SESOC / NZGS SPECIFICATION

Bored and Driven Piles

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This document supersedes the Auckland Structural Group publication "Piling Specification" (Rev G, 2002).

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1 GENERAL

1.1 SCOPE AND INTERPRETATION

This Specification sets out requirements for the construction of a number of pile types. It is intended that this document be read in conjunction with the Project Specific Requirements, which shall be prepared by the Engineer for each project.

In the event of a conflict between the requirements of this Specification and the Project Specific Requirements, the requirements of the Project Specific Requirements shall take precedence.

In this Specification, the word 'shall' indicates a requirement that is to be adopted in order to comply with the Specification, while the word 'should' indicates a recommended practice.

Reference to any standard in this Specification shall be taken to mean the current published revision at the time of publication of this Specification.

1.2 DEFINITIONS AND NOTATIONS

1.2.1 Definitions

The following terms are used within this specification:

Project Specific Requirements: A list of requirements supplemental to the requirements of this Specification that pertain to an individual project. These are prepared by the specifier and are usually included in the project Specifications.

Specifier: The author of the overall project Specification (including the Project Specific Requirements). Usually a consulting or local authority engineer.

Ultimate Driving Resistance: The load capable of being supported by the soil or rock. To be greater than the ultimate limit state load (with appropriate strength reduction factor) or working load (with appropriate factors of safety).

Engineer: The person or her or his duly authorised representative responsible for understanding, interpreting and enforcing the pile design, construction and verification requirements of this Specification.

Contractor: The organisation responsible for construction of the physical pile works as specified.

1.2.2 Notation

~~DL~~	~~Dead Load~~	~~kN~~
DVL	Design Verification Load	kN
f_c'	Concrete compressive strength	MPa

f_{pe}	Prestress within prestressed piles	MPa
f_y	Steel yield strength	MPa
G	Permanent Action	kN
~~LL~~	~~Live Load~~	~~kN~~
NSF	Negative Skin Friction	kN
Q	Imposed Action	kN
σ_a	Allowable stress of timber piles	MPa
$\emptyset_g$	Strength reduction factor	-

1.3 PROJECT SPECIFIC REQUIREMENTS

The following items, where appropriate, are detailed in the project specification:

- location and description of the Site
- nature and extent of the work
- site datum and grid references
- nature of the ground and subsurface conditions
- requirement for proving bores
- requirements for tolerances
- requirements for quality management
- requirements for Producer Statements
- technical requirements for consideration of alternative pile designs
- requirements for pile testing

1.4 HEALTH AND SAFETY

The requirements for health and safety are detailed in the Project Specific Requirements. Where not specified, the piling works shall comply with the requirements of the following documents as a minimum precaution:

- ~~Health and Safety in Employment Act~~Health and Safety at Work Act 2015
- ~~OSH Code of Practice: Excavation and Shafts for Foundations~~Good Practice Guidelines for Excavation Safety (WorkSafe, Good Practice Guidelines for Excavation Safety, 2016)
- Approved Code of Practice for Load-Lifting Rigging (MBIE, Approved Code of Practice for Load-lifting Rigging, 2012)
- Approved Code of Practice for Cranes (WorkSafe, Approved Code of Practice for Cranes, 2009)

- Best Practice Guidelines for Working at Height in New Zealand (MBIE, Best practice guidelines for working at height in New Zealand, 2019)
- Good Practice Guideline for Temporary Works (TWfNZ, GPG01, 2019)
- Working (Piling) Platform Information Poster (TWfNZ, Working Platforms, 2018)

1.5 METHOD STATEMENT

The Contractor shall provide a detailed method statement for each piling operation to be undertaken in executing the Works. The method statement shall describe all proposed Equipment and detail the construction sequence. The method statement shall be submitted to the Engineer prior to commencement of piling work on Site.

The Engineer's review of the Contractor's method statement shall not relieve the Contractor of its obligations to meet the requirements of this Specification and the project Specifications.

1.6 PILING PROGRAMME

The Contractor shall submit a detailed programme for the execution of the piling work prior to piling work commencing on Site.

1.7 PILE DESIGN

The requirements specified on the Drawings or the Project Specific Requirements are the minimum requirements for the piles in the completed structure.

The Contractor shall be responsible for the design and detailing of the piles for all handling and installation effects during construction, as appropriate.

1.8 PILE LENGTHS

The anticipated lengths of piles are shown on the Drawings or the Project Specific Requirements. The actual length of pile will be determined on site and will be the length required to achieve the loads specified on the Drawings or the Project Specific Requirements.

1.9 PILE CONSTRUCTION

The Contractor shall construct the piles of the type(s) and dimensions specified ~~on the Drawings,~~ to the requirements of this Specification or the project Specifications.

Submission of a tender shall be deemed as evidence that the Contractor accepts the full and sole responsibility for the method of working, including the maintenance of pile excavation stability, the construction of defect free piles and positioning the completed piles within the required tolerances to the approximate founding depth specified. ~~on the Drawings.~~

1.10 HANDLING, STORAGE AND MARKING OF PILES

All operations such as handling, transporting, lifting and pitching of piles shall be carried out in such a manner as to prevent damage to the piles and/or their coatings.

Piles and pile casings shall be stacked on suitable supports on firm ground, in a manner which will eliminate excessive handling stresses or other damage.

Piles to be driven shall be clearly marked with paint prior to installation with the pile number, overall length and at regular intervals, the cumulative length measured from the pile tip.

1.11 NATURE OF GROUND AND SUBSURFACE CONDITIONS

It is deemed that the Contractor has inspected the Site and considered the nature of the ground through which piles are to be constructed.

The Contractor shall inform the Engineer of any circumstances which indicates, in the Contractor's opinion, that ground conditions differ from those reported or which could have been inferred from ground investigation reports or preliminary pile results.

Should the Contractor consider that such a change in the ground conditions could not have been reasonably foreseen by an experienced contractor when tendering and will, in the Contractor's opinion, change the construction methodology or substantially increase the Contractor's costs, then redress may be sought in accordance with the unforeseen physical conditions of the project Conditions of Contract.

No warranty is expressed or implied that any information, opinions or conclusions, given in any factual or interpretative ground investigation report, supplied in good faith by the Engineer, will present a complete or accurate picture of the whole of the Site. ~~The Contractor shall be responsible for any inference it may draw from any information made available to it.~~

1.12 PROVING BORE REQUIREMENTS

The requirements for proving bores are detailed in the Project Specific Requirements.

Proving bores shall be drilled before piling commences. Proof-boring shall be carried out in the presence of the Engineer, who will require at least one Working Day's notice of when proving will take place. Proving bores shall be drilled at each location specified on the Drawings, to enable the Engineer to carry out further inspection of the founding material.

1.13 SETTING OUT AND AS-BUILT LOCATIONS

The position of all piles shall be accurately set out by the Contractor. The pile positions shall be checked by the Contractor immediately prior to installation.

After construction, actual pile locations shall be surveyed by an appropriately qualified and suitably experienced surveyor ~~certified by a surveyor engaged by a Registered Surveyor and~~ employed by the Contractor for this purpose. The Contractor shall submit an as-built pile plan to the Engineer within five Working Days of completion

of the last pile. Partial as-built information may be submitted throughout construction of the piles as required.

1.14 TOLERANCES

Pile tolerances are specified in the Project Specific Requirements.

The Contractor shall make all necessary provisions to the pile construction procedure, initial spotting and inclination of piles in order to achieve installation of piles to the specified tolerances. Standard tolerances are as follows:

Positional (at pile commencement level): Within 75mm of location indicated.

Verticality:

Construction Method	Verticality Tolerance
All Bearing Piles - minimum	1 : 75
Bored Piles – standard equipment	1 : 100
CFA Piles	1 : 100
CFA Piles – extra heavy duty augers	1 : 125
Bored Piles – full depth heavy wall casing	1 : 200

If records or measurements show that piles have been installed outside the specified tolerances the Contractor shall provide the Engineer with details of measures to be adopted to enable the piles to comply with the Specification. Forcible correction of laterally displaced piles shall not be made unless the Contractor can demonstrate that the strength, integrity and durability performance of the pile will not be adversely affected.

Should the Contractor fail to meet the above requirements, the Engineer reserves the right to order such extra work as may be required to overcome the resultant structural problems. No additional cost to the Principal shall arise from any such extra work. Any additional engineering design work required because of piles placed outside the specified tolerances (for example, the strengthening of existing piles or design of additional piles) shall be carried out by the Engineer and paid for by the Contractor.

The Contractor shall not carry out any remedial work on any pile, without the written approval of the Engineer.

1.15 SUPERVISION

The Contractor shall nominate a suitably experienced person as the "Piling Supervisor". The Contractor shall submit a curriculum vitae for the proposed Piling Supervisor prior to commencement of pile construction.

The Piling Supervisor shall be responsible for ensuring that all piling operations comply with the requirements of this Specification. The Piling Supervisor shall also ensure that all monitoring and pile records are maintained up to date and are available for inspection by the Engineer.

The Piling Supervisor shall not be removed from the Works without the Engineer being notified one week in advance. The Contractor ~~and Engineer shall agree on a~~shall nominate a~~–~~ suitable replacement before the Piling Supervisor is removed from the Works.

1.16 OBSERVATION

The Engineer requires to have the opportunity of observing all phases of the piling operations and of inspecting particular items such as (but not limited to) set and rebound, the bottom of bored piles, jointing of casings, concreting, fabrication of reinforcing cages, etc. The Contractor shall therefore keep the Engineer informed daily as to the work anticipated to be carried out on the next working day.

1.17 PILE ~~STABILITY~~ SUPPORT DURING CONSTRUCTION

As required, ~~A~~at all times during pile construction and until incorporation of the piles in the completed structure, the free length of the pile shall be adequately restrained and supported by a pile support system (for example, by leaders, trestles, temporary supports, stay laths or other arrangements) to maintain position and to prevent buckling or other damage to the piles.

Particular care shall be taken when placing rock, earth or other fill around or near piles to prevent displacing piles from their constructed positions or causing other damage to the piles and/or their protective coatings.

1.18 PROTECTION OF EXISTING STRUCTURES AND PROPERTY

The Contractor shall take all care to ensure that no damage is caused by any of the piling works to any existing structure or adjoining public or private property and shall undertake to make good, at no cost to the Principal, any damage caused by piling operations. If at any stage the Contractor suspects that the piling operation may cause any damage to existing structures or property it shall notify the Engineer immediately.

1.19 EXISTING SERVICES

The Contractor shall give all required notices to the appropriate utility ~~company's~~ companies and territorial authorities and pay all relevant fees and charges.

The Contractor shall also locate and protect existing services, rectify any damage or interference to them and provide temporary support while repairs are being carried out.

1.20 COMPLETION

On completion, the Contractor shall leave the Site and the Contract Works safe, tidy and ready for immediate use by following contractors.

2 MATERIALS AND WORKMANSHIP

2.1 CONCRETE

2.1.1 Project Specific Requirements

The following items, where appropriate, are detailed in the project S~~s~~pecification:

- details of concrete strength and mix proportions
- requirements for alkali-aggregate reaction
- variations to NZS3109 (where specified)

2.1.2 Referenced Documents

This Specification shall be read in conjunction with the following standards, guidelines, and other documents, which are deemed to form part of this Specification. In the event of this Specification being at variance with any provision of these referenced documents, the requirements of this Specification shall take precedence. All ~~M~~materials and workmanship shall comply with these documents unless expressly noted otherwise. All documents referenced below shall be the latest revision, complete with current amendments, as at the commencement of the Contract Works.

NZS3109	Concrete Construction
EFFC/DFI	Guide to Tremie Concrete for Deep Foundations (EFFC/DFI, 2018)
CIA	Recommended Practice Tremie Concrete for Deep Foundations (CIA, 2012)

2.1.3 Material

All concrete, reinforcing steel and prestressing steel shall comply with the requirements of NZS3109 and related standards.

2.1.4 Concreting of Piles

Concreting of piles shall be generally in accordance with NZS3109, noting the following.

The Contractor shall include its proposals for placing and compacting concrete in the method statement submitted in accordance with section 1.5. Concrete mix design, placement and compaction techniques proposed should be in accordance with current industry best practice and guidelines as appropriate.

No concreting shall begin until the Engineer has approved the founding of the pile in question.

The time period between completion of pile excavation and completion of concreting shall not exceed 24 hours for piles which are less than 20 m long and/or 1000 mm in diameter. For all piles of a greater length or diameter the time period shall be mutually agreed by the Engineer and Contractor prior to the commencement of construction.

~~The time period shall begin when excavation below the permanent or temporary casing commences. Clean out and groove (where required) excavations immediately prior to commencing concreting.~~ No loose or disturbed material shall lie at the bottom of the excavation when concreting is started, nor be permitted to fall into the concrete as concreting proceeds.

The concreting technique shall be approved in advance by the Engineer, who will require to be satisfied that the method of placing and the concrete mix design will result in concrete fully compacted in place, possessing the specified strength and having the necessary density, integrity and durability. No concrete shall be placed in wet conditions or under water without the Engineer's approval (where the Engineer's approval is given verbally, this shall be followed up in writing as soon as practicable).

Wet conditions are defined when more than 75 mm of water is present at the base of the pile immediately prior to the concrete being discharged to the pile bore and/or inflow of water into the excavation during the pile pour process exceeds 200 mm of bore depth per hour. Measures shall be taken to ensure that the structural strength of the concrete is not impaired through grout loss, segregation or bleeding.

