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Report Number	0429
Inspection Address	13 Granada Drive Highfields QLD, Australia
Client's Name	Emma Pearce
Date of Inspection	23/08/2025
Inspector	Dr. Shoja Jamali (RPEQ No. 28509)

Front view of the property

SERVICE REQUESTED: As agreed with Client which includes assessing the house for visual structural defects. No building and pest report was available at the time of inspection.

SPECIAL CONDITIONS OR INSTRUCTIONS: No

IMPORTANT NOTE: The Client acknowledges that, unless stated otherwise, the Client as a matter of urgency should implement any recommendation or advice given in this Report. The Summary is not the Report. The following Report must be read in full in conjunction with this Summary. If there is a discrepancy between the information provided in this Summary and that contained within the body of the Report, the information in the body of the Report shall override this Summary. Inspection was carried out in accordance with AS 4349.

1. Summary of Findings

Recommendations were provided for repair of cracks on internal and external walls which were mainly caused due to the ground movement.

This report is limited to the agreed service requested. For all other aspects pertaining to the property, it is Clients' responsibility to engage relevant experts as required. These aspects may include, but are not limited to structural design, fire and segregation, egress, disabled access, plumbing, electrical, town planning, occupational health and safety and regulatory compliance. No inspection was made to covered areas including roof truss, buried structures and other inaccessible items.

Any safety issues with this property raised or not in the report are the responsibility of the client/recipient of this report to rectify.

2. General Information of the Building and Inspection Scope

Brief description of the building and other structures on the property (if any) are as follows:

Type: Domestic

Height: Single Storey

Building: Block

Columns: Reinforced Concrete (RC) slab (not visible)

Floor: Timberdecking

Roof: Concrete tiles

At the time of inspection, the weather was fine and sunny.

As for the scope of the investigation, Ostanes was involved by Ms. Emma Pearce to visually investigate the structural condition of cracks on external and internal walls; and to confirm if any of these defects have any structural concern related to the overall structural integrity of the building.

In the following section, the details of identified defects are provided with recommendation and appropriate preventive measures.

On the day of the inspection, this inspection is based on “visible and accessible” areas only as agreed with the client. It is recommended that access be gained to all areas due to possible concealment of faults. An opinion on the shrinkage and swelling of reactive soils to dry and wet conditions affecting foundations and any subsequent movement of “inaccessible areas” cannot be given. The Inspector will not be held responsible for deliberate concealment of defects.

3. Inspected Items

No.	Defect	Description	Recommendation
1		Sign of foundation cracking due to ground movement is visible on the exterior block walls which has caused staggered cracking around the window sill, expansion joint and at corners. Additionally, clear sign of separation movement is noted in the front entrance. In the absence of soil report to understand the type of the soil the house is sitting on, there appears to be ground movement across the house. Ground naturally moves and settles and with variations in the moisture level (such as during raining seasons) as well as fluctuation in the ambient temperature, the amount of ground movement varies. Variation in the moisture level at ground causes slight movement for all houses (which is common), and usually cracking occurs at the locations where there is not enough flexibility for the material to move with the ground.	It is suggested to carry out soil testing to understand the ground condition at this site noting the presence of red clay during inspection. After which appropriate strengthening solutions can be implemented such as underpinning, resin injection and alike for the area of the house which is sitting on brick stump. It should be noted some cracking were less than 3mm wide and mainly appeared to be through the rendered parts of block walls. Such cracks can be repaired by removing the rendering, then applying high-strength low-shrinkage mortar in the affected areas to match the same rendering finish as existing wall. Blocks to be inspected after removal of rendering to confirm no evidence of defects on the blocks. All repair works in the future shall be completed by licensed tradesman experienced in similar repair. Once repair work is completed, repaired area shall be monitored for 6 to 12 months to check the effectiveness of repair and appearance of new cracks.

