Geotechnical Engineers ACT

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15 December 2022
Our ref: JM/13820

Peter Davies
Via email: pdavies@dutt.com.au

Attention: Peter Davies

PROPOSED GARAGE – MERRITS LODGE – 13 MOUNTAIN DRIVE, THREDBO, NSW
GEOTECHNICAL SITE CLASSIFICATION REPORT

1 Introduction

At the request of Chris Jarrett, ACT Geotechnical Engineers Pty. Ltd. carried out a site classification to AS2870 - 2011 *Residential Slabs & Footings*, of the residential block located at13 Mountain Drive, in Thredbo, NSW. It is understood that the project involves the construction of a 6.2m x 4.1m garage adjacent to the existing lodge.

It is understood the site is within "Zone G" of the Kosciusko National Parks Alpine Resorts, so under the NSW Department of Planning Geotechnical Policy, a geotechnical investigation and slope instability risk assessment is required. However, as per Section 10.4 of The Policy, where only minor construction works are proposed, that present minimal or no geotechnical impact on the site or related land, then a "Form 4 - Minimal Impact Certification" can be provided instead. However, the submission of a Form 4 still requires a qualified geotechnical engineer to conduct a site inspection and complete a site classification report in accordance with AS2870.

The site is legally described as Lot 601 of DP 118588. The ~500m^2 block is currently occupied by the existing Merrits Lodge in the centre of the lot, and the proposed garage additions will be to the NW of the existing lodge. The generally slopes gently south, but there is a shallow gully/dry creek that drains east across the front of the lodge and through the area of the proposed garage. The groundsurface is covered in scattered granite cobbles and boulders. These appear to be detached boulders, but some could have been placed for landscaping purposes.

To establish the subsurface conditions, a 50mm diameter pushtube was used to drill one (1) borehole on the block designated BH1, on 14 December 2022. Figure 1 is an aerial photograph that shows the location of the investigation borehole, while Figures 2 and 3 are photos of the site taken at the time of investigation.

The subsurface profile was logged in general accordance with AS1726 – 2017 "*Geotechnical Site Investigations*" by an experienced geotechnical engineer, and the borehole log is attached to this report.

2 Investigation Results

2.1 Geology

The Thredbo area is documented on the NSW Department of Mineral Resources Monaro 1: 500,000 Geological Map (Ref. 1), as underlain by the Kosciuszko Granite Formation of Devonian age. This was formed as a large batholith that cooled deep in the Earth's crust. Processes active in the earth caused this to be forced to the surface, with the overlying rock being subsequently eroded away. During this process, major faults and fractures developed in the granitic rock which became areas of weakness that were more easily eroded than the stronger unaltered rock. The faulted zones have in many cases become drainage pathways, of which the Thredbo River course is one. The elevated topography in the area, combined with high water flows during the snow melt has caused the Thredbo River to cut its way down into the valley, with consequent steep slopes on either side in the vicinity of Thredbo Village.

The bedrock is mainly a granodiorite, but is locally referred to simply as "granite" or "decomposed granite" if more weathered. As is typical for this formation, there are numerous less-weathered corestones or "floaters" and surface boulders which are surrounded by decomposed granite. These boulders have often become more concentrated in watercourses where soil and finer gravel has been washed away. The massive bedrock often has joints which can contain water, resulting in localised deep weathering, and springs on the slopes.

The upper subsurface profile typically comprises loose black topsoil, ~0.1m to 0.5m thick, often containing granitic cobbles and boulders, then loose to medium dense colluvial soil, and then medium dense to dense residual soils typically to between 1m to 2m depth. Extremely weak, extremely weathered (EW) massive granite underlies the soil, and may contain corestones of less-weathered rock to large boulder size. Wet zones can be present in the colluvium in particular, and there are often aquifers or seepage zones associated with rock jointing or sheet flows over less-weathered bedrock, especially after rain.

2.2 Subsurface Conditions

Investigation borehole BH1 found a subsurface profile comprising:

Geological Profile	Depth Interval	Description
TOPSOIL	0.0m to 0.3m	Silty SAND; fine to coarse sand, low plasticity, black, some fine granite gravel, some grass roots, moist, loose.
COLLUVIAL SOIL	0.3m to >1.5m	Gravelly Clayey SAND; brown, fine to coarse sand, low plasticity clay, fine to coarse sub-angular gravel, moist, medium dense. The boreholes was terminated at 1.5m depth at refusal on cobbles or boulders within the colluvial soil.

Groundwater was not encountered and the soils were mostly moist. However, temporary, perched seepages could be present following rainfall within the more pervious colluvial soils.

The colluvial soils at the site within the depth of suction change are reactive in terms of potential shrink-swell movements that may occur due to soil moisture changes. The characteristic ground surface movement "ys", as defined by AS2870 for the range of normal soil moisture conditions is estimated to be between 20mm to 30mm for the encountered subsurface profile described in Section 2. The site is therefore Class "M" (moderately reactive).

Normal moisture conditions are those caused by seasonal and regular climatic effects.

Should earthworks (cut or fill) be undertaken on the site, or other activities which may cause abnormal moisture conditions to impact the soils within or near the building envelope beyond those addressed herein, the site classification shall be reassessed.

4 Building Footings & Slabs

AS2870 provides "deemed-to-comply" footing/slab designs, which for a Class "M" site includes stiffened rafts, stiffened footing slabs, waffle rafts, and strip and/or pad footings with above ground floors. Footings and slabs should be designed in accordance with the principles of AS2870.

Footings including thickened sections of slabs must be founded below any topsoil, loose material and uncontrolled fill, into the colluvial soils. Footings should be inspected by a geotechnical engineer to confirm the ground conditions. Table 1 below gives recommended allowable end bearing pressures for design purposes.

Table 1: Recommended Foundation Design Parameters

Foundation Material Type	Depth Below existing surface level	Allowable End-Bearing Pressure		
		Strips/Beams	Pads	Bored Piers[1]
Colluvial Soils (Stiff or better)	Below 0.4m	100 kPa	125 kPa	200kPa
Extremely Weathered material	Depth Unknown >1.5m	NA	NA	600kPa

[1] Assumes a minimum embedment depth of 4 pile diameters

Consideration should be given to the design of footings where interaction with slopes, retaining walls, service trenches and existing foundations will occur, and specific geotechnical advice sought.

Ground slabs can be constructed on the natural soils or newly placed controlled fill, following the removal of any topsoil and uncontrolled fill material. Following excavation to required level, slab areas on soil should be proof-rolled by a pad foot roller to check for any weak, wet or deforming soils that may require replacement. Suitable replacement fill should be compacted in not thicker than 150mm layers to not less than 95%ModMDD.

If required for design of ground slabs, a modulus of subgrade reaction of 30kPa/mm can be assumed for a natural soil or controlled fill foundation.

4.1 Excavation Conditions & Use of Excavated Material

The depth of proposed excavations is not known, however, it is expected that any future development will require excavations of up to 0.5m (for forming level cut-to-fill platforms or for trenching for installing underground services). Such excavations would be through topsoil and colluvial soils, which are readily diggable by backhoe and medium sized excavator; however, floaters or boulders of granite bedrock could be encountered below ~1m.

The low and medium plasticity colluvial soils can be used in controlled fill construction of building platforms, although rock particles should be broken down to <75mm size. Topsoil and the existing uncontrolled fill material should not be used in controlled fill construction, but could be used in non-structural applications such as landscaping.

If imported fill is required, a suitable select fill material would include a low or medium plasticity soil such as clayey sand or gravelly clayey sand, containing between 25% and 50% fines less than 0.075mm size (silt and clay), and no particles greater than 75mm size.

