STANDARDS NEW ZEALAND
TE MANA TAUTIKANGA O AOTEAROA®

NZS 4431:2022

NEW ZEALAND STANDARD

Engineered fill construction for lightweight structures

Superseding NZS 4431:1989

NZS 4431:2022

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This standard was prepared by the P4431 Earth Fill Practices Committee. The membership of the committee was approved by the New Zealand Standards Approval Board and appointed by the New Zealand Standards Executive under the Standards and Accreditation Act 2015.

The committee consisted of representatives of the following nominating organisations:

Auckland Council
Building System Performance (BSP)
Civil Engineering Testing Association of New Zealand (CETANZ)
Christchurch City Council
Civil Contractors New Zealand
GNS Science (Institute of Geological and Nuclear Sciences)
Heritage New Zealand Pouhere Taonga
Kāinga Ora – Homes and Communities
New Zealand Geotechnical Society
Registered Master Builders Association
University of Canterbury
University of Waikato

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Engineered fill construction for lightweight structures

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REFERENCED DOCUMENTS

Reference is made in this document to the following:

New Zealand standards

NZS 3604:2011	Timber-framed buildings
NZS 4402:- - - -	Methods of testing soils for civil engineering purposes
Test 2.1:1986	Determination of the water content
Test 2.7.1:1986	Soil classification tests – Method for coarse, medium and fine soils
Test 2.7.2:1986	Soil classification tests – Method for medium and fine soils
Test 2.8.1:1986	Soil classification tests – Standard method by wet sieving
Test 4.1.1:1986	Soil compaction tests – Determination of the dry density/water content relationship – New Zealand standard compaction test
Test 4.1.2:1986	Soil compaction tests – Determination of the dry density/water content relationship – New Zealand heavy compaction test
Test 4.1.3:1986	Soil compaction tests – Determination of the dry density/water content relationship – New Zealand vibrating hammer compaction test
Test 4.2.1:1988	Soil compaction tests – Determination of the minimum and maximum dry densities and relative density of a cohesionless soil – Minimum dry density
Test 4.2.2:1988	Soil compaction tests – Determination of the minimum and maximum dry densities and relative density of a cohesionless soil – Maximum dry density
Test 4.2.3:1988	Soil compaction tests – Determination of the minimum and maximum dry densities and relative density of a cohesionless soil – Relative density
NZS 4404:2010	Land development and subdivision infrastructure
NZS 4407:2015	Methods of sampling and testing road aggregates
NZS 4431:1989	Earth fill for residential development

American standards

ASTM D5874-16	Standard test methods for determination of the impact value (IV) of a soil
ASTM D4718-15	Standard practice for correction of unit weight and water content for soils containing oversize particles

German standards

DIN 18134:2012-04	Soil – Testing procedures and testing equipment – Plate load test

Other standards

AASHTO T224	Standard method of test for correction for coarse particles in the soil compaction test
AS 1289: (multiple dates)	Methods of testing soils for engineering purposes
CEN/TS 17006:2016	Earthworks. Continuous compaction control (CCC)

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Chartered Professional Engineers of New Zealand Act 2002

Health and Safety at Work Act 2015

Heritage New Zealand Pouhere Taonga Act 2014

Resource Management Act 1991

Resource Management (National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health) Regulations 2011

Websites

www.heritage.org.nz

www.legislation.govt.nz

www.nzgs.org

www.worksafe.govt.nz

LATEST REVISIONS

The users of this standard should ensure that their copies of the above-mentioned New Zealand standards are the latest revisions. Amendments to referenced New Zealand and joint Australian/New Zealand standards can be found on www.standards.govt.nz.

REVIEW OF STANDARDS

Suggestions for improvement of this standard will be welcomed. They should be sent to the National Manager, Standards New Zealand, PO Box 1473, Wellington 6140.

FOREWORD

NZS 4431 provides the process for the geotechnical investigation, design, construction, quality assurance testing, and certification of engineered fill as foundation support for lightweight residential and commercial buildings and associated infrastructure. Evidence of adherence to this standard, alongside appropriate professional review and certification, can be used to demonstrate compliance with the relevant sections of the New Zealand Building Code for these development projects.

This revision of NZS 4431 reflects changes in geotechnical investigation, design and construction practice, test methods, and environmental, consenting, and health and safety obligations since the original publication in 1989.

The layout of this revision reflects the iterative processes used by the geotechnical designer, certifier, and contractor to enable engineered fill construction to deliver safe and stable foundation support for lightweight residential and commercial buildings and associated infrastructure.

NZS 4431 is not a specification. An earthworks specification needs to be developed for each development in accordance with the requirements of this standard. The earthworks specification will provide the site- and contract-specific requirements in addition to those presented in this standard. To comply with this standard, certified engineered fill construction shall meet the requirements of the project- and site-specific earthworks specification, as well as the design documentation, engineering drawings, quality assurance and testing requirements, and building and consent conditions.

The *New Zealand earthworks specification* (NZGS, 2022) is an example of a generic specification developed to be compatible with this standard. It is appropriate for use on most residential (and many other) development projects with common soil and rock types found in New Zealand and comes in both a long and a short form to suit larger and smaller projects respectively.

Because of the variability of the natural materials used in earthworks, specialist geotechnical input is needed to ensure that the specified soil and rock materials are suitable for the intended use and that the proposed testing regime is appropriate for the selected materials.

The primary intended users of this standard are the geotechnical designer and the certifier. In the context of this standard, the geotechnical designer is responsible for the design of the engineered fill and the preparation of the earthworks specification. The certifier is responsible for confirming that the engineered fill has been constructed in accordance with the design, consent conditions, and earthworks specification. In many smaller projects, the geotechnical designer will also take the role of certifier.

The contractor responsible for placing the engineered fill should have a good understanding of this standard. It is expected that they will use this standard to direct any filling operations in conjunction with the earthworks specification created by the geotechnical designer in accordance with this standard.

NOTES

New Zealand Standard

Engineered fill construction for lightweight structures

1 GENERAL

1.1 Scope

1.1.1 Overview

This standard sets out practices that are needed to produce geotechnically stable and resilient engineered fill for projects where the engineered fill will provide a foundation for lightweight structures.

The geotechnical designer shall assess whether it is appropriate to use this standard for each project.

1.1.2 Inclusions

This standard covers engineered fill construction for lightweight structures such as:

(a) Residential building development undertaken in accordance with NZS 3604, or other developments with similar foundation loadings and sensitivity to ground settlement;

(b) Commercial building developments with foundation loads and performance expectations similar to what is described in (a) above.

This standard is appropriate for the placement of fill associated with the following structure types, where these structures are being constructed for the purposes described above:

(c) Mechanically stabilised earth (MSE) slopes with a face inclined at less than 60° from the horizontal;

(d) Retaining walls (excluding drainage media and services).

C1.1.2

To assess if this standard is suitable for use with a proposed development, the geotechnical designer should carefully consider whether the unfactored bearing stress applied to the ground will be similar to or less than a light timber-framed (with lightweight wall and roof cladding) residential three-storey building. The geotechnical designer should assess the sensitivity of the proposed structure(s) to settlement or deformation. Construction of engineered fill in accordance with this standard, and using the criteria presented in Appendix A, should result in a fill platform that will limit the settlement or deformation to acceptable levels without causing loss of amenity during construction or when in use. This standard will probably not be suitable for developments where a structure is more sensitive to differential or total settlement or deformation.

1.1.3 Exclusions

The following are not covered by this standard:

(a) Managing contaminated materials;

(b) Permanent cut slopes;

(c) Stability of temporary cut batters;

(d) Evaluating the suitability of existing natural ground for founding earthworks;

(e) Retaining-wall construction and retaining-wall drainage;

(f) Service construction and backfilling of service trenches;

(g) Chemically stabilised fill (for example, cement or lime);

(h) Pavement sub-base, base course, or surfacing;

(i) Contractual aspects of earthfill construction.

The processes associated with undertaking site investigations and the design of engineered fill are not covered by this standard, except to define the minimum considerations that have to be addressed in the investigation and design to achieve a stable and resilient engineered fill.

1.2 Objectives

The standard has the following objectives:

(a) To set out a process to ensure the construction of engineered fill is implemented as the geotechnical designer intended;

(b) To provide a framework from which engineered fill placed in accordance with the standard can be shown to meet the geotechnical design and the consent conditions – and can be certified;

(c) To provide a pathway by which consent authorities can accept engineered fill placed and certified in accordance with this standard.

1.3 Interpretation

For the purposes of this standard, the word 'shall' refers to requirements that are essential for compliance with the standard, whereas the word 'should' refers to practices that are advised or recommended.

Clauses prefixed 'C' and printed in italic type are intended as comments on the corresponding clauses. They are not to be taken as the only or complete interpretation. The standard can be complied with if the comment is ignored.

The terms 'normative' and 'informative' have been used in this standard to define the application of the appendix to which they apply. A 'normative' appendix is an integral part of the standard, whereas an 'informative' appendix is only for information and guidance.

1.4 Definitions

For the purposes of this standard the following definitions shall apply:

Archaeological site	An archaeological site is defined in the Heritage New Zealand Pouhere Taonga Act. It is any place (including buildings, structures, or shipwrecks) in New Zealand that is associated with pre-1900 human activity and where there is evidence relating to the history of New Zealand that can be investigated using archaeological methods
Building platform	An area of land suitable for buildings to be constructed
Certifier	The independent professional engineer or engineering geologist responsible for the certification of the completed earthworks in accordance with the design and consent conditions. The certifier needs to be independent of the contractor or the developer and have suitable experience of earthworks in similar materials. The geotechnical designer can also take the role of certifier
Certifier's representative	The independent and suitably qualified person delegated by the certifier to represent them on the engineered fill construction site
Cleared ground	The material exposed by stripping the site to the cleared ground level
Cleared ground level (CGL)	The ground level after completion of site excavation and removal of all harmful or unsuitable material and before any fill is placed
Collapse compression	Settlements developing in partially saturated and low- to medium-dense soils because of fluid infiltration. Collapse compression settlements can be rapid or develop over an extended period
Compaction	The process where mechanical effort is applied to a soil and/or aggregate matrix to facilitate a reduction in voids with resulting increase in density
Contaminated site management plan	A site management plan prepared in accordance with the Ministry for the Environment's *Contaminated land management guidelines no. 1*
Continuous compaction control	A quality-control method in earthworks by means of roller-integrated dynamic measuring and documentation systems
Contractor	The organisation leading the physical construction of the earthworks
CUSUM	CUmulative SUM method

Design	A plan for the construction of an engineered fill prepared by a geotechnical designer in accordance with recognised New Zealand standards and accepted geotechnical engineering practice, and detailed on engineering drawings and in the earthworks specification
Developer	The individual or organisation that has engaged the contractor. This is commonly one or more of the landowner, builder, and consent holder
Earthworks	The act of excavating natural soil and rock materials, transporting these materials, and placing these materials (or manufactured equivalents) in a controlled manner with or without the addition of reinforcement to form the engineered fill. The term 'earthworks' can also refer to the finished product (a structure made from fill). Earthworks can be controlled (producing engineered fill) or uncontrolled. Uncontrolled earthworks are not covered by this standard
Earthworks specification	The specification approved by the geotechnical designer providing details of the classification, testing, and compaction requirements for the engineered fill. In the absence of a site-specific earthworks specification developed by the geotechnical designer, this shall be the *New Zealand earthworks specification* published by the New Zealand Geotechnical Society (NZGS)
Engineered fill	Soil, rock, or manufactured equivalents that have been placed in a controlled manner and tested to demonstrate compliance with the design
Fill	Soil, rock, or manufactured equivalents that have been placed by human activity
Finished ground level (FGL)	The level of the ground after all earthworks and any landscaping or surface paving are complete
Geotechnical designer	The authorised representative of the organisation undertaking the earthworks design (including the earthworks specification). The geotechnical designer shall be a geotechnical engineer and/or engineering geologist who holds a current chartered registration under the Chartered Professional Engineers of New Zealand Act 2002, or equivalent as appropriate. Currently, the Chartered Professional Engineer (CPEng) and Professional Engineering Geologist (PEngGeol) quality marks are registered as assessed and administered by Engineering New Zealand. The geotechnical designer can also take the role of certifier. The geotechnical designer shall have suitable experience of earthworks in similar materials

Heave	Upward movements that occur because of stress changes in the ground. Heave can be uniform or differential. Heave can either be sudden or develop over a wide range of time frames depending on the properties of the soil, the loading conditions, and the resultant changes in stress. Heave occurring at the toe of a slope or next to a loaded area could be indicative of a shear failure in the soil mass
Hold point	A stage in the earthworks at which work shall not proceed without approval from the relevant authority. In most cases, for engineered fill this approval will be given by the certifier, and in some cases, it could be ecologists, arborists, heritage experts, or others
Independent	'Independent' in this context means the party is able to act independently and with professional skill and judgement that is not compromised by their contract, ownership structure, or other relationship. The independent party shall be free from any business relationship or circumstance that could materially interfere with the exercise of the independent party's judgement
Inspection and test plan (ITP)	The schedule of required inspections and tests to confirm that the engineered fill meets the requirements of the design, including the earthworks specification and other requirements that could require inspection or testing (for example, consent conditions)
Layer	A layer is a thickness of engineered fill compacted in one operation. Each layer of engineered fill is commonly required to be no thicker than 250 mm. The thickness of each layer is specified as the loose thickness – that is, the thickness as tipped out of the truck or scraper, but before any compaction other than spreading. Each layer is usually compacted several times before the next layer is placed
Lift	A lift is several engineered fill layers that are tested as a group. Each lift needs to have consistent material that is placed and compacted using the same methodology throughout. A single lift usually comprises three or four layers, which when compacted make about 750 mm to 850 mm of compacted engineered fill, the surface of which would then be tested. The thickness of a lift will vary by material type and compaction method
Lightweight structure	A building or other structure that is designed in accordance with NZS 3604 or whose foundations imparts a bearing stress of no more than 100 kPa on the engineered fill and which is not highly sensitive to differential settlement
Natural ground level (NGL)	The ground level before the site has been cleared

Non-compliance (NC)	Failure to meet the required standard or condition
Quality management plan (QMP)	The plan, incorporating the ITP, to enable the contractor to integrate the statutory, technical, and performance framework requirements for the engineered fill construction with the contractor's quality systems during delivery of the specified works
Random verification tests	Tests carried out by an independent party in addition to what is required by the ITP. Random verification testing is risk-based and carried out to confirm inspection and test results, or where areas of concerns have been identified
Recognised laboratory	The independent, accredited engineering laboratory engaged to sample and test the earthworks in accordance with recognised New Zealand standards
Registered professional surveyor	A professional surveyor with recognised qualifications and experience in construction survey work related to earthworks development
Services, maintenance, and access area (SMAA)	An area of land outside the proposed building platform that contains services (such as driveways, wastewater pipes, soakage devices, and wastewater disposal fields) or which will be used to provide access for maintenance to the structure, the services, or any retaining walls. It should be sufficiently wide to allow for whatever plant or equipment is likely to be required for future maintenance activities. For example, adjacent to a house, it could include room for scaffolding so that future maintenance on the roof can be undertaken safely
Settlement	Downward movements occurring because of stress changes in the ground. Settlements can be uniform or differential. They can be immediate or develop over a wide range of time frames depending on the properties of the soil, the loading conditions, and the resultant changes in stress. The deleterious properties of, or ongoing changes in some materials (for example, decomposition of organic material) could contribute to settlement in both the short and the long term
Shear failure	Unacceptable ground movements that occur because the soil's shear strength is exceeded. Shear failures can sometimes be identified by slip surfaces, large deformations (particularly in sloping ground), slumping, and heave
Shrink-swell	Volumetric changes associated with the seasonal variation in moisture content of clay-rich soils, usually manifested by downward or upward ground movement and tension cracks

Subcontractor	A specialist organisation with delegated responsibility from the contractor for construction of all or part of the earthworks
Suitably qualified and experienced practitioner (SQEP)	A suitably qualified and experienced practitioner as per the Ministry for the Environment's *Contaminated land management guidelines no. 1*
Temporary works	Temporary works are parts of the works that either enable the construction or protection of the permanent works or support or provide access to the permanent works, and which are not expected to remain in place at the completion of the works

1.5 Abbreviations

Abbreviations have the following meanings:

ACM	Asbestos-containing materials
AP	All passing. Used as an equivalent for GAP. GAP is the preferred term
CBR	California bearing ratio
CCC	Continuous compaction control
CGL	Cleared ground level
CPT	Cone penetration test
CPTu	Cone penetration test with pore water pressure measurement
DCP	Dynamic cone penetrometer
FGL	Finished ground level
GAP	General all passing
HAIL	Hazardous activities and industries list
HNZPT	Heritage New Zealand Pouhere Taonga
IC	Intelligent compaction
ITP	Inspection and test plan
IV	Impact value
MDD	Maximum dry density
MSE	Mechanically stabilised earth
NC	Non-compliance

NDM	Nuclear density meter
NGL	Natural ground level
NZGS	New Zealand Geotechnical Society
OMC	Optimum moisture content
PSD	Particle size distribution
QA	Quality assurance
QMP	Quality management plan
RVT	Random verification test
SMAA	Services, maintenance, and access area
SPC	Statistical process control
SPT	Standard penetration test
SQEP	Suitably qualified and experienced practitioner
VENM	Virgin excavated natural material

2 INVESTIGATION, DESIGN, AND PLANNING

2.1 General

In the investigation and design of any engineered fill, the geotechnical designer shall:

(a) Take into consideration the geotechnical history of the site and adjoining land;

(b) Incorporate published findings from previous site and material investigations;

(c) Ensure new site and material investigations have been carried out correctly and are then used to inform the design;

(d) Incorporate the requirements of the New Zealand Building Code (NZBC), regional and district plans, and specific consent conditions into the design correctly;

(e) Consider the effects of earthworks on the adjoining land and structures;

(f) Design the earthworks;

(g) Communicate the earthworks assumptions design and design intent in:

 (i) a design report

 (ii) an earthworks specification, and

 (iii) drawings showing the location of each intended fill use type.

C2.1

The term ‘fill use type’ used in 2.1(g)(iii) is described further in 3.5.

Factors that affect the earthworks investigation, design, and construction preparation can include:

(a) Cultural heritage and archaeology;

(b) Distributions of soil and rock on the site;

(c) Evidence of contamination or human disturbance of the ground on the site and adjoining land;

(d) Evidence of previous ground movement or instability on the site and adjoining land;

(e) Evidence that debris has fallen or slid into the site;

(f) Health and safety requirements;

(g) Local and regional geology and hydrogeology;

(h) Performance of comparable earthworks nearby;

(i) Sub-surface drainage and groundwater conditions on the site and adjoining land;

(j) Surface drainage on the site and adjoining land;

(k) The existing and intended land use;

(l) The extent and scale of the earthworks, both temporary and permanent;

(m) The nature and shape of the site and adjoining land.