Concreting of piles shall be carried out continuously so that no segregation occurs, thorough compaction is effected in all parts of the pile and previously placed concrete does not achieve a stiffness which could prevent proper amalgamation of subsequent concrete batches.

Unless approved otherwise by the Engineer, in a dry pile bore, ~~C~~concrete ~~may~~ shall be placed using a chute, hopper and discharge pipe or pump line. ~~chuted into piles and allowed to freefall~~ The concrete may fall freely below the discharge point up to 10 m ~~to the pile base~~ as long as concrete placement can be controlled and there is no segregation of the concrete (such as may be caused by concrete hitting the pile reinforcement during placement).

The reinforcing steel shall always be adequately supported ~~at all times~~ to prevent displacement during or after placement of the concrete.

Where only a short section of reinforced concrete is to be placed at the top of the pile (for example, to make connection with a reinforced concrete superstructure), the Contractor shall ensure that adequate support is provided to the concrete to prevent any settlement of the newly placed or plastic concrete.

Concrete shall be placed such that the specified construction joint can be prepared at the top of the pile. Where not specified, construction joints shall be type B in accordance with NZS3109.

No concrete shall be placed when there is any danger of adverse weather causing damage to plastic or partially set concrete due to movement of pile liners.

Where temporary casing is used to effect a dry pile bore, there must be a sufficient head of concrete inside the casing when extracted to fill the annulus left by the casing as well as resist any outside groundwater infiltrating into the fresh concrete.

~~The Contractor shall include its proposals for placing and compacting concrete in the method statement submitted in accordance with section 1.5.~~

Recording actual versus theoretical concrete volume shall be undertaken during concreting of the pile and any interruption to the continuous concreting procedure (truck exchange, breaking of the tremie or any other unforeseen circumstance) also recorded.

2.1.5 Placing Concrete Under Water

The preferred method of placing concrete in piles shall be in a dry excavation ~~and the Contractor shall make all effort to achieve this where feasible~~. However, should either;

- The depth of water at the base of the pile at the commencement of concrete placement exceed ~~100~~ 75 mm, ~~or~~
- the inflow of water exceeds 200 mm of bore depth per hour, or
- the use of drilling fluid prove necessary to maintain excavation stability,

then concrete shall be placed using ~~an~~ the tremie or another appropriate underwater concreting technique approved by the Engineer.

2.1.5.1 Workplan

The Contractor shall submit a detailed written workplan for underwater concreting to the Engineer as part of the method statement submitted in accordance with section 1.5. This workplan shall be provided five Working Days prior to underwater concreting commencing on Site. The workplan shall explain in detail the proposed method of placement of concrete, including the sequence of operations in the event that either a blockage occurs or the concrete charge is lost during concreting.

2.1.5.2 Tremie

Where used, the bore of the tremie shall be smooth to allow the free flow of concrete and have a uniform internal diameter of at least:

- Six times the maximum size of aggregate, or
- ~~150~~ 100 mm

whichever is the greater.

The external shape and dimension of the tremie, including its joints, shall allow its free movement within the reinforcement cage. The maximum outside diameter of the tube, including its joints, should be not more than:

- 0.35 times the pile diameter, or the inner diameter of a casing
- ~~0.6~~0.45 times the inner diameter of the reinforcing cage for circular piles, unless agreed otherwise with the Engineer

The tremie shall be equipped with a hopper at its upper end to receive fresh concrete and to prevent spillage of concrete that could otherwise fall into the pile. The hopper shall hold a minimum capacity of concrete to fill not less than 1.5 m of bore depth and should have a means of holding this concrete until ready for the initial discharge.

The tremie and hopper shall be clean ~~and~~ with all pipes and joints watertight. All previously hardened concrete shall be removed from the tremie prior to insertion of

the tremie in the pile. A bung, hinged flap or sacrificial closure plate (closed tremie) or travelling plug of suitable material (open tremie) shall be ~~inserted into the pipe~~ employed prior to commencement of concrete placement to ensure that fresh concrete can be placed without it coming into contact with water or drilling fluid.

2.1.5.3 Concrete Mix

The following shall apply to concrete ~~for use in tremie pipes~~to be placed underwater:

- minimum ~~cement content~~cementitious materials of not less than 400 kg/m³
- maximum total water content of 170 kg/m³
- maximum aggregate size ~~35~~ 20 mm
- target concrete slump shall be ~~175 mm~~ 230 mm, ±25 mm
- minimum slump retention of 2hrs (extended further as required)

2.1.5.4 Method

The method adopted by the Contractor shall ensure that;

~~• Concrete placement shall proceed quickly to fill the entire base of the pile so that no concrete that may have become segregated at the beginning of the discharge is trapped. Concreting of piles shall then be carried out continuously so that no segregation occurs and thorough compaction will be effected in all parts of the pile.~~

~~the discharge pipe must be fully charged with concrete before it is lifted off the base of the pile to commence concrete placement.~~

- There is sufficient delivery capacity to discharge the concrete, e.g. a 200 mm (8-inch) diameter tremie pipe requires 2 x 125 mm (5-inch) boom pumps;
- with a closed tremie (utilising a bung, hinged flap or sacrificial closure plate), the discharge pipe must be fully charged with concrete before it is lifted off the base of the bore to commence concrete placement;
- with an open tremie (utilising a travelling plug) that is held close to but not on the base of the bore, the discharge pipe must be fully charged with concrete before concrete placement;
- the initial concrete flow is sufficient to achieve embedment of the tremie and the concrete can be placed continuously so that no segregation occurs and thorough compaction results in all parts of the pile;
- the discharge pipe shall at all times penetrate the concrete which has previously been placed with a minimum embedment of 1.5 metres and maximum embedment of 9.0 metres;~~for piles less than 1200 mm in diameter and 2.5 metres for piles greater than 1200 mm in diameter and shall not be withdrawn until the completion of concreting.~~
- surging of the tremie pipe is not permitted.

Towards the completion of the pour when the head of concrete in the tremie is becoming low, do not plunge the tremie pipes up and down to release the last of the concrete. Instead, calculate the required amount of concrete to fill the pile shaft and fill the hopper with the correct amount (plus some) then lift the tremie out slowly releasing the last of the concrete to the hole.

2.1.5.5 Loss of Immersion of ~~Discharge~~ Tremie Pipe

When the immersion of the ~~discharge~~ tremie pipe is lost during concreting (for example, to repair breakages or to remove a blockage), further placement of concrete shall not proceed unless:

- The concrete into which fresh concrete is to be placed has maintained its workability, and
- The ~~discharge~~ tremie pipe is re-immersed sufficiently deep into the previously placed concrete (as noted above – refer to section 2.1.5.4), and
- No water or other contaminant is introduced into concrete which will remain below the final pile cut-off level~~.~~, and
- The base of the tremie pipe is fully sealed and watertight and can withstand the pressures that will be applied to it at re-immersion depth. This seal can be released when the re-immersed tremie pipe is embedded 1.5m into the existing workable concrete.

If these conditions cannot be met, concrete placement shall be suspended, the ~~discharge~~ tremie pipe shall be removed and alternative measures shall be agreed with the Engineer to form a sound pile.

In cases where immersion of the ~~discharge~~ tremie pipe is lost and inflow of contaminant (water, air or other material) into the freshly placed concrete is likely to have occurred, the placement of concrete shall be suspended.

The pile may be completely replaced or reformed in its original position if the reinforcement cage can be extracted and the previously placed concrete removed.

Piles may be recovered by the formation of a construction joint (in accordance with NZS3109) after all concrete of insufficient quality has been removed and sound concrete over the full section of the pile has been exposed, forming a faultless interface. Where the preparation of a construction joint is not possible, the pile shall be abandoned and the empty bore above the placed concrete backfilled with an appropriate material approved by the Engineer.

Integrity tests shall be carried out to document the quality of any pile where loss of immersion of the ~~discharge~~ tremie pipe has occurred, or where a construction joint has been formed in the pile. Refer to section 5.1 for requirements for integrity testing.

2.1.6 Precast Concrete Piles

Precast concrete piles shall be cast in one continuous operation and shall be properly cured.

Units shall be handled, transported and erected so that no damage is caused to them at any stage. Units shall only be lifted using properly designed and installed lifting devices. The Contractor shall be responsible for the design, provision and subsequent removal of lifting devices as required.

2.1.6.1 Splicing of Precast Piles

Details of the design, manufacture and tests of the jointing system shall be submitted to the Engineer prior to the commencement of precast pile manufacture.

A spliced pile shall be capable of withstanding the same driving stresses as a single unjointed pile of the same cross sectional dimensions, length and materials.

The welding of a joint to main reinforcement in lieu of a lapped connection with projecting bars shall not be permitted without the prior approval of the Engineer.

Each pile splice shall be square to the axis of the pile. The alignment of the spliced pile sections shall not vary by more than ±5 mm from a 1000 mm long straight edge. The centroid of the splice shall lie within ±5 mm of the centroid of the adjacent pile sections.

2.1.6.2 Cutting off and Preparing of Pile Heads

When the pile has been installed in accordance with the requirements of this specification, the concrete at the head of the pile shall be cut off to the levels specified on the Drawings.

Care shall be taken to avoid shattering or otherwise damaging the remaining section of the pile. Any cracked or defective concrete or reinforcement shall be cut away and the pile repaired to provide a full and sound section at the pile cut off level.

2.2 STRUCTURAL STEEL

2.2.1 Project Specific Requirements

The following items, where appropriate, are detailed in the project specification:

- Weld category for welds in accordance with NZS3404 (GP or SP)
- corrosion protection for steel piles
- grade and category of steel
- material testing requirements
- weld inspection requirements

2.2.2 Referenced Documents

This Specification shall be read in conjunction with the following standards, guidelines, and other documents, which are deemed to form part of this Specification. In the event of this Specification being at variance with any provision of these referenced documents, the requirements of this Specification shall take precedence. All m~~M~~aterials and workmanship shall comply with these documents unless expressly

noted otherwise. All documents referenced below shall be the latest revision, complete with current amendments, as at the commencement of the Contract Works.

AS/NZS1554.1-	Welding of Steel Structures
BS3100	Specification for Steel Castings for General Engineering Purposes
NZS3404	Steel Structures Standard

2.2.3 Steel H Piles

Steel H piles shall comply with the requirements of NZS3404.

2.2.4 Steel Pipe Pile and Steel Casing Manufacturing Process

All piles shall be of the type and minimum cross section dimensions as specified on the Drawings or Project Specific Requirements.

Steel casings shall be approved longitudinally or spirally welded mild steel, or an approved substitute, capable of withstanding the forces induced by driving without deformation. The casings shall also be capable of being dewatered if required by the Engineer.

The rolling or manufacturing tolerances for steel tubular piles shall be such that the actual weight of section does not differ from the theoretical weight by more than ±5%. The external diameter at any section, measured using a steel tape on the circumference, shall not differ from the theoretical diameter by more than ±1%. The deviation from straightness on any longitudinal face shall not exceed 1/600 of the length of the pile, nor 5 mm in any 3000 mm length.

The Contractor shall submit details of the manufacturing and welding processes to the Engineer, before commencement of pile manufacture. The Contractor shall provide the Engineer with works test certificates, analyses, and mill certificates, together with the tube manufacturer's certificate showing details of the pile number, cast number of the steel and a record of all tests and inspections carried out. The Contractor shall give the Engineer adequate notice of the start of each stage of the manufacturing process and any production tests, and shall make facilities available to the Engineer for inspection. The Contractor shall provide the Engineer with samples when required.

~~All piles shall be of the type and minimum cross section dimensions as specified on the Drawings.~~

~~The rolling or manufacturing tolerances for steel tubular piles shall be such that the actual weight of section does not differ from the theoretical weight by more than ±5%. The external diameter at any section, measured using a steel tape on the circumference, shall not differ from the theoretical diameter by more than ±1%. The deviation from straightness on any longitudinal face shall not exceed 1/600 of the length of the pile, nor 5 mm in any 3000 mm length.~~

~~Steel casings shall be approved longitudinally or spirally welded mild steel, or an approved substitute, capable of withstanding the forces induced by driving without~~

~~deformation. The casings shall also be capable of being dewatered if required by the Engineer.~~

2.2.5 Welding

Where not specified in the Project Specific Requirements, all welds shall be weld category SP in accordance with NZS3404.

All welding procedures shall be in accordance with AS/NZS1554. The Contractor shall submit full details of the proposed welding procedures and electrodes, with drawings and schedules as required. Only welders qualified to AS/NZS1554 or who have attained a similar standard shall be employed on the Works. Proof of welders proficiency and qualification shall be made available to the Engineer on request.

Splices between adjacent lengths of pile shall be made with full penetration~~strength~~ butt welds, complete with backing plates (where required).

The standard for interpretation of non-destructive testing shall be AS/NZS1554.1. The extent of non-destructive examination (NDE) is set out in Table 2.2.5.

Table 2.2.5 : Extent of Non Destructive Examination

Extent of Non-Destructive Examination (%)				
Weld Category	Visual Means		Other Means	
	Visual Scanning (1)	Visual Examination (2)	Magnetic Particle or Liquid Penetrant	Radiography or Ultrasonics
GP	100%	25%	Nil	Nil
SP	100%	100% (3)	10%~~Nil~~	10%~~15%~~

Notes:

(1) Visual scanning shall determine that no welds called for in the Drawings or Specification are omitted. Visual scanning shall also detect gross welding defects.

