Auckland Transport
An Auckland Council Organisation

15 Earthworks and Geotechnical Engineering

15.1 Site Investigations

15.1.1 Preliminary Site Evaluation

The preliminary site evaluation should be carried out to access the general suitability of a site for its proposed use and to gain an appreciation of the geotechnical design and testing requirements and the associated risks.

The investigation should be based on a visual inspection of the site, desktop study (geological maps and aerial photograph), local knowledge and review of existing information (e.g. old reports).

A Preliminary Geotechnical Appraisal Report should be carried out to summarise the findings and should include the following information:

- ownership of the land
- regional geology
- topography and predominant features
- drainage and groundwater regimes
- local subsoil conditions
- stability
- proposed geotechnical field investigation

15.1.2 Soil Contamination

An assessment of the site shall be undertaken in accordance with the requirements of the Ministry for the Environment's "National Environmental Standard (NES) for Assessing and Managing Contaminants in Soil to Protect Public Health".

15.1.3 Comprehensive Geotechnical Investigation

Following the preliminary site evaluation phase, the Comprehensive Geotechnical Investigation should be carried out to complete a detailed earthwork design. This involves performing the geotechnical testing and appraisal of the site.

a) Geotechnical Testing

The purpose of a site investigation is to identify and confirm the subsurface condition. When planning a site investigation it is important to determine the appropriate testing regime in order to gather satisfactory information for detail design. This can range from hand augers for a simple one storey building to numerous exploration bores (CPT and boreholes) for a detail bridge design. Sufficient borings, probing, or open cuts should be made to:

- Classify the soil strata by field and visual methods
- Evaluate the likely extent and variation in depths of the principal soil type
- Establish the natural groundwater level.

The soil information thus obtained should form the basis for:

- Further sampling and testing which may be required on representative soil types
- Relating subsequent soil test properties to relevant strata over the site.

The appropriate test data in different areas must be determined by a Geotechnical Engineer and/or Geologist. Testing must be carried out in accordance with NZS 4402:1986 "Method of testing soils for civil engineer purposes" and must be logged base on the NZGS field description of soil and rock guidelines (2005).

Where saturated uncohesive material is anticipated, a suitable site investigation into liquefaction potential must include the measurement of groundwater level, in-situ testing (CPT and/or SPT testing) and laboratory testing. Refer to the NZGS Geotechnical earthquake engineering practice module 1 – Guideline for the identification, assessment and mitigation of liquefaction hazards for more detail.

All test data must be presented in the Geotechnical Factual Report which should include a summary of the testing locations and results that has been carried out. Note this report can be integrated into the Geotechnical Interpretive Report depending on the size and impact of the proposed development. The Geotechnical Factual Report must include a location plan showing the as-built information of the exploration holes.

b) Geotechnical Appraisal

This assessment is to enable the preparation of a detailed earthworks design and recommend mitigation measures and development of a construction methodology. A Geotechnical Assessment Report must be completed and must cover the following:

- The factors describe in the preliminary site evaluation but in more detail
- Subsurface condition base on the outcome of the geotechnical testing
- Statement on the applicable design standards, codes and/or guidelines adopted
- Parameters adopted for design (e.g. soil parameters, groundwater level, loadings)
- Design analysis (e.g. foundation strength, settlement, stability, slips, wash outs, trench stability)
- Special design or construction requirements (e.g. required foundation strength)
- Site constraints (e.g. services and access)
- Effects (e.g. Impact on adjacent and nearby properties, contamination, effluent disposal)
- Other information (e.g. geotechnical risks, groundwater effects)
- Weather of climate effects that may impact or potentially increase the risk of movement or landslips.
- Recommendation for mitigation measures or design (where applicable)

In some cases supplementary reports may be required to support the Geotechnical Assessment Report. The content of the report must more or less follow the format as describe above.

15.1.4 Construction Observation and Reporting

The purpose of this phase is to verify the quality of construction and monitor the changes made during construction with respect to the design.

A Construction Observation Report must detail the progress of construction and must be prepared in a regular basis during the construction phase.

The report must cover the following:

- A description of construction activities and control testing carried out
- Identification and re-evaluation of situations arising during construction
- A description on the geotechnical risks remaining in the project.

