ABN. 24156426274

Sydney Office
PO Box A203 Sydney NSW 1235
Suite 12, 327 Pitt St, Sydney NSW 2000

Adelaide Office
L2/1 King William Rd
Unley SA 5061

Darwin Offce
GPO Box 4174 Darwin NT 0801
Suite 13, 84 Smith Street, Darwin NT 0800

Mudgee Offce
46 Market St, Mudgee, NSW, 2850

FOOTING & SOIL CONSTRUCTION REPORT

e. admin@triaxialconsulting.com.au
www.triaxialconsulting.com.au

Project: Proposed Residence
Address: 71 East Ave Allenby Gardens SA
Job No: TX12816.00

CONTENTS

PAGES

LOAD SUMMARY

Gravity/Permanent Self Weight of Structure Only

Revision	By	Date
A	FT	14/05/18

TRIAXIAL CONSULTING

GEOTECHNICAL SITE ASSESSMENT

Project:	Proposed House
Address:	71 East Ave Allenby Gardens SA
Job No:	TX12816.00

SUMMARY

Site Classification		Class H1-D / P	
Movement Summary			
Surface Movement	*ys*	47 mm	H1-D
Tree Induced Surface Movement	*yt*	16 mm	
Differential Mound Movement	*ym*	48 mm	
Critical Factors			
Trees		Yes	
Fill		No	
Other Factors			
H_s		4000 mm	
Suction Depth >3m		Yes	*Deep Seated Movement*
Bearing Strength		Medium	*100-200 kPa*
Excessive Loading/Mine Subsidence/Severe Moisture Changes		No	

Design Parameters

Ground floor Construction Type	Render Power Panel
Upper Floor Construction Type	Render Power Panel
Roof Construction Type	Colorbond Roof
Foundation Type	Stiffened raft slab
Beam Specification	300(W)

APPENDIX

APPENDIX A	WIND SPEED ASSESSMENT
APPENDIX B	AS2870-2011 CALCULATIONS
APPENDIX C	GEOTECHNICAL REPORT
BY:	*GeoDrill*
DATE:	*03/05/18*
REF:	*TX12816.00*
APPENDIX D	EXPLANATORY NOTES

Engineer: FT

Revision	By	Date
A	FT	14/05/18

APPENDIX A

WIND SPEED ASSESSMENT

Wind

The site is located at 71 East Ave Allenby Gardens

The site is a Region A1 site

The terrain category is – TC2.5

Importance Level 2

The site wind speed for this building is – 28m/s

The site wind classification as per AS 4055 2012 is – N1

Earthquake

AS 1170.4

Importance Level 2

Domestic Structure with Roof height less than 8.5m

KpZ – 0.1 (Adelaide)

Standard construction

As per AS 1170.4 Table A1 – No specific earthquake design required.

APPENDIX B

AS2870-2011 CALCULATIONS

Job Number: TX12816.00

Soil Classification

71 East Ave Allenby Gardens SA

Engineer: FT
Date: 14/05/18

GEOTECHNICAL REPORT

BY:	GeoDrill	
DATE:	03/05/18	**REFER APPENDIX B**
REF:	TX12816.00	

SOIL CLASSIFICATION

Classification of soil to AS2870-2011

delta_u	1.2		*AS2870 Table 2.4*
H_s		*mm*	*AS2870 Table 2.4*

Number of Layers , N 5 *(Max 10)*

BORELOG 1

N	*Description*	*I_pt* %/pF	*d1* mm	*d2* mm		Layer Depth h mm	Soil suction *Delta_u,1* pF	I_pt.deltabar_u*h mm
1	*clay silty sandy*	1.5	0	350		350	1.15	6.0
2	*clay silty sandy*	2.5	350	800		450	1.03	11.6
3	*clay silty*	2	800	1600		800	0.84	13.4
4	*clay silty*	2	1600	2250		650	0.62	8.1
5	*clay silty*	2	2250		4000	1750	0.26	9.2

y_s= **48.3** mm
H1-D

Number of Layers , N 5 *(Max 10)*

BORELOG 2

N	Description	I_pt	d1	d2		Layer Depth	Soil suction	I_pt.deltabar_u*h
1	*clay silt sandy*	1.5	0	450		450	1.13	7.6
2	*clay silty sandy*	2.5	450	950		500	0.99	12.4
3	*clay silty*	2	950	2150		1200	0.74	17.6
4	*clay silty*	1.5	2150	2550		400	0.50	3.0
5	*clay silty*	2	2550		4000	1450	0.22	6.3

y_s= **46.9** mm
H1-D

Number of Layers , N 6 *(Max 10)*

BORELOG 3

N	Description	I_pt	d1	d2		Layer Depth	Soil suction	I_pt.deltabar_u*h
1	*clay silty sandy*	1.5	0	550		550	1.12	9.2
2	*clay silt sandy*	2.5	550	800		250	1.00	6.2
3	*clay silty*	2	800	1100		300	0.92	5.5
4	*clay silty*	2	1100	2100		1000	0.72	14.4
5	*clay silty*	1.5	2100	2400		300	0.53	2.4
6	*clay silty*	2	2400		4000	1600	0.24	7.7

y_s= **45.4** mm
H1-D

Maximum y_s	**48**	**mm**
Classification	**H1-D**	

ASSESSMENT OF TREE INFLUENCE

	Single Tree		
delta_ub	0.43	*pF*	
delta_u	1.2		*AS2870 Table 2.4*
H_t	4000	*mm*	*AS2870 Table 2.4*

Depth of design suction change, (H_s)	Single tree		Tree group	
	Maximum extra suction change (Δu_{base})	Maximum design drying depth (H_t)	Maximum extra suction change (Δu_{base})	Maximum design drying depth (H_t)
m	pF	m	pF	m
1.5	0.30	2.5	0.38	3.0
1.8	0.33	2.7	0.40	3.3
2.3	0.35	3.0	0.43	3.6
3	0.38	3.4	0.46	4.1
4	0.43	4.0	0.55	4.5

Number of Layers , N 5 *(Max 10)*

BORELOG 1

N	*Description*	*I_pt* (*%/pF*)	*d1* (*mm*)	*d2* (*mm*)		Layer Depth *h* (*mm*)	Soil suction *Delta_u,1* (*pF*)	I_pt.deltabar_u*h (*mm*)
1		1.5	0	350		350	1.17	6.1
2		2.5	350	800		450	1.09	12.3
3		2	800	1600		800	0.97	15.5
4		2	1600	2250		650	0.66	8.6
5		2	2250		4000	1750	0.60	20.9

y_t,max= **15.1** mm

Tree Parameters Based on Appendix H

Distance to Building	*Dt*	1.5	*m*
Design Height	*HT/HTg*	5	*m*
Influence Distance	*Di*	5	m
Dt/HT=		0.3	< 0.5 - Use y_t=y_t,max

Tree Induced Surface Movement, yt	**15.1**	***mm***
Differential Mound Movement, ym=0.7ys+yt	**49**	***mm***
Classification	**H1-D**	

Number of Layers , N 5 *(Max 10)*

BORELOG 2

N	*Description*	*I_pt* (*%/pF*)	*d1* (*mm*)	*d2* (*mm*)		Layer Depth *h* (*mm*)	Soil suction *Delta_u,1* (*pF*)	I_pt.deltabar_u*h (*mm*)
1		1.5	0	450		450	1.16	7.8
2		2.5	450	950		500	1.07	13.3
3		2	950	2150		1200	0.90	21.6
4		1.5	2150	2550		400	0.61	3.6
5		2	2550		4000	1450	0.57	16.5

y_t,max= **16.0** mm

Tree Parameters Based on Appendix H

Distance to Building	*Dt*	1.5	*m*
Design Height	*HT/HTg*	5	*m*
Influence Distance	*Di*	5	m
Dt/HT=		0.3	< 0.5 - Use y_t=y_t,max

Tree Induced Surface Movement, yt	**16.0**	***mm***
Differential Mound Movement, ym=0.7ys+yt	**49**	***mm***
Classification	**H1-D**	

