NZGS Specification

NZGS_0510 EARTHWORKS

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NEW ZEALAND GEOTECHNICAL SOCIETY INC

A Collaborating Technical Society of Engineering New Zealand

Document Status

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The document may be updated from time to time following the issue date. The latest version is available from the New Zealand Geotechnical Society (NZGS) website www.nzgs.org

About the New Zealand Geotechnical Society

The New Zealand Geotechnical Society (NZGS) is the affiliated organisation in New Zealand of the International Societies representing practitioners in Soil Mechanics, Rock Mechanics and Engineering Geology. NZGS is also a collaborating Technical Society of Engineering New Zealand.

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Foreword

This long-form specification has been developed to be used in conjunction with:

- NZS3910:2013 Conditions of contract for building and civil engineering construction
- NZS4431:2022 Engineered fill construction for lightweight structures
- The other components of the NZGS Specification series, notably:
  - NZGS_000 Standard Specifications User Guide
  - NZGS_100 Preliminary and general
  - NZGS_200 Ground Investigations [1]
  - NZGS_110 Method of measurement
  - NZGS_520 Reinstatement
- The project-specific details in the form of NZGS_0100P

It may be used in conjunction with other specifications where appropriate.

This specification is intended to be appropriate for use on most residential or light commercial development projects with common soil and rock types found in New Zealand. It is also intended to be flexible enough to be used on major earthworks projects, but may require more significant additions to the project-specific details by the Geotechnical Designer.

A separate short-form version of this specification is being developed for smaller projects.

Acknowledgements

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A technical review has been undertaken by Richard Neate and Hayden Bell of GHD Ltd.

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A draft version of this document was released for industry review in mid-2022. Feedback was received from the following individuals and organisations:

- To be listed following feedback

[1] Currently presented as Volume 1 of the New Zealand Ground Investigation Specification, NZGS 2017

Table of contents

NZGS_510.1 General

NZGS_510.1.1 Introduction and scope

This specification covers detailed requirements for Earthworks contracts only. Where the contract includes other works, appropriate clauses from this document can be included in the project-specific preliminary and general specification for the Contract.

It is expected that this specification will be used in conjunction with NZGS_100 “Preliminary and general”, or that the relevant clauses from that specification will be incorporated into the main contract specification.

> Notes for guidance are presented in blue boxes similar to this example. They do not form part of the Specification or contract.

This document shall be read together with all documents forming part of the Contract.

> The order of precedence for the documents that together form the Contract, including the specification(s) should be defined in the Contract. They have not been repeated here in the Specification to avoid contradiction.

NZGS_510.1.2 Standards

All works shall comply with the minimum standards set out in:

- NZS4431:2022 Engineered fill construction for lightweight structures
- NZS4402 Methods of testing soils for civil engineering purposes
- NZS4404 Land development and subdivision infrastructure
- WorkSafe NZ Code of Practice for excavations and shafts

Additional standards (including client or region-specific requirements) shall be defined in the project-specific specification.

In the case of any contradictions, the following order of precedence shall be applied (items higher up list take precedence over items lower down list):

- NZGS_0510P (project-specific Earthworks specification)
- NZGS_0510 (NZGS Earthworks specification)
- NZS4431:2022 (NZ Standard engineered fill construction for lightweight structures)

Where any parties involved in the Works identify that the specified works would fall below the minimum standards set out in NZS4431:2022 they shall inform the Geotechnical Designer and the Client. Works may continue if the Geotechnical Designer and Client agree in writing that this lower standard is acceptable.

NZGS_510.1.3 Preliminary and General

See NZGS_0100 Preliminary and General for definitions and abbreviations, quality assurance, safety, site management and other requirements.

NZGS_510.2 Classification of soil and rock material

NZGS_510.2.1 Purpose

This section allows the classification of soil and rock materials sourced from excavations or stockpiles for use in the construction of new engineered fill.

The soil and rock classifications can be further categorised and used for payment purposes, when allowed for in the Contract, as defined in NZGS_110 Methods of Measurement, and the Project-Specific Specification NZGS_110P.

NZGS_510.2.2 General requirements

Soil and rock materials proposed for use in the construction of an engineered fill shall be classified as follows, unless otherwise required in the Contract:

- Source material type
- Material condition
- Fill use type

Soil and rock materials which will not be used in an engineered fill construction but may be used for other purposes such as landscape fill can be classified by source material type and material condition only.

Tables A1 and A2 in the Technical Appendix provide specific information about the soil and rock materials for use in engineered fill construction for residential or light commercial Earthworks using selected site-won or imported materials. The tables include test requirements to be used by the Contractor to successfully source, classify, and compact soil and rock materials in accordance with NZS4431. All site-specific test requirements shall be included in the Contractor's ITP.

Additional materials may be defined by the Geotechnical Designer in the Project-Specific Specification tables A1P and A2P.