Information that would normally be provided to those preparing for earthworks can include:

(n) *Design reports, drawings, and technical specifications;*

(o) *Maps and documents describing the site's cultural heritage and archaeology, geology, hazards, current and past land use, existing and proposed utility services, and property boundaries;*

(p) *Resource and building consent conditions as well as conditions stipulated by any other relevant authorities;*

(q) *Site investigation factual reports, photographs, and samples;*

(r) *Site-specific health and safety and risk requirements.*

Geotechnical information that can help those preparing for earthworks can include:

(s) *NZGS guidelines for the field description of soil and rock classification;*

(t) *Modules 1 to 6 of NZGS/MBIE's* Earthquake geotechnical engineering practice*;*

(u) *The NZS 4402 series and NZS 4407;*

(v) Specification for earthworks construction TNZ F/1 *(Transit New Zealand, now Waka Kotahi, 1997);*

(w) Specification for pipe subsoil drain construction NZTA F2 *(NZTA Waka Kotahi, 2013).*

2.2 Safety in design

The geotechnical designer shall evaluate safety risks and recommend appropriate mitigations in the earthworks design and earthworks specification to remove safety hazards during the construction, operation, maintenance, and future deconstruction or renewal of the engineered fill, where reasonably practical.

The geotechnical designer shall communicate any residual safety risks through their design report and drawings.

C2.2
Some considerations common to earthworks projects include:

(a) *Initiating instability in adjacent slopes;*

(b) *Work in any pit, shaft, trench, or other excavation. This is particularly challenging when any person is required to work in a space that is more than 1.5 m deep with a depth greater than the horizontal width at the top – but even shallower spaces should be considered;*

(c) *Work in any excavation below any cut batters is particularly risky when the height is greater than 3 m and the average slope is steeper than a ratio of 1 horizontal to 2 vertical;*

(d) *Work involving the use of explosives or storage of explosives;*

(e) *Maintenance of steep slopes including vegetation management and watering;*

(f) Maintenance of drainage systems;

(g) Decommissioning of soil or slope reinforcement elements (such as geogrids) at the end of their design life.

2.3 Sustainability in design

The geotechnical designer shall design the works to allow for materials that can be sourced and used sustainably and, where possible, for waste materials to be reused.

C2.3

Climatic warming caused by the emissions of anthropogenic greenhouse gases is occurring across the globe. These changes will increase the exposure of the built environment to hazards such as sea level rise and coastal inundation and exacerbate existing hazards such as expansive soils and landslides. Such effects should be addressed in the design where possible. Where there is insufficient evidence to make an informed engineering decision, cautious assumptions should be made.

Considerations relating to climate change include changes in:

(a) Groundwater level;

(b) Sea level and increased coastal erosion;

(c) Storm frequency and intensity;

(d) Drought frequency and intensity.

For example, in an area where sea level rise requires managed retreat, engineered fill should be resilient to erosion or able to be moved easily to another location.

Examples of sustainable material sourcing and use include:

(e) Minimising greenhouse gas emissions by using carbon accounting to select the most efficient design options;

(f) Identifying appropriate recycled materials;

(g) Selecting materials that can be sourced as close to site as possible;

(h) Using mass haul diagrams, particularly on large or linear sites;

(i) Bringing material to site using rail transport or similar low-impact options;

(j) Designing works to maximise the use of materials that could otherwise be considered unsuitable (such as for landscaping).

Examples of recycled materials include:

(k) Crushed concrete or bricks for fill;

(l) Crushed glass as an alternative to sand.

The feasibility of using recycled materials will vary depending on the availability of materials within a suitable distance from the site and the potential environmental impact.

Consideration of the sustainable use of materials is discussed in C3.4.1 as well as clauses 3.3.2, 3.4.5, and 3.4.6 and the associated comment boxes.

Changes in use can also change the performance demanded of the engineered fill. For example, land use intensification could increase the potential loadings. Where these changes are foreseeable, they should be considered in the design process.

The geotechnical designer shall evaluate how predictable changes in loadings, environmental conditions (such as groundwater levels), or land use could affect the engineered fill and include mitigation features in the design where appropriate.

2.4 Site and material investigations – Factual data and interpretative reports

Site and material investigations shall be sufficiently detailed to achieve all of the following:

(a) Describe the site geology;

(b) Establish the extent and depths of the principal soil and rock types and groundwater conditions within the zone of influence of any proposed fill or associated structures (which could include both the site and adjoining land);

(c) Classify the condition and material properties of the principal soil and rock types at the site by recognised methods;

(d) Inform an assessment of the effects (including slope stability, bearing capacity, and ground settlement) that the proposed fill could have on the site and surrounding area;

(e) Identify problematic materials and conditions;

(f) Identify geotechnical and geological hazards.

C2.4

Assessments and testing should include literature review, site inspections, borings, probings, and open cuts. The physical ground investigation should include logging of soil and rock units, sampling of representative and problematic areas, and laboratory testing. The required testing will be unit specific and targeted to address the geotechnical problems that could be encountered. These tests commonly include natural water content, liquid and plastic limits, particle size distribution, consolidation and shear strength parameters, sensitivity characteristics, liquid and plastic limits, relative density, and in-situ density.

Soil and rock classification should be made using the NZGS guidelines for the field description of soil and rock as well as recognised material test standards such as the NZS 4402 series and NZS 4407.

The depth to the groundwater should be measured and, where there is any possibility of it affecting the earthworks, monitored to understand seasonal fluctuations and annual range.

Inadequate identification of clean topsoil resources risks good soil becoming mixed with spoil or contaminated materials, thereby restricting or preventing its reuse, and could also result in the need to import additional topsoil for landscape works. This will inevitably increase the cost and result in adverse environmental effects.

Identification of topsoil and subsoil resources is important as part of a construction site's waste management plan as most greenfield developments generate topsoil surpluses. On most sites, a soil survey will be carried out, either as part of the geotechnical site investigation or by a soil scientist using hand-operated soil sampling equipment. Some test pits could be needed to investigate soil layers that are inaccessible by hand auger.

Initial topsoil investigations would typically be undertaken on a rectilinear or herringbone grid pattern, with the characteristics (colour, texture, drainage, and whether topsoil or subsoil) of each soil layer recorded. This can be combined with a geotechnical or geo-environmental investigation, provided the relevant expertise is applied.

Investigations should also assess the depth to liquefiable soils, the presence of soils that collapse on loading, and the possibility of a reduction in soil strength or stiffness as excavation depth increases.

The potential for contaminated land should be assessed and, where this risk is possible, an SQEP engaged to advise on appropriate management options.

Factual data about soil and rock material conditions and strengths shall be obtained for areas, whether on-site or off-site, which are intended to:

(g) Form in-situ foundations for engineered fill; or

(h) Yield material for the construction of engineered fill.

Geotechnical assessment, along with sampling, testing in the field, and testing in a recognised laboratory, shall provide information on the following:

(i) Areas where the founding materials beneath any depth of engineered fill could adversely affect the works, including areas with:

- (i) Low strength
- (ii) Inadequate bearing capacity
- (iii) Wet soils
- (iv) Contamination
- (v) Unstable or settlement-prone ground;

(j) Areas where natural surface or sub-surface drainage will be extensively altered or reversed by the works;

(k) Areas where global or local area slope stability on the site or adjoining land will be altered by the temporary or permanent works;

(l) Areas on- or off-site from where soil and rock material intended for use in the construction of engineered fill will be obtained;

(m) Any other considerations that the geotechnical designer considers relevant in accordance with geotechnical engineering practice.

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An interpretative geotechnical report shall be prepared and shall include (or refer to other published reports that include):

(n) All site, material, and laboratory investigation and factual test results;

(o) A description of the assumptions made in the geotechnical interpretation;

(p) A commentary on uncertainties and an assessment of risk;

(q) Recommendations to be addressed in the earthworks design, construction, and monitoring.

2.5 Design

2.5.1 General

The geotechnical designer shall design the engineered fill to meet NZBC requirements and ensure that buildings, building elements, services, utilities, and all site works shall have a low probability of loss of amenity through ground deformation, bearing failure, slope movement, piping, erosion, or stormwater damage.

The design shall be presented in a design report and on drawings that include adequate detail for the intended scope and scale of the works as well as a clear description of the geotechnical designer's assumptions and recommendations to support safe construction.

The design shall address at least the following aspects:

(a) Settlement and consolidation;

(b) Bearing capacity;

(c) Liquefaction and earthquake-related deformation;

(d) Shrinkage and expansion;

(e) Slope stability;

(f) Stormwater drainage;

(g) Stormwater erosion;

(h) Sub-surface drainage;

(i) The effect of construction, maintenance, or failure of utility services on the engineered fill;

(j) Planting and revegetation;

(k) Temporary works.

When evaluating seismic load cases, the geotechnical designer shall refer to published guidance or standards relevant to New Zealand conditions for expected seismic hazards at the location of interest.

Where applicable, the design shall show on a site plan and appropriately detailed cross sections:

(l) The fill use type, as defined in the earthworks specification, to be placed in each location (see 3.5). Boundaries between fill use types shall be shown;

(m) The positions of proposed building foundations, retaining walls, and other structures;

(n) The position of proposed utilities;

(o) The services and maintenance access area.

2.5.2 Settlement and consolidation

The design of engineered fill shall be such that settlements are kept within the acceptable limits determined by the geotechnical designer. These acceptable limits shall be documented in the design. The geotechnical designer shall evaluate the level of expected impacts on existing structures and infrastructure where these are in the zone of influence of the fill, and include any measures necessary to prevent unacceptable settlements affecting adjoining land.

The geotechnical designer shall evaluate the expected total and differential settlement performance of the engineered fill during and after construction, recommending as needed a lapse of time between site filling and commencement of development and building.

The geotechnical designer shall consider the possibility of collapse compression and, where needed, appropriate mitigations shall be recommended in the design. This assessment shall consider collapse compression resulting from all of the following:

(a) Surface infiltration;

(b) Ground water seepage;

(c) The potential for rising groundwater levels.

C2.5.2

One of the most important factors in ensuring satisfactory performance of stable fills is the limiting of post-construction differential settlements. Acceptable differential settlements should be identified and documented. This could require taking advice from the structural engineer for the project.

Testing in support of settlement and consolidation evaluation can include site testing (such as the cone penetration test with pore water pressure measurement [CPTu] or a borehole with the standard penetration test [SPT]) and laboratory testing (such as one-dimensional consolidation or triaxial testing). The results of these tests are often used in settlement evaluation by proprietary software tools using the principles of elastic theory and a range of numerical models.

During construction, measurement of ground deformation (combined settlement and consolidation) can include precise engineering surveying of the as-built fill surface and embedded settlement plates and specialised in-built soil testing (for example, pore pressure measurements in cohesive fill soils).

Additional fill placed close to a building (for example, a raised patio) during or after construction will likely result in extra loads in the soil below the foundation, causing unplanned differential ground deformation with the potential for related or subsequent damage to the adjacent structure. Although design mitigations are normally outside the scope of this standard, they should be considered.

2.5.3 Bearing capacity

The geotechnical designer shall evaluate the expected strength of the as-built engineered fill and the resulting geotechnical ultimate bearing capacity for the expected range of foundation types intended for the project and, where needed, recommend appropriate mitigations in the earthworks design and earthworks specification.

C2.5.3

Bearing failure (and resulting gross deformation) under building foundations is a local phenomenon, distinct from settlement and consolidation. While earthwork fill constructed to minimise settlement and consolidation would normally be expected to have adequate shear strength and therefore bearing capacity, the bearing capacity should also be checked. This check should consider a range of load cases, including the possible additional loading that could arise from earthquake loading. Testing to support this bearing capacity assessment can include the plate bearing test and use of a lightweight deflectometer, dynamic cone penetrometer (DCP), and shear vane (hand-held or drill-rig mounted).

2.5.4 Shrink and swell

The geotechnical designer shall evaluate if expansive soils could adversely affect the construction and long-term performance of the engineered fill and, where needed, recommend appropriate mitigations in the earthworks design and earthworks specification.

C2.5.4

The engineering properties of expansive soils, including highly plastic clays, can deteriorate over time due to cracking and swelling. This can adversely affect building foundations and utility services. Expansive soils within the existing foundation materials can be covered to help maintain stable moisture conditions. Expansive soil in-fill source materials could require modification (such as lime stabilisation) or selected removal during the cut-to-fill operations. The undertaking of earthworks on a site with expansive soils fundamentally changes the shrink-swell behaviour. It is possible that where excessive shrink-swell has occurred, it is due to the misclassification of the site following earthworks.

2.5.5 Slope stability

The geotechnical designer shall evaluate the stability of the site and adjoining land during and after the construction of the engineered fill. The geotechnical designer shall consider what temporary works will be required to achieve the design, and allow for them in the stability analyses. The geotechnical designer shall ensure that an adequate factor of safety is achieved at all stages and, where needed, shall recommend appropriate mitigations in the earthworks design and earthworks specification. See 2.2 for more information.

C2.5.5

Slope stability analysis should consider:

(a) Permanent loads, including:

(i) Self-weight

(ii) Imposed gravity loads arising from current or future use (such as buildings)

(iii) Non-structural building elements and contents;

(b) Temporary loads, such as:

(i) Earthquakes

(ii) Snow

(iii) Ash

(iv) Water and other liquids

(v) Equipment, plant, and vehicles;

(c) Time-dependent effects, such as:

(i) Creep

(ii) Shrinkage

(iii) Temperature changes

(iv) Groundwater changes;

(d) Physical inclusions and changes, such as:

(i) Current and future trenches for services

(ii) Loss of support through excavation or erosion;

(e) Three-dimensional topography where this could have a significant effect on stability.

Testing for slope stability analysis can include site testing (such as CPTu or a borehole with SPT) and laboratory testing (such as shear strength, moisture content, plasticity indices, gradation, and moisture sensitivity).

2.5.6 Stormwater drainage

The geotechnical designer shall evaluate the works needed, both temporary and permanent, to ensure that overland flow paths, stormwater discharges, adjoining flood plains, and stormwater infrastructure (structures, pipes, and culverts) do not adversely affect the condition of the engineered fill. The geotechnical designer shall recommend appropriate mitigations in the earthworks design and earthworks specification where they are needed.

Disposal of stormwater or wastewater through soakage or infiltration shall only be used when this is explicitly allowed for in the design of the fill.

C2.5.6

The assessment of overland flow paths and stormwater discharge volumes should be undertaken in accordance with current good practice by an appropriately experienced stormwater engineer. Guidance is available from most territorial authorities.

It is not normally appropriate for stormwater soak-pits to be in or to discharge onto filled ground as this can trigger slope instability, bearing failure, or collapse compression in the fill materials. Extra care is required in the design if this is intended.

The assessment of stormwater structures should consider overflow, blockage, running under pressure, and infrastructure failure.

The design for stormwater structures, pipes, and culverts installed above, in, around, or below fill should include careful evaluation of drainage capacity, strength, and water tightness to ensure stormwater drainage does not compromise the stability and integrity of the engineered fill during construction and in service. The design should consider the potential for movement of the fill (for example, from settlement or shrink-swell behaviour) to affect the integrity of pipes and culverts.

2.5.7 Surface water erosion

The geotechnical designer shall evaluate the works needed, both temporary and permanent, to ensure fill surfaces or natural ground near the toe or sides of the fill are not eroded by surface water, including overland flows, springs, discharges from buildings and building elements, or discharges from hardstand and pavement areas. Where needed, the geotechnical designer shall recommend appropriate mitigations in the earthworks design and earthworks specification.

C2.5.7

Where surface water could cause erosion of batters, an interceptor drain should be provided above the top of the batter. Special precautions will be necessary with soils that are known to be prone to erosion (such as loess, pumice, and similar soils).

Surface protection should be included as the fill is being constructed and should be completed as soon as practical after construction of the fill is substantially completed.

Further information can be found in clause 2.3.7.2 of NZS 4404.

2.5.8 Sub-surface drainage

The geotechnical designer shall evaluate the works needed, both temporary and permanent, to ensure that the stability and integrity of the engineered fill cannot be adversely affected by current or likely future groundwater conditions. Where needed, the geotechnical designer shall recommend appropriate mitigations in the earthworks design and earthworks specification.

C2.5.8(1)

Saturation of the engineered fill could result in settlements developing because of collapse compression. These can develop rapidly or slowly, depending on the type of material present in the fill.

Well-engineered fills should not be at risk of collapse compression. However, groundwater control could still be required to maintain fill stability.

Measures to reduce the likelihood of groundwater ingress to the engineered fill mass could include underfill drainage blankets, the use of no-fines rock fill in certain parts of the fill mass, groundwater cut-off drains, and other subsoil drainage measures.

Transportation of fine-grained particles because of long-term seepage towards the drains can cause the drainage layers or drainage systems to become clogged.

To prevent clogging, the designer could use one or more filter layers to prevent the migration of fine-grained material. Specific advice related to the selection of material gradations in filters should be sought.

Care should be taken when specifying geotextiles in place of granular filter layers. Inappropriately designed or specified woven geotextile filters ('filter cloth') have been shown to be susceptible to clogging (either chemical, physical, or biological). These geotextile filters can be effective when designed and used appropriately.

Sub-surface drainage systems should be designed to lead seepage away to permanent and well-maintained outlets. They shall be designed to:

(a) Ensure that flows from all springs, or potential seepage from natural ground towards the engineered fill, are controlled in the long term;

(b) Prevent saturation of the engineered fill during or after construction, as saturation could delay the certification of the works;

(c) Prevent internal erosion ('piping');

(d) Prevent internal seepage pressures, which reduce shear strength and adversely affect long-term slope stability.

Sub-surface drainage shall be designed to limit the possibility of drainage systems becoming clogged over time unless it can be shown that a loss of drainage capacity does not cause:

(e) A loss of stability in the fill;

(f) An inability to support the applied surface loads;

(g) The unacceptable deformations as a result of collapse compression, changes in effective stress, or other foreseeable mechanisms.

The effect of clogging of filter materials shall be considered in the design, with conservative assumptions made for the long-term efficacy of these materials.

When undertaking assessments of any of the following, the geotechnical designer shall include a design case that represents the potential failure of any sub-surface drainage system, including:

(h) Slope stability;

(i) Settlement;

(j) Collapse compression.

C2.5.8(2)
Subsoil drains should discharge via flexible jointed pipes to a location approved by the consent authority, preferably a stable watercourse or reticulated stormwater system. To ensure sediment is collected, subsoil drains should enter a gully trap or equivalent before discharging into a watercourse or stormwater system. Most subsoil drainage systems will need inspection points for maintenance. The accessibility of these systems and the ability of future owners to maintain them should be considered in the 'safety in design' process.

2.5.9 Utility services

The geotechnical designer shall evaluate the works needed, both temporary and permanent, to ensure that the stability and integrity of the engineered fill will not be adversely affected by the operation, maintenance, future upgrade or replacement, or removal of the utility services. Where needed, the geotechnical designer shall recommend appropriate mitigations in the earthworks design and earthworks specification.

Service-trench backfill shall be specified, placed, and compacted in a manner that ensures it has similar strength and stiffness characteristics to the surrounding fill to minimise differential ground deformation.

Trenches for services should not be located around the top of steep slopes without specific design, as they can contribute to slope failure.

When going down steep faces, trenches should include dams and/or filters around the services to reduce slope stability issues arising from flow through the backfill or bedding materials.

C2.5.9
See sections 3, 4, 5, 6, and 8 of NZS 4404 for further information.