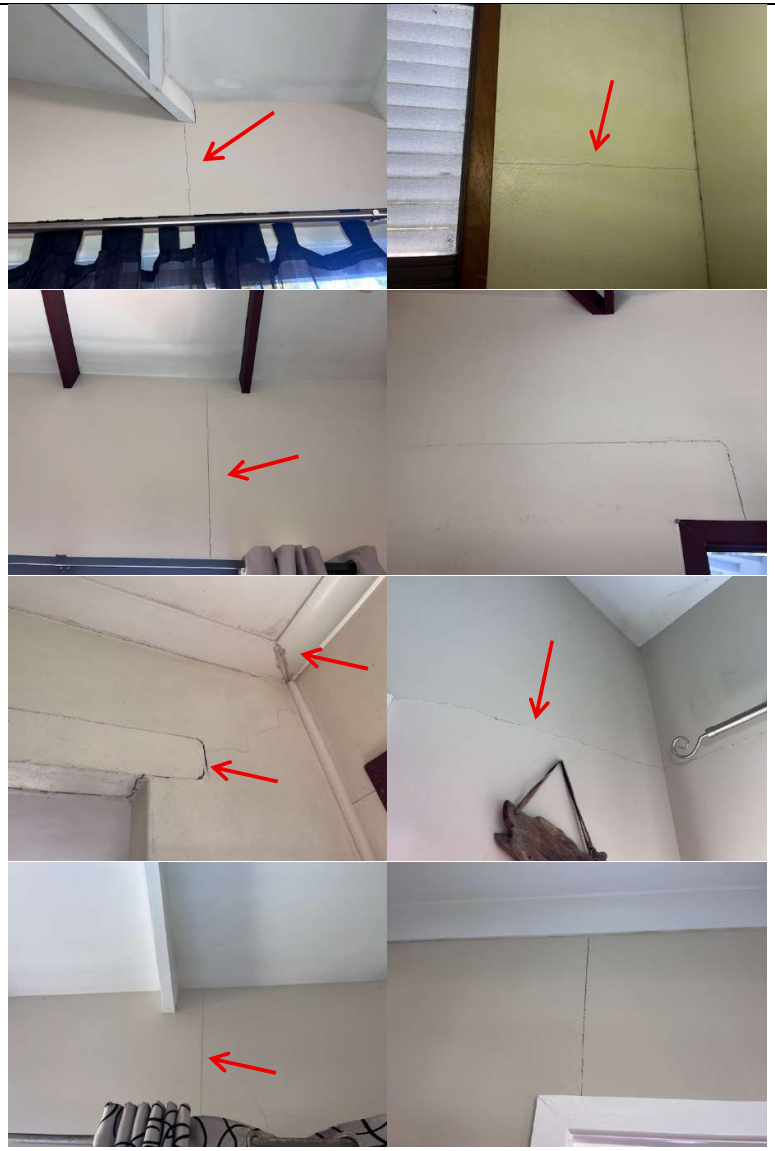
No.	Defect	Description	Recommendation
2		On continuation from the previous page, additional cracking is shown on the exterior block walls. Given that the exterior face of walls is rendered, it is difficult to quantify if the cracking has also occurred through the blocks or not. Almost all of the cracks appears not to be recent and have occurred in the past over long period of time.	Refer to page 4

No.	Defect	Description	Recommendation
3		On continuation from the previous page, additional cracking is shown on the exterior block walls.	Refer to page 4

No.	Defect	Description	Recommendation
4		On continuation from the previous page, additional cracking is shown on the exterior block walls. Also noted evidence of previous patch repair on some of the existing cracks. It should be noted the arched walls in the outside may crack again in the future given that these walls are connected via slab on ground, making them more prone to ground movement. Additionally, it is unclear if the arched walls and external block walls are reinforced or not.	Refer to page 4. Cracks on the arch walls can also be repaired using helical bar and high strength grout low shrinkage mortar. This method is also known as crack stitching, which involves inserting stainless steel helical bars at the affected locations that offers an effective and permanent solution.

No.	Defect	Description	Recommendation
5	   	Subfloor framing was visually inspected and no sign of structural defect was observed at the accessible areas on the floor joist and floor bearer. Note that no visual inspection was conducted inside the roof ceiling.	N/A

No.	Defect	Description	Recommendation
6		Plastering defects observed on the internal lining walls and ceiling panels in terms of separation gaps at cornices, cracks at sharp corners and jointed panel locations. In addition to ground movement, natural thermal movement (expansion/contraction of materials during wet/dry cycles), such defects on plastering could be due to poor workmanship and insufficient use of adequate filler / patching materials during the plastering stages as all of the observed cracks appeared to be superficial.	It is recommended to have the cracks on the walls and ceilings to be repaired by a qualified plasterer using suitable patching / filler materials. Some of the defective panels may require full replacement if the panel is split up. During repair process, the timber framing and its connections behind the wall shall be checked for presence of any damage. Then, the repaired locations should be monitored to check the adequacy of the repair works and to monitor for appearance of any additional defect.

No.	Defect	Description	Recommendation
7		On Continuation from the previous page. Additional, photos are showing the internal defects on wall and ceiling panels; which are made up of gyprock and FC sheets.	Refer to page 9

No.	Defect	Description	Recommendation
8		On Continuation from the previous page. Additional, photos are showing the internal defects on wall and ceiling panels; which are made up of gyprock and FC sheets.	Refer to page 9

4. Limitation and Exclusion of this Report

Special attention should be given to the Scope, Limitations and Exclusions in this document.

Unless stated otherwise in this Report, the Client as a matter of urgency should implement any recommendation or advice given in this Report. If the Client has any doubt about the Scope of this Report please discuss your concerns with the Consultant on receipt of the Report. If the Client fails to implement our recommendations or advice as stated within this Report, the client agrees and accepts that they will not or cannot hold Ostanes responsible.

Importantly, Australian Standard Inspection of Buildings. Part 1: Property Inspections – Residential Buildings recognises that a standard property report is not a warranty or an insurance policy against problems developing with the building in the future. Accordingly, a preventative maintenance program should be implemented for the property which includes systematic inspections, detection and prevention of incipient failure.

