Site Classification

Neilson Street, Edgeworth – Stage 11

Report Ref: G0109-SC-001-Rev1

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Prepared for

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Project Details

Site Address:	Neilson Street, Edgeworth – Stage 11	
Project Type:	Site Classification	
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Report Register

Revision Number	Reported By	Reviewed By	Date
Rev0	JR	DB	28/02/2023
Rev1	JR	NR	01/03/2023

We confirm that the following report has been produced for Edgeworth Developments, based on the described methods and conditions within.

For and on behalf of Hunter Civilab,

Nathan Roberts
Geotechnical Engineering Manager

Table of Contents

Annex List:

Annex A – Borehole Location Plan

Annex B – Falling Weight Penetrometer Results

Annex C – Hunter Civilab Laboratory Test Report

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

1 Background Information

This limited geotechnical investigation report has been prepared by Hunter Civilab (HC) for Edgeworth Developments to provide a Site Classification at Neilson Street, Edgeworth – Stage 11 for the development of proposed residential lots.

The following report should be read in conjunction with the Level 1 supervision and testing report undertaken at the site (HC report ref: P22721-L1R-001_Rev 0, dated 13/02/2023).

1.1 Desktop Study - Mine Subsidence

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

2 Site Description

At the time of the investigation, the existing development at the site consisted of undeveloped lots. Access to the proposed areas of development were unrestricted for the use of a Trailer Mounted Drill Rig to undertake the limited investigation. Topographically the site consisted of minor slopes from right to left.

3 Subsurface Conditions

A summary of the subsurface soil conditions encountered during the limited geotechnical investigation can be found below in **Table 3.2** to **Table 3.1** with the results of the Falling Weight Penetrometer tests found in **Annex B.**

Table 3.2 - Summary of borehole BH1 field logs.

Borehole: BH1 **Fieldwork By:** SH	**Location**: Refer to site plan **Date Logged:** 20/02/2023 **Date Sampled:** N/A	
Depth	**Material Description (soil type, colour, moisture)**	**Strength**
0.0 – 1.1	FILL: Sandy Silty CLAY, light grey / yellow / brown, with gravel, semi-moist	-
1.1 – 1.8	FILL: Sandy Silty CLAY, light grey / green / brown, trace gravel, semi-moist to moist	-
1.8 – 3.0	Sandy Silty CLAY, light grey / green / brown, trace gravel, moist	Stiff to Very Stiff
Borehole BH1 terminated at 3.0m.		

Table 3.3 - Summary of borehole BH2 field logs.

Borehole: BH2	**Location**: Refer to site plan	
Logged By: SH	**Date Logged:** 20/02/2023	**Date Sampled:** 20/02/2023
Depth	**Material Description (soil type, colour, moisture)**	**Strength**
0.0 – 1.0	FILL: Sandy Silty CLAY, light grey / yellow / brown, with gravel, semi-moist	-
1.0 – 1.4	FILL: Sandy CLAY, light grey / yellow / white, with gravel, dry to semi-moist	-
1.4 – 3.0	Sandy Silty CLAY, light grey / green / brown, trace gravel, semi-moist to moist	Stiff
Borehole BH2 terminated at 3.0m. Sample obtained at a depth of 1.4m to 1.5m.		

Table 3.4 - Summary of borehole BH3 field logs.

Borehole: BH3	**Location**: Refer to site plan	
Logged By: SH	**Date Logged:** 20/02/2023	**Date Sampled:** N/A
Depth	**Material Description (soil type, colour, moisture)**	**Strength**
0.0 – 0.6	FILL: Sandy Silty CLAY, dark grey / brown / white, with gravel, dry to semi-moist	-
0.6 – 1.0	FILL: Sandy Silty CLAY, light grey / yellow / brown, trace gravel, semi-moist to moist	-
1.0 – 1.4	FILL: Sandy CLAY, light grey / yellow / white, trace gravel, dry to semi-moist	-
1.4 – 3.0	Sandy Silty CLAY, light grey / brown, trace gravel, semi-moist to moist	Very Stiff
Borehole BH3 terminated at 3.0m.		

Table 3.5 - Summary of borehole BH4 field logs.

Borehole: BH4	**Location**: Refer to site plan	
Logged By: SH	**Date Logged:** 20/02/2023	**Date Sampled:** 20/02/2023
Depth	**Material Description (soil type, colour, moisture)**	**Strength**
0.0 – 0.6	FILL: Sandy Silty CLAY, dark grey / brown / white, with gravel, dry to semi-moist	-
0.6 – 1.0	FILL: Sandy CLAY, light grey / brown / white, with gravel, dry to semi-moist	-
1.0 – 2.0	Sandy Silty CLAY, dark grey / brown, trace gravel, semi-moist	Firm to Stiff
2.0 – 2.5	Sandy Silty CLAY, dark grey / brown, trace gravel, semi-moist to moist	Stiff
2.5 – 3.0	CLAY, light grey / yellow / brown, trace silt, trace sand, moist	Very Stiff
Borehole BH4 terminated at 3.0m. Sample obtained at a depth of 1.2m to 1.4m.		

Table 3.6 - Summary of borehole BH5 field logs.

Borehole: BH5	**Location**: Refer to site plan	
Logged By: SH	**Date Logged:** 20/02/2023	**Date Sampled:** 20/02/2023
Depth	**Material Description (soil type, colour, moisture)**	**Strength**
0.0 – 0.5	FILL: Sandy Silty CLAY, dark grey / brown, trace gravel, dry to semi-moist	-
0.5 – 1.0	FILL: Sandy CLAY, light grey / yellow / white, with weathered sandstone inclusions, dry	-
1.0 – 1.4	FILL: Sandy Silty CLAY, dark grey / black / brown, trace gravel, dry to semi-moist	-
1.4 – 2.4	FILL: Sandy Silty CLAY, dark grey / brown, trace gravel, moist	-
2.4 – 3.0	Sandy Silty CLAY, light grey / brown, moist	Stiff to Very Stiff
Borehole BH5 terminated at 3.0m. Sample obtained at a depth of 1.4m to 1.5m.		

Table 3.7 - Summary of borehole BH6 field logs.

Borehole: BH6 **Logged By:** SH	**Location**: Refer to site plan **Date Logged:** 20/02/2023 **Date Sampled:** N/A	
Depth	**Material Description (soil type, colour, moisture)**	**Strength**
0.0 – 0.5	FILL: Sandy Silty CLAY, dark grey / brown, trace gravel, dry to semi-moist	-
0.5 – 1.0	FILL: Sandy CLAY, light grey / yellow / white, with weathered sandstone inclusions, dry	-
1.0 – 1.4	FILL: Sandy Silty CLAY, dark grey / black / brown, trace gravel, dry to semi-moist	-
1.4 – 2.4	FILL: Sandy Silty CLAY, dark grey / brown, trace gravel, moist	-
2.4 – 3.0	Sandy Silty CLAY, light grey / brown, moist	Stiff to Very Stiff
Borehole BH6 terminated at 3.0m.		