Utility service pipes, ducts, poles, and service boxes installed on, under, or through the engineered fill should have adequate capacity, strength, and water tightness to prevent leakage into the engineered fill through blockage, running under pressure, or structural failure.

The trench bedding material needs to be appropriate for the utility type and should be specified by the geotechnical designer in collaboration with the civil designer responsible for the utility.

2.5.10 Planting and revegetation

The geotechnical designer shall evaluate the planting and revegetation needed, both temporary and permanent, to protect the topsoil, prevent erosion, and contribute to the long-term stability and integrity of the engineered fill. The geotechnical designer shall also recommend appropriate planting in the earthworks design and earthworks specification.

C2.5.10
See section 7 of NZS 4404 for further information. The geotechnical designer should seek advice from a suitably qualified person who can develop a planting schedule to meet the specific project needs.

2.5.11 Temporary works

The geotechnical designer shall evaluate the likely scope of temporary works required for the construction of the engineered fill and ensure that the earthworks design and earthworks specification inform the contractor's design and application for temporary works.

C2.5.11
The design and construction of temporary works, including excavation safety, sheet pile support, trench support, platforms and working at height, and temporary shuttering, should follow appropriate good practice, including WorkSafe guidelines.

2.6 Conditions and authorities

2.6.1 General

The developer shall check whether an earthworks permit or other approval is required.

C2.6.1
Consents for earthworks are often required by regional or district plans or the building consent authority. The geotechnical designer and contractor should check that the appropriate consents are in place. Preparations for the fill construction should ensure that the works meet the consent conditions at all times.

2.6.2 Archaeological authority

The developer shall check whether an archaeological authority is required.

The geotechnical designer shall ensure that any requirements of an archaeological authority granted by HNZPT are addressed in the design, in the earthworks specification, and in other relevant documentation provided to the contractor.

C2.6.2

It is an offence under section 87 of the Heritage New Zealand Pouhere Taonga Act to modify or destroy an archaeological site, recorded or unrecorded, without an authority from HNZPT, irrespective of whether the works are permitted or consent has been issued under the Resource Management Act.

HNZPT can be contacted to ascertain if an archaeological authority is required. If one is required, the developer is advised to obtain it at an early stage in the planning to avoid project delays.

3 EARTHWORKS MATERIAL AND SPECIFICATION DOCUMENTATION

3.1 General

The geotechnical designer shall prepare an earthworks specification for the project or shall customise a generic earthworks specification where appropriate.

The design (including the earthworks specification and drawings) shall present all the information required to enable the contractor to plan, prepare, and construct the engineered fill as intended in the design and in accordance with this standard.

3.2 Fill material classifications

Soil and rock materials proposed for use in the construction of an engineered fill shall be classified in the earthworks specification by:

(a) Source material type – see 3.3;

(b) Material condition – see 3.4;

(c) Fill use type – see 3.5.

In most cases, all three classifications will be applied. Soil and rock materials that will not be used in engineered fill construction can be classified by source material type and material condition only.

If the materials are removed to be used on other sites or projects as engineered fill, they should be given a fill use type defined for that project.

> ***C3.2***
> *The use of three parallel classifications enables a clear distinction between inherent characteristics and temporary characteristics and between the origin of a material and its end use. The use of these is expanded on in clauses 3.3, 3.4, and 3.5.*

The earthworks specification shall use the definitions for these classifications presented in this standard. The geotechnical designer can add additional project-specific or site-specific requirements where they do not conflict with this standard.

3.3 Source material type

3.3.1 Primary categories

Source materials (including site-won and imported soil and rock materials, or manufactured equivalents) shall be classified according to the following primary categories:

(a) Material type T (topsoil) – see 3.3.2;

(b) Material type F (fine-grained soil) – see 3.3.3;

(c) Material type I (intermediate-grained soil) – see 3.3.4;

(d) Material type C (coarse-grained soil or aggregate) – see 3.3.5;

(e) Material type R (rock) – see 3.3.6;

(f) Material type M (manufactured) – see 3.3.7.

A numerical suffix can be added to each of these categories to allow for project-specific or site-specific requirements. This suffix could be a sequential number or a more descriptive term reflecting the name in common usage.

C3.3.1

Source material type classification is intended to group material being excavated (or imported) primarily for the purposes of defining how it should be handled and what it can be used for. It could also be used as a basis for payment based on the difficulty of excavation and handling.

Source material type classifications are normally assessed at the point of excavation.

Suffixes allow for more detailed differentiation of materials if required for the project.

As an example, on a site with different fine-grained source materials, these could be referred to as F1, F2, and so on in the project earthworks specification. This allows them to be tested and treated differently and allows the geotechnical designer to ensure that the appropriate materials are used in the earthworks.

It is common practice for rock to be divided into R1 (weak rock), R2 (medium-strength rock), and R3 (hard rock). This division is primarily used to support payment claims for excavation but is also useful as a starting point in defining appropriate end uses for each material. Common definitions for these are presented in the NZGS's New Zealand earthworks specification *and in Waka Kotahi's* TNZ F/1 *specification (originally published by Transit New Zealand). Site-specific definitions could be appropriate for certain projects.*

Other common material type descriptors that could be appended include those used to describe materials defined by grading curves such as the GAP (general all passing) materials. For example:

(a) Processed site-won rock or run-of-pit material imported to the site from a quarry could be identified as R-GAP 65, R-GAP 100, and so on;

(b) Material derived from the demolition of a concrete structure and appropriately graded could be designated M-GAP 40;

(c) Material for filling gabion baskets could include R2-gabion or C-gabion, depending on the source. The geotechnical designer would be expected to define appropriate acceptance testing (for example, strength, angularity, size, weathering resistance, and so on) for such materials.

Natural materials from a single source could show considerable variability in both composition and properties. Depending on the original depositional environment, the variation can be distinct (and easily recognised) or incremental. If the material properties vary significantly, then the engineer should consider whether previously determined acceptable material conditioning parameters (such as moisture content and target densities) are still appropriate.

For some materials, NZS 4431:1989 clause 11.7.2 requires the oversize fraction to be excluded from the density determination – that is, an oversize correction needs to be applied to account for material not included in the maximum dry density test. Although Note 1 in NZS 4402 Test 4.1.1 and Note 1 in NZS 4402 Test 4.1.2 state that the exclusion of more than 5% of oversize can have a major effect on the density obtained, they do not provide a definitive method to apply a correction to the density. It is important to ensure that relative compaction values are calculated accurately for these soil types. Methods available include those found in ASTM D4718, AASHTO T224, and AS 1289 clause 5.4.3. Further advice on the testing of gravelly soils can be found in the Bureau of Reclamation's Guidelines for earthwork construction control testing of gravelly soils *(Farrar, 2006).*

A representative sample of materials that were originally used to consider the appropriate conditions for compaction should be kept at the site office to enable both the contractor and the certifier to identify when material changes have occurred. The material samples should be moved to an off-site location once the contractor has completed all compaction activities associated with that material and the certifier is satisfied that the compaction targets have been achieved.

3.3.2 Material type T (topsoil)

Material type T (topsoil) is a natural material that comprises the 'O' and 'A' horizons as defined in the *Australian soil and land survey field handbook* (National Committee on Soil and Terrain, CSIRO Publishing, 2009).

Leaf litter can be mixed with the 'O' or 'A' horizons during excavation.

C3.3.2

The 'O' (organic) surface layer is dominated by the presence of large amounts of organic matter in varying stages of decomposition. The 'O' horizon is distinct from the layer of leaf litter covering many heavily vegetated areas and which contains no weathered mineral particles and is not part of the soil itself. 'O' horizons generally contain ≥ 20% organic carbon.

The 'A' horizon is the top layer of the mineral soil horizons. This layer contains dark, decomposed, organic matter. 'A' horizons could be darker than deeper layers and contain more organic matter, or they could be lighter but contain less clay or fewer oxides. The 'A' horizon is the zone in which most biological activity occurs. Soil organisms such as earthworms and fungi are concentrated here, often in close association with plant roots.

Some of the most significant impacts on topsoil properties occur because of activities associated with construction. Construction activity can have adverse impacts on topsoil by:

(a) Covering soil with impermeable materials, effectively sealing it and resulting in significant detrimental impacts on the soil's physical, chemical, and biological properties, including drainage characteristics;

(b) Contaminating soil by accidental spillage or the use of chemicals;

(c) *Over-compacting soil through the use of heavy machinery or the storage of construction materials;*

(d) *Reducing soil quality, for example, by mixing topsoil with subsoil;*

(e) *Wasting soil by mixing it with construction waste or contaminated materials, which will then need to be treated before reuse or even disposed of at landfill as a last resort;*

(f) *Allowing soil to be eroded and lost into waterways.*

Further guidance is provided in the Construction code of practice for the sustainable use of soils on construction sites *(Defra, 2009).*

3.3.3 Material type F (fine-grained soil)

Material type F is a natural soil material that can be described as fine-grained using the method defined in the *Field description of soil and rock – Guideline for the field classification and description of soil and rock for engineering purposes* (NZGS, 2005) and based on more than 35% material passing through the 63 μm sieve.

C3.3.3
Type F materials include gravelly clays, silty clays, and sandy clays. The category commonly includes material that could be derived from loess, residual soils, volcanic ashes, and alluvial depositional environments.

3.3.4 Material type I (intermediate soil)

Material type I is a natural soil material with between 15% and 35% material passing through the 63 μm sieve.

C3.3.4
Important changes in the soil response to compaction are expected to occur at significantly lower fines contents than typically used to distinguish between fine-grained and coarse-grained materials. Although these intermediate soils would be considered coarse-grained under the NZGS's Field description of soil and rock*, as fill materials they are likely to exhibit some behaviours that are more like fine-grained soil, and should therefore be handled differently.*

These behaviours include the likelihood that:

(a) *Significant excess pore water pressures are developed during compaction, as would be expected with fine-grained soil. These excess pore water pressures can influence the effectiveness of the compaction, and the stability of the fill over time. However, they would normally dissipate much more quickly than in a fine-grained soil. It could be inappropriate to use compaction techniques that are well suited to coarse-grained soils such as vibratory rollers;*

(b) *Compaction by 'kneading' will be ineffective due to the relatively lower plasticity. It could be inappropriate to use compaction techniques that are well suited to fine-grained soils (such techniques could include the use of sheep's-foot rollers).*

The relationship between dry density and moisture content for a standard compactive effort is likely to be well defined in materials containing more than 15% fines content, meaning that these type I materials are likely to be tested in a similar manner to fine-grained soils for dry density.

For general design purposes other than fill placement, compaction, and testing, these soils should be considered coarse-grained in accordance with the NZGS's Field description of soil and rock.

3.3.5 Material type C (coarse-grained soil or aggregate)

Material type C is a natural soil material with no more than 15% material passing through the 63 μm sieve.

C3.3.5
Examples of type C materials include gravel, sandy gravel, and beach sand. Type C materials also include completely weathered rocks (for example, siltstones or sandstones) where these are recovered as coarse-grained materials such as angular gravels or clayey gravels.

3.3.6 Material type R (rock)

Material type R is any natural material that can be described as rock using the method defined in the NZGS's *Field description of soil and rock*.

C3.3.6
Type R materials would include most hardfills, such as GAP 65 and GAP 40, and other crushed aggregate resources.

3.3.7 Material type M (manufactured)

Material type M is manufactured material created or modified for the purpose of earthworks.

C3.3.7
Examples of type M materials include recycled concrete aggregate, crushed glass sand, and blended, recycled aggregate.

3.4 Material condition

3.4.1 Condition suffixes

The condition of each proposed engineered fill shall be described as one or a combination of the following suffix codes alongside the source material classification (see 3.3):

(a) -A (acceptable) – see 3.4.2;

(b) -W (wet) – see 3.4.3;

(c) -D (dry) – see 3.4.4;

(d) -U1 (physically unsuitable) – see 3.4.5;

(e) -U2 (chemically unsuitable) – see 3.4.6;

(f) -X (restricted) – see 3.4.7.

The condition shall be assigned when the material is excavated and shall be modified if the condition has changed, whether this change be through treatment or the result of natural changes.

C3.4.1

Material condition classification is intended to guide whether the material can be reused and whether it needs treatment or special handling.

Material condition classifications are normally assessed at the point of excavation, but they can change so should be reassessed as required.

Examples of source material type and material condition combinations include:

(a) F-W (fine-grained soil that is wet of optimum and needs drying before use);

(b) F-D (fine-grained soil that is dry of optimum and needs wetting before use);

(c) R-A (rock that is acceptable for use without further treatment);

(d) F-U1 (fine-grained soil that is unacceptable because of its physical condition, such as having a high liquid limit);

(e) C-U2 (coarse-grained soil that is unacceptable because of its chemical condition, having unacceptable levels of hydrocarbon contamination);

(f) F-X (fine-grained soil requiring careful method controls over cut, placement, and compaction, such as volcanic-rich clay with a high allophane content).

Clauses 3.4.2 to 3.4.7 expand these definitions.

Fill materials can be modified from their original state to improve their characteristics so as to meet the engineering requirements for their use as an engineered fill material.

For example:

(g) A clay soil could be too wet to be immediately placed as fill and would need to be spread out to dry first. In this case, it would be described as F-W initially and then F-A once it had reached the appropriate water content;

(h) A sensitive volcanic ash could have characteristics requiring careful compaction and could be too dry to compact effectively. It would need to be wetted before placement, then compacted following specific instructions from the geotechnical designer. In this case, it would be described as F-XD initially, then F-X once it had been wetted to the appropriate water content.

With adequate care and process, most natural materials can be successfully compacted into engineered fill. Materials that are unsuitable for compaction are those that are very sensitive or likely to create future hazards, or which contain elements that prevent successful compaction.

Processing of the materials could enable an initially unsuitable material to become acceptable or suitable for use in a less critical area of the site, reducing waste and potentially improving the sustainability of the project.

3.4.2 Material condition A (acceptable)

Condition A material can be placed and compacted using normal engineering practice and does not fall into any other material condition.

C3.4.2
Designating a material as 'acceptable' does not guarantee or imply that it can be used for the particular site or project. It could be generally acceptable for use as engineered fill, but not meet the project-specific requirements that are documented in the fill material type.

3.4.3 Material condition W (wet)

Condition W material is significantly wetter than optimum moisture content and likely to need drying before placement.

The geotechnical designer shall define the moisture content beyond which a particular source material is considered too wet to be successfully compacted within the engineered fill. Materials with moisture contents exceeding this limit shall be classified as wet.

In the absence of project-specific limits, materials shall be classified as wet if their moisture content exceeds 4% of the optimum moisture content for that material (or mixture of materials) determined in laboratory testing. The optimum moisture content shall be defined using a compaction test prescribed by the geotechnical designer from the tests in NZS 4402.4.1.1, NZS 4402.4.1.2, or NZS 4402.4.1.3.

C3.4.3

Most materials with a well-defined moisture-density relationship will not be able to be effectively compacted with a moisture content more than 4% above optimum primarily owing to the development of excess pore water pressure.

The compaction test used to define the optimum moisture content should be selected to be representative of the fill material and compaction plant likely to be used when the fill is placed. NZS 4402.4.1.1 (New Zealand standard compaction test) is appropriate for small, lightweight, non-vibratory rollers, whereas NZS 4402.4.1.2 could be more appropriate for heavy plant.

Condition testing to determine a material's current water content is usually undertaken at the point of excavation (or for imported material, on its arrival at the site) to enable the contractor to handle the material appropriately. Condition testing should be undertaken on samples that represent the bulk material. If there is to be significant time between excavation (or importation) and placement, further testing will be needed. Failure to undertake sufficient condition testing is likely to result in material being mishandled or more difficult to compact. It is in the contractor's interests to have good condition testing. This testing is defined in the material acceptance testing section.

3.4.4 Material condition D (dry)

Condition D material is significantly drier than optimum moisture content and likely to need wetting before placement.

The geotechnical designer shall either set the moisture content limits to define dry material or, in the absence of a site-specific limit, expect that any material with a moisture content more than 2% below the target optimum moisture content for that material or mix of materials be 'dry'.

The optimum moisture content shall be defined using a compaction test from NZS 4402.4.1.1, NZS 4402.4.1.2, or NZS 4402.4.1.3.

3.4.5 Material condition U1 (physically unsuitable)

Condition U1 material is unsuitable for immediate placement in an engineered fill owing to one or a combination of detrimental physical properties. The geotechnical designer shall determine if U1 material can be used when modified in accordance with the earthworks specification by mechanical, chemical, or other means. If such processing is successful, the material should then be reclassified. Otherwise, U1 material shall be safely removed from the site (or disposed of on-site, if allowed for by the geotechnical designer in the design and earthworks specification).

C3.4.5

Some material should not be used as engineered fill in its natural state owing to one or more of its following inherent properties:

(a) Strength;

(b) Sensitivity to handling (such as materials with allophane or other sensitive clays);

(c) Moisture sensitivity;

(d) Moisture content where that moisture content cannot be practically changed to acceptable levels;

(e) Organic content;

(f) Frozen materials that cannot be economically defrosted to meet the specification.

The following materials shall be classified as U1 unless the geotechnical designer specifies otherwise in the site-specific earthworks specification:

(a) Peat;

(b) Materials from swamps, marshes, and bogs;

(c) Material mixed with logs, stumps, significant quantities of topsoil, or perishable material;

(d) Material mixed with artificial detritus (such as plastics, fenceposts, wire, bricks, and concrete slabs);

(e) Clay having a liquid limit exceeding 60% or plasticity index exceeding 35%;

(f) Frozen material.

3.4.6 Material condition U2 (chemically unsuitable)

Condition U2 material is unsuitable for immediate placement in an engineered fill due to one or a combination of detrimental chemical properties. This includes any contamination above levels suitable for intended land use, as reviewed and approved by an SQEP.

The geotechnical designer, with specialist advice from an SQEP, shall have determined if U2 material can be used when modified in accordance with the earthworks specification by mechanical, chemical, or other means to render the material suitable for use as specified, or when safely buried and encapsulated in full accordance with the conditions of consent. Otherwise, U2 material should be disposed of securely and safely off-site.

C3.4.6

Type U2 material would normally be identified by an SQEP, although in some circumstances, such as aggressive ground or acid sulphate soils, it can be identified by a geotechnical engineer or engineering geologist.

3.4.7 Material condition X (restricted)

Condition X materials are those with recognised construction difficulties, longer-term performance deficiencies, or other complicating factors.

Condition X material shall only be used in the construction of engineered fill when the project and site methods of excavation, stockpiling, and placement included in the earthworks specification can be successfully implemented by the contractor to meet the design intent and in full accordance with the conditions of consent.

The following materials shall always be classed as X:

(a) Clay having a liquid limit of 50% to 60% or plasticity index of 25% to 35%;

(b) Soils with a significant allophane content or known sensitive properties.

C3.4.7
Some materials require project-specific approaches to compaction to achieve a satisfactory end performance and should be classed as 'restricted'. Examples of restricted materials can include some volcanic soils (such as some pumice soils), where the effects of low crushing strength and internal porosity (which could be saturated) can make these materials extremely sensitive to compactive effort.

