Building Code Clause(s) B1

PRODUCER STATEMENT – PS1 – DESIGN

(Guidance on use of Producer Statements (formerly page 2) is available at www.engineeringnz.org)

ISSUED BY: STRATUM CONSULTANTS LTD
(Design Firm)

TO: SPENCER AND LISA ADLAM
(Owner/Developer)

TO BE SUPPLIED TO: ROTORUA LAKES COUNCIL
(Building Consent Authority)

IN RESPECT OF: POST FOOTING, BEAMS, RETAINING WALLS,
(Description of Building Work)

AT: 33 GREAT WEST ROAD
(Address)

Town/City: ROTORUA (Address) **LOT** 52 **DP** 333017 **SO** ……

We have been engaged by the owner/developer referred to above to provide:

FOUNDATION DESIGN / BEAMS / RETAINING / GENERAL STRUCTURAL DESIGN

(Extent of Engagement)

services in respect of the requirements of Clause(s) B1 of the Building Code for:

☐ All or ☒ Part only (as specified in the attachment to this statement), of the proposed building work.

The design carried out by us has been prepared in accordance with:

☒ Compliance Documents issued by the Ministry of Business, Innovation & Employment AS1 / VM1/ VM4 or
(verification method/acceptable solution)

☐ Alternative solution as per the attached schedule ……

The proposed building work covered by this producer statement is described on the drawings titled:

33 GREAT WEST ROAD, ROTORUA and numbered PROJECT NO: 235655;
together with the specification, and other documents set out in the schedule attached to this statement.

On behalf of the Design Firm, and subject to:
(i) Site verification of the following design assumptions AS PER GAR BY STRATUM JAN 22 REF 235655
(ii) All proprietary products meeting their performance specification requirements;

I believe on reasonable grounds that a) the building, if constructed in accordance with the drawings, specifications, and other documents provided or listed in the attached schedule, will comply with the relevant provisions of the Building Code and that b), the persons who have undertaken the design have the necessary competency to do so. I also recommend the following level of construction monitoring/observation:

☐ CM1 ☐ CM2 ☒ CM3 ☐ CM4 ☐ CM5 (Engineering Categories) or ☐ as per agreement with owner/developer (Architectural)

I, STEPHEN BOS am: ☒ CPEng 154367 # ☐ Reg Arch …… #
(Name of Design Professional)

I am a member of: ☒ Engineering New Zealand ☐ NZIA and hold the following qualifications: NZCE, BE, CMEngNZ, CPEng
The Design Firm issuing this statement holds a current policy of Professional Indemnity Insurance no less than $200,000*.
The Design Firm is a member of ACENZ: ☐

SIGNED BY STEPHEN BOS (Signature) Stephen Bos
(Name of Design Professional)

ON BEHALF OF STRATUM CONSULTANTS LTD Date 16/02/2022
(Design Firm)

Note: This statement shall only be relied upon by the Building Consent Authority named above. Liability under this statement accrues to the Design Firm only. The total maximum amount of damages payable arising from this statement and all other statements provided to the Building Consent Authority in relation to this building work, whether in contract, tort or otherwise (including negligence), is limited to the sum of $200,000.*

This form is to accompany **Form 2 of the Building (Forms) Regulations 2004** for the application of a Building Consent.

Form 2A

Memorandum from licensed building practitioner: Certificate of design work

Section 45 and Section 30C, Building Act 2004

Please fill in the form as fully and correctly as possible.

If there is insufficient room on the form for requested details, please continue on another sheet and attach the additional sheet(s) to this form.

THE BUILDING

Street address: 33 Great West Road	
Suburb:	
Town/City: Rotorua	Postcode: 3015

THE OWNER

Name(s): Spencer and Lisa Adlam

Mailing address: As noted above

Suburb:	PO Box/Private Bag:
Town/City:	Postcode:
Phone number:	Email address:

BASIS FOR PROVIDING THIS MEMORANDUM

I am providing this memorandum in my role as the: Please tick the option that applies (√)	
( )	**sole** designer of all of the RBW design outlined in this memorandum – I carried out all of the RBW design myself – no other person will be providing any additional memoranda for the project
( )	**lead** designer who carried out some of the RBW design myself but also supervised other designers – this memorandum covers their RBW design work as well as mine, and no other person will be providing any additional memoranda for the project
( )	**lead** designer for all but specific elements of RBW – this memorandum only covers the RBW design work that I carried out or supervised and the other designers will provide their own memoranda relating to their specific RBW design
(√)	**specialist** designer who carried out specific elements of RBW design work as outlined in this memorandum – other designers will be providing a memorandum covering the remaining RBW design work

IDENTIFICATION OF DESIGN WORK THAT IS RESTRICTED BUILDING WORK (RBW)

I Stephen Bos carried out / **supervised** the following design work that is restricted building work

PRIMARY STRUCTURE: B1

Design work that is restricted building work	Description	Carried out/ supervised	Reference to plans and specifications
Tick(√)if included *Cross (X) if excluded*	*[If appropriate, provide details of the restricted building work]*	*[Specify whether you carried out this design work or supervised someone else carrying out this*	*[If appropriate, specify references]*

	design work]	

Primary structure

All RBW Design work relating to B1	( )		( ) Carried out ( ) Supervised	
Foundations and subfloor framing	(√)	*Foundation and Footings*	( ) Carried out (√) Supervised	Refer to Stratum PS1 (235655) and drawings 235655-STR-D001
Walls	(√)	*Retaining Wall*	( ) Carried out (√) Supervised	Refer to Stratum PS1 (235655) and drawings 235655-STR-D001
Roof	( )		( ) Carried out ( ) Supervised	
Columns and beams	(√)	*Beams and Posts*	( ) Carried out (√) Supervised	Refer to Stratum PS1 (235655) and drawings 235655-STR-D001
Bracing	(√)	*Post footing*	( ) Carried out (√) Supervised	Refer to Stratum PS1 (235655) and drawings 235655-STR-D001
Other	(√)	*Retaining Wall*	( ) Carried out (√) Supervised	Refer to Stratum PS1 (235655) and drawings 235655-STR-D001

EXTERNAL MOISTURE MANAGEMENT SYSTEMS: E2

All RBW design work relating to E2	( )		( ) Carried out ( ) Supervised	
Damp proofing	( )		( ) Carried out ( ) Supervised	
Roof cladding or roof cladding system	( )		( ) Carried out ( ) Supervised	
Ventilation system (for example, subfloor or cavity)	( )		( ) Carried out ( ) Supervised	
Wall cladding or wall cladding system	( )		( ) Carried out ( ) Supervised	
Waterproofing	( )		( ) Carried out ( ) Supervised	
Other	( )		( ) Carried out ( ) Supervised	

FIRE SAFETY SYSTEMS: C1 – C6

Emergency warning systems, evacuation and fire service operation systems,	( )		( ) Carried out ( ) Supervised	

suppression or control systems, or other			

Note: The design of fire safety systems is only restricted building work when it involves small-to-medium apartment buildings as defined by the Building (Definition of Restricted Building Work) Order 2011.

Note: continue on another page if necessary.

WAIVERS AND MODIFICATIONS

Waivers or modifications of the building code are required ( ) Yes (√) No

If Yes, provide details of the waivers or modifications below:

Clause	**Waiver/modification required**
[List relevant clause numbers of building code]	*[Specify nature of waiver or modification of building code]*

Note: continue on another page if necessary.

ISSUED BY

Name: Stephen Bos	LBP or Registration number: 154367
The practitioner is a: ( ) Design LBP ( ) Registered architect (√) Chartered professional engineer	
Design Entity or Company (optional): Stratum Consultants Ltd	
Mailing address (if different from below):	
Street address / Registered office: Level 1, Rydal House, 29 Grey Street,	
Suburb:	Town/City: Tauranga
PO Box/Private Bag: 13651	Postcode: 3141
Phone number: (07) 571 4500	Mobile:
After Hours:	Fax: (07) 571 3500
Email address: Stephen.bos@stratumnz.co.nz	Website:

DECLARATION

I Stephen Bos [*name of practitioner*] , CMEngNZ,

state that I have applied the skill and care reasonably required of a competent design professional in carrying out or supervising the Restricted Building Work (RBW) described in this form, and that based on this, I also state that the RBW:

- Complies with the building code; or
- Complies with the building code subject to any waiver or modification of the building code recorded on this form.

Signature:

Date: 16/02/2022

Stratum CONSULTANTS
Experience. Knowledge. Better Outcomes.

INSPECTION SCHEDULE

Project No: 235655

Site: 33 Great West Road, Rotorua

Date: 16/02/22

Client: Spencer and Lisa Adlam

By: Daniel Archbold

Subject: Post footing inspections / observation

The following inspections / observations are recommended for completion of the proposed works to CM3.

Engineering inspections:

1. Foundation and Footing inspection.
2. Retaining Wall Block Inspection.
3. Beam and Post Inspection.

Any further inspections required are to be undertaken by council.

Yours faithfully,

Stratum Consultants Ltd

Daniel Archbold

Structural Engineer
BE (Hons), MEngNZ

Stratum Consultants Limited
Planners | Engineers | Surveyors

Level 1, 29 Grey Street, PO Box 13651, Tauranga 3141 **P** 07 571 4500 **F** 07 571 3500 **W** www.stratum.nz

GENERAL NOTES

1. THESE STRUCTURAL DRAWINGS SHALL BE READ IN CONJUNCTION WITH ALL ARCHITECTURAL DRAWINGS AND SPECIFICATIONS. THE ENGINEER IS TO BE INFORMED OF ANY DISCREPANCIES.

2. SET OUT OF STRUCTURAL MEMBERS AS PER ARCHITECTURAL DRAWINGS UNLESS NOTED OTHERWISE.

3. DURING CONSTRUCTION THE CONTRACTOR SHALL BE RESPONSIBLE FOR MAINTAINING THE STRUCTURE IN A STABLE CONDITION AND ENSURING NO PART IS OVERSTRESSED UNDER CONSTRUCTION ACTIVITIES. THE CONTRACTOR SHALL DESIGN AND PROVIDE PROPPING TO SUPPORT ALL CAST-INSITU AND PRECAST CONCRETE WORK UNTIL SUCH CONCRETE HAS REACHED THE REQUIRED STRENGTH TO BE SELF SUPPORTING. (TYPICALLY FOR A MINIMUM OF 14 DAYS AFTER POURING).

4. WORKMANSHIP AND MATERIALS SHALL BE IN ACCORDANCE WITH THE RELEVANT NEW ZEALAND STANDARDS AND LOCAL AUTHORITY REGULATIONS, EXCEPT WHERE VARIED BY THE CONTRACT DOCUMENTS.

STEELWORK

1. ALL MATERIAL AND WORKMANSHIP SHALL BE IN ACCORDANCE WITH NZS 3404.

2. ALL WELDING SHALL COMPLY WITH AS/NZS 1554 ALL WELDS TO BE 6mm CATEGORY SP CONTINUOUS FILLET WELDS UNLESS NOTED OTHERWISE.
   FOR THE WELDING OF STRUCTURAL STEEL WELDING PERSONNEL SHALL BE QUALIFIED IN ACCORDANCE WITH CLAUSE 4.11 OF AS/NZS 1554.1 OR AS/NZS 1554.5 AS APPROPRIATE.

3. WHERE STEEL BEAM ENDPLATES FACE FIX TO CONCRETE, PACKING (BETWEEN THE WALL AND THE ENDPLATE) MAY BE A MAXIMUM OF 5mm THICK. IF THE REQUIRED PACKER THICKNESS EXCEEDS 5mm INFORM ENGINEER AND REQUEST A FIXUP DETAIL.

4. ALL STEEL TO BE OF THE FOLLOWING GRADE U.N.O.

   GRADE 250
   CHS, TFC, TFB, PL, EA -< 100 x 100, UA -<125 x 75

   GRADE 300
   UB, PFC, UC, EA >= 125 x 125, UA >= 150 x 90

   GRADE 350
   RHS, SHS

   BOLTS
   GRADE 4.6 SNUG TIGHT U.N.O.

   PLATE AND RODS
   PLATE GRADE 250, ROD GRADE 300, UNLESS NOTED OTHERWISE.

5. ALL BOLTS SHALL BE GRADE 4.6 SNUG TIGHT (4.6/S) U.N.O.
   ALL EXTERIOR BOLTS IN STEEL WORK OR BOLTS CAST OR DRILLED INTO CONCRETE SHALL BE HOT DIPPED GALVANISED U.N.O.

6. UNLESS OTHERWISE SPECIFIED ALL STEELWORKS SHALL BE PAINTED WITH ONE COAT OF AN APPROVED INORGANIC ZINC PRIMER IN ACCORDANCE WITH THE MANUFACTURER'S RECOMMENDATIONS.
   ALL EXPOSED STEELWORK TO BE PAINTED AS FOLLOWS TO ACHIEVE 20 YEARS TIME TO FIRST MAINTENANCE AS SPECIFIED BY AS/NZS 2312:1994. ALL SURFACES SHALL BE FREE OF OIL, GREASE, AND SALT CONTAMINATION. ABRASIVE BLAST CLEAN IN ACCORDANCE WITH AS1627.9 CLASS 2.5 PRIME COAT WITH INORGANIC ZINC SILICATE WITH DRY FILM THICKNESS OF 75 MICRONS. TOP COAT TO BE HIGH BUILT/HIGH SOLIDS EPOXY WITH DRY FILM THICKNESS OF 175 MICRONS. PAINTING SHALL BE IN ACCORDANCE WITH MANUFACTURERS RECOMMENDATIONS. ANY ALTERNATIVE COATING SYSTEMS PROPOSED BY CONTRACTOR TO BE APPROVED BY ENGINEER.
   TENSION BOLTED CONNECTION SURFACES TO BE PAINTED WITH PRIMER IN ACCORDANCE WITH MANUFACTURERS RECOMMENDATIONS AS APPROVED BY ENGINEER.

CONCRETE

1. ALL WORKMANSHIP AND MATERIALS SHALL BE IN ACCORDANCE WITH NZS 3109.

2. MINIMUM COVER TO REINFORCEMENT TO CAST INSITU CONCRETE SHALL BE AS FOLLOWS:

MEMBER	CAST AGAINST EARTH	EXPOSED TO WEATHER	NOT EXPOSED TO WEATHER
FOOTINGS	75mm	-	-
PILES	75mm	-	-
SLAB	50mm	35	25
PANELS	40mm	35	25

   MINIMUM COVER TO REINFORCEMENT TO PRECAST CONCRETE AS PER NZS 3101.

3. NO HOLES, CHASES OR EMBEDMENT OF PIPES OTHER THAN THOSE SHOWN ON THE STRUCTURAL DRAWINGS SHALL BE MADE IN CONCRETE WITHOUT THE APPROVAL OF THE ENGINEER.

4. FOUNDATIONS 25 MPa
   SLAB ON GRADE 25 MPa
   FLOOR TOPPING 40 MPa
   WALLS PRECAST 50 MPa
   COLUMNS 40 MPa
   INSITU BEAMS 40 MPa

REINFORCEMENT

1. REINFORCEMENT BARS SHALL CONFORM WITH NZS 3402 AND WELDED WIRE FABRIC SHALL CONFORM WITH NZS 3421 & NZS 3422. REINFORCING WHICH IS NOT MANUFACTURED BY PACIFIC STEEL IN NEW ZEALAND IS REQUIRED TO BE APPROVED BY THE ENGINEER.

2. ALL REINFORCING BARS HAVE BEEN DESIGNATED AS FOLLOWS:

   GRADE 500E HD
   GRADE 300 D

No.	Date	By	Issue/Revision
C	-	-	-
B	-	-	-
A	16/02/22	DA	FOR BUILDING CONSENT

NOTES/KEY:

1. CONFIRM ALL DIMENSIONS PRIOR TO CONSTRUCTION.

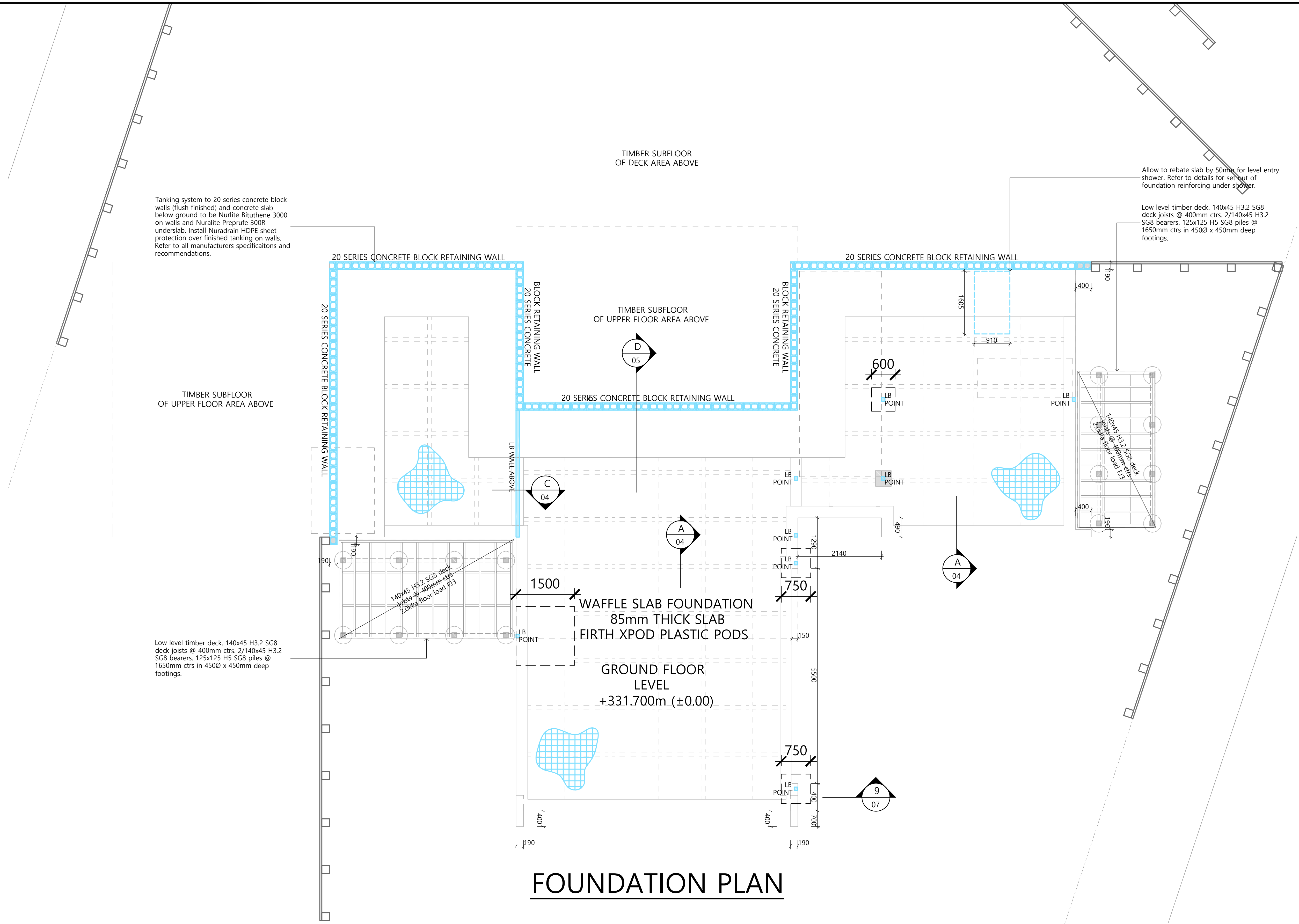
DRAWN BY:	DA
CHECKED BY:	SB
DESIGNED BY:	DA
APPROVED BY:	SB
OFFICE:	TAURANGA
CONTACT:	07 571 4500