Table 3.8 - Summary of borehole BH7 field logs.

Borehole: BH7 **Logged By:** SH	**Location**: Refer to site plan **Date Logged:** 20/02/2023 **Date Sampled:** N/A	
Depth	**Material Description (soil type, colour, moisture)**	**Strength**
0.0 – 0.6	FILL: Sandy CLAY, light grey / yellow / brown, trace gravel, dry	-
0.6 – 1.2	FILL: Sandy CLAY, light grey / orange / brown, trace gravel, dry to semi-moist	-
1.2 – 1.6	Sandy Silty CLAY, light grey / yellow / brown, trace gravel, moist	Stiff
1.6 – 3.0	Sandy CLAY, dark grey / brown, moist	Stiff
Borehole BH7 terminated at 3.0m.		

Table 3.9 - Summary of borehole BH8 field logs.

Borehole: BH8	**Location**: Refer to site plan	
Logged By: SH	**Date Logged:** 20/02/2023	**Date Sampled:** 20/02/2023
Depth	**Material Description (soil type, colour, moisture)**	**Strength**
0.0 – 0.5	FILL: Sandy CLAY, dark grey / orange / yellow / brown, with weathered sandstone inclusions, trace gravel, dry	-
0.5 – 1.5	Sandy CLAY, light grey / brown, trace gravel, semi-moist	Firm to Stiff
1.5 – 2.0	Sandy CLAY, light grey / red / yellow, with weathered sandstone inclusions, semi-moist	Stiff
2.0 – 2.5	Sandy CLAY, light grey / yellow / brown, trace gravel, moist	Stiff
2.5 – 3.0	Sandy CLAY, dark grey / brown, trace gravel, moist	Stiff
Borehole BH8 terminated at 3.0m. Sample obtained at a depth of 0.8m to 1.0m.		

Table 3.10 - Summary of borehole BH9 field logs.

Borehole: BH9	**Location**: Refer to site plan	
Logged By: SH	**Date Logged:** 20/02/2023	**Date Sampled:** 20/02/2023
Depth	**Material Description (soil type, colour, moisture)**	**Strength**
0.0 – 0.3	FILL: Sandy Silty CLAY, dark grey / brown, trace gravel, dry	-
0.3 – 0.5	FILL: Sandy CLAY, light grey / orange / yellow, with weathered sandstone inclusions, dry	-
0.5 – 1.5	FILL: Sandy CLAY, light grey / yellow, trace gravel, dry to semi-moist	-
1.5 – 2.2	Sandy CLAY, dark grey / brown, trace gravel, moist	Stiff
2.2 – 3.0	Sandy CLAY, light grey / brown / white, trace gravel, moist	Stiff to Very Stiff
Borehole BH9 terminated at 3.0m. Sample obtained at a depth of 1.0m to 1.2m.		

Table 3.11 - Summary of borehole BH10 field logs.

Borehole: BH10	**Location**: Refer to site plan	
Logged By: SH	**Date Logged:** 20/02/2023	**Date Sampled:** N/A
Depth	**Material Description (soil type, colour, moisture)**	**Strength**
0.0 – 0.4	FILL: Sandy Silty CLAY, dark grey / yellow / brown, with gravel, semi-moist	-
0.4 – 1.1	FILL: Sandy CLAY, light grey / yellow / brown, trace gravel, dry to semi-moist	-
1.1 – 1.8	FILL: Sandy CLAY, light grey / yellow / brown, trace gravel, semi-moist	-
1.8 – 2.1	Sandy Silty CLAY, dark grey / green / brown, trace gravel, moist	Stiff to Very Stiff
2.1 – 2.3	Extremely Weathered SANDSTONE, light grey / yellow / white, dry	Inferred extremely low strength
Borehole BH10 refusal at 2.3m.		

Table 3.12 - Summary of borehole BH11 field logs.

Borehole: BH11	**Location**: Refer to site plan	
Logged By: SH	**Date Logged:** 20/02/2023	**Date Sampled:** 20/02/2023
Depth	**Material Description (soil type, colour, moisture)**	**Strength**
0.0 – 0.3	FILL: Sandy Silty CLAY, dark grey / brown, trace gravel, semi-moist	-
0.3 – 1.2	FILL: Sandy CLAY, light grey / brown, trace gravel, dry to semi-moist	-
1.2 – 1.5	Sandy CLAY, dark grey / yellow / brown, trace gravel, semi-moist	Stiff
1.5 – 1.7	Weathered SILTSTONE, dark grey / yellow / brown, dry	Inferred extremely low strength
Borehole BH11 refusal at 2.3m. Sample obtained at a depth of 0.9m to 1.1m.		

Table 3.13 - Summary of borehole BH12 field logs.

Borehole: BH12 **Logged By:** SH	**Location**: Refer to site plan **Date Logged:** 20/02/2023	**Date Sampled:** N/A
Depth	**Material Description (soil type, colour, moisture)**	**Strength**
0.0 – 0.3	FILL: Sandy Silty CLAY, dark grey / brown, trace gravel, semi-moist	-
0.3 – 1.2	FILL: Sandy CLAY, light grey / brown, trace gravel, dry to semi-moist	-
1.2 – 1.5	Sandy CLAY, dark grey / yellow / brown, trace gravel, semi-moist	Stiff
1.5 – 1.7	Sandy CLAY, light grey / white, with weathered sandstone inclusions, moist	Stiff
1.7 – 2.0	Extremely Weathered SANDSTONE, light yellow / brown, dry	Inferred extremely low strength
Borehole BH12 refusal at 2.0m.		

Table 3.14 - Summary of borehole BH13 field logs.

Borehole: BH13 **Logged By:** SH	**Location**: Refer to site plan **Date Logged:** 20/02/2023	**Date Sampled:** 20/02/2023
Depth	**Material Description (soil type, colour, moisture)**	**Strength**
0.0 – 0.4	FILL: Sandy Silty CLAY, dark grey / brown, trace gravel, semi-moist	-
0.4 – 1.4	FILL: Sandy CLAY, light grey / brown, trace gravel, dry to semi-moist	-
1.4 – 1.9	Sandy CLAY, dark grey / orange / yellow, trace gravel, moist	Stiff to Very Stiff
1.9 – 2.2	Extremely Weathered SANDSTONE, light yellow / brown, dry	Inferred extremely low strength
Borehole BH13 refusal at 2.2m. Sample obtained at a depth of 0.8m to 1.0m.		

