

## STRUCTURAL CALCULATIONS & DETAILS

Pole Retaining Wall

at

61 Exploration Way  
Whitby

Lot 100 DP 478324

Prepared for:

Keys Construction

Project Ref: 1548  
Revision: -  
Date 1 December 2015

Synge Consulting Ltd  
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Structure Loading Standard	AS/NZS 1170
Timber Structures Standard	NZS 3603:1993
Concrete Structures Standard	NZS 3101:2006

## PRODUCER STATEMENT – PS1 – DESIGN

**ISSUED BY:** Syngé Consulting Ltd  
(Design Firm)

**TO:** Keys Construction  
(Owner/Developer)

**TO BE SUPPLIED TO:** Porirua City Council  
(Building Consent Authority)

**IN RESPECT OF:** Pole Retaining Wall  
(Description of Building Work)

**AT:** 61 Exploration Way Whitby  
(Address)

Lot 100 DP 478324

We have been engaged by the owner/developer referred to above to provide .. Specific design of pole retaining wall services in respect of the requirements of

(Extent of Engagement)

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 B1/VM1, B1/AS1....

(verification method / acceptable solution)

The proposed building work covered by this producer statement is described on the drawings titled Pole Retaining Wall, 61 Exploration Way, Whitby and numbered 1548 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
- (ii) All proprietary products meeting their performance

Ground ultimate bearing capacity > 300 kPa

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

I, A J Syngé am CPEng # 62314

(Name of Design Professional)

I am a Member of IPENZ and hold the following qualifications: MIPENZ, CPEng, IntPE(NZ)

The Design Firm issuing this statement holds a current policy of Professional Indemnity Insurance no less than \$200,000\*.

**SIGNED BY:** A J Syngé

**ON BEHALF OF:** Syngé Consulting Ltd

(Design Firm)

**Date:** 1 December 2015

(signature)



*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.

THIS FORM AND ITS CONDITIONS ARE COPYRIGHT TO ACENZ, IPENZ AND NZIA

## Memorandum from licensed building practitioner of design work

### Section 30C or section 45, Building Act 2004

#### The building

Street address of building: 61 Exploration Way Whitby

#### The owner

Name: Progeni Ltd  
Address: 61 Exploration Way Whitby  
Telephone number: Email:

#### Basis for providing this memorandum

I am providing this memorandum in my role as the:

- ☒ 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

I, A J Synge, carried out or supervised the following design work that is restricted building work:

##### Primary structure

Design work that is restricted building work	Description	Carried out / supervised	Reference to plans and specifications
Foundations <input checked="" type="checkbox"/>		<input checked="" type="checkbox"/> Carried out Supervised	
Walls <input checked="" type="checkbox"/>	Pole retaining wall	<input checked="" type="checkbox"/> Carried out Supervised	
Roof		Carried out Supervised	
Coulmns and beams	Roof beams	Carried out Supervised	
Bracing		Carried out Supervised	
Other		Carried out Supervised	

#### Waivers or Modifications

Are waivers or modifications of the building code required? ( ) Yes (✓) No

#### Issued by

Name: A J Synge Registration No: 62314  
The practitioner is a: Chartered professional engineer  
Street address or registered office: 3 Vera St, Karori, Wellington, 6012  
Phone number: 04 4764 328 Mobile: 021 519 085 Fax: 04 4764 329  
Email address: tony@synge.co.nz

#### Declaration

I Anthony Synge state that the design work that is restricted building work recorded on this form:

- (a) complies with the building code; or  
(b) complies with the building code subject to any waiver or modification of the building code recorded on this form.

Signature:



Date: 1 December 2015

**Synge Consulting Ltd**

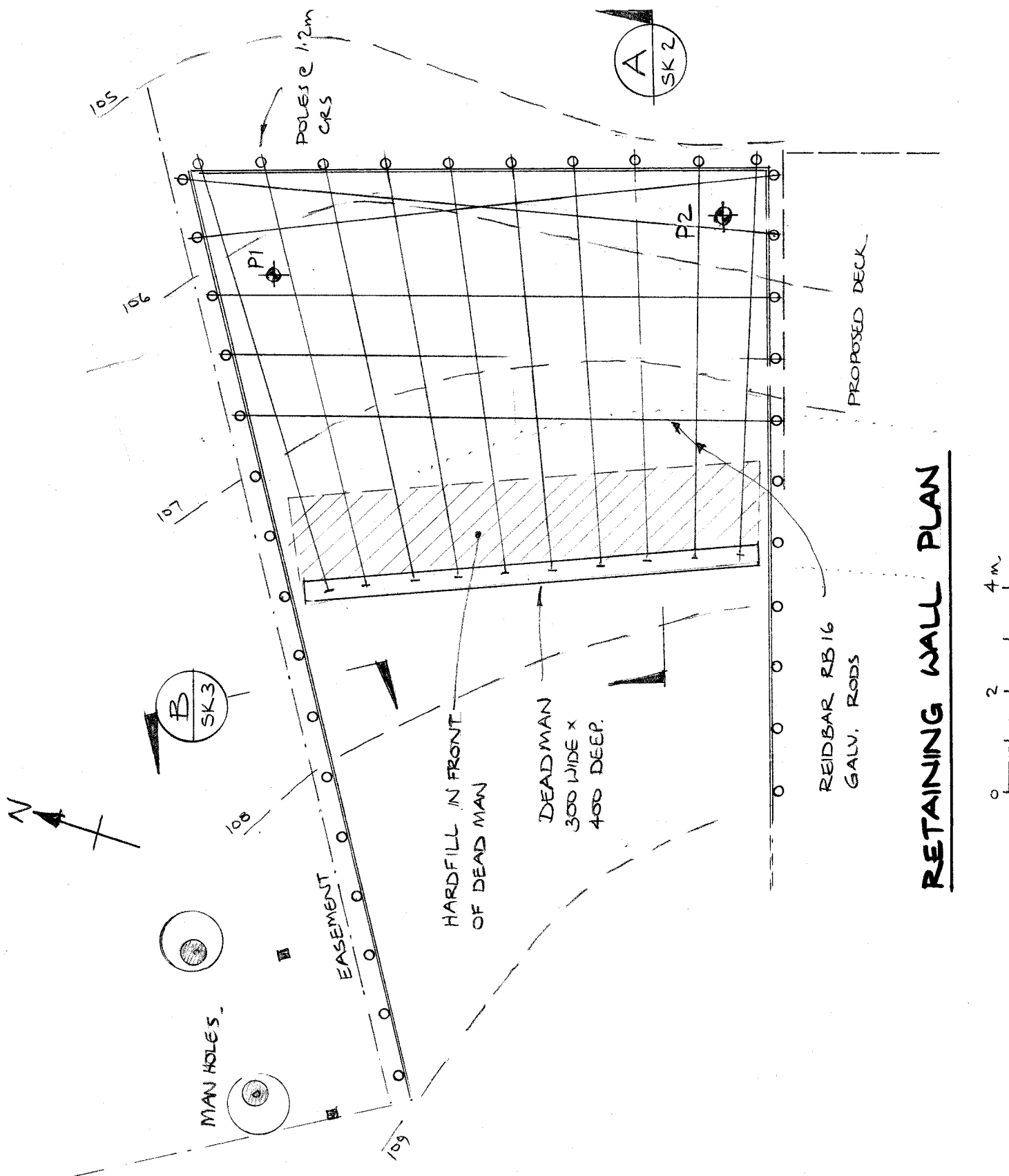
3 Vera St, Wellington 6012  
04 4764 328