> It is expected that the Geotechnical Designer will specify additional materials to suit the local geological conditions and the project requirements.
>
> Where the project is being undertaken for the purposes of lightweight residential or commercial construction, the Geotechnical Designer is expected to ensure that the end product earthworks achieve a performance at least as good as the materials defined in table A1 of NZS4431. For well-understood soil types this performance may, in some circumstances, be achieved with less rigorous requirements than defined in NZS4431. Robust evidence should be provided if this approach is proposed.
>
> For other purposes, lower (or higher) performance requirements may be appropriate.

NZGS_510.3 Source material type

NZGS_510.3.1 Primary categories

Source materials (including site-won, stockpiled, and imported soil and rock materials, or manufactured equivalents) shall be classified as defined in NZS4431 into the following primary categories:

- Material type T (topsoil)
- Material type F (fine-grained soil)
- Material type I (intermediate-grained soil)
- Material type C (coarse-grained soil or aggregate)
- Material type R (rock)
- Material type M (manufactured)

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

> Examples of such categorisation are provided in NZS 4431:2022 C3.3.1.

The Geotechnical Designer shall ensure that the way in which different soil and rock materials have been incorporated into the design and construction is confirmed by way of the Fill Use Type descriptions (refer NZGS_510.5 - Fill use) and clearly identified on the drawings and in the specification.

The descriptions of the primary categories may be changed by the Geotechnical Designer in response to project specific material requirements. Any such changes must be presented as an alternative Fill Use Type with a different name. The Geotechnical Designer shall confirm that any such Fill Use Types will meet the requirements of the design and NZS4431. Any changes shall then be incorporated into the design of the engineered fill and subsequently confirmed in the specification and Contract.

NZGS_510.3.2 Material Type T (topsoil)

Material Type T (topsoil) is a natural material that comprises the ‘O’ and ‘A’ horizons.

> For more information about topsoil, including descriptions of the O and A horizons, see NZS4431:2022 C3.3.2

NZGS_510.3.3 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 NZGS Guideline for the Field Description of Soil and Rock and is based on more than 35% material passing the 63µm sieve.

NZGS_510.3.4 Material Type I (intermediate soil)

Material Type I is a natural soil material that has between 15% and 35% material passing the 63µm sieve.

NZGS_510.3.5 Material Type C (coarse-grained soil)

Material Type C is a natural soil material with no more than 15% by mass passing the 63µm sieve.

NZGS_510.3.6 Material Type R (rock)

Material Type R is any natural material that can be described as rock using the NZGS Guideline for the Field Description of Soil and Rock

> Rock can be further categorised as R1, R2 and R3 for payment purposes, see NZGS_0110 Measurement.

NZGS_510.3.7 Material Type M (manufactured)

Material Type M is manufactured material specifically created or modified for the purpose of Earthworks, as defined on the drawings and in the specification. Type M material includes crushed concrete; recycled asphalt; natural materials that have been mixed with cement or other binding agents to change their physical properties.

NZGS_510.4 Material condition

NZGS_510.4.1 Condition suffixes

The condition of each soil and rock material shall be described as one or a combination of the following suffix codes alongside the source material classification given in Section NZGS_510.3 - Source material type :

- A (acceptable).
- W (wet).
- D (dry).
- U (unsuitable).
- X (restricted).

The condition shall be assigned when the material is excavated or taken from stockpile for use in the fill. The suffix descriptor shall be modified if the condition has changed whether this change be through treatment or the result of natural changes.

Whenever the Contractor wishes material excavated or taken from stockpile for use in the engineered fill to be classified as other than A, the Contractor shall notify the Engineer in writing immediately seeking a reclassification decision which shall not be unreasonably withheld.

NZGS_510.4.2 Material Condition A (acceptable)

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

NZGS_510.4.3 Material Condition W (wet)

Condition W material is significantly wetter than optimum moisture content (OMC) and likely to need controlled drying before placement and compaction.

The Contractor shall employ a Recognised Laboratory to determine the OMC using the specified compaction effort from NZS 4402:1989, Test 4.1.1, Test 4.1.2, or Test 4.1.3. The Contractor shall then seek confirmation from the Engineer in writing of the moisture content beyond which a particular soil and rock material is too wet to be successfully compacted. Materials with moisture contents at or exceeding this limit shall be classified as wet (W).

In the absence of project-specific limits, materials shall be classified as wet (W) if their moisture content exceeds 4% of the OMC for that material or mixture of materials) determined by laboratory testing.

NZGS_510.4.4 Material Condition D (dry)

Condition D material is significantly drier than OMC and likely to need controlled wetting before placement and compaction.

The Contractor shall employ a recognised laboratory to determine the OMC using the specified compaction effort from NZS 4402:1989, Test 4.1.1, Test 4.1.2, or Test 4.1.3. The Contractor shall then seek confirmation from the Engineer in writing of the moisture content below which a particular soil and rock material is too dry to be successfully compacted. Materials with moisture contents at or below this limit shall be classified as dry (D).

In the absence of a project-specific limit, materials shall be classified as dry (D) if their moisture content is more than 2% below the optimum moisture content for that material or mix of materials determined by laboratory testing.