	Number of Layers , N		6							
BORELOG 3	**1**		1.5	0	550		550	1.15	9.5	
	2		2.5	550	800		250	1.07	6.7	
	3		2	800	1100		300	1.02	6.1	
	4		2	1100	2100		1000	0.89	17.8	
	5		1.5	2100	2400		300	0.61	2.8	
	6		2	2400		4000	1600	0.58	18.7	

		y_t,max=	**16.2**	mm
		Tree Induced Surface Movement, yt	**16.2**	***mm***
		Differential Mound Movement, ym=0.7ys+yt	**48**	***mm***
		Classification	**H1-D**	

Tree Parameters Based on Appendix H

Distance to Building	*Dt*	1.5	*m*	
Design Height	*HT/HTg*	5	*m*	
Influence Distance	*Di*	5	m	
Dt/HT=		0.3	< 0.5 - Use y_t=y_t,max	

SUMMARY

	y_s	y_t	y_m
	mm	*mm*	*mm*
BORELOG 1	*48.3*	15	49
BORELOG 2	*46.9*	16	49
BORELOG 3	*45.4*	16	48
DESIGN VALUES	*48*	16	49
	H1-D		**H1-D**

Job Number: TX12816.00

Soil Classification

71 East Ave Allenby Gardens SA

Engineer: FT
Date: 14/05/18

GEOTECHNICAL REPORT

BY:	GeoDrill
DATE:	03/05/18 — **REFER APPENDIX B**
REF:	TX12816.00

SOIL CLASSIFICATION

Classification of soil to AS2870-2011

delta_u	1.2		*AS2870 Table 2.4*
H_s		*mm*	*AS2870 Table 2.4*

Number of Layers , N 6 *(Max 10)*

	N	*Description*	*I_pt* (%/pF)	*d1* (mm)	*d2* (mm)		Layer Depth h (mm)	Soil suction *Delta_u,1* (pF)	I_pt.deltabar_u*h (mm)
BORELOG 4	**1**	*clay silty sandy*	1.5	0	550		550	1.12	9.2
	2	*clay silty sandy*	2.5	550	950		400	0.98	9.8
	3	*clay silty*	2	950	1500		550	0.83	9.2
	4	*clay silty*	2	1500	2000		500	0.68	6.8
	5	*clay silty*	1.5	2000	2350		350	0.55	2.9
	6	*clay silty*	2	2350		4000	1650	0.25	8.2

y_s=	**45.9**	mm
	H1-D	

Number of Layers , N 5 *(Max 10)*

	N	*Description*	*I_pt*	*d1*	*d2*		Layer Depth	Soil suction	I_pt.deltabar_u*h
BORELOG 5	**1**	*clay silty sandy*	1.5	0	550		550	1.12	9.2
	2	*clay silty sandy*	2.5	550	800		250	1.00	6.2
	3	*clay silty*	2	800	1650		850	0.83	14.2
	4	*clay silty*	2	1650	2250		600	0.62	7.4
	5	*clay silty*	2	2250		4000	1750	0.26	9.2

y_s=	**46.2**	mm
	H1-D	

Number of Layers , N 4 *(Max 10)*

	N	*Description*	*I_pt*	*d1*	*d2*		Layer Depth	Soil suction	I_pt.deltabar_u*h
BORELOG 6	**1**	*clay silty sandy*	1.5	0	550		550	1.12	9.2
	2	*clay silty sandy*	2.5	550	1000		450	0.97	10.9
	3	*clay silty*	2	1000	2200		1200	0.72	17.3
	4	*clay silty*	2	2200		4000	1800	0.27	9.7

y_s=	**47.1**	mm
	H1-D	

Maximum y_s	**47**	**mm**
Classification	**H1-D**	

ASSESSMENT OF TREE INFLUENCE

	Single Tree		
delta_ub	0.43	*pF*	
delta_u	1.2		*AS2870 Table 2.4*
H_t	4000	*mm*	*AS2870 Table 2.4*

Depth of design suction change, (H_s)	Single tree		Tree group	
	Maximum extra suction change (Δu_{base})	Maximum design drying depth (H_t)	Maximum extra suction change (Δu_{base})	Maximum design drying depth (H_t)
m	pF	m	pF	m
1.5	0.30	2.5	0.38	3.0
1.8	0.33	2.7	0.40	3.3
2.3	0.35	3.0	0.43	3.6
3	0.38	3.4	0.46	4.1
4	0.43	4.0	0.55	4.5

Number of Layers , N 6 *(Max 10)*

BORELOG 4

N	*Description*	*I_pt*	*d1*	*d2*		Layer Depth *h*	Soil suction *Delta_u,1*	I_pt.deltabar_u*h
		%/pF	*mm*	*mm*		*mm*	*pF*	*mm*
1		1.5	0	550		550	1.15	9.5
2		2.5	550	950		400	1.06	10.6
3		2	950	1500		550	0.96	10.6
4		2	1500	2000		500	0.86	8.6
5		1.5	2000	2350		350	0.62	3.3
6		2	2350		4000	1650	0.59	19.4

y_t,max=	**16.0**	mm
Tree Induced Surface Movement, yt	**16.0**	***mm***
Differential Mound Movement, ym=0.7ys+yt	**48**	***mm***
Classification	**H1-D**	

Tree Parameters Based on Appendix H

Distance to Building	*Dt*	1.5	*m*
Design Height	*HT/HTg*	5	*m*
Influence Distance	*Di*	5	m
	Dt/HT=	0.3	< 0.5 - Use y_t=y_t,max

Number of Layers , N 5 *(Max 10)*

BORELOG 5

N	*Description*	*I_pt*	*d1*	*d2*		Layer Depth *h*	Soil suction *Delta_u,1*	I_pt.deltabar_u*h
1		1.5	0	550		550	1.15	9.5
2		2.5	550	800		250	1.07	6.7
3		2	800	1650		850	0.96	16.4
4		2	1650	2250		600	0.66	7.9
5		2	2250		4000	1750	0.60	20.9

y_t,max=	**15.2**	mm
Tree Induced Surface Movement, yt	**15.2**	***mm***
Differential Mound Movement, ym=0.7ys+yt	**48**	***mm***
Classification	**H1-D**	

Tree Parameters Based on Appendix H

Distance to Building	*Dt*	1.5	*m*
Design Height	*HT/HTg*	5	*m*
Influence Distance	*Di*	5	m
	Dt/HT=	0.3	< 0.5 - Use y_t=y_t,max

Number of Layers , N		4						
BORELOG 6								
1		1.5	0	550		550	1.15	9.5
2		2.5	550	1000		450	1.05	11.8
3		2	1000	2200		1200	0.72	17.3
4		2	2200		4000	1800	0.60	21.7

			y_t,max=	**13.1**	mm
Tree Parameters Based on Appendix H			***Tree Induced Surface Movement, yt***	**13.1**	***mm***
Distance to Building	*Dt*	1.5 *m*	***Differential Mound Movement, ym=0.7ys+yt***	**46**	***mm***
Design Height	*HT/HTg*	5 *m*	***Classification***	**H1-D**	
Influence Distance	*Di*	5 m			
Dt/HT=	0.3	< 0.5 - Use y_t=y_t,max			

SUMMARY

	y_s	y_t	y_m
	mm	*mm*	*mm*
BORELOG 4	*45.9*	16	48
BORELOG 5	*46.2*	15	48
BORELOG 6	*47.1*	13	46
DESIGN VALUES	*47*	16	48
	H1-D		**H1-D**

TRIAXIAL CONSULTING
COMPLEX PROBLEMS RESOLVED SIMPLY

DESIGN LOADS

Edge Load on North end

Lower Wall	(Brick Veneer)	2.4 x	0 m	=	0	KN/m
Floor	(Timber)	0.6 x	2.5 m	=	1.5	KN/m
Upper Wall	(Hebel)	0.7 x	6 m	=	4.2	KN/m
Roof	(Sheeted)	0.4 x	2.8 m	=	1.12	KN/m
			Total	=	**6.82**	KN/m

