Nepean Geotechnics

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Preliminary Geotechnical Investigation Report

Proposed Residential Development

32 – 34 Kent Street, Belmore NSW

Report No. R25082. Rev0

Prepared for:

Multiform Design & Construction Pty Ltd

8 April 2025

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1. Introduction

This report presents the results of a preliminary geotechnical investigation undertaken for proposed residential development at 32 – 34 Kent Street, Belmore NSW. The job was undertaken in accordance with Nepean Geotechnics general terms of engagement.

We've been advised that the development comprises the demolition of existing structures prior to the construction of four storey unit type boarding house,with a single level basement carparking. Based on the provided conceptual drawings, the finished floor level of basement carparking will be at RL 30.975 m and involve excavations up to approximate depth of 3 m below the ground surface.

The objective of the preliminary investigation was to identify subsurface conditions in order to provide preliminary comments on the bearing capacity of subsurface material, likely excavation conditions and the requirements for temporary support of the excavations.

2. Site Description

The site occupies a total area of approximately 960 m^2 and the existing structures consists of single storey brick dwellings together with secondary dwelling at the rear of each allotment and carports at the front of the site. Site vegetation comprised grasses in the rear yards and shrubs and trees adjacent to the site boundaries.

The site has frontage to Kent Street along the western boundary and is bordered by residential properties to the remaining sides. The existing structure at the north of the allotment was a residential flat building with basement carparking.

3. Regional Geology

According to the Sydney 1:100 000 Geological Series Sheet, the site is underlain by Ashfield shale of Wianamatta group which typically consist of gravelly clays, siltstone and dark grey shale.

4. Field Work

The field work comprised drilling of two boreholes (BH1 – BH2) across the site. Due to restricted access, the boreholes were drilled using hand portable augers. An experienced geotechnical engineer attended site for a walkover assessment and borehole logging. An experienced geotechnical engineer attended site for a walkover assessment and borehole logging.

A marked up site plan showing the approximate borehole locations is provided in Appendix A.

5. Subsurface Conditions

At the borehole locations, the surface material consisted of minor topsoil overlying silty clays of firm to stiff consistency in dry conditions. These materials extended to approximate depths of 0.8 m in BH1 and 0.9 m in BH2. Below these depths, gravelly clays of stiff to very stiff consistency were encountered and continued to the termination depths of 1.0 m in BH1 and 1.3 m in BH2. Further drilling could not be continued below these depths due to refusal on rock floaters/oversized particles.

Based on DCP test results, extremely weathered bedrock is likely to be encountered at approximate depths of 1.3 m and 1.5 m in BH1 and BH2, respectively. However, the DCP test does not provide a visual assessment of subsurface conditions, and the conditions may vary across the site. It should be noted that estimated soil consistency/strength assessed by DCP testing and the depth of bedrock in the boreholes are approximate and variations should be expected throughout the site.

No groundwater seepage was encountered during the fieldwork or before the boreholes were backfilled.

6. Soil Classification

Given the presence of existing structures, the site will be classified as Class P in accordance with AS2870 – 2011 '*Residential Slabs & Footings*'. Based on the subsurface materials encountered, a characteristic ground surface movement equivalent to 'Class M – Moderately Reactive' may be adopted for the existing subsurface material, provided that the footings of the proposed development are founded into the underlying bedrock.

7. Bearing Capacity

Near surface soft to firm clays are not suitable foundation material for the proposed development. All footings shall be extended into the underlying residual soils or bedrock. It is noted that footings/piers shall be founded into similar foundation material to avoid differential settlement and premature cracking.

High level pad or strip footings founded in natural stiff clays/dense clayey sands may be designed based on an allowable bearing capacity of 100 kPa.

High level footings or bored piers founded in the extremely to highly weathered bedrock (equivalent to Class V shale/sandstone, may be designed based on an allowable bearing capacity of 700 kPa.

Allowable shaft resistance values of 30 kPa and 50 kPa may be adopted for residual soils and extremely to highly weathered rock, respectively.