15.1.5 Completion Report

The purpose of this phase is to verify that construction has been carried out in accordance with the design and to record the site modifications.

The report should cover the following:

- Description of construction activities and control testing carried out.
- Description of specific foundation and siting limitations or requirements. This may result in notices being registered on the titles of the affected sites, the earliest possible notification of these requirement should therefore be given.
- As-built and RAMM information (if applicable)
- Engineering certification of the works (e.g. a PS3 and PS4 form)

15.2 Natural Hazards

15.2.1 Slips and Stability

Preliminary terrain evaluation using site inspection, air photography interpretation and available geological and geotechnical records provides an initially low cost sound basis for the conceptual planning of a transport infrastructure project. This preliminary appraisal should identify:

- Areas where previous slope failures have been positively identified,
- Areas where it is suspected that slope failures may have occurred many years ago (i.e. historic features),
- Areas of surface soil creep,
- Springs, swamps, or other areas of either poor drainage or high groundwater conditions

Subsequent specific investigation should provide data on subsurface conditions and establish specific design criteria for such factors as maximum slopes, subsoil drainage, retention or establishment of vegetation.

The evaluation of slope stability by the measurement of soil strengths and groundwater conditions and the calculations of theoretical factor of safety, is a difficult task and requires the exercise of a large measure of skill and judgement. The problem is exacerbated by the need to consider:

- The range of parameters assumed to be applicable, given the present state of stability of a slope,
- Present and future groundwater levels
- The consequences of and limitations of future site developments

Where mitigation measures are necessary, the evaluation into slope stability and the minimum factor of safety must be consistent to that described in *ATCOP Section 15.2.1 Slips and stability*. Mitigation may include methods as described in *Section 15.3.3 Ground Improvements and Stabilisation*. In some cases, a mass earthwork (dig out) of the slip may be the most convenient option.

15.2.2 Slips, Slumps, Falls of Existing Slopes and Infrastructure

Most repairs and maintenance of existing slopes and infrastructures outside of the existing road reserve area will not be carried out by Auckland Transport or under its supervision. Any sudden persistent or unusual ground movements within the road reserve or on land where the movement could threaten the safety of the road reserve area should be notified to the Auckland Transport Call Centre. Visual signs may include cracked or hummocky surfaces, crescent shaped depressions, croaked fences, leaning trees or power poles.

The ground movement must be inspected by an Auckland Transport officer who must make recommendations on the next steps to be taken, firstly ensuring the safety of the public and then deciding whether further investigation or remedial works are required.

Depending upon the nature of the ground movement the Auckland Transport Maintenance Team Leader for the affected area must decide whether the remedial works are to be undertaken by the Auckland Transport or affected landowners.

15.2.3 Call Centre Response

Auckland Transport operates a call centre that is operational 24 hour per day, 7 day per week. Emergency calls will be routed to the Roading Corridor Maintenance (RCM) Contractor via this Call Centre.

15.2.4 Emergency Response Inspections

The RCM Contractor is required to attend all emergency work promptly and establish emergency patrols during emergency events or periods of expected damage to facilities, disruption of traffic flows and/or danger to the public. Where there is doubt over the status of the event the RCM Contractor will respond regardless with the first patrol as an inspection.

The first patrol will ascertain the priority of the emergency works and must carry out remedial works in response according to priority assigned to each work:

- **Dangerous** - first priority; divert resources to attend immediately.
- **Serious** - second priority; divert resources to attend next working day.
- **Ordinary** - third priority; include in next work schedule, according to response time specified.
- **Low** - fourth priority; include in work schedule when resources (labour and funds) permit.

15.2.5 Initial Emergency Response Criteria

The RCM Contractor must provide an adequate number of attendance vehicles, staff and plant to cater for emergencies within the response times specified. All emergency callout attendance vehicles must be equipped with a flashing orange lights mounted on its roof, complying with all legal requirements and COPTTM.

Minimum equipment on the attendance vehicle must include:

- temporary signs and barriers/cones for lane closures and temporary speed restrictions
- The Contractor must undertake the initial response work in accordance with the following designated staging:
- **Stage 1** - the site of the works is protected and signed to the appropriate standard which ensures the safety of the public and the work force.
- **Stage 2** – further property damage is prevented.
- **Stage 3** – Alternative routes are signed for the **full length** of the route in the case of a total road blockage/closure.
- **Stage 4** - trafficable access is restored as soon as is practicably possible.