Materials that require special consideration or control during compaction should also be classed as restricted. Reactive clays (typically clays with high plasticity) can undergo significant seasonal shrinkage and swelling and hence require careful consideration by the designer with regards to where and how they can be incorporated into engineered fill in such a way as to minimise the impact of volume change on the overlying structures or buried services.

3.5 Fill use type

The geotechnical designer shall specify the fill use types for the project in the earthworks specification. Each fill use type shall have a defined set of material acceptance tests.

The fill use types shall include all those presented in Appendix A of this specification, as well as any additional types required for the project as determined by the geotechnical designer.

C3.5

Each fill use type can have multiple uses with different requirements. For example, low-plasticity clay could be used for residential structural fill, landscape fill, or road subgrade. Although the material is the same, the performance requirements are different, so the compaction and testing applied could be different. These different uses need to be shown on site plans and defined separately in the earthworks specification to allow the compaction and testing to be undertaken appropriately.

Fill use type is used to differentiate between potential uses for a particular material and to define how these materials can be tested, placed, and compacted as engineered fill.

Fill use type will be shown on engineering drawings to identify the appropriate materials for each location. 'Fill use type' describes both the material ('fill type') and the purpose to which the material will be put ('use type'). Material acceptance testing is used to confirm each fill type; compaction acceptance testing is used to check that the fill type has been compacted appropriately for the intended use type.

For example, 'GAP 65' is a fill type, and it can be used in many ways. 'Bulk fill' is one of the common-use types for GAP 65. Where GAP 65 is used for bulk fill, it is referred to as 'GAP 65 – bulk fill'.

The geotechnical designer could choose to show only the use type (for example, 'bulk fill') on the drawing, or could define the material to be used more precisely by showing both the fill type and the use type. The former is appropriate where the contractor chooses the most cost-effective and sustainable fill type. The latter is appropriate where it is essential that a specific fill type is used (for example, because of a need for specific permeability characteristics).

Examples of fill use type and fill material type combinations include:

(a) Landscape fill – GAP 65 (material that meets GAP 65 grading requirements and is to be used as landscape fill);

(b) Bulk 4431 fill – GAP 65 (material that meets GAP 65 grading requirements and is to be used as structural fill for the purposes of residential development);

(c) Trench backfill – GAP 65 (material that meets GAP 65 grading requirements and is to be used as backfill for buried services trenches).

In the examples above, the fill material type is the same (GAP 65), but the placing, compaction, and testing requirements could be different because of the different end use.

Material acceptance tests for each fill use type will depend on the type of material and its intended use. These tests commonly include grading curves and could also include Atterberg limits, weathering-quality index, chemical acceptability, or other tests as required to achieve the designer's intent.

The fill use type 'bulk 4431 fill' is used to refer specifically to fill that has been placed and tested in accordance with the requirements of this standard and, in particular, in accordance with the testing regime presented for bulk 4431 fill in Appendix A. This name is used to differentiate it from other bulk fills. For example, in a large development project, the geotechnical designer could define a different testing regime for bulk fill used to form a road embankment.

3.6 Earthworks specification preparation

3.6.1 Introduction

The earthworks specification shall present the tests and minimum test frequencies required to certify each combination of fill use type and source material type.

The earthworks specification shall include the following information for each fill use type:

(a) Source material acceptance testing (the testing required to confirm the suitability for use), including:

  (i) The type of test and the standard method to be followed

  (ii) The frequency of testing

  (iii) The acceptance criteria for these tests;

(b) Placement and handling requirements, including where appropriate:

  (i) Maximum loose-layer thickness

  (ii) Special placement methods to mitigate against strength loss during reworking;

(c) Compaction acceptance testing (the testing required to confirm that the desired level of compaction has been achieved):

  (i) The type of test and the standard method to be followed

  (ii) The frequency of testing

  (iii) The acceptance criteria for these tests.

The earthworks specification shall include the 'fill use type – source material type' combinations shown in Appendix A. Where the geotechnical designer considers it appropriate, 'fill use type – source material type' combinations could be presented in the earthworks specification in addition to those in Appendix A.

The geotechnical designer can develop additional site-specific and material-specific testing and acceptance criteria to suit the needs of the particular project and present these in the earthworks specification, subject to the limitations of 3.6.4.

C3.6.1

Examples of additional site-specific and material-specific classes that the geotechnical designer could define include:

(a) High-strength fill – R-GAP 65: A material to be used in areas subject to high loads, with exactly the same grading curves as 'bulk 4431 fill – R-GAP 65' but with more onerous requirements for compaction and testing;

(b) Surface capping – F1: A material to encapsulate contaminated ground, with a well-defined grading curve and compacted slightly wetter than usual of optimum to minimise infiltration;

(c) Trench backfill – R-GAP 40: A material to backfill service trenches, with the same grading curve as 'GAP 40 general' but different compaction requirements to suit work in trenches;

(d) Riprap size 1 – R-riprap 1: A material to provide erosion- and scour-protection at outfalls. Sizing should be defined based on the project-specific requirements.

3.6.2 Defining material acceptance tests and compaction acceptance tests

In the earthworks specification, the geotechnical designer shall define the test types, frequency of testing, and acceptance criteria that give a high degree of confidence that the earthworks meet the requirements of the design and the NZBC, including:

(a) Provision of adequate foundation-bearing capacity;

(b) Compaction outcomes that limit total and differential settlement;

(c) Provision of adequate long-term slope stability.

If the material to be used is potentially contaminated, the required testing shall be reviewed and approved by an SQEP.

Testing in addition to that defined in Appendix A or the earthworks specification could be required by the certifier as defined in 5.3.6.

C3.6.2

Source material acceptance testing

The tests required by the earthworks specification for certification of the selection of fill materials to be used in the engineered fill need to ensure that the geotechnical designer's requirements for controls on source properties (crushing strength, weathering, resistance), gradation (particle size distribution [PSD]), plasticity, shear strength, compaction parameters (compacted strength, compacted density, optimum moisture content), permeability, sensitivity, contamination, and so on can be met during construction.

For all materials where water content has a significant effect on the ability to compact the material, the earthworks specification should include maximum and minimum acceptable water content limits based on the geotechnical designer's requirements for the type(s) of fill material being used. The limits selected for water content during compaction should be such as to ensure that the specified degree of compaction can be achieved. Water content limits should be set in accordance with the type of uniform or mixed material being placed and for the type of compaction plant in use.

The water content limits are normally between 4% above and 2% below optimum moisture content. Alternative values could be appropriate where detailed laboratory testing or full-scale field trial compaction has been undertaken to establish water content limits within which the fill can be compacted to a satisfactory density and shear strength.

For cohesionless soils, no quantitative water content limits need be given if tests show that there is not a defined optimum water content for maximum density.

Coarse-grained soils with soft grains (for example, pumice) with particular gradings could exhibit an optimum water content even though the silt content is low.

Tests on some clays (such as allophane-rich clay) could suggest a range of optimal water contents requiring considerable care on site.

Any materials that are imported to a site are subject to regional plan rules. These rules should be checked. The source should be assessed to determine if it is on the hazardous activities and industries list (HAIL) and whether the Resource Management (National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health) Regulations apply. Any testing that is required as a result of this should be integrated with the material acceptance testing in the earthworks specification by an SQEP.

Depending on the fill source, type, and intended use, source material acceptance testing could include:

(a) Compaction curves (usually one curve for each fill type and source);

(b) Grading curves;

(c) Plasticity index testing;

(d) Solid density tests (usually one per fill type and source);

(e) Contamination testing.

For some larger projects, pre-start compaction trials could also prove beneficial in determining the suitability of a particular fill source.

Compaction acceptance testing

Traditionally, compaction has been assessed with reference to either a maximum dry density and percentage air voids or a relative density. Other methods to evaluate whether adequate compaction (and therefore adequate strength or stiffness) has been achieved in an engineered fill include:

(f) Undrained shear strengths;

(g) California bearing ratios (CBR);

(h) Impact values (IV);

(i) Lightweight deflectometers;

(j) Dynamic cone penetrometers (such as Scala penetrometers);

(k) Nuclear density meters (NDM); and

(l) Plate load tests.

Indirect methods such as an impact value associated with a 4.5 kg impact soil tester (a Clegg hammer), or the use of a dynamic cone penetrometer (a Scala penetrometer) should only be included as additional to traditional methods of control. These could allow the frequency of traditional tests to be reduced where consistent relationships can be determined. In cases where such methodologies are being used, relationship testing for each material being compacted should be carried out to establish the link between the measured property and the degree of compaction.

3.6.3 Minimum requirements for compliance with this standard

For fill to be certified as having been placed in accordance with this standard:

(a) Fill use type 'bulk 4431 fill' shall be specified wherever engineered fill supports:

  (i) Building platforms

  (ii) Services and maintenance access areas;

(b) Material acceptance testing and compaction acceptance testing shall be in accordance with Appendix A, unless alternatives have been agreed in accordance with 3.6.4.

3.6.4 Alternative tests and acceptance criteria

Alternative testing methods could be accepted if the geotechnical designer and certifier agree that these provide at least the same degree of confidence in the strength, stiffness, and stability of the fill.

C3.6.4

Intelligent compaction (IC) and continuous-compaction control systems provide real-time measurements related to the degree of compaction that has been achieved. These systems have the potential to offer significant benefits to larger developments, which include a more optimised compaction process, and an enhanced ability to identify potential problem areas (and their extent) within an engineered fill that requires further investigation.

It is important to note that in order to be used successfully, the monitoring equipment on the IC system should be regularly calibrated, and threshold measurements for acceptability criteria should be determined for each material through field compaction trials. In the field compaction trials, the IC measurements should be correlated to the geotechnical designer's compaction requirements.

4 ENGINEERED FILL CONSTRUCTION PROCEDURES

4.1 General

Earthworks shall be undertaken in accordance with the earthworks specification and design prepared by the geotechnical designer.

All engineered fill construction work shall be appropriately scaled to suit the design and the site. The earthworks shall generally follow these steps:

(a) Planning;

(b) Site preparation, protection, and temporary works;

(c) Engineered fill construction;

(d) Finishing works.

The geotechnical designer shall have considered these steps and incorporated appropriate measures in the design drawings and earthworks specification.

The process for site preparation and engineered fill construction and placement should follow the actions set out below, each of which is the responsibility of the contractor. Deviations from this process are acceptable where agreed with the geotechnical designer or certifier.

4.2 Planning the earthworks

4.2.1 General

Before works commence on site, the contractor shall confirm the requirements of any resource or building consent conditions of the earthworks with the geotechnical designer and certifier.

The earthworks shall be organised to ensure the works can be completed safely and in accordance with the design and conditions of any consent, permit, or authority, meeting all requirements of the site management and works quality assurance (QA) plans.

The methodology and processes to be used on the site shall be documented in a quality management plan or equivalent document.

C4.2.1

The following list provides a sequence that is common for preparing an earthworks operation. The scale of earthworks and site-specific requirements will determine the need for some of the items.

(a) Prepare a quality management plan – see section 5

(b) Develop a methodology for cut-to-fill operation, including staging and order of works;

(c) Contractor and certifier agree fill sources;

(d) Determine the appropriate plant and machinery;

(e) Mark out any:

- *(i) Archaeological sites*
- *(ii) Buried services*
- *(iii) Vegetation to be retained;*

(f) Set out erosion and sediment control;

(g) Set up site security;

(h) Construct any haul roads;

(i) Install site drainage.

The contractor shall liaise with the certifier prior to the start of works on site to discuss and agree upon the source for all proposed fill materials. Material acceptance testing is to be completed (per the earthworks specification), with the results given to the certifier for approval. Where a particular fill source is determined as unsuitable, alternative sources should be agreed on and tested until a compliant fill source is found.

The contractor shall monitor for indicators of any unforeseen contamination during construction. If signs of contamination are encountered, work shall cease in that area and the certifier or the certifier's representative shall be notified immediately.

4.2.2 Sites with known contamination

Where a site is confirmed to contain actual or potential contamination, or contaminated materials are to be used as fill, the contractor shall ensure that a 'contaminated site management plan' is present on site and implemented at all times. The contaminated site management plan shall be prepared by an SQEP in accordance with the Ministry for the Environment's *Contaminated land management guidelines no. 1*.

4.2.3 Contamination – Accidental discovery protocol

The quality management plan (QMP) shall include provisions for unexpected contamination discovery. All site personnel shall be inducted into the requirements of the QMP and if evidence of unexpected discovery is observed on site, works shall cease and an SQEP shall be notified immediately for further advice.

All site earthworks personnel shall be trained to identify potential asbestos to the appropriate required standard as per the requirements of the Health and Safety at Work Act.

C4.2.3
Some material should not be used as engineered fill owing to contamination. This should include any materials that present an unacceptable risk to human health or the environment through construction and operation of the development, as guided by a contaminated land professional (SQEP). This should also include any material with physical or chemical properties that reduce the integrity or resilience of services, foundations, or other buried infrastructure below the intended performance requirements and specifications.

Signs of contamination include, but are not limited to, the presence of:

(a) Hydrocarbon staining and odours;

(b) Fibrous material – for example, asbestos-containing materials (ACM);

(c) Soil mounds or excavations that do not match the natural contour of the land;

(d) Deposited inorganic waste (such as car bodies, construction debris, and drums);

(e) Deposited organic waste (such as household waste and some vegetation);

(f) Underground storage tanks;

(g) Unnatural staining of soil or pooled water;

(h) Unusual odours;

(i) Unstable ground;

(j) Gas bubbles in pooled water;

(k) General refuse.

The contractor shall monitor for indicators of unforeseen contaminators during construction. If signs of contamination are encountered, work shall cease in that area and the certifier or their representative shall be notified immediately. The contaminated site management plan shall be followed, where one exists.

4.2.4 Sites with known or suspected archaeological features

The contractor shall advise all parties to the earthworks (including designers, subcontractors, and consultants) as to the requirements of an archaeological authority.

4.2.5 Heritage – Accidental discovery protocol

Where no archaeological authority is required, the contractor shall prepare a ‘heritage – accidental discovery’ protocol, or use the example in C4.2.5, and document this in the quality management plan. The contractor shall ensure that staff working on the site understand the requirements of the accidental discovery protocol.

C4.2.5
The following protocol applies to any accidental discovery of an archaeological site, archaeological material, artefacts, or potential human remains (kōiwi):

(a) Work shall cease immediately within 10 m around the accidental discovery. Where a larger buffer zone is required by a rule in a regional or district plan, the larger distance should take precedence;

(b) The contractor needs to shut down machinery in the immediate vicinity (but can continue working outside the exclusion zone), secure the area, and notify iwi and an HNZPT regional archaeologist at the nearest HNZPT regional office (see www.heritage.org.nz/contact-us);

(c) If the archaeologist determines that the site is of Māori origin, the developer or consent holder needs to notify the appropriate iwi groups or kaitiaki representative of the discovery and ensure site access to enable appropriate cultural procedures and tikanga to be undertaken;

> *(d) If human remains (kōiwi) are uncovered, the developer or consent holder needs to advise the New Zealand Police, HNZPT's regional archaeologist, and iwi;*
>
> *(e) HNZPT will determine if an archaeological authority under the Heritage New Zealand Pouhere Taonga Act is required for works to continue, if one is not already in place;*
>
> *(f) Works (other than those essential for immediate safety) that affect the archaeological site and any human remains (kōiwi) should not resume until appropriate authority and protocols are in place.*

The contractor shall advise all parties to the earthworks (including designers, subcontractors, and consultants) as to the requirements of the 'heritage – accidental discovery' protocol.

4.2.6 Planning for inspections and testing

The contractor shall allow sufficient time in their programme for inspections and testing and shall document these in the inspection and test plan (see section 5). Where it is not practical to conduct retrospective inspections or testing, the contractor shall ensure that the required inspections and tests specified in the inspection and testing plan are completed before moving on to the next stage of construction.

> ***C4.2.6***
>
> *Depending on the scale of the earthworks, critical inspections could include some or all of the following:*
>
> *(a) Material acceptance testing;*
>
> *(b) Cleared ground and bench preparation;*
>
> *(c) Proof-rolling or compaction testing of the prepared cleared ground surface;*
>
> *(d) Cut-off drain installation;*
>
> *(e) Drainage blanket installation;*
>
> *(f) Subsoil drains;*
>
> *(g) Placement of geotextiles as a separation layer beneath the fill;*
>
> *(h) Compaction acceptance testing;*
>
> *(i) Surface finishing and testing.*
>
> *Failure to complete the required inspections could result in the certifier not being able to certify the engineered fill.*

4.3 Site preparation, protection, and temporary works

4.3.1 Site clearance

The area of work shall be cleared of trees, scrub, fencing, and the like as specified in the design. Any salvageable materials shall be stockpiled in a safe and secure area away from the earthworks area.

4.3.2 Erosion and sediment controls

Controls shall be put in place to manage erosion and minimise related damage or environmental deterioration of the fills, surrounding property, or receiving environment during the period of the works in accordance with the consent conditions and regional or district plans.

4.3.3 Vegetation, topsoil, and organic material stripping

The areas of vegetation, topsoil, and any other organic material shall be stripped as specified in the design, followed by an inspection by the certifier to determine if any further stripping is required. The stripped topsoil shall be stockpiled in a safe and secure area away from the earthworks area unless the topsoil is directly respread on a completed and approved cut or fill area. All stockpiles shall be protected by suitable erosion and sediment controls.

C4.3.3

If an archaeological authority covers the site, the nominated archaeologist and other affected parties such as iwi could be on site to witness the topsoil removal and undertake other work in compliance with conditions of the archaeological authority.

Topsoil is a vulnerable resource. One hectare of topsoil, the most productive soil layer, can contain up to 5 tonnes of living organisms. Because it can take more than 500 years to form a 20 mm thickness, it is in practical terms non-renewable. It therefore needs to be treated with care and preserved wherever possible.

4.3.4 Slope preparation

Benches shall be cut in the ground wherever the fill abuts or is built on sloping ground, unless otherwise specified by the geotechnical designer.

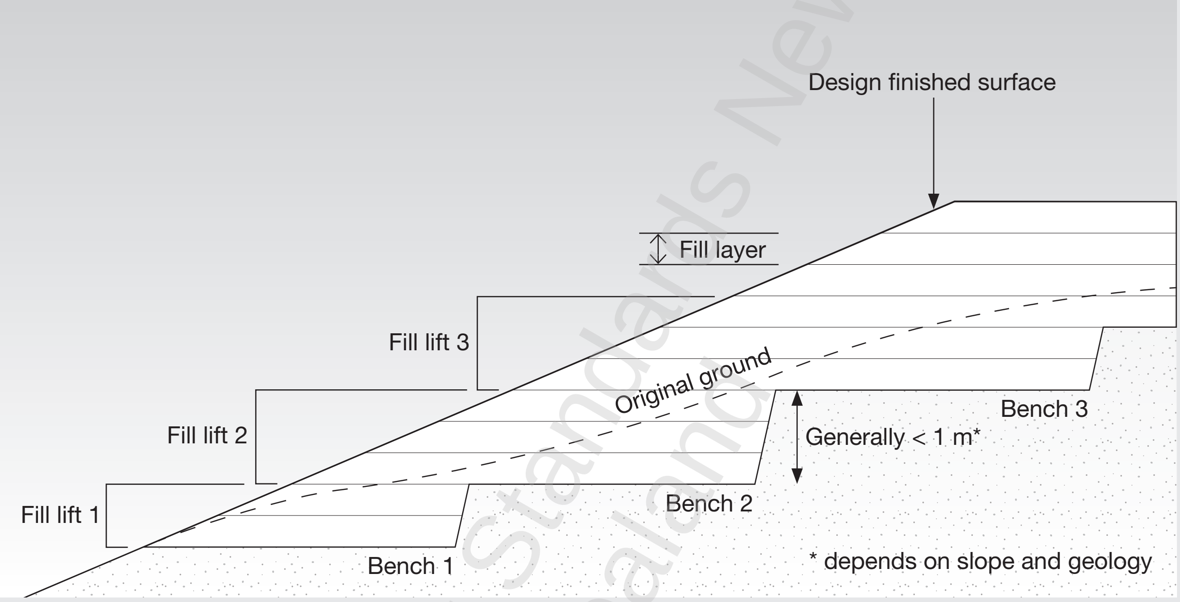
Benches shall be constructed with a minimum width of 1 m. Where practical, each bench shall be constructed to a width adequate to permit the proposed construction equipment to operate on it. In locations where the bench cannot be made wide enough to permit suitable construction equipment to operate on it, the bench shall be cut only once the filling has reached the level of the bench.