LIMITATIONS

The Client acknowledges:

1. This Report does not include the inspection and assessment of items or matters outside the scope of the requested inspection and report. Other items or matters may be the subject of a Special-Purpose Inspection Report, which is adequately specified (see Exclusions below).
2. This Report does not include the inspection and assessment of items or matters that do not fall within the Consultant's direct expertise.
3. The inspection only covered the Readily Accessible Areas of the property. The inspection did not include areas, which were inaccessible, not readily accessible or obstructed at the time of inspection. Obstructions are defined as any condition or physical limitation which inhibits or prevents inspection and may include – but are not limited to – roofing, fixed ceilings, wall linings, floor coverings, fixtures, fittings, furniture, clothes, stored articles/materials, thermal insulation, sarking, pipe/duct work, builders' debris, vegetation, pavements or earth.
4. Australian Standard Inspection of Buildings. Part 1: Property Inspections – Residential Buildings recognises that a standard property inspection report is not a warranty or an insurance policy against problems developing with the building in the future.
5. This Report was produced for the use of the Client. The Company and the Consultant are not liable for any reliance placed on the report by any third party.
6. This report does not include inspection to or assessment of asbestos containing materials.

EXCLUSIONS

The Client acknowledges that this Report does not cover or deal with:

(a) any 'minor fault or defect', i.e. a matter, in view of the age, type and condition of the building being inspected, does not require substantial repairs or urgent attention and rectification;
(b) solving or providing costs for any rectification or repair work;
(c) the structural design of any element of construction.
(d) detection of wood destroying insects such as termites and wood borers;
(e) the operation of fireplaces and solid fuel heaters, including chimneys and flues;
(f) any services including building, engineering (electronic), fire and smoke detection, air-conditioning, light switches and fittings, TV, sound and communications, intercom systems, garage door mechanisms, alarm and security systems or mechanical;
(g) any swimming pools and associated pool equipment or spa baths and spa equipment or the like;
(h) any appliances such as dishwashers, incinerators, ovens, stoves and ducted vacuum systems;
(i) a review of occupational, health or safety issues such as asbestos content, or the provision of safety glass or swimming pool fencing;
(j) a review of environmental or health or biological risks (e.g. asbestos content or presence thereof, toxic mould, allergies, soil toxicity, lead content, radon or urea formaldehyde)
(k) whether the building complies with the provision of any building act, code regulation(s) or by-laws; and
(l) whether the ground on which the building rests has been filled, is liable to subside, swell or shrink, is subject to landslip or tidal inundation, or if it is flood prone.
(m) comment on any material containing asbestos.
(n) Concealed plumbing, insulation, sarking, gas fittings and fixtures, any air-conditioning systems including ducted or split systems, solar panels or associated equipment.

Any of the above matters may be the subject of a special-purpose inspection report, which is adequately specified and undertaken by an appropriately qualified inspector.

DISPUTE RESOLUTION

In engaging our services, the client hereby agrees and accepts to abide by our dispute resolution process.

If the client becomes aware of any concern regarding this Report, the client must notify our office immediately within 5 business days of receiving this Report. Upon receipt of the client's complaint, Ostanes will endeavour to resolve the matter with the client in a telephone conversation. An onsite visit with the client may be required in an effort to address and resolve the matter. If we are unable to resolve the matter onsite, we will respond to the client's complaint in writing within 7 days. If the client is not satisfied with our response, the client may choose to contact the relevant local authority.

5. General Maintenance Tip Sheet

1. Check and clear roof & gutters and silicone joins. If not regularly cleaned timber rot and water damage can occur to fascia and soffits.
2. Check silicone sealants to roof flashings – ultraviolet rays of the sun will breakdown these (if unprotected) in a few years. All minor cracks to roof tiles should be sealed and all pointing to capping tiles regularly maintained with silicone to prevent any leakage and water damage to internal ceilings.
3. Adjust and lubricate sliders (doors & windows) – silicone (non-oily).
4. Check sealants and grouts to all decks & balconies and "wet areas". Upper-level patio floors which are not waterproofed may leak onto lower levels. Tiled shower cubicles are likely to leak if not sealed at floor levels. Tile glues can "crystallise" in a few years if incorrectly applied. Timber rot and decay can be concealed behind showers and other wet areas.
5. Treat all exposed timbers – 50% raw linseed oil + 50% turps. Tops of open decks, floor joists and tops of open pergolas – moisture will cause timber to decay (dry & wet rot).
6. Check moisture around timber and steel stumps/supports and posts – moisture causes decay and rust and can attract termites.
7. Avoid having timbers, posts, stairs, cladding etc. in direct contact with the ground. This will help reduce the risk of termites and timber rot. Oregon timbers are highly prone to timber rot and should not be used externally for pergolas, hand rails, external floor joists and beams, etc. When freshly painted timber rot can be hard to detect through visual inspection.
8. All windows and glass to home should be in accordance with Australian Standards AS2047 & AS1288.
9. Drain all surface water away from house. Water will swell ground clays and cause movement to foundations and crack brick and block walls. Recommend diverting all downpipes to curb where possible. Internal retaining walls can leak in heavy rain.
10. Any patched or repaired cracking past or present to brickwork or sheeting may require further investigation and should be monitored in the future.
11. For safety reasons, handrails and balustrading higher than 1 meter above the finished ground level should be brought into accordance with current building codes and regulations.
12. Keep trees and gardens away from foundations of house. Keep weep holes in brickwork clear at all times. Covered weep holes can lead to rising damp and termite infestation.
13. Older homes should be checked for lead-based paint and should have all lead-based paint removed by a professional painter due to safety concerns.
14. Recommend installation or renewal of termite treatment and/or an annual pest inspection and report.
15. All gas fittings and storage cylinders should be checked by a licensed installer for safe operation and operation of all fixtures.
16. **Additional useful tips on preventing house structural damage issued by QBCC and foundation maintenance by CSIRO are provided as supplementary information in the following pages.**

qbcc
queensland building and construction commission

A guide to preventing structural damage

Build better.

