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Project			
32 TORRINGTON SQUARE			
Part of structure			
SHEET PILE RETAINING WALL			
Date		Job number	
17.07.2017		J2889	
Engineer	Checked by	Checked date	Sheet number
CP			1

RETAINING WALL - INPUT DATA TO FREW

- MADE GROUND: E = 5000 kPa
- LYNCH HILL GRAVEL: E = 16 000 kPa
- LONDON CLAY: E = Cu x 600 + GRADIENT x Z
  = 45000 kN/m² + 6000 kN/m²/m.

ALLOWANCE FOR 10 kN/m² SURCHARGE (TORRINGTON SQ).

ALLOWANCE FOR GROUND WATER LEVEL 1,0m BGL.

STIFFNESS OF PERM. PROP (SCAFS):

(A x E) / L = (250 mm x 1000 mm x 28000 MPa) / 1500 mm/m

= 466,666 kN/m/m

@ +21,50 & +26.00 (LEVELS).

SHEET PILE DIMENSION ASSUMED:

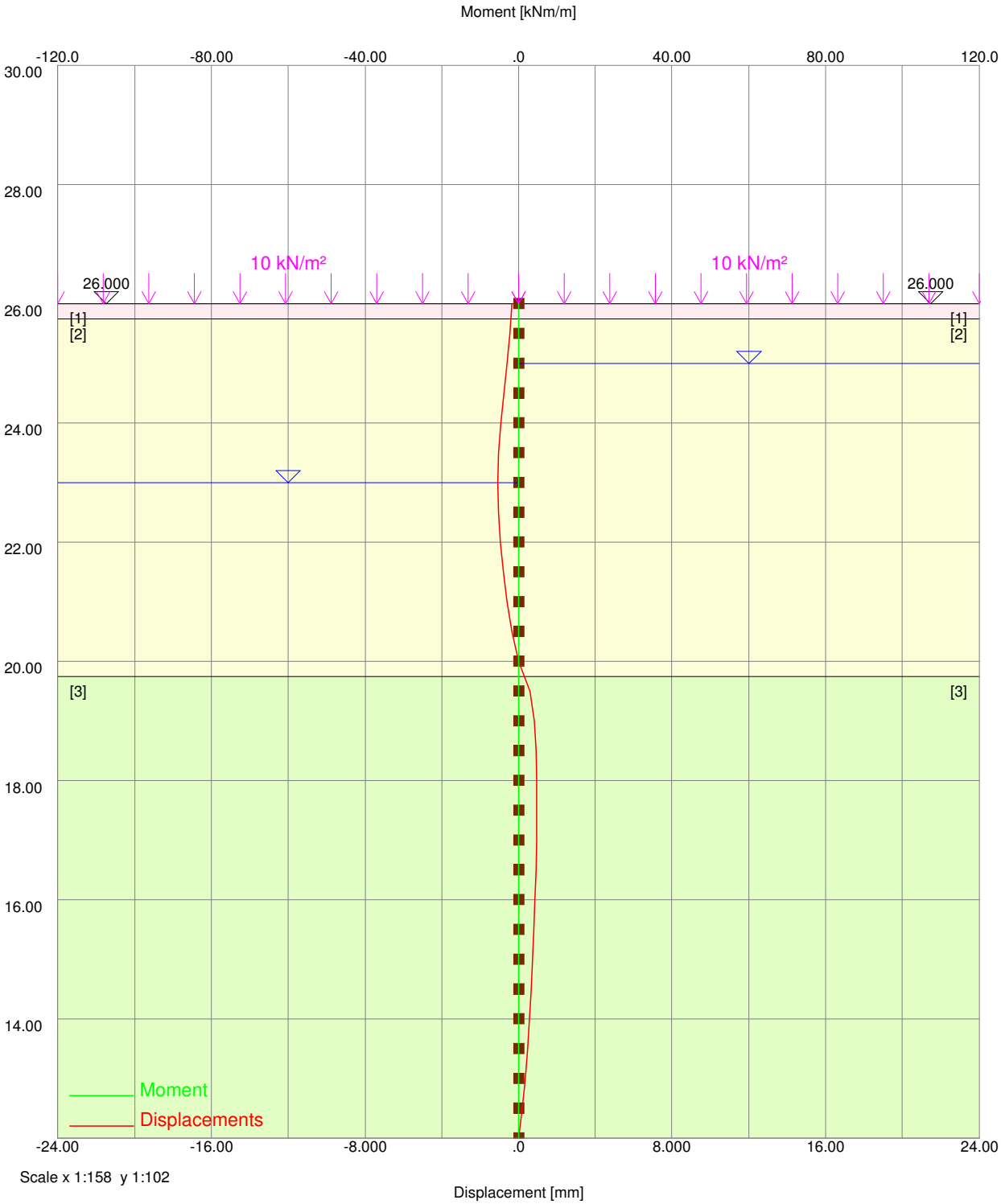
$I_y = 63840 \times 10^4 mm^4/m$ (53,4 kg/m)

$E = 0,205 \times 10^6$ MPa

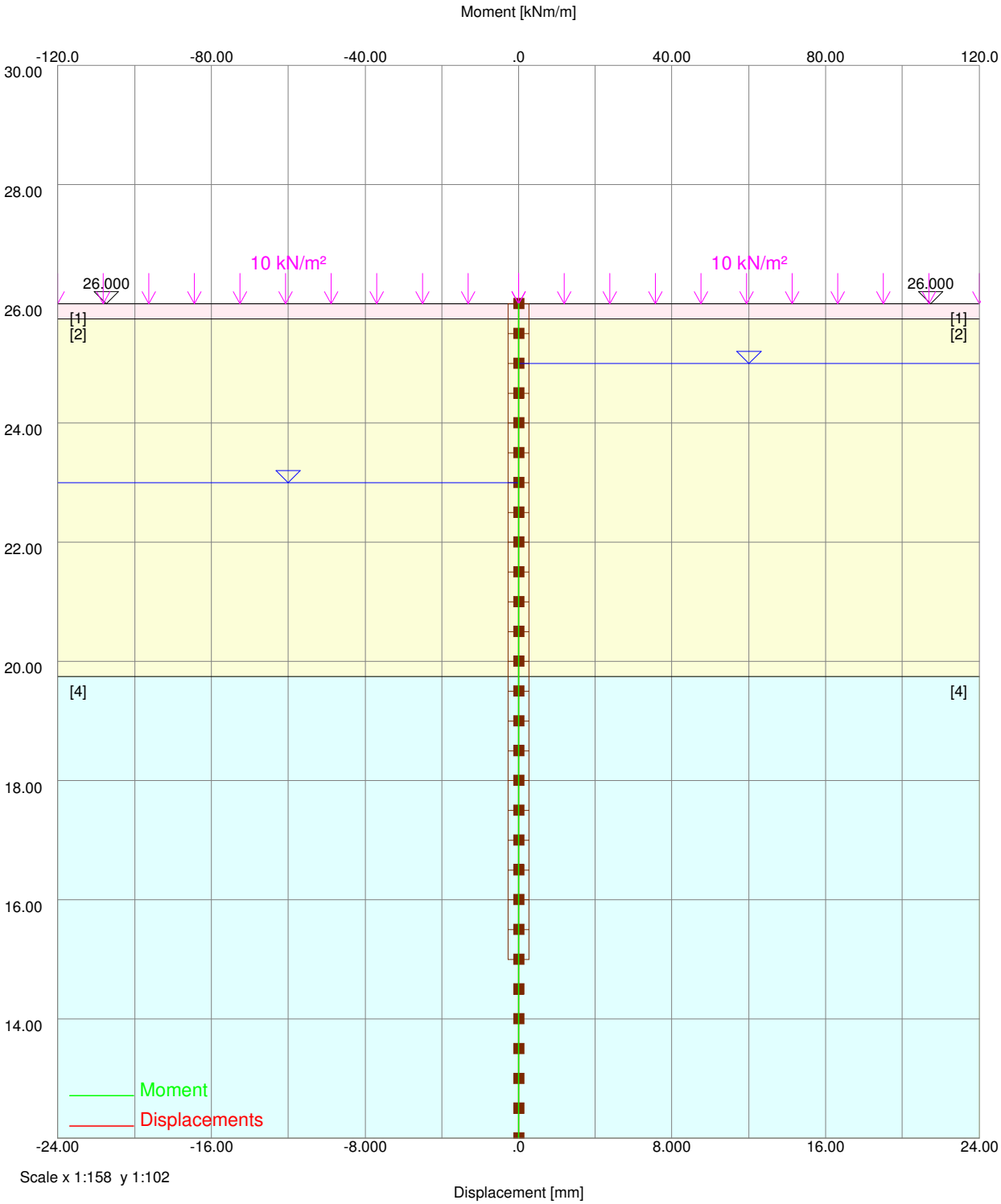
$EI = 63840 \times 0,205 \times 10$
$= 130872$ kNm²/m

HALF SHEET PILES EXTENDED INTO CLAY:

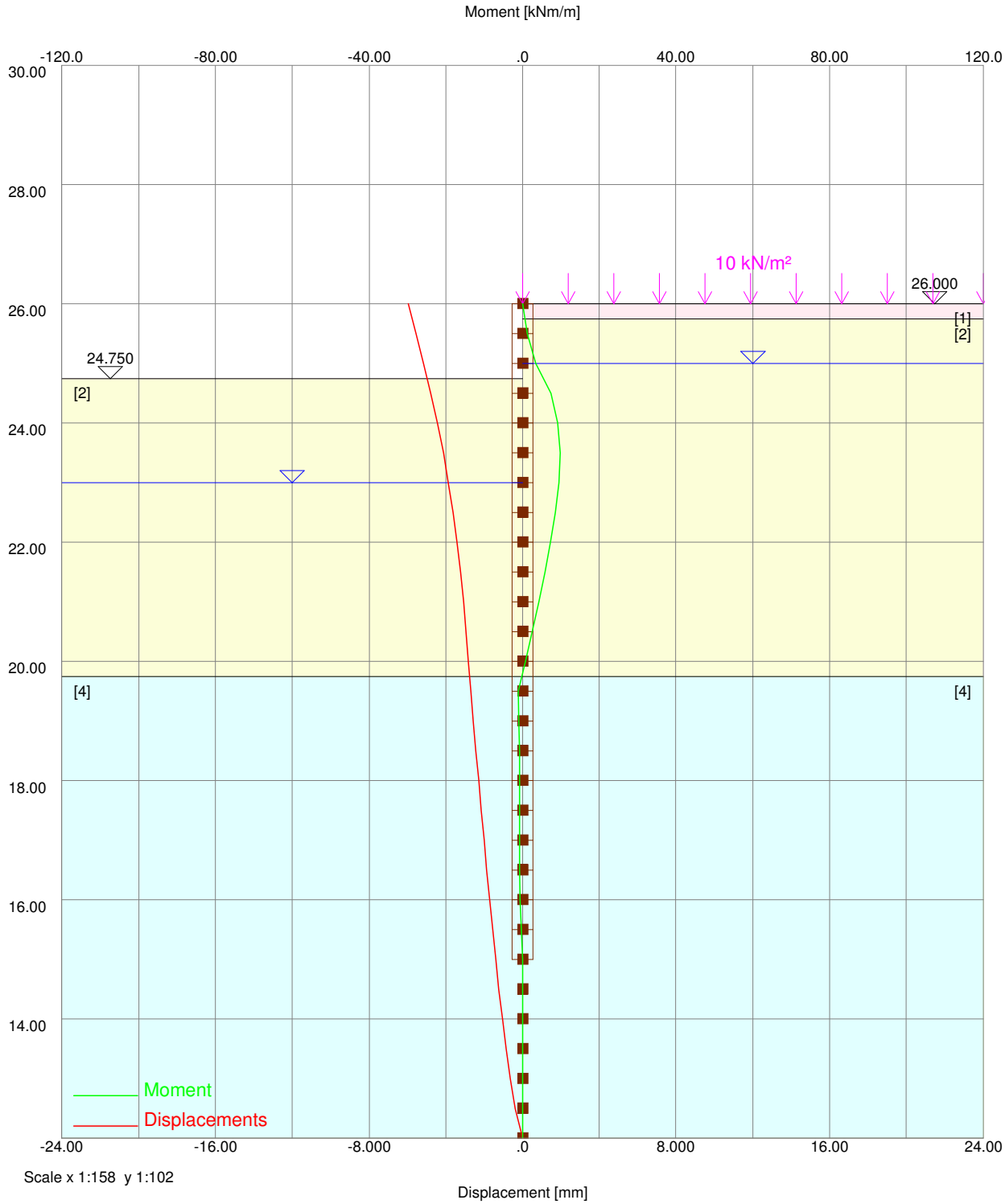
$EI = 0,5 \times 130872$ kNm²/m = 65436 kNm²/m