NZGS_510.4.5 Condition U (unsuitable)

Condition U material is unsuitable for use in its current form because it has one or more physical and/or chemical properties that make it unsuitable for placement as engineered fill. NZS4431 Sections 3.4.5 and 3.4.6 describe the physical and chemical properties likely to render the material as being unsuitable.

NZS4431 Sections 3.4.5 and 3.4.6 further subdivide Condition U into U1 (physically unsuitable) and U2 (chemically unsuitable). The U1 and U2 descriptions may be used by the Geotechnical Designer, and subsequently the Contractor and the Engineer, in response to material and site-specific requirements, as outlined in the design of the engineered fill and subsequently confirmed in the specification and the Contract.

Otherwise, Condition U will describe all material that is unsuitable for use in its current form.

Condition U material may be processed by mechanical, chemical, or other means to render the material suitable for use. If the Engineer agrees processing is successful, the material may then be reclassified.

NZGS_510.4.6 Condition X (restricted)

Condition X materials are those with recognised construction difficulties, longer-term performance deficiencies, or other complicating factors. Condition X material may be able to be used as engineered fill but will require project/site specific design and approval by the Engineer.

NZS4431 Section 3.4.7 describes the physical properties likely to render the material as being restricted.

Condition X material may be processed by mechanical, chemical, or other means to render the material suitable for use. If the Engineer agrees processing is successful, the material may then be reclassified.

NZGS_510.5 Fill use type

The fill use type shall be used to confirm where and how materials are used in the construction of engineered fill, in accordance with the design and as detailed on the engineering drawings.

> See NZS4431:2022 C3.5 for examples of using fill use types

NZGS_510.6 Excavation

NZGS_510.6.1 General

Excavation to project design levels and for the supply of materials for fill construction works involves several inter-related construction operations needed to achieve the specified outcomes including, but not limited to excavation; benching; trimming; foundation treatments (if specified).

All excavation works shall be undertaken in accordance with the requirements of NZS 4431.

Materials encountered in excavations and intended for use as fill shall be handled carefully so that they meet the specified material outcomes (refer Sections NZGS_510.3 - Source material type , NZGS_510.4 - Material condition , and NZGS_510.5 - Fill use).

NZGS_510.6.2 Safe practices

Safe excavation practices shall always be followed in accordance with WorkSafe NZ: Approved Code of Practice for Safety in Excavations and Shafts for Foundations.

NZGS_510.6.3 Excavation management

The batter slopes in cuttings shall be constructed in accordance with the design and drawings or as directed by the Engineer based on observations from on-going site inspection. The Contractor's planning and implementation of the excavation and cartage operations shall always optimise the use of the available soil and rock materials and prevent unplanned strength loss due to poor management of the Earthworks operations.

Where material is being excavated as cut to fill, cut to stockpile, or cut to waste, the excavations shall prevent the mixing of incompatible materials unless otherwise specified, or as directed by the Engineer.

All excavated materials shall by preference be spread, placed, and compacted immediately rather than being stockpiled. If stockpiling of excavated materials is either specified (into a nominated stockpile area), directed by the Engineer, or is otherwise undertaken by the Contractor during the execution of the Earthworks the Contractor shall always use the material in a manner that minimises condition loss and strength loss.

Care should be taken to avoid changes which result in the material classification changing (for example, from Acceptable to Wet) or any other changes to the material which may compromise later reuse.

The Contractor shall ensure that materials selected by the Geotechnical Designer for use in specific areas of the fill construction are protected for this purpose.

> Examples of specific end use may include material for shear key construction or platform construction immediately below new building foundations.

Engineered fill construction operations shall be managed preferably as cut to fill. Where double handling is necessary because of the location of material in the borrow areas and cut batters, the works shall be cut to stockpile followed by cut stockpile to fill.

All excavation works shall be carried out in a manner that limits overbreak and slips as far as is reasonably practicable.

The Contractor shall take all practicable steps to prevent damage to cuts and fills.

Should the Contractor choose to use material stockpiling as a part of the earthwork operations rather than place the material directly into the fill when this is possible, then this will be treated as a cut to fill operation only for payment purposes, and not two separate cut to stockpile and then cut stockpile to fill operations.

NZGS_510.6.4 Topsoil stripping

Topsoil shall be removed within the limits of the Earthworks as designed. Care shall be taken to avoid contamination of the topsoil during the removal process.

The depth of topsoil stripped shall be as designed and shown on the drawings, or as directed by the Engineer.

Topsoil shall, wherever practicable, be re-used immediately after stripping.

NZGS_510.6.5 Ripping productivity trials

Where agreement cannot otherwise be reached on classification of excavated materials as Type R1, R2 and R3, ripping productivity trials shall be carried out by the Contractor under the supervision of the Engineer, and with the full support of the Contractor, using a suitable crawler tractor or tracked excavator.

See NZGS_110 Measurement for definitions of R1, R2 and R3.

NZGS_510.6.6 Rock blasting

The Contractor shall be responsible for planning, implementing, and monitoring all blasting works of Type R3 material, including planning drill patterns, charge sizes and rock fall collection and transportation operations, providing appropriate health and safety protection, and for obtaining all necessary legislative approvals. Such approvals may include conditions that require monitoring the environmental effects of the blasting operations (air blast, noise, dust, and vibration) and ensuring that adjoining landowners are kept informed in advance of blasting operations and are not adversely affected.