Home owners guide to planning landscaping and maintenance of foundations

Structural damage can result from movement in clay soils caused by varying moisture conditions around the perimeter of homes.

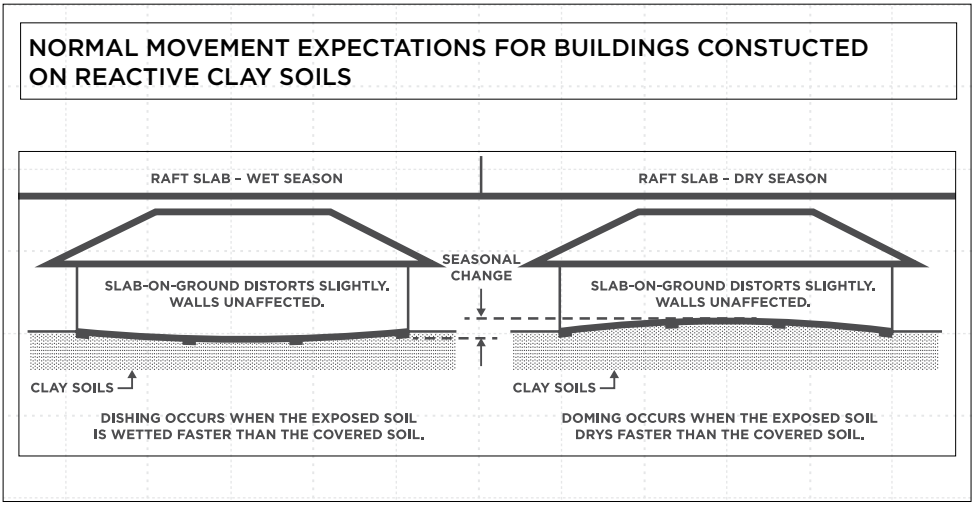
The majority of Queensland homes are situated on what are termed reactive clay soils. These soils are subject to expansion and contraction depending on seasonal weather and site conditions. Sandy sites and rocky terrain are usually not prone to this expansion and contraction.

In Queensland, engineers design footings to the **Australian Standard AS2870 – 2011 Residential slabs and footings**. Footings correctly designed to this standard are intended to accommodate the expected movements caused by seasonal volume changes in the soil (swelling when wet and shrinking when dry) - under **normal conditions**. The performance of footings under this standard requires **normal conditions** to be **maintained** around the house.

This guideline identifies **abnormal conditions** that should be avoided and/or corrected.

Dry seasons cause soils to dry out rapidly. Wet seasons cause soils to become wet quickly. This results in sudden extreme volume changes and movement in soil.

Abnormal conditions (other than seasonal changes), may include the effect of trees, poor surface drainage and/or leaking plumbing. If not allowed for in the engineer's design, these types of abnormal conditions may lead to movement and damage varying from minor to extreme.



How much can the soils under my house move?

The amount of movement that may occur depends on the site classification, which is defined under the **Australian Standard AS2870**.

The relevant classifications and expected movements under normal site conditions and seasonal influences are:

Site classification	Description of type of clay and reactivity	Expected range of movement
A	Mostly sand and rock with little or no ground movement from moisture changes.	0
S	Slightly reactive clays that do not present significant trouble. Very limited damage could be expected in the life of the building.	0 to 20mm
M	Moderately reactive clays that may cause minor movement and damage in the life of the building. Reasonable care is required in planning the site.	20 to 40mm
H **(H1 & H2)**	Highly reactive clays have potential to move more, and react to variable moisture change conditions. Some minor damage may occur in the life of the building under normal conditions. More significant damage may occur where site maintenance conditions are a problem e.g. influence of trees or leaking underground plumbing or poor drainage. Particular care is required in planning the site.	**H1** 40 to 60mm **H2** 60 to 75mm
E	Extremely reactive clays have the potential to react significantly to any variable moisture changes in the foundation clays and require significant attention to detail in planning the site works. Extreme movement and damage may occur if the site conditions and foundation maintenance requirements are not observed. Footing systems and site conditions on “E” sites require very detailed specification from an engineer.	>75mm (Note: Movements on **E** sites have been known to move up to and in excess of 100 to 150mm in SE Qld)

Is it normal to expect cracking to occur in brickwork, walls and ceilings?

Yes, damage in varying degrees can be expected in the life of the building depending on the relevant site classification.