The longitudinal profile of each bench shall be graded to ensure adequate drainage and safe discharge of water.

C4.3.4

Benching helps to prevent the development of a continuous surface of low shear strength (see Figure 1). In general, the base of the benches should be gently sloped down towards the natural ground, commonly at a slope of approximately 12 horizontal to 1 vertical. This helps ensure that groundwater (and surface water during construction) is collected and drained to an appropriate outfall. Outward-sloping benches could be appropriate in circumstances where the bench drainage would not naturally fall to a suitable collection location.

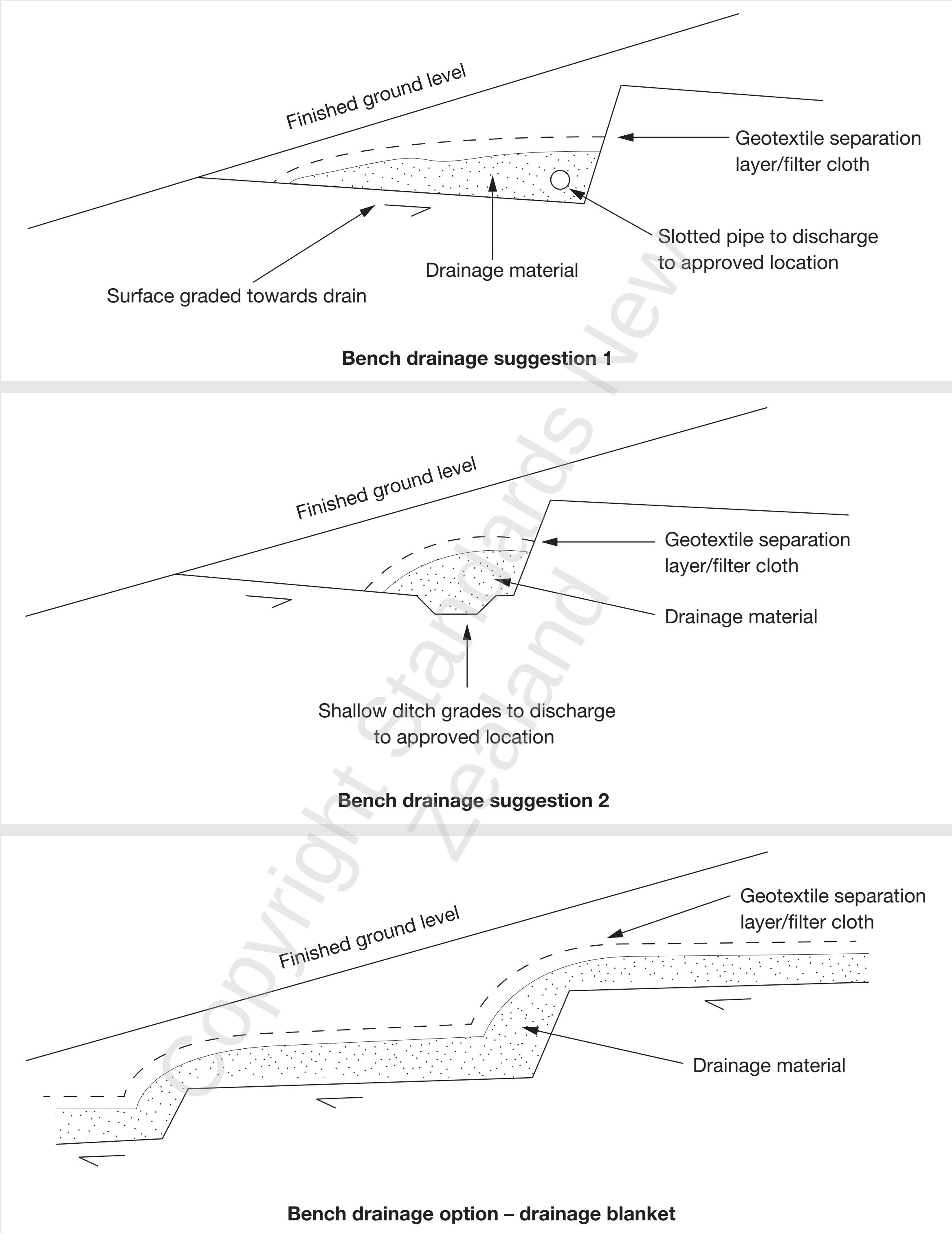
Please note that the illustrations provided in this standard are not to scale.



NOTE – Not to scale.

Figure 1 – Typical benching and lift configuration schematic

Not all benches will require drainage. The need for bench drainage will depend on the underlying geology, the fill type, and the purpose. The certifier should inspect all benches before filling and advise on the need for any drainage (regardless of whether bench drains are included in the specification or design). Some bench drain options are shown in Figure 2. The details (including the type and extent of geotextiles and filter materials) are site-specific and need to be specifically designed to suit the conditions on site. Geotextiles are often wrapped fully around the drainage material. Where this occurs, care needs to be taken in the design to avoid clogging. See section 2 for details.



NOTE – Not to scale.

Figure 2 – Bench drainage schematic options

In the drainage blanket option, the benches are graded to allow the groundwater seepage to follow the drainage blanket and drain towards the base of the slope, where it is collected.

4.3.5 Cleared ground compaction

Cleared ground should be shaped and compacted to the same standard as the overlying layers of fill, unless otherwise specified by the geotechnical designer.

C4.3.5

The suitability of this prepared surface can be checked by performing proof-rolling or standard compaction acceptance tests as required in the specification.

Proof-rolling consists of slowly driving a fully laden truck (commonly minimum 20 tonnes total load and a test axle load of 8 tonnes) in a random, zig-zag pattern across the prepared surface while observing the ground in the immediate vicinity of the loaded tyres. Areas of soft or wet ground will depress or sink and return, or the wheels will leave a deep rut. This is a quick, easy way to find softer patches in the prepared ground, which can then be targeted for remedial treatment as necessary.

4.3.6 Surface drainage

Surface drainage shall be installed as designed to ensure that the fill is not compromised by standing water or fast-flowing or concentrated run-off.

The following practices shall be adopted, unless otherwise specified in the design or conditions of consent:

(a) The surfaces of fills and cuts shall be graded to prevent ponding;

(b) Batters shall be provided with sufficient surface protection to minimise erosion from rainfall run-off, wind, and fretting under adverse climatic conditions;

(c) If there is the possibility of overland flow, cut-off drains shall be installed above the work site to minimise erosion. The installed drains should lead stormwater into an outfall approved by the consent authority, and preferably into a stable watercourse or piped stormwater system;

(d) To keep water out of the fill when rain is impending or when the site is to be left unattended, the upper surfaces of fills shall be compacted with rubber-tyred or smooth-wheeled plant;

(e) The completed battered surfaces of fills shall be compacted with tracked plant or similar non-smooth plant to reduce run-off velocities;

(f) Drains or ditches shall be formed to prevent surface water from discharging over batter faces. Surface run-off collected in the drains or ditches shall be discharged via stable channels or pipes into stable watercourses or piped stormwater systems that have been approved by the local authority;

(g) Where sufficient space exists and the trench or drain is long enough, silt traps shall be constructed to slow run-off and capture silt so that it is prevented from being washed to where it could cause damage.

C4.3.6

Follow the regional council guideline as available for detailed information on erosion and sediment control. When none is available, the Auckland Council's GD2016/005 *guideline (Leersnyder, et al., 2018) is recommended.*

The 'approved location' for stormwater, surface water, or subsoil discharge can be:

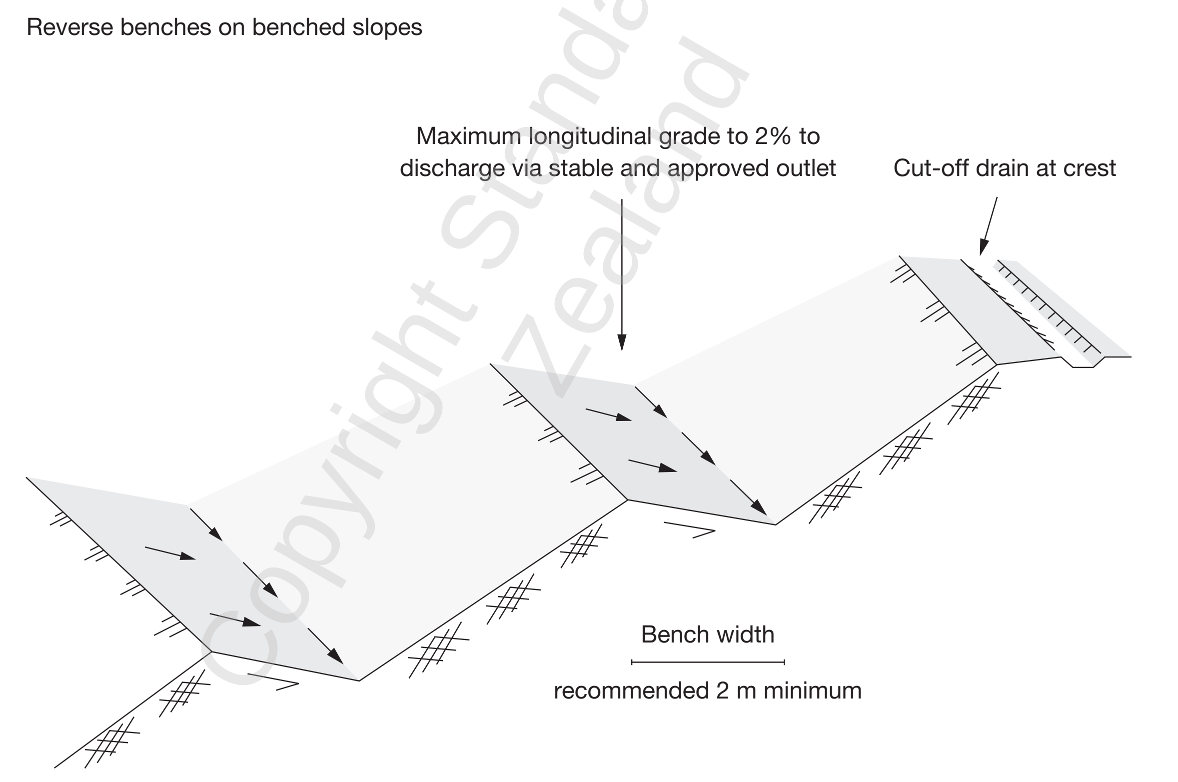
(a) Via a spreading system over a well-vegetated and diverging slope;

(b) Via a reticulated system incorporating sumps or other settling devices;

(c) Via a detention pond where sediment can slowly settle from the water before being discharged to an adjacent waterway;

(d) Other systems as set out in the erosion and sediment control plan or engineered design drawings and as agreed with the local territorial authority before the works start.

Where final batters are constructed to a benched shape, the benches should be sloped back and graded longitudinally to reduce spillage of stormwater down the batter. Run-off emerging from the end of a bench should be dispersed to existing well-vegetated slopes clear of the sides of the fill or discharged via a non-erodible channel or pipe into a stable watercourse (see Figure 3).



NOTE – Not to scale.

Figure 3 – Stormwater management schematic

Surface protection can be included while the fill is being constructed and should be completed as soon as practical after construction of the fill is substantially completed.

4.3.7 Sub-surface drainage

Sub-surface drainage shall be installed as specified in the design, with modifications or additions as instructed by the certifier during the works.

During construction of earthworks, steps shall be taken to ensure that drainage materials are not subject to clogging by fine-grained material carried in surface run-off.

C4.3.7

Many subsoil drainage options are available. The suitability of each will depend on the site contours, the underlying geological and groundwater conditions, the proposed fill source and fill types, and the proposed intended long-term use of the finished fill surface.

A typical sketch detail for subsoil drainage is shown in Figure 4 and for inclined drains in Figure 5.

Examples of situations where subsoil drains are used include:

(a) Picking up seepage or flows from springs or wet areas;

(b) Ensuring that the cut-fill interface is well drained to avoid build-up of pore pressures that could lead to failure or movement of the fill block (see Figure 6);

(c) Installing additional drains where faults intersect the cleared ground surface (whether the fault is active or not).

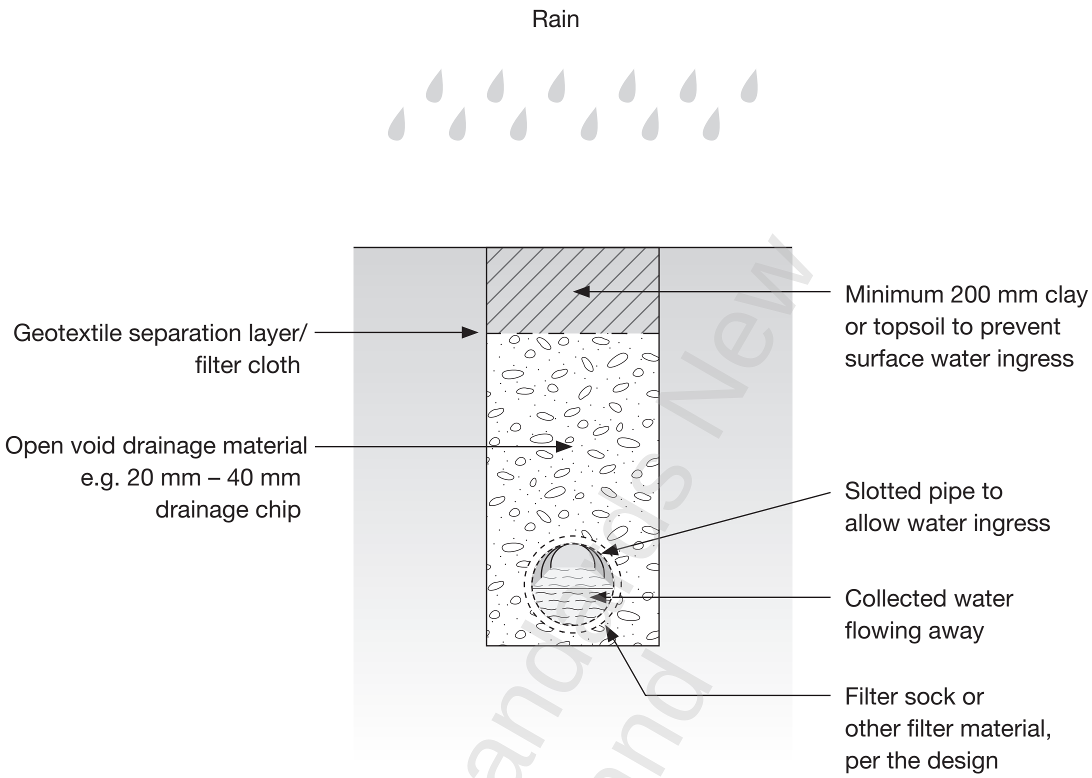
Some common subsoil drainage options include:

(d) Underfill drainage blankets to stop groundwater from rising into the fill mass;

(e) Herringbone drains targeting a particular part of the site;

(f) Drilled or inclined drains targeting a particular soil layer.

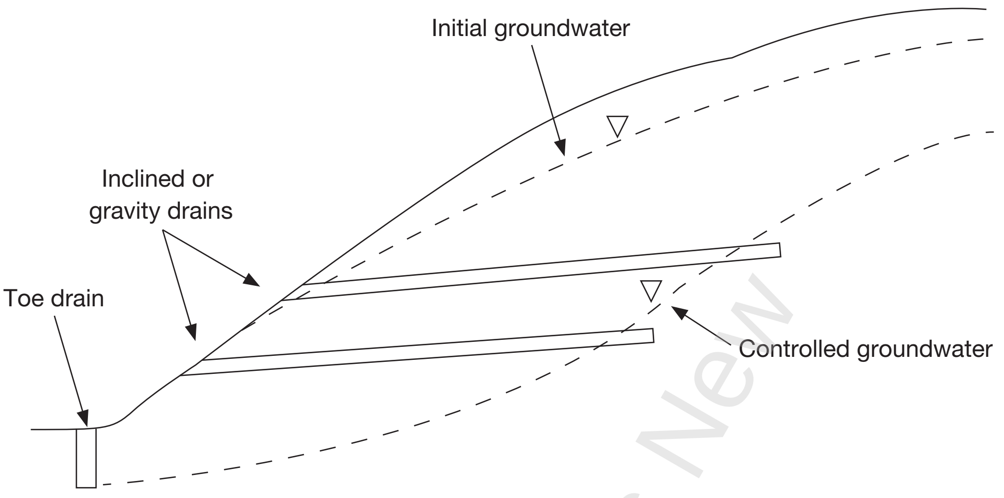
Where a subsoil drain is mid-construction at the end of a day or before a break in the works, the exposed drainage material should be covered with a filter fabric (or similar) to prevent fines being washed into it (or in the case of a drain located below steep slopes, material slumping off the slope or batter face above) and blocking the voids.



NOTE – Specific design is required for drainage material and geotextiles to ensure compatibility with surrounding material.

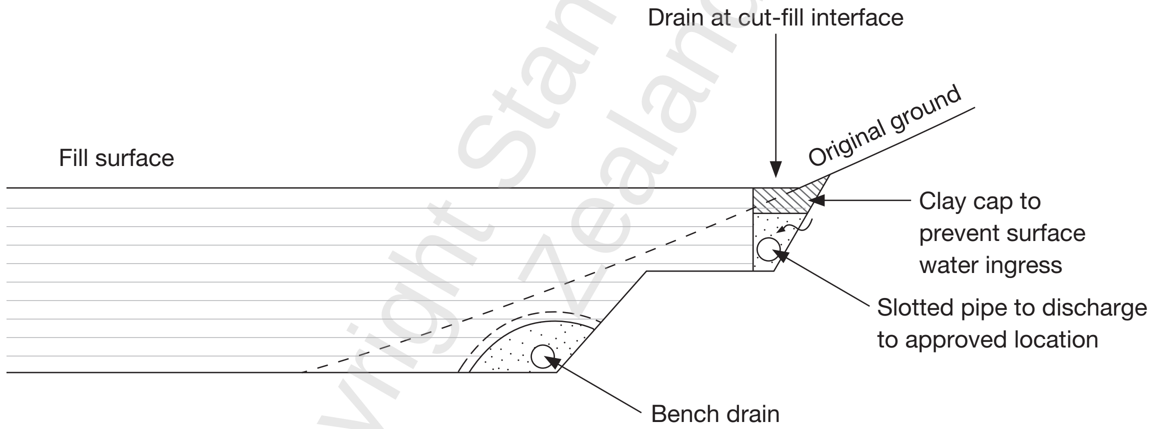
NOTE – Not to scale.

