TAYLOR
CONSULTING ENGINEERS

SOIL CLASSIFICATION REPORT

Site Details			
Address	9 Church Street, Bonnie Doon VIC 3720		
Client	Kate Holdsworth		
Owner/Developer	As Above		
Proposed Development	Additions & Alterations to Existing Dwelling		
Lot Plan	Lot 1 TP921139T	**Property Zoning**	General Residential Zone

Report Details			
Prepared By	Guy Taylor		
Site Investigation Date	29/01/2024	**Report Date**	12 February 2024
Reference No	TCE2404-2023	**Revision**	REV 1 – February 2024

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1. SUMMARY

Taylor Consulting Engineers have been commissioned to carry out a site investigation to obtain site and soil classifications for the owner of 9 CHURCH STREET, BONNIE DOON VIC 3720 for alterations and additions to the existing building (former church) at the site. The investigation was required to provide comment on the following:

- Site and Soil Classification are accordance with AS2870 – 2011 Australian Standard Residential slabs and footings.
- Recommendations for proposed footings design in accordance with AS2870-2011 and/or AS3600-2018.
- Identifying a Wind Classification in accordance with AS4055 – 2006 Wind Loading for housing.
- Other site conditions that may impact the site classification and footing longevity.

1.1 SUMMARY OF SITE SOIL ASSESSMENT

A summary of the assessment results for the site is provided below.

Summary	
Site Classification	Site Classification of “P” in accordance with AS2870-2011
Soil Classification	Soil Classification of “H1” in accordance with AS2870-2011
Wind Rating	“N2” in accordance with AS4055-2012

2. SITE AND REGION DESCRIPTION

2.1 SITE ASSESSMENT & PHOTOS

The key features of the site are summarised in Table 1 below.

Table 1: Site Assessment

Feature	Description
Site conditions	Existing timber building (former church) on a grassed and treed, gently sloping allotment.
Slope	An approximate fall of 1-2° to the N/NW
Drainage	Good-further site drainage works are recommended to be carried out during and at the completion of the building works to control water pooling near footings.
Fill	No fill was observed at the proposed site of construction.
Trees	Currently, there are several medium sized trees within the limit of influence to the proposed site of construction.
Climatic Region	The Bonnie Doon region lies within **Zone 3** of the Climatic Map of Victoria with reference to AS2870- 2011 Australian Standard Residential slabs and footings, with the region predominantly being made up of expansive clay soils. The effect expansive clays have on surface movement in this area is estimated from the Thornthwaite Moisture Index (TMI) for the region **(≥-15 to ≤-5)**. This coincides with a depth of design suction change **(Hs)** of **2.3m**. The soil suction change at the surface (**Δu**) for this climatic zone is **1.2pF**. The field investigation did not encounter any surface cracking in the area.

Photo 1: Proposed site of construction

Photo 2: Soil profile at borehole

2.2 SITE GEOLOGY AND SOIL CLASSIFICATION

The Geological Survey of Victoria maps suggest that the site lies within alluvial terrace deposits of Pleistocene aged sand, gravel and silt.

