



Geotechnical Site Classification

Dungog Library, 17 Mackay Street, Dungog

Report Ref: P21419-R-001-Rev0

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Client: Dungog Shire Council

4 March 2021**Prepared for****Dungog Shire Council**

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Site Address:	Dungog Library, 17 Mackay Street, Dungog	
Project Type:	Proposed Public Space Development	
Project no	Report type	Report no
P21419	R	001

Report Register

Revision Number	Reported By	Reviewed By	Date
Rev0	ML	NR	4/03/2021

We confirm that the following report has been produced for Dungog Shire Council, based on the described methods and conditions within.

For and on behalf of **Hunter Civilab**,

**Nathan Roberts**

Geotechnical Engineering Manager

Executive Summary

The following report details the geotechnical investigation undertaken by Hunter Civilab (HC) under the request of Dungog Shire Council. The investigation was undertaken at Dungog Library, 17 Mackay Street, Dungog on the 17th of February 2021 and consisted of a desktop study, a visual site assessment and intrusive excavations and testing.

The desktop study indicated that the site lies within an area of no known occurrences of acid sulfate soils.

The desktop study also indicated that the site does not lie within a mine subsidence district.

The site is a flat, undeveloped area at the rear of the existing library in a mixed commercial/residential area.

The subsurface profile generally consisted of residual silty sandy clays overlying sandstone rock with rock encountered between 0.3m and 0.8m along the eastern boundary and rock encountered and 2.5m along the western boundary.

A site classification was undertaken based on the laboratory testing results and the subsurface profile encountered at the time of investigation. The results indicated a Class P site with a reactivity of Class H1, having a characteristic free surface movement of 40 – 60 mm. Therefore, a site classification of Class P-H1 is recommended for the site.

The site would be suitable for the use of both shallow and deep footings. Refer to **Section 8** for footing details and recommended allowable bearing capacity.

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Annex C – Hunter Civilab Laboratory Test Reports

Annex D – BTF 18-2011- CSIRO - Foundation Maintenance and Footing Performance - A Homeowner's Guide

1 Introduction

At the request of Dungog Shire Council, Hunter Civilab (HC) have carried out a limited geotechnical investigation for the purpose of a site classification at Dungog Library, 17 Mackay Street, Dungog. It is understood that the proposed development is to consist of the construction of a new extension to the existing library and a new amphitheatre. The investigation works were undertaken in accordance with HC services agreement Q2021_013, dated the 14th of January 2021.

The purpose of the investigation was to provide recommendations on the following:

- surface and sub-surface conditions;
- geotechnical laboratory testing results;
- site classification to AS 2870-2011;
- alternative footing types and foundation design parameters.

2 Site Description

The site was located at Dungog Library, 17 Mackay Street, Dungog. The site was bordered by Mackay Street to the south, by parkland and a stormwater drainage channel to the west and by a mix of commercial and residential development to the north and east.

At the time of investigation, existing development consisted of a small, single storey library building and a small, detached public amenities building.

Existing vegetation consisted of short grass with several trees around site boundaries.

Topographically the site sloped gently down from Mackay street and becoming flat at the rear of the existing library.

3 Preliminary Site Investigation

3.1 Geological and Soil Landscape Setting

Reference to the 1:250,000 Newcastle Geological Map indicates that the site is underlain by the Wootton Beds consisting of sandstone, siltstone, claystone, shale, limestone and lavas.

Reference to the 1:100,000 Dungog Soil Landscape Map indicates that the site is located within the Dungog Landscape. The landscape is characterized by rolling hills and low hills on Carboniferous sediments in the Clarencetown Hills and Dungog Hills. Slope gradients are generally between 10 to 20% on reliefs of 40 to 120m at elevations ranging between 60 to 200m. The soil is known to consist of shallow to moderately deep, well to imperfectly drained Brown Sodosols (Soloths). Some shallow, well-drained Bleached-Leptic Tenosols (Lithosols). The vegetation in the landscape is comprised of mainly cleared tall open-forest.

3.2 Acid Sulfate Soils Risk Maps

Reference to the NSW Office of Environment and Heritage's online database 'ESPADE' indicates that the site lies in an area of no known occurrences of acid sulfate soils.

3.3 Mine Subsidence

Reference to Subsidence Advisory NSW Mine District Maps indicates that the site does not lie within a Mine Subsidence District.