If cracking becomes apparent the site maintenance conditions should be checked as noted under "key points to consider..."

Corrective action should be carried out immediately and may include regrading surface drainage, moving gardens and trees or repairing leaks in water supply, stormwater and/or sewer drainage.

A sound plan for a reactive clay site is to provide a consistent moisture regime around the building by installing paths and patios against the house. Locate lawns up against paths & patios. Garden beds, the most heavily watered parts of a garden, should be kept well away from the house.

If gardens must be placed in close proximity to the house, they should be sealed with plastic and contain only a few small plants. Take care not to trap water against the building if using garden edging.

Caution: Care should also be taken if placing filling against the house. Always ensure weep holes are not covered and that existing Termite Management Systems are not compromised.

Key points to consider when planning landscaping to avoid structural damage.

- Plan type and location of gardens, paths, driveways, lawns, filling and retaining walls
- Take care in selection of trees and shrubs. Do not over plant next to the house
- Keep trees with high water demand well away from buildings in reactive clay areas.
- Avoid variable conditions around the house and maintain adequate moisture/watering. Do not ***over*** water and avoid the use of unregulated sprinkler systems.
- Locate ponds and water features away from the house.
- Direct surface water away from the house. Do not allow water to be trapped or pond near the house.
- Repair leaking pipes and taps.

Note: these issues should be considered as part of planning and maintaining the home. Aim to provide a consistent moisture regime around the house. This will minimise soil moisture variations that may cause movement and result in structural damage.

Common sense guidelines for landscaping and gardens

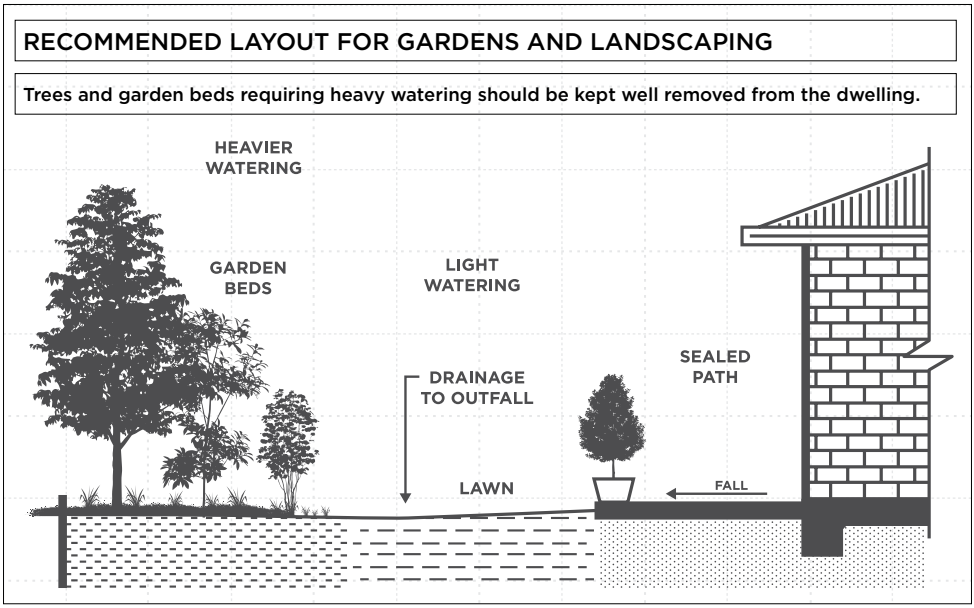
1. Gardens

Important: It is quite impractical to try to prevent gardening activities from increasing the moisture content around the foundations of your home. The only practical course is to keep such activities away from the immediate vicinity of the building and so minimise their effects.

A sound plan for a reactive clay site is to provide a consistent moisture regime around the building by installing paths and patios against the house. Locate lawns up against paths & patios. Garden beds, the most heavily watered parts of a garden, should be kept well away from the house.

If gardens must be placed in close proximity to the house, they should be sealed with plastic and contain only a few small plants. Take care not to trap water against the building if using garden edging.

Caution: Care should also be taken if placing filling against the house. Always ensure weep holes are not covered and that existing Termite Management Systems are not compromised.



2. Paths, patios and driveways

Paths should be laid hard against brickwork or footings with a fall away from the house to a stormwater discharge point.