4.2 Stable Excavation Batters

Temporary site excavations to 1.5m depth can be formed near vertical, although loose fill should be cut back at 1(H):1(V). If required and space allows, deeper temporary cuts can be formed at 1(H):1(V) or benched at 1.5m intervals in soils. A geotechnical engineer should inspect all cut batters during construction to confirm stability. Exposed temporary batters should be protected from the weather by black plastic pinned to the face with link-wire mesh, or similar.

Permanent cut & fill batter slopes should be formed at no steeper than 2(H):1(V) in soil. Permanent cuts in HW and less weathered bedrock could be formed at 1(H):1(V). All soil cut and fill surfaces should be protected against erosion by topsoiling and grassing, or other suitable means. Steeper permanent cuts should be supported by structural retaining walls.

4.3 Low Retaining Walls

Retaining walls constructed in open excavation, with the gap between the excavation face and the wall backfilled later, can be designed for an earth pressure distribution given by:

$$\sigma h = (K\gamma' h) + Kq$$

where,

σh is the horizontal earth pressure acting on the back of the wall, in kPa

K is the dimensionless coefficient of earth pressure; this can be assumed to be 0.4 when the top of the wall is unrestrained horizontally, and 0.6 when the top of the wall is restrained (i.e. by building slabs etc.)

γ' is the effective unit weight of the backfill, and can be assumed to be 20kN/m3 for a lightly compacted soil backfill

h is the height of the backfill, in metres

q is any uniform distributed vertical surcharge acting on the top of the backfill, in kPa

Apart from structural restraints such as floor slabs, resistance to overturning and sliding of retaining walls is provided by frictional and adhesive resistance on the base, and by passive resistance at the toe of the wall. For a natural soil or controlled fill foundation, an ultimate base friction factor (tanδ) of 0.4, base adhesion (c) of 5kPa, and allowable passive earth pressure coefficient Kp=2.5 can be used for calculation of sliding resistance.

Free-draining granular backfill or synthetic fabric drains should be installed behind all walls. These should connect to weep holes and/or a collector drain, and ultimately to the stormwater system. Granular backfill should be wrapped in a suitable filter fabric to minimise infiltration of silt/clay fines.

4.4 Controlled Fill Construction

For construction of any new fill foundation platforms and driveway subgrades, it is recommended that:

- Areas be fully stripped of all topsoil and uncontrolled fill material. A stripping depth of ~0.3m may be required. Stripped foundations should be proof-rolled by a vibratory pad-foot roller of not less than 9 tonne static mass to check for any weak or wet areas that would require replacement. No fill should be placed until a geotechnical engineer has confirmed the suitability of the foundation.

- Controlled fill comprising suitable site excavated or imported materials of not greater than 75mm maximum particle size, be compacted in not greater than 150mm layers to not less than 95%ModMDD at about OMC.

- Fill placement and control testing be overviewed and certified by a geotechnical engineer at Level 1 involvement of AS3798 – 1996 "Guidelines on Earthworks for Commercial & Residential Developments".

4.5 Design CBR Values

On-grade driveway subgrades should be stripped of all fill, and soil subgrades then proof-rolled by a pad-foot roller to check for any wet or otherwise weak spots which may require additional removal. Suitable replacement fill can be compacted in not thicker than 150mm layers, to not less than 95%ModMDD.

On-grade carpark pavements are expected to comprise colluvial soil or newly placed controlled fill of similar material. An indicative design CBR value of 5% can be used for colluvial soils and controlled fill subgrades. A geotechnical engineer should inspect prepared subgrades to confirm design values, and preferably view a proof-roll to identify any soft spots or other weaknesses.

4.6 Earthquake Site Factor

Table 2.3 of AS1170.4 "Minimum Design Loads on Structures - Part 4: Earthquake Loads" (Reference 4) lists the earthquake acceleration coefficients for major centers to be considered in structural design. The Thredbo area has an acceleration coefficient of 0.08.

Section 4.2 of AS1170.4 "Minimum Design Loads on Structures – Part 4: Earthquake Loads" lists the site sub-soil classes to be considered in structural design. The site is classified as a "Class Ce – Shallow Soil Site".

4.7 Drainage and Foundation Maintenance

The effective drainage of the site is a prerequisite for satisfactory performance of building footings. Site drainage should be installed to prevent ponding of surface water adjacent to structures. Surface water run-off should be directed away from foundations and collected by a suitably designed stormwater system to maintain normal soil moisture conditions.

Trees, gardens, landscaping and ponds can also induce abnormal soil moisture conditions. Caution should be exercised when planting, or constructing these items near the perimeter of the structure.

Your attention is drawn to the CSIRO publication *Foundation Maintenance and Footing Performance: A Homeowners Guide* (BTF 18) for further information.

4.8 Form 4 – Minimal Impact Certification

It is understood the site is within "Zone G" of the Kosciusko National Parks Alpine Resorts, so under the NSW Department of Planning Geotechnical Policy, a geotechnical investigation and slope instability risk assessment is required. However, as per Section 10.4 of The Policy, where only minor construction works are proposed, that present minimal or no geotechnical impact on the site or related land, then a "Form 4 - Minimal Impact Certification" can be provided instead.

A site inspection was carried out by Jeremy Murray, an experienced, Chartered, senior geotechnical engineer, and a site classification to AS2870 was conducted. Based on this, and a review of the architectural drawings, the following conclusions have been drawn:

- the current load-bearing capacity of the existing building will not be exceeded or adversely impacted by the proposed development, and
- the proposed works are of such minor nature that the requirement for geotechnical advice in the form of a geotechnical report, prepared in accordance with the "Policy", is considered unnecessary for the adequate and safe design of the structural elements to be incorporated into the new works, and
- in accordance with AS2870 "Residential slabs & footings", the site is classified as a Class "M" (moderately reactive) site.

5 Closure

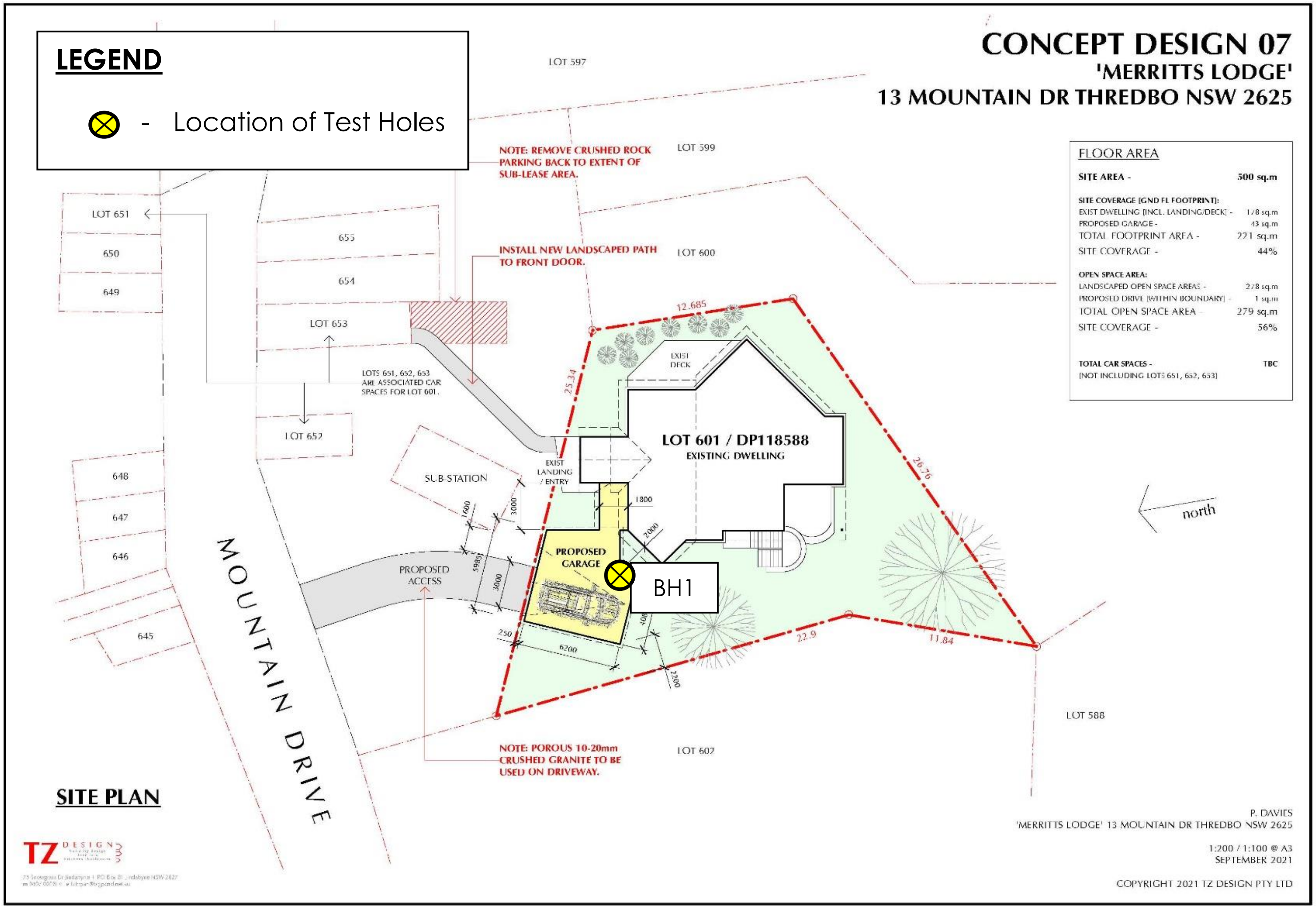
Should you require any further information regarding this report, please do not hesitate to contact our office.