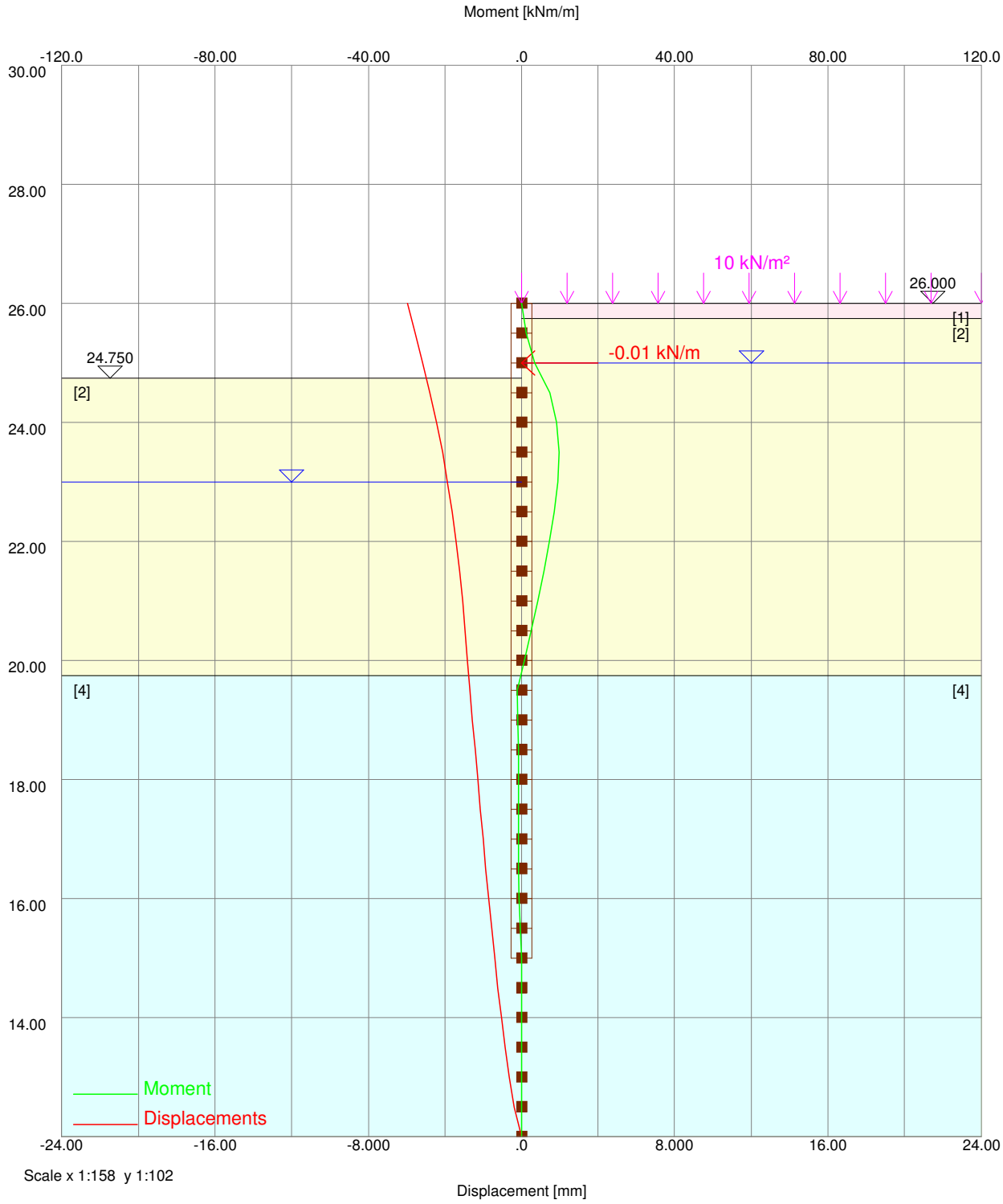
STAGE 0 : Initial condition



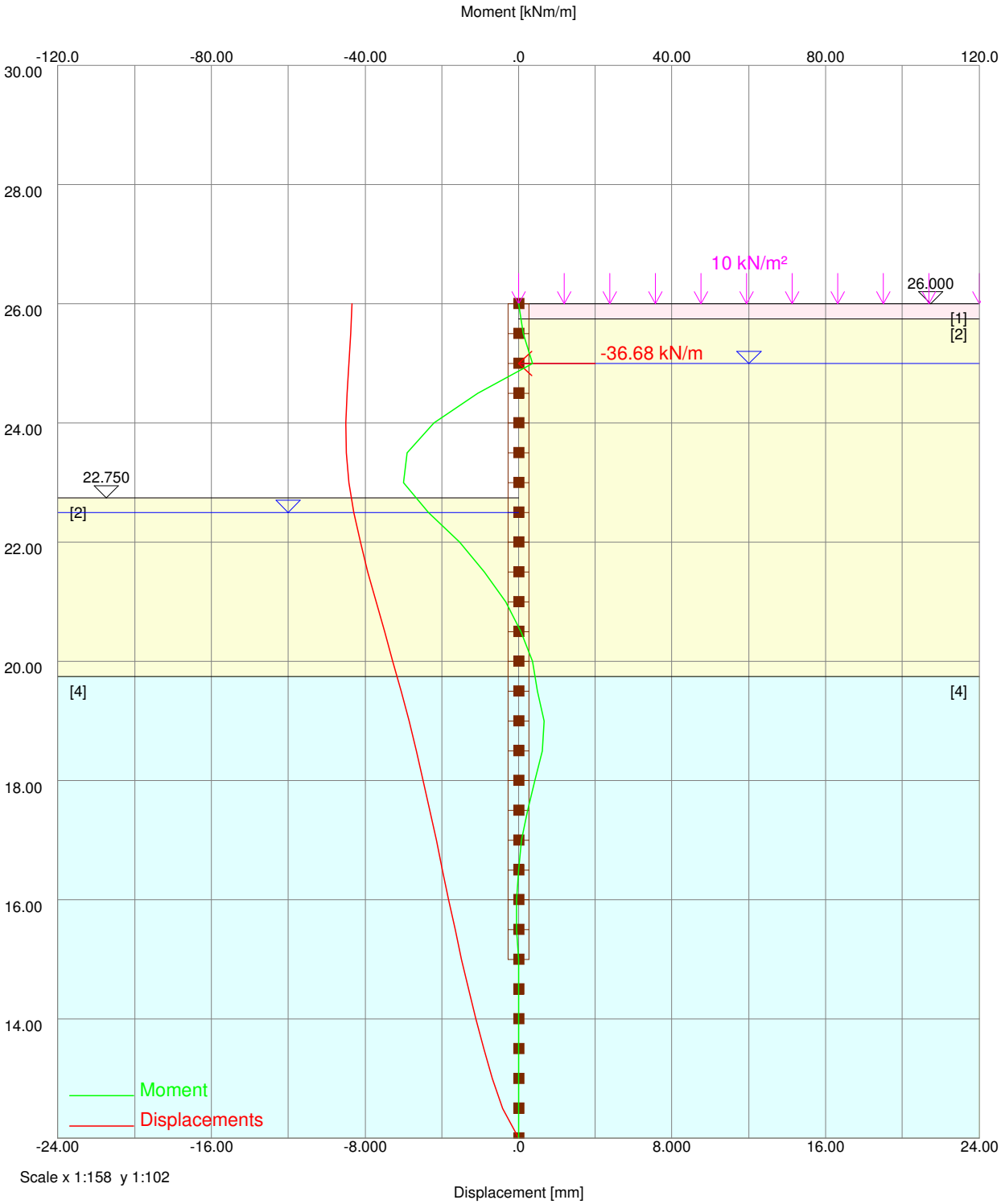
STAGE 1 : Install wall



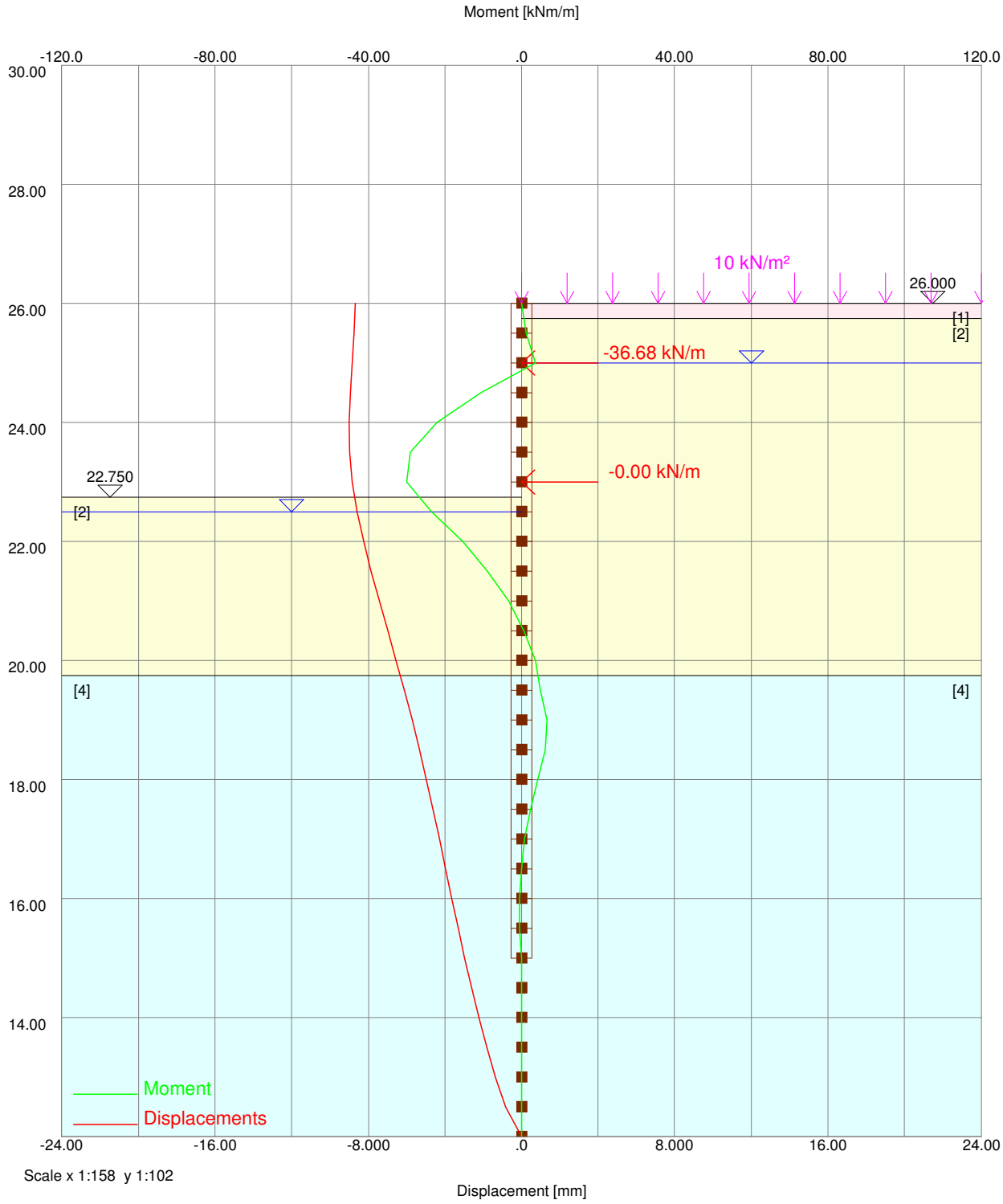
STAGE 2 : Excavate to -1.0m



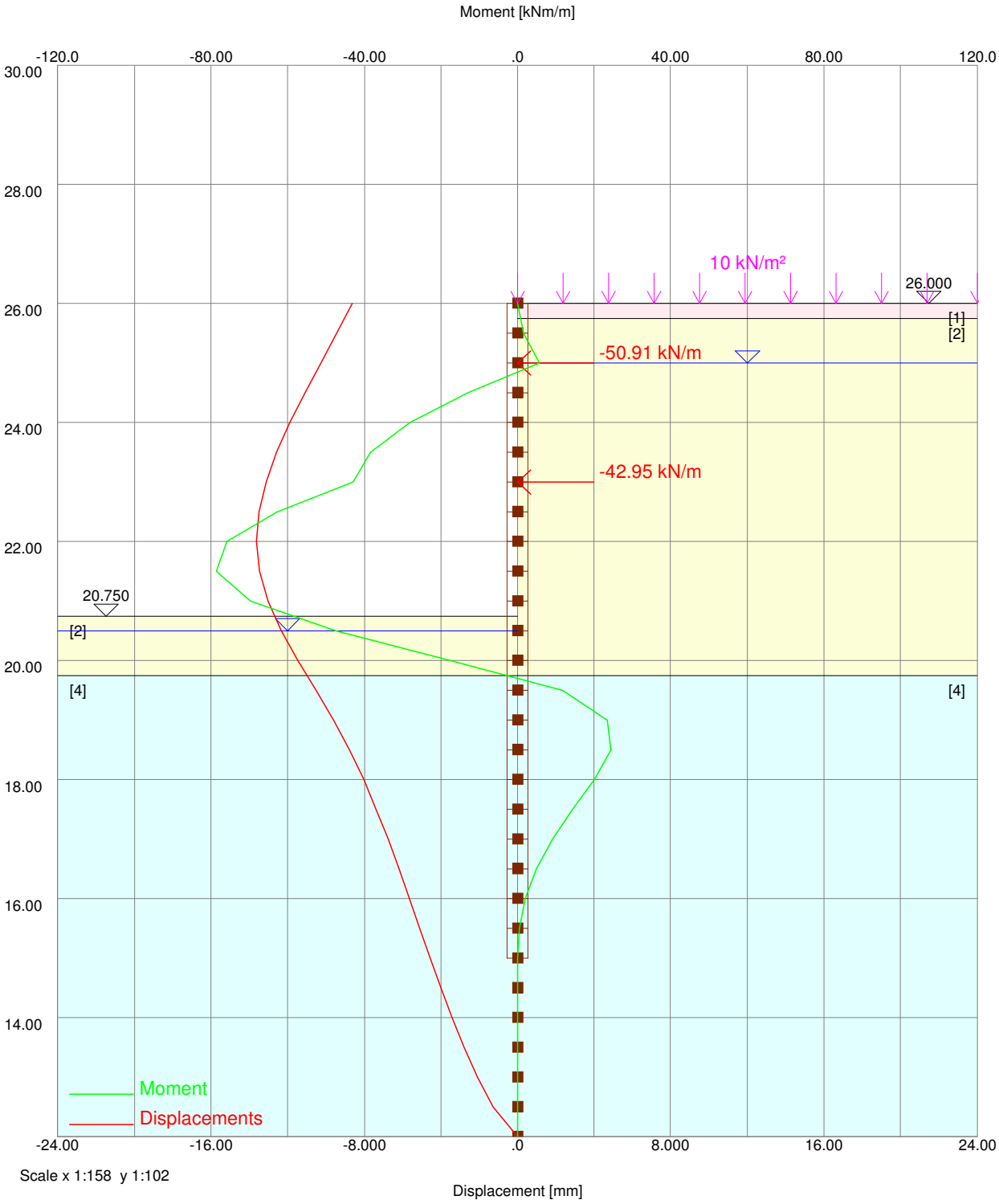
STAGE 3 : Install temporary props at -1.0m