Page:  
Ref: 1548  
Date: 1-Dec-15

Project: 61 Exploration Way Whitby

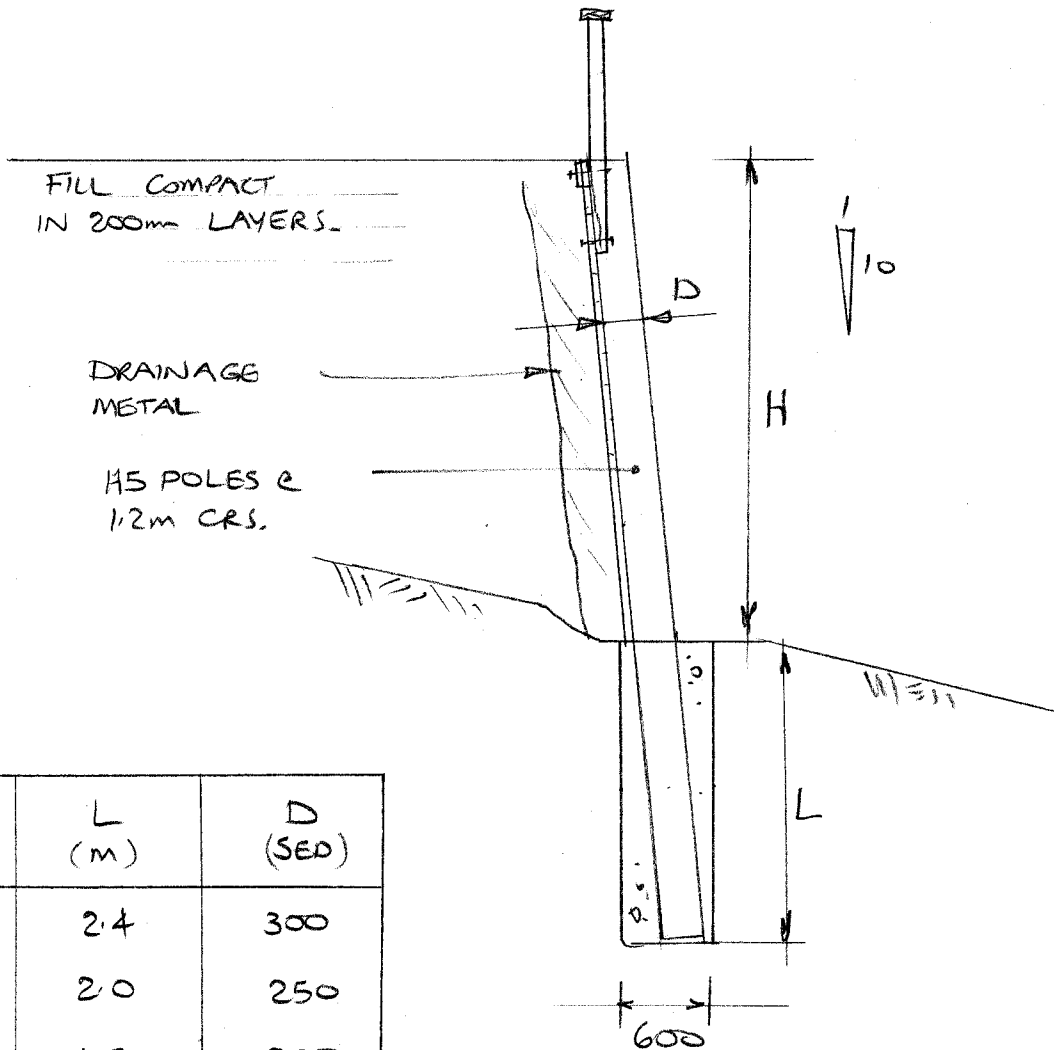
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**STRUCTURAL DETAILS**



**RETAINING WALL PLAN**





H (m)	L (m)	D (SED)
≤ 3.1	2.4	300
≤ 2.6	2.0	250
≤ 2.0	1.5	200

## CANTILEVER WALL

### SECTION B.B.



## STRUCTURAL SPECIFICATION

### 1 TIMBER POLE RETAINING WALL

#### 1.1 Scope

Supply all materials and erect timber pole retaining wall, as shown on the drawings.

#### 1.2 Materials

##### TIMBER POLES

Poles shall be radiata pine, selected in accordance with NZS 3602 and treated to H5 in accordance with NZMP 3640.