Yours faithfully,
ACT Geotechnical Engineers Pty Ltd

Jeremy Murray
Senior Geotechnical Engineer | Director
FIEAust CPEng Eng Exec NER RPEQ APEC Engineer IntPE(Aust)
Registered Professional Engineer of Queensland (RPEQ) #19719
NSW Professional Engineer Registration #PRE0001487

Attachments:

- Site Plan
- Borehole Logs
- Form 4
- Limitation of Geotechnical Reports
- BTF18 – *Foundation Maintenance and Footing Performance: A Homeowners Guide*



PATER DAVIES

PROPOSED GARAGE – MERRITS LODGE – 13 MOUNTAIN DRIVE, THREDBO, NSW

SITE PLAN & LOCATION OF BOREHOLE

ACT Geotechnical Engineers Pty Ltd	**C13820**	**FIGURE 1**

Photo 1 – 14/12/2022 – View of the proposed garage site looking from Mountain Drive.

Photo 2 – 14/12/2022 – View of the proposed garage site looking from Lot 602 at the west.

PETER DAVIES
PROPOSED GARAGE – MERRITS LODGE – 13 MOUNTAIN DR, THREDBO
SITE PHOTOS

ACT Geotechnical Engineers Pty Ltd	**C13820**	**FIGURE 2**

Photo 3 – 14/12/2022 – View of the dry creek looking towards Lot 602 to the west.

Photo 4 – 14/12/2022 – View of the dry creek looking towards Merrits Lodge.

PETER DAVIES
PROPOSED GARAGE – MERRITS LODGE – 13 MOUNTAIN DR, THREDBO
SITE PHOTOS

ACT Geotechnical Engineers Pty Ltd	**C13820**	**FIGURE 3**

ACT GEOTECHNICAL ENGINEERS

ACT Geotechnical Engineers
Unit 5, 9 Beaconsfield Street Fyshwick ACT 2609
Phone: (02) 6285 1547

Engineering Log - Borehole

Borehole No: BH1

UTM : 55H
Easting : 0
Northing : 0
RL : N/A
Total Depth : 1.5m

Driller Rig : Push Tube Drill
Driller Supplier : ACT Geotechnical Engineers
Logged By : Jeremy Murray
Reviewed By : MD
Date : 14/12/2022

Job Number : C13820
Client : Peter Davies
Project : Proposed Garage - Merrits Lodge
Location : 13 Mountain Drive, Thredbo NSW

Water	Depth (m)	Soil Origin	Graphic Log	Classification Code	Weathering	Material Description	Consistency	Moisture	Testing	Remark
	0.3	Topsoil	░	SM		SILTY SAND (SM) : black, coarse grained, with fine sized gravel, loose,	L			
	0.5 1 1.5	Colluvium	▨	SC		CLAYEY SAND (SC) : brown grey, medium to coarse grained, low plasticity, with coarse sized gravel, moist, medium dense,	MD	M		
	2 2.5					**BH1 refusal at 1.5m (at refusal on cobbles or boulders within colluvial soils)**				

NSW GOVERNMENT | Planning & Environment

Geotechnical Policy
Kosciuszko Alpine Resorts

Form 4 – Minimal Impact Certification

DA Number: ____________________

This form may be used where minor construction works which present minimal or no geotechnical impact on the site or related land are proposed to be erected within the "G" line area of the geotechnical maps.

A geotechnical engineer or engineering geologist must inspect the site and/or review the proposed development documentation to determine if the proposed development requires a geotechnical report to be prepared to accompany the development application. Where the geotechnical engineer determines that such a report is not required then they must complete this form and attach design recommendations where required. A copy of Form 4 with design recommendation, if required, must be submitted with the development application.

Please contact the Alpine Resorts Team in Jindabyne for further information - phone 02 6456 1733.

To complete this form, please place a cross in the appropriate boxes ☐ and complete all sections.

1. Declaration made by geotechnical engineer or engineering geologist in relation to a nil or minimal geotechnical impact assessment and site classification

I,

Mr ☑ Ms ☐ Mrs ☐ Dr ☐ Other ☐

First Name	Family Name
Jeremy	Murray

OF

Company/organisation

ACT Geotechnical Engineers

certify that I am a geotechnical engineer /engineering geologist as defined by the "Policy" and I have inspected the site and reviewed the proposed development known as

Proposed Garage - Merrits Lodge - 13 Mountain Drive, Thredbo

As a result of my site inspection and review of the following documentation

(List of documentation reviewed)

TZ Design - Concept Design 07

I have determined that;

- ☑ the current load-bearing capacity of the existing building will not be exceeded or adversely impacted by the proposed development, and
- ☑ the proposed works are of such a minor nature that the requirement for geotechnical advice in the form of a geotechnical report, prepared in accordance with the "Policy", is considered unnecessary for the adequate and safe design of the structural elements to be incorporated into the new works, and
- ☑ in accordance with AS 2870.1 Residential Slabs and Footings, the site is to be classified as a type

(insert classification type)

Class "M"

- ☑ I have attached design recommendations to be incorporated in the structural design in accordance with this site classification.

I am aware that this declaration shall be used by the Department as an essential component in granting development consent for a structure to be erected within the "G" line area (as identified on the geotechnical maps) of Kosciuszko Alpine Resorts without requiring the submission of a geotechnical report in support of the development application.

2. Signatures

Signature

Chartered professional status

CPEng #2122247

Name

Jeremy Murray

Date

15/12/22

3. Contact details

Alpine Resorts Team
Shop 5A, 19 Snowy River Avenue
P O Box 36, JINDABYNE NSW 2627
Telephone: 02 6456 1733
Facsimile: 02 6456 1736
Email: alpineresorts@planning.nsw.gov.au

DESCRIPTION AND CLASSIFICATION OF SOILS

The methods of description and classification of soils used in this report are based on the Australian Standard 1726 – 1993, Geotechnical site investigations. In general, descriptions cover the following properties – soil type, colour, secondary grain size, structure, inclusions, strength or density and geological description.