(2) Visual examination shall determine whether the required weld quality (in accordance with Table 6.2 of AS/NZS1554.1) has been achieved.

(3) Per Appendix D, NZS3404

Where the proportion of NDE called for above is less than 100%, the Contractor shall agree a programme of testing with the Engineer prior to commencement of any welding. The programme shall involve full testing of the first 5% of welds, in order to pick up and correct the cause of any major defect at the commencement of welding. The frequency of testing may then be progressively reduced on the basis of continuing compliance with this Specification. In the event of a non-compliant test result, a return to full testing of the next 5% of welds will be required.

Results of weld testing shall be submitted to the Engineer within ten days of completion of the tests. If the tests of any weld do not conform to the specified requirements, two additional specimens from the same length of pile shall be tested. In the case of failure of one or both of these additional tests, the length of pile covered by the tests shall be rejected.

2.2.6 Site Splices

Splices between adjacent lengths of pile shall be made with full ~~strength~~ penetration butt welds.

Site splices shall meet all of the requirements of section 2.2.5.

All work associated with welding shall be protected from the weather so that the quality of work meets the requirements of the Specification.

2.2.7 Driving Shoes

Cast steel shoes shall be of steel to BS3100 Grade A1. Flat plate and welded fabricated steel shoes shall be mild steel complying with NZS3404. Fabricated pile shoes, or the strengthening to the toe of a pile in lieu of a shoe, or the strengthening of the head of a pile for driving, shall be made using material of the same grade as the pile.

2.2.8 Preparation of Pile Heads

If a steel structure is to be welded to the piles, the piles shall be cut square and to within 5 mm of the level specified.

If the pile heads are to be encased in concrete, they shall be cut to within 20 mm of the levels specified, and protective coatings (where specified) removed from the surfaces of the pile heads down to a level 100 mm above the soffit of the concrete.

2.2.9 Steel Sheet Piles

2.2.9.1 Manufacture

Steel sheet piles shall be mild steel complying with NZS3404 or a recognised international standard. Only new sheet piles shall be used for permanent works (used sheet piles may be used in place of new sheet piles but only with the prior written approval of the Engineer).

All fabricated pile components, such as corners, junctions, box piles, and high modulus piles, shall be fabricated and supplied in accordance with the sheet pile manufacturer's written instructions.

All piles and production facilities shall be made available for inspection at any time. All sheet piles shall be carefully examined at the time of delivery to the Site, and damaged piles shall be repaired or replaced. The Contractor shall ensure that all interlocks are clean and free from distortion.

2.2.9.2 Welding

Welding of sheet piles shall comply with section 2.2.5. Welded site splices shall comply with section 2.2.6.

Where sheet piles are to be spliced by butt welding, the interlocks shall not be welded unless a seal weld is required.

2.3 TIMBER

2.3.1 Project Specific Requirements

The following items, where appropriate, are detailed in the project specification:

- size and shape of timber piles
- timber species
- ~~treatment for timber piles~~timber hazard class

2.3.2 Referenced Documents

This Specification shall be read in conjunction with the following standards, guidelines, and other documents, which are deemed to form part of this Specification. In the event of this Specification being at variance with any provision of these referenced documents, the requirements of this Specification shall take precedence. All Materials and workmanship shall comply with these documents unless expressly noted otherwise. All documents referenced below shall be the latest revision, complete with current amendments, as at the commencement of the Contract Works.

NZS3605 ~~Load Bearing Round~~ Timber Piles and Poles for use in Buildings

NZS3640 Chemical Preservation for Round and Sawn Timber

~~NZMP3640 The Minimum Requirements of the New Zealand Timber Preservation Council Incorporated~~

2.3.3 Material

The requirements for timber species are detailed in the Project Specific Requirements.

Timber poles and piles shall meet the requirements of NZS3605.

The timber shall be new and free from defects, decay, large loose or dead knots, undue shake, excessive sap, rot, pests, fungal or pest attack which may affect the strength or durability of piles. The grain shall be straight and parallel to the axis of the pile.

The minimum requirements for pile sizes are shown on the Drawings or Project Specific Requirements.

~~Timber poles and piles shall meet the requirements of NZS3605.~~

2.3.4 Timber Treatment

Unless specified otherwise in the Project Specific Requirements timber piles shall be treated to TPC Brand H6 (refer to ~~NZMP3640~~NZS3640).

Cutting and boring or timber shall be done as far as ~~possible~~ practicable before preservative treatment, but where this is impracticable, any piles that are cut or notched after pressure treatment shall be well dried and brush treated with a suitable preservative, in accordance with NZS3605.~~protected by a liberal brush application of Ensele Tanalith concentrated solution or copper napthalene.~~

Certificates of treatment shall be submitted to the Engineer for all treated timber.

2.3.5 Marking, Handling and Storage of Timber Piles

The Contractor shall notify the Engineer of the delivery of the timber piles to the Site, and provide all labour and equipment to enable the Engineer to inspect each piece of timber on all faces, and to measure it, all at the time of delivery and prior to driving.

Each timber pile shall be clearly marked ~~with white paint~~ prior to installation, with its number and overall length.

Timber piles shall be stacked in lengths clear of the ground with an air space around them. The piles shall be separated vertically by suitable blocks or spacers placed vertically one above the other, and positioned at centres which are close enough to prevent sagging. Timber piles shall be protected from the sun and rain by means of tarpaulins or other appropriate covers which allows free circulation of air.

All operations such as handling, transporting and pitching of piles shall be carried out in such a manner as to prevent damage to piles.

2.3.6 Splicing of Timber Piles

Piles shall be provided in one piece unless specified otherwise.

If the piles are to be spliced, the splice shall be capable of resisting any stresses which may develop during lifting, pitching, driving or under the action of the design loads in the completed structure. The position and details of the splice shall be reviewed by the Engineer prior to driving of piles.

Splices shall be made using two timbers of the same cross sectional dimensions, each cut at right angles to its axis, to make contact over the whole of the cross section when the two pile sections are aligned. A jointing compound shall be applied to the contact surfaces. Round timbers shall be joined by a section of steel tube. Rectangular piles shall be joined by a prefabricated steel box section fitting the timber closely, or by steel splice plates. The steel connectors shall be bolted, screwed, or spiked to the timbers to ensure that the ends of the timbers are kept in close contact. The axial alignment of the two timber sections shall not vary by than 10 mm from a 1000 mm straightedge. The requirements for corrosion protection of steel joining elements are detailed in the Project Specific Requirements.

2.3.7 Preparation of Pile Heads

No timber pile head shall be cut off without the approval of the Engineer.

Unless noted otherwise in the project specification, all ~~P~~portions of cut off pile heads shall become the property of the Contractor and shall be removed from the Site.

When timber piles are installed by driving, the heads shall be cut off square to sound timber, to within ± ~~5~~ 20 mm of the levels specified on the Drawings. The cut surfaces shall be well dried and brush treated with a suitable preservative, in accordance with NZS3605.~~heavily coated with preservative, as specified for the initial treatment.~~

3 BORED PILES

3.1 SCOPE

This section covers the construction of bored piles with or without the use of permanent or temporary steel casings to maintain bore stability. ~~The piles will typically be constructed using permanent or temporary steel liners penetrating to founding level.~~ Piles will be excavated to the required depths necessary to achieve the specified loads, and then backfilled with reinforced concrete. This section also covers the use of timber, steel or precast concrete piles placed in predrilled sockets.

3.2 PROJECT SPECIFIC REQUIREMENTS

The following items, where appropriate, are detailed in the particular specification:

- disposal of excavated material
- requirement for support fluid
- pressure grouting
- trial piles

3.3 REFERENCED DOCUMENTS

This Specification shall be read in conjunction with the following standards, guidelines, and other documents, which are deemed to form part of this Specification. In the event of this Specification being at variance with any provision of these referenced documents, the requirements of this Specification shall take precedence. All Materials and workmanship shall comply with these documents unless expressly noted otherwise. All documents referenced below shall be the latest revision, complete with current amendments, as at the commencement of the Contract Works.

NZS3404 Steel Structures Standard

AS2159 Piling Design and Installation

~~OSH Code of Practice: Excavation and Shafts for Foundations~~

3.4 STEEL ~~LINERS (~~CASINGS~~)~~

3.4.1 Permanent Steel ~~Liners~~Casings

Permanent steel ~~liners~~ casings shall be mild steel complying with NZS3404. The requirements of section 2.2 shall also apply.

~~Liners~~ Casings shall be of the thickness specified on the Drawings, or other such greater thickness as is necessitated by the conditions met and the Contractor's method of working. The choice of the ~~liner~~ casing thickness is the sole responsibility of the Contractor provided the above requirements are met.

Surplus lengths of ~~liner~~ casings shall be cut off when construction of the superstructure begins. Unless noted otherwise in the project specification, all ~~Such~~ such lengths shall

remain the property of the Contractor and shall be removed from the Site on completion of the Works.

3.4.2 Temporary Steel ~~Liners~~Casings

The Contractor shall determine requirements for temporary ~~liners~~casings.

A short length of temporary ~~liner~~ casing shall be provided for all piles to maintain an upstand of at least ~~300 mm~~0.9 m above existing ground level to prevent contamination of the pile bore and provide a safe barrier prior to and during concreting. Contamination from flood waters shall be considered if applicable at the site. Alternative methods to prevent contamination and provide a safe barrier may be submitted to the Engineer for review.

The use of vibration to install and remove temporary casings shall be subject to the requirements of section 1.18.

When the temporary casing is being extracted, a sufficient quantity of concrete shall be maintained within it to ensure that the pressure from external water, support fluid or soil is exceeded and that the pile concrete is not reduced in section or contaminated.

3.5 BELLING OR UNDER REAMING

Where specified on the Drawings, each pile bore shall be constructed with a mechanically enlarged base which shall be no smaller than the size specified and shall be concentric with the pile shaft to within 10% of the shaft diameter. Where not specified on the Drawings the sloping surface of the bell shall make an angle to the axis of the pile of not more than 35º. At the specified diameter of the under-ream at the perimeter of the base, there shall be a minimum height of 150 mm.

3.6 PILE GROOVING

~~Where~~ If sidewall grooving is specified on the Drawings but details are not provided, each pile bore shall be spirally grooved with a 50 x 50 mm finger withdrawn to achieve a pitch of 300 mm, over the entire length of minimum embedment shown on the Drawings. If a temporary or permanent casing is used, the minimum length of embedment, as specified on the Drawings, shall be measured from below the bottom of the casing.

A grooving trial shall be carried out on the first production pile. The Contractor shall allow for inspection of the grooved pile by the Engineer.

3.7 EXCAVATION FOR PILES

Each pile shall be in intimate contact with the ground over its full length so that it is able to effectively transmit horizontal loads. Any space between the permanent ~~liner~~ casing and surrounding ground shall be completely filled with compacted sand or other approved material.

The use of explosives is forbidden without the written approval of the Engineer. If approved, explosives shall be used strictly in accordance with the requirements of ~~the Labour Department~~WorkSafe and the relevant Authorities.

On completion of excavation, loose, disturbed or softened soil shall be removed from the pile bore using an appropriate method. Base cleanliness should then be checked using a weighted tape or similar instrument, sounding over at least 3 locations on the pile base. Examples of base testing weights are provided in Appendix D.

Pumping from pile bores shall not be permitted unless groundwater inflow is limited to an inflow of water not exceeding 200 mm of bore depth per hour and written approval of the Engineer obtained. ~~the Contractor can demonstrate that the bore has been sealed against further water entry or that the soil is stable and will allow pumping to take place without ground disturbance below or around the pile~~Due care shall be taken to ensure that the pile bore (sidewall and base) remains stable at all times until the completion of construction.

3.8 ~~INSPECTION~~CONSTRUCTION OBSERVATIONS

~~If concrete can be placed in dry conditions, the~~ The Engineer shall be given the opportunity to observe geotechnical conditions encountered, confirm key design assumptions, and all aspects of pile construction before concrete is poured in accordance with the approved Inspection and Testing Plan or otherwise agreed between the Engineer and Contractor. ~~will require the opportunity to inspect the bottom of every pile before concrete is poured~~. The Contractor shall inform the Engineer at least one Working Day in advance when such ~~inspections~~ observations will be required.~~,~~ ~~and ensure that the piles are clean of all loose material, mud and excess water at the time of inspection.~~ This section shall be read in conjunction with section 3.7.

For dry bores, bore cleanliness assessments, when specified by the Engineer, are to be undertaken remotely using video equipment lowered progressively down the pile excavation. Such equipment shall be capable of taking clear, focussed, high quality video images which should be referenced with pile number depth and orientation. The images shall be retained by the Contractor as part of the permanent pile as-builts records. Alternatively, as agreed with the Engineer, where visibility permits, visual inspection of shaft cleanliness may be undertaken from the surface using spotlights, mirrors of similar.

For wet bores, cleanliness assessments, when specified by the Engineer, should at least require a base cleanliness check using a weighted tape or similar instrument per section 3.7.

The Contractor shall remain responsible for the safety of all personnel ~~descending piles~~undertaking construction observations and shall provide all necessary facilities to enable the Engineer to ~~make an inspection of~~observe any pile, including facilities to check the depth, verticality and position. The full requirements of Good Practice Guidelines for Excavation Safety (WorkSafe, Good Practice Guidelines for Excavation Safety, 2016) ~~OSH Code of Practice: Excavation and Shafts for~~

~~Foundations~~ shall be followed as a minimum, and observations shall be undertaken using the safest possible method.