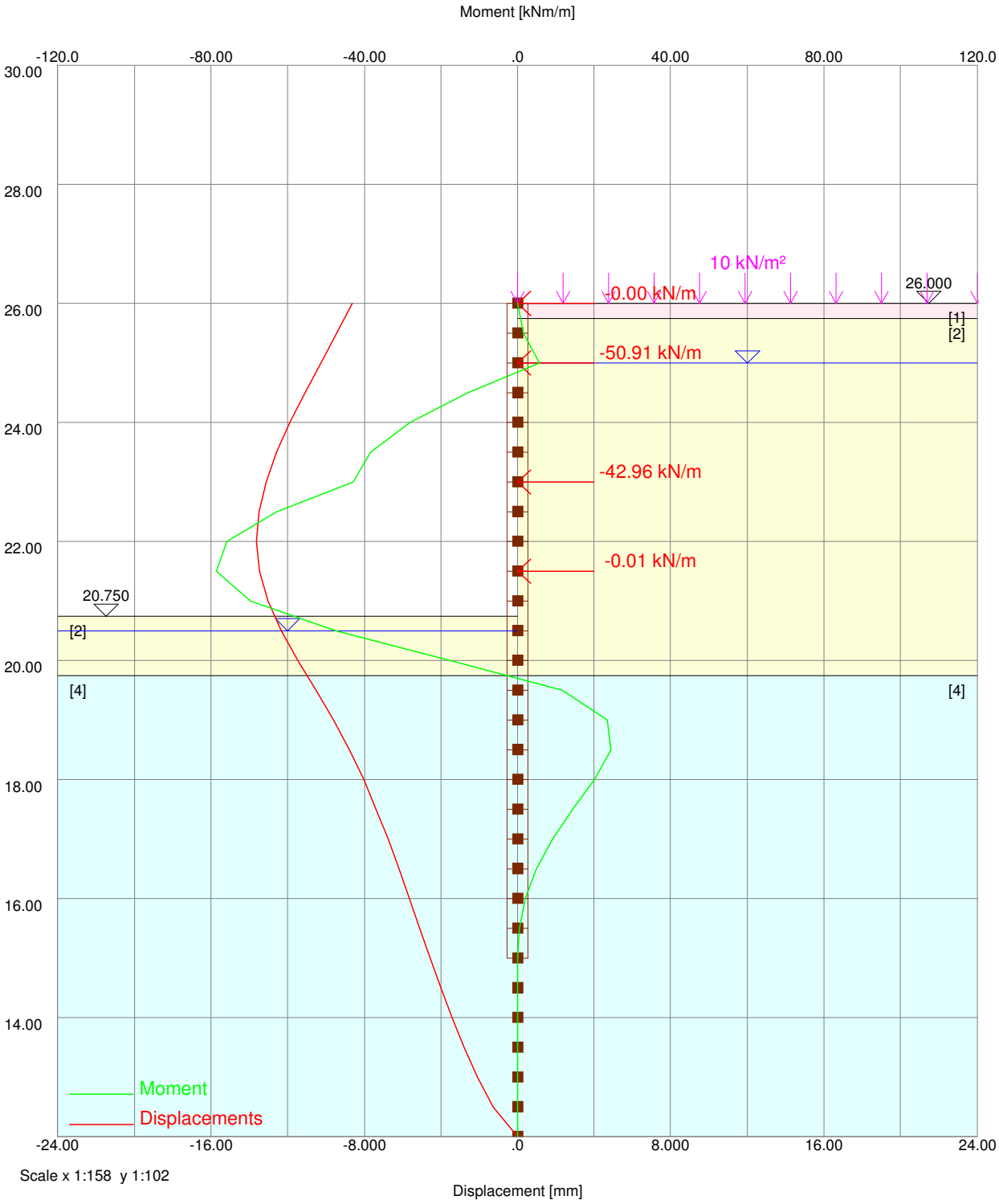
STAGE 4 : Excavate to -3.0m



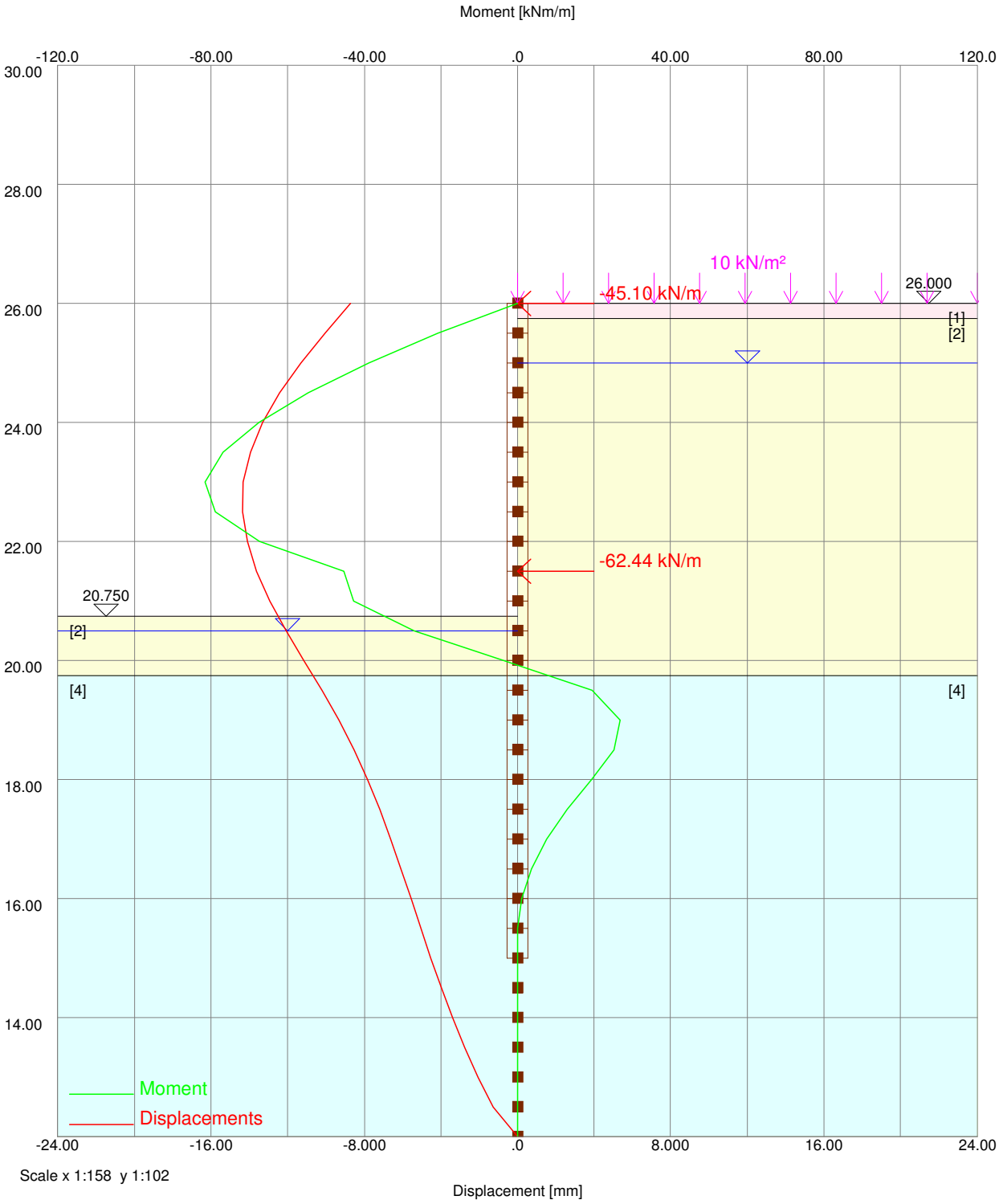
STAGE 5 : Install prop at lower level



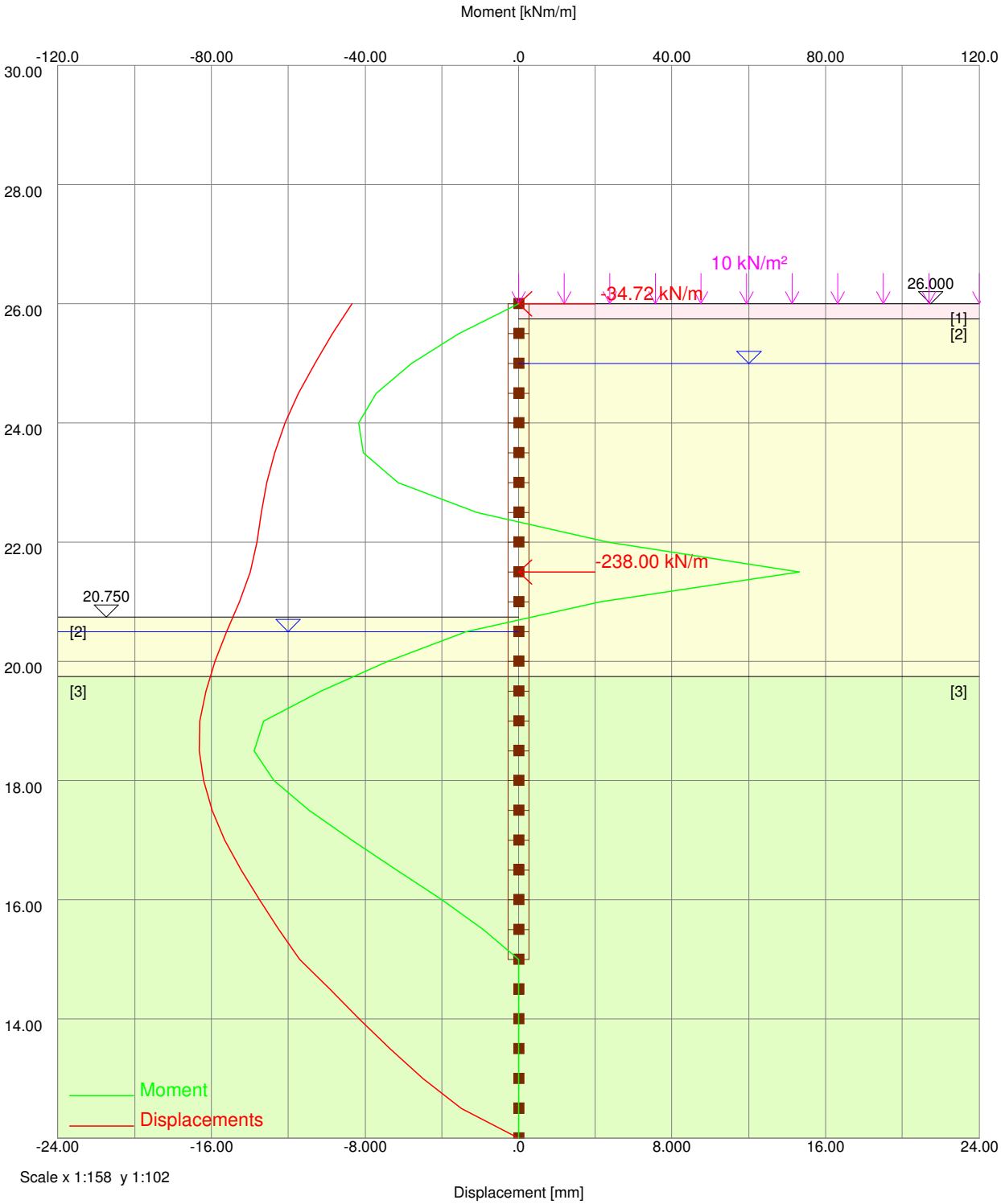
STAGE 6 : Excavate to final level 21.00



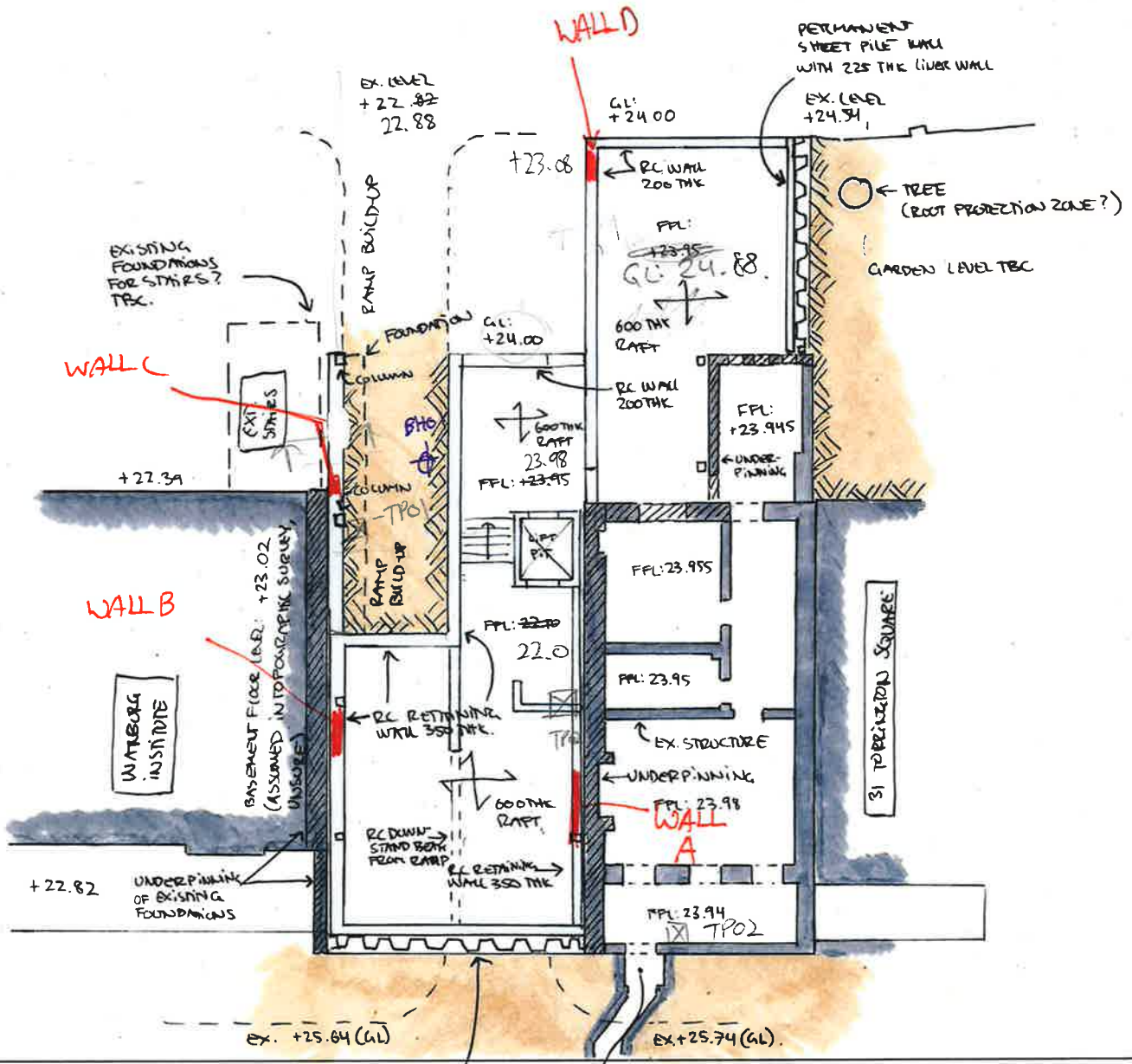
STAGE 7 : Install basement box (permanent props)



STAGE 8 : Remove temporary props



STAGE 9 : Undrained permanent condition



NOTE

- SITE BOUNDARY TBC
- EXISTING LEVELS TBC (BASED ON SEVERAL SURVEYS).
- LEVELS ARE BASED ON
  - TOPOGRAPHIC SURVEY BY GREENWITCH GROUP DATED 06.11.2013
  - BUILDING SURVEY OF 32 TORRINGTON SQUARE (4103) BY RANDALL SURVEYS DATED 13.12.2016
- BASED ON ASSUMPTIONS ON EXISTING GROUND & SOIL PARAMETERS, TBC FOLLOWING GEOTECHNICAL SURVEY.

KEY

- EXISTING STRUCTURE
- UNDERPINNING EXISTING STRUCTURE
- NEW RC WALLS OR RC RETAINING WALLS
- PERMANENT SHEET PILE WALL
- SOIL / GROUND TO BE RETAINED

SERVICES (EXISTING)

- EXISTING ABOVE GROUND SERVICES ARE ASSUMED TO BE REROUTED
- FULL SURVEY OF BELOW GROUND SERVICES PRIOR TO CONSTRUCTION TO AVOID DAMAGE.

! ALL UNDERPINNING OF EXISTING WALLS TO BE CONSTRUCTED IN TRADITIONAL HIT & MISS FASHION

! RC RETAINING WALLS ALONG UNDERPINS OF EXISTING STRUCTURES TO BE CAST IN TRADITIONAL HIT & MISS FASHION

! UNDERPINNING OF ALL EXISTING WALLS MAY

PERMANENT SHEETPILE WITH 225 THK LINER WALL

FLOOR LEVEL IN ENTRANCE TO HEATING CHAMBER: FL: 23.54

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Drawing No: 32889 -S-SK-0009			
Project: TORRINGTON SQUARE		Status: INFORMATION	
Drawing Title: INITIAL BASEMENT LAYOUT			
Date: 10.04.2017	Drawn by: CP	Scale: NTS	Revision: 01

