DOYLE SOIL CONSULTING

SITE AND SOIL EVALUATION REPORT

FOUNDATION AND WINDLOADING ASSESSMENT

12 Streamside Way

Kingston

June 2025

Doyle Soil Consulting: 6/76 Auburn Rd Kingston Beach 7050 – 0488 080 455 – robyn@doylesoilconsulting.com.au

SITE INFORMATION

Client: CMH Industries

Address: 12 Streamside Way, Kingston (CT 187971/411)

Site Area: Approximately 250 m^2

Date of inspection: 20/06/2025

Building type: New house

Services: Mains water and sewer

Relevant Planning Overlays: None

Mapped Geology - Mineral Resources Tasmania 1:25 000 Taroona sheet:
Rqp = Sandstone, siltstone, mudstone

Soil Depth: > 3.4 m

Subsoil Drainage: poorly drained

Vegetation: nil

Rainfall in previous 7 days: Approximately 1 mm

Slope: Approximately 3° to the southeast

SITE ASSESSMENT AND SAMPLE TESTING

Site investigation and soil classification in accordance with AS 2870-2011 *Residential slabs and footings* and in accordance with AS 4055-2021 *Wind load for Housing.* Test holes were dug using a Christie Post Driver Soil Sampling Kit, comprising CHPD78 Christie Post Driver with Soil Sampling Tube (50 mm OD x 1600/2100 mm). For test hole and DCP locations, see Appendix 1.

- One test hole (TH) core:
  - TH1 with **no refusal** at 1.9 m
- One Dynamic Cone Penetrometer (DCP) test:
  - DCP1 with **no refusal** at 2.4 m
- Emerson Dispersion test on subsoils and linear shrinkage tests on all likely founding layers.

SOIL PROFILES – Test Hole 1

Depth (m)	Horizon	Description and field texture grade	USCS Class
0.0 – 0.3	FILL	Uncontrolled FILL	
0.3 – 0.4	A1/A2	Very dark greyish brown (2.5Y 3/2) grading to grey (10YR 6/1), **Loamy Fine Sand**, weak fine polyhedral structure, dry loose consistency	**SM**
0.4 – 1.0	$B2_{1g}$	Brownish yellow (10YR 6/6) with grey (10YR 5/1) mottles, **Fine Sandy Medium Clay**, massive, very moist soft consistency, Fe oxides down root channels.	**CH**
1.0 – 1.5	$B2_{2g}$	Mottled light grey (2.5Y 7/1) and yellow (10YR 7/6), **Sandy Silty Light Clay**, massive, moist soft consistency	**CH**
1.5 – 1.9	$B2_3$	Mottled light grey (2.5Y 7/1) and yellow (10YR 7/6), **Sandy Light Clay**, weak coarse angular blocky structure, slightly moist firm to soft consistency, sand down cracks **No Refusal**	**SC/CL**

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SITE AND SOIL COMMENTS

Layers of uncontrolled fill are present on the site to maximum observed depths of 0.5 m.

The soil profiles are formed from windblown sands over clayey colluvium derived from Triassic sandstone. The profiles are deep with effective refusal occurring at approximately 2.4 m. The field textures of the soil profile are dominated by clay, which is highly reactive, weakly structured and mildly dispersive. The clays are poorly drained, evidenced by iron oxides down root channels deep in the soil profile. The DCP indicates a low bearing capacity to at least 2.1 m. Founding on the deeper more competent materials, at or below approximately 3.2 m depth, is recommended.

LINEAR SHRINKAGE AND SOIL REACTIVITY

Samples of the clayey subsoils were tested for reactivity using the linear shrinkage test. Linear shrinkage provides an approximate guide to aid site classification (for foundations) based on the reactivity of clays. The results suggest the clays are highly reactive (refer to tables below and *AS2870-2011 clause 2.1.2 table 2.1*).