Table 3.15 - Summary of borehole BH14 field logs.

Borehole: BH14 **Logged By:** SH	**Location**: Refer to site plan **Date Logged:** 20/02/2023	**Date Sampled:** N/A
Depth	**Material Description (soil type, colour, moisture)**	**Strength**
0.0 – 1.1	FILL: Sandy Silty CLAY, dark grey / yellow / brown, trace gravel, moist	-
1.1 – 1.8	Sandy CLAY, light grey / orange / yellow / brown, with weathered sandstone inclusions, semi-moist to moist	Stiff
1.8 – 2.1	Extremely Weathered SANDSTONE, light grey / brown, dry	Inferred extremely low strength
Borehole BH14 refusal at 2.1m.		

Table 3.16 - Summary of borehole BH15 field logs.

Borehole: BH15 **Logged By:** SH	**Location**: Refer to site plan **Date Logged:** 20/02/2023	**Date Sampled:** N/A
Depth	**Material Description (soil type, colour, moisture)**	**Strength**
0.0 – 1.0	FILL: Sandy Silty CLAY, dark grey / yellow / brown, trace gravel, semi-moist	-
1.0 – 1.4	Sandy Silty CLAY, dark grey / brown, trace gravel, moist	Stiff to Very Stiff
1.4 – 1.9	Sandy Silty CLAY, light grey / yellow / brown, semi-moist to moist	Very Stiff
1.9 – 2.7	Sandy Silty CLAY, dark grey / black, trace gravel, semi-moist to moist	Firm to Stiff
2.7 – 3.0	Sandy CLAY, light grey / white, with weathered sandstone inclusions, semi-moist	Stiff
Borehole BH15 terminated at 3.0m.		

Table 3.17 - Summary of borehole BH16 field logs.

Borehole: BH16	**Location**: Refer to site plan	
Logged By: SH	**Date Logged:** 20/02/2023	**Date Sampled:** 20/02/2023
Depth	**Material Description (soil type, colour, moisture)**	**Strength**
0.0 – 0.6	FILL: Sandy Silty CLAY, light grey / brown, trace gravel, dry to semi-moist	-
0.6 – 1.0	FILL: Sandy CLAY, light grey / yellow / brown, trace gravel, semi-moist	-
1.0 – 2.1	Sandy CLAY, dark grey / yellow / brown, moist	Stiff
2.1 – 3.0	Sandy Silty CLAY, dark grey / black / brown, trace gravel, moist	Firm to Stiff
Borehole BH16 terminated at 3.0m. Sample obtained at a depth of 1.0m to 1.2m.		

Table 3.18 - Summary of borehole BH17 field logs.

Borehole: BH17	**Location**: Refer to site plan	
Logged By: SH	**Date Logged:** 20/02/2023	**Date Sampled:** N/A
Depth	**Material Description (soil type, colour, moisture)**	**Strength**
0.0 – 0.6	FILL: Sandy Silty CLAY, dark grey / brown, trace gravel, dry to semi-moist	-
0.6 – 1.1	FILL: Sandy CLAY, light grey / brown, trace gravel, dry to semi-moist	-
1.1 – 2.1	Sandy Silty CLAY, dark grey / yellow / brown, moist	Stiff
2.1 – 3.0	Sandy Silty CLAY, light grey / mottled red / white, trace gravel, dry to semi-moist	Stiff
Borehole BH17 terminated at 3.0m.		

Table 3.19 - Summary of borehole BH18 field logs.

Borehole: BH18	**Location**: Refer to site plan	
Logged By: SH	**Date Logged:** 20/02/2023	**Date Sampled:** 20/02/2023
Depth	**Material Description (soil type, colour, moisture)**	**Strength**
0.0 – 1.3	FILL: Sandy Silty CLAY, dark grey / brown, trace gravel, semi-moist to moist	-
1.3 – 2.0	Sandy CLAY, light grey / mottled red / white, with weathered sandstone inclusions, dry to semi-moist	Firm to Stiff
2.0 – 2.2	Extremely Weathered SANDSTONE, light grey / white, dry	Inferred extremely low strength
Borehole BH18 refusal at 2.2m. Sample obtained at a depth of 1.1m to 1.3m.		

Table 3.20 - Summary of borehole BH19 field logs.

Borehole: BH19	**Location**: Refer to site plan	
Logged By: SH	**Date Logged:** 20/02/2023	**Date Sampled:** N/A
Depth	**Material Description (soil type, colour, moisture)**	**Strength**
0.0 – 0.4	FILL: Sandy Silty CLAY, dark grey / brown, trace gravel, dry to semi-moist	-
0.7 – 0.7	FILL: Sandy Silty CLAY, light grey / yellow / brown, trace gravel, dry	-
0.7 – 1.2	FILL: Sandy Silty CLAY, dark grey / brown, semi-moist to moist	-
1.2 – 1.8	Sandy CLAY, light grey / red / white, with weathered sandstone inclusions, semi-moist to moist	Very Stiff
1.8 – 3.0	Sandy Silty CLAY, dark grey / brown, trace gravel, moist	Stiff
Borehole BH19 terminated at 3.0m.		

Table 3.21 - Summary of borehole BH20 field logs.

Borehole: BH20 **Logged By:** SH	**Location**: Refer to site plan **Date Logged:** 20/02/2023	**Date Sampled:** 20/02/2023
Depth	**Material Description (soil type, colour, moisture)**	**Strength**
0.0 – 1.4	FILL: Sandy Silty CLAY, dark grey / yellow / brown, trace gravel, semi-moist to moist	-
1.4 – 2.0	Sandy CLAY, light grey / white, moist	Stiff
2.0 – 3.0	Sandy Silty CLAY, dark grey / brown, semi-moist to moist	Stiff
Borehole BH20 terminated at 3.0m. Sample obtained at a depth of 1.2m to 1.4m.		

Table 3.22 - Summary of borehole BH21 field logs.

Borehole: BH21 **Logged By:** SH	**Location**: Refer to site plan **Date Logged:** 20/02/2023	**Date Sampled:** 20/02/2023
Depth	**Material Description (soil type, colour, moisture)**	**Strength**
0.0 – 0.7	FILL: Sandy Silty CLAY, light grey / brown, trace gravel, dry	-
0.7 – 1.4	Sandy CLAY, light grey / white, with weathered sandstone inclusions, semi-moist	Firm to Stiff
1.4 – 1.5	Extremely Weathered SANDSTONE, light grey / red / white, dry	Inferred extremely low strength
Borehole BH21 refusal at 1.5m. Sample obtained at a depth of 0.9m to 1.1m.		

