

Report on Property Inspection

Engineer's Inspection Report for unit [REDACTED]
[REDACTED]

Prepared for [REDACTED].



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Document Control

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1. Introduction

This report presents the findings of the inspection undertaken at the existing property at [REDACTED] by the author, Structura Engineering Inspections, on 30/06/2026. The report highlights issues found within the structure, categorises these issues based on risk assessment criteria, and provides recommendations on how to resolve/monitor compliance issues or increase building and general safety.

2. Methodology

Structura Engineering Inspections inspected this property via; desktop study and physical examination, including photographing for documentation and analytical review against risk assessment criteria. The first step in the desktop study was classifying damage from foundation movements to the structure regarding the walls and footings. The consultant performed the classification as per AS2870:2011, Appendix C, Table C1 and AS2870:2011, Appendix C, Table C2. The author also completed a risk matrix and presented it in Chapters 5. See Appendices in this report and the discussion in Chapter 6.

The physical inspection was conducted at the property on 30/06/2026 at 11:00 AM. The client was in attendance. The attending consultant measured and documented structural damage and visually inspected the external drainage system.

3. Limitations

The inspection was visual and non-invasive unless expressly stated otherwise. No destructive testing, excavation, geotechnical investigation, footing exposure, plumbing pressure testing or concealed framing inspection was undertaken. The findings and opinions in this report are based on the conditions observed at the time of inspection and the information available to Structura Engineering Inspections at the time of reporting. Concealed defects may exist and could not be assessed without further investigation.

This report does not constitute certification of compliance with the National Construction Code, Australian Standards, planning approvals or building permit documentation unless expressly stated.

4. Inspection Findings

4.1. Floor Structure

Floor level discrepancies were recorded at approximately 24 mm over a 3-metre span on the lower level of the house, and up to approximately 23mm mm over a 3-metre span on the upper level. Across the entire building footprint, the total floor level deviation measured up to 42 mm. (Refer to Appendix B for floor level data.)

Refer to Section 5 for recommendations and Appendix A for the photo log.

4.2. Wall Structure

4.2.1. Internal Wall Structure

Overall observations of the internal wall surfaces reveal the presence of cracks, ranging up to approximately 10mm in width, throughout the building. The cracking on the internal walls is consistent with the floor deviations measured.

Refer to Section 5 for recommendations and Appendix A for the photo log.

4.2.2. External Wall Structure

The external wall structure shows signs of displacement, with several cracks ranging from approximately 3 mm to 25 mm in width observed throughout the structure, predominantly on the western and southern perimeter of the property. These cracks presented as both step cracks through the mortar, and as cracking through the bricks.



Refer to Section 5 for recommendations and Appendix A for the photo log.

4.3. Effect of Trees

Groups of trees up to approximately 5 metres in height were observed at the western, southern, and eastern side of the property, with the closest spacing being approximately 1 metre between the trees and the structure. This proximity may negatively affect the surrounding soil conditions and the building's footings. Tree-induced effects typically occur when roots extend beneath or near the footing system, resulting in moisture variations within the foundation soils.

4.4. External Drainage

There is a lack of external drainage or pits around the sides of the property to collect surface moisture and prevent it from entering the footing zone or underlying soils. Without an adequate drainage system, unwanted moisture may infiltrate the natural soil, potentially reduce its bearing capacity and compromise the overall stability of the structure. This condition can lead to footing movement and subsequent structural distress.

Refer to Section 5 for recommendations and Appendix A for the photo log.

5. Risk Assessment and Mitigation Analysis

5.1 Risk Matrix

Risk matrix										
Consequence	Description	Likelihood	Description			Likelihood				
						Rare	Unlikely	Possible	Likely	Almost certain
Catastrophic	Fatality or severe irreversible injury. Non-reparable structural damage. National level reputational risk.	Almost certain	Already happened or will occur in most circumstances within one year	Consequence	Catastrophic	Moderate	Moderate	High	Critical	Critical
Major	Extensive injuries or impairment, Repairable but costly structural damage. State-level reputational risk.	Likely	Will probably occur within one year		Major	Low	Moderate	Moderate	High	Critical
Moderate	Injury requiring medical treatment. Disruption to regular operation in the building. Local-level reputational risk.	Possible	May occur within the foreseeable future, such as within 1 – 3 years		Moderate	Low	Moderate	Moderate	Moderate	High
Minor	First aid treatment. Significant maintenance work is required to amend the issue.	Unlikely	May occur at some time but is unlikely in the foreseeable future		Minor	Very low	Low	Moderate	Moderate	Moderate
Insignificant	No treatment is required. Minor maintenance works to amend the issue.	Rare	Only occurs in exceptional circumstances		Insignificant	Very low	Very low	Low	Low	Moderate