TH #	Depth (m)	Length of mould (mm)	Longitudinal Shrinkage (LS) in mm	LS (%)	Soil Class
1	0.4 – 1.0	125	17	13.6	H – 1
1	1.0 – 1.5	125	14	11.2	M
1	1.5 – 1.9	125	12	9.6	M

DCP TESTS AND ESTIMATED BEARING CAPACITY

A minimum bearing capacity of 100 kPa is required for strip and pad footings and under the edge footings and associated slab foundations (refer to tables below and *AS2870-2011 clause 2.4.5*). We provide an estimated allowable soil bearing capacity based on a review of published literature relating field Dynamic Cone Penetrometer (DCP) readings to triaxial soil strength tests.

The DCP penetrometer is a method of estimating *in situ* strength of the soil. Soil moisture level at the time of measurement will greatly affect DCP readings. Moisture-related variability in soil bearing capacity is most pronounced in coherent soils (clays and silty clays) which may be stiff/hard when dry but become soft/firm when moist/slightly moist.

Surface layers (upper ~0.7 m) are subject to seasonal variation in soil moisture content, leading to possible higher DCP values in summer/drought conditions. Soil moisture below ~0.7 m will vary less with the season, meaning DCP values; hence, soil-bearing capacity at these depths is likely to be representative of year-round conditions.

When estimating the suitable foundation depth, we take into account the interplay between soil bearing capacity and seasonally variable soil moisture conditions in the upper layers (refer to *soil consistency* in Soil Profile descriptions). The subsoils in the upper 0.7 m were slightly moist when tested (June ’25).

The data from DCP1 indicate the bearing capacity of the soil is at a *suitable* strength below 2.1 m. However, the deeper and more competent material at and below approximately 3.2 m would be the *recommended* foundation material.

DCP 1				
Depth (mm)	**DCP n-number (Blows/100 mm)**	**DCP Penetration Index (mm/Blow)**	**Estimated Allowable Bearing Capacity (kPa = n x 30)**	**Likely Variance (+/-)**
0 - 100	3	33.3	90	30
100 - 200	5	20.0	150	50
200 - 300	9	11.1	270	90
300 - 400	17	5.9	510	170
400 - 500	12	8.3	360	120
500 - 600	4	25.0	120	40
600 - 700	3	33.3	90	30
700 - 800	3	33.3	90	30
800 - 900	2	50.0	60	20
900 - 1000	2	50.0	60	20
1000 - 1100	2	50.0	60	20
1100 - 1200	3	33.3	90	30
1200 - 1300	5	20.0	150	50
1300 - 1400	4	25.0	120	40
1400 - 1500	4	25.0	120	40
1500 - 1600	4	25.0	120	40
1600 - 1700	3	33.3	90	30
1700 - 1800	3	33.3	90	30
1800 - 1900	5	20.0	150	50
1900 - 2000	7	14.3	210	70
2000 - 2100	9	11.1	270	90
2100 - 2200	10	10.0	300	100
2200 - 2300	15	6.7	450	150
2300 - 2400	15	6.7	450	150
2400 - 2500	13	7.7	390	130
2500 - 2600	9	11.1	270	90
2600 - 2700	9	11.1	270	90
2700 - 2800	11	9.1	330	110
2800 - 2900	11	9.1	330	110
2900 - 3000	13	7.7	390	130
3000 - 3100	14	7.1	420	140
3100 - 3200	14	7.1	420	140
3200 - 3300	18	5.6	540	180
3300 - 3400	17	5.9	510	170

EMERSON AGGREGATE DISPERSION TEST

Soils with an excess of exchangeable sodium ions on the cation exchange complex (clays), can cause clay dispersion. Under some circumstances, the presence of dispersive soils can also lead to significant erosion, and in particular, tunnels leading to eventual gully erosion. Dispersive clay subsoil materials can also cause sealing of the soil surface – if left out in wet weather, they then dry and set very hard in dry weather. A field survey of the property and the surrounding area found no erosion due to soil dispersion.

The subsoil was tested for dispersion using the Emerson Aggregate Test (EAT). Testing resulted in (worst-case) Emerson class 2(2), indicating presence of soils with moderate dispersion characteristics. As such, exposure to rainfall may lead to spontaneous clay dispersion and erosion, as discussed above. To minimise this, we recommend coverage of exposed subsoil with topsoil or regular treatment with gypsum at 1.0 Kg/m^2 along with minimising subsoil disturbance whenever possible.