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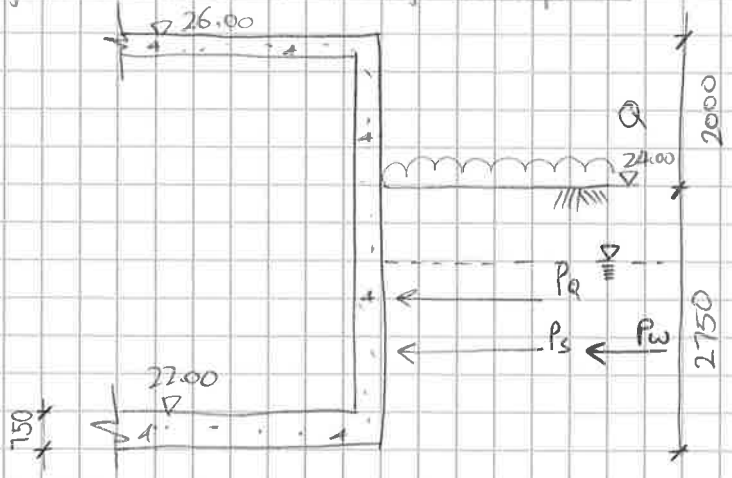
Project	Torrington Square		
Part of structure	Basement wall A		
Date	22.06.2017	Job number	J2889
Engineer	Checked by	Checked date	Sheet number
GW			1

Retaining wall adjacent to 32 Torrington Square



Assumptions

Soil properties: Gravel

friction angle ϕ: 30°

Bulk density, δ_s: 20 kN/m³

Cover, mm: 50 mm
Cover, def: 10 mm

Horizontal bars, ϕ_h: 10 mm
Vertical bars, ϕ_v: 16 mm

f_{ck}: 30 MPa
f_{yk}: 500 MPa

Water table at 1.0m below neighbour G.L

$$k_a = \frac{1-\sin\phi}{1+\sin\phi}$$

$$= \frac{1-\sin 30}{1+\sin 30} = 0.33$$

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Project			
Torrington Square			
Part of structure			
Basement wall A			
Date		Job number	
22.06.2017		J2889	
Engineer	Checked by	Checked date	Sheet number
GW			2

$P_s = K_a \times \gamma_s \times \frac{(H-1.0m)^2}{2}$ (above water table)

$= 0.33 \times 20 \times \frac{1.0^2}{2}$

$= 3.3$ kN/m

$P_s = K_a \times (\gamma_s - \gamma_w) \times \frac{(H-1)^2}{2}$ (below water table)

$= 0.33 \times (20-10) \times \frac{2.75^2}{2}$

$= 12.5$ kN/m

$P_q = K_a \times Q \times H$

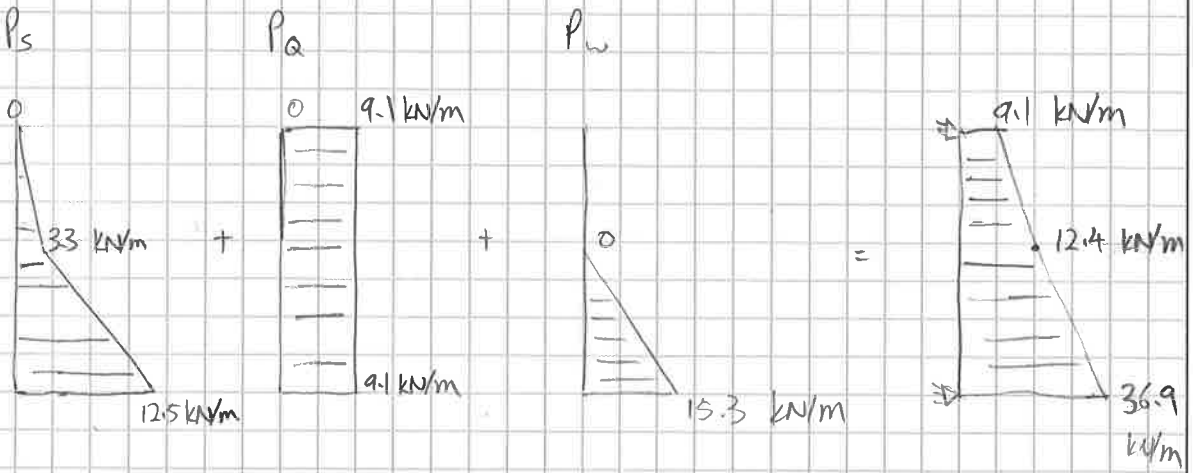
$= 0.33 \times 10\ kN/m^2 \times 2.75m$

$= 9.1$ kN/m

$P_w = \gamma_w \times \frac{(H-1.0m)^2}{2}$

$= 10\ kN/m^3 \times \frac{(2.75-1.0m)^2}{2}$

$= 15.3$ kN/m



Total wall height = 4.75m

wall thickness = 250mm

Since top and bottom of wall are propped, wall is modelled as a simply supported beam

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Project			
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Part of structure			
Basement wall A			
Date		Job number	
22.06.2017		J2889	
Engineer	Checked by	Checked date	Sheet number
GW			3.

Moment from GSA 8.7 = 79.9 kNm

Deflection from GSA 8.7 = 3.0 mm

$$K = \frac{M}{b h^2 f_{ck}}$$

$$= \frac{79.9 \times 10^6}{1000 \times 258^2 \times 30} = 0.0426$$

$$Z = (250 - 50 - 10 - 10 - \frac{16}{2}) \times (0.5 + \sqrt{0.25 - \frac{0.0426}{1.134}} = 165 \text{ mm}$$

$$A_{s,req} = \frac{M}{0.87 \cdot f_{yk} \times Z}$$

$$= \frac{79.9 \times 10^6}{0.87 \times 500 \text{ N/mm}^2 \times 165 \text{ mm}} = 1111 \text{ mm}^2/\text{m}$$

H16 @ 200 mm c/s. provides 1206 mm²/m

δ = 30 mm = $\frac{4750}{3.0}$ = $\frac{\text{Span}}{1583}$ ∴ OKAY.

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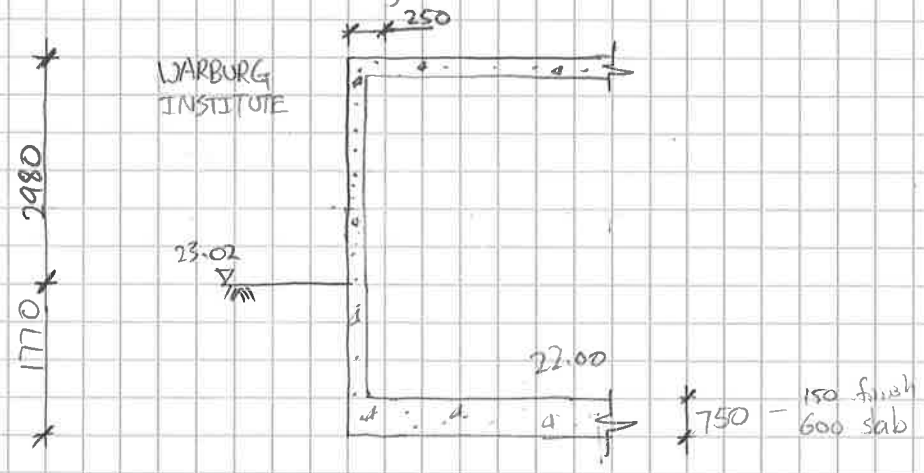
Project	Torrington Square		
Part of structure	Basement Wall B		
Date	22.06.2017	Job number	J2889
Engineer	Checked by	Checked date	Sheet number
GW			1

Retaining wall adjacent to Warburg Institute



Assumptions :

Soil properties - Gravel
friction angle, ϕ = 25°
Bulk density, γ_s = 20 kN/m³

Cover, min = 50mm
Cover, dev = 10mm

Horizontal bar, ϕ_h = 10mm
Vertical bar, ϕ_v = 16mm

fck = 30 MPa
fyk = 500 MPa

Water table at 1.0m below Warburg Institute GL.

$$k_a = \frac{1+\sin\phi}{1+\sin\phi}$$

$$= \frac{1-\sin 30}{1+\sin 30} = 0.33$$

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Project	Torrington Square		
Part of structure	Basement wall B		
Date	22.06.2017	Job number	J2889
Engineer	Checked by	Checked date	Sheet number
GW			2

$P_s = K_a \times \gamma_s \times \frac{(H=1.0m)^2}{2}$

$= 0.33 \times 20 kN/m^3 \times \frac{1.0^2}{2}$

above water table

$= 3.3 kN/m$

$P_s = K_a \times (\gamma_s - \gamma_w) \times \frac{H^2}{2}$

$= 0.33 \times (20-10) \times \frac{1.77m^2}{2}$

below water table

$= 5.2 kN/m$

$P_q = K_a \times Q \times H$

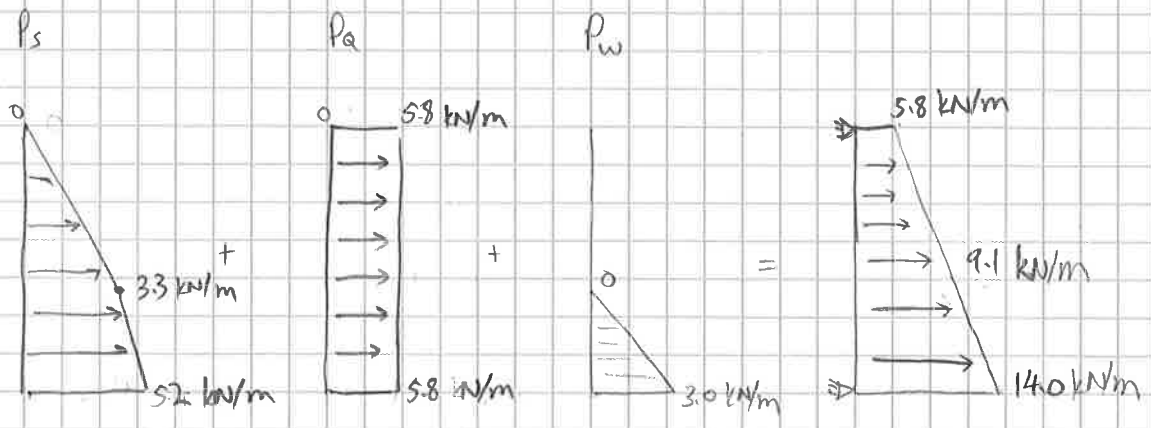
$= 0.33 \times 10 kN/m^2 \times 1.77m$

$= 5.8 kN/m$

$P_w = \gamma_w \times \frac{(H-1.0)^2}{2}$

$= 10 kN/m^3 \times \frac{(1.77-1.0)^2}{2}$

$= 3.0 kN/m$



Total wall height = 4.75 m

Wall thickness = 250 mm

Since top and bottom are propped, wall is modelled as a simply supported beam.