15.2.6 Inundation

The occurrence and magnitude of inundation should be assessed and considered in all proposed transport infrastructure development proposed in areas susceptible to inundation.

15.2.7 Seismicity

It is essential that AT's Seismic Management Guidelines are read before reading the rest of this chapter.

a) Seismic Loadings

Unless otherwise specified, all transport infrastructures must be designed to withstand seismic loading requirements stated in *NZS 1170.5:2004 – Structural Design Actions Part 5: Earthquake Actions – New Zealand and the NZTA Bridge Manual*. The design life and the Annual Probability of Exceedence must be based on *NZS 1170.0:2002 – Structural Design Actions Part 0: General Principles and the NZTA Bridge Manual.*

b) Liquefaction

Liquefaction assessment must be considered in all transport infrastructure projects. A good guide for liquefaction assessment is the “NZGS Geotechnical earthquake engineering practice module 1 – Guideline for the identification, assessment and mitigation of liquefaction hazards”.

15.3 Earthworks Design

Earthworks design must be carried out in a manner as described in the requirements of the Geotechnical Appraisal Report. The Earthworks design must cover:

a) Existing and proposed contours

b) Rock profiles – where appropriate
c) Existing services
d) The extent of works
e) Stability of embankments and cuttings
f) Compaction criteria and quality control
g) Specific geotechnical requirements (e.g. Underfill drainage)
h) Stockpiling areas
i) Stabilising measures

Refer to the sections below for more detail on e) to f).

15.3.1 Stability of Embankments and Cuttings

The minimum requirements for the stability of embankments and cuttings are as follow:

- Slopes steeper than 1 vertical to 5 horizontal must be subject to specific design
- Slopes steeper than, or equal to, 1 vertical to 5 horizontal must have adequate consideration shown in the design process for appropriate vegetation cover, slope drainage and adequate erosion control measures. Any vegetation cover must be low maintenance varieties.
- Works within adjoining properties must require the approval of the affected landowners.
- Ponding or flow restrictions to natural stormwater runoff must not be permitted unless by specific agreement for temporary situations
- Cuts and fills of over 4.0m must be subject to specific design including the type of underfill drainage required to cope with the higher loads.
- Existing services affected by earthworks must be evaluated for adequacy and must be upgraded or relocated as necessary.
- Impacts of climate change and associated weather impacts.

Stability assessments must also take into account of the probability and consequences of failure. The minimum factor of safety under long term static condition and normal groundwater level (including appropriate live load surcharge) for any embankment or cut slope must be 1.5. This is considered to be an acceptable range in the industry.

A lower factor of safety criteria can be considered for short term cases (or extreme circumstances) but must not be less than 1.2. Seismic stability must be designed for a factor of safety between 1.0

and 1.2. Any adjustments in the factors of safety for seismic stability are to be discussed and agreed in advance with Auckland Transport. Seismic stability factors for arterial and collector routes must not be less than 1.2.

15.3.2 Settlement

Settlement of soils (consolidation) is a complicated natural phenomenon, which is influenced by a number of factors, including the nature and mineralogy of the soil, the soil particular arrangement, whether the soil is undisturbed or remoulded, its past stress history, the drainage conditions affecting the particular circumstances etc.

For transport infrastructure works, the predevelopment soil investigations should identify areas of risk, such as organic soils and the likely performance of foundation under earthfills.

Settlement will also occur within earthfills due to its self-weight. The earth fill should be designed and compacted in an optimal condition to ensure the fill does not deteriorate significantly over time.

Monitoring requirements must be considered to verify the assumptions made in the embankment design.

15.3.3 Ground Improvements and Stabilisation

Ground Improvement measures are designed to strengthen or provide support to weak soils to withstand the design loadings and/or to minimise the effects to a tolerable level. A good guidance manual to evaluate whether ground improvement is necessary is Auckland Transporting and Design Guidelines on Ground Improvement for Structures and Facilities (1999). All ground improvement design must be based on appropriate sound design method and must satisfy the Building Code where applicable.