TH #	Depth (m)	Visual sign	Class
1	0.4 – 1.0	Some dispersion (obvious milkiness < 50% of aggregate affected)	2(2)
1	1.0 – 1.5	Some dispersion (Slight milkiness immediately adjacent to aggregate)	2(1)
1	1.5 – 1.9	Some dispersion (Slight milkiness immediately adjacent to aggregate)	2(1)

WIND CLASSIFICATION

The following wind classification for the site is in accordance with AS 4055-2021 (*Wind loads for Housing*). For structures other than class 1 and class 10 structures, or that exceed the geometric limits in Clause 1.2 of AS 4055-2021, the wind classification shall be calculated in accordance with AS 1170.2-2021 (*Structural Design Actions – Wind Actions)*.

The wind classification for the site, per AS 4055-2021:

Region:	**A**
Terrain Category:	**TC2.5**
Shielding Classification:	**FS – Full shielding**
Topographic Classification:	**T1**
Wind Classification:	**N2**
Design Wind Gust Speed ($V_{h,u}$):	**40 m/sec**

SITE CLASSIFICATION AND RECOMMENDATIONS

For standard foundations (100 kPa bearing capacity), the site meets the criteria for a **Class P** site classification, as set out in AS2870-2011 (*Residential slabs and footings*). This classification is appropriate due to the presence of deep uncontrolled fill to maximum observed depths of approximately 0.5 m (clauses 2.4.5(a)) and materials with low bearing capacity to approximately 2.1 m depth (clause 2.5.3(b)(ii)). Founding on the deeper more competent materials, at or below approximately 3.2 m depth, is recommended.

Note 1 – In addition to the **Class P** site classification, the site/clays meet the reactivity levels of **Class M** or moderately reactive, with 20 – 40 mm the dominant reactivity of expected surface movement under normal soil moisture ranges for the location.

Note 2 – All foundations require ongoing adequate drainage and vegetation management – please refer to the attached CSIRO foundation management BTF 18 sheet.

Note 3 – If any foundations are placed on FILL that is > 0.5 m in depth, then **Class P** is applicable.

Note 4 – Based on the upper 0.6 m of soil, all plumbing fixtures and fittings should be installed using **Class M** as per *Appendix G AS/NZS 3500.2.2021*.

General Notes – Important points pertinent to the maintenance of foundation soil conditions

This report relates to the soil and site conditions on the property at the time of the site assessment. The satisfactory long-term performance of footings is dependent upon ongoing site maintenance by the owner.

Examples of abnormal moisture conditions developing after construction include the following:

A) The effect of trees too close to the footings.
B) Excessive or irregular watering of gardens adjacent to the footings.
C) Failure to maintain site drainage affecting footings.
D) Failure to repair plumbing leaks affecting footings.
E) Loss of vegetation from near the building.

All earthworks on site must comply with AS 3798-2007 Guidelines on Earthworks for commercial and residential developments.

REPORT LIMITATIONS

Whilst every attempt is made to describe sub-surface conditions, natural variation will occur that cannot be determined by limited investigative soil testing. Therefore, discrepancies are possible between test results and observations during construction. It is our intention to accurately indicate the most probable soil type(s) and conditions for the area assessed. However, due to the nature of sampling an area, variations in soil type, soil depth and site conditions may occur.

We accept no responsibility for any differences between what we have reported and actual site and soil conditions for particular regions we could not directly assess at the time of inspection.

It is recommended that during construction, Doyle Soil Consulting and/or the design engineer be notified of any major variation to the foundation conditions as predicted in this report. Any changes to the site through excavations may alter the site classification.