Table 3.23 - Summary of borehole BH22 field logs.

Borehole: BH22	**Location**: Refer to site plan	
Logged By: SH	**Date Logged:** 20/02/2023	**Date Sampled:** N/A
Depth	**Material Description (soil type, colour, moisture)**	**Strength**
0.0 – 0.9	FILL: Sandy Silty CLAY, light grey / brown, trace gravel, dry	-
0.9 – 1.2	FILL: Sandy CLAY, light grey / brown, trace gravel, semi-moist to moist	-
1.2 – 1.4	FILL: Sandy Silty CLAY, light grey / orange / brown, with weathered sandstone inclusions, semi-moist to moist	-
1.4 – 2.4	FILL: Sandy Silty CLAY, dark brown, trace gravel, semi-moist to moist	-
2.4 – 3.0	Sandy Silty CLAY, light grey / orange / black, trace gravel, semi-moist to moist	Stiff to Very Stiff
Borehole BH22 terminated at 3.0m.		

Refer to **Annex A** for the borehole location plan.

4 Laboratory Results

8 x disturbed samples and 3 x undisturbed samples were recovered from the boreholes and transported to the Hunter Civilab's NATA accredited soil testing laboratory for analysis.

The results of the laboratory tests are summarised in **Table 4.1** and **Table 4.2** below.

Table 4.1 - Shrink-Swell Index test laboratory results.

Borehole	Depth (m)	Material Description	ISS (%)
BH16	1.0 – 1.2	Sandy CLAY	1.5
BH18	1.1 – 1.3	Sandy CLAY	1.0
BH20	1.2 – 1.4	FILL: Sandy Silty CLAY	1.8

Table 4.2 - Atterberg Limit Test Results

Borehole	Depth (m)	Soil description	Plasticity Index (%)	Linear Shrinkage (%)
BH2	1.4 – 1.5	Sandy Silty CLAY	17	9.5
BH4	1.4 – 1.5	Sandy Silty CLAY	22	5.5
BH5	1.4 – 1.5	Sandy Silty CLAY	18	8.0
BH8	0.8 – 1.0	Sandy CLAY	12	6.0
BH9	1.0 – 1.2	FILL: Sandy Silty CLAY	16	7.0
BH11	0.9 – 1.1	FILL: Sandy CLAY	16	6.5
BH13	0.8 – 1.0	FILL: Sandy CLAY	20	8.5
BH21	0.9 – 1.1	Sandy CLAY	20	9.0

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

5 Site Classification

The site was assessed by a suitably qualified Geotechnical Engineer to determine the Site Classification in accordance with AS2870-2011 "Residential Slabs & Footings". The Site Classification provides an indication of the characteristic surface movement due to shrink-swell properties of the underlying soils and ground moisture variations. The Site Classification provided below in **Table 5.1** is based on review of the subsurface profile and laboratory testing as well as an assessment of the site at the time of the investigation including depths of cut and fill.

Table 5.1 - Site Classification to AS2870:2011 – Residential Slabs and Footings.

Lot	Site Classification	Characteristic Surface Movement (y_s)
1101	Class H1	40mm - 60mm
1102	Class H1	40mm - 60mm
1103	Class H1	40mm - 60mm
1104	Class H1	40mm - 60mm
1105	Class H1	40mm - 60mm
1106	Class H1	40mm - 60mm
1107	Class H1	40mm - 60mm
1108	Class H1	40mm - 60mm
1109	Class H1	40mm - 60mm
1110	Class H1	40mm - 60mm
1111	Class H1	40mm - 60mm

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.

5.1 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.

5.2 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 not been taken into consideration in the characteristic surface movement calculation.

5.3 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.

6 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 classifications provided 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, as such, all classifications provided in this report should be confirmed by a suitably qualified builder, Engineering Geologist or Engineer prior to commencing construction. If the site undergoes any earthworks, which vary the subsurface conditions from those outlined in this report, the site must be reassessed by a suitably qualified Engineering Geologist or Geotechnical Engineer.

The subsurface 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.

Subsurface 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. 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 subsurface 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:

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Geotechnical Engineer
Bachelor of Engineering Technology (Mechanical)
GradCert of Engineering Technology (Civil)

Reviewed by:

Nathan Roberts
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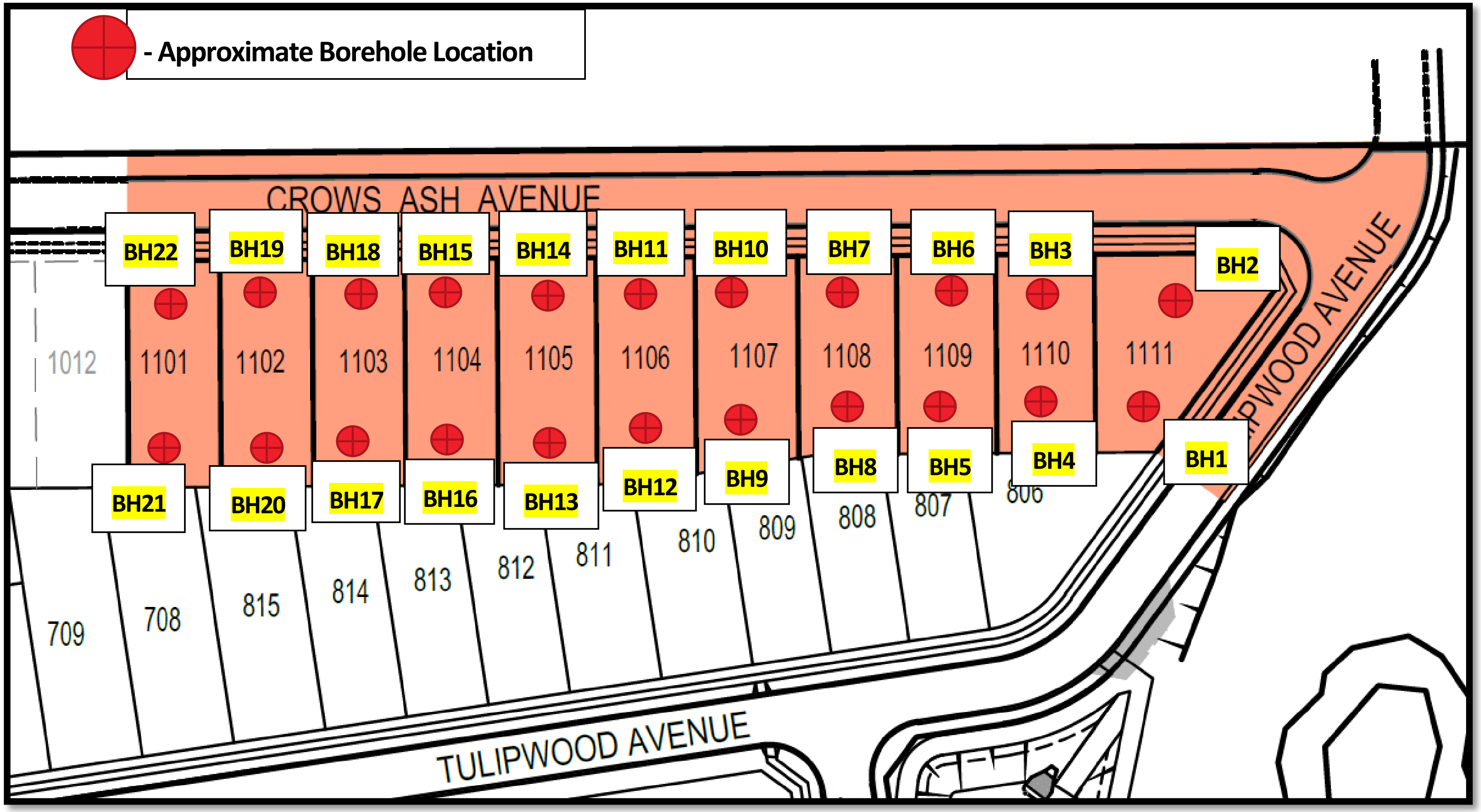
Council of Standards Australia. (2021). *AS4055-2021 Wind Loading for Housing*. Sydney: Standards Australia Limited.