5.2 Risk Assessment

Serial	Risk Event	Hazard	Unmitigated Likelihood	Unmitigated Consequence	Unmitigated Risk	Mitigation Measures	Residual Likelihood	Residual Consequence	Residual Risk
4.1	Floor Structure	Footings/soil movement causing current deflection to worsen, leaning to Structural failure	Possible	Minor	Moderate	Recommendations in Chapter 6	Unlikely	Insignificant	Very Low
4.2	Wall Structure	Cracks observed in both internal and external walls indicate movement affecting the existing structure, which may lead to structural failure.	Likely	Minor	Moderate	Recommendations in Chapter 6	Unlikely	Insignificant	Very Low
4.3	Effect of Trees	Tree roots can extend deep into the soil and absorb moisture from the surrounding area. Variations in soil moisture levels can significantly affect the soil's bearing capacity, particularly in clayey soils, and may ultimately contribute to structural failure.	Possible	Moderate	Moderate	Recommendations in Chapter 6	Unlikely	Minor	Low
4.4	External Drainage	Inadequate drainage may allow moisture variation within the footing zone, which can contribute to further foundation movement and associated serviceability damage.	Possible	Moderate	Moderate	Recommendations in Chapter 6	Unlikely	Minor	Low

6. Discussion & Recommendations

Based on the observations and measurements taken on site, the property exhibits structural movement exceeding the tolerances generally expected under Australian Standards for similar residential dwellings founded on reactive clay soils.

The observed conditions are assessed as exceeding serviceability limits and necessitate rectification works to be undertaken at the earliest opportunity to remedy the identified issues.

1. Overall Structural Assessment

Based on the risk criteria and the evaluation tools provided in the Australian Standards and NCC 2022, the structure shows moderate structural distortion inconsistent with its age and soil conditions.

While the building shows no obvious evidence of imminent structural stability, movement may affect the following performance requirements under the NCC 2022 Volume Two, Part H1:

- H1D1 Structural robustness: Localised slab movement and wall cracking indicate reduced uniformity of support.
- H1D2 Weatherproofing and surface water management: Inadequate site drainage and tree influence have affected moisture equilibrium around footings.

2. Floor Level Variation

- **Lower Level**

In accordance with AS 2870—Residential slabs and footings (2011), Section 2 – table C2: Classification of damage with reference to concrete floors (Appendix D).

Measured site data indicated deviations of **maximum 24 mm per 3 meters**, classifying the slab distortion as **Moderate Damage (Category 3)** under AS 2870 Appendix C2.

This variation exceeds acceptable tolerance and represents significant differential settlement, primarily towards the rear of the dwelling.

- **Upper Level**

The floor level upstairs shows deviations consistent with the movement of the slab footing system downstairs. Movement is most apparent in the south-east corner of the property on both levels.

The upstairs floor level deviations of **up to 23mm per 3 metres** classify the upstairs slab distortion as **Moderate Damage (Category 3)** under AS 2870 Appendix C2.

Recommendation:

Remedial foundation works may be considered to restore uniform support to the affected area downstairs. Depending on site conditions and the extent of movement, this may include underpinning or resin injection methods to mitigate further differential settlement.

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Any contributing external factors, such as **drainage rectification or tree removal**, should be addressed prior to undertaking foundation stabilisation works to ensure long-term effectiveness.

3. External Wall Structure:

Cracks of up to 25mm were observed on the external masonry walls around the property, primarily on the western and southern sides of the building.

In accordance with AS 2870:2011, the observed wall damage is classified as **Severe (Category 4)** for the external elements.

Recommended Action:

It is recommended that a suitably qualified builder or contractor be engaged to inspect the affected area and undertake any necessary sealing or remedial works in accordance with relevant standards.

It is recommended that this rectification work be undertaken after the foundation has stabilised following remediation works.

4. Internal Wall Structure:

Cracks of up to 10mm were observed inside the property. These are consistent with footing movement, as indicated by the recorded floor level deviations. (Refer to Appendix A)

In accordance with AS 2870:2011, the observed wall damage is classified as **Moderate Damage (Category 3)** for internal elements.

Recommended Action:

Undertake crack monitoring over a 12-month period. It is recommended that the monitoring period commence after the foundation has stabilised following remediation works.

Cosmetic repairs may be undertaken following the monitoring period, provided no progression in cracking is observed.

5. Tree Influence

Trees were noted within approximately 1 metre of the building perimeter.

Per AS 2870:2011, Clause 5.2.4 and Appendix F, vegetation this close can cause significant soil moisture variation, especially in reactive clay soils, leading to cyclical foundation movement.

Recommended Action:

Engage a qualified arborist to undertake further assessment and provide recommendations for vegetation management.

Vegetation located within 1.5 m of the building perimeter should be removed to minimise physical intrusion of roots or to avoid moisture extraction to the footing zone. As an alternative where removal is not feasible, a suitable root barrier system should be installed to restrict future root ingress and associated ground moisture variation.

Following tree remediation, a soil re-equilibration period of minimum to 24 months should be anticipated to allow moisture conditions within the founding soils to stabilise.

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Important Notes:

- Tree remediation works should be carried out by a qualified arborist or experienced tradesperson.
- Excavation near existing footings should be undertaken carefully to avoid undermining the footing system.

