Forest Practice Guide
Non-Regulatory

Earthworks Construction 1.4 Fill Placement and Compaction

The construction of forest roads and *landings* in steep country often requires the construction of embankment *fills*. Poorly *compacted fills* present a slope instability risk and can be prone to slumping and *sediment* generation.

Compaction is an essential earthworks process to ensure that the strength and stability requirements of road or *landing* formations are achieved.

The aim of the *compaction* process is to increase the soils' shear strength, limit future settlement and reduce permeability.

Landing site constructed of a well graded granular *fill* material – note the range of particle sizes.

Please refer to the 'how to use' section of the introduction at http://docs.nzfoa.org.nz/forest-practice-guides/ for advice on how to use this guide.

Version 2.0, January 2020

Earthworks Construction
1.4 Fill Placement and Compaction

Scope

This guide covers the construction of embankments *fills* and outlines best practice techniques for placing and *compacting fill*. It should be read in conjunction with FPG EC #1 Planning and Design, FPG EC #2 Stripping and Clearing and FPG EC #3 Bulk Earthworks. Users of the guide are also referred to the following reference documents:

- National Environmental Standards for Plantation Forestry (regulations 22-35)
- New Zealand Forest Owners Association – New Zealand Forest Road Engineering Manual (2020)
- NZTA Standard Specification F/1 – Earthworks Construction www.nzta.govt.nz/assets/resources/earthworks-const/docs/earthworks-const.pdf
- Guideline for the Field Classification and Description of Soils and Rock for Engineering Purposes: NZ Geotechnical Society, December 2005 www.nzgs.org/library/field-description-of-soil-and-rock-field-sheet
- NZS 4402.4.1:1986 Methods of testing soils for civil engineering purposes – Part 4 Soil Compaction tests

Fill construction materials

Fill placement and *compaction* methods will depend on the available material and the structural requirements of the *fill*. Distinction needs to be made between cohesive and non-cohesive (granular) *fill* materials.

Cohesive soils – fine grained soils with a high **clay** content where the particles of the soil bond to one another.

A quick and simple way to test whether or not a soil is a clay is to moisten the soil sample and test its pliability with your hands. A clay content is indicated if the moist soil feels sticky and continues to stick to your hands or when rolled into a 'snake-like' form it stays connected without splitting.

Clay content test

Simple test for clay content – soil rolled into a snake by hand holds it form.

Granular soils – are relatively coarse-grained soils, such as **sand** (particle size of 0.06 mm to 2 mm) and **gravels** (particle size between 2 mm and 200 mm), where the particles lie side by side without bonding. Most pumice material will be classified as granular.

Earthworks Construction
1.4 Fill Placement and Compaction

Operational planning and management

The suitability of the in-situ soils should be assessed against the *fill* requirements prior to earthworks commencing. *Fills* should be classified as structural (load bearing) and non-structural (landscape *fill*). The planning process should optimise the use of materials (notably achieve cut to *fill* balance and reduce unnecessary cut to waste) and confirm what soil material is not suitable for bulk *fill*.

Often there will be more than one soil type on a construction site. Consideration will need to be given to how best to manage the range of soil types that may be present. *Fill* design should consider how soils will be mixed (and behave) depending on the site geology and geography and the contractor's construction methodology.

Batter* slope and *compaction are integral components of embankment *fill* stability. Steeper *batter* slopes require a higher shear strength to maintain stability. **It is important that *fills* are not over-steepened relative to the soil strength that can be achieved**. *Compaction* needs to be optimised to ensure that the soil strength and *batter* slope stability is achieved.

Fill *batters* should be overfilled to support earthmoving equipment and allow *compaction* plant to compact the full width of the design cross-section and then trimmed back to the design *batter* slope as the *fill* is built up. This will ensure the full width, including the outer edge of the *fill*, is effectively *compacted*.

Batter slope and *compaction* requirements should be provided to the contractor in the project prescription.

Batter slope

Well constructed *fill*. The *batter* slope has been controlled and effective *compaction* achieved. Benches have been constructed to avoid overloading the *fill*.

Earthworks Construction
1.4 Fill Placement and Compaction

Operational planning and management

continued

Fill placement

Fill material should be spread and *compacted* in layers of uniform quality and thickness across the full cross-section for the road/*landing*.

The thickness of each layer shall be limited to ensure that the required level of *compaction* is achieved for the full depth of each layer. The following maximum layer thicknesses are recommended:

Recommended maximum layer thickness

Nominal maximum particle size	Maximum layer thickness
Up to 100 mm	200 mm
100 mm to 200 mm	1.5 times the 85th percentile size
Over 200 mm	Determine on site

The movement of all construction vehicles and other traffic should, where practicable to do so, be evenly distributed over the full width of the *filling* area, so as not to damage or overstress the construction.

Compaction

Compaction of a large embankment *fill* in shallow layers using a pad foot roller.

Compaction processes

Compaction is the process of increasing the density of a soil by packing the particles closer together through the application of external forces. Specialist *compaction* equipment (such as steel drum rollers, pneumatic-tyre rollers, sheep foot or cleated rollers) is necessary. *Compaction* cannot be effectively achieved by tracked machinery as tracks distribute the load over a wider area effectively minimising *compaction*. *Compaction* processes vary for cohesive and granular material.