Edge Load on East end

Lower Wall	(Brick Veneer)	2.4 x	0 m	=	0	KN/m
Floor	(Timber)	0.6 x	2.5 m	=	1.5	KN/m
Upper Wall	(Hebel)	0.7 x	6 m	=	4.2	KN/m
Roof	(Sheeted)	0.4 x	2.8 m	=	1.12	KN/m
			Total	=	**6.82**	KN/m

Edge Load on South end

Lower Wall	(Brick Veneer)	2.4 x	0 m	=	0	KN/m
Floor	(Timber)	0.6 x	2.5 m	=	1.5	KN/m
Upper Wall	(Hebel)	0.7 x	6 m	=	4.2	KN/m
Roof	(Sheeted)	0.4 x	2.8 m	=	1.12	KN/m
			Total	=	**6.82**	KN/m

Edge Load on West end

Lower Wall	(Brick Veneer)	2.4 x	0 m	=	0	KN/m
Floor	(Timber)	0.6 x	2.5 m	=	1.5	KN/m
Upper Wall	(Hebel)	0.7 x	6 m	=	4.2	KN/m
Roof	(Sheeted)	0.4 x	2.8 m	=	1.12	KN/m
			Total	=	**6.82**	KN/m

North South Centre load **3** KN/m

East-west Centre Load 0 KN/m

Uniform distributed Load 0.75 Kpa

INPUT DATA   Footing Analysis by: SLOG

Site:	71 East Ave Allenby Gardens SA
Reference:	TX12816.00
Date:	14/05/18

Structure geometry

Length of Structure L:	28.7	m
Breadth of Structure:	5	m
No. beams parallel to Long Span:	3	
No. beams parallel to Short Span:	9	
Deflection Ratio △/L:	400	
Maximum Allowable Deflection △:	30	mm
Depth Footing not Embedded:	0.2	m

Soil Properties

Soil Heave Ym:	49	mm
Depth of suction change Hs:	4	m
Mound stiffness k:	1000	kPa/m

Structure loads

Edge Load on West End:	7	kN/m
Edge Load on East End:	7	kN/m
Edge Load on North Side:	7	kN/m
Edge Load on South Side:	7	kN/m
North-South Centre Load:	3	kN/m
East-West Centre Load:	0	kN/m
Uniform distributed load:	0.75	kPa

Raft Footing Properties

Sub-Beam Width	300	mm
Top Concrete Cover:	50	mm
Bottom Concrete Cover:	50	mm
Slab Thickness:	100	mm
Area Slab Steel:	287	mm^2/m
Steel Grade fsy:	500	MPa
Concrete Compressive Strength f'c:	20	MPa
Concrete Tensile Strength Hogging:	1.8	MPa
Concrete Tensile Strength Sagging:	2.7	MPa
Young's Modulus of Concrete:	15000	MPa
Requested Mu/Mcr Ratio Hogging:	1.5	
Requested Mu/Mcr Ratio Sagging:	1.5	

Additional Properties

Soil Edge Heave:	34	mm
Beam Side Friction:	25	kPa

OUTPUT - Raft Footing

Footing Analysis by: SLOG

Site: 71 East Ave Allenby Gardens SA
Reference: TX12816.00
Date: 14/05/18

Required Capacities per Beam

Centre Heave	Long Span		Short Span	
Ultimate Negative Moment:	-42.6	kNm	-84.7	kNm
Ultimate Positive Moment:	4.2	kNm	0.0	kNm
Max Shear:	-17.6	kN	-40.2	kN
Required Stiffness:	14.476	MNm^2	13.516	MNm^2
Edge Heave				
Ultimate Negative Moment:	-0.2	kNm	-5.9	kNm
Ultimate Positive Moment:	3.7	kNm	1.1	kNm
Max Shear:	-9.5	kN	19.3	kN
Required Stiffness:	1.667	MNm^2	3.189	MNm^2

RAFT REQUIREMENTS

Sub-beams:	300	**mm wide x**	450	**mm deep**
Slab:	100	**mm**	287	**mm^2/m**
Subbeam top bars:	219	**mm^2**		
Subbeam bottom bars:	261	**mm^2**		
Concrete:	20	**MPa**		

Actual Capacities per Beam

	Centre Heave		Edge Heave	
Sub-beam depth:	450	mm	450	mm
Minimum top bars	219	mm^2		
Minimum bottom bars			261	mm^2
Ultimate Moment Mu:	84.7	kNm	51.6	kNm
Cracking Moment Mcr:	34.8	kNm	34.1	kNm
Mu/M* =	1.25		15.32	
Mu/Mcr =	2.43		1.51	
Stiffness:	15.237	MNm^2	51.558	MNm^2