6. External Drainage

The property exhibits evidence of water ponding and surface water flow directed toward the footing zone, which may indicate inadequate stormwater management measures to prevent moisture ingress affecting the footing system. Surface drainage improvements, including drainage pits, spoon drains, and/or appropriately graded pavements, should be considered in accordance with a civil engineering design to ensure effective diversion of surface runoff away from the building perimeter and footing zone.

Recommended action:

Refer to a suitably qualified civil engineer and licensed plumber to design and install an appropriate surface and/or subsurface drainage system in accordance with relevant standards. The system should incorporate perimeter collection points and ensure all stormwater is effectively conveyed and discharged away from the structure.

A licensed plumber should conduct a drainage audit in line with CSIRO Footing Maintenance and Performance Guidelines (2011) to ensure long-term stability.

Important Notes:

- To mitigate the risk of soil movement compromising the existing underground water system, it is recommended that a comprehensive drainage and plumbing inspection be undertaken to identify and rectify any existing leaks or blockage prior to the commencement of the recommended remedial works.

7. Structural Safety Statement

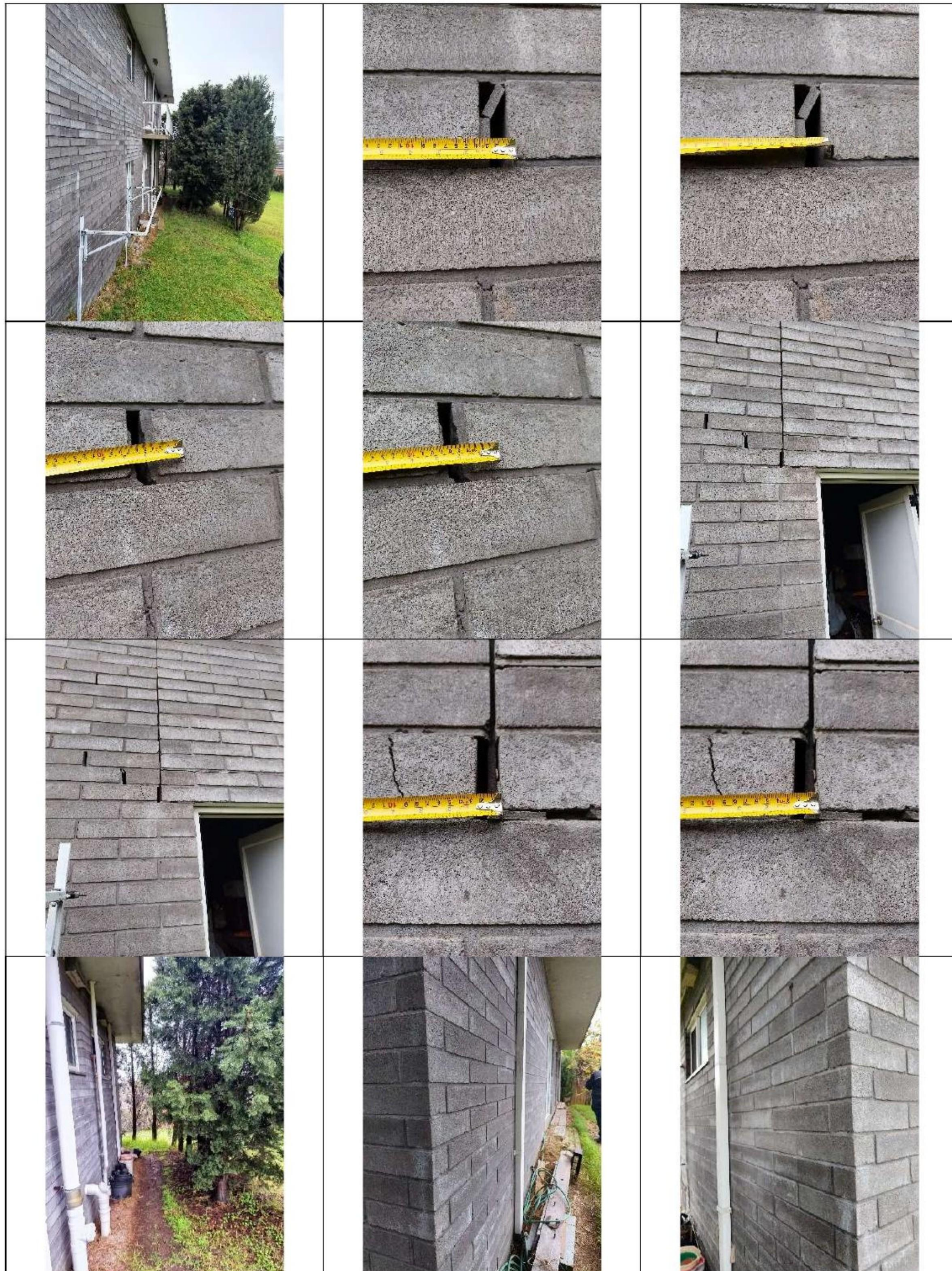
Based on the observations made at the time of inspection, the structure does exhibit evidence of structural damage **at the footing**. The observed footing movement, floor distortion, and associated structural defects indicate reduced serviceability performance, and rectification works are recommended to be undertaken as soon as practicable to prevent further deterioration and ongoing differential movement.