SPENCER AND LISA ADLAM
33 GREAT WEST ROAD
ROTORUA

GENERAL NOTES

ORIGINAL DWG. SIZE A3
SCALE: N.T.S
DRAWING No. 235655-STR-D001
SHEET No. S00
ISSUE A

Stratum CONSULTANTS
Experience. Knowledge. Better Outcomes.
Planners I Engineers I Surveyors



FOUNDATION PLAN

C	-	-	-
B	-	-	-
A	16/02/22	DA	FOR BUILDING CONSENT
No.	Date	By	Issue/Revision

NOTES/KEY:

1. CONFIRM ALL DIMENSIONS PRIOR TO CONSTRUCTION.

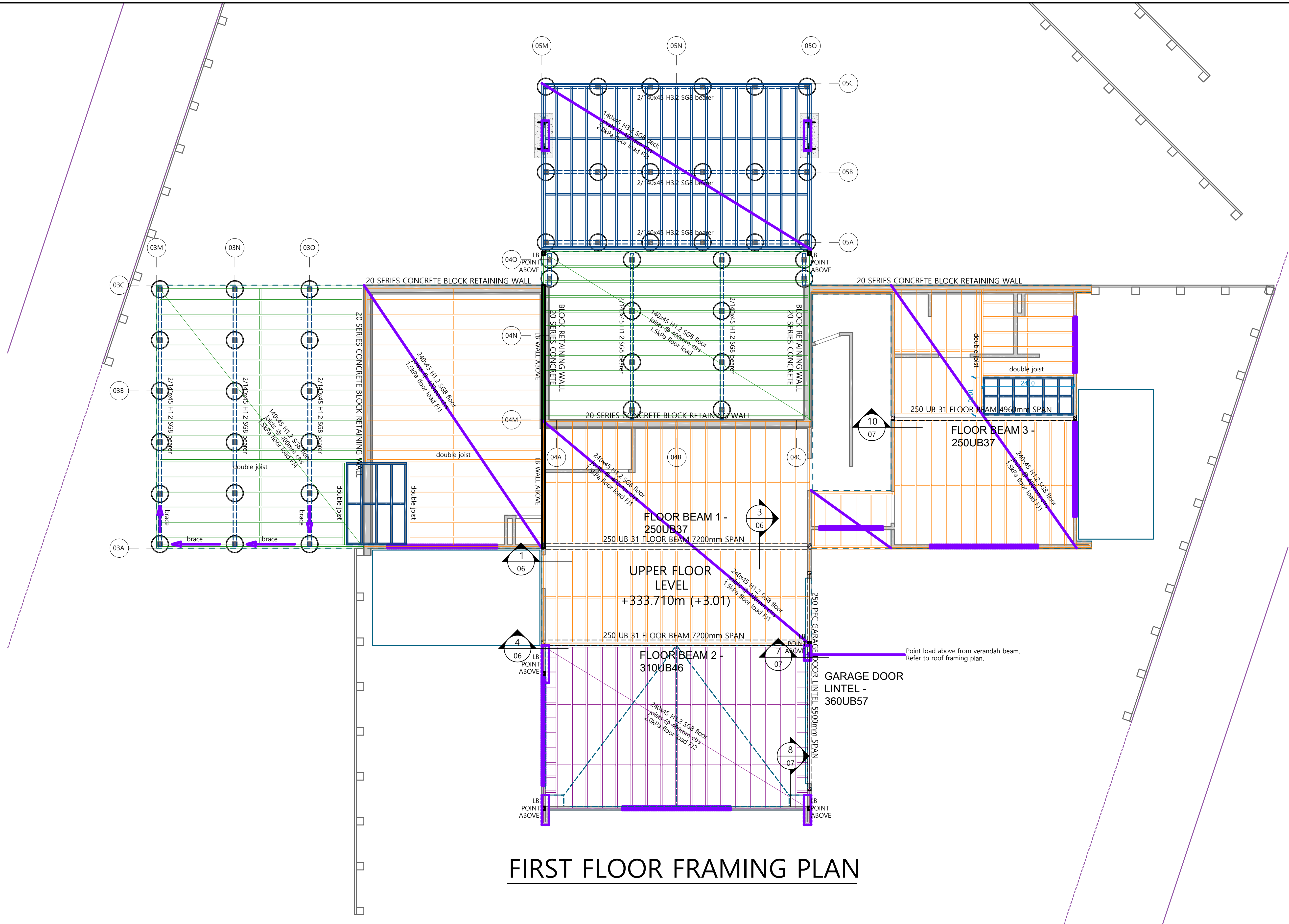
DRAWN BY:	DA
CHECKED BY:	SB
DESIGNED BY:	DA
APPROVED BY:	SB
OFFICE:	TAURANGA
CONTACT:	07 571 4500

SPENCER AND LISA ADLAM
33 GREAT WEST ROAD
ROTORUA

FOUNDATION PLAN

ORIGINAL DWG. SIZE A3
SCALE: 1:100@A3
DRAWING No. 235655-STR-D001
SHEET No. S01
ISSUE A

Stratum CONSULTANTS
Experience. Knowledge. Better Outcomes.
Planners I Engineers I Surveyors



FIRST FLOOR FRAMING PLAN

No.	Date	By	Issue/Revision
A	16/02/22	DA	FOR BUILDING CONSENT
B	-	-	-
C	-	-	-

NOTES/KEY:

1. CONFIRM ALL DIMENSIONS PRIOR TO CONSTRUCTION.

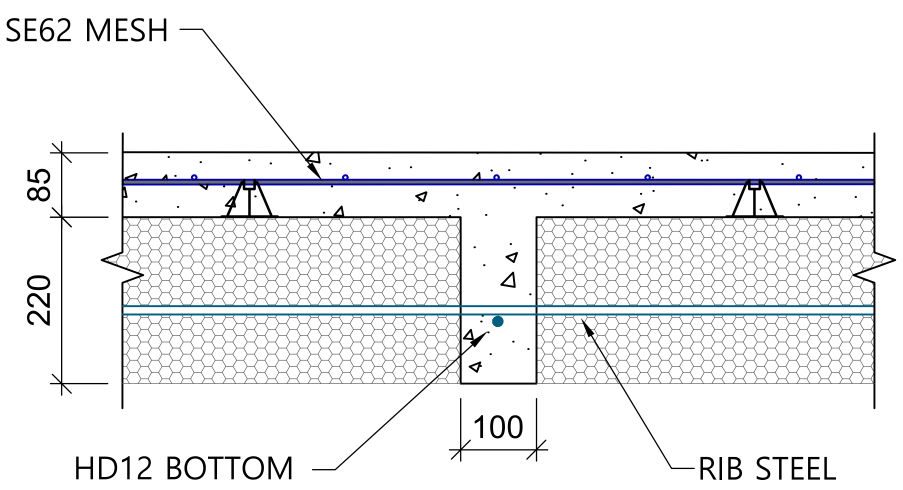
DRAWN BY:	DA
CHECKED BY:	SB
DESIGNED BY:	DA
APPROVED BY:	SB
OFFICE:	TAURANGA
CONTACT:	07 571 4500

SPENCER AND LISA ADLAM
33 GREAT WEST ROAD
ROTORUA

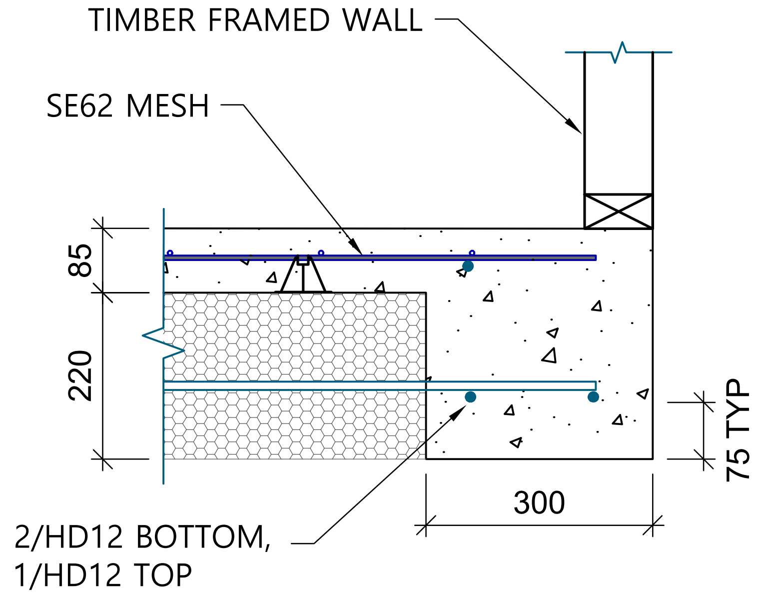
FIRST FLOOR FRAMING PLAN

ORIGINAL DWG. SIZE A3
SCALE: 1:100@A3
DRAWING No. 235655-STR-D001
SHEET No. S02
ISSUE A

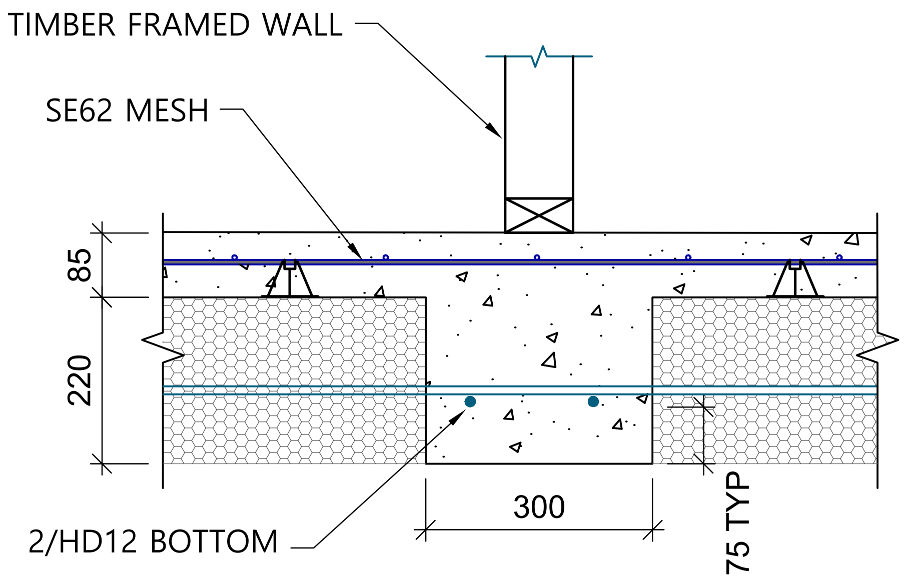
Stratum CONSULTANTS
Experience. Knowledge. Better Outcomes.
Planners I Engineers I Surveyors



A
01
TYPICAL INTERNAL RIB DETAIL



B
01
TYPICAL EDGE BEAM



C
01
INTERNAL THICKENING DETAIL

No.	Date	By	Issue/Revision
C	-	-	-
B	-	-	-
A	16/02/22	DA	FOR BUILDING CONSENT

NOTES/KEY:

1. CONFIRM ALL DIMENSIONS PRIOR TO CONSTRUCTION.

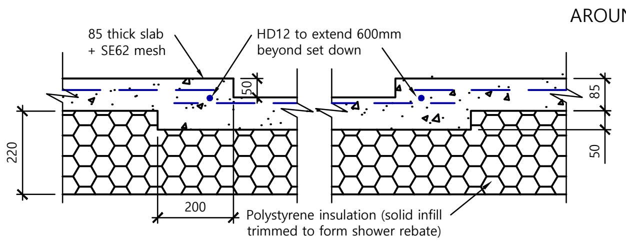
DRAWN BY:	DA
CHECKED BY:	SB
DESIGNED BY:	DA
APPROVED BY:	SB
OFFICE:	TAURANGA
CONTACT:	07 571 4500

SPENCER AND LISA ADLAM
33 GREAT WEST ROAD
ROTORUA

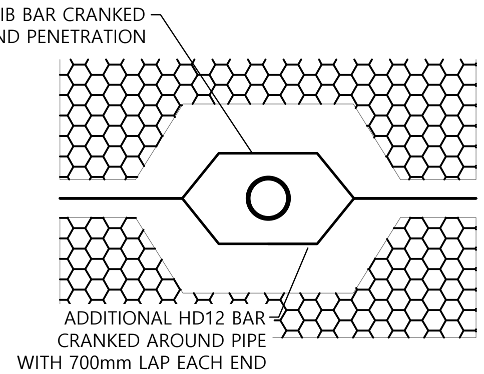
FOUNDATION DETAILS

ORIGINAL DWG. SIZE A3
SCALE: 1:10@A3
DRAWING No. 235655-STR-D001
SHEET No. S03
ISSUE A

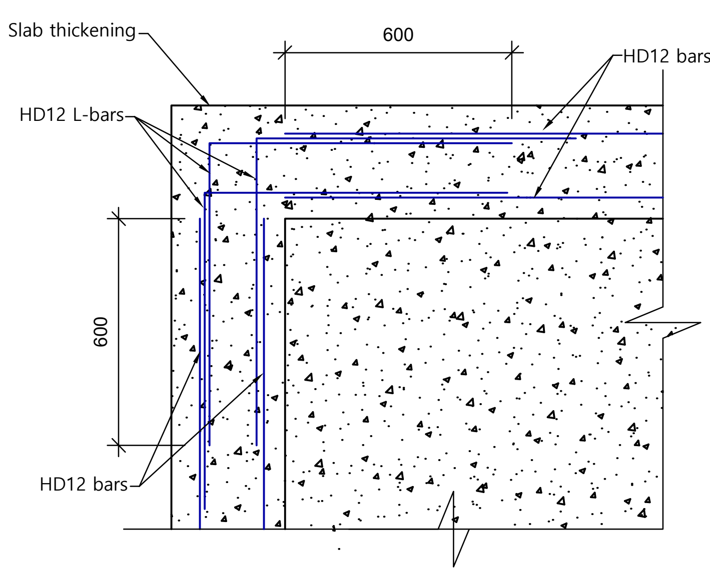
Stratum CONSULTANTS
Experience. Knowledge. Better Outcomes.
Planners I Engineers I Surveyors



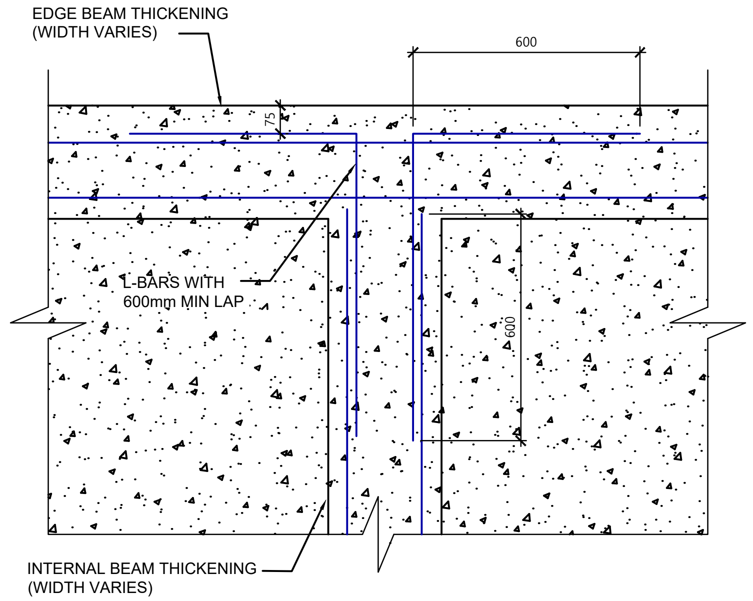
Typical Shower Rebate Detail
(1:20)



Pipe Through 100mm Rib
(1:20)

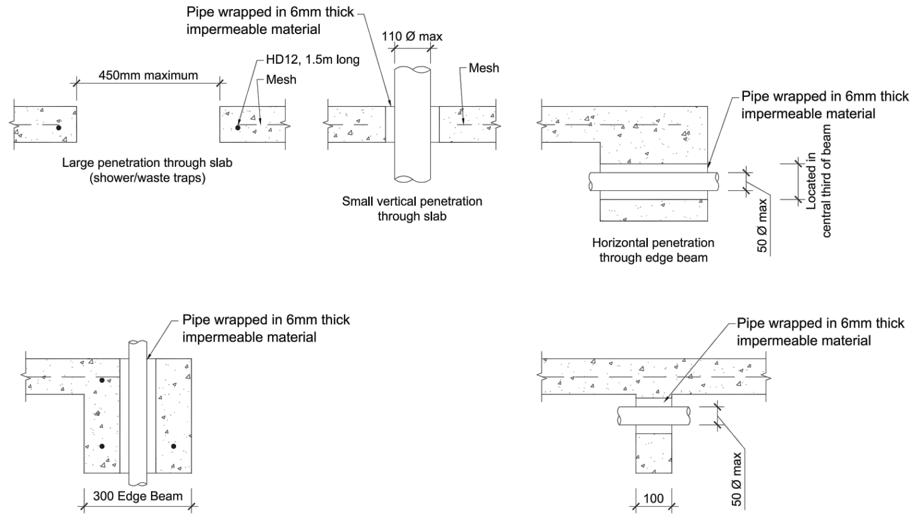


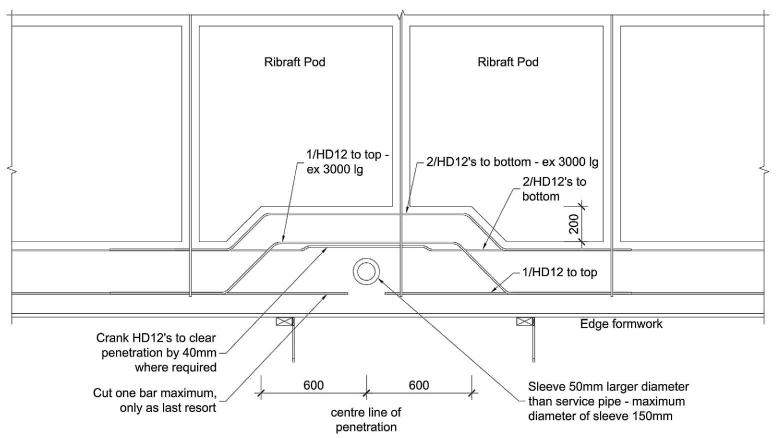
Typical Corner Detail
(1:20)