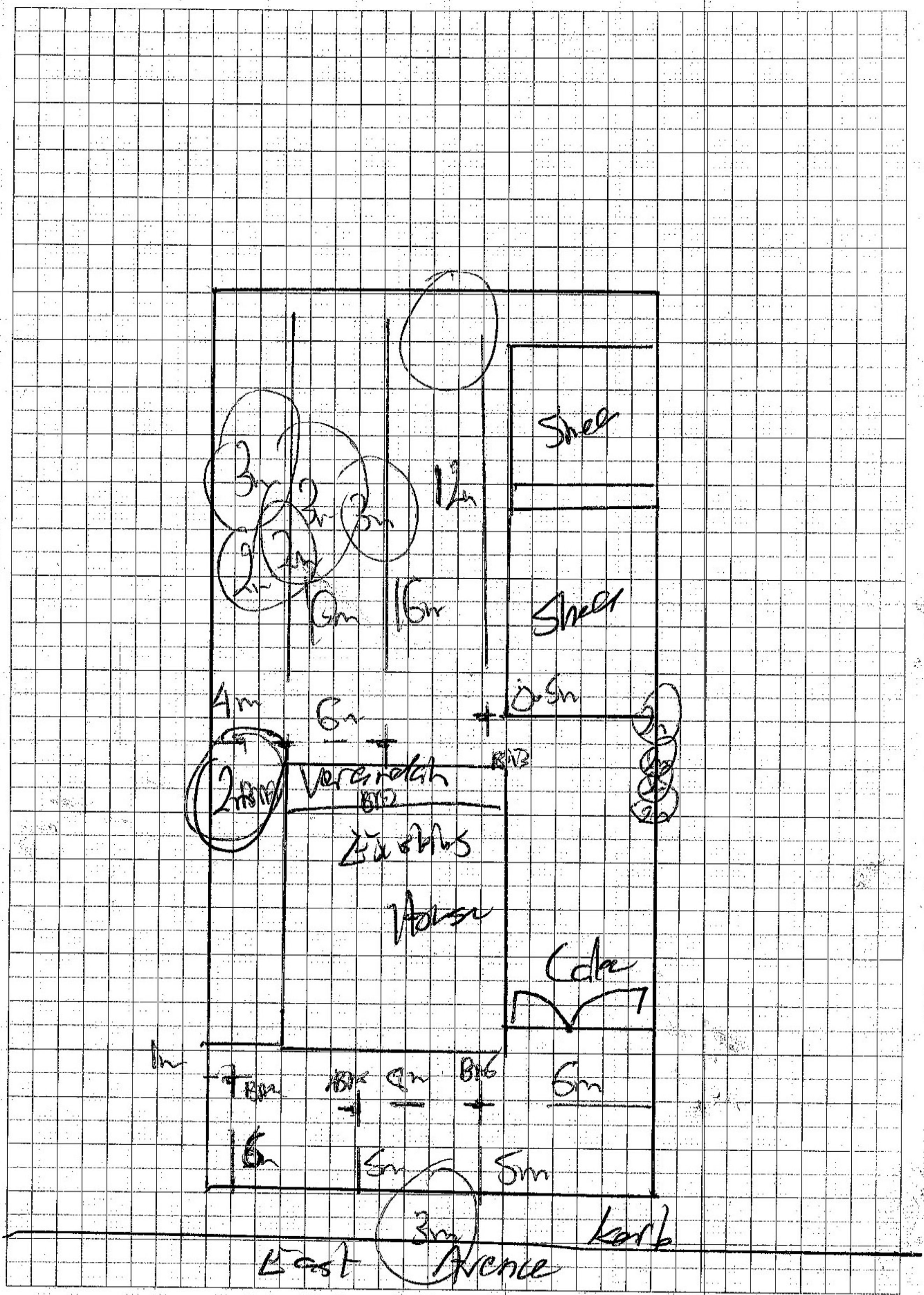
APPENDIX C

GEOTECHINICAL REPORT

BY: GeoDrill
DATE: 3/05/18
REF: TX12816.00

GEODRILL JOB SHEET

71 East Avenue, ALLENBY GARDENS



FRED TO LOG RESULTS AND INVOICE TO GEODRILL

GEODRILL

ENGINEER: TRIAXIAL
JOB NO.: TX12816.00

SITE INFORMATION			
NEW STRUCT. ✓	ADDITION	S/ POOL	OTHER
HYDRAULIC	PUSH TUBE	HYD HAMMER	AUGER
HAND GEAR	ENVIRON		

AUGER USED FROM										
START ROCK DEPTH										
END ROCK DEPTH										
CORES	1	2	3	4	5	6	7	8	9	10
DEPTH	3	3	3	3	3	3				
RESISTANCE										
LOW	✓	✓	✓	✓	✓	✓				
MEDIUM										
HIGH										
WATER TABLE										
CORE RECOVERY										
100%	✓	✓	✓	✓	✓	✓				
LOSS										
STRETCHED										

SURFACE	DRY ✓	MOIST	WET	
SOIL STRENGTH	HARD	FIRM ✓	SOFT	LOOSE
VEGETATION	GRASS ✓	TREES	GRAVEL	PAVED
CRACKING	YES	NO ✓		

UNUSUAL FEATURES – SHOW ON LOCATION MAP

HEAPS OF FILLING	YES ?	NO ✓
ROCK OUTCROPS	YES	NO ✓
PITS	YES	NO ✓
EXCAVATIONS	YES	NO ✓
DRAINAGE CHANNELS	YES	NO ✓
OTHER (specify if yes)		
SLOPE	LEVEL ✓	FALL

CRACKING IN EXISTING BUILDING	YES	NO ✓
BUILDING LOCATED WITHIN 600mm OF BUILDING	YES ✓	NO
LARGE TREES ON BLOCKS BORDERING SITE IN QUESTION. SHOW ON LOCATION MAP IF YES	YES ✓	NO

REMARKS:

DRILLERS INITIALS	**UNIT NO**	**DATE DRILLED**
DL	2	3/5/18

SPK Geodrill Ph: 8186 3690 Fax: 8326 4471 Email: sales@geodrill.com.au

Fred Enever

Job No: TX12816.00

Sampling Method:

Site: 71 East Ave Allenby Gdns

Date:

BORE	BORE	BORE 5	BORE 6	SOIL DESCRIPTION	TEXTURE	COLOUR	FMC	REACT	EST Ipt	BRG	SYMBOL
		0 - 550	0 - 550	clay silty sandy	Fd Fb	Br	da	LM	015	M	CL
		550-800	550-1000	clay silty sandy	H	RBr	da	MH	025	M	CL CH
		800-1650	1000-2200	clay silty, traces sand & lime	F	Br Mott	da	M	02	M	CL
		1650-2250	-	clay silty, trace sand	F	Br	da	M	02	M	CL
		2250-3000	2200-3000	clay silty	F	Greyish Br Mott	da	M	02	M	CL

Abbreviations:

S,VS	soft, very soft	MC	Moisture Content
F,VF	firm, very firm	PL	Plastic Limit
St,VSt	stiff, very stiff	OMC	Optimum MC
H	hard	L,M,H	Low, Medium, High
Fb	friable	NP	Non Plastic
Fg	fine grained	P	Plasticity
		<>	Less than, Greater than
		Da	Damp

Fred Enever

Job No: TX12816.00

Sampling Method:

Site: 71 East Ave Allenby Gdns

Date:

BORE 1	BORE 2	BORE 3	BORE 4	SOIL DESCRIPTION	TEXTURE	COLOUR	FMC	REACT	EST Ipt	BRG	SYMBOL
0-350	0-450	0-550	0-550	clay silty sandy	F & Fb	Br	da	LM	015	M	CL
350-800	450-950	550-800	550-950	CLAY silty sandy	H	R/Br	da	MH	025	M	CLCH
800-1600	950-2150	800-1100	950-1500	clay silty. traces sand & lime	F	Reddish Br few cream patches	da	M	02	M	CL
1600-2250	—	1100-2100	1500-2000	clay silty. trace sand	F	Br	da	M	02	M	CL
—	2150-2550	2100-2400	2000-2350	clay silty	F	Br	da	LM	015	M	CL
2250-3000	2550-3000	2400-3000	2350-3000	clay silty	F	Greyish Br mott	da	M	02	M	CL

Abbreviations:

S,VS	soft,very soft	MC	Moisture Content
F,VF	firm,very firm	PL	Plastic Limit
St,VSt	stiff, very stiff	OMC	Optimum MC
H	hard	L,M,H	Low, Medium,High
Fb	friable	NP	Non Plastic
Fg	fine grained	P	Plasticity
		<>	Less than,Greater than
		Da	Damp

APPENDIX D

EXPLANATORY NOTES

FOOTING CONSTRUCTION REPORT

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1300 874 294

GENERAL NOTES & CONSTRUCTION REQUIREMENTS

SITE WORKS:

Building site to be cleared of all vegetation and organic material, and cut/fill to meet required levels.

100mm minimum of granular fill is to be placed and fully compacted on top of bench level under the proposed concrete slab.

The location and extent of the cut/fill line, footing piers, slab thickening and any additional reinforcement provided for uncontrolled filling and/or other subsurface conditions are indicated as a guide only. Additional slab thickenings, reinforcement, footing piers or concrete may be required subject to site conditions. The extent of any such measures can only be accurately determined when the footing trenches and piers have been excavated.

If uncontrolled filling material and/or other subsurface conditions are encountered, the Triaxial Office must be contacted immediately prior to continuing any work on site. Refer to General Notes, Site Plan and Geotechnical Report for further details.

ADDITONAL CONSTRUCTION REQUIREMENTS:

1) Full height control joints are to be provided to masonry (and equivalent type construction including hebel) in positions shown on the articulation plan and also in accordance with manufacturers requirements
2) Stormwater run-off is to be taken away from all footings during and after construction.
3) Lagging is to be provided to all non-vertical pipes and services going through footing beams.
4) The owner or builder is to contact the engineer if anything on-site differs to that mentioned in this report, or if after reading this report would like a stiffer footing construction to reduce, even further, the likelihood of any cracking occurring to the building.

SITE INSPECTIONS DURING THE CONSTRUCTION PHASE:

The scheduled inspections listed below are recommended as the minimum requirement:

· Trench Inspection (To occur prior to vapour barrier being laid)

· Reinforcement Inspection (To occur prior to pouring any concrete)

SITE CLASSIFICATION

The soil borelogs undertaken for this site have been completed based on the visual-tactile logging method. Unless otherwise noted, the characteristics are estimated using the methods outlined in Australian Standard AS1726-1993 Geotechnical Site Investigations. FCR global``

The following table set out a soil classification which defines a range of soil types separated into groups which have a known range of potential movements. The soil on site has been given a classification from this table.

Various soil types have different engineering properties; eg, - reactive soils are clays which shrink and swell as a result of a changing moisture content, whereas collapsing soils lose volume and settle as a result of increasing moisture content or applied load.

It can be seen that soils classified as type M-D, H1-D, H2-D or E-D have significant potential for movement. Buildings on such soils must be constructed in a manner which will take account of these movements. Well planned articulated superstructures, provisions of properly planned and constructed site drainage and landscaping or gardening planting, in conjunction with properly engineered footing systems, can provide a successful solution on most foundation soils.

The classification given is based on an assessment of the overall characteristics of the soils on site. Site calluses shall be designated as per AS2870-2011.