Some ground improvement measures that may be applicable to Auckland development are as follows:

Table 50: Ground Improvement Measures

Purpose	Method
• Liquefaction and seismic displacement resistance	• Vibrocompaction • Stone columns • Dynamic compaction • Deep soil mixing • Jet grouting • Lateral resistance piles
• Reduce settlement and differential settlement or accelerate consolidation	• Deep soil mixing • Stone columns • Vibrocompaction • Dynamic compaction • Vertical drains with/without surcharge fills

Purpose	Method
• Stabilise structures that have undergone differential settlement	• Jet grouting • Underpinning • Mini-piles
• Increase stability of slopes and embankments	• Buttress fills and shear keys • Horizontal bored drains • Retaining structure (cantilever wall etc) • Deep soil mixing • Counterfort drains • Stone columns • Reinforcements (Geotextile, geogrids, steel mesh) • Soil nailing
• Improve seepage barriers	• Diaphragm or secant wall • Slurry trenches • Deep soil mixing
• Erosion control	• Erosion mats • Retaining structure (Gabion walls, mattresses etc) • Rip Raps

15.3.4 Earthworks Construction Requirements

This chapter is to be read in conjunction with *ATCOP Chapter 16 – Road Pavements and Surfacings* for specific requirements relating to road pavement subgrade preparation and quality control.

This chapter is also to be read in conjunction with *ATCOP Chapter 18 – Structures* to establish the relevant industry standard document for the design and construction for specific structures.

Earthworks fill must comply with the material requirements specified in the NZTA specification F/1 Earthworks Construction.

Particular attention is drawn to the requirements of maximum particle size permitted in bulk fill and subgrade fill (Section 10 of NZTA F/1 specification- Earthworks Construction) and the corresponding maximum layer thickness requirements in order to ensure the proper compaction of fill material.

a) Earthworks Plan

Earthworks must be carried out in accordance with the provisions of the existing Regional, District or City Plan , TP 90 (formerly ARC). In small size projects, NZS 4404:2010 Land Development and Subdivision Infrastructure can be adopted for earthworks requirements. A specific earthworks plan will be required for medium to large size projects and can be based on

NZTA F/1 Earthworks Construction standards depending on the Principal's Requirements of a specific project.

Earthworks must be constructed so as to minimise soil erosion, noise, vibration, sediment discharge and dust. Provision should be made to control erosion, dust nuisance and sediment discharge from any area of earthworks and resource consent must be gained for any projects incorporating earthworks as required by an existing Regional, District or City Plan.

b) Compaction Criteria and Control

The compaction standard should be described using the relative compaction, air voids, shear strength, relatively density and field relative compaction tests depending on the type of material. In some cases, a performance specification may be required to ensure sufficient compaction is achieved in the earth fill.

The standard of compaction and method of determination must be as set out in NZS 4431. Where NZS 4431 is not applicable, the methods and standard of compaction must be specified by an appropriately qualified geotechnical engineer and agreed with Auckland Transport.

c) Topsoil

The design of topsoil must address the following:

- Ensuring adequate preparation of subsoil to receive topsoil
- Specifying requirements of imported topsoil
- Specifying requirements of existing topsoil
- Ensuring testing of topsoil takes place to bring standard up to that specified.

Topsoil should have a loose depth between 100 and 300 mm.

The receiving subsoil surface should be ripped or scarified to 150 – 300 mm depth to key the topsoil in the ground and to ensure relieve drainage and assist root development of planting.

If topsoil should be tested, appropriate actions should be undertaken to ensure the soil meets the required standards. The basic soil test should comprise of an organic soil profile that includes a description / content of pH, phosphorous, potassium, calcium, magnesium, sodium, base saturation, volume weight, nitrogen (available and total), organic matter percentage.

Road berm areas should comprise a 100mm thick layer of compacted approved quality topsoil with a good loam structure. It must be free of weeds and stones. Any large clods, stones larger than 20mm, roots, stumps or other litter that remains after the topsoil has been spread must be raked up and disposed of off-site. The berm should then be sown with a grass seed mix of:

15% Chewings Fescue
7.5% Brown Top
7.5% Crested Dogs tail
70% Perennial Rye Grass

d) Contamination

Contamination assessment must be carried out on the development site and must comply with the requirements of the Ministry for the Environment's "National Environmental Standard (NES) for Assessing and Managing Contaminants in Soil to Protect Public Health" (January 2012).