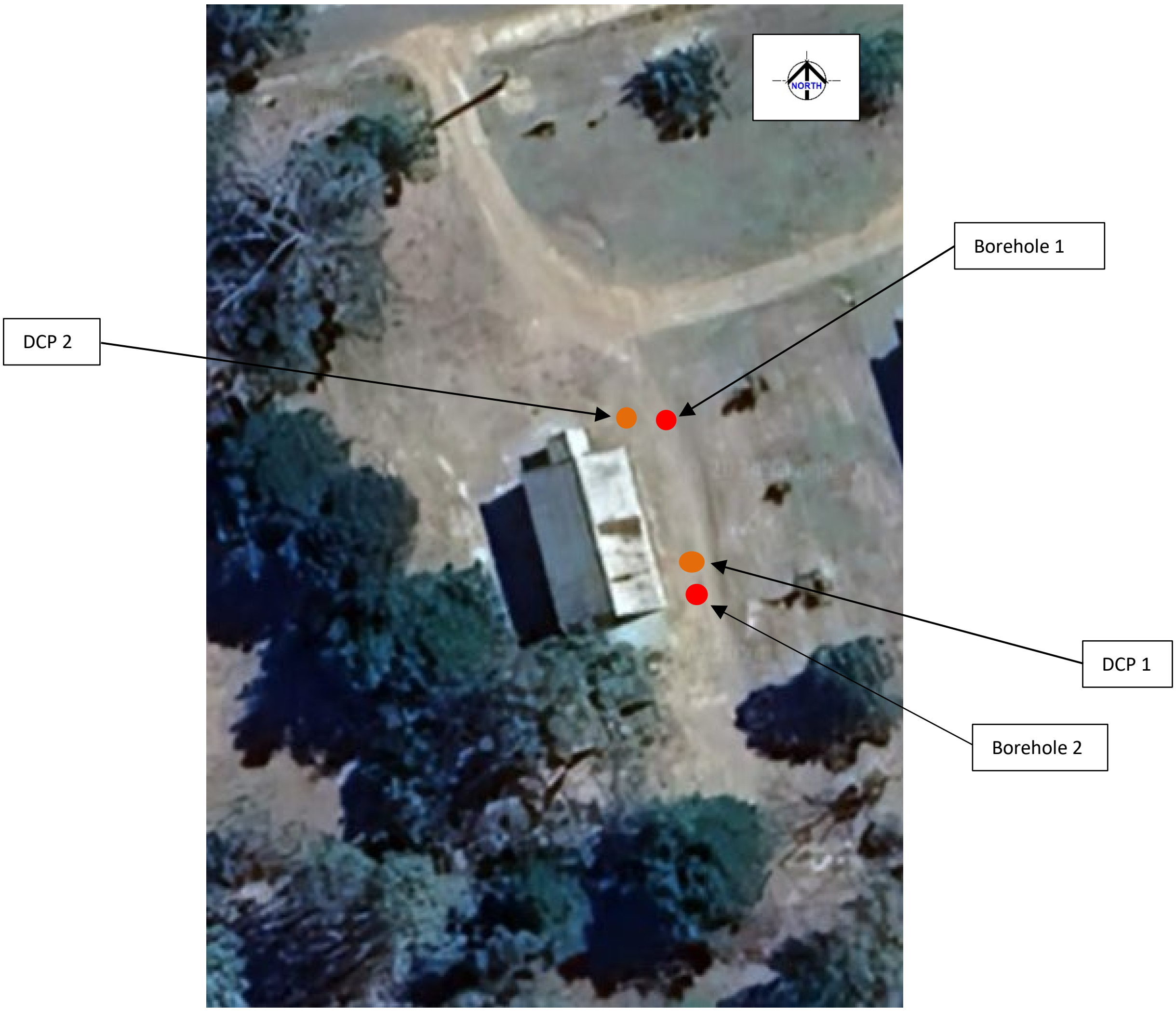
Under the Australian Soil Classification (Isbell 1996) the soils of the subject site are classified as Sodosol. **SODOSOLS** are a duplex soil as they have a strong texture contrast between the surface (A) horizons and the subsoil (B) horizons. The subsoil horizons are sodic and prone to erosion.

2.3 INVESTIGATION METHOD AND RESULTS

The investigation method involved drilling two (2) boreholes using a mechanical auger and two (2) dynamic cone penetrometer (DCP) test holes. Descriptions of the soil profile at the bore/test hole locations including DCP test results indicating bearing capacity are shown in Section 2.4.

Soils were tested in accordance with AS1289 with the results summarised in Section 3.2.