CLASS	DESCRIPTION	CHARACTERISTIC SURFACE MOVEMENT (y_s)	FOUNDATION
A	Sand/Rock	0	Most sand and rock sites with little or no ground movement from moisture change
S	Stable	0-20	Slightly reactive clay sites, which may experience only slight ground movement from moisture changes
M	Moderate	20-40	Moderately reactive clay or silt sites, which may experience moderate ground movement from moisture changes
H1	High	40-60	Highly reactive clay sites, which may experience high ground movement from moisture changes
H2	High	60-75	Highly reactive clay sites, which may experience high ground movement from moisture changes
E	Extreme	>75	Extremely reactive sites, which may experience extreme ground movement from moisture changes

P	Problem	N/A	Sites including inadequate bearing strength or abnormal other factors including; soft clay or silt or loose sands, landslips, mine subsidence, collapsing soils, controlled/uncontrolled fill, trees etc

Note: Deep seated moisture changes can occur if the depth of suction change (Hs) is greater than 3m. In these cases, '-D' is added to the classification, e.g. M-D, H1-D

SPECIFICATION FOR MATERIALS AND WORKMANSHIP – FOOTINGS

1.0 MATERIALS

1.1 CONCRETE

All concrete shall be no less the grade 20 (i.e f'c = 20MPa), unless otherwise noted on the drawings, with 20mm nominal maximum aggregate size as per AS3600-2009 and AS2870-2011. Concrete shall be ordered so that its slump range will be within the following limits:

a) For all footing beams, piers or pads cast in the ground, Slump Range 80 – 120mm

b) For slabs and beams poured integrally with them, Slump Range 80 – 100mm

Refer to *AS1379-2007 Specification and supply of concrete* for allowable tolerances.

1.2 REINFORCEMENT

Specified reinforcement shall be the following type:

- Reinforcement specified is typically shown on S2.0 Triaxial's drawing set.
- Hot rolled deformed bars designated 400Y, 'Tempcore' or equivalent in accordance with *AS1302-1991 Steel reinforcing bars for concrete*.
- Ligatures shall be hard drawing steel wire in accordance with *AS1303-1991 Steel reinforcing wire for concrete*.
- Fabric/mesh shall be hard drawn wire in accordance with *AS1304-1191 Welded wire reinforcing for concrete*.

1.3 VAPOUR BARRIER BELOW CONCRETE SLABS

The vapour barrier or damp-proof membrane shall be 200micron (0.2mm) thick high impact resistant polythene film, eg, - Fortecon or similar approved product.

The use of re-cycled polythene sheeting is not permitted.

2.0 WORKMANSHIP

2.1 FOOTING BEAM EXCAVATIONS

Footing beam locations, depths and widths shall be excavated in accordance with the Footing Plan. Where required, piers shall be drilled or dug in the locations shown on the footing plan with the founding depth as specified, or a minimum of 200mm into natural ground (in accordance with the borelogs).

Beams and piers (where required) shall be excavated to firm, natural ground, trimmed to size and all loose soil shall be removed from the base of the excavations. Over-excavation shall not be backfilled but must be filled with concrete at the time of pouring the footings.

Where beams are excavated through site filling, the specified width may be increased if necessary to allow the required depth of excavation to be achieved. In the case of integral slab/bea, footing systems, eg, - a stiffened raft, provide a 125mm x 125mm fillet shall be provided at the slab/beam intersection in accordance with the provided footing details.

At all times, footing beam shall be excavated so that at one corner (preferably the lowest corner) of the trench, the trench excavation shall be dug beyond the line of the house to permit drainage of any run-off and prevent water seepage entering the trenches. The water shall be diverted away from the working area of the site or to a low spot whereupon it may be removed by pump.

2.2 INSTALLATION OF PLUMBING AND OTHER SERVICE PIPES

Penetrations of pipes through vapour barrier beneath the concrete slab shall be wrapped in polythene and carefully taped to the vapour barrier to ensure a moisture proof joint is obtained.

2.3 TERMITE TREATMENT

Termite treatment to be provided in accordance with *AS3660.1 Termite Management*.

2.4 VAPOUR BARRIER BELOW SLAB

The high impact polythene sheet vapour barrier is to be installed below all internal floor slabs as shown in relevant details. All laps shall not be less then 200mm and shall be taped using a minimum 50mm adhesive tape.

Securely flash and seal the vapour barrier around all service pipes and plumbing to ensure a moisture proof joint is provided.

2.5 FOOTING BEAM REINFORCMENT

Reinforcement shall be placed in strict accordance with the typical details specified for the footing beam. Where splices in bars are necessary, the minimum lap length in all cases should be in accordance with the table below:

Bar Size	Minimum Lap Length (mm)
N12	500
N16	750
N20	1000
N24	1375

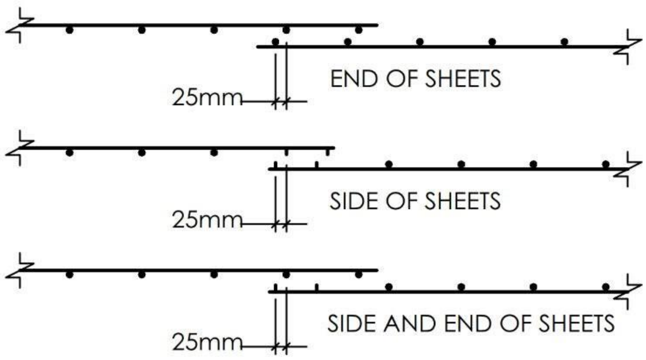
N28	1560
N32	1810

All bars shall be straight, free from loose rust, dirt and grease, and shall be supported by blocks or hanging wires as necessary to ensure the specified cover requirements are maintained during pouring of the concrete.

For standard raft footings, top bars which terminate at a rebated footing shall be cogged downwards a minimum of 150mm or continued across the full width of the ligature. At other beam intersections, and/or corners, cogging is not required unless corner bars are specified in the appropriate detail.

2.6 SLAB REINFORCMENT

Fabric reinforcement shall be lapped in accordance with the figure below:



The fabric shall be supported on chairs (not concrete blocks) at a spacing not exceeding 1000mm in each direction.

Concrete cover shall be specified typically on Triaxial drawing S2.0.

2.7 PLACING OF CONCRETE

Concrete shall be carefully placed in trenches and slabs, ensuring that reinforcement is maintained in its correct location at all times. Unless plasticising admixtures have been added to the mix, concrete shall be placed as close as possible to its final location to avoid segregating during spreading.

All concrete shall be vibrated, unless (because of the nature of the site), vibrating is likely to cause the formwork to collapse. In this case, careful rodding and spading is required to thoroughly compact the concrete without damage to formwork. Concrete is not to be spread with vibrators.

Concrete shall not be poured in the air temperature exceeds 32 Degrees Celsius at the time of pouring unless instruction from a senior engineer is given.

2.8 CONSTRUCTION JOINTS BETWEEN CONCRETE POURS

Where construction joints occur between trench footings or piers, and surface beams or slabs, the face of the poured concrete shall be brushed and thoroughly cleaned. A neat cement slurry shall be applied to its surface in a thin layer immediately before pouring concrete.

2.9 FINISHING OF CONCRETE SLABS

The surface of all slabs shall be screeded and trowelled to a hard, dense finish. Driers shall be avoided where possible, but when used shall not exceed 1-2mm in thickness and must not be used to absorb excess moisture from the concrete. Driers must not be used after 24hours from the time of the concrete being poured.

After trowelling slabs or finishing beam pouring, apply the second selected curing method as soon as possible. Curing shall commence on the same day as the concrete is poured. Failure to do so may result in excessive shrinkage cracking.

The finished surface of the slab is have a tolerance of +/- 6mm over a 3m straight edge.

2.10 CURING METHODS FOR CONCRETE SLABS

Concrete shall be cured continuously for a period of at least seven (7) days and loading with stacked materials shall not be permitted during this time. The construction of wall frames and setting out of brickwork is permitted during this time.