It's noted that rocks below the auger refusal depths of boreholes may be underlain by layers of weak or decomposed rock before reaching a consistent solid bedrock. Footings/piers shall be inspected prior to the placement of steel and the pouring of concrete to ensure the design criteria are met.

If steel screw piles are adopted for the site, a copy of this report should be provided to the contractors and the assessment of working loads, pile depths. The selection of a suitable size equipment shall be undertaken by the piling contractor.

Consideration shall be given to further subsurface investigation including rock cored boreholes to confirm the quality of bedrock below the design level of basement for shoring walls and footings. Rock cores will enable the classification of good quality bedrock (Class III or better) for sizing the piers based on higher bearing capacities.

8. Excavation Conditions

Based on the provided conceptual drawings, the finished floor level of basement carparking will be at RL 30.975 m and involve excavations up to approximate depth of 3 m below the ground surface. It is understood that due to sloping ground conditions, the excavation depths will be decreasing to a depth of 2 m at the rear of the site.

Based on the subsurface material encountered in the boreholes, the bulk excavations for the proposed basement would likely be in clayey soils of firm to stiff consistency underlain by weathered shale bedrock. The natural soils and extremely weathered bedrock shall be excavated using a medium size excavator equipped with toothed bucket. Some minor ripping may be required for the excavations of bands of the better quality rock. It’s however noted that good quality bedrock may be present below auger refusal depths of boreholes and may involve the use of diamond blade rock saw and the use of hydraulic rock hammers.

The excavation of soils and any bedrock using excavators and toothed buckets is not expected to cause significant vibrations. Vibrations induced ground movements are anticipated in surrounding ground when excavating the bedrock using hydraulic rock breaker equipment. As such, the efforts shall be made to limit ground vibrations resulting from the excavations at the adjacent properties.

If the use of hydraulic jack hammers is required, the contractor should allow for a vibration monitoring program during bulk excavations to ensure the operational works do not generate ground vibrations higher than 10 mm (peak particle velocity) and 5 mm/sec within a 3 m distance from the site boundaries. The suitability of rock breaking equipment should be determined by trial at various setback distances from the site boundaries after installing the vibration monitoring equipment.

A dilapidation survey of the adjacent properties should be undertaken prior to the bulk excavations.

9. Safe Batters and Retaining Walls

Unsupported excavations in the fill and clayey material shall be battered safely to avoid structural damages to the adjacent infrastructures and existing dwellings on the adjoining properties. Temporary batter slope of 2(H): 1(V) may be adopted for cut batters in near surface fill or firm clays in dry conditions. This may be decreased to 1:1 for the cuts in the stiff clays or extremely weathered rock (equivalent to Class V). Vertical cut batters in good quality bedrock may remain stable with no additional support.

Based on the provided conceptual drawings, the proposed basement footprint has setback distance of 6 m from the eastern and western boundaries and a distance of 3.0 m from the north and southern site boundaries. The nominated setback distances would likely allow the construction of temporary safe batters for the proposed basement. If the construction of safe batters will not be feasible, temporary support will be required to support the bulk excavations.

Retaining walls may be designed based on the following estimated design parameters:

Table 2: Retaining Wall Design Parameters

Material	Bulk Unit Weight (kN/m^3)	Cohesion, C' (kPa)	Effective Friction Angle (Φ')	Elasticity Modulus (MPa)	Poisson's ratio	Allowable Bond Strength (kPa)
Fill/firm clays	18	0	25	5	0.3	N/A
Stiff Clays	18	0	25	8	0.3	N/A
Shale (Class V)	22	30	32	50	0.3	50

The above parameters are estimated values and were adopted from the available literatures.

Granular material shall be placed directly behind the retaining walls. Efficient drainage shall be provided by placing perforated drainage pipes along the bottom of the wall. The effect of water pressure needs to be considered in the design of retaining walls where there is a potential for the saturation of backfill material and residual soil.

10. General Notes

Our professional services were performed, our findings obtained, and our recommendations prepared in accordance with generally accepted engineering principles and practices. This warranty is in lieu of all other warranties, either expressed or implied.