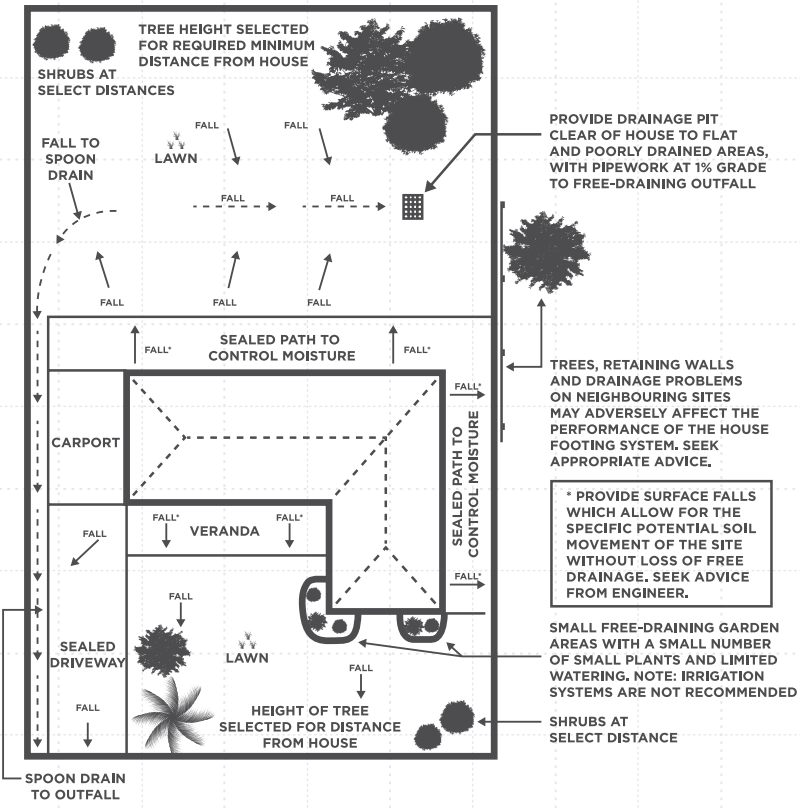
Avoid placing large expanses of concrete on one side of the house and heavily watered garden beds on the other.

The water saturated clay in the gardens will expand and swell while the soil under the concrete may not move. Structural damage can result from this unco-ordinated movement.

Concrete pavements should be constructed in a way that will not impede surface water flowing away from the building or cause water to pond adjacent to the footings causing clay foundations to swell.

On “H” & “E” site classifications, particular detail is required to prevent pavement from moving away from the building. Movement in paths could cause stress on pipes and inspection openings and/or breakages in pipes. Resulting leakages may cause movement and damage as a result of clay soils under the house swelling.

RECOMMENDED LANDSCAPING



3. Lawns

If placing lawn areas against the house, ensure that filling built up against the wall is graded away and will not allow ponding of water to occur. The filling should be impervious clay soil and not sandy loam.

REMEMBER: Do not cover weep holes.

4. Filling

Prior to preparing for gardens, lawns or filling as part of site works, care should be taken to ensure the sub-grade or ground level is graded or sloped away, especially when filling or top dressing with sandy loam. The sub-grade should consist of impervious natural site clay.

Where elevated floors exist ensure that the final finished ground level outside the house is not higher than the sub-floor area and that water cannot flow back under the house.

5. Excessive watering of gardens and lawns

The erection of a building also indirectly brings with it changes in the moisture content to the site. While it is normal to water gardens and lawns, excessive or over watering should be avoided. Consistent and adequate watering should be observed at all times.

The location of sprinkler systems next to houses should also be avoided on H and E sites.

Sprinkler systems should be as well controlled and maintained as practical, and only used in gardens and on lawns away from the building.

6. Site drainage and sloping sites

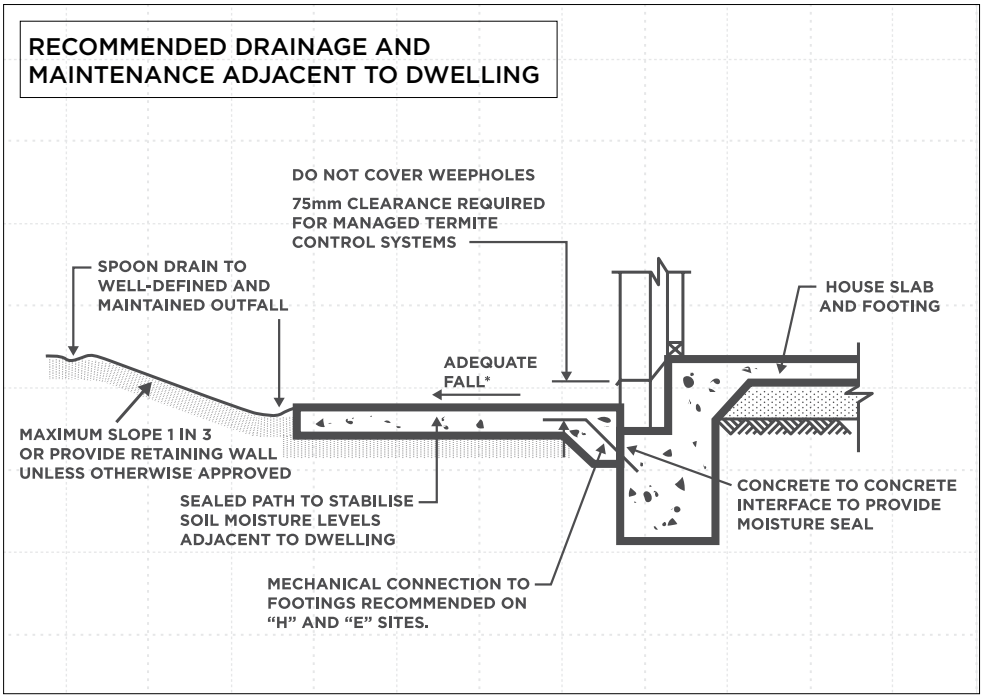
Design for site conditions, location of retaining walls, paths, swimming pools, future structures or proposed extensions etc. should all be considered when preparing the site for correct surface water flow.

