ISSUE 675 BULLETIN

USING A SCALA PENETROMETER

August 2022

- NZS 3604:2011 *Timber-framed buildings* sets out the criteria for 'good ground' for buildings to be constructed using the standard.
- A Scala penetrometer can be used to help assess the site of a proposed building to determine whether it meets the requirements of good ground.
- This bulletin updates and replaces Bulletin 438 of the same name.

1 INTRODUCTION

1.0.1 NZS 3604:2011 *Timber-framed buildings* section 3 sets out the site requirements for constructing a low-rise, timber-framed building and in particular the criteria for soil conditions under or adjacent to a proposed building. A site must comply with the definition of 'good ground' for building foundations to be constructed using the standard. Where a site does not comply, the foundations must follow specific engineering design. In these cases, the MBIE/NZGC modules provide good-practice advice (see section 5).

1.0.2 One way to help determine good ground is through using a Scala penetrometer, as set out in NZS 3604:2011 section 3.3. This section references another standard covering the use of Scala penetrometers, NZS 4402.6.5.2:1988 *Methods of testing soils for civil engineering purposes – Soil strength tests – Determination of the penetration resistance of a soil – Test 6.5.2 Hand method using a dynamic cone penetrometer.*

1.0.3 A Scala penetrometer – sometimes called a dynamic cone penetrometer – is typically a stainless steel rod of 16 mm diameter, graduated in 50 mm intervals to an accuracy of 1 mm. It is made up of several pieces with threaded joints. This rod is driven into the ground with a 9 kg sliding weight that is allowed to drop 510 mm onto an anvil (Figure 1). This is done at a number of points around a building site. The number of blows required to achieve a particular depth of penetration into the ground helps establish the soil's bearing capacity.

1.0.4 Although the principles behind it are relatively straightforward, using and interpreting the results of a Scala penetrometer test requires expertise (and ideally advanced technical education), local knowledge and good judgement. The tests should always be used in conjunction with other investigations and should never be taken by themselves as sufficient evidence of good ground. Test results are sensitive to factors that may not be apparent at the time of testing or capable of being accounted for by review of data from the test results alone.

1.0.5 Other practical testing carried out on site at the same time will help provide additional useful information. For example, use of a soil auger (a metal pipe with a blade at the bottom that is rotated into the earth) will help provide visual confirmation of the soils that are being tested. This is a requirement in NZS 3604:2011 section 3.3.6. More details are given in section 4 below.

1.0.6 Where there is any doubt or uncertainty about the presence of good ground or for larger projects or sites with complex geology, consult a geotechnical engineer or engineering geologist familiar with the geology of the area. They will be able to provide more context and employ more-sophisticated site investigations and testing.

1.0.7 Testing with a Scala penetrometer provides information about a very small area. Soils often vary between test locations, even over short distances.

1.0.8 If unexpected conditions are found when excavating for the foundations, seek expert advice from a geotechnical engineer or engineering consultant.

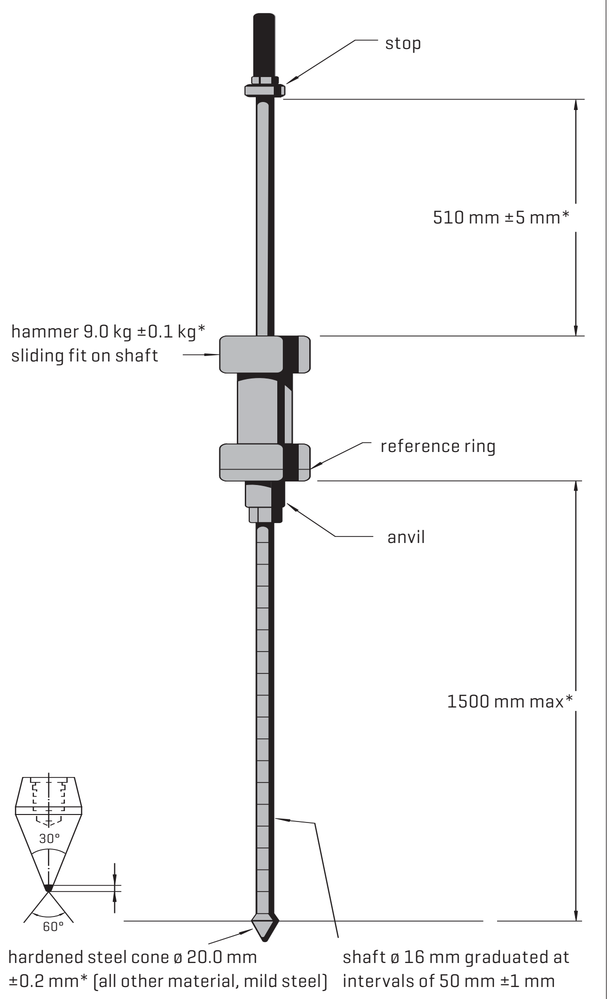

Figure 1. A Scala penetrometer (not to scale) with dimensions and weights as described in NZS 4402.6.5.2:1988.