4 Methodology

Fieldwork was undertaken on the 17th of February 2021 and consisted of:

- underground utility service clearances using a Telstra accredited locator;
- a visual assessment of the existing surface of the site and surrounding area;
- locating borehole locations by approximate measurements from existing site features;
- the drilling of 3 x boreholes (BH1 – BH3) to depths of up to 3.0m;
- the driving of 3 x Dynamic Cone Penetrometer (DCP) probes at BH locations to depths of up to 1.3m;
- recovery of 1 x undisturbed soil sample for laboratory testing.

Laboratory testing consisted of:

- 1 x Shrink Swell Index tests.

5 Subsurface Conditions

The subsurface soil conditions encountered at the site have been summarised into the following units:

UNIT 1 – RESIDUAL:

- Silty Sandy CLAY, dark brown/grey or brown, firm or firm to stiff
- Silty Sandy CLAY, brown/grey or brown, trace of gravel, stiff to very stiff

UNIT 2 – ROCK:

- Extremely Weathered SANDSTONE, brown, inferred very low to low strength
- Weathered SANDSTONE, light grey/brown, inferred very low to low strength

A summary of the soil unit depths encountered in each borehole are presented below in **Table 5.1**.

Table 5.1 - Summary of the soil unit depths encountered

Borehole	Depth (m)	Depth (m)	
		UNIT 1	UNIT 2
BH1	0.5	0.0-0.3	0.3-0.5
BH2	1.6	0.0-0.8	0.8-1.6
BH3	3.0	0.0-2.5	2.5-3.0

Groundwater was not encountered at the site. Surface soils were quite damped under foot and there were some areas of minor ponding noted.

Refer to **Annex A** for the borehole location plan and **Annex B** for detailed borehole logs.

6 Laboratory Test Results

1 x undisturbed sample was recovered from the boreholes. The sample was transported to Hunter Civilab's NATA accredited soil testing laboratory for analysis. The laboratory test results are summarised below in **Table 6.1** below.

Table 6.1 - Shrink Swell Index test results

Borehole	Depth (m)	Soil description	I _{ss} (%)
BH3	0.5-0.85	Silty Sandy CLAY	5.0

Laboratory test results from the soil sample can be found in **Annex C**.

7 Site Classification

7.1 Background Information

Site classification is based off the characteristic surface movements encountered at the site due to the moisture variations within the soil profile. Characteristic surface movements are estimated in accordance with AS2870-2011 "Residential Slabs & Footings". Surface movement calculation take into consideration the depth of the soil profile layers, the soil reactivity and the soil suction depth. The site classification based on characteristic surface movements are summarised below in **Table 7.1**.

Table 7.1 - Summary of AS2870-2011 characteristic surface movement & site classification

Characteristic surface movement (y_s) (mm)	Site classification AS2870-2011	Underlying soil / geology
0	Class A	SAND or ROCK site (non-reactive)
0 – 20mm	Class S	CLAY (slightly reactive)
20 – 40mm	Class M	CLAY (moderately reactive)
40 – 60mm	Class H1	CLAY (highly reactive)
60 – 75mm	Class H2	CLAY (highly reactive)
> 75mm	Class E	CLAY (extremely reactive)

Sites subjected to deep-seated moisture change are modified with the addition of "-D". As defined by AS2870-2011 other sites should be classified as a Class P (Problem) site. These sites include sites with:

- inadequate bearing capacity;
- expected excessive foundation settlement due to loading on the foundation;
- significant moisture variations;
- mine subsidence risk;
- slope stability risk;
- erosion issues;

- greater than 0.8m of fill for sand sites and greater than 0.4m for other sites (in general).

7.2 Site Classification

The proposed development should be designed in accordance with AS2870-2011 “Residential Slabs and Footings”. Based on the visual inspection, dynamic cone penetrometer tests and soil profile shown above in **Section 5**, the site classification is summarised below in **Table 7.2**.

Table 7.2 - Site classification & characteristic surface movement (y_s)

Site classification	Site reactivity	Characteristic surface movement (y_s)
Class P	Class H1	40 – 60 mm

The site was classified as a Class P due to the existing development surrounding the area and the impervious areas that drain towards the site that may create abnormal moisture conditions in the soil.

Based on the subsurface profile and the results of the laboratory testing a site reactivity of Class H1 has been assigned to the Class P site.

Classification of the site has not taken into account the effects of abnormal moisture conditions. If the site undergoes any earthworks operations, the site shall be reclassified in accordance with AS2870-2011.