3.9 PILE CONSTRUCTION RECORD CARD

The Contractor shall complete a Pile Construction Record Card for every pile constructed on the Site. A copy of the proposed Pile Construction Record Card shall be submitted to the Engineer on week prior to commencing pile construction. The Pile Construction Record Card shall contain the following information as a minimum;

- contract and structure name
- pile number, location, pile type, and pile dimensions.
- the drillers record, showing date and time of drilling, the type of materials encountered, and the depths at which the materials were encountered.
- the expected and actual constructed founding levels.
- casing finished levels (top and bottom) and total length.
- water levels inside the pile.
- confirmation of cleaning of pile base, including the recorded depth of the shaft at the end of drilling and immediately prior to placing concrete.
- weather conditions (including tide and wave height if applicable) at the time of concreting.
- concreting records, including the total volume of concrete placed, the volume supplied with each truck, slump measurements and number of cube or cylinder samples taken, time of batching, and concrete placing start and completion times.
- the time and date of casing extraction (if applicable).
- the design and actual constructed elevation of the top of the pile.
- cross reference proving bores (if appropriate).
- pile load test records (if applicable).
- the Contractors signature verifying that all work has been completed satisfactorily.

Pile construction records shall be submitted to the Engineer within 24 hours of the completion of concrete placement of each pile. An example bored pile construction record card indicating typical information required is provided in Appendix B. It is noted that all items shown on this example may not be relevant to all projects.

~~3.10 ADDITIONAL REQUIREMENTS FOR CAST IN PLACE BORED CONCRETE PILES~~

~~3.10.1 Pile Construction Record Card~~

~~The requirements of section 3.7 shall apply. Additional information shall be recorded on the Pile Construction Record card as follows:~~

- ~~reinforcement and other pre-pour checks.~~
- ~~the level of the top of the reinforcement cage before and after pouring.~~

~~3.11~~3.10 ADDITIONAL REQUIREMENTS FOR PRECAST CONCRETE, STEEL OR TIMBER PILES PLACED IN BORED SOCKETS

~~3.11.1~~3.10.1 Pile Lengths

~~The Contractor shall be responsible for determining the length of the pile to be placed within the drilled socket.~~ The length of the pile shall be selected to ensure that the pile by itself satisfies the minimum penetration into the substrata as defined on the Drawings. Any additional length to satisfy the construction methodology for placing the pile into the drilled socket shall be the responsibility of the Contractor.

A schedule of pile lengths shall be prepared by the Contractor and reviewed by the Engineer before pile manufacture begins.

~~3.11.2~~3.10.2 Excavation of Piles

The requirements of section 3.7 shall apply.

Each pile shall be in intimate contact with the ground over its concreted length so that it is able to effectively transmit horizontal loads. Any space, above the concreted layer, between the pile and the surrounding ground shall be completely filled with clean sand or other approved material.

~~3.11.3~~3.10.3 Pile Construction Record Card

The requirements of section 3.9 shall apply. Reference should be made to Appendix B for an example pile construction card. Additional information shall be recorded on the Pile Construction Record card as follows:

- The production number of the precast pile (this shall be the number stated on the precaster's concrete pour card).
- the level of the top of the pile before and after placing concrete.
- Steel grade, cross referencing to NDE, position of splices, welder's information, time of weld, end plate details.

4 DRIVEN PILES

4.1 SCOPE AND INTERPRETATION

This section covers the installation of driven piles, including steel H piles, steel pipe piles (both bottom and top driven), precast concrete piles, timber piles and sheet piles.

Use of modified or alternative driven pile techniques, such as wet driving requirements employing modified Hiley formulas or driven precast plugs, shall be agreed by the Engineer.

4.2 PROJECT SPECIFIC REQUIREMENTS

The following items, where appropriate, are detailed in the project specification:

- trial piles,
- pile acceptance criteria, i.e. minimum depth, embedment into founding strata, set and resistance,
- pile testing requirements, i.e. number or frequency and type of testing.

4.3 REFERENCED DOCUMENTS

This Specification shall be read in conjunction with the following standards, guidelines, and other documents, which are deemed to form part of this Specification. In the event of this Specification being at variance with any provision of these referenced documents, the requirements of this Specification shall take precedence. All Materials and workmanship shall comply with these documents unless expressly noted otherwise. All documents referenced below shall be the latest revision, complete with current amendments, as at the commencement of the Contract Works.

AS2159 Piling Design and Installation

~~4.3~~4.4 PILE LOADS

Piles shall be driven to depths such that they are capable of achieving the ultimate driving resistances specified on the Drawings.

~~4.4~~4.5 SET AND RESISTANCE

The ultimate driving resistance of each pile shall be checked in accordance with one of the methods set out in Appendix C. Other methods of assessing ultimate driving resistance may be used where approved in advance by the Engineer.

The use of a pile driving analyser may also be used to check driving resistance, subject to the requirements of section 5.3.

The sets and rebound shall be measured and recorded for each pile at the completion of driving. When a set or resistance is being measured, the following requirements shall be met;

- the pile shall be in good condition, without damage or distortion.

- the hammer blow shall be in line with the axis of the pile, and the impact surfaces shall be flat and perpendicular to the hammer axis.
- the hammer shall be in good condition, delivering the required energy per blow as specified in section 4.7~~4.6~~ and operating correctly.
- the rebound shall be measured and recorded.

The set shall be recorded ~~either~~ as the penetration in millimetres per blow averaged over ten blows~~, or the number of blows required to produce a penetration of 25 millimetres~~.

For piles that exhibit hydraulicing ~~are subject to hydraulicaling~~, characterised by no set with high rebound, driving shall be temporarily suspended to allow pore pressures to dissipate and then attempt to drive again, repeating as necessary until hydraulicing is no longer observed or the set at re-drive is achieved to the satisfaction of the Engineer.~~sets shall be remeasured for a minimum of 5% of the total number of piles at least 24 hours after completion of driving. The set shall be measured over the first ten blows.~~

~~4.5~~4.6 PILE DRIVING

The Contractor shall carry the sole responsibility for providing all necessary equipment for the pitching, positioning and driving of piles. The driving procedure shall avoid damage to the piles.

The Contractor shall provide the Engineer with information on the efficiency and energy of the driving equipment, including when mandrels or followers are used. Where a drop hammer is used no drop shall exceed 2500 mm for a bottom driven pile or 2000 mm for a top driven pile unless agreed by the Engineer. The Contractor shall include in its method statement details of the proposed pile driving equipment, including hammer weight and an example set of Hiley calculations that show that the required ultimate driving resistance specified on the Drawings can be achieved.

An appropriate hammer and packer shall be used to minimise damage to the pile during driving. The helmet shall be entirely suited to the profile of the top of the pile, upon which it shall fit snugly. ~~The~~ A packer ~~should fit~~shall be fitted between this helmet and the pile top of all concrete piles and comprise replaceable material that deforms more readily than the pile or helmet.

The driving equipment shall be capable of redriving piles after the suspension of driving.

The minimum weight of driving hammer shall provide an efficiency of hammer blow ~~as determined by the following calculation of~~ not less than or equal to 0.45. Hammer blow efficiency shall be calculated in accordance with Appendix C. ~~Hammer weight drops and type shall be submitted to the Engineer prior to commencement of pile driving for approval.~~

$$(\eta^2 P_w + H_w)/(P_w + H_w) >= 0.45$$

~~Where~~

~~H_w = weight of the hammer (kN)~~

~~P_w = weight of the pile, anvil, helmet and follower (if any) (kN)~~

~~η = coefficient of restitution of the materials subject to impact (dimensionless)~~

The Engineer shall be given 24 hours notice of the commencement of pile driving. The Contractor shall give the Engineer adequate notice and provide all necessary facilities to enable the Engineer to check driving resistances, sets, and rebounds. The driving of each pile shall be continuous until the depth and/or resistance or set, as required by the design, has been achieved. In the event of an unavoidable interruption to driving, a pile may be redriven provided it can be driven to the specified depth and/or resistance or set without damage.

Where top driving of piles employs a mandrel or follower, the set shall be revised to take into account the reduction in the effectiveness of the hammer blow.

The Contractor shall inform the Engineer without delay if an unexpected change in driving characteristics is encountered.

Care shall be taken when using drop hammers on floating craft to avoid instability of the craft and to prevent damage to the pile.

Maximum permissible driving stresses shall comply with the requirements of Table 4.6-1~~Table 4.5-1~~ below.

Table 4.6-1~~4.5-1~~ : Maximum Permissible Driving Stresses

Pile Type	Compression Stress (MPa)	Tension Stress (MPa)
Steel	$0.9f_y$	$0.9f_y$
Prestressed Concrete	$0.85f_c' - f_{pe}$	Initial prestress
Precast Concrete[1] Reinforcement qty < 2% Reinforcement qty > 2%	 $0.8f_c'$ $0.8f_c'$	 $0.8\sqrt{f_c'}$ $\sqrt{f_c'}$
Timber	$1.5\sigma_a$	$1.5\sigma_a$
Notes: 1. Tension stress shall be the value specified but not greater than the yield stress of the principal pile reinforcement		

~~4.6~~4.7 RISEN PILES

The sequence and method of piling shall limit uplift and lateral movement so that the final position of each pile is within the specified tolerances. At all times, the

deflections of each pile from its axis as formed shall not be such as to cause damage or impair durability of the piles or any structures or services.

The maximum permitted uplift of any pile due to pile driving operations is 3 mm. All piles that are uplifted more than the maximum permitted amount shall be redriven.

The Contractor shall make checks of uplift for nominated piles once a week for the duration of the piling operation and report the results to the Engineer. The Engineer shall review the requirements for continuing pile survey periodically.

~~4.7~~4.8 REDRIVING OF PILES

The Contractor may be required to redrive piles selected by the Engineer after pile installation. Such piles may be required to be remobilised by a minimum of 50 blows, prior to checking the set and rebound. Redriven piles shall be driven to the required set as per section 4.5~~refusal, by which is meant the last 10 blows shall cause a penetration of 10 mm or less~~. Piles shall be accurately marked in 25 mm intervals to observe penetration. Piles selected for redriving shall not be cut off until redriving is completed and approved by the Engineer.

The Contractor shall provide an updated legible set card for each pile at the completion of redriving.

~~4.8~~4.9 PREBORING AND JETTING OF PILES

Piles shall not be prebored without the written approval of the Engineer. Preboring of piles may be allowed by the Engineer as long as the piles remain in intimate contact with surrounding soil and the completed piles comply with the requirements of the Specification. If boring is oversize, any gap between tube and ground shall be filled with compacted sand prior to driving to the Engineer's approval.

Piles shall not be jetted without the written approval of the Engineer. Prior to jetting any pile, the Contractor shall submit to the Engineer details of the equipment to be used and the proposed method to be adopted.

~~4.9~~4.10 PILE CONSTRUCTION RECORD CARD

The Contractor shall complete a Pile Construction Record Card for every pile constructed on the Site. A copy of the proposed Pile Construction Record Card shall be submitted to the Engineer on week prior to commencing pile construction. The Pile Construction Record Card shall contain the following information as a minimum;

- contract and structure name
- pile number, location, type, steel grade, pile dimensions, preformed length, end plate details, locations of splices and cross referencing to NDE.
- date and time of driving, redriving, jetting or preboring, including stoppages and delays, from start to finish.
- type, weight, drop and mechanical condition of the hammer, and equivalent information for other equipment.

- the height of the working platform on which the piling machine operates.
- final drop height, etc, and the set and rebound, recorded ~~either~~ as the average penetration in millimetres recorded over ~~per~~ ten blows~~, or the number of blows required to produce a penetration of 25 millimetres~~, including a legible copy of the set card and the calculated ultimate driving resistance.
- any information regarding obstructions, delays and other interruptions to the sequence of work.
- the expected and actual constructed founding levels.
- weather conditions (including tide and wave height if applicable).
- the design and actual constructed elevation of the top of the pile, including compliance with tolerances.
- cross referencing to proving bores (if applicable).
- cross referencing to pile load test results (if applicable).
- updated set cards for piles that been redriven.
- the Contractors signature verifying that all work has been completed satisfactorily.

Pile construction records shall be submitted to the Engineer within 24 hours of the completion of each pile. An example driven pile construction record card indicating typical information required is provided in Appendix B. It is noted that all items shown on this example may not be relevant to all projects.

~~4.10~~4.11 ADDITIONAL REQUIREMENTS FOR DRIVEN PRECAST CONCRETE PILES

~~4.10.1~~4.11.1 Additional Reinforcement

The Contractor shall ensure that pile heads and toes are adequately reinforced or banded to prevent bursting of the pile during driving.

~~4.10.2~~4.11.2 Pile Construction Record Card

The requirements of section 4.11~~4.10~~ shall apply. Additional information shall be recorded on the Pile Construction Record card as follows:

- Concreting records for the precast pile, including pre-pour cards and material certificates.