##### TIMBER ELEMENTS

Corsican or radiata pine, selected in accordance with NZS 3602 and treated in accordance with NZMP 3640, as follows:.

Horizontal retaining timbers	H4
Above ground timber	H3.2

##### FIXINGS AND BOLTS

All bolts, nuts and washers shall be stainless steel

##### DRAINAGE MATERIAL

Shall be free draining crushed stone, 7mm to 20mm in size.

##### CONCRETE

Shall be ordinary grade to NZS 3108, minimum 17.5MPa. Maximum aggregate size 10mm.

#### 1.3 EXECUTION

##### ERECT DRILLED TIMBER POLE WALLS

Excavate, form base for, and set poles in concrete in pre-drilled holes. Space poles nominally as specified on the drawings.

Place poles butt end down. Do not put cut ends into ground. Treat all cut ends or notches with a liberal brush coat of copper naphthenate or equivalent wood preservative.

The Engineer is to confirm the adequacy of pole embedment depths prior to placing poles.

Install horizontal timbers with staggered joints. All timber joints are to be close butted at poles. Provide 20mm vertical gap between the bottom rails to allow ground water to dissipate when required.

Setout tolerances shall be:

From pole centre line:	max.	60mm from centre line
Misalignment:		max. 20mm at retaining face
Minimum back slope:		4 degrees back slope from vertical
Drill diameter:		pole butt end diameter + 100mm

##### BACKFILLING

Compact backfilling in 150mm loose layers, using a suitable vibrating equipment. Use reduced compactive effort and care within 1.0m of the retaining wall.

Place a 300mm min wide layer of drainage material immediately adjacent to the retaining wall.

Finish backfilling with 150mm of clean topsoil.

##### TAKE AWAY

Remove from the site all plant and material not used.

### 2 SCHEDULE OF INSPECTIONS

Site inspections shall be carried out by the Engineer at the following stages of construction:

- Pole excavation, prior to concreting
- Pre-pour for deadman and tie back anchors
- Completed wall.

A reasonable notification period of not less than 24 hours shall be provided.

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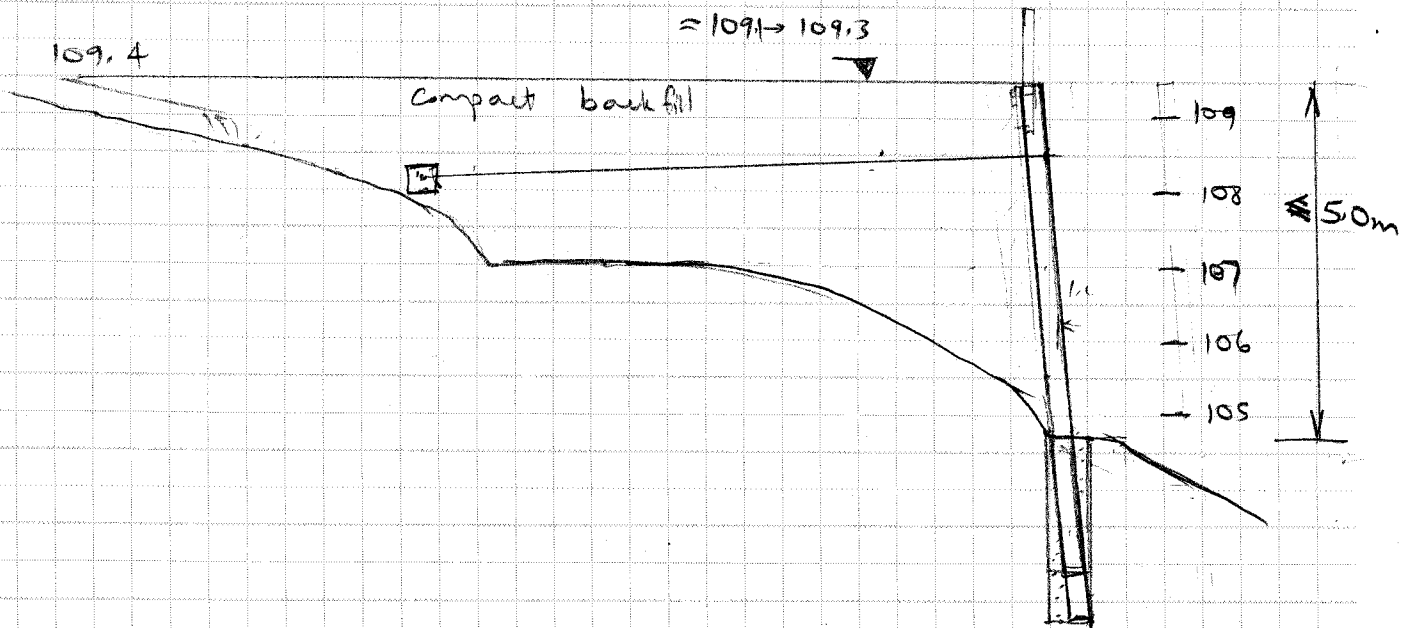
Project: 61 Exploration Way Whitby

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## STRUCTURAL CALCULATIONS

TIMBER POLE RETAINING WALL.

Typical Section.



Foundation Soil.

Penetrometer tests > 2 blows / 50mm.

Silty clay, cohesive.

From Stockwell 25mm / blow  $\approx$  stiff clay  $\rightarrow$  very stiff.

Terrazghi  $\neq$  Peak stiff  $\rightarrow$  very stiff clay.