Internal Thickening - Edge Beam
(1:20)

MAX DIAMETER OF PIPE SERVICES		
Element	Vertical Services	Horizontal Services
300mm wide edge beam	50mm NB pipe	100mm NB pipe
500mm wide localised beam	100mm NB pipe	100mm NB pipe
300mm wide internal rib (or localised)	50mm NB pipe	100mm NB pipe
Slab	100 NB pipe, or 450mm SQ with HD12 bars as per detail	NIL





No.	Date	By	Issue/Revision
C	-	-	-
B	-	-	-
A	16/02/22	DA	FOR BUILDING CONSENT

NOTES/KEY:

1. CONFIRM ALL DIMENSIONS PRIOR TO CONSTRUCTION.

DRAWN BY:	DA
CHECKED BY:	SB
DESIGNED BY:	DA
APPROVED BY:	SB
OFFICE:	TAURANGA
CONTACT:	07 571 4500

SPENCER AND LISA ADLAM
33 GREAT WEST ROAD
ROTORUA

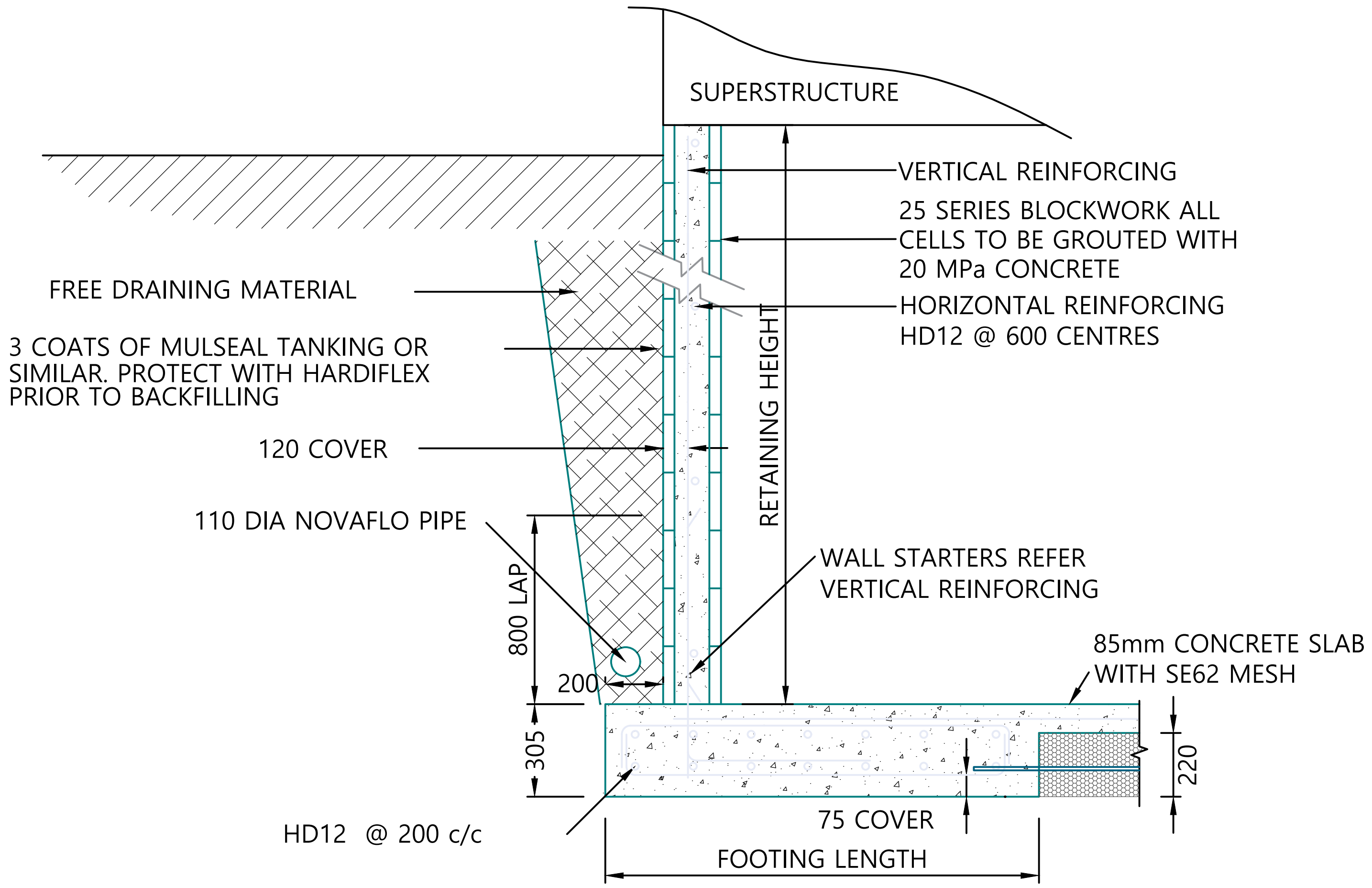
FOUNDATION DETAILS

ORIGINAL DWG. SIZE A3
SCALE: 1:10@A3
DRAWING No. 235655-STR-D001
SHEET No. S04
ISSUE A

Stratum CONSULTANTS
Experience. Knowledge. Better Outcomes.
Planners I Engineers I Surveyors

RETAINING HEIGHT (Maximum)	VERTICAL REINFORCING		HORIZONTAL REINFORCING	FOOTING LENGTH
	SIZE	SPACING		
1000	HD12	400	HD12 BARS AT 600mm CENTRES	1250
1500	HD16	400		1850
2000	HD16	400		2250
2800	HD20	200		2450

NOTE: - DO NOT BACKFILL WALL UNTIL GROUT HAS CURED FOR 5 DAYS
- HD DENOTES DEFORMED GRADE 500E REINFORCING
- ALL CONCRETE 25 MPa UNLESS NOTED OTHERWISE



CONCRETE MASONRY BLOCK RETAINING WALL

G 01

No.	Date	By	Issue/Revision
C	-	-	-
B	-	-	-
A	16/02/22	DA	FOR BUILDING CONSENT

NOTES/KEY:

1. CONFIRM ALL DIMENSIONS PRIOR TO CONSTRUCTION.

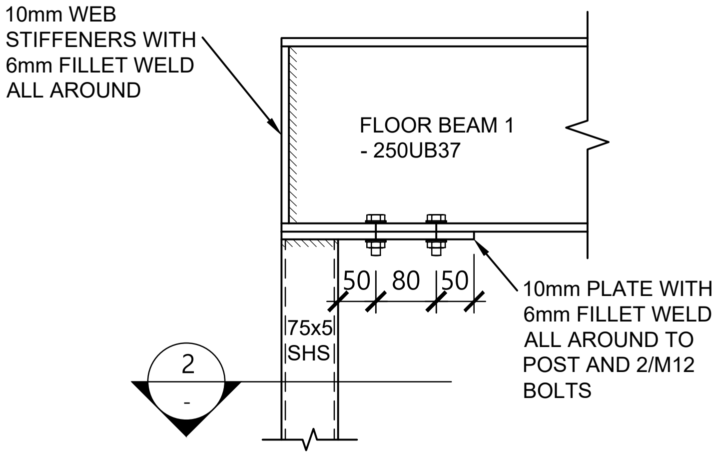
DRAWN BY:	DA
CHECKED BY:	SB
DESIGNED BY:	DA
APPROVED BY:	SB
OFFICE:	TAURANGA
CONTACT:	07 571 4500

SPENCER AND LISA ADLAM
33 GREAT WEST ROAD
ROTORUA

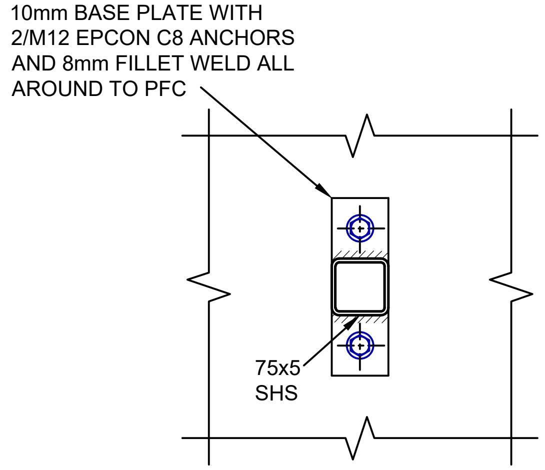
RETAINING WALL DETAILS

ORIGINAL DWG. SIZE A3
SCALE: N.T.S
DRAWING No. 235655-STR-D001
SHEET No. S05
ISSUE A

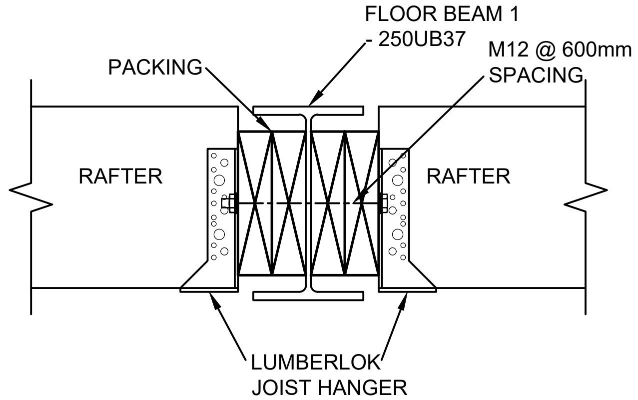
Stratum CONSULTANTS
Experience. Knowledge. Better Outcomes.
Planners I Engineers I Surveyors



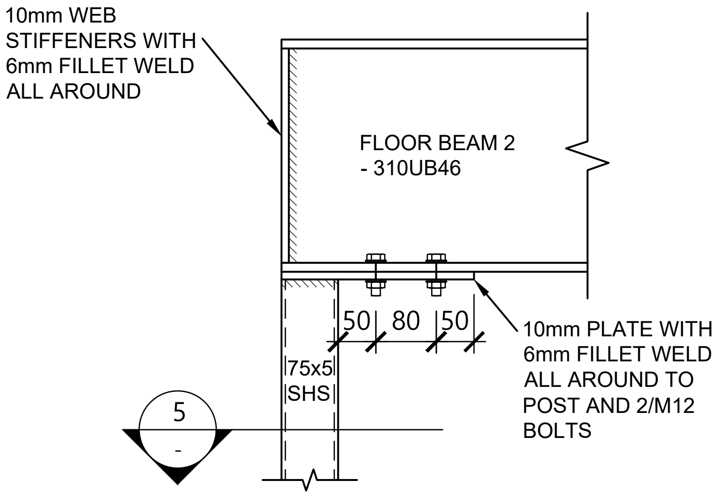
1 / 02 FLOOR BEAM 1 TO POST



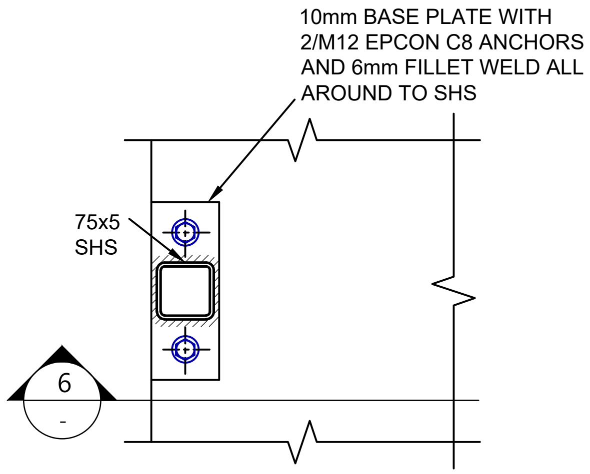
2 / - FLOOR BEAM 1 TO FOOTING



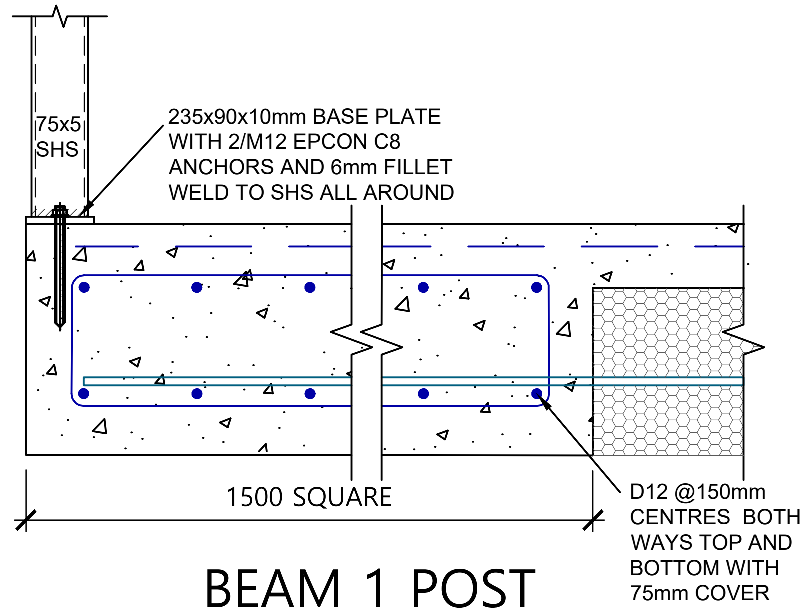
3 / 02 FLOOR BEAM 1 TO RAFTERS



4 / 02 FLOOR BEAM 1 TO POST



5 / - FLOOR BEAM 1 TO FOOTING



6 / - BEAM 1 POST TO FOOTING

No.	Date	By	Issue/Revision
C	-	-	-
B	-	-	-
A	16/02/22	DA	FOR BUILDING CONSENT

NOTES/KEY:

1. CONFIRM ALL DIMENSIONS PRIOR TO CONSTRUCTION.

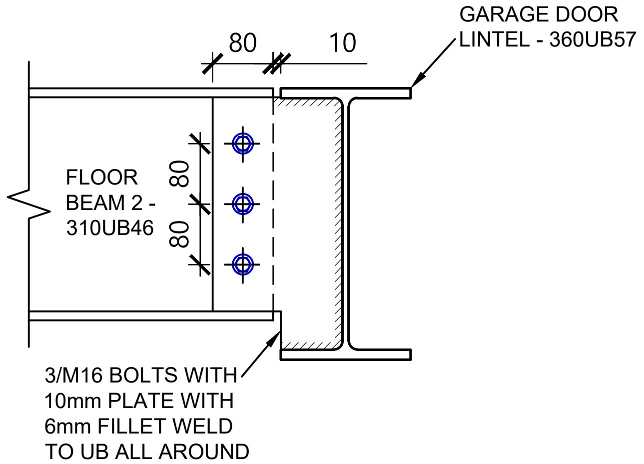
DRAWN BY:	DA
CHECKED BY:	SB
DESIGNED BY:	DA
APPROVED BY:	SB
OFFICE:	TAURANGA
CONTACT:	07 571 4500

SPENCER AND LISA ADLAM
33 GREAT WEST ROAD
ROTORUA

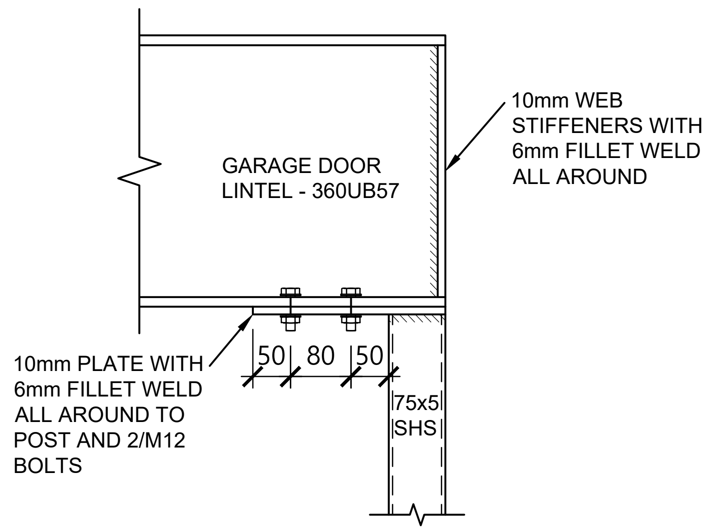
DETAILS

ORIGINAL DWG. SIZE A3
SCALE: 1:10@A3
DRAWING No. 235655-STR-D001
SHEET No. S06
ISSUE A

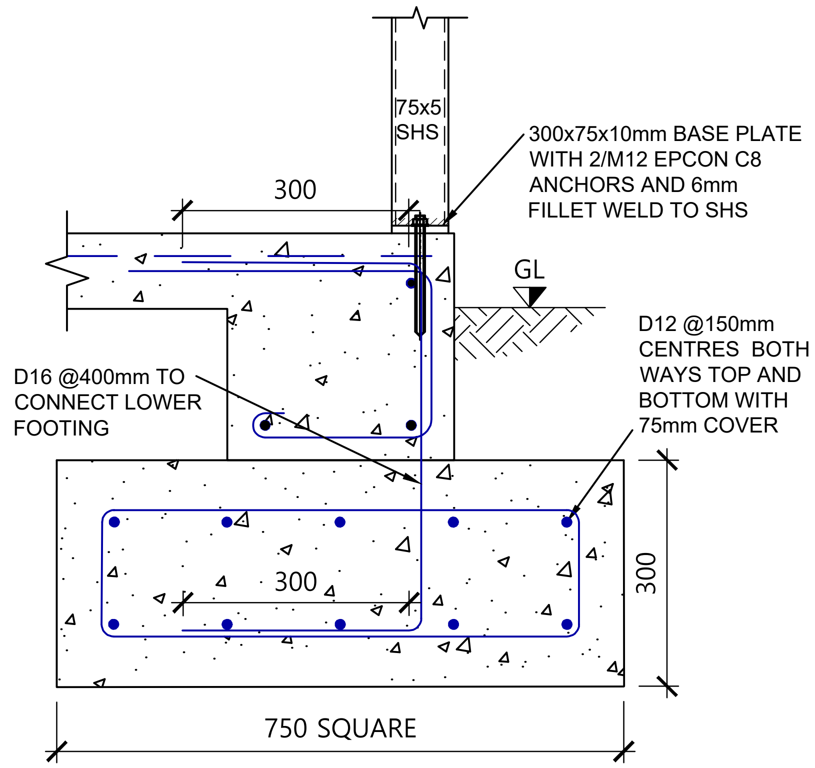
Stratum CONSULTANTS
Experience. Knowledge. Better Outcomes.
Planners I Engineers I Surveyors