Soil types are described according to the predominating particle size, qualified by the grading of other particles present (e.g. sandy clay) on the following basis:

Classification	**Particle Size**
Clay	Less than 0.002mm
Silt	0.002mm to 0.06mm
Sand	0.06mm to 2.00mm
Gravel	2.00mm to 60.00mm
Cobbles	60mm (63mm) to 200mm
Boulders	>200mm

Soils are also classified according to the Unified Soil Classifications System which is included in this Appendix. Rock types are classified by their geological names.

<u>Cohesive soils</u> are classified on the basis of strength either by laboratory testing or engineering examination. The terms are defined as follows:

Consistency	**Shear Strength su(kPa) (Representative Undrained Shear)**	
Very soft	< 12	<2 (~SPT “N”)
Soft	12 - 25	2-4
Firm	25 - 50	4-8
Stiff	50 – 100	8-15
Very Stiff	100 – 200	15-30
Hard	> 200	>30

<u>Non-cohesive</u> soils are classified on the basis of relative density, generally from the results of in-situ standard penetration tests as below:

Term	**Relative Density (%)**	**SPT Blows/300mm ‘N’**
Very loose	< 15	<4
Loose	15-35	4-10
Medium dense	35-65	10-30
Dense	65-85	30-50
Very Dense	>85	>50

SAMPLING

Sampling is carried out during drilling to allow engineering examination (and laboratory testing where required) of soil or rock.

Disturbed samples taken during drilling provide information on colour, type, inclusions and depending upon the degree of disturbance, some information on strength and structure.

Undisturbed samples are generally taken by one of two methods:

1. Driving or pushing a thin walled sample tube into the soil and withdrawing with a sample of soil in a relatively undisturbed state.

2. Core drilling using a retractable inner tube (R.I.T.) core barrel.

Such samples yield information on structure and strength in additions to that obtained from disturbed samples and are necessary for laboratory determination of shear strength and compressibility. Undisturbed sampling is generally effective only in cohesive soils.

Details of the type and method of sampling are given in the report.

PENETRATION TESTING

The relative density of non-cohesive soils is generally assessed by in-situ penetration tests, the most common of which is the standard penetration test. The test procedure is described in Australian Standard 1289 “Testing Soils for Engineering Purposes” Testing Soils for Engineering Purposes” – Test No. F3.1.

The standard penetration test is carried out by driving a 50mm diameter split tube penetrometer of standard dimensions under the impact of a 63 kg hammer having a free fall of 750mm.

The “N” value is determined as the number of blows to achieve 300mm of penetration (generally after disregarding the first 150mm penetration through possibly disturbed material). The results of these tests can be related empirically to the engineering properties of the soil.

The test is also used to provide useful information in cohesive soils under certain conditions, a good quality disturbed sample being recovered with each test. Other forms of in situ testing are used under certain conditions and where this occurs, details are given in the report.

DEFINITIONS OF ROCK, SOIL, AND DEGREES OF CHEMICAL WEATHERING

GENERAL DEFINITIONS – ROCK AND SOIL

ROCK In engineering usage, rock is a natural aggregate of minerals connected by strong and permanent cohesive forces.

Note: Since "strong" and "permanent" are subject to different interpretations, the boundary between rock and soil is necessarily an arbitrary one.

SOIL In engineering usage, soil is a natural aggregate of mineral grains which can be separated by such gentle mechanical means as agitation in water, can be remoulded and can be classified according to the Unified Soil Classification System. Three principal classes of soil recognized are:

Residual soils: soils which have been formed in-situ by the chemical weathering of parent rock. Residual soil may retain evidence of the original rock texture or fabric or, when mature, the original rock texture may be destroyed.

Transported soils: soils which have been moved from their places of origin and deposited elsewhere. The principal agents of erosion, transport and deposition are water, wind and gravity. Two important types of transported soil in engineering geology and materials investigations are:

Colluvium – a soil, often including angular rock fragments and boulders, which has been transported downslope predominantly under the action of gravity assisted by water. The principle forming process is that of soil creep in which the soil moves after it has been weakened by saturation. It may be water borne for short distances.

Alluvium – a soil which has been transported and deposited by running water. The larger particles (sand and gravel size) are water worn.

Lateritic soils: soils which have formed in situ under the effects of tropical weathering include all reddish residual and non residual soils which genetically form a chain of material ranging from decomposed rock through clay to sesqui-oxide rich crusts. The term does not necessarily imply any compositional, textural or morphological definition; all distinctions useful for engineering purposes are based on the differences in geotechnical characteristics.

ROCK WEATHERING DEFINITIONS

Extremely Weathered (EW)	Rock substance affected by weathering to the extent that the rock exhibits soil properties, i.e. it can be remoulded and can be classified according to the Unified Classification System, but the texture of the original rock is still evident.
Highly Weathered (HW)	Rock substance affected by weathering to the extent that limonite staining or bleaching affects the whole of the rock substance and other signs of the chemical or physical decomposition are evident. Porosity and strength may be increased or decreased compared to the fresh rock usually as a result of iron leaching or deposition. The colour and strength of the original fresh rock substance is no longer recognisable.
Moderately Weathered (MW)	Rock substance affected by weathering to the extent that staining extends throughout the whole of the rock substance and the original colour of the fresh rock is no longer recognisable.
Slightly Weathered (SW)	Rock substance affected by weathering to the extent that partial staining or discolouration of the rock substance, usually by limonite, has taken place. The colour and texture of the fresh rock is recognisable.
Fresh (Fr)	Rock substance unaffected by weathering.

The degrees of rock weathering may be gradational. Intermediate stages are described by dual symbols with the prominent degree of weathering first (e.g. EW-HW).

The various degrees of weathering do not necessarily define strength parameters as some rocks are weak, even when fresh, to the extent that they can be broken by hand across the fabric, and some rocks may increase in strength during the weathering process.

Fresh drill cores of some rock types, such as basalt and shale may disintegrate after exposure to the atmosphere due to slaking, desiccation, expansion or contraction, stress relief or a combination of any of these factors.

AN ENGINEERING CLASSIFICATION OF SEDIMENTARY ROCKS

This classification system provides a standardised terminology for the engineering description of the sandstone and shales in the Sydney area, but the terms and definitions may be used elsewhere when applicable. Where other rock types are encountered, such as in dykes, standard geological descriptions are used for rock types and the same descriptions as below are used for strength, fracturing and weathering.

Under this system rocks are classified by Rock Type, Strength, Stratification Spacing, Degree of Fracturing and Degree of Weathering. These terms do not cover the full range of engineering properties. Descriptions of rock may also need to refer to other properties (e.g. durability, abrasiveness, etc) where these are relevant.

ROCK TYPE DEFINITIONS

ROCK TYPE	**DEFINITION**
Conglomerate:	More than 50% of the rock consists of gravel sized (greater than 2mm) fragments.
Sandstone:	More than 50% of the rock consists of sand sized (0.06 to 2mm) grains.
Siltstone:	More than 50% of the rock consists of silt-sized (less than 0.06mm) granular particles and the rock is not laminated.
Claystone:	More than 50% of the rock consists of silt or clay sized particles and the rock is not laminated.
Shale:	More than 50% of the rock consists of silt or clay sized particles and the rock is laminated.

Rocks possessing characteristics of two groups are described by their predominant particle size with reference also to the minor constituents, e.g. clayey sandstone, sandy shale.