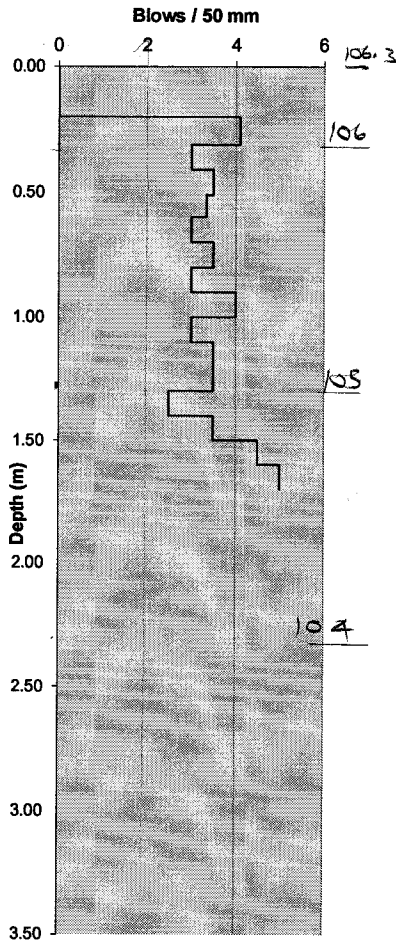
$S_u \approx 100 \text{ kPa}$

Conservatively assumed  $S_u > 80 \text{ kPa}$ .

PENETROMETER RESULTS

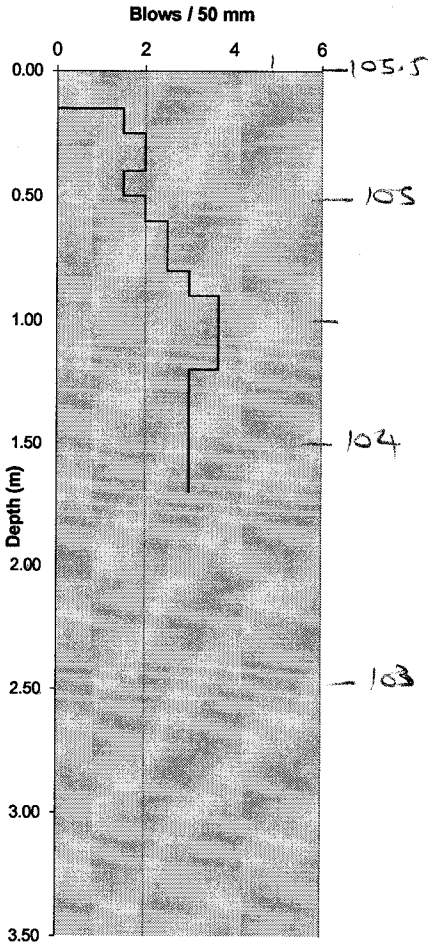
Location : P1

Depth mm	Blows
0	0
200	9
310	6
410	7
510	6
600	6
700	6
800	7
900	6
1000	8
1100	6
1200	7
1300	7
1400	5
1500	7
1600	9
1700	10
	7
	15



Location : P2

Depth mm	Blows
0	0
150	3
250	2
300	4
400	3
500	4
600	5
700	5
800	6
900	11
1050	11
1200	6
1300	6
1400	6
1500	6
1600	6
1700	6



## RETAINING WALL -

Poles up to 5.0m out of ground

### Wall Geometry & Loading

Pole Height	Hw =	5 m
Pole spacing	S =	1.2 m
Distance down to tie back	L1 =	1 m
Distance from ground to tie back	L2 =	4 m

### Backfill Soil Properties

Soil Height	H =	5 m
Soil Density	$\gamma$ =	19 kN/m <sup>3</sup>
Friction angle	$\phi$ =	32 °
Slope of wall	$\beta$ =	-5.7 °
Fric angle soil on wall	$\delta$ =	21.3 °
Slope of backfill	$\omega$ =	°

### Wall Loading

Surcharge on retained soil	q =	0 kPa
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### Active Earth Pressure:

$$K_a = \frac{\cos^2(\phi - \beta)}{\cos^2 \beta \cdot \cos(\delta + \beta)} \cdot A^2 = 0.24$$

Where  $A = \frac{\sqrt{(\sin(f+d) \cdot \sin(f+w) + 1)}}{\cos(d+b) \cdot \cos(b-w)}$

$$P_a = (0.5 \gamma H + q) K_a H S = 67.42 \text{ kN}$$

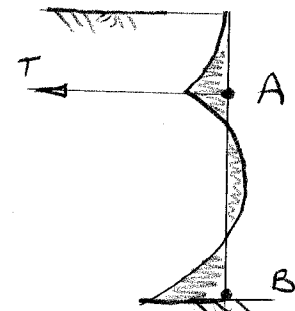
### Mononobe-Okabe EQ Soil Pressure

Seis Coefficient :	MBIE 2014 Recommendations	
Zone factor	Z =	0.4
Soil Class factor	Ch(T) =	1.33
Wall Displacemen factor	Wd =	0.3
Seismic coefficient	kh =	0.16 g
	(atan(9.07 °))	
Kae =		0.34
Pae =		98.03 kN
Height of Pae above base, Hae		1.93 m

$\Delta$  Pae acts 0.5H above base.

### Pole Moments

		Active $\Delta$ EQ			
Soil UDL (kN/m)	At A	5.4	6.1		
	At B	27.0	6.1		
		Active $\Delta$ EQ		1.5.Active	EQ
Pole Moments (kNm)	At A	0.9	3.1	1.3	4.0
	At B	26.7	10.7	40.0	37.4



### Tie back Force:

		Active $\Delta$ EQ		1.5.Active	EQ
Tension (kN)		21.4	16.4	32.1	37.9
Capacity of RB 16 Reid bar		= 90 kN		OK	

### Pole Embedment

Pole Embedment	L =	2.5 m	Cohesive soil: Cu =	60 kPa
Hole diameter	B =	0.6 m		
Lateral pressure varies from 2 Cu at the surface to 9 Cu at a depth of 3 diameters. (Broms)				
	Pp =	653 kN		
Overturning moment	Mb =	243.97 kNm		
Restoring moment	Mr =	$\phi P_p L/3$		271.9 kNm
Mr > Mb, Thus embedment ok.				
			$\phi$ =	0.5

**Post Bending Capacity**

Pole Small End Diameter SED	=	300
Pole Dia at Embedment depth x,	=	325 mm
Bending stress fb	=	38 MPa
Section modulus Z	=	3368 cm <sup>3</sup>
k20	=	0.9
k21	=	0.85