1.0.9 Refer to NZS 3604:2011 for more details about Scala penetrometer testing and to New Zealand Building Code clause B1 *Structure* for more details about good ground.

2 ASSESSMENT OF GOOD GROUND

2.0.1 The assessment of good ground is effectively the assessment of the bearing pressure of soil – its ability to carry the load of a building without excessive settlement (more than 25 mm over a distance of 6 m). Bearing pressure depends on soil type. It must be assessed from the depth of the base of the foundations to at least the depth of three times the footing width.

2.0.2 There is a definition of 'good ground' in NZS 3604:2011:

"Any soil or rock capable of permanently withstanding an ultimate bearing capacity of 300 kPa (that is, an allowable bearing pressure of 100 kPa using a factor of safety of 3.0), but excludes:

a) Potentially compressible ground such as topsoil, soft soils such as clay which can be moulded easily in the fingers, and uncompacted loose gravel which contains obvious voids;

b) Expansive soils being those that have a liquid limit of more than 50% when tested in accordance with

NZS 4402 Test 2.2, and a linear shrinkage of more than 15% when tested from the liquid limit in accordance with NZS 4402 Test 2.6; and

c) Any ground which could foreseeably experience movement of 25 mm or greater for any reason including one or a combination of land instability, ground creep, subsidence, seasonal swelling and shrinking, frost heave, changing groundwater level, erosion, dissolution of soil in water, and effects of tree roots."

2.0.3 Clause B1 *Structure* also has a definition of good ground. This has been amended and is slightly different from the definition in NZS 3604:2011, in particular, excluding all ground at risk from liquefaction and lateral spreading from the definition of good ground.

2.0.4 Clause B1 *Structure* has Acceptable Solutions that can be used to demonstrate Code compliance. B1/AS1 references NZS 3604:2011 but with amendments to reflect the fact that ground subject to liquefaction or lateral spread is not good ground. In everyday practice, the tighter definition of good ground in B1/AS1 is therefore the one that applies.

2.0.5 NZS 3604:2011 section 3.1.3 states that soil can be assumed to be good ground when four criteria are met:

- There is no evidence of buried services in project information memoranda (PIM reports) or site observation, and none are uncovered when excavation for footings begins.
- PIM reports, site investigation and reasonable enquiries show no indication of landslips or surface creep in the immediate location.
- Reasonable enquiry turns up no evidence of earth fill, and no fill materials are found when excavation begins. Fill can be accepted where a certificate of suitability of earth fill for residential construction has been issued under NZS 4431:1989 *Code of practice for earth fill for residential development* and any limitations on the certificate complied with. (Note that NZS 3604:2011 currently cites the 1989 version of NZS 4431. If NZS 4431:2022 *Engineered fill construction for lightweight structures* is used to demonstrate compliance, it will be as part of an Alternative Solution.)
- Excavation for footings does not uncover buried organic topsoil, soft peat, soft or very soft or expansive clay. (A word of explanation beyond the standard here. It's not just about looking at the footings excavations – they may only be 300 mm or 400 mm deep. It is about knowing what's in the ground at least three times the depth of those footings. So for a 600 mm deep pile hole, you need to know what's down at 1.8 m depth. Hence the use of the Scala penetrometer.)

2.0.6 In addition to these four requirements, NZS 3604:2011 requires any of three further criteria:

- A satisfactory site investigation using the section 3.3 test method – a Scala penetrometer and a borehole for each test.
- Other inspections or enquiries on this or neighbouring sites and of council records, local history or published geological data that shows no evidence of erosion, surface creep, slips, falling debris, uncertified fill, fill over an original water course or subsidence.
- A geotechnical completion report in accordance with NZS 4404:2010 *Land development and subdivision infrastructure* that indicates good ground.

2.0.7 Useful sources of information for investigating the ground conditions on potential building sites include:

- local authority (city, district or regional council) – PIM reports, GIS maps (including liquefaction maps)
- New Zealand Geotechnical Database – previous test results
- GNS Science – geology maps
- New Zealand Geotechnical Society – its field description of soil and rock guideline is a useful tool to help identify ground conditions.