Annex A



Note: *Plan taken from Construction Certificate of Lot 1 and 2 DP1011589, Drawing No. ST11-01, Revision 2, dated 30.09.21*

Figure 1 – Plan of the development at Neilson Street, Edgeworth showing the approximate location of the Geotechnical boreholes.

Annex B

Falling Weight Penetrometer Results

Depth (m)	BH1 DCP	BH2 DCP	BH3 DCP	BH4 DCP	BH5 DCP	BH6 DCP	BH7 DCP	BH8 DCP
0.0 - 0.1	7	6	9	9	12	7	12	10
0.1 - 0.2	6	6	11	11	8	13	11	14
0.2 - 0.3	5	4	8	12	9	6	10	15
0.3 - 0.4	4	8	9	15	11	14	10	16
0.4 - 0.5	5	9	5	3	14	20	9	14
0.5 - 0.6	4	3	6	4	10	20/T	10	20
0.6 - 0.7	4	3	5	5	9		6	12
0.7 - 0.8	4	3	5	6	14		4	12
0.8 - 0.9	5	3	7	10	8		4	10
0.9 - 1.0	3	7	7	12	7		10	10
1.0 - 1.1	3	12	6	14	8		5	9
1.1 - 1.2	5	12	9	15/T	9		10	10
1.2 - 1.3	4	20/T	11		9		8	9
1.3 - 1.4	6		9		10		6	5
1.4 - 1.5	7		10		3		5	15
1.5 - 1.6	9		10/T		4		5	16/T
1.6 – 1.7	10				3		4	
1.7 – 1.8	10				4		4	
1.8 – 1.9	11/T				5		5	
1.9 – 2.0					6		4	
2.0 – 2.1					6		4	
2.1 – 2.2					7		5	
2.2 – 2.3					9		6	
2.3 – 2.4					9/T		8	
2.4 – 2.5							4	
2.5 - 2.6							4	
2.6 - 2.7							3	
2.7 - 2.8							4/T	

Note: *T - Terminated*

Dynamic Cone Penetrometer (DCP) tests were undertaken in accordance with AS 1289.6.3.2-1997.

Falling Weight Penetrometer Results

Depth (m)	BH9 DCP	BH10 DCP	BH11 DCP	BH12 DCP	BH13 DCP	BH14 DCP	BH15 DCP	BH16 DCP
0.0 - 0.1	11	12	13	14	8	12	14	12
0.1 - 0.2	6	8	6	12	4	8	9	10
0.2 - 0.3	4	11	10	8	9	6	11	9
0.3 - 0.4	11	9	9	6	12	4	9	8
0.4 - 0.5	9	8	15	12	14	4	8	9
0.5 - 0.6	8	4	17	14	12	5	6	8
0.6 - 0.7	12	3	18/T	17/T4	15	4	5	7
0.7 - 0.8	7	4			16/T	7	4	7
0.8 - 0.9	8	5				6	6	8
0.9 - 1.0	7	6				5	4	9
1.0 - 1.1	15	9				8	4	5
1.1 - 1.2	16	8				5	4	4
1.2 - 1.3	17/T	10				4	7	4
1.3 - 1.4		12				8	9	5
1.4 - 1.5		14				9	9	5
1.5 - 1.6		14/T				10/T	10/T	5
1.6 – 1.7								5
1.7 – 1.8								6
1.8 – 1.9								7
1.9 – 2.0								8
2.0 – 2.1								8
2.1 – 2.2								8
2.2 – 2.3								8
2.3 – 2.4								9/T

Note: *T - Terminated*

Dynamic Cone Penetrometer (DCP) tests were undertaken in accordance with AS 1289.6.3.2-1997.

Falling Weight Penetrometer Results

Depth (m)	BH17 DCP	BH18 DCP	BH19 DCP	BH20 DCP	BH21 DCP	BH22 DCP
0.0 - 0.1	14	12	8	11	8	10
0.1 - 0.2	12	11	9	10	9	9
0.2 - 0.3	11	10	12	8	10	14
0.3 - 0.4	9	9	12	4	4	15
0.4 - 0.5	10	9	11	12	8	4
0.5 - 0.6	9	8	10	9	9	8
0.6 - 0.7	8	9	9	7	11	10
0.7 - 0.8	7	4	9	6	6	9
0.8 - 0.9	7	10	8	10	5	8
0.9 - 1.0	9	8	8	12	6	8
1.0 - 1.1	9	6	8	14	5	7
1.1 - 1.2	8	5	4	9	7	6
1.2 - 1.3	4	6	4	8	8	8
1.3 - 1.4	4	9	5	8	9/R	9
1.4 - 1.5	5	12	4	6		14
1.5 - 1.6	4	14/T	4	4		8
1.6 – 1.7	4		5	4		4
1.7 – 1.8	4		3	5		4
1.8 – 1.9	5		3	5		5
1.9 – 2.0	5		4	7		4
2.0 – 2.1	8		3	6		6
2.1 – 2.2	9		4	8		8
2.2 – 2.3	11		5	7		9
2.3 – 2.4	12/T		5	4		9/T
2.4 – 2.5			5	5		
2.5 - 2.6			4	6		
2.6 - 2.7			4	4		
2.7 - 2.8			6/T	4/T		

Note: *T – Terminated, R - Refusal*

Dynamic Cone Penetrometer (DCP) tests were undertaken in accordance with AS 1289.6.3.2-1997.