~~4.11~~4.12 ADDITIONAL REQUIREMENTS FOR CLOSED ENDED STEEL PIPE PILES (BOTTOM DRIVEN)

~~4.11.1~~4.12.1 Driving Plug

~~Where used, a concrete plug, suitable for driving, shall be placed at the bottom of each pile. This shall consist of a mix of 10-20 mm aggregate, with less than 5% fines, and a cement content of not less than 375 kg/m³. The water/cement ratio may be altered to suit the driving conditions, but shall not exceed 0.25. The length of the concrete plug shall be not less than 2.5 pile diameters, and not greater than 4000 mm. The actual length of the plug may be varied to suit the driving conditions.~~

Where used, a bottom driving plug shall consist of hard, durable screened and washed aggregate conforming to Table 4.12-1, with cement content in the initial plug not exceeding 60 kg. The length of the driving plug shall not be less than 1.5 casing diameters. The length of the driving plug shall not be greater than 4 m without the prior approval of the Engineer. Driving plug material should be recharged at maximum intervals of 40 minutes during continuous driving or when the plug becomes powdered resulting in a soft response indicating a loss of driving efficiency. The recharge plug length shall be between 450 mm and 600 mm long. A recharge plug shall have at least 20 blows and no more than 75 blows applied to it prior to measuring the set. Recharge of the driving plug does not require cement to be added.

Table 4.12-1: Aggregate properties for driving plug

Gradation	**Sieve Size**	**Percent Passing**
	19 mm	100
	13.2 mm	0 - 5
Crushing Resistance	230 kN per NZS4407 Test 3.10	
Solid Density	At least 2.60 per NZS4407 Test 3.7.1	

~~Driving shall be carried out on freshly placed concrete. Any hardened concrete shall be topped with further fresh concrete or similar mix.~~

The use of alternative driving plugs shall be agreed with the Engineer prior to commencement of pile driving.

~~4.11.2~~4.12.2 Pile Construction Record Card

The requirements of section 4.10 shall apply. Additional information shall be recorded on the Pile Construction Record card as follows:

- the amount of ~~concrete~~ material used to form the driving plug, and the length of the plug
- reinforcement checklist
- the level of the top of the reinforcement cage before and after pouring

- concreting records, including the total volume of concrete placed, the volume supplied with each truck, slump measurements and number of cube or cylinder samples taken, time of batching, and concrete placing start and completion times
- depth to top of concrete for each truck placed and depth of tremie tube (if appropriate).
- The number of blows for each driving plug (or part).

~~4.12~~4.13 ADDITIONAL REQUIREMENTS FOR OPEN ENDED STEEL PIPE PILES (TOP DRIVEN)

~~4.12.1~~4.13.1 Pile Construction Record Card

The requirements of section 4.11~~4.10~~ shall apply. Additional information shall be recorded on the Pile Construction Record card as follows:

- reinforcement and other pre-pour checks (if applicable)
- the level of the top of the reinforcement cage before and after pouring (if applicable)
- concreting records, including the total volume of concrete placed, the volume supplied with each truck, slump measurements and number of cube or cylinder samples taken, time of batching, and concrete placing start and completion times (if applicable)
- depth to top of concrete for each truck placed and depth of tremie tube (if appropriate).

~~4.13~~4.14 ADDITIONAL REQUIREMENTS FOR DRIVEN TIMBER PILES

~~4.13.1~~4.14.1 Pile Heads

The requirements of section 2.3.7 shall apply.

The pile head shall be flat and perpendicular to the axis of the pile.

Unless specified otherwise, the head of the pile shall be trimmed to a circular cross section and fitted with a tight steel ring. The ring shall be not less than a 50x12 mm mild steel flat, and the join shall be butt welded over the full section. The top of the ring shall be positioned between 10 mm and 20 mm below the top of the pile. If the ring is displaced during driving, it shall be refitted. If the ring is broken, a new ring shall be fitted.

As an alternative to a ring, a metal helmet may be used. The top of the pile must be trimmed to fit closely into the recess in the underside of the helmet. A 25 mm thick plywood packer shall be used between the helmet and the hammer.

~~4.13.2~~4.14.2 Driving Shoes

Where used, pile shoes shall be attached to the pile by steel straps fixed, spiked or bolted to the timber. The shoes shall be coaxial with the pile and firmly bedded into it.

~~4.14~~4.15 ADDITIONAL REQUIREMENTS FOR STEEL SHEET PILES

~~4.14.1~~4.15.1 Storage

If sheet piles of different grades are stored on Site, each pile shall be clearly marked showing its grade, with piles of different grades stored separately.

~~4.14.2~~4.15.2 Pile Driving

The piles shall be guided and held in position by temporary gates, with each pile properly interlocked with its neighbour. Piles shall not bypass one another in place of interlocking unless agreed by the Engineer. At all stages during driving, the free length of the sheet pile shall be adequately supported and restrained if required.

The Contractor shall ensure that sheet piles are driven without significant damage or declutching.

Pile driving hammers shall be correctly positioned on the sheet pile so that the hammer is aligned as near to the sheet pile axis as is practically possible. Freely suspended pile hammers shall be equipped with correctly adjusted leg guides and inserts. Where a hammer is mounted in a rigid leader, the leader shall be stable. The anvil block or driving plate shall be of a sufficient size to cover as much as possible of the cross section of the pile.

5 INTEGRITY TESTING, PHYSICAL LOAD TESTING AND USE OF PILE DRIVING ANALYSERS (PDA)

5.1 INTEGRITY TESTING

5.1.1 Project Specific Requirements

The following items, where appropriate, are detailed in the project specification:

- the number, type and location of the piles to be tested
- the stages in the programme when integrity testing will be required

5.1.2 Referenced Documents

This Specification shall be read in conjunction with the following standards, guidelines, and other documents, which are deemed to form part of this Specification. In the event of this Specification being at variance with any provision of these referenced documents, the requirements of this Specification shall take precedence. All Materials and workmanship shall comply with these documents unless expressly noted otherwise. All documents referenced below shall be the latest revision, complete with current amendments, as at the commencement of the Contract Works.

ASTM D5882 Low Strain Impact Integrity Testing of Deep Foundations

ASTM D6760 Integrity Testing of Concrete Deep Foundations by Ultrasonic Crosshole Testing

~~5.1.2~~5.1.3 Method

Where integrity testing is required by the Project Specific Requirements, the method to be adopted shall be either:

- full depth coring of the pile, or
- sonic echo/impulse method~~s~~, or
- crosshole sonic logging method.

Other methods, such as thermal integrity profiling, may be considered by the Engineer subject to satisfactory evidence of performance.

The Engineer may order additional integrity testing of any pile when the Engineer has reasonable cause to doubt the integrity of the pile.

~~5.1.3~~5.1.4 Independent Observer

All ~~I~~integrity testing shall be carried out ~~in the presence of~~by a suitably qualified and experienced independent ~~observer~~specialist in strict accordance with the methodologies outlined in ASTM D5882 (sonic echo) and/or ASTM D6760 (crosshole sonic logging). The Contractor shall submit ~~to~~ for approval by the Engineer the name of ~~the observer~~such specialist, their professional qualifications, relevant experience, a description of the test equipment and any associated calibration certificates, a test

method statement and a programme for executing the work, prior to integrity testing commencing on Site. Upon request, a copy of the unprocessed test data shall be provided to the Engineer within 48 hours.

~~5.1.4~~5.1.5 Interpretation of Results and Reporting

The interpretation of test results shall be carried out by suitably experienced and competent persons. Preliminary results of each test shall be submitted to the Engineer within 24 hours of completion of the test. The final test results and findings shall be submitted to the Engineer within ten Working Days of completion of the test.

The report shall contain a summary of the method used in conducting the test, a summary of the method of interpretation, including all assumptions, calibrations, and corrections used in the analysis. The units and scales shall be clearly marked on all diagrams. Current calibration certificates shall be provided for all impulse equipment.

~~5.1.5~~5.1.6 Anomalous Results

In the event that the tests indicate that an anomaly is found in the pile, the Contractor shall demonstrate to the Engineer that the pile is fit for its intended purpose or shall carry out remedial work to make it so. The Contractor shall provide the Engineer with details of measures to be adopted to enable the defective pile to comply with the Specification. The Contractor shall not carry out any remedial work on any pile, without the written approval of the Engineer.

Should the Contractor fail to meet the above requirements, the Engineer reserves the right to order such extra work as may be required to overcome the resultant structural problems. No additional cost to the Principal shall arise from any such extra work.

5.2 PHYSICAL LOAD TESTING

5.2.1 Project Specific Requirements

The following items, where appropriate, are detailed in the project specification:

- the number, type and location of the piles to be tested
- the stages in the programme when load testing will be required
- the test load

5.2.2 Referenced Documents

This Specification shall be read in conjunction with the following standards, guidelines, and other documents, which are deemed to form part of this Specification. In the event of this Specification being at variance with any provision of these referenced documents, the requirements of this Specification shall take precedence. All Materials and workmanship shall comply with these documents unless expressly noted otherwise. All documents referenced below shall be the latest revision, complete with current amendments, as at the commencement of the Contract Works.

AS2159 Piling Design and Installation

5.2.3 Compressive Load Tests

Where required by the Project Specific Requirements, physical load testing of piles shall be carried out using the incremental sustained load test procedure specified in AS2159 “Piling Design and Installation”.

5.3 PILE DRIVING ANALYSER

5.3.1 Project Specific Requirements

The following items, where appropriate, are detailed in the Project Specific Requirements:

- ~~extent of dynamic testing (percentage of piles tested)~~
- ~~the test load~~
- proportion of piles to be dynamically tested
- proportion of dynamically tested piles which will be subject to wave signal matching (CAPWAP analyses)
- if any pile must be dynamically tested (and wave signal matched), a list of these piles

5.3.2 Referenced Documents

This Specification shall be read in conjunction with the following standards, guidelines, and other documents, which are deemed to form part of this Specification. In the event of this Specification being at variance with any provision of these referenced documents, the requirements of this Specification shall take precedence. All Materials and workmanship shall comply with these documents unless expressly noted otherwise. All documents referenced below shall be the latest revision, complete with current amendments, as at the commencement of the Contract Works.

AS2159 Piling Design and Installation

ASTM D4945 High-Strain Dynamic Testing of Deep Foundations

5.3.3 General

Dynamic pile testing shall be carried out in accordance with the requirements of AS2159 and ASTM D4945.

~~. All strain gauges and accelerometers used in for the pile testing shall have been calibrated within the last two years. Calibration certificates shall be made available to the Engineer within 5 days on request.~~

~~The number of gauges to be used to test each pile shall be as follows:~~

~~Pile Type Test Load Instrumentation~~

~~Concrete Piles~~	~~Test Load ≤ 8,000 kN~~	~~2 strain gauges~~ ~~2 accelerometers~~
	~~Test Load > 8,000 kN~~	~~4 strain gauges~~ ~~4 accelerometers~~
~~Steel or Timber Piles~~	~~All~~	~~2 strain gauges~~ ~~2 accelerometers~~

~~The test procedure shall include rigorous analysis using full wave signal matching (e.g. CAPWAP or TNOWAVE) of a representative blow or average blows for each pile tested unless stated in the Project Specific Requirements.~~

5.3.4 Extent of Testing

The actual piles to be tested and the programme of dynamic tests shall be agreed with the Engineer prior to piling works commencing on Site.

5.3.5 Pre-testing Analysis

Two days prior to driving the piles, the Contractor shall submit to the Engineer a wave equation analysis (e.g. GRLWEAP) indicating the pile is able to be driven to achieve the required test load without overstressing the pile. Guidelines on permissible driving stresses are presented in Table 4.6-1~~Table 4.5-1~~.

5.3.6 Reporting

Field results providing indicative pile capacities shall be made available to the Engineer as testing is undertaken. A detailed report on the piles tested for the project shall be forwarded to the Engineer within ~~15~~ 10 working days of the completion of the test piling. The report shall include all items listed in ~~Clause 8.4.8 of AS 2159~~Clause 7 of ASTM D4945. Upon request, an electronic copy of the unprocessed data shall be provided to the Engineer with 48 hours in a database format such as W01 extension files.~~Field results providing indicative pile capacities shall be made available to the Engineer as testing is undertaken.~~

6 REFERENCES

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APPENDIX A: SAMPLE PROJECT SPECIFIC REQUIREMENTS

A1: SUMMARY OF PROJECT SPECIFIC RQUIREMENTS

A2: SAMPLE CAST IN PLACE BOARD PILE PROJECT SPECIFIC REQUIREMENTS

A3: SAMPLE DRIVEN STEEL H PILE PROJECT SPECIFIC REQUIREMENTS

A1: SUMMARY OF PROJECT SPECIFIC REQUIREMENTS

The following items, where appropriate, are detailed in the Project Specific Requirements.

A1.1 GENERAL

- location and description of the Site
- nature and extent of the work
- site datum and grid references
- nature of the ground and subsurface conditions
- requirement for proving bores
- requirements for tolerances
- requirements for quality management
- requirements for Producer Statements
- technical requirements for consideration of alternative pile designs
- requirements for pile testing

A1.2 MATERIALS

- details of concrete strength and mix proportions
- requirements for alkali-aggregate reaction
- weld category for welds in accordance with NZS3404 (GP or SP)
- corrosion protection for steel piles
- grade and category of steel
- size and shape of timber piles
- timber species
- ~~treatment for timber piles~~timber hazard class

A1.3 BORED PILES

- requirement for support fluid
- pressure grouting

- trial piles
- disposal of excavated material
- reinforcement checklist.
- the level of the top of the reinforcement cage before and after pouring.