2.4 BORE HOLE AND D.C.P. RESULTS



The soil profiles at the bore holes are as follows below:

BOREHOLE 1 – Auger

Depth (mm)		Observation	Comments	Symbol	Moisture Condition	Test
0		Light Brown Gravelly Silt		LBGS	Semi-Moist	
100						
200		Brown Silty Clay		BSC	Moist	
300						
400		Brown Clay		BC	Moist	
500						
600						
700						SOIL SAMPLE
800						
900						
1000		Orange Brown Clay		OBC	Moist	
1100						
1200						
1300		Yellow Brown Gravelly Clay		YBGC	Moist	
1400						
1500		Yellow Brown Grey Mottled Clay		YB(G)C	Dry	
1600						
1700						
1800			BHT @ 1800mm, Refusal			

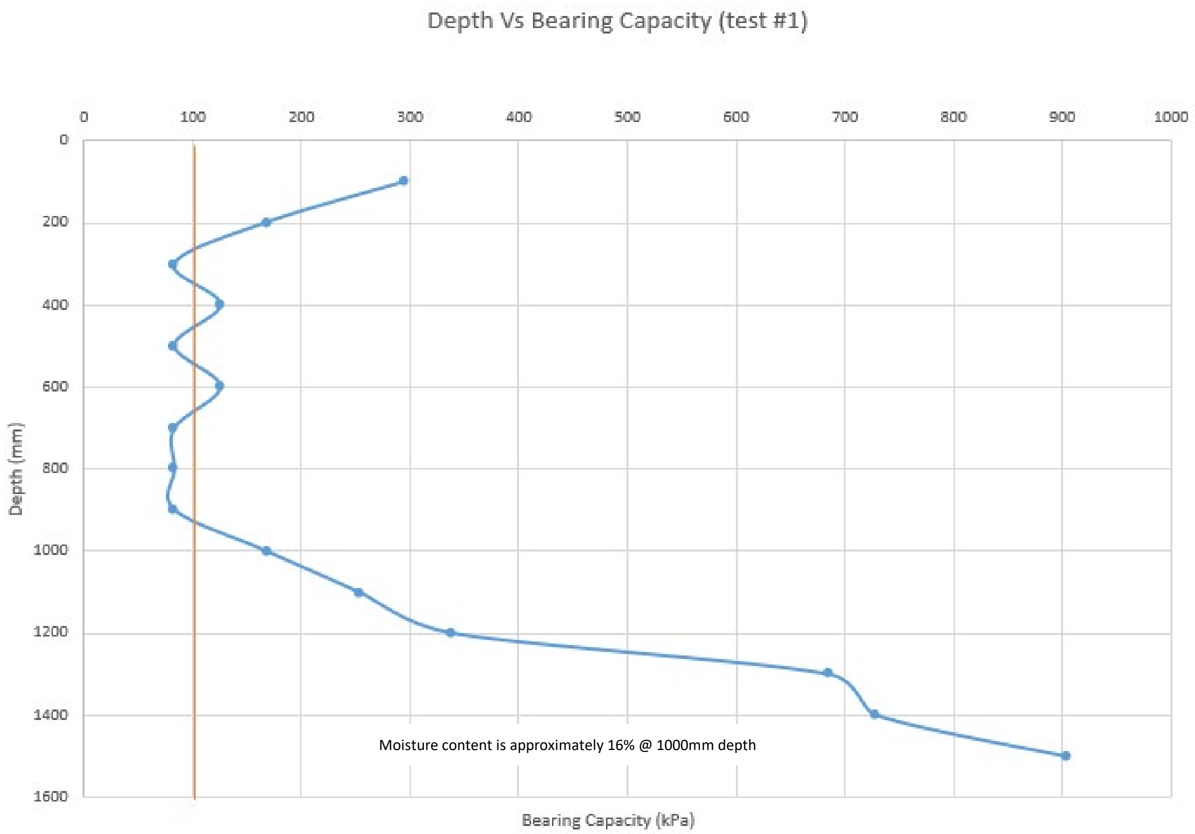
BOREHOLE 2 – Auger

Depth (mm)	Observation	Comments	Symbol	Moisture Condition	Test
0–200	Brown Orange Mottled Clay		B(O)C	Moist	
200–600	Yellow Brown Clay		YBC	Moist	
600–800	Orange Brown Clay		OBC	Moist	
800–1100	Orange Brown Sandy Clay		OBSaC	Moist	
1100–1500	Yellow Brown Clay		YBC	Dry	
1500–1600	Yellow Brown Gravelly Clay		YBGC	Dry	
1600		BHT @ 1600mm, Refusal			