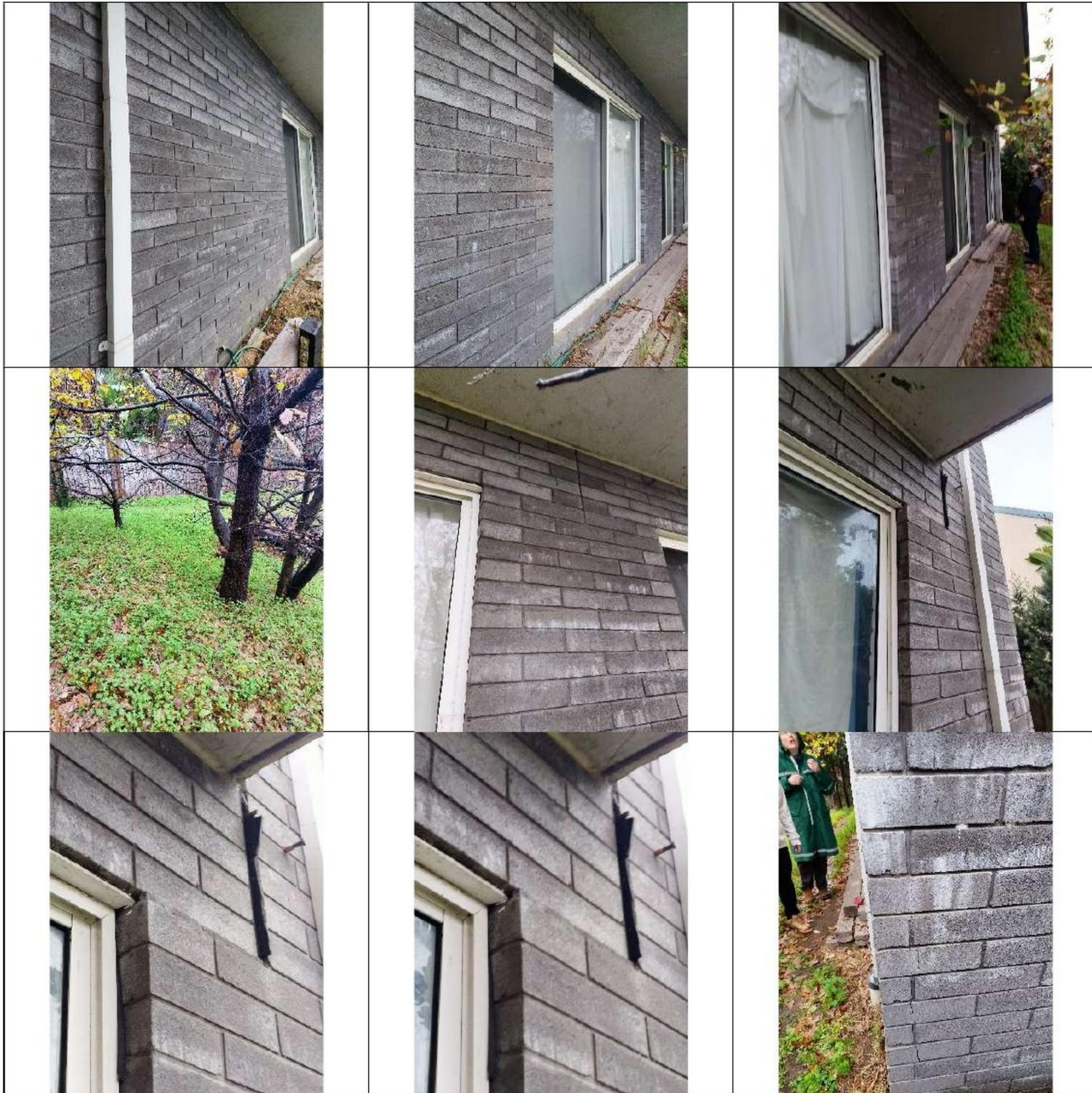
8. Summary of Recommended Actions

1. Rectify drainage issues and engage a licensed plumber & civil engineer to inspect the existing stormwater and underground drainage systems, and design an additional appropriate external drainage system.
2. Remove nearby trees/shrubs or install root barriers to minimise footing moisture variation.
3. Allow soil conditions to stabilise following vegetation remediation (up to 24 months).
4. Undertake foundation stabilisation works to the slab footing system, such as underpinning or resin injection
5. Monitor internal & external cracking for 12 months following completion of the foundation remedial works.
6. Carry out cosmetic crack repairs only if no further movement is observed during the monitoring period.

7. Appendix A: Photo Log







8. Appendix B: Floor Level of the Building.



9. Appendix C: Classification of damage due to foundation movements concerning walls.
(AS2870-2011 Appendix C, Table C1).

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APPENDIX C

CLASSIFICATION OF DAMAGE DUE TO FOUNDATION MOVEMENTS

(Normative)

Classification of damage with reference to wall is given in Table C1. Classification of damage with reference to concrete floors is given in Table C2.