Capacity	Load case	k1	$\phi$ Mn	M*	
	1.5 Pa	0.6	47.0	40.0	OK
	Pae	1	78.3	37.4	OK

For Pole Height	=	5 m
SED	=	300 m
Embedment Depl	=	2.5 m

**Dead Man**

Depth to centre deadman	Dd	=	1.2 m
Soil friction angle	$\phi$	=	34 °
	$\delta$	=	22.7 °
Passive pressure	Kp	=	8.9
Height of anchor	da	=	0.4 m
Soil density		=	19 kN/m <sup>3</sup>
Passive resistance	P <sub>p</sub>	=	82 kN/m
Anchor spacing	s	=	1.0 m
Capacity reduction factor		=	0.5
Dependable capacity	$\phi$ P <sub>p</sub> s	=	41 kN/anchor
Required Anchor tension	T*	=	38 OK

## RETAINING WALL -

Poles up to 4.2m out of ground

### Wall Geometry & Loading

Pole Height	Hw =	4.2 m
Pole spacing	S =	1.2 m
Distance down to tie back	L1 =	1 m
Distance from ground to tie back	L2 =	3.2 m

### Backfill Soil Properties

Soil Height	H =	4.2 m
Soil Density	$\gamma$ =	19 kN/m <sup>3</sup>
Friction angle	$\phi$ =	32 °
Slope of wall	$\beta$ =	-5.7 °
Fric angle soil on wall	$\delta$ =	21.3 °
Slope of backfill	$\omega$ =	°

### Wall Loading

Surcharge on retained soil	q =	0 kPa
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### Active Earth Pressure:

$$K_a = \frac{\cos^2(\phi - \beta)}{\cos^2 \beta \cdot \cos(\delta + \beta) \cdot A^2} = 0.24$$

$$P_a = (0.5 \gamma H + q) K_a H S = 47.57 \text{ kN}$$

$$\text{Where } A = \frac{\sqrt{(\sin(f+d) \cdot \sin(f+w) + 1)}}{\cos(d+b) \cdot \cos(b-w)}$$

### Mononobe-Okabe EQ Soil Pressure

#### Seis Coefficient :

MBIE 2014 Recommendations

Zone factor

$$Z = 0.4$$

Soil Class factor

$$Ch(T) = 1.33$$

Soil Class C

Wall Displacemen factor

$$W_d = 0.3$$

Table 1, Case 6.

Seismic coefficient

$$k_h = 0.16 g$$

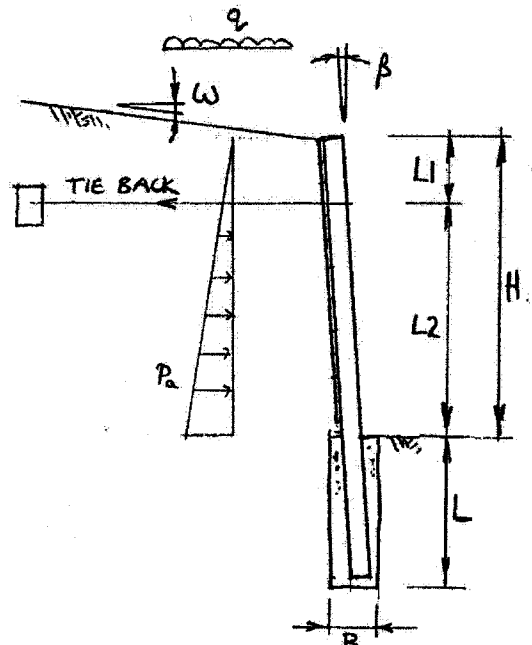
$$(\tan^{-1}(9.07^\circ))$$

$$K_{ae} = 0.34$$

$$P_{ae} = 69.17 \text{ kN}$$

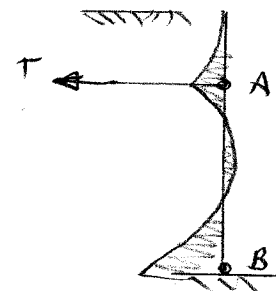
$$\text{Height of } P_{ae} \text{ above base, } H_{ae} = 1.62 \text{ m}$$

$\Delta P_{ae}$  acts 0.5H above base.



### Pole Moments

		Active $\Delta$ EQ			
Soil UDL (kN/m)	At A	5.4	5.1	1.5.Active	EQ
	At B	22.7	5.1		
Pole Moments (kNm)	At A	0.9	2.6	1.3	3.5
	At B	14.6	5.3	21.9	19.9



### Tie back Force:

	Active	$\Delta$ EQ	1.5.Active	EQ
Tension (kN)	16.3	12.5	24.4	29
Capacity of RB 16 Reid bar	= 90 kN		OK	

### Pole Embedment

Pole Embedment	L =	2.3 m	Cohesive soil: $C_u$ =	60 kPa
Hole diameter	B =	0.6 m		

Lateral pressure varies from 2  $C_u$  at the surface to 9  $C_u$  at a depth of 3 diameters. (Broms)

$$P_p = 559 \text{ kN}$$

$$\text{Overturning moment } M_b = 146 \text{ kNm}$$

$$\text{Restoring moment } M_r = \phi P_p L/3 = 214 \text{ kNm}$$

$$\phi = 0.5$$

$M_r > M_b$ , Thus embedment ok.