Annex C

Material Test Report

Report Number:	**P22767-114A**
Issue Number:	1
Date Issued:	27/02/2023
Client:	Hunter Civilab 3/62 Sandringham Avenue, Thornton New South Wales 2322
Contact:	Nathan Roberts
Project Number:	P22767
Project Name:	Geotechnical Consulting Services
Project Location:	Neilson Street, Edgeworth - Stage 11
Client Reference:	G0109
Work Request:	10394
Sample Number:	23-10394H
Date Sampled:	20/02/2023
Dates Tested:	21/02/2023 - 27/02/2023
Sampling Method:	AS 1289.1.3.1 3.1.3.2 - Open-drive samplers - thin-walled sampler
Site Selection:	Selected by Client
Sample Location:	**BH16, Depth: 1.0-1.2m**

HUNTER CIVILAB

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NATA WORLD RECOGNISED ACCREDITATION

Accredited for compliance with ISO/IEC 17025 - Testing

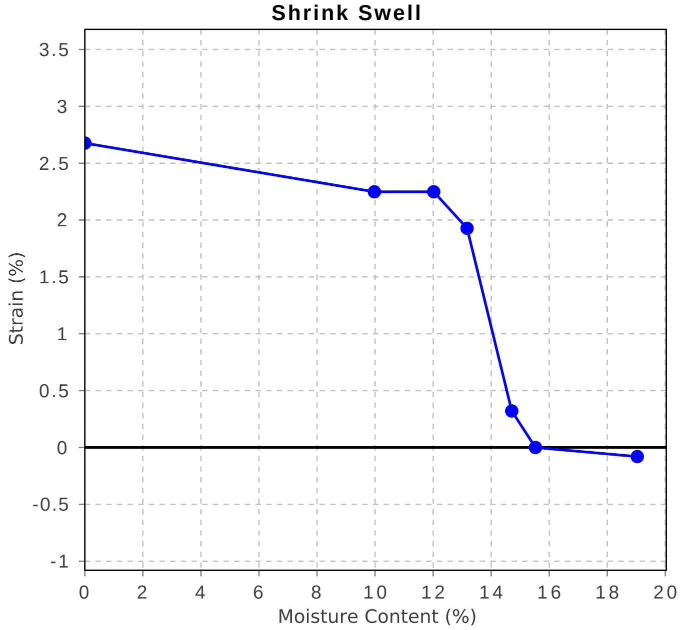
Approved Signatory: Scott Picton
Technician

NATA Accredited Laboratory Number: 14975

Shrink Swell Index (AS 1289 7.1.1 & 2.1.1)	
Iss (%)	**1.5**
Visual Description	Silty Sandy Clay grey
* Shrink Swell Index (Iss) reported as the percentage vertical strain per pF change in suction.	
Variation to the test method: Readings between some shrink & swell measurements exceed 12 hours.	

Core Shrinkage Test	
Shrinkage Strain - Oven Dried (%)	**2.7**
Estimated % by volume of significant inert inclusions	2
Cracking	Uncracked
Crumbling	No
Moisture Content (%)	15.5

Swell Test	
Initial Pocket Penetrometer (kPa)	450
Final Pocket Penetrometer (kPa)	300
Initial Moisture Content (%)	15.9
Final Moisture Content (%)	19.0
Swell (%)	**0.1**
* NATA Accreditation does not cover the performance of pocket penetrometer readings.	



Material Test Report

Report Number:	**P22767-114A**
Issue Number:	1
Date Issued:	27/02/2023
Client:	Hunter Civilab 3/62 Sandringham Avenue, Thornton New South Wales 2322
Contact:	Nathan Roberts
Project Number:	P22767
Project Name:	Geotechnical Consulting Services
Project Location:	Neilson Street, Edgeworth - Stage 11
Client Reference:	G0109
Work Request:	10394
Sample Number:	23-10394J
Date Sampled:	20/02/2023
Dates Tested:	21/02/2023 - 27/02/2023
Sampling Method:	AS 1289.1.3.1 3.1.3.2 - Open-drive samplers - thin-walled sampler
Site Selection:	Selected by Client
Sample Location:	**BH18, Depth: 1.1-1.3m**

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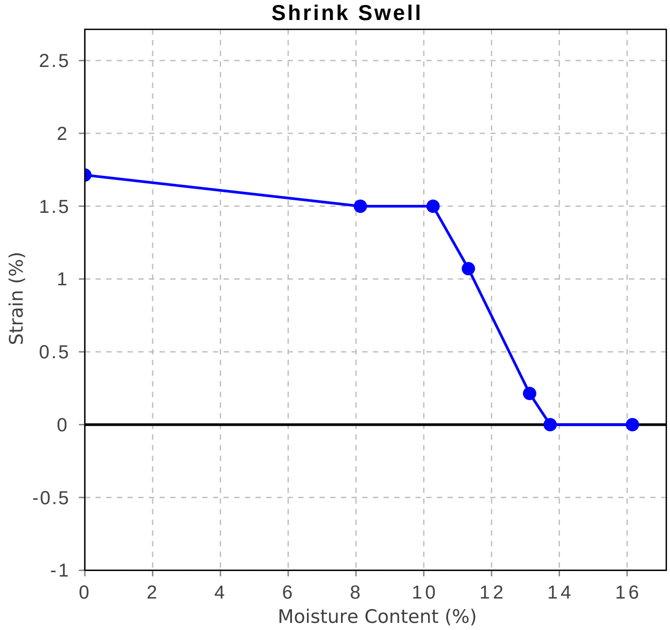
Technician

NATA Accredited Laboratory Number: 14975

Shrink Swell Index (AS 1289 7.1.1 & 2.1.1)	
Iss (%)	**1.0**
Visual Description	Silty Clay trace rock brown
* Shrink Swell Index (Iss) reported as the percentage vertical strain per pF change in suction.	
Variation to the test method: Readings between some shrink & swell measurements exceed 12 hours.	