CONDITIONS FOR USE OF THIS FOOTING REPORT

1. This footing report has been prepared at the request of the Owner (or his agent). It is a condition of the use of this report that the owner accepts the basis on which the footing design has been prepared (as outlined below), and that the owner ensures that the Engineer is advised of the times he/she should attend for each of the recommended mandatory site inspections as called upon.
2. This report contains advice designed to minimise the risk to the building. It is an important document and should be kept in a safe place. It is essential that this report be supplied to subsequent Owners so that they are aware of the consequences of making changes to the building, garden and surrounding areas. Without this information, there is potential that the new Owners will make changes to the site management which could jeopardise the long term serviceability of the building.
3. The Engineer may (and the Owner hereby authorises the Engineer to):
    a. Make such modifications to the Footing design as the Engineer may deem necessary during the course of construction of the building;
    b. Issue instructions (including an instruction to cease construction of the building) on behalf of the Owner to any persons engaged in construction of the building in accordance with this Report and any modification thereof, <u>PROVIDED THAT</u>, if any modifications as aforesaid would likely to result in additional construction costs exceeding $1,000.00, the Engineer may only issue an instruction to cease construction in order to obtain the approval of the Owner to such modification.

4. The Owner shall be responsible for, and indemnify the Engineer against all and any costs and charges and all claims and demands made for any additional costs incurred by reason of any act, requirement or instruction of the Engineer made or given pursuant to Clause 3.
5. The owner will comply and procure compliance in all respects and at all times with all terms, conditions and recommendations contained in, or attached to this Construction Report.
6. The Engineer shall not be liable for any defect in, or damage to the building (which included the footing) arising from footing inadequacy or movement of the building, including its footings, caused by or contributed to by any breach of the terms, conditions and recommendations committed, permitted or allowed by the Owner.
7. Where more than one person is named as the Owner, all these terms, conditions and recommendations shall bind all such persons jointly and each such personal severally, and any instruction or information given to the Engineer by any such person shall be deemed to be given by all other such persons.

SITE INSPECTIONS

It is recommended that the Engineer carry out the minimum required site inspections as required in the footing recommendation section above.

The inspections listed in the above Item 1 refer to some or all those relevant inspections of (1) to (6) below.

These are minimum inspection requirements and do not preclude any other inspections that the client may require.

It is the client's responsibility to inform the Engineer a minimum of 48 hours before the mandatory inspection is required.

The intention of the inspections is to ensure that the work is being carried out substantially in accordance with the requirements of this report. The inspection shall not be of a detailed supervisory nature, and it shall remain the client's responsibility to ensure the overall adequacy of construction.

The inspection shall specifically exclude the checking of levels, layout dimensions, squareness, relationship to boundaries and other items which will not affect the structural performance of the building.

RECOMMENDED INSPECTIONS

1. Upon completion of primary earthworks, where the depth of excavation exceeds 600mm. The inspection shall be limited to a visual inspection of the earthworks, and any approval shall be conditional upon the client completing the final earthworks to the correct levels and slopes at a later stage. Where the Engineer considers that additional testing or investigation is required as a result of the earthworks, he/she will advise the client that the building work shall not proceed until the additional work has been

completed. The additional testing, investigation and report is deemed to be an extra to the standard requirements.

2. Upon excavation for footings and prior to the placement of any waterproof membrane or reinforcement. Where footing construction is to be completed in staged (e.g, - pierand-beam construction, split level buildings), an inspection should be carried out at each stage.
3. Upon completion of fixing/placement of reinforcement, and at the commencement of, or prior to, the concrete pour, the following items shall be checked during the inspection, but it shall remain the client's responsibility to ensure that:
    a. The correct cover to reinforcement, the concrete quality and quality of workmanship are maintained throughout the pour;
    b. Waterproof membranes are not punctured or split, and;
    c. The concrete is finished to the correct levels.
4. Upon completion of excavation for main sewers, to ensure that the trenches, as constructed, do not contravene the design parameters determined from the original plans. The checking of sewers for compliance with the requirements of statutory authorities is specifically excluded.
5. Upon completion of brickwork, to ensure control joints have been provided at specified locations. The checking of joint details which are not visible are specifically excluded.
6. Upon completion of the installation of paving, stormwater drains, pipes and structures, to check their compliance with drainage requirements. The checking of sections which are not visible is specifically excluded. Maintenance of ground slopes to ensure continued proper drainage will be required subsequent to the inspections, and shall remain the client's responsibility.

GENERAL NOTES ON FOOTINGS, BUILDING CONSTRUCTION AND SITE MANAGEMENT

FOOTING PERFORMANCE

The details in this report contain advice designed to help minimise risk to the building. The following information represents the basis on which the construction report has been prepared. It should be noted that the intention of the footing design is to prevent cracking exceeding the *Damage Category 2 (Refer to AS2870-2011 Residential footings, Appendix C, Table C1 & C2)* It is emphasised that in the event of leaking water or sewer pipes, or a significant departure from site management requirements contained during this report, the above Damage Category becomes inapplicable.

It is important for the Owners to understand that reactive clays move because of moisture changes and even relatively stable clays will move significantly if subject to extreme moisture conditions. The Owner is the only person who can maintain reasonable moisture condition on site.

The Owner should appreciate that on reactive clays, it is impossible to design a footing system that will totally prevent movement (unless of course there is no limit on expenditure). Some minor aesthetic (not structural) cracking, while undesirable, will occur in significant proportion of the building. Limits of performance are set out in *AS2870-2011 Residential footings, Appendix C, Table C1 & C2*, and while occasional Category 2 behaviour may occur, for most situations Categories 0 and 1 should be the limit. Even significantly masonry cracking with widths over 5mm (Category 3) usually has no influence on the function of the wall and only presents aesthetic problems.

For complete protection against any possibility of damage, the planting of trees should be avoided on reactive clay sites. This is not a normal practice, but the planting of trees must accord with recommendations set out elsewhere in these notes.

The attachment of floor surfacing to concrete slabs that have not fully dried can cause problems via moisture reactions with glues or concrete shrinkage. Drying times vary (and up to six months may be required).

Concrete shrinks as it dries and this usually results in some surface cracking, often about 1mm in width. This has little effect on the structural performance or water tightness of the slab, but could affect some brittle floor coverings if they are installed too soon.

Tree Effect

If there are trees in the vicinity of the proposed works we have attempted to account for their effects by designing for a greater soil movement than would otherwise occur, however, due to the complex tree root geometry, variable moisture extraction by the tree and the difficulty in predicting future tree growth, a precise design for the effect of trees is outside current knowledge. The owner must be aware that although precautions have been taken for the effects of trees in our design, some distortion must be accepted. Engineers are not experts in tree growth and cannot be expected to know the anticipated growth and mature height of trees.

SOIL BORELOGS

The soil profiles as indicated by the test bores from the basis of the footing recommendations contained in this report. The footings have been selected on the basis of the recognised characteristics of the soil profile. Unless otherwise stated, these characteristics have been visually assessed and related to known performance of soils under optimum conditions of site development and use; it has been assumed that aspects of site drainage, paving and landscaping which are described in this report have been, or will be implemented.

Where all of these aspects do not form part of the building contract, it is a mandatory requirement that they be carried out within a period stated in this Construction Report.

The Engineer will as part of mandatory inspections, inspecting all footing beams and piers prior to pouring of concrete.

SITE PREPARATION

After completion of primary earthworks, the site must be prepared for footing construction. Ideally, for raft constructions, soils beneath the house should be kept as moist as possible. For strip footings with timber floors, the building area should be kept as dry as possible.

For rafts, provide a working surface of a minimum compacted thickness of 50mm quarry rubble or other approved material. The selected material must be free at the surface of any sharp aggregate which could damage the vapour barrier.

Note: the thickness of the working surface may be dictated by Local Council requirements or statutory requirements, depending upon the relationship between finished floor level, external pavement and/or the sewer flood gully. This shall be taken into account when establishing building platform levels.