The geotechnical report was prepared for the use of the owner in the design of the subject project and should be made available to potential contractors for information on factual data only. This report should not be used for contractual purposes as a warranty of interpreted subsurface conditions such as those indicated by the interpretive borehole logs, cross-sections, or discussion of subsurface conditions contained herein.

The analyses, conclusions and recommendations contained in the report are based on site conditions as they presently exist and assume that the boreholes are representative of the subsurface conditions of the site. If, during construction, subsurface conditions are found which are significantly different from those observed in the boreholes, or assumed to exist in the excavations, Nepean Geotechnics should be advised immediately to review these conditions and review recommendations where necessary. If there is a substantial lapse of time between the submission of this report and the start of work at the site, or if conditions have changed due to natural causes or construction operations at or adjacent to the site, this report should be reviewed to determine the applicability of the conclusions and recommendations considering the changed conditions and time lapse.

The borehole logs are our opinion of the subsurface conditions revealed by periodic sampling of the ground as the field work progressed. The soil descriptions and interfaces between strata are interpretive and actual changes may be gradual.

The logs and related information depict subsurface conditions only at these specific locations and at the particular time designated on the logs. Soil conditions at other locations may differ from conditions occurring at these borehole locations. Also, the passage of time may result in a change in the soil conditions at these borehole locations.

Groundwater levels often vary seasonally. Groundwater levels reported on the borehole logs or in the body of the report are factual data only for the dates shown.

Unanticipated soil conditions are commonly encountered on construction sites and cannot be fully anticipated by merely taking soil samples or boreholes. Such unexpected conditions frequently require that additional expenditures be made to attain a properly constructed project.

Nepean Geotechnics cannot be responsible for any deviation from the intent of this report including, but not restricted to, any changes to the scheduled time of construction, the nature of the project or the specific construction methods or means indicated in this report; nor can our firm be responsible for any construction activity on sites other than the specific site referred to in this report.

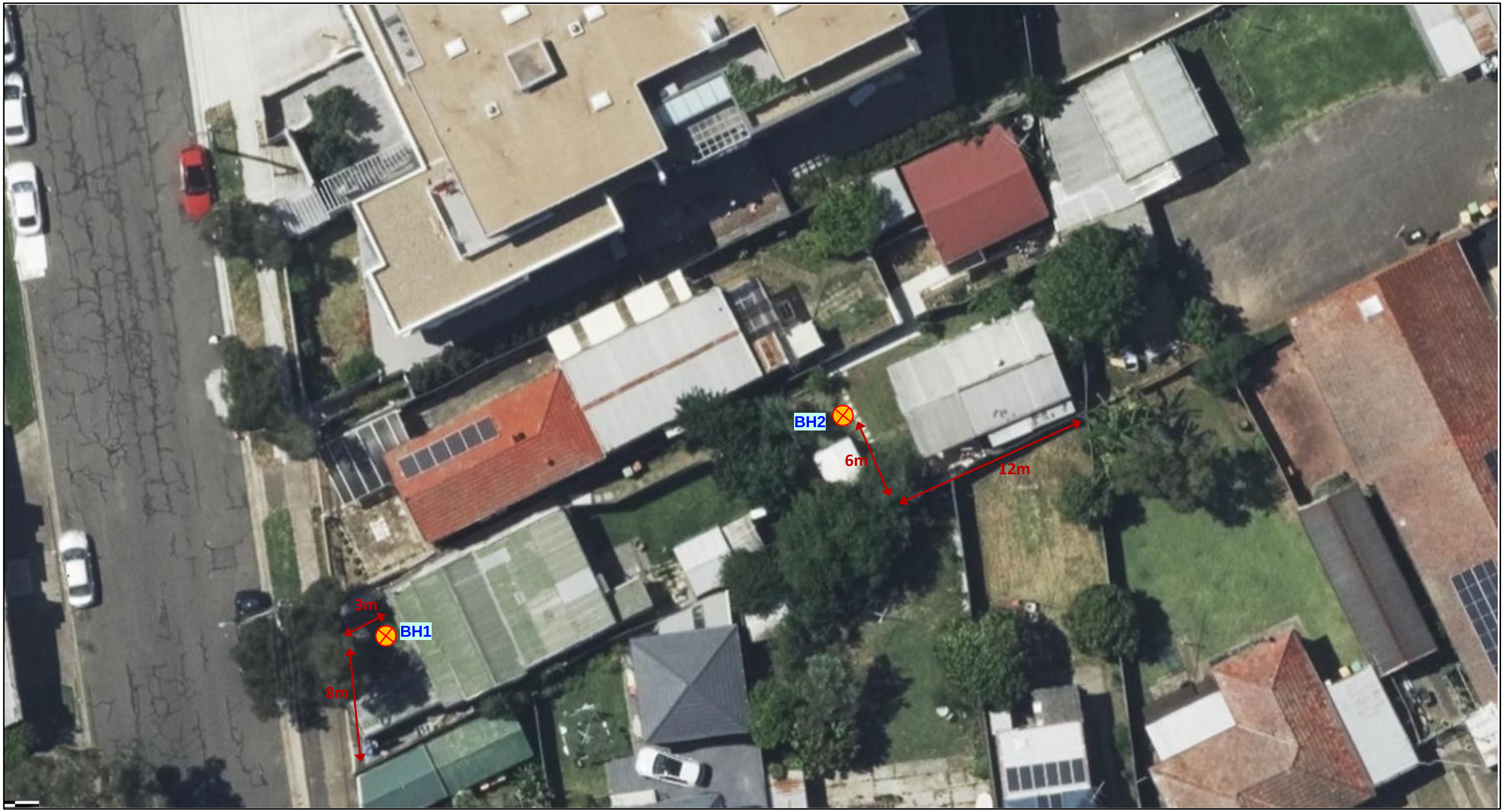
We trust the above is sufficient for your requirements. Please do not hesitate to contact the undersigned should you require further information or need to discuss any aspect of this report.

Yours sincerely,

Rasoul Machiani (MIEAust/CPEng/NER)
Senior Geotechnical Engineer
For and on behalf of Nepean Geotechnics

Appendix A

Approximate Borehole Locations



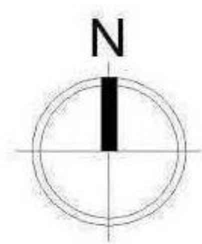
Approximate Borehole Locations

Proposed Childcare Development

32 – 34 Kent Street, Belmore NSW

Project No: R25082

Date: 4 April 2025



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Appendix B

Soil & Rock Descriptions Sheets

Borehole Logs (BH1 – BH2)

Photographs of subsurface material

Soil & Rock Descriptions

The methods of descriptions and classifications used by Nepean Geotechnics in this report are in general accordance with Australian Standard AS1726 - 2017 as detailed in the following tables:

Soil Classification

Grading

Term		Particle Size(mm)
Coarse Grained Soils (more than 50% of material is larger than 0.075mm)	Boulders	>200
	Cobbles	63 – 200
	Gravels	2.36 – 63
	Sand	0.075 – 2.36
Fine Grained Soils (more than 50% of material is smaller than 0.075mm)	Silt	0.002 – 0.075
	Clay	<0.002

Consistency (Cohesive Soils)

Term	Undrained Shear Strength (kPa)	Field Guide to Consistency
Very soft	≤ 12	Exudes between the fingers when squeezed in hand
Soft	>12 ≤25	Can be moulded by light finger pressure
Firm	>25 ≤50	Can be moulded by strong finger pressure
Stiff	>50 ≤100	Can not be moulded by fingers/can be indented by thumb
Very stiff	>100 ≤200	Can be indented by thumb nail
Hard	>200	Can be indented with difficulty by thumb nail

Consistency (Non-Cohesive Soils)

Term	Density Index (%)
Very loose	≤ 15
Loose	>15 ≤35
Medium dense	>35 ≤65
Dense	>65 ≤85
Very dense	>85

Rock Classification

Strength of Rock Material

Term	Letter Symbol	Point Load Index, Is_{50} (MPa)	Filed Guide to Strength
Extremely low	EL	≤0.03	Easily remoulded by hand to a material with soil properties
Very low	VL	>0.03 ≤0.1	Material crumbles under firm blows with sharp end of pick; can be peeled with knife; pieces up to 3 cm thick can be broken by finger pressure
Low	L	>0.1 ≤0.3	Easily scored with a knife; indentations 1 – 3 mm show in the specimen with firm blows of the pick point; a piece of core 150 mm long may be broken by hand
Medium	M	>0. 3 ≤1.0	Readily scored with a knife; a piece of core 150 mm long can be broken by hand with difficulty
High	H	>1 ≤3	A piece of core 150 mm long cannot be broken by hand but can be broken by a pick with a single firm blow; rock rings under hammer
Very high	VH	>3 ≤10	Hand specimen breaks with pick after more than one blow; rock rings under hammer

Rock Material Weathering Classification

Term	Letter Symbol	Filed Guide to Strength
Residual soil	RS	Soil developed on extremely weathered rock; the mass structure and substance fabric are no longer evident; there is a large change in volume but the soil has not been significantly transported
Extremely weathered	XW	Rock is weathered to such an extent that has 'soil' properties (i.e. either disintegrated or can be remoulded in water)
Highly weathered	HW	Rock strength usually changed by weathering. The rock may be highly discoloured, usually be ironstaining. Porosity may be increased by leaching, or may be decreased due to deposition of weathering in pores
Slightly weathered	SW	Rock is slightly discoloured but shows little or no change of strength from fresh rock
Fresh rock	FR	Rock shows no sign of decomposition or staining

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Borehole Log

Client:	Multiform Design & Construction P/L	**Surface Level:**	N/A	**Job No. :**	R25082
Project:	Proposed Childcare Development	**South:**	Refer to site	**Borehole:**	BH1
Location:	32 - 34 Kent Street Belmore	**Easting:**	plan	**Date:**	04-April-2025
		Logged/Checked by:	RM	**Sheet:**	1 of 1

Method	Groundwater	Sample	DCP	SPT	RL	Depth (m)	Classification Symbol	Material Description	Moisture Content	Consistency/Relative Density	Pocket Penetrometer (kPa)	Origin
Hand Auger			2 3 3				SM	Silty SAND grey, dry to moist, loose to medium dense	D/M	L		Topsoil
			3 3				CI	Silty CLAY dark brown, dry to moist, firm	D/M	F		Natural
			3 4 10			0.5	CI	Silty CLAY brown/orange brown mottled, dry to moist, firm to stiff	D/M	F/St		Natural
			10 12 20			1.0	CI	Gravelly CLAY pale grey/pale brown, dry, very stiff with trace highly weathered rock	D	V-St		Residual
			24 Refusal					Hand Auger Refusal				
						1.5						
						2.0						
						2.5						
						3.0						
						3.5						
						4.0						
						4.5						

Equipment: Hand Auger

Water Observations: N/A


Subsurface Material - BH1

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Borehole Log

Client:	Multiform Design & Construction P/L	**Surface Level:**	N/A	**Job No. :**	R25082
Project:	Proposed Childcare Development	**South:**	Refer to site	**Borehole:**	BH2
Location:	32 - 34 Kent Street Belmore	**Easting:**	plan	**Date:**	04-April-2025
		Logged/Checked by:	RM	**Sheet:**	1 of 1

Method	Groundwater	Sample	DCP	SPT	RL	Depth (m)	Classification Symbol	Material Description	Moisture Content	Consistency/Relative Density	Pocket Penetrometer (kPa)	Origin
Hand Auger			1 1 2				SM	Silty SAND grey, dry to moist, loose to medium dense	D/M	L		Topsoil
			2 3			0.5	CI	Silty CLAY dark brown, dry to moist, firm	D/M	F		Natural
			4 4 5				CI	Silty CLAY brown/orange brown mottled, dry to moist, firm to stiff	D/M	F/St		Natural
			4 5 6			1.0	CI	Silty CLAY brown/pale brown/pale grey mottled, dry, stiff	D	St		Natural
			8 10 12				CI	Gravelly CLAY pale grey/pale brown, dry, very stiff with trace highly weathered rock	D	V-St		Residual
			Refusal			1.5		Hand Auger Refusal				
						2.0						
						2.5						
						3.0						
						3.5						
						4.0						
						4.5						

Equipment: Hand Auger

Water Observations: N/A


Subsurface Material – BH2

Appendix C

Foundation Maintenance and Footing Performance (CSIRO)

Foundation Maintenance and Footing Performance: A Homeowner's Guide

CSIRO

BTF 18 replaces Information Sheet 10/91

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

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

Soil Types

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

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

Causes of Movement

Settlement due to construction

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

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

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

Erosion

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

Saturation

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

Seasonal swelling and shrinkage of soil

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

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

Shear failure

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

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

GENERAL DEFINITIONS OF SITE CLASSES

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

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

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

Unevenness of Movement

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

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

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

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

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

Effects of Uneven Soil Movement on Structures

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

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

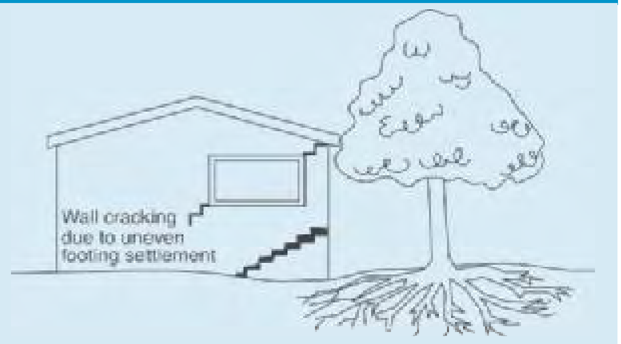
Isolated piers affected by erosion or saturation of foundations will eventually lose contact with the bearers they support and may tilt or fall over. The floors that have lost this support will become bouncy, sometimes rattling ornaments etc.

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

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

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

Trees can cause shrinkage and damage



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

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

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

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

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

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

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

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

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

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

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

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

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

Water Service and Drainage

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

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

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

Seriousness of Cracking

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

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

Prevention/Cure

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

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

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

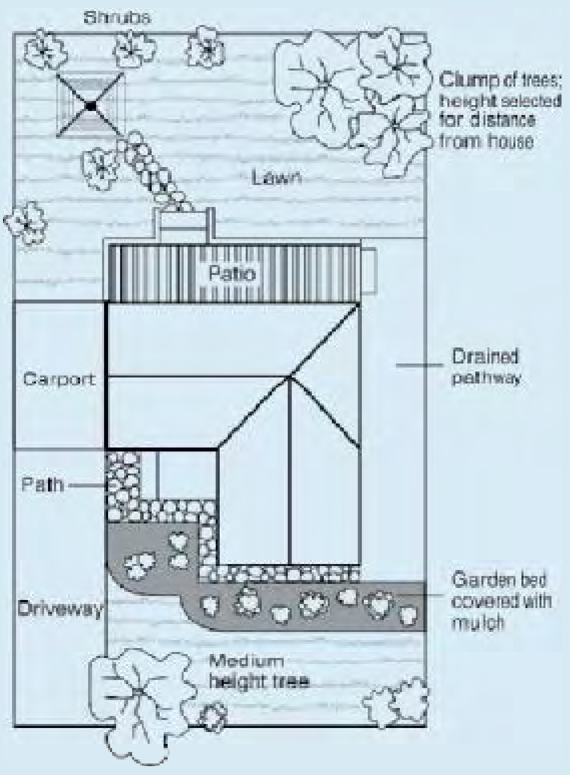
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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

CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS

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

Gardens for a reactive site



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

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

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

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

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

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

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

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

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

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

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

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

Remediation

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

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

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