Core Shrinkage Test	
Shrinkage Strain - Oven Dried (%)	**1.7**
Estimated % by volume of significant inert inclusions	5
Cracking	Uncracked
Crumbling	No
Moisture Content (%)	13.7

Swell Test	
Initial Pocket Penetrometer (kPa)	550
Final Pocket Penetrometer (kPa)	380
Initial Moisture Content (%)	15.0
Final Moisture Content (%)	16.2
Swell (%)	**0.0**
* NATA Accreditation does not cover the performance of pocket penetrometer readings.	



Material Test Report

Report Number: **P22767-114B**
Issue Number: 1
Date Issued: 28/02/2023
Client: Hunter Civilab
3/62 Sandringham Avenue, Thornton New South Wales 2322
Contact: Nathan Roberts
Project Number: P22767
Project Name: Geotechnical Consulting Services
Project Location: Neilson Street, Edgeworth - Stage 11
Client Reference: G0109
Work Request: 10394
Sample Number: 23-10394A
Date Sampled: 20/02/2023
Dates Tested: 21/02/2023 - 28/02/2023
Sampling Method: AS 1289.1.3.1 3.1.3.2 - Open-drive samplers - thin-walled sampler
Site Selection: Selected by Client
Sample Location: **BH02, Depth: 1.4-1.5m**

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Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Oven Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	37		
Plastic Limit (%)	20		
Plasticity Index (%)	**17**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Moisture Condition Determined By	AS 1289.3.1.2		
Linear Shrinkage (%)	**9.5**		
Cracking Crumbling Curling	None		

Material Test Report

Report Number: **P22767-114B**
Issue Number: 1
Date Issued: 28/02/2023
Client: Hunter Civilab
3/62 Sandringham Avenue, Thornton New South Wales 2322
Contact: Nathan Roberts
Project Number: P22767
Project Name: Geotechnical Consulting Services
Project Location: Neilson Street, Edgeworth - Stage 11
Client Reference: G0109
Work Request: 10394
Sample Number: 23-10394B
Date Sampled: 20/02/2023
Dates Tested: 21/02/2023 - 28/02/2023
Sampling Method: AS 1289.1.3.1 3.1.3.2 - Open-drive samplers - thin-walled sampler
Site Selection: Selected by Client
Sample Location: **BH04, Depth: 1.4-1.5m**

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Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Oven Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	40		
Plastic Limit (%)	18		
Plasticity Index (%)	**22**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Moisture Condition Determined By	AS 1289.3.1.2		
Linear Shrinkage (%)	**5.5**		
Cracking Crumbling Curling	Cracking		

Material Test Report

Report Number: **P22767-114B**
Issue Number: 1
Date Issued: 28/02/2023
Client: Hunter Civilab
3/62 Sandringham Avenue, Thornton New South Wales 2322
Contact: Nathan Roberts
Project Number: P22767
Project Name: Geotechnical Consulting Services
Project Location: Neilson Street, Edgeworth - Stage 11
Client Reference: G0109
Work Request: 10394
Sample Number: 23-10394C
Date Sampled: 20/02/2023
Dates Tested: 21/02/2023 - 28/02/2023
Sampling Method: AS 1289.1.3.1 3.1.3.2 - Open-drive samplers - thin-walled sampler
Site Selection: Selected by Client
Sample Location: **BH05, Depth: 1.4-1.5m**

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Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Oven Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	39		
Plastic Limit (%)	21		
Plasticity Index (%)	**18**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Moisture Condition Determined By	AS 1289.3.1.2		
Linear Shrinkage (%)	**8.0**		
Cracking Crumbling Curling	Cracking		

Material Test Report

Report Number:	**P22767-114B**
Issue Number:	1
Date Issued:	28/02/2023
Client:	Hunter Civilab 3/62 Sandringham Avenue, Thornton New South Wales 2322
Contact:	Nathan Roberts
Project Number:	P22767
Project Name:	Geotechnical Consulting Services
Project Location:	Neilson Street, Edgeworth - Stage 11
Client Reference:	G0109
Work Request:	10394
Sample Number:	23-10394D
Date Sampled:	20/02/2023
Dates Tested:	21/02/2023 - 28/02/2023
Sampling Method:	AS 1289.1.3.1 3.1.3.2 - Open-drive samplers - thin-walled sampler
Site Selection:	Selected by Client
Sample Location:	**BH08, Depth: 0.8-1.0m**

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Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Oven Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	33		
Plastic Limit (%)	21		
Plasticity Index (%)	**12**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Moisture Condition Determined By	AS 1289.3.1.2		
Linear Shrinkage (%)	**6.0**		
Cracking Crumbling Curling	Cracking		

Material Test Report

Report Number: **P22767-114B**
Issue Number: 1
Date Issued: 28/02/2023
Client: Hunter Civilab
3/62 Sandringham Avenue, Thornton New South Wales 2322
Contact: Nathan Roberts
Project Number: P22767
Project Name: Geotechnical Consulting Services
Project Location: Neilson Street, Edgeworth - Stage 11
Client Reference: G0109
Work Request: 10394
Sample Number: 23-10394E
Date Sampled: 20/02/2023
Dates Tested: 21/02/2023 - 28/02/2023
Sampling Method: AS 1289.1.3.1 3.1.3.2 - Open-drive samplers - thin-walled sampler
Site Selection: Selected by Client
Sample Location: **BH09, Depth: 1.0-1.2m**

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Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Oven Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	35		
Plastic Limit (%)	19		
Plasticity Index (%)	**16**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Moisture Condition Determined By	AS 1289.3.1.2		
Linear Shrinkage (%)	**7.0**		
Cracking Crumbling Curling	Cracking		

Material Test Report

Report Number: **P22767-114B**
Issue Number: 1
Date Issued: 28/02/2023
Client: Hunter Civilab
3/62 Sandringham Avenue, Thornton New South Wales 2322
Contact: Nathan Roberts
Project Number: P22767
Project Name: Geotechnical Consulting Services
Project Location: Neilson Street, Edgeworth - Stage 11
Client Reference: G0109
Work Request: 10394
Sample Number: 23-10394F
Date Sampled: 20/02/2023
Dates Tested: 21/02/2023 - 28/02/2023
Sampling Method: AS 1289.1.3.1 3.1.3.2 - Open-drive samplers - thin-walled sampler
Site Selection: Selected by Client
Sample Location: **BH11, Depth: 0.9-1.1m**

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Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Oven Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	34		
Plastic Limit (%)	18		
Plasticity Index (%)	**16**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Moisture Condition Determined By	AS 1289.3.1.2		
Linear Shrinkage (%)	**6.5**		
Cracking Crumbling Curling	Cracking		