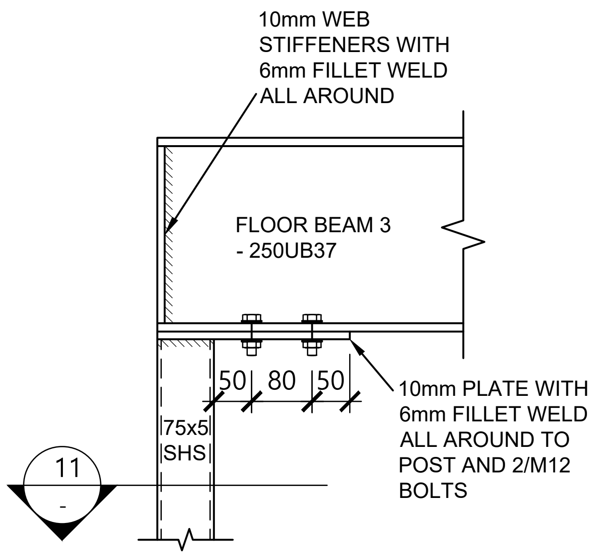
7 / 02 FLOOR BEAM 2 TO GARAGE DOOR LINTEL



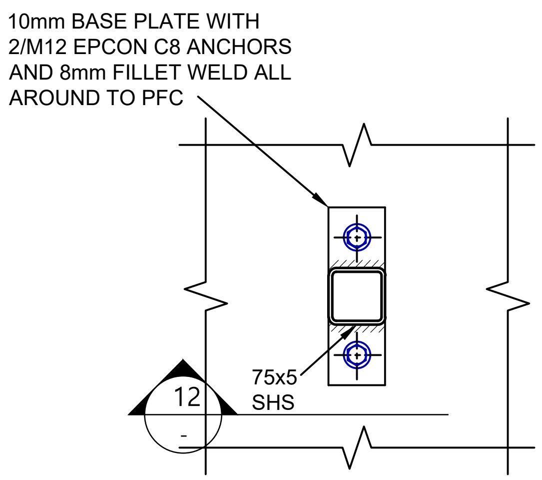
8 / 02 GARAGE DOOR LINTEL TO POST



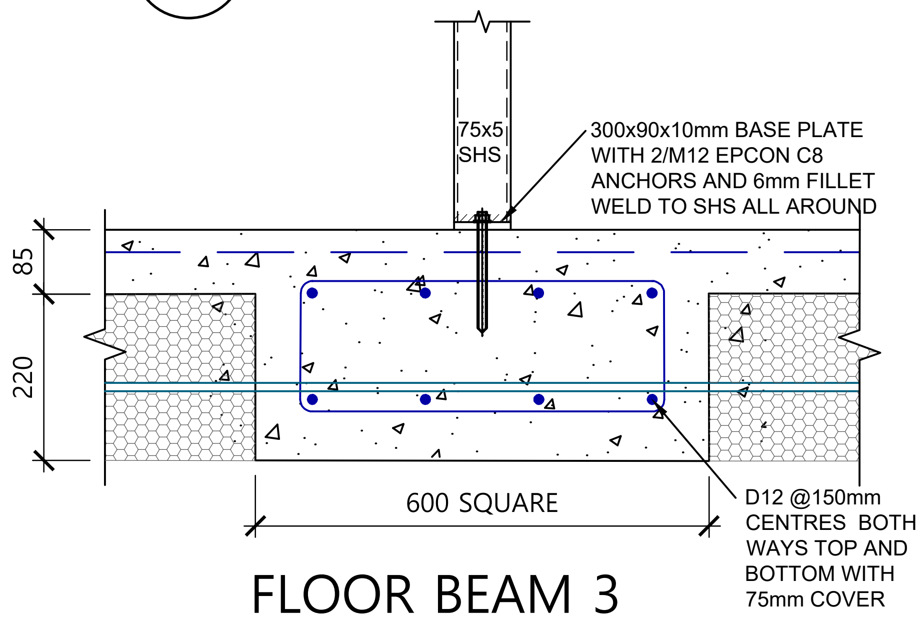
9 / 01 GARAGE DOOR LINTEL TO FOOTING



10 / 02 FLOOR BEAM 3 TO POST



11 / - FLOOR BEAM 3 TO FOOTING



12 / - FLOOR BEAM 3 POST TO FOOTING

No.	Date	By	Issue/Revision
C	-	-	-
B	-	-	-
A	16/02/22	DA	FOR BUILDING CONSENT

NOTES/KEY:

1. CONFIRM ALL DIMENSIONS PRIOR TO CONSTRUCTION.

DRAWN BY:	DA
CHECKED BY:	SB
DESIGNED BY:	DA
APPROVED BY:	SB
OFFICE:	TAURANGA
CONTACT:	07 571 4500

SPENCER AND LISA ADLAM
33 GREAT WEST ROAD
ROTORUA

DETAILS

ORIGINAL DWG. SIZE A3
SCALE: 1:10@A3
DRAWING No. 235655-STR-D001
SHEET No. S07 ISSUE A

Stratum CONSULTANTS
Experience. Knowledge. Better Outcomes.
Planners I Engineers I Surveyors

Job Title	Spencer and Lisa Adlam	***Page***	
Site Address	33 Great West Road	***No of Pages***	
City	Rotorua	***Date***	Feb 22
Job No.	235655	***By***	DA

Stratum CONSULTANTS
Experience. Knowledge. Better Outcomes.

LOADING SUMMARY

LOADINGS IN ACCORDANCE WITH NZS 1170

Importance Level = 2, Normal Structures and structures not falling into other levels
Design Life = 50 Years

1. CALCULATION OF WIND ACTIONS

1.1 SITE WIND SPEED

$V_{sit,\beta} = V_R\, M_d\, (M_{z,cat}\, M_s\, M_t)$ — Eqn 2.2

Regional Wind Speed	V_R =	37.0	m/s	Region A7, R=25 (Design Life=50, AEP=1/25)
Regional Wind Speed	V_R =	45.0	m/s	Region A7, R=500 (Design Life=50, AEP=1/500)
Wind Direction Multiplier	M_d =	1.0		East Wind Direction
Terrain/Height Multiplier	$M_{z,cat}$ =	0.83		Terrain Category 3
Shielding Multiplier	M_s =	1.0		
Topographic Multiplier	M_t =	1.2		

H = 50.0 m, x = 70.0 m
Lu = 117.0 m, z = 8.0 m

Ult $V_{sit,\beta}$ = 41.51 m/s 149.452 Km/hr **Ser** $V_{sit,\beta}$ = 34.13 m/s

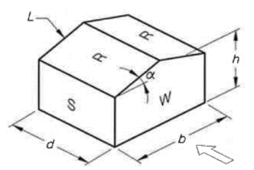
Wind Zone: High Equivalent to NZS3604:2011

1.2 DESIGN WIND PRESSURE

$p = (0.5\rho_{air})\,[V_{des,\theta}]^2\, C_{fig}\, C_{dyn}$ — Eqn 2.4(1)

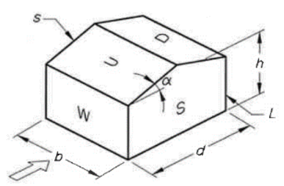
Density of air	ρ_{air} =	1.2	kg/m^3	
Site Wind Speed	$V_{des,\theta}$ =	41.5	m/s	From 2.2
	C_{fig} =	C_{pn},k_p		for external pressures
	K_a, K_c, K_l, K_p =	1		
	C_{dyn} =	1.0		

Walls - windward
$C_{p,e}$ = 0.7 Table 5.2(A)
$C_{p,i}$ = -0.3 Table 5.2(B)
$C_{fig\ combined}$ = 1.0



d = 19.5	m		θ =	90
b = 14.5	m		d/b =	1.34
h = 7.8	m		h/d =	0.40
α = 30.0			b/d =	0.74

Walls - leeward
$C_{p,e}$ = -0.5 Table 5.2(A)
$C_{p,i}$ = 0.0 Table 5.2(B)
$C_{fig\ combined}$ = -0.5



d = 14.5	m		θ =	0
b = 19.5	m		d/b =	0.74
h = 7.8	m		h/d =	0.54
α = 30.0			b/d =	1.34

Roof (R) - 90 deg
$C_{p,e}$ = -0.6

Roof (U) - 0 deg
$C_{p,e}$ = -0.3

Roof (D) - 0 deg
$C_{p,e}$ = -0.6

	ULS		**SLS**	
p walls $_W$ =	1.03	kPa	0.70	kPa
p walls $_L$ =	-0.52	kPa	-0.35	kPa
p roof $_R$ =	-0.62	kPa	-0.42	kPa
p roof $_U$ =	-0.31	kPa	-0.21	kPa
p roof $_D$ =	-0.62	kPa	-0.42	kPa

2. CALCULATION OF EARTHQUAKE ACTIONS

2.1 ELASTIC SITE SPECTRA

$C = C_h(T)\ Z\ R\ N(T,D)$			Eqn 3.1(1)
Estimte of Building Period	T1 =	0.4	Seconds
Spectral Shape Factor	$C_h(T) =$	3.0	Class D - Deep Soil, T_1 =< 0.4 seconds (assumed)
Hazard Factor	Z =	0.24	Rotorua
Return Period	$R_u =$	1	Ultimate - 1:500 return period (Table 3.5)
Return Period	$R_s =$	0.25	Use 0.25 although no AEP specified for Serviceability
Near Fault Factor	N(T,D) =	1.00	

$C_u =$ 0.72 $C_s =$ 0.18

2.2 HORIZONTAL DESIGN ACTION COEFFICIENTS

$C_d\ (T_1) = C(T_1)\ S_p\ /\ k_\mu$			Eqn 5.2(1)
Ordinate of Elastic Site Spectrum	$C_u(T_1) =$	0.72	From Eqn 3.1(1)
	$C_s(T_1) =$	0.18	
Structural Perfomance Factor	Sp =	1.3-0.3μ	4.4.2 Sp = 0.7 except where 1<u<2.0
Structural Ductility Factor	μ =	1	Ultimate Category 3 (Section 12 NZS 3404)
	μ =	1	Serviceability
	Sp =	1	Ultimate
	Sp =	0.7	Serviceability
Inelastic Spectrum Scaling Factor	$k_\mu =$	$\frac{(\mu-1)\ T_1+1}{0.7}$	where T < 0.7s
	$k_\mu =$	1.00	Ultimate
	$k_\mu =$	1.00	Serviceability

$C_d\ (T_1) =$	0.72	Ultimate
$C_d\ (T_1) =$	0.13	Serviceability

2.3 EQUIVALENT STATIC METHOD - Horizontal Seismic Shear, V

$V = C_d(T_1)\ W_t$			Eqn 6.2(1)
Seismic Weght	$W_t =$	$G + \psi_E Q$	G = Permanent Action / Dead Load
			Q = Imposed Action / Live Load
Combination factor	$\Psi_E =$	0.3	Clause 4.2
Design Action Coefficient	$C_d\ (T_1) =$	0.72	Non Storage Applications
	$C_d\ (T_1) =$	0.13	

Job Title	Spencer and Lisa Adlam	***Page***	
Site Address	33 Great West Road	***No of Pages***	
City	Rotorua	***Date***	Feb 22
Job No.	235655	***By***	DA

Stratum CONSULTANTS
Experience. Knowledge. Better Outcomes.

Proposed Strip Footing Foundation Loading - per metre

GENERAL UNIFORMLY DISTRIBUTED LOADS Load (kN/m^2)

Roof	Corrugated Metal	0.35	kN/m^2
External Walls	Weatherboard	0.45	kN/m^2
First Floor	Timber	0.5	kN/m^2
Ground Floor	Concrete Floor	2.4	kN/m^2
Foundation beams	0.3 x 0.3 x24 kN/m^3	2.16	kN/m^2

LOADS

UDL(kN/m)	G	Q	WIDTH	WG	WQ
ROOF	0.350	0.250	4.000	1.40	1.00
WALL	0.450		4.800	2.16	0.00
FIRST FLOOR	0.500	1.500	1.800	0.90	2.70
GROUND FLOOR	2.400	1.500	1.000	2.40	1.50
FOUNDATION	2.160		1.000	2.16	0.00
TOTAL				9.02	5.20

LOAD COMBINATIONS	ULTIMATE	wu = 1.2G + 1.5Q =	18.62	kN/m
	SERVICEABILITY	ws = G + 0.7 Q =	12.66	kN/m

BEARING

FACTORED ULTIMATE BEARING CAPACITY (kPa) = 105 (ALLOWABLE = 70)

FOOTING LENGTH (l) = 1.00 m

B,REQ = (R*/(ϕUBC x l) = 197.08 mm => USE **300mm WIDE FOOTING OK**

Floor Beam 1

(a) GENERAL BEAM SPAN = 7.100 m

(b) LOADS

UDL(kN/m)	G	Q	WIDTH	W_G	W_Q
ROOF				0.00	0.00
WALL				0.00	0.00
FLOOR	0.500	1.500	2.900	1.45	4.35
DECK				0.00	0.00
SELF	0.200		1.000	0.20	0.00
TOTAL				1.65	4.35

Wind	
W (kPa)	
0.9G+w	
kPa	0
kN/m	0

LOAD COMBINATIONS

ULTIMATE	wu = 1.2G + 1.5Q =	8.51	kN/m	governs
SERVICEABILITY	ws = G + 0.7 Q =	4.70	kN/m	

(c) FLEXURE (ULTIMATE)

$M^* = w_u l^2 / 8$ = 53.59 kNm

TRY: 250 UB 37 ϕ Ms = 135 kNm

$Le = k_t\ k_l\ k_r\ L$ WHERE k_t = 1.1 k_l = 1.4 k_r = 1.0

Le = 10.9 m

FROM TABLES GRADE 300

ϕ Mb = 28.1 kNm

αm = 1.13

ϕ Mb (αm) = 31.7 kNm **TOO SMALL**

BUT JOISTS WILL PROVIDE LATERAL RESTRAINT => Le = 1.0 ϕ Mb (αm) = 149.2 kNm

αm = 1.13 **> M* OK**

(d) DEFLECTION (SERVICEABILITY)

DEFLECTION = $\frac{5\ w_s L^4}{384\ E\ I}$ E = 200000 MPa

I = 55.6 x 10^6 mm ^{4}

= 14.0 mm **< 15mm OK**

= $\frac{\text{span}}{508}$ **> L/350 OK**

DEAD LOAD DEFLECTION = 4.9 mm

LIVELINESS DEFLECTION (1 kN AT MIDSPAN) = 0.67 mm **<= 1.5mm OK**

But OK

(e) REACTION R* = 0.5 wu L = 30.19 kN

(f) POST USE **75X75X5.0 SHS**

(g) FOOTING FACTORED ULTIMATE BEARING CAPACITY (kPa) = 105 (ALLOWABLE = 70)

Breq = $(R^*/\phi UBC)^{1/2}$: 536 mm => USE **600X600X300mm DEEP RC PAD**

(h) UPLIFT R* = 0.5 Wind* L = 0.00 kN

Wall Weight		kN
Floor Weight		kN
Footing Weight		kN
	0.00	kN

Uplift = 0.00

Additional Weight Required = 0 m^3

=> USE **Specific Design Reqd**

Calculate

SUMMARY

Floor Beam 1

SIZE 250 UB 37 CAMBER NIL SPAN 7.100 m

BOLT TOP PLATE TO BEAM WITH 2/M12 @ 900mm c/c

POST 75X75X5.0 SHS

FOOTING 600X600X300mm DEEP RC PAD

WITH D12 @ 150mm c/c BOTH WAYS WITH 75mm COVER

OR STANDARD 300 WIDE STRIP FOOTING

Job Title	Spencer and Lisa Adlam	***Page***	
Site Address	33 Great West Road	***No of Pages***	
City	Rotorua	***Date***	Feb 22
Job No.	235655	***By***	DA

TGA REV 2 9/07/2010

Stratum CONSULTANTS
Experience. Knowledge. Better Outcomes.

Floor Beam 2

(a) GENERAL BEAM SPAN = 7.100 m

(b) LOADS

UDL(kN/m)	G	Q	WIDTH	WG	WQ
ROOF				0.00	0.00
WALL	0.450		3.600	1.62	0.00
FLOOR	0.500	1.500	3.500	1.75	5.25
DECK				0.00	0.00
SELF	0.200		1.000	0.20	0.00
TOTAL				3.57	5.25

Wind	
W (kPa)	
0.9G+w	
kPa	0
kN/m	0

LOAD COMBINATIONS ULTIMATE $w_u = 1.2G + 1.5Q =$ 12.16 kN/m governs
SERVICEABILITY $w_s = G + 0.7\,Q =$ 7.25 kN/m

(c) FLEXURE (ULTIMATE)

$M^* = w_u l^2 / 8 =$ 76.62 kNm

TRY: 310 UB 46 ϕ Ms = 202 kNm

$Le = k_t\ k_l\ k_r\ L$ WHERE $k_t =$ 1.1 $k_l =$ 1.4 $k_r =$ 1.0

Le = 10.9 m

FROM TABLES GRADE 300

ϕ Mb = 43.3 kNm

αm = 1.13

ϕ Mb (αm) = 49.0 kNm **TOO SMALL**

BUT JOISTS WILL PROVIDE LATERAL RESTRAINT => Le = 1.0 ϕ Mb (αm) = 226.0 kNm

αm = 1.13 **> M* OK**

(d) DEFLECTION (SERVICEABILITY)

DEFLECTION = $\dfrac{5\,w_s L^4}{384\,E\,I}$ E = 200000 MPa

I = 99.5 x 10^6 mm ^{4}

= 12.0 mm **< 15mm OK**

= $\dfrac{\text{span}}{589}$ **> L/350 OK**

DEAD LOAD DEFLECTION = 5.9 mm

LIVELINESS DEFLECTION (1 kN AT MIDSPAN) = 0.37 mm **<= 1.5mm OK**

But OK

(e) REACTION R* = 0.5 wu L = 43.16 kN USE 3/M16 BOLTS WHERE CONNECTED TO BE.