The procedures for planning, implementing, and monitoring of all blasting operations shall be documented in the Contractors Quality Management Plan (QMP).

When planning, implementing, and monitoring blasting work the Contractor shall ensure that the charges used are able to deliver the required outcomes without unnecessary blast or gas pressure damage during or following the works.

Should the Contractor choose to use drill and blast techniques to speed up a normal excavation process, and the material being excavated could have been productively ripped and moved as either Type A, R1, or R2 material, then the material will not be re-classified as R3.

NZGS_510.6.7 Cut batters

Cut batters shall be constructed to the specified lines, levels, and tolerances, using suitable excavation equipment that allows the Contractor to present stable and resilient cut shapes, that do not pond water or are vulnerable to being damaged (for example, by surface erosion). Cut batters must be cleared of loose or unstable material progressively as the excavation proceeds.

The tops of cuttings shall be rounded and drained to the specified dimensions or as directed by the Engineer. Batters shall generally require progressive flattening at the ends of cuttings owing to the likely presence of less stable materials and the need to safely transition in with the surrounding ground contours. All cut batters designed to be vegetated shall be left with a rough surface texture to assist with specified re-vegetation unless otherwise specified.

NZGS_510.6.8 Borrow areas

Borrow areas shall be opened and excavated in an order that allows work to progress efficiently, in a manner that does not pond water or are vulnerable to being damaged (for example, by surface erosion). The borrow areas shall be at the specified locations and/or at locations as directed by the Engineer. When use of borrow areas is complete, the borrow areas shall be restored as designed and specified. In the absence of any specific design or direction from the Engineer, borrow areas shall be cleared of loose or unstable material, shaped to blend with surrounding ground contours, left with a rough surface texture to assist with re-vegetation, and re-vegetated with plants consistent with those removed before and during the works.

NZGS_510.6.9 Surface water drains

Surface water drains shall be formed and/or installed as specified and detailed in the drawings, or as required by the Engineer, during excavation and temporary works to effectively manage stormwater and surface water discharge. Surface water drains shall have an even and true grade to outlets onto stable ground so that water will not stand in any part. Surface reinstatement shall limit the potential for erosion during the works and shall provide a texture that will aid the establishment of approved vegetation, or as otherwise specified or directed by the Engineer.

All surface water drain outlets shall be formed on stable ground, clear of any deleterious materials and with the specified erosion and vegetation measures, unless otherwise directed by the Engineer. Material excavated from below the ground water table shall be utilised or disposed of as appropriate

to the classification and condition (refer Sections NZGS_510.3 - Source material type , NZGS_510.4 - Material condition , and NZGS_510.5 - Fill use).

NZGS_510.6.10 Excavation level and overbreak

Excavation shall be to the formation levels required by the design and drawings. The Contractors earthwork operations and site management shall then as far as reasonably practicable protect the site from overbreak.

Soft soil, loose rocks and other unsuitable material from overbreak found at the formation levels shall be removed immediately, or as directed by the Engineer.

NZGS_510.6.11 Weather and trafficking protection

At the end of each day of construction and at any time in anticipation of adverse weather, the Contractor will take all practical steps to ensure that the current as-built earthwork surfaces (both cuts and fills) are rolled smooth and graded to discharge stormwater onto stable ground without causing an erosion or surplus water/silt nuisance and in accordance with all conditions of consent.

Whenever construction traffic needs to use live construction surfaces as a haul or access road, excavations shall be left a minimum of 1.0 m above the design surface or cut batter surface respectively, and fill areas left a minimum of 0.5 m below the underside of the design surface until the area(s) in question are no longer needed as a haul or access road.

NZGS_510.6.12 Stockpiling and handling of Earthworks materials

The requirements for stockpiling and handling of fill materials on site shall be in accordance with Section 4 of NZS4431

The Contractor shall control all stockpiling and temporary material storage operations to ensure the safe utilisation of the site without interfering with the passage of traffic and/or pedestrians or affecting the stability of slopes, structures, or excavations.

Unless otherwise required by the conditions of consent or project specific requirements, stockpiles of suitable site-won material (including Topsoil) shall be held at the site.

Wherever possible, material shall be handled and stockpiled in such a way as to maintain or improve the quality of material for future re-use on site, and thereby optimise use of the resource.

Separate stockpiles shall be used for each material type, or approved mixture of materials.

Stockpiles shall be located on prepared, stable ground and kept safe and stable with sloped faces that prevent any ponding.

Erosion and sediment controls shall be maintained around all stockpiles, and in accordance with all conditions of consent.

Stockpiles which are to be in place for more than 14 days, or when heavy rain is forecast, shall have the surface adequately sealed to prevent inundation or erosion and to maintain the viability and stability of stockpiled material.