Material Test Report

Report Number:	**P22767-114B**
Issue Number:	1
Date Issued:	28/02/2023
Client:	Hunter Civilab 3/62 Sandringham Avenue, Thornton New South Wales 2322
Contact:	Nathan Roberts
Project Number:	P22767
Project Name:	Geotechnical Consulting Services
Project Location:	Neilson Street, Edgeworth - Stage 11
Client Reference:	G0109
Work Request:	10394
Sample Number:	23-10394G
Date Sampled:	20/02/2023
Dates Tested:	21/02/2023 - 28/02/2023
Sampling Method:	AS 1289.1.3.1 3.1.3.2 - Open-drive samplers - thin-walled sampler
Site Selection:	Selected by Client
Sample Location:	**BH13, Depth: 0.8-1.0m**

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Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Oven Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	42		
Plastic Limit (%)	22		
Plasticity Index (%)	**20**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Moisture Condition Determined By	AS 1289.3.1.2		
Linear Shrinkage (%)	**8.5**		
Cracking Crumbling Curling	Cracking		

Material Test Report

Report Number:	**P22767-114B**
Issue Number:	1
Date Issued:	28/02/2023
Client:	Hunter Civilab 3/62 Sandringham Avenue, Thornton New South Wales 2322
Contact:	Nathan Roberts
Project Number:	P22767
Project Name:	Geotechnical Consulting Services
Project Location:	Neilson Street, Edgeworth - Stage 11
Client Reference:	G0109
Work Request:	10394
Sample Number:	23-10394I
Date Sampled:	20/02/2023
Dates Tested:	21/02/2023 - 28/02/2023
Sampling Method:	AS 1289.1.3.1 3.1.3.2 - Open-drive samplers - thin-walled sampler
Site Selection:	Selected by Client
Sample Location:	**BH21, Depth: 0.9-1.1m**

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Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Oven Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	39		
Plastic Limit (%)	19		
Plasticity Index (%)	**20**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Moisture Condition Determined By	AS 1289.3.1.2		
Linear Shrinkage (%)	**9.0**		
Cracking Crumbling Curling	Cracking		

Material Test Report

Report Number:	**P22767-114B**
Issue Number:	1
Date Issued:	28/02/2023
Client:	Hunter Civilab 3/62 Sandringham Avenue, Thornton New South Wales 2322
Contact:	Nathan Roberts
Project Number:	P22767
Project Name:	Geotechnical Consulting Services
Project Location:	Neilson Street, Edgeworth - Stage 11
Client Reference:	G0109
Work Request:	10394
Sample Number:	23-10394K
Date Sampled:	20/02/2023
Dates Tested:	21/02/2023 - 28/02/2023
Sampling Method:	AS 1289.1.3.1 3.1.3.2 - Open-drive samplers - thin-walled sampler
Site Selection:	Selected by Client
Sample Location:	**BH20, Depth: 1.2-1.4m**

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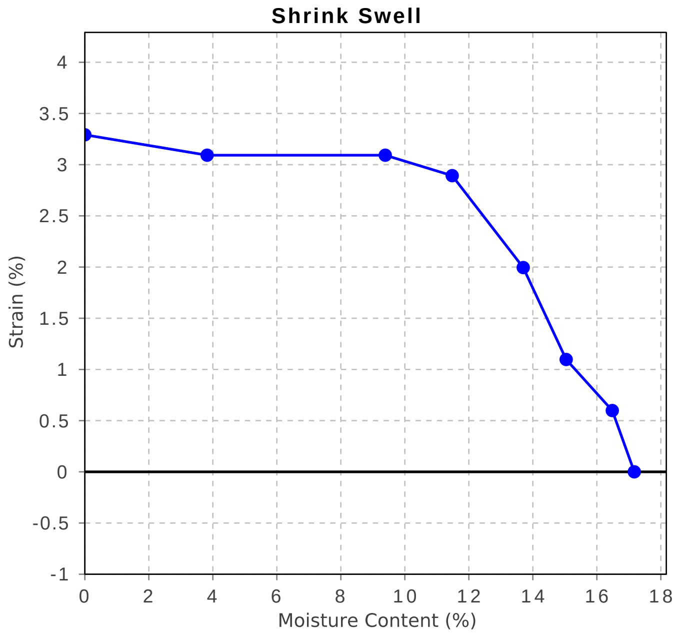
Technician
NATA Accredited Laboratory Number: 14975

Shrink Swell Index (AS 1289 7.1.1 & 2.1.1)	
Iss (%)	**1.8**
Visual Description	Silty Sandy Clay trace rock brown
* Shrink Swell Index (Iss) reported as the percentage vertical strain per pF change in suction.	
Variation to the test method: Readings between some shrink & swell measurements exceed 12 hours.	

Core Shrinkage Test	
Shrinkage Strain - Oven Dried (%)	**3.3**
Estimated % by volume of significant inert inclusions	5
Cracking	Uncracked
Crumbling	No
Moisture Content (%)	17.2

Swell Test	
Initial Pocket Penetrometer (kPa)	425
Final Pocket Penetrometer (kPa)	270
Initial Moisture Content (%)	14.6
Final Moisture Content (%)	
Swell (%)	**0.0**
* 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; landslip; 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 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.

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.

Trees can cause shrinkage and damage

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.

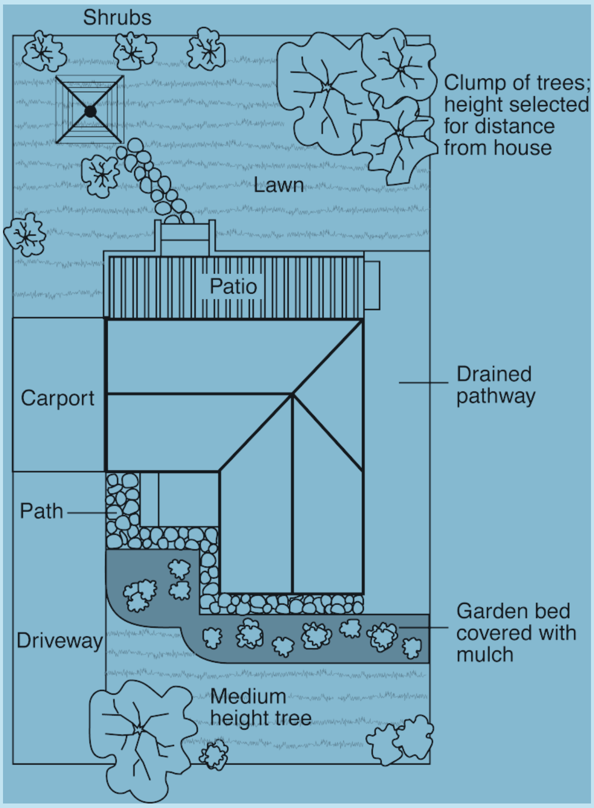
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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.

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