(f) POST USE **75X75X5.0 SHS**

(6) FOOTING

FOUNDATION SIZE			**DESIGN ACTIONS**			
$B_{footing}$ =	1500	mm	**M* =**	0.00	kNm	
$L_{footing}$ =	1500	mm	N_c^* =	43.16	kN	Post
$D_{footing}$ =	300	mm	N_c^* =		kN	Other
B_{column} =	235	mm	N_c^* =		kN	Other
L_{column} =	90	mm	N_c^* =	2.40	kN	Wt floor

N_c^* total = 43.16

V* = kN

(i) COMPRESSION

N* c = 43.2 kN

ASSUME ALLOWABLE BEARING CAPACITY = 105 kPa

THEREFORE DEPENDABLE BEARING CAPACITY = 157.5 kPa

REQUIRE B > 524 mm

(ii) CHECK OVERTURNING

N* c = 43.2 kN N*c base : 19.4 kN

M* max = 0.0 kNm Total N_{tot} = 62.6 kN

DISTANCE FROM CENTRE OF THE FOOTING

e = $\dfrac{\text{Fvew+Fh h + M}}{\text{Fv + Fbase}}$

Fc Portal	43.2	Ew portal	0.700	m
Fc Fnd	0.0	Ew portal	0.000	m
Fc Panel	0.0	Ew panel	0.000	m
Fc floor	2.4	Ew panel	0.000	m
Fh =	0.0	Eh =	0.150	m

E = 30.22
65.00

0.4648

e = m/r = 0.46

Therefore outside middle third l/6 = 0.25

f = kR/bl k= **4l/3(l-2e)**

k= **3.51**

Ult Bearing Pressure : **101.31 kPa**

kF/BL

SUMMARY

Floor Beam 2

SIZE 310 UB 46 CAMBER NIL SPAN 7.100 m

BOLT TOP PLATE TO BEAM WITH 2/M12 @ 900mm c/c

POST 75X75X5.0 SHS

FOOTING 1500x1500x300 RC FOOTING

WITH D12 @ 150mm c/c BOTH WAYS WITH 75mm COVER

Floor Beam 3

(a) GENERAL BEAM SPAN = 5.000 m

(b) LOADS

UDL(kN/m)

	G	Q	WIDTH	W_G	W_Q
ROOF	0.400	0.250	4.100	1.64	1.03
WALL	0.350		2.450	0.86	0.00
FLOOR	0.500	1.500	3.500	1.75	5.25
DECK				0.00	0.00
SELF	0.200		1.000	0.20	0.00
TOTAL				4.45	6.28

Wind	
W (kPa)	
0.9G+w	
kPa	0.36
kN/m	1.476

LOAD COMBINATIONS

ULTIMATE	wu = 1.2G + 1.5Q =	14.75	kN/m	governs
SERVICEABILITY	ws = G + 0.7 Q =	8.84	kN/m	

(c) FLEXURE (ULTIMATE)

$M^* = w_u\, l^2 / 8$ = 46.09 kNm

TRY: 250 UB 31 ϕ Ms = 110 kNm

Le = $k_t\ k_l\ k_r$ L WHERE k_t = 1.1 k_l = 1.4 k_r = 1.0

Le = 7.7 m

FROM TABLES   GRADE 300

ϕ Mb = 28.2 kNm

αm = 1.13

ϕ Mb (αm) = 31.9 kNm **TOO SMALL**

BUT JOISTS WILL PROVIDE LATERAL RESTRAINT => Le = 1.0 ϕ Mb (αm) = 121.2 kNm

αm = 1.13   **> M* OK**

(d) DEFLECTION (SERVICEABILITY)

DEFLECTION = $\frac{5\, w_s\, L^4}{384\, E\, I}$ E = 200000 MPa

I = 44.4 x 10^6 mm^4

= 8.1 mm **< 15mm OK**

= span / 617 **> L/350 OK**

DEAD LOAD DEFLECTION = 4.1 mm

LIVELINESS DEFLECTION (1 kN AT MIDSPAN) = 0.29 mm **<= 1.5mm OK**

But OK

(e) REACTION R* = 0.5 wu L = 36.87 kN

(f) POST USE **75X75X5.0 SHS**

(g) FOOTING FACTORED ULTIMATE BEARING CAPACITY (kPa) = 105 (ALLOWABLE = 70)

Breq = $(R^*/\phi UBC)^{1/2}$: 593 mm => USE **600X600X300mm DEEP RC PAD**

(h) UPLIFT R* = 0.5 Wind* L = 3.69 kN

Wall Weight		kN
Floor Weight		kN
Footing Weight		kN
	0.00	kN

Uplift = 3.69

Additional Weight Required = N/A m^3

=> USE **600X600X300mm DEEP RC PAD**

SUMMARY

Floor Beam 3

SIZE 250 UB 31   CAMBER NIL   SPAN 5.000 m

BOLT TOP PLATE TO BEAM WITH 2/M12 @ 900mm c/c

POST 75X75X5.0 SHS

FOOTING 600X600X300mm DEEP RC PAD

WITH D12 @ 150mm c/c BOTH WAYS WITH 75mm COVER

OR STANDARD 300 WIDE STRIP FOOTING

Job Title	Spencer and Lisa Adlam	***Page***	
Site Address	33 Great West Road	***No of Pages***	
City	Rotorua	***Date***	Feb 22
Job No.	235655	***By***	DA

TGA REV 2 9/07/2010

Stratum CONSULTANTS
Experience. Knowledge. Better Outcomes.

GARAGE LINTEL

(a) GENERAL BEAM SPAN = 5.800 m

(b) LOADS

UDL(kN/m)	G	Q	WIDTH	WG	WQ
ROOF	0.400	0.250	3.600	1.44	0.90
WALL	0.450		3.600	1.62	0.00
FLOOR	0.500	1.500	0.500	0.25	0.75
SELF	0.300		1.000	0.30	0.00
TOTAL				3.61	1.65

POINT (kN)	G	Q	WIDTH	LENGTH	WG	WQ
ROOF					0.00	0.00
WALL	0.450		3.600	3.600	5.83	0.00
FLOOR	0.500	1.500	3.500	3.600	6.30	18.90
SELF					0.00	0.00
TOTAL					12.13	18.90

LOAD COMBINATIONS

ULTIMATE wu = 1.2G + 1.5Q = 6.81 kN/m SERVICEABILITY ws = G + 0.7 Q = 4.77 kN/m

Pu = 1.2G + 1.5Q = 42.91 kN Ps = G + 0.7 Q = 25.36 kN

LET: a=DISTANCE TO POINT LOAD FROM SUPPORT CLOSEST TO POINT LOAD. a= 2.000

b=DISTANCE TO POINT LOAD FROM SUPPORT FURTHEREST FROM POINT LOAD. b= 3.800

(c) FLEXURE (ULTIMATE)

$M^* = w_u l^2 / 8 + Pu\ a / 2 =$ 71.53 kNm

$M^*_{POINT} = P_U\ a\ b/L + wu\ a(L-a)/2 =$ 82.09 kNm **CRITICAL**

TRY: 360 UB 57 ϕ Ms = 273 kNm

$Le = k_t\ k_l\ k_r\ L$ WHERE k_t = 1.1 k_l = 1.4 k_r = 1.0

Le = 8.9 m

FROM TABLES GRADE 300

ϕ Mb = 73.7 kNm

αm = 1.13 ϕ Mb (αm) = 83.3 kNm **> M* OK**

BUT JOISTS WILL PROVIDE LATERAL RESTRAINT => Le = 1.0 ϕ Mb (αm) = 271.1 kNm

αm = 1.00 **> M* OK**

(d) DEFLECTION (SERVICEABILITY)

Point of max deflection for point load = a.(1/3+2b/3/a)^0.5 = 2.530 (m) E = 200000 MPa

I = 161 E 6 mm^4

DEFLECTION AT MIDSPAN FROM UDL = $\frac{5\ w_s\ L^4}{384\ E\ I}$ = 2.18 mm

MAX d FROM POINT LOAD = $\frac{Ps\ L^2 .b.x/L}{6EI}$(1-(b/L)^2-(x/L)^2) = 2.80 mm

4.99 mm **<15mm OK**

Span / d = 1163.5 **> L/350 OK**

LIVELINESS DEFLECTION (1 kN AT MIDSPAN) : 0.1 mm **<= 1.5mm OK**

(e) REACTION R^* LEFT = 0.5 w_u L + Pu b / L = 47.85 kN **CRITICAL**

R^* RIGHT = 0.5 w_u L + Pu a / L = 34.54 kN

(f) POST USE **75X75X5.0 SHS**

(g) FOOTING FACTORED ULTIMATE BEARING CAPACITY (kPa) = 105 (ALLOWABLE = 70)

Breq = $(R^*/\phi UBC)^{1/2}$ = 675 mm => USE **750X750X300mm DEEP RC PAD**

SUMMARY

GARAGE LINTEL

SIZE 360 UB 57 CAMBER NIL SPAN 5.800 m

BOLT TOP PLATE TO BEAM WITH 2/M12 @ 900mm c/c

POST 75X75X5.0 SHS

FOOTING 750X750X300mm DEEP RC PAD

WITH D12 @ 150mm c/c BOTH WAYS WITH 75mm COVER

Job Title : Spencer and Lisa Adlam
Site Address : 33 Great West Road
City : Rotorua
Job No : 235655

Page :
No of Pages :
Date : Feb 22
By : DA

Stratum CONSULTANTS

Retaining Wall Design

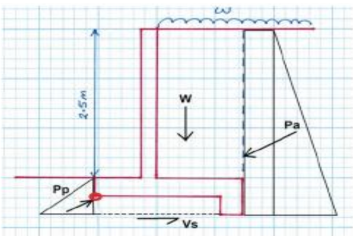
Cantilever Wall Parameters

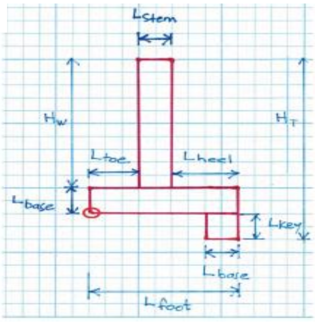
Allow atotal wall height, with varying retaining heights. Extension of wall to act as a fence/barrier

H_w =	2.70 m	*Height of wall*
H_{ret} =	2.30 m	*Height of retained ground*
L_{stem} =	0.24 m	*Thickness of wall*
L_{toe} =	2.00 m	*Length of toe*
L_{base} =	0.30 m	*Thickness of base*
L_{heel} =	0.00 m	*Length of heel*
L_{key} =	0.00 m	*Depth of shear key*
γ_{soil} =	17.0 kN/m3	*Soil unit weight*
γ_{conc} =	21.0 kN/m3	*Masonry unit weight*
ω_g =	6.00 kPa	*Factored Surcharge, gravity case, destabilising (1.2G+1.5Q)*
ω_{gs} =	4.50 kPa	*Factored Surcharge, gravity case, stabilising (0.9G)*
ω_{eq} =	5.00 kPa	*Factored Surcharge, EQ, destabilising (G+Eu+0.3Q)*

Seismic Coefficients for the Overturning of Wall Itself

C_d (T_1) =	0.58	Ultimate
C_d (T_1) =	0.13	Serviceability





Reinforcement Summary

Wall Reinforcement

A_{wv} =	HD20 Bars @200crs (1571mm2/m)
A_{wallv} =	HD20 Bars @200crs (1571mm2/m)
A_{wh} =	HD12 Bars @400crs (283mm2/m)

Footing Reinforcement

A_{ft} =	HD20 Bars @200crs (1571mm2/m)
A_{fl} =	8 x HD12 Bars

LRFD parameters

Φ_{bc} =	0.5
Φ_{sl} =	0.8
Φ_p =	0.5
α_{G_stab}=	0.9
α_{G_destab}=	1.2
α_{EP_static}=	1.5

Job Title :	Spencer and Lisa Adlam	**Page :**	
Site Address :	33 Great West Road	**No of Pages :**	
City :	Rotorua	**Date :**	Feb 22
Job No :	235655	**By :**	DA

Stratum CONSULTANTS
Experience. Knowledge. Better Outcomes.

Computed Parameters

L_{foot} =	$L_{toe} + L_{stem} + L_{heel}$	=	2.2 m	*Width of footing*
H_T =	$H_W + L_{base} + L_{key}$	=	2.6 m	*Total retained height*
W_{foot} =	$L_{foot} \cdot L_{base} \cdot \gamma_{conc}$	=	14.1 kPa	*Weight of footing*
W_{key} =	$L_{key} \cdot L_{base} \cdot \gamma_{conc}$	=	0.0 kPa	*Weight of key (same thickness as base)*
W_{stem} =	$H_w \cdot L_{stem} \cdot \gamma_{conc}$	=	13.6 kPa	*Weight of wall stem*
W_{soil} =	$L_{heel} \cdot H_w \cdot \gamma_{soil}$	=	0.0 kPa	*Weight of soil above heel*

Check 'middle third rule'

P_a =	$0.5 \cdot k_a \cdot \gamma_{soil} \cdot H_T^2$	=	18.3 kN/m	*Active thrust, soil weight component*
P_{av} =	$P_a \cdot \sin(\delta_a)$ =	=	8.6 kN/m	*Vertical components*
P_{ah} =	$P_a \cdot \cos(\delta_a)$ =	=	16.2 kN/m	*Horizontal components*
$P_{a\omega}$ =	$\omega_g \cdot K_a \cdot H_T$	=	5.0 kN/m	*Active thrust, surcharge component*
$P_{av\omega}$ =	$P_{a\omega} \cdot \sin(\delta_a)$ =	=	2.3 kN/m	*Vertical components*
$P_{ah\omega}$ =	$P_{a\omega} \cdot \cos(\delta_a)$ =	=	4.4 kN/m	*Horizontal components*
P_ω =	$\omega_{gs} \cdot L_{heel}$	=	0.0 kN/m	*Surcharge above heel*
M_{ah} =	$(P_{ah} \cdot (H_T/3 - L_{key}) + P_{ah\omega} \cdot (H_T/2 - L_{key}))\alpha_{EP\_static}$	=	29.6 kN/m	*Moment from horizontal active pressure (+ve)*
M_{av} =	$(P_{av} + P_{av\omega}) \cdot L_{foot}$	=	24.5 kN/m	*Moment from vertical active pressure (-ve)*
M_ω=	$P_\omega \cdot (L_{foot} - L_{heel}/2)$	=	0.0 kN/m	*Moment from surcharge above heel (-ve)*
$\alpha_{G\_stab} \cdot M_G$=	see working below	=	40.2 kN/m	*Restoring moment from self weight of wall and soil above heel (-ve)*

	Weight, W	**x**	**Dist from toe**		=	M*
Footing	14.1 kN/m		$L_{foot}/2$ =	1.1 m	=	15.8 kNm/m
Stem	13.6 kN/m		$L_{toe} + L_{stem}/2$ =	2.1 m	=	28.8 kNm/m
Key	0.0 kN/m		$L_{foot} - L_{key}/2$ =	2.2 m	=	0.0 kNm/m
Soil	0.0 kN/m		$L_{foot} - L_{heel}/2$ =	2.2 m	=	0.0 kNm/m
W_{total} =	27.7 kN/m				M_G =	44.7 kNm/m

M_{net} =	$M_{ah} - M_{av} - M_G - M_\omega$	=	-35.1 kNm/m	*Net moment must be < 0 for stability*
P_{vert} =	$W_{total} \cdot \alpha_{G\_stab} + P_{av} + P_{av\omega} + P_\omega$	=	35.9 kNm/m	*factored vertical load on footing*
L_{net} =	$-M_{net} / P_{vert}$	=	1.0 m	*Line of action of net vertical force (distance from toe)*

Check bearing capacity

L_{third} =	$1/3 \cdot L_{foot}$ =	0.7 m	<< L_{net} =	1.0 m	<< $2 \cdot L_{third}$ =	1.5 m	**=>> OK**
B_{eff} =	$2 \cdot L_{net}$	=	1.96 m	*Effective footing width*		Check B_{eff}<<L_{foot} =>> OK	

<u>If footing is eccentric</u>

k =	1+6.Lnet/Lfoot	=	3.6	*eccentric load factor*
$V_{u,eccentricity}$ =	$k\ P_{vert} / L_{foot}$	=	58.0 kN/m	*factored vertical loading for eccentricity*
V_u =	Pvert	=	35.9 kN/m	*Ultimate vertical load on footing*
H_u =	$(P_{ah} + P_{ah\omega}) \cdot \alpha_{EP\_static}$	=	30.9 kN/m	*Ultimate horizontal load on footing*

<u>Drained bearing capacity shallow footing - Vesic</u>

L =	=	6.00 m	*Length of wall*
D_e =	=	4.00 m	*min horizontal distance from edge of underside of footing to face of adjacent downward slope*
β =	=	0.0 deg	*Ground slope in front of footing*
c =	=	0 kPa	*Soil effective cohesion*
s_u =		80 kPa	*undrained shear strength*
q = $\gamma_{soil} \cdot L_{base}$	=	5.1 kPa	*Surcharge*

$N_q = e^{\pi \cdot \tan(\phi)} \cdot \tan(\phi/2+45)^2$ = 14.720

$N_c = (N_q - 1)1/\tan(\phi)$ = 25.80

$N_\gamma = (\phi > 0) = 2 \cdot (N_q + 1)\tan(\phi)$ = 16.72

Shape factors

$\lambda_{qs} = 1 + (B_{eff}/L) \cdot \tan(\phi)$ = 1.173

$\lambda_{cs} = 1 + (B_{eff} \cdot N_q)/(L \cdot N_c)$ = 1.186

$\lambda_{\gamma s} = 1 - 0.4(B_{eff}/L)$ = 0.870

Depth factors

$\lambda_{qd} = (L_{base}/B_{eff} < 1) = 1 + 2\tan(\phi)(1-\sin(\phi))^2(L_{base}/B_{eff})$ = 1.042

$\lambda_{cd} = (\phi > 0) = \lambda_{qd} - (1-\lambda_{qd})/(N_q \cdot \tan(\phi))$ = 1.048

$\lambda_{\gamma d} = 1$

Load Inclination factors - (loading parallel to B_{eff})

$n_B = (2+B_{eff}/L)/(1+B_{eff}/L)$ = 1.754

$\lambda_{qi} = (\phi > 0) = (1 - (L \cdot H_u/(L \cdot V_u + B_{eff} \cdot L \cdot c \cdot 1/\tan(\phi))))^{nB}$ = 0.032

$\lambda_{ci} = (\phi > 0) = \lambda_{qi} - (1-\lambda_{qi})/(N_c \cdot \tan(\phi))$ = -0.039

$\lambda_{\gamma i} = (\phi > 0) = (1 - (H_u/(V_u + B_{eff} \cdot L \cdot c \cdot 1/\tan(\phi))))^{nB+1}$ 0.004