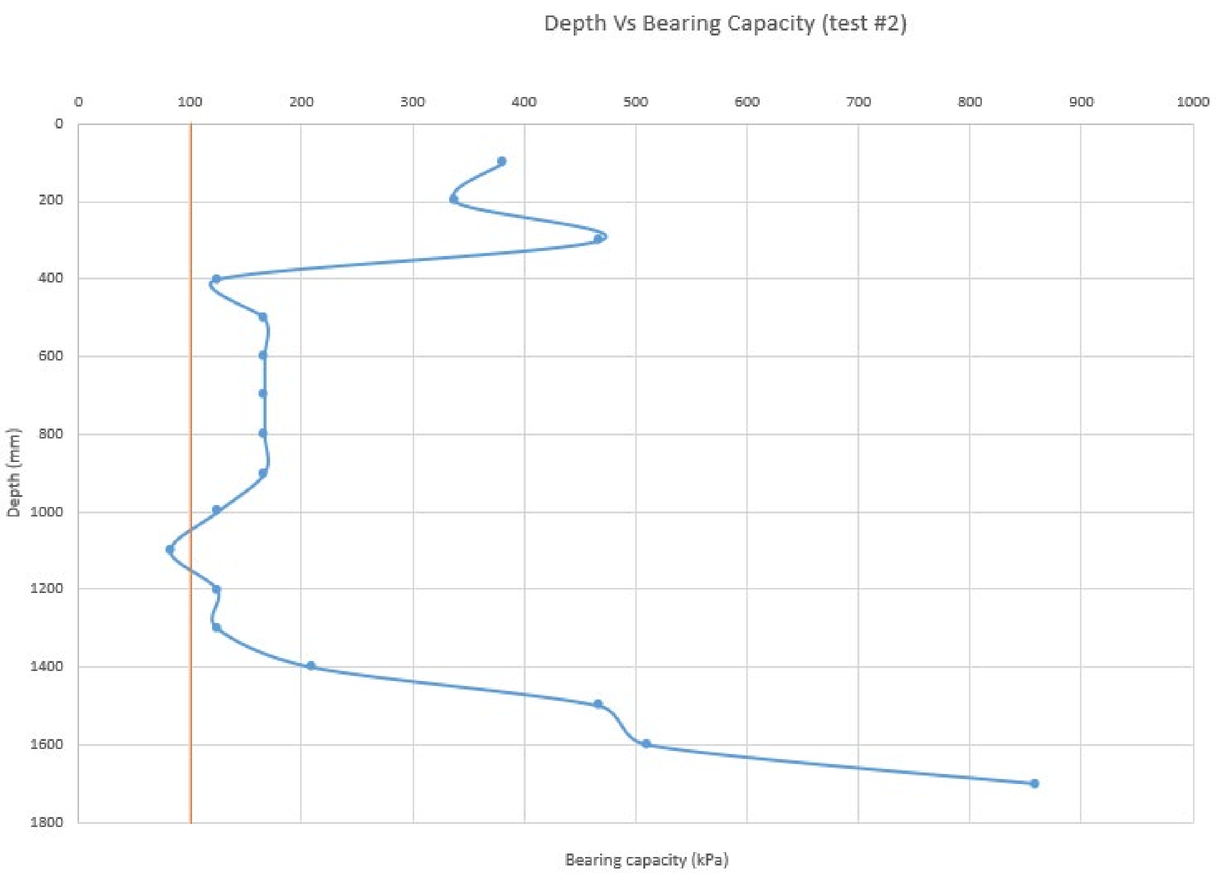
SYMBOLS

Colour		Material Type		Moisture Condition		Test Type	
Dark	D	Topsoil	T	Dry	D	ATT	Atterberg Limits
Light	L	Silt/Silty	S	Slightly Moist	SM	SA	Sieve Analysis
Brown/Black	B/BL	Clay/Clayey	C	Moist	M	SH-SW	Shrink Swell
Grey	G	Gravel/Gravelly	G	Very Moist	VM	FS	Free Swell
Orange	O	Sand/Sandy	Sa	Wet	W		
Red	R	Fill	F				

D.C.P. Test 1



D.C.P. Test 2



3. SOIL CLASSIFICATION

CHARACTERISTIC SURFACE MOVEMENT

The suction depth characteristics have been analysed in accordance with the methods and principles as described in AS2870 to establish a total characteristic surface movement for the site.