Figure 4 – Subsoil drainage schematic



NOTE – Not to scale.

Figure 5 – Inclined drains schematic



NOTE – Not to scale.

Figure 6 – Drain at cut-fill interface schematic

4.4 Fill construction

4.4.1 Placement

Fill materials shall be placed in accordance with the design, including the requirements presented in the earthworks specification.

Fill shall be placed in a systematic manner, with near-horizontal layers of uniform thickness of material each being deposited progressively across the fill area.

The method of excavation, transport, and depositing of fill material shall be such as to ensure that the fill is as uniform a mixture as possible.

The thickness of each layer shall be limited to ensure that the bottom of each layer is adequately compacted. The uncompacted thickness of the layer shall be less than 250 mm unless it is shown to the satisfaction of the certifier by compaction trials (or other tests of equivalent rigour) that satisfactory results can be continuously obtained throughout the entire layer's thickness.

Before any loose layer of fill is compacted, the water content of the layer shall be as uniform as possible, and the soil shall be free of lumps that exceed half the uncompacted layer in thickness.

Any compacted layer that has deteriorated after an interruption in the earthmoving operation shall be reconditioned (if required) and recompacted before any further layer is placed over it.

4.4.2 Reinforcement and inclusions

The contractor shall ensure that the correct geotextiles or geogrids are included within the engineered fill as defined in the design and specification, including correct alignment and lapping.

4.4.3 Fill conditioning

For materials with a defined density/water content relationship, the water content of source materials shall be monitored in accordance with the earthworks specification. The contractor shall condition the fill as required to stay as close to the optimum moisture content as possible throughout the works. When the water content of uncompacted material is non-uniform, the material could be mixed to improve the consistency.

Control of water content shall be applied not only to the upper layer of uncompacted material but also to the loose surface material of the previously compacted layer. This surface material shall be brought to the correct water content before it is covered by a new layer.

C4.4.3

The presence of some water in the material is needed to enable compaction. In fine-grained soils, excessive water can fill the voids, resist compaction, and cause instability. Too little water can also act to resist compaction, particularly in fine-grained soils.

Where the source material is drier than optimum, a common practice is to use a water cart to spray water onto the loose fill surface, but this will not always result in the best mix and application. Where wetter and drier materials are available on site (for example, materials sourced near the surface versus those sourced from deeper), these can be mixed (perhaps in the dump trucks or as they are tipped, spread, and compacted), often with good outcomes. Good results can also be achieved by wetting the material in the cut before it is transported to the fill area. Other techniques are often developed locally to deal with particular material types, and local contractor experience can be beneficial in this regard.

When the water content of uncompacted material rises above the specified maximum, drying can be accelerated by aeration. If this is done by blading, special care is needed to ensure that this method of working does not produce segregation of the material.

4.4.4 Compaction

The certifier shall be given the opportunity to assess the suitability of the proposed plant for the materials and the specified testing and targets.

Each layer shall be compacted as a single operation, using plant specifically assigned to the compaction task and following systematic patterns of travel tracks that progressively work across the surface of the fill.

The compaction of each layer shall continue until the whole layer has attained a dense, stable state. The number of passes by suitable compaction equipment shall be chosen to suit the conditions and type of soil or rock being compacted to deliver the outcomes required in the fill design. The type and size of compaction plant shall be chosen to best match the type of soil, rock, or mix of soil and rock being worked, the location of a layer being compacted in the overall works, and the planned depth of each successive fill layer in order to deliver the required compaction criteria.

Compaction operations shall be directed to optimise the utilisation of the available soil and rock materials, delivering optimum compaction outcomes, and thereby achieving long-term stability in all constructed fills.

Fill batter faces should be compacted as a separate operation, or alternatively be overfilled and cut back.

Engineered fills should be sealed off using appropriate plant at the end of the working day or before rain. For longer periods where the earthworks are left sealed off but not completed, the surface should be further protected with some form of temporary stabilisation or sacrificial materials, or both.

Earthworks shall continue to the design grades and levels.

The contractor shall give the certifier adequate notice to complete all the inspections detailed on the inspection and testing plan.

The contractor shall immediately contact the certifier whenever unusual or unexpected conditions, wet ground, or springs are encountered.

> ***C4.4.4***
> *'Sealing off' is compacting in a manner that produces a relatively low-permeability surface to minimise water infiltration.*

4.4.5 Settlement markers

All settlement markers shall be installed per the specification and fill design. The contractor shall endeavour to ensure they are not disturbed after they have been installed. Any disturbance to the settlement markers shall immediately be reported to the certifier.

> ***C4.4.5***
> *Disturbance of settlement markers can result in a delay to fill certification. Due to the decaying rate of settlement with time, this delay can amount to several months as it will require significant time to install replacement settlement markers and to gather sufficient data to allow a reliable assessment of settlement. It is therefore vital that every effort is made to protect the markers from disturbance once measurements have begun.*

Settlement readings shall be supplied to the certifier at the frequency and accuracy specified. These readings shall not stop until the certifier instructs that they can stop. The certifier shall assess the measured settlement against the predictions made by the geotechnical designer and identify any areas where the settlement is outside expected parameters. Where this occurs, the certifier shall work with the contractor and the geotechnical designer to identify appropriate mitigation measures.

No settlement markers shall be removed until the certifier has confirmed in writing that the settlement markers can be removed.

4.4.6 Weaving

In areas of fill where excessive surface weaving has developed, in-situ density and water-content tests shall be undertaken, with agreed mitigations (such as drying or resting) completed before any more fill is placed.

C4.4.6

Surface weaving is characterised by the pronounced elastic compression of the surface of the fill and an immediate rebound during the passage of heavy-wheeled plant (see Figure 7). It is the manifestation of development of shear instability in areas where over-compaction has contributed to the materials approaching full saturation.

The development of surface weaving can be avoided by:

(a) Ensuring that the water content of material being placed is kept below the specified maximum;

(b) Providing drainage on the surface of the fill and preventing accumulation of surface water in puddles;

(c) Routing of heavy earthmoving plant to prevent excessive compaction of materials having relatively high water content;

(d) Providing drainage layers within the fill to dissipate excess pore pressures.

If soil that has developed weaving is left to rest in warm, dry conditions, the weaving could reduce or stop. If the soil continues to weave, it should be removed to a stockpile and allowed to dry, 'disked' and allowed to dry, or chemically stabilised.

Figure 7 – Example of weaving in clay fill

4.4.7 Temporary fill works

All temporary works shall be designed by a suitably qualified person before being put in place.

C4.4.7

Examples of temporary works include:

(a) Support to trenches, excavations, temporary slopes, and stockpiles;

(b) Groundworks for crane pads.

If temporary works are not removed, this shall be referred to the geotechnical designer to confirm their suitability for inclusion in the permanent works.

Testing of fill placed for temporary works shall be in accordance with the requirements for the equivalent permanent fill, unless otherwise specified.

4.5 Finishing works

Fills should be left in a condition that results in a stable surface (as per the design and earthworks specification).

Prior to topsoiling or other stabilisation as given in the design, the contractor shall confirm that ground levels are correct, that all relevant testing has been completed at required test locations, and that all results are acceptable by reference to inspection and test plans (ITPs) signed by the certifier. (See Appendix B and Appendix C for example ITPs.)

Unless otherwise specified by the geotechnical designer, the surface of any slope steeper than 1 in 3 shall be scarified before topsoiling.

C4.5

Scarifying or roughening the surface of sloping ground (see Figure 8) reduces the risk of topsoil sliding off the slope, particularly where rainfall seeps into the slope and could flow along the topsoil or fill boundary. This can be readily achieved by using tracked equipment to run up and down the slope.

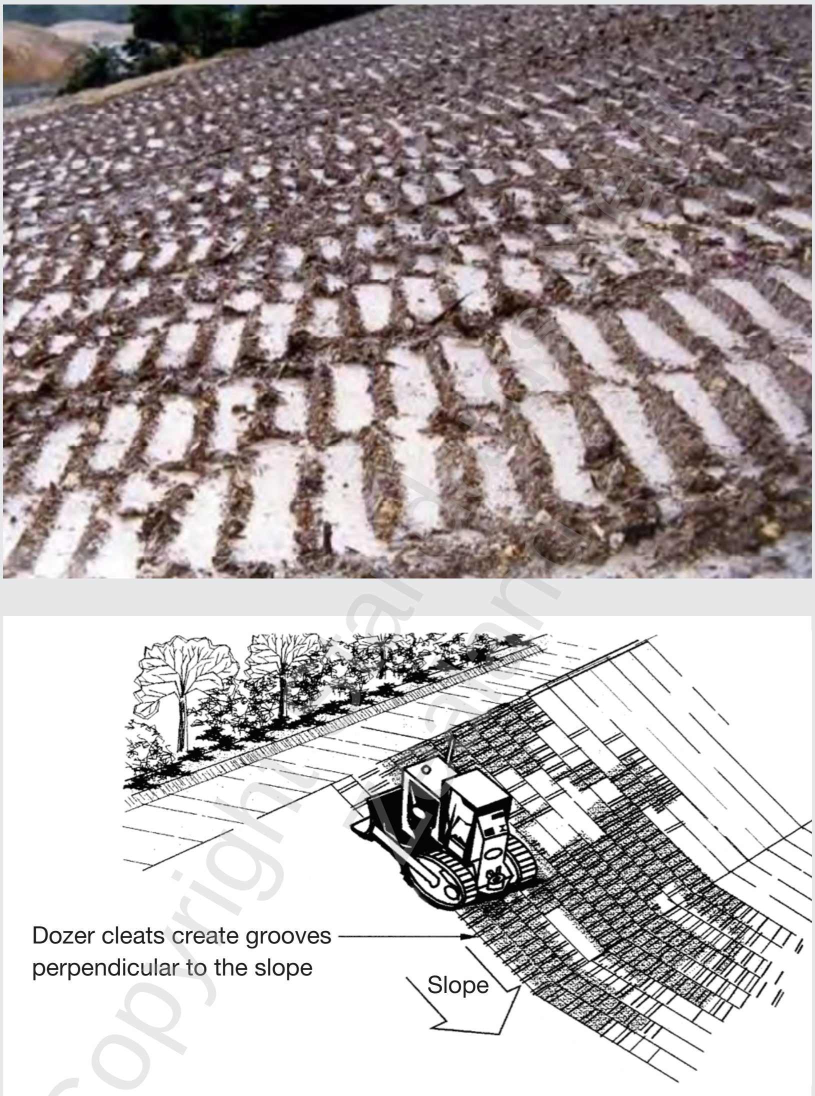


Figure 8 – Surface roughening

Topsoil shall be spread to the thickness in the earthworks specification and the surface stabilised (for example, using grass seed, hydroseeding, or another method as defined in the specification).

Erosion and sediment controls should be removed once the site is stabilised to the territorial or regional authority’s requirements.

5 QUALITY ASSURANCE

5.1 General

5.1.1 Purpose of quality assurance

Quality assurance inspection, sampling, testing, and certification of engineered fill construction shall be undertaken to:

(a) Provide the contractor and certifier with current, explicit information about the works to support informed decision making that leads to consistent and compliant physical works;

(b) Provide tangible evidence that the specified and consented works have been successfully delivered in accordance with the design by means of an appropriate, systematic approach that is acceptable to all parties.

5.1.2 Quality management plan

The contractor shall prepare and use a contract-specific and appropriately detailed quality management plan (QMP) that integrates the statutory, technical, and performance framework requirements for the engineered fill construction with the contractor's quality systems during the delivery of the specified works.

The QMP should include:

(a) Links to the contractor's overarching quality policy, objectives, and systems;

(b) The names, roles, and accountabilities of the contractor's key personnel;

(c) The inspection and test plans (ITP), including hold points.

C5.1.2
The contractor's QMP describes how the contractor and nominated suppliers and subcontractors should supply, build, and test the specified works.

The QMP should also describe how the contractor will:

(a) Deliver the specified works on time and within budget;

(b) Plan, undertake, and report on the outcomes of the agreed inspection and test plan (ITP);

(c) Respond to feedback from the random verification test (RVT) programmes (the RVT will be determined by the certifier);

(d) Gather the necessary evidence during the work to enable efficient approval to pass project-specific hold points;

(e) Identify, report, and respond to non-compliance (NC) when and wherever this occurs;

(f) Manage and implement corrective action, continuous improvement, and lessons learnt in response to NC when and wherever this occurs.

The QMP will also normally include:

(g) Resource consent conditions;

(h) Erosion and sediment controls plan, as well as a flocculation plan;

(i) A contaminated site management plan (for contaminated sites) – see 4.2.2;

(j) A contamination – accidental discovery plan – see 4.2.3;

(k) A sustainability plan;

(l) A job safety environmental analysis;

(m) A traffic management plan;

(n) A Heritage New Zealand Pouhere Taonga archaeological authority (where required) – see 4.2.4;

(o) A heritage – accidental discovery protocol – see 4.2.5;

(p) A briefing for site staff of the requirements of the accidental discovery protocol or archaeological authority by the archaeologist approved under section 45 of the HNZPT Act.

Guidance on the development, maintenance, and use of quality management plans can be found in these references:

(q) Minimum standard for quality management plans NZTA Z1 *(NZTA Waka Kotahi, 2021);*

(r) Quality system for road construction, road maintenance and structures physical works contracts having a high QA level TQS1 *(TNZ, now Waka Kotahi, 2005);*

(s) Quality system for road construction, road maintenance and structures physical works contracts having a normal QA level TQS2 *(TNZ, now Waka Kotahi, 2005).*

Guidance on the development, maintenance, and use of ITPs can be found in:

(t) Minimum standard for inspection, sampling and testing NZTA Z8 *(NZTA Waka Kotahi, 2021).*

Before works commence on site, the certifier and contractor shall together prepare, review, and agree on the ITP, incorporating all the requirements of this standard. The contractor's use of the ITP shall then enable the contractor to provide all the evidence needed to demonstrate compliance with the intent of the design, the specification, and the conditions of consent.

The contractor shall ensure that a copy of the approved design, the conditions of consent, the agreed ITP, and records of completed inspections and tests are always available to be viewed on site by the contractor's staff and the certifier.

5.1.3 Competence and standards for inspections, sampling, and testing

All inspection, sampling, and testing of the engineered fill construction works shall be in accordance with the referenced standards, completed by competent, suitably qualified, and experienced personnel, and include, as required, accredited laboratory test results from a recognised laboratory.

5.1.4 Random verification testing

The certifier or the certifier's representative can undertake or arrange random verification testing (RVT) at any time during the works. The contractor shall ensure safe access is provided to those undertaking an RVT when this is requested. Where the RVT demonstrates non-compliance with the design, the earthworks specification, or conditions of consent, the contractor shall be advised as soon as practical.

The certifier or the certifier's representative can order a 'stop work' if the evidence from on-site inspections, the ITP, and/or the RVT demonstrates non-compliance with the design, the specification, or the conditions of consent. The contractor shall comply with this order.

Where the certifier or the certifier's representative stops work, they shall collaborate with the contractor to determine what work needs to continue in order to make the site safe and stable.

C5.1.4
The certifier or their representative usually defines the RVT locations to cover the range of conditions expected of the works and include any areas that the certifier or their nominated representative thinks will yield the least acceptable results.

5.1.5 Non-compliance

Where the contractor's ITP demonstrates non-compliance with the design, the specification, or conditions of consent, the certifier shall be advised as soon as practical.

In the event of any non-compliance, the contractor's QMP shall direct the response, including securing approval for work to recommence following any necessary remedial actions.

The contractor shall ensure that all fill with a non-compliant test result is reworked, and retested with a validation test. Remedial actions are to continue until the certifier is satisfied that the material and compaction are acceptable.

Failed test results shall be included in the final documentation (as defined in section 7) along with the later validation test results.

5.2 Inspections

As a minimum, and as documented in the ITP, on-site inspection of the quality of engineered fill construction shall be made:

(a) After any part of the existing ground has been stripped and prepared and before placement of any fill on that ground (including benches) commences;

(b) During proof-rolling of the prepared ground surface;

(c) After any drainage system (surface water, subsoil, or groundwater drain) has been installed and before drains are covered by fill or drainage media;

(d) During final surface testing and finishing;

(e) Whenever the certifier deems it necessary in order to enable an assessment of the general standard of a site, fill material, fill compaction, and finishing works so that:

   (i) No fill is placed over soft, organic, or otherwise deleterious and unsuitable foundation material (unless specifically permitted in the design)

   (ii) No unsuitable materials, including wet or contaminated cut ground, are used as engineered fill

   (iii) Water content control during compaction is within the appropriate range

   (iv) All compaction operations achieve the in-situ density and strength parameters expected in the design

   (v) All areas of existing ground on the site (and where necessary on adjoining properties) that are wet as a result of groundwater seepage have been inspected and responded to in the design

   (vi) All areas of existing ground on the site and where necessary on adjoining properties where slope stability is in doubt have been inspected and responded to in the design

   (vii) Surface water flows are not concentrated (onto, within, and off the site) unless specified in the design.

The certifier can undertake additional inspections during the works. The contractor shall ensure appropriate and safe access is provided to those undertaking such inspections when requested.

Records for all inspections shall include the time, date, and location, a description of the observations made with supporting photographs, and reports of non-compliance.

> ***C5.2***
> *Each earthworks project will have specific features that can require additional inspection. In many cases, it will be appropriate for the certifier to add additional inspection or hold points to the ITP. Examples include supply and installation of geogrids and geotextiles; installation and survey of ground movement markers; installation and measurement from ground sensors (for example, pore pressure transducers); and inspection and testing of ground to be used under a future pavement or hardstand.*

5.3 Sampling and testing

5.3.1 General

Sampling and testing shall be completed as scheduled in the agreed ITP and RVT.

5.3.2 Source material acceptance testing

All source material acceptance testing shall be undertaken by a recognised laboratory before the material is used in fill construction and shall:

(a) Target a representative site coverage vertically, horizontally, and temporally;

(b) Represent all material types used on site.

> ***C5.3.2***
>
> *Source material acceptance testing is undertaken to demonstrate that fill materials are suitable for use in construction before these are placed or, more crucially, covered up by the earthworks.*
>
> *When subsequent testing shows materials to be non-conforming, the result is unnecessary, and often costly, rework.*
>
> *The need for the source material acceptance testing to be completed by a recognised laboratory does not prevent the contractor from completing their own tests; on the contrary, they should be encouraged to do so. Where a contractor regularly completes their own testing during the works, the source material acceptance testing tends to pass more often, with fewer rework requirements. Failure to do this can end up causing project delays and additional cost. The contractor will also get a better feel for the source material and water content variations and can adjust conditioning methods as necessary as the works progress.*

5.3.3 Compaction acceptance testing

All compaction acceptance testing undertaken in accordance with the ITP shall be completed by a recognised laboratory, the certifier, or the certifier's representative and shall:

(a) Target a representative site coverage vertically, horizontally, and temporally;

(b) Be distributed across each lift completed, or part thereof, in a single day;

(c) Represent all fill types used on the site;

(d) Represent all compaction methodologies used on the site;

(e) Ensure that all fill material(s) sampled for water content and compaction control tests shall be taken from the spread layer immediately before, during, or after compaction.