Sites will be checked against the criteria for activity type and contamination thresholds established by the Ministry for the Environment in National Environmental Standard (NES) and their guideline documents and also in the Auckland Council "Auckland Regional Plan for Air Land and Water" (ALW).

In particular the contaminants that may be present in some of the existing pavement materials are;

- Polycyclic aromatic hydrocarbons (PAH)
- Total petroleum hydrocarbons (TPH)
- Benzene, toluene, ethylbenzene and xylene (BTEX)
- Heavy metals

If a site is identified as having potential contamination issues a sampling plan shall be developed and submitted to the Auckland Transport representative for approval.

All agreed sampling, contaminant testing and analysis are to be carried out by an approved IANZ (International Accredited New Zealand) certified laboratory.

All results shall be checked against the contaminant criteria in the NES to see if the specific contaminant levels have been exceeded. If the levels are exceeded, then the Contractor must establish if resource consent is required for the pavement renewal works.

In any required design process it must be clearly demonstrated that all options have been considered for mitigating the presence of contaminated materials within the requirements of the NES the Ministry guidelines and the ALW. The first preference is to maintain and use the materials on site with the excavation and removal of the contaminated materials to landfills as the least preferred option.

If material is to be removed from site, then the materials must be classified using the following system;

- Contaminated Fill – contains contaminants above the maximum admissible concentrations for fill at local landfill sites;
- Managed Fill - contains contaminants below the maximum admissible concentrations for fill at local landfill sites;
- Cleanfill – material defined as cleanfill under the ALW and the Ministry "Guide for the Management of Cleanfills".

Where resource consent is required for the pavement renewal works, the Contractor shall obtain the consent and provide all reports and testing data required, including a Remedial Action Plan (RAP).

15.3.5 Foundation Design

There are various types of foundations and in general are as follow:

- Shallow foundations – Rafts, Strip, Pad
- Deep foundations - Pile

Unless otherwise specified, all structures must be specifically designed to withstand seismic loading as detailed in Section 13.2.7 – Seismicity. All foundations must have a minimum design life of 100 years for bridge foundations and 50 years for other infrastructures. A building consent may be required for foundations.

Where foundations are to be designed and constructed for bridges the requirements of the latest edition of the New Zealand transport Agency's (NZTA's) "Bridge Design Manual" are to be complied with.

The design of all foundations shall be undertaken by a suitably qualified geotechnical engineer in accordance with accepted industry best practice, standards and guidelines and shall meet the requirements of the Building Act and associated Building Code.

15.3.6 Shallow Foundations

Shallow foundations are generally founded on competent ground condition. As a minimum, shallow foundation design must cover the following:

- Bearing capacity
- Settlement
- Overturning and sliding
- Any existing underground services and pipelines.

There are various standards and guidelines relating to foundation design, namely:

- New Zealand Building Code Handbook, Verification Method B1/VM4
- NZTA Bridge Manual

Foundation design must be based on appropriate sound design methods and must satisfy the Building Act and associated Building Code. Appropriate strength reduction factors must be adopted for bearing capacity, overturning and sliding analysis and must be based on the *NZ Building Code Handbook Verification Method B1/VM4 or NZTA Bridge Manual*. The overall ground stability must also be checked.

15.3.7 Piles

Pile foundations are often used as an alternative to other foundation systems. Piles may transfer the foundation load to the bearing stratum through the means of skin friction, end bearing or the combination of both.

There are in general two basic piling methods and they are as follow:

- Displacement or driven piles – Piles are driven into ground displacing the soil
- Non-displacement piles (bored piles) – Soil is prebored and replaced with the pile

There are various piling standards and guidelines such as the following:

- New Zealand Building Code Handbook, Verification Method B1/VM4
- NZTA Bridge Manual
- AS 2159 – 1995 Piling Design and Installation

Foundation design must be based on appropriate sound design methods and must satisfy the building code.

Appropriate strength reduction factors must be adopted for all pile capacity design and must be based on the *NZ Building Code Handbook Verification Method B1/VM4 or NZTA Bridge Manual*. The overall ground stability must also be checked.

Piles must be constructed in accordance with the Auckland Structural Group Piling Specification (2002)