The calculated characteristic surface movement (y_s) indicates that the underlying soil is to be classified as **"H1"** with a site classification of **"P"** (refer to Table 2 below).

Soil Description:

Table 2: Classification by Characteristic Surface Movement

Characteristic surface movement	Site Classification	Symbol
0 < ys ≤ 20	Slightly reactive clay sites which may experience only slight ground movement from moisture changes	*S*
20 < ys ≤ 40	Moderately reactive clay or silt sites, which may experience moderate ground movement from moisture changes	*M*
40 < ys ≤ 60	Highly reactive clay sites which may experience high ground movement from moisture changes	*H1*
60 < ys ≤ 75	Highly reactive clay sites, which may experience very high ground movement from moisture changes	*H2*
ys > 75	Extremely reactive sites which may experience extreme ground movement from moisture changes	*E*
NA	Sites which include soft soils, landslip, mine subsidence, collapsing soils; soils subject to erosion; sites subject to abnormal moisture conditions or sites which cannot be classified otherwise. Sites which include soft soils, landslip, mine subsidence, collapsing soils; soils subject to erosion; sites subject to abnormal moisture conditions, controlled or uncontrolled fill or changes which cannot be classified otherwise. Sites which may be subject to other factors resulting in foundation movement beyond the reactive soil movements caused by an existing building or structure likely to have significantly modified the soil moisture conditions under the footprint of the footing system of the construction. The presence or removal of trees on the building site or adjacent site.	*P*

4. WIND CLASSIFICATION

The wind classification for the site, based on the wind speed region, site terrain and topography and likely shielding of the site, has been assessed as **N2**.

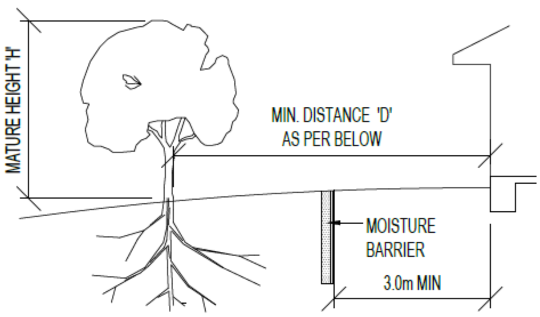
5. FOOTING RECOMMENDATIONS

- It is recommended that the footings design be adopted in accordance with AS2870-2011 Residential Slabs and Footings and/or AS3600-2018 Concrete Structures Code & engineering principles.

- Where slabs and footings are founded on fill, bored piers or screw piles are to be used; details to be provided by a structural engineer.

- Soil built up against the slab shall be constructed so that all water drains away from the dwelling. Site works must generally be designed and constructed to maintain stable moisture conditions of the foundation soils. The ground immediately adjacent to the building should be graded to a uniform fall of 50mm for the first metre.

- Restrictions on tree locations close to buildings. Trees and shrubs that are allowed to grow in the vicinity of footings can cause foundation movement. To reduce the risk of damage the minimum distances outlined in Appendix 1 **(B2.2c *Restrictions on Trees and Shrubs*)** must be achieved unless a **vertical root barrier** is provided.



