

Geotechnical earthquake engineering practice

MODULE 5A: Specification of ground improvement for residential properties in the Canterbury region



MINISTRY OF BUSINESS,
INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI



**NEW ZEALAND
GEOTECHNICAL
SOCIETY INC**

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This document is issued as guidance under section 175 of the Building Act 2004 to assist parties to comply with their obligations under the Building Act 2004.

While MBIE and the NZGS have taken care in preparing this document, it is only a guide and, if used, does not relieve any person of the obligation to consider any matter to which that information relates, according to the circumstances of the case. All users should satisfy themselves as to the applicability of the content and should not act on the basis of any matter contained in this document without considering, and if necessary, taking appropriate professional advice.

Users should consider taking appropriate professional advice prior to entering into a construction contract which incorporates all or parts of this document.

This document may be updated from time to time, the latest version is available from the Ministry of Business Innovation & Employment www.building.govt.nz or the New Zealand Geotechnical Society's www.nzgs.org/publications/guidelines.htm.

This document is part of a series of geotechnical guidance documents being produced jointly by MBIE and NZGS.

Important Notice

The ground improvement techniques described in this document are intended to support methods as described in the MBIE Guidance Document¹ for repair and rebuilding of houses affected by the Canterbury earthquakes, for improving ground within TC3² sites to allow the construction of TC2² type foundations.

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1 *Repairing and rebuilding houses affected by the Canterbury earthquakes* (Chapter 15.3 update issued in April 2015)

2 MBIE technical category (TC) as outlined in the MBIE Guidance Documents

CONTENTS

INTRODUCTION	IV		
Foreword	iv		
Content and objective of guidance	v		
Incorporation into a Contract Agreement	vi		
Structure and contents of guidance	vi		
How to use this Guidance for developing Contract Specifications	viii		
Guidance Notes	viii		
General	viii		
1 PRELIMINARY AND GENERAL	1		
1.1 General	1		
1.2 Definition of General Terms	1		
1.3 Definition of Material Types	2		
1.4 Drawings	2		
1.5 Statutory Authority Approvals	2		
1.6 Pre-construction Condition Survey	3		
1.7 Protection of Adjoining Public and Private Property	3		
1.8 Construction Management, Programme and QA/QC	3		
1.8.1 Construction Management Plan (CMP)	3		
1.8.2 Construction Programme	3		
1.8.3 Quality Assurance and Control (QA/QC)	4		
1.9 Pre-Construction Survey and Setting Out	4		
1.10 Safety during Construction	4		
1.11 Meetings	4		
1.12 Inspections and Approvals	5		
1.13 Dayworks	5		
1.14 Hours of Work	5		
1.15 Environmental Considerations	5		
1.15.1 Dust Control	5		
1.15.2 Stormwater and Sediment Control	5		
1.15.3 Construction Noise	6		
1.15.4 Construction Vibrations	6		
1.15.5 Contaminated Material	8		
1.15.6 Contractor's Plant	8		
1.15.7 Traffic Control	8		
1.15.8 Archaeological Sites	8		
1.16 Contractor's Working Area, Site Access and Amenities	9		
1.17 Existing Services	9		
1.18 Temporary Works Design	9		
1.19 Existing Subsoil Conditions	9		
1.20 Unforeseen Underground Obstructions/ Ground Conditions	9		
1.21 Approved Materials	9		
1.22 Advertising and Publicity	10		
1.23 Demobilisation and Reinstatement	10		
1.24 As-built Documentation	10		
1.24.1 As-built Drawings	10		
1.24.2 As-built QA/QC Records	10		
2 TESTING	11		
2.1 Laboratory and Field Testing	11		
2.2 Cone Penetration Tests	12		
2.3 Standard Penetration Tests	12		
2.4 Dynamic Probe Heavy	12		
3 EARTHWORKS	13		
3.1 Earthworks Inspection	13		
3.2 Groundwater and Surface Water Control	13		
3.3 Clearing and Stripping	14		
3.3.1 Clearing of Vegetation and Obstructions	14		
3.3.2 Topsoil Stripping	14		
3.3.3 Site-won Fill Material	14		
3.4 Excavations	14		
3.4.1 General	14		
3.4.2 Excavation Management	14		
3.4.3 Subgrade Preparation	15		
3.5 Filling	15		
3.5.1 General	15		
3.5.2 Placement and Compaction of Fill Material	15		
3.5.3 Nuclear Densometer Testing	16		
3.5.4 The Hardfill Plateau Density Test Procedure	16		
3.5.5 Imported Soil Fill	16		
3.6 Surface Protection and Maintenance	17		

3.7	Earthworks Tolerances	17	6	STONE COLUMNS	35
3.8	Earthworks Stockpiles	17	6.1	General	35
3.9	Temporary Haul Roads and Hardstands	17	6.2	Set Out, Tolerance and Replacement Ratio	36
3.10	Geogrid and Geotextile	17	6.3	Inspection, Review and Approval Hold Points	37
4	DENSIFIED CRUST	19	6.4	Obstructions and Pre-boring	38
4.1	General	19	6.5	Surface Treatment	38
4.2	Set out and Tolerances	20	6.6	Stone Column Material Suitability Tests	38
4.3	Inspection, Review and Approval Hold Points	20	6.6.1	General Requirements	38
4.4	Hardfill Material Suitability and Reference Testing Requirements	21	6.6.2	Aggregate Broken Face Content	38
4.4.1	General	21	6.6.3	Crushing and Weathering Resistance	39
4.4.2	Suitability Test Requirements for AP40 & AP65	21	6.6.4	Grading	39
4.4.3	Hardfill Reference Test Requirements	22	6.7	Degree of Improvement Tests	39
4.5	Site-won and Imported Soil Fill Material Reference and Suitability Testing Requirements	22	6.8	Construction Records and Monitoring	40
4.6	Permanent Works Testing Requirements	23	6.8.1	General	40
4.6.1	Verification Test Methods and Frequencies	23	6.8.2	Stone Volume Monitoring and Recording	40
4.6.2	Verification Test Criteria	25	7	DRIVEN TIMBER POLES	41
4.7	Geogrid and Geotextile Requirements	26	7.1	General	41
5	STABILISED CRUST	27	7.2	Standard Specifications	42
5.1	General	27	7.3	Set Out, Tolerance and Replacement Ratio	42
5.2	Set out and Tolerances	28	7.4	Inspection, Review and Approval Hold Points	43
5.3	Inspection, Review and Approval Hold Points	29	7.5	Materials	43
5.4	Cement Dosage	30	7.6	Treatment of Exposed Timber	44
5.5	Soil-Cement Blending	30	7.7	Construction	44
5.6	QA Records	30	7.8	Backfilling Over Timber Poles	44
5.7	Material Reference and Suitability Testing Requirements	30	7.9	Surface Treatment	45
5.7.1	Site-won Fill Materials for Stabilisation	31	7.10	Degree of Improvement Tests	46
5.7.2	Imported Soil Fill for Stabilisation	32	7.11	Construction Records	46
5.8	Construction	32	8	PROJECT SPECIFIC REQUIREMENTS	47
5.9	Permanent Works Testing Requirements	32			
5.9.1	Verification Test Methods and Frequencies	32			
5.9.2	Verification Test Criteria	34			
5.10	Geogrid and Geotextile Requirements	34			

APPENDIX 1. SPECIFICATION GUIDANCE NOTES	49	GN 5 Stabilised Crust	54
Specification Guidance Notes Preface	49	GN 5.1 General	54
GN 1 Preliminary and General	49	GN 5.4 Cement Dosage	54
GN 1.1 General	49	GN 5.9.2 Verification Test Criteria	55
GN 1.6 Pre-construction Condition Survey	49	GN 6 Stone Columns	55
GN 1.8.1 Construction Management Plan (CMP)	50	GN 6.1 General	55
GN 1.8.2 Construction Programme	50	GN 6.2 Set out, Tolerance and Replacement Ratio	56
GN 1.8.3 Quality Assurance and Control	51	GN 6.5 Surface Treatment	56
GN 1.9 Pre-Construction Survey and Setting Out	51	GN 6.6 Material Suitability	56
GN 1.15.3 Construction Noise	51	GN 6.7 Degree of Improvement Testing	56
GN 1.15.4 Construction Vibrations	51	GN 7 Driven Timber Poles	57
GN 1.15.5 Contaminated Material	51	GN 7.1 General	57
GN 1.15.8 Archaeological Sites	52	GN 7.10 Degree of Improvement Testing	57
GN 1.18 Temporary Works Design	52	APPENDIX 2. POSSIBLE PROJECT SPECIFIC REQUIREMENTS	58
GN 2 Testing	52	1 Preliminary and General	58
GN 2.1 Laboratory and Field Testing	52	2 Background Information	58
GN 2.2 Cone Penetration Tests	53	3 Materials	58
GN 4 Densified Crust	53	4 Testing	58
GN 4.1 General	53	5 Construction	58
GN 4.4.3.2 Maximum Dry Density	53		
GN 4.6.2 Verification Test Criteria	54		



INTRODUCTION

Foreword

This document has been produced in response to the Canterbury earthquake sequence that started on 4 September 2010 with the Darfield earthquake. The sequence continued with a series of aftershocks, the most significant events were on 22 February 2011, 13 June 2011 and 23 December 2011. These earthquakes caused widespread damage from liquefaction and lateral spreading within the Canterbury region as well as shaking damage, and extensive rock falls and landslides on the Port Hills. As a result of the damage, many properties required ground improvement work and re-construction of buildings.

In December 2010, MBIE first produced guidance for the repair and rebuilding of houses affected by the Canterbury earthquakes and it has been progressively updated³. The guidance states that residential properties in the Canterbury Green Zone have been assigned one of three technical categories (TC1, TC2 and TC3) for foundation investigation and design. These technical categories are based on an area wide analysis of observed damage and known geological conditions. They act as a guide for consent authorities, engineers, builders, and insurance companies on the level of site investigation required, and the most appropriate foundation system that will reduce the risk of injury and damage for a particular site.

A substantial science and research programme to test residential scale ground improvement options and to identify affordable and practical ground improvement (GI) solutions to mitigate the effects of liquefaction for residential properties, was undertaken by the Earthquake Commission (EQC), USA National Science Foundation, MBIE and other parties in the Canterbury Red Zone. The ground improvement section of the MBIE guidance (section 15.3) was amended in April 2015 as a result.

In parallel, EQC undertook a pilot programme for ground improvement (GI) trials within the Canterbury region. The purpose of the trials was to provide a full-scale costing exercise for liquefaction related ground improvement techniques on TC3 properties. This was done by competitively tendering and constructing various types of GI work on a variety of residential sites around Christchurch and Kaiapoi. Pilot programme construction Specifications were developed for each of the GI techniques. EQC and MBIE recognised that those specifications would be useful to others (ie private land owners, insurers, project management organisations (PMOs) and the geotechnical community) involved in specifying similar work. EQC and MBIE set about to agree the technical specifications with geotechnical industry experts with the aim of producing an industry standard specification for earthquake damage ground improvement work that could be used throughout the Canterbury region. Although the document has been written with the Canterbury recovery in mind it was recognised that it may also be a useful guide for others areas within New Zealand prone to liquefaction (with appropriate modifications to suit local conditions).

At the time of publication, a document entitled, *Lessons Learned from the Ground Improvement Programme* was being produced by EQC which describes the main learnings from the GI Trial Project. This document will be made available through the EQC website.

This Foreword is not part of any Specification or Contract between parties undertaking ground improvement Works. The Foreword provides background information and outlines the purpose of the document.

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³ *Repairing and rebuilding houses affected by the Canterbury earthquakes* Version 3, December 2012 and Version 3a to Chapter 15.3 issued in April 2015

Content and objective of guidance

The intention of this document is to provide guidance on what should be included in a technical specification when designing and constructing ground improvement (for liquefaction mitigation purposes) for the four ground improvement techniques covered by this document. It is intended that the guidance is used for small scale ground improvement Works as typically required for single residential sites (typically approximately 500m² plan area).

The guidance includes a proposed Preliminary and General specification (section 1), a Testing specification (section 2), a General Earthworks specification (section 3) and four technical specifications for the different ground improvement options covered. Where it is agreed that construction activities other than residential scale ground improvement are contemplated within the same contract, the inclusion of the Preliminary and General specification, section 1, may not be appropriate. In addition, depending on the ground improvement method chosen and the location of the site, some aspects of section 1 may not be necessary for all ground improvement contracts – refer to the Specification Guidance Notes. Technical specifications, per sections 4 to 7 of this document, can be included in the contract depending on the type of ground improvement selected for the contract. All sections included in the contract need to be carefully reviewed to make sure they are appropriate for the specific work being proposed. Using the specifications are not mandatory for residential scale ground improvement contracts but are strongly recommended. If a decision is made to include any of these Specification sections into contract documentation and changes are needed to suit the specific work, it is intended that they are amended under an additional specification section highlighting the changes. Appendix 2 provides a list of possible project specific requirements that may need to be included into the contract specification or alternatively shown on the drawings.

Large residential or commercial developments may have different/additional requirements, not covered in this guidance.

The ground improvement techniques in this guideline intend to support methods described in the MBIE Guidance Document⁴ for improving ground within TC3⁵ sites. The ground improvement methods are to provide an integrated foundation solution consisting of both the improved ground and the enhanced surface foundation (constructed in accordance with TC2 foundation options, refer to section 5 of the MBIE guidance), to provide a minimum acceptable performance for the supported superstructure etc. The ground improvement methods provide a means to improve resilience and mitigation against the effects of future liquefaction (such as differential settlement at the ground surface) but do not mitigate the risk and effects of liquefaction that occurs below the improved depth in future large earthquakes.

The main objectives and benefits of producing this guidance document are to:

- 1 Provide a guidance document that is available for use by individuals and organisation involved in designing and constructing ground improvement (GI) Works.
- 2 Lower overall industry costs to design GI Works as standard specifications are readily available.
- 3 Lower overall construction costs as GI techniques, specifications and materials are standardised.
- 4 Standardise and improve consistency in ground improvement design and construction.
- 5 Provide a supporting document to the MBIE Guidance Document.

⁴ *Repairing and rebuilding houses affected by the Canterbury earthquakes* (Chapter 15.3 update issued in April 2015)

⁵ MBIE technical category (TC) as outlined in the MBIE Guidance Document

Incorporation into a Contract Agreement

Figure 1 below illustrates how this guidance is intended to be used as part of a construction contractual agreement.

Figure 1: Use of this Guidance within a Contractual Agreement

CONTRACT AGREEMENT	Not part of this guidance. Documents such as NZS 3902, NZS 3910, or other, could be used as general conditions. Special conditions of contract could include certification requirements (PS3, PS4, etc.)
↳ DRAWINGS	Not part of this guidance – templates will be made available by MBIE separately
↳ SPECIFICATION	<ul style="list-style-type: none"> – P&G Requirements – section 1 of this document (if applicable), section 2 Testing, section 3 Earthworks – Requirements particular to the repair method ie sections 4, 5, 6 and 7 of this document – Other project/site specific requirements (refer Appendix 2)
↳ SCHEDULE OF PRICES/ BASIS OF PAYMENT	Not part of this guidance – templates will be made available by MBIE separately
↳ SITE SPECIFIC INFORMATION	<ul style="list-style-type: none"> – Geotechnical investigation data – Consent conditions, Contamination test data, etc.

Structure and contents of guidance

This guidance covers the following ground improvement techniques:

- Densified Crusts
- Stabilised Crusts (ex-situ/rotovated or in-situ mixed)
- Stone Columns
- Driven Timber Poles

Other repair methods may be added to this document in later revisions, if they become more commonly used repair methods in the future.

The methods covered by this document have the same meaning and types as defined by the MBIE Guidance Document⁶, ie

- Densified Crust, Type G1a (excavate and recompact) and Type G1d (reinforced crushed gravel raft).
- Shallow Cement Stabilised Crust, Types G2a (ex-situ mixing) and G2b (stabilised in-situ mixing).
- Stone Columns, Type G4 (deep stone columns) and Type G5a (shallow stone columns).
- Driven Timber Poles, Type G5b.

⁶ *Repairing and rebuilding houses affected by the Canterbury earthquakes* (Chapter 15.3 update issued in April 2015)

Users of this guidance should take the following into account:

- 1 It is intended that the specification components of this guidance will form part of a contractual agreement between two parties. The document describes good practice technical requirements for the various ground improvement techniques covered and avoids references to payment and contractual issues as far as possible as it is assumed these are covered elsewhere in the contract documents.
- 2 It is possible that the specification clauses may need to be varied by the Engineer as considered appropriate depending on the type, size and quality/performance requirements of any particular project. In particular the Engineer should ensure that the P&G, Testing and Earthworks sections of this guidance are checked and altered as appropriate for the particular project and that there is no conflict between these sections and any other similar preliminary and general, testing and earthworks requirements that may be contained within or referred to elsewhere in the contract documents
- 3 It is intended that the guidance would be accompanied by a set of construction drawings, which would be used to describe the ground improvements in detail eg depth, extent of improvement, etc.
- 4 It is intended that the guidance would be accompanied by a set of Drawings, Bills of Materials and Basis of Payments documents which will assist in pricing the works in a standardised manner. Templates of these documents will be made available on the MBIE website.
- 5 It is intended that the guidance is used for ground improvement Works within the Canterbury region.
- 6 The guidance is intended to provide a set of minimum requirements. Additional requirements may be required for sites that have particular constraints, ground or groundwater conditions that are not typical for the Canterbury region.
- 7 There may be additional requirements for dealing with contaminated ground or materials not covered by this guidance

The guidance document contains the following sections:

- Preliminary and General (P&G)
- Testing
- Earthworks
- Densified Crusts
- Stabilised Crusts (in-situ and ex-situ mixed)
- Stone Columns
- Driven Timber Poles
- Project Specific Requirements
- Specification Guidance Notes
- List of Possible Project Specific Requirements

The Engineer should review the P&G section of this guidance and alter it as appropriate for the particular project and check that there is no conflict between the P&G section of this guidance and any other similar preliminary and general items that may be contained within or referred to in the project contract documents. Any amendments made should be highlighted to assist in understanding what has been amended. The Preliminary and General section also provides a comprehensive list of potential requirements. Depending on the project location, nature and specific project requirements a number of these may not be required. The specification writer should use judgement as to what is necessary and appropriate and which party is best suited for being responsible for them.

How to use this Guidance for developing Contract Specifications

The P&G, Testing and Earthworks section describe general requirements, which may be applicable to all improvement types. Judgement is required to decide which parts are relevant to any particular project. The next four sections describe requirements for each particular technique. Typically only five sections of the Specification would be used on any particular project ie:

- the P&G section (or part thereof if P&G items are covered elsewhere within the contract documents), refer section 1 and Guidance Notes Appendix 1
- the Testing section, refer section 2 and Guidance Notes Appendix 1
- Earthworks section (or part thereof if these items are covered elsewhere within the contract documents), refer section 3
- the section corresponding to the particular ground improvement technique to be used, refer sections 4 to 7 and Guidance Notes Appendix 1
- the Project Specific Requirements section, refer section 8. Project Specific specification requirements should be populated with text to include the particular aspects of the project, refer to Appendix 2 for guidance.

Where Specification sections 1 to 7 are being included in the contract, they should be included without amending the wording. Where specific clauses need to be amended, replaced or deleted due to the particular aspects of a project, these changes should be made in the Project Specific Requirements. Any amendments should be highlighted to assist in understanding what has been amended from the terms provided in this guidance document.

Each specification section of the guidance will be made available on the MBIE website as a separate pdf file to aid in the compilation of the contract documents.

Guidance Notes

Specification Guidance Notes are provided at the end of the document, that provides additional background information to help to explain the intent of the Specification clauses and provide commentary on other factors that may need to be covered by the relevant Specification clause.

It is recommended that all requirements for a particular project should be listed in the Schedule of Quantities to ensure that they are specifically priced and allowed for in the Contract.

Further consideration should also be given to the development of template plans so as to make it easier for the Contractor to understand the requirements of each plan and prepare a submission.

It is intended that this document is used as general guidance for the technical specifications for the four specific ground improvement methods covered. The technical specifications may need to be varied by the Engineer as considered appropriate depending on the type, size and quality/performance requirements of any particular project.

General

Advice should be sought from an appropriately qualified and experienced geotechnical professional where ground improvement Works are proposed to confirm that the contents of this guidance are appropriately applied and implemented within a construction contract.

It should be noted that, although the MBIE Guidance Document provides guidance on general design solutions for ground improvement in order to mitigate against liquefaction, other general engineering considerations such as settlement, slope stability, lateral spreading and flooding still need to be taken into account in the design on sites where these aspects are of concern. This may require additional site specific investigations and additional ground improvement measures not covered by the MBIE Guidance Document or this document.

This document is not to be used as a design guide for design of liquefaction ground improvement Works.

1 PRELIMINARY AND GENERAL

1.1 General

This Specification sets out requirements for the construction of four different ground improvement techniques (Densified Crusts, Stabilised Crusts, Stone Columns and Driven Timber Poles). It is intended that this document be read in conjunction with any Project Specific Requirements, which shall form part of the Contract Agreement. In the event of a conflict between the requirements of this Specification and the Project Specific Requirements, the Project Specific Requirements shall take precedence.

1.2 Definition of General Terms

The following definitions are used in this Specification:

Principal	Shall mean the person/entity that is funding the Works. When Works are procured under NZS3902, <i>Housing Alterations and Small Building Contracts</i> , replace 'Principal' with 'Owner'.
Engineer	Shall mean the primary company or individual employed or contracted by the Principal to design, inspect and certify the construction of the proposed Works. Where Works are procured under a Design and Build contract the Engineer shall be the primary company or individual employed by the Contractor to design, inspect and certify the construction of the proposed Works. When Works are procured under NZS3910 Conditions of Contract, the definition in that standard will apply.
Contractor	Shall mean the primary company or individual employed or contracted by the Principal to construct the proposed Works. The Contractor shall be responsible for all elements undertaken by appointed Subcontractors. Any reference to Subcontractors in this Specification shall be the ultimate responsibility of the Contractor. When Works are procured under NZS3902, <i>Housing Alterations and Small Building Contracts</i> , replace 'Contractor' with 'Builder'.
Sub-contractor	Shall mean any appointed company or individual employed or contracted to undertake an element of the Works on behalf of the Contractor.
Statutory Authority	Shall mean the local authority, eg Christchurch City Council (CCC), Waimakariri District Council (WDC), Selwyn District Council (SDC) or the regional council, Environment Canterbury (ECan).
Site	Shall mean the land or properties listed in the Contract Documents and/or the extents shown on the Contract Drawings that is made available to the Contractor for the purposes of constructing the Works. Shall be replaced by 'Sites' where the Works require construction to be undertaken on multiple properties.
Drawings	Drawings included in the Contract, together with any additions to, or modification of such Drawings approved and notified to the Contractor and such other Drawings as may from time to time be supplied by the Engineer to the Contractor for the purpose of the Contract. Drawings also include those that have been prepared by, or on behalf of the Contractor, as required by the Contract.
Works/ Contract Works	All work, including temporary work to be executed to complete the scope shown on the Drawings, required by the Specification and the Contract.
Zone of Influence	Zone around the perimeter of the ground improvement Works which is assessed by the Engineer as possibly being affected by the proposed Works, as shown on the Drawings or identified in the Contract.

1.3 Definition of Material Types

The following material type definitions are used in this Specification:

Topsoil	Topsoil is defined as any material which is considered by the Engineer to be suitable for re spreading as a surface soil layer for establishing vegetation growth upon completion of the Works. Any material which contains Topsoil shall not be used as fill for other purposes.
Site-won Fill	Site-won Fill shall comprise non-organic, clean soil material which is sourced on the Site and approved for use as Site-won Fill by the Engineer.
Unsuitable material	Unsuitable material is defined as any material that contains an unacceptable proportion of organic material (including Topsoil), demolition rubble and/or material which by its inherent nature cannot be satisfactorily reconditioned by wetting or drying for use as Site-won Fill.
Rubbish	Rubbish is defined as any man-made inorganic material eg steel, concrete, timber, plastic, refuse and any other un-natural debris. All materials that contain Rubbish shall be categorised as Unsuitable material unless otherwise approved by the Engineer.
Hardfill	Hardfill shall comprise a graded hard stone aggregate and shall conform to the appropriate grading envelopes and physical properties provided in this Specification.
Contaminated Material	Material which has been shown to be Contaminated through the Detailed Site Investigation (DSI) Contamination Testing and identified in the Contamination Site Management Plan (SMP) as requiring specific precautions when disturbing or as identified as contaminated by a suitably qualified and experienced contamination practitioner. Refer to section 1.15.5.

1.4 Drawings

This Specification should be read in conjunction with the Drawings.

The Contractor shall inform the Engineer immediately of any apparent errors, inconsistencies or omissions in any of the Drawings that the contractor is aware of. The Engineer will respond to any such information as soon as is practicable by means of clarification, confirmation or instruction.

1.5 Statutory Authority Approvals

No Works shall be undertaken until all necessary consents and approvals have been obtained.

The Works shall be carried out in consideration of, and in strict compliance with, the relevant consents and approvals (including resource consents and building consents) issued by the relevant Statutory Authority. For the Canterbury region these include the following:

- 1 Christchurch City Council, City Plan, Volume 3, Part 9, Rule 5.2A;
- 2 Environment Canterbury:
 - a Proposed Land and Water Regional Plan (pLWRP), which includes:
 - Rules 8.5.2 or 8.5.3 of the Waimakariri sub-regional section; or
 - Rules 9.5.6 or 9.5.7 of the Christchurch-West Melton sub-regional section; or
 - Rules 11.5.1 or 11.5.2 of the Selwyn-Waihora sub-regional section.
 - b Natural Resources Regional Plan (NRRP) – Rule WQL36A.

The Contractor shall note restrictions on a variety of aspects related to ground improvement work and in particular:

- 1 control of Contaminated materials
- 2 offsets of Works from property boundaries
- 3 offsets of Works to streams, rivers, lakes, waterways, wetlands and coastlines
- 4 restrictions on Works around protected trees, ecological significant areas and heritage sites
- 5 limitations on the use of grout
- 6 restrictions on the types of materials to be used for ground improvement
- 7 restrictions of Works near and over groundwater aquifer systems and community drinking water supply protections zones
- 8 restrictions on groundwater dewatering
- 9 the restriction on the use of treated Timber Poles where they intercept groundwater in the Coastal Confined Aquifer System and within the Community Drinking Water Supply system.

1.6 Pre-construction Condition Survey

The Contractor shall undertake a pre-construction condition survey of all buildings, structures, road and above ground service infrastructure, which are located within the Zone of Influence of the proposed Works, prior to the start of work. CCTV inspections may also be required for sewer and stormwater pipes. The need for CCTV inspections shall be identified on the Drawings or instructed by the Engineer. The pre-condition survey shall be completed by an appropriately qualified and experienced professional proposed by the Contractor and accepted by the Engineer.

If, in the opinion of the Engineer, damage may have occurred as a result of the construction activities, the Contractor shall arrange for a second condition survey by an appropriately qualified and experienced professional accepted by the Engineer, to inspect the area of possible damage and provide an opinion on the extent of the damage, if any, the likely cause, and any remedial measures necessary to rectify the damage.

1.7 Protection of Adjoining Public and Private Property

The Contractor shall take all necessary care to prevent damage to adjoining public and private property (buildings, structures, road and services infrastructure etc.) Any damage caused by the Contractor's construction activities shall be reinstated by the Contractor at their own expense as soon as practicable and prior to demobilising from the Site.

1.8 Construction Management, Programme and QA/QC

1.8.1 Construction Management Plan (CMP)

Prior to the commencement of construction, the Contractor shall prepare a Construction Management Plan (CMP). The CMP shall be reviewed by the Engineer and Statutory Authority (if necessary). The Contractor shall make any reasonable changes to the CMP as requested by the Engineer or as required by the Statutory Authority.

The CMP shall describe the sequence and methodology for the main construction activities, including the equipment to be used, the expected environmental effects and how those effects will be managed and mitigated.

The CMP shall be updated and revised by the Contractor as reasonably requested by the Engineer.

The Contractor shall discuss and agree any proposed changes to the CMP with the Engineer prior to proceeding with the Works.

1.8.2 Construction Programme

Prior to commencing the Works, the Contractor shall submit a programme of the proposed work flow to the Engineer.

The Contractor shall at all times maximise efficient use of its workforce having regard to actual and expected weather conditions and shall keep the Engineer informed of any likely delays.

Where, in the opinion of the Engineer, the Contractor's progress has deviated from the programme to the extent that it no longer reflects the true situation, the Contractor shall prepare an updated programme. The Contractor shall remain responsible for ensuring that the contractual completion date is achieved.

1.8.3 Quality Assurance and Control (QA/QC)

The Contractor shall implement an effective quality assurance system and prepare a Quality Control Plan to verify that the selection of materials, workmanship, testing and performance of the Works complies with the standards set out in the Contract and this Specification.

The Engineer may, from time to time, carry out audits of the Contractor's quality records and work practices to verify compliance with the Quality Control Plan.

The Contractor shall provide in a timely manner copies of all quality control information, shall co-operate fully with the Engineer's audits and rectify any non-conformance without delay.

The Contractor shall collate and hold all specified records on-site in a form that makes the information easily accessible when it is needed. Copies shall be distributed as and when necessary to those persons entitled under the Contract to that information.

1.9 Pre-Construction Survey and Setting Out

The Contractor shall take pre-modifications ground surface levels prior to start of the Works to a datum agreed with the Engineer. Surface ground levels shall be taken on a minimum 5m x 5m grid as well as any other additional points where there is a sharp change in levels so as to accurately record the ground surface profile prior to start of Works.

The Contractor shall be responsible for the correct setting out and construction of the Works in accordance with the Drawings.

The Principal shall be responsible for establishing the accurate property boundaries locations prior to the start of the Works.

1.10 Safety during Construction

The Contractor shall be responsible for all matters which affect the safety and security of the Site and its employees, sub-contractors and any other persons which require access to the Site in order for the Works to be

constructed or inspected. The Contractor shall recognise its accountability and responsibility for the safety of its staff and others attending the Site and shall observe and comply with all relevant legislative safety requirements, including reporting of injuries to WorkSafe New Zealand.

The Contractor shall submit to the Engineer for approval a Site-Specific Safety Plan and Site Hazard Identification (Hazard ID) Schedule prior to commencement of the works on the Site, in accordance with the Health and Safety in Employment Act and its Regulations and the Canterbury Safety Charter. The Contractor shall identify a suitably qualified on-site Safety Supervisor. A copy of the Contractor's Site-Specific Safety Plan and Hazard Identification Schedule shall be kept at the Site at all times for inspection by employees, Sub-contractors, the Principal, Site visitors and the Engineer. All people entering the Site shall review and sign the Hazard ID before entering the Site. The Contractor shall also forward this information to all Sub-contractors working on the Site.

The Contractor shall provide the Principal and Engineer with written advice of every personal injury or near-miss to their own and/or Sub-contractor staff or other visitors to the Site, including any other incidents that result in loss of progress and/or damage to property.

1.11 Meetings

Site progress meetings are to be held as mutually agreed between the Contractor and Engineer. The Contractor's Project Manager shall represent the Contractor at these meetings.

At each meeting, the Contractor shall:

- 1 report on any health and safety incidents
- 2 report on the progress of the Works relative to the construction programme
- 3 provide a proposed update to the construction programme, if required
- 4 report on any delays and methods to mitigate
- 5 report on any issues which may affect the Contract Price
- 6 report any conflicts at the Site.

1.12 Inspections and Approvals

In addition to the requirements for inspection contained elsewhere in the Contract, the Contractor shall give reasonable notice⁷ to the Engineer that they wish to proceed to the following stages of the Works:

- 1 commencement of mobilisation to the Site
- 2 commencement of general earthworks/
Topsoil stripping
- 3 commencement of ground improvement operations
- 4 inspection or testing of any part of the Works as required under the Contract.

The Contractor shall not proceed to any stage of the Works until the Engineer has undertaken all necessary inspections, measurements and, where necessary, has accepted the Works at the previous stage.

The Contractor shall be responsible for notifying the Statutory Authority and arranging for any Resource Consent or Building Consent inspections required by them.

1.13 Dayworks

Where Dayworks are instructed by the Engineer, daily Dayworks vouchers shall be signed by the Contractor's representative as confirming the labour, plant, equipment and materials used as well as the durations and quantities used, before being supplied to the Engineer the following day for approval and signature.

1.14 Hours of Work

The Works shall be restricted to the hours between 7.30am and 6pm Monday to Friday and 8am to 5pm on Saturday, or as required by the Resource Consent conditions (if applicable). No Works shall occur on Sundays or Public Holidays.

Work outside these hours may be permitted at the Engineer's discretion and provided the Contractor obtains the Engineer's prior written approval. The impact of the proposed work on neighbouring properties will be considered by the Engineer in assessing if work outside of these hours is allowable. Upon approval of the Engineer, the Contractor shall also be responsible for

⁷ unless otherwise agreed, 'reasonable notice' shall be taken as 24 hours prior for work to be inspected on Tuesdays to Fridays; if work is to be inspected on Saturday notice shall be given the previous Thursday; and if work is to be inspected on Monday notice shall be given by the previous Friday.

obtaining all necessary permits and permission for such work from the Statutory Authority.

1.15 Environmental Considerations

1.15.1 Dust Control

In dry conditions it is possible that the proposed Works will produce dust that could migrate beyond the boundary of the Site and affect neighbouring properties and residents. The effects of dust shall be appropriately managed within the boundary of the Site.

Dust emissions shall be controlled in accordance with the Ministry for the Environment (MfE), *Good Practice Guide for Assessing and Managing the Environmental Effects of Dust*.

In particular, to avoid the potential generation of dust, any exposed areas that remain open shall be dampened down with water spray during dry and windy conditions. Should dust become an issue, the Contractor shall provide a watercart or other agreed measures to manage the issue.

Should the Works cause dust that can be visually identified on neighbouring buildings, structures, vehicles or other property, the Contractor shall, on instruction from the Engineer and approval of the neighbour, clean away such dust at their own cost.

1.15.2 Stormwater and Sediment Control

The Contractor shall programme their operations and construct the Works in full compliance with the relevant local authority sediment control and discharge guidelines. For the Canterbury Region this is the Canterbury Regional Council's (ECan), *Erosion and Sediment Control Guidelines: A better way of managing earthworks and the environment* (Report No. R06/23). When undertaking land repair work on a single residential site, all erosion and sediment control measures shall be constructed, inspected and maintained in accordance with ECAN's, *Erosion and Sediment Control Guidelines for Small Sites*.

The Contractor shall establish suitably stabilised (eg paved with aggregate) vehicle entry/exit points or vehicle wash-down facilities so sediment is not tracked on and off the Site.

Erosion and sediment control measures shall be maintained and remain in place until surface reinstatement has been established.

1.15.3 Construction Noise

Permitted construction noise levels shall be the lesser of those required by the local Statutory Authority and those set out in NZS 6803, *Acoustics – Construction Noise*, set out in Table 1.1 below.

Table 1.1: Summary of Construction Noise Limits

TIME OF WEEK	TIME PERIOD	DURATION OF WORK					
		Typical duration (dBA)		Short-term duration (dBA)		Long-term duration (dBA)	
		L _{eq}	L _{max}	L _{eq}	L _{max}	L _{eq}	L _{max}
Weekdays	0630–0730	60	75	65	75	55	75
	0730–1800	75	90	80	95	70	85
	1800–2000	70	85	75	90	65	80
	2000–0630	45	75	45	75	45	75
Saturday	0630–0730	45	75	45	75	45	75
	0730–1800	75	90	80	95	70	85
	1800–2000	45	75	45	75	45	75
	2000–0630	45	75	45	75	45	75
Sunday and Public Holidays	0630–0730	45	75	45	75	45	75
	0730–1800	55	85	55	85	55	85
	1800–2000	45	75	45	75	45	75
	2000–0630	45	75	45	75	45	75

1 L_{eq} (Equivalent continuous noise level) – the energy average of the varying noise over a sample period

2 L_{max} (Maximum noise level) – the maximum noise level measured over a sample period.

Noise monitoring shall be undertaken by the Contractor when:

- required by the Resource Consent, or
- in the opinion of the Engineer, construction operations are likely to result in (or are likely to result in) the noise limits being exceeded at the Site boundaries, or
- any noise complaints are received from neighbours.

Where required by the Resource Consent, the Contractor shall prepare a Construction Noise Plan in accordance with this section. This is to form part of the CMP.

Where noise monitoring is required, the Contractor shall undertake monitoring at times when construction operations are most likely to result in maximum noise at the Site boundaries, or when construction plant or methodology changes are likely to result in noise limits being exceeded.

All noise monitoring shall be undertaken by appropriately qualified and experienced personnel.

1.15.4 Construction Vibrations

The Contractor shall ensure that vibrations generated from construction activities in close proximity to third party buildings or structures are less than the maximum limits recommended in the German Standard DIN 4150-3, *Structural Vibration – Effects of Vibration on Structures*. The maximum peak particle velocity (ppv) limits which are to be applied are summarised in Table 1.2 or as otherwise required by the Resource Consent.

Vibration monitoring shall be undertaken by the Contractor when:

- required by the Resource Consent, or
- in the opinion of the Engineer, construction operations are likely to result in (or are likely resulting in) the vibration limits being exceeded at the Site boundaries, or
- if any vibration complaints are received from neighbours.

Where required by the Resource Consent, the Contractor shall prepare a Construction Vibration Plan in accordance with this section. This is to form part of the CMP.

In the first instance the Contractor shall undertake vibration monitoring at the property boundary. Where vibration levels at the boundary exceed the specified limits or where complaints are received, additional monitoring inside the neighbouring property shall be undertaken (subject to access agreement with the neighbours). Such additional monitoring shall be undertaken either outside the building but connected to the building foundation or inside the building. Vibration measurement instruments shall be placed by the Contractor at varying distances from the Site to ensure that vibration is within the limits set out in the DIN standard 4150-3, and to ensure that effects from vibration on occupants of adjacent structures are no more than minor and the occupants shall not be subject to unreasonable disturbance.

Where vibration monitoring is required, the Contractor shall undertake monitoring when construction operations are most likely to result in maximum vibration at the Site boundaries, or when construction plant or methodology

changes that is likely to result in an exceedance of the above vibration limits.

All vibration monitoring shall be undertaken by appropriately qualified and experienced personnel.

The Contractor shall note that building occupants may notice or be disturbed by vibrations at levels lower than those cited in DIN 4150-3 (ie vibration is perceptible at levels above 0.3mm/s), which might give rise to complaints. This is often due to occupants concern over building damage, and can generally be mitigated through effective consultation regarding the project objectives and timeframes, vibration monitoring and demonstration to the occupant that vibration levels are within acceptable levels. The Contractor and the Engineer shall collectively take responsibility for liaison and discussions with neighbouring occupants to relay this information to them and to keep them informed of construction activities and programme. On request of the Engineer, the Contractor shall provide vibration records to the occupants. The Contractor shall also take all practical steps to minimise disruption to the occupants as much as possible.

Table 1.2: Summary of Vibration Velocity Limits during Construction

TYPE OF STRUCTURE	MAXIMUM PERMITTED VIBRATION VELOCITY (MM/S)			
	Intermittent Vibration (frequency)			Continuous Vibration (all frequencies)
	Less than 10 Hz	10 to 50 Hz	50 to 100 Hz ⁽¹⁾	
Sensitive Structures Structures that, because of their sensitivity to vibration, do not correspond to those listed below and/or are of great intrinsic value (eg buildings that are under a preservation order)	3	3 to 8	8 to 10	3
Residential Structures Residential dwellings and buildings of similar design and/or use	5	5 to 15	15 to 20	5
Commercial Structures	20	20 to 40	40 to 50	5

Notes:

1 For frequencies above 100Hz, at least the values specified in this column shall be applied.

1.15.5 Contaminated Material

Contaminated material known to be present on the Site shall be identified in the Contract and where possible the approximate extent of this material shall be shown on the Drawings. The Engineer will provide the Contractor with a Ground Contamination Site Management Plan (SMP) identifying requirements for dealing with Contaminated material. The Contractor will follow the requirements of the SMP, including which materials need to be removed from Site, where materials are to be disposed of, and which material may remain on Site or are able to be used within the ground improvement Works. The Contractor shall also follow procedures within the SMP for managing contaminated soil-related effects during soil disturbance associated with ground improvement Works.

All material classified as sufficiently contaminated and requiring removal from Site shall be stripped and transported to a suitable and approved disposal site. No material is to be removed from the Site without the prior approval of the Engineer.

The Site-specific health and safety plan (to be provided by the Contractor) shall complement the SMP and address other health and safety requirements that may be applicable to the particular Works.

If any unforeseen Contaminated material (or suspected contamination) is uncovered during construction, the Contractor shall cease work immediately and seek direction from the Engineer.

1.15.6 Contractor's Plant

All areas where the Contractor refuels plant shall be provided with temporary stormwater contamination control provisions to prevent pollution of stormwater courses, natural water or groundwater.

The Contractor shall take all necessary steps to ensure that no hydrocarbons or other contaminants are allowed to drain to ground during any operation.

Any soils which may have been contaminated by hydrocarbons must not be spread on-Site, but shall be disposed of in a controlled manner suited to the type and level of contamination, including, but not limited to, double bagging and disposal at a registered contaminated landfill, if appropriate.

All plant and machinery brought to the Site shall be clean to prevent the introduction of undesirable or Contaminated material. All fill, cement, gravel or spoil with a risk of spillage arriving or leaving the Site shall be covered.

The Contractor shall ensure all plant and equipment complies fully with all relevant health and safety regulations at all times during execution of the Works.

1.15.7 Traffic Control

The normal traffic flow, including pedestrian traffic on any public road or private access road, rail, or property affected by the Works, shall not be unreasonably interrupted during any operations covered by the Works.

Adequate safeguards to the public in respect of temporary fences, signals, signs and lights shall be provided at all times. Any necessary traffic signs shall be provided and operated by the Contractor in accordance with the Statutory Authority or NZ Transport Agency (NZTA) requirements but erected only with the prior written approval of the Statutory Authority or NZTA.

Where a Traffic Management Plan (TMP) is required, the Contractor shall prepare, operate and update this plan as necessary throughout the duration of the Works. The TMP shall conform to the requirements of the Statutory Authority or the NZTA, as applicable. The Contractor shall be fully and solely responsible for obtaining the prior TMP approvals and maintaining the TMP for the entire construction duration.

Vehicle movements may only take place during the hours of work stated elsewhere in this document.

The Contractor shall comply with all Resource Consent conditions related to traffic movements and control.

1.15.8 Archaeological Sites

Where archaeological artefacts have been identified as being present or likely to be present on the Site, they shall be identified in the Contract and, where possible, their approximate extent shall be shown on the Drawings. The Engineer will provide the Contractor with an Archaeological Site Management Plan (SMP) which identifies requirements for dealing with archaeological sites. The Contractor will follow the requirements of the SMP which shall outline procedures for managing the protection and/or the removal of archaeological artefacts from the Site.

If any unforeseen archaeological discovery (or suspected discovery) is made on Site, the Contractor shall cease work immediately and seek direction from the Engineer.

1.16 Contractor's Working Area, Site Access and Amenities

The Contractor shall confine their operations to within the Site boundaries shown on the Drawings. The Contractor's plant and materials shall not pass beyond these limits without the prior written approval of the Engineer.

The Contractor shall familiarise themselves with the Site conditions and access restrictions and determine the plant and equipment required to successfully construct the proposed Works and meet the requirements of this Specification.

The Contractor shall provide and maintain all necessary fencing around the perimeter of the Site prior to the Works commencing in order to prevent unauthorised entry by the public onto the Site.

The Contractor shall make appropriate arrangements for the provision of all services and amenities for the Works, including facilities for Site staff. These shall be located in a position within the Site boundaries. All Rubbish and wastewater shall be removed from the Site as appropriate on at least a weekly frequency.

1.17 Existing Services

The Contractor shall be responsible for verifying the location of any services present on the Site and shall take necessary steps to protect any existing services (that do not require removal or modification as part of the Works) to avoid disruption and/or damage to any services or utilities that may be affected by the construction of the Works.

All services, buried or otherwise (that are not scheduled for demolition), that are damaged by construction activities shall be reinstated by the relevant service authority at the Contractor's cost prior to demobilising from Site. Essential services shall be reinstated the same day if they are damaged.

1.18 Temporary Works Design

The Contractor is responsible for the design of all temporary Works, in particular the design of any retention systems or cut batters that are required to maintain stability of the excavation and prevent damage to adjacent buildings, structures, infrastructure and services that are located beyond the Site boundaries.

All temporary retention systems and temporary batters shall be designed with appropriate factors of safety for all construction load cases in compliance with the Building Code.

All retention systems and cut batters shall also consider deflection during all construction load cases and limit deflections as appropriate to prevent damage to adjacent buildings structures, infrastructure and services.

The Contractor shall nominate the person who is responsible for the design of temporary Works and shall supply their qualifications and experience in design of similar work to the Engineer.

1.19 Existing Subsoil Conditions

The Contractor shall undertake all necessary inspections and review and assess any factual geotechnical information or laboratory testing available for the Site or surrounding area included in the Contract Documents or from any other readily available source (such as the Canterbury Geotechnical Database) and take full account of such information in their rates, their proposed methodology and the choice of machinery to be used to construct the Works.

1.20 Unforeseen Underground Obstructions/Ground Conditions

The Contractor shall immediately contact the Engineer to receive further instruction, in the event that a significant unforeseen underground obstruction is encountered or where unforeseen ground conditions are encountered. Where the Contractor believes that such obstructions or ground conditions could not reasonably have been foreseen they shall prepare a variation claim and submit this to the Engineer before proceeding with any additional Works that the Contractor considers to be a variation.

1.21 Approved Materials

Where the Contract requires the Contractor to work in accordance with a given manufacturer's recommendations or requirements, the Contractor shall contact the manufacturer(s) and/or supplier(s) concerned, ascertain the relevant criteria, and, where appropriate, arrange for the manufacturer's representative to be on the Site while the relevant work is undertaken.

In all cases where a particular brand or product is specified, the Contractor may, subject to the approval of the Engineer, and at no additional cost to the Principal, substitute an alternative product or brand of the same kind, size and equal or better quality, provided that that the substitution fully meets the design intent and design life.

1.22 Advertising and Publicity

The Contractor shall not use (or cause to be used) any advertising or publicity material, photographs, notice boards or other media in connection with the Works without the prior written approval from the Engineer.

1.23 Demobilisation and Reinstatement

The Site shall be kept clean and tidy during the course of construction.

On completion of the Works, the Contractor shall remove all debris, temporary access or storage facilities, construction plant and materials no longer required.

1.24 As-built Documentation

Within ten working days of the Engineer's acceptance of completion of the Works, the Contractor shall supply to the Engineer, the as-built documentation identified below. The Contractor shall provide two colour hard copies and an electronic copy of all as built documentation.

1.24.1 As-built Drawings

The Contractor shall at all times maintain one full set of Drawings on the Site specifically for the purpose of recording as-built locations and details. All as-built information shall be clearly and legibly marked in red on this drawing set.

The Contractor shall supply to the Engineer a colour copy of the draft as-built drawings for review. The as-built drawings are to be finalised and issued by the Contractor within three weeks of receiving the Engineer's review comments.

The as-built drawings shall record any changes to the design including:

- 1 depth of excavations/undercut
- 2 subgrade improvement
- 3 depth, spacing or extent/diameter of ground improvement
- 4 material types
- 5 depth of Site-won Fill over ground improvement
- 6 depth of Topsoil
- 7 surface ground levels taken on a minimum 5m x 5m grid as well as any other additional points where there is a sharp change in levels so as to accurately record the final ground surface profile
- 8 location and levels of any services or infrastructure removed or replaced.

1.24.2 As-built QA/QC Records

The Contractor shall supply the following QA/QC information:

- 1 materials testing results/certificates
- 2 material quantity records, including records of quantities/percentage of additives (such as cement) added
- 3 laboratory suitability test and field verification test results
- 4 field verification test positions measured relative to two perpendicular property boundaries together with depth below the boundary ground level.

2 TESTING



2.1 Laboratory and Field Testing

All laboratory and field verification testing shall be performed by an IANZ-accredited testing organisation. All testing shall be in accordance with the latest available published version of the standard or procedure identified in the Specification.

Laboratory testing within the Specification is separated into 'mandatory' testing and 'discretionary' testing. The amount of discretionary testing shall be as instructed by the Engineer, after discussion with the Contractor, and shall be based on previous experience with similar materials. Where previous experience with similar materials is limited, the Engineer may instruct all or some of the discretionary testing to be undertaken to provide confidence that the material will be able to meet the requirements of this Specification. The tests listed as mandatory shall be undertaken for all sites and shall be paid for by the Contractor. Any discretionary testing instructed by the Engineer and not included in the Schedule of Prices shall be priced as a Variation.

The Specification, as far as is reasonable, also allows for 'recently' (undertaken within the previous three months) available testing (such as might be available from the quarry) to be used rather than requiring specific testing to be undertaken. Where such test information is not available or where such information is not representative of the proposed materials to be used on Site, then additional site specific testing will be required. The costs of such testing shall be paid for by the Contractor.

Where testing is undertaken in accordance with the Specification and such testing fails the minimum test criteria required by the Specification, then any subsequent retesting shall be paid for by the Contractor.

2.2 Cone Penetration Tests

The Contractor shall engage a suitably experienced Sub-contractor to undertake Cone Penetration Tests (CPTs). CPTs shall be electric cone type that use the weight of the machine to provide the reaction force. Where anchors are required to provide the reaction force to the CPT machine, the CPT contractor shall demonstrate that the anchors are sufficiently far away from the cone or that the investigation methodology is such that the anchors have no influence on the CPT results.

The CPT shall be undertaken and reported in accordance with ASTM standard D5778-12. The CPT Sub-contractor is to be approved by the Engineer prior to engagement.

CPT results shall be reported to the Engineer in electronic format as provided by the CPT Sub-contractor within 48 hours of the tests being completed. The results shall include a copy of the current cone calibration certificate and report of zero load readings for tip resistance, sleeve friction and pore water pressure.

2.3 Standard Penetration Tests

Standard Penetration Tests (SPTs) are to be performed at 1.5m intervals or as required by the Engineer in machine drilled boreholes in accordance with ASTM standard D1586 and as described below.

Split spoon SPT samplers are to be used in all soils, including coarse soils unless otherwise instructed or agreed with the Engineer.

SPT results are to be recorded by the Contractor as the number of blows for each 75mm of penetration, followed by the uncorrected SPT-N value (eg 3/2/3/5/4/3, N=15). In the instance where a refusal of penetration is reached the amount of penetration for the current test increment must be recorded as blows over penetration in mm (eg 15 blows/40mm). All measurements are to be recorded in millimetres.

Sub-contractors shall provide the Engineer with a current, measured hammer efficiency for the SPT hammer being used. SPT hammer efficiency testing is to be conducted in accordance with ASTM D4633-10⁸.

⁸ ASTM D4633-10, Standard test method for energy measurement for dynamic penetrometers, ASTM International

2.4 Dynamic Probe Heavy

There are numerous types of heavy dynamic probing (DPH) machines with variations on the drop weight, drop distance, cone type and diameter etc. The Contractor shall seek the Engineer's approval of the type of DP testing that is proposed to be used. Sufficient correlation data is required to enable the data obtained to be able to be converted to an equivalent SPT N-value.

The most common type is the Dynamic Probing Super Heavy-B (DPSH-B). This category specifies an approximately 63.50 kilogram weight to be dropped over a 760mm drop height and blows recorded over 100mm increments. Rods and cone dimensions are also specified. All DPSH-B testing should be completed in accordance with the recommendations and requirements stipulated in British Standard BS EN ISO 22476-2.

The Contractor shall provide the Engineer with a measured hammer efficiency. As there is no published standard specifically for measuring the hammer efficiency of a Dynamic Probe rig, the Contractor shall use and adapt the ASTM method for SPT hammers as covered above.

3 EARTHWORKS

3.1 Earthworks Inspection

The Contractors programme shall allow for the earthworks inspections described in this Specification.

Before any cut is commenced or fill placed in any area, the Engineer shall be notified in order to inspect the stripped surface and instruct whether further excavation/undercutting or other ground improvement work such as underfill drainage, geogrid, subgrade stabilisation, etc, is required. No cut or fill earthworks shall be undertaken in an area until such inspections of the stripped surface, and any other work that may be required below the stripped surface, have been completed.

The Contractor shall allow sufficient time for any necessary as-built subsurface and surface inspections and/or testing and shall programme operations to provide drainage, access and survey control so that any further work instructed prior to any filling can be carried out in an orderly manner without delay or damage to the Works.

The surface of all earthworks areas shall be maintained in its approved condition until filled over. Where there is a delay of more than 24 hours between approval of a stripped area and placement of fill, or if rainfall has deteriorated the stripped area, the Contractor shall advise the Engineer. The Engineer shall decide whether a re-inspection of the affected surface/layer is required.



3.2 Groundwater and Surface Water Control

All earthworks shall be carried out in fully drained conditions with no free water on the working surfaces. All preparatory excavation work and subsequent excavations or areas to be filled shall be kept effectively drained at all times. All cut and fill areas shall be sloped and graded adequately at all times so that they do not pond water or allow water to infiltrate. Temporary drains shall be installed or pumping carried out as necessary on a regular basis to remove or deflect surface water from the areas of operations.

Where work is undertaken below the groundwater table, appropriate groundwater control measures (eg sheetpiling and pumping) may be required in order to draw down the groundwater table sufficiently below the working surface so as to permit plant movements and compaction operations on the working surface without causing the upwards pumping of groundwater and strength degradation of the subgrade.

All excess water (surface or groundwater) shall be diverted to an appropriate sediment control system (refer to section 1.15.2) before discharge from the Site.

Any fill or final excavation surface materials that have been allowed to become too wet or soft shall be removed and dried, stabilised or replaced. All fill surfaces shall be graded and rolled at the end of each day to prevent any

ponding and erosion. Prior to commencement of the day's filling operations, any previously softened material shall be removed or the previously graded and rolled surface shall be scarified by approved plant and the material reworked to prevent formation of sub-standard, or weak layers within the fill.

3.3 Clearing and Stripping

3.3.1 Clearing of Vegetation and Obstructions

Except where instructed otherwise by the Engineer, the Contractor shall remove from the Site all vegetation within the area of earthworks and shall clear all obstructions from the area of the Works. Clearing shall mean the removal of all organic growth (other than grass and weeds), the extraction of stumps, the removal of all other items remaining above the surface of the ground (such as fence posts), and the off-site disposal of all such items. Extraction of stumps (if any) shall remove all roots greater than 25mm diameter. The removal of surface grass and weeds shall be completed as part of the Topsoil stripping operation.

3.3.2 Topsoil Stripping

All turf and organic Topsoil shall be stripped from the areas subject to earthworks before any earthwork operations commence in these areas.

Except where limited by boundaries, existing works or other limiting features, stripping shall extend 0.5m beyond the limits of areas subject to earthworks or ground improvement. The Contractor shall co-operate with the Engineer ahead of, and during stripping operations, to determine the stripping depth and shall avoid unnecessary over-excavation.

Topsoil stockpiles shall at all times be kept separate from stockpiles of other materials. The Contractor shall manage stockpiles to minimise mixing of Topsoil with other materials and allow maximum reuse on the Site. No Topsoil is to be removed from the Site without the prior approval of the Engineer.

3.3.3 Site-won Fill Material

All fill material which is currently present on the Site and assessed by the Engineer as suitable for re-use as Site-won Fill shall be stripped and stockpiled on the Site before any bulk excavation or ground improvement treatment operations commence in these areas.

Site-won Fill stockpiles shall at all times be kept separate from stockpiles of other materials. Stockpiles shall be appropriately managed so as to avoid degradation of the material intended for use in the Works. No material suitable for re-use as Site-won Fill is to be removed from the Site without the prior approval of the Engineer.

All Unsuitable materials shall be disposed off-site or as directed by the Engineer. All Unsuitable material shall be classified as such by the Engineer prior to excavation or removal from Site.

3.4 Excavations

3.4.1 General

All excavations that are necessary to enable the ground improvement Works to be completed shall be carried out to the dimensions, batters, lines and levels detailed on the Drawings. Under no circumstances shall excavation be allowed to extend beyond a Site boundary without prior written approval from the Engineer.

The Contractor shall avoid over excavation beyond the limits shown on the Drawings, unless agreed with the Engineer, due to the risk of damage to surround infrastructure and structures.

The Contractor shall be responsible for all costs and consequences associated with unsatisfactory performance and/or failure of a temporary batter slope or temporary retaining structure.

All excavations are to be undertaken in accordance with *The Approved Code of Practice for Safety in Excavations and Shafts for Foundation*⁹. The stacking of excavation material close to excavated faces should be avoided where this would have a de-stabilising effect on the excavation.

3.4.2 Excavation Management

All cut areas shall be progressively excavated to form a uniformly graded surface within the batter limits. The Contractor shall construct the excavations in a logical and orderly manner to minimise wastage and shall undertake continuous visual inspections of materials as they are excavated. Any unexpected variations in material types or properties, or observations of buried vegetation, groundwater flows or seepages, shall be immediately reported to the Engineer.

⁹ Occupational Safety and Health Service, Department of Labour (now WorkSafe New Zealand)

All earthworks operations shall be managed so that appropriate materials are stockpiled and used for the various fill types shown and specified in the Contract Documents and/or Drawings. The Contractor shall plan the earthworks carefully so as to optimise the use of all Site-won Fill materials.

Where unprotected exposed earthworks surfaces (including material stockpiles) may result in degradation (such as loss of strength due to increased moisture content), such surfaces shall be protected by suitable means (such as by sealing by rolling with rubber tyre plant) when rain is imminent.

3.4.3 Subgrade Preparation

The Contractor shall excavate down to the subgrade level and stockpile Site-won Fill material for reuse on Site or dispose of excess or Unsuitable materials off-site as shown on the Drawings or as instructed by the Engineer. The subgrade shall then be inspected by the Engineer and Contractor (and tested where required) to determine if it is suitable to allow the ground improvement Works to be undertaken. Where the subgrade is deemed unsuitable by the Engineer or of insufficient strength by the Contractor to allow construction plant to adequately place and construct the ground improvement works above the subgrade, the Engineer and the Contractor shall agree the most suitable and practical method to use in order to bring the subgrade to within minimum specified criteria or minimum strength to allow the construction plant to adequately place and construct the ground improvement works above the subgrade. Subgrade testing shall be undertaken by using hand held equipment such as shear vanes or Scala penetrometers. Subgrade testing shall be included by the Contractor in the cost of the subgrade preparation.

The Contractor shall make good any areas of the unsuitable subgrade, as instructed by the Engineer, by a method agreed with the Engineer (eg stabilisation, undercut and replacement, geogrid/geotextile placement etc.).

New fill shall not be spread over surfaces (subgrade and subsequent fill layers) that have deteriorated from their specified and/or approved condition. Where necessary and appropriate, the old surface shall be scarified, conditioned, and re-compacted before placing new fill.

The Contractor shall be responsible for all costs associated with subgrade improvement that is the result of insufficient drainage control, insufficient protection of the subgrade from rain or trafficking plant which causes deterioration of the subgrade.

3.5 Filling

3.5.1 General

The Contractor shall take all precautions and maintain a tidy operation to minimise the presence of any loose, excavated materials that could become wet during rain. The Contractor shall also ensure that all fill is free of organic matter or other Unsuitable materials.

3.5.2 Placement and Compaction of Fill Material

All fill material shall be brought to an appropriate water content prior to compaction by drying and/or blending as is necessary. Each layer shall be compacted to the minimum strength and density requirements detailed in this Specification. Where wet and dry fill is blended to achieve suitable average water content, the blended fill must be mixed thoroughly before it is compacted.

Soil fill shall be broken up into lumps of less than 80mm size and shall be spread uniformly in layers with 200mm maximum loose placement thickness. Hardfill aggregates shall be placed in uniform layers not less than 2.5 the maximum particle size and not exceeding 200mm maximum loose thickness.

Allowances should be made by the Contractor for specialised mixing, blending and/or compaction equipment where necessary. Equipment used in fill transportation and spreading shall not be permitted as compaction equipment. Compaction plant shall cover the entire area of each layer of fill and give each layer a uniform degree of compactive effort. The Contractor shall interrupt their operations as necessary to permit the Engineer to carry out inspections and/or control tests on the fill.

Drainage zones, if shown on the Drawings, shall be placed and compacted without segregation and at all times shall be protected to avoid silt laden water, soil and other materials entering the drainage zones/materials.

The Contractor shall employ appropriate compaction equipment to achieve the specified minimum in-situ density and/or strength test criteria without degrading the fill material.

Where fill batters are required to be constructed above existing ground level then the outside batter profiles shall be overfilled as necessary and trimmed to final profile to ensure full compaction.

3.5.3 Nuclear Densometer Testing

In-situ density field tests may be completed by the 'Rapid¹⁰' method offered by a nuclear densometer provided that an appropriate correlation has previously been established for each soil material type between the bulk density obtained by the particular densometer and the bulk density obtained by the 'Fully specified¹¹' method.

Preliminary density and air voids tests results may be calculated immediately after testing, by assuming a value of the soil water content derived by applying a correction to the nuclear densometer water content. Oven moisture content (NZS4402, Test 2.1) must however be done in order for the final moisture content and final density and air voids ratio to be determined.

Nuclear densometer results will be affected by cement or lime added to the soil. When using cement or lime, a specific correlation/calibration adjustment will need to be developed based on oven dried moisture contents and the percentage of cement or lime added.

3.5.4 The Hardfill Plateau Density Test Procedure

The Hardfill plateau density field test procedure is as follows:

- 1 A suitable roller for the Plateau Density Test shall be agreed with the Engineer. For guidance on suitable roller types, maximum and minimum sizes and vibration frequency, refer to the NZTA specification TNZ B/02, *Notes for the Specification of Construction of Unbound Granular Pavement Layer*.
- 2 The Hardfill shall be given a minimum number of passes with a smooth drum vibratory roller to provide a smooth surface.
- 3 Two locations for density testing (using a nuclear densometer) shall be marked on the smooth surface with paint to allow accurate positioning of the instrument.
- 4 An initial density measurement shall be taken and the moisture content checked to confirm it is at the Optimum Moisture Content (OMC).
- 5 The material is then given a number of passes with the vibratory roller and the density is re-measured at the previously marked locations.

- 6 Step 5 is repeated until the measured density, when plotted against the recorded number of passes, reaches a clear plateau, while the material is held at OMC.
- 7 The final surface is then rolled a minimum of four static passes with the vibration turned off and the density re-measured.
- 8 The maximum dry density measured for the material is the maximum field dry density (field MDD) for the material.

3.5.5 Imported Soil Fill

Where imported soil fill is required it should generally be provided from a single source able to provide material of a consistent type and quality and with sufficient volume of material to sustain the Contractor's proposed Works programme. Where the Contractor proposes to import fill approval shall be sought from the Engineer before delivery to the Site.

Testing of proposed Imported Fill, as detailed in this Specification, shall be completed at source with samples taken from in-situ cut or from the current stockpile. If requested, the Contractor shall arrange for the Engineer to view the proposed fill materials at source.

If requested by the Engineer, the Contractor shall provide all necessary certificates or testing to the satisfaction of the Engineer to demonstrate that the proposed imported fill complies with the Resource Management (National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health) Regulations 2011. Costs for such testing shall be paid for by the Contractor.

Two 25kg bags of Engineer-approved materials shall be kept on the Site by the Contractor throughout the duration of the Works as a 'reference' for subsequent materials being delivered to the Site.

Additional tests during the construction of the Works shall be carried out by the Contractor at source and/or on delivery of materials to the Site at the Contractor's cost if, in the opinion of the Engineer, the consistency of the Imported Fill material varies from that indicated by the initial source testing.

10 NZS 4407: Test 4.2.1. (Nuclear Densometer Direct Mode) or NZS 4407:Test 4.2.2 (Nuclear Densometer Backscatter Mode)

11 NZS 4402:Test 5.1.1, 5.1.3 (Sand replacement or core cutter)

3.6 Surface Protection and Maintenance

The Contractor shall protect all approved subgrade surfaces from the effects of weather and groundwater seepage, prior to any undercut treatment and/or fill placement.

In addition, the Contractor shall maintain all earthworks, including all finished surfaces as well as partly completed earthworks, so they remain within the relevant specified standard, and shall make good, at their own cost, any earthworks which have deteriorated below the specified standards, until handover to the Principal.

If the surface of any areas becomes damaged or deteriorates prior to placement of additional layers then the affected area should be scarified, reshaped, replaced, re-compacted or otherwise treated and retested until the requirements of this Specification are met.

The Contractor shall carry out the Works so as to minimise passage of construction plant over areas of fill or cut formed to final profiles. Areas of fill or cut that are softened or otherwise damaged due to repeated passage of construction plant shall be undercut and replaced at the Contractor's cost. The Engineer shall inspect and approve the depth and extent of any such undercutting and the requirements for the replacement materials.

3.7 Earthworks Tolerances

All earthworks shall be carried out to the lines, levels and grades shown on the Contract Drawings or as otherwise instructed by the Engineer. Final levels shall be constructed to $\pm 50\text{mm}$ of the original ground surface or specified levels shown on the Drawings.

All finished earthworks surfaces shall exhibit a uniform line and level, be of a neat and regular shape and be free of any abrupt irregularities.

3.8 Earthworks Stockpiles

All stockpiles shall be constructed to be free-draining and with overall grades and profiles which avoid ponding and minimise erosion.

All stockpiles shall be managed and sufficiently separated so as to avoid intermixing of materials and allow maximum re-use on the Site.

Stockpiles shall be set back an appropriate distance from property boundaries to avoid settlement of neighbouring property; and from open excavations or slopes or so as to avoid increasing the risk of instability beyond acceptable limits.

All stockpiles considered Contaminated shall be managed in accordance with the Ground Contamination Site Management Plan (refer to section 1.15.5) and as a minimum shall be covered with geotextile or polyethylene. Geotextile or polyethylene shall also be placed beneath the stockpile to prevent contamination of underlying clean materials.

3.9 Temporary Haul Roads and Hardstands

The construction and use of haul roads shall not compromise the construction and future integrity of the permanent Works. The footprint of all haul roads and temporary hardstands shall be stripped of Topsoil and organic materials.

3.10 Geogrid and Geotextile

All geogrid and geotextile reinforcements shall be stored as per the manufacturer's recommendations so as to prevent degradation of the strength of the reinforcements due to exposure to UV light. Any components which is in any way damaged or fails to meet the specified requirements shall not be used.

The Contractor shall handle and store all geogrid and geotextile materials in accordance with the manufacturer's recommendations and good practice.

Geogrid and geotextile reinforcements shall be placed in accordance with the manufacturer's recommendations. Geogrid and geotextile reinforcements shall be placed at the levels, spacing and the appropriate strength (or Grade/Type) shown on the Drawings or as instructed by the Engineer.

Construction procedures shall comply with the following:

- 1 The geogrid and geotextiles shall be placed in structurally continuous, longitudinal strips within 75mm of the design elevation and extent shown on the Drawings. Mono directional geogrid shall be oriented with the highest strength axis in the direction of load application and as shown on the Drawings.
- 2 The geogrid and geotextile strips shall be laid horizontally on the compacted backfill. A layer of backfill shall then be placed, sufficient to stabilise the geogrid, and the geogrid tensioned, one reinforcing strip at a time, using a tensioning beam inserted into the apertures in the free end of the grid. Alternatively U-shaped pins can be used to stabilise the tensioned geogrid.
- 3 The geogrid and geotextile shall then remain tensioned while the balance of the backfill is placed and compacted up to the level of the next geogrid layer.
- 4 Geogrid reinforcement strips shall be placed side-by-side, with no gaps, so as to provide 100% coverage at each level. The position of the boundaries between geogrid strips shall be such that they are staggered between adjacent layers and do not have the boundaries aligned vertically. Bodkins may be used (in accordance with the manufacturer's recommendations) for longitudinal joining of uniaxial geogrid. A suitable overlap as specified by the manufacturer (or as otherwise shown on the drawings) shall be used for joining other geogrid or geotextile materials. Plastic ties are to be used to hold adjacent geogrid strips together while placing fill over.
- 5 Under no circumstances shall any vehicle or compaction plant be allowed to come in direct contact with the geogrid or geotextile. At least 150mm of backfill shall be placed over a particular geogrid or geotextile layer before any vehicle or compaction plant is allowed over the top. Turning of tracked vehicles on this fill should be kept to a minimum to prevent tracks from displacing the fill and the geogrid/geotextile.
- 6 Backfill shall be spread along the geogrid strips using mechanical plant such as an excavator bucket, or similar, which causes the fill to cascade onto the geogrid/geotextile in the same direction as tensioning. The placement or compaction process shall not disturb the alignment and level of the tensioned geogrid/geotextile.
- 7 Minimum vertical spacing between geogrids shall be 150mm.

4 DENSIFIED CRUST

4.1 General

This section covers the work necessary to excavate and fill to the required levels, grades and standards for construction of the Densified Crust ground improvement option. Densified Crust may be constructed from imported Hardfill, Imported Soil Fill or re-compacted Site-won material, together with geogrid reinforcement.

The main activities associated with the Densified Crust construction include:

- 1 clearing the Site
- 2 stripping existing Topsoil to stockpile
- 3 excavation and temporary stockpiling of existing soils (Site-won material) or removal of soils off-site to the depth specified on the Drawings or as instructed by the Engineer
- 4 placing and compacting imported Hardfill, Imported Soil Fill or Site-won Fill material with geotextile and geogrid reinforcement as shown on the Drawings
- 5 verification testing and QA documentation
- 6 re-spreading of Topsoil to finished ground level
- 7 any necessary groundwater control and temporary support of excavations.

Where soft subgrade conditions are encountered at the base of the Densified Crust to the extent that it is not considered to remain stable (non yielding) under the action of compaction plant, some form of subgrade improvement or 'subgrade bridging' will be required to

allow the Densified Raft to be constructed. A number of alternative subgrade improvement techniques, available to be used are listed below. The most appropriate method and degree of improvement, which suit the Site conditions, shall be agreed with the Engineer before proceeding.

- Additional subgrade undercut and replacement with compacted crushed rock or crushed concrete to create a working platform.
- Geofabric and geogrid placed over the subgrade, to provide both a separation and bridging layer to the soft subgrade.
- Cement-binder added into the subgrade or first layer of fill.
- Dewatering of the subgrade.

During excavation any organic material encountered shall be reported to the Engineer and shall not be used in formation of the Densified Crust.

Where it is necessary to construct the Densified Crust in separate sections, strips or panels, additional care is required at the vertical edge joins to produce a homogenous Crust without compromising the compaction integrity across the joins. The join shall be formed by cutting into the previously compacted zone with a maximum of 300mm high steps to form a join at an angle of 1.5 horizontal to 1.0 vertical.

Refer to section 3 for earthworks requirements for soil and Hardfill materials.



4.2 Set out and Tolerances

The Densified Crust shall be installed so as to meet the following construction tolerances:

- Horizontal location: $\pm 100\text{mm}$
- Vertical extent (depth): $\pm 50\text{mm}$

More precise tolerances may be required where ground improvement Works are close to existing building foundations, services, other structures or infrastructure.

4.3 Inspection, Review and Approval Hold Points

The Contractor's programme shall allow for inspection, review and approval hold points as detailed in Table 4.1 below and as described elsewhere in this Specification.

Table 4.1: Densified Crust Inspection, Review and Approval Hold Points

HOLD POINT			RESPONSIBILITY
No.	NAME	DESCRIPTION	
1	Contractor's CMP	The Contractor shall submit a detailed Construction Management Plan to the Engineer, as outlined in in Section 1.8.1, prior to mobilising any specialist machinery to the Site.	Engineer to review
2	Material Suitability	The Contractor shall submit for the approval of the Engineer the laboratory suitability test results for each type of material that is expected to be incorporated into the Works as required by this Specification. The Engineer will review and approve the laboratory test results against the requirements of this Specification. No bulk excavation or import of proposed fill materials to the Site shall commence until the Engineer has confirmed the suitability of the proposed materials.	Engineer to review and approve
3	Temporary Batters, Retaining Structures and Groundwater Control Measures	The Contractor shall review and be responsible for the temporary works, including batter slopes/retaining structures and groundwater control measures. The suitability of the as-built temporary batter slopes/retaining structures and groundwater control measures shall be monitored by the Contractor as the Works are progressed. These shall be adjusted, as necessary, to allow the Works to be completed in accordance with this Specification.	Contractor
4	Excavation Subgrade	The base of the excavation shall be inspected by the Engineer prior to being surveyed by the Contractor. The Engineer shall confirm the extent of any undercutting of Unsuitable subgrade materials or additional subgrade improvement Works that may be required.	Engineer to inspect and approve/instruct
5	Crust Construction General	The construction of the Densified Crust shall be observed by the Engineer on a regular basis during the construction period to check compliance with the Specification and Drawings. Such observations should generally be done together with the Contractor. The frequency of observations shall be determined by the Engineer depending on the size, importance, complexity of the project together with their assessment of the Contractor's track record and experience.	Engineer to observe
6	Quality Assurance Tests	The Contractor shall submit for the ongoing review of the Engineer, copies of all imported fill source and Site suitability laboratory testing and on-going in-situ field test results.	Engineer to review
7	Completion of Densified Crust	The surface of the Densified Crust shall be inspected and approved by the Engineer after completion, prior to re-spreading of Topsoil (where required).	Engineer to inspect and approve
8	Final Surface	The final surface shall be inspected and approved by the Engineer after re-spreading of Topsoil.	Engineer to inspect and approve

4.4 Hardfill Material Suitability and Reference Testing Requirements

4.4.1 General

This section sets out the material suitability the reference testing requirements where hardfill aggregate or crushed gravels are to be used for construction of Densified Crusts. (such as Type G1d reinforced crushed gravel rafts in MBIE Guidance Document, section 15.3).

The following Hardfill aggregate approval procedure shall be followed:

- 1 Contractor to advise Engineer of the proposed Hardfill aggregate source.
- 2 Contractor to supply a sample of the proposed Hardfill aggregate to the Engineer. Samples of the proposed aggregate stone shall be obtained from stockpiles at source and/or stockpiles of materials delivered to Site, as directed by the Engineer.
- 3 Suitability tests as outlined below to be provided by the Contractor to the Engineer no less than five working days prior to their required use in the Works.
- 4 Engineer to confirm suitability of proposed Hardfill aggregate, prior to start of Densified Crust construction.

Hardfill aggregate shall be free of deleterious and organic material.

Hardfill aggregate to be used for the Densified Crust (type G1d reinforced crushed gravel rafts) shall either be TNZ M/4 40mm aggregate or a crushed AP40 or AP65 aggregate complying with the following suitability test criteria.

4.4.2 Suitability Test Requirements for AP40 & AP65

The following suitability laboratory testing shall be undertaken by the Contractor for all AP40 & AP65 Hardfill materials proposed to be used for the Densified Crust construction prior to the commencement of construction.

4.4.2.1 Aggregate Broken Face Content

The aggregate broken face content of imported Hardfill material shall not be less than 70% by weight, and shall have two or more broken faces, between 19mm and 63mm sieve sizes. This test shall be undertaken in accordance to NZS 4407: Test 3.14 Broken Face Test.

4.4.2.2 Grading

The Hardfill aggregate is to have a grading which falls within the limits defined in Table 4.2 below or shall meet the Christchurch City Council Civil Engineering Standard Specification grading curves for 'CCC AP65' or 'CCC Stabilised AP40', when tested in accordance with NZS 4407: Test 3.8.1, *The Particle Size Distribution – Preferred Method by Wet Sieving*.

Material grading curves may, at the discretion of the Engineer, be obtained from quarry records supplying the proposed aggregate, if 'recent' testing is available for the proposed aggregate.

Where the Engineer considers that the available grading information is not representative of the proposed aggregate to be used or where the Contractor is having difficulty in achieving the required minimum density, the Engineer may instruct the Contractor to supply additional grading curves. It should be noted that a suitably well graded material is required in order to achieve the required compacted density.

Table 4.2: Hardfill Grading Envelopes

APERTURE SIZE (mm)	PERCENTAGE PASSING BY WEIGHT	
	GAP65	GAP40
63.0	100	100
37.5	65–80	100
19.0	40–60	66–81
9.50	25–45	43–57
4.75	15–35	28–43
2.36	10–25	19–33
1.18	7–20	12–25
0.60	5–15	7–19
0.30	3–12	3–14
0.150	2–10	0–10
0.075	0–5	0–7

4.4.2.3 Crushing and Weathering Resistance

Weathering and crushing resistance tests may be obtained from quarry records supplying the material, if 'recent' and representative testing is available. Once the sample of the material has been provided, the Engineer shall decide if project specific Crushing Resistance testing and/or Weathering Resistance testing is required. In many cases the Engineer will be able to approve the use of the aggregate without the need for project specific tests, based on previous experience and quarry records. However where the Engineer considers that the available test information is not representative of the proposed aggregate, where available testing is not 'recent' or there is risk that it will not meet the minimum Crushing and Weathering Resistance criteria, then the Engineer will instruct the Contractor to undertake Crushing and Weathering Resistance tests for actual aggregate proposed to be used.

Aggregate shall be a hard rock aggregate which is not subject to strength degradation over time. The minimum crushing resistance shall not be less than 120kN for GAP65 and GAP40, when the aggregate is testing according to NZS4407: Test 3.10, *The Crushing Resistance of Coarse Aggregate under a specific load*.

An aggregate will be considered to have met this criterion if the sample produces less than 10% fines when loaded so that the specified peak load is reached in 10 minutes. In this case the test shall follow the standard method in all other respects.

In addition the aggregate shall have a quality index of AA, AB, AC, BA, BB or CA when tested according to NZS 4407: Test 3.11, *The Weathering Quality Index of Coarse Aggregate*.

4.4.3 Hardfill Reference Test Requirements

The following reference testing shall be undertaken for all Hardfill aggregate proposed for use in the Densified Crust.

4.4.3.1 Solid Density

Solid density tests may, at the discretion of the Engineer, be obtained from quarry records supplying the Hardfill aggregate if 'recent' testing information is available for the proposed aggregate and previous testing demonstrates that the solid density is not highly variable.

The solid density of the material shall be determined in accordance with NZS 4407: Test 3.7.

4.4.3.2 Maximum Dry Density

In reference to Table 4.5, it is noted that the minimum requirement for in-situ density testing of Hardfill can either be set using a minimum percentage of the solid density or by a minimum percentage of the maximum dry density (MDD) as determined by the test method listed below. The intention is that these two testing criteria require the same field density to be achieved. The solid density method is however simpler and avoids the need to undertake the MDD test. However the Contractor may choose to test in accordance with the minimum percentage of MDD, in which case, the laboratory MDD test will need to be undertaken.

The MDD of the Hardfill material shall be determined in accordance with NZS 4402: Test 4.1.3, *Determination of the Dry Density/Water content relationship, using Vibratory Hammer Compaction*.

Where the minimum density, determined either by percentage of solid density or percentage of MDD from laboratory testing ('Lab MDD'), cannot be reasonably achieved, the Contractor may request that the maximum field MDD be determined by using the Plateau Density Test as described in section 3.5.4. This shall be referred to as the 'field MDD'. Where agreed by the Engineer, the 'field MDD' may then be used for verification purposes as the MDD in Table 4.5. The Plateau Density Test shall be paid for by the Contractor.

4.5 Site-won and Imported Soil Fill Material Reference and Suitability Testing Requirements

Where sufficient experience and local knowledge of the use of certain soil material exists, it may not be necessary to undertake any pre-construction material reference or suitability testing for the construction of the Densified Crust using soil fill. Where local knowledge and experience is limited or there is doubt over the suitability of the soil fill material, then the Engineer may require some or all of the testing identified in Table 4.3. Where instructed, the Contractor shall undertake the required tests to confirm suitability of the material for use prior to the start of construction.

Table 4.3: Discretionary Material Testing for Site-won and Imported Soil Fill

TEST DESCRIPTION	TEST METHOD	INDICATIVE NUMBER OF TESTS PER RESIDENTIAL SITE
Organic Content by mass loss ignition	NZS 4402:Test 3.1.2	2
Dry Density/Moisture Content relationship with CBR or Shear Vanes ⁽¹⁾ on natural soils	NZS 4402: Test 4.1.1 (Standard Compaction) with CBR or laboratory Shear Vane testing undertaken at each moisture content tested.	2
Particle size distributions	NZS 4407:Test 3.8.1 The Particle Size Distribution – Preferred Method by Wet Sieving	2

Notes:

- 1 Shear vane testing shall be undertaken where the material type, as defined by NZ Geotechnical Society publication, *Guideline for the Field Classification and Description of Soil and Rock for Engineering purposes*, is classified as 'cohesive'.

Soil fill material shall have less than 5% organic content.

The testing detailed above shall be completed on a mixed representative sample taken from three large bulk samples spread across the full extent of the Site. Where the Contractor proposes to blend Site soils with Imported Fill, the requirements of this section shall relate to the blended material.

All laboratory test results shall be reported to the Engineer within two days of completing the tests.

For Imported Soil Fill material, additional tests shall be carried out by the Contractor during the Works at source and/or on materials delivered to the Site if, in the opinion of the Engineer, the consistency of the Imported Soil Fill material varies from that indicated by the initial source testing. Refer to section 3.5.5 for additional Imported Soil Fill requirements. Such additional testing shall be paid for by the Contractor.

Two 25kg bags of Engineer-approved materials shall be kept on the Site by the Contractor throughout the duration of the Works as a 'reference' for subsequent materials being delivered to the Site.

4.6 Permanent Works Testing Requirements

4.6.1 Verification Test Methods and Frequencies

The Contractor shall undertake in-situ testing (type and frequency) in accordance with Table 4.4 below.

All in-situ density tests shall be undertaken on a staggered grid pattern across the plan extent of the Densified Crust. The Contractor shall make every effort to make certain an even spread of test locations, both vertically and horizontally, through all fill areas. Details of testing location, layer depth, test pass or fail, and if the test is a re-test shall be recorded. Test positions shall be recorded to 0.3m accuracy of position and 0.1m accuracy of level, or as otherwise approved by the Engineer.

All holes associated with the as-built testing programme which are larger than 50mm diameter shall be backfilled with a clean sand or recompacted fill.

The Contractor shall control the earthworks operations so as to minimise the failure rate of any tests carried out as part of the Quality Assurance (QA)/Quality Control (QC) testing programme. Should any test result fail to meet the required design criteria, the Contractor shall propose appropriate remedial measures. Such measures are expected to comprise the additional compaction or removal, replacement and satisfactory re-testing of any fill within an area of influence of the failed test location. The extent of rework shall be as instructed by the Engineer.

For Hardfill placement, where the certifying Engineer has sufficient experience in the use of a particular material and where sufficient history of density testing of material with particular plant, water content, and layer thickness has been established, then it may be possible for the

Engineer to specify a Method Specification based on a minimum number of passes under a specific roller weight with reduced testing requirements. This shall be at the Engineer's discretion.

Table 4.4: Minimum Densified Crust Verification Testing Schedule

PARAMETER	TEST DESCRIPTION	TEST METHOD	MINIMUM TEST FREQUENCY
HARDFILL MATERIAL			
In-situ Density⁽¹⁾	'Fully Specified' Method or 'Rapid' Method ⁽²⁾	NZS 4402:Test 5.1.1, 5.1.3 (Sand replacement or core cutter); or NZS 4407:Test 4.2.1 (Nuclear Densometer Direct Mode); or NZS 4407:Test 4.2.2 (Nuclear Densometer Backscatter Mode)	Undertake tests at 600mm vertical intervals with 1 set of tests per 50m ² but with at least 3 set of tests per interval.
Strength	Impact Test ⁽³⁾ (Clegg or similar)	ASTM D5874	
SOIL MATERIAL			
Air Voids⁽¹⁾	'Fully Specified' Method or 'Rapid' Method ⁽²⁾	NZS 4402:Test 5.1.1, 5.1.3 (Sand replacement or core cutter); or NZS 4407:Test 4.2.1 (Nuclear Densometer Direct Mode)	Undertake tests at 600mm vertical intervals with 1 set of tests per 50m ² but with at least 3 set of tests per interval.
Strength	Undrained Shear Strength ⁽³⁾	Hand Held Shear Vane with corrected undrained shear strength determined in accordance with NZ Geotechnical Society Inc., <i>Guideline for hand held shear vane test</i>	
	DCP ('Scala') Test	NZS 4402:Test 6.5.2	Undertake tests at 600mm vertical intervals with 1 test per 50m ² but with at least 3 tests per interval.

Notes:

- 1 In-situ density and air voids content of the compacted soil at any test location shall be taken as the mean of a set of tests. A set of density tests shall comprise 2 measurements using the same probe hole but orientated at 90 degrees to each other.
- 2 Refer to sections 3.5.3 and 4.4.3.2.
- 3 Impact test and undrained shear strength of the compacted soil at any test location shall be taken as the mean of a set of tests, comprising 3 tests undertaken within an area of 0.5m² of each other.

4.6.2 Verification Test Criteria

The as-built Densified Crust shall meet the criteria stipulated below in Table 4.5.

Table 4.5: Minimum Densified Crust Verification Test Criteria

TEST DESCRIPTION	HARDFILL MATERIAL ⁽¹⁾	SOIL TYPE ^{(2)&(3)}	
		Non-cohesive (Sands and fine Gravels)	Cohesive (Silts and Clays)
In-situ density	Minimum average of 92% of maximum dry density as determined by the vibratory hammer compaction test ⁽⁴⁾ . Minimum single test of 90%; or Minimum average of 82% of solid density with a minimum single test of 80% of solid density.	Minimum average of 92% of maximum dry density as determined by the vibratory hammer compaction test ⁽⁴⁾ . Minimum single test of 90%; or Minimum average of 95% of maximum dry density as determined by the standard compaction test ⁽⁵⁾ . Minimum single test of 92%; or Minimum average of 82% of solid density with a minimum single test of 80% of solid density.	Use air voids and undrained shear strength criteria listed below; or Minimum average of 95% of maximum dry density as determined by the standard compaction test ⁽⁵⁾ . Minimum single test of 92%.
Impact Test (IV)	Minimum Average 20. Minimum Single 15.	N/A	N/A
Air Voids	N/A	N/A	Maximum Average 8%. Maximum Single 10%.
Undrained Shear Strength	N/A	N/A	Minimum Average 140kPa. Minimum Single 120kPa.
DCP ('Scala') Test	N/A	Minimum average of 7 blows/100mm. Minimum single value of 5 blows/100mm. (A lower standard may be approved by the Engineer for the upper 100mm 'unconfined' surface).	N/A

Notes:

- 1 Based on 1.2m thick Densified Crust (constructed of compacted Hardfill) as per the MBIE Guidance Document.
- 2 Based on 2.0m thick Densified Crust (constructed of compacted soil fill) as per the MBIE Guidance Document.
- 3 Soil type as defined by NZ Geotechnical Society publication, *Guideline for the Field Classification and Description of Soil and Rock for Engineering purposes*.
- 4 NZS 4402: Test 4.1.3 Determination of the Dry Density/Water content relationship.
- 5 NZS 4402: Test 4.1.1 Determination of the Dry Density/Water content relationship.
- 6 Average shall mean running average of five consecutive tests or if less than five tests per interval then the average of all tests required on an interval.

4.7 Geogrid and Geotextile Requirements

The types, locations and dimensions of geogrids and geotextiles to be used within the Densified Crust shall be shown on the Drawings.

Only Hardfill aggregate with a stone size equal to or smaller than 40mm shall be used in zones with geogrid.

Requirements for the installation of geogrids and geotextiles are provided in section 3.10.

5 STABILISED CRUST



5.1 General

This section covers the work necessary to construct the Stabilised Crust ground improvement option to the required levels, grades and standards. Stabilised Crusts are constructed by mixing of cement into existing Site soils or suitable Imported Soils.

This option may also include the use of a lime/cement mix rather than just cement, particularly for those sites where silty soils are prevalent. Any reference to 'cement' or 'cement-stabilised' in this Specification shall include a lime/cement mix, as is appropriate.

There are three main methods for forming the Stabilised Crust. These are referred to as 'in-situ', 'ex-situ' and 'rotovated' soil mixing.

The in-situ method involves mixing of cement into the undisturbed ground by way of a cement injector and some form of mixing paddles to the full depth of the Stabilised Crust. The cement can either be added as dry cement powder or as a cement slurry. The Stabilised Crust is formed in a series of overlapping side-by-side panels.

The ex-situ method involves excavating all soil to the full depth of the Stabilised Crust, mixing cement into the soil outside of the excavation (using a pugmill or other suitable means) and then placing the stabilised soil mixture back into the excavated area in layers and compacting to form the Stabilised Crust.

The rotovated method involves excavating the soil from the Stabilised Crust area to above the lowest layer. Cement is then spread onto the lowest layer, mixed into the soil using a rotovating hoe (or similar approved equipment) and then compacted. The next layer of unstabilised soil is then placed into the excavation, cement spread, mixed into the soil using the same equipment and compacted. The process is repeated until the full depth of the Stabilised Crust is formed.

Mixing can be undertaken by any one of these methods, a combination of all methods or with other methods approved by the Engineer provided a Stabilised Crust of suitable thickness and strength is obtained.

The main activities associated with the Stabilised Crusts construction include:

- 1 clearing the Site
- 2 stripping existing Topsoil to stockpile
- 3 cement-stabilisation of natural ground to a defined depth (as shown on the Drawings) using in-situ mixing, ex-situ mixing, rotovated mixing or a combination of these techniques. Ex-situ cement Stabilised Crusts may also include the use of geogrid
- 4 verification testing and QA documentation
- 5 re-spreading of Topsoil to the finished ground level
- 6 any necessary groundwater control and temporary support of excavations.

For the ex-situ and rotovated methods where soft subgrade conditions are encountered at the base of the Stabilised Crust, to the extent that it is not considered to remain stable (non yielding) under the action of compaction plant, some form of subgrade improvement or 'subgrade bridging' will be required to allow the Densified Raft to be constructed. A number of alternative subgrade improvement techniques, available to be used are listed below. The most appropriate method and degree of improvement, which suit the Site conditions, shall be agreed with the Engineer before proceeding.

- Additional subgrade undercut and replacement with compacted crushed rock or crushed concrete to create a working platform.
- Geofabric and geogrid placed over the subgrade, to provide both a separation and bridging layer to the soft subgrade.
- Cement-binder added into the subgrade or first layer of fill.
- Dewatering of the subgrade.

Where materials Unsuitable for stabilisation are present, these will need to be undercut and replaced with imported materials suitable for stabilisation.

The depth of cement stabilised material and any overlying re-compacted soil fill material shall be as shown on the Drawings. For the ex-situ and rotovated mixing options, materials to be stabilised shall be existing Site-won Fill or Imported Fill or a blend of these materials, as approved by the Engineer.

Construction shall be undertaken such that a homogeneous layer of stabilised materials is attained and no significant abrupt change in the in-situ density and/or stiffness is present within the as-built Stabilised Crust. Care shall be taken to knit and overlap joints between panels or cells of in-situ, ex-situ and rotovated mixed material which are constructed at different times to produce a homogeneous Stabilised Crust. Where it is necessary to construct the Stabilised Crust in separate sections, strips or panels, additional care is required at the vertical edge joins by cutting into the previously compacted zone to produce a homogeneous crust without compromising the compaction integrity across the joins.

The Contractor shall review the existing available geotechnical data and laboratory testing and, undertake all necessary pre-construction inspections to assess the suitability of their construction methodology and plant to each material type to be utilised in the Works prior to the commencement of construction (including proposed Imported Fill material). The density and strength of the as-built Stabilised Crust ground improvement shall be verified via in-situ testing as specified in 'Permanent Works Testing Requirements' section of this Specification.

5.2 Set out and Tolerances

The Stabilised Crust shall be installed so as to meet the following construction tolerances:

- Horizontal location: $\pm 100\text{mm}$
- Vertical extent (depth): $\pm 50\text{mm}$

More precise tolerances may be required where ground improvement Works are close to existing building foundations, services, other structures or infrastructure.

5.3 Inspection, Review and Approval Hold Points

The Contractor's programme shall allow for inspection, review and approval hold points as detailed in Table 5.1 below and as described elsewhere in this Specification.

Table 5.1: Stabilised Crust Inspection and Hold Points

HOLD POINT			RESPONSIBILITY
NO.	NAME	DESCRIPTION	
1	Contractor's CMP	The Contractor shall submit a detailed Construction Management Plan to the Engineer, as outlined in section 1.8.1, prior to mobilising any specialist machinery to the Site.	Engineer to review
2	Material Suitability	The Contractor shall submit the required laboratory suitability material testing results for acceptance by the Engineer, for each type of material that is expected to be incorporated into the Works. The Engineer will review the laboratory test results against the Specification requirements. No bulk excavation, import of proposed fill materials to the Site or cement-stabilisation Works shall commence until the Engineer has agreed to the suitability of the proposed materials.	Engineer to review and approve
3	Temporary Batters, Retaining Structures and Groundwater Control Measures	The Contractor's engineer shall review and certify (where required) the suitability of the proposed temporary batter slopes/retaining structures and groundwater control measures prior to the Contractor commencing the excavation Works. The suitability of the as-built temporary batter slopes/retaining structures and groundwater control measures shall be monitored by the Contractor as the Works are progressed. These shall be adjusted, as necessary, to allow the Works to be completed in accordance with the Specification.	Contractor's engineer to review and certify (where required)
4	Excavation Subgrade	The base of the excavation shall be inspected by the Engineer prior to being surveyed by the Contractor. The Engineer shall confirm the extent of any undercutting of Unsuitable subgrade materials or subgrade improvement Works that may be required.	Engineer to inspect and approve
5	Crust Construction General	The construction of the Stabilised Crust shall be observed by the Engineer on a regular basis during the construction period to check compliance with the Specification and Drawings. Such observations should generally be done together with the Contractor. The frequency of observations shall be determined by the Engineer depending on the size, importance, complexity of the project together with their assessment of the Contractor's track record and experience.	Engineer to observe
6	Quality Assurance Tests	The Contractor shall submit for the ongoing review of the Engineer, copies of all imported fill source and Site suitability laboratory testing and on-going in-situ field test results.	Engineer to review
7	Completion of Stabilised Crust	The surface of the Stabilised Crust shall be inspected and approved by the Engineer after completion, prior to re-spreading of Topsoil (where required).	Engineer to inspect and approve
8	Final Surface	The final surface shall be inspected and approved by the Engineer after re-spreading of Topsoil.	Engineer to inspect and approve

5.4 Cement Dosage

Cement shall be general purpose Portland Cement, Type GP, complying with NZS 3122. Cement shall be stored under cover and protected from dampness until used. Any cement containing lumps shall not be used in the Works.

The Contractor shall decide on the percentage of cement to be added in order to meet the minimum test criteria required by this Specification. The dosage rates may need to be adjusted by the Contractor during construction in order to achieve the required strength criteria. Any costs associated with rework or increase in the cement dosage rate, to achieve minimum test criteria, shall be borne by the Contractor.

The Contractor shall nominate the cement dosage rate in their tender submission. The minimum cement dosage rate shall however be 8% for ex-situ and rotovated mixing and 10% for in-situ mixing.

5.5 Soil-Cement Blending

The Contractor shall treat all soil material which lies within the ground improvement zone with an appropriate dose of cement and shall thoroughly mix the cement into the soil so as to achieve the minimum density and strength testing criteria.

Thorough mixing of cement into the soil is a key aspect in achieving the minimum strengths requirements.

The Contractor shall detail in their CMP the machinery and equipment that will be used and the QA procedure that will be implemented in order to provide assurance that the cement is thoroughly mixed into the soil.

This shall include details of how the location of each panel or area that is stabilised will be surveyed and sequencing of panel construction in order avoid disturbing recently stabilised material and ensuring sufficient overlap and interlocking of panel joints.

The Engineer may request that inspection test pits are undertaken within the soil-cement Stabilised Crust to verify that panel joints are sufficiently overlapped and that there is sufficient mixing of cement, to provide a homogeneous crust.

5.6 QA Records

During mixing the following records shall be kept for each day's production, or part thereof:

- 1 Date and weather conditions
- 2 Details of the time that cement was added to the soil and when mixing was completed
- 3 Cement-stabilised soil panel/cell number, including location and depth
- 4 Total volume and/or mass of cement added to the above total mass of soil for each panel/cell.

5.7 Material Reference and Suitability Testing Requirements

The Contractor shall undertake the material reference and suitability tests listed below and shall submit the required tests for acceptance by the Engineer prior to the start of the ground improvement construction.

Two 25kg bags of Engineer-approved materials shall be kept on the Site by the Contractor throughout the duration of the Works as a 'reference' for subsequent materials being delivered to the Site.

5.7.1 Site-won Fill Materials for Stabilisation

The material reference and suitability testing for ex-situ, rotovated and in-situ mixed soil-cement Stabilised Crusts is listed below in Table 5.2 and shall be undertaken on each different type of existing subsoil materials.

Table 5.2 Material Testing for Site-won Materials to be used for Stabilisation

TEST DESCRIPTION	TEST METHOD	MINIMUM NUMBER OF TESTS PER RESIDENTIAL SITE	
		Ex-Situ and Rotovated	In-Situ
MANDATORY TESTING			
Dry Density/Moisture Content relationship with CBR or Shear Vanes⁽¹⁾	NZS 4402: Test 4.1.1 (Standard Compaction) with CBR or laboratory Shear Vane testing undertaken at each moisture content tested.	2	N/A
California Bearing Ratio⁽²⁾ (CBR) on samples mixed with cement; or	RRU TR7 Test 8, placed into mould as follows: – Ex-situ and Rotovated : Standard Compaction ⁽³⁾ @ natural water content – In-Situ : Mixed into mould in liquid state	Test @ 5%, 8% and 10% dry mass of cement with tests at 7 and 14 days (6 tests total)	Test @ 7%, 10% and 13% dry mass of cement with tests at 7 and 14 days (6 tests total)
Unconfined Compression Test^{(2)&(4)} (UCS) on soil samples mixed with cement	NZS 4402:Test 6.3.1 with stress strain measurement Ex-situ and Rotovated: Standard Compaction ⁽³⁾ @ natural water content In-Situ: Mixed into mould in liquid state	Test @ 5%, 8% and 10% dry mass of cement with tests at 7 and 14 days (6 tests total)	Test @ 7%, 10% and 13% dry mass of cement with tests at 7 and 14 days (6 tests total)
DISCRETIONARY TESTING			
Atterberg Limits	NZS 4402:Test 2.2, 2.3 and 2.4	2	2
Particle Size Distribution (with hydrometer if silt and clay fraction is >10%)	NZS 4402:Test 2.8.1, 2.8.2 and 2.8.4	2	2

Notes:

- 1 Shear vane testing shall be undertaken where the material type, as defined by NZ Geotechnical Society publication, *Guideline for the Field Classification and Description of Soil and Rock for Engineering purposes*, is classified as 'cohesive'.
- 2 Only required if not undertaken pre-tender. Also this testing is not required where the Contractor can demonstrate to the satisfaction of the Engineer that this testing is not required due to the Contractor having extensive previous experience and knowledge with undertaking similar works in local soil conditions.
- 3 NZS 4402: Test 4.1.1 (Standard Compaction).
- 4 UCS tests to be undertaken on minimum 100mm diameter moulds and only with the approval of the Engineer. UCS tests are only suitable for certain types of materials and the sample can be disturbed when removed from the mould and test results may also be affected by planes of weakness introduced into the sample when compacted into the mould.

Material used for cement stabilisation shall be substantially free of all organic matter and other Unsuitable materials. Where testing is instructed by the Engineer it shall have less than 5% organic content when tested in accordance with NZS 4402: Test 3.1.2.

The testing detailed above shall be completed on a minimum of three large bulk samples obtained from across the full extents of the Site. Where the Contractor proposes to blend Site soils with imported fill, the requirements of this section shall relate to the blended material.

All laboratory test results shall be reported to the Engineer within two days of completing the tests. The Contractor shall inform the Engineer of the proposed cement dosage rate prior to proceeding with the soil stabilisation Works.

5.7.2 Imported Soil Fill for Stabilisation

Refer to section 3.5.5 for general requirements for Imported Soil Fill.

The same testing criteria as required for Site-won Fill Materials for Stabilisation (section 5.7.1) shall apply to Imported Soil Fill material. Additional tests shall be carried out by the Contractor during the Works at source and/or on materials delivered to the Site if, in the opinion of the Engineer, the Imported Soil Fill material varies from that indicated by the initial source testing. Such additional testing shall be paid for by the Contractor.

5.8 Construction

Spreading and mixing of cement shall not be carried out either when the ground temperature is less than five degrees Celsius, when rain is falling or if there is ponded water in the mixing area. Spreading of cement shall be carried out with a suitably calibrated distributor capable of producing consistent and even addition of cement.

Mixing of cement shall follow immediately after spreading. Where excessive delay (greater than four hours) occurs between spreading and mixing, the Engineer is to be informed. The Engineer shall, after consultation with the Contractor, decide whether the delay is likely to have affected the soil stabilisation process and whether additional cement needs to be added. Any such re-work shall be at the Contractor's cost.

Mixing shall be undertaken using purpose built machines until the maximum clod size is no greater than 40mm. Mixing shall continue until the soil is uniform in texture and colour and free of streaks or pockets of cement.

For the ex-situ and rotovated mixed methods, the Contractor shall complete compaction of the stabilised mix immediately following mixing. Where excessive delay (greater than four hours) occurs between mixing and compaction, the Engineer is to be informed. The Engineer shall, after consultation with the Contractor, decide whether the delay is likely to have affected the soil stabilisation process and whether additional cement needs to be added. Any such re-work shall be at the Contractor's cost.

For the ex-situ and rotovated method, compaction of fine grained (Silt and Clay) stabilised soils shall be carried out using a 'tamping foot' type roller (sheepsfoot, wedgefoot, padfoot or similar) of sufficient weight to allow compaction of the full depth of the stabilised layer to the requirements of section 5.9. Compaction shall be undertaken in a systematic manner so that all areas receive adequate compaction. The compacted stabilised surface shall be sealed off at the end of each day.

For the rotovated method, the blades shall extend 50mm into the underlying layer except in zones where geogrids are used.

If heavy rain falls before that cement stabilised layer has set up, leaching of the upper surface may occur, leaving a slurried surface. Where this occurs, the top layer is either to be removed or the surface scarified and additional cement mixed in and the layer reworked in accordance with the Specification. Such additional work shall be at the Contractor's cost.

5.9 Permanent Works Testing Requirements

5.9.1 Verification Test Methods and Frequencies

The type and frequency of testing which is to be completed by the Contractor is listed below in Table 5.3. Additional tests and/or changes to the testing frequency may be instructed by the Engineer as the Works proceed.

Table 5.3 Minimum Stabilised Crust Verification Testing Schedule

PARAMETER	TEST DESCRIPTION	TEST METHOD	MINIMUM TEST FREQUENCY	
			Ex-situ and Rotovated ⁽³⁾	In-situ
In-situ⁽¹⁾ Density	'Fully Specified' Method or 'Rapid' Method⁽²⁾	NZS 4402:Test 5.1.1, 5.1.3 (Sand replacement, or core cutter); or NZS 4407:Test 4.2.1 (Nuclear Densometer Direct Mode); or NZS 4407:Test 4.2.2 (Nuclear Densometer Backscatter Mode)	Undertake tests at 600mm vertical intervals with 1 set of tests per 25m ² .	N/A
Strength – Laboratory Testing	CBR	RRU TR7 Test 8 in 100mm diameter test cylinders cured for 7 days (increased to 28 days at the discretion of the Engineer)	N/A	1 sample per 100m ³ material treated ⁽⁴⁾
	UCS	NZS 4402:Test 6.3.1 in 100mm diameter test cylinders cured for 7 days (increased to 28 days at the discretion of the Engineer)	N/A	1 sample per 100m ³ material treated ⁽⁴⁾
Strength – In-situ Testing (one or a combination of these tests)	DCP ('Scala') Test⁽⁵⁾	NZS 4402:Test 6.5.2	Undertake tests at 600mm vertical intervals with 1 test per 25m ² .	1 test per 25m ² (but with a minimum of 8 tests per residential site), driven from top of crust to 100mm above base of Crust; or
	SPT	ASTM D1586	1 test per 50m ² (but with a minimum of 3 tests per residential site) from top of Crust to 100mm above base of Crust (alternative refer note 3).	1 test per 50m ² (but with a minimum of 3 tests per residential site) from top of crust to 100mm above base of Crust; or
	Dynamic Probe Heavy (DPH)	BS EN ISO 22476-2	1 test per 50m ² (but with a minimum of 3 tests per residential site) from top of Crust to 100mm above base of Crust (alternative refer note 3).	1 test per 50m ² (but with a minimum of 3 tests per residential site) from top of crust to 100mm above base of Crust; or
	CPT	ASTM D5778	1 test per 50m ² (but with a minimum of 3 tests per residential site) from top of Crust to 100mm above base of Crust (alternative refer note 3).	1 test per 50m ² (but with a minimum of 3 tests per residential site) from top of crust to 100mm above base of Crust.

Notes:

- 1 In-situ density of the compacted soil at any test location shall be taken as the mean of a set of tests. A set of density tests shall comprise 2 measurements using the same probe hole but orientated at 90 degrees to each other.
- 2 Refer to section 3.5.3.
- 3 For the ex-situ and rotovated methods, the SPT, DPH and CPT tests are alternative tests to the in-situ density and Scala testing and shall be done on completion of the crust construction but only with the approval of the Engineer. The in-situ density and Scala testing is preferred as it allows quality control of the placement to be undertaken as the Works are constructed rather than at the end of the construction.
- 4 Samples to be taken from the treated material and placed into 4 x 100mm diameter test cylinders within 1 hour of cement mixing. One test cylinder is to be selected for initial testing. The remaining cylinders shall be used for additional testing after additional curing if the first test fails the minimum strength criteria.
- 5 In order to avoid friction on the Scala rods affecting the strength results, the Scala is to be driven in 300mm intervals with the Scala rods withdrawn between intervals and the disturbed material removed using a 50mm diameter hand auger. This process is to be repeated to the full depth of the Crust.

5.9.2 Verification Test Criteria

All cement Stabilised Crust material shall meet the minimum criteria stipulated below in Table 5.4.

Table 5.4: Minimum Stabilised Crust Verification Test Criteria

PARAMETER	TEST DESCRIPTION	CEMENT STABILISED MATERIAL ⁽¹⁾	
		Ex-situ and Rotovated ⁽²⁾	In-situ ^{(3)&(4)}
In-situ Density	'Fully Specified' Method or 'Rapid' Method	Minimum average of 95% of maximum density as determined by the standard compaction test ⁽⁵⁾ . Minimum single test of 92%.	N/A
Strength – Laboratory Testing	CBR; or	N/A	Minimum CBR 25
	UCS	N/A	Minimum UCS 1 MPa
Strength – In-situ	DCP ('Scala') Test; or	Minimum average of 10 blows/100mm with a minimum single value 7 blows/100mm.	Minimum average of 10 blows/100mm with a minimum single value of 7 blows/100mm.
	SPT; or	Minimum average N value of 20 with a minimum single N value of 15 (uncorrected).	Minimum average N value of 20 with a minimum single N value of 15 (uncorrected).
	Dynamic Probe Heavy (DPH); or	Minimum average N value of 20 with a minimum single N value of 15 (uncorrected).	Minimum average N value of 20 with a minimum single N value of 15 (uncorrected).
	CPT	qc > 6 MPa (uncorrected) with 5% within the stabilised layer in any CPT allowed below this value.	qc > 6 MPa (uncorrected) with 5% within the stabilised layer in any CPT allowed below this value.

Notes:

- 1 Average shall mean running average of 5 consecutive tests or if less than 5 tests per interval then the average of all tests required on an interval.
- 2 Based on 1.2m thick Stabilised Crust as per the MBIE Guidance Document.
- 3 Based on 2.0m thick Stabilised Crust as per the MBIE Guidance Document.
- 4 For the In-situ method, testing shall be undertaken through the full depth of the Stabilised Crust up to 100mm from the base of the Crust.
- 5 NZS 4402: Test 4.1.1 (Standard Compaction).

Where a combination of in-situ, ex-situ and rotovated methods are to be adopted, a combination of the testing requirements will be required, as instructed by the Engineer.

The minimum strength requirement is expected to be able to be achieved within seven days of placement. Where this minimum strength is not achieved within seven days the Contractor may choose to rework the material or to wait for additional strength gain to be obtained and to then retest the material. Where the minimum strength has not been achieved within 28 days, the Contractor shall remediate the non-conforming material. Any such delays or rework shall be at the Contractor's expense.

Test methods which leave a hole size greater than 25mm shall be backfilled with cement grout.

5.10 Geogrid and Geotextile Requirements

The types, locations and dimensions of geogrids and geotextiles to be used within the ex-situ Stabilised Crust will be shown on the Drawings.

Requirements for the installation of geogrids and geotextiles are provided in section 3.10.

6 STONE COLUMNS



6.1 General

This section covers the work necessary for the construction of Stone Column ground improvement to the required dimensions, grades and standards detailed on the Drawings. The ground treatment shall be carried out by deep vibratory compaction incorporating stone columns constructed from imported granular backfill. Only methods which displace and densify the soil between the columns (not ones that replace the soil) shall be allowed.

The main activities associated with the Stone Column ground improvement construction include:

- 1 clearing the Site
- 2 stripping existing Topsoil to stockpile
- 3 installing Stone Columns at the required diameter, spacing and depths
- 4 verification testing and QA documentation
- 5 appropriate surface treatment
- 6 re-spreading Topsoil.

The Contractor shall have inspected the Site and considered the nature of the ground through which Stone Columns are to be constructed and shall have allowed for penetrating through all materials, that could reasonably have been expected between the ground surface and the base of the columns, based on the available geotechnical information.

Stone columns shall be installed by bottom feed methods unless otherwise specified or agreed with the Engineer.

The Contractor shall install the columns in a way that minimises the amount of ground heave at the Site. Ground heave shall be monitored by the Contractor using level survey at the property boundary with the heave alert and alarm trigger limits, locations, frequencies and survey precision identified on the Drawings or otherwise instructed by the Engineer, taking into account the nature of the surrounding buildings, structures, infrastructure, services etc. If the ground heave exceeds the proposed alert trigger limits then the Contractor shall inform the Engineer and shall propose an alternative installation methodology to limit heave movements to within the alarm levels or other mitigation measures, all as agreed with the Engineer.

The need for Degree of Improvement testing shall be noted on the Drawings or instructed by the Engineer. Refer to section 6.7.

6.2 Set Out, Tolerance and Replacement Ratio

Stone Columns shall be installed so as to meet the following construction tolerances:

- Horizontal location: $\pm 100\text{mm}$
- Vertical extent (depth): $\pm 200\text{mm}$
- Verticality: Maximum 1:20 deviation from vertical

More precise tolerances may be required where ground improvement Works are close to existing building foundations, services, other structures or infrastructure.

The minimum plan extent, layout, depth and area replacement ratio (ARR) shall be shown on the Drawings. An indicative column diameter and spacing may also be shown on the Drawings but the final diameter and spacing shall be agreed with the Engineer based on the Contractor's proposed plant and equipment but shall meet the minimum area replacement ratio (ARR).

The area replacement ratio (ARR) shall be calculated as follows: $ARR = C_1 (D/s)^2$

Where: C_1 = constant dependant on the pattern of stone columns

= $\pi/4$ for a square layout

= $\pi/(2\sqrt{3})$ for a triangular layout

D = average diameter of compacted stone column over depth of column

s = centre to centre spacing of stone columns

The minimum column diameter along the depth of the column shall however not be less than the probe diameter multiplied by 1.5 with the average diameter along the length of the column no less than D in the above formula.

6.3 Inspection, Review and Approval Hold Points

The Contractor's programme shall allow for inspection, review and approval hold points as detailed in Table 6.1 below and as described elsewhere in this Specification.

Table 6.1: Stone Column Inspection and Hold Points

HOLD POINT			RESPONSIBILITY
NO.	NAME	DESCRIPTION	
1	Contractor's CMP	The Contractor shall submit a detailed Construction Management Plan to the Engineer, as outlined in section 1.8.1, prior to mobilising any specialist machinery to the Site.	Engineer to review
2	Material Suitability	The Contractor shall submit the required laboratory suitability material testing results for acceptance by the Engineer, for each type of material that is expected to be incorporated into the Works. The Engineer will review the laboratory test results against the Specification requirements. No bulk excavation, import of proposed fill materials to the Site or cement-stabilisation Works shall commence until the Engineer has agreed to the suitability of the proposed materials.	Engineer to review and approve
3	Stone Column Construction General	The construction of the Stone Columns shall be observed by the Engineer on a regular basis during the construction period to check compliance with the Specification and Drawings. Such observations should generally be done together with the Contractor. The frequency of observations shall be determined by the Engineer depending on the size, importance, complexity of the project together with their assessment of the Contractor's track record and experience.	Engineer and Contractor to inspect
4	Quality Assurance	The Contractor shall submit for the ongoing review of the Engineer, copies of all imported fill source, material suitability laboratory testing, stone volume records and Degree of Improvement field test results (where required).	Engineer to review
5	Surface Undercut	The surface undercut shall be inspected and approved by the Engineer prior to recompaction of the soil fill.	Engineer to inspect and approve
6	Final Surface	The final surface shall be inspected and approved by the Engineer after placement of the drainage aggregate.	Engineer to inspect and approve

6.4 Obstructions and Pre-boring

If physical obstructions to the installation of the Stone Columns are encountered, the Contractor shall report this to the Engineer. The Engineer may instruct that the obstruction be removed or left in place, and that ground improvement be undertaken around the obstruction in such a manner that an equivalent replacement ratio as described in section 6.2 is obtained.

If the Contractor considers that pre-boring is necessary, this shall be identified at the time of pricing. The Contractor shall obtain the Engineer's approval prior to undertaking any pre-boring.

6.5 Surface Treatment

After verifying that the target improvement has been achieved, the entire improvement area is to be sub-excavated to a depth of 400mm (or to the base of any disturbed materials as determined by the Engineer, but no less than 300mm) and recompacted to within 100mm of the final ground surface as engineered soil fill in accordance with Tables 4.4 and 4.5. The final ground surface shall be trimmed and levelled in accordance with the Drawings or as instructed by the Engineer.

Finally, 100mm of well graded drainage aggregate (GAP40 or similar approved) shall be spread and compacted to match the final ground surface. The aggregate shall be compacted to meet the minimum Impact Test values in accordance with Tables 4.4 and 4.5.

6.6 Stone Column Material Suitability Tests

6.6.1 General Requirements

This section sets out the requirements for the proposed aggregate materials to be used for construction of the Stone Columns.

The following stone aggregate approval procedure shall be followed:

- 1 Contractor to advise Engineer of the proposed aggregate source.
- 2 Contractor to supply a sample of the proposed aggregate to the Engineer. Samples of the proposed aggregate stone shall be obtained from stockpiles at source and/or stockpiles of materials delivered to Site, as directed by the Engineer.
- 3 Suitability tests as outlined below to be provided by the Contractor to the Engineer no less than five working days prior to their required use in the Works.
- 4 Engineer to confirm suitability of proposed aggregate, prior to start of Stone Column construction.

Two 25kg bags of Engineer approved materials shall be kept on Site for the duration of the construction for comparison with materials supplied and used. Separate samples shall be provided for materials from different sources.

All imported aggregate shall comply with the following sections unless otherwise instructed by the Engineer. Some of the testing requirements outlined below note that such testing may be supplied from quarry records if 'recent' test data is available. 'Recent' shall be taken to be tests conducted within the previous three months.

6.6.2 Aggregate Broken Face Content

The aggregate retained on the 19mm sieve shall have a broken face content of not less than 50% by weight and shall have two or more broken faces. This test shall be undertaken in accordance to NZS 4407: Test 3.14. Rounded gravels may only be used where approved by the Engineer.

6.6.3 Crushing and Weathering Resistance

Aggregate should be a hard rock aggregate which is not subject to strength degradation over time. The minimum crushing resistance shall not be less than 120kN for GAP65 and GAP40, when the aggregate is testing according to NZS4407: Test 3.10, *The Crushing Resistance of Coarse Aggregate under a specific load*.

An aggregate will be considered to have met this criterion if the sample produces less than 10% fines when loaded so that the specified peak load is reached in 10 minutes. In this case the test shall follow the standard method in all other respects.

In addition the aggregate shall have a quality index of AA, AB, AC, BA, BB or CA when tested according to NZS 4407: Test 3.11, *The Weathering Quality Index of Coarse Aggregate*.

Weathering and crushing resistance tests may be obtained from quarry records supplying the material, if recent and representative testing is available. Once the sample of the material has been provided, the Engineer shall decide if project specific Crushing Resistance testing and/or Weathering Resistance testing is required.

In many cases the Engineer will be able to approve the use of the aggregate without the need for project specific tests, based on previous experience and quarry records. However, where the Engineer considers that the available test information is not representative of the proposed aggregate and that there is risk that it will not meet the minimum Crushing and Weathering Resistance criteria, then they will instruct the Contractor to undertake Crushing and Weathering Resistance tests for actual aggregate proposed to be used.

6.6.4 Grading

The aggregate shall have a grading which falls within the limits defined in Table 6.2 below when tested in accordance with NZS 4407: Test 3.8.1. Alternative materials with a non-complying grading envelope may be proposed by the Contractor but may not be incorporated into the Works without the prior written approval of the Engineer.

Table 6.2: Stone Column Aggregate Grading Envelope

APERTURE SIZE (mm)	PERCENTAGE PASSING BY WEIGHT	
	Minimum	Maximum
75.0	100	100
37.5	30	100
26.5	0	100
19.0	0	50
9.50	0	30
4.75	0	15
2.36	0	10
1.18	0	5
0.60	0	5
0.30	0	5
0.150	0	0

6.7 Degree of Improvement Tests

Degree of improvement CPT testing, to demonstrate sufficient improvement of ground improvement zone, shall be undertaken where specified on the Drawings or if instructed by the Engineer. The minimum CPT penetration resistance shall be as provided in the MBIE Guidance Document¹², or as otherwise shown on the Drawings or specified by the Engineer. CPTs shall be undertaken not less than two weeks after completing the ground improvement Works.

The CPTs shall be positioned at the midpoint between Stone Columns and undertaken at a frequency of a minimum of 1/100m² of treated ground with no less than three tests per residential house site or as otherwise instructed by the Engineer where ground improvement on large sites are undertaken.

All CPTs shall extend to a minimum depth of 1.0m below the base of the surrounding Stone Columns.

Where the minimum degree of improvement criteria are not achieved, the Contractor shall advise the Engineer. The Engineer shall then advise on any additional works that are required.

¹² *Repairing and rebuilding houses affected by the Canterbury earthquakes* (Chapter 15.3 update issued in April 2015)

6.8 Construction Records and Monitoring

6.8.1 General

The Contractor shall provide all plant, equipment, safety provisions and experienced personnel necessary to enable the safe and satisfactory execution, completion, supervision and monitoring of Stone Column construction.

The following information shall be measured, recorded, calculated and reported to the Engineer within two days of completion:

- 1 equipment used and key construction personnel involved
- 2 start and finish time and date of the Stone Column construction
- 3 dimensions and spacing of the Stone Columns installed
- 4 results and locations of degree of improvement testing (eg CPT etc) completed on Stone Columns
- 5 the volume of compacted gravel introduced to the ground compared with volumes delivered to Site as measured from the truck delivery dockets. Gravel spread or spilt on the ground surface shall not be included in the volume and an appropriate allowance for construction losses shall be included in the calculation
- 6 a plan clearly showing the location of each individual Stone Column.
- 7 For each column, the following data shall be recorded:
 - unique column identifier
 - location of the column, measured from the property boundary to 0.1m accuracy
 - date and time of installation
 - vibrator power consumption (amperage or hydraulic pressure) with time and depth
 - volume or weight of material introduced to the ground and depth of tip of tremie pipe for each batch of material added
 - depth of column.

All records shall be presented on standard forms prepared by the Contractor.

6.8.2 Stone Volume Monitoring and Recording

6.8.2.1 Automated Volume Verification

An automated system shall be provided by the Contractor for monitoring the volume of stone introduced into each Stone Column where installation is by bottom fed methods. The automated system shall allow for volume of stone for each batch vs depth to be recorded and records shall be provided to the Engineer on a daily basis.

The Contractor shall describe in their CMP the way in which accurate measurement of stone volumes inserted into the ground will be undertaken.

The Contractor shall obtain the Engineer's approval for the proposed monitoring system prior to construction.

For a construction methodology involving the use of a vibroflot, the automated monitoring system shall also provide the operator with continuous real-time information on the depth of the base of the vibroflot and vibrator power consumption with depth.

6.8.2.2 Manual Volume Verification

A manual check of the stone volumes added shall also be recorded by the Contractor for all installation methods. This shall include as a minimum logging of total bucket loads installed into each column as well as logging of time and depth at which each bucket was added.

The bucket volume shall be accurately measured and a minimum fill level identified on the bucket. The operator shall ensure that this minimum level is obtained before filling the hopper.

The Contractor shall also supply a square sided steel container that is larger in volume than the bucket volume so that the bucket volume can be easily measured on Site. The amount of stone in each bucket is to be independently verified by pouring the stone into the container. Each test shall consist of filling the container three times and an average volume determined. The Engineer shall be invited to inspect this verification test. This container shall be kept on Site for such independent volume measurement at the following intervals:

- 1 prior to start of work
- 2 if the machinery or filling method changes
- 3 on request of the Engineer.

7 DRIVEN TIMBER POLES

7.1 General

This section covers the work necessary for the construction of Driven Timber Poles ground improvement to the required dimensions, grades and standards detailed on the Drawings. The Works specified in this section covers the requirements for the supply of materials, installation and construction of Driven Timber Poles for ground improvement.

The minimum pole diameter, lengths and setout are shown on the Drawings.

The main activities associated with Driven Timber Pole construction include:

- 1 clearing the Site
- 2 stripping Topsoil and stockpile
- 3 driving poles to depths and spacings shown on the Drawings including any specified overdriving below existing ground level
- 4 backfilling and compacting Site-won or imported material in layers over top of pile
- 5 Re-spreading Topsoil.

Material other than timber may be able to be used but only with written approval of the Engineer.

The need for Degree of Improvement testing shall be noted on the Drawings or instructed by the Engineer. Refer to section 6.7.

The Contractor shall install the timber poles in a way that minimises the amount of ground heave at the Site. Ground heave shall be monitored by the Contractor using level survey at the property boundary with the heave alert and alarm trigger limits, locations, frequencies and survey precision identified on the Drawings or otherwise instructed by the Engineer, taking into account the nature of the surrounding buildings, structures, infrastructure, services etc. If the ground heave exceeds the proposed alert trigger limits then the Contractor shall inform the Engineer and shall propose an alternative installation methodology to limit heave movements to within the alarm levels or other mitigation measures, all as agreed with the Engineer.



7.2 Standard Specifications

The construction of the Driven Timber Poles ground improvement shall fully comply with the materials and workmanship required by the latest revisions and amendments of the standards:

- NZS 3603 Timber Structures Standard
- NZS 3631 New Zealand Timber Grading Rules
- NZS 3640 Chemical Preservation of Round and Sawn Timber.

7.3 Set Out, Tolerance and Replacement Ratio

Driven Timber Poles shall be installed so as to meet the following construction tolerances:

- Horizontal location: $\pm 75\text{mm}$
- Vertical extent (cut off level): $\pm 0.2\text{m}$ from the average depth, this variation to be evenly spread over the site
- Verticality: Maximum 1:75 deviation from vertical.

More precise tolerances may be required where ground improvement Works are close to existing building foundations, services, other structures or infrastructure.

The Contractor shall accept the full and sole responsibility for selecting the method of working, and for constructing the timber poles within the required tolerances.

The Contractor shall demonstrate correct timber pole location and alignment in accordance with the Specification by measurement or other means.

The Contractor shall make good or replace at its own expense any timber poles that are outside the tolerances stated within the Specification.

The minimum plan extent, layout, depth and area replacement ratio (ARR) shall be shown on the Drawings. An indicative layout and spacing may also be shown on the Drawings but the final layout and spacing shall be agreed with the Engineer but shall meet the minimum area replacement ratio (ARR).

The area replacement ratio (ARR) shall be calculated as follows: $ARR = C_1 (D/s)^2$

Where: C_1 = constant dependant on the pattern of timber poles

= $\pi/4$ for a square layout

= $\pi/(2\sqrt{3})$ for a triangular layout

D = average diameter of timber poles

s = centre to centre spacing of timber poles

7.4 Inspection, Review and Approval Hold Points

The Contractor's programme shall allow for inspection, review and approval hold points as detailed in Table 7.1 below and as described elsewhere in this Specification.

Table 7.1: Driven Timber Pole Inspection and Hold Points

HOLD POINT			RESPONSIBILITY
NO.	NAME	DESCRIPTION	
1	Contractor's CMP	The Contractor shall submit a detailed Construction Management Plan to the Engineer, as outlined in in section 1.8.1, prior to mobilising any specialist machinery to the Site.	Engineer to review
2	Pole condition on arrival	The Engineer shall inspect the condition of the poles stockpiled on Site and certificates relating to the density and treatment of the poles, prior to installation.	Engineer to inspect and approve
3	Pole treatment after cutting	After treatment of poles if they are required to be cut.	Engineer to inspect and approve
4	Pole installation start	Inspection of the installation of the first pole.	Engineer to inspect
5	Driven Timber Poles Construction General	The construction of the Driven Timber Poles shall be observed by the Engineer on a regular basis during the construction period to check compliance with the Specification and Drawings. Such observations should generally be done together with the Contractor. The frequency of observations shall be determined by the Engineer depending on the size, importance, complexity of the project together with their assessment of the Contractor's track record and experience.	Engineer to observe
6	Quality Assurance	The Contractor shall submit, for the ongoing review of the Engineer, copies of all degree of Improvement field test results (where required).	Engineer to review
7	Completion of pole driving and backfill	The surface of the ground shall be inspected and approved by the Engineer after completion of pole driving and backfilling over the poles prior to undertaking the surface treatment outlined in section 7.9.	Engineer to inspect and approve
8	Final Surface	The final surface shall be inspected and approved by the Engineer after completion of the surface treatment outlined in section 7.9.	Engineer to inspect and approve

7.5 Materials

Unless noted otherwise on the Drawings, all timber poles shall be Radiata Pine (or approved equivalent), bored, cut, machined, processed and treated to NZS 3640 Hazard Class H5, in accordance with the requirements of the NZ Timber Quality Scheme, jointly administered by Wood Processors and Manufacturers Association and Timber Industry Federation.

The poles shall have a minimum average diameter (over the length of the pole) of 200mm with no more than 50mm variation from the average and a maximum taper of 10mm per metre. Any variation of pile diameters must be evenly distributed throughout the pile grid.

Poles that have not been shaved (commonly referred to as 'uglies') are permissible provided the outer bark has been removed.

Poles shall be supplied in one piece and splicing shall not be allowed unless specifically approved by the Engineer.

7.6 Treatment of Exposed Timber

Surfaces exposed after pressure treatment or cutting shall be protected by three coats of undiluted copper naphthalene (4% min concentration) or zinc naphthate (8% min concentration) in a hydrocarbon solvent, or equivalent as approved by the Engineer. Treatment should be applied accordance with manufacture's recommendations. Re-treated ends shall not be placed at the lower end of the pole.

7.7 Construction

Poles shall be installed to the set out and to the minimum required depths as shown on the Drawings.

The Contractor shall be responsible for using techniques and equipment appropriate for the conditions expected to be encountered at the Site. Poles may be installed by drop hammer or vibratory methods as appropriate for the ground conditions in a manner so as to avoid causing damage to the poles during installation. If any poles are damaged during their installation then the Contractor shall notify the Engineer immediately. Poles that split during installation shall be removed unless directed otherwise by the Engineer. Maximum noise and vibration limits during installation (refer sections 1.15.3 and 1.15.4) shall be complied with.

Poles shall not be tipped, rolled or dropped from the delivery vehicle and any pole with evidence of handling damage shall be removed from the Site. The poles shall be installed with the 'small end' downwards.

Poles shall be driven to the specified depth. The use of jetting shall not be used during installation of the poles. If it is not possible to drive the poles to the required depth due to the presence of a hard stratum then predrilling may be required. Predrilling shall only be undertaken after approval of the predrilling methodology by the Engineer. Considerations by the Engineer shall include the depth and diameter of predrilling and the likely effect on the reduction in density of the surrounding soils. Pre-drilling is not to be continued into the bearing stratum.

The Contractor shall provide the methodology for installation of the poles in the CMP (refer to 1.8.1) prior to the start of Works.

7.8 Backfilling Over Timber Poles

Once the pole has been installed and overdriven to the depth shown on the Drawings, Site-won material or approved imported material shall be placed in maximum 200mm thick layers and re-compacted over the top of the pile to fill up the hole. The material shall be tested in accordance with Table 7.1. Imported Soil Fill material shall comply with the requirements of section 3.5.5.

Table 7.2: Testing Requirements for Material Re-compacted Over Top of Poles

TEST DESCRIPTION	TEST METHOD(S)	MINIMUM TEST	
		Target Criteria	Frequency
Dynamic Cone Penetrometer ('Scala') test	NZS 4402:Test 6.5.2	Minimum average of 10 blows/100mm Minimum single value of 7 blows/100mm	10% of Poles

Notes:

- The Contractor shall spread out test locations evenly across the area of ground improvement.

7.9 Surface Treatment

After completion of the pile driving and any backfill required over the top of the piles and verification of the target strength improvement has been achieved (where required), the entire improvement area is to be sub-excavated to a depth of 200mm and a 200mm layer of well graded compacted Hardfill (GAP65 or similar approved) shall be spread and compacted. The final ground surface shall be trimmed and levelled in

accordance with the Drawings. The Hardfill aggregate shall be compacted to meet the minimum Impact Test values in accordance with Tables 4.4 and 4.5.

The 100mm of drainage aggregate is not required where ground improvement is required beyond 1.5m from the building platform. Where ground improvement beyond 1.5m from the build foundation is required, the upper 200mm ground surface layer shall be scarified and re-compacted to form a layer of engineered fill in accordance with Tables 7.3 and 7.4, prior to respreading topsoil to the final finished level.

Table 7.3 Surface Recompaction Verification Testing Schedule

PARAMETER	TEST		MINIMUM TEST FREQUENCY
	Description	Test Method	
SOIL MATERIAL			
Air Voids⁽¹⁾	'Fully Specified' Method or 'Rapid' Method ⁽²⁾	NZS 4402:Test 5.1.1, 5.1.3 (Sand replacement or core cutter); or NZS 4407:Test 4.2.1 (Nuclear Densometer Direct Mode)	1 test per 50m ²
Strength	Undrained Shear Strength	Hand held Shear Vane with corrected undrained shear strength determined in accordance with NZ Geotechnical Society Inc., <i>Guideline for hand held shear vane test</i>	1 test per 50m ²
	DCP ('Scala') Test	NZS 4402:Test 6.5.2	1 test per 50m ²

Notes:

- 1 Air -voids of the compacted soil at any test location shall be taken as the mean of a set of tests. A set of density tests shall comprise 2 measurements using the same probe hole but orientated at 90 degrees to each other.
- 2 Refer to sections 3.5.3.

Table 7.4: Surface Recompaction Test Criteria

TEST DESCRIPTION	SOIL TYPE ⁽¹⁾	
	Non-cohesive (Sands and Gravels)	Cohesive (Silts and Clays)
Air Voids	N/A	Maximum Average 8% Maximum Single 10%
Undrained Shear Strength	N/A	Minimum Average 140kPa Minimum Single 120kPa
DCP ('Scala') Test	Minimum average of 10 blows/100mm Minimum single value of 7 blows/100mm	Not required

Notes:

- 1 Soil type as defined by NZ Geotechnical Society publication, *Guideline for the Field Classification and Description of Soil and Rock for Engineering purposes*.
- 2 Average shall mean running average of 5 consecutive tests or if less than 5 tests per layer then the average of all tests required on a layer.

7.10 Degree of Improvement Tests

Degree of improvement CPT testing, to demonstrate sufficient improvement of ground improvement zone, shall be undertaken where specified on the Drawings or if instructed by the Engineer. The minimum CPT penetration resistance shall be as provided in the MBIE Guidance Document¹³, or as otherwise shown on the Drawings or specified by the Engineer. CPTs shall be undertaken not less than two weeks and not more than five weeks after completing the ground improvement Works.

The CPTs shall be positioned at the midpoint between Driven Timber Poles, at a minimum of 1/100m² of the improved ground with no less than three tests per house site or as otherwise instructed by the Engineer where ground improvement on large sites are undertaken.

All CPTs shall extend to a minimum depth of 1.0m below the base of the timber poles.

Where the minimum degree of improvement criteria are not achieved, the Contractor shall advise the Engineer. The Engineer shall then advise on any additional works that are required.

7.11 Construction Records

The Contractor shall prepare detailed and accurate construction records for each pile as construction progresses. As a minimum these records shall include:

- 1 pile reference number with date/time driven
- 2 pile average diameter
- 3 pile position to 20mm accuracy
- 4 founding and poles head level of pile to 10mm accuracy
- 5 any damage to the pole
- 6 details marked on the as-built Drawings where the constructed Works differ from those shown on the Drawings
- 7 for hammer drop installation:
 - log of number of blows to drive timber pole to the required depth recorded as blows per/0.25m
 - weight of hammer and drop height
- 8 for vibration installation:
 - type of vibration machinery used
 - rate of penetration
 - amperage and frequency used.

¹³ *Repairing and rebuilding houses affected by the Canterbury earthquakes* (Chapter 15.3 update issued in April 2015)

8 PROJECT SPECIFIC REQUIREMENTS

(To be completed by the specification writer)

APPENDIX 1. SPECIFICATION GUIDANCE NOTES

Specification Guidance Notes Preface

These specification guidance notes are not part of the Specification or Contract between parties undertaking ground improvement Works. Their purpose is to provide background information to help users understand the principles behind certain clauses in the Specification and to assist contract specification writers in the development of an appropriate specifications, depending on the type of ground improvement chosen and the location of the site. The clause numbers refer to the relevant sections in the Specification.

GN 1 Preliminary and General

The P&G section provides a comprehensive list of potential project requirements. Depending on the project location, nature and specific project requirements a number of these may not be required. The specification writer should use judgement as to whether the following are necessary and appropriate and which party is best suited to being responsible for them:

- 1 Pre construction condition survey
- 2 Construction management plan
- 3 QA/QC system and plan
- 4 Pre-works survey level plan
- 5 Construction noise plan
- 6 Construction vibration plan
- 7 Ground contamination site management plan
- 8 Archeological site management plan
- 9 Traffic management plan
- 10 Formal meetings to prescribed format

It is recommended that where some or all of the above requirements are needed for a particular project then these items should be listed in the Schedule of Quantities to ensure that they are specifically priced and allowed for in the Contract. Further consideration should also be given to the development of template plans so make it easier for the Contractor to understand the requirements of each plan and prepare a submission.

GN 1.1 General

When determining final reinstatement levels the Design Engineer needs to consider the minimum floor levels that may be required by the Regulatory Authority in areas prone to flooding and the amount of filling that might be required to allow future building foundations to be constructed.

GN 1.6 Pre-construction Condition Survey

The Design Engineer should make an assessment during the design phase of the likely sensitivity of existing buildings, structures, existing infrastructure and in-ground services to the construction of the proposed ground improvement. Pre-condition survey of in-ground services pipelines may need to include for inspection by CCTV. Where there is a likelihood of damage to such items, the Design Engineer should allow for inclusion of pre-construction condition survey within the Contract Bill of Quantities.

The Design Engineer shall also give consideration for the need for heave and/or settlement monitoring on adjacent properties that may be affected by the Works which would complement the pre-construction survey. Such monitoring would be required where there is a risk of damage to any public or private property, services, roading infrastructure, buildings, structures etc. and would be undertaken prior to the start of construction and at appropriate time intervals during construction. Appropriate alert and alarm trigger levels together with locations, frequencies and survey precision should be identified on the Drawings or otherwise instructed by the Engineer, taking into account the nature of the surrounding buildings, structures, infrastructure, services etc. The Contractor should nominate actions and mitigation measures, in their CMP, that can be implemented where these levels are triggered.

GN 1.8.1 Construction Management Plan (CMP)

The detail required for inclusion in the Contractor's CMP will depend on the complexity of the project. A list of items that should be considered for inclusion in the CMP are listed below:

- 1 A programme clearly showing the proposed Works sequence with identification of activities, as outlined in GN 1.8.2 below.
- 2 An outline of quality assurance and quality control (QA/QC) procedures for monitoring compliance of the constructed Works in accordance with the Specification and Drawings, as outlined in GN 1.8.3 below. This shall include procedures for identifying and rectifying non-compliances.
- 3 Details of how the various Statutory Authority consent conditions and other environmental requirements are to be monitored, complied with and reported.
- 4 A detailed method statement in respect of each stage of the Works. The method statement should include the following:
 - erosion and Sediment Control Plan (ESCP), including proposed measures to contain untreated water within the Site and prevent untreated water flowing into a stormwater line, watercourse, adjacent private land and/or adjacent public land outside of the extent of the Site
 - dewatering plan, including anticipated inflow rates, proposed collection and pumping regime, proposed treatment and discharge methods (if required)
 - details of any temporary Works such as batter slopes or temporary retaining structures
 - earthworks and ground improvement methodology, including proposed sequence of Works, testing regime and timings
 - details of the methodology for the removal and off-site disposal of Contaminated soil materials, if known to exist or encountered during the Works, including proposed sequence of Works, environmental and safety controls, test details and timings.
- 5 Details of construction methodology, including proposed material handling and treatment, methods and procedures for conditioning of soils, proposed construction plant and laboratory test programme.

- 6 Estimates of the quantities of each cut and fill material type, and the location of the stockpile and/or handling areas for each material type.
- 7 A description of the proposed method to monitor the volumes of each type of cut or fill material used.
- 8 Outline methods and techniques that will mitigate the risk of subsidence and/or collapse of earthworks batters that are within the Zone of Influence of the proposed Works, that might affect:
 - buildings and other structures
 - site boundaries and fences
 - roads, right of ways
 - service infrastructure.
- 9 A list of any Sub-contractors expected to be employed for various tasks on the Site.
- 10 Proposed hours of operation (refer to section 1.14).
- 11 A description of how the methodology will allow all construction to be completed in accordance with appropriate safe working procedures in accordance the Specification.

GN 1.8.2 Construction Programme

The level of detail required for inclusion in the Contractor's programme will depend on the complexity of the project. Typically the Contractor's programme should show the following:

- 1 delineate the timing and duration of each activity
- 2 delineate the timing and duration of inputs required from other parties (including Sub-contractors)
- 3 delineate the earliest and latest starting and finishing times for each activity
- 4 include the proposed sequence of all significant on-site and off-site activities, any intermediate key dates in the Contract, and the critical path
- 5 all inspections as detailed in the Specification
- 6 all testing requirements as detailed in the Specification.

GN 1.8.3 Quality Assurance and Control

The level of detail required for inclusion in the Contractor's Quality Control (QC) Plan will depend on the complexity of the project. A list of items that should be considered for inclusion in the CMP are listed below:

- 1 a statement of the Contractor's commitment to quality
- 2 the objectives of the QC Plan
- 3 a clear statement of individual responsibilities to implement the QA Plan
- 4 the qualifications and experience of key QA personnel
- 5 procedures both on- and off-site
- 6 control and checking of setting out
- 7 protection of material in transit to the Site
- 8 confirmation of quality of imported materials
- 9 storage of materials
- 10 monitoring of work in progress
- 11 supervision of Sub-contractors
- 12 checking of completed work
- 13 remedial methods
- 14 identification of stages of work requiring inspection by the Engineer before proceeding to the next stage
- 15 testing facilities on- and off-site
- 16 the control of amended drawings
- 17 the preparation of as-built drawings
- 18 training
- 19 compliance of Sub-contractors with the QC Plan.

GN 1.9 Pre-Construction Survey and Setting Out

It is noted that due to the recent seismic activity within the Canterbury region existing boundary pegs may not be able to be relied upon as being accurate. The Designer should check with Land Information New Zealand about the need for re-establishment of property boundaries. It is also common that property fences are not located along the property boundaries.

The Principal or Engineer should establish the accurate position of the property boundaries during the design phase and, where necessary, arrange for the property boundary to be accurately surveyed so that the

Contractor can set out the Works accurately from these boundary marks at the start of construction.

GN 1.15.3 Construction Noise

When designing the ground improvement Works and deciding on the most appropriate method, the Design Engineer should consider the likely construction noise effects on the existing surrounding built environment and any mitigation measures that may be required to be incorporated into the design or Contract in order to allow the Works to be constructed.

When tendering for the Works, the Contractor should likewise consider if their particular method and equipment will allow the Works to be constructed within the noise limits defined in the Contract and should include for any mitigation measures that may be required in order to allow the Works to be constructed without exceeding the limits. Where the Contractor does not consider it feasible to construct the Works within the specified noise limits then this should be identified at the time of tender.

GN 1.15.4 Construction Vibrations

When designing the ground improvement Works and deciding on the most appropriate method the Design Engineer should consider the likely construction vibration effects on the existing surrounding built environment and any mitigation measures that may be required to be incorporated into the design or contract in order to allow the Works to be constructed.

When tendering for the Works, the Contractor should likewise consider if their particular method and equipment will allow the Works to be constructed within the vibration limits defined in the Contract and should include for any mitigation measures that may be required in order to allow the Works to be constructed without exceeding the limits. Where the Contractor does not consider it feasible to construct the Works within the specified vibration limits then this should be identified at the time of tender.

GN 1.15.5 Contaminated Material

Where a subject Site is listed on the Hazardous Activities and Industries List (HAIL), under the Resource Management (National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health) Regulations 2011, and more than 25m³ of soil per 500m² of the property is to be disturbed, a Detailed Site Investigation (DSI) is required to investigate if the identified HAIL activity has led to contamination

of the ground that may pose a risk to human health. Sampling procedures shall generally comply with the MfE Contamination Land Management Guidelines No.5 – *Site Investigation and Analysis of Soils*.

Where the DSI shows that Contaminated material is present on Site, the Principal should engage a suitably qualified and experienced practitioner (as defined in the NES Soil Users' Guide – April 2012), to prepare and certify a Site Management Plan (SMP) for Ground Contamination. The objective of the SMP is to identify which material needs to be removed from Site, where materials are to be disposed of and which material may remain on Site or be able to be used within the ground improvement Works. The SMP will also provide procedures to manage contaminated soil-related effects during soil disturbance associated with ground improvement Works.

The SMP shall be approved by the Statutory Authority (where necessary) prior to the start of Works. The SMP shall be prepared in general accordance with Ministry for the Environment Contamination Land Management Guidelines No.1, *Guidelines for Consultants Reporting on Contaminated Sites in New Zealand*, and the NES Soil Regulations.

The Contamination SMP should be made available to the Contractor at the time of tender so that all costs associated with complying with the SMP can be allowed for by the Contractor in the tendered or quoted price.

GN 1.15.8 Archaeological Sites

In addition to any consent requirements from Christchurch City Council (CCC) or Environment Canterbury (ECan), any activity which may modify, damage or destroy any archaeological sites (generally places associated with pre-1900 human activity) is subject to the archaeological authority process under the Heritage New Zealand Pouhere Taonga Act 2014. An archaeological authority is required from the Heritage New Zealand to modify, damage or destroy any archaeological site, whether recorded or not in the NZAA Site Recording Scheme website.

The Design Engineer should check the local authority records if the proposed Site is listed as being an archaeological site. Where the site is listed, the Principal should engage a suitably qualified and experienced practitioner to prepare an Archaeological Site Management Plan (SMP). The objective of the SMP shall outline procedures for managing the protection and/or the removal of archaeological artefacts from the Site.

The SMP shall be approved by the Statutory Authority (where necessary) prior to the start of Works.

The Archaeological SMP should be made available to the Contractor at the time of tender so that all costs associated with complying with the SMP can be allowed for by the Contractor in the tendered or quoted price.

GN 1.18 Temporary Works Design

The complexity of the temporary Works design will vary depending on the proposed ground improvement technique and the proximity of the proposed Works to surrounding buildings, structures and existing infrastructure. The level of temporary Works design could vary between no specific design required to detailed analysis and design by a Chartered Professional Engineer where for example deep excavations/retention is required in close proximity to existing buildings/structures etc.

The Design Engineer should assess the likely complexity of the temporary Works design at the time of design and, where necessary, specify the minimum qualifications (eg CPEng) and any certification requirements (eg PS1, PS2) within the Contract tender document or Specifications.

GN 2 Testing

GN 2.1 Laboratory and Field Testing

The testing requirements specified in the guidance document have been minimised as much as possible, considering the intention that the document will be used for single residential house developments, while maintaining a reasonable level of construction quality assurance. The intention is that where there is recent existing testing information or where there is a high level of previous experience with the use of particular materials, that this is used to minimise the amount of Site specific laboratory and in-situ testing that is required. The guideline document lists what is considered to be 'mandatory' and 'discretionary' testing. Mandatory testing is what is considered to be the minimum testing that would normally be required. It is considered appropriate that a suitably qualified Geotechnical Professional make an assessment during the design phase of the type and amount of testing that is required and that the Specification be amended accordingly.

The amount of discretionary testing will need to be assessed by the Design Engineer based on several factors and in discussion with the Contractor depending on previous experience with similar materials. Where previous experience with similar materials is limited, the Engineer may instruct all or some of the discretionary testing to be undertaken in order to provide confidence that the material will be able to meet the requirements of the Specification.

Allowance for discretionary testing may be made in the Contract by inclusion as a Provisional Item, Provisional Sum or by inclusion of an appropriate amount into the project contingency, with such additional testing then undertaken as a variation to the Contract. Consideration should be given by the Design Engineer at the time of writing the contract document, which of these would be most appropriate for the size of the project and likelihood of needing such additional testing. Consideration should also be given by the Design Engineer of the likely delay (and resulting costs) any such additional testing may result in where such testing is undertaken as a variation to the Contract.

GN 2.2 Cone Penetration Tests

CPT operators who have machines that are anchored into the ground to provide a reaction force, should demonstrate in their operating methodology that the anchors will not influence the CPT results. This may involve, for example, installation of anchors at sufficient distance away from the CPT probe so as not to influence the results (outside a cone of influence of the anchor tip) or allow the CPT probe to be pushed in under static weight initially until the probe is a sufficient distance into the ground so as to be outside the influence of the anchors once deployed.

GN 4 Densified Crust

GN 4.1 General

Selection of both the geotextile and geogrid to be used within the Densified Crust should consider the particle size and grading of the imported Hardfill to be used.

Where Densified Crust ground improvement Works are proposed directly beneath anticipated new building foundations, it is preferable that the top of the improved

ground is constructed up to the underside of the proposed building foundations. Where it is proposed that ground improvement stabilisation Works be undertaken outside of the building footprint, it may be preferable to lower the depth of the Densified Crust and place a layer of compacted soil material (400mm to 600mm) over the top of the Crust in order to allow landscape planting and services trenches to be more easily constructed. Such additional thickness of material should not be relied upon as part of the Densified Crust. The degree of compaction and details of this landscaping zone should be shown on the Drawings.

Reference should be made to the MBIE Guidance Document¹⁴ for the minimum depth and width of ground improvement beyond the proposed building foundations.

GN 4.4.3.2 Maximum Dry Density

There may be a number of reasons why the dry density as determined in the laboratory cannot be achieved in the field. These factors include material grading, moisture content, layer thickness, weight and vibration frequency of compaction plant, and strength of subgrade. These factors are critical to achieving the required density and should be the first things that are checked when the target density cannot be achieved. Where the required density cannot be achieved and the Engineer is confident that all other issues have been addressed in attempting to achieve the minimum density test criteria, then they may allow a field Plateau Density Test to be undertaken in order to establish the MDD for verification purposes. It should however be noted that this may result in acceptance of a lower density and hence a crust of lower stiffness. In such cases the Engineer would likely need to change the design in order to achieve an equivalent Densified Crust. This may involve, for example, use of cement stabilised materials, additional geogrid layers or increasing the thickness of the Densified Crust.

The percentage Solid Density (SD) test criteria is offered as a simple alternative for Contractors to use for Hardfill compaction rather than the more complex minimum percentage of MDD as determined in a laboratory. It removes the need (and delays) for laboratory tests and provides an immediate pass/fail. It may mean the Contractor is required to pay a small premium for a good quality material in order to allow the density target to be achieved.

¹⁴ *Repairing and rebuilding houses affected by the Canterbury earthquakes* (Chapter 15.3 update issued in April 2015)

Roading subbase and basecourse complying with the NZTA material B2 and M4 Specifications respectively, will generally meet the target densities proposed. 82% SD ($e^{15}=0.22$) is achievable for a B2 subbase and 84% SD ($e=0.19$) is often specified for the M4 basecourse used on highly trafficked roads. Given that the residential sites will not have heavy compactors available, the target of 82% SD is considered achievable and appropriate.

If the target density is set below 82% SD to account for a supply of poorly graded product, then there is a risk that a subsequent change in materials to an optimally graded aggregate could result in poor compaction achieving the lower target. The method should therefore not be applied at lower target levels.

GN 4.6.2 Verification Test Criteria

The minimum strength test criteria provided align with the foundation types as proposed in the MBIE Guidance Document¹⁶. Where a different foundation type or bearing capacity is proposed then the required strength testing should be adjusted accordingly by the Design Engineer.

GN 5 Stabilised Crust

GN 5.1 General

Where Stabilised Crust ground improvement Works are proposed directly beneath anticipated new building foundations, it is preferable that the top of the improved ground is constructed up to the underside of the proposed building foundations. Where it is proposed that ground improvement Works are undertaken outside of the building footprint, it may be preferable to lower the depth of the Stabilised Crust and place a layer of compacted soil material (400mm to 600mm) over the top of the Crust in order to allow landscape planting and services trenches to be more easily constructed. Such additional thickness of material should not be relied upon as part of the

Stabilised Crust. The degree of compaction and details of this landscaping zone should be shown on the Drawings.

Reference should be made to the MBIE Guidance Document¹⁵ for the minimum depth and width of ground improvement beyond the proposed building foundations.

GN 5.4 Cement Dosage

The cement dosage rates required to achieve the specified strengths are affected by a number of factors including silt/clay content, water content, the proposed mixing method and degree of compaction. It is considered that specialist Contractors are likely to have the best experience in judging the amount of cement to be added, as the construction methodology and the particular plant and equipment proposed to be used will have a large influence on the ultimate strength gain achieved. Experienced Contractors should be able to optimise the volume of cement required (rather than a specific percentage being nominated in the Contract) and hence minimise the overall remediation cost for the Principal.

In order for the Contractor to be able to control their risk, however, a certain level of pre-tender soil testing should be undertaken by the Principal so as to allow the Contractor to make an informed decision on the cement dosage rate. This testing will lower the risk carried by the Contractor and hence will likely reduce the construction costs.

The testing shown in the table below are the suggested relevant minimum tests to be undertaken by the Principal and provided to the Contractors at the time of tender. The types and number of testing undertaken should be adjusted based on the size of the project, the variability of the soils at the Site and previous experience with similar materials.

The Engineer should consider instructing inspection test pits to be undertaken within the soil-cement Stabilised Crust where the Engineer suspects that the general mixing and panel joints is insufficient to provide a homogeneous crust.

15 Void ratio

16 *Repairing and rebuilding houses affected by the Canterbury earthquakes* (Chapter 15.3 update issued in April 2015)

Table GN 5.1: Suggested Material Testing for Soils to be used for Stabilisation

TEST DESCRIPTION	TEST METHOD	NUMBER OF TESTS PER RESIDENTIAL SITE	
		Ex-Situ and Rotovated	In-Situ
Atterberg Limits⁽¹⁾	NZS 4402:Test 2.2, 2.3 and 2.4	2	2
Particle Size Distribution⁽²⁾ (PSD)	NZS 4402:Test 2.8.1, 2.8.2 and 2.8.4	2	2
California Bearing Ratio⁽³⁾ (CBR) on samples mixed with cement	RRU TR7 Test 8, placed into the mould as follows: – Ex-situ and Rotovated: Standard Compaction ⁽⁴⁾ @ natural water content – In-Situ: Mixed into mould at liquid limit	Test @ 5%, 8% and 10% dry mass of cement with tests at 7, 14 and 28 days (9 tests total)	Test @ 7%, 10% and 13% dry mass of cement with tests at 7, 14 and 28 days (9 tests total)

Notes:

- 1 Atterberg Limits test provides basic soil classification information and the natural water content of the material.
- 2 PSD tests provides soil grading information and clay/silt content which affects the percentage of cement required.
- 3 CBR tests provide a correlation between cement percentage and strength. It should be noted that previous experience with the use of cement in stabilisation of soils is that the laboratory tests will generally return higher strengths that can be obtained in the field with the same cement dosage rate. Field dosage rates should therefore be adjusted accordingly, based on experience.
- 4 NZS 4402: Test 4.1.1 (Standard Compaction).

In-situ methods generally require higher cement dosage rates than ex-situ methods as compaction of the material is not possible for in-situ methods, where cement is mixed into the soil in a semi liquid state.

The testing detailed above should be obtained from representative bulk samples obtained from across the full extents of the Site.

GN 5.9.2 Verification Test Criteria

The minimum strength test criteria provided align with the foundation types as proposed in the MBIE Guidance Document¹⁷. Where a different foundation type or bearing capacity is proposed then the required strength testing should be adjusted accordingly by the Design Engineer.

GN 6 Stone Columns

GN 6.1 General

For relatively small residential properties, 'bottom fed' methods of installation of stone columns are preferred to 'top fed' methods for two main reasons:

- 1 Groundwater outflow and silt discharge control is easier to control.
- 2 There is much better surety about the volume of stone introduced and profile of stone down the column, especially in sandy soils where open holes may collapse before stone is able to be introduced.

Other methods for installation of stone columns such as conventional top fed methods may be suitable depending on the ground conditions and end use. Careful consideration should, however, be given to these and possible other implications before the approval of top fed methods by the Design Engineer. Where top fed methods are being considered, the Design Engineer should ask the Contractor to outline in their proposed methodology how the above two aspects would be controlled.

Reference should be made to the MBIE Guidance Document¹⁸ for the minimum depth and width of ground improvement beyond the proposed building foundations.

¹⁷ *Repairing and rebuilding houses affected by the Canterbury earthquakes* (Chapter 15.3 update issued in April 2015)

¹⁸ *Repairing and rebuilding houses affected by the Canterbury earthquakes* (Chapter 15.3 update issued in April 2015)

GN 6.2 Set out, Tolerance and Replacement Ratio

The Stone Column diameter installed will be effected by the stiffness of the surround soils. The actual column diameter is expected to vary with depth especially where the stratigraphy is layered and varies with depth.

GN 6.5 Surface Treatment

The Stone Column installation process can loosen the surface soils which could make them unsuitable for building foundations. Additional inspections or investigations may be required below the sub-excavated 400mm in order to confirm that soils below this level meet the minimum building subgrade strength criteria. With this method there is a risk that soil/Topsoil placed over the Stone Columns will, over time, wash through into the openly graded Stone Column aggregate resulting in 'surface depressions'. The drainage aggregate is intended to mitigate this risk below the building platform as well as to allow for the release of porewater pressure that may develop during future seismic events. Consideration needs to be given to the drainage aggregate grading to ensure that the material does not wash through the openly graded stone column material or that a geotextile is used at the interface to prevent this from happening. Likewise, in areas outside of the building platform where a drainage aggregate is not used and where Topsoil or soil fill is placed over the top of the stone columns, the use of a geotextile should be considered to avoid material washing through into the stone columns.

GN 6.6 Material Suitability

Broken face aggregate provides greater interlock between particles than rounded gravels and results in a stiffer stone column. It may, however, be possible in certain circumstances (depending on the design) to use rounded gravels but with a greater replacement ratio. In some situations this may provide a more cost effective solution. The Engineer will need to assess the effect of using rounded gravels on the design and determine any increase in replacement ratio required to provide equivalent performance.

The grading provided assumes bottom fed methods will be used as outlined in section 4.1 and GN4.1.

Using dry bottom feed stone column equipment, the practical maximum size is generally about 40mm as the tremie pipes are not large enough to accommodate larger sized aggregate from arching in the pipe walls and clogging up. Similarly, on the lower end of the grading envelope, stone sizes less than about 20mm are also not generally used. The grading envelope provided extends above and below these sizes to allow flexibility in the use of available materials. It is however expected that for dry bottom fed methods, an aggregate generally between 20mm and 40mm would be used.

Alternative aggregate gradings would be expected to be used where top fed methods are approved for use by the Engineer.

GN 6.7 Degree of Improvement Testing

The Design Engineer may choose to include or exclude the effects of densification of the soils between the stone columns in the design of the ground improvement Works.

The percentage of fines (silt and clay) present in the existing soils will affect the increase in density of the soils between the columns. The Design Engineer will need to assess during the design, the degree of improvement that could reasonably be expected, based on the in-situ material type and strength.

Where a density increase between the columns can reasonably be expected and where this increase in density is relied upon in the ground improvement design, then CPT degree of improvement testing should be undertaken after installation of the stone columns to demonstrate that the minimum specified density or increase in density has been achieved. Where the degree of improvement is of critical importance, the Design Engineer should also consider whether pre-construction CPT testing is available or required in order to assess the degree of improvement that has been achieved.

In silty soils, little or no increase in the density between the stone columns may be obtained and the Design Engineer may therefore base the design only on the increased in stiffness obtained from the installation of the stone columns. In this case no post construction CPT testing is required provided the minimum replacement ratio of stone introduced into the ground is obtained.

GN 7 Driven Timber Poles

GN 7.1 General

This guidance document has been written to align with the MBIE Guidance Document, which refers to Timber Poles. It is considered feasible that other products such as pre-cast concrete poles may also be able to be used instead of timber. This would need to be approved by the Design Engineer and would require alternative requirements and associated specifications.

Reference should be made to the MBIE Guidance Document¹⁹ for the minimum depth and width of ground improvement beyond the proposed building foundations.

GN 7.10 Degree of Improvement Testing

The Design Engineer may choose to include or exclude the effects of densification of the soils between the driven timber poles in the design of ground improvement Works.

The percentage of fines (silt and clay) present in the existing soils will affect the increase in density of the soils between the timber poles. The Design Engineer will need to assess during the design the degree of improvement that could reasonably be expected, based on the in-situ material type and strength.

Where a density increase between the poles can reasonably be expected and where this increase in density is relied upon in the ground improvement design, then CPT degree of improvement testing should be undertaken after installation of the poles to demonstrate that the minimum specified density or increase in density has been achieved. Where the degree of improvement is of critical importance, the Design Engineer should also consider whether pre-construction CPT testing is available or required in order to assess the degree of improvement that has been achieved.

In silty soils, little or no increase in the density between the timber poles may be obtained and the Design Engineer may therefore base the design only on the increased in stiffness obtained from the installation of the timber poles. In this case no post construction CPT testing is required provided the minimum number of poles are installed at the nominated spacing.

¹⁹ *Repairing and rebuilding houses affected by the Canterbury earthquakes* (Chapter 15.3 update issued in April 2015)

APPENDIX 2. POSSIBLE PROJECT SPECIFIC REQUIREMENTS

The following items, where appropriate, should be included or detailed in the Project Specific Requirements:

1 Preliminary and General

- Location and description of the Site
- Any site specific constraints
- Nature and extent of works
- Extent of Contractor's working area
- Site datum and grid references
- Requirements for P&G items as outlined in GN1
- Requirement to establish site datum and property boundaries
- Requirement and extent of pre-condition surveys
- Requirements for Producer Statements
- Requirements for any temporary works design, where required
- Specific technical ground improvement requirements not covered by general specification or drawings
- Particular precautions required to avoid damage to neighbouring buildings, structures, services or other infrastructure
- Resource consent conditions and requirements
- The presence of any particularly sensitive or vulnerable neighbouring buildings, structures, services or other infrastructure that may be affected by the works
- Any particular requirements around pedestrian, traffic control or access to the site

2 Background Information

- Nature of ground and expected subsurface conditions
- Geotechnical investigation data
- Contamination test data
- Areas of known archeological interest
- Pre-tender soil cement strength testing

3 Materials

- Sources of materials proposed to be used
- Re-use and or disposal of on-site material
- Any specified fill disposal sites

4 Testing

- Requirements for any additional site investigations
- Requirements for any pre-construction or discretionary laboratory testing not covered by the general specification
- Requirement for any site trials
- Requirements for any degree of improvement testing either prior to or after completion of the ground improvement works

5 Construction

- Likely subgrade improvements that may be required prior to construction of the ground improvement
- Extent of ground improvement in relation to proposed building footprint
- Surface reinstatement details
- Finished level of ground improvement taking into account if the area is susceptible to flooding and proposed building's finished floor level

NOTES