SITE DRAINAGE

Because different moisture variation (wetting or drying) is the main cause of movement in clay soils, the achievement of effect drainage is of the greatest importance as it reduces the chance of the footing having to cope with extremes of soil movement/

The following list covers the most common causes of moisture change:

Wetting up:

1. Leaking sewer of water pipes
2. Downpipes discharging to close to the house
3. Sloping sites and inadequate drainage causing water to pond are or collect close to the house.
4. Seepage on sloping sites caused by water travelling on the top-soil clay interface; cutoff drains are required in this situation.
5. Garden or lawn watering immediately adjacent to the footings. As a general rule this is not acceptable and must not be done without the explicit approval of the engineer.
6. Septic tanks with inadequate soakage trenches
7. Flooding during house construction Drying out:

1. The non-provision of paving particularly on the north and west sides of the house coupled with the non-establishment of a garden.
2. A change from an established garden situation to a native garden, coupled with a substantially reduced level of watering.
3. The most common cause of drying out by far is that caused by trees being planted too close to the house. Trees should be planted in accordance with the recommendations in the CSIRO Information Sheet attached in this report.

Because of these factors the following work must be undertaken.

a) Establish lawns and gardens around the house as soon as possible and certainly within six months of occupation of the house.

b) After footings have been completed the site surface adjacent to the footings shall be graded by additional cutting and/or filling to achieve a positive surface gradient of not less than 1 in 10 away from the footing for a distance of not less than 1m. The channel so formed must be graded in turn so as to discharge ALL RUN-OFF away from the house area. Generally, any cut area shall be drained via a surface drain at the base of the cut embankment. Water MUST NOT POND within surface footing beams or adjacent to perimeter footings; if this occurs must be pumped out immediately and the above grading and drainage specified.

Site containing reactive clays (e.g, - Class M-D to Class E-D) will require additional drainage specifications to adequately protect the footings from adverse movements.

a) Surface drainage of the site should be considered, and appropriate action taken before the start of the construction. The drainage system should be completed by the finish of the construction of the house.

b) The drainage shall be such to avoid water ponding against or near the house. The ground in the immediate vicinity of the house should be graded to slope 50mm away from the house area, a distance of 1m from the house. Any paving should also be suitably sloped.

   E.g, - Class S: 1 in 30 crossfall

   Class M-D to E-D: 1 in 20 crossfall

SUBSOIL DRAINAGE

Where specified in the recommendations subsoil drainage shall be installed as shown on the site drainage plan and in accordance with the enclosed standard details.

Note: Potential seepage or subsoil drainage problems cannot always be recognised from the results of a domestic site investigation. All the potential problems with respect to sub-surface water flow or seepage may not be evident until after the site has been occupied for the first winter.

Sites containing reactive clays (e.g, - Class M-D to Class E-D) will require closer attention: Subsurface drains should be avoided near footings as the introduce water to the foundation if the become blocked. In some circumstances, sub-surface drains will be essential for drainage steps and sub-surface flows, and care should be taken to ensure that they are free draining and able to be inspected and maintained. Sub-surface drains should be protected by filters and geotextiles. Where possible, the base of the sub-surface trench should be capable of providing some drainage in the event the main drain becoming blocked.

PAVING REQUIREMENTS

- Concrete pavements shall have a thickness not less than 75mm. Where the soil class given in the attached Report is Class M-D to E-D, it is recommended that concrete paving be reinforced with SL52 fabric in a single top layer.
- Pavements shall not be less then 0.9m (preferably 1.2m) and shall have a cross fall as per Site Drainage for reactive clays as described above.
- Where estimated free-soil swell is in excess of 40mm, it is recommended that paving be constructed at the end of winter when the site soils are wet so that crossfalls constructed in the paving will not reduce. It is important however, if the house is occupied during a winter period and no paving is provide, that the soil surface around the perimeter of

the house is maintained in a well-drained state until such paving is installed. If on these soils it is necessary to construct paving at other times of the year (Summer), the crossfall provided should not be less than 70mm.

- Paving shall be constructed on a well graded granular sub base such as sand, gravel or crushed rock, minimum 75mm thick. Any local soft spots shall be corrected to achieve a level of compaction similar to the subgrade. Quality of the subgrade is also important and shall be void of all organic material and be well compacted.
- The paving must be constructed below base of footing rebate creating a minimum slab edge exposure of 50mm. Depending upon type of termite protection, this edge exposure may be increased to 75mm.
- On reactive soil sites, it may be found that paving separates horizontally from the perimeter of the house. It is important that any gaps between the brickwork and the footing be immediately sealed with a flexible mastic sealant.

EARTHWORKS

1. MATERIALS

Where specified in the Footing Report selected approved site materials, excluding topsoil or organic bearing soil, may be used for compacted filling. Alternatively, where site materials are unsuitable because of their nature or moisture content, quarry rubble or other approved filling may be used.

2. COMPACTED FILL ON STEEP SITES

Where the surface slope of an area which is to receive filling is steeper than 1 (vertical) in 8 (horizontal), a serious of beams shall be excavated along the contour over the whole of the area which will receive filling. This will stabilise fill against downhill slip. Contact the Engineer if further information or clarification is required.

3. STANDARD OF COMPACTION

The standard of compaction of filling shall for the various material types given, be not less than noted in the below table. The specified standard of compaction shall be provided to an area extending not less than 1metre beyond the perimeter of the building and shall also not be provide beneath any filled driveways or other traffic pavements.

The footings specified in this report have been proportioned assuming the builder will achieve the specified compaction. Notwithstanding this, no footing beam shall be founded in the filling unless the Engineer has checked its compaction standard and given his written acceptance of its compliance with the specification.

To achieve the above compaction requirements, smooth drum rollers (for granular materials) or vibrating sheepsfoot rollers (for clays) are required. Take care with vibrating rollers, particularly if there are houses constructed on adjacent allotments.

If the builder elects to place filling without the use of compaction equipment, the filling will be assumed to be incapable of supporting any building load. Accordingly, any concrete slab over such filling will be increased in thickness and have an additional layer of bottom fabric reinforcement.

COMPACTIONS REQUIREMENTS

Type of Filling Material	Quarry rubble, well graded quarry scalpings, crushed rock	Fine sands or silts	Silty or sandy clay low plasticity	Silty clays or clays – medium to high plasticity
Recommended Compaction Equipment	Smooth drum vibratory or dead weight roller	Smooth drum vibratory roller	Sheepsfoot or smoothdrum vibratory roller	Sheepsfoot vibratory roller
Target Density	95% of E.2.1	75% relative density	95% of E.1.1	95% of E.1.1
Minimum Acceptable Density	90% of E.2.1	70%	90%	90%
Comment	Easy materials to compact provided moisture content is near optimum	Difficult to compact – keep moisture level above optimum when compacting	Compacts with some difficulty – keep moisture near or just above optimum when compactig	Difficult to compact – keep moisture level at or just below optimum when compacting
Layer Thickness for Hand Roller or Vibrator Plate	Maximum 75mm loose thickness	Maximum 75mm loose thickness	N/A to this material	N/A to this material

EXCAVATOR

It is imperative that the Owner or his servant or agent provide sufficient supervision of the cut and fill operation in order to ensure that the following requirements for satisfactory completion of the cut and fill, and drainage scheme proposal are adhered to.

Vegetation and roots must be scraped off and removed from the site prior to cutting and filling. The bench level set on the cut and fill proposal must be adhered to.

The extent of cut and fill outside the building line should not be exceeded with respect to the following requirements:

1. Cut or fill on the boundary should not exceed 600mm, unless a suitable retaining wall is specified.
2. Cut on the boundary should not undermine any structure that exists on an adjacent property.
3. Generally, cut or fill within the property (ie – not on a boundary) should not exceed 900mm (unless a suitable retaining wall is specified).
4. Where bank heights do not exceed 1.5m and the natural slope of the site does not exceed 1 in 5, the batter slopes recommended below may be used.

DESIRABLE BATTER SLOPES

These surface slopes are only appropriate when the natural surface slope does not exceed 1 (vertical) in 5 (horizontal).

Material	Surface Slope (vertical to horizontal)
Heavy Clay	1 to 1
Sands and cohesionless material	1 to 2
Friable and sandy cohesionless soils	1 to 1.5

Weather rock in good condition	1 to 0.5
Sound rock	Nearly vertical

Note: embankments should be protected from damage arising from surface erosion or ground water flow/ If a retaining wall has been specified, the cut and fill should not exceed the design height of the specified retaining wall.

Slopes and gradings of the cut bench or platform shown on the cut and fill plans are to be adhered to strictly to allow for the site to be drained. In particular, a temporary toe may need to be cut in the floor at the base of cut banks to provide a drain. This drain should fall sufficiently to the low side to that water does not pond. On sand sites and sites where erosion may be a critical problem, provision of trench drains above the cut bank to prevent erosion during the construction phase may be required.

BUILDING CONSTRUCTION AND ARTICULATION

It should be realised that there are many factors which affect the performance of the building. Visible cracking can be caused by shrinkage of roof timbers, crazing of plaster, expansion of brickwork, brick growth and shrinkage of concrete, as we as the most commonly attributed case, footing distortion.

Generally, minor cracking is of no significance and will not detract from the performance or durability of the building. It is uneconomical, if not impossible to eliminate all such imperfections.

It is generally recommended that masonry walls be articulated at all or some openings. Articulation involves the incorporation of movement joints at doors and windows. The location of the control joints will be given in the footing report together with the required details needed for correct articulation.

It should be noted that significant economies in footing costs may be achieved using an articulated structure.

Where either expansive or collapsing soils are encountered, special care must be taken to ensure that flexible service connections are used to allow for differential soil movement. Similarly, where new masonry abuts existing masonry, full height mastic filled control joints shall be implemented.

It is very difficult to prevent tilting of the extension relative to the existing building, and hence the extension should be constructed so as to permit relative movement between new and existing. This provision for relative movement applies to all work including floors, tiled walls and ceiling finishes.

SERVICES

SERVICE TRENCHES

Unless approved otherwise, service trenches must be positioned so that the distance between the edge of the trench and the edge of the footing is not less than the depth of the trench, below the founding base of the footing. If this cannot be achieved, the Engineer must eb notified BEFORE footing construction commences so that appropriate alternatives can be made to the footing design, or to the specification for the service trench.

All sewer trenches both within and outside the perimeter of the house must be carefully backfilled with approved material and compacted.

The trenches shall be sloped away from the house and backfilled with clay in the top 300mm within 1.5m of the house. Where pipes pass under the footing slab, the trench shall be backfilled with clay or concrete to prevent the ingress of water beneath the footing.

Sewer pipes are to have a fall to either septic tank or Sewer IP as specified in AS3500.2. The connection from internal and external pipes at highest point of sewer run are to have an invert level of 650mm minimum below finished floor level of house or as indicated on Triaxial's Site Works & Drainage Plan (if provided).

Septic tanks and associated soakage areas are to be located to minimise their effect on the foundations.

SERVICE PENETRATIONS

Service penetrations are permitted through footings subject to the following requirements:

Sleeves shall desirably be placed at mid-depth of the footing and a minimum of 50mm cover shall be provided between the sleeve or pipe and the reinforcing steel. Where this is not achieved, the following must be carried out:

1. Provide additional reinforcement correctly placed and lapped appropriately either side of the sleeve.
2. Where the sleeve is close to the bottom reinforcement, additional excavation must occur below the pipe and the bottom rods placed and lapped to provide the correct cover.

FLEXIBLE CONNECTIONS

On Class H-D and E-D sites, flexible connections shall be provided in stormwater and sewer pipes where they exit from external footings.

LAGGING

Lagging shall be used around stormwater and sewer pipe penetrations in accordance with the following:

A. Horizontal Penetrations (including any pipes that are not completely vertical)

    a. External Footings

i. Class E-D and H2-D sites – min. 40mm closed cell polyethylene

ii. Class H1-D sites – min. 20mm closed cell polyethylene

iii. Class M-D or S sites – lagging not required

b. Internal Footings

i. All soil classes – lagging not required.

B. Vertical Penetrations

a. Lagging is not required around vertical pipe penetrations through footing beams and floor slabs.

Foundation Maintenance and Footing Performance:

A Homeowner's Guide

BTF 18
replaces
Information
Sheet 10/91

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

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

Soil Types

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

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

Causes of Movement

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

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

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

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

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

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

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

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

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

GENERAL DEFINITIONS OF SITE CLASSES	
Class	Foundation
A	Most sand and rock sites with little or no ground movement from moisture changes
S	Slightly reactive clay sites with only slight ground movement from moisture changes
M	Moderately reactive clay or silt sites, which can experience moderate ground movement from moisture changes

H	Highly reactive clay sites, which can experience high ground movement from moisture changes
E	Extremely reactive sites, which can experience extreme ground movement from moisture changes
A to P	Filled sites
P	Sites which include soft soils, such as soft clay or silt or loose sands; landslip; mine subsidence; collapsing soils; soils subject to erosion; reactive sites subject to abnormal moisture conditions or sites which cannot be classified otherwise

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

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

Unevenness of Movement

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

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

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

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

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

Effects of Uneven Soil Movement on Structures

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

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

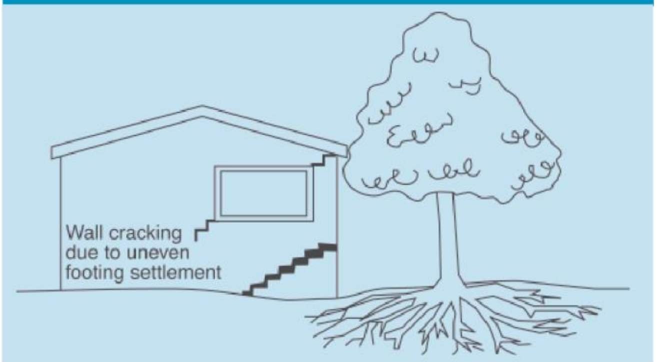
Isolated piers affected by erosion or saturation of foundations will eventually lose contact with the bearers they support and may tilt or fall over. The floors that have lost this support will become bouncy, sometimes rattling ornaments etc.

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

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

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

Trees can cause shrinkage and damage



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

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

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

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

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

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

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

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

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

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

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

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

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

Water Service and Drainage

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

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

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

Seriousness of Cracking

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

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

Prevention/Cure

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

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

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

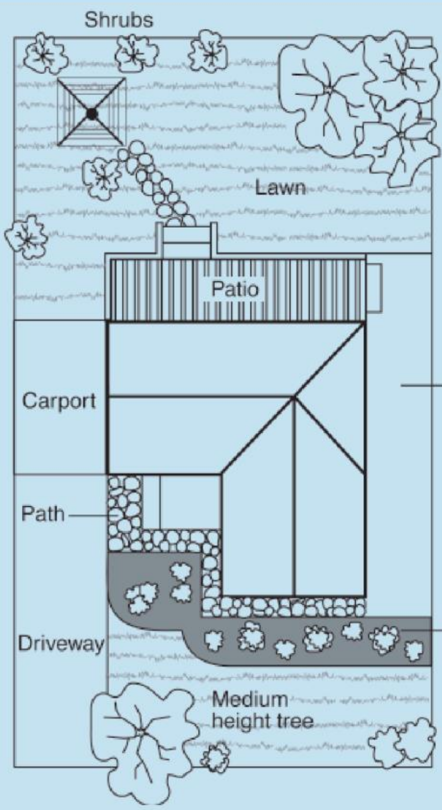
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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

CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS

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

Gardens for a reactive site



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

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

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

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

Condensation

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

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

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

The garden

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

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

Existing trees

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

Information on trees, plants and shrubs

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

Excavation

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

Remediation

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

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

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

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CSIRO PUBLISHING PO Box 1139, Collingwood 3066, Australia

Freecall 1800 645 051 Tel (03) 9662 7666 Fax (03) 9662 7555 www.publish.csiro.au

Email: publishing.sales@csiro.au