**Post Bending Capacity**

Pole Small End Diameter SED = 250  
Pole Dia at Embedment depth x, = 271 mm  
Bending stress fb = 38 MPa  
Section modulus Z = 1953 cm<sup>3</sup>  
k20 = 0.9  
k21 = 0.85

Capacity	Load case	k1	$\phi$ Mn	M*	
	1.5 Pa	0.6	27.3	21.9	OK
	Pae	1	45.4	19.9	OK

For Pole Height	=	4.2 m
SED	=	250 m
Embedment Depl	=	2.3 m

**Dead Man**

Depth to centre deadman Dd = 1.2 m  
Soil friction angle  $\phi$  = 32 °  
 $\delta$  = 21.3 °  
Passive pressure Kp = 7.3  
Height of anchor da = 0.4 m  
Soil density = 19 kN/m<sup>3</sup>  
Passive resistance P<sub>p</sub> = 67 kN/m  
Anchor spacing s = 1.2 m  
Capacity reduction factor = 0.5  
Dependable capacity  $\phi P_p s$  = 40 kN/anchor  
Required Anchor tension T\* = 29 OK



**RETAINING WALL -**

Posts up to 3.5m out of ground

**Wall Geometry & Loading**

Pole Height  $H_w = 3.5$  m  
Pole spacing  $S = 1.2$  m  
Distance down to tie back  $L_1 = 1$  m  
Distance from ground to tie back  $L_2 = 2.5$  m

**Backfill Soil Properties**

Soil Height  $H = 3.5$  m  
Soil Density  $\gamma = 18$  kN/m<sup>3</sup>  
Friction angle  $\phi = 32^\circ$   
Slope of wall  $\beta = -5.7^\circ$   
Fric angle soil on wall  $\delta = 21.3^\circ$   
Slope of backfill  $\omega = 0^\circ$

**Wall Loading**

Surcharge on retained soil  $q = 0$  kPa

**Active Earth Pressure:**

$$K_a = \frac{\cos^2(\phi - \beta)}{\cos^2 \beta \cdot \cos(\delta + \beta)} \cdot A^2 = 0.24$$

$$P_a = (0.5 \gamma H + q) K_a H S = 31.30 \text{ kN}$$

Where  $A = \frac{\sin(f+d) \cdot \sin(f+w) + 1}{\cos(d+b) \cdot \cos(b-w)}$

**Mononobe-Okabe EQ Soil Pressure**

Seis Coefficient : MBIE 2014 Recommendations  
Zone factor  $Z = 0.4$   
Soil Class factor  $Ch(T) = 1.33$  Soil Class C  
Wall Displacemen factor  $Wd = 0.3$  Table 1, Case 6.  
Seismic coefficient  $kh = 0.16$  g  
(  $\tan^{-1}(9.07^\circ)$  )

$K_{ae} = 0.34$   
 $P_{ae} = 45.51$  kN  
Height of  $P_{ae}$  above base,  $H_{ae} = 1.35$  m

$\Delta P_{ae}$  acts 0.5H above base.

**Pole Moments**

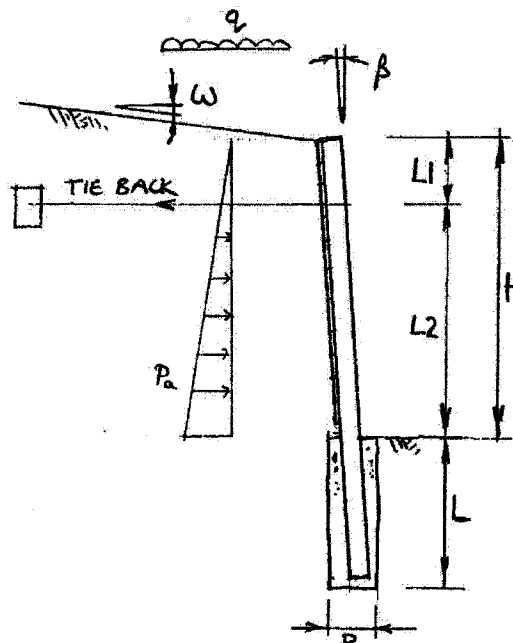
		Active $\Delta$ EQ			
Soil UDL (kN/m)	At A	5.1	4.1	1.5.Active	EQ
	At B	17.9	4.1		
		Active $\Delta$ EQ			
Pole Moments (kNm)	At A	0.9	2.0	1.3	2.9
	At B	7.1	2.2	10.7	9.3

**Tie back Force:**

	Active $\Delta$ EQ		1.5.Active	EQ
Tension (kN)	11.8	9.1	17.6	20.8
Capacity of RB 16 Reid bar	= 90 kN		OK	

**Pole Embedment**

Pole Embedment  $L = 2$  m Cohesive soil:  $C_u = 60$  kPa  
Hole diameter  $B = 0.6$  m  
Lateral pressure varies from 2  $C_u$  at the surface to 9  $C_u$  at a depth of 3 diameters. (Broms)  
 $P_p = 432$  kN  
Overturning moment  $M_b = 76.85$  kNm  
Restoring moment  $M_r = \phi P_p L/3 = 144.0$  kNm  $\phi = 0.5$   
 $M_r > M_b$ , Thus embedment ok.



**Post Bending Capacity**

Pole Small End Diameter SED = 200  
Pole Dia at Embedment depth x, = 218 mm  
Bending stress fb = 38 MPa  
Section modulus Z = 1010 cm<sup>3</sup>  
k20 = 0.9  
k21 = 0.85

Capacity	Load case	k1	$\phi$ Mn	M*	
	1.5 Pa	0.6	14.1	10.7	OK
	Pae	1	23.5	9.3	OK

For Pole Height	=	3.5 m
SED	=	200 m
Embedment Depl	=	2 m

**Dead Man**

Depth to centre deadman Dd = 1.2 m  
Soil friction angle  $\phi$  = 32 °  
 $\delta$  = 21.3 °  
Passive pressure Kp = 7.3  
Height of anchor da = 0.4 m  
Soil density = 19 kN/m<sup>3</sup>  
Passive resistance Pp = 67 kN/m  
Anchor spacing s = 1.2 m  
Capacity reduction factor = 0.5  
Dependable capacity  $\phi P_p s$  = 40 kN/anchor  
Required Anchor tension T\* = 21 OK