The certifier shall be given the opportunity to ensure that all test locations proposed by the contractor are representative of each lift, to modify the locations where they deem this is needed, and to identify areas of potential concern.

On projects with multiple acceptance testing stages, statistical process control (SPC) could be appropriate. Where this approach is adopted, the reported changes in the mean, standard deviation, and percentile value of tested material properties should be continually monitored by the contractor during construction against the specified outcomes or range of outcomes using a recognised statistical process control method such as the CUSUM (CUmulative SUM) method.

The results of the ongoing SPC monitoring should be used by the contractor to enable informed decision making and timely corrective actions in accordance with the contractor's QMP.

C5.3.3

The collection and use of compaction acceptance test information is needed to ensure the as-built earthworks fill is safe and appropriate, and that the contractor and certifier have confidence in the ongoing works, and to avoid unnecessary and costly rework.

Where one test fails, the certifier will consider if other tests need to be redone at the same time.

Site-calibrated intelligent compaction (IC) and continuous compaction control (CCC) systems can provide excellent and responsive feedback of compaction performance and enable more efficient fill placement and testing.

On projects with multiple stages of acceptance testing and more test data from IC and CCC systems, the use of statistical process control (SPC) methods enables the contractor and certifier to make informed and productive decisions.

When interpreting data and making decisions based on SPC methods such as CUSUM, the contractor and certifier are reminded that geotechnical data are often not normally distributed. This should be considered when using statistical process control methods.

Acceptance criteria used in SPC methods will be different from, and often more stringent than the criteria used for traditional approaches.

5.3.4 Sampling and testing documentation

Each sample and test shall be formally documented, including:

(a) The time and date of all samples and tests;

(b) The sample and test locations in three dimensions using the method in the agreed ITP.

Unless otherwise specified, the contractor shall be responsible for ascertaining and recording the location of each test and sample.

C5.3.4

On projects where large amounts of fill are placed daily, the horizontal location should be measured to an accuracy of ± 3.0 m or better and the vertical location to ± 0.1 m or better. For small (such as single building platforms) or remote projects where suitable survey equipment is not readily available, test locations still need to be recorded in sufficient detail to allow the correct area to be reworked or re-compacted should the test fail and to be able to demonstrate that a good spread of testing has been achieved. Photographs showing the test location with commentary indicating lift height can suffice. Where insufficient detail is included and a test result fails, this could – at significant cost to the developer or contractor – result in a much larger area being reworked than would have otherwise been necessary.

5.3.5 Communication of test results

Field and laboratory test results, including all tests undertaken in accordance with the ITP, the RVT, or otherwise, shall be provided to the contractor and the certifier (or the certifier's representative) on the day the test is completed, with follow-up reports as required. Thereafter, all sampling and test results shall be available for viewing by all parties at all times.

5.3.6 Additional tests

The certifier can request additional or alternative tests to ensure they are sufficiently satisfied to certify the fill for its intended purpose. The contractor shall ensure appropriate and safe access is provided to those undertaking additional testing when this is requested.

Testing should be more frequent than defined in the specification under any of the following circumstances:

(a) During the first 4000 m^3 of filling carried out on the project;

(b) On the final lift where the minimum frequency of in-situ density tests shall be three sets of tests for each 3000 m^2;

(c) When soil type or conditions are variable;

(d) When the certifier or the certifier's representative is in any doubt about the adequacy of construction methods or any of the soil properties;

(e) When a decision to reject work, based on the judgement of the certifier or the certifier's representative, is disputed;

(f) When relatively small quantities of fill are concentrated in localised areas or are placed discontinuously over a long period of time.

Should the routine foundation inspection by the contractor, local territorial authority, or certifier suggest that localised soft areas are present, additional tests shall be undertaken to determine the required treatment of the fill material or of the foundations. These tests should extend to a depth below the footings of not less than twice the width of the footings or 1.2 m (whichever is the greater).

C5.3.6

Testing should be more frequent than defined in the specification where circumstances could cause inconsistent or variable results or where consistent performance has not been demonstrated or where consistent performance is unlikely.

The testing frequencies included in Appendix A are recommended minimums intended to assist with the preparation of the earthworks specification, the ITP, and the RVT.

It could be impracticable to provide sufficient supervision of construction to be sure that localised soft areas do not occur in the upper layers of the fill within the zone of influence of small foundations. Where this risk exists, it should be noted in the certification. Tests to assess remedial actions in the vicinity of foundations can include shear strength, plate load, dynamic cone penetrometer, or other recognised soil strength tests. The certifier should consider each test's suitability for that material type (for example, shear vane testing is not appropriate in sands or material with gravel content, and Scala testing is not appropriate for assessing the bearing capacity of clays and is unreliable in coarse-grained materials).

Alternative or additional testing can be required where unusual or unexpected ground conditions are encountered or where alternative fill materials are agreed on during the filling operation or where a specified test method is not available for any reason.

6 AS-BUILT SURVEY AND PLANS

An appropriately scaled as-built topographic survey of the engineered fill shall be undertaken (normally by a registered professional surveyor) and then used to record at least the following on appropriately accurate and scaled site plans, drawings, or models:

(a) Original contours (natural ground level);

(b) Stripped and undercut surface contours (cleared ground level [CGL]);

(c) Finished contours;

(d) Cut-fill contours;

(e) Property and easement boundaries;

(f) As-built locations of any subsoil drains and the position of their outlets;

(g) As-built locations, types, and sizes of all stormwater drains and the position of their outlets;

(h) As-built locations of geosynthetics (geogrid and geotextile) used to strengthen the made or existing ground;

(i) As-built locations of any geotechnical instrumentation, including settlement markers;

(j) When the design includes a fill use type drawing with cross sections, these shall be updated to show as-built locations and depths of all fill use types;

(k) As-built locations of compliance acceptance tests as required by the ITP and RVT.

Contours should be standard either as 1 m intervals or in line with consenting requirements. The local council's code of practice and consent conditions should be checked.

C6

Where the size of the engineered fill is constrained (for example, a small house building platform only) and detailed engineering survey data are not available during construction, an appropriately accurate and scaled site plan should be prepared to clearly show at least the position and depth(s) of the engineered fill in relation to legal property boundaries and easements, as-built information for subsoil and stormwater drains, geotechnical instrumentation and survey controls, and any other information that the certifier deems relevant.

The recording of as-built locations of compliance acceptance tests should enable the results to be presented in an appropriately accurate and scaled site plan, drawing, or model (with site coverage vertically, horizontally, and temporally). It is not always necessary or appropriate for compliance acceptance test locations to be located by professional survey.

7 FINAL DOCUMENTATION

7.1 Earthworks completion report

The engineered fill construction shall be documented by the certifier in an appropriately scaled earthworks completion report. This final documentation shall present design and testing information relevant to all earthworks on the site for which the certifier has been engaged to assess.

This report shall include:

(a) A description of the works completed, specifically noting any departures from the original design and earthworks specification;

(b) A commentary on all non-compliances and confirmed remedial actions;

(c) Evidence of compliance with all conditions of consent;

(d) Confirmation that the fill placed will achieve the design intent in both the short and the long term;

(e) Confirmation that both the magnitude and the rate of any settlement and consolidation being measured are within the bounds predicted by the geotechnical designer.

The following shall be appended to the report:

(f) Certification of the engineered fill (see Appendix D and 7.2);

(g) The as-built survey as defined in section 6;

(h) An appropriately scaled site plan showing:

  (i) foundation restriction zones

  (ii) building limitation lines

  (iii) designated building foundation platforms

  (iv) services, maintenance, and access areas

  (v) service easements;

(i) The inspection and test plan (ITP);

(j) The random verification test (RVT) results;

(k) All test results (including the location of the test or sample, where appropriate);

(l) All inspection records.

7.2 Earthworks certification

The certifier shall undertake an assessment of the completed engineered fill construction records and as-built drawings. The certifier shall assess whether the fill has been placed in accordance with the design and the specification, and in a way that will achieve the design's intent.

Where they are satisfied that this is the case, the certifier shall provide confirmation that the fill is acceptable. The template in Appendix D can be used for this purpose. This confirmation is not to be construed as a guarantee or warranty. Where the certifier cannot provide this confirmation, they shall provide a statement describing the problems preventing certification of the engineered fill.

C7.2

When undertaking their review, the certifier should also assess whether the relevant conditions of consent have been met.

It is good practice to show the locations of tests and inspections on a series of plans. This enables an assessment of any gaps to be easily undertaken and allows forensic analyses of failures to be conducted more easily, should they be needed.

The certifier could be engaged to supervise more than just the placement of engineered fill as covered by this standard. It would be normal practice for their final documentation to cover many more aspects of the earthworks that have been completed, and it is not necessary to limit that report to covering just the engineered fill. The details given in this section present the minimum documentation requirements for the aspects of their involvement related to the construction of the fill. Their report could be extended to cover additional aspects, including cut-slope formation, excavation and preparation of the building pad, the construction of retaining walls, and so on.

Where the certifier has been engaged only for the role of certifier (and not as geotechnical designer and/or geo-professional as defined in NZS 4404), the final documentation should be presented as an earthworks completion report.

Where applicable (that is, for residential subdivision purposes), the geotechnical designer and/or the geo-professional should incorporate this earthworks completion report into their geotechnical completion report prepared in accordance with the requirements of NZS 4404, and a statement of professional opinion on the suitability of land for building construction (in accordance with NZS 4404 schedule 2A) should be appended.

Where the certifier has been also been engaged as the geotechnical designer and/or subdivision geo-professional, the combined requirements of NZS 4404 and this standard should be presented in a single geotechnical completion report.

APPENDIX A – MINIMUM SUITABILITY AND ACCEPTANCE TEST REQUIREMENTS FOR ENGINEERED FILL TO SUPPORT LIGHTWEIGHT STRUCTURES

(Normative)

Tables A1 and A2 can be used as templates for the earthworks specification and present minimum requirements for engineered fill used to support lightweight structures. These minimum requirements shall be incorporated in the earthworks specification regardless of the format used. These minimum requirements shall be reviewed by the geotechnical designer.

The geotechnical designer (or certifier in conjunction with the geotechnical designer) can modify these to suit the project-specific requirements, the available materials and plant, and advances in testing as long as:

(a) They can provide evidence that the amended requirements will result in engineered fill with strength, stiffness, and stability that are the same as or better than those provided for in this appendix;

(b) The material acceptance testing and compaction acceptance testing can provide at least the same level of confidence in the quality of the engineered fill.

CA

The minimum requirements presented in this appendix assume a relatively low-risk site with consistent, easily managed materials. In many cases, more frequent and more rigorous testing would be appropriate. The geotechnical designer should increase the testing requirements as appropriate to manage project risks.

The geotechnical designer should select tests that are appropriate for the site conditions and that are readily available to the contractor.

Where multiple tests are listed, it is expected that all the tests will be undertaken. If the geotechnical designer proposed multiple tests with the intent that the site team chooses which test to undertake, they should make it clear which tests are mandatory and how the other tests should be selected.

For 'clean' imported materials where no chemical acceptance testing is proposed, the supplier should be asked to demonstrate that the material is VENM (virgin excavated natural material) as defined in Technical guidelines for disposal to land *(WasteMINZ, 2018).*

An SQEP contaminated land professional could add tests for chemical suitability where there is the possibility of site contamination or where materials are being imported from unproven sources. A check should be made of the site history and all material source sites to assess if they are on the hazardous activities and industries list (HAIL) or if they could be contaminated with asbestos. An SQEP should be involved for these sites.

Table A1 – Minimum testing requirements for fill materials

Material definition	**Fill use type**	Bulk 4431 fill		
	Source material type	F–A (fine-grained – acceptable)		
	Typical use description	General fill for residential or light commercial earthworks using selected site-won or imported materials		
Source material acceptance testing	**Test (and method)**	**Minimum test frequency**	**Normal acceptance criteria**	**Notes**
	Particle size distribution (NZS 4407 test method 3.8 or NZS 4402.2.8.1)	1 for each source and 1 for each change in material	As per Table A2	Completed before works begin (and during the works if the material changes) to confirm the material's suitability
	Dry density/water content relationship (NZS 4402.4.1.1, NZS 4402.4.1.2)	1 for each source and 1 for each change in material	OMC and MDD determined	Completed before works begin (and during the works if the material changes) to determine OMC and MDD for later use in compaction acceptance testing
	Water content (NZS 4402.2.1)	1 for each source and 1 for each change in material	Between OMC – 2% and OMC + 4%	Ongoing during the works to confirm conditioning requirements
	Solid density of soil particles (NZS 4402.2.7.1 or 2.7.2)	1 for each source and 1 for each change in material	Solid density determined	Used to define the solid density of aggregate particles for later use in compaction acceptance testing with in-situ nuclear moisture-density gauge Can be omitted where the geotechnical designer can provide a reliable estimate for the specific source material
	Liquid and plastic limit (NZS 4402.2.2, NZS 4402.2.3, and NZS 4402.2.4)	1 for each source and 1 per 4000 m^3 and 1 for each change in material	Plasticity index < 25% Liquid limit < 50%	Completed before works begin (and during the works if the material changes) to confirm the material's suitability
Placement requirements	Loose layer thickness < 250 mm			
Compaction acceptance testing	**Test (and method)**	**Minimum test frequency**	**Normal acceptance criteria**	**Notes**
	Field water content and density (NZS 4402 test 2.1 and NZS 4407 4.1, 4.2, or 4.3)	2 per 1000 m^3 (min 2 per lift)	≥ 95% maximum dry density < 10% air voids	
	Shear strength (NZGS *Guideline for hand held shear vane test*)	2 per 1000 m^3 (min 2 per lift)	Lowest value > 150 kPa	
	Plate load test (DIN 18134)	As specified by the certifier	≥ 300 kPa ultimate bearing capacity < 25 mm settlement at 300 kPa	Typical frequency 1 per lot at completion of final lift

Material definition	**Fill use type**	Bulk 4431 fill		
	Source material type	I-A (intermediate – acceptable)		
	Typical use description	General fill for residential or light commercial earthworks using site-won or imported materials		
Source material acceptance testing	**Test (and method)**	**Minimum test frequency**	**Normal acceptance criteria**	**Notes**
	Particle size distribution (NZS 4407 test method 3.8 or NZS 4402.2.8.1)	1 for each source and 1 for each change in material	As per Table A2	Completed before works begin (and during the works if the material changes) to confirm the material's suitability
	Dry density/water content relationship (NZS 4402.4.1.1, NZS 4402.4.1.2)	1 for each source and 1 for each change in material	OMC and MDD determined for compaction acceptance testing	Completed before works begin (and during the works if the material changes) to determine OMC and MDD
	Water content (NZS 4402.2.1)	1 for each source and 1 for each change in material	Between OMC – 2% and OMC + 4%	Ongoing during the works to confirm conditioning requirements
	Solid density of soil particles (NZS 4402.2.7)	1 for each source and 1 for each change in material	Solid density determined for in-situ density testing	Used to define the solid density of aggregate particles for later use in compaction acceptance testing with in-situ nuclear moisture-density gauge Can be omitted where the geotechnical designer can provide a reliable estimate for the specific source material
	Liquid and plastic limit (NZS 4402.2.2, NZS 4402.2.3, and NZS 4402.2.4)	1 for each source and 1 per 4000 m^3 and 1 for each change in material	Plasticity index < 25% Liquid limit < 50%	Completed before works begin (and during the works if the material changes) to confirm the material's suitability
Placement requirements	Loose layer thickness < 250 mm			
Compaction acceptance testing	**Test (and method)**	**Minimum test frequency**	**Normal acceptance criteria**	**Notes**
	Field water content and density (NZS 4402.2.1 and NZS 4407 test methods 4.1, 4.2, and 4.3)	2 per 1000 m^3 (min 2 per lift)	≥ 95% maximum dry density < 10% air voids	
	Shear strength (NZGS *Guideline for hand held shear vane test*)	2 per 1000 m^3 (min 2 per lift)	Lowest value ≥ 150 kPa	DCP and shear vane locations as directed by the certifier
	Dynamic cone penetrometer	2 per 1000 m^3 for full depth of lift (min 2 per lift)	≥ 5 blows per 100 mm	The DCP test is indicative only and should not be used alone for compaction compliance
	Plate load test (DIN 18134)	As specified by the certifier	≥ 300 kPa ultimate bearing capacity < 25 mm settlement at 300 kPa	Typical frequency 1 per lot at completion of final lift

Table A1 – Minimum testing requirements for fill materials (continued)

Material definition	**Fill use type**	Bulk 4431 fill		
	Source material type	C–A (coarse-grained – acceptable)		
	Typical use description	General fill for residential or light commercial earthworks using site-won or imported materials		
Source material acceptance testing	**Test (and method)**	**Minimum test frequency**	**Normal acceptance criteria**	**Notes**
	Particle size distribution (NZS 4407 3.8 or NZS 4402 2.8.1)	1 for each source and 1 for each change in material	As per Table A2	Completed before works begin (and during the works if the material changes) to confirm the material's suitability
	Dry density/water content relationship (NZS 4402.4.1.3 or NZS 4402.4.2.1, NZS 4402.4.2.2 and NZS 4402.4.2.3)	1 for each source and 1 for each change in material	OMC and MDD determined for compaction acceptance testing	Completed before works begin (and during the works if the material changes) to determine OMC and MDD Not required for coarse-grained soils where continuous compaction control will be used to assure compaction quality
	Water content (NZS 4407.3.1)	1 for each source and 1 for each change in material	Between OMC – 2% and OMC + 4%	Ongoing during the works to confirm conditioning requirements Not used if there is no well-defined density/water content relationship
	Solid density of soil particles (NZS 4402 test 2.7)	1 for each source and 1 for each change in material	Solid density determined for in-situ density testing	Used to define the solid density of aggregate particles for later use in compaction acceptance testing with in-situ nuclear moisture-density gauge Can be omitted where the geotechnical designer can provide a reliable estimate for the specific source material or where alternative compaction acceptance testing is proposed
Placement requirements	Loose layer thickness < 250 mm			
Compaction acceptance testing	**Test (and method)**	**Minimum test frequency**	**Normal acceptance criteria**	**Notes**
	For coarse-grained soils with maximum particle size < 65 mm, test field water content and density (NZS 4402.2. 1 and NZS 4407 test method 4.1, 4,2, and 4.3)	1 per 1000 m^3 (min 2 per lift)	> 95% MDD < 15% air voids	
	For coarse-grained soils with maximum particle size from 65 mm to 250 mm, proof-roll to target maximum calibrated dynamic response modulus or relative density (CEN/TS 17006)	Ongoing continuous compaction control	Target minimum calibrated compaction machine specific dynamic response modulus or minimum 80% relative density	Target minimum modulus set by correlation with plate load test(s) or as otherwise defined by the certifier
	Dynamic cone penetrometer	2 per 1000 m^3 for full depth of lift (min 2 per lift)	≥ 5 blows per 100 mm	DCP locations as directed by the certifier This test is indicative only and should not be used alone for compaction compliance
	Impact test – 4.5 kg hammer (ASTM D5874)	1 per 50 m^3 on each compacted layer (min 2 for each lift of fill)	IV > 25	This test is indicative only and should not be used alone for compaction compliance
	Plate load test (DIN 18134)	As specified by the certifier	≥ 300 kPa ultimate bearing capacity < 25 mm settlement at 300 kPa	Typical frequency 1 per lot at completion of final lift