* Refer to "Basement wall A" - By inspection wall section OKAY.

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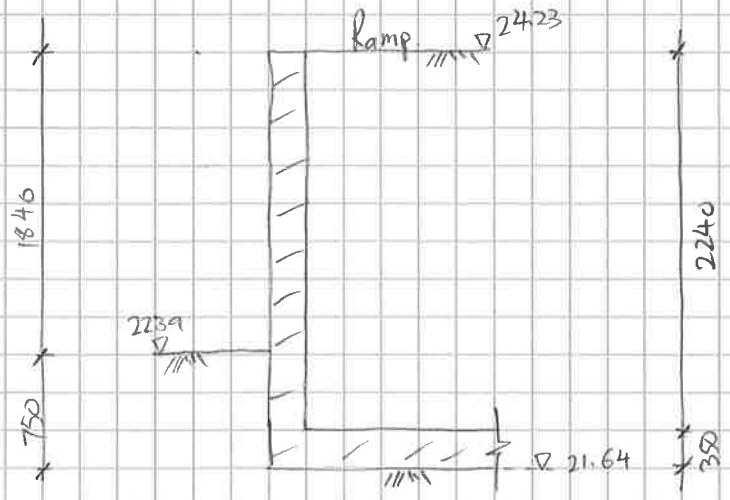
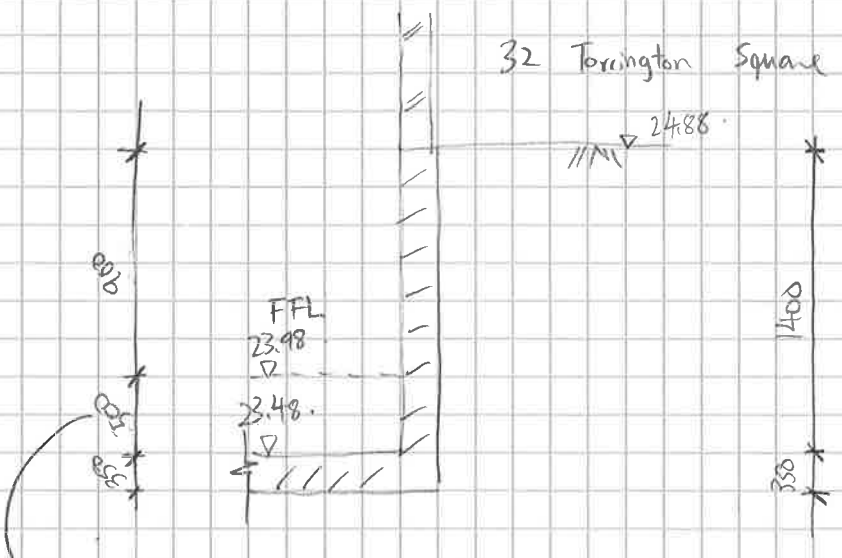
Project			
Torrington Square.			
Part of structure			
Basement wall C			
Date		Job number	
22.06.2017		J2889	
Engineer	Checked by	Checked date	Sheet number
GW			1

Wall height comparison : Between warburg institute side and 32 Torrington square side.



* worst case



500mm allowance for ground bearing slab + finish

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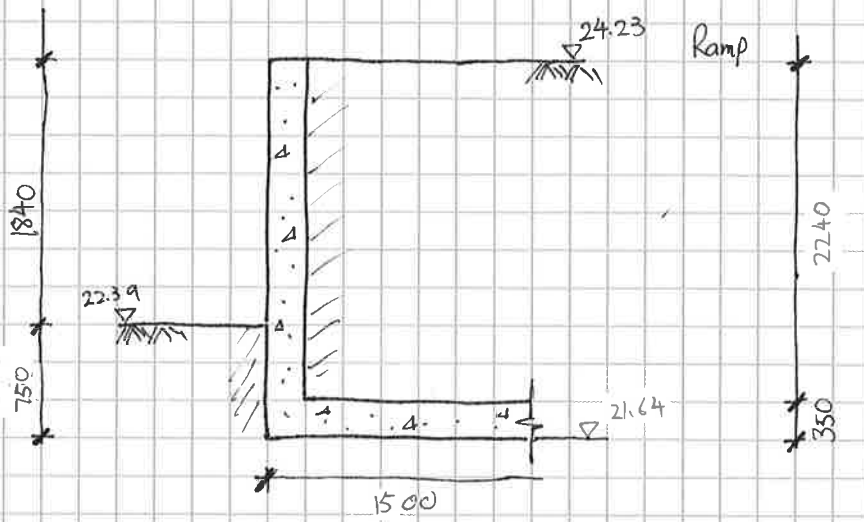
Project	Torrington Square		
Part of structure	Basement wall C		
Date	22.06.2017	Job number	J2889
Engineer	Checked by	Checked date	Sheet number
GW			2

Retaining wall between the ramp and Warburg Institute



Assumptions :

Soil properties	:	Gravel
friction angle	:	30°
Bulk density	:	20 kN/m³
Cover, nm	:	50 mm
Cover, dev	:	10 mm
Horizontal bar, ϕ_h	=	10 mm
Vertical bar, ϕ_v	=	16 mm
fck	=	30 MPa
fyk	=	500 MPa

Water table at 1.0m below 24.23m.

$$K_a = \frac{1 - \sin\phi}{1 + \sin\phi}$$

$$= \frac{1 - \sin 30}{1 + \sin 30} = 0.33$$

$$K_p = 1/K_a = 3.0$$

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Part of structure	Basement wall C		
Date	22.06.2017	Job number	J2889
Engineer	Checked by	Checked date	Sheet number
GW			3

$P_s = K_a \times \gamma_s \times \frac{(H - 1.0m)^2}{2}$

$= 0.33 \times 20\,kN/m^3 \times \frac{1.0^2}{2}$

(above water table)

$= 3.3\ kN/m$

$P_s = K_a \times (\gamma_s - \gamma_w) \times \frac{H^2}{2}$

$= 0.33 \times (20-10) \times \frac{2.24m^2}{2}$

(below water table)

$= 11.2\ kN/m$

$P_q = K_a \times Q \times H$

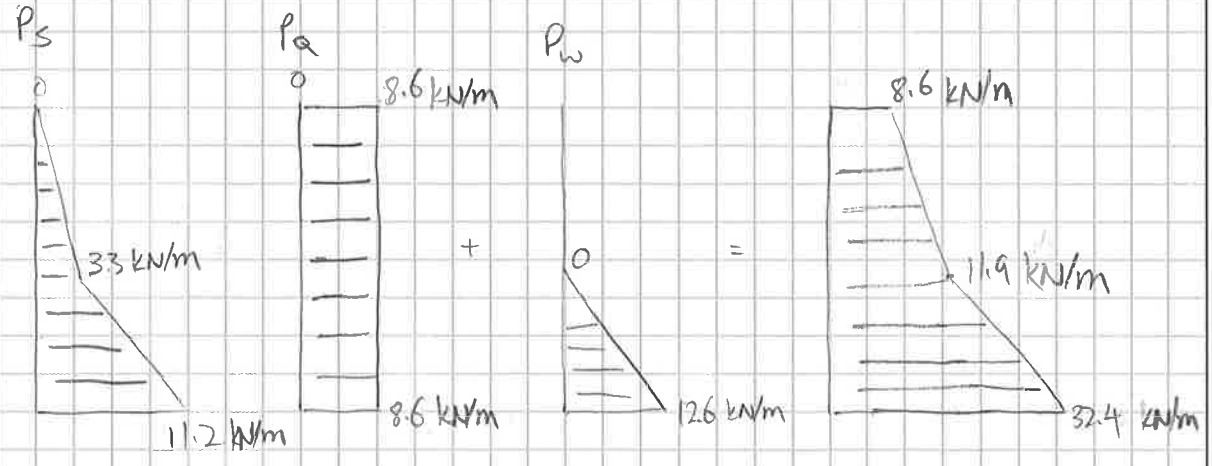
$= 0.33 \times 10\,kN/m^2 \times 2.24m$

$= 8.6\ kN/m$

$P_w = \gamma_w \times \frac{(H - 1.0)^2}{2}$

$= 10\,kN/m^3 \times \frac{(2.24m - 1.0)^2}{2}$

$= 12.6\ kN/m$



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Project	Torrington Square		
Part of structure	Basement wall C		
Date	04.07.2017	Job number	J2889
Engineer	Checked by	Checked date	Sheet number
GW			4