7.3 Abnormal Moisture Effects

Abnormal moisture conditions in the foundation can be caused by the following:

- existing development;
- leaking water services;
- prolonged periods of draught or heavy rainfall;
- trenches or other man-made water courses;
- poor roof plumbing or obstruction to the roof plumbing system;
- poor rainfall runoff control;
- corroded gutters or downpipes.

Abnormal moisture conditions specified above can cause adverse effects to the development’s foundation such as:

- erosion significantly effecting the lateral and founding support of the structure’s footing system;
- saturation of the founding material which can cause a significant decrease in the strength of the founding material;
- shrinkage creating subsidence of the founding material and causing additional stresses within the building structure;
- swelling which creates an upward force in the footings which causes additional stresses within the building structure.

7.4 Effects from Trees

The existence of trees within or adjacent to the building footprint can cause significant soil movement due to the following:

- roots growing within the foundation and causing an upward force on footings;
- roots drawing in and absorbing the moisture below a footing system causing subsidence due to shrinkage of the soil volume.

The site should take into account the tree score effect in accordance with and designed to AS2870-2011. The site was found to have a “Low” tree score effect and has been taken into consideration.

8 Footing Recommendations

The site is suitable for the use of both shallow and deep footing systems dependant on the development and structural bearing pressure required. Refer to **Section 8.1** and **Section 8.2** below for recommended allowable bearing pressure parameters.

8.1 Shallow Footings

A maximum allowable bearing capacity of 100kPa is recommended at the site for shallow level footings founded within stiff clay soils, below topsoil or other deleterious material (e.g. root affected soils, soft / loose soils, silt soils, uncontrolled fill etc).

If weathered rock is exposed at the base of the excavation of footings it is recommended that the rest of the footing system be piered / taken to bedrock to reduce the risk of differential settlement.

The footing systems must be designed by a structural engineer in accordance with engineering principles and AS 2870 - 2011 “Residential Slabs and Footings” for no less than the minimum requirements for the site classification and soil reactivity given as per **Section 7.2** above.

8.2 Deep Footings

The site is suitable for bored piers with an approximate allowable end bearing pressures and shaft adhesion estimated below in **Table 8.1**.

Table 8.1 - Summary of allowable end bearing pressures and shaft adhesion for deep footings

Soil strata	Typical depth encountered	Allowable shaft adhesion (kPa)	Allowable end bearing pressure (kPa)
Residual Silty Sandy CLAY	From surface to up to 2.5m	20	150
Extremely Weathered and Weathered SANDSTONE	>0.3m (rock depth is deeper towards stormwater channel)	40	500

The bearing pressures presented above have been correlated from Dynamic Cone Penetration (DCP) or tests and should be considered as estimates only. Bearing pressures of all exposed foundation areas should be confirmed at the time of earthworks and prior to concrete pour by a qualified Geotechnical Engineer.

8.3 Footing Construction

All footings should be excavated, cleaned and inspected by a qualified Geotechnical Engineer. Concrete should be poured with minimal delay. If delays in pouring mass concrete footings is anticipated, a concrete blinding layer should be provided to protect the foundation material.

Should softening of exposed foundation occur, the effected material should be over excavated and backfilled to design footing level by engineered fill or mass concrete.

8.4 Ongoing Footing Maintenance

Foundations including effective site drainage are required to be maintained over the life of the development to ensure footing performance. Refer to **Annex D** for the following:

- BTF 18-2011- CSIRO - Foundation Maintenance and Footing Performance – A Homeowner's Guide.

9 Earthworks

Any earthworks conducted at the site should be controlled in accordance with AS3798-2007 and guided by the sections below.

9.1 Site Preparation

It is recommended that the following be undertaken where controlled filling is to be undertaken:

- remove all topsoil, root effected zones, material assessed as unsuitable and other deleterious zones (noting the stripped soil is not considered suitable as engineered fill but may be considered for landscaping purposes);
- exposed suitable foundation areas should then be ripped 300mm and re-compacted to 100% standard maximum dry density (SMDD) at $\pm 2\%$ of optimum moisture content (OMC);
- the foundation area should then be proof rolled under the supervision of an experienced geotechnical consultant and any soft spots / heaving areas identified. If identified these areas should be over excavated under the direction of the geotechnical consultant and replaced with engineered fill.