When the Contractor has stockpiled material inappropriately and in the opinion of the Engineer, the material has become unsuitable for reuse, the material shall be removed from site and replaced as directed by the Engineer. Topsoil shall be carefully stockpiled and protected to maintain or improve the quality of the organic material for future re-use on site. Topsoil stockpiles shall not be higher than 3 m, not kept for more than six months, nor over compacted.

NZGS_510.6.13 Disposal of unwanted material (cut to waste)

The quantity of material cut to waste shall be minimised as far as reasonably practicable.

The locations of disposal areas shall be as specified and identified on the drawings or directed by the Engineer. The Contractor shall control all dumping operations to optimise the utilisation of each area. Existing Topsoil shall be removed and stockpiled separately for re-use (see Section NZGS_510.6.4 - Topsoil stripping). If specified or directed by the Engineer, benching and subsurface drainage shall be installed.

All dump sites shall be shaped during the progress of the work to conform to the contours of the adjoining land and prevent ponding of storm water, or as directed by the Engineer.

Should the Contractor wish to provide alternative dumpsites, the Contractor will need to obtain and provide evidence to the Engineer that all necessary site-specific Resource Consents and Land Entry Approvals have been obtained and condition of consent can be met before opening and using any alternative dump sites.

NZGS_510.7 Fill construction

NZGS_510.7.1 General

The Contractor shall meet the requirements of NZS4431 for all engineered fill construction.

Unless otherwise specified or directed by the Engineer, the objectives of the fill construction shall be to:

- Optimise the use of the available soil and rock materials within the designated construction site or approved borrow areas
- Limit future settlement under imposed or self-weight loads
- Control fill permeability to achieve the intended purpose
- Achieve the specified material strengths in support of long-term stable fill slopes and building platform foundations in accordance with the design intent.

NZGS_510.7.2 Fill management

Soil and rock materials used as fill material shall be spread and compacted in layers of uniform quality and thickness, in a manner that avoids segregation or contamination.

The thickness of each layer shall be managed to ensure that the specified compaction outcomes are always achieved, for the full depth of the layer.

Unless directed by the Engineer, fill batters shall be adequately compacted beyond the limits of the design profile as the filling proceeds and then trimmed back to the lines and levels shown on the drawings. The fill shall then present a stable and resilient shape, that does not pond water or undergo erosion.

The movement of all construction vehicles and other traffic over fill materials shall be carefully controlled and monitored so as not to damage or overstress the construction fills. Construction haul roads shall be located outside the limits of the fill, unless specified in the design, or approved by the Engineer.

Engineered fill shall be constructed in a continuous operation resulting in the construction of a stable, consistent new building platform.

If material which has already been placed in the fill is considered by the Engineer to be too wet then, the Contractor shall either:

- Dry or mix the material so that it is suitable as fill, or
- Excavate the material to waste and replace with suitable fill material.

When drying is necessary, it shall be carried out to allow the full depth of the layer to dry uniformly. Drying and subsequent compaction operations shall be carried out only under favourable weather conditions.

Wetting of material which has become too dry for use in the fill shall be carried out with sprinkling or direct injection equipment in a manner that ensures uniform and controlled distribution of water. After wetting, the material shall be conditioned to ensure a uniform distribution of moisture throughout the layer.

If the condition of in-place fill has deteriorated (for example where the fill has become either too wet or too dry), then any remedial works required (including but not limited to those described above) shall be undertaken as directed by the Engineer.

At the end of each day of construction and at any time in anticipation of adverse weather, the current as-built fill surfaces shall be rolled smooth and graded to discharge water evenly onto stable ground clear of the fill.

NZGS_510.7.3 Choice of compaction plant

When choosing the type and size of compaction plant to be used in the Earthworks, the Contractor shall carefully consider the type of soil, the mix of soils being worked, the location of a fill in the overall works, and the planned depth of each successive layer in order to deliver the specified compaction outcomes.

NZGS_510.7.4 Compaction trials

The Contractor shall complete on-going compaction trials over the duration of the works to demonstrate that the specified compaction outcomes can be delivered in an effective and efficient manner using the available compaction plant. The Contractor shall complete compaction trials whenever there are changes in the soil and rock material being used in the engineered fill to demonstrate specified compaction outcomes are met. The frequency of testing and methods used to complete and respond to the results of the compaction trials shall be documented in the QMP.

The Contractor shall be responsible for planning and delivering the compaction trials, including all necessary Earthworks testing, as detailed in the ITP. The results from each compaction trial shall be reported to the Engineer before any subsequent Earthworks are undertaken. The Contractor will be expected to use the outcomes of the compaction trials to support effective and proactive planning and implementation of the compaction works, and ensuring that all staff, including field operations staff, are aware of the expected compaction outcomes and how to achieve these effectively.

NZGS_510.7.5 Site preparation

The requirements of Section 4.3 of NZS4431 shall be met, including site clearance; erosion and sediment controls; topsoil stripping; slope preparation including benching; cleared ground compaction; surface drainage; subsurface drainage.

NZGS_510.7.6 Fill placement and compaction

The requirements of Section 4.4 of NZS4431 shall be met, including fill placement and conditioning; compaction; settlement markers; weaving; temporary fill works.