TABLE C1

CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS

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

NOTES:

- Where the cracking occurs in easily repaired plasterboard or similar clad-framed partitions, the crack width limits may be increased by 50% for each damage category.
- Crack width is the main factor by which damage to walls is categorized. The width may be supplemented by other factors, including serviceability, in assessing category of damage.
- In assessing the degree of damage, account shall be taken of the location in the building or structure where it occurs, and also of the function of the building or structure.

10. Appendix D: Classification of damage due to foundation movements concerning concrete floor. (AS2870-2011 Appendix C, Table C2).

TABLE C2
CLASSIFICATION OF DAMAGE WITH REFERENCE TO CONCRETE FLOORS

Description of typical damage	Approx. crack width limit in floor	Change in offset from a 3 m straightedge centred over defect (see Note 1)	Damage category
Hairline cracks, insignificant movement of slab from level	<0.3 mm	<8 mm	0 Negligible
Fine but noticeable cracks. Slab reasonably level	<1.0 mm	<10 mm	1 Very slight
Distinct cracks. Slab noticeably curved or changed in level	<2.0 mm	<15 mm	2 Slight
Wide cracks. Obvious curvature or change in level	2 mm to 4 mm	15 mm to 25 mm	3 Moderate
Gaps in slab. Disturbing curvature or change in level	4 mm to 10 mm	>25 mm	4 Severe

NOTES:

- 1 The straightedge is centred over the defect, usually, and supported at its ends by equal height spacers. The change in offset is then measured relative to this straightedge, which is not necessarily horizontal.
- 2 Local deviation of slope, from the horizontal or vertical, of more than 1:100 will normally be clearly visible. Overall deviations in excess of 1:150 is undesirable.
- 3 Account should be taken of the past history of damage in order to assess whether it is stable or likely to increase.

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2.07 Finished floor levels

Finished floor levels (FFL) or reduced levels (RL) are defective where they do not comply with specified planning and/or building permit requirements.

In other cases, FFL or RL are defective where:

- a) they depart from the documented RL or FFL by more than 40 mm; or
- b) floors are documented to be on the same plane but are constructed on different planes; or
- c) the building work is an extension or addition and new floor levels do not match the existing building floor levels. Also refer to Item I of this Guide.

2.08 Levelness of concrete floors

Except where documented otherwise, new floors are defective if within the first 24 months of handover they differ in level by more than 10 mm in any room or area, or more than 4 mm in any 2 m length. The overall deviation of floor level to the entire building footprint shall not exceed 20 mm. Refer to Item I of this Guide where the new floor is to abut an existing floor.

2.09 Dimensions of building elements

Deviations from the documented height or cross-sectional dimension of building elements such as beams and posts are defective if they exceed $L/200$ where L is the documented dimension or 5 mm, whichever is the greater.

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2.10 Cracks in concrete slabs

Refer to Table 2.10 for descriptions of categories of cracks.

Cracks to slabs are defective where they are Category 3 and 4.

Category 1 and 2 cracks to slabs are to be monitored for a period of 12 months. At the end of the monitoring period, cracks are defective if they are greater than category 2 and attributed to the actions of the builder.

TABLE 2.10 CLASSIFICATION OF DAMAGE TO CONCRETE FLOORS

Description of typical damage	Approximate crack width limit in floor	Change in offset from 3 m straight edge placed over defect	Damage category
Hairline cracks, insignificant movement of slab from level	< 0.3 mm	< 8 mm	0 Negligible
Fine but noticeable cracks. Slab reasonably level	< 1.0 mm	< 10 mm	1 Very slight
Distinct cracks. Slab noticeably curved or changed in level	< 2.0 mm	< 15 mm	2 Slight
Wide cracks. Obvious curvature or change in level	2 mm to 4 mm	15 mm to 25 mm	3 Moderate
Gaps in slab. Disturbing curvature or change in level	4 mm to 10 mm	> 25 mm	4 Severe

Taken from AS 2870: Residential slabs and footings – Construction, Table C2: Classification of damage with reference to concrete floors. Reproduced with permission from SAI Global Ltd under Licence 1407-c122.

Notes to Table 2.10

1. The straightedge is centred where possible over the defect, and supported at its ends by equal height spacers. The change in offset is then measured relative to this straightedge, which is not necessarily horizontal.
2. Local deviation of slope, from the horizontal or vertical, of more than 1:100 will normally be clearly visible. Overall deviations in excess of 1:150 is undesirable.
3. Account should be taken of the past history of damage in order to assess whether it is stable or likely to increase.