Material definition	**Fill use type**	Bulk 4431 fill		
	Source material type	R-GAP 100-A (rock crushed to GAP 100 grading – acceptable)		
	Typical use description	General fill for residential or light commercial earthworks using selected site-won or imported pit run materials		
Source material acceptance testing	**Test (and method)**	**Minimum test frequency**	**Normal acceptance criteria**	**Notes**
	Particle size distribution (NZS 4407 test method 3.8 or NZS 4402.2.8.1)	1 for each source and 1 for each change in material or source	As per Table A2	Completed before works begin (and during the works if the material changes) to confirm the material's suitability
	Dry density/water content relationship (NZS 4402.4.1.3 or NZS 4402.4.2)	1 for each source and 1 for each change in material	OMC and MDD determined for compaction acceptance testing	Completed before works begin (and during the works if the material changes) to determine OMC and MDD
	Solid density of soil particles (NZS 4402.2.7.1 or 2.7.2)	1 for each source and 1 for each change in material	Solid density determined for in-situ density testing	Used to define the solid density of aggregate particles for later use in compaction acceptance testing with in-situ nuclear moisture-density gauge Can be omitted where the geotechnical designer can provide a reliable estimate for the specific source material or where alternative compaction acceptance testing is proposed
	Weathering quality index (NZS 4407 test method 3.11)	1 for each source and 1 for each change in material or source	AA, AB, AC, BA, BB, or CA	Completed before works begin (and during the works if the material changes) to confirm the material's suitability
Placement requirements	Loose layer thickness < 300 mm			
Compaction acceptance testing	**Test (and method)**	**Minimum test frequency**	**Normal acceptance criteria**	**Notes**
	For coarse-grained soils with maximum particle size < 65 mm, test field water content and density (NZS 4402.2.1 and NZS 4407 test methods 4.1, 4.2, and 4.3)	1 per 1000 m^3 (min 2 per lift)	> 95% MDD < 15% air voids	
	For coarse-grained soils with maximum particle size from 65 mm to 250 mm, proof-roll to target maximum calibrated dynamic response modulus or relative density (CEN/TS 17006)	Ongoing continuous compaction control	Target minimum calibrated compaction machine specific dynamic response modulus or minimum 80% relative density	Target minimum modulus set by correlation with plate load test(s) or as otherwise defined by the certifier
	Dynamic cone penetrometer	1 per 500 m^3 for full depth of lift (min 2 per lift)	≥ 5 blows per 100 mm	DCP locations as directed by the certifier This test is indicative only and should not be used alone for compaction compliance
	Impact test – 4.5 kg hammer (ASTM D5874)	1 per 50 m^3 on each compacted layer (min 2 for each lift of fill)	IV > 25	Impact test locations as directed by the certifier This test is indicative only and should not be used alone for compaction compliance
	Plate load test (DIN 18134)	As specified by the certifier	≥ 300 kPa ultimate bearing capacity < 25 mm settlement at 300 kPa	Typical frequency 1 per lot at completion of final lift

Table A1 – Minimum testing requirements for fill materials (continued)

Material definition	**Fill use type**	Bulk 4431 fill		
	Source material type	R-GAP 65-A (rock crushed to GAP 65 grading – acceptable)		
	Typical use description	General fill for residential or light commercial earthworks using selected site-won or imported pit run materials		
Source material acceptance testing	**Test (and method)**	**Minimum test frequency**	**Normal acceptance criteria**	**Notes**
	Particle size distribution (NZS 4407 test method 3.8 or NZS 4402.2.8.1)	1 for each source and 1 for each change in material or source	As per Table A2	Completed before works begin (and during the works if the material changes) to confirm the material's suitability
	Dry density/water content relationship (NZS 4402.4.1.3 or NZS 4402.4.2)	1 for each source and 1 for each change in material	OMC and MDD determined	Completed before works begin (and during the works if the material changes) to determine OMC and MDD for later use in compaction acceptance testing
	Solid density of soil particles (NZS 4402.2.7.1 or 2.7.2)	1 for each source and 1 for each change in material	Solid density determined for in-situ density testing	Used to define the solid density of aggregate particles for later use in compaction acceptance testing with in-situ nuclear moisture-density gauge Can be omitted where the geotechnical designer can provide a reliable estimate for the specific source material or where alternative compaction acceptance testing is proposed
	Weathering quality index (NZS 4407 test method 3.11)	1 for each source and 1 for each change in material or source	AA, AB, AC, BA, BB, or CA	Completed before works begin (and during the works if the material changes) to confirm the material's suitability
Placement requirements	Loose layer thickness < 250 mm			
Compaction acceptance testing	**Test (and method)**	**Minimum test frequency**	**Normal acceptance criteria**	**Notes**
	For coarse-grained soils with maximum particle size < 65 mm, test field water content and density (NZS 4402.2.1 and NZS 4407 test method 4.1, 4.2, and 4.3)	1 per 1000 m^3 (min 2 per lift)	> 95% MDD < 15% air voids	
	For coarse-grained soils with maximum particle size from 65 mm to 250 mm, proof-roll to target maximum calibrated dynamic response modulus or relative density (CEN/TS 17006)	Ongoing continuous compaction control	Target minimum calibrated compaction machine specific dynamic response modulus or minimum 80% relative density	Target minimum modulus set by correlation with plate load test(s) or as otherwise defined by the certifier
	Dynamic cone penetrometer	1 per 500 m^3 for full depth of lift (min 2 per lift)	≥ 5 blows per 100 mm	DCP locations as directed by the certifier This test is indicative only and should not be used alone for compaction compliance
	Impact test – 4.5 kg hammer (ASTM D5874)	1 per 50 m^3 on each compacted layer (min 2 for each lift of fill)	IV > 25	Impact test locations as directed by the certifier This test is indicative only and should not be used alone for compaction compliance
	Plate load test (DIN 18134)	As specified by the certifier	≥ 300 kPa ultimate bearing capacity < 25 mm settlement at 300 kPa	Typical frequency 1 per lot at completion of final lift

Material definition	**Fill use type**	Bulk 4431 fill		
	Source material type	M-GAP 40-A (recycled concrete or brick crushed to GAP 40 grading – acceptable)		
	Typical use description	General fill for residential or light commercial earthworks using imported recycled concrete or brick		
Source material acceptance testing	**Test (and method)**	**Minimum test frequency**	**Normal acceptance criteria**	**Notes**
	Particle size distribution (NZS 4407 test method 3.8 or NZS 4402.2.8.1)	1 for each source and 1 for each change in material or source	As per Table A2	Completed before works begin (and during the works if the material changes) to confirm the material's suitability
	Dry density/water content relationship (NZS 4402.4.1.3 or NZS 4402.4.2)	1 for each source and 1 for each change in material	OMC and MDD determined for compaction acceptance testing	Completed before works begin (and during the works if the material changes) to determine OMC and MDD
	Solid density of soil particles (NZS 4402.2.7.1 or NZS 4402.2.7.2)	1 for each source and 1 for each change in material	Solid density determined for in-situ density testing	Used to define the solid density of aggregate particles for later use in compaction acceptance testing with in-situ nuclear moisture-density gauge Can be omitted where the geotechnical designer can provide a reliable estimate for the specific source material or where alternative compaction acceptance testing is proposed
	Weathering quality index (NZS 4407 test method 3.11)	1 for each source and 1 for each change in material or source	AA, AB, AC, BA, BB, or CA	Completed before works begin (and during the works if the material changes) to confirm the material's suitability
	Chemical acceptability	1 for each source and 1 for each change in material or source and 1 per 1000 m^3	As per Tables 54 and 55 in *Methodology for deriving standards for contaminants in soil to protect human health* (Ministry for the Environment, 2011)	Recommended testing for recycled crushed concrete or brick from relatively clean sources – alternative testing could be required for other materials or sources with more complex chemistry Completed before works begin (and during the works if the material changes) to confirm the material's suitability, and ongoing throughout placement to allow for source variability Not appropriate for materials from HAIL sites. Advice from an SQEP is needed for these
Placement requirements	Loose layer thickness < 250 mm			
Compaction acceptance testing	**Test (and method)**	**Minimum test frequency**	**Normal acceptance criteria**	**Notes**
	For coarse-grained soils with maximum particle size < 65 mm, test field water content and density (NZS 4402.2. 1 and NZS 4407 test method 4.1, 4.2, and 4.3)	1 per 1000 m^3 (min 2 per lift)	> 95% MDD < 15% air voids	
	For coarse-grained soils with maximum particle size from 65 mm to 250 mm, proof-roll to target maximum calibrated dynamic response modulus or relative density (CEN/TS 17006)	Ongoing continuous compaction control	Target minimum calibrated compaction machine specific dynamic response modulus or minimum 80% relative density	Target minimum modulus set by correlation with plate load test(s) or as otherwise defined by the certifier
	Dynamic cone penetrometer	1 per 500 m^3 for full depth of lift (min 2 per lift)	≥ 5 blows per 100 mm	DCP locations as directed by the certifier This test is indicative only and should not be used alone for compaction compliance
	Impact test – 4.5 kg hammer (ASTM D5874)	1 per 50 m^3 on each compacted layer (min 2 for each lift of fill)	IV > 25	Impact test locations as directed by the certifier This test is indicative only and should not be used alone for compaction compliance
	Plate load test (DIN 18134)	As specified by the certifier	≥ 300 kPa ultimate bearing capacity < 25 mm settlement at 300 kPa	Typical frequency 1 per lot at completion of final lift

Table A2 – Particle size criteria for material types defined in this standard

	Sieve aperture size (mm)		250	150	100	75	65 or 63	40 or 37.5	20 or 19	13.2	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075	Uniformity coefficient
Acceptable range for percentage passing sieve	F (fine-grained) bulk fill	Min		-	-	-	-	-	-	-	-	-	-	-	-	-	-	35	
		Max		-	-	-	-	-	100	-	-	-	-	-	-	-	-	-	
	I (intermediate-grained) bulk fill	Min		-	-	-	-	-	-	-	-	-	-	-	-	-	-	15	
		Max		-	-	100	-	-	-	-	-	-	-	-	-	-	-	35	
	C (coarse-grained) bulk fill	Min		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		Max		100	-	-	-	-	-	-	-	-	-	-	-	-	-	15	
	GAP 100	Min		-	100	80	70	54	39	32	27	20	15	10	6	3	1	-	
		Max		-	-	92	85	75	60	52	46	34	25	18	13	10	7.5	5	
	GAP 65	Min		-	-	-	100	80	50	-	30	20	15	10	6	4	2	-	
		Max		-	-	-	-	90	70	-	55	40	30	22	18	14	10	7	
	GAP 40	Min		-	-	-	-	100	61	-	38	23	14	7	2	-	-	-	
		Max		-	-	-	-	-	80	-	57	43	33	25	19	14	10	7	

APPENDIX B – SIMPLE EXAMPLE OF AN INSPECTION AND TEST PLAN (ITP)

(Informative)

This is an example inspection and test plan for a small earthworks project. (For larger projects, create an ITP for each activity.) This example ITP can be customised to suit the needs of the project. The contractor owns the ITP and the process and can use their own template as an alternative – but they should involve the certifier.

INSPECTION AND TEST RECORD

Project name:	*Example project 01*	**ITP no. and revision:**	*001 rev 0*
Project address:	*Paradise, New Zealand*		
Main contractor:	*Top Class Civil*		
Certifier:	*Ash Geoguru*		
ITP title:	*Preparation of building platform*		
Area of works being signed off (describe or reference plan)	*Lots 1, 2, and 3*		

Signatures (and names) as required in the ITP upon satisfactory completion of each operation

O = Observation point (work continues, signed ITP and observation record)
I = Inspection point (work continues, signed ITP)
W = Witness by third party (work continues, signed ITP)
H = Hold point (stop work until ITP has been signed)
R = Records review (signed record per package)

No.	**Operation to be inspected or tested**	**Responsible organisation**	**Contractor**	**Lab/testing group**	**Certifier**	**Other**
1	Earthworks specification and design drawings on-site	Developer	H		I	
2	Earthworks management plan in place	Contractor	H		I	
3	Protected areas (for example, trees, heritage, services) marked	Contractor	H			H – Archaeologist
4	Erosion and sediment control and stormwater control measures in place	Contractor	H			
5	Strip and stockpile topsoil	Contractor				
6	Cut benches (where required), shape and compact cleared ground	Contractor			O	
7	Test cleared ground	Lab/ testing group		H	R	
8	Install sub-surface/bench drainage where required	Contractor			H	
9	Place, compact, and test fill in accordance with earthworks specification	Contractor and lab/ testing group		H	R, I	
10	Finish fill surface				I	

Figure 9 – Inspection and test plan (ITP) – Simple example

APPENDIX C – DETAILED EXAMPLE OF AN INSPECTION AND TEST PLAN (ITP)

(Informative)

This is an example inspection and test plan for stripping on a large earthworks project (create an ITP for each activity). This example ITP could be used as a template ITP for other activities and should be customised to suit the needs of the project. The contractor owns the ITP and the process and can use their own template as an alternative – but they should involve the certifier.

INSPECTION AND TEST PLAN

Project name:	*Example project 01*	**ITP number:**	*001*	**ITP revision:**	*0*
Project address:	*Paradise, New Zealand*				
Main contractor:	*Top Class Civil*				
Earthworks certifier:	*Ash Geoguru*				
ITP title:	*Topsoil stripping*				

INSPECTION AND TEST CODES

O = Observation point (work continues, signed ITP and ob. record)

I = Inspection point (work continues, signed ITP)

W = Witness by third party (work continues, signed ITP)

H = Hold point (stop work until ITP has been signed)

R = Records review (signed record per package)

No.	**Operation to be inspected or tested**	**Controlled by (position)**	**Accept/reject criteria**	**Frequency/time of inspection or test**	**Reference document/ consent clause**	**Evidence required**	**Roles**				
							Earthworks subcontractor	**Main contractor**	**Lab/ testing group**	**Certifier**	**Other (specify)**
1	Safe system of work in place	Main contractor – site supervisor	Approved safe system of work in place	Prior to commencing work		Authorised work plan on-site	-	H	-	-	-
2	Protected areas (for example, trees, heritage) marked	Main contractor – site supervisor	All sensitive features protected	Prior to commencing work	Consent clause no.	None	I	I	-	-	-
3	Stripping area and depth defined	Main contractor – site supervisor		Prior to commencing work			I	I	-	-	-
4	Strip and stockpile topsoil	Main contractor – site supervisor	Stockpiles as per specification	Weekly during topsoil stripping		Observation record	-	-	-	O	-
5	Shape cleared ground	Main contractor – site supervisor	Formation shape as per design			Observation record	-	I	-	O	-
6	Test cleared ground	Main contractor – site supervisor	As per earthworks specification	As per earthworks specification		Test records	-	-	-	H	-

Prepared by:	Reviewed by:	Page:
Prepared date:	Reviewed date:	of:

Figure 10 – Inspection and test plan (ITP) – Detailed example

The ITP record below shows how the example ITP above would be signed off in practice.

INSPECTION AND TEST RECORD

Project name: **Project address:** **Main contractor:** **Certifier:** **ITP title:**	*Example project 01* *Paradise, New Zealand* *Top Class Civil* *Ash Geoguru* *Topsoil stripping*	**ITP no. and revision:**	*001 rev 0*
Area of works being signed off (describe or reference plan)	*Lots 1, 2, and 3*		

No.	**Operation to be inspected or tested**	**Inspection and test points. Sign on satisfactory completion of each operation.**				
		Earthworks subcontractor	**Main contractor**	**Lab/testing group**	**Certifier**	**Other**
1	Safe system of work in place		H Doug Spade			
2	Protected areas (for example, trees, heritage) marked	I Kristalle Rock	I Doug Spade			
3	Stripping area and depth defined	I Kristalle Rock	I Doug Spade			
4	Strip and stockpile topsoil				O Ash Geoguru	
5	Shape cleared ground		I Doug Spade		O Ash Geoguru	
6	Test cleared ground				H Ash Geoguru	

Figure 11 – Detailed ITP example as would be signed off in practice

APPENDIX D – STATEMENT OF SUITABILITY OF ENGINEERED FILL FOR LIGHTWEIGHT STRUCTURES

(Informative)

<table>
<tr><td>To: (name and address of local authority)</td><td colspan="2"></td></tr>
<tr><td>Development name:</td><td colspan="2"></td></tr>
<tr><td>Land title(s):</td><td colspan="2"></td></tr>
<tr><td>Development location/address:</td><td colspan="2"></td></tr>
<tr><td>Relevant resource consent number(s):</td><td colspan="2"></td></tr>
<tr><td>Developer’s name and company:</td><td colspan="2"></td></tr>
<tr><td>Geotechnical designer’s name and company:</td><td colspan="2"></td></tr>
<tr><td>Certifier’s name and company:</td><td colspan="2"></td></tr>
<tr><td colspan="3">Attachments (give reference numbers):
(1) Site layout plan(s)
(2) Fill layout plan(s)
(3) Fill section(s)
(4) Design report
(5) Earthworks completion report, including the following appendices:
(a) As-built survey;
(b) Cut-fill plan (with contours);
(c) Inspection and test plan;
(d) Earthworks specification;
(e) All test results;
(f) All inspection records.</td></tr>
<tr><td colspan="3">I confirm I am qualified as a certifier as defined in NZS 4431:2022.
During this work, I was retained as certifier, and I or my certifier’s representative undertook inspections and testing as documented in the attached earthworks completion report.
I am satisfied that the engineered fill shown in the attached as-built survey was placed, compacted, and tested in accordance with the attached earthworks specification and that all variations and non-compliances have been documented in the earthworks completion report.
Based on the information available, I certify that, to the best of my knowledge, the intent of the geotechnical designer (as presented in their design, drawings, and earthworks specification) has been achieved.
The area shown on the as-built survey plan referenced above is considered suitable for development as per NZS 3604. (strike out if not relevant)
This certification does not remove the necessity for normal inspection and design of foundations as would be made in natural ground.</td></tr>
<tr><td colspan="2">Certifier’s signature:</td><td>Date:</td></tr>
<tr><td colspan="3">Certifier’s qualifications, professional registration type, and number:</td></tr>
</table>

Figure 12 – Statement of suitability of engineered fill for lightweight structures

NOTES

Approved by the New Zealand Standards Approval Board on 6 April 2022 to be a New Zealand Standard pursuant to section 12 of the Standards and Accreditation Act 2015.

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HĪKINA WHAKATUTUKI

New Zealand Government