Quality assurance of the works shall be in accordance with the A1 and A1P Tables, following the Quality Management Plan outlined in NZGS_100 Preliminary and General.

Fill placement and compaction acceptance criteria shall be as presented within the A1 Tables of this Specification, and the A1P tables in the Project-Specific Specification where relevant.

The Geotechnical Designer is expected to define appropriate testing for the materials to be used. These shall be defined in the Project-Specific Specification.

A traditional approach to the measurement and control of compaction outcomes in soil and rock fill materials in New Zealand typically uses Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) targets derived from laboratory and field compaction tests.

The MDD/OMC approach alone has been found from practical experience to not suit some New Zealand soils (for example, clay rich fine-grained soils in the Auckland and Bay of Plenty regions.

Other soil and rock material properties that can be measured during earthworks and then used to confirm whether the as placed fill material meets expected conditions include:

- Bulk Density
- Air Void or Total Void content
- Shear Strength
- Surface Deflection of a compacted fill layer or layers

The Geotechnical Designer should determine which property or combination of properties gives the best measure of compaction outcomes for selected soil and rock materials.

For example, earthworks involving fill construction with clay rich materials benefits from ongoing testing and control of moisture content, and in-situ measurement of as compacted air voids and shear strength. It is common for moisture content testing to be undertaken on “grab” samples returned to the laboratory for testing, with results processed and analysed daily, to support on-site testing from NDM or ‘rapid microwave’ tests which may be less reliable.

Testing for air voids by calibrated Nuclear Densometer and alongside this shear strength measurement using a Hand Shear Vane can also be undertaken, with the results processed and analysed daily to enable timely and informed decision making on site.

NZGS_510.7.7 Finishing works

Fills should be left in a stable condition in accordance with Section 4.5 of NZS4431.

NZGS_510.7.8 Engineered fill certification

When the engineered fill construction is deemed by the Contractor to be complete for the works (or parts thereof), the Contractor shall inform the Engineer, and shall supply the evidence of compliance with the specification including:

- Signed, complete Inspection and Test Plan
- All testing results

The Engineer will use the evidence provided by the Contractor, and independent Random Verification Testing (RVT), to either confirm that the engineered fill (or part hereof) meets the design intent and specification, or if additional works are required by the Contractor.

The engineered fill construction shall be documented by the Certifier in an appropriately scaled Earthworks Completion Report in accordance with NZS4431 Section 7.1.

Certification shall be in accordance with NZS4431 Section 7.2.

The Engineer will not unreasonably withhold certification of the works if the Contractor has provided sufficient information from which a sound, technical decision can be made.

NZGS_510.8 Earthworks maintenance

The Contractor shall maintain the completed works (or parts thereof), including:

- all earthworks
- new grassing and vegetation cover
- all temporary and permanent environmental protection measures

until either they are covered or otherwise used for later construction or building works or until the end of the specified maintenance period, whichever comes first.

The Contractor shall ensure that any certified fill is protected and not able to deteriorate through excessive drying, wetting or contamination.

Material from any slips and debris flows shall be removed to waste or as directed by the Engineer. Material recovered from slips which occur prior to completion of engineered fill shall be treated as earthworks cut to waste (where the material is no longer suitable, or where there is no reasonable location to use the material) or as cut to fill where appropriate.

The area affected by any slip or debris flow shall be shaped, trimmed, and repaired to return it to the specified condition or as directed by the Engineer. The extra work involved shall be treated as a variation, unless the slip or debris flow has been caused by events resulting from the Contractor's poor site management. In such a case the required works will be part of the Contractor's on-going maintenance obligations and will not be separately compensated.

The Engineer shall be immediately notified if any areas of weakness appear in the fill either before, or during, the maintenance period. The Engineer will then determine what remedial works are required (if any), if a new Inspection & Test Plan is required, and if the Geotechnical Designer needs to be notified. All remedial work at this stage shall be treated as a variation, unless the damage has been caused by events resulting from the Contractor's poor site management, including allowing traffic onto the surface without approval, poor surface drainage, or failing to comply with the minimum requirements for classification and testing of fill materials. In such a case the required works will be part of the Contractor's on-going maintenance obligations.

NZGS_510.9 Minimum requirements for the classification and testing of fill materials

Tables A1 and A2 provide templates for the minimum requirements for the classification of soil and rock materials and testing of materials used in engineered fill construction. These are based on the classifications for source material type, material condition and fill use type. The tables are expanded from those presented in NZS4431.

The Geotechnical Designer can amend these minimum requirements to suit the project-specific design, material supply and construction outcomes, or changes in testing methods if:

- Evidence is available to show that the modified material requirements will result in engineered fill with strength, stiffness, and stability that are the same as or better than those provided for in these tables.

That the material acceptance testing, and compaction acceptance testing can provide the Engineer with at least the same level of confidence in the quality of the engineered fill construction.

All test results shall be presented in AGS4.0NZ format.