9.2 Controlled Fill

Any earthworks conducted at the site should be controlled in accordance with AS3798-2007. Based on the soil profile shown above in **Section 5**, visual observations and in-situ Dynamic Cone Penetrometer (DCP) testing, the material encountered at the site is deemed unsuitable for reuse as controlled fill. If the sub-surface conditions encountered at the site during construction differ from those discussed in **Section 5** HC should be consulted to determine if the material is suitable for controlled fill. Similarly, any won

material imported from external sites should consult HC to determine if the fill is suitable for controlled fill.

9.2.1 Compaction Criteria

Fill material should be compacted in near-horizontal uniform layers with a maximum compacted thickness of 300mm. It is important to ensure layers are placed in such a way that provides adequate drainage and prevent ponding during construction. The thickness of fill placed during construction should take into account the compaction equipment available.

The moisture of the fill material should be controlled within a specified range of OMC in order to achieve the compaction criteria. In general, soils should be compacted within a moisture range of $\pm 2\%$ of OMC.

For commercial developments the following compaction criteria applies:

- cohesive soils – 98% Minimum Density Ratio (standard compactive effort);
- non-cohesive soils – 75% Minimum Density Index.

A suitably qualified geotechnical professional must be consulted to determine that the specified compaction has been achieved.

9.3 Excavations Conditions

Excavations within the fill, natural soils and extremely low to very low strength rock that was encountered during the investigations is thought to be achievable with conventional earthmoving equipment such excavators, backhoes and dozers. Very low to low strength rock may also require ripper tyres attached to excavator arms or dozers for effective excavation. Rock of low strength or greater may possibly require a 12-tonne excavator (or greater) with rock ripper or hydraulic rock hammer, depending on the degree of strength and fracturing in the rock. Excavations in rock would require minimising vibration to neighbouring residences and structures, else other methods may be required (for example pre-drilling the rock, rock sawing using diamond wire saw equipment, grinding or engaging a rock breaking and removal specialist).

Bored piers could be drilled using a 12-tonne excavator or greater with an attached auger. It is recommended that the bottom of bored pier holes should be cleaned out with the excavator fitted with a bucket attachment.

Excavations should be conducted in accordance with The Safe Work Australia “Excavation Work” Code of Practice March 2015.

<https://www.safeworkaustralia.gov.au/system/files/documents/1705/mcop-excavation-work-v3.pdf>

Excavations can seriously affect the stability of adjacent buildings. Careful consideration must be taken in order to prevent the collapse of partial collapse of adjacent structures.

Construction material and equipment should not be placed within the zone of influence of an excavation unless a suitably qualified geotechnical engineer has designed ground support structures to withstand these loads. The zone of influence is dependent on the material encountered at the site and is the area in which possible failures can occur.

Refer to Council development guidelines before conducting any excavation works.

9.4 Batter Slopes

9.4.1 Temporary Batter Slopes

Temporary excavations in natural material or extremely low to very low strength rock may be near vertical provided that:

- the depth does not exceed 1.5m;
- they are open for no more than 24hrs;
- no surcharge loading is applied to the surface within 2.5m of the excavation;
- no one enters the excavation e.g. workers.

All other temporary batter slopes during construction should not exceed 1H:1V in soils and 1H:4V in rock and benched, planned and managed in accordance with Safe Work Australia Excavation Work Code of Practice March 2015.

9.4.2 Permanent Batter Slopes

Recommended permanent batter slopes in general are as follows:

- 2H:1V in cohesive soils (e.g. clays) or extremely to very low weathered rock else retained by an engineered retaining wall;
- 3H:1V in non-cohesive soils (e.g. sands) else retained by an engineered retaining wall;
- 1H:1V in low strength rock or greater (permanent rock batters may be steepened to near vertical – subject to inspection by a qualified geotechnical engineer).

10 Report Limitations

This report has been prepared by Hunter Civilab (HC) for the specific site and purposes described within this report. HC will accept no responsibility or liability for the use of this report by any third party, without the express consent of HC or the Client, or for use at any other site or purpose than that described in this report.

This report and the services provided have been completed in accordance with relevant professional and industry standards of interpretation and analysis. This report must be read in its entirety without separation of pages or sections and without any alterations, other than those provided by HC.

The scope of the investigation described in this report is based on information and plans provided to HC by the Client as well as any additional limitations imposed by either the Client and / or site restraints. Such limitations may include but are not limited to budget restraints, the presence of underground services or accessibility issues to a site. Where the report has been prepared for a specific design proposal the information and interpretation may not be relevant if the design proposal is changed. HC should be consulted if site plans or design proposal is changed as the recommendations and / or opinions presented may not be suitable for the new revisions or variations made.