12. Appendix F: Tree Effect Zone

I. Tree effect Score table (AS 2870-2011).

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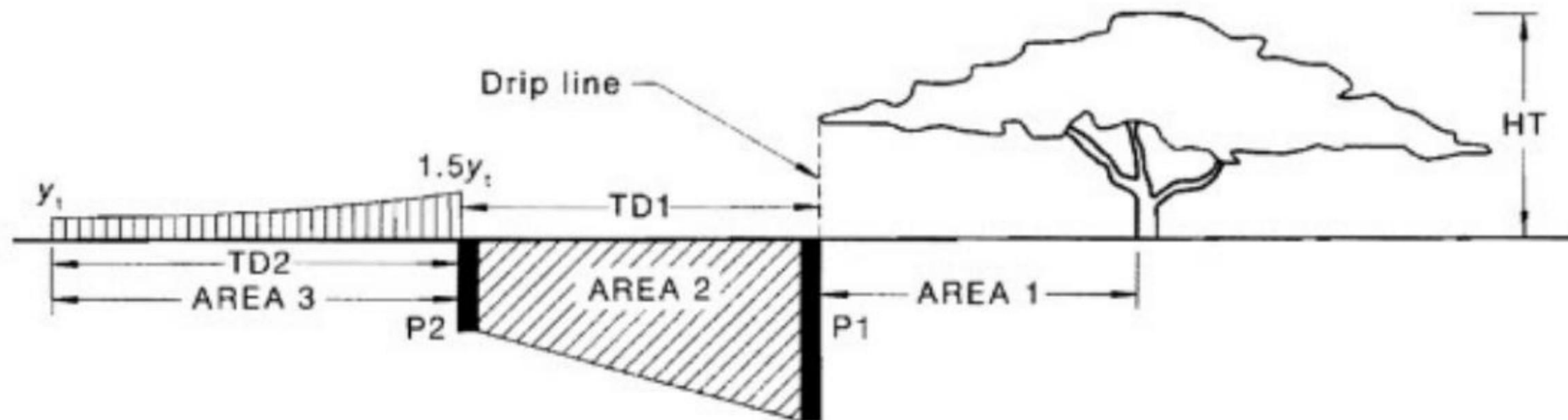


FIGURE CH3 TREE HEIGHTS AND SOIL SUCTION CHANGES

TABLE CH5.1

TREE EFFECT SCORE—SINGLE TREE

	Characteristic	Option	Option score	Characteristic score
Tree characteristics	Canopy	Dense	3	2
		Med Dense	2	
		Sparse	1	
	Height	Tall = >15 m	3	1
		Med = 8 – 15 m	2	
		Small = <8 m	1	
	Stage of growth	Growing	2	N/A
		Mature	1	
	Drought resistance	Resistant	2	N/A
Not resistant		0		
Ground and site conditions	Depth of fill	≥1 m	2	N/A
		<1 m	0	
	Adverse conditions	Yes	1-2	N/A
		No	0	
	Soil profile reactivity	High/Extreme reactivity	2	N/A
		Moderate reactivity	1	
Total tree effect score (sum characteristic scores above)				N/A

II. Climate zone of Victoria (AS 2870-2011).



FIGURE D1 MELBOURNE AND ENVIRONS CLIMATIC ZONES
(Outside Melbourne inset area—refer Figure D2)

III. Tree effect scores by climate zone (AS 2870-2011).

TABLE CH5.2
TD1 AND TD2 VALUES FOR TREE EFFECT SCORES
BY CLIMATE ZONE

Tree effect score	Tree effect	Climate zones		
		1	2	3/4/5
		Distances (TD1 or TD2), m		
<6	Low	1	2	3
6-9	Moderate	3	4	5
9-12	High	5	6	7
12-15	Very High	7	8	9
≥15	Extreme	9	10	11

NOTES:

- 1 P1 = minimum pile/pier depth = $1.5 H_s$ or bedrock, whichever is shallower.
P2 = minimum pile/pier depth = H_s or bedrock, whichever is shallower.
- 2 TD1 = TD2.
- 3 Table 2 only applies to predominantly clay sites.
- 4 For tree groups distances TD1 and TD2 should be increased by up to 50%.
- 5 Pier/pile footings in soil Area 2 may be extended to soil Area 3 at P2 depths. Alternatively, this part of the footing should be designed to an increased y_1 .

Foundation Maintenance and Footing Performance: A Homeowner's Guide



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

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

Soil Types

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

Classifications for a given area can generally be obtained by application to the local authority, but these are sometimes unreliable and if there is doubt, a geotechnical report should be commissioned. As most buildings suffering movement problems are founded on clay soils, there is an emphasis on classification of soils according to the amount of swell and shrinkage they experience with variations of water content. The table below is Table 2.1 from AS 2870-2011, the Residential Slab and Footing Code.

Causes of Movement

Settlement due to construction

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

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

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

Erosion

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

Saturation

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

Seasonal swelling and shrinkage of soil

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

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

Shear failure

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

- Significant load increase.
- Reduction of lateral support of the soil under the footing due to erosion or excavation.

In clay soil, shear failure can be caused by saturation of the soil adjacent to or under the footing.