Table A1.1 - Bulk 4431 fill (F-A)

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 m3 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 Test 4.1, 4.2, or 4.3)	2 per 1000 m3 (min 2 per lift)	≥ 95% maximum dry density < 10% air voids	
	Shear strength (NZGS Guideline for hand held shear vane test)	2 per 1000 m3 (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

Table A1.2 - Bulk 4431 fill (I-A)

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 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
	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	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 m3 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 4)	2 per 1000 m3 (min 2 per lift)	≥ 95% maximum dry density < 10% air voids	
	Shear strength (NZGS Guideline for hand held shear vane test)	2 per 1000 m3 (min 2 per lift)	Lowest value ≥ 150kPa	Locations as directed by the certifier.
	Dynamic cone penetrometer	2 per 1000 m3 for full depth of lift (min 2 per lift)	≥ 5 blows per 100 mm	Locations as directed by the certifier. 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 A1.3 - Bulk 4431 fill (C-A)

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	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
	(NZS 4407 3.8 or NZS 4402 2.8.1)	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
	Dry density/water content relationship	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
	(NZS 4402.4.1.3 or NZS 4402.4.2.1, NZS4402.4.2.2 and NZS4402.4.2.3)	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 Test 2. 1 and NZS 4407 test 4)	1 per 1000 m3 (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 m3 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 D 5874)	1 per 50 m3 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 18134:2012-04)	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 A1.4 - Landscaping fill (F-A)

Material definition	**Fill use type**	Landscaping fill		
	Source material type	F-A (fine grained – acceptable)		
	Typical use description	General fill for landscaping in areas where no design loads will be imposed and where no infrastructure will rely on the stability of the fill. 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 m3 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 < 300 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 Test 4.1, 4.2, or 4.3)	1 per 4000 m3 (min 1 per lift)	≥ 90% maximum dry density < 15% air voids	
	Shear strength (NZGS Guideline for hand held shear vane test)	1 per 1000 m3 (min 2 per lift)	Lowest value > 100 kPa	

Table A1.5 - Landscaping fill (I-A)

Material definition	**Fill use type**	Landscaping fill		
	Source material type	I–A (intermediate – acceptable)		
	Typical use description	General fill for landscaping in areas where no design loads will be imposed and where no infrastructure will rely on the stability of the fill. 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 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
	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	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 m3 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 < 300 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 4)	1 per 4000 m3 (min 1 per lift)	≥ 90% maximum dry density < 15% air voids	
	Shear strength (NZGS Guideline for hand held shear vane test)	1 per 1000 m3 (min 2 per lift)	Lowest value > 100 kPa	Locations as directed by the certifier.
	Dynamic cone penetrometer	1 per 1000 m3 for full depth of lift (min 1 per lift)	≥ 4 blows per 100 mm	Locations as directed by the certifier. The DCP test is indicative only, and should not be used alone for compaction compliance.

Table A1.6 - Landscaping fill (C-A)

Material definition	**Fill use type**	Landscaping fill		
	Source material type	C–A (coarse-grained – acceptable)		
	Typical use description	General fill for landscaping in areas where no design loads will be imposed and where no infrastructure will rely on the stability of the fill. Using selected site-won or imported materials.		
Source material acceptance testing	**Test (and method)**	**Minimum test frequency**	**Normal acceptance criteria**	**Notes**
	Particle size distribution	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
	(NZS 4407 3.8 or NZS 4402 2.8.1)	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
	Dry density/water content relationship	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
	(NZS 4402.4.1.3 or NZS 4402.4.2.1, NZS4402.4.2.2 and NZS4402.4.2.3)	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 < 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 Test 2. 1 and NZS 4407 test 4)	1 per 4000 m3 (min 1 per lift)	≥ 90% maximum dry density < 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 75% 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 1000 m3 for full depth of lift (min 1 per lift)	≥ 4 blows per 100 mm	Locations as directed by the certifier. The DCP test is indicative only, and should not be used alone for compaction compliance.
	Impact test – 4.5 kg hammer (ASTM D 5874)	1 per 250 m3 on each compacted layer (min 1 for each lift of fill)	IV > 15	This test is indicative only and should not be used alone for compaction compliance

Table A1.7 - Bulk 4431 fill (R-GAP 150-A)

Material definition	**Fill use type**	Bulk 4431 fill		
	Source material type	R-GAP150-A (rock crushed to GAP 150 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 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 Test 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
	Solid density of soil particles (NZS 4402 Test 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 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 (NZS4402 Test 2.1 and NZS 4407 Test 4)	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, should not be used alone for compaction compliance
	Impact test – 4.5 kg hammer (ASTM D 5874)	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, should not be used alone for compaction compliance
	Plate load test (DIN 18134:2012-04)	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 A1.8 - Bulk 4431 fill (R-GAP 100-A)

Material definition	**Fill use type**	Bulk 4431 fill		
	Source material type	R-GAP100-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 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 Test 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
	Solid density of soil particles (NZS 4402 Test 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 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 (NZS4402 Test 2.1 and NZS 4407 Test 4)	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, should not be used alone for compaction compliance
	Impact test – 4.5 kg hammer (ASTM D 5874)	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, should not be used alone for compaction compliance
	Plate load test (DIN 18134:2012-04)	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 A1.9 - Bulk 4431 fill (R-GAP 65-A)