The conclusions, recommendations and opinions expressed within this report are subject to the specific conditions encountered and the limited geotechnical data gathered at the site during the time of the current investigation. The sub-surface conditions and results presented in this report are indicative of the conditions encountered at the discrete sampling and testing locations within the site at the time of the investigation and within the depths investigated. Variations in ground conditions may exist between the locations that were investigated, and the subsurface profile cannot be inferred or extrapolated from the limited investigation conducted by HC. For this reason, the report must be regarded as interpretative, rather than a factual document.

Sub-surface conditions are subject to constant change and can vary abruptly as a result of human influences and /or natural geological and / or climatic processes and events. As such, conditions may exist at the site that could not be identified during or may develop after the current investigation has been conducted and as such, may impact the accuracy of this report. HC should be contacted for further consultation and site re-assessment should sub-surface conditions differ from those conditions identified in this report.

We are pleased to present this report and trust that the recommendations provided are sufficient for your present requirements. If you have any further questions about this report, please contact the undersigned.

For and on behalf of

Valley Civilab Pty Ltd, trading as Hunter Civilab

Reported by:



Matthew Lay

Senior Geotechnical Engineer
Bachelor of Engineering (Civil)

Reviewed by:



Nathan Roberts

Geotechnical Engineering Manager
Bachelor of Engineering (Civil)

References:

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Annex A



Note: Overhead image taken from SIX Maps

Figure 1 – Overhead image of 17 Mackay Street, Dungog showing the approximate location of boreholes.



Annex B



Annex C

Material Test Report

Report Number: P21419-1
Issue Number: 1
Date Issued: 25/02/2021
Client: Dungog Shire Council
PO Box 95, Dungog NSW 2420
Project Number: P21419
Project Name: Geotechnical Investigation
Project Location: Dungog Library, 17 Mackay Street, Dungog
Work Request: 2775
Sample Number: 21-2775A
Date Sampled: 17/02/2021
Dates Tested: 17/02/2021 - 25/02/2021
Sampling Method: Sampled by Engineering Department
The results apply to the sample as received
Remarks: Variation to the test method: Readings between some shrink & swell measurements exceed 12 hours.
Sample Location: BH3, Depth: 0.5-0.85m
Material Source: U50



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Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: Grant Burgess
Senior Technician
NATA Accredited Laboratory Number: 14975

Shrink Swell Index (AS 1289 7.1.1 & 2.1.1)

Iss (%)	5.0
Visual Description	CLAY trace silt & gravel, brown
* Shrink Swell Index (Iss) reported as the percentage vertical strain per pF change in suction.	

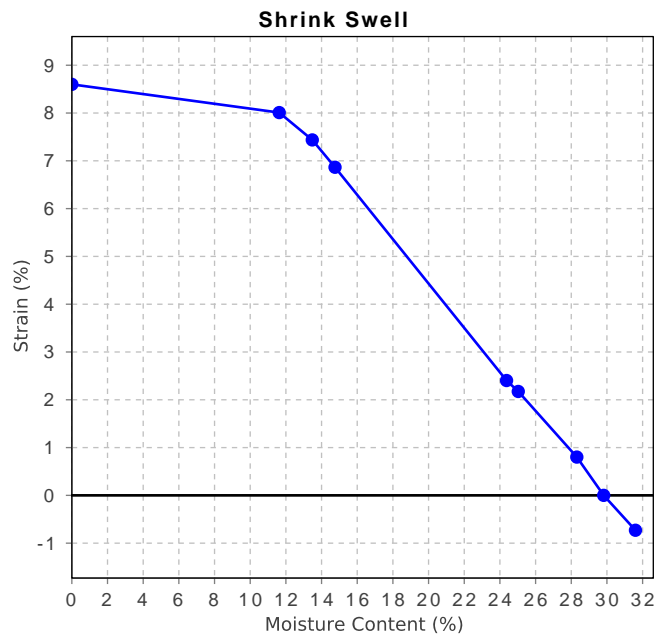
Core Shrinkage Test

Shrinkage Strain - Oven Dried (%)	8.6
Estimated % by volume of significant inert inclusions	5
Cracking	Slightly Cracked
Crumbling	No
Moisture Content (%)	29.8

Swell Test

Initial Pocket Penetrometer (kPa)	130
Final Pocket Penetrometer (kPa)	100
Initial Moisture Content (%)	28.9
Final Moisture Content (%)	31.6
Swell (%)	0.7

* NATA Accreditation does not cover the performance of pocket penetrometer readings.