Ground Inclination factors

$\lambda_{qg} = (D_e > 2 \cdot L_{foot}) = \lambda_{cg} = \lambda_{qg} = \lambda_{gg} = 1$ = 1.00

$\lambda_{cg} = (D_e > 2 \cdot L_{foot}) = \lambda_{cg} = \lambda_{qg} = \lambda_{gg} = 1$ = 1.00

$\lambda_{\gamma g} = (D_e > 2 \cdot L_{foot}) = \lambda_{cg} = \lambda_{qg} = \lambda_{gg} = 1$ = 1.00

$q_{uq} = q \cdot \lambda_{qs} \cdot \lambda_{qd} \cdot \lambda_{qi} \cdot \lambda_{qg} \cdot Nq$ = 2.9 kPa

$q_{uc} = c \cdot \lambda_{cs} \cdot \lambda_{cd} \cdot \lambda_{ci} \cdot \lambda_{cg} \cdot Nc$ = 0.0 kPa

$q_{u\lambda} = 0.5\ \gamma \cdot B_{eff} \cdot \lambda_{\gamma s} \cdot \lambda_{\gamma d} \cdot \lambda_{\gamma i} \cdot \lambda_{\gamma g} \cdot N_\gamma$ = 1.1 kPa

$q_u = q_{uq} + q_{uc} + q_{u\lambda}$ = 4.0 kPa
= 300 kPa

q_u = 210.0 kPa *check against ultimate bearing pressure*

V_{ustar} =	$B_{eff} \cdot q_u \cdot \Phi_{bc}$	=	205.4 kN/m	Check V_{ustar}>V_u **=>> OK**

Wall Sliding (Gravity Case)

W_{slide} =	$(L_{foot} - L_{base}).L_{key}.\gamma_{soil}$	=	0.0 kN/m	*Weight of soil trapped under footing*
P_p =	$0.5 .K_p .\gamma_{soil} .(L_{base}+L_{key})^2$	=	3.1 kN/m	*Passive resistance*
P_{ph} =	$P_p .\cos(\delta_p)$	=	2.9 kN/m	*Horizontal component*
P_{pv} =	$P_p .\sin(\delta_p)$	=	0.9 kN/m	*Vertical component*
H_s =	$(V_u + W_{slide} .\alpha_{G\_stab} - P_{pv}).\tan(\phi)$	=	18.6 kN/m	*Friction under footing*
H_{star} =	$P_{ph} .\phi_p + H_s.\phi_{sl}$	=	16.3 kN/m	*Factored ultimate resistance* Check $H_{star}>H_u$

=>> base sliding NG
BUT OK AS RESTRAINED BY SLAB

Calculate maximum bending moment in wall stem

Assume waterproof membrane with padding, i.e negligible interface friction

δ_s = 0

K_{as} = 0.33

P_{as} =	$0.5 .K_{as} . \gamma_{soil} .H_w^2$	=	14.8 kN/m	*Active thrust*
P_{ahs} =	$P_{as} .\cos(\delta_s)$	=	14.8 kN/m	*Horizontal component*
$P_{a\omega s}$ =	$\omega_g .K_{as} .H_w$	=	4.6 kN/m	*Active thrust, surcharge component*
$P_{ah\omega s}$ =	$P_{a\omega s} .\cos(\delta_s)$	=	4.6 kN/m	*Horizontal component*
M_{uG} =	$(P_{ahs} .H_w/3 + P_{ah\omega s}.H_w/2).\alpha_{EP\_static}$	=	24.9 KNm/m	*Ultimate bending moment in stem*

Foundation bearing (Earthquake case)

K_h =	see previous working	=	0.308	*horizontal acceleration*
K_{aE} =	see previous working	=	0.661	

Check 'middle third rule'

P_{aE} =	$0.5 .k_{aE} .\gamma_{soil} .H_T^2$	=	38.0 kN/m	*Active thrust, soil weight component*
P_{aEv} =	$P_{aE}.\sin(\delta_a)$ =	=	17.8 kN/m	*Vertical components*
P_{aEh} =	$P_{aE}.\cos(\delta_a)$ =	=	33.5 kN/m	*Horizontal components*
$P_{aE\omega}$ =	$\omega_{EQ} .K_{aE}. (H_{ret} + L_{base} + L_{key})$	=	8.6 kN/m	*Active thrust, surcharge component*
$P_{aEv\omega}$ =	$P_{aE\omega}.\sin(\delta_a)$ =	=	4.0 kN/m	*Vertical components*
$P_{aEh\omega}$ =	$P_{aE\omega}.\cos(\delta_a)$ =	=	7.6 kN/m	*Horizontal components*
$P_{E\omega}$ =	$\omega_{gs} . L_{heel}$	=	0.0 kN/m	*Surcharge above heel*
M_{aEh} =	$(P_{aEh}.(H_T/3-L_{key}) + P_{aEh\omega}.(H_T/2-L_{key}))$	=	38.9 kN/m	*Moment from horizontal active pressure (+ve)*
M_{aEv} =	$(P_{aEv} + P_{aEv\omega}).L_{foot}$	=	49.0 kN/m	*Moment from vertical active pressure (-ve)*
$M_{E\omega}$=	$P_{E\omega}.(L_{foot} - L_{heel}/2)$	=	0.0 kN/m	*Moment from surcharge above heel (-ve)*
M_I=	$(W_{stem}.C_d(T_1))(H_w/2+L_{base})+(W_{soil}.K_h).(H_w/2+L_{base})+W_{foot}.Kh.L_{base}/2 - W_{key}.k_h.L_{key}/2$	=	13.7 kN/m	*Moment from inertia forces (+ve)*
M_{EG}=	as above	=	44.7 kN/m	*Restoring moment from self weight of wall and soil above heel (-ve)*
M_{net} =	$M_{aEh} + M_I - M_{aEv} - M_{EG} - M_{E\omega}$	=	-41.0 kN/m	*Net moment must be < 0 for stability*
P_{vert} =	$W_{total} + P_{aEv} + P_{aEv\omega} + P_{E\omega}$	=	49.6 kN/m	*factored vertical load on footing*
L_{net} =	$-M_{net} / P_{vert}$	=	0.8 m	*Line of action of net vertical force (distance from toe)*

Check bearing capacity

L_{third} = $1/3 .L_{foot}$ = 0.7 m << L_{net} = 0.8 m << $2.L_{third}$ = 1.5 m **=>> OK**

B_{eff} = $2. L_{net}$ = 1.7 m *Effective footing width* Check $B_{eff}<<L_{foot}$ =>> OK

<u>If footing is eccentric</u>

k =	1+6.Lnet/Lfoot	=	3.21	*eccentric load factor*
$V_{u,eccentricity}$ =	$k\ P_{vert} / L_{foot}$	=	71.1 kN/m	*factored vertical loading for eccentricty*
V_{uEq} =	Pvert	=	35.9 kN/m	*Ultimate vertical load on footing*
H_{uEq} =	$P_{aeh} + P_{aeh\omega}+W_{stem}.k_h+W_{soil}.K_h+W_{foot}.K_h+W_{key}.k_h$	=	49.6 kN/m	*Ultimate horizontal load on footing*

<u>Undrained bearing capacity shallow footing - Vesic</u>

L =		=	6.00 m	*Length of wall*
D_e =		=	4.00 m	*min horizontal distance from edge of underside of footing to face of adjacent downward slope*
β =		=	0.0 deg	*Ground slope in front of footing*
s_u =		=	80.0 kPa	*undrained shear strength*
c =	s_u	=	80.0 kPa	*Soil effective cohesion*
q =	$\gamma_{soil}.L_{base}$	=	5.1 kPa	*Surcharge*
ϕ =		=	0.0 deg	*undrained friction angle*

$N_q = e^{\pi.\tan(\phi)}.\tan(\phi/2+45)^2$ = 1.000

N_c = $(\phi = 0) = 5.14$ = 5.14

N_γ = $(\phi = 0) = 5.14$ = 0.00

Shape factors

λ_{qs} = $1+ (B_{eff}/L).\tan(\phi)$ = 1.000

λ_{cs} = $1+ (B_{eff}.N_q)/(L.N_c)$ = 1.054

$\lambda_{\gamma s}$ = $1- 0.4(B_{eff}/L)$ = 0.890

Depth factors

λ_{qd} = $(L_{base}/B_{eff} < 1) = 1+2\tan(\phi)(1-\sin(\phi))^2(L_{base}/B_{eff})$ = 1.050

λ_{cd} = $(\phi > 0) = \lambda_{qd}-(1-\lambda_{qd})/(N_q.\tan(\phi))$ = 1.144

$\lambda_{\gamma d}$ = 1

Load Inclination factors

n_B = $(2+B_{eff}/L)/(1+B_{eff}/L)$ = 1.784

λ_{qi} = $(\phi = 0) = 1$ = 1.000

λ_{ci} = $1-(n_B.H_{uEq}.L)/(c.N_c.B.L)$ = 0.870

$\lambda_{\gamma i}$ = λ_{qi} = 1.000

Ground Inclination factors

λ_{qg}= (D_e > 2.L_{foot}) = λ_{cg} = λ_{qg} = λ_{gg} = 1
= 1.000

λ_{cg}= (D_e > 2.L_{foot}) = λ_{cg} = λ_{qg} = λ_{gg} = 1
= 1.000

$\lambda_{\gamma g}$ = (D_e > 2.L_{foot}) = λ_{cg} = λ_{qg} = λ_{gg} = 1
= 1.000

q_{uq}= $q.\lambda_{qs}.\lambda_{qd}.\lambda_{qi}.\lambda_{qg}.Nq$
= 5.4 kPa

q_{uc}= $c.\lambda_{cs}.\lambda_{cd}.\lambda_{ci}.\lambda_{cg}.Nc$
= 431.0 kPa

$q_{u\lambda}$= $0.5\gamma.B_{eff}.\lambda_{\gamma s}.\lambda_{\gamma d}.\lambda_{\gamma i}.\lambda_{\gamma g}.N_{\gamma}$
= 0.0 kPa

q_u = q_{uq} + q_{uc} + $q_{u\lambda}$ = 436.3 kPa
= 300 kPa

q_u = 210.0 kPa *check against ultimate bearing pressure*

V_{ustar} = B_{eff} . q_u . Φ_{bc} = 173.5 kN/m Check V_{ustar}>V_u **=>> OK**

Wall Sliding (Earthquake Case)

Passive pressure neglected due to possible desiccation and disturbance

k_p = 1 *as ϕ = 0*
S_u = 70 kPa *Undrained shear strength (as stated in getotechnical report)*
C_a = 70 kPa *(where C_a = Su)*

P_p =	0.5 .K_p .γ_{soil} .$(L_{base}+L_{key})^2$ + 2.S_u.L_{key}	=	0.8 kN/m	*Passive resistance*	
H_{star} =	P_p + c_a.B_{eff}	=	116.4 kN/m	*Factored ultimate resistance*	Check H_{star}>H_u **=>> OK**

Calculate maximum bending moment in wall stem

Assume waterproof membrane with padding, i.e negligible interface friction

δ_s = 0
K_{aEs} = 0.792

P_{aEs} =	0.5 .K_{aEs} . γ_{soil} .H_w^2	=	35.6 kN/m	*Active thrust*
P_{aEhs} =	P_{aEs} .cos(δ_s)	=	35.6 kN/m	*Horizontal component*
$P_{aE\omega s}$ =	ω_{EQ} .K_{aEs} .(H_w + L_{base} + L_{key})	=	8.6 kN/m	*Active thrust, surcharge component*
$P_{aEh\omega s}$ =	$P_{aE\omega s}$ .cos(δ_s)	=	8.6 kN/m	*Horizontal component*
M_{uEQ} =	P_{aEhs} .H_w/3 + $P_{aEh\omega s}$ .H_w/2+W_{stem}.C_d.$T_1$$H_w$/2	=	47.9 KNm/m	*Ultimate bending moment in stem*

Design of Wall - Flexural Capacity

M_{max} = Max(M_{uG}, M_{UEQ}) = 47.9 KNm/m

Try Vertical Reinforcing **HD20 Bars @200crs (1571mm2/m)**

ϕ Mi = ϕ As fy (d - 0.59 As.fy / f'm b) = 54.3 KNm/m

M_{max} >> ϕ Mi **=>> OK**

ϕ =	0.85
cover =	120 mm
d =	120 mm
fc =	25 MPa
fy =	500 MPa
f'm =	12 MPa
b =	1000 mm
As =	1571 mm2/m

Retaining Wall Design

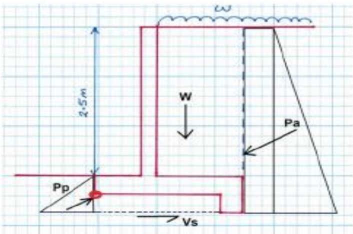
Cantilever Wall Parameters

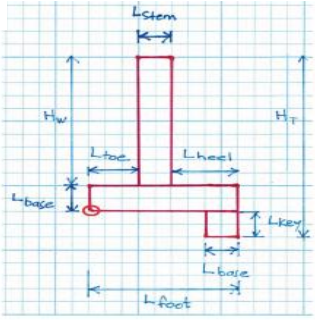
Allow atotal wall height, with varying retaining heights. Extension of wall to act as a fence/barrier

H_w =	2.70 m	*Height of wall*
H_{ret} =	1.50 m	*Height of retained ground*
L_{stem} =	0.24 m	*Thickness of wall*
L_{toe} =	1.60 m	*Length of toe*
L_{base} =	0.30 m	*Thickness of base*
L_{heel} =	0.00 m	*Length of heel*
L_{key} =	0.00 m	*Depth of shear key*
γ_{soil} =	17.0 kN/m3	*Soil unit weight*
γ_{conc} =	21.0 kN/m3	*Masonry unit weight*
ω_g =	6.00 kPa	*Factored Surcharge, gravity case, destabilising (1.2G+1.5Q)*
ω_{gs} =	4.50 kPa	*Factored Surcharge, gravity case, stabilising (0.9G)*
ω_{eq} =	5.00 kPa	*Factored Surcharge, EQ, destabilising (G+Eu+0.3Q)*

Seismic Coefficients for the Overturning of Wall Itself

C_d (T_1) =	0.58	Ultimate
C_d (T_1) =	0.13	Serviceability





Reinforcement Summary

Wall Reinforcement

A_{wv} =	HD16 Bars @400crs (503mm2/m)
A_{wallv} =	HD16 Bars @400crs (503mm2/m)
A_{wh} =	HD12 Bars @400crs (283mm2/m)

Footing Reinforcement

A_{ft} =	HD16 Bars @400crs (503mm2/m)
A_{fl} =	7 x HD12 Bars

LRFD parameters

Φ_{bc} =	0.5
Φ_{sl} =	0.8
Φ_p =	0.5
α_{G_stab}=	0.9
α_{G_destab}=	1.2
α_{EP_static}=	1.5

Computed Parameters

L_{foot} =	$L_{toe} + L_{stem} + L_{heel}$	=	1.8 m	*Width of footing*
H_T =	$H_W + L_{base} + L_{key}$	=	1.8 m	*Total retained height*
W_{foot} =	$L_{foot} \cdot L_{base} \cdot \gamma_{conc}$	=	11.6 kPa	*Weight of footing*
W_{key} =	$L_{key} \cdot L_{base} \cdot \gamma_{conc}$	=	0.0 kPa	*Weight of key (same thickness as base)*
W_{stem} =	$H_w \cdot L_{stem} \cdot \gamma_{conc}$	=	13.6 kPa	*Weight of wall stem*
W_{soil} =	$L_{heel} \cdot H_w \cdot \gamma_{soil}$	=	0.0 kPa	*Weight of soil above heel*

Check 'middle third rule'

P_a =	$0.5 \cdot k_a \cdot \gamma_{soil} \cdot H_T^2$	=	8.8 kN/m	*Active thrust, soil weight component*
P_{av} =	$P_a \cdot \sin(\delta_a)$ =	=	4.1 kN/m	*Vertical components*
P_{ah} =	$P_a \cdot \cos(\delta_a)$ =	=	7.8 kN/m	*Horizontal components*
$P_{a\omega}$ =	$\omega_g \cdot K_a \cdot H_T$	=	3.4 kN/m	*Active thrust, surcharge component*
$P_{av\omega}$ =	$P_{a\omega} \cdot \sin(\delta_a)$ =	=	1.6 kN/m	*Vertical components*
$P_{ah\omega}$ =	$P_{a\omega} \cdot \cos(\delta_a)$ =	=	3.0 kN/m	*Horizontal components*
P_ω =	$\omega_{gs} \cdot L_{heel}$	=	0.0 kN/m	*Surcharge above heel*
M_{ah} =	$(P_{ah} \cdot (H_T/3 - L_{key}) + P_{ah\omega} \cdot (H_T/2 - L_{key}))\alpha_{EP\_static}$	=	11.1 kN/m	*Moment from horizontal active pressure (+ve)*
M_{av} =	$(P_{av} + P_{av\omega}) \cdot L_{foot}$	=	10.6 kN/m	*Moment from vertical active pressure (-ve)*
M_ω=	$P_\omega \cdot (L_{foot} - L_{heel}/2)$	=	0.0 kN/m	*Moment from surcharge above heel (-ve)*
$\alpha_{G\_stab} \cdot M_G$=	see working below	=	30.7 kN/m	*Restoring moment from self weight of wall and soil above heel (-ve)*

	Weight, W	x	Dist from toe		=	M*
Footing	11.6 kN/m		$L_{foot}/2$ =	0.9 m	=	10.7 kNm/m
Stem	13.6 kN/m		$L_{toe} + L_{stem}/2$ =	1.7 m	=	23.4 kNm/m
Key	0.0 kN/m		$L_{foot} - L_{key}/2$ =	1.8 m	=	0.0 kNm/m
Soil	0.0 kN/m		$L_{foot} - L_{heel}/2$ =	1.8 m	=	0.0 kNm/m
W_{total} =	25.2 kN/m				M_G =	34.1 kNm/m

M_{net} =	$M_{ah} - M_{av} - M_G - M_\omega$	=	-30.1 kNm/m	*Net moment must be < 0 for stability*
P_{vert} =	$W_{total} \cdot \alpha_{G\_stab} + P_{av} + P_{av\omega} + P_\omega$	=	28.4 kNm/m	*factored vertical load on footing*
L_{net} =	$-M_{net} / P_{vert}$	=	1.1 m	*Line of action of net vertical force (distance from toe)*

Check bearing capacity

L_{third} = $1/3 \cdot L_{foot}$ = 0.6 m << L_{net} = 1.1 m << $2 \cdot L_{third}$ = 1.2 m **=>> OK**