Cohesive soils

Compaction of cohesive soils is achieved by impact and weight to break down the 'cohesive' bonds to increase the soil density. Kneading *compactors* with high point loads, such as **sheep and pad foot rollers** are required for cohesive soils (see photo overleaf).

The strength of cohesive soils is influenced by moisture content. *Compaction* should be carried out at the optimum moisture content (OMC) to produce a required *compaction* outcome (maximum dry density – MDD). The general rule of thumb is, that if materials are *compacted* at OMC, then the MDD should be achievable.

A rough check for most materials is to squeeze a lump in the hand and, if it just holds together when pressure is taken off and the material does not stick to the fingers, the water content will be approximately at optimum.

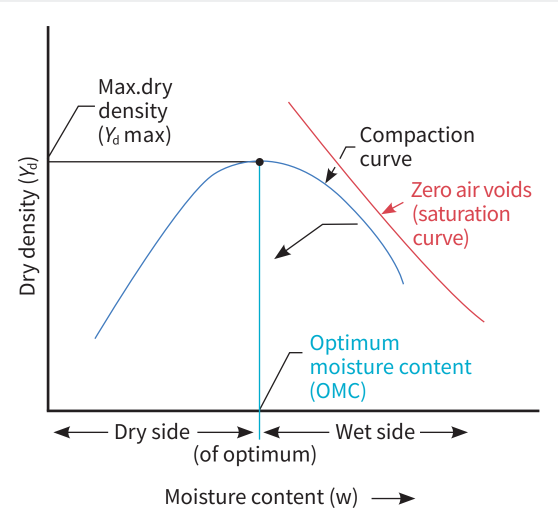
Earthworks Construction
1.4 Fill Placement and Compaction

Compaction processes continued

Notes:

1. If cohesive material is rolled when it is too wet or too dry for efficient *compaction*, the consequences can be high air void and lower short and long term strength. Further rolling is of limited value and may be detrimental to the *fill* stability.
2. Cohesive soils placed in *fills* when drier than optimum moisture content may appear to have good strength but may suffer a marked reduction in strength when wetted at a later date.

Compaction curve



A *compaction* curve showing the relationship between density and moisture and water content.

Site management should consider soil water content and apply any corrections necessary to facilitate soil placement and *compaction* to satisfy the strength and stability requirements of the *fill*. In some materials a significant gain in strength is obtained if the water content is adjusted to be nearer optimum. The feasibility and economics of changing in-situ water content should be considered during the operational planning phase.

Soil compaction machinery

Pad foot roller suitable for *compacting* cohesive soils.

Granular soils

Compaction of granular soils can be carried out with static *compactors* that simply apply weight and tend to *compact* from the bottom of the layer up; vibratory *compactors* that use a mechanical action to consolidate soil particles; impact *compactors* that use a high-amplitude whack to *compact* material.

Granular *fills* are usually suitable for *fill* construction as strength is usually adequate over a range of moisture conditions.

Earthworks Construction
1.4 Fill Placement and Compaction

Compaction testing and field monitoring

The following are recognised methods for testing the quality of *fill* materials and construction. The specific tests and testing frequency should be determined during the planning and design phase and reflect the scale and complexity of the earthworks, and the consequence of the *fill* failing.

Parameter	Test description	Test method
In-situ density	"Rapid"	NZS 4407:1991, Test 4.2.1 (Nuclear Densometer Direct Mode) NZS 4407:1991, Test 4.2.2 (Nuclear Densometer Backscatter Mode)
	"Fully Specified"	NZS 4402:1986, Test 5.1.1, 5.1.2, 5.1.3 (Sand replacement, balloon densometer or core cutter)
MDD & OMC determination	Standard *Compaction*	NZS 4402: 1986, Test 4.1.1
	Heavy *Compaction*	NZS 4402: 1986, Test 4.1.2
Strength	Scala Penetrometer	NZS 4402: 1986, Test 6.5.2
	Pilcon Shear Vane	NZ Geotechnical Society Inc "Guideline for hand held share vane"
	Clegg Impact Test	ASTM D5874-95
Permeability	Laboratory Triaxle Permeability	Based on Head, Vol. 3, 1988, Section 20.4.2
Solid density	Solid Density	NZS 4402: 1986, Test 2.7.1
Moisture content	Moisture Content	NZS 4402:1986, Test 2.1
Particle size distribution	PSD Wet Sieving	NZS 4402:1986, Test 2.1
	Hydrometer	NZS 4402:1986, Test 2.1

The following field testing equipment is considered suitable for *compaction* testing on most forest earthworks projects:

- Scala Pentrometer – strength testing in cohesionless soils. Results are converted into an 'inferred CBR'.
- Shear Vane – strength testing in cohesive soils. The results are expressed in kPa.
- Clegg Impact Test – testing surface hardness or stiffness. The result (impact value) can be used as an indication of *compaction* but is not a direct measurement. Impact values can be converted into an inferred CBR (Inferred CBR = 0.07 x (IV)2).
- Nuclear Densometer – testing of water content and percentage *compaction* (if MDD target is provided).

Earthworks Construction
1.4 Fill Placement and Compaction

Contact

Forest Owners Association
Level 9, 93 The Terrace
Wellington 6143

www.nzfoa.org.nz

Other Practice Guides in this series

Visit: **https://docs.nzfoa.org.nz/forest-practice-guides/** to view all guides

supported by forestgrowers commodity levy