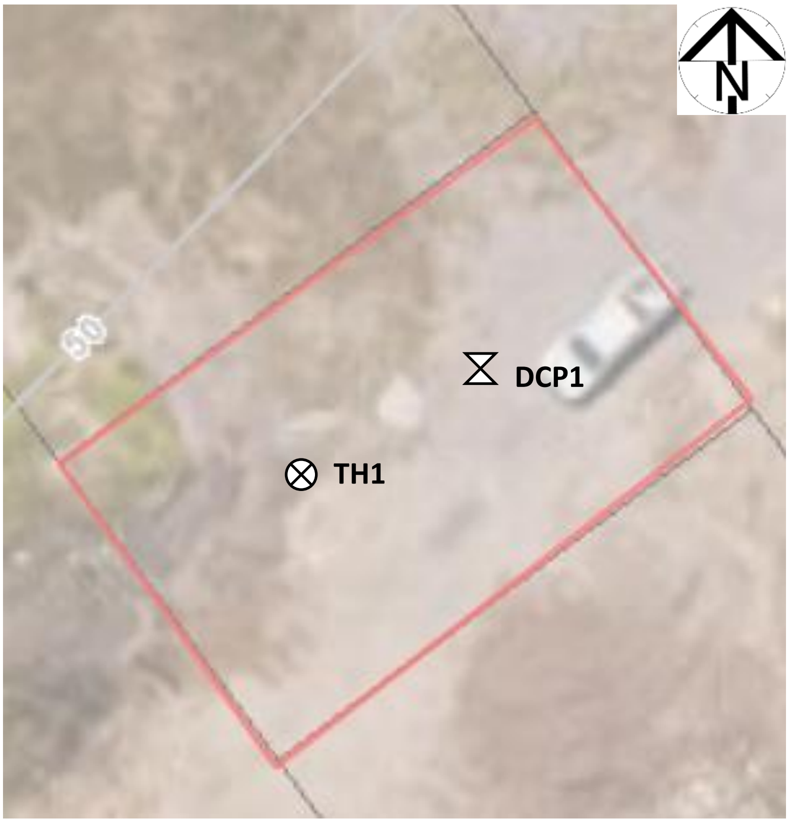
In these cases, it is expected that the owner consults the author for a reclassification. This report requires certification via a form 55 certificate from Doyle Soil Consulting to validate its contents.

Because site discrepancies may occur between this report and actual site conditions, it is a condition of certification of this report that the builder be provided with a copy of this report.

Rowan Mason
B.Agr.Sc.(Hons).
Soil Scientist

Dr. Richard Doyle
B.Sc.(Hons), M.Sc.(Geol), Ph.D. (Soil Sci.),
CPSS (Certified Prof Soil Scientist)
Geologist and Soil Scientist

APPENDIX 1 – Approximate test hole and DCP locations



APPENDIX 2 – Definitions of Soil Horizons

Horizon name	Meaning
A1	Dark topsoils, zone of maximum organic activity
A2 or E	Leached, light/pale washed-out sandy layer
A3 or AB	Transition from A to B, more like A
B1 or BA	Transition from A to B, more like B
B2	Main subsoils layer with brown colouration, accumulations of clay, humus, iron oxide, etc
B3	Transitional from B2 to C
C	Weakly weathered soil parent materials
Subscript	**Meaning**
r	Reducing conditions (anaerobic)
t	Enriched in translocated clay
s	Iron/aluminium oxide accumulations in subsoil
g	Mottled, suggesting periodic/seasonal wetness
m	Cemented layer (oxides, carbonates, humus, silica etc)
k	Calcium carbonate (lime) accumulation
h	Humus accumulation in subsoil

CERTIFICATE OF QUALIFIED PERSON – ASSESSABLE ITEM

Section 321

Form **55**

To:	CMH Industries	*Owner name*
	80 Cowle Rd	*Address*
	Bridgewater TAS 7030	*Suburb/postcode*

Qualified person details:

Qualified person:	Robyn Doyle		
Address:	6/76 Auburn Rd	Phone No:	0488 080 455
	Kingston Beach 7050	Fax No:	
Licence No:	N/A	Email address:	robyn@doylesoilconsulting.com.au

Qualifications and Insurance details:

Certified Professional Soil Scientist (CPSS)
Professional Indemnity cover –

About Underwriting -Lloyd's of London
ENG 21 000305

(description from Column 3 of the Director's Determination - Certificates by Qualified Persons for Assessable Items

Speciality area of expertise:

Classification of foundation conditions according to AS2870-2011

(description from Column 4 of the Director's Determination - Certificates by Qualified Persons for Assessable Items)

Details of work:

Address:	12 Streamside Way	Lot No:	411
	Kingston TAS 7050	Certificate of title No:	187971/411