B_{eff} = $2 \cdot L_{net}$ = 2.12 m *Effective footing width* Check $B_{eff} << L_{foot}$ =>> Allow for eccentricity

<u>If footing is eccentric</u>

k =	1+6.Lnet/Lfoot	=	4.5	*eccentric load factor*
$V_{u,eccentricity}$ =	$k\ P_{vert} / L_{foot}$	=	68.9 kN/m	*factored vertical loading for eccentricty*
V_u =	Vu,eccentricity	=	68.9 kN/m	*Ultimate vertical load on footing*
H_u =	$(P_{ah} + P_{ah\omega}) \cdot \alpha_{EP\_static}$	=	16.2 kN/m	*Ultimate horizontal load on footing*

<u>Drained bearing capacity shallow footing - Vesic</u>

L =		=	6.00 m	*Length of wall*
D_e =		=	4.00 m	*min horizontal distance from edge of underside of footing to face of adjacent downward slope*
β =		=	0.0 deg	*Ground slope in front of footing*
c =		=	0 kPa	*Soil effective cohesion*
s_u =			80 kPa	*undrained shear strength*
q =	$\gamma_{soil} \cdot L_{base}$	=	5.1 kPa	*Surcharge*

$N_q = e^{\pi \cdot \tan(\phi)} \cdot \tan(\phi/2+45)^2$ = 14.720

$N_c = (N_q - 1)1/\tan(\phi)$ = 25.80

$N_\gamma = (\phi > 0) = 2.(N_q + 1)\tan(\phi)$ = 16.72

Shape factors

$\lambda_{qs} = 1 + (B_{eff}/L) \cdot \tan(\phi)$ = 1.188

$\lambda_{cs} = 1 + (B_{eff} \cdot N_q)/(L \cdot N_c)$ = 1.202

$\lambda_{\gamma s} = 1 - 0.4(B_{eff}/L)$ = 0.859

Depth factors

$\lambda_{qd} = (L_{base}/B_{eff} < 1) = 1+2\tan(\phi)(1-\sin(\phi))^2(L_{base}/B_{eff})$ = 1.039

$\lambda_{cd} = (\phi > 0) = \lambda_{qd} - (1-\lambda_{qd})/(N_q \cdot \tan(\phi))$ = 1.044

$\lambda_{\gamma d} = 1$

Load Inclination factors - (loading parallel to B_{eff})

$n_B = (2+B_{eff}/L)/(1+B_{eff}/L)$ = 1.739

$\lambda_{qi} = (\phi > 0) = (1 - (L \cdot H_u/(L \cdot V_u + B_{eff} \cdot L \cdot c \cdot 1/\tan(\phi))))^{nB}$ = 0.627

$\lambda_{ci} = (\phi > 0) = \lambda_{qi} - (1-\lambda_{qi})/(N_c \cdot \tan(\phi))$ = 0.600

$\lambda_{\lambda i} = (\phi > 0) = (1 - (H_u/(V_u + B_{eff} \cdot L \cdot c \cdot 1/\tan(\phi))))^{nB+1}$ 0.480

Ground Inclination factors

$\lambda_{qg} = (D_e > 2 \cdot L_{foot}) = \lambda_{cg} = \lambda_{qg} = \lambda_{gg} = 1$ = 1.00

$\lambda_{cg} = (D_e > 2 \cdot L_{foot}) = \lambda_{cg} = \lambda_{qg} = \lambda_{gg} = 1$ = 1.00

$\lambda_{\gamma g} = (D_e > 2 \cdot L_{foot}) = \lambda_{cg} = \lambda_{qg} = \lambda_{gg} = 1$ = 1.00

$q_{uq} = q \cdot \lambda_{qs} \cdot \lambda_{qd} \cdot \lambda_{qi} \cdot \lambda_{qg} \cdot Nq$ = 58.1 kPa

$q_{uc} = c \cdot \lambda_{cs} \cdot \lambda_{cd} \cdot \lambda_{ci} \cdot \lambda_{cg} \cdot Nc$ = 0.0 kPa

$q_{u\lambda} = 0.5\ \gamma \cdot B_{eff} \cdot \lambda_{\gamma s} \cdot \lambda_{\gamma d} \cdot \lambda_{\gamma i} \cdot \lambda_{\gamma g} \cdot N_\gamma$ = 124.2 kPa

$q_u = q_{uq} + q_{uc} + q_{u\lambda}$ = 182.3 kPa

= 300 kPa

q_u = 210.0 kPa *check against ultimate bearing pressure*

V_{ustar} = $B_{eff} \cdot q_u \cdot \Phi_{bc}$ = 222.7 kN/m Check $V_{ustar} > V_u$ **=>> OK**

Wall Sliding (Gravity Case)

W_{slide} =	$(L_{foot} - L_{base}).L_{key}.\gamma_{soil}$	=	0.0 kN/m	*Weight of soil trapped under footing*
P_p =	$0.5 .K_p .\gamma_{soil} .(L_{base}+L_{key})^2$	=	3.1 kN/m	*Passive resistance*
P_{ph} =	$P_p .\cos(\delta_p)$	=	2.9 kN/m	*Horizontal component*
P_{pv} =	$P_p .\sin(\delta_p)$	=	0.9 kN/m	*Vertical component*
H_s =	$(V_u + W_{slide} .\alpha_{G\_stab} - P_{pv}).\tan(\phi)$	=	36.1 kN/m	*Friction under footing*
H_{star} =	$P_{ph} .\phi_p + H_s.\phi_{sl}$	=	30.4 kN/m	*Factored ultimate resistance* Check $H_{star}>H_u$ **=>> OK** **BUT OK AS RESTRAINED BY SLAB**

Calculate maximum bending moment in wall stem

Assume waterproof membrane with padding, i.e negligible interface friction

δ_s = 0

K_{as} = 0.33

P_{as} =	$0.5 .K_{as} . \gamma_{soil} .H_w^2$	=	6.3 kN/m	*Active thrust*
P_{ahs} =	$P_{as} .\cos(\delta_s)$	=	6.3 kN/m	*Horizontal component*
$P_{a\omega s}$ =	$\omega_g .K_{as} .H_w$	=	3.0 kN/m	*Active thrust, surcharge component*
$P_{ah\omega s}$ =	$P_{a\omega s} .\cos(\delta_s)$	=	3.0 kN/m	*Horizontal component*
M_{uG} =	$(P_{ahs} .H_w/3 + P_{ah\omega s}.H_w/2).\alpha_{EP\_static}$	=	8.1 KNm/m	*Ultimate bending moment in stem*

Foundation bearing (Earthquake case)

K_h =	see previous working	=	0.308	*horizontal acceleration*
K_{aE} =	see previous working	=	0.661	

Check 'middle third rule'

P_{aE} =	$0.5 .k_{aE} .\gamma_{soil} .H_T^2$	=	18.2 kN/m	*Active thrust, soil weight component*
P_{aEv} =	$P_{aE}.\sin(\delta_a)$ =	=	8.5 kN/m	*Vertical components*
P_{aEh} =	$P_{aE}.\cos(\delta_a)$ =	=	16.1 kN/m	*Horizontal components*
$P_{aE\omega}$ =	$\omega_{EQ} .K_{aE}. (H_{ret} + L_{base} + L_{key})$	=	5.9 kN/m	*Active thrust, surcharge component*
$P_{aEv\omega}$ =	$P_{aE\omega}.\sin(\delta_a)$ =	=	2.8 kN/m	*Vertical components*
$P_{aEh\omega}$ =	$P_{aE\omega}.\cos(\delta_a)$ =	=	5.2 kN/m	*Horizontal components*
$P_{E\omega}$ =	$\omega_{gs} . L_{heel}$	=	0.0 kN/m	*Surcharge above heel*
M_{aEh} =	$(P_{aEh}.(H_T/3-L_{key}) + P_{aEh\omega}.(H_T/2-L_{key}))$	=	14.4 kN/m	*Moment from horizontal active pressure (+ve)*
M_{aEv} =	$(P_{aEv} + P_{aEv\omega}).L_{foot}$	=	20.9 kN/m	*Moment from vertical active pressure (-ve)*
$M_{E\omega}$=	$P_{E\omega}.(L_{foot} - L_{heel}/2)$	=	0.0 kN/m	*Moment from surcharge above heel (-ve)*
M_I=	$(W_{stem}.C_d(T_1))(H_w/2+L_{base})+(W_{soil}.K_h).(H_w/2+L_{base})+W_{foot}.Kh.L_{base}/2 - W_{key}.k_h.L_{key}/2$	=	13.6 kN/m	*Moment from inertia forces (+ve)*
M_{EG}=	as above	=	34.1 kN/m	*Restoring moment from self weight of wall and soil above heel (-ve)*
M_{net} =	$M_{aEh} + M_I - M_{aEv} - M_{EG} - M_{E\omega}$	=	-26.9 kN/m	*Net moment must be < 0 for stability*
P_{vert} =	$W_{total} + P_{aEv} + P_{aEv\omega} + P_{E\omega}$	=	36.5 kN/m	*factored vertical load on footing*
L_{net} =	$-M_{net} / P_{vert}$	=	0.7 m	*Line of action of net vertical force (distance from toe)*

Check bearing capacity

L_{third} =	$1/3 .L_{foot}$ =	0.6 m	<< L_{net} =	0.7 m	<< $2.L_{third}$ =	1.2 m	**=>> OK**	
B_{eff} =	$2. L_{net}$	=	1.5 m		*Effective footing width*	Check B_{eff}<<L_{foot} =>> OK		

<u>If footing is eccentric</u>

k =	1+6.Lnet/Lfoot	=	3.40	*eccentric load factor*
$V_{u,eccentricity}$ =	$k\ P_{vert} / L_{foot}$	=	67.6 kN/m	*factored vertical loading for eccentricty*
V_{uEq} =	Pvert	=	28.4 kN/m	*Ultimate vertical load on footing*
H_{uEq} =	$P_{aeh} + P_{aeh\omega}+W_{stem}.k_h+W_{soil}.K_h+W_{foot}.K_h+W_{key}.k_h$	=	29.1 kN/m	*Ultimate horizontal load on footing*

<u>Undrained bearing capacity shallow footing - Vesic</u>

L =		=	6.00 m	*Length of wall*
D_e =		=	4.00 m	*min horizontal distance from edge of underside of footing to face of adjacent downward slope*
β =		=	0.0 deg	*Ground slope in front of footing*
s_u =		=	80.0 kPa	*undrained shear strength*
c =	s_u	=	80.0 kPa	*Soil effective cohesion*
q =	$\gamma_{soil}.L_{base}$	=	5.1 kPa	*Surcharge*
ϕ =		=	0.0 deg	*undrained friction angle*

$N_q = e^{\pi.\tan(\phi)}.\tan(\phi/2+45)^2$ = 1.000

$N_c = (\phi = 0) = 5.14$ = 5.14

$N_\gamma = (\phi = 0) = 5.14$ = 0.00

Shape factors

$\lambda_{qs} = 1+ (B_{eff}/L).\tan(\phi)$ = 1.000

$\lambda_{cs} = 1+ (B_{eff}.N_q)/(L.N_c)$ = 1.048

$\lambda_{\gamma s} = 1- 0.4(B_{eff}/L)$ = 0.902

Depth factors

$\lambda_{qd} = (L_{base}/B_{eff} < 1) = 1+2\tan(\phi)(1-\sin(\phi))^2(L_{base}/B_{eff}))$ = 1.056

$\lambda_{cd} = (\phi > 0) = \lambda_{qd}-(1-\lambda_{qd})/(N_q.\tan(\phi))$ = 1.161

$\lambda_{\gamma d} = 1$

Load Inclination factors

$n_B = (2+B_{eff}/L)/(1+B_{eff}/L)$ = 1.803

$\lambda_{qi} = (\phi = 0) = 1$ = 1.000

$\lambda_{ci} = 1-(n_B.H_{uEq}.L)/(c.N_c.B.L)$ = 0.914

$\lambda_{\gamma i} = \lambda_{qi}$ = 1.000

Ground Inclination factors

λ_{qg}= (D_e > 2.L_{foot}) = λ_{cg} = λ_{qg} = λ_{gg} = 1
= 1.000

λ_{cg}= (D_e > 2.L_{foot}) = λ_{cg} = λ_{qg} = λ_{gg} = 1
= 1.000

$\lambda_{\gamma g}$ = (D_e > 2.L_{foot}) = λ_{cg} = λ_{qg} = λ_{gg} = 1
= 1.000

q_{uq}= q.λ_{qs}.λ_{qd}.λ_{qi}.λ_{qg}.Nq
= 5.4 kPa

q_{uc}= c.λ_{cs}.λ_{cd}.λ_{ci}.λ_{cg}.Nc
= 457.1 kPa

$q_{u\lambda}$= 0.5γ.B_{eff}.$\lambda_{\gamma s}$.$\lambda_{\gamma d}$.$\lambda_{\gamma i}$.$\lambda_{\gamma g}$.N_γ
= 0.0 kPa

q_u = q_{uq} + q_{uc} + $q_{u\lambda}$ = 462.5 kPa

= 300 kPa

q_u = 210.0 kPa *check against ultimate bearing pressure*

V_{ustar} = B_{eff} . q_u . Φ_{bc} = 154.8 kN/m Check V_{ustar}>V_u **=>> OK**

Wall Sliding (Earthquake Case)

Passive pressure neglected due to possible desiccation and disturbance

k_p = 1 *as ϕ = 0*
S_u = 70 kPa *Undrained shear strength (as stated in getotechnical report)*
C_a = 70 kPa *(where C_a = Su)*

P_p =	0.5 .K_p .γ_{soil} .(L_{base}+L_{key})^2 + 2.S_u.L_{key}	=	0.8 kN/m	*Passive resistance*	
H_{star} =	P_p + c_a.B_{eff}	=	104.0 kN/m	*Factored ultimate resistance*	Check H_{star}>H_u **=>> OK**

Calculate maximum bending moment in wall stem

Assume waterproof membrane with padding, i.e negligible interface friction

δ_s = 0
K_{aEs} = 0.792

P_{aEs} =	0.5 .K_{aEs} . γ_{soil} .H_w^2	=	15.2 kN/m	*Active thrust*
P_{aEhs} =	P_{aEs} .cos(δ_s)	=	15.2 kN/m	*Horizontal component*
$P_{aE\omega s}$ =	ω_{EQ} .K_{aEs} .(H_w + L_{base} + L_{key})	=	5.9 kN/m	*Active thrust, surcharge component*
$P_{aEh\omega s}$ =	$P_{aE\omega s}$ .cos(δ_s)	=	5.9 kN/m	*Horizontal component*
M_{uEQ} =	P_{aEhs} .H_w/3 + $P_{aEh\omega s}$ .H_w/2+W_{stem}.C_d.$T_1$$H_w$/2	=	22.7 KNm/m	*Ultimate bending moment in stem*

Design of Wall - Flexural Capacity

M_{max} = Max(M_{uG}, M_{UEQ}) = 22.7 KNm/m

Try Vertical Reinforcing **HD16 Bars @400crs (503mm2/m)**

ϕ Mi = ϕ As fy (d - 0.59 As.fy / f'm b) = 23.0 KNm/m

M_{max} >> ϕ Mi **=>> OK**

ϕ =	0.85
cover =	120 mm
d =	120 mm
fc =	25 MPa
fy =	500 MPa
f'm =	12 MPa
b =	1000 mm
As =	503 mm2/m

Retaining Wall Design

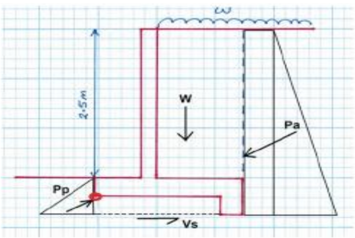
Cantilever Wall Parameters

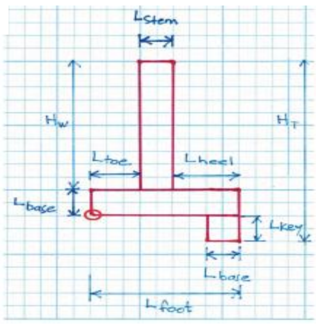
Allow atotal wall height, with varying retaining heights. Extension of wall to act as a fence/barrier

H_w =	2.70 m	*Height of wall*
H_{ret} =	1.00 m	*Height of retained ground*
L_{stem} =	0.24 m	*Thickness of wall*
L_{toe} =	1.20 m	*Length of toe*
L_{base} =	0.30 m	*Thickness of base*
L_{heel} =	0.00 m	*Length of heel*
L_{key} =	0.00 m	*Depth of shear key*
γ_{soil} =	17.0 kN/m3	*Soil unit weight*
γ_{conc} =	21.0 kN/m3	*Masonry unit weight*
ω_g =	6.00 kPa	*Factored Surcharge, gravity case, destabilising (1.2G+1.5Q)*
ω_{gs} =	4.50 kPa	*Factored Surcharge, gravity case, stabilising (0.9G)*
ω_{eq} =	5.00 kPa	*Factored Surcharge, EQ, destabilising (G+Eu+0.3Q)*

Seismic Coefficients for the Overturning of Wall Itself

C_d (T_1) =	0.58	Ultimate
C_d (T_1) =	0.13	Serviceability





Reinforcement Summary

Wall Reinforcement

A_{wv} =	HD16 Bars @400crs (503mm2/m)
A_{wallv} =	HD16 Bars @400crs (503mm2/m)
A_{wh} =	HD12 Bars @400crs (283mm2/m)

Footing Reinforcement

A_{ft} =	HD16 Bars @400crs (503mm2/m)
A_{fl} =	5 x HD12 Bars

LRFD parameters

Φ_{bc} =	0.5
Φ_{sl} =	0.8
Φ_p =	0.5
α_{G_stab}=	0.9
α_{G_destab}=	1.2
α_{EP_static}=	1.5

Job Title :	Spencer and Lisa Adlam	**Page :**	
Site Address :	33 Great West Road	**No of Pages :**	
City :	Rotorua	**Date :**	Feb 22
Job No :	235655	**By :**	DA

Stratum CONSULTANTS
Experience. Knowledge. Better Outcomes.