GENERAL DEFINITIONS OF SITE CLASSES

Class	Foundation
A	Most sand and rock sites with little or no ground movement from moisture changes
S	Slightly reactive clay sites, which may experience only slight ground movement from moisture changes
M	Moderately reactive clay or silt sites, which may experience moderate ground movement from moisture changes
H1	Highly reactive clay sites, which may experience high ground movement from moisture changes
H2	Highly reactive clay sites, which may experience very high ground movement from moisture changes
E	Extremely reactive sites, which may experience extreme ground movement from moisture changes

Notes

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

Tree root growth

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

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

Unevenness of Movement

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

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

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

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

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

Effects of Uneven Soil Movement on Structures

Erosion and saturation

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

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

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

Seasonal swelling/shrinkage in clay

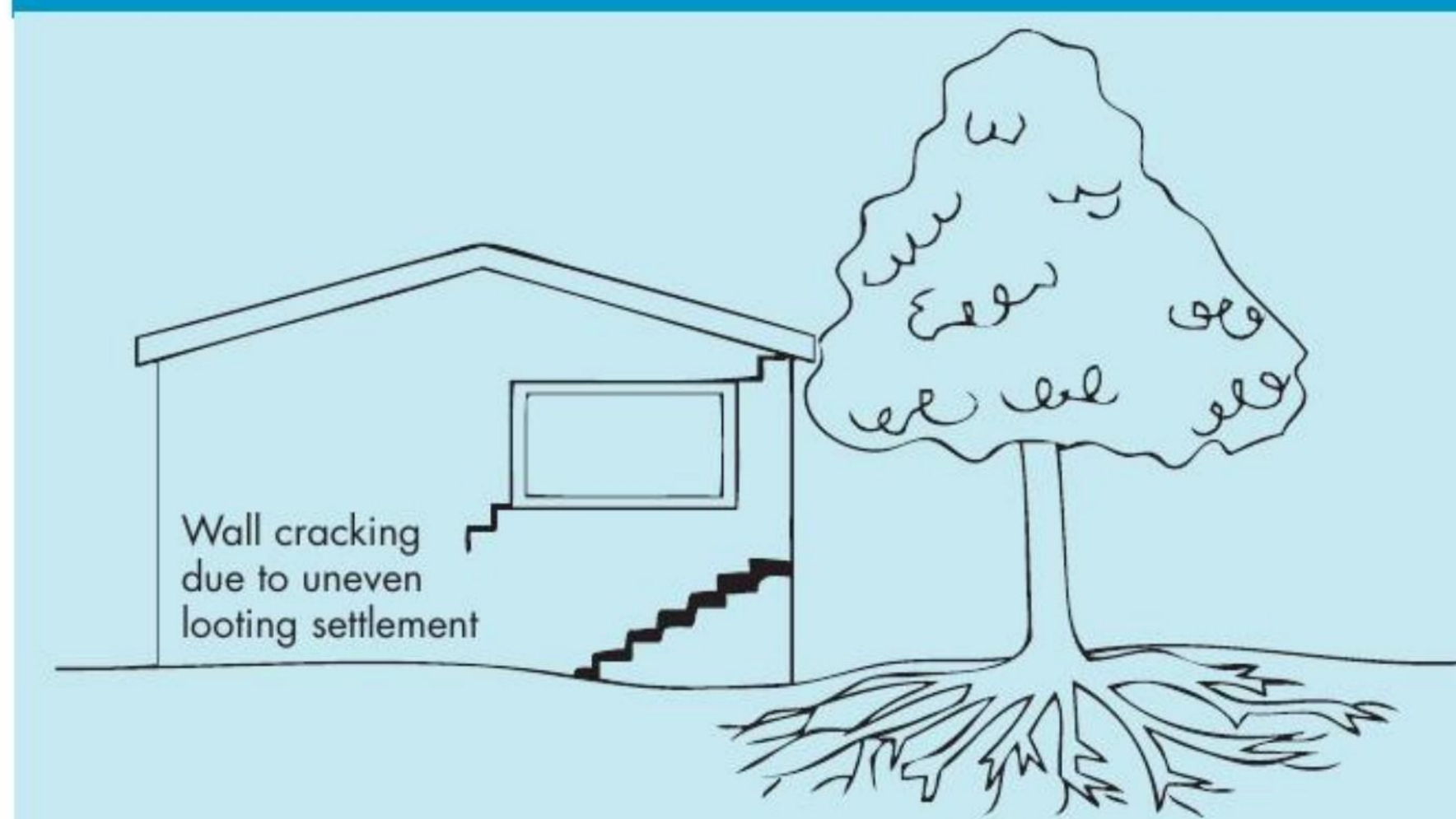
Swelling foundation soil due to rainy periods first lifts the most exposed extremities of the footing system, then the remainder of the perimeter footings while gradually permeating inside the building footprint to lift internal footings. This swelling first tends to create a dish effect, because the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

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

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

As the weather pattern changes and the soil begins to dry out, the external footings will be first affected, beginning with the locations where the sun's effect is strongest. This has the effect of lowering the

Trees can cause shrinkage and damage



external footings. The doming is accentuated and cracking reduces or disappears where it occurred because of dishing, but other cracks open up. The roof lines may become convex.