STRATIFICATION SPACING

Term	**Separation of Stratification Planes**
Thinly Laminated	< 6mm
Laminated	6mm to 20mm
Very thinly bedded	20mm to 60mm
Thinly bedded	60mm to 0.2m
Medium bedded	0.2m to 0.6m
Thickly bedded	0.6m to 2m
Very thickly bedded	> 2m

DEGREE OF FRACTURING

This classification applies to diamond drill cores and refers to the spacing of all types of natural fractures along which the core is discontinuous. These include bedding plane partings, joints and other rock defects, but exclude known artificial fractures such as drilling breaks.

Term	**Description**
Fragmented:	The core is comprised primarily of fragments of length less than 20mm, and mostly of width less than the core diameter
Highly Fractured:	Core lengths are generally less than 20mm – 40mm with occasional fragments.
Fractured:	Core lengths are mainly 30mm – 100mm with occasional shorter and longer section.
Slightly Fractured:	Core lengths are generally 300mm – 1000mm with occasional longer sections and occasional sections of 100mm – 300mm.
Unbroken:	The core does not contain any fracture.

ROCK STRENGTH

Rock strength is defined by the Point Load Strength Index (Is 50) and refers to the strength of the rock substance in the direction normal to the bedding. The test procedure is described by the International Society of Rock Mechanics.

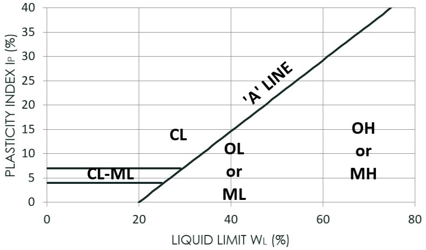
Term	**Point Load Index Is(50) MPa**	**Field Guide**	**Approx qu MPa***
Extremely Weak:	0.03	Easily remoulded by hand to a material with soil properties.	0.7
Very Weak:	0.1	May be crumbled in the hand. Sandstone is “sugary” and friable.	2.4
Weak:	0.3	A piece of core 150mm long x 50mm dia. May be broken by hand and easily scored with a knife. Sharp edges of core may be friable and break during handling.	7
Medium Strong:	1	A piece of core 150mm long x 50mm dia. can be broken by hand with considerable difficulty. Readily scored with knife.	24
Strong: (SW)	3	A piece of core 150mm long x 50mm dia. core cannot be broken by unaided hands, can be slightly scratched or scored with knife.	70
Very Strong (SW)	10	A piece of core 150mm long x 50mm dia. may be broken readily with hand held hammer. Cannot be scratched with pen knife.	240
Extremely Strong (Fr)	>10	A piece of core 150mm long x 50mm dia. is difficult to break with hand held hammer. Rings when struck with a hammer.	>240

The approximate unconfined compressive strength (qu) shown in the table is based on an assumed ration to the point load index of 24:1. This ratio may vary widely.

Unified Soil Classification System (Metricated)
Data for Description Indentification and Classification of Soils

MAJOR DIVISIONS				DESCRIPTION				FIELD IDENTIFICATION									LABORATORY CLASSIFICATION					
				Group Symbol	Graphic Symbol	TYPICAL NAME	DESCRIPTIVE DATA					GRAVELS AND SANDS				Group Symbol		% [2] < 0.06mm	PLASTICITY OF FINE FRACTION			NOTES
												GRADATIONS		NATURE OF FINES	DRY STRENGTH							
COARSE GRAINED SOILS	More than 50% by dry mass, less than 60mm is greater than 0.06mm.	GRAVELS	More than 50% of coarse grains are greater than 2.0mm	GW	▨	Well graded gravels and gravel-sand mixtures, little or no fines	Give typical name, indicate approximate percentages of sand and gravel, maximum size, angularity, surface condition and hardness of the coarse grains, local or geological name and other perfinent descriptive information, symbols in parenthesis. For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics. EXAMPLE: Silty Sand, gravelly, about 20% hard, angular gravel particles, 10mm maximum size, rounded and sub angular sand grains coarse to fine, about 15% non-plastic fines with low dry strength, well compacted and moist in place, light brown alluvial sand, (SM)	Determine approximate percentages of material over 60mm size, maximum size, shape, surface texture, hardness of material, geological description Identify on estimated percentage mass of the various fractions.	COARSE GRAINED SOILS	More than half of the material less than 60mm is larger than 0.06mm	0.05mm is about the smallest particle visible to the naked eye	GOOD	Wide range in grain size	"Clean" materials (not enough fines to band coarse grains)	None	GW	Use the gradation curve of material passing 60mm for classification of fractions according to criteria given under "Major Division".	0-5	-	>4	Between 1 and 3	1. Identify Fines by the method given for fine grained soils. 2. Borderline classifications occur when the percentage of fines (fraction smaller than 0.06mm size) is greater than 5% and less than 12%. Borderline classifications require the use of dual symbols eg SP-SM GW-GC
				GP	▨	Poorly graded gravels and gravel-sand mixtures, little or no fines						POOR	Predominantly one size or range of sizes			GP		0-5	-	Fails to comply with above		
		GRAVELLY SOILS		GM	▨	Silty gravels, gravel-sand-silt mixtures						GOOD TO FAIR	"Dirty" materials (Excess of fines)	Fines are non-plastic (1)	None to medium	GM		12-50	Below 'A' line and Ip >7	-	-	
				GC	▨	Clayey gravels gravel-sand-clay mixtures								Fines are plastic (1)		GC		12-50	Above 'A' line and Ip > 7	-	-	
		SANDS	More than 50% of coarse grains are greater than 2.0mm	SW	▨	Well graded sands and gravelly sands, little or no fines						GOOD	Wide range in grain size	"Clean" materials (not enough fines to band coarse grains)	None	SW		0-5	-	>6	between 1 and 3	
				SP	▨	Poorly graded sands and gravelly sands, little or no fines						POOR	Predominantly one size or range of sizes			SP		0-5	-	Fails to comply with above		
		SANDY SOILS		SM	▨	Silty sand, sand-silt mixtures						GOOD TO FAIR	"Dirty" materials (Excess of fines)	Fines are non-plastic (1)	None to medium	SM		12-50	Below 'A' line or Ip < 4	-	-	
				SC	▨	Clayey sands, sand-clay mixtures								Fines are plastic (1)		SC		12-50	Above 'A' line and Ip > 7	-	-	

									SILT AND CLAY FRACTION					
									Fraction smaller than 0 20mm AS sieve size					
									DRY STRENGTH	DILATANCY	TOUGHNESS			
FINE GRAINED SOILS	More than 50% by dry mass, less than 6mm is less than 0.06mm	Liquid Limit less than 50%	ML	▨	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands.	Give typical name, indicate degree and character of plasticity, amount and maximum size of coarse grains, colour in wet condition, odour if any, local or geological name and r pertinent descriptive information, symbols in parenthesis. For undisturbed soil add information on structure, stratification, consistancy in undisturbed and remoulded states, moisture and drainage conditions. EXAMPLE Clayey Silt, brown, low plasticity, small percentage of fine sand, numerous vertical root-holes, firm and dry in place, fill, (ML).	FINE GRAINED SOILS	More than half of the material less than 50mm is less than 0.06mm	None to low	Quick to slow	None	ML	More than 50% passing 0.06mm	Below 'A' line
			CL	▨	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.				Medium to high	None to very slow	Medium	CL		Above 'A' line
			OL	▨	Organic silts and organic silty clays of low plasticity				Low to medium	Slow	Low	OL		Below 'A' line
		Liquid Limit more than 50%	MH	▨	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts.				Low to medium	Slow to none	Low to medium	MH		Below 'A' line
			CH	▨	Inorganic clays of high plasticity, fat clays.				High to very high	None	High	CH		Above 'A' line
			OH	▨	Organic clays of medium to high plasticity.				Medium to high	None to very slow	Low to medium	OH		Below 'A' line
			Pt	▨	Peat muck and other highly organic soils.		Readily identified by colour, odour, spongy feel and generally by fibrous texture					Pt*	*Effervescence with H2O2	



PLASTICITY CHART

FOR CLASSIFICATION
OF FINE GRAINED SOILS

Geotechnical Engineers ACT

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Limitations in the Use and Interpretation of this Geotechnical Report

Our Professional services were performed, our findings obtained, and our recommendations prepared in accordance with generally accepted engineering principles and practices. This warranty is in lieu of all other warranties, either expressed or implied.