The assessable item related to this certificate:

Site and soil classification

(description of the assessable item being certified)
Assessable item includes –
- *a material;*
- *a design*
- *a form of construction*
- *a document*
- *testing of a component, building system or plumbing system*
- *an inspection, or assessment, performed*

Certificate details:

Certificate type: Geotechnical Assessment

(description from Column 1 of Schedule 1 of the Director's Determination - Certificates by Qualified Persons for Assessable Items n)

This certificate is in relation to the above assessable item, at any stage, as part of - *(tick one)*

building work, plumbing work or plumbing installation or demolition work: X

or

a building, temporary structure or plumbing installation: ☐

In issuing this certificate the following matters are relevant –

Documents:	The attached Geotechnical Assessment Report for the address detailed above in, 'Details of Work'.
Relevant calculations:	Refer to above report.
References:	AS1726-2017 Geotechnical site investigations CSIRO Building Technology File -18

Substance of Certificate: *(what it is that is being certified)*

Geotechnical Assessment -Site and soil classification

Scope and/or Limitations

The classification applies to the site as inspected and does not account for future alteration to foundation conditions as a result of earthworks, drainage condition changes or variations in site maintenance.

I certify the matters described in this certificate.

	Signed:	*Certificate No:*	*Date:*
Qualified person:		1757	12/06/2025

CERTIFIED PROFESSIONAL SOIL SCIENTIST
CPSS
Ms Robyn Doyle

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.

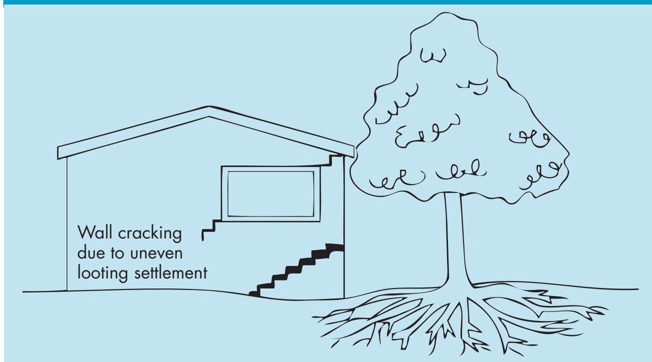
Seasonal swelling/shrinkage in clay
Swelling foundation soil due to rainy periods first lifts the most exposed extremities of the footing system, then the remainder of the perimeter footings while gradually permeating inside the building footprint to lift internal footings. This swelling first tends 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.

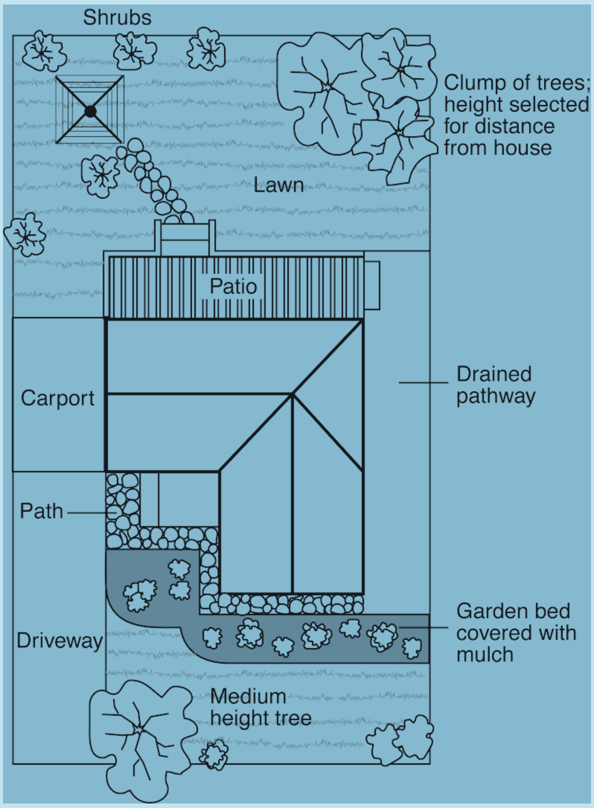
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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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