Class	Distance (m)
E	1.5 x Mature Height
H1/H2	1.0 x Mature Height
M	0.75 x Mature Height

- **Considering the proximity of existing adjacent trees, a root/moisture barrier and/or deepened footings must be part of the footing structure.**

- Should stump footings be adopted, it is recommended that stumps be founded a minimum of **300mm** into natural stiff clay layer or a minimum of **1000mm** below finished surface level – **WHICH EVER IS DEEPER.**

- In accordance with Clause 2.5.2 of AS2870-2011, where a site cut exceeds 500mm a second site investigation is recommended. As such:

  - Where the cut depth is > 500mm and < 1000mm the relevant design engineer may choose to design for a reduced crack zone from first principles.
  - Where the site cut exceeds 1000mm a second soil investigation must be carried out to confirm the effects of the cut on the classification.

6. CONDITIONS OF REPORT

The recommendations contained within this report are based on:

- Soil layer variations are commonplace. The recommendations made in this report assume that the test results are representative of the overall subsurface conditions. In all cases the foundation soil chosen should have a similar consistency and strength to that recommended but need not be of the same type.

- DCP graph(s) illustrated in Section 2.4 provide an indicative bearing capacity for the soil at the site of testing ONLY. Variations may occur across the site (due to soil type texture and moisture and seasonal conditions) but for the purposes of this report it is assumed that these values are indicative of subsurface bearing pressures of the soils across the proposed site of construction. If a more detailed assessment is required, Taylor Engineering and Design can provide where necessary.

- If during construction the recommended foundation material is not found within 200mm of our recommended foundation depths, or if the builder/contractor is in doubt, then Taylor Engineering + Design must be contacted immediately. Responsibility cannot be taken for footing construction deeper than the recommended foundation depths without prior approval (some allowance should be made for the removal of organic matter, roots etc. which may be found in localised areas in the footing trenches). The owner's attention is drawn to Appendix B of A.S.2870 "Foundation Performance Requirements and Maintenance" (attached) and Foundation Maintenance and Footing Performance – A Homeowners Guide (attached).

7. APPENDICIES

APPENDIX 1: Appendix B AS2870-2011
APPENDIX 2: Foundation Maintenance and Footing Performance – A Homeowners Guide

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PE0001251

Date: February 2024

APPENDIX B

FOUNDATION PERFORMANCE AND MAINTENANCE

(Informative)

B1 GENERAL

The designs and design methods given in this Standard are based on the performance criteria of Clause 1.3. Importantly, significant damage may be avoided provided the foundation site conditions are properly maintained. This is expressed in Section 1 by the statement that the probability of failure for reasonable site conditions is low but is higher if extreme conditions are encountered. It is neither practicable nor economical to design for the extreme conditions that could occur in the foundation if a site is not properly maintained. The expected standard of foundation maintenance is described in Paragraph B2.

Some minor cracking and movement will occur in a significant proportion of buildings, particularly those on reactive clays, and the various levels of damage are discussed in Paragraph B3.

The performance requirements of a concrete floor in respect to shrinkage cracking and moisture reaction with adhesives are discussed in Paragraph B4.

A more extensive discussion of the material is Paragraphs B2 and B4 is contained in the CSIRO pamphlet, Building Technology File 18, *Foundation maintenance and footing performance: A homeowner's guide,* and its recommendations should be followed.

B2 FOUNDATION MAINTENANCE

B2.1 Foundation soils

All soils are affected by water. Silts are weakened by water and some can settle if heavily watered, but most problems arise on clay foundations. Clays swell and shrink due to changes in moisture content and the potential amount of the movement is implied in the site classification in this Standard, which is designated as follows:

(a) A – stable (non – reactive).

(b) S – slightly reactive.

(c) M – moderately reactive

(d) H1 and H2 – highly reactive.

(e) E – extremely reactive.

Sites classified Cass A and Class S may be treated as non-reactive sites in accordance with Paragraph B2.2. Sites classified as Class M and Class H1, Class H2 and Class E should comply with the recommendations given in Paragraph B2.3.

B2.2 Class A and Class S sites

Sands, slits and clays should be protected from becoming extremely wet by adequate attention to site drainage and prompt repair of plumbing leaks.