A1.4 DRIVEN PILES

- trial piles

A1.5 INTEGRITY TESTING, PHYSICAL LOAD TESTING AND USE OF PILE DRIVING ANALYSERS (PDA)

- the number, type and location of the piles to be tested
- the stages in the programme when integrity or load testing will be required
- proportion of piles to be dynamically tested~~extent of dynamic testing (percentage of production piles)~~
- proportion of dynamically tested piles which will be subject to wave signal matching (CAPWAP analyses)
- if any pile must be dynamically tested (and wave signal matched), a list of these piles

A2: PROJECT SPECIFIC REQUIREMENTS : SAMPLE CAST IN PLACE BORED PILE

~~A1.6~~ A2.1 GENERAL

~~A1.1.1~~ A2.1.1 Location And Description Of The Site

The site is located approximately 30 kilometres south east of Whangarei adjacent to the Samuel Marsden Canning facilities at Marsden Point and may be accessed from Marsden Point Road.

The extent of the site is generally as shown on the Drawings.

~~A1.1.2~~ A2.1.2 Nature And Extent Of The Work

The extent of work is shown on the Drawings and generally comprises construction of 24 – 1200 mm diameter permanently cased reinforced concrete piles in dense sand.

~~A1.1.3~~ A2.1.3 Site Datum And Grid References

All levels shown on the drawings and referred to in the specifications are in terms of chart datum. Grid references are specified in terms of the Mount Eden co-ordinate system.

~~A1.1.4~~ A2.1.4 Nature Of The Ground And Subsurface Conditions

A factual geotechnical report has been prepared for this project and may be inspected at the offices of Sardine & Glass Limited at 131 Victory Street, Auckland.

The site is located in Marsden Bay on the southwestern side of the entrance to Whangarei harbour. The seabed level at the existing wharf is approximately 8 to 9 metres below chart datum. Much of the seabed in the dredge area is mantled with algae covered shell. Zones of active sediment transport occur along the northeastern margin and southwestern corner of the dredge area. Blacksmiths Creek extends inland generally southwest from the western end of the development.

The oldest rocks in the area are greywacke and argillite of the Waipapa Group. These rocks outcrop north, south and southwest of the harbour and constitute the basement to younger coastal and estuarine sediments at the site. Basement rocks are discontinuous and are not encountered in the Marsden Point area.

~~A1.1.5~~ A2.1.5 Requirement For Proving Bores

Proving bores shall be drilled at each location shown on the Drawings.

Each proving bore shall be wash drilled from existing ground surface level down to five metres above the anticipated founding level specified on the Drawings. Below this level, the bore shall be cored using triple tube sampling equipment

with SPT tests undertaken at 1.5 metre centres to a depth of twelve pile diameters below the anticipated founding level specified on the Drawings. The retrieved cores shall be fully labelled, sealed in plastic and securely stored in fully labelled core boxes on Site by the Contractor for the duration of the contract. Cores shall be made available for inspection by the Engineer as required.

~~A1.1.6~~ A2.1.6 Requirements For Tolerances

Piles shall be constructed in accordance with the following tolerances:

- Tops of piles shall not vary more than 75 mm horizontally and 25 mm vertically from their true position as specified on the Drawings.
- The maximum permitted deviation of piles from the vertical at any level shall be not more than 1:75.

~~A1.1.7~~ A2.1.7 Requirements For Quality Management

Refer to the Preliminary and General section for requirements for Quality Management.

~~A1.1.8~~ A2.1.8 Requirements For Producer Statements

Producer Statements are not required.

~~A1.7~~ A2.2 MATERIALS

~~A1.1.9~~ A2.2.1 Details Of Concrete Strength And Mix Proportions

Concrete strengths are shown on the Drawings.

~~A1.1.10~~ A2.2.2 Requirements For Alkali-Aggregate Reaction

All concrete for use in piles shall meet the requirements of NZS3109. The Contractor shall supply the Engineer with the concrete mix design five Working Days prior to placing concrete on Site.

The total free water content shall not exceed 170 kg/m³. The maximum aggregate size shall not exceed 19 mm. No calcium chloride accelerator or other chloride containing admixtures shall be added to the mix.

~~A1.1.11~~ A2.2.3 Weld Category For Welds In Accordance With NNZ3404

All welds shall be category SP.

~~A1.8~~ A2.3 BORED PILES

~~A1.1.12~~ A2.3.1 Requirement For Support Fluid

Support fluid shall not be used without the written approval of the Engineer.

~~A1.1.13~~ A2.3.2 Trial Piles

Trial piles are not required.

~~A1.1.14~~ A2.3.3 Disposal Of Excavated Material

Excavated material may be disposed of on site at locations to be agreed with the Engineer.

A3: PROJECT SPECIFIC REQUIREMENTS : SAMPLE DRIVEN STEEL H PILE

~~A1.9~~ A3.1 GENERAL

~~A1.1.15~~ A3.1.1 Location And Description Of The Site

The site is located approximately 30 kilometres south east of Whangarei adjacent to the Samuel Marsden Canning Company facilities at Marsden Point and may be accessed from Marsden Point Road.

The extent of the site is generally as shown on the Drawings.

~~A1.1.16~~ A3.1.2 Nature And Extent Of The Work

The extent of work is shown on the Drawings and generally comprises installation of 24 – 360 mm universal bearing piles in dense sand.

~~A1.1.17~~ A3.1.3 Site Datum And Grid References

All levels shown on the drawings and referred to in the specifications are in terms of chart datum. Grid references are specified in terms of the Mount Eden co-ordinate system.

~~A1.1.18~~ A3.1.4 Nature Of The Ground And Subsurface Conditions

A factual geotechnical report has been prepared for this project and may be inspected at the offices of Sardine & Glass Limited at 131 Victory Street, Auckland.

The site is located in Marsden Bay on the southwestern side of the entrance to Whangarei harbour. The seabed level at the existing wharf is approximately 8 to 9 metres below chart datum. Much of the seabed in the dredge area is mantled with algae covered shell. Zones of active sediment transport occur along the northeastern margin and southwestern corner of the dredge area. Blacksmiths Creek extends inland generally southwest from the western end of the development.

The oldest rocks in the area are greywacke and argillite of the Waipapa Group. These rocks outcrop north, south and southwest of the harbour and constitute the basement to younger coastal and estuarine sediments at the site. Basement rocks are discontinuous and are not encountered in the Marsden Point area.

~~A1.1.19~~ A3.1.5 Requirement For Proving Bores

Proving bores shall be drilled at each location shown on the Drawings.

Each proving bore shall be wash drilled from existing ground surface level down to five metres above the anticipated founding level specified on the Drawings. Below this level, the bore shall be cored using triple tube sampling equipment with SPT tests undertaken at 1.5 metre centres to a depth of twelve pile diameters below the

anticipated founding level specified on the Drawings. The retrieved cores shall be fully labelled, sealed in plastic and securely stored in fully labelled core boxes on Site by the Contractor for the duration of the contract. Cores shall be made available for inspection by the Engineer as required.

~~A1.1.20~~ A3.1.6 Requirements For Tolerances

Piles shall be constructed in accordance with the following tolerances:

- Tops of piles shall not vary more than 75 mm horizontally and 25 mm vertically from their true position as specified on the Drawings.
- The maximum permitted deviation of piles from the vertical at any level shall be not more than 1:75.

~~A1.1.21~~ A3.1.7 Requirements For Quality Management

Refer to the Preliminary and General section for requirements for Quality Management.

~~A1.1.22~~ A3.1.8 Requirements For Producer Statements

Producer Statements are not required.

~~A1.10~~ A3.2 MATERIALS

~~A1.1.23~~ A3.2.1 Corrosion Protection For Steel Piles

Corrosion protection is not required for the steel H piles.

~~A1.1.24~~ A3.2.2 Weld Category For Welds In Accordance With NNZ3404

All welds shall be category SP.

~~A1.4~~ A3.4 DRIVEN PILES

~~A1.1.25~~ A3.4.1 Trial Piles

Trial piles are not required.

~~A1.5~~ A3.5 INTEGRITY TESTING, PHYSICAL LOAD TESTING AND USE OF PILE DRIVING ANALYSERS (PDA)

~~A1.1.26~~ A3.5.1 Number, Type And Location Of The Piles To Be Tested

The capacity of not less than 10% of piles shall be calculated using a dynamic pile driving analyser. The location and timing of pile tests shall be agreed with the Engineer as production piling proceeds.

The test load shall be not less than the ultimate driving resistance specified on the Drawings.

APPENDIX B: SAMPLE PILE CONSTRUCTION RECORD CARDS

B1: BORED PILE RECORD

B2: DRIVEN PILE RECORD

BORED PILE RECORD

CONTRACT: JOB NO:

PILE NO: AREA:

Piling Details	Date	Time
Casing Install:		
Start Drilling:		
Finish Drilling:		
Start Concrete:		
Finish Concrete:		
Casing Withdrawn:		
Piling Rig Type:		

Depth	Drilling Log	Date	Time

Special Notes

Approval

Design Representative:	Date:	
Contractors Representative:	Date:	

Location & Offset Sketch

Platform Level:	RL
Offsets	Initial
	Final
Vert:	mm/m

Offsets

Initial	
Final	
Vert:	mm/m

Drilling Details

Pile Diameter:			mm
Casing Diameter:			mm
Casing Length:			m
Temp or Perm:			
Design Toe Level:			RL
Actual Toe Level:			RL
Check by:		Date:	

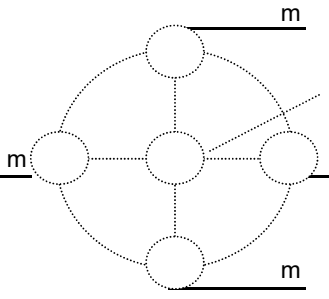
Reinforcing Details

Main Bars:			
Helical:			
Splice Length:			mm
Total Cage Length:			m
Cage Mass:			t
Design Top of Steel			RL
Actual Top of Steel			RL
Check by:		Date:	

Concrete Details

Water or Bentonite Level:			
Bentonite Viscosity:			sec
Bentonite Density:			g/ml
Bentonite Sand Content:			%
Base Test Rating:			
Concrete Mix Code:			
Design Slump:			mm
Theoretical Volume:			m3
Actual Volume:			m3
Design Top of Conc:			RL
Actual Top of Conc:			RL
Concrete Length:			m
Casing Withdrawn OK:			
Check by:		Date:	

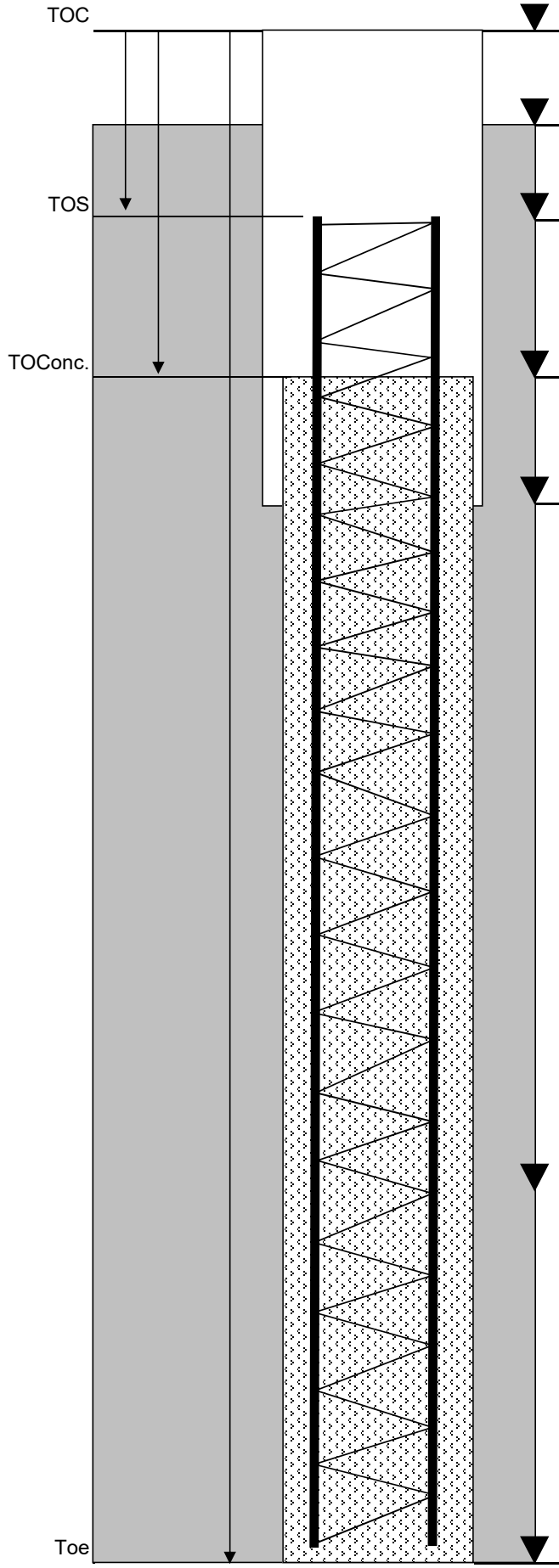
BASE TEST



BORED PILE RECORD

CONTRACT: JOB NO:

PILE NO: AREA:



Top of Casing Level:		RL
Piling Platform Level:		RL
Top of Steel Level:		RL
Design Steel Level:		RL
Length of Cage:		m
Top of Concrete Level:		RL
Design Concrete Level:		RL
Toe of Casing Level:		RL
Length of Casing:		m