2.0.8 Important new sources of information have been developed since NZS 3604:2011 was published. The most notable may be maps of areas subject to natural hazards such as erosion, instability and liquefaction prepared by most local authorities. Where available, these should be consulted at an early stage when a building site is being assessed. They can save time – when a BCA has determined that a site is at risk of liquefaction, for example, you know automatically that specific engineering design will be required for the design of a building's foundations on that site.

2.0.9 Geotechnical field investigations typically involve a combination of actions that may include:

- visual appraisal
- hand-augered boreholes
- exploratory machine-excavated test pits
- hand-held shear vane testing
- CPT soundings
- machine boreholes
- collection of soil samples for laboratory testing.

2.0.10 For typical light timber-frame residential (1 or 2-storey) structures, bearing capacity failure of soils due to foundation loading is not normally critical and rarely dictates foundation design. Typically, other geotechnical mechanisms will be more critical for foundation design. These include, for example, consolidation of soils, soil swell/shrink or slope instability.

3 WHEN TO USE A SCALA PENETROMETER

3.0.1 Scala penetrometers are used to determine the penetration resistance of in situ near-surface soils (up to 5.0 m below ground level).

3.0.2 These devices are typically used in cohesionless fine-grained materials such as sands and fine gravels. In natural clays and silts, they can also provide a conservative estimate of safe bearing pressure provided the material has not been exposed to excessive drying.

3.0.3 Although Scala penetrometers can be used in cohesive materials such as clays and silts, they may not be as reliable at greater depths due to 'skin friction' on the rod. This can result in overestimation of the penetration resistance and consequently overestimation of the geotechnical ultimate bearing capacity of the soil. Shear vane tests are more suitable for cohesive soils such as silts and clays as they measure the undrained shear strength of a cohesive soil.

3.0.4 Scala penetrometers are not able to penetrate rock or dense gravels. (Where a Scala penetrometer is not able to penetrate, such as through compacted engineered hardfill underneath a building platform, an engineer may be able to use another type of test to measure the degree of compaction of backfill and give an indication of the available surface bearing pressure.) Where site-won fill material (or other fill material approved by the engineer) is used, Scala penetrometer testing may still be appropriate.

4 USING A SCALA PENETROMETER

4.0.1 Anyone using a Scala penetrometer should follow the requirements in NZS 3604:2011 section 3 and NZS 4402.6.5.2:1988.

4.0.2 Always carry out desktop investigations before visiting the site. This can help determine whether Scala penetrometer testing will be appropriate and help identify what to look for on site. It is especially important to check with councils and utility service providers for the presence of underground cables or pipes for electricity, water, piped gas or communications. There is a risk of electrocution striking a power cable while carrying out a Scala penetrometer test. On site, try to match the plans with site features such as a toby box or junction box or service lines or drains visible on existing buildings. The site owner or site manager could provide additional information. If required, service location specialists can be engaged to mark up the position of services. If a buried service line is suspected in the work area, move the test position or excavate with hand tools to find the location of the service.

4.0.3 Before undertaking any testing on site, make sure everyone present is familiar with the equipment, the testing process and the safety precautions required. Identify hazards with the equipment and how to avoid injury such as keeping hands away from the falling weight. Scala penetrometers are available with handles on the weight to reduce the likelihood of trapping fingers.

4.0.4 Remove any surface rock or gravel that may be too hard to penetrate or that may damage the equipment. Holding the penetrometer in a vertical position, tap the hammer on the anvil until the top of the cone is flush with the soil surface. Take a reading to the nearest 1 mm and note this as the starting point before hammer blows begin.

4.0.5 Raise the hammer to the top and let it drop the full 510 mm onto the anvil. After each blow, take the depth reading to the nearest millimetre. The preference is to record the number of blows taken to drive the penetrometer 50 mm or 100 mm rather than recording the distance travelled for each set of five or 10 blows. The results then provide more-accurate data and show up changes at various depths more accurately.

4.0.6 Where a Scala penetrometer is driven to depths of more than a metre below existing ground, it is important that the first metre of soil is augered out and removed before starting the next metre of testing. If this isn't done, the friction on the rods causes the results to show a gradual increase in strength over depth that is not necessarily related to the actual condition of the soils. This needs to be done for each metre of test depth so that no more than a metre of the rods is enclosed in soil at any time.