If the ground slopes towards the house, paths with spoon drains should be provided.

It is also important to place drains uphill of the footings so as to direct water around the house and away from the footings. A stormwater and roof water drainage management plan should be considered and take into account water flowing from adjoining properties.

Seek advice from an engineer

1. To ascertain surface falls which allow for the specific potential soil movement of the site without loss of free drainage
2. To provide correct mechanical connection of perimeter paths of footings



7. Trees and shrubs

The roots of trees and shrubs can affect footings by removing moisture from clay soils immediately underneath the building causing subsidence as the clays shrink.

In its search for water, a tree root system can spread a lateral distance equal to the height of the tree. If in rows or grouped with other trees the roots may spread up to twice the height of the tree.

Care should be taken when selecting trees and, as a guide, the trees listed should not be planted within the distance of their mature height from the house depending on the site classification and whether they are to be planted in a line or in a group.

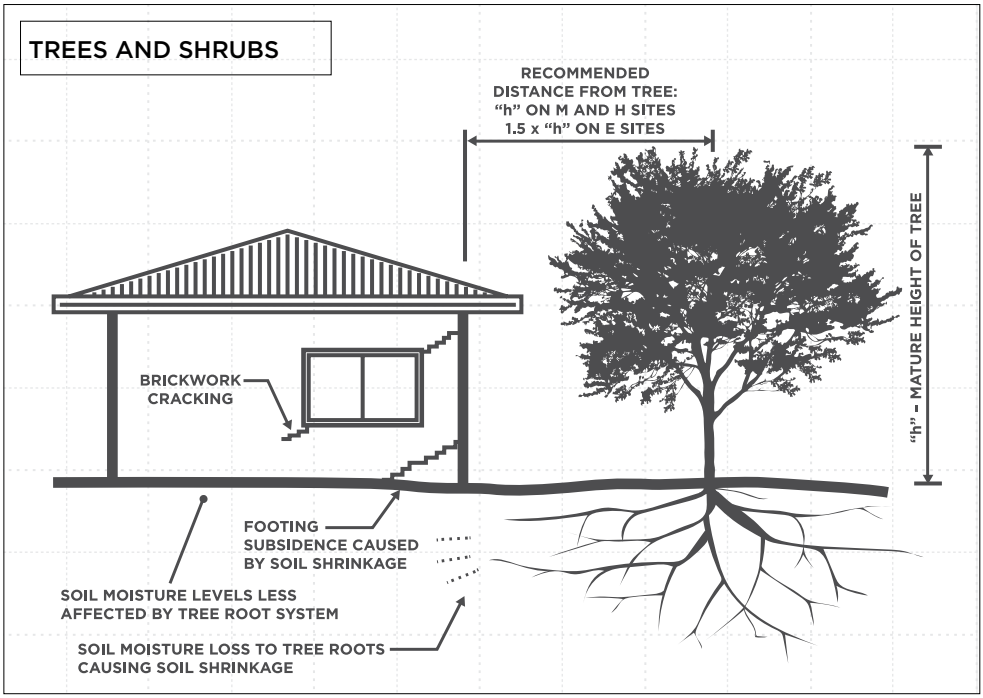
Height of Tree(h)
Distance from house (d)

d = 1 h for class **H** and **M** sites.

d = 1.5 h for class **E** sites.

d = 2 h for rows or groups of trees.

10 to 20 metres	20 to 30 metres	30 to 60 metres
Acacias	But-But	Blue Gum
Ash	Cedars	Cypress
Athel Tree	English Oak	English Elm
Candlebark	Lemon Gum	Figs
Manna Gum	Palms	Karri
Pepper tree	Planes	Pines
Willows	Sheoaks	Poplars
Yate	Silky Oak	River Gum
Yellow Gum	Spotted Gum	Sugar
	Casuarina	



Summary of owner responsibilities for houses under warranty

1. Maintain the site drainage at all times.

2. Do not alter the site drainage provided by the builder. Any changes to the site drainage should ensure that water will be directed away from the building and not pond adjacent to the footing and slab system. Care should also be taken to avoid directing water flow to adjoining properties.