# POLE RETAINING WALL

Up to 3.1m High

Pole Height Hw = 3.1 m  
Pole spacing S = 1.2 m

## Backfill Soil Properties

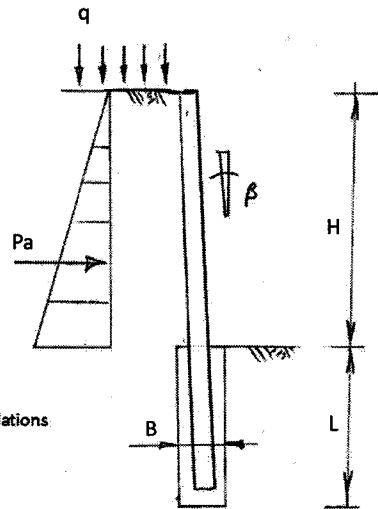
Soil Height H = 3.1 m  
Soil Density  $\gamma$  = 18 kN/m<sup>3</sup>  
Friction angle  $\phi$  = 32 °  
Slope of wall  $\beta$  = -5.7 °  
Fric angle soil on wall  $\delta$  = 21.3 °  
Slope of backfill  $\omega$  = 0 °

## Wall Loading

Surcharge on retained soil q = 0 kPa  
Seis Coefficient :  
Zone factor Z = 0.4  
Soil Class factor Ch(T) = 1  
Wall Displacemen factor Wd = 0.3  
Seismic coefficient kh = 0.12 g  
( atan(C) 6.84 ° )

MBIE 2014 Recommendations

Soil Class B  
Table 1, Case 4.



## Active Earth Pressure:

$K_a = \frac{\cos^2(f-b)}{\cos^2 b \cdot \cos(d+b) \cdot A^2}$  = 0.24  
Pa = (0.5 gH + q) Ka H S = 24.6 kN

Where  $A = \frac{\sin(f+d) \cdot \sin(f+w)}{\cos(d+b) \cdot \cos(b-w)} + 1$

## Mononobe-Okabe EQ Soil Pressure

Kae = 0.30  
Pae = 31.21 kN  
Height of Pae above base, Hae = 1.14 m  
 $\Delta$  Pae acts 0.5H above base.

## Pole Embedment

Pole Embedment L = 2.4 m  $\phi$  foundation = 45  
Hole diameter B = 0.6 m  
Passive pressure Kp =  $\frac{1+\sin \phi}{1-\sin \phi}$  = 5.83  
Pp = 0.5 · 3Kp g B L<sup>2</sup> = 543.8 kN (Broms)  
Overturning moment Mo  
Due to 1.5Pa = 1.5 Pa (H/3 + L) = 126 kNm  
Due to Pae = Pae (H/2 + L) = 123 kNm  
Restoring moment Mr =  $\phi$  Pp L/3 = 218 kNm f = 0.5  
Mr > Mo, Thus embedment ok.

## Pole Bending Moment

Moment at ground level Mg = Pa · H/3 = 25.4 kNm  
Depth to max moment x = 0.10 m  
Max. Moment (@ depth x) Mmax = 27.8 kNm  
M\* = 1.5 Mmax = 41.7 kNm  
EQ Moment due to Pae = 35.3 kNm

## Pole Bending Capacity

Bending Capacity  $\phi$  Mn =  $\phi$  fb Z k1 k20 k21  
Pole Small End Diameter SED = 300  
Pole Dia at Embedment depth x, D = 316 mm  
Bending stress fb = 38 MPa  
Section modulus Z = 3096 cm<sup>3</sup>  
k20 = 0.9  
k21 = 0.85

Load Case	k1	$\phi$ Mn	M*	
1.5 Pa	0.6	43.2	41.7	OK
Pae	1	72.0	35.3	OK

For Pole Height	=	3.1 m
SED	=	300 mm
Embedment Depth	=	2.4 m

**POLE RETAINING WALL**

Pole Height  $H_w = 2.6$  m  
Pole spacing  $S = 1.2$  m

**Backfill Soil Properties**

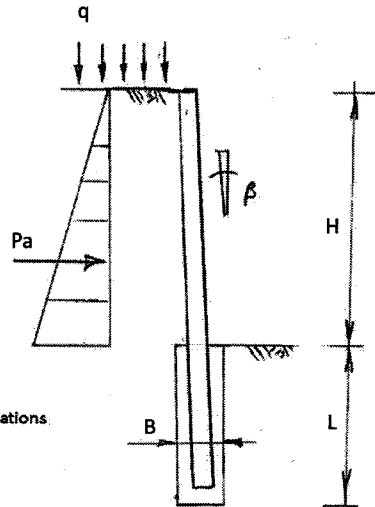
Soil Height  $H = 2.6$  m  
Soil Density  $\gamma = 18$  kN/m<sup>3</sup>  
Friction angle  $\phi = 32^\circ$   
Slope of wall  $\beta = -5.7^\circ$   
Fric angle soil on wall  $\delta = 21.3^\circ$   
Slope of backfill  $\omega = 0^\circ$

**Wall Loading**

Surcharge on retained soil  $q = 0$  kPa  
Seis Coefficient :  
Zone factor  $Z = 0.4$   
Soil Class factor  $Ch(T) = 1$   
Wall Displacemen factor  $Wd = 0.3$   
Seismic coefficient  $kh = 0.12$  g  
(atan(C)  $6.84^\circ$ )

MBIE 2014 Recommendations

Soil Class B  
Table 1, Case 4.



**Active Earth Pressure:**

$$K_a = \frac{\cos^2(f-b)}{\cos^2 b \cdot \cos(d+b) \cdot A^2} = 0.24$$

$$P_a = (0.5 gH + q) K_a H S = 17.3 \text{ kN}$$

Where  $A = \frac{\sqrt{\sin(f+d) \cdot \sin(f+w)}}{\cos(d+b) \cdot \cos(b-w)} + 1$

**Mononobe-Okabe EQ Soil Pressure**

$K_{ae} = 0.30$   
 $P_{ae} = 21.95$  kN  
Height of  $P_{ae}$  above base,  $H_{ae} = 0.96$  m  
 $\Delta P_{ae}$  acts  $0.5H$  above base.