B2.3 Classes M, H1, H2 and E sites

Sites classified as M, H1, H2 and E should be maintained at essentially stable moisture conditions and extremes of wetting and drying prevents. This will require attention to the following:

(a) *Draining of the site.* The site should be graded or drained so that the water cannot pond against or near the building. The ground immediately adjacent to the building should be graded to a uniform fall of 50mm minimum away from the building over the first meter. The subfloor space for buildings with suspended floors should be graded or drained to prevent ponding where this may affect the performance of the footing systems.

The site drainage recommendations should be maintained for the economic life of the building.

(b) *Limitations or gardens*. The development of the gardens should not interfere with the drainage requirements or the subfloor ventilation and weep hole drainage systems. Garden beds adjacent to the building should be avoided. Care should be taken to avoid overwatering of gardens close to the building footings.

(c) *Restrictions on trees and shrubs* Planting of trees should be avoided near the foundation of a building or neighbouring building on reactive sites as they can cause damage due to drying of the clay at substantial distances. To reduce, but not eliminate, the possibility of damage, tree planting should be restricted to a distance from the house as follows:

(i) 1 ½ x mature height for Class E sites.

(ii) 1 x mature height for Class H1 and Class H2 sites.

(iii) ¾ x mature height for Class M sites.

Where rows or groups of trees are involved, the distance from the building should be increased. Removal of trees from the site can also cause similar problems.

Alternatively, the footing systems may be designed for the effect of trees, for example as given in Appendix H

(d) *Repair of leaks* in plumbing, including storm water and sewage drainage, should be repaired promptly.

The level to which these measures are implemented depends on the reactivity of the site. The measures apply mainly to masonry buildings and masonry veneer buildings. For frame buildings clad with timber or sheeting, lesser precautions may be appropriate.

B3 PERFORMANCE OF WALLS

It is acknowledged that minor foundation movements occur on nearly all sites and that it is impracticable to design a footing system that will protect the building from movements under all circumstances. The expected performance of footing systems designed in accordance with the Standard is defined in terms of the damage classifications in Table C1, Appendix C.

Crack width is used as the major criterion for damage assessment, although tilting and twisting distortions can also influence the assessment. Local deviations of the slope walls exceeding 1:150 are undesirable. The assessment of damage may also be affected where it occurs and the function of the building, although these effects are not likely to be significant in conventional buildings. In the classification of damage, account should also be taken of the history of cracking. For most situations, Category 0 or 1 should be the limit: however, under adverse conditions, Category 2 should be expected although such damage should be rare. Significant damage is defined as Category 3 or worse.

For category 1 or 2 damage, remedial action should consist of stabilising the moisture conditions of the clay and paying attention to repairing or disguising the visual damage. This should be regarded as part of the normal maintenance of buildings on reactive clays.

Even significant masonry cracking with crack widths over 5mm often has no influence on the function of the wall and only presents an aesthetic problem. Generally, the remedial action for such damage should start with an investigation to establish the cause of the damage. In many cases the treatments should consist of stabilizing moisture conditions by physical barriers or paths, or replenishing moisture in dry foundations. This may be followed by repair of the masonry and, wherever possible added articulation should be included while repairs are being affected. Structural repairs to the footing systems, such as deep underpinning, should only be considered as the last resort.

Underpinning should generally be avoided where the problem is related to reactive clays, although it is recognized there may be occasional situations where underpinning or other structural augmentation work is appropriate. None of this structural augmentation work should be undertaken without proper engineering appraisal.

In some cases, walls may be designed to span sagging footings and cantilever beyond hogging footings. In such cases, satisfactory performance will involve the wall remaining free of cracks and articulation joint movements and remaining within the limits for the jointing system.

B4 PERFORMANCE OF CONCRETE FLOORS

Shrinkage cracking can be expected in concrete floors. Concrete floors can also be damaged by shrinkage or swelling of reactive clays or settlement of fill. The categories of movements causing the damage are given in Table C2, Appendix C. In the classification, account should be taken of whether the damage is stable or likely to increase, and an allowance should be made for any deviations in level which resulted from, or occurred during, construction.

The time of attachment of floor coverings and the selection of adhesive for them should take into account the moisture in the concrete floor and its possible effect on adhesion. Concrete floors can take a considerable time to dry (three to nine months).