PREPOUR INSPECTION		
Reinforcing Details	**Initials**	**Date**
Bar Size / Number:		
Spiral Size / Spacing:		
Spiral Lap Welds:		
Ubolts Installed:		
Cover Spacers:		
Splice Lengths:		
Grout Tube Details	**Initials**	**Date**
TaMs checked		
Tube unbolts checked		
Couplers checked		
Tubes coloured		
Drill Details	**Initials**	**Date**
Toe Level checked:		
Bentonite tested clean?		
Base tested clean?		
BPC Representative:		
Design Representative:		

Actual Toe Level:		RL
Design Toe Level:		RL

Tremie POUR RECORD

CONTRACT: JOB NO:

PILE NO: AREA:

Notes / Sketch:	Prepour Checks	
	Pipes Clean?	
	Joints Properly Sealed?	
	Tremies to Bottom?	
	Vermiculite Plug?	
	Grout Mix?	
	Pile Length:	
	Tremie Pipe Length:	
	Check by:	Date:

Tremie POUR DETAILS

Depth Top Conc	Tremie Length	Embedment	Truck Docket	Batch Time	Pour Time	Truck Vol	Total Vol	Conc Slump	Samples Taken
m	m	m				m3	m3	mm	

Special Notes

Weather Conditions Wind Wave Height

Approval

Design Representative:		Date:	
Contractors Representative:		Date:	

BORED PILE RECORD

CONTRACT: JOB NO:

PILE NO: AREA:

Piling Checklist

Item No	Description of check	Date Check Completed	Checked by Who?	Not Applicable
1	Workplan, Method Statement and JRA briefing completed			
2	Daily team briefing completed			
3	Traffic management installed to approved plan and checked in good order			
4	Permit to excavate acquired			
5	Services marked, exposed or relocated			
6	Hot work permit acquired			
7	Overwater permit acquired			
8	Free-fall permit acquired			
9	Anti two-block permit acquired			
10	Environmental controls installed to approved plan and checked in good order			
11	Spill kit available			
12	Daily plant, crane, vibro and piling rig checks completed			
13	Daily bentonite line and valve checks completed			
14	Pile setout by Surveyor and offsets installed and recorded			
15	Pilot hole drilled and stopped above ground water level			
16	Ground water level recorded on drill log			
17	Check for collapsing and potential voids			
18	Casing installed, levels taken, final verticallity and offset position recorded			
19	Water pumped to sediment control device			
20	Pile flooded with bentonite, current depth and time recorded			
21	Pile drilled to depth and strata recorded on drill log			
22	Soil samples taken and labelled			
23	Base of pile cleaned by cleaning bucket			
24	Base of pile cleaned by airlift			
25	Base testing completed, agreed by Engineer and recorded			
26	Bentonite cleaning required and completed			
27	Bentonite tested and final results recorded			
28	Prepour inpsections completed			
29	Reinforcing installed correctly and levels recorded			
30	Grout tube filled with water and capped before concreting			
31	Pile concreted and Tremie record completed			
32	Casing removed at slow steady rate with vibrohammer and time recorded			
33	Final reinforcing and concrete levels recorded			
34	All checks completed, pile card completed and ready to submit			

Special Notes

DRIVEN PILE RECORD

CONTRACT: CEP NO:

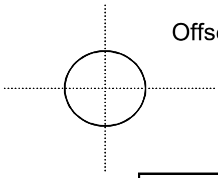
PILE NO: AREA:

Piling Details	Date	Time
Start Driving:		
Start Splicing:		
Finish Splicing:		
Finish Driving:		
Crane Type:		
Hammer Type:		
Welder:		

Depth	Notes	Date	Time

Location & Offset Sketch

Platform Level:		RL



Offsets

	Initial
	Final
Vert:	mm/m

Offsets

	Initial
	Final
Vert:	mm/m

Pile Details		
Section Type:		
Dimensions:		mm
Thickness:		mm
Steel Grade:		MPa
Pile Length:		m
Pile Weight:		kg
Check Safe to Lift by:		
Temp or Perm:		
Check by:	Date:	

Level Details		
Design Top Level:		RL
Actual Top Level:		RL
Design Toe Level:		RL
Actual Toe Level:		RL
Design Rock Level:		RL
Actual Rock Level:		RL
Check by:	Date:	

Driving Details		
Hammer Weight:		t
Helmet Weight:		t
Target Load (Ru):		kN
Target Drop:		mm
Target Set (S):		mm
Target Compression (C):		mm
Actual Load (Ru):		kN
Actual Drop:		mm
Actual Set (S):		mm
Actual Compression (C):		mm
Check by:	Date:	

Special Notes

Approval			
Design Representative:		Date:	
Contractors Representative:		Date:	

SET RECORD

CONTRACT: CEP NO:

PILE NO: AREA:

Notes / Sketch:

Special Notes

Weather Conditions Wind

Approval

Design Representative:		Date:	
Contractors Representative:		Date:	

APPENDIX C: PILE DRIVING FORMULA

~~A2:~~C1: FORMULA AND SYMBOLS

~~A3:~~C2: TEMPORARY COMPRESSION

~~A4:~~C3: BLOW EFFICIENCY

~~A5:~~C4: ALTERNATIVE FORMULA FOR HARD DRIVING

~~A6:~~C5: PILE STRESSES AND HARDNESS OF DRIVING

~~A7:~~C6: BEARING CAPACITY

~~A8:~~C7: FIELD MEASUREMENTS

C1: FORMULA AND SYMBOLS

C1.1 The Hiley dynamic pile-driving formula estimates the ultimate axial compressive pile capacity for a driven pile. The estimate is referred to as the ultimate driving resistance to driven piles and is expressed as:

$$R = \frac{W\ h\ n}{S + C/2}$$

where:

R = ultimate driving resistance (kN)

W = weight of hammer (kN)

S = final set or penetration per blow (mean of final ten blows) (mm)

C = sum of temporary compressions of pile dolly, packings and ground (mm)

n = efficiency of blow (dimensionless)

h = free-fall height of hammer (mm)

The free fall height shall be calculated as:

For trigger operated drop hammers - the full fall

For normally-proportioned winch operated hammers-80% of the fall.

For single-acting hammers-90% of the stroke

For hydraulic hammer-the equivalent drop specified by the manufacturer

C2:TEMPORARY COMPRESSION

C2.1 Total temporary compression C is derived from:

$$C = C_c + C_p + C_q$$

where:

C_c = elastic compression of pile head or dolly. C_p = elastic compression of the pile itself.

C_q = quake of the ground beneath the pile.

C2.2 Wherever possible C_p and C_q should be determined by field measurements (see Paragraph C7), especially in soft or peaty soils, or where soft ground exists below the pile

toe, or in circumstances where resistance is reduced on re-driving. Field measurement is important to allow confirmation or revision of preliminary estimates of R.

C2.3 If field measurements are not possible C shall be determined from paragraph C2.1 and Table C1.

C2.4 As C_c cannot be readily specified by field measurements, its value is to be determined from Table C1.

C2.5 For steel piles driven with a double acting hammer and no driving cap, the value of C_c is zero.

C2.6 In calculating Cp, the length L of the pile shall be the distance from pile top to the centre of driving resistance. The assumed centre of driving resistance shall be taken as:

- Half the pile penetration depth in soil which is homogeneous and provides resistance by skin friction only.
- The toe of the pile where resistance is by end bearing only.

C2.7 See Paragraph C7.3 regarding the field measurement of C_p.

Table C1: Temporary Compressions (Paragraphs C2.3, C2.4, C4.5, C5.2.1(c) and C7.3)

Form of Compression	Material (mm)	Easy Driving (mm)	Medium Driving (mm)	Hard Driving (mm)	Very Hard Driving (mm)
Pile head and cap, C_c	Head of timber pile	1.0	2.0	3.0	4.0
(see note 1)	Short dolly in helmet or driving cap	1.0	2.0	3.0	4.0
	75mm packing under helmet or driving cap.	3.0	6.0	9.0	12.0
	25mm pad only	0.5	1.0	1.5	2.0
Pile length, C_p	Timber pile, E= 10.0 GPa.	$3.5 \times 10^{-4}L$	$7.0 \times 10^{-4}L$	$10.5 \times 10^{-4}L$	14.0×10^{-4}
(see notes 2 and 3)	Pre-cast concrete pile, E = 30.0 GPa.	$1.2 \times 10^{-4}L$	$2.4 \times 10^{-4}L$	$3.6 \times 10^{-4}L$	$4.8 \times 10^{-4}L$
	Steel pile, steel tube pile, steel mandrel for cast-in-place pile, E = 207.0 GPa.	$2.4 \times 10^{-4}L$	$4.8 \times 10^{-4}L$	$7.2 \times 10^{-4}L$	$9.6 \times 10^{-4}L$
Quake, C_q	Ground surrounding pile and under pile point.	1.0 to 2.0	2.5 to 5.0	4.0 to 6.5	1.5 to 4.0

NOTES:

If a short dolly in the helmet or driving cap is used in combination with 75mm packing, the two compressions should be added together to obtain C_c.

L is length of pile (mm).

E is modulus of elasticity. The value of E given for concrete is only valid when it is manufactured from ordinary Portland cement. It will be greater for rapid-hardening or aluminous cement concrete.

C3: BLOW EFFICIENCY

C3.1 The efficiency of the hammer blow is to be determined from the following formulae, according to the relationship between pile, hammer weight W and ground conditions.

If W > Pe, and the pile has not reached refusal:

$$n = \frac{W + Pe^2}{W + P} \quad \text{— Eqtn (1)}$$

If W < Pe, and the pile has not reached refusal:

$$n = \frac{W + Pe^2}{W + P} - \frac{(W - Pe^2)}{W + P} \quad \text{— Eqtn (2)}$$

where:

n = efficiency of the blow. (dimensionless)

W = weight of the hammer (kN).

P = weight of the pile, anvil, helmet and follower (if any) (kN).

e = coefficient of restitution of materials subject to impact (dimensionless).

C3.2 If the pile has reached refusal in rock, 0.5 P should be substituted for P in equations (1) and (2) above.

C3.3 The coefficient of restitution ‘e’, as determined experimentally for different materials and conditions, is approximately:

For piles driven with a double-acting hammer:

steel piles without driving cap: 0.5

reinforced-concrete piles without helmet but with packing on top of piles: 0.5

reinforced concrete piles with short dolly, helmet and packing: 0.4

timber piles: 0.4

For piles driven with single-acting or drop hammer:

reinforced concrete piles without helmet but with packing on top of piles: 0.4

steel or steel tube piles with driving cap and short dolly covered with steel plate: 0.32

reinforced concrete piles with helmet ,packing and dolly in good condition: 0.25
timber piles in good condition: 0.25

timber piles in poor condition: 0.0

C3.4 For piles in penetrable (not rock) ground only, and provided W > Pe, the blow efficiency n may be obtained from Table C2 for different combinations of P/W and e. For situations where the pile point is on rock, the formulae in paragraph C3.1 as modified by Paragraph C3.2 must be used.

C4: ALTERNATIVE FORMULA FOR HARD DRIVING

C4.1 Where the set S in the Hiley formula (see Paragraph C1.1) is small or zero, R is approximately proportional to C. Thus:

$R = mC$

where:

m = a constant for any particular pile (kN/mm)

C4.2 Substituting R/m for C, the Hiley formula becomes:

$$S + \frac{R}{2m} = \frac{W\,h\,n}{R}$$

or

$$R = (2\,W\,h\,n\,m + (mS)^2)0.5 - m\,S$$

C4.3 If the pile is driven to refusal, S becomes zero and the equation simplifies to:

$$R = (2\,W\,h\,n\,m)^{0.5}$$

C4.4 The value of m is determined from:

$$m = R_1/C$$

where R_1 is either the anticipated ultimate axial compressive load assessed by another method (not the Hiley formula),based on the soil and rock information

available, or the value or R_1 obtained from clause C4.5.

C4.5 R_1 may be calculated using the Hiley formula:

$$R_1 = \frac{W\ h\ n}{S + C/2}$$

taking the value of S = 0, and of C from the appropriate figures for very hard driving in Table C1. Where possible Cp and C_q should be determined from observation, and only C_c from Table C1.

Table C2: Efficiency of Blow (Paragraph C3.4)

Ratio P/W	e = 0.5	e=0.4	e=0.32	e = 0.25	e = 0.0
0.5	0.75	0.72	0.70	0.69	0.67
1.0	0.63	0.58	0.55	0.53	0.50
1.5	0.55	0.50	0.46	0.44	0.40
2.0	0.50	0.44	0.40	0.37	0.33
2.5	-	0.40	0.36	0.33	0.28
3.0	-	-	0.33	0.30	0.25
4.0	-	-	-	0.25	0.20
5.0	-	-	-	-	0.16
6.0	-	-	-	-	0.14

C5: PILE STRESSES AND HARDNESS OF DRIVING:

C5.1 Hardness of driving

~~A8.2~~ C5.1.1 The comparative hardness of driving is expressed in terms of the compressive stress in the pile or shoe. This is related directly to the pile cross sectional area and indicative values are given in Table C3.

Table C3: Pile Stresses (Paragraphs C5.1 and C5.2.1(b))		
Driving Conditions	**Stress in pile (MPa)**	
	Concrete or timber pile	Steel Pile
Easy driving	3.5	50
Medium driving	7.0	100
Hard driving	10.5	150
Very hard driving	14.0	200

~~A8.3~~ C5.1.2 For steel piles, tubes or mandrels the stress is governed by the cross sectional area of steel only.

~~A8.4~~ C5.1.3 If a dolly is used for driving steel piles, C_c is obtained by separately classifying the hardness of driving for the dolly, corresponding to a dolly stress determined by:

$$\text{Stress in dolly} = \text{Stress in steel pile} \times \frac{\text{Net area of steel}}{\text{Total area of pile}}$$

C5.2 Preliminary calculations

~~A8.5~~ C5.2.1 For preliminary design calculations when test pile data is unavailable, it is necessary to estimate the value of R. This is done by:

- Assuming a compressive stress in the pile,
- Obtaining a hardness of driving from Table C3,
- Obtaining the corresponding value of C from Paragraph C2.1 and Table C1,
- Calculating R from the Hiley formula,
- Calculating the compressive stress in the pile or shoe,
- Comparing that stress with the assumed value,
- If the two stress values do not coincide, assuming another compressive stress and repeating the calculation, and
- Repeating the process until agreement is reached.

C5.3 Use of published data

Where available, tables, graphs and other information from relevant literature on use of the Hiley formula, may be used to obtain data for calculating resistance for various piles and driving conditions.

C6: BEARING CAPACITY

C6.1 Test loadings

~~A8.6~~ C6.1.1 The Hiley formula, being an empirical design tool, has its accuracy improved when adjusted with site-specific data. The ultimate axial compressive pile capacity should be obtained whenever possible from test loadings. If a sufficient proportion of piles are tested, the data obtained may be used for refining variables in the formula, which can then be readily applied to the control of the remaining piles.

~~A8.7~~ C6.1.2 If load tests are not used, the ultimate driving resistance determined from the formula should be used with a greater factor of safety than would be required for accurate test results. The factor of safety should be further increased if re-driving tests show a reduction in resistance.

C6.2 Factors of safety

~~A8.8~~ C6.2.1 The ultimate axial compressive pile capacity, determined either by test loadings or as the ultimate driving resistance derived from the Hiley formula, shall be divided by a factor of safety appropriate to the circumstances prevailing, particularly the reliability of the available data and the consequences of failure of the structure being considered.

~~A8.9~~ C6.2.2 Table C4 is a guide to suitable factors of safety for average conditions. These should be increased where necessary to accommodate:

- a) Requirements for limiting total or differential settlement (e.g. in buildings having fragile finishings or machinery that must be accurately aligned).
- Large impact loads.
- The expected reduced bearing capacity of a pile in a pile group where test loads have been applied only to single piles.
- Any likely deterioration of soil or rock properties over time.
- The degree of confidence in the available data.
- A loading situation on friction piles where the live load is long term and a major part of the total loads.

~~A8.10~~ C6.2.3 Factors of safety Table C4 may be reduced for temporary work and where large settlements are permissible.

Table C4: Factors of safety for average conditions (Paragraphs C6.2.2 and C6.2.3)		
	Factors of safety applied when ultimate resistance determined from:	
Type of ground	**Test loading**	**Formula only, resistance not reduced on re-driving**
Rock	-	2.0
Non-cohesive soil	2.0	3.0
Hard cohesive soil	2.0	3.0
Soft cohesive soil	2.0	Not applicable

C6.3 Raked Piles

~~A8.11~~ C6.3.1 Where piles are driven with single-acting drop hammers in leader guides inclined on an angle, the ultimate driving resistance calculated from the Hiley formula should be reduced. Table C5 provides recommended percentages by which calculated values for vertical piles, should be reduced to suit different rake angles.

Table C5: Reduction of calculated value of R for raked piles (see note 1) (Paragraph C6.3.1)	
Rake	**Percent to be deducted**
1 in 12	1.0
1 in 10	1.5
1 in 8	2.0
1 in 6	3.0
1 in 5	4.0
1 in 4	5.5
1 in 3	8.5
1 in 2	14.0
NOTE: 1. R is the ultimate driving resistance from the formula in Paragraph C1.1	

C7: FIELD MEASUREMENTS

C7.1 The recording of set (S), and temporary compressions of pile (C_p) and of the ground (C_q) on site, can be done by:

a) Erecting a horizontal straight-edge close to the face of the pile.

b) Ensuring the straight edge supports are outside the zone of ground movement, and no less than 1.2m from the pile under test.

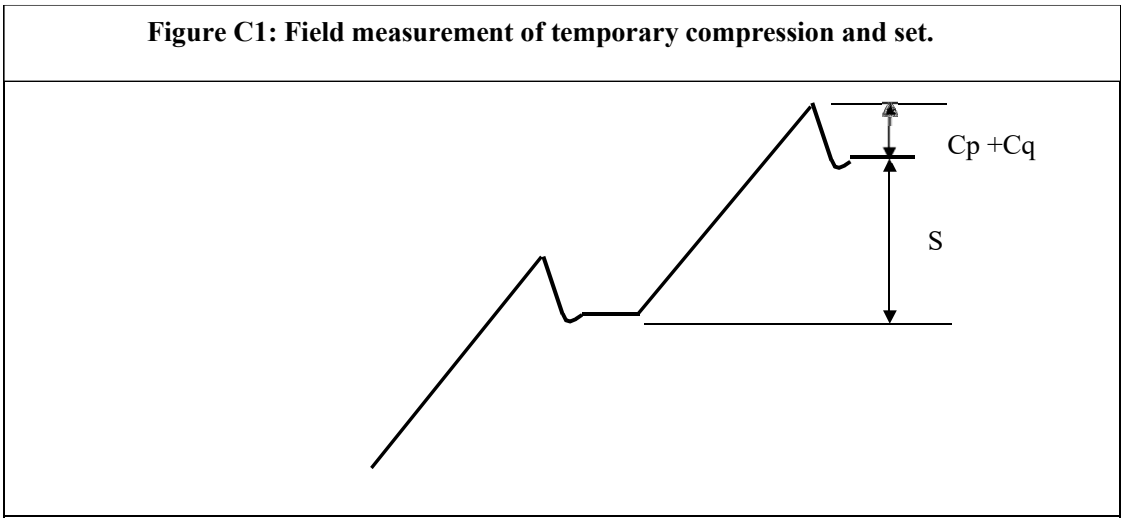
c) Attaching a sheet of cardboard or heavy paper to the straightedge.

d) Holding a pencil horizontally on top of the straight-edge, and drawing it slowly across the card while the pile is being driven.

Alternatively electronic set measurement equipment (e.g. Pile Driving Monitor) may be used.

C7.2 The resulting graphical record will be as shown in Figure C1.

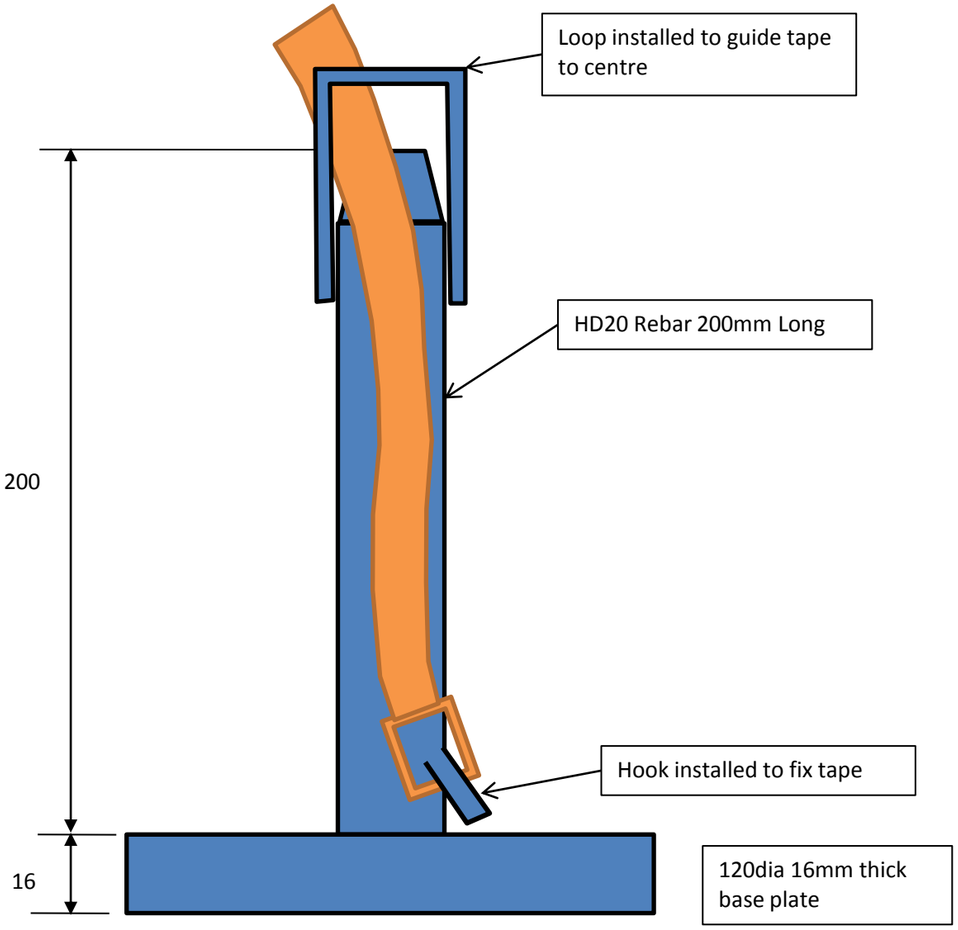
Figure C1: Field measurement of temporary compression and set.



C7.3 If the record card is attached some distance below the pile top, the elastic compression in the upper part of the pile (part of C_p) will not be shown on the graph. That compression should be calculated from Table C1 and added to the sum of the temporary compressions used to derive C, i.e. $C = C_c + C_p + C_q$ + upper pile compression.

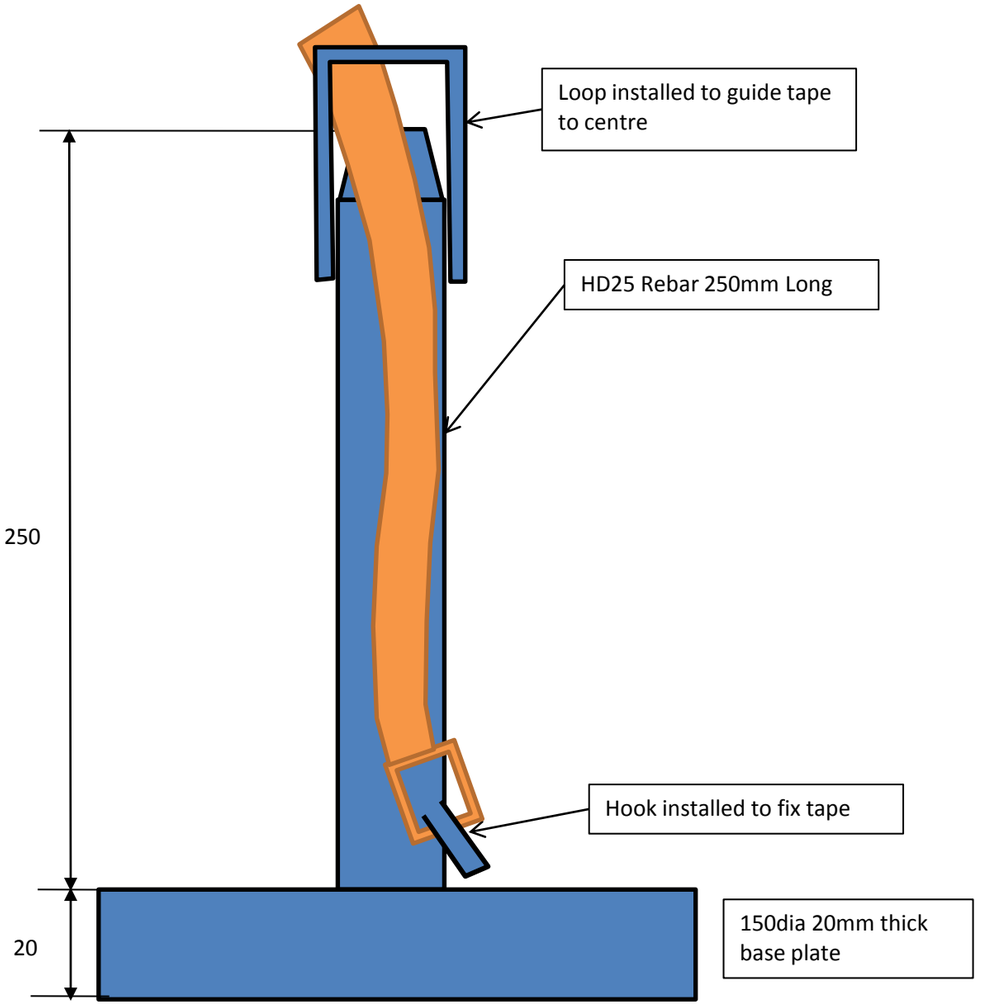
APPENDIX D: BASE TESTING WEIGHT EXAMPLES

Project:	BORED PILE	Drawing No.	
		Job No.	
Description:	Std Base Testing Weight	Date	
		Drawn By	



BASE TESTING WEIGHT = APPROX 1.5kg

Project:	BORED PILE	Drawing No.	
		Job No.	
Description:	Extra Heavy Base Testing Weight	Date	
		Drawn By	



BASE TESTING WEIGHT = APPROX 2.5kg

FOR USE ON DEEP, LARGE DIAMETER BENTONITE PILES.