Computed Parameters

L_{foot} =	$L_{toe} + L_{stem} + L_{heel}$	=	1.4 m	*Width of footing*
H_T =	$H_W + L_{base} + L_{key}$	=	1.3 m	*Total retained height*
W_{foot} =	$L_{foot} \cdot L_{base} \cdot \gamma_{conc}$	=	9.1 kPa	*Weight of footing*
W_{key} =	$L_{key} \cdot L_{base} \cdot \gamma_{conc}$	=	0.0 kPa	*Weight of key (same thickness as base)*
W_{stem} =	$H_w \cdot L_{stem} \cdot \gamma_{conc}$	=	13.6 kPa	*Weight of wall stem*
W_{soil} =	$L_{heel} \cdot H_w \cdot \gamma_{soil}$	=	0.0 kPa	*Weight of soil above heel*

Check 'middle third rule'

P_a =	$0.5 \cdot k_a \cdot \gamma_{soil} \cdot H_T^2$	=	4.6 kN/m	*Active thrust, soil weight component*
P_{av} =	$P_a \cdot \sin(\delta_a)$ =	=	2.2 kN/m	*Vertical components*
P_{ah} =	$P_a \cdot \cos(\delta_a)$ =	=	4.0 kN/m	*Horizontal components*
$P_{a\omega}$ =	$\omega_g \cdot K_a \cdot H_T$	=	2.5 kN/m	*Active thrust, surcharge component*
$P_{av\omega}$ =	$P_{a\omega} \cdot \sin(\delta_a)$ =	=	1.2 kN/m	*Vertical components*
$P_{ah\omega}$ =	$P_{a\omega} \cdot \cos(\delta_a)$ =	=	2.2 kN/m	*Horizontal components*
P_ω =	$\omega_{gs} \cdot L_{heel}$	=	0.0 kN/m	*Surcharge above heel*
M_{ah} =	$(P_{ah} \cdot (H_T/3 - L_{key}) + P_{ah\omega} \cdot (H_T/2 - L_{key}))\alpha_{EP\_static}$	=	4.8 kN/m	*Moment from horizontal active pressure (+ve)*
M_{av} =	$(P_{av} + P_{av\omega}) \cdot L_{foot}$	=	4.8 kN/m	*Moment from vertical active pressure (-ve)*
M_ω =	$P_\omega \cdot (L_{foot} - L_{heel}/2)$	=	0.0 kN/m	*Moment from surcharge above heel (-ve)*
$\alpha_{G\_stab} \cdot M_G$ =	see working below	=	22.0 kN/m	*Restoring moment from self weight of wall and soil above heel (-ve)*

	Weight, W	x	Dist from toe		=	M*
Footing	9.1 kN/m		$L_{foot}/2$ =	0.7 m	=	6.5 kNm/m
Stem	13.6 kN/m		$L_{toe} + L_{stem}/2$ =	1.3 m	=	18.0 kNm/m
Key	0.0 kN/m		$L_{foot} - L_{key}/2$ =	1.4 m	=	0.0 kNm/m
Soil	0.0 kN/m		$L_{foot} - L_{heel}/2$ =	1.4 m	=	0.0 kNm/m
W_{total} =	22.7 kN/m				M_G =	24.5 kNm/m

M_{net} =	$M_{ah} - M_{av} - M_G - M_\omega$	=	-22.1 kNm/m	*Net moment must be < 0 for stability*
P_{vert} =	$W_{total} \cdot \alpha_{G\_stab} + P_{av} + P_{av\omega} + P_\omega$	=	23.7 kN/m	*factored vertical load on footing*
L_{net} =	$-M_{net} / P_{vert}$	=	0.9 m	*Line of action of net vertical force (distance from toe)*

Check bearing capacity

L_{third} = $1/3 \cdot L_{foot}$ = 0.5 m << L_{net} = 0.9 m << $2 \cdot L_{third}$ = 1.0 m **=>> OK**

B_{eff} = $2 \cdot L_{net}$ = 1.86 m *Effective footing width* Check $B_{eff} << L_{foot}$
=>> Allow for eccentricity

If footing is eccentric

k =	1+6.Lnet/Lfoot	=	4.9	*eccentric load factor*
$V_{u,eccentricity}$ =	$k\ P_{vert} / L_{foot}$	=	80.3 kN/m	*factored vertical loading for eccentricty*
V_u =	Vu,eccentricity	=	80.3 kN/m	*Ultimate vertical load on footing*
H_u =	$(P_{ah} + P_{ah\omega}) \cdot \alpha_{EP\_static}$	=	9.4 kN/m	*Ultimate horizontal load on footing*

Drained bearing capacity shallow footing - Vesic

L =		=	6.00 m	*Length of wall*
D_e =		=	4.00 m	*min horizontal distance from edge of underside of footing to face of adjacent downward slope*
β =		=	0.0 deg	*Ground slope in front of footing*
c =		=	0 kPa	*Soil effective cohesion*
s_u =			80 kPa	*undrained shear strength*
q =	$\gamma_{soil} \cdot L_{base}$	=	5.1 kPa	*Surcharge*

$N_q = e^{\pi \tan(\phi)} \cdot \tan(\phi/2+45)^2$ = 14.720

$N_c = (N_q - 1)1/\tan(\phi)$ = 25.80

$N_\gamma = (\phi > 0) = 2 \cdot (N_q + 1)\tan(\phi)$ = 16.72

Shape factors

$\lambda_{qs} = 1 + (B_{eff}/L) \cdot \tan(\phi)$ = 1.165

$\lambda_{cs} = 1 + (B_{eff} \cdot N_q)/(L \cdot N_c)$ = 1.177

$\lambda_{\gamma s} = 1 - 0.4(B_{eff}/L)$ = 0.876

Depth factors

$\lambda_{qd} = (L_{base}/B_{eff} < 1) = 1 + 2\tan(\phi)(1-\sin(\phi))^2(L_{base}/B_{eff})$ = 1.044

$\lambda_{cd} = (\phi > 0) = \lambda_{qd} - (1-\lambda_{qd})/(N_q \cdot \tan(\phi))$ = 1.050

$\lambda_{\gamma d} = 1$

Load Inclination factors - (loading parallel to B_{eff})

$n_B = (2+B_{eff}/L)/(1+B_{eff}/L)$ = 1.763

$\lambda_{qi} = (\phi > 0) = (1 - (L \cdot H_u/(L \cdot V_u + B_{eff} \cdot L \cdot c \cdot 1/\tan(\phi))))^{nB}$ = 0.804

$\lambda_{ci} = (\phi > 0) = \lambda_{qi} - (1-\lambda_{qi})/(N_c \cdot \tan(\phi))$ = 0.789

$\lambda_{\lambda i} = (\phi > 0) = (1 - (H_u/(V_u + B_{eff} \cdot L \cdot c \cdot 1/\tan(\phi))))^{nB+1}$ 0.710

Ground Inclination factors

$\lambda_{qg} = (D_e > 2 \cdot L_{foot}) = \lambda_{cg} = \lambda_{qg} = \lambda_{gg} = 1$ = 1.00

$\lambda_{cg} = (D_e > 2 \cdot L_{foot}) = \lambda_{cg} = \lambda_{qg} = \lambda_{gg} = 1$ = 1.00

$\lambda_{\gamma g} = (D_e > 2 \cdot L_{foot}) = \lambda_{cg} = \lambda_{qg} = \lambda_{gg} = 1$ = 1.00

$q_{uq} = q \cdot \lambda_{qs} \cdot \lambda_{qd} \cdot \lambda_{qi} \cdot \lambda_{qg} \cdot Nq$ = 73.4 kPa

$q_{uc} = c \cdot \lambda_{cs} \cdot \lambda_{cd} \cdot \lambda_{ci} \cdot \lambda_{cg} \cdot Nc$ = 0.0 kPa

$q_{u\lambda} = 0.5\ \gamma \cdot B_{eff} \cdot \lambda_{\gamma s} \cdot \lambda_{\gamma d} \cdot \lambda_{\gamma i} \cdot \lambda_{\gamma g} \cdot N_\gamma$ = 164.3 kPa

$q_u = q_{uq} + q_{uc} + q_{u\lambda}$ = 237.6 kPa
= 300 kPa

q_u = 210.0 kPa *check against ultimate bearing pressure*

V_{ustar} = $B_{eff} \cdot q_u \cdot \Phi_{bc}$ = 195.2 kN/m Check $V_{ustar} > V_u$
=>> OK

Wall Sliding (Gravity Case)

W_{slide} =	$(L_{foot} - L_{base}).L_{key}.\gamma_{soil}$	=	0.0 kN/m	*Weight of soil trapped under footing*
P_p =	$0.5 .K_p .\gamma_{soil} .(L_{base}+L_{key})^2$	=	3.1 kN/m	*Passive resistance*
P_{ph} =	$P_p .\cos(\delta_p)$	=	2.9 kN/m	*Horizontal component*
P_{pv} =	$P_p .\sin(\delta_p)$	=	0.9 kN/m	*Vertical component*
H_s =	$(V_u + W_{slide} .\alpha_{G\_stab} - P_{pv}).\tan(\phi)$	=	42.2 kN/m	*Friction under footing*
H_{star} =	$P_{ph} .\phi_p + H_s.\phi_{sl}$	=	35.2 kN/m	*Factored ultimate resistance* Check $H_{star}>H_u$

=>> OK

BUT OK AS RESTRAINED BY SLAB

Calculate maximum bending moment in wall stem

Assume waterproof membrane with padding, i.e negligible interface friction

δ_s = 0

K_{as} = 0.33

P_{as} =	$0.5 .K_{as} . \gamma_{soil} .H_w^2$	=	2.8 kN/m	*Active thrust*
P_{ahs} =	$P_{as} .\cos(\delta_s)$	=	2.8 kN/m	*Horizontal component*
$P_{a\omega s}$ =	$\omega_g .K_{as} .H_w$	=	2.0 kN/m	*Active thrust, surcharge component*
$P_{ah\omega s}$ =	$P_{a\omega s} .\cos(\delta_s)$	=	2.0 kN/m	*Horizontal component*
M_{uG} =	$(P_{ahs} .H_w/3 + P_{ah\omega s}.H_w/2).\alpha_{EP\_static}$	=	2.9 KNm/m	*Ultimate bending moment in stem*

Foundation bearing (Earthquake case)

K_h =	see previous working	=	0.308	*horizontal acceleration*
K_{aE} =	see previous working	=	0.661	

Check 'middle third rule'

P_{aE} =	$0.5 .k_{aE} .\gamma_{soil} .H_T^2$	=	9.5 kN/m	*Active thrust, soil weight component*
P_{aEv} =	$P_{aE}.\sin(\delta_a)$ =	=	4.5 kN/m	*Vertical components*
P_{aEh} =	$P_{aE}.\cos(\delta_a)$ =	=	8.4 kN/m	*Horizontal components*
$P_{aE\omega}$ =	$\omega_{EQ} .K_{aE}. (H_{ret} + L_{base} + L_{key})$	=	4.3 kN/m	*Active thrust, surcharge component*
$P_{aEv\omega}$ =	$P_{aE\omega}.\sin(\delta_a)$ =	=	2.0 kN/m	*Vertical components*
$P_{aEh\omega}$ =	$P_{aE\omega}.\cos(\delta_a)$ =	=	3.8 kN/m	*Horizontal components*
$P_{E\omega}$ =	$\omega_{gs} . L_{heel}$	=	0.0 kN/m	*Surcharge above heel*
M_{aEh} =	$(P_{aEh}.(H_T/3-L_{key}) + P_{aEh\omega}.(H_T/2-L_{key}))$	=	6.1 kN/m	*Moment from horizontal active pressure (+ve)*
M_{aEv} =	$(P_{aEv} + P_{aEv\omega}).L_{foot}$	=	9.3 kN/m	*Moment from vertical active pressure (-ve)*
$M_{E\omega}$=	$P_{E\omega}.(L_{foot} - L_{heel}/2)$	=	0.0 kN/m	*Moment from surcharge above heel (-ve)*
M_I=	$(W_{stem}.C_d(T_1))(H_w/2+L_{base})+(W_{soil}.K_h).(H_w/2+L_{base})+W_{foot}.Kh.L_{base}/2 - W_{key}.k_h.L_{key}/2$	=	13.5 kN/m	*Moment from inertia forces (+ve)*
M_{EG}=	as above	=	24.5 kN/m	*Restoring moment from self weight of wall and soil above heel (-ve)*
M_{net} =	$M_{aEh} + M_I - M_{aEv} - M_{EG} - M_{E\omega}$	=	-14.2 kN/m	*Net moment must be < 0 for stability*
P_{vert} =	$W_{total} + P_{aEv} + P_{aEv\omega} + P_{E\omega}$	=	29.2 kN/m	*factored vertical load on footing*
L_{net} =	$-M_{net} / P_{vert}$	=	0.5 m	*Line of action of net vertical force (distance from toe)*

Check bearing capacity

L_{third} = $1/3 .L_{foot}$ = 0.5 m << L_{net} = 0.5 m << $2.L_{third}$ = 1.0 m **=>> OK**

B_{eff} = $2. L_{net}$ = 1.0 m *Effective footing width* Check $B_{eff}<<L_{foot}$ =>> OK

<u>If footing is eccentric</u>

k =	1+6.Lnet/Lfoot	=	3.03	*eccentric load factor*
$V_{u,eccentricity}$ =	$k P_{vert} / L_{foot}$	=	61.3 kN/m	*factored vertical loading for eccentricty*
V_{uEq} =	Pvert	=	23.7 kN/m	*Ultimate vertical load on footing*
H_{uEq} =	$P_{aeh} + P_{aeh\omega}+W_{stem}.k_h+W_{soil}.K_h+W_{foot}.K_h+W_{key}.k_h$	=	19.1 kN/m	*Ultimate horizontal load on footing*

<u>Undrained bearing capacity shallow footing - Vesic</u>

L =		=	6.00 m	*Length of wall*
D_e =		=	4.00 m	*min horizontal distance from edge of underside of footing to face of adjacent downward slope*
β =		=	0.0 deg	*Ground slope in front of footing*
s_u =		=	80.0 kPa	*undrained shear strength*
c =	s_u	=	80.0 kPa	*Soil effective cohesion*
q =	$\gamma_{soil}.L_{base}$	=	5.1 kPa	*Surcharge*
ϕ =		=	0.0 deg	*undrained friction angle*

$N_q = e^{\pi.\tan(\phi)}.\tan(\phi/2+45)^2$ = 1.000

N_c = $(\phi = 0) = 5.14$ = 5.14

N_γ = $(\phi = 0) = 5.14$ = 0.00

Shape factors

$\lambda_{qs} = 1+ (B_{eff}/L).\tan(\phi)$ = 1.000

$\lambda_{cs} = 1+ (B_{eff}.N_q)/(L.N_c)$ = 1.032

$\lambda_{\gamma s} = 1- 0.4(B_{eff}/L)$ = 0.935

Depth factors

$\lambda_{qd} = (L_{base}/B_{eff} < 1) = 1+2\tan(\phi)(1-\sin(\phi))^2(L_{base}/B_{eff}))$ = 1.085

$\lambda_{cd} = (\phi > 0) = \lambda_{qd}-(1-\lambda_{qd})/(N_q.\tan(\phi))$ = 1.244

$\lambda_{\gamma d} = 1$

Load Inclination factors

$n_B = (2+B_{eff}/L)/(1+B_{eff}/L)$ = 1.860

$\lambda_{qi} = (\phi = 0) = 1$ = 1.000

$\lambda_{ci} = 1-(n_B.H_{uEq}.L)/(c.N_c.B.L)$ = 0.911

$\lambda_{\gamma i} = \lambda_{qi}$ = 1.000

Ground Inclination factors

λ_{qg}= ($D_e > 2.L_{foot}$) = $\lambda_{cg} = \lambda_{qg} = \lambda_{gg} = 1$
= 1.000

λ_{cg}= ($D_e > 2.L_{foot}$) = $\lambda_{cg} = \lambda_{qg} = \lambda_{gg} = 1$
= 1.000

$\lambda_{\gamma g}$ = ($D_e > 2.L_{foot}$) = $\lambda_{cg} = \lambda_{qg} = \lambda_{gg} = 1$
= 1.000

q_{uq}= $q.\lambda_{qs}.\lambda_{qd}.\lambda_{qi}.\lambda_{qg}.Nq$
= 5.5 kPa

q_{uc}= $c.\lambda_{cs}.\lambda_{cd}.\lambda_{ci}.\lambda_{cg}.Nc$
= 480.8 kPa

$q_{u\lambda}$= $0.5\gamma.B_{eff}.\lambda_{\gamma s}.\lambda_{\gamma d}.\lambda_{\gamma i}.\lambda_{\gamma g}.N_{\gamma}$
= 0.0 kPa

q_u = $q_{uq} + q_{uc} + q_{u\lambda}$ = 486.4 kPa

= 300 kPa

q_u = 210.0 kPa *check against ultimate bearing pressure*

V_{ustar} =	$B_{eff} . q_u . \Phi_{bc}$	=	102.3 kN/m	Check $V_{ustar}>V_u$	**=>> OK**

Wall Sliding (Earthquake Case)

Passive pressure neglected due to possible desiccation and disturbance

k_p = 1 *as $\phi = 0$*
S_u = 70 kPa *Undrained shear strength (as stated in getotechnical report)*
C_a = 70 kPa *(where C_a = Su)*

P_p =	$0.5 .K_p .\gamma_{soil} .(L_{base}+L_{key})^2 + 2.S_u.L_{key}$	=	0.8 kN/m	*Passive resistance*		
H_{star} =	$P_p + c_a.B_{eff}$	=	69.0 kN/m	*Factored ultimate resistance*	Check $H_{star}>H_u$	**=>> OK**

Calculate maximum bending moment in wall stem

Assume waterproof membrane with padding, i.e negligible interface friction

δ_s = 0
K_{aEs} = 0.792

P_{aEs} =	$0.5 .K_{aEs} . \gamma_{soil} .H_w^2$	=	6.7 kN/m	*Active thrust*
P_{aEhs} =	$P_{aEs} .\cos(\delta_s)$	=	6.7 kN/m	*Horizontal component*
$P_{aE\omega s}$ =	$\omega_{EQ} .K_{aEs} .(H_w + L_{base} + L_{key})$	=	4.3 kN/m	*Active thrust, surcharge component*
$P_{aEh\omega s}$ =	$P_{aE\omega s} .\cos(\delta_s)$	=	4.3 kN/m	*Horizontal component*
M_{uEQ} =	$P_{aEhs} .H_w/3 + P_{aEh\omega s} .H_w/2+W_{stem}.C_d.T_1H_w/2$	=	15.1 KNm/m	*Ultimate bending moment in stem*

Design of Wall - Flexural Capacity

M_{max} = Max(M_{uG}, M_{UEQ}) = 15.1 KNm/m

Try Vertical Reinforcing **HD16 Bars @400crs (503mm2/m)**

ϕ Mi = ϕ As fy (d - 0.59 As.fy / f'm b) = 23.0 KNm/m

M_{max} >> ϕ Mi **=>> OK**

ϕ =	0.85
cover =	120 mm
d =	120 mm
fc =	25 MPa
fy =	500 MPa
f'm =	12 MPa
b =	1000 mm
As =	503 mm2/m