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

Movement caused by tree roots

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

Complications caused by the structure itself

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

Effects on full masonry structures

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

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

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

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

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

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

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

Effects on framed structures

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

Effects on brick veneer structures

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

Water Service and Drainage

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

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

- Incorrect falls in roof guttering may result in overflows, as may gutters blocked with leaves etc.

- Corroded guttering or downpipes can spill water to ground.
- Downpipes not positively connected to a proper stormwater collection system will direct a concentration of water to soil that is directly adjacent to footings, sometimes causing large-scale problems such as erosion, saturation and migration of water under the building.

Seriousness of Cracking

In general, most cracking found in masonry walls is a cosmetic nuisance only and can be kept in repair or even ignored. The table below is a reproduction of Table C1 of AS 2870-2011.

AS 2870-2011 also publishes figures relating to cracking in concrete floors, however because wall cracking will usually reach the critical point significantly earlier than cracking in slabs, this table is not reproduced here.

Prevention/Cure

Plumbing

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

Ground drainage

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

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

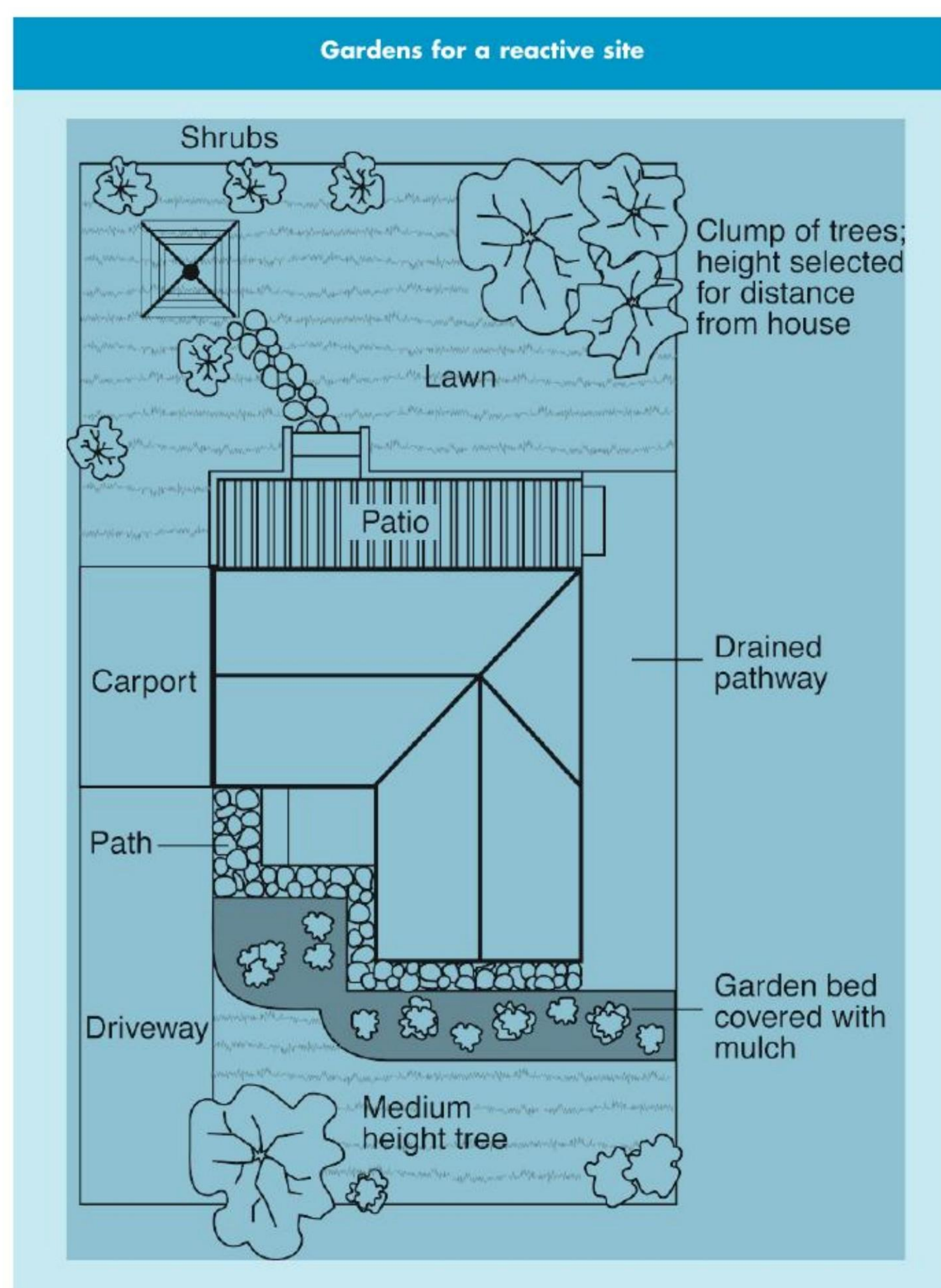
Protection of the building perimeter

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

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

CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS

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



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

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

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

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

Condensation

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

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

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

The garden

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

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

Existing trees

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

Information on trees, plants and shrubs

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

Excavation

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

Remediation

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

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

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

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

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

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

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