**Pole Embedment**

Pole Embedment  $L = 2$  m  
Hole diameter  $B = 0.6$  m  
Passive pressure  $K_p = \frac{1+\sin \phi}{1-\sin \phi} = 5.83$   
 $P_p = 0.5 \cdot 3K_p g B L^2 = 377.6$  kN (Broms)  
Overturning moment  $M_o$   
Due to  $1.5P_a = 1.5 P_a (H/3 + L) = 74$  kNm  
Due to  $P_{ae} = P_{ae} (H/2 + L) = 72$  kNm  
Restoring moment  $M_r = \phi P_p L/3 = 126$  kNm  
 $f = 0.5$   
 $M_r > M_o$ , Thus embedment ok.

**Pole Bending Moment**

Moment at ground level  $M_g = P_a \cdot H/3 = 15.0$  kNm  
Depth to max moment  $x = 0.10$  m  
Max. Moment (@ depth  $x$ )  $M_{max} = 16.7$  kNm  
 $M^* = 1.5 M_{max} = 25.0$  kNm  
EQ Moment due to  $P_{ae} = 21.2$  kNm

**Pole Bending Capacity**

Bending Capacity  $\phi M_n = \phi f_b Z k_1 k_{20} k_{21}$   
Pole Small End Diameter  $SED = 250$   
Pole Dia at Embedment depth  $x$ ,  $D = 264$  mm  
Bending stress  $f_b = 38$  MPa  
Section modulus  $Z = 1795$  cm<sup>3</sup>  
 $k_{20} = 0.9$   
 $k_{21} = 0.85$

Load Case	k1	$\phi M_n$	$M^*$	
1.5 Pa	0.6	25.1	25.0	OK
Pae	1	41.8	21.2	OK

For Pole Height	=	2.6 m
SED	=	250 mm
Embedment Depth	=	2 m

**POLE RETAINING WALL**

Pole Height  $H_w = 2.0$  m  
Pole spacing  $S = 1.2$  m

**Backfill Soil Properties**

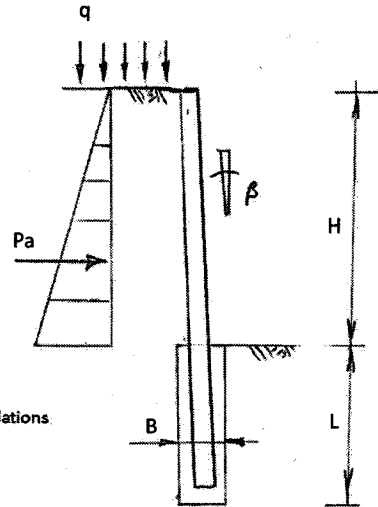
Soil Height  $H = 2.0$  m  
Soil Density  $\gamma = 18$  kN/m<sup>3</sup>  
Friction angle  $\phi = 32^\circ$   
Slope of wall  $\beta = -5.7^\circ$   
Fric angle soil on wall  $\delta = 21.3^\circ$   
Slope of backfill  $\omega = 0^\circ$

**Wall Loading**

Surcharge on retained soil  $q = 0$  kPa  
Seis Coefficient :  
Zone factor  $Z = 0.4$   
Soil Class factor  $Ch(T) = 1$   
Wall Displacemen factor  $Wd = 0.3$   
Seismic coefficient  $kh = 0.12$  g  
(atan(C)  $6.84^\circ$ )

MBIE 2014 Recommendations

Soil Class B  
Table 1, Case 4.



**Active Earth Pressure:**

$K_a = \frac{\cos^2(f-b)}{\cos^2 b \cdot \cos(d+b) \cdot A^2} = 0.24$  Where  $A = \frac{\sqrt{\sin(f+d) \cdot \sin(f+w)}}{\cos(d+b) \cdot \cos(b-w)} + 1$   
 $Pa = (0.5 gH + q) K_a H S = 10.2$  kN

**Mononobe-Okabe EQ Soil Pressure**

$K_{ae} = 0.30$   
 $P_{ae} = 12.99$  kN  
Height of  $P_{ae}$  above base,  $H_{ae} = 0.74$  m  $\Delta P_{ae}$  acts  $0.5H$  above base.

**Pole Embedment**

Pole Embedment  $L = 1.5$  m  $\phi$  foundation = 45  
Hole diameter  $B = 0.6$  m  
Passive pressure  $K_p = \frac{1+\sin \phi}{1-\sin \phi} = 5.83$   
 $P_p = 0.5 \cdot 3K_p g B L^2 = 212.4$  kN (Broms)  
Overturning moment  $M_o$   
Due to  $1.5Pa = 1.5 Pa (H/3 + L) = 33$  kNm  
Due to  $P_{ae} = P_{ae} (H/2 + L) = 32$  kNm  
Restoring moment  $M_r = \phi P_p L/3 = 53$  kNm  $f = 0.5$   
 $M_r > M_o$ , Thus embedment ok.

**Pole Bending Moment**

Moment at ground level  $M_g = Pa \cdot H/3 = 6.8$  kNm  
Depth to max moment  $x = 0.10$  m  
Max. Moment (@ depth x)  $M_{max} = 7.8$  kNm  
 $M^* = 1.5 M_{max} = 11.7$  kNm  
EQ Moment due to  $P_{ae} = 9.9$  kNm

**Pole Bending Capacity**

Bending Capacity  $\phi M_n = \phi f_b Z k_1 k_{20} k_{21}$   
Pole Small End Diameter SED = 200  
Pole Dia at Embedment depth x, D = 211 mm  
Bending stress  $f_b = 38$  MPa  
Section modulus  $Z = 915$  cm<sup>3</sup>  
 $k_{20} = 0.9$   
 $k_{21} = 0.85$

Load Case	k1	$\phi M_n$	M*	
1.5 Pa	0.6	12.8	11.7	OK
Pae	1	21.3	9.9	OK

For Pole Height	=	2 m
SED	=	200 mm
Embedment Depth	=	1.5 m