Material definition	**Fill use type**	Bulk 4431 fill		
	Source material type	R-GAP65-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 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 Test 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
	Solid density of soil particles (NZS 4402 Test 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 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 (NZS4402 Test 2.1 and NZS 4407 Test 4)	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, should not be used alone for compaction compliance
	Impact test – 4.5 kg hammer (ASTM D 5874)	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, should not be used alone for compaction compliance
	Plate load test (DIN 18134:2012-04)	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 A1.10 - Bulk 4431 fill (R-GAP 40-A)

Material definition	**Fill use type**	Bulk 4431 fill		
	Source material type	R-GAP40-A (rock crushed to GAP 40 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 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 Test 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
	Solid density of soil particles (NZS 4402 Test 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 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**
	Field water content and density (NZS4402 Test 2.1 and NZS 4407 Test 4)	1 per 1000 m^3 (min 2 per lift)	> 95% MDD < 15% air voids	
	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, should not be used alone for compaction compliance
	Impact test – 4.5 kg hammer (ASTM D 5874)	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, should not be used alone for compaction compliance
	Plate load test (DIN 18134:2012-04)	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 A1.11 - Bulk 4431 fill (M-GAP 65-A)

Material definition	**Fill use type**	Bulk 4431 fill		
	Source material type	M-GAP65-A (recycled concrete or brick crushed to GAP 65 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 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 Test 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
	Solid density of soil particles (NZS 4402 Test 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 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 m3	As per Ministry for the Environment, 2011, Methodology for Deriving Standards for Contaminants in Soil to Protect Human Health (Tables 54 and 55)	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 a 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 (NZS4402 Test 2.1 and NZS 4407 Test 4)	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, should not be used alone for compaction compliance
	Impact test – 4.5 kg hammer (ASTM D 5874)	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, should not be used alone for compaction compliance

	Plate load test (DIN 18134:2012-04)	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 A1.12 - Bulk 4431 fill (M-GAP 40-A)

Material definition	**Fill use type**	Bulk 4431 fill		
	Source material type	M-GAP40-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 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 Test 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
	Solid density of soil particles (NZS 4402 Test 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 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 m3	As per Ministry for the Environment, 2011, Methodology for Deriving Standards for Contaminants in Soil to Protect Human Health (Tables 54 and 55)	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 a 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**
	Field water content and density (NZS4402 Test 2.1 and NZS 4407 Test 4)	1 per 1000 m^3 (min 2 per lift)	> 95% MDD < 15% air voids	
	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, should not be used alone for compaction compliance
	Impact test – 4.5 kg hammer (ASTM D 5874)	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, should not be used alone for compaction compliance
	Plate load test (DIN 18134:2012-04)	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 A1.13 - Water detention clay (F-A)

Material definition	**Fill use type**	Water detention clay		
	Source material type	F-A (fine grained – acceptable)		
	Typical use description	Stormwater detention bunds, low-risk stopbanks and trench water-stops. Specific design required for dams and higher risk stopbanks.		
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 m3 and 1 for each change in material	Plasticity index 10-35% Liquid limit < 70%	Completed before works begin (and during the works if the material changes) to confirm the material's suitability
	Pinhole soil dispersion (ASTM D4647-13)	1 for each source and 1 per 4000 m3 and 1 for each change in material	Class ND1 or ND2	Completed before works begin (and during the works if the material changes) to confirm the material's suitability
Placement requirements	Loose layer thickness < 200 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 Test 4.1, 4.2, or 4.3)	2 per 1000 m3 (min 2 per lift)	≥ 90% maximum dry density < 5% air voids	
	Shear strength (NZGS Guideline for hand held shear vane test)	2 per 1000 m3 (min 2 per lift)	Lowest value > 100 kPa	

Table A2 – Particle size criteria for material types

Table A2 presents the acceptable ranges for percentage passing each of the sieve aperture sizes.

Material / Sieve aperture size (mm)		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
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 150	Min	100	79	64	58	41	28	-	21	15	9	6	4	3	1	-	
	Max	-	95	89	85	73	54	-	40	30	23	18	14	10	8	5	
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	
Clean coarse sand	Min	-	-	-	-	-	-	-	-	100	95	-	-	-	-	-	
	Max	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	
Fine pipe bedding (SAP7 or similar)	Min	-	-	-	-	-	-	-	100	-	-	-	-	-	-	-	10
	Max	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	
Coarse pipe bedding	Min	-	-	-	-	-	100	-	75	-	-	-	-	-	-	-	10
	Max	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	
Retaining wall drainage	Min	-	-	-	-	100	-	-	-	60	-	15	-	-	-	-	
	Max	-	-	-	-	-	-	-	-	100	-	45	25	-	5	-	
Water detention clay	Min	-	-	-	-	-	-	-	-	-	80	-	50	-	-	20	
	Max	-	-	-	-	-	100	-	-	-	-	-	90	-	-	65	
	Min																
	Max																