The geotechnical report was prepared for the use of the Owner in the design of the subject development and should be made available to potential contractors and/or the Contractor for information on factual data only. This report should not be used for contractual purposes as a warranty of interpreted subsurface conditions such as those indicated by the interpretive borehole and test pit logs, cross- sections, or discussion of subsurface conditions contained herein.

The analyses, conclusions and recommendations contained in the report are based on site conditions as they presently exist and assume that the exploratory bore holes, test pits, and/or probes are representative of the subsurface conditions of the site. If, during construction, subsurface conditions are found which are significantly different from those observed in the exploratory bore holes and test pits, or assumed to exist in the excavations, we should be advised at once so that we can review these conditions and reconsider our recommendations where necessary. If there is a substantial lapse of time between conducting this investigation and the start of work at the site, or if conditions have changed due to natural causes or construction operations at or adjacent to the site, this report should be reviewed to determine the applicability of the conclusions and the recommendations considering the changed conditions and time lapse.

The summary bore hole and test pit logs are our opinion of the subsurface conditions revealed by periodic sampling of the ground as the test holes progressed. The soil descriptions and interfaces between strata are interpretive and actual changes may be gradual.

The bore hole and test pit logs and related information depict subsurface conditions only at the specific locations and at the particular time designated on the logs. Soil conditions at the other locations may differ from conditions occurring at these bore hole and test pit locations. Also, the passage of time may result in a change in the soil conditions at these test locations.

Groundwater levels often vary seasonally. Groundwater levels reported on the boring logs or in the body of the report are factual data only for the dates shown.

Unanticipated soil conditions are commonly encountered on construction sites and cannot be fully anticipated by merely taking soil samples, bore holes or test pits. Such unexpected conditions frequently require that additional expenditures be made to attain a properly constructed project. It is recommended that the Owner consider providing a contingency fund to accommodate such potential extra costs.

This firm cannot be responsible for any deviation from the intent of this report including, but not restricted to, any changes to the scheduled time of construction, the nature of the project or the specific construction methods or means indicated in this report: nor can our company be responsible for any construction activity on sites other than the specific site referred to in this report.

Foundation Maintenance and Footing Performance:

A Homeowner's Guide

CSIRO

BTF 18
replaces
Information
Sheet 10/91

Buildings can and often do move. This movement can be up, down, lateral or rotational. The fundamental cause of movement in buildings can usually be related to one or more problems in the foundation soil. It is important for the homeowner to identify the soil type in order to ascertain the measures that should be put in place in order to ensure that problems in the foundation soil can be prevented, thus protecting against building movement.

This Building Technology File is designed to identify causes of soil-related building movement, and to suggest methods of prevention of resultant cracking in buildings.

Soil Types

The types of soils usually present under the topsoil in land zoned for residential buildings can be split into two approximate groups – granular and clay. Quite often, foundation soil is a mixture of both types. The general problems associated with soils having granular content are usually caused by erosion. Clay soils are subject to saturation and swell/shrink problems.

Classifications for a given area can generally be obtained by application to the local authority, but these are sometimes unreliable and if there is doubt, a geotechnical report should be commissioned. As most buildings suffering movement problems are founded on clay soils, there is an emphasis on classification of soils according to the amount of swell and shrinkage they experience with variations of water content. The table below is Table 2.1 from AS 2870, the Residential Slab and Footing Code.

Causes of Movement

Settlement due to construction

There are two types of settlement that occur as a result of construction:

- Immediate settlement occurs when a building is first placed on its foundation soil, as a result of compaction of the soil under the weight of the structure. The cohesive quality of clay soil mitigates against this, but granular (particularly sandy) soil is susceptible.
- Consolidation settlement is a feature of clay soil and may take place because of the expulsion of moisture from the soil or because of the soil's lack of resistance to local compressive or shear stresses. This will usually take place during the first few months after construction, but has been known to take many years in exceptional cases.

These problems are the province of the builder and should be taken into consideration as part of the preparation of the site for construction. Building Technology File 19 (BTF 19) deals with these problems.

Erosion

All soils are prone to erosion, but sandy soil is particularly susceptible to being washed away. Even clay with a sand component of say 10% or more can suffer from erosion.

Saturation

This is particularly a problem in clay soils. Saturation creates a bog-like suspension of the soil that causes it to lose virtually all of its bearing capacity. To a lesser degree, sand is affected by saturation because saturated sand may undergo a reduction in volume – particularly imported sand fill for bedding and blinding layers. However, this usually occurs as immediate settlement and should normally be the province of the builder.

Seasonal swelling and shrinkage of soil

All clays react to the presence of water by slowly absorbing it, making the soil increase in volume (see table below). The degree of increase varies considerably between different clays, as does the degree of decrease during the subsequent drying out caused by fair weather periods. Because of the low absorption and expulsion rate, this phenomenon will not usually be noticeable unless there are prolonged rainy or dry periods, usually of weeks or months, depending on the land and soil characteristics.

The swelling of soil creates an upward force on the footings of the building, and shrinkage creates subsidence that takes away the support needed by the footing to retain equilibrium.

Shear failure

This phenomenon occurs when the foundation soil does not have sufficient strength to support the weight of the footing. There are two major post-construction causes:

- Significant load increase.
- Reduction of lateral support of the soil under the footing due to erosion or excavation.
- In clay soil, shear failure can be caused by saturation of the soil adjacent to or under the footing.

GENERAL DEFINITIONS OF SITE CLASSES

Class	Foundation
A	Most sand and rock sites with little or no ground movement from moisture changes
S	Slightly reactive clay sites with only slight ground movement from moisture changes
M	Moderately reactive clay or silt sites, which can experience moderate ground movement from moisture changes
H	Highly reactive clay sites, which can experience high ground movement from moisture changes
E	Extremely reactive sites, which can experience extreme ground movement from moisture changes
A to P	Filled sites
P	Sites which include soft soils, such as soft clay or silt or loose sands; landslip; mine subsidence; collapsing soils; soils subject to erosion; reactive sites subject to abnormal moisture conditions or sites which cannot be classified otherwise

Tree root growth

Trees and shrubs that are allowed to grow in the vicinity of footings can cause foundation soil movement in two ways:

- Roots that grow under footings may increase in cross-sectional size, exerting upward pressure on footings.
- Roots in the vicinity of footings will absorb much of the moisture in the foundation soil, causing shrinkage or subsidence.

Unevenness of Movement

The types of ground movement described above usually occur unevenly throughout the building's foundation soil. Settlement due to construction tends to be uneven because of:

- Differing compaction of foundation soil prior to construction.
- Differing moisture content of foundation soil prior to construction.

Movement due to non-construction causes is usually more uneven still. Erosion can undermine a footing that traverses the flow or can create the conditions for shear failure by eroding soil adjacent to a footing that runs in the same direction as the flow.

Saturation of clay foundation soil may occur where subfloor walls create a dam that makes water pond. It can also occur wherever there is a source of water near footings in clay soil. This leads to a severe reduction in the strength of the soil which may create local shear failure.

Seasonal swelling and shrinkage of clay soil affects the perimeter of the building first, then gradually spreads to the interior. The swelling process will usually begin at the uphill extreme of the building, or on the weather side where the land is flat. Swelling gradually reaches the interior soil as absorption continues. Shrinkage usually begins where the sun's heat is greatest.