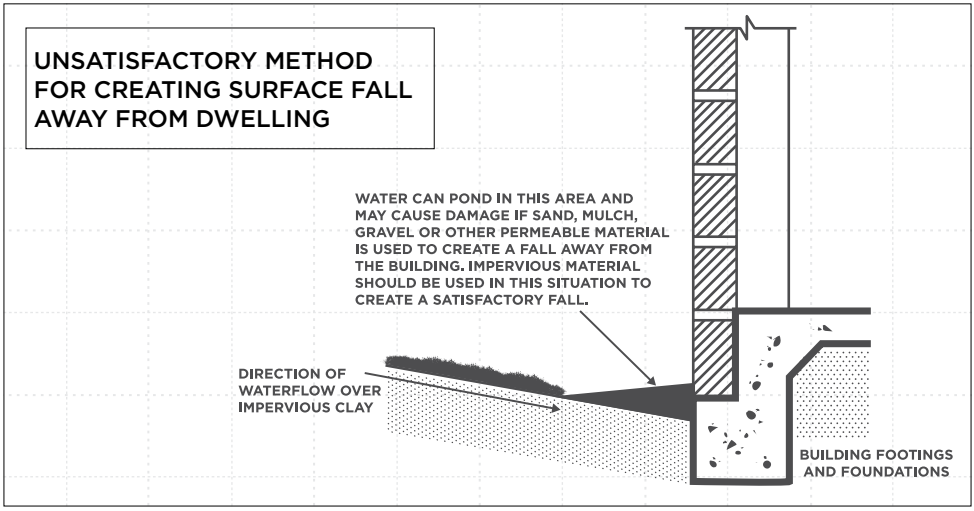
3. Where possible on reactive clay sites (Type M,H,E Classifications), avoid placing gardens or installing garden edging, gravel pavements etc next to the building. This may cause water retention and/or promote a greater variation in moisture conditions around the building.

4. Installation of sprinkler systems next to dwellings on highly and extremely reactive sites (Type H & E Classifications) should be avoided. Adequate and consistent watering only is recommended. Over watering should be avoided.

5. Do not plant trees within a distance from a building that equates to their mature height. Always plant in accordance with the requirements for the relevant site classification.

6. Regularly check and maintain plumbing, drainage and stormwater systems by immediately carrying out repairs to leakages or breakages when observed (usually displayed by seepage and/or greener lawns etc.), or when minor damage or cracking exceeding 3-5mm appears in walls or ceilings.

By observing these requirements, movement and damage which may be expected in the life of the building can be minimised and maintained within normal performance requirements.



FOUNDATION MAINTENANCE AND FOOTING PERFORMANCE

Preventing soil-related building movement

This Building Technology Resource is designed as a homeowner's guide on the causes of soil-related building movement, and suggested methods to prevent resultant cracking.

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 home owner 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. Generally soil classification is provided by a geotechnical report.

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.

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. Table 1 below is a reproduction of Table 2.1 from Australian Standard AS 2870-2011, Residential slabs and footings.

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 may be the province of the builder and should be taken into consideration as part of the preparation of the site for construction.

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, from AS 2870). 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.

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.

TABLE 1. 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

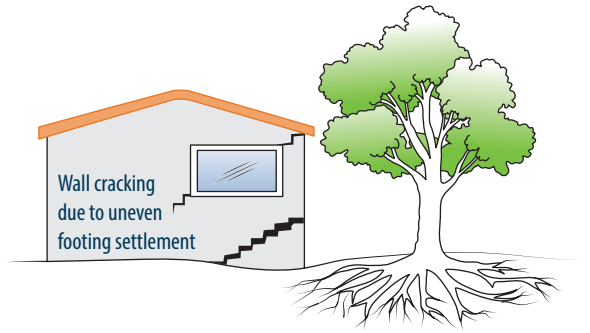


FIGURE 1 Trees can cause shrinkage and damage.

- 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 through absorption. The swelling process will usually begin at the uphill extreme of the building, or on the weather side where the land is flat. Shrinkage usually begins on the side of the building where the sun's heat is greatest.

EFFECTS OF UNEVEN SOIL MOVEMENT ON STRUCTURES

EROSION AND SATURATION

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

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

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

SEASONAL SWELLING/SHRINKAGE IN CLAY

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

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

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

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

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. Table 2 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 AND 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 may 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 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.

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.

TABLE 2. CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS.

Description of typical damage and required repair	Approximate crack width limit	Damage category
Hairline cracks	<0.1 mm	0 – Negligible
Fine cracks which 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. Weathertightness often impaired.	5–15 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 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 – Severe

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Warning: Although this Building Technology Resource 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, and mould.
- 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

Existing trees may cause problems with the upheaval of footings by their roots, or shrinkage from soil drying. 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. Soil drying is a more complex issue and professional advice may be required before considering the removal or relocation of the tree.

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.

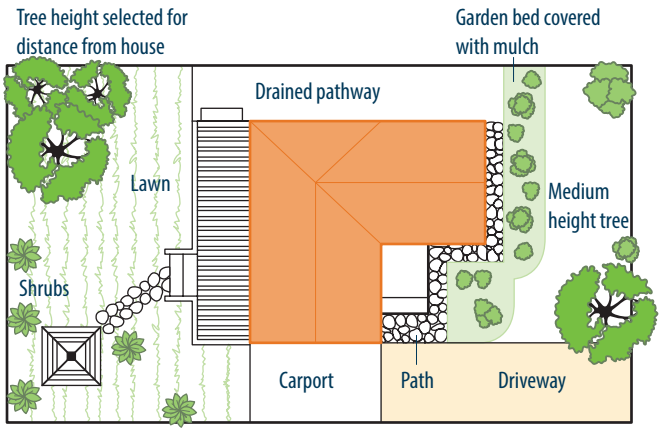

FIGURE 2 Gardens for a reactive site.

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 home owner 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.