Passive Pressure

$P_{as} = k_p \times \gamma_s \times \frac{H^2}{2}$

$= 3.0 \times 20\,kN/m^3 \times \frac{0.75^2}{2}$ $= 16.9$ kN/m

Self weight of wall stem
$= 24\,kN/m^3 \times 0.25m\,(thk) \times 2.24m\,(h)$ $= 13.4$ kN/m

Self weight of wall heel
$= 24\,kN/m^3 \times 0.35m\,(thk) \times 1.5m\,(l)$ $= 12.6$ kN/m

Self weight of retaining soil
$= 20\,kN/m^3 \times 2.24m\,(h) \times (1.5m - 0.25m)\,thk$ $= 35.0$ kN/m

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Project			
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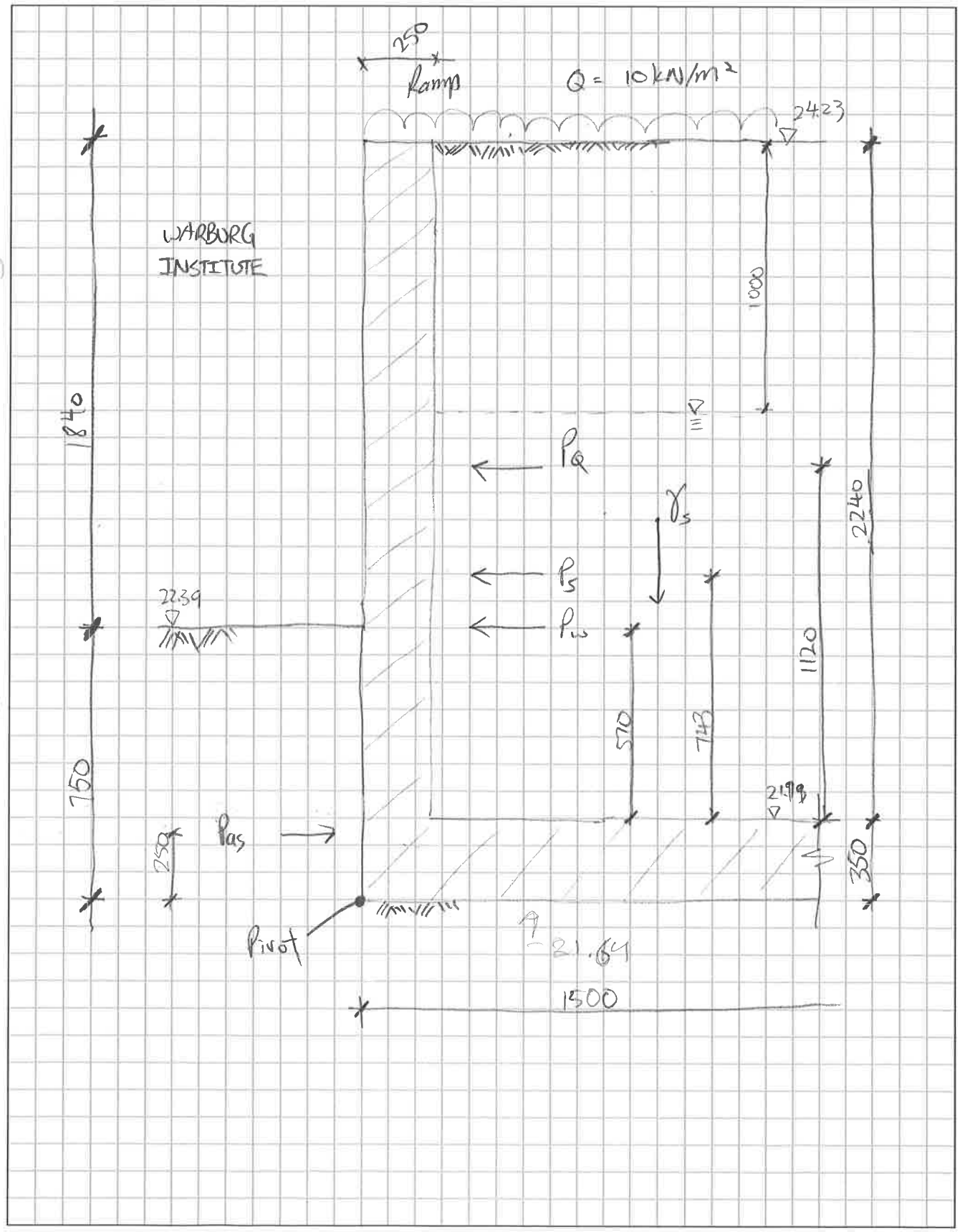
Part of structure			
Basement wall C			
Date		Job number	
22.06.2017		J2889	
Engineer	Checked by	Checked date	Sheet number
GW			5



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Part of structure	Basement wall C		
Date	04.07.2017	Job number	J2889
Engineer	Checked by	Checked date	Sheet number
GW			6

Acting moment

- Since both favourable and unfavourable permanent actions originate from a single source, the same partial factor can be applied to both permanent actions.
- ULS - $1.1\,G_k + 1.5\,Q_k + 1.0$ water
- Acting moment calculated in GSA 8.7 = 66.9 kNm/m

Returning moment

$$= P_{dis} \times \frac{H}{3} + \text{wall stem} \times \frac{\text{stem thk}}{2} + \text{wall heel} \times \frac{\text{heel length}}{2}$$

$$+ 1.1(FoS) \times \text{Retaining soil} \times \frac{(\text{heel length} - \text{stem thk})}{2}$$

$$= 16.9 \times \frac{0.75m}{3} + 13.4 \times \frac{0.25m}{2} + 12.6 \times \frac{1.5m}{2} + 1.1 \times 35.0 \times \frac{(1.5-0.25)}{2}$$

$$= 4.2 + 1.7 + 9.5 + 38.5 = 53.8 \text{ kNm/m}$$

- 66.9 kNm/m - 53.8 kNm/m
  - A residual 13.1 kNm/m is present

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Project	Torrington Square		
Part of structure	Basement wall C		
Date	04.07.2017	Job number	J2889
Engineer: GW	Checked by:	Checked date:	Sheet number: 7

Eccentricity, $e = \frac{M}{N}$

N = weight of wall stem + heel + retaining soil $\times 1.1$ FoS

= 13.4 kN/m + 12.6 kN/m + 35.0 $\times 1.1$

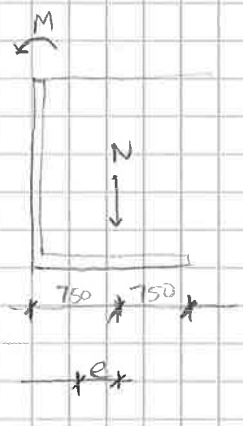
= 64.5 kN/m

$e = \frac{13.1 \text{ kNm/m}}{64.5 \text{ kN/m}}$ = 211 mm

middle third of wall

$= \frac{1500\text{mm}}{2} \times \frac{1}{3}$

= 250mm



eccentricity acts within middle third of the wall heel. ∴ The full length of the wall heel is in compression

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Basement Wall C			
Date		Job number	
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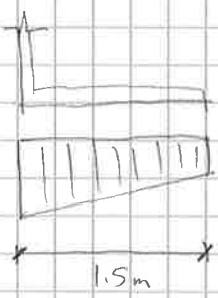
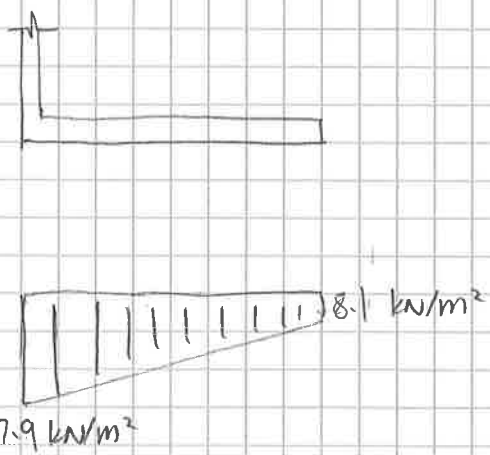
Engineer	Checked by	Checked date	Sheet number
GW			8

Bearing Pressure

$$P = \frac{N}{l} \pm \frac{6M}{l^2}$$



$$\frac{645\ kN/m}{1.5m} \pm \frac{6 \times 13.1\ kNm/m}{1.5m^2} = 77.9\ kN/m^2 \text{ OR } 8.1\ kN/m^2$$



- Allowable bearing pressure = 125 kN/m² > 77.9 kN/m²

∴ Proposed wall section is adequate

residual capacity = 125 - 77.9 = 47.1 kN/m²

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Project	Torrington Square		
Part of structure	Basement wall C		
Date	04.07.2017	Job number	J2889
Engineer: GW	Checked by	Checked date	Sheet number: 9

Sliding check :

Acting force Soil + Surcharge + water.

γ_{fav} = 1.1
γ_{fav} = 1.5
γ_w = 1.0

= 1.1 × (11.2 kN/m) + 1.5 × (8.6 kN/m) + 1.0 × (12.6 kN/m)

= 37.8 kN/m.

Resisting force

Coefficient of friction between concrete and soil