Effects of Uneven Soil Movement on Structures

Erosion and saturation

Erosion removes the support from under footings, tending to create subsidence of the part of the structure under which it occurs. Brickwork walls will resist the stress created by this removal of support by bridging the gap or cantilevering until the bricks or the mortar bedding fail. Older masonry has little resistance. Evidence of failure varies according to circumstances and symptoms may include:

- Step cracking in the mortar beds in the body of the wall or above/below openings such as doors or windows.
- Vertical cracking in the bricks (usually but not necessarily in line with the vertical beds or perpends).

Isolated piers affected by erosion or saturation of foundations will eventually lose contact with the bearers they support and may tilt or fall over. The floors that have lost this support will become bouncy, sometimes rattling ornaments etc.

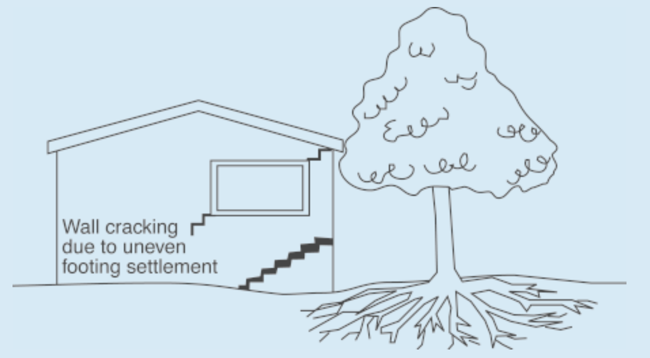
Seasonal swelling/shrinkage in clay

Swelling foundation soil due to rainy periods first lifts the most exposed extremities of the footing system, then the remainder of the perimeter footings while gradually permeating inside the building footprint to lift internal footings. This swelling first tends to create a dish effect, because the external footings are pushed higher than the internal ones.

The first noticeable symptom may be that the floor appears slightly dished. This is often accompanied by some doors binding on the floor or the door head, together with some cracking of cornice mitres. In buildings with timber flooring supported by bearers and joists, the floor can be bouncy. Externally there may be visible dishing of the hip or ridge lines.

As the moisture absorption process completes its journey to the innermost areas of the building, the internal footings will rise. If the spread of moisture is roughly even, it may be that the symptoms will temporarily disappear, but it is more likely that swelling will be uneven, creating a difference rather than a disappearance in symptoms. In buildings with timber flooring supported by bearers and joists, the isolated piers will rise more easily than the strip footings or piers under walls, creating noticeable doming of flooring.

Trees can cause shrinkage and damage



As the weather pattern changes and the soil begins to dry out, the external footings will be first affected, beginning with the locations where the sun's effect is strongest. This has the effect of lowering the external footings. The doming is accentuated and cracking reduces or disappears where it occurred because of dishing, but other cracks open up. The roof lines may become convex.

Doming and dishing are also affected by weather in other ways. In areas where warm, wet summers and cooler dry winters prevail, water migration tends to be toward the interior and doming will be accentuated, whereas where summers are dry and winters are cold and wet, migration tends to be toward the exterior and the underlying propensity is toward dishing.

Movement caused by tree roots

In general, growing roots will exert an upward pressure on footings, whereas soil subject to drying because of tree or shrub roots will tend to remove support from under footings by inducing shrinkage.

Complications caused by the structure itself

Most forces that the soil causes to be exerted on structures are vertical – i.e. either up or down. However, because these forces are seldom spread evenly around the footings, and because the building resists uneven movement because of its rigidity, forces are exerted from one part of the building to another. The net result of all these forces is usually rotational. This resultant force often complicates the diagnosis because the visible symptoms do not simply reflect the original cause. A common symptom is binding of doors on the vertical member of the frame.

Effects on full masonry structures

Brickwork will resist cracking where it can. It will attempt to span areas that lose support because of subsided foundations or raised points. It is therefore usual to see cracking at weak points, such as openings for windows or doors.

In the event of construction settlement, cracking will usually remain unchanged after the process of settlement has ceased.

With local shear or erosion, cracking will usually continue to develop until the original cause has been remedied, or until the subsidence has completely neutralised the affected portion of footing and the structure has stabilised on other footings that remain effective.

In the case of swell/shrink effects, the brickwork will in some cases return to its original position after completion of a cycle, however it is more likely that the rotational effect will not be exactly reversed, and it is also usual that brickwork will settle in its new position and will resist the forces trying to return it to its original position. This means that in a case where swelling takes place after construction and cracking occurs, the cracking is likely to at least partly remain after the shrink segment of the cycle is complete. Thus, each time the cycle is repeated, the likelihood is that the cracking will become wider until the sections of brickwork become virtually independent.

With repeated cycles, once the cracking is established, if there is no other complication, it is normal for the incidence of cracking to stabilise, as the building has the articulation it needs to cope with the problem. This is by no means always the case, however, and monitoring of cracks in walls and floors should always be treated seriously.

Upheaval caused by growth of tree roots under footings is not a simple vertical shear stress. There is a tendency for the root to also exert lateral forces that attempt to separate sections of brickwork after initial cracking has occurred.

The normal structural arrangement is that the inner leaf of brickwork in the external walls and at least some of the internal walls (depending on the roof type) comprise the load-bearing structure on which any upper floors, ceilings and the roof are supported. In these cases, it is internally visible cracking that should be the main focus of attention, however there are a few examples of dwellings whose external leaf of masonry plays some supporting role, so this should be checked if there is any doubt. In any case, externally visible cracking is important as a guide to stresses on the structure generally, and it should also be remembered that the external walls must be capable of supporting themselves.

Effects on framed structures
Timber or steel framed buildings are less likely to exhibit cracking due to swell/shrink than masonry buildings because of their flexibility. Also, the doming/dishing effects tend to be lower because of the lighter weight of walls. The main risks to framed buildings are encountered because of the isolated pier footings used under walls. Where erosion or saturation cause a footing to fall away, this can double the span which a wall must bridge. This additional stress can create cracking in wall linings, particularly where there is a weak point in the structure caused by a door or window opening. It is, however, unlikely that framed structures will be so stressed as to suffer serious damage without first exhibiting some or all of the above symptoms for a considerable period. The same warning period should apply in the case of upheaval. It should be noted, however, that where framed buildings are supported by strip footings there is only one leaf of brickwork and therefore the externally visible walls are the supporting structure for the building. In this case, the subfloor masonry walls can be expected to behave as full brickwork walls.

Effects on brick veneer structures
Because the load-bearing structure of a brick veneer building is the frame that makes up the interior leaf of the external walls plus perhaps the internal walls, depending on the type of roof, the building can be expected to behave as a framed structure, except that the external masonry will behave in a similar way to the external leaf of a full masonry structure.

Water Service and Drainage

Where a water service pipe, a sewer or stormwater drainage pipe is in the vicinity of a building, a water leak can cause erosion, swelling or saturation of susceptible soil. Even a minuscule leak can be enough to saturate a clay foundation. A leaking tap near a building can have the same effect. In addition, trenches containing pipes can become watercourses even though backfilled, particularly where broken rubble is used as fill. Water that runs along these trenches can be responsible for serious erosion, interstrata seepage into subfloor areas and saturation.

Pipe leakage and trench water flows also encourage tree and shrub roots to the source of water, complicating and exacerbating the problem.
Poor roof plumbing can result in large volumes of rainwater being concentrated in a small area of soil:

- Incorrect falls in roof guttering may result in overflows, as may gutters blocked with leaves etc.
- Corroded guttering or downpipes can spill water to ground.
- Downpipes not positively connected to a proper stormwater collection system will direct a concentration of water to soil that is directly adjacent to footings, sometimes causing large-scale problems such as erosion, saturation and migration of water under the building.

Seriousness of Cracking

In general, most cracking found in masonry walls is a cosmetic nuisance only and can be kept in repair or even ignored. The table below is a reproduction of Table C1 of AS 2870.

AS 2870 also publishes figures relating to cracking in concrete floors, however because wall cracking will usually reach the critical point significantly earlier than cracking in slabs, this table is not reproduced here.

Prevention/Cure

Plumbing
Where building movement is caused by water service, roof plumbing, sewer or stormwater failure, the remedy is to repair the problem. It is prudent, however, to consider also rerouting pipes away from the building where possible, and relocating taps to positions where any leakage will not direct water to the building vicinity. Even where gully traps are present, there is sometimes sufficient spill to create erosion or saturation, particularly in modern installations using smaller diameter PVC fixtures. Indeed, some gully traps are not situated directly under the taps that are installed to charge them, with the result that water from the tap may enter the backfilled trench that houses the sewer piping. If the trench has been poorly backfilled, the water will either pond or flow along the bottom of the trench. As these trenches usually run alongside the footings and can be at a similar depth, it is not hard to see how any water that is thus directed into a trench can easily affect the foundation's ability to support footings or even gain entry to the subfloor area.

Ground drainage
In all soils there is the capacity for water to travel on the surface and below it. Surface water flows can be established by inspection during and after heavy or prolonged rain. If necessary, a grated drain system connected to the stormwater collection system is usually an easy solution.

It is, however, sometimes necessary when attempting to prevent water migration that testing be carried out to establish watertable height and subsoil water flows. This subject is referred to in BTF 19 and may properly be regarded as an area for an expert consultant.

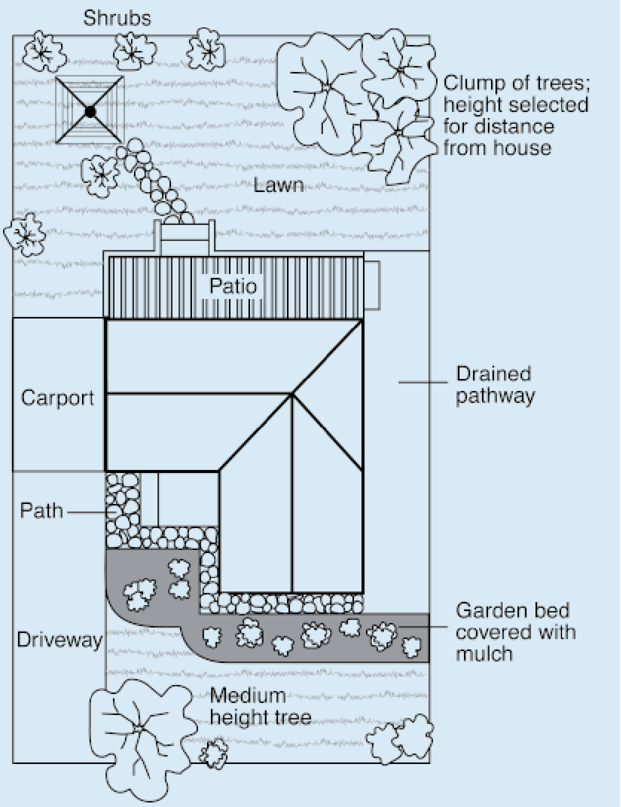
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

For this reason, particularly where problems exist or are likely to occur, it is recommended that an apron of paving be installed around as much of the building perimeter as necessary. This paving

CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS

Description of typical damage and required repair	Approximate crack width limit (see Note 3)	Damage category
Hairline cracks	<0.1 mm	0
Fine cracks which do not need repair	<1 mm	1
Cracks noticeable but easily filled. Doors and windows stick slightly	<5 mm	2
Cracks can be repaired and possibly a small amount of wall will need to be replaced. Doors and windows stick. Service pipes can fracture. Weathertightness often impaired	5–15 mm (or a number of cracks 3 mm or more in one group)	3
Extensive repair work involving breaking-out and replacing sections of walls, especially over doors and windows. Window and door frames distort. Walls lean or bulge noticeably, some loss of bearing in beams. Service pipes disrupted	15–25 mm but also depend on number of cracks	4

Gardens for a reactive site



should extend outwards a minimum of 900 mm (more in highly reactive soil) and should have a minimum fall away from the building of 1:60. The finished paving should be no less than 100 mm below brick vent bases.

It is prudent to relocate drainage pipes away from this paving, if possible, to avoid complications from future leakage. If this is not practical, earthenware pipes should be replaced by PVC and backfilling should be of the same soil type as the surrounding soil and compacted to the same density.

Except in areas where freezing of water is an issue, it is wise to remove taps in the building area and relocate them well away from the building – preferably not uphill from it (see BTF 19).

It may be desirable to install a grated drain at the outside edge of the paving on the uphill side of the building. If subsoil drainage is needed this can be installed under the surface drain.

Condensation

In buildings with a subfloor void such as where bearers and joists support flooring, insufficient ventilation creates ideal conditions for condensation, particularly where there is little clearance between the floor and the ground. Condensation adds to the moisture already present in the subfloor and significantly slows the process of drying out. Installation of an adequate subfloor ventilation system, either natural or mechanical, is desirable.

Warning: Although this Building Technology File deals with cracking in buildings, it should be said that subfloor moisture can result in the development of other problems, notably:

- Water that is transmitted into masonry, metal or timber building elements causes damage and/or decay to those elements.
- High subfloor humidity and moisture content create an ideal environment for various pests, including termites and spiders.
- Where high moisture levels are transmitted to the flooring and walls, an increase in the dust mite count can ensue within the living areas. Dust mites, as well as dampness in general, can be a health hazard to inhabitants, particularly those who are abnormally susceptible to respiratory ailments.

The garden

The ideal vegetation layout is to have lawn or plants that require only light watering immediately adjacent to the drainage or paving edge, then more demanding plants, shrubs and trees spread out in that order.

Overwatering due to misuse of automatic watering systems is a common cause of saturation and water migration under footings. If it is necessary to use these systems, it is important to remove garden beds to a completely safe distance from buildings.

Existing trees

Where a tree is causing a problem of soil drying or there is the existence or threat of upheaval of footings, if the offending roots are subsidiary and their removal will not significantly damage the tree, they should be severed and a concrete or metal barrier placed vertically in the soil to prevent future root growth in the direction of the building. If it is not possible to remove the relevant roots without damage to the tree, an application to remove the tree should be made to the local authority. A prudent plan is to transplant likely offenders before they become a problem.

Information on trees, plants and shrubs

State departments overseeing agriculture can give information regarding root patterns, volume of water needed and safe distance from buildings of most species. Botanic gardens are also sources of information. For information on plant roots and drains, see Building Technology File 17.

Excavation

Excavation around footings must be properly engineered. Soil supporting footings can only be safely excavated at an angle that allows the soil under the footing to remain stable. This angle is called the angle of repose (or friction) and varies significantly between soil types and conditions. Removal of soil within the angle of repose will cause subsidence.

Remediation

Where erosion has occurred that has washed away soil adjacent to footings, soil of the same classification should be introduced and compacted to the same density. Where footings have been undermined, augmentation or other specialist work may be required. Remediation of footings and foundations is generally the realm of a specialist consultant.

Where isolated footings rise and fall because of swell/shrink effect, the homeowner may be tempted to alleviate floor bounce by filling the gap that has appeared between the bearer and the pier with blocking. The danger here is that when the next swell segment of the cycle occurs, the extra blocking will push the floor up into an accentuated dome and may also cause local shear failure in the soil. If it is necessary to use blocking, it should be by a pair of fine wedges and monitoring should be carried out fortnightly.

This BTF was prepared by John Lewer FAIB, MIAMA, Partner, Construction Diagnosis.

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