4.0.7 For each test, continue the blows until:
- the tip of the penetrometer is driven to a certain depth below the underside of the proposed foundation – not less than 2 m for strip or pile footings or 600 mm below the actual depth of the pile for short driven-timber piles
- eight consecutive blows penetrate less than 20 mm (see 4.0.11).

4.0.8 NZS 3604:2011 section 3.3.7.1(b) explains when soils are assumed to have the required ultimate bearing capacity of not less than 300 kPa. This is when the number of blows per 100 mm depth below the proposed foundation is greater than:
- five down to a depth equal to twice the width of the widest footing below the underside of the proposed footing
- three at greater depths.

4.0.9 A conversion may need to be done based on the measurements made. Providing the blows are uniform, the number of blows per 100 mm can be estimated by averaging the number of blows for depths down to 300 mm.

4.0.10 The results at all test sites must show that soil conditions are closely similar.

4.0.11 If there have been eight blows without getting 20 mm penetration, do not continue with that test as the equipment may break or get stuck. If you think there is likely to be an obstruction, move the location of the test area slightly (at least 100 mm and up to approximately 0.5 m) and start again. If there is evidence of a very hard top layer with softer material underneath, more investigation will be required.

4.0.12 NZS 3604:2011 points out in a comment that large numbers of blows in some tests followed by small number in others may indicate stony ground. "In this case the average reading over 100 mm may give the wrong information."

4.0.13 Use a Scala penetrometer lifter to extract the device from the ground. Back hammering is not recommended because it carries a risk of damage and can also result in injury to the user.

4.0.14 Enough different spots need to be tested to give sufficient information about the whole area the proposed building will cover. There must be at least four test sites for a building up to 200 m² and at least one additional test site for every additional 100 m² building plan area. Choose locations near the corners of the proposed building.

4.0.15 Keep a record of the testing including the date. NZS 3604:2011 requires the location and level of each Scala penetrometer test and borehole to be marked on the site plan. Take photographs of the testing that identify the different sites.

4.0.16 NZS 3604:2011 section 3.3.6 requires a borehole of not less than 50 mm in diameter for each test. This can be made with a manual auger. A record needs to be noted for every 300 mm of every bore. The borehole log should also record the number of blows per 100 mm for each test and the water table, if seen.

4.0.17 Scala testing alone cannot identify organic materials nor differentiate between natural ground and filled ground, so it is important to visually confirm the material encountered. The record kept of soils found in the bore test should note the presence of stones, gravel or other hard material and topsoil, peat, fill or other foreign material. Taking photographs is useful. Natural chunks of cohesive soil could be described as stiff, firm, soft or very soft. Non-cohesive soils such as sands could be described as very dense, dense, medium dense, loose and very loose. Refer to the NZGS *Field description of soil and rock – field sheet* (see section 5).

4.0.18 Note any information about where water is found in the testing, the presence or depth of the water table and any other information – where you encounter water is important.

4.0.19 MBIE has noted that Scala penetrometers cannot be used in designing shallow foundations to resist earthquake loading. *Earthquake geotechnical engineering practice Module 4 states*: "The Scala penetrometer may, however, be useful as an ancillary tool for checking consistency of shallow surface layers and detecting local shallow 'soft spots' between other more widely spaced CPT and SPT soundings, etc. The Scala is also useful for other purposes such as quality control of engineered fills."

5 MORE INFORMATION

MBIE

Practice Advisory 17: Well-planned ground investigations can save costs – www.building.govt.nz/building-code-compliance/b-stability/b1-structure/practice-advisory-17/

Earthquake geotechnical engineering practice

- Module 2: Geotechnical investigations for earthquake engineering – www.building.govt.nz/assets/Uploads/building-code-compliance/b-stability/b1-structure/geotechnical-guidelines/geotech-module-2.pdf
- Module 3: Identification, assessment and mitigation of liquefaction hazards – www.building.govt.nz/building-code-compliance/b-stability/b1-structure/module-3-identify-liquefaction-hazards
- Module 4: Earthquake resistant foundation design – www.building.govt.nz/building-code-compliance/b-stability/b1-structure/module-4-earthquake-foundation-design/

Planning and engineering guidance for potentially liquefaction-prone land – www.building.govt.nz/assets/Uploads/building-code-compliance/b-stability/b1-structure/planning-engineering-liquefaction.pdf

OTHER

GNS Science – www.gns.cri.nz

New Zealand Geotechnical Database – www.nzgd.org.nz

New Zealand Geotechnical Society – www.nzgs.org/library/field-description-of-soil-and-rock

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ISSN: 2537-7310 (Online)