Floor coverings and their adhesives can be damaged by moisture in the concrete and by the shrinkage that occurs as the concrete dries. The time of fixing if floor coverings and the selection of the adhesives should take these factors into account.

Foundation Maintenance and Footing Performance: A Homeowner's Guide

BTF 18 replaces Information Sheet 10/91

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

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

Soil Types

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

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

Causes of Movement

Settlement due to construction

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

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

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

Erosion

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

Saturation

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

Seasonal swelling and shrinkage of soil

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

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

Shear failure

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

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

GENERAL DEFINITIONS OF SITE CLASSES

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

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

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

Unevenness of Movement

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

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

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

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

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

Effects of Uneven Soil Movement on Structures

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

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

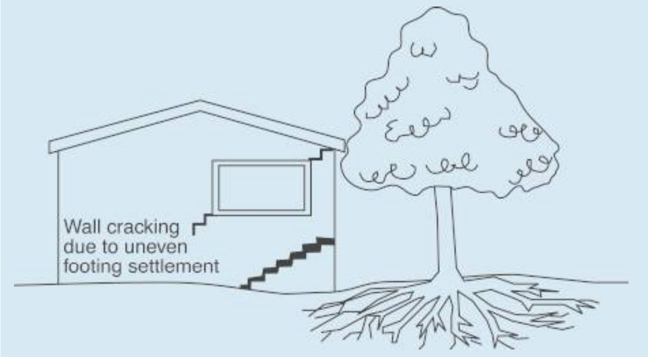
Isolated piers affected by erosion or saturation of foundations will eventually lose contact with the bearers they support and may tilt or fall over. The floors that have lost this support will become bouncy, sometimes rattling ornaments etc.

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

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

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

Trees can cause shrinkage and damage



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

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

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

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

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

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

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

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

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

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

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

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

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

Water Service and Drainage

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

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

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

Seriousness of Cracking

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

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

Prevention/Cure

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

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

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

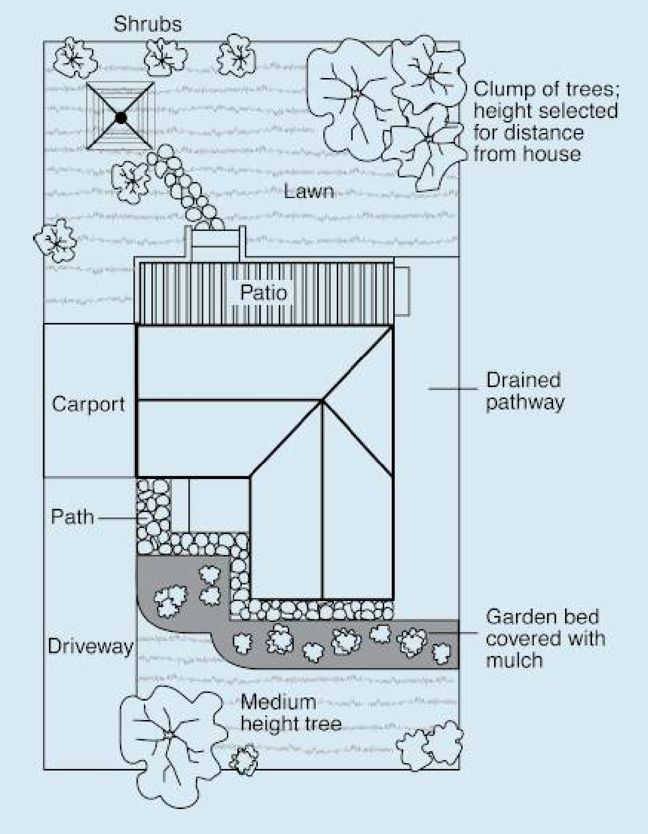
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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

CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS

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

Gardens for a reactive site



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

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

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

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

Condensation

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

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

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

The garden

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

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

Existing trees

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

Information on trees, plants and shrubs

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

Excavation

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

Remediation

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

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

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