Annex D

Foundation Maintenance and Footing Performance: A Homeowner's Guide



PUBLISHING

BTF 18-2011
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 2870-2011, 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, which may experience only slight ground movement from moisture changes
M	Moderately reactive clay or silt sites, which may experience moderate ground movement from moisture changes
H1	Highly reactive clay sites, which may experience high ground movement from moisture changes
H2	Highly reactive clay sites, which may experience very high ground movement from moisture changes
E	Extremely reactive sites, which may experience extreme ground movement from moisture changes

Notes

1. Where controlled fill has been used, the site may be classified A to E according to the type of fill used.
2. Filled sites. Class P is used for sites which include soft fills, such as clay or silt or loose sands; landslide; mine subsidence; collapsing soils; soil subject to erosion; reactive sites subject to abnormal moisture conditions or sites which cannot be classified otherwise.
3. Where deep-seated moisture changes exist on sites at depths of 3 m or greater, further classification is needed for Classes M to E (M-D, H1-D, H2-D and E-D).

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 perpend).

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

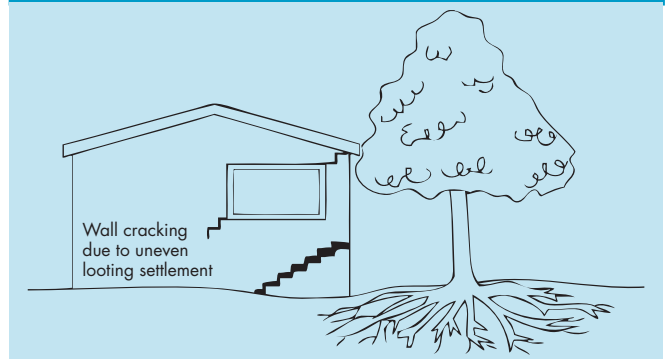
Swelling foundation soil due to rainy periods first lifts the most exposed extremities of the footing system, then the remainder of the perimeter footings while gradually permeating inside the building footprint to lift internal footings. This swelling first tends to create a dish effect, because the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

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

Trees can cause shrinkage and damage



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 causes 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 2870-2011.

AS 2870-2011 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.

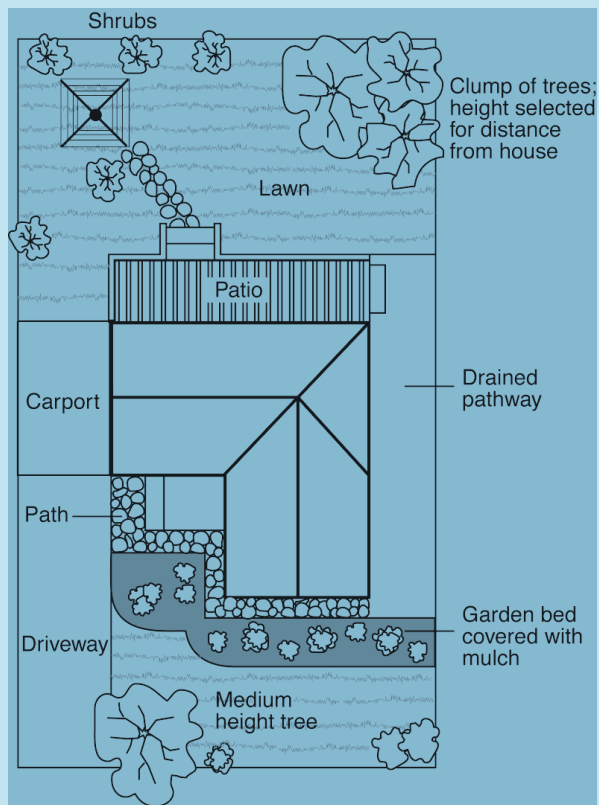
Protection of the building perimeter

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 should

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 depends on number of cracks	4

Gardens for a reactive site



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.

The information in this and other issues in the series was derived from various sources and was believed to be correct when published.

The information is advisory. It is provided in good faith and not claimed to be an exhaustive treatment of the relevant subject.

Further professional advice needs to be obtained before taking any action based on the information provided.

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