

Piling Specification

Auckland Structural Group



TABLE OF CONTENTS

<u>1. GENERAL</u>	<u>1</u>
1.1 SCOPE AND INTERPRETATION	1
1.2 DEFINITIONS AND NOTATIONS	1
1.2.1 DEFINITIONS	1
1.2.2 NOTATION	1
1.3 PROJECT SPECIFIC REQUIREMENTS	2
1.4 HEALTH AND SAFETY	2
1.5 METHOD STATEMENT	2
1.6 PILING PROGRAMME	2
1.7 PILE DESIGN	3
1.8 PILE LENGTHS	3
1.9 PILE CONSTRUCTION	3
1.10 HANDLING, STORAGE AND MARKING OF PILES	3
1.11 NATURE OF GROUND AND SUBSURFACE CONDITIONS	3
1.12 PROVING BORE REQUIREMENTS	4
1.13 SETTING OUT AND AS-BUILT LOCATIONS	4
1.14 TOLERANCES	4
1.15 SUPERVISION	5
1.16 OBSERVATION	5
1.17 PILE STABILITY DURING CONSTRUCTION	5
1.18 PROTECTION OF EXISTING STRUCTURES AND PROPERTY	5
1.19 EXISTING SERVICES	5
1.20 COMPLETION	6
<u>2. MATERIALS AND WORKMANSHIP</u>	<u>7</u>
2.1 CONCRETE	7
2.1.1 PROJECT SPECIFIC REQUIREMENTS	7
2.1.2 REFERENCED DOCUMENTS	7
2.1.3 MATERIAL	7
2.1.4 CONCRETING OF PILES	7
2.1.5 PLACING CONCRETE UNDER WATER	8
2.1.6 PRECAST CONCRETE PILES	10
2.2 STRUCTURAL STEEL	11
2.2.1 PROJECT SPECIFIC REQUIREMENTS	11
2.2.2 REFERENCED DOCUMENTS	11
2.2.3 STEEL H PILES	12
2.2.4 STEEL PIPE PILE AND STEEL CASING MANUFACTURING PROCESS	12
2.2.5 WELDING	12
2.2.6 SITE SPLICES	13
2.2.7 DRIVING SHOES	13
2.2.8 PREPARATION OF PILE HEADS	14
2.2.9 STEEL SHEET PILES	14
2.3 TIMBER	14
2.3.1 PROJECT SPECIFIC REQUIREMENTS	14
2.3.2 REFERENCED DOCUMENTS	15
2.3.3 MATERIAL	15

2.3.4	TIMBER TREATMENT	15
2.3.5	MARKING, HANDLING AND STORAGE OF TIMBER PILES	15
2.3.6	SPLICING OF TIMBER PILES	16
2.3.7	PREPARATION OF PILE HEADS	16
3.	<u>BORED PILES</u>	17
3.1	SCOPE	17
3.2	PROJECT SPECIFIC REQUIREMENTS	17
3.3	REFERENCED DOCUMENTS	17
3.4	STEEL LINERS (CASINGS)	17
3.4.1	PERMANENT STEEL LINERS	17
3.4.2	TEMPORARY STEEL LINERS	18
3.5	BELLING OR UNDER REAMING	18
3.6	PILE GROOVING	18
3.7	EXCAVATION FOR PILES	18
3.8	INSPECTION	19
3.9	PILE CONSTRUCTION RECORD CARD	19
3.10	ADDITIONAL REQUIREMENTS FOR CAST IN PLACE BORED CONCRETE PILES	20
3.10.1	PILE CONSTRUCTION RECORD CARD	20
3.11	ADDITIONAL REQUIREMENTS FOR PRECAST CONCRETE, STEEL OR TIMBER PILES PLACED IN BORED SOCKETS	20
3.11.1	PILE LENGTHS	20
3.11.2	EXCAVATION OF PILES	20
3.11.3	PILE CONSTRUCTION RECORD CARD	20
4.	<u>DRIVEN PILES</u>	22
4.1	SCOPE AND INTERPRETATION	22
4.2	PROJECT SPECIFIC REQUIREMENTS	22
4.3	PILE LOADS	22
4.4	SET AND RESISTANCE	22
4.5	PILE DRIVING	23
4.6	RISEN PILES	24
4.7	REDRIVING OF PILES	24
4.8	PREBORING AND JETTING OF PILES	24
4.9	PILE CONSTRUCTION RECORD CARD	25
4.10	ADDITIONAL REQUIREMENTS FOR DRIVEN PRECAST CONCRETE PILES	26
4.10.1	ADDITIONAL REINFORCEMENT	26
4.10.2	PILE CONSTRUCTION RECORD CARD	26
4.11	ADDITIONAL REQUIREMENTS FOR CLOSED ENDED STEEL PIPE PILES (BOTTOM DRIVEN)	26
4.11.1	DRIVING PLUG	26
4.11.2	PILE CONSTRUCTION RECORD CARD	26
4.12	ADDITIONAL REQUIREMENTS FOR OPEN ENDED STEEL PIPE PILES (TOP DRIVEN)	27
4.12.1	PILE CONSTRUCTION RECORD CARD	27
4.13	ADDITIONAL REQUIREMENTS FOR DRIVEN TIMBER PILES	27
4.13.1	PILE HEADS	27
4.13.2	DRIVING SHOES	27
4.14	ADDITIONAL REQUIREMENTS FOR STEEL SHEET PILES	28
4.14.1	STORAGE	28
4.14.2	PILE DRIVING	28

5. INTEGRITY TESTING, PHYSICAL LOAD TESTING AND USE OF PILE DRIVING ANALYSERS (PDA)	29
5.1 INTEGRITY TESTING	29
5.1.1 PROJECT SPECIFIC REQUIREMENTS	29
5.1.2 METHOD	29
5.1.3 INDEPENDENT OBSERVER	29
5.1.4 INTERPRETATION OF RESULTS AND REPORTING	29
5.1.5 ANOMALOUS RESULTS	30
5.2 PHYSICAL LOAD TESTING	30
5.2.1 PROJECT SPECIFIC REQUIREMENTS	30
5.2.2 REFERENCED DOCUMENTS	30
5.2.3 COMPRESSIVE LOAD TESTS	30
5.3 PILE DRIVING ANALYSER	30
5.3.1 PROJECT SPECIFIC REQUIREMENTS	30
5.3.2 REFERENCED DOCUMENTS	31
5.3.3 GENERAL	31
5.3.4 EXTENT OF TESTING	31
5.3.5 PRE-TESTING ANALYSIS	31
5.3.6 REPORTING	31
APPENDIX A: SAMPLE PROJECT SPECIFIC REQUIREMENTS	33
A2.1.1 LOCATION AND DESCRIPTION OF THE SITE	36
A2.2.1 DETAILS OF CONCRETE STRENGTH AND MIX PROPORTIONS	37
A2.3.1 REQUIREMENT FOR SUPPORT FLUID	37
A2.3.2 TRIAL PILES	38
A2.3.3 DISPOSAL OF EXCAVATED MATERIAL	38
A3.1.1 LOCATION AND DESCRIPTION OF THE SITE	39
A3.2.1 CORROSION PROTECTION FOR STEEL PILES	40
A3.4.1 TRIAL PILES	40
A3.5.1 NUMBER, TYPE AND LOCATION OF THE PILES TO BE TESTED	40
APPENDIX B: SAMPLE PILE CONSTRUCTION RECORD CARDS	41
APPENDIX C: PILE DRIVING FORMULA	44

COMMITTEE REPRESENTATION

This specification was prepared by a sub-committee of the Auckland Structural Group comprised of the following persons:

Albert Smith	Smithbridge
Andrew Langbein	Tonkin and Taylor
Chris MacKenzie	Holmes Consulting Group
Dean Coleman	Hauraki Piling Limited
Dick Salter	Downer Construction
Glyn East	Opus International Consultants
John Young	Gilberd Hadfield Piling Company Limited
Malcolm Stapleton	Babbage Consultants Limited – liaison with the New Zealand Geotechnical Society
Paul Swinburne	Brian Perry Civil
Stuart Tucker	Beca Carter Hollings & Ferner Limited

AMENDMENTS

N°	Date	Description	By
A	11 April 2001	First Draft	SJT
B	24 April 2001	Section 1 Reviewed	SJT
C	23 May 2001	Section 2 Reviewed – Changes Marked	SJT
D	30 June 2001	Sections 3 and 4 Reviewed – Changes	SJT
E	16 August 2001	Sections 4 and 5 Updated – Changes Marked	SJT
F	6 November 2001	Final Draft	SJT
G	12 March 2002	Public Release	AGS

PUBLICATION LICENSE

DISCLAIMER

NO WARRANTY. AUCKLAND STRUCTURAL GROUP PILING SPECIFICATION IS LICENSED AND PROVIDED "AS IS" WITHOUT WARRANTY OF ANY KIND, EXPRESS OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE OR A WARRANTY OF NON-INFRINGEMENT.

Every effort has been made during the publication of this specification to ensure that the statements made and opinions expressed represent a safe and accurate guide to the construction of piles. However, no liability or responsibility of any kind can be accepted in this respect by the authors, the Auckland Structural Group or the ASG Piling Specification

review sub-committee, or IPENZ. Specifiers of piles are responsible for ensuring that the requirements of this specification are appropriate for particular projects and for amending the specification where necessary for their project's particular circumstances.

COPYRIGHT

The copyright to Auckland Structural Group (ASG) Piling Specification is owned by the Auckland Structural Group, a non profit, technical group of the Institution of Professional Engineers New Zealand (IPENZ). No part of this document may be reproduced without the prior written permission of the Auckland Structural Group unless the circumstances are covered by the Copyright Act 1994, or meet the following requirement of this license.

REPRODUCTION OF WHOLE DOCUMENT

The Auckland Structural Group Piling Specification may be reproduced and distributed in whole, in any medium physical or electronic, provided that the terms of this license are adhered to, and that this license is displayed in the reproduction.

Any whole publication in standard (paper) book form shall require the citation of the original publisher and author. The publisher and author's names shall appear on all outer surfaces of the book. On all outer surfaces of the book the original publisher's name shall be as large as the title of the work and cited as possessive with respect to the title.

End of Publication License

CONTACT ADDRESS

Auckland Structural Group
C/o Northern Regional Office
Institution of Professional Engineers New Zealand
PO Box 6748
Auckland
NEW ZEALAND

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.

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).

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
LL	Live Load	kN
NSF	Negative Skin Friction	kN
σ_a	Allowable stress of timber piles	MPa
ϕ_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

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

OSH Code of Practice: Excavation and Shafts for Foundations

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.

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 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, as appropriate.

1.8 PILE LENGTHS

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

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.

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 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.

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 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 DURING CONSTRUCTION

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 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 specification:

- 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 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

2.1.3 Material

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

2.1.4 Concreting of Piles

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

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. 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). 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.

Concrete may be chuted into piles and allowed to freefall 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 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.

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

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 mm, or
- the use of drilling fluid prove necessary to maintain excavation stability,

then concrete shall be placed using an appropriate underwater concreting technique.

2.1.5.1 Workplan

The Contractor shall submit a detailed written workplan for underwater concreting to the Engineer. 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 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 times the inner diameter of the reinforcing cage for circular piles

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 tremie and hopper shall be clean and 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 plug of suitable material shall be inserted into the pipe 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:

- minimum cement content of not less than 400 kg/m³
- maximum total water content of 170 kg/m³
- maximum aggregate size 35 mm
- concrete slump shall be 175 mm ±25 mm

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.

- the discharge pipe shall at all times penetrate the concrete which has previously been placed with a minimum embedment of 1.5 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.

2.1.5.5 Loss of Immersion of Discharge Pipe

When the immersion of the discharge 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 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.

If these conditions cannot be met, concrete placement shall be suspended, the discharge 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 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.

Integrity tests shall be carried out to document the quality of any pile where loss of immersion of the discharge 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.

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

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 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.

AS/NZS1554 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

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 $\pm 5\%$. The external diameter at any section, measured using a steel tape on the circumference, shall not differ from the theoretical diameter by more than $\pm 1\%$. 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 strength butt welds, complete with backing plates (where required).

The standard for interpretation of non-destructive testing shall be AS/NZS1554. 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%	Nil	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) has been achieved.

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 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:

- timber species
- treatment for timber piles

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
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.

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.

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).

Cutting and boring of timber shall be done as far as possible before preservative treatment, but where this is impracticable, any piles that are cut or notched after pressure treatment shall be protected by a liberal brush application of Ensele Tanalith concentrated solution or copper naphthalene.

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.

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 mm of the levels specified on the Drawings. The cut surfaces shall be heavily coated with preservative, as specified for the initial treatment.

3. BORED PILES

3.1 SCOPE

This section covers the construction of bored piles. 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

OSH Code of Practice: Excavation and Shafts for Foundations

3.4 STEEL LINERS (CASINGS)

3.4.1 Permanent Steel Liners

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

Liners 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 thickness is the sole responsibility of the Contractor provided the above requirements are met.

Surplus lengths of liner shall be cut off when construction of the superstructure begins. 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

The Contractor shall determine requirements for temporary liners.

A short length of temporary liner shall be provided for all piles to maintain an upstand of at least 300 mm above existing ground level to prevent contamination of the pile bore prior to and during concreting.

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 35°. 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 specified on the Drawings, 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 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 and the relevant Authorities.

On completion of excavation, loose, disturbed or softened soil shall be removed from the pile bore using an appropriate method.

Pumping from pile bores shall not be permitted unless 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.

3.8 INSPECTION

If concrete can be placed in dry conditions, the Engineer 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 will be required, and ensure that the piles are clean of all loose material, mud and excess water at the time of inspection.

The Contractor shall remain responsible for the safety of all personnel descending piles and shall provide all necessary facilities to enable the Engineer to make an inspection of any pile, including facilities to check the depth, verticality and position. The full requirements of OSH Code of Practice: Excavation and Shafts for Foundations shall be followed as a minimum.

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.

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

3.11.1 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.

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

3.11.2 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 Pile Construction Record Card

The requirements of section 3.9 shall apply. 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, 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.

4.2 PROJECT SPECIFIC REQUIREMENTS

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

- trial piles

4.3 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 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 4.6 and operating correctly.
- the rebound shall be measured and recorded.

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

For piles that are subject to hydraulicaling, 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 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. 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 packer should fit between this helmet and pile top 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 0.45. Hammer weight drops and type shall be submitted to the Engineer prior to commencement of pile driving for approval.

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

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 4.5 below.

Table 4.5 Maximum Permissible Driving Stresses		
Pile Type	Compression Stress (MPa)	Tension Stress (MPa)
Steel	$0.9 f_y$	$0.9 f_y$
Prestressed concrete	$0.85 f_c' - f_{pe}$	Initial prestress
Precast concrete ¹		
Reinforcement qty <2%	$0.8 f_c'$	$0.8 \sqrt{f_c'}$
Reinforcement qty >2%	$0.8 f_c'$	$\sqrt{f_c'}$
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 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 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 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 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 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 penetration in millimetres 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.

4.10 ADDITIONAL REQUIREMENTS FOR DRIVEN PRECAST CONCRETE PILES

4.10.1 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 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:

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

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

4.11.1 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.

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

4.12.1 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:

- 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 ADDITIONAL REQUIREMENTS FOR DRIVEN TIMBER PILES

4.13.1 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 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 ADDITIONAL REQUIREMENTS FOR STEEL SHEET PILES**4.14.1 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 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. At all stages during driving, the free length of the sheet pile shall be adequately supported and restrained.

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 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
- impulse methods

Other methods 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 Independent Observer

Integrity testing shall be carried out in the presence of a suitably qualified and experienced independent observer. The Contractor shall submit to the Engineer the name of the observer, a description of the test equipment, a test method statement and a programme for executing the work, prior to integrity testing commencing on Site.

5.1.4 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 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

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

5.3.3 General

Dynamic pile testing shall be carried out in accordance with the requirements of AS2159. 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 \leq 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 4.5.

5.3.6 Reporting

A detailed report on the piles tested for the project shall be forwarded to the Engineer within 15 days of the completion of the test piling. The report shall include all items

listed in Clause 8.4.8 of AS 2159. Field results providing indicative pile capacities shall be made available to the Engineer as testing is undertaken.

APPENDIX A: SAMPLE PROJECT SPECIFIC REQUIREMENTS

A1 : SUMMARY OF PROJECT SPECIFIC REQUIREMENTS

A2: SAMPLE CAST IN PLACE BORED 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

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
- timber species
- treatment for timber piles

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
- extent of dynamic testing (percentage of production piles)

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

A2.1 GENERAL

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.

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.

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.

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.

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.

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.

A2.1.7 Requirements For Quality Management

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

A2.1.8 Requirements For Producer Statements

Producer Statements are not required.

A2.2 MATERIALS

A2.2.1 Details Of Concrete Strength And Mix Proportions

Concrete strengths are shown on the Drawings.

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.

A2.2.3 Weld Category For Welds In Accordance With NNZ3404

All welds shall be category SP.

A2.3 BORED PILES

A2.3.1 Requirement For Support Fluid

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

A2.3.2 Trial Piles

Trial piles are not required.

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

A3.1 GENERAL

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.

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.

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.

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.

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.

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.

A3.1.7 Requirements For Quality Management

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

A3.1.8 Requirements For Producer Statements

Producer Statements are not required.

A3.2 MATERIALS

A3.2.1 Corrosion Protection For Steel Piles

Corrosion protection is not required for the steel H piles.

A3.2.2 Weld Category For Welds In Accordance With NNZ3404

All welds shall be category SP.

A3.4 DRIVEN PILES

A3.4.1 Trial Piles

Trial piles are not required.

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

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

DRIVEN PILE RECORD CARD

JOB NO:

CONTRACT:

PILE NO/REF:

		DATE	TIME	LOCATION & OFFSET SKETCH					
PITCH & DRIVE SPLICE FINAL DRIVE: RE-DRIVE (update set card): CUT OFF:				Ground RL _____		Peg RL _____			
				(Platform RL)					
DEPTH	DROP	BLOWS	TIME	RAKE:					
0				PILE DETAILS					
2				PILE TYPE: _____					
4				PILE SIZE: _____					
6				STEEL GRADE: _____					
8				END PLATE: _____					
10				LENGTH	LENGT	WELDE	VIS SCA	VIS EX	NDT
12				1 ST DRIVE					
14				2 ND DRIVE					
16				3 RD DRIVE					
18				TOTAL DRIVEN LENGTH					
20				LEVELS					
22				CUTOFF DESIGN RL: _____					
24				CUTOFF ACTUAL RL: _____					
26				THEORETICAL TIP RL: _____					
28				ACTUAL TIP RL: _____					
30				NOTES:(e.g. max rebound, proving bores, load test setting/pre-boring					
32				_____					
34				_____					
36				_____					
38				DRIVING RECORD					
40				HAMMER TYPE: _____					
QA-TESTING Visual Examination ☐ NDT Examination ☐ NDT testing type: _____ Weld Inspection No. _____ Welder _____				HAMMER WEIGHT: _____					
								THEORY	ACTUAL
OBSTRUCTIONS/DELAYS: _____ _____ _____ _____				SET DROP:					
				S mm:					
				C/2 mm:					
				S + C/2=					
DRIVING RIG: _____ CRANE: _____				ULTIMATE RESISTANCE					
				S = Set C= Rebound from Card over					
				APPROVED:					
				FOREMAN _____					
				ENGINEER _____					

APPENDIX C: PILE DRIVING FORMULA

C1 : FORMULA AND SYMBOLS

C2 : TEMPORARY COMPRESSION

C3 : BLOW EFFICIENCY

C4 : ALTERNATIVE FORMULA FOR HARD DRIVING

C5 : PILE STRESSES AND HARDNESS OF DRIVING

C6 : BEARING CAPACITY

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 C_p , 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 (see note 1)	Head of timber pile	1.0	2.0	3.0	4.0
	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 (see notes 2 and 3)	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}
	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:

1. 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 .
2. L is length of pile (mm).
3. 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 $W > P_e$, 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:

$$R = \frac{W h n}{S + (R / 2m)}$$

or

$$R = (2 W h n m + (mS)^2)^{0.5} - mS$$

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

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

A4.4 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 C_p and C_q should be determined from observation, and only C_c from Table C1.

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

A5 PILE STRESSES AND HARDNESS OF DRIVING:

C5.1 Hardness of driving

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

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

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

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

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.

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

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.

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.

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

	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

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.

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:

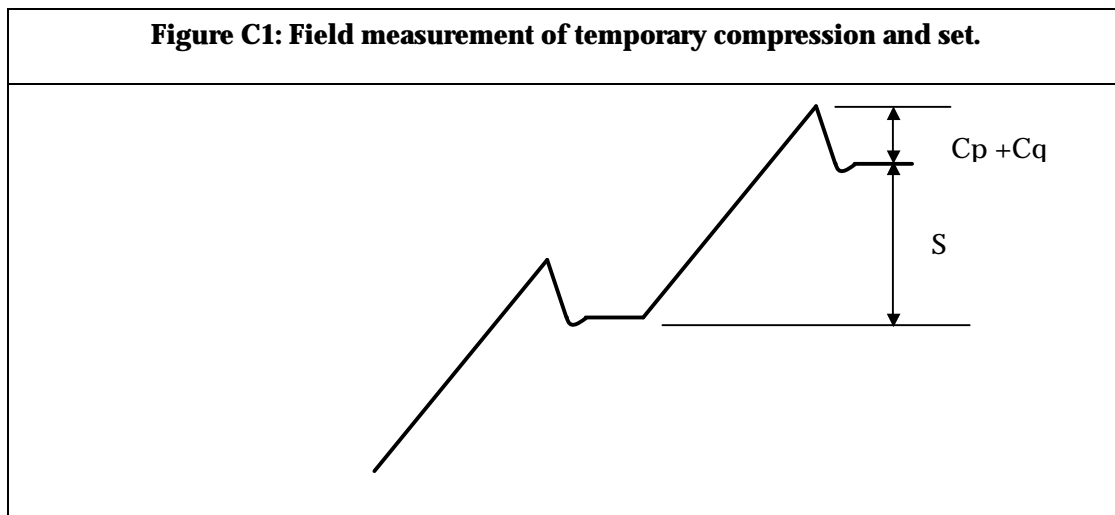
1. R is the ultimate driving resistance from the formula in Paragraph C1.1

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.

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



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. $C = C_c + C_p + C_q + \text{upper pile compression}$.