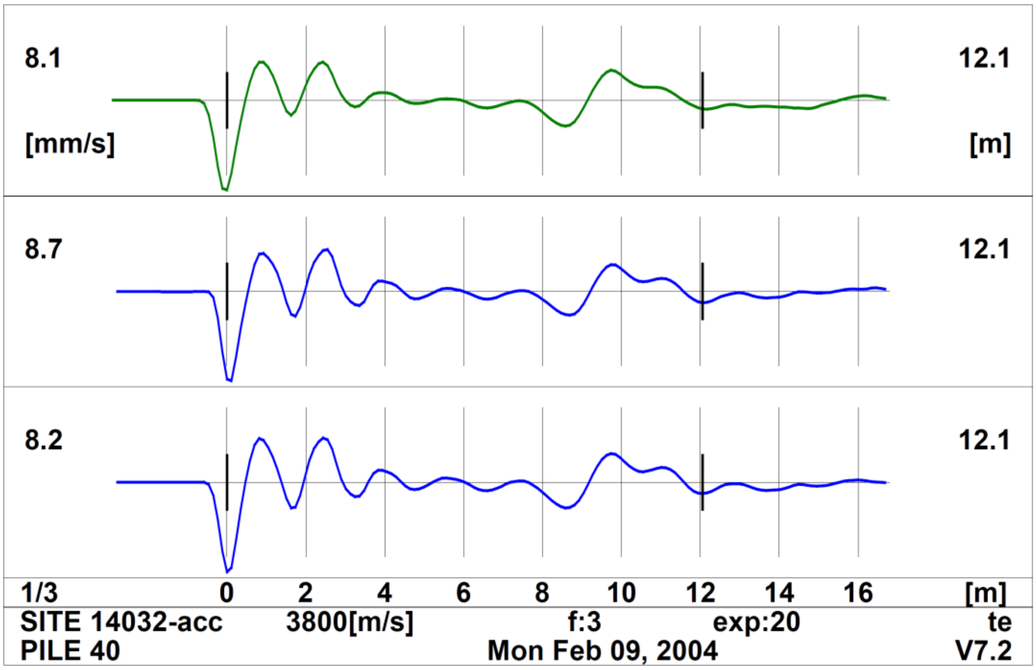


Figure 5.3-40 Class.3 Reflection from discontinuity at 1.5 m from the pile head. Possible cause, crack, necking, low material quality.

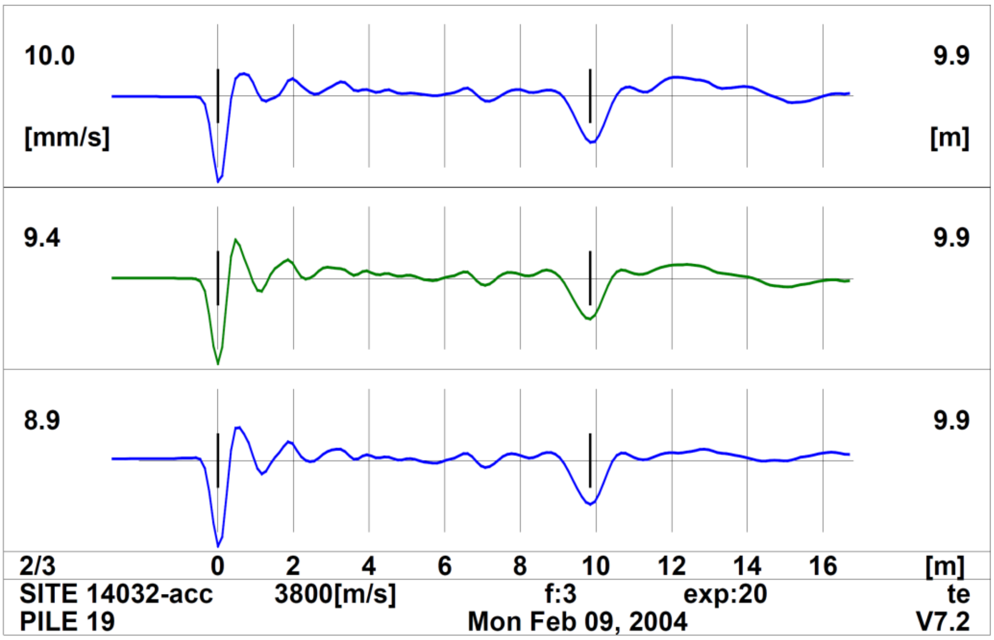


Figure 5.3-41 Class 4. Pile too short, reflection at 10m, should be 12m.

Possible cause: made too short, broken, heavily cracked or serious necking at 10 from the top.

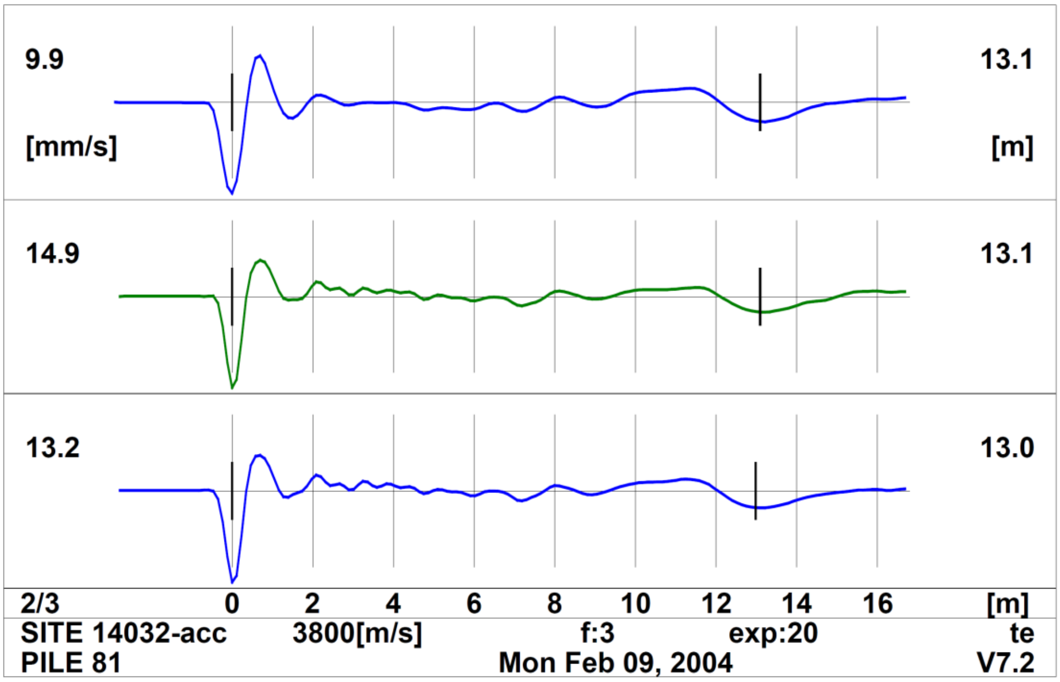


Figure 5.3-42 Class 5. Toe reflection too late.

Possible cause: Pile made too long, lower material quality, pile younger than other piles

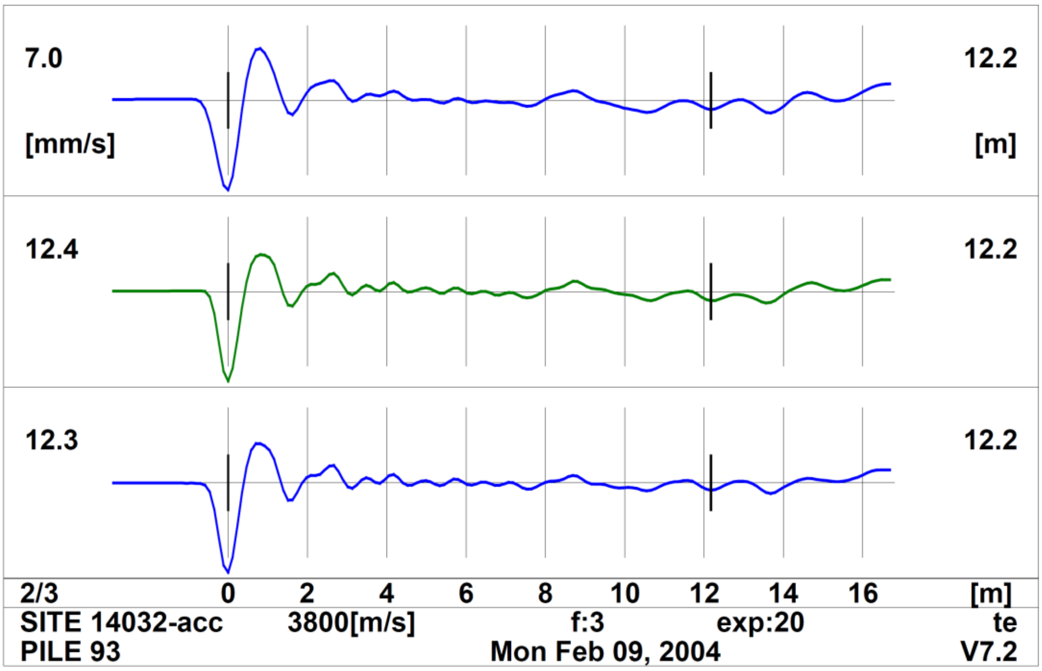


Figure 5.3-43 Class 6. No clear toe reflection

Possible cause, large friction, deviating material properties at pile toe

(7) Pile Preparation

Driven piles : Trim pile top if cracked

Cast-in-situ piles : Remove soft pile top to sound concrete

All piles : Cut away over break or overspill at ground level.

Pile tops must be clean, though not necessarily flat and smooth.

(8) Placing the Sensor

Place the accelerometer with a small amount of Pietoplast to the top of the pile, ensuring that the sensor is vertical. Choose a relatively flat, off-center spot and press with hand weight. (The Pietoplast helps transfer the signal and damp the resonance from pile to sensor.) Do not position the sensor close to the location of impact.

Note: If the pile top is not easily accessible, the accelerometer can also be attached to the pile shaft.

Figure 5.3-44 Example of Pile Top with Sound Concrete

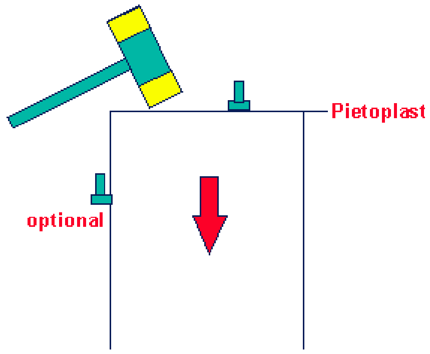


Figure 5.3-45 Example of Placement of Transducer

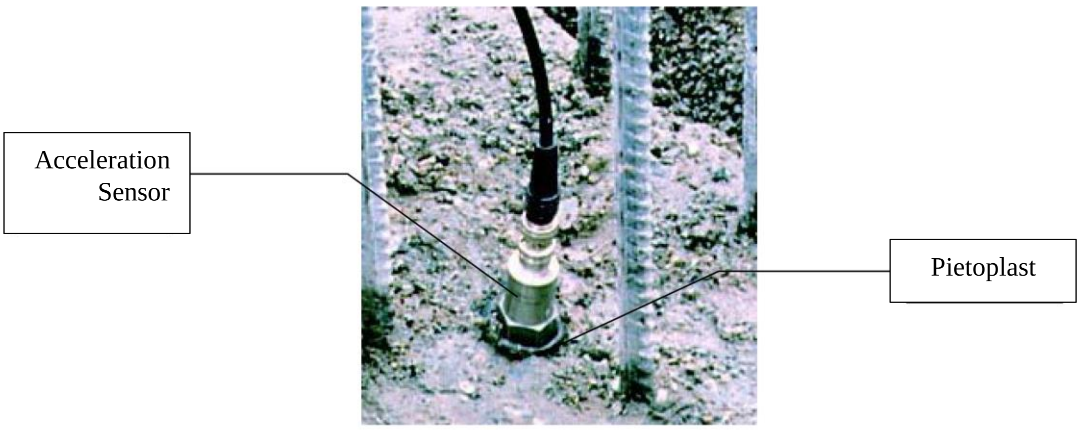


Figure 5.3-46 Example of Placement of Transducer

(9) Reliable Testing

The requirements for reliable testing include:

- for the highest confidence, test all pile. This is MOC's existing policy
- However, considering other condition, such as schedule, budget etc, should be considered to determine the number of test pile for SIT.
- use proper hammer with a blow length of 1 m or less (see Appendix).
- record at least 3 similar signals per pile
- process all signals in a similar way, with minimal filtering and optimal amplification
- determine characteristic signal
- check characteristic signal with soil investigation data (see Appendix)
- check signals that deviate from the characteristic signal
- perform qualitative interpretation
- use all available information
- follow the guidelines

If necessary, perform quantitative interpretation with integrity testing signal matching using TNOWAVE (SITWAVE). If there are still doubts, excavate the pile, do coring, or conduct a load test (DLT, STN, SLT) or reject the pile.

CHAPTER 6. QUALITY CONTROL OF CAST-IN-PLACE PILE METHOD

This chapter shall apply to the construction of a cast-in-place pile foundation constructed by the cast-in-place pile method (all-casing method, reverse circulation drilling method, and earth drilling method) using machine excavation or the deep foundation method. Because the cast-in-place pile depends for its reliability largely on its installation, the construction methods treated in this volume are restricted to the following four methods, distinguished by their excavation methods, considering the experience and the like at this point of time.

6.1 All-casing Method

6.1.1. Outline of Construction

Earth is excavated to a specified depth by repeating a combined process of i) vibration and pressurization of a casing tube by using a tubing device and ii) excavation and discharge of earth in the tube interior by using a hammer glove. Excavated bore walls and bottoms are usually protected by casing tubes covering the whole length of the bore and water in it, but only a casing tube may be used in some cases depending on properties of soil layers. When concrete is placed, the casing tubes are pulled out.

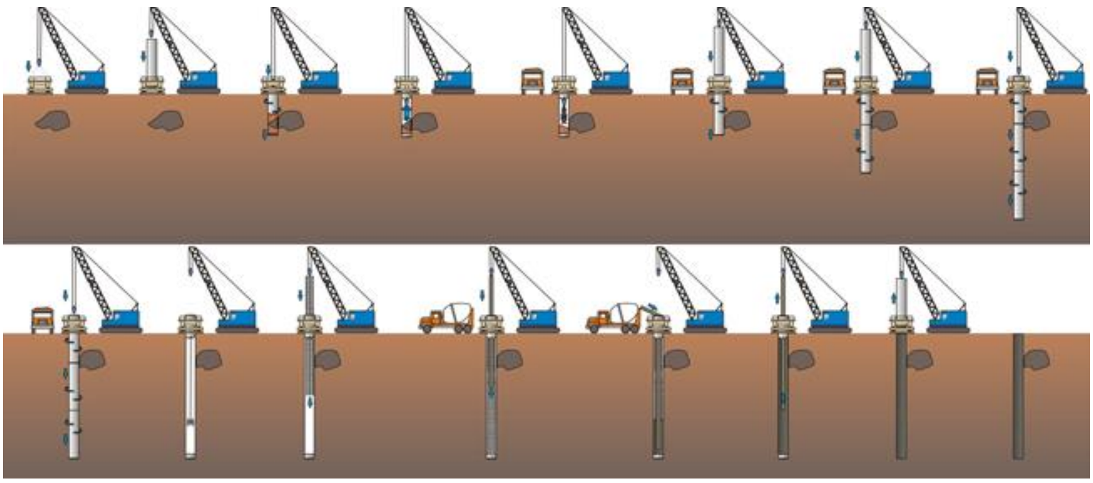


Figure 6.1-1 Construction Procedure of Cast-in-place Pile

6.1.2. Construction Machineries

The construction machines and instruments shall be selected on full examination of the pile dimensions, environment at the work site, ground condition, work safety and the like to satisfy the required dimensions and functions. The different cast-in-place pile methods not only intrinsically differ in their excavation methods, but also involve many application-specific techniques in their details to be suitable for various construction conditions. Therefore, it is important to be familiar with their features and machines and instruments used.

(1) Excavator for Placement of Casing Tube.

(i) Rotary Excavator

Rotary excavator shall excavate and place casing tube by rotating cutter bit on cutting edge. Casing tube can be placed through underground obstructs or hard soil, because of its high torque of cutter bit. Rotary excavator can be applicable for large depth pile construction.

(ii) Shaking Excavator

Vibration excavator shall shake casing tube repeatedly and place it under ground. Excavator should be selected with considering pile diameter, depth and soil condition.

Figure 6.1-2 Rotary Excavator

Figure 6.1-3 Shaking Excavator

Table 6.1-1 Standard of Rotary Excavator and Shaking Excavator

		Maximum Diameter(mm)	Machine Weight(t)	Rotary/Vibration Torque (kN*m)
Rotary	Crawler Type	2,000	62 – 96	1,180-1,860
	Stationary Type	2,000	25- 87	1,060-4,400
Shaking	Crawler Type	2,000	24-54	620-15,70
	Stationary Type	3,000	14-15	1,110-1,390

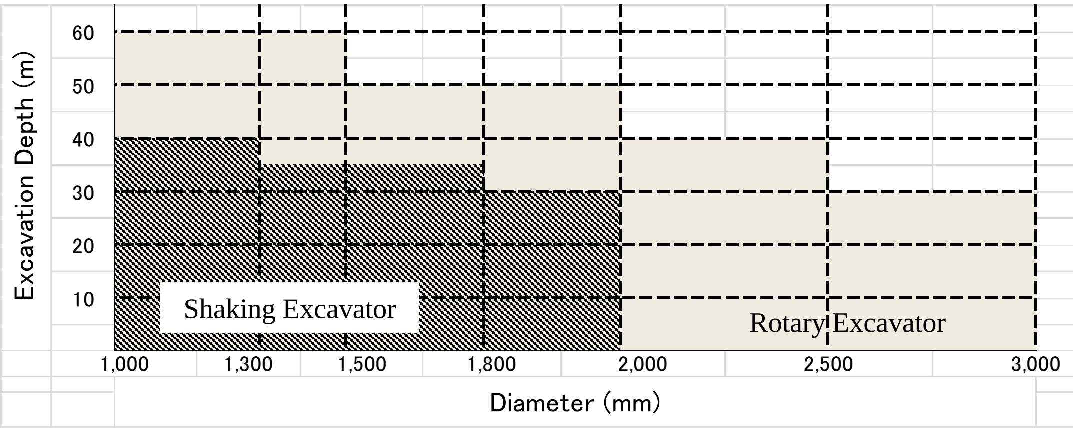


Figure 6.1-4 Standard of Rotary Excavator and Shaking Excavator

(2) Casing Tube

Casing tube can work for preventing from wall collapse. The normal length is 6 m and 4 -1 m are also used as an adjustment tube. Casing tube should be 3 – 6 m longer than designed depth of excavation.

Bottom of casing tube, called "First Tube", has a cutting edge. Outer blade of cutting edge works for making excavation easily and reducing surface friction force of casing tube. On the other hand, if the size of outer blame is excessive, it can cause looseness of ground.

Therefore, standard size of outer blade should be less than10-15 mm.

Figure 6.1-5 Casing Tube

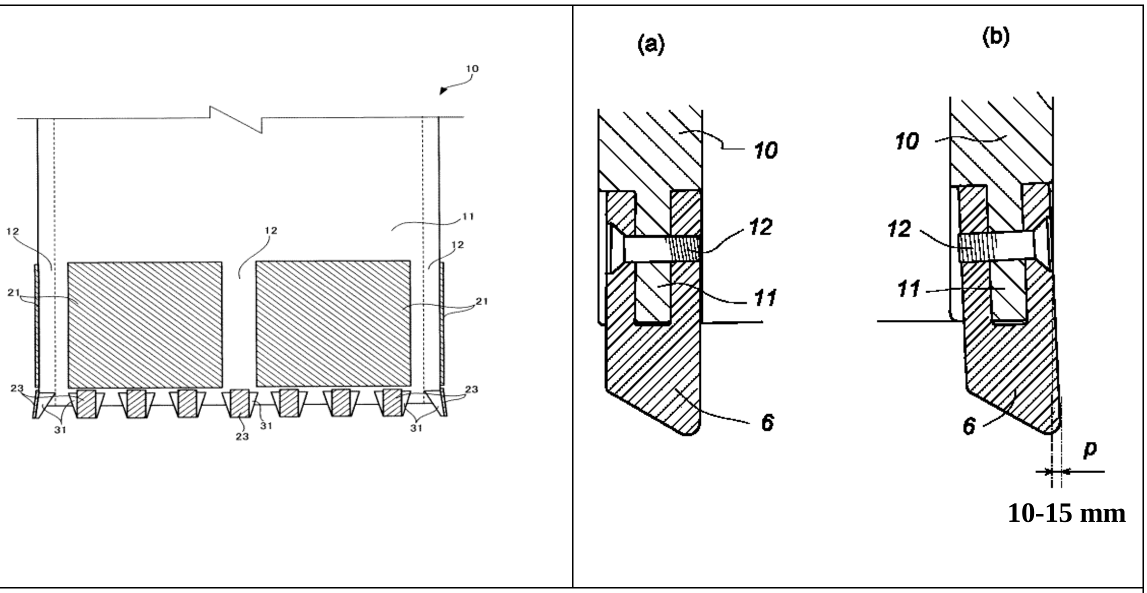


Figure 6.1-6 Edge of Casing Tube

(3) Hammer Grab

Width of hammer grab shell shall be less than casing tube diameter by 40-90mm in order to prevent casing tube from defect.

However, if hammer grab with is much less than it, it could affect on the progress of excavation.

Figure 6.1-7 Hammer Grab

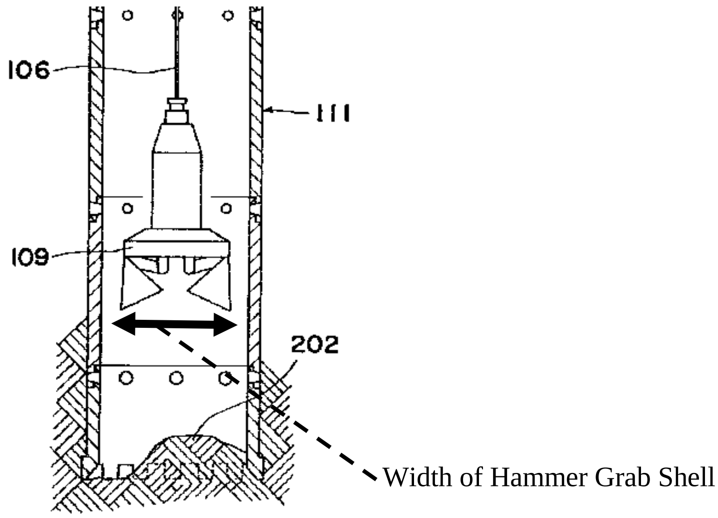


Figure 6.1-8 Size of Hammer Grab

(4) Support Crane

Generally, crawler type is useful for construction. Support crane should be selected with considering weight of hammer grab, casing tube, reinforcement bar, etc. and operation radius.

(5) Slash Tank

Slash tank is used for storage of water provide to inside of the hole. Size of it should be determined with considering quantity of water in hole and handling for installation and removal. Generally, the size of 10-30 m^3 is mostly used.

Figure 6.1-9 Slash Tank

(6) Other

Table 6.1-2 All Casing Method

Bucket for Slurry	Used for slurry removal. Have opening and closing device on the edge.
Pump	Circulation for water to hole
Tremie	Inner diameter 200-300 mm, length 6.0 m (Basically)

6.1.3. Construction

(1) Excavation

(i) Settlement of Casing Tube

Management for accuracy of casing tube settlement is essential for accuracy of pile construction. Position and inclination of casing tube should be surveyed from cross point.

Rotation of casing tube should not be stopped, because once rotation is stopped, it could be difficult to re-moving or pull-up.

Center of the pile should be surveyed according to design document, and temporary pile should be settled. Also, offset point should be settled because of machinery effects. Surveyed point should be confirmed at the time of machinery settlement.

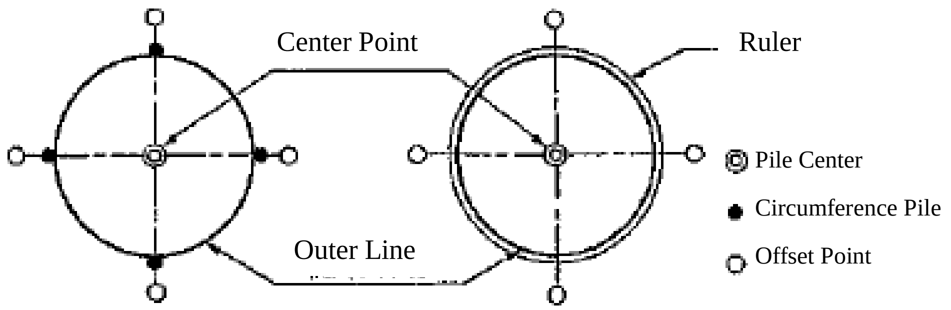


Figure 6.1-10 Survey

Figure 6.1-11 Excavation

(ii) Confirmation of Excavation Depth

Inspection tool should be installed for confirmation of excavated depth. More than 4 places at one hall should be inspected on excavated section.

Figure 6.1-12 Confirmation of Excavation Depth

(iii) Embedment to Support Layer

Support layer should be confirmed during settlement of casing tube.

- Compare excavated soil with designed condition or geotechnical survey.
- Confirm excavation speed and torque

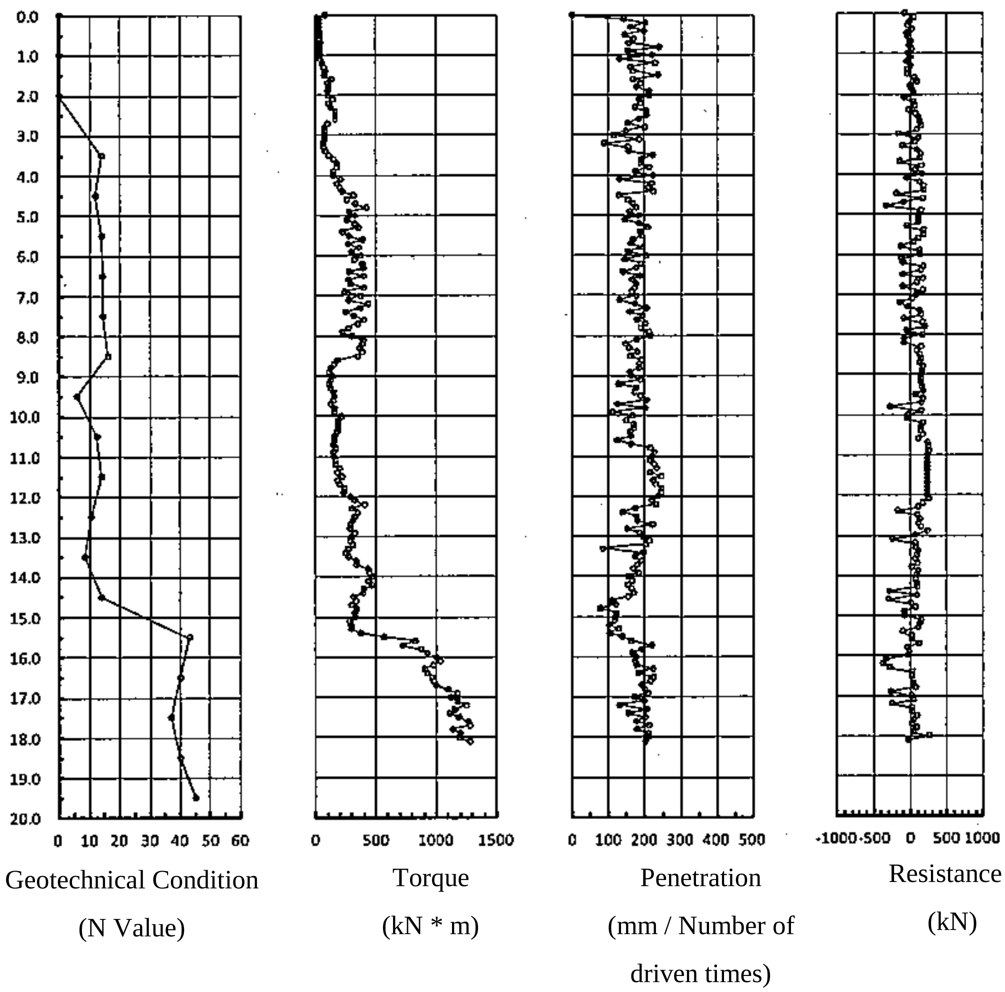


Figure 6.1-13 Construction Record

(iv) Hole Wall Stabilization

Basically, hole wall is stable by using casing tube. However, it should be cared that boiling of bottom of casing tube, soil loosen by excavation.

In order to prevent boiling, it should be considered to deepen embedment depth or keep height of hole water.

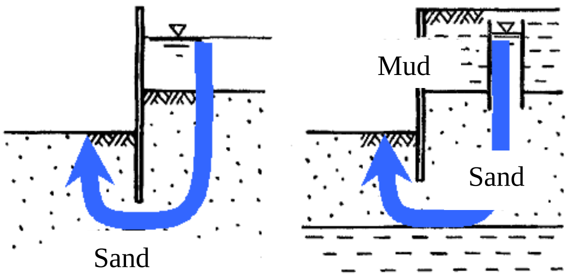


Figure 6.1-14 Boiling

(2) Reinforcement Work

(i) Rebar Cage

Before rebar cage placed, it should be needed to check design and drawing and confirm rebar cage assembled appropriately.

[Axial Reinforcement Bar]

Length of axial reinforcement bar should have a margin because of excavation depth allowance.

[Support Material]

In order to keep the shape of rebar cage during placement, support material should be installed. Size and strength of support material should be confirmed not to be deformed during construction.

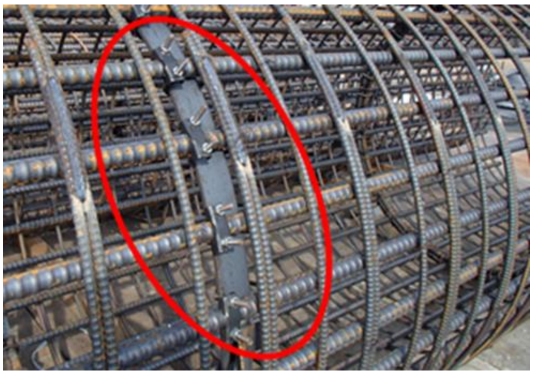


Figure 6.1-15 Support Material

[Spacer]

In order to keep cover appropriately, spacer should be placed by 3 m each axial direction.

And, 4 to 8 spacers are needed on each dimension.

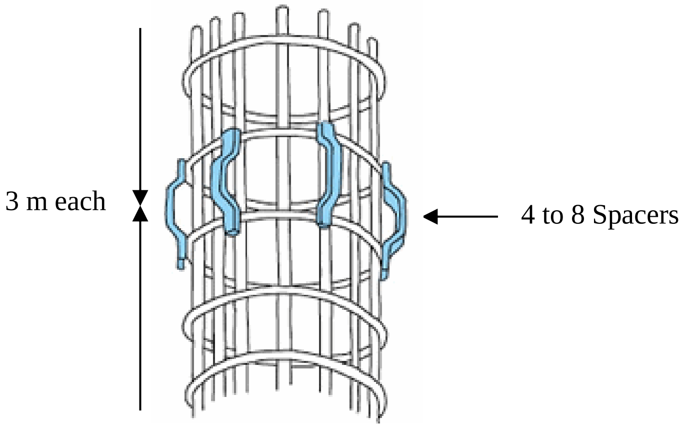


Figure 6.1-16 Spacer

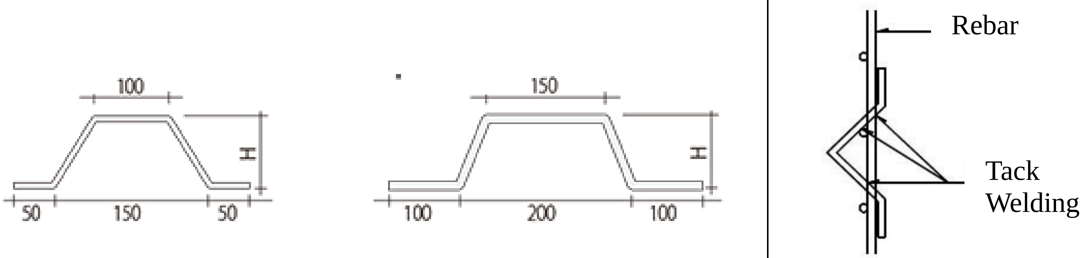


Figure 6.1-17 Spacer

[Alignment Confirmation]

Before placing rebar cage, diameter and alignment should be confirmed for each rebar cage.

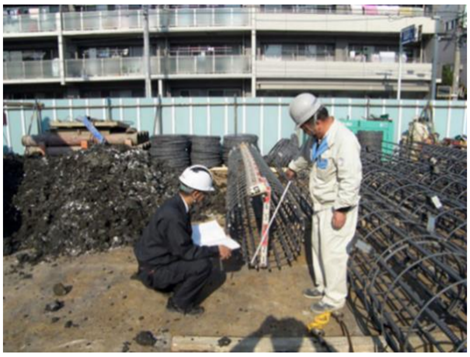


Figure 6.1-18 Diameter

Figure 6.1-19 Alignment

[Placement]

Rebar cage should be hanged on at least 2 points and hanging tool should be installed appropriately. Rebar cage should be kept vertical not to effect on hole wall during placement.

Figure 6.1-20 Hanging Tool

At the connection of rebar cage should be fixed on top of casing tube or stand pipe. And the connection of wire attachment or binging equipment should be installed in order to prevent rebar cage deformation.

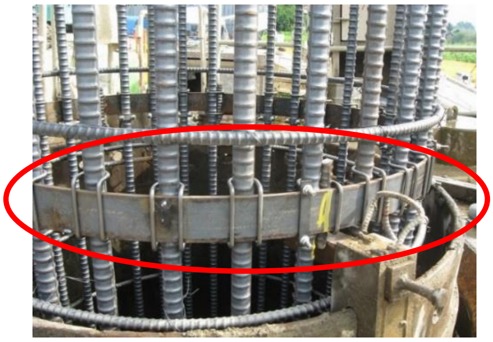


Figure 6.1-21 Fixer

Figure 6.1-22 Wire Connection

Figure 6.1-23 Connection Tool

(ii) Concrete Work

Pile concrete should be designed as underwater concrete.

Table 6.1-3 Concrete Quality

Item	Criteria	
Unit cement quantity	More than 350 kg/m^3	
W/C	Less than 55 %	
Slump	180 – 210 mm	JIS A 1101
Nominal strength of concrete	30 N / mm^2	JIS A 1132, JIS A 1108, JIS A 5308
Air content	4.5% ± 1.5%	JIS A 1116, JIS A 1118, JIS A 1128
Chloride content	0.30 kg/m^3	JIS A 1144

a) **Concrete Casting Work Planning**

Concrete should be casted within 1.5 hour after mixing started and it should be conducted continuously. Planning is essential for quality control of concrete casting work.

b) **Tremie Pipe**

Standard length of tremie pipe is 6 m or 3 m, but it should be used 1,2 m type as an adjustment.

In order to prevent displacement of rebar cage by concrete casting pressure, Tremie should be placed center of pile. If it could not be able to place the center, spacer should be added or reinforced.

Connection of Tremie should be watertight not to leaking water from concrete. Connection types of Tremie are flange type, screw type, socket type.

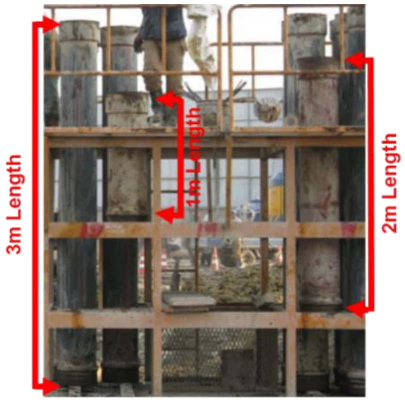


Figure 6.1-24 Tremie Pipe Length

Figure 6.1-25 Flange Type Tremie Pipe

Figure 6.1-26 Screw Type Tremie Pipe

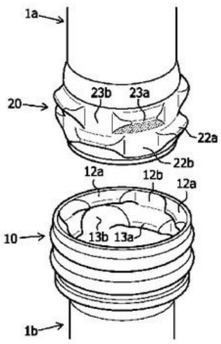


FIG. 3b

Figure 6.1-27 Socket Type Tremie Pipe

Tremie should be placed not to touch to rebar cage and buried at least 2 m on concrete. Then, it should hold on the top of casing tube or stand pipe.

Figure 6.1-28 Tremie Pipe Placement

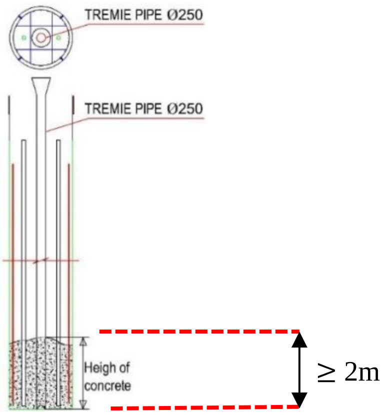


Figure 6.1-29 Tremie Pipe 2 m Buried to Concrete

(iii) Pile Head Treatment

Excess concrete should be placed on the top of pile, in order to remove impurity concrete. Excess concrete can be removed by breaker or pick. In order to prevent reinforce bar from being damaged during pile head treatment, it is necessary to pace cover on top of rebar cage before rebar cage placement.

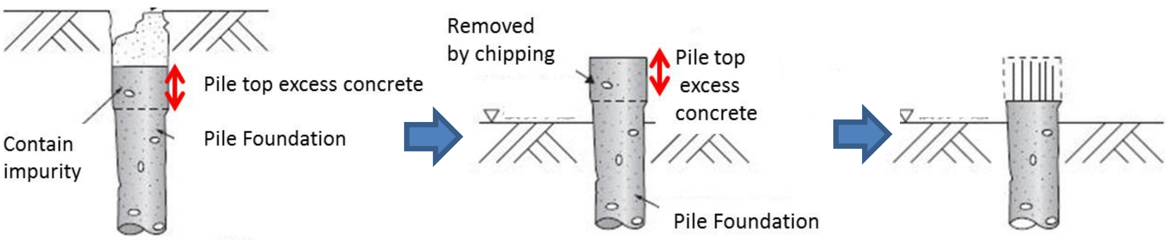
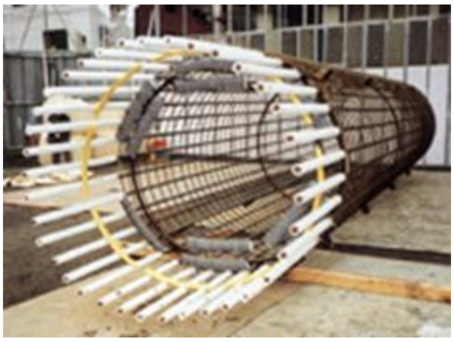


Figure 6.1-30 Pile Head Treatment

	
Figure 6.1-31 Pile Head Treatment	**Figure 6.1-32 Cover on Top of Rebar**

6.2 Earth Drilling Method and Reverse Circulation Drilling Method

6.2.1. Outline of Construction

(1) Earth Drilling Method

Stand pipe are used to protect surface course, and earth in deeper layers is excavated by rotating a rotary bucket while protecting bore walls with a stabilizing agent, and earth in the bucket interior is to be discharged onto the ground surface.

Figure 6.2-1 Earth Drilling Method

(2) Reverse Circulation Drilling Method

In this method, a stand pipe is installed on the ground surface, and earth is excavated by rotating a rotary bit while the bore walls are protected by water level (Bentonite level) in the bore interior, at least 2 meters higher than an external water level (ground water level).

Excavated earth is discharged together with the bore water by means of a reverse circulation method until a specified depth is dug out. The bore water may be replaced with a stabilizing agent in some cases.

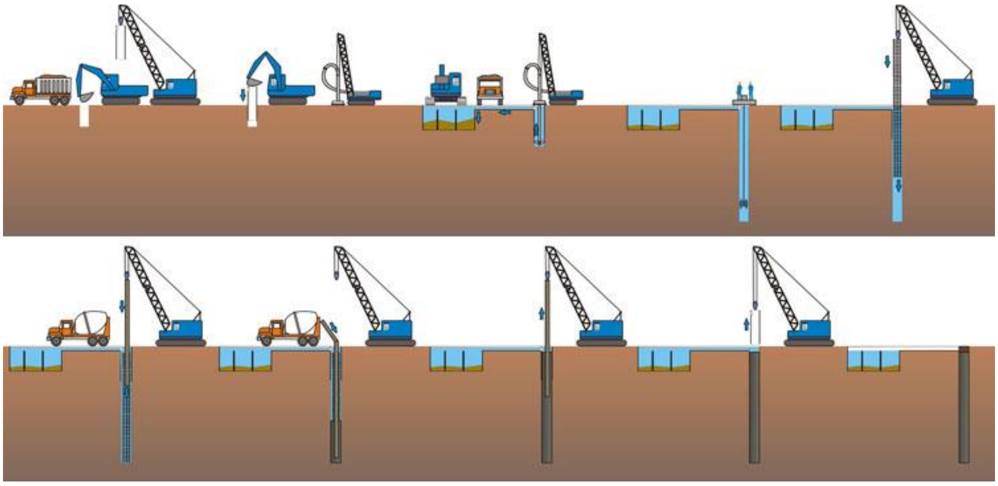


Figure 6.2-2 Reverse Circulation Drilling Method

6.2.2. Machineries

The construction machines and instruments shall be selected on full examination of the pile dimensions, environment at the work site, ground condition, work safety and the like to satisfy the required dimensions and functions. The different cast-in-place pile methods not only intrinsically differ in their excavation methods, but also involve many application-specific techniques in their details to be suitable for various construction conditions. Therefore, it is important to be familiar with their features and machines and instruments used.

(1) Excavation Machine

(i) Earth Drilling Method

Excavation machine for earth drilling method is consisted of rotary drive and press for Kelly-bar. Bucket placed on the edge of Kelly-bar rotated and up-down by rotary drive and press.

Figure 6.2-3 Excavation Machine for Earth Drilling Method

(ii) Reverse Circulation Drilling Method

Excavation machine for reverse circulation drilling method is consisted of power engine and pump. Power engine shall work for rotating drill bit for excavation. Pump shall work for circulate slurry and water. The one type, power engine and pump are set on ground (Suction type) and another type, integrate engine and pump with excavation drill (Uplift type). Recently, Suction type is more general because of handling superiority.

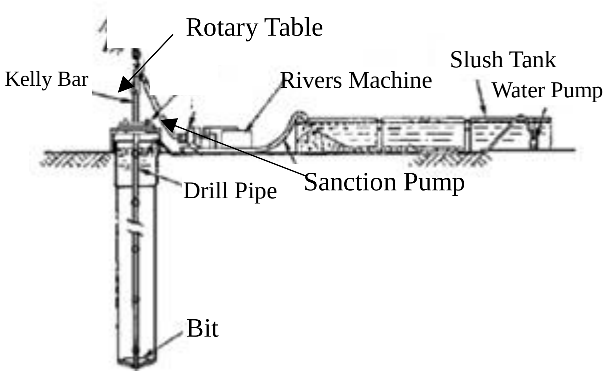


Figure 6.2-4 Suction Type

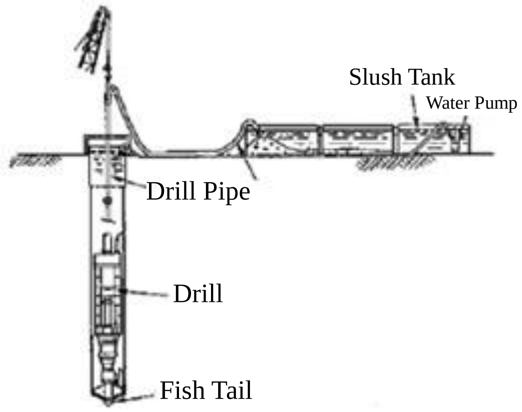


Figure 6.2-5 Uplift Type

Table 6.2-1 Standard for Suction Type and Uplift Type

	Suction Type	**Uplift Type**
Diameter (mm)	600 – 4,800	1,300 - 4,200
Pump Power (kw)	45 - 55	55
Maximum Torque(kN*m)	41.2 - 98	47 – 78.5
Slime Pipe Diameter (mm)	200 - 250	190 – 200
Size of Excavation Machine(t)	6.1 - 15	11 – 16.5

(2) Bucket and Bit

(i) Earth Drilling Method

Basically, drilling bucket and Slurry removal bucket are used, and chopping and rock bucket are used depend on the soil condition.

Table 6.2-2 Standard for Bucket

Type	Soil Condition	Excavation Diameter (mm)
Drilling Bucket	Sand, Silt, Mud, Gravel	800 – 3,000
Slurry Removal Bucket	Sediment Slurry	700 – 2,900
Chopping Bucket	Rubble, Stone, Gravel	400 – 2,000
Rock Bucket	Rubble, Stone	500-2,000

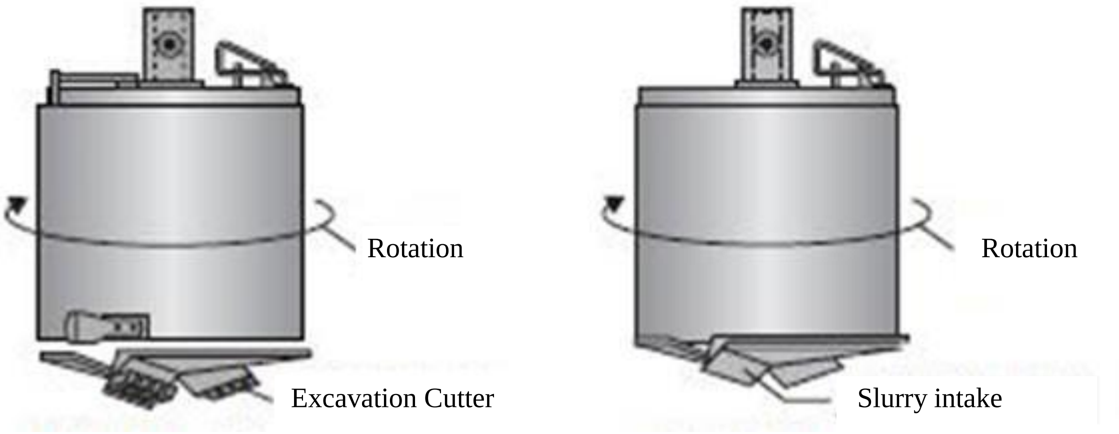
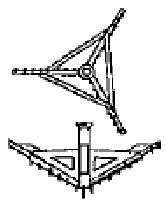
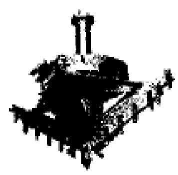


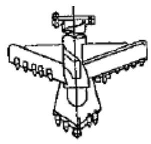
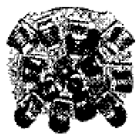
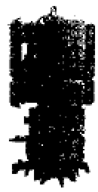
Figure 6.2-6 Drilling and Slurry Removal Bucket

(ii) Reverse Circulation Drilling Method

Bit should be selected depend on soil condition.

Table 6.2-3 Bit Type

Bit Type		Soil Condition	Reference
General condition	Three wings	Mud, Silt, Sand, Gravel	
	Four wings		

Bit Type		Soil Condition	Reference
Special condition	Conical	Soft rock	
	Roller	Soft rock, Hard rock	
	Three or Four axis	Mud, Silt, Sand, Gravel	

(3) Stand Pipe

Stand pile is essential for preventing from wall collapse.

- Diameter should be larger than excavation diameter by 150 - 200 mm
- Bottom of stand pile should be embedded on stable mud layer more than 0.5 m.
- In case, the impermeable layer is too deep (more than 10 m), it can be settled on around 10 m depth. In this case, it should be cared to prevent from piling and boiling.

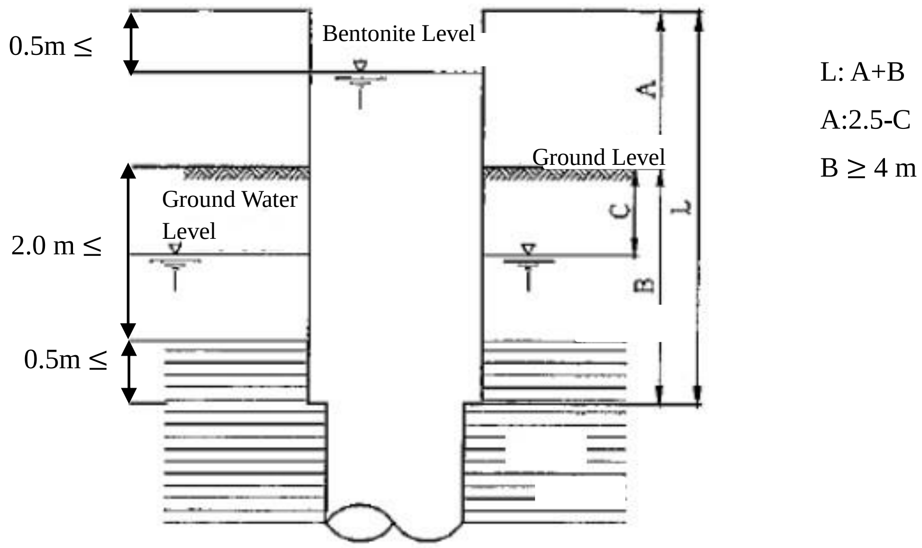


Figure 6.2-7 Stand Pipe

(4) Hydraulic Jack

Hydraulic jack is used for stand pipe settlement and pull-out. Capacity of hydraulic jack can affect on efficiency for stand pipe settlement, and, if capacity of jack is short, stand pile might be able to be pulled out after concrete placement.

Table 6.2-4 Hydraulic Jack Type

Type		1200	1750	2250	2750	3250
D	mm	1,200	1,750	2,250	2,750	3,250
Weight	T	7.7	8.4	9.4	10.1	18.0
Press capacity	kN	1,000				1,000
Pulling out capacity	kN	3,600				4,800
Stand pipe size	Minimum	800	1,300	1,800	2,300	2,800
	Maximum	1,200	1,750	2,250	2,750	3,250

(5) Other Machinery

Table 6.2-5 Other Machinery

Machinery	Point of Consideration
Slash tank	About 1.5 times as excavation hall About 1.2 times as slurry
Support crane	Used for machine settlement, stand pipe, Excavation etc.
Hammer grab	Used for stand pipe settlement
Driving pipe	Inner diameter 150-250 mm Length 3.0m
Water pump Sand pump	Used for slurry circulation
Tremie	Inner diameter 200-300 mm Length 6.0 m

6.2.3. Construction

(1) Machinery Installation

(i) Confirmation of Bearing Capacity of Ground

(ii) Survey and Indication of Pile Center

Center of the pile should be surveyed according to design document, and temporary pile should be settled. Also, offset point should be settled because of machinery effects. Surveyed point should be confirmed at the time of machinery settlement.

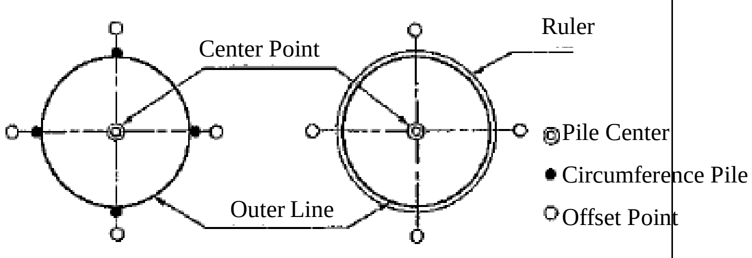


Figure 6.2-8 Survey

(iii) Confirmation of Excavation Depth

Inspection tool should be installed for confirmation of excavated depth. More than 4 places at one hall should be inspected on excavated section.

Figure 6.2-9 Confirmation of Excavation Depth

(iv) Settlement of Stand Pipe

Management for accuracy of stand pipe settlement is essential for accuracy of pile construction. Position and inclination of stand pipe should be surveyed from cross point.

Depth of inner excavation by hammer grab should not be deeper than bottom of stand pipe.

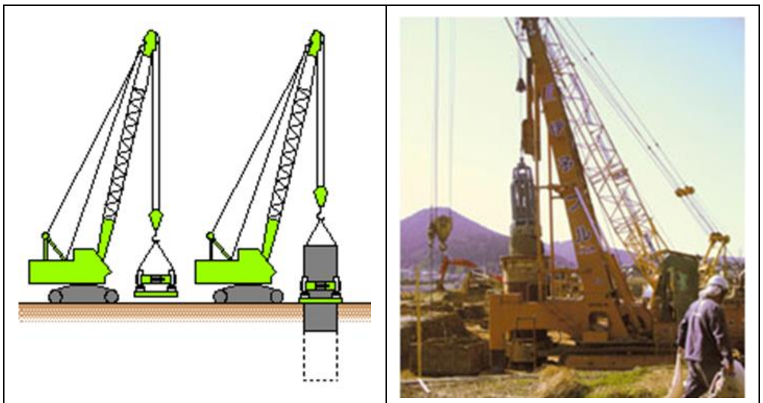


Figure 6.2-10 Settlement of Stand Pipe

(v) Settlement of Rotary Machinery

Machine for rotary should be settled without touching stand pipe. It should be settled on stage and kept flat.

Figure 6.2-11 Settlement of Stand Pipe

(2) Excavation

(i) Prevention from Wall Collapse

- Height of drilled hole water (Bentonite) should be higher than ground water by 2 m.
- Specific gravity of hole water (Bentonite) should be kept on 1.02-1.08, in order to form water-impermeable coat.

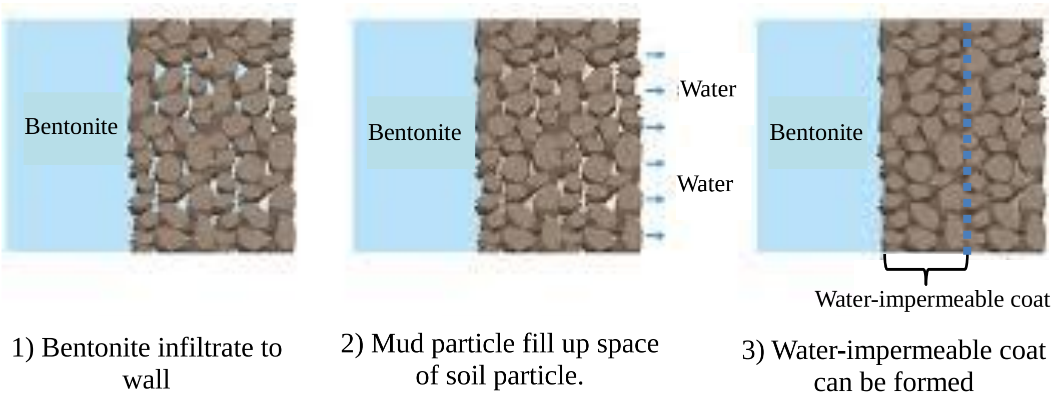


Figure 6.2-12 Prevention Hole Wall from Collapse

(ii) Position and Inclination

- Ground surface should be strong enough for supporting machinery
- Accuracy of position and inclination of stand pipe should be confirmed
- Excavation speed should be managed properly.
- Excavation machine should be surveyed during excavation.

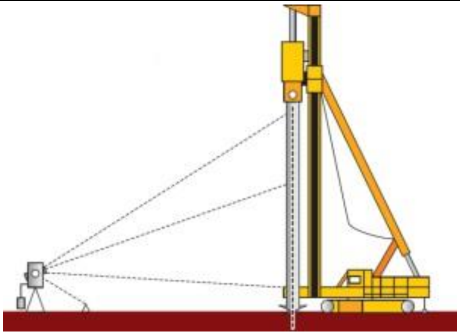


Figure 6.2-13 Drilling Position Survey

(iii) Confirmation of Support Layer

Basically, support layer can be confirmed by comparison between excavated soil and designed condition and geotechnical survey. Additionally, excavation speed change could be reflected soil condition.

(iv) Embedment to Support Layer

Excavation should reach to confirm support layer. Inspection tool should be installed for confirmation of excavated depth. More than 4 places at one hall should be inspected on excavated section.

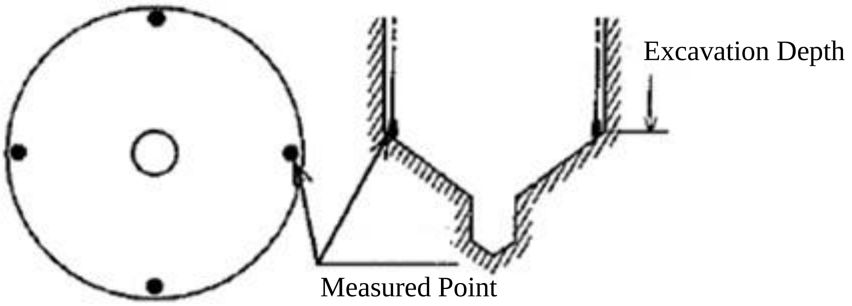


Figure 6.2-14 Measuring Point for Embedment

Figure 6.2-15 Measurement

(v) Hole Wall Stabilization

Inner hole water should be kept higher than ground water by 2 m, at least. Quality of inner hole water should be checked during excavation, at least 4 times by each pile.

At sand or gravel soil (permeability coefficient larger than 10^{-2} cm/sec), leaking water could occur, and it should be prevented in order to keep hole wall stable.

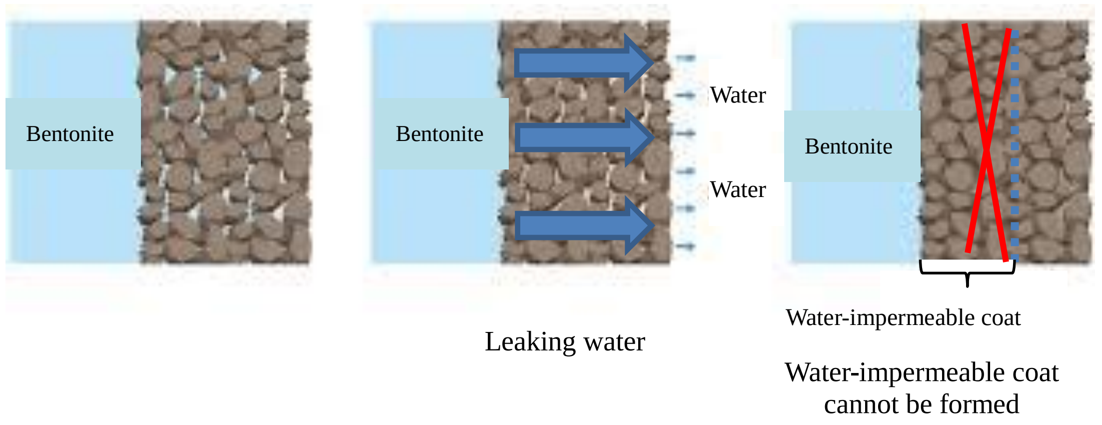


Figure 6.2-16 Hole Wall Stabilization

Table 6.2-6 Bentonite Quality

				Silt, Mud	Sand	Gravel
Mix design	Base material	Bentonite	%	2 -4	4 - 6	5 – 8
		CMC	%	0 – 0.1	0.05 – 0.1	0.05 – 0.2
	Support material	Leaking inhibitor	%	-	0 – 0.5	0 – 1
Properties	Viscosity		Sec	20 - 24	22 - 30	25 – 40
	Filtering water		ml	10 - 20	≤ 15	≤ 15
	Specific gravity*		-	1.01 –	1.02 -	1.03 –
	pH		-	9 – 10.5	9 – 10.5	9 – 10.5

*Attention for affection of Sedimental Velocity and Replacement are needed as below (Table 6.2-7) if more than 1.05.

Table 6.2-7 Effecting of Bentonite Quality

	Water Height		Specific Gravity		Viscosity		Filtering Water		Sand Content	
	High	Low	High	Low	High	Low	High	Low	High	Low
Wall Collapse Prevention	◎		◎		○			◎		
Sedimentation Velocity			*	◎		◎				
Replaceability			*	◎		○				◎

◎ ：More Effective

○ ：Effective

Table 6.2-8 Comparison Bentonite and CMC

	Bentonite	CMC
Viscosity, Specific Gravity, Filtering Water	Effected by Situation	Stable
Sedimentation Velocity	Slow	Fast
Deterioration Factor	Lot	Few
Recycle	Not easy	Easy
Material	Lot, but low cost	Few, but high cost
Waste	Lot	Few
Cost	Low	High

CMC: Carboxymethyl Cellulose

(vi) Bottom Processing

After completion of excavation, sediment on bottom of pile, such as slime, suspended sand, which could affect quality of concrete should be removed. Also, if slime is remained, concrete cannot reach support appropriately.

Basically, bottom processing is conducted twice during pile construction, primary and secondary.

(vii) Primary Bottom Processing

After excavation completed, before rebar cage placed, bottom processing is conducted in order to remove slime or suspended sand as primary bottom processing.

Hammer grab or bucket can be used for primary bottom processing.

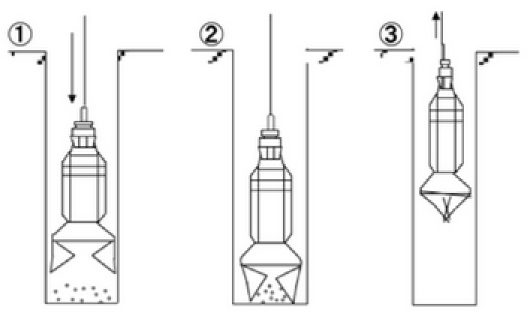


Figure 6.2-17 Bottom Processing by Grab

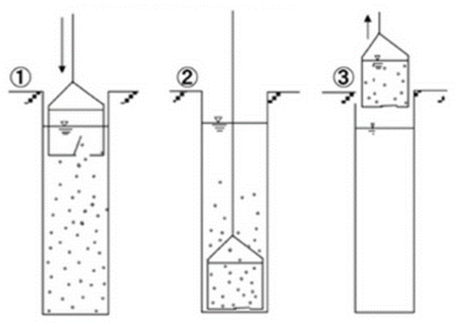


Figure 6.2-18 Bottom Processing by Bucket

Figure 6.2-19 Removed Slurry

Before starting bottom processing, it is necessary to take time for slime sediment duration (at least 20 – 30 minutes). Slime sediment duration should be measured at test pile construction.

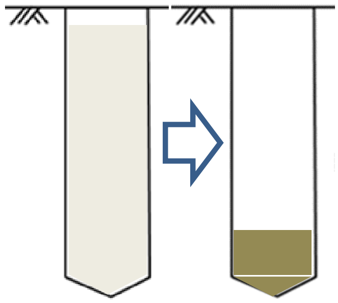


Figure 6.2-20 Slurry Sediment

(viii) Secondary Bottom Processing

After rebar placed, before casting concrete, situation of slime sediment should be measured and if needed, secondary bottom processing should be conducted.

Figure 6.2-21 Measurement of Slurry Sediment

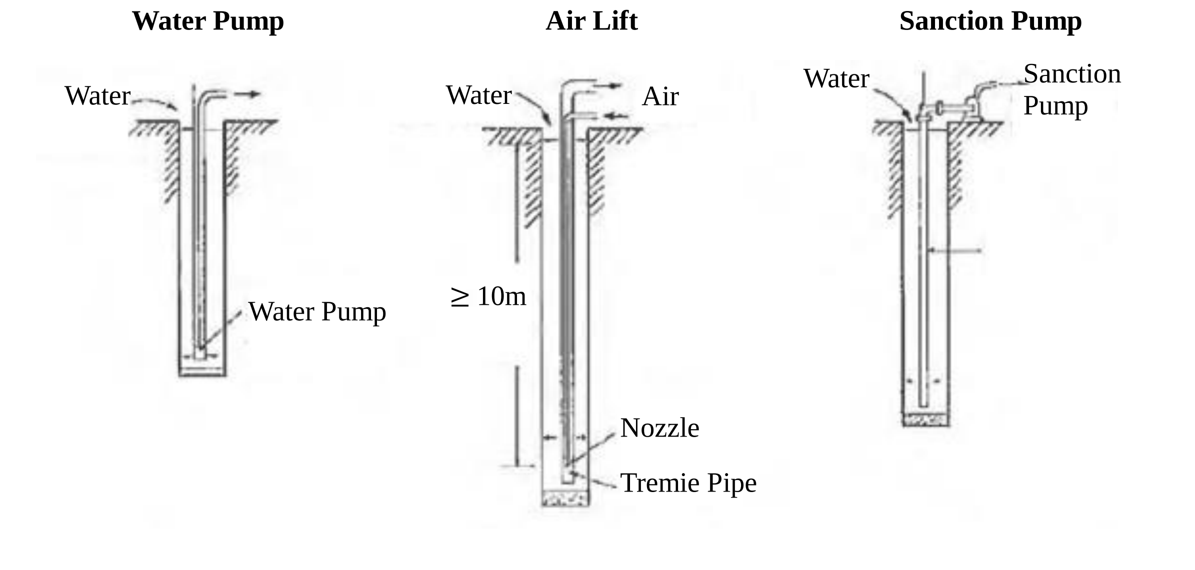


Figure 6.2-22 Secondary Bottom Processing (Slurry Removal)

(3) Reinforcement Work

Details in the reinforcement work shall be referred to 6.1 All-casing Method.

CHAPTER 7. QUALITY CONTROL OF PRE-CAST PILE METHOD

Precast pile foundations by a pile driving method and a pre-boring pile driving method are explained in this chapter. The precast piles refer to include reinforced concrete piles, PHC piles, steel piles and steel concrete piles fabricated at a factory.

7.1 Pile Driving Method

7.1.1. Outline of Construction

The driving method is a method to drive precast piles to a designed depth by a diesel hammer, a drop hammer, a hydraulic hammer. And the vibratory hammer method is a method to drive steel pipe piles to a prescribed depth by a vibratory hammer. Methods not simultaneously using a water jet are intended here.

When using this method in districts specified by these laws, constructors have to notify the mayor, the town manager, or the village headman concerned of specified items including measures to reduce noises and vibration.

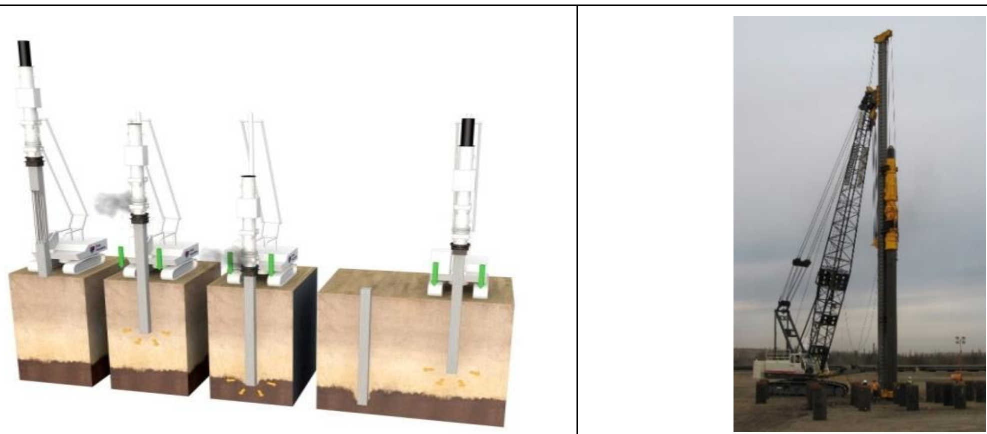


Figure 7.1-1 Pile Driving Method

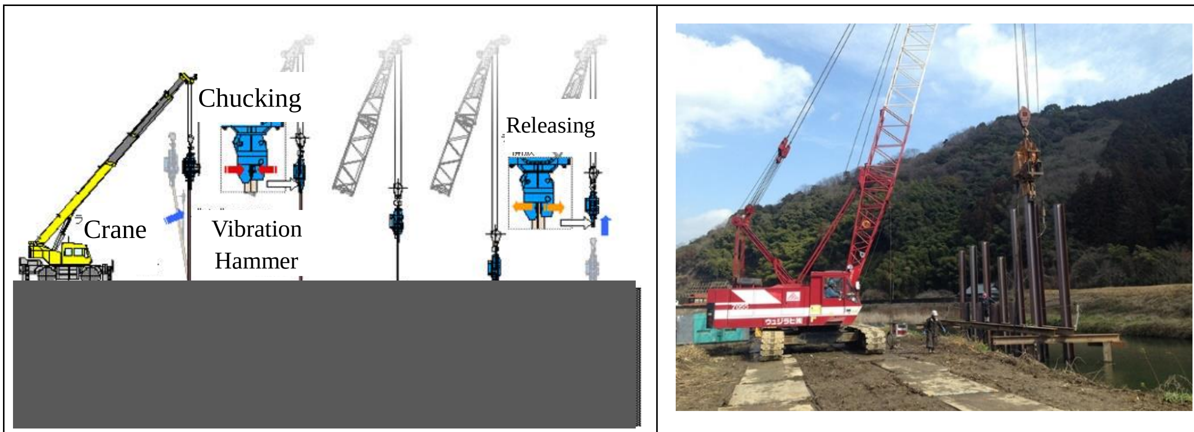


Figure 7.1-2 Vibrator

7.1.2. Construction Machineries

(1) Pile Driver

Pile driver is composed of hoisting device, base machine and leader. Hosting device is used to pull up and place a pile. Base machine is for traveling machine. Leader which has guide used for keep accuracy for driving.

One traditional type of pile driver includes a heavy weight placed between guides so that it is able to freely slide up and down in a single line. It is placed above a pile. The weight is raised, which may involve the use of hydraulics, steam, diesel, or manual labor. When the weight reaches its highest point, it is then released and smashes on to the pile in order to drive it into the ground.

Suspended pile driver is installed for small size pile construction.

Three point supporting pile driver is installed for medium to large size pile driving.

	
Figure 7.1-3 Suspended Pile Driver	**Figure 7.1-4 Three Point Supporting Pile Driver**

(2) Hammer

Hammer sizes should be selected by considering soil layer conditions and specifications of piles in addition to safety of piles to be driven. Since if the vibratory hammer is used for a long time to give vibrations, the motor may be burnt out or the ground at the pile periphery may be disturbed, due care is needed when selecting a hammer.

(i) Drop Hammer

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

The weight of the hammer should be 10 times larger than the pile weight per 1 m length.

(ii) Hydraulic Hammer

A hydraulic hammer is a modern type of piling hammer used in place of diesel and air hammers for driving steel pipe, precast concrete, and timber piles. Hydraulic hammers are more environmentally acceptable than the older, less efficient hammers as they generate less noise and pollutants. However, in many cases the dominant noise is caused by the impact of the hammer on the pile, or the impacts between components of the hammer, so that the resulting noise level can be very similar to diesel hammers.

(iii) Vibratory Hammer

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

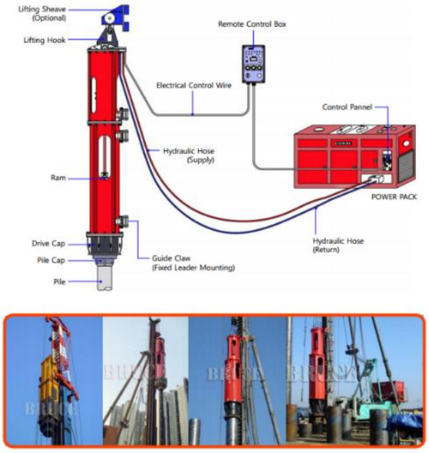


Figure 7.1-5 Hydraulic Hammer

Figure 7.1-6 Vibratory Hammer

(3) Cap and Cushion

When selecting a cap and a cushion, prevention of eccentric percussion must be considered. Thus, a cap suitable for the pile diameter and a cushion free of deformation should be used.

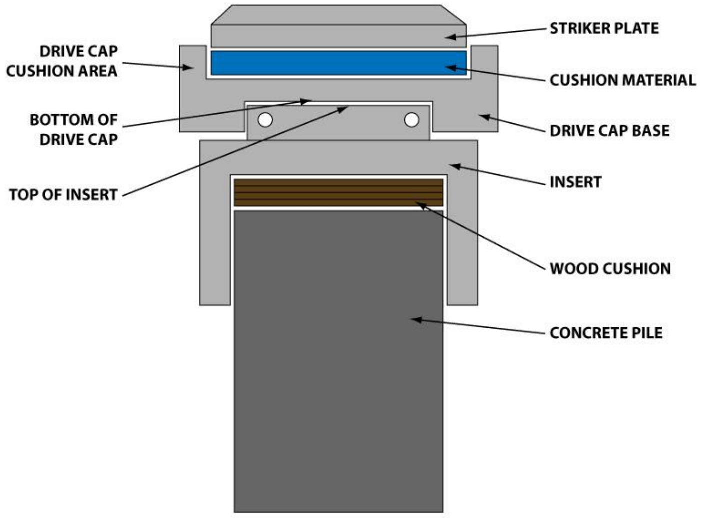


Figure 7.1-7 Cap and Cushion

(4) Follower

A follower should have a structure to hold the pile as securely as a cap does and to fully transfer the driving force of a hammer to the pile while protecting it. It is recommended, therefore, to use a follower of the same material and the same cross section as those of the pile. Should a follower of different quality be used for any unavoidable reasons, it is desirable to have the same equivalent cross section. A follower which is used in the pile installation by inner excavation method should be open-ended and hollow to allow earth to be discharged through it. Following items should be considered.

1) Diameter should be the same with pile diameter.

2) Stiffness should be similar to pile structure.

3) Length should be not too long.

4) Strength for continuous use.

5) Surface facing to pile should be smooth.

6) Length of guide should be appropriately not to remove from pile during piling.

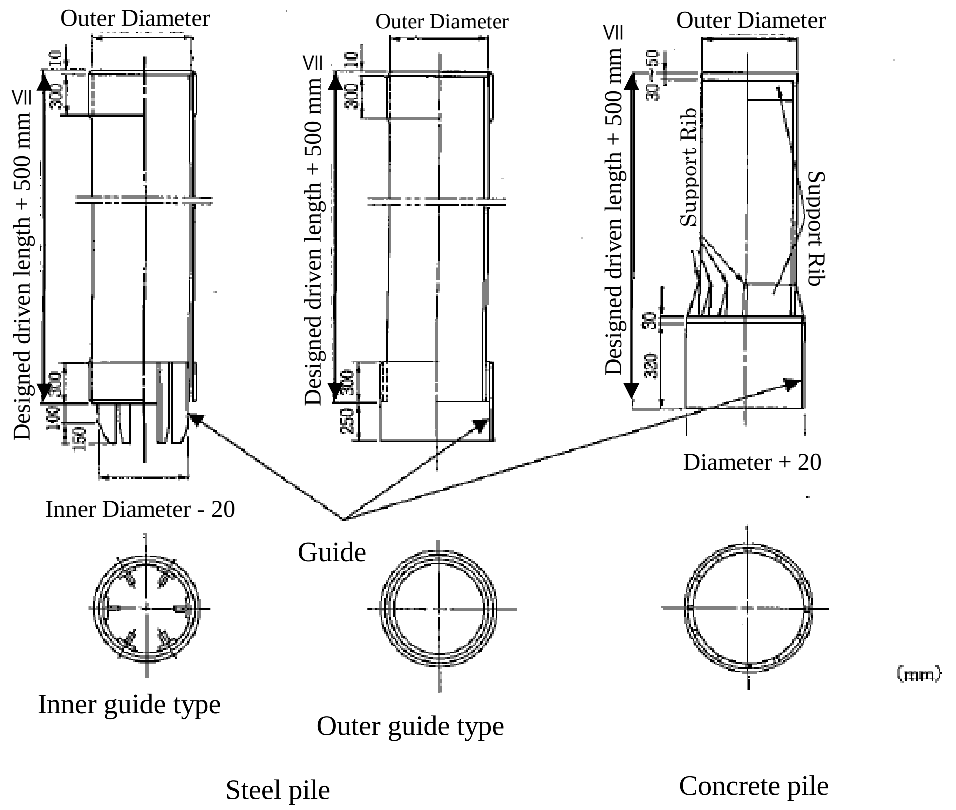


Figure 7.1-8 Follower

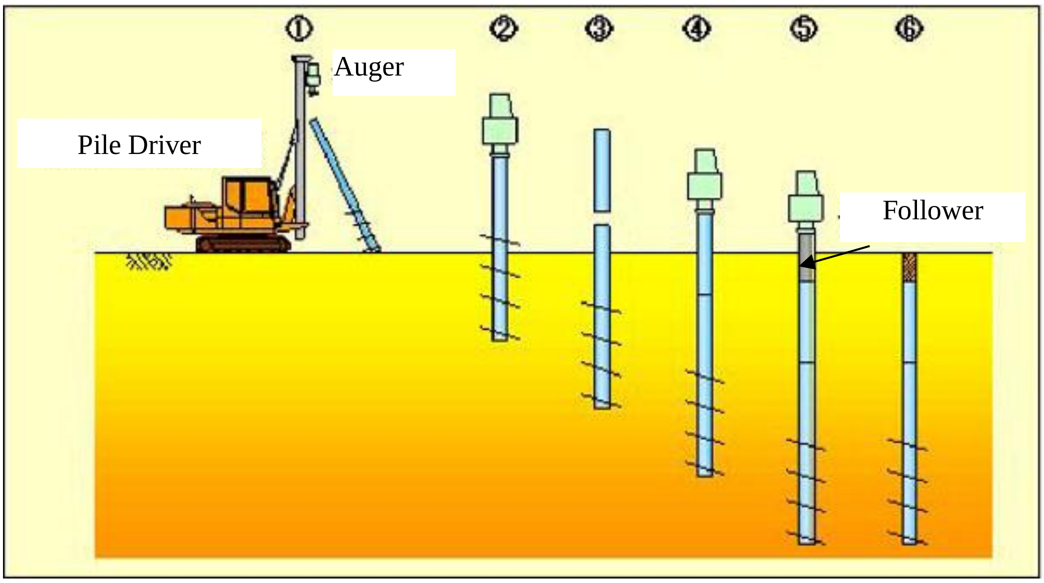


Figure 7.1-9 Follower

7.1.3. Construction

(1) Preparation

Prior to the construction of piles, preparatory work shall be done so that the construction can be done safely and surely.

(i) Arrangement of Working Ground

Grounding pressure of pile driving machines usually employed in this work ranges from 0.1 to 0.2 N/mm^2, and the site ground should be prepared for withstanding such pressure.

(ii) Temporary Storage of Piles

When temporarily storing piles at a construction site, sleepers should be appropriately spaced under them to protect them from harmful deformation. Height of piles to be heaped one on the other should be determined in accordance with bearing capacity of the ground and conditions of surrounding areas.

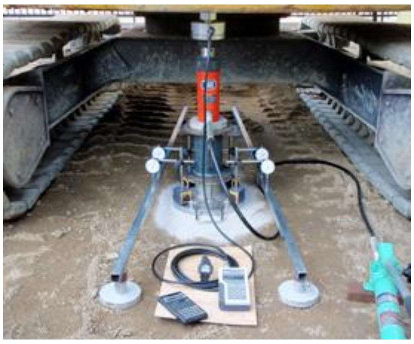


Figure 7.1-10 Measuring Ground Pressure

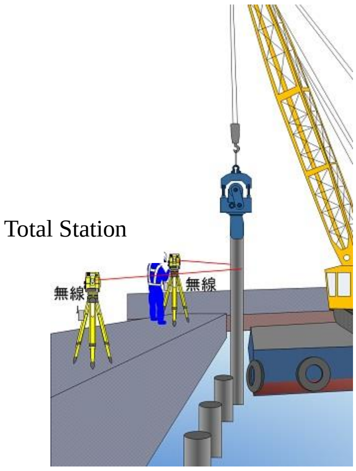
(2) Installation

A pile-driving machines and accessories should be installed at a correct location on the solid ground so that it may locate a pile accurately on a specified point.

In advance of pile installation, it is necessary to confirm the accurate point of pile center on ground by survey and put temporary wooden marker or paint on the ground. For accurate pile driving, the pile must be installed with the pile axis directed at the angle assumed in the design. After the installation, it is good to inspect the pile by measuring it from two perpendicular directions.

Hanging point of pile can be around 2 m from top of the pile. Pile should be hold by hanging wire firmly and moved to certain point which is surveyed in advance.

Figure 7.1-11 Pile Center Position



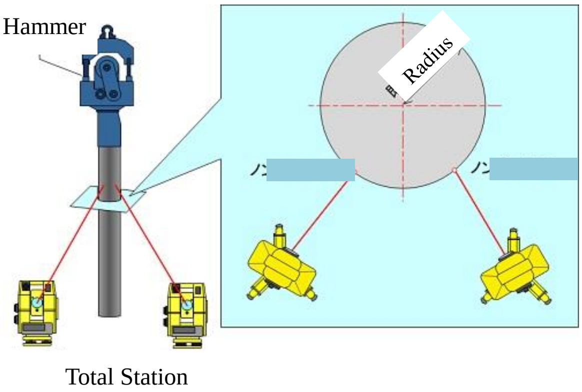


Figure 7.1-12 Survey for Pile Position

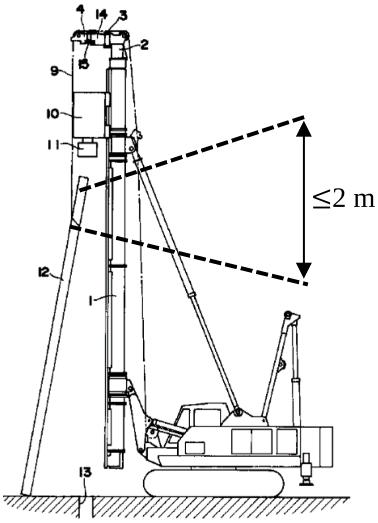


Figure 7.1-13 Pile Hanging Point

(3) Driving

(i) Selection of Hammer

In order to driving pile appropriately and efficiently, accurate selection of hammer is essential. Soil condition, pile type and surrounding environment should be considered for selection of hammer type.

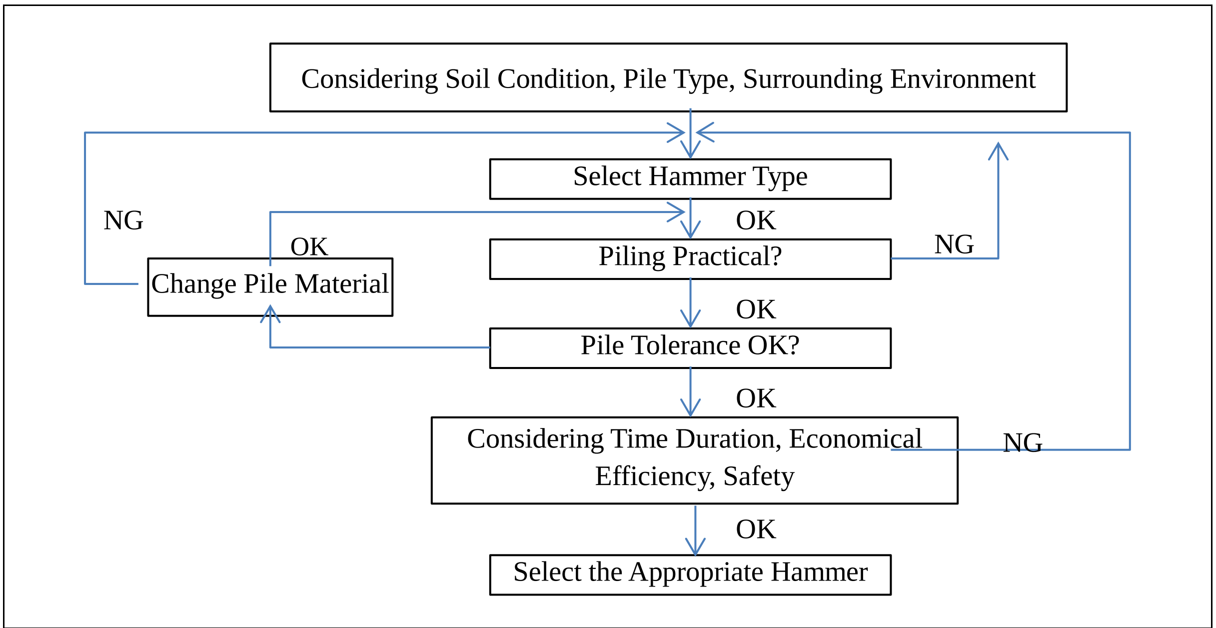


Figure 7.1-14 Hammer Selection Procedure

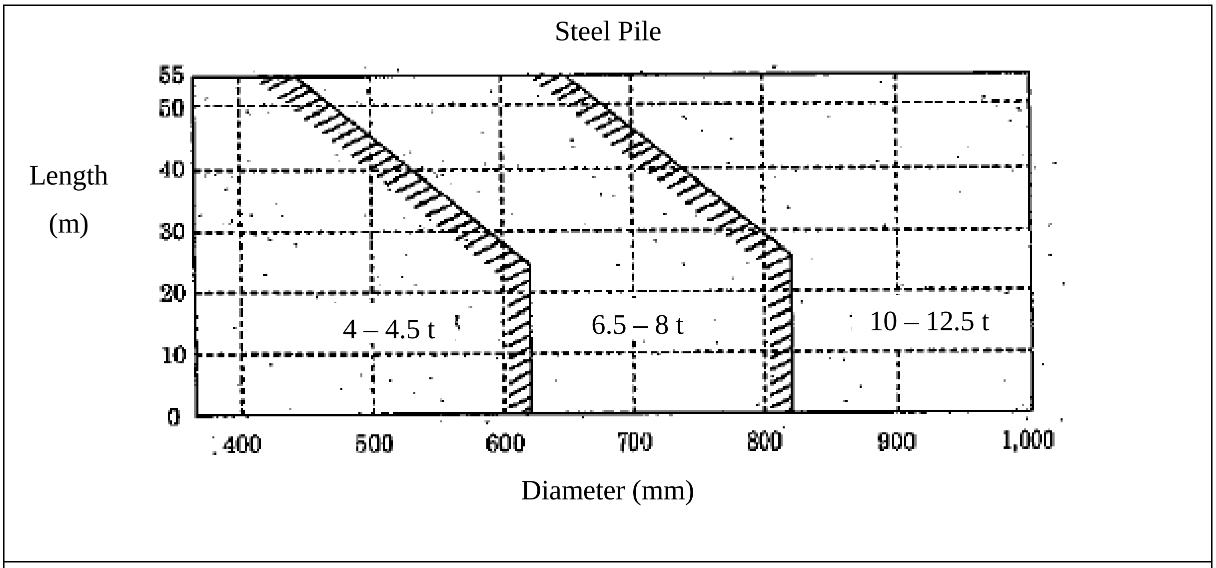


Figure 7.1-15 Hammer for Steel Pipe

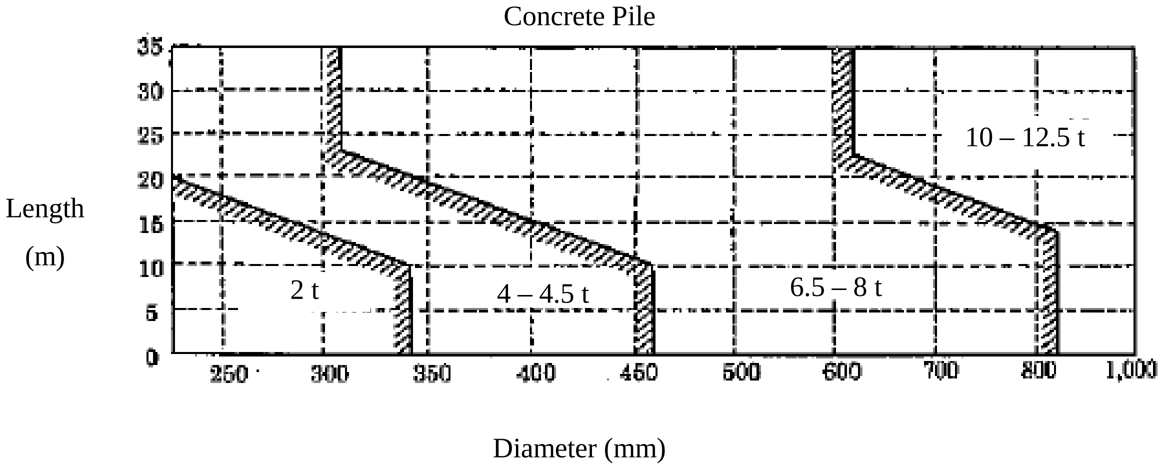


Figure 7.1-16 Hammer for Concrete Pipe

(4) Driving

Because eccentric driving sometimes generates buckling and damage of a pile head, tilts the pile axial line, and damages caps and cushions, the hammering direction should always be along the same line with the axes of the cap, the hammer, and the pile. Should a pile tip be damaged due to miss operation while being located or by boulders while being driven, the constructors should have to review substitution of the pile with a new one or increase a total length of piles.

When driving is suspended during the driving operation, driving becomes more difficult with the lapse of time and a larger driving facility is required. Therefore, driving should be done continuously as a general rule, and it is desirable to make available a facility having a capacity margin from the first.

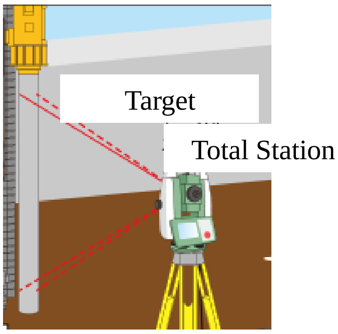


Figure 7.1-17 Pile Position Survey

(5) Accuracy

Confirmation items for construction accuracy are placement of pile, inclination and diameter for cast in place pile. Table 7.1-1 are required accuracy for pre-cast pile construction. Also, ground condition for pile driving machine and pile positioning are essential for accuracy.

Strength of ground surface should be confirmed and baseplate should be used if necessary. In case of soft soil condition, control point for survey should be placed where not effected by soil movement caused by machinery.

Table 7.1-1 Accuracy

Displacement from Designed Pile Center	D/4 or Less than 100 mm (Choose Smaller)
Pile Inclination	Less than 1/100

(6) Finishing

Based on result of test pile, driving stop position should be decided according to pile depth, dynamic bearing capacity (quantity of rebound), embedment depth, condition of support layer, etc.

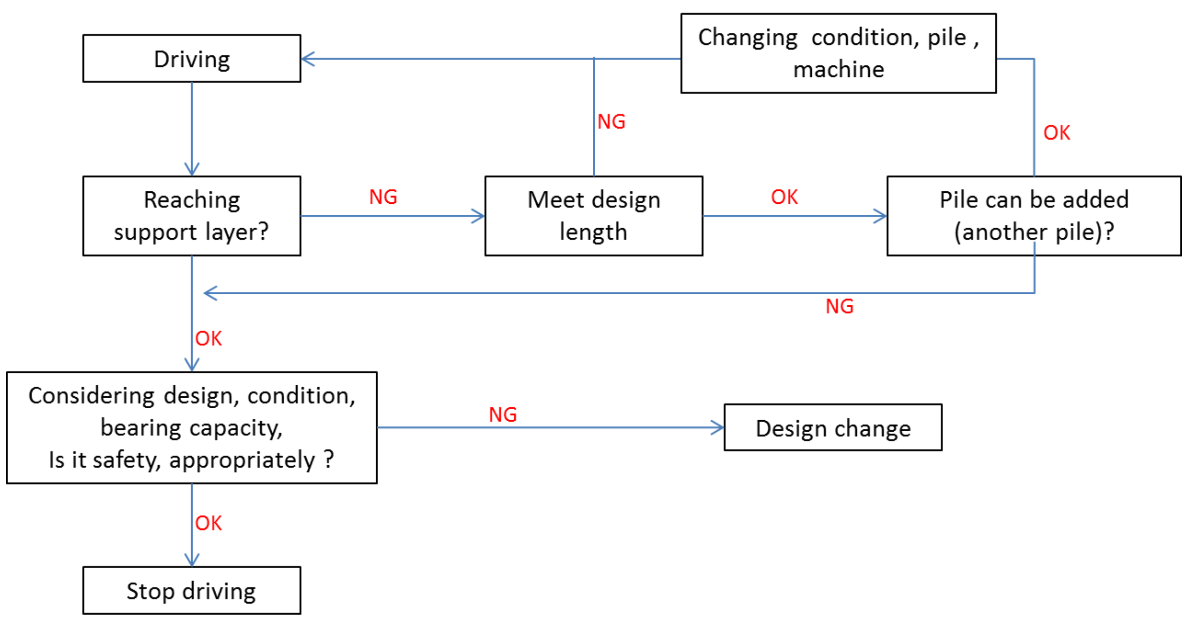


Figure 7.1-18 Finishing Confirmation

(i) Embedded Depth

Embedded depth of a pile specified in design documents or confirmed by results of test piling.

(ii) Dynamic Bearing Capacity

The dynamic bearing capacity in the driving method may be calculated using a formula for controlling finishing operation.

$$R_a = \frac{1}{3}\left(\frac{AEK}{e_0 l_1} + \frac{\overline{N}Ul_2}{e_f}\right)$$

where

R_a:	Allowable bearing capacity (kN) of the pile
A:	Net sectional area (m^2) of the pile
E:	Young's modulus (kN/m^2) of the pie
l_1:	Pile length (m) used for calculation of dynamic end bearing capacity as shown as Table-C. 17.10.1
l_2:	Length (m) of the pile driven in the ground
l:	Length (m) from the pile top end to a hammering point
l_m:	Length (m) from the pile top end to a point where rebounding is measured
U:	Circumferencial length (m) of the pile
$\overline{N}$:	Average N-value of the pile periphery
K:	Degree (m) of rebound
e_0, e_f:	Correction factors of values in Table-C. 17.10.2. However, W_H/W_P is the weight ratio of the hammer to the pile, and if a follower is used, W_P is the sum of the weight of the pile and follower.

Table-C. 17.10.1 Correction of Pile Length

Value of e_0	Value of l_1
$e_0 \geq 1$	l_m
$1 > e_0 \geq l_m / l$	l_m / e_0
$e_0 \leq l_m / l$	l

Table-C. 17.10.2 Connection Factor

Pile type	Installation method	e_0	e_f	Remarks
Steel pipe pile	Pile-driving method Boring and final driving	$1.5\ W_H / W_P$	0.25	
PHC, RC and SC piles	Pile-driving method	$2.0\ W_H / W_P$	0.25	
	Boring and final driving	$4.0\ W_H / W_P$	1.00	
Steel pipe, PHC, RC and SC piles	Pile-driving method	$(1.5\ W_H / W_P)^{1/3}$	0.25	Applied to hydraulic hammer

Figure 7.1-19 Rebound Survey

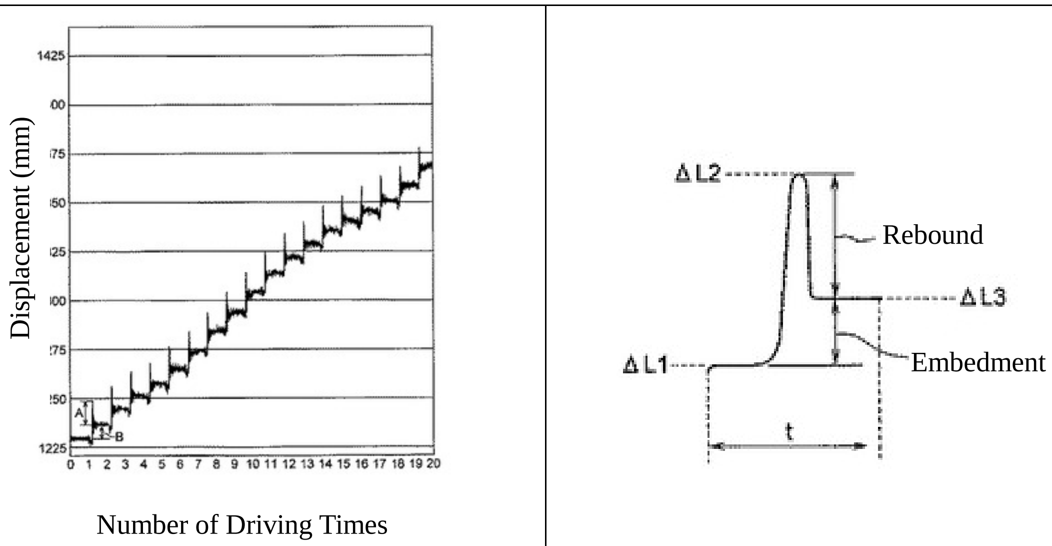


Figure 7.1-20 Rebound

7.2 Pre-boring Pile Method

7.2.1. Outline of Construction

The pre-boring pile driving method contains many technical processes. However, the one referred to here is the process in which the ground is bored by a boring bit or rod and a foot protection fluid and pile periphery fixing fluid are injected, and then a reinforced concrete pile, a PHC pile or a steel concrete pile fabricated at a factory is installed there. That is, the pre-boring pile driving method referred to here is restricted to methods that can surely fill the gap between the borehole wall and pile peripheral surface.

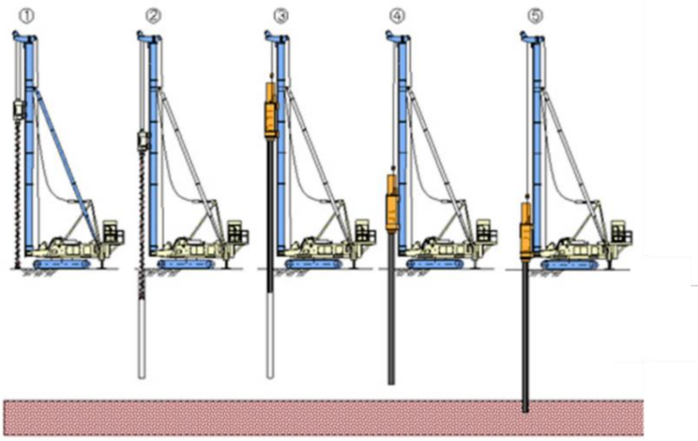


Figure 7.2-1 Pre-boring Method

7.2.2. Construction Machineries

(1) Pile Driver

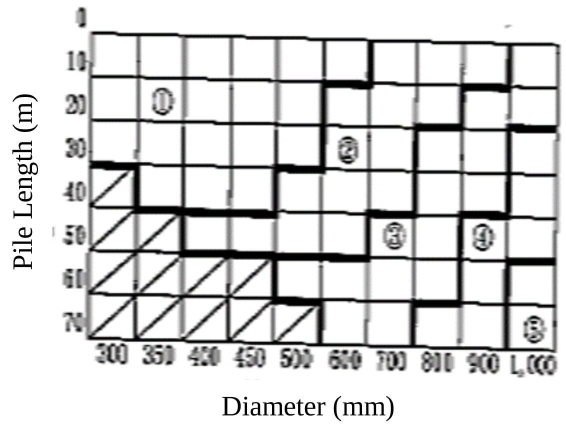
Generally, three-Point supporting pile driver is installed. Boom suspension type is also used at narrow space.

Figure 7.2-2 Three-Point Supporting Pile Driver

Figure 7.2-3 Boom Suspension Type

(2) Auger Driving Motor

Auger should be selected with considering soil condition. Basically, motor capacity for driving auger should be selected depend on pile length and capacity.



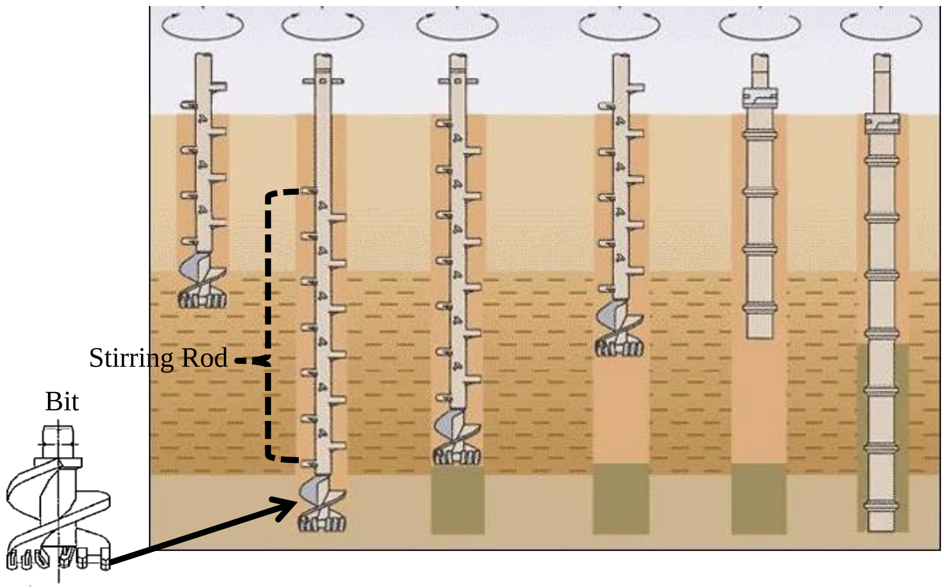
Motor Capacity	
- 45kw	①
55kw	②
90kw	③
110kw	④
150kw	⑤

Figure 7.2-4 Capacity of Auger Driving Motor

(3) Drilling and Stirring Machine

Two types of drilling and stirring machine is used, drilling bit and stirring machine is separated, combined. Combined type is effective for accurate construction. The length of it should be longer than designed drilling depth.

Diameter of drilling bit and stirring rod should be selected with considering pile diameter.



Pile Diameter (mm)	300	350	400	450	500	600	700	800	900	1000
Stirring Diameter (mm)	400	450	500	550	600	700	800	900	1000	1100

Figure 7.2-5 Stirring Rod

7.2.3. Construction

(1) Drilling

During boring, a drilling fluid is discharged from the drill bit to reduce the drilling resistance and protect hole wall of the ground. At this time, it is necessary to adjust the discharge rate of the drilling fluid according to the drilling speed.

It is important for the drilling speed to take a value that suits the ground. When a cohesive or hard ground is drilled, note that the drill rod can be bent or damaged if an unreasonable load is applied.

If the borehole will collapse because of the soil condition there, it is good to use a drilling fluid of bentonite slurry with a lost circulation material or the like added.

When the auger tip has reached the prescribed depth, care should be taken not to disturb the neighboring ground by excessive drilling, mixing for a long time, or the like. The bearing layer is ascertained by keeping the drilling speed constant, reading the changes of auger driving current value on the ammeter and collating the relationship with drilled depth against the preliminary ground survey results. When pulling out the auger, it is good to check the earth adhering to its tip by direct visual observation.

Drilling speed should be set up based test pile result. At the time of the drilling on hard soil, torque could be going up and rod could be damaged. Therefore, drilling speed should be managed. Drilling speed can be measured by the speed of certain the point on the rod.

Table 7.2-1 Excavation Speed

Soil	Excavation Speed (m/min)
Silt, Soft mud, Soft sand	0.5 – 4
Hard mud, sand	0.5 – 3
Hard sand, Gravel	0.5 - 1

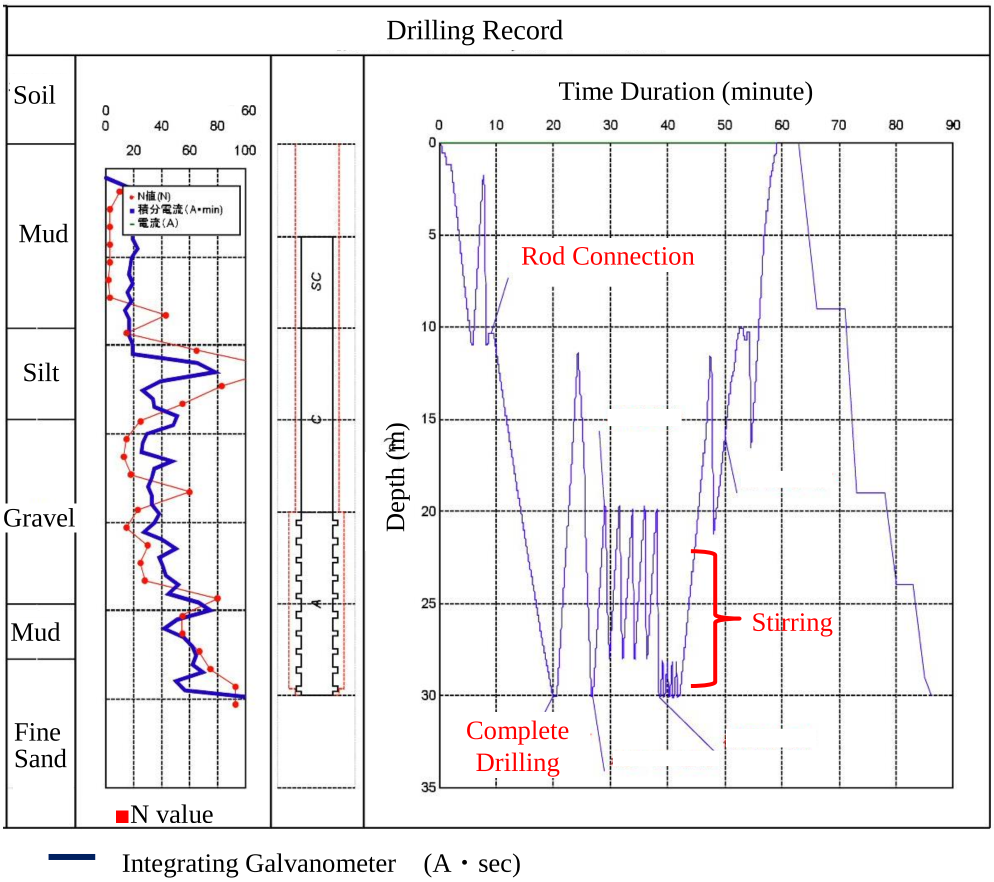


Figure 7.2-6 Excavation Record

(2) Accuracy

Confirmation items for construction accuracy are placement of pile, inclination and diameter for cast in place pile. Table 7.2-2 are required accuracy for pre-cast pile construction. Also, ground condition for pile driving machine and pile positioning are essential for accuracy.

Strength of ground surface should be confirmed and baseplate should be used if necessary. In case of soft soil condition, control point for survey should be placed where not effected by soil movement caused by machinery. Drilling depth should be measured by survey the marking on road.

Drilling speed should be managed based on test pile construction.

Table 7.2-2 Accuracy

Displacement from Designed Pile Center	D/4 or Less than 100 mm (Choose Smaller)
Pile Inclination	Less than 1/100

Figure 7.2-7 Measurement of Drill Core Position

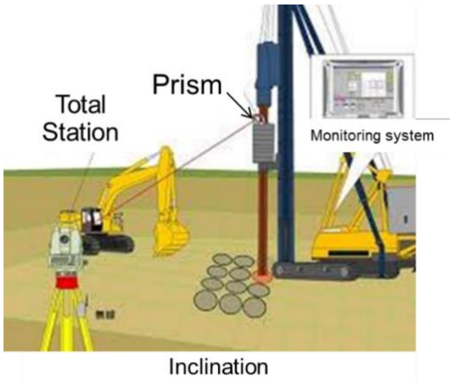
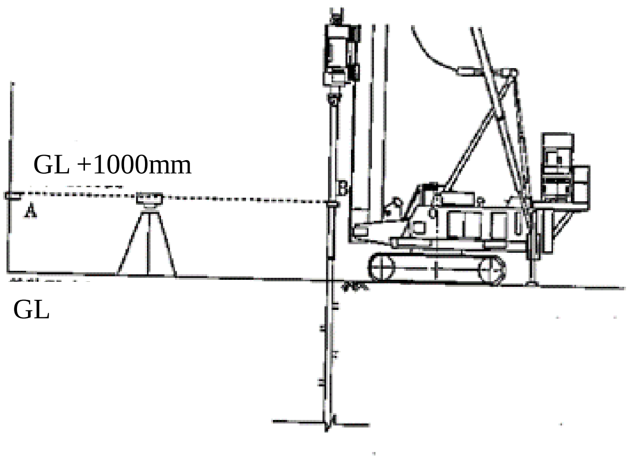


Figure 7.2-8 Survey of Drill Core Position



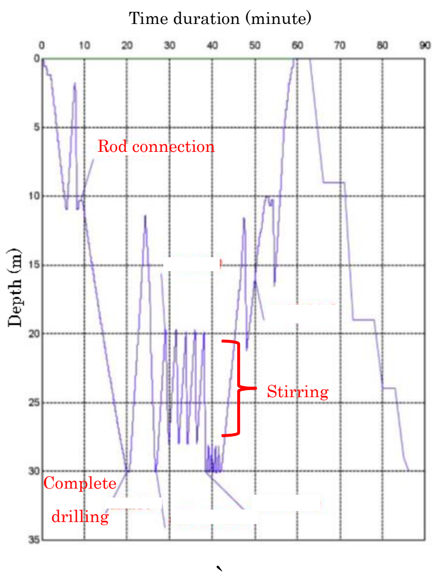


Figure 7.2-9 Survey of Excavation Progress

(3) Support Layer Confirmation

Embedment to support layer is essential for bearing capacity of precast pile.

Reaching support layer of drilling can be confirmed by the record of drilling torque or integrating galvanometer.

In case, if significant difference compared with test pile, review each data carefully, and, if needed, additional boring survey could be conducted.

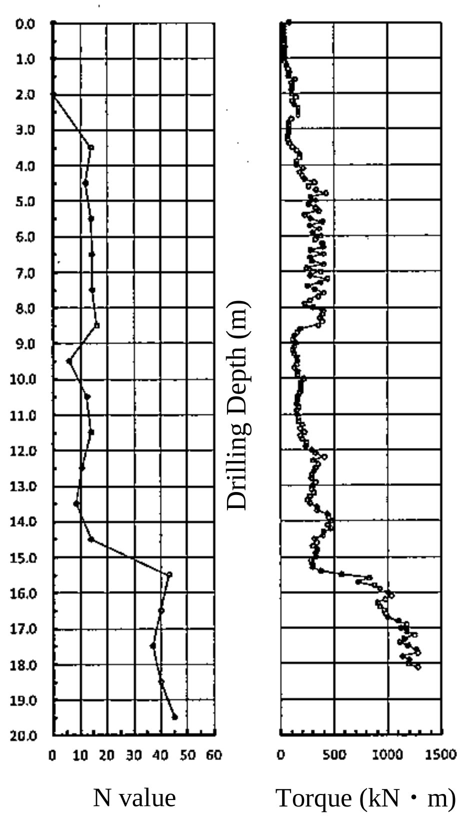


Figure 7.2-10 Excavation Record

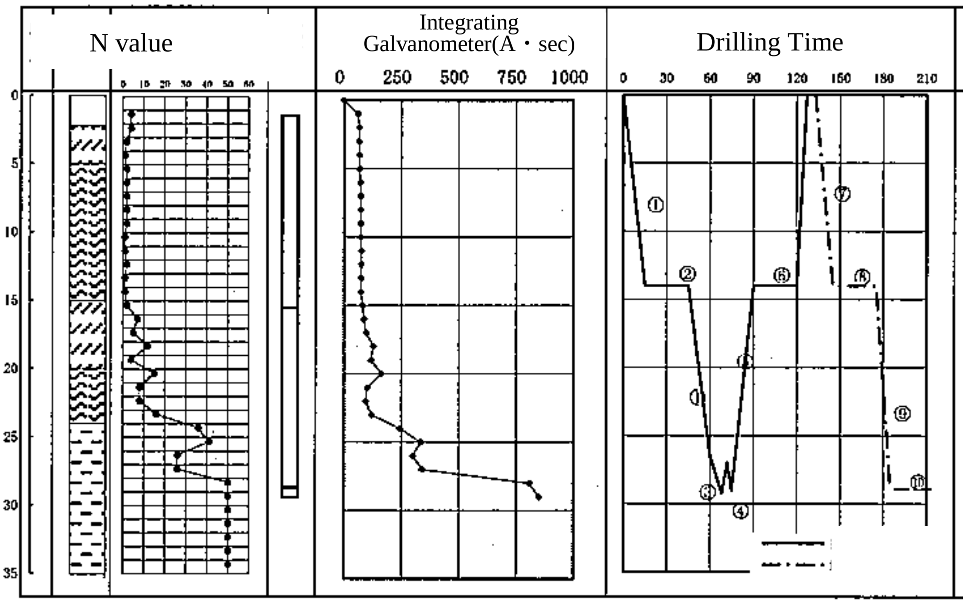


Figure 7.2-11 Excavation Record

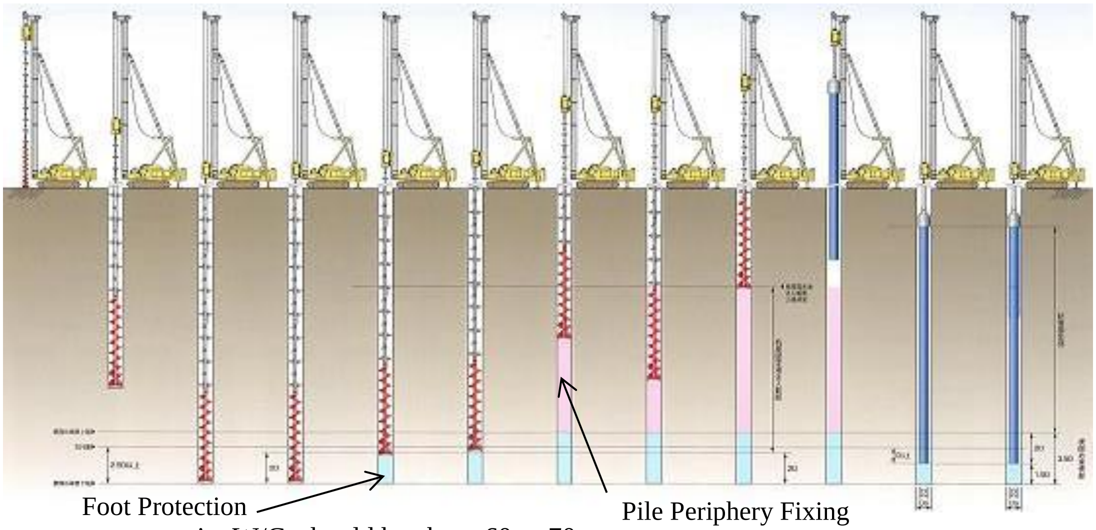
(4) Injection of Foot Protection Fluid and Pile Periphery Fixing Fluid

(i) Foot Protection

The foot protection fluid shall be injected without fail to develop the prescribed bearing capacity. The water-cement ratio, W/C, of the cement milk used for the foot protection fluid should be about 60 to 70 percent, and the foot protection fluid should be injected without fail to the prescribed position while sufficiently mixing with the sandy ground around the pile tip. It is desirable to take the compressive strength of the foot protection fluid sampled from the plant at σ 28 = 20 N/mm^2.

(ii) Pile Periphery

The pile periphery fixing fluid shall be injected without fail to fill the gap between the borehole wall and pile body. The cement milk used for the pile periphery fixing fluid should be injected without fail, paying attention to the amount injected, injection rate and the like. If the fluid level sinks due to water gain or loss accompanying the curing of the pile peripheral fixing fluid and a gap forms between the borehole wall and pile body, the pile peripheral fixing fluid must be replenished. It is desirable to take the compressive strength of the pile peripheral fixing fluid sampled from the overflow atσ_{28} = 0.5 N/mm^2.



The water-cement ratio, W/C, should be about 60 to 70 .

Compressive strength : Foot protection $\sigma_{28} > 20$ N/mm^2

Pile Periphery Fixing $\sigma_{28} > 0.5$ N/mm^2

Figure 7.2-12 Injection of Foot Protection Fluid and Pile Periphery Fixing Fluid

(5) Pile Placement

The pile shall be scuttled or screwed sunk to the depth of support layer which is considered in the design. The pile should be set up accurately in the borehole, paying attention to inclination.

When sinking the pile, proceed with the work, being sure not to scrape the hole wall or do damage to the pile body, and check that the injected pile periphery fixing fluid overflows from the pile head.

The insertion of a pile should be done by its own weight or rotary press-in. Be sure to sink the pile to the prescribed depth.

Figure 7.2-13 Pile Placement

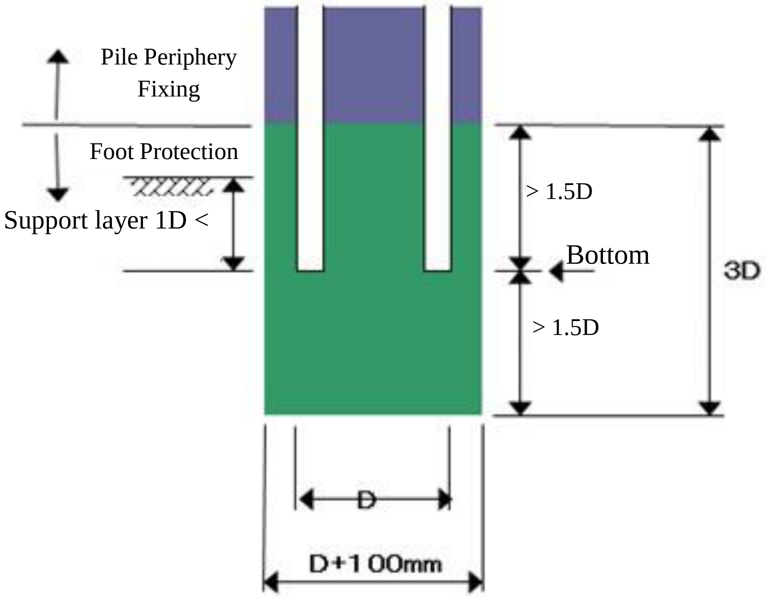


Figure 7.2-14 Foot Protection

(6) Connection

Pile connection, basically welding, is key element of pile structure. It should be managed properly and tested after finishing connection (Chapter 5). Typical connection structure for precast pile is following.

During welding work, lower pile should be held with stand flame.

Table 7.2-3 Welding Size

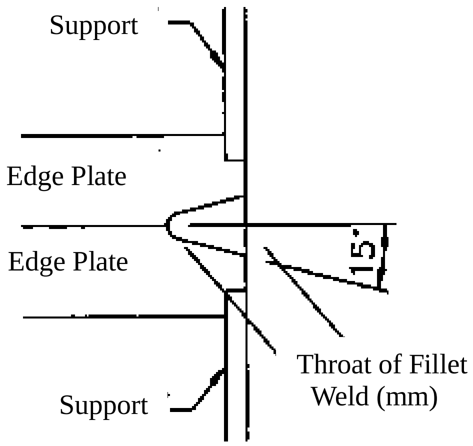
Pile Diameter (mm)	Throat of Fillet Weld (mm)	
300	8.0	
350	8.5	
400	9.5	
450	10.0	
500	11.0	
600	12.0	
700	13.0	
800	14.0	
900	15.0	
1000	16.0	

Figure 7.2-15 Welding

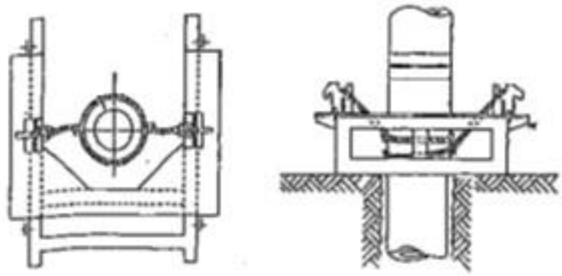


Figure 7.2-16 Holding Flame

7.3 Jack in Piling Method

7.3.1. Outline of Construction

Jack in piling method is displacement piling method. The reinforced square or round pile is pressed into the ground by using the hydraulic pressure.

Therefore, there are three advantages, during pile installation, no noise, no pollution and no vibration that means this type of piling method is environmentally friendly method. And it is considerable that the sounding soil move to side away and the movement make certain affection on existing structure when a pile material is installed simply without any treatment.

Thus, the method for piling work is planned as firstly removing the soil by pre-boring machine and installation the pre-stressed spun pile by hydrostatic machine since the method is believable to reduce the risk. The loading force for piling is monitored by hydraulic pressure gauge incorporated into the system to prevent excessive condition and provide quality assurance.

Figure 7.3-1 Basic Procedure of Jack in Piling Method

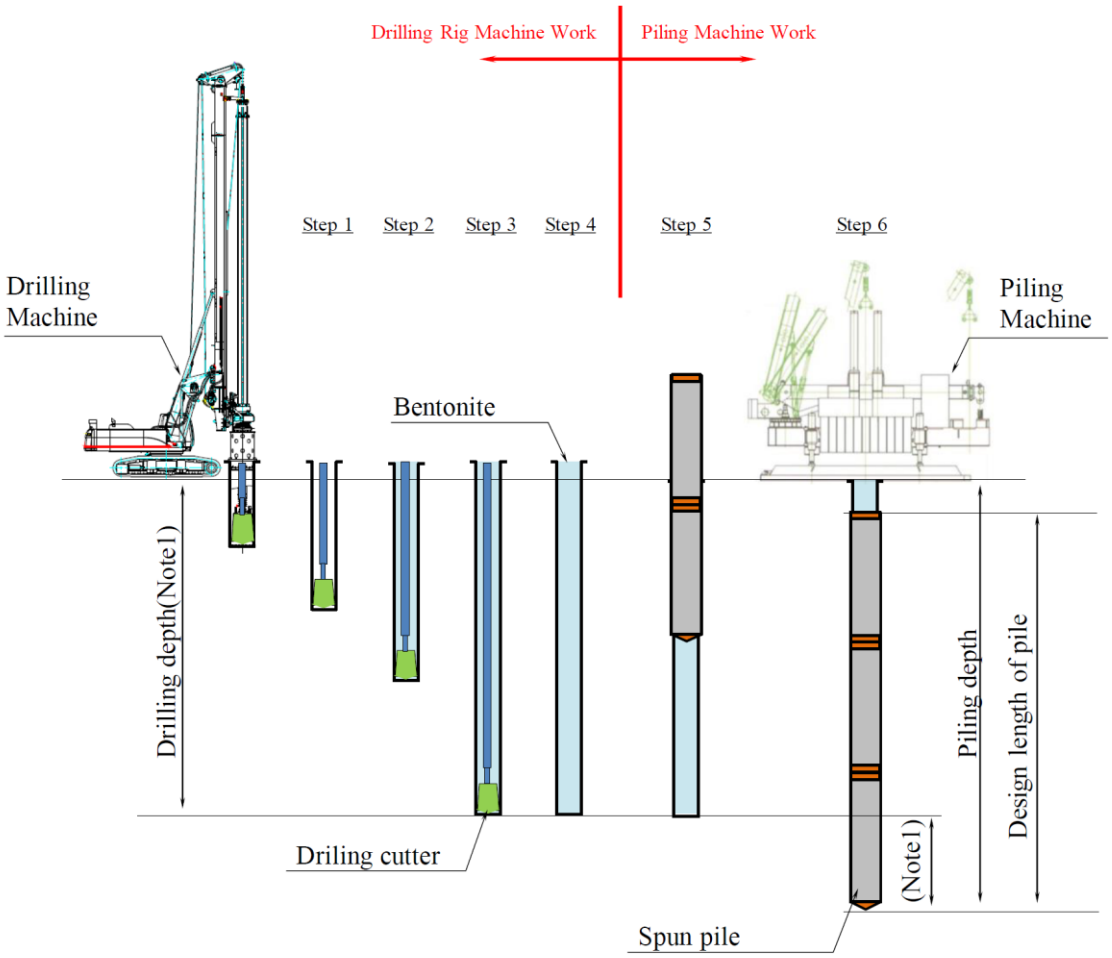


Figure 7.3-2 Basic Procedure of Jack in Piling Method

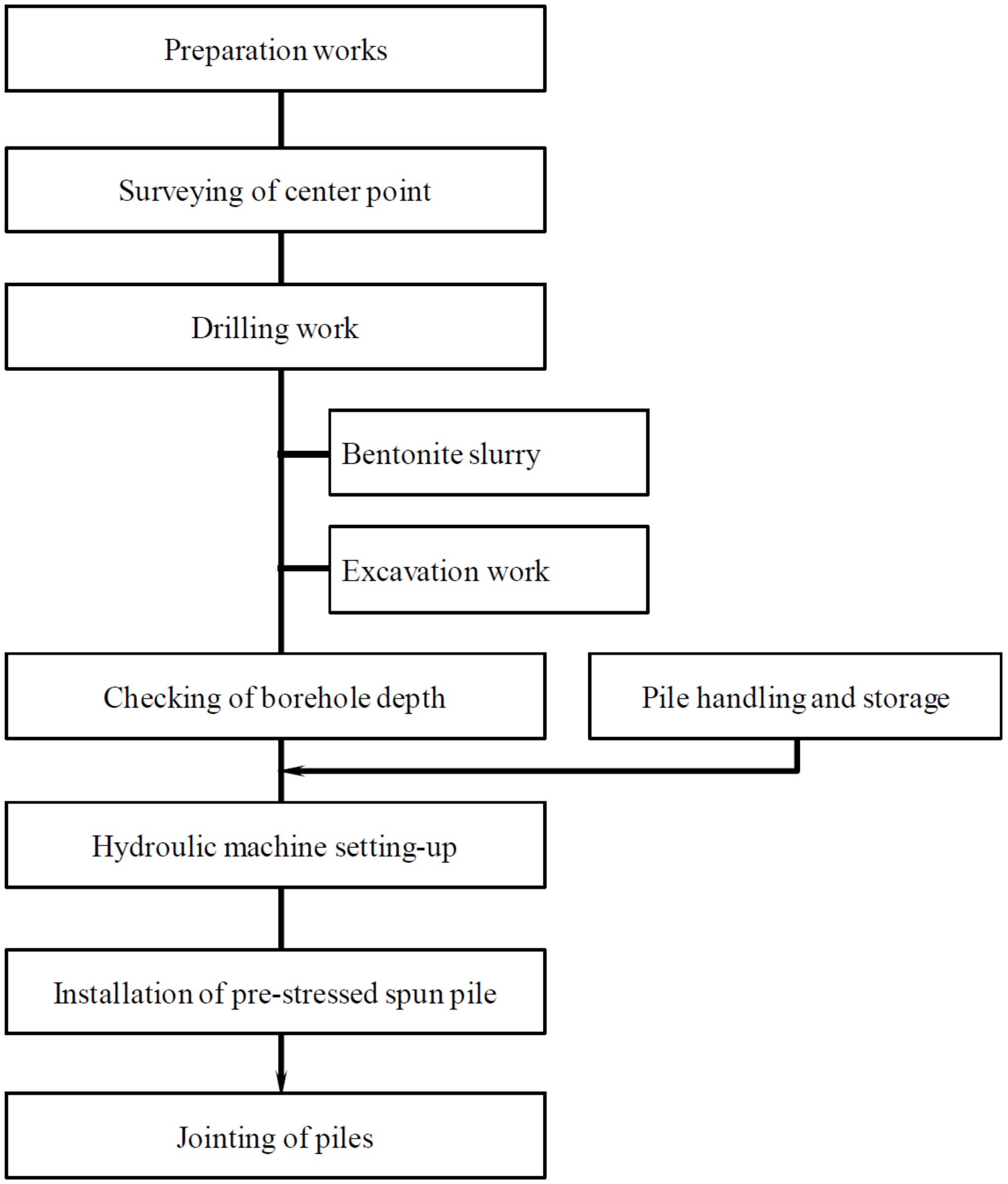


Figure 7.3-3 Basic Procedure of Jack in Piling Method

7.3.2. Ultimate Bearing Capacity and Friction

(1) Ultimate End Bearing Capacity Intensity

The ultimate end bearing capacity intensity may be evaluated by Figure 7.3-4 same as driven pile. This figure gives the ratio of qd to the characteristic N value at the ground at the pile tip as a function of the pile embedment ratio to the supporting layer (ratio of the equivalent embedment depth above the supporting layer to the pile diameter).

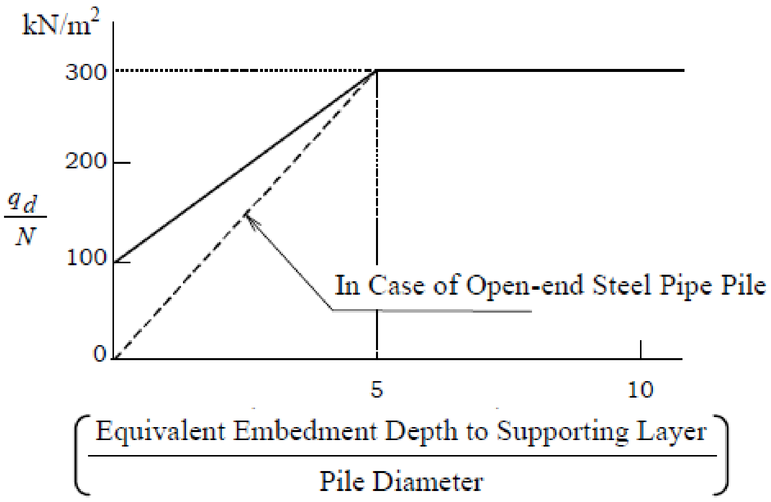


Figure 7.3-4 Evaluation Chart for Ultimate End Bearing Capacity Intensity

(2) Friction Capacity

The maximum shaft resistance intensity acting on the pile skin shall take the values shown in Table 7.3-1, depending on the pile installation method and ground type.

Table 7.3-1 Maximum Shaft Resistance Intensity (kN/m²)

	Sandy Soil	**Cohesive Soil**
Driven Pile Method Jack in Piling Method	2N (<100)	c or 10N (<150)
Bored Pile Method	2N (<100)	0.8c or 8N (<100)
Pre-boring Method	5N (<150)	c or 10N (<100)

C: cohesion of ground (kN/m²), N: N value from SPT

7.3.3. Construction

(1) Preparation Works

Piling machine will transport by barge because of its own weight is more than 50 tonnages.

Prior to the commencement of the spun piling works, the site shall be cleaned out and made as flat and these areas, if necessary, will be compacted by vibratory roller in order for heavy machinery to stand and move safety.

And if it is not enough for piling activities including of shifting between working areas, steel plate shall be placed on it to serve working platform.

The facilities for mixing and treatment of bentonite, which used as filler materials during/ after boring, will be installed beside of each working area. As per environmental requirement, the spillage and loss of the bentonite liquid material shall be monitored periodically during construction.

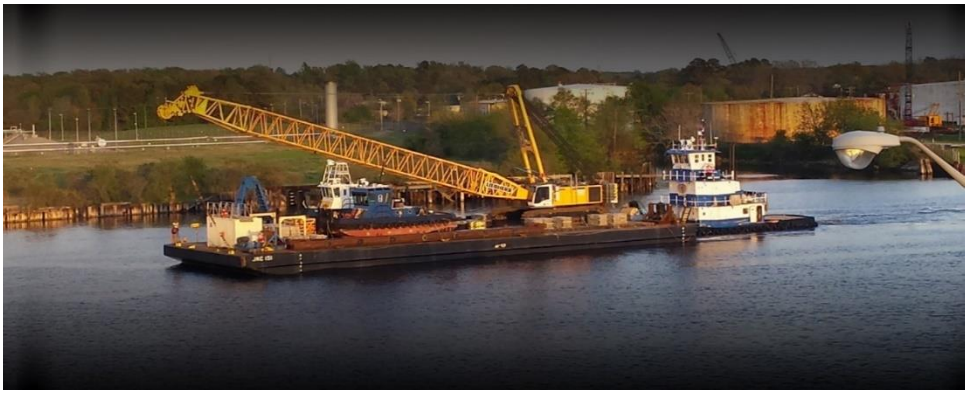


Figure 7.3-5 Piling Machine transported by Barge

(2) Survey the Center Point of Pile

The coordinate of each spun pile center shall be found out by land surveying with Total Station survey equipment. The offset marking shall be prepared in at least two directions in the coordination at 2.0 meters away from the center of designed location.

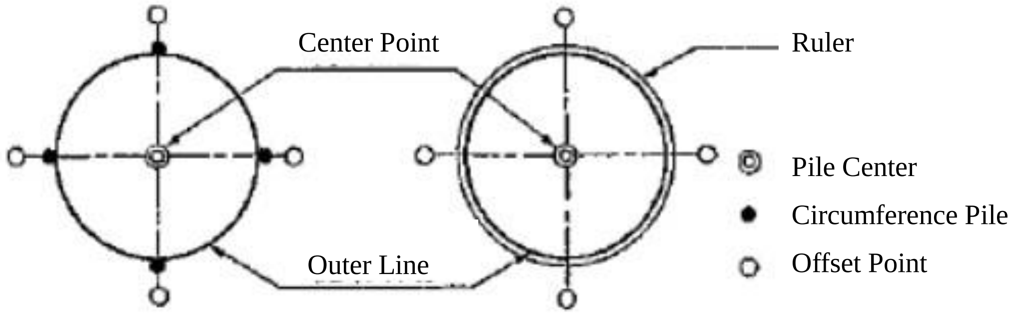


Figure 7.3-6 Survey

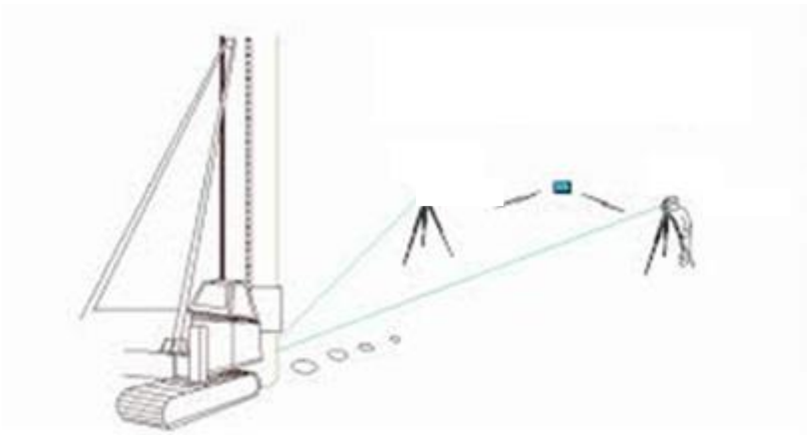


Figure 7.3-7 Drilling Position Survey

(3) Setting of the Temporary Casing

If necessary, the stand pipe might be installed temporary by machineries to prevent the influents into opening by boring before commencement of construction work.

The length of the stand pipe shall be considered and justified based on the soil condition and underground water level for maintaining the stability of the pile excavation and preventing.

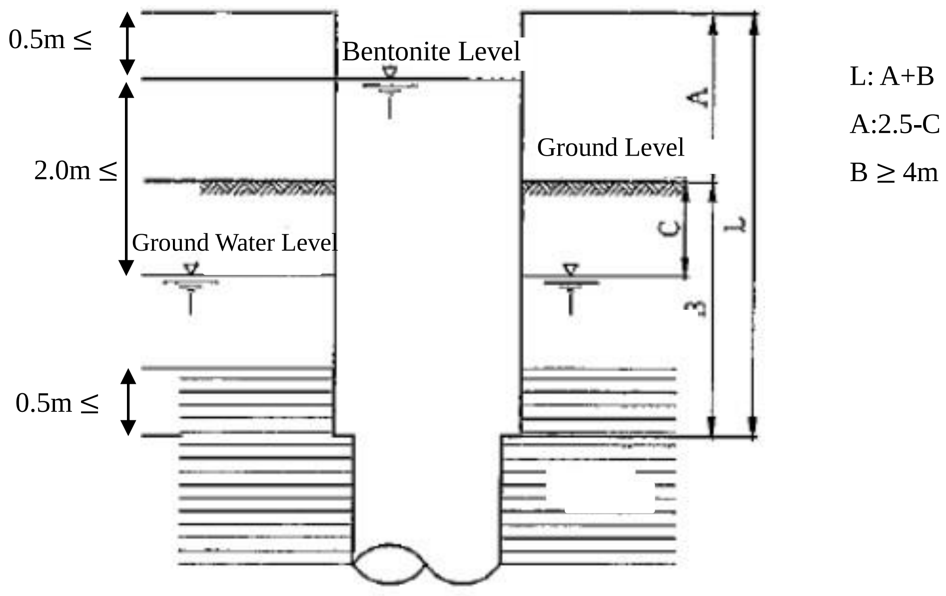


Figure 7.3-8 Stand Pipe

(4) Drilling Work

The depth of drilled hole shall be reached to planned depth with tolerance. The excavated holes shall be protected from collapse by the bentonite slurry.

(i) Bentonite Slurry

The facility with circulating function for bentonite slurry using shall be set up on site since the material will be re-cycled to use according to collection and filtering during piling work.

Prior to the drilling works, the stabilization liquid as the bentonite suspension shall be prepared and tested to meet the criteria described as follows:

Table 7.3-2 Standard Criteria of Bentonite Slurry

				Silt, Mud	Sand	Gravel
Mix Design	Base Material	Bentonite	%	2 -4	4 - 6	5 – 8
		CMC	%	0 – 0.1	0.05 – 0.1	0.05 – 0.2
	Support Material	Leaking Inhibitor	%	-	0 – 0.5	0 – 1
Properties	Viscosity		Sec	20 - 24	22 - 30	25 – 40
	Filtering Water		ml	10 - 20	≤ 15	≤ 15
	Specific Gravity*		-	1.01 –	1.02 -	1.03 –
	pH		-	9 – 10.5	9 – 10.5	9 – 10.5

*Attention for affection of Sedimental Velocity and Replacement are needed as below (Table 7.3-3) if more than 1.05.

Table 7.3-3 Effecting of Bentonite Quality

	Water Height		Specific Gravity		Viscosity		Filtering Water		Sand Content	
	High	Low	High	Low	High	Low	High	Low	High	Low
Wall Collapse Prevention	◎		◎		○			◎		
Sedimentation Velocity			*	◎		◎				
Replaceability			*	◎		○				◎

◎ ：More Effective

○ ：Effective

Bentonite will be mixed thoroughly with clean fresh water to make a suspension which will maintain the stability of the pipe excavation for the period of casting concrete. Dry powder bentonite is mixed with clean water according to required ratio by mixing machine and stored in the tanks for supplying to bored hole. The drilling fluid properties shall be measured by taking samples before concreting.

The density of freshly mixed bentonite suspension shall be measured daily as a check on the quality of the suspension being formed. In that case, the bentonite with mortar, which cannot be adjusted or treated with the additive, shall be rejected.

(ii) Excavation Work

Diameter of pre-boring is 500 mm (-100 mm of pile diameter). During excavation work will be executed continuously by drilling machine, the top level of bentonite slurry shall be maintained at 2.0m or higher than ground water level for prevention of borehole collapse. During the drilling work, the verticality of drill shall be checked by plumb with string line or theodolites from two directions in 90 degree. When the bucket is lifted up, the bucket is rotated reversibly to release from the bottom and lifted up slowly to prevent of borehole collapse.

The soil stratum shall be monitored and recorded carefully to check actual soil condition. The soil sample will be collected every layer. When the drilling reaches the planed level, the drilling machine will be changed to jack-in machine for piling work.

Step1: Drilling cutter, which equipped on drilling machine, is driving into ground by drilling machine.

Step2: Driving of cutter is continued till design drilling depth with Bentonite treatment.

Step3: Drilling work is reaching to designed depth.

Step4: After drilling work, Bentonite is refreshed.

Step5: Spun pile, which size is larger than drilled hole is installed by piling machine.

Step6: Planned pile with designed length is installed.

Note: Drilling depth and the depth where the spun pile is installed without pre-boring are defined after consideration.

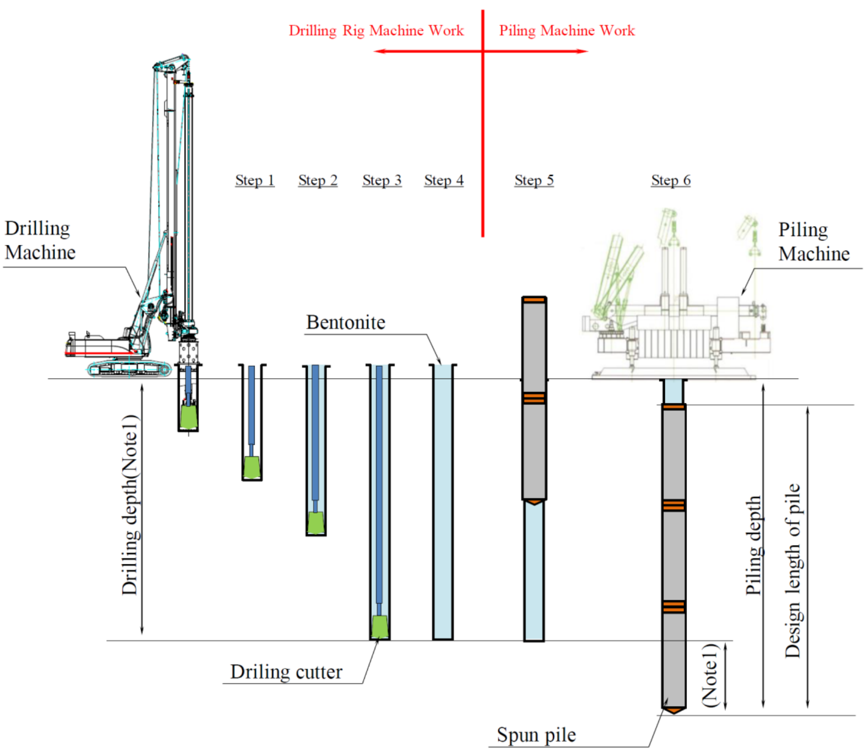


Figure 7.3-9 Basic Procedure of Jack-in Piling Method

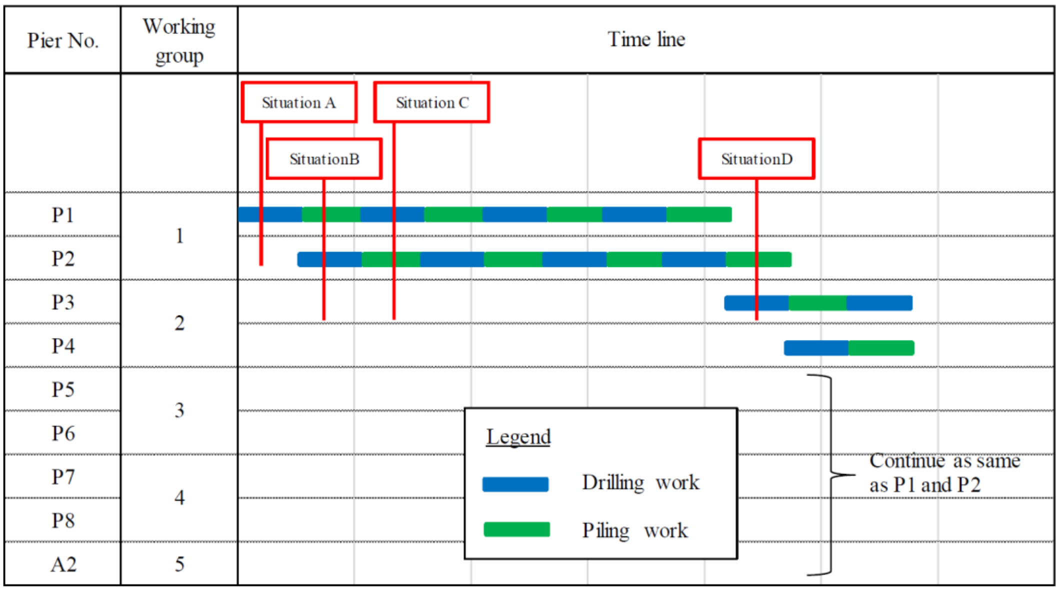


Figure 7.3-10 Example of Sequence of Arrangement for Machinery Shifting

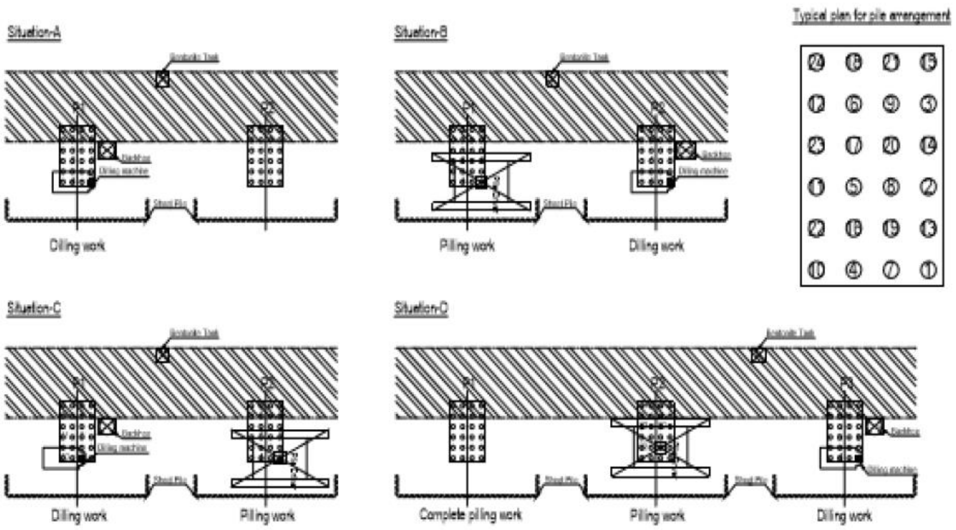


Figure 7.3-11 Machinery Arrangement

(5) Checking of Borehole Depth

Figure 7.3-12 Checking of Borehole Depth

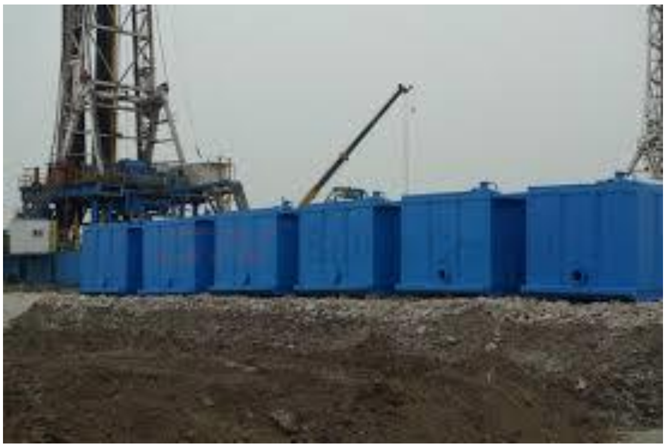


Figure 7.3-13 Tank for Storing Fresh Bentonite Slurry

(6) Requirement of Pile Quality

Pre-stressed spun piles will be used, and the length of pile product is planned variously as 7 to 13 meters in length. The tolerance of spun pile product is followings.

Table 7.3-4 Tolerance for Concrete Pile (JIS A 5372, A 5373)

	Length (L)	Dimension (D)	Thickness (t)
D ≤ 600mm	± 0.3% of Length (L)	(+) 5mm (−) 2mm	(+) Not specified (−) 0 mm
700mm≤D <1200mm		(+) 7mm (−) 4mm	

(7) Pile Handling and Storage

The engineer and supervisor for piling shall supervise unloading, handling and pitching of pile to ensure that piles are not damaged whilst carrying to the project site. During lifting of the product, slings shall be attached at designated lifting points or ends shall be clamped.

Piles are lifted at each end with lifting clamps for two-point lifting and 0.2 times of the pile length from end for one-point lifting since it shall be ensured to serve minimum lifting stress on pile product and checked by crane operator before every operating. It shall be made sure that all outriggers are extended fully and footed on steel plates or hardcore. It shall be checked that all valve, alarms and mechanisms are working properly and lifting devise such a wire rope is in good condition before use. Supervisor shall support proper slinging and check the lifting equipment before working.

Figure 7.3-14 Storage Condition of Pre-stressed Spun Pile Product

(8) Hydrostatic Pile Driver Movement, Pile Pitching& Installation

The main component of piling machine is consisted by the hydraulic device system. The hydraulic system activated by electrical power from portable generator is used to grip down the pile into the ground, mobilize the machine and run the winch.

The machine itself can move into two directions, X and Y directions. Therefore, it is very easy to adjust the location for piling.

The Hydrostatic pile driver consists of the following components.

a) Main body with long ship & short ship

b) Hydraulic system with controls

c) Accessary crane, lifting the materials

d) Counter weight

e) Welding equipment, available for jointing work between piles

Figure 7.3-15 Pressing Driver

Accessary crane is used to slot the pile product into the champing box and mechanical hydraulic system can grip the pile and move into two directions for adjusting the piling location. And it can press the pile into the ground by hydraulic pressure of main cylinder.

A pressure gauge, attached to the hydraulic system of main cylinder show the installed volume in term of MPa. This hydraulic pressure can be converted into load values (Tons) depending on the diameter of main cylinder used.

To press-down the pile into ground with hydraulic pressure, the weight of Kentledge (Counter Weight) must be fixed on the piling frame as larger than required loading force for piling. After attaining the designed load of pile, the pressure is maintained for 30 seconds to ensure that the design load is succeeded.

For machine movement, operator shall ensure the accessibility whether the slope for next place is not too steep, not existing of any obstruction and make sure that the all person is in safety position when the piling machine and counter weight shifting. Before make any movement of the piling machine, At least one signal man and one rigger man must follow the piling machine. If the access is "not firm and level", request supervisor to rectify.

For piling operation, all workers shall wear necessary PPE. It must be kept clear from unnecessary disturbance in front of the piling machine. It shall make sure the horizontal and vertical level of machine frame before piling starts. It shall make sure the proper clamp devise is fitted. When one person climb-up on high place of machinery, he must wear proper safety belt and the machine do never work when the operator cannot recognize and never get signal.

(9) Jointing of Piles

After one pile installation, the jointing work by welding work shall be applied for connection part with next pile.

The type of welding is fillet weld on joint shown in Figure 7.3-16 and welding thickness depends on end plate thickness is at least 3 mm around the joint.

The welding electrode shall be designed as suitable with mother plate property. Welding activities shall be conducted by welder who has been trained enough and by referring the electrical setting as shown in Table 7.3-5.

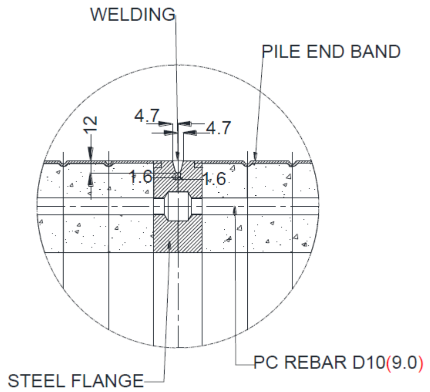


Figure 7.3-16 Connection Part

Table 7.3-5 Sample for Electrical Combination at Welding Work

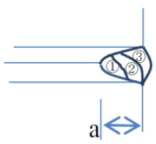
Groove Depth	Joint Shape	Numbers of Passes	Current (A)	Voltage (V)	Welding Speed
Dia. – 600 a = 12 mm		1	350 ~ 420	26 ~ 30	25 ~ 35
		2			
		3			

Figure 7.3-17 Welding Work Condition	Figure 7.3-18 Welding Work Condition

(10) Termination Criteria

The termination criterion is to press the pile to 2.0 times of the design load. The corresponding pressure has to be held for 30 seconds and take the settlement graph. The settlements before holding the set pressure and after release to 0 should not be exceeded 5 mm.

(11) Testing by Piling Loading and Determination of Required Design Load

The required design load will be 2.0 times of working loads. The pressure will be maintained in 30 seconds under required design load. The requested design load can be verified according to static load test doing and the test result getting in advance.

Figure 7.3-19 Loading Test

(12) **Tolerance**

(i) **Alignment**

The acceptable deviation of the pile center from the designed center point shall not exceed 100 mm in any direction unless otherwise directed by the Engineer.

.

Figure 7.3-20 Measuring for Alignment

Figure 7.3-21 Centering of the Pile to Designed Point

Figure 7.3-22 Measuring for Alignment

(ii) **Elevation**

Excavation shall not vary from the plan alignment by more than ± 50 mm of depth.

(iii) **Verticalness**

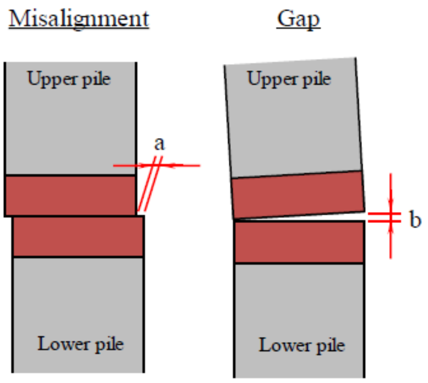
The acceptable deviation for verticalness on each pile during installation is 1:100.

Figure 7.3-23 Measuring for Elevation

Figure 7.3-24 Measuring for Inclination

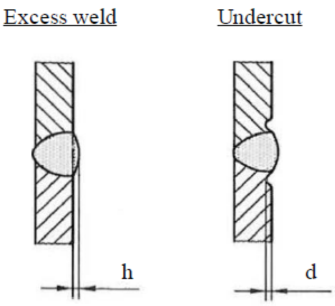
(iv) Jointing

Criteria for joining are shown in followings.



No.	Item	Legend	Tolerance	Spec.
1	Misalignment	a	Less than 2 mm	JIS A 7201
2	Gap	b	Less than 4 mm	JIS A 7201

Figure 7.3-25 Criteria for Geometric Condition



No.	Item	Legend	Tolerance	Spec.
1	Excess weld	h	Less than 3 mm	WES 2031
2	Undercut	d	Less than 0.5 mm	WES 2031

Figure 7.3-26 Criteria for Weld Bead

Table 7.3-6 Throat of Fillet Weld

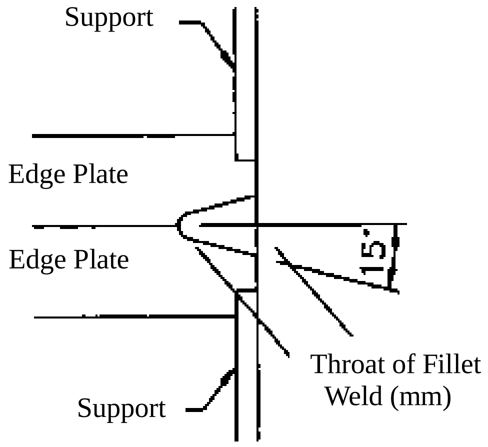
Pile Diameter (mm)	Throat of fillet Weld (mm)	Figure
300	8.0	
350	8.5	
400	9.5	
450	10.0	
500	11.0	
600	12.0	
700	13.0	
800	14.0	
900	15.0	
1000	16.0	

Figure 7.3-27 Welding Work Condition

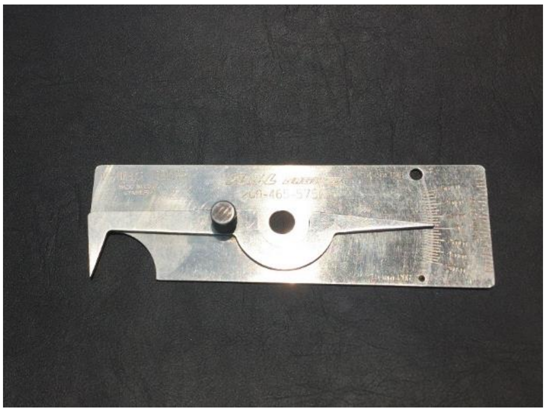
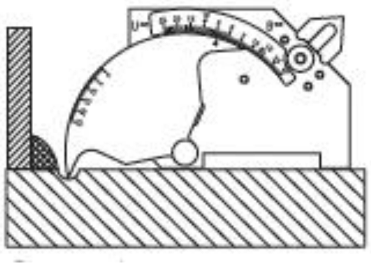
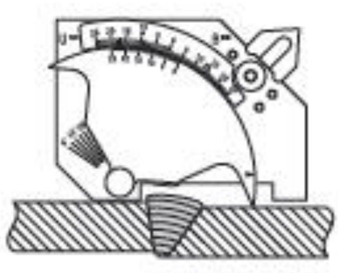


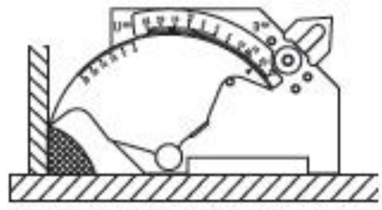
Figure 7.3-28 Welding Inspection Gauge



Undercut



Misalignment



Excess Weld

Figure 7.3-29 Welding Work Measurement

7.3.4. Test Pile

(1) Preparation Work

The loading system for this test is selected as “Kentledge” system, is commonly established by piling machine with counter weight and supporting beam as shown in Figure 7.3-30 below. The machinery parts and necessary counter weight shall be delivered to testing site by suitable transportation method, ex. trailer, truck and sea barge if its weight over the limitation in regulation of transportation. And the assembly work of the machineries, counter weight, supporting beam, jacking devise and instrument for measurement is executed for setting-up the testing.

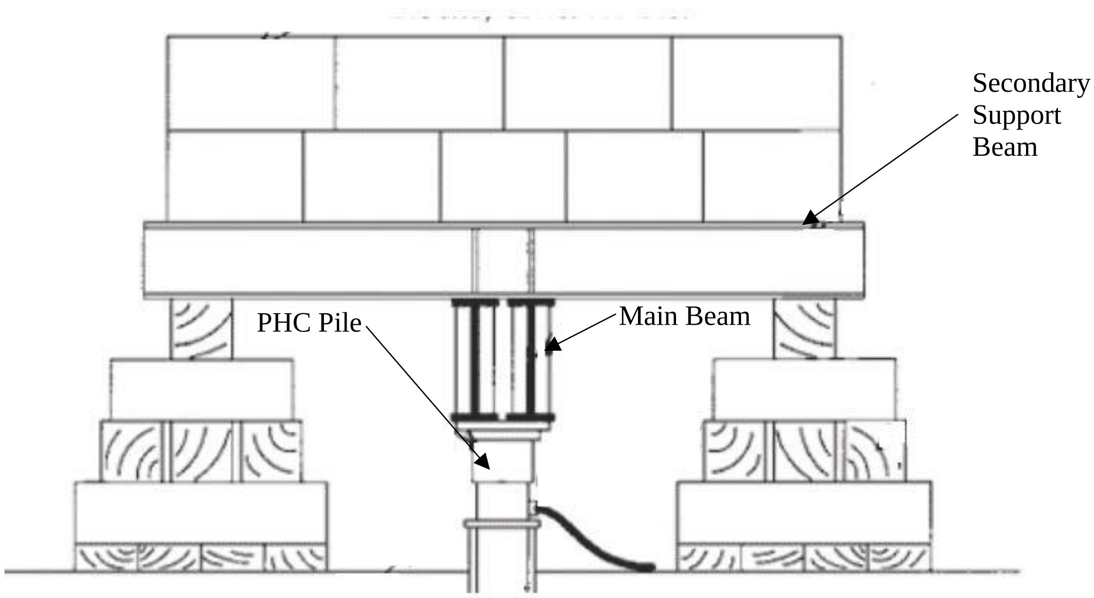


Figure 7.3-30 Concept of “Kentledge” System

Figure 7.3-31 Preparation of Main Beam onto Machine Body

The pressing force is applied on pre-stressed spun pile according to taking reaction force from main beam supported secondary beam member with counter weight. During pressing force applying, the record regarding of displacement of pile top shall be taken step by step for analysis later. The pile for testing shall be installed as same as application for actual construction.

(2) Loading Work

The loading will be arranged as four (4) cycles in the test to record the loading and displacement and to recognize the condition under design loading and under loading capacity, which is assumable as limited durability against for vertical external force. The peak force in loading test is arranged as 0.25 times for maximum loading force 300 ton increasing as shown in Figure 7.3-32.

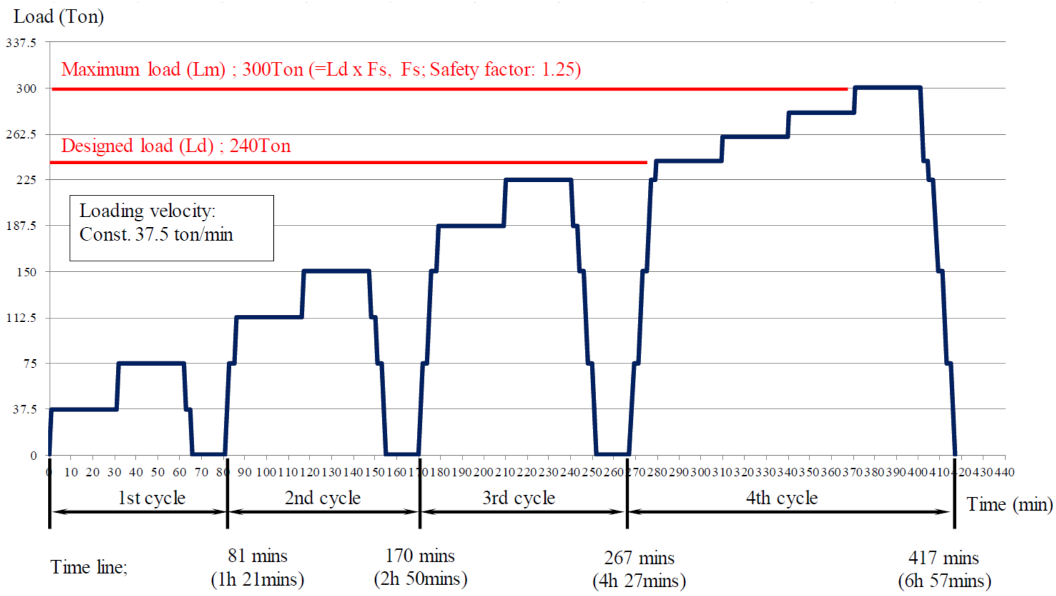


Figure 7.3-32 Example of Loading Procedure for Testing

(3) Recording

During execution of loading force, the measuring work for displacement is conducted by optical level instrument and dial gauge to trace the pile top elevation as shown in Figure 7.3-33 and Figure 7.3-34.

	
Figure 7.3-33 Level Survey	**Figure 7.3-34 Dial Gauge**

Two (2) nos. dial gauges are fixed on an independent ‘frame’ to measure the pile head displacement. The frame shall be supported on two foundations away from the pile and reaction system to be unaffected by ground movements resulting from the test, the minimum distance shall be 3 times test pile diameter or width but should not be less than 2 m. Movement of the pile head shall be measured using the two (2) nos. dial gauge and checked with a leveling instrument. The dial gauges shall have an accuracy of 1 mm, visually interpretable to 0.01 mm. Two dial gauges and two scale rules shall be fixed on top of the pile head on diagonally opposite sides. Two scale rules will also be installed at the pile to measure the settlement and at least one reference rules will be installed at a permanent location. The accuracy of rules by leveling instrument will be 0.5 mm. All testing equipment shall be protected from unnecessary disturbance prior to and throughout the load test. The record of displacement taken during testing will be summarized in the graph, “Load- Displacement” curve as shown in Figure 7.3-35 below. According to describing the linier line on the taken data, loading capacity at testing place is recognizable as it is over the design load.

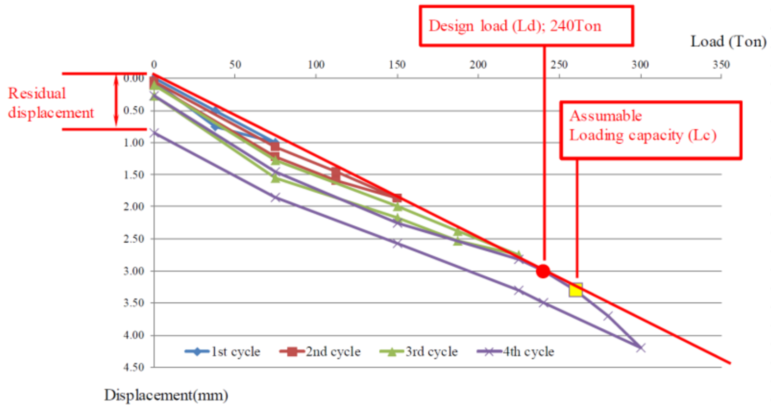


Figure 7.3-35 Load-Displacement Graph

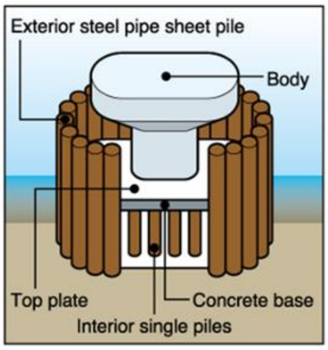
(4) Termination Criteria

When the displacement reaches till 10%of spun pile diameter, 60 mm, testing work shall be stopped.

7.4 Steel Pile Sheet Pile Foundation

7.4.1. Outline of Construction

Steel pipe sheet piles, in which steel pipe piles are provided with joints, are employed to construct high-rigidity walls. Widely used in harbor facilities, urban civil engineering and bridges (steel pipe sheet pile foundations).



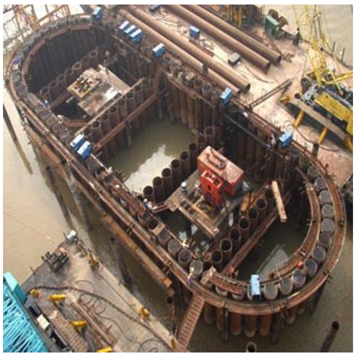


Figure 7.4-1 Steel Pipe Sheet Pile

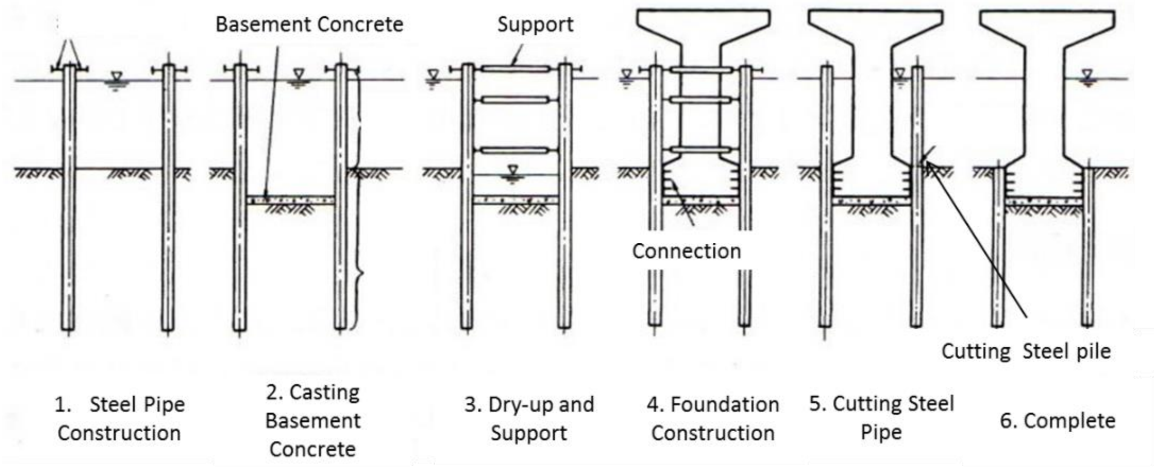


Figure 7.4-2 Procedure of Steel Pipe Sheet Pile

In a steel pipe sheet pile foundation, steel pipe sheet piles having P-P type joints are driven into the supporting layer. They are then arranged in a planar fashion in an enclosed form such as a circular, rectangle, or oval shape. Filling the joint pipes of the steel pipe sheet piles with mortar and providing their heads with rigid connection by means of footing allow a group of steel pipe sheet piles to behave as an integral foundation. This type of foundation is employed with many long-span bridges and large structures.

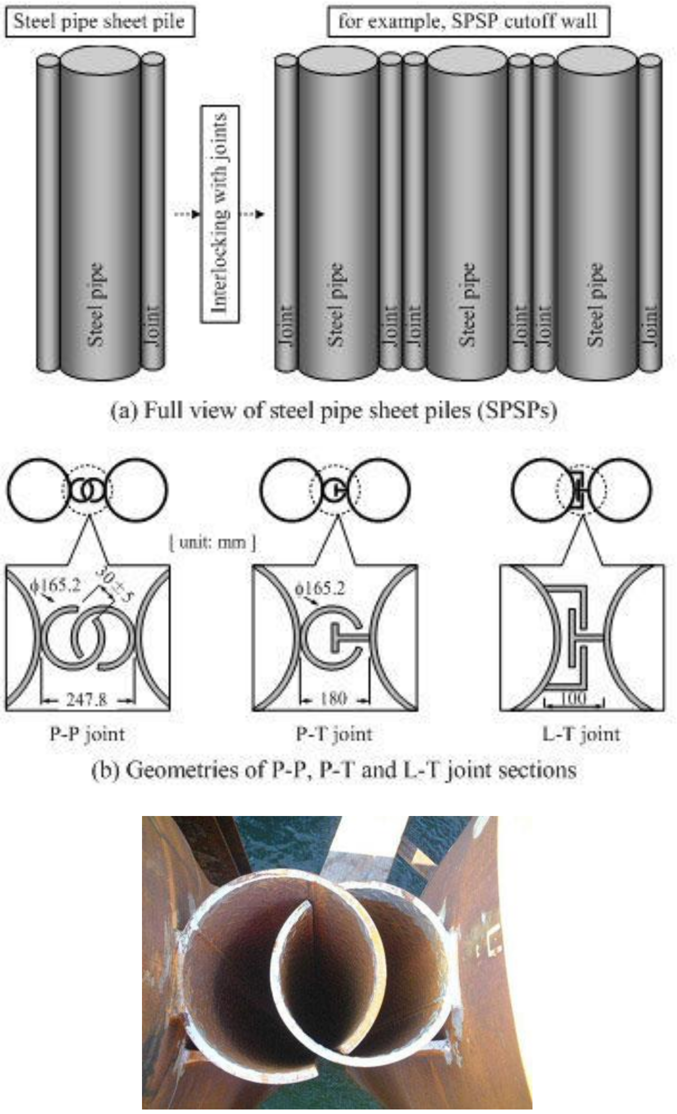


Figure 7.4-3 Joint of Steel Pipe Sheet Pile

7.4.2. Construction

(1) Accuracy

Since a steel pipe sheet pile foundation is formed in a shape of a well by connecting joint pipes of steel pipe sheet piles with each other, it requires higher construction accuracy than a steel pipe-driven does. It must be carefully constructed. The installation methods of steel pipe sheet piles are explained as a precast pile foundation.

Table 7.4-1 Accuracy

Inclination	1/500
Well diameter	± 100mm

(2) Machinery

Construction machines and instruments should be selected in accordance with the provisions in Chapter 7. When selecting a driving hammer, however, it is necessary that penetration resistance may be increased by interaction of joint pipes of steel pipe sheet piles adjacent to each other as the piles are moved and rotated while they are driven. Generally, therefore, a hammer of an offer rank in performance is often used than in the case of steel pipes of the same size.

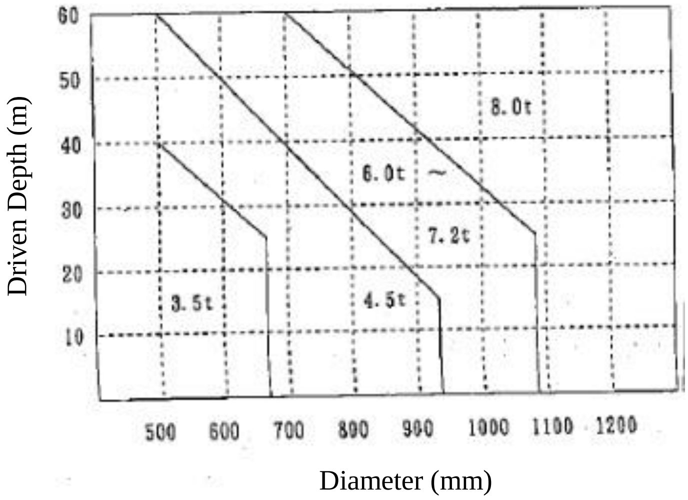


Figure 7.4-4 Diesel Hammer Size

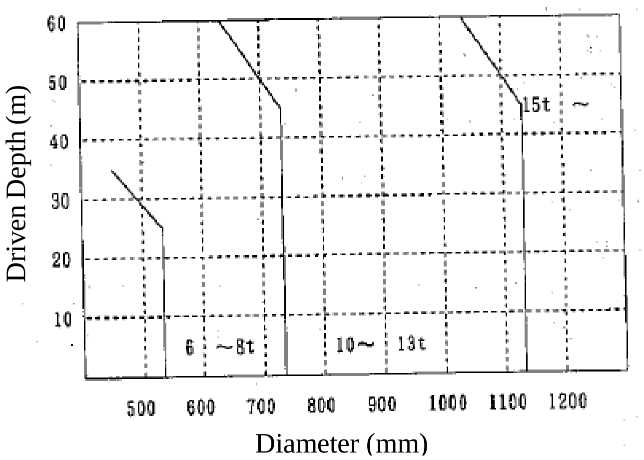
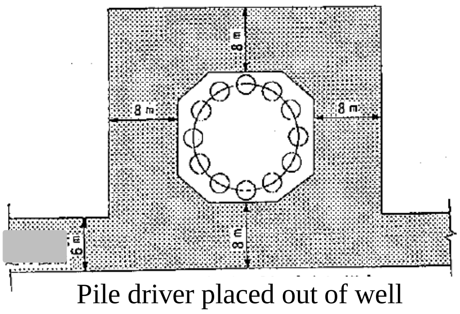


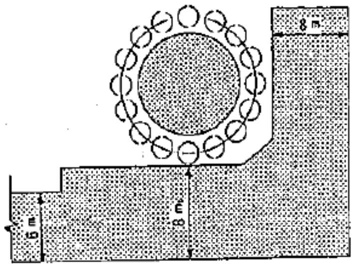
Figure 7.4-5 Hydraulic Hammer Size

(3) Staging

Requiring higher construction accuracy than ordinary pile driving methods, this steel pipe sheet pile foundation method needs stout scaffoldings and accurate survey. Since this method is often applied to construction in water due to the characteristics of this method, it is necessary to review landing piers acting as scaffoldings for full rigidity.

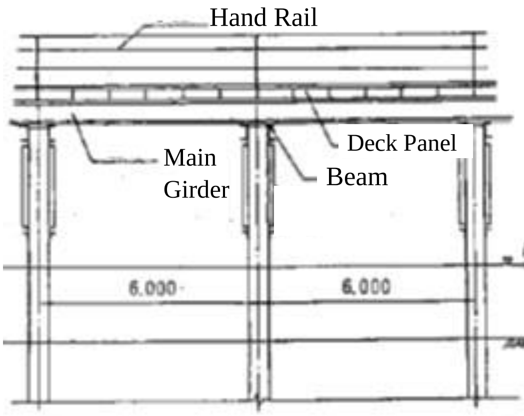


Pile driver placed out of well



Pile driver can be placed inside of well

Figure 7.4-6 Staging



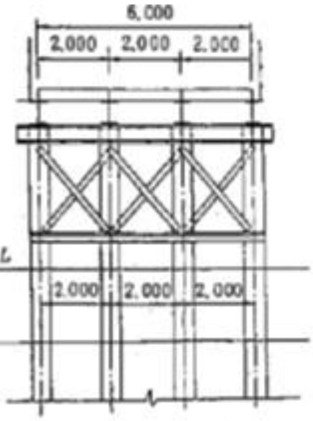


Figure 7.4-7 Staging

(4) Transportation, Storage and Inspection.

Provisions in Chapter 7 shall apply for transportation, storage and inspection.

(5) Installation of Guide Materials

Workability of a steel pipe sheet pile foundation depends substantially on degree of accuracy of driving steel pipe sheet piles. Hence, this section provides that guide materials which possess a shape suitable for intended driving procedures and have necessary strength should be provided for constructing the foundation to assure driving accuracy and to improve workability. As shown in Figure 7.4-8, the guide materials are generally used by combining guide frames acting as ruler and guide piles supporting the guide frames.

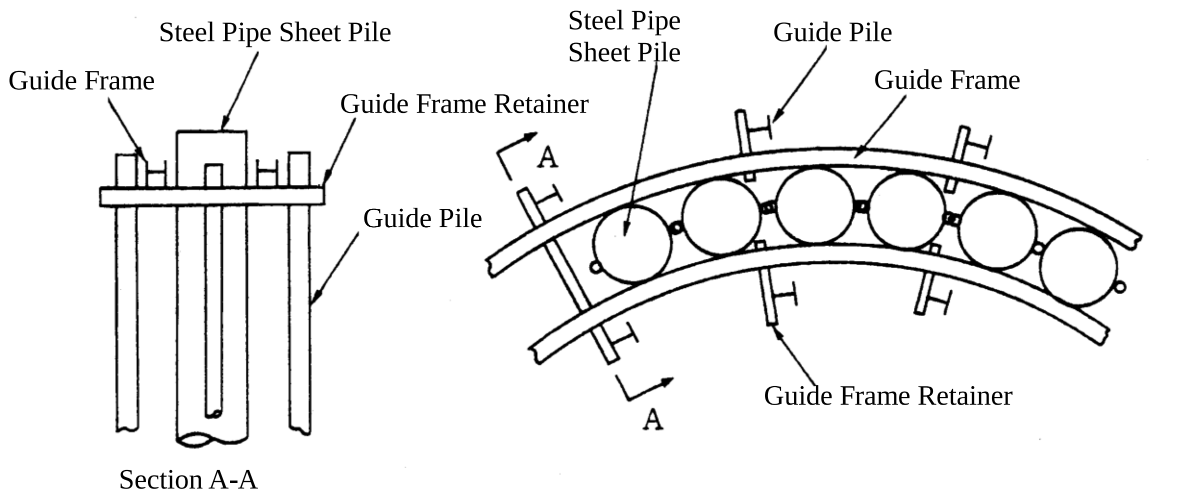


Figure 7.4-8 Guide Material

(6) Driving

Setup of the steel pipe sheet pile should be done by installing the steel pipe sheet pile at the marked position on the guide frame while ascertaining the verticality from two directions using a transit. When driving steel pipe sheet piles, the lower steel pipe sheet piles are connected first, followed by closing of the middle and upper steel pipe sheet piles in that order.

When the pile boring method is used, if the lower steel pipe sheet piles cannot be connected first as in the case of ship driving, then positioning of the steel pipe sheet piles should be done one by one, and the lower, middle and upper steel pipe sheet piles should be driven continuously. The setup method and sequence must be examined to secure sufficient setup accuracy because connection of the steel pipe sheet piles generally becomes difficult in this case.

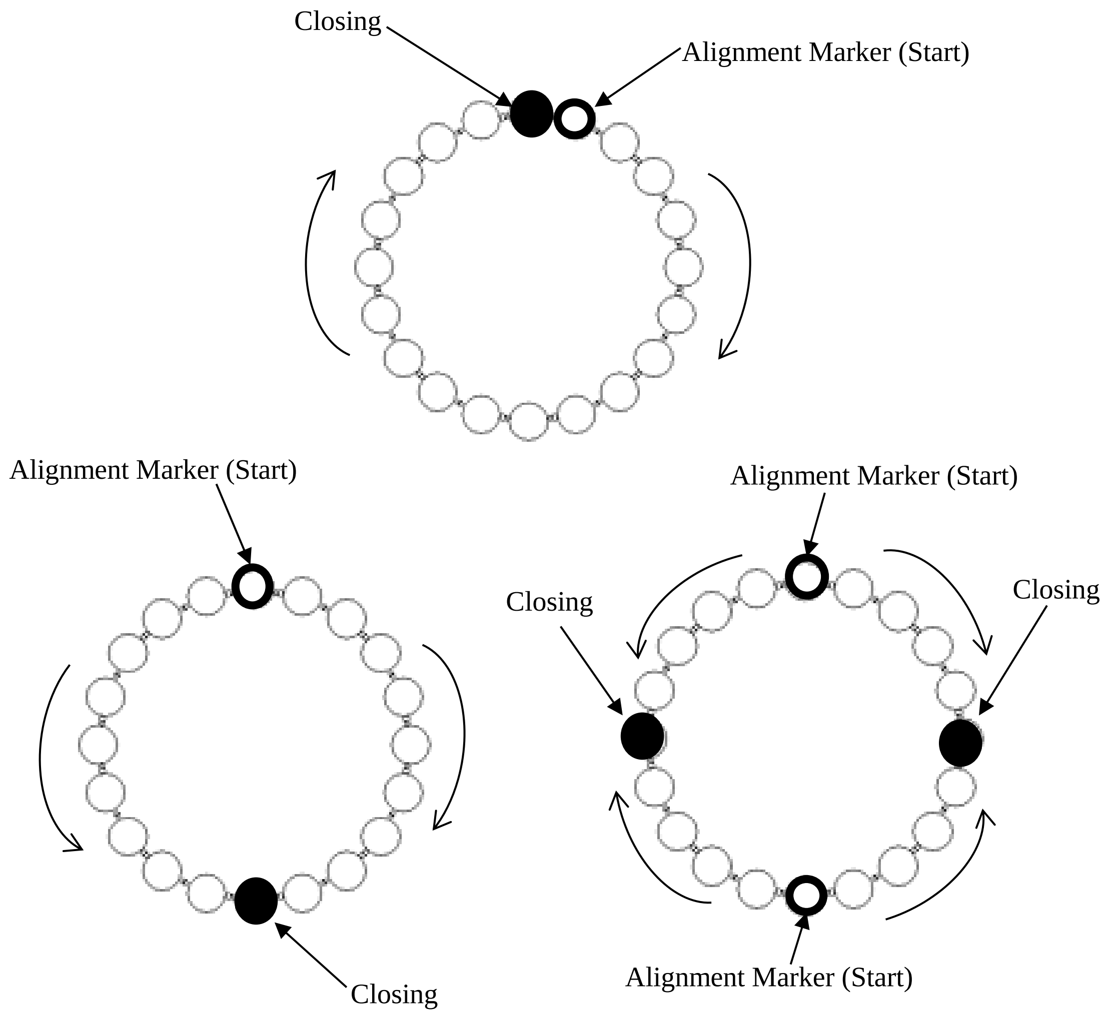


Figure 7.4-9 Construction Procedure

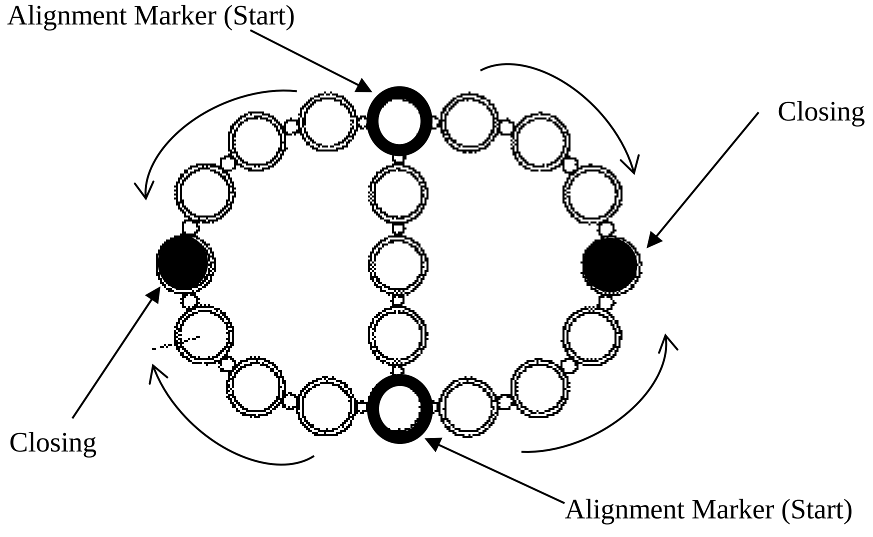


Figure 7.4-10 Construction Procedure

(7) Pile Connection

The details of field-welded joints of steel pipe sheet piles should be in accordance with the stipulations in Chapter 7.4.

In order to conduct outer welding work properly, lower pile head height should have a gap with each adjacent pile.

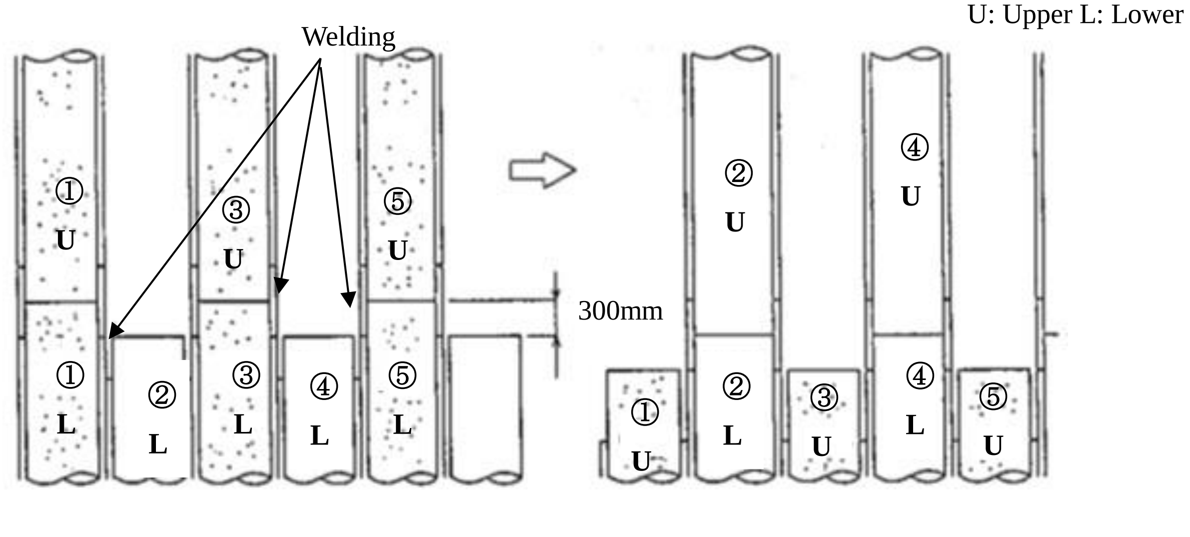


Figure 7.4-11 Pipe Connection

(8) Joint Filling

Joint part of steel pile should be filled by mortar for water retaining of removed part and strength of main structure. Joint is filled by lean-mix mortar on removed part. Before casting mortal on joint, it is necessary to clean inside of joint. High-pressure water or air lift can be used for cleaning joint.

Table 7.4-2 Mortar Strength

Mortar for Main Structure	Lean-mixing Mortar
20 – 24 N/mm^2	0.1 – 0.25 N/mm^2

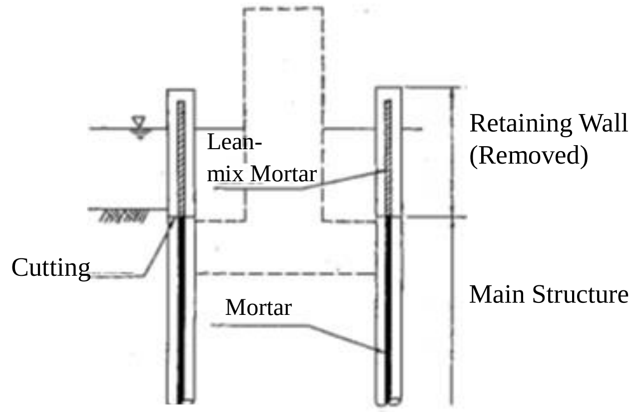


Figure 7.4-12 Mortal Type of Joint

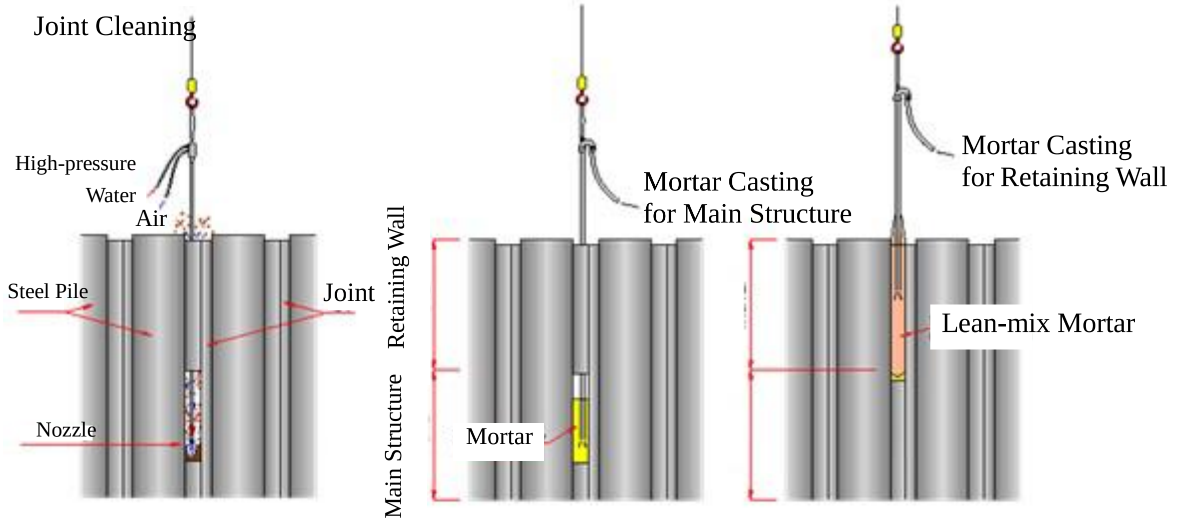


Figure 7.4-13 Mortar Casting

Figure 7.4-14 Joint Filled by Mortar

(9) Concrete Filling

Filling concrete shall be placed in a steel pipe sheet pile interior near a pile cap connection. It is required to support steel pile foundation around the connection with pile cap by filling concrete.

Prior to casting filling concrete, earth and impurities adhering to the steel pipe sheet pile interior should be eliminated to enhance adhesion and to produce a one-piece body between the pile and the concrete.

Area of filling concrete should be twice as pile cap thickness.

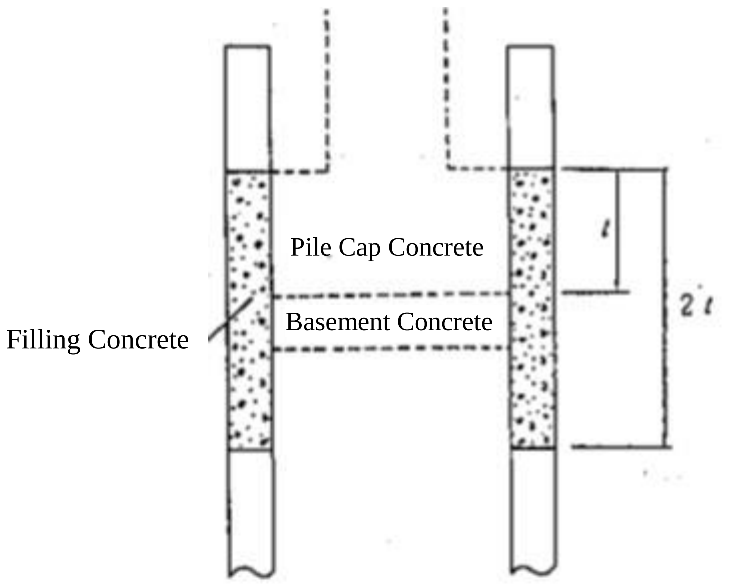


Figure 7.4-15 Filling Concrete Area

(10) Excavation

Normal and under water excavation can be installed for well excavation. Excavation method should be considered conditions for construction.

Table 7.4-3 Excavation Type

	Underwater Excavation	**Normal Excavation**
Soil condition	Soft (mud, sand etc.)	Good
Excavation depth	Large	Small
Efficiency	No effected	Effected
Soil and water discharge	Large amount	Small amount
Steel pile deformation and stress	Small	Effected

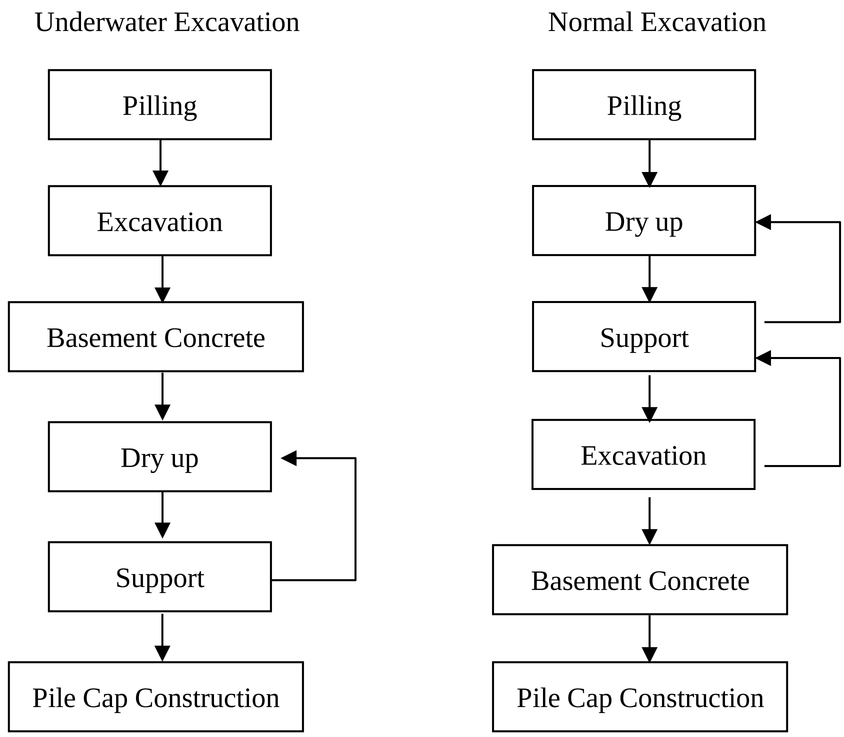


Figure 7.4-16 Excavation Procedure

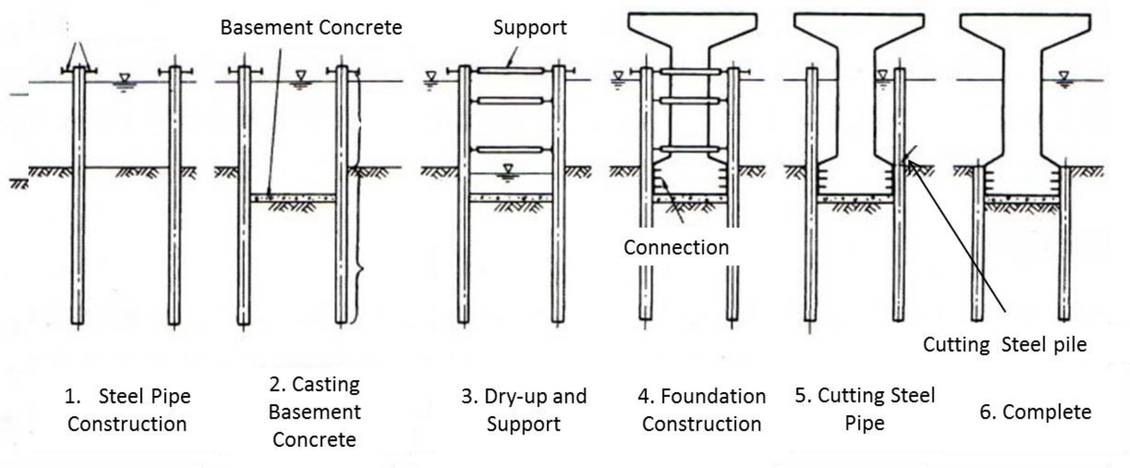


Figure 7.4-17 Construction Procedure

(11) Support

During underwater excavation, water level should be in the cofferdam kept the level specified in the design documents. After constructing the basement concrete, supports should be installed while drying up. When installing the supports, a spacer or the like should be used to keep the spacing of the walling and prevent its vertical movement. Openings between the waling and the steel pipe sheet piles should be filled with concrete or mortar.

The cofferdam water level when installing the support works should be about 1 meter below the supporting works. During draining, full construction control must be exercised, such as measures against leakage at the joints.

In the case of normal excavation, less than one-meter ground below of the supports should be excavated.

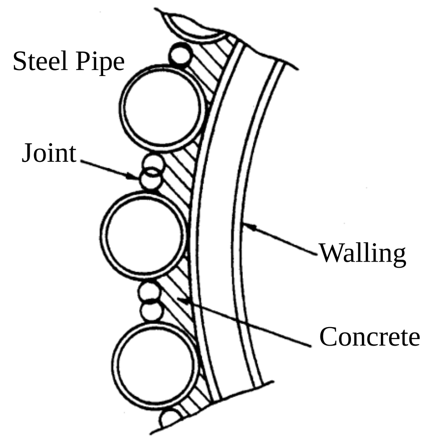


Figure 7.4-18 Support Material

(12) Pile Cap Construction

Connection between a pile cap and a steel pipe sheet pile as well as the top slab shall be mounted in a manner to securely transfer loads acting on the top slab to the steel pipe sheet pile. The connection should be mounted securely in accordance with the design documents and the execution program.

Following types of connection structure can be installed.

1) Plate Bracket Type

Plate bracket is welded to the face of steel pile, and it works as a shear connector. Point of attention should be followings.

a) Cleaning up, if necessary, and polishing of pile surface should be conducted.

b) Dry up of pile surface

2) Joint Bar Type

Drilling hole on the face of steel pile, then set up reinforcement car on the hole and welding.

a) Cleaning up, if necessary, and polishing of pile surface should be conducted.

b) During drilling steel pile, support material should not be defected.

c) Frame works for reinforcement bars after placement

d) Inner filling concrete for pile should be casted after reinforcement bar placed.

3) Stud Type

Reinforcement baes which are welded on the face of steel pile works as stud.

a) Cleaning up and polishing of pile surface should be conducted.

b) During drilling steel pile, support material should not be defected.

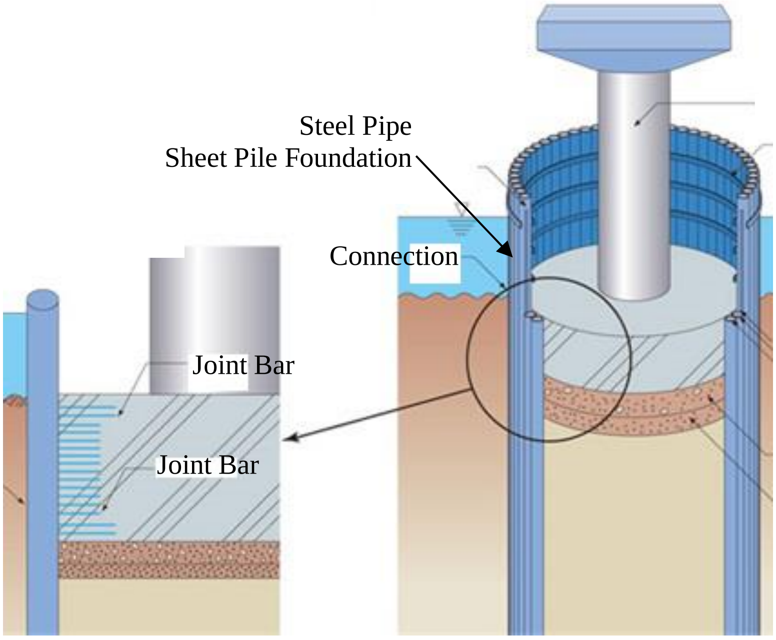
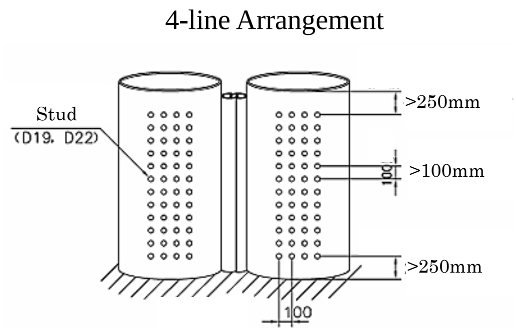


Figure 7.4-19 Pile Cap Connection



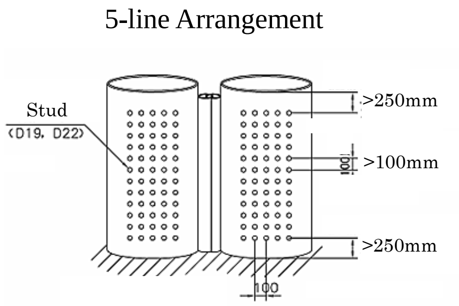


Figure 7.4-20 Stud Type

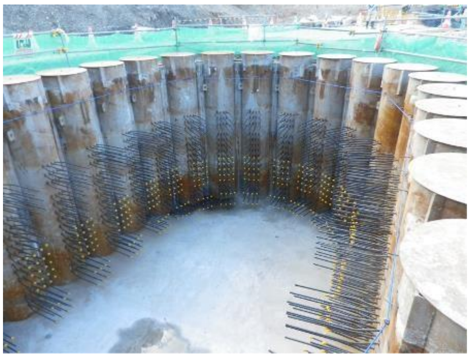


Figure 7.4-21 Stud Type

CHAPTER 8. BASIC KNOWLEDGE FOR DESIGN

8.1 Bearing Capacity

8.1.1. Allowable Bearing Capacity

The axial allowable bearing capacity of a single pile shall be obtained from following formula.

$$R_a = \frac{\gamma}{n}(R_u - W_s) + W_s - W$$

R_a : Axial allowable bearing capacity of pile (kN)

n : Factor of safety (Table 8.1-1)

g : Modification coefficient for factor of safety depending on ultimate bearing capacity estimation method (Table 8.1-2)

R_u : Ultimate bearing capacity of pile (kN)

Ws: Effective weight of soil replaced by pile (kN)

W : Effective weight of pile and soil inside pile (kN)

In cases, if pile weight is small, following formula shall be applied

$$R_a = \frac{\gamma}{n} R_u$$

Table 8.1-1 Factor of Safety

Design Case	End Bearing Pile	Friction Pile
Normal	3	4
Earthquake	2	3

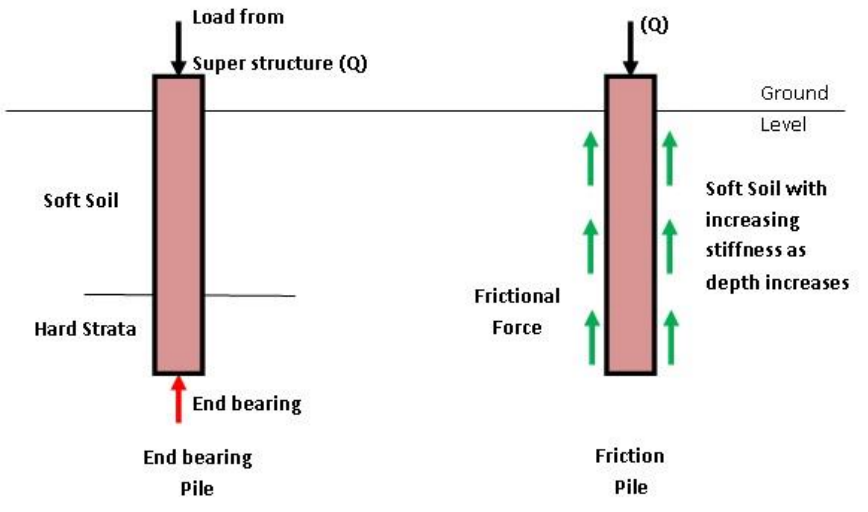


Figure 8.1-1 End Bearing Pile and Friction Pile

Table 8.1-2 Modification Coefficient for Factor of Safety depending on Ultimate Bearing Capacity Estimation Method

	Modification Coefficient for Factor of Safety
calculation of bearing capacity estimation formula	1.0
results of loading tests	1.2

8.1.2. Ultimate Bearing Capacity

The ultimate bearing capacity can be obtained either by calculation of bearing capacity estimation formula or from the results of loading tests.

(1) Calculation of Bearing Capacity Formula

The ultimate bearing capacity can be obtained from the bearing capacity estimation formula on the basis of the results of geotechnical survey.

$$R_u = q_d\ A + U \sum L_i\ f_i$$

R_u: Ultimate bearing capacity of pile (kN)

A: Area of pile tip (m^2)

q_d: Ultimate end bearing capacity intensity per unit area (kN/m^2) (Table 8.1-1)

U: Diameter of pile (m)

Li: Thickness of soil layer considering shaft resistance (m)

fi: Maximum shaft resistance of soil layer considering pile shaft resistance (kN/m^2) Table 8.1-2

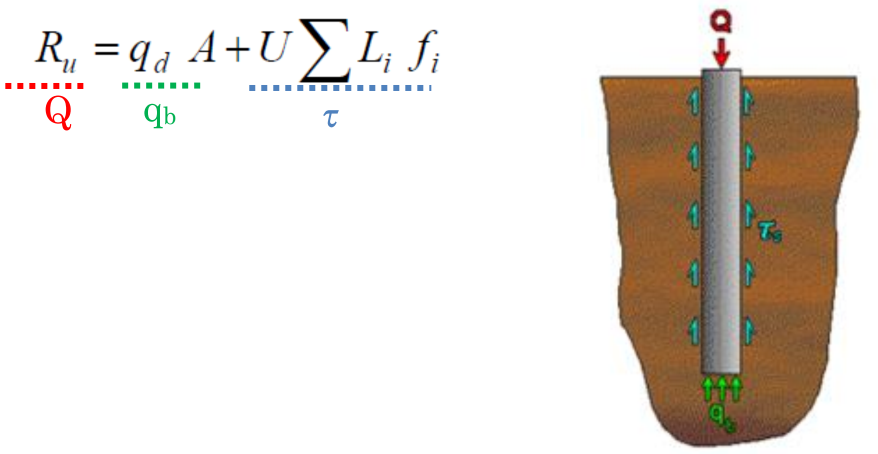


Figure 8.1-2 Ultimate Bearing Capacity

Table 8.1-3 Ultimate End Bearing Capacity Intensity per Unit Area

Construction Method	Soil	q_d: Ultimate end bearing capacity intensity per unit area (kN/m^2)
Driven	Sand, Gravel, Mud	qd =300N (L/D≧5) qd =60*(L/D) *N (L/D<5) L: Embedment Depth to Supporting Layer (Figure 8.1-1, Figure 8.1-2) D: Pile diameter N: N value for design
Pre-boring, Inner excavation	Sand	150N (≤ 7,500)
	Gravel	200N (≤ 10,000)
Cast-in-Situ	Gravel, sand (N≥30)	3,000
	Gravel, sand (N≥50)	5,000
	Mud (N≥20, q_u≥0.4N/mm^2)	3 qu qu: Unconfined compressive strength

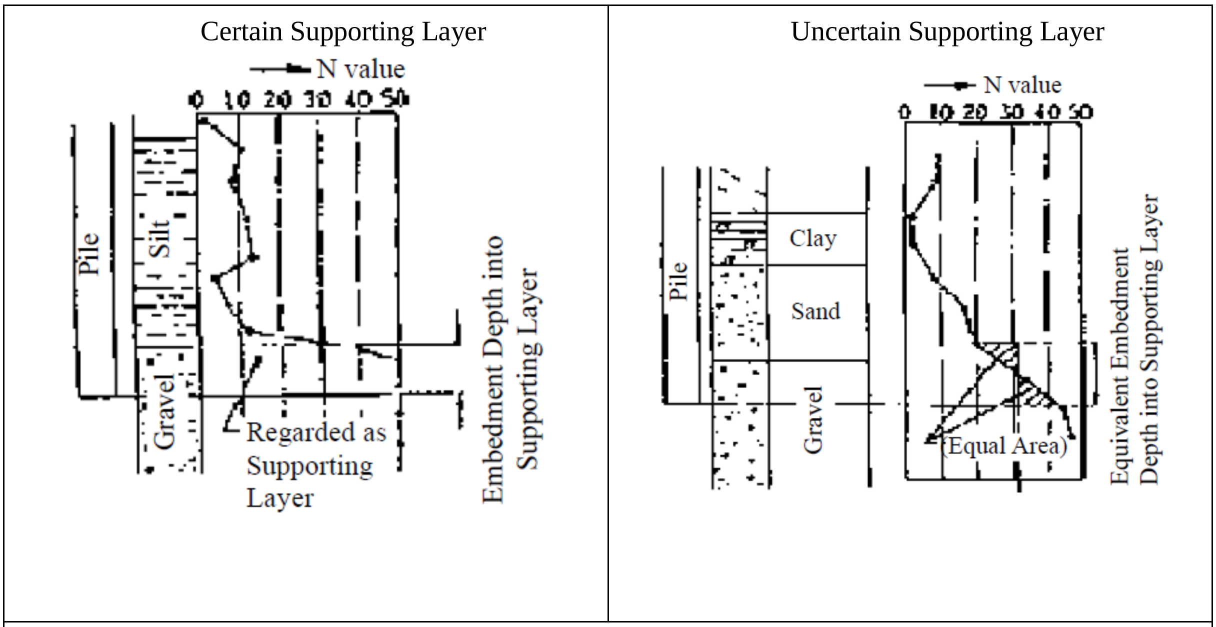


Figure 8.1-3 Embedment Depth to Support Layer

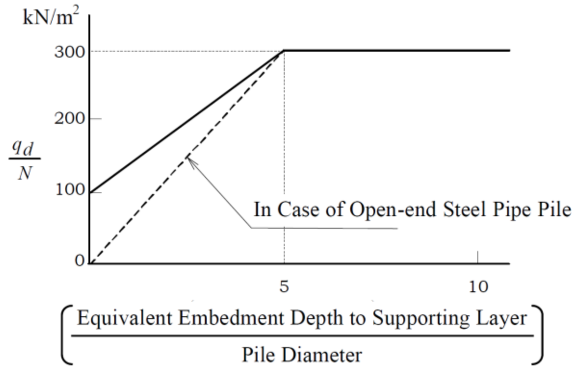


Figure 8.1-4 Ultimate End Bearing Capacity per Unit Area for Driven Pile depend on Embedment Depth to Support Layer

Table 8.1-4 Maximum Shaft Resistance of Soil Layer Considering Pile Shaft Resistance (kN/m²)

Construction Method	Soil Condition	
	Gravel, Sand	Mud
Driven	2N (≤100)	*C* or 10N (≤150)
Inner excavation	2N (≤100)	0.8*C* or 8N (≤100)
Pre-boring	5N (≤150)	*C* or 10N (≤150)
Cast-in-situ	5N (≤200)	*C* or 10N (≤150)

The axial allowable bearing capacity of a single pile shall be obtained from following formula.

8.2 Bearing Capacity of Concrete Pile and PHC Pile

8.2.1. Calculation of Allowable Bearing Capacity

Allowable bearing capacity of pile structure is calculated following formula.

Pa = fc × A × (1-κ-λ)

Pa: Pile Bearing Capacity (N/mm²)

fc: Allowable Compressive Strength (Pre-stress Force should be subtracted) Table 8.2-1

A: Cross Section (mm²)

κ: Reduction Coefficient for Pile Connection (0.05 for each)

λ: Reduction Coefficient for Slenderness Ratio

$$\lambda = (L/d-n)/100\ (\geq 0)$$

L: Pile Length

D: Pile Diameter

n: Cast in Site 60, RC 70, PC 80, Steel 100

Table 8.2-1 Allowable Compressive Strength (fc)

		Cast in Situ			Pre-cast	
					RC	**PHC**
Designed Strength		24	27	30	40	80
Compressive Strength	Bearing	8.0	9.0	10.0	13.5	27.0
	Axial	6.5	7.5	8.5	11.5	23.0
Shear Stress		0.23	0.24	0.24	0.36	0.86

8.2.2. Comparison of Cast-in-situ and PHC Pile

(1) Bearing Capacity

Calculation example of allowable bearing capacity for cast in situ and PHC pile at the same diameter and same length (600mm, 28m).

(i) Calculation of Pile Bearing Capacity for Cast-in-situ Concrete Pile

Diameter: 600mm, Length: 28 m, Designed Strength 24N/mm^2

Pa = fc × A × (1-κ-λ)

where;

fc = 6.5 N/mm^2

A = π (6002 / 4) = 282,600 mm^2

λ = (28000/600 – 60) / 100 = -0.13 ⇒ λ = 0

Pa = 6.5× 282,600 × (1-0-0) = 1,836,900 N

(ii) Calculation of Pile Bearing Capacity for PHC pile

Pre-stress 4N /mm^2, Diameter: 600mm, Concrete Thickness: 90mm, Length: 28 m

Pa = fc × A × (1-κ-λ)

where;

fc = 23 – 4 = 19 N/mm^2

A = π (6002 – 4202) / 4 = 144,126 mm^2

K = 0.05 ×2 = 0.1

λ = (28000/450 – 80) / 100 = -0.18 ⇒ λ = 0

Pa = 19 × 144,126 × (1-0.1-0) = 2,462,555 N

At the same diameter case, bearing capacity of PHC pile is far greater than the case of cast-in-situ pile.

(2) Bending Capacity

The stress caused by bending moment of cast-in-situ (concrete) pile and PHC shall be calculated following. At the PHC pile, tension side of concrete stress is reduced by prestress.

Cast-in-situ (Concrete)	PHC Pile
$\sigma = \frac{N}{A} \pm \frac{M}{Z}$	Compressive Side $\sigma_c = \sigma_{ce} + \frac{M}{Z_e} + \frac{N}{A_e} \leqq \sigma_{ca1}$ Tension Side $\sigma_c' = \sigma_{ce} - \frac{M}{Z_e} + \frac{N}{A_e} \geqq \sigma_{ta}$ σ_{ce} = Prestress (N/mm^2), Ze = Module of Section

Figure 8.2-1 Comparison of Cast-in-situ and PHC

8.3 Pile and Footing Connection

8.3.1. Structural Details of Cast-in-place Piles

The anchoring length shall be L_0 +10 d (d is diameter of reinforcing bar) from the center of the lower main reinforcing bar in footing. The embedded length of piles into the footing shall be 100 mm or greater.

Bonds between reinforcement and concrete are released by the effects of seismic cyclic loads, and some portions of anchoring reinforcing bars become ineffective. Anchoring length of 10d is designed to include an additional allowance.

A cover of 200 mm should be ensured from the viewpoint of workability. Anchoring length of bars into the footing shall be calculated by following.

$$L_0 = \frac{\sigma_{sa} \ A_{st}}{\tau_{0a} \ U}$$

where,

L_0: necessary anchoring length of bars (mm)

A_{st}: cross-sectional area of bars (mm^2)

τ_{oa} t: allowable bond stress of concrete (N/mm^2)

U: perimeter of bars (mm)

σ_{sa}: allowable tensile stress of bars (N/mm^2)

d: Bar diameter (mm)

In general, L0 ≧35 d may be taken.

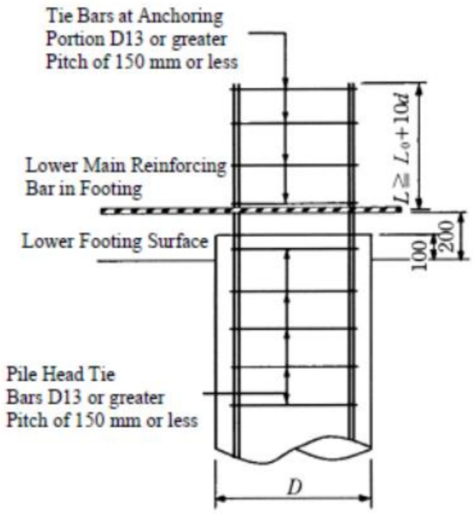


Figure 8.3-1 Pile Head Anchors on Cast-in-situ Pile

8.3.2. Structural Details of Pre-cast Piles

The anchoring length when the pile head is cut is increased by 50f (f is diameter of the PC steel member), and the pile analyzed as a member of the reinforced concrete section.

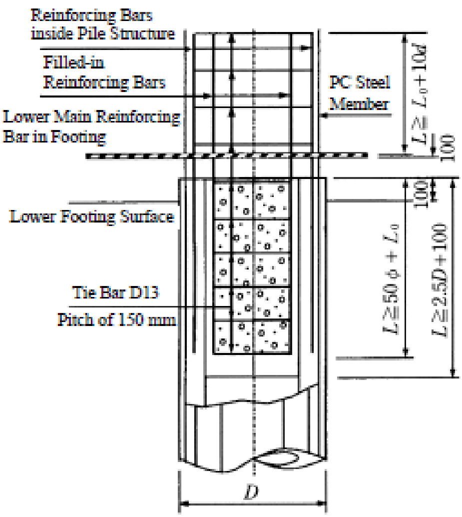


Figure 8.3-2 Pile Head Anchors on Pre-cast Pile

8.4 Liquefaction Analysis

1) Identify the potentially liquefiable layers to be analyzed.

2) Calculate the shear stress required to cause liquefaction (resisting forces). Based on the characteristics of the potentially liquefiable layers (e.g., fines content, normalized standardized blow count), the critical(cyclic) stress ratio (CSRL) can be determined using the graphical methods included in the U.S. EPA guidance referenced above.

3) Calculation of the design earthquake’s effect on the critical zone (driving force).

4) Calculate the factor of safety against liquefaction (resisting force divided by driving force).

$$FS = \frac{CSR_{L(M-M)}}{CSR_{EO}}$$

FSL	:	Factor of safety against liquefaction,
$CSR_{L(M—M)}$	:	Shear stress ratio required to cause liquefaction
CSREQ	:	Equivalent uniform cyclic stress ratio.

Table 8.4-1 Geographical Ground Conditions in Terms of Probability of Occurrence of Liquefaction

Probability	Geographical Ground Conditions
(A) High	Active riverbeds, Dry Riverbeds, Areas Filled or Reclaimed at Coastal Areas, Lakes, Marshes and Rice Paddies
(B) Moderate	Alluvial Lowlands and Tablelands with Shallow Ground Water Tables
(C) Low	Plateaus, Hills, and Mountainous Lands

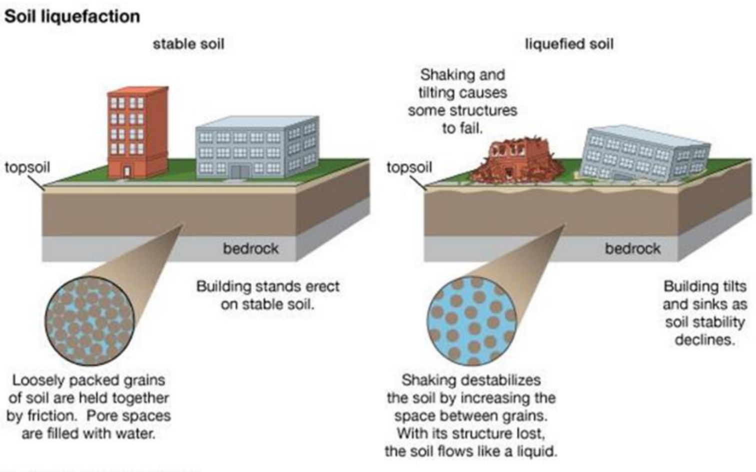


Figure 8.4-1 Liquefaction Image

Figure 8.4-2 Damages caused by Liquefaction

8.5 Consolidation Settlement

Amount of consolidation settlement can be calculated by following formula.

$$S = \frac{C_c H}{1+e_o} \log\left(\frac{p_o + \Delta p}{p_o}\right)$$

S: Ultimate primary consolidation settlement

$C_{c:}$ Consolidation index

H: Saturated clay soil layer of thickness

P_o: Existing overburden pressure

P: Increase in pressure

e_o: Initial void ratio

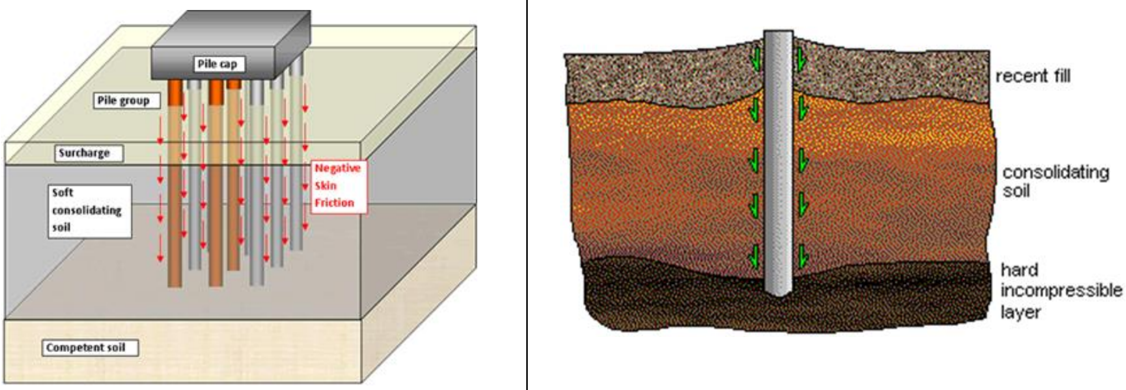


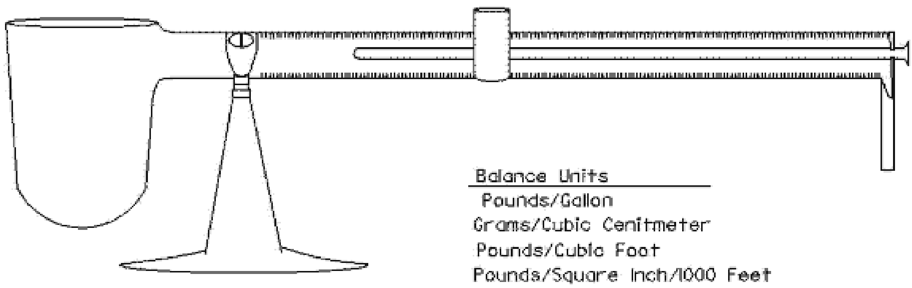
Figure 8.5-1 Negative Friction caused by Consolidation

<u>Appendices</u>

Appendix 1 - Specific Gravity Test

(i) APPARATUS

1. Mud Balance, or any instrument of sufficient accuracy to permit measurement within ± 0.01 g/cc; however, the mud balance is the instrument generally used.
2. The mud balance consists of a mud cup attached to one end of a beam, which is balanced on the other end by a fixed counterweight and a rider free to move along a graduated scale.
3. A level bubble is mounted on the beam.
4. Attachments for extending the range of the balance may be used.



Mud Balance

(ii) PROCEDURE

Set up the instrument base approximately level.

1. Fill the clean, dry cup with slurry to be tested. Place the cap on the cup and rotate until firmly seated. Make sure some of the slurry is expelled through the hole in the cap to free trapped air or gas.
2. Wash or wipe the excess slurry from the outside of the cup.
3. Place the beam on the support and balance it by moving the rider along the graduated scale. The beam is horizontal when the leveling bubble is on the center line.
4. Read the density at the side of the rider toward the knife-edge. Make appropriate corrections when a range extender is used.
5. Clean and dry the instrument thoroughly after each use.

(iii) CALCULATIONS

Convert the density to other units using the following relationships:

Specific gravity = read directly off balance.

Specific gravity (p) in lb./ft.3 (kg/m^3) = (specific gravity (p) in g/cc) (1000) (62.4)

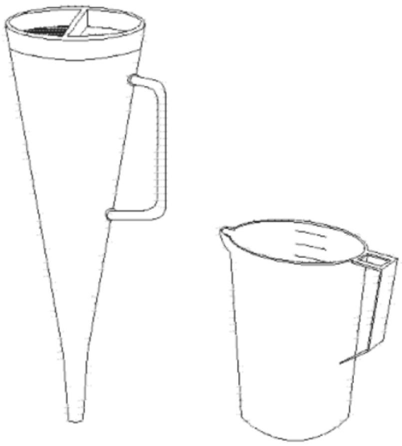
Specific gravity (p) in lb./gal. (kg/L) = (specific gravity (p) in g/cc) (70.0) (8.35)

Appendix 2 - Viscosity Test

(i) APPARATUS

1. Graduated cup, 1 L (1 qt.)
2. Stopwatch.
3. Marsh Funnel, calibrated to outflow 1 qt. of fresh water at a temperature of 70 ± 5°F (21 ±3°C) in 26 ± 0.5 seconds.
4. Orifice fixed at a level ¾ in (19.0 mm) below top of funnel.

Item	Measurement	Requirement
Funnel Core	Length	12.0 in (305 mm)
	Diameter	6.0 in (152 mm)
	Capacity to Bottom of Screen	1500 cc
Orifice[1]	Length	2.0 in (50.8 mm)
	Inside Diameter	3/16 in (4.7 mm)
	Screen	No. 12 (1.70 mm)



Funnel Core

(ii) PROCEDURE

1. Cover the funnel orifice with a finger and pour freshly sampled drilling fluid through the screen into the clean, upright funnel. Fill until fluid reaches the bottom of the screen.
2. Remove finger and start stopwatch. Measure the time for the mud to fill to the 1 qt. (946 cm^3) mark on the cup.
3. Report the time to nearest second as Marsh funnel viscosity.

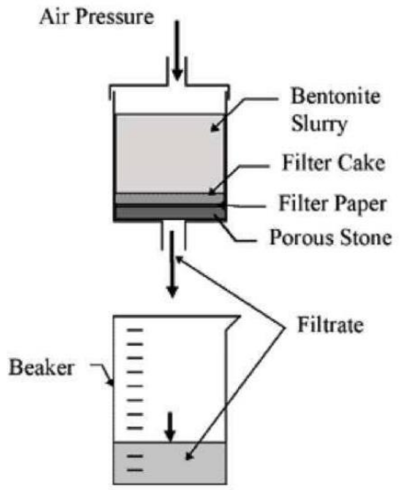
Appendix 3 - Filtering Water Test

(i) APPARATUS

1. 75 mm cylinder
2. Filter cake, Filter paper
3. Porous stone
4. Beaker

(ii) PROCEDURE

1. The test is performed in a 75 mm cylinder, approximately 60 mm in height.
2. A porous stone is placed at the base of the cylinder, with a thin filter paper placed over it, and together they represent the porous formation.
3. A predetermined ratio of bentonite and water is mixed into slurry (typically 6 % slurry) and poured into the cylinder. The cylinder is then pressurized approximately 700 Pa. As water (filtrate) drains from the bottom of the cylinder, a filter cake forms on the filter paper, retarding the flow of filtrate.
4. Filtrate is allowed to flow for the first 7.5 minutes of the test, at which time the flow is collected for the next 30 minutes.
5. The volume collected or total fluid loss in 30 minutes is measured and reported in milliliters (ml).
6. A lower amount of filtrate collected indicates the bentonite is more effective at sealing and therefore less permeable.



APPARATUS

Appendix 4 - Checking List for Cast-in-place Pile Method

(1) All Casing Method

BF 01

Procedure	Point to be checked	Comment
Preparation for excavation	Casing tube length Casing tube shape Cutting edge diameter Hammer grab size Hammer grab	
Machinery placement	Placement of pile center Placement condition Placement plan	
Excavation	Place and inclination of casing tube Connection of casing tube Depth and embedment of casing tube Height of hole inner water	
Support layer	Conformation of support layer Excavation depth	
Reinforcement work	Conformation of rebar quality Rebar cage deterioration Conformation of designed rebar cage Support material and fixing material Rebar cage shape Pile head cover Inclination during placement Connection strength	
Bottom processing	Processed appropriately Conformed by measurement	
Concrete work	Tremie length Tremie connection Preparation of concrete canting Concrete quality Casting continuously Top of tremie Depth of tremie into concrete Quantity of concrete Height of completion	

(2) Reverse Circulation Method

BF 02

Procedure	Point to be checked	Comment
Preparation for excavation	Size and place of tank Stand pile diameter and length Machinery and bit	
Machinery placement	Placement of pile center Inclination of stand pipe	
Excavation	Prevention of hole wall collapse Stabilization of Kelly-bar Inclination	
Support layer	Conformation of support layer Excavation depth	
Reinforcement work	Conformation of rebar quality Rebar cage deterioration Conformation of designed rebar cage Support material and fixing material Rebar cage shape Pile head cover Inclination during placement Connection strength	
Bottom processing	Processed appropriately Conformed by measurement	
Concrete work	Tremie length Tremie connection Preparation of concrete canting Concrete quality Casting continuously Top of tremie Depth of tremie into concrete Quantity of concrete Height of completion	

(3) Earth Drilling Method

BF 03

Procedure	Point to be checked	Comment
Preparation for excavation	Slurry preparation (Bentonite) Casing length Machinery, bucket size	
Machinery placement	Placement of pile center Placement condition Casing inclination	
Excavation	Prevention of hole wall collapse Stabilization of Kelly-bar Inclination	
Support layer	Conformation of support layer Excavation depth	
Reinforcement work	Conformation of rebar quality Rebar cage deterioration Conformation of designed rebar cage Support material and fixing material Rebar cage shape Pile head cover Inclination during placement Connection strength	
Bottom processing	Processed appropriately Conformed by measurement	
Concrete work	Tremie length Tremie connection Preparation of concrete canting Concrete quality Casting continuously Top of tremie Depth of tremie into concrete Quantity of concrete Height of completion	

Site manager	

All Casing Method Check Sheet

Project name	

Pier No	Pile No	Method	Diameter(m)	Date	Inspector Name

	Design	Construction	Difference
Excavation Depth(m)	m	m	m
Pile length(m)	m	m	m
Top of Rebar	TP- m	TP- m	m
Top of concrete	TP- m	TP- m	m
Quantity of concrete	m^3	m^3	m^3

Check Item		Result	
		Result	Criteria
Pile Position	1.Pile center position		< 100 mm
	2.Inclination		<1/100
	3.Offset point		>4
Machinery	4.Earth strength		>0.1-0.2 N/mm^2
	5.Position		Planning
	6.Hammer grab		< Casing diameter-40-90 mm
Casing	7.Casing size (diameter, length)		Meet diameter
	8.Casing outer blame		< 10 – 15 mm
	9.Casing position		< 100 mm (Center) <1/100(Inclination)
Excavation	10.Time		
	11. Support layer depth		Compare with design
	12.Excavation depth		Compare with design Measure at least 4 points
	13.Embedment to support layer		>1.5 D
Primary bottom processing	14. Measuring deposition	Before	
		After	
Reinforcement work	15. Rebar cage length		>Design length
	16.Rebar cage – Size		Compare Design
	16.Rebar cage – Number		

		Alignment		
		Spacer		
		Support		
	17.Inclination during placement			< 1/100
	18.Preparation for pile head treatment			Design
Secondary bottom processing	19.Measuring deposition		Before	
			After	
Concrete quality	20.W/C			<55%
	21.Slump			180-210mm
	22.Strength			30N/mm^2
	23.Air content			4,5%±1.5%
	24.Chloride content			0.3kg/m^3
Concrete work	25.Tremie length			Buried to concrete more than 2m
	26.Time duration			
	27.Quantity of concrete			
	28.Excess concrete			About 0.8 – 1.0 m

Site manager	

BF 05

Reverse Circulation Drill Method Check Sheet

Project name	

Pier No	Pile No	Method	Diameter(m)	Date	Inspector Name

	Design	Construction	Difference
Excavation Depth(m)	m	m	m
Pile length(m)	m	m	m
Top of Rebar	TP- m	TP- m	m
Top of concrete	TP- m	TP- m	m
Quantity of concrete	m^3	m^3	m^3

Check Item		Result	
		Result	Criteria
Pile Position	1.Pile center position		< 100 mm
	2.Inclination		<1/100
	3.Offset point		>4
Machinery	4.Earth strength		>0.1-0.2 N/mm^2
	5.Position		Planning
	6.Bit		Adequate for diameter, Soil condition
Stand pipe	7.Diameter		>larger than designed diameter by 150-200mm
	8.Length		< Buried to mad by 0.5m
	9. Position		< 100 mm (Center) <1/100(Inclination)
Excavation	10.Time		Compare with test pile
	11.Drilling torque		Compare with test pile
	12.Drilling Integrating galvanometer		Compare with test pile
	13. Support layer depth		Compare with design
	14.Excavation depth		Compare with design Measure at least 4point
	15.Embedment to support layer		>1.5 D
Bentonite quality	16.Viscosity		Adequate to soil condition 4 times by one pile construction
	17.Specific gravity		Adequate to soil condition 4 times by one pile construction
Primary bottom processing	18. Measuring deposition	Before	
		After	

Reinforcement work	19. Rebar cage length			>Design length
	20.Rebar cage	Size		Compare Design
		Number		
		Alignment		
		Spacer		
		Support		
	21.Inclination during placement			< 1/100
	22.Preparation for pile head treatment			Design
Secondary bottom processing	23.Measuring deposition		Before	
			After	
Concrete quality	24.W/C			<55%
	25.Slump			180-210mm
	26.Strength			$30N/mm^2$
	27.Air content			4,5%±1.5%
	28.Chloride content			$0.3kg/m^3$
Concrete work	29.Tremie length			Buried to concrete more than 2m
	30.Time duration			
	31.Quantity of concrete			
	32.Excess concrete			About 0.8 – 1.0 m

BF 06

Site manager	

Earth Drilling Method Check Sheet

Project name	

Pier No	Pile No	Method	Diameter(m)	Date	Inspector Name

	Design	Construction	Difference
Excavation Depth(m)	m	m	m
Pile length(m)	m	m	m
Top of Rebar	TP- m	TP- m	m
Top of concrete	TP- m	TP- m	m
Quantity of concrete	m^3	m^3	m^3

Check Item		Result	
		Result	Criteria
Pile Position	1.Pile center position		< 100 mm
	2.Inclination		<1/100
	3.Offset point		>4
Machinery	4.Earth strength		>0.1-0.2 N/mm^2
	5.Position		Planning
	6.Bit		Adequate for diameter, Soil condition
Stand pipe	7.Diameter		>larger than designed diameter by 150-200mm
	8.Length		< Buried to mad by 0.5m
	9. Position		< 100 mm (Center) <1/100(Inclination)
Excavation	10.Time		Compare with test pile
	11.Drilling torque		Compare with test pile
	12.Drilling Integrating galvanometer		Compare with test pile
	13. Support layer depth		Compare with design
	14.Excavation depth		Compare with design Measure at least 4point
	15.Embedment to support layer		>1.5 D
Bentonite quality	16.Viscosity		Adequate to soil condition 4 times by one pile construction
	17.Specific gravity		Adequate to soil condition 4 times by one pile construction
Primary bottom processing	18. Measuring deposition	Before	
		After	
	19.Waiting time after excavation		20-30 minutes

Reinforcement work	20. Rebar cage length			>Design length
	21.Rebar cage	Size		Compare Design
		Number		
		Alignment		
		Spacer		
		Support		
	22.Inclination during placement			< 1/100
	23.Preparation for pile head treatment			Design
Secondary bottom processing	24.Measuring deposition		Before	
			After	
Concrete quality	25.W/C			<55%
	26.Slump			180-210mm
	27.Strength			$30N/mm^2$
	28.Air content			4,5%±1.5%
	29.Chloride content			$0.3kg/m^3$
Concrete work	30.Tremie length			Buried to concrete more than 2m
	31.Time duration			
	32.Quantity of concrete			
	33.Excess concrete			About 0.8 – 1.0 m

Appendix 5 - Checking List for Pre-cast Pile

(1) Checking List for Pile Driving Method

BF 07

Procedure	Point to be checked	Comment
General	Confirmation of check point for construction at the meeting Design drawing Survey for construction Construction plan Negotiation with related organization Understanding the point for construction report License Safety manual Specification of machinery Position of machinery and material Organization emergency	
Preparation	Access road to the site Access road on the site Geotechnical condition for each machinery position Examination machinery Land Survey Capacity if electrical facilities Schedule of order for material	
Obstacle	Position of obstacles	
Transportation Storage	Management of transportation and handling Storage condition Storage place	
Pile quality	Shape, Size Quality, Quantity Appearance	
Pile Placement	Position of pile center Capacity of machine for positioning pile Method of positioning Length of leader Verticality	

Procedure	Point to be checked	Comment
Driving	Procedure Hammer size Inclination Driving stop position Deformation of placed pile Deformation of driving pile Accuracy Reporting construction record	
Welding	Connection of each pile Technical level of welding operator (License) Cleaning and drying before welding Dislocation between each connected pile Welding machine Management of welding condition Tackling Time duration Appearance	
Pile head treatment	Pile head elevation Holder size, position Reinforcement size, shape, specification Concrete specification Concrete compaction	
Safety, Surrounding Environment	Isolation of construction area Stability of crane and pile driving machine Safety procedure for electrical facilities Fall prevention Prevention of vibration and noise Safety procedure for neighbors	
Other		

Site manager	

Pile driving Method Check Sheet

Project name	

Pier No	Pile No	Method	Diameter(m)	Date	Inspector Name

	Design	Construction	Difference
Driven Depth(m)	m	m	m
Pile length(m)	m	m	m
Top of pile	TP- m	TP- m	m

Check Item		Result	
		Result	Criteria
Pile Position	1.Pile center position		< 100 mm
	2.Inclination		<1/100
	3.Offset point		>4
Machinery	4.Earth strength		>0.1-0.2 N/mm^2
	5.Position		Planning
	6.Pie driver, Hammer		Adequate for diameter, Soil condition, Surrounding environment
	7.Follower		Item: Diameter, Stiffness, Length, Strength, Surface
	8.Cap and cushion		Strong enough for pile top protection
Driving	8.Holding position		Around 2m from top
	9.Time		Compare with test pile
	10.Driven depth by one driving		Compare with test pile
Finishing Support layer conformation	11. Rebound measurement		Each pile
	12.Dynamic bearing capacity		Compare with design

Appendix 6 - Checking List for Pre-boring Method

BF 09

(1) Checking list for Pre-Boring Method

Procedure	Point to be checked	Comment
General	Confirmation of check point for construction at the meeting Design drawing Survey for construction Construction plan Negotiation with related organization Understanding the point for construction report License Safety manual Specification of machinery Position of machinery and material Organization emergency	
Preparation	Access road to the site Access road on the site Geotechnical condition for each machinery position Examination machinery Land Survey Capacity if electrical facilities Schedule of order for material	
Obstacle	Position of obstacles	
Transportation Storage	Management of transportation and handling Storage condition Storage place	
Pile quality	Shape, Size Quality, Quantity Appearance	
Excavation	Position of pile center Position of bit Inclination of excavation rod Discharge slurry from top point of bid Excavation speed Excavation depth Reaching support layer	

Procedure	**Point to be checked**	**Comment**
Foot protection	Depth Quantity of injection	
Pulling up rod	Changing chemical liquid from foot protection to Pile Periphery Fixing Pulling up speed Quantity of chemical Mixing design	
Welding	Connection of each pile Technical level of welding operator (License) Cleaning and drying before welding Dislocation between each connected pile Welding machine Management of welding condition Tackling Time duration Appearance	
Pile head treatment	Pile head elevation Holder size, position Reinforcement size, shape, specification Concrete specification Concrete compaction	
Safety, Surrounding Environment	Isolation of construction area Stability of crane and pile driving machine Safety procedure for electrical facilities Fall prevention Prevention of vibration and noise Safety procedure for neighbors	
Other		

Site manager	

BF 10

Pre-boring Method Check Sheet

Project name	

Pier No	Pile No	Method	Diameter(m)	Date	Inspector Name

	Design	Construction	Difference
Pre-boring Depth(m)	m	m	m
Pile length(m)	m	m	m
Top of pile	TP- m	TP- m	m

Check Item		Result	
		Result	Criteria
Pile Position	1.Pile center position		< 100 mm
	2.Inclination		<1/100
	3.Offset point		>4
Machinery	4.Earth strength		>0.1-0.2 N/mm^2
	5.Position		Planning
	6.Pie driver, Auger, Stirring rod		Adequate for diameter, Soil condition, Surrounding environment
	7.Stirring diameter		Around 100 mm larger than pile diameter
Drilling	8.Speed		Soft soil 0.5-4m/min Hard mad, sand 0.5-3m/min Hard sand, Gravel 0.5-1m/min
	8.Holding position		Around 2m from top
	9.Accuracy		< D/4 or 100mm <1/100
	10.Drilling depth by one driving		Compare with test pile
	11. Support layer depth		Compare with design
	12. Drilling torque		Compare with test pile
	13. Drilling Integrating galvanometer		Compare with test pile
Foot protection and Pile periphery fixing	14.Quality		W/C 60-70 Foot protection δ28 > 20N/mm^2 Pile periphery fixing δ28 > 0.5N/mm^2
	15.Foot protection thickness		>3D
	16.Foot protection depth		Deeper than 1.5D from bottom of pile

Appendix 7 - Checking List for Steel Pipe Sheet Pile

Procedure	Point to be checked	Comment
General	① Confirmation of check point for construction at the meeting ② design drawing ③ Survey for construction ④ Construction plan ⑤ Negotiation with related organization ⑥ Understanding the point for construction report ⑦ License ⑧ Safety manual ⑨ Specification of machinery ⑩ Position of machinery and material ⑪ Organization emergency	
Preparation	① Access road to the site ② Access road on the site ③ Geotechnical condition for each machinery position ④ Examination machinery ⑤ Land Survey ⑥ Capacity if electrical facilities ⑦ Schedule of order for material	
Obstacle	Position of obstacles	
Transportation Storage	① Management of transportation and handling ② Storage condition ③ Storage place	
Pile quality	① Shape, Size ② Quality, Quantity ③ Appearance	
Guide Materials	① Position ② Size and shape ③ Stability	

Procedure	Point to be checked	Comment
Driving	① Procedure ② Hammer size ③ Inclination ④ Driving stop position ⑤ Deformation of placed pile ⑥ Deformation of driving pile ⑦ Accuracy ⑧ Reporting construction record	
Welding	① Connection of each pile ② Technical level of welding operator (License) ③ Cleaning and drying before welding ④ Dislocation between each connected pile ⑤ Welding machine ⑥ Management of welding condition ⑦ Tackling ⑧ Time duration ⑨ Appearance	
Inner concrete	① Excavation depth ② Cleaning inner pile ③ Mix design ④ Quantity ⑤ Top height of casting	
Joint	① Cleaning ② Mix design of mortar ③ Quantity ④ Casting depth and height ⑤ Quality of package	

Procedure	Point to be checked	Comment
Excavation and support	① Planning ② Excavation depth and water height ③ Support position ④ Inner concrete ⑤ Filling concrete ⑥ Pile Deformation ⑦ Leaking water from retaining pile wall ⑧ Surface of pile	
Basement concrete	① Mix design, strength, quantity ② Setting time ③ Crush stone cover ④ Casting depth ⑤ Floor heave	
Connection	① Planning ② Water leaking ③ Cleaning pile face ④ Ventilation	
Pile cap concrete	① Mix design, strength, quantity ② Casting ③ Reinforcement ④ Curing period	
Safety, Surrounding Environment	① Isolation of construction area ② Stability of crane and pile driving machine ③ Safety procedure for electrical facilities ④ Fall prevention ⑤ Prevention of vibration and noise ⑥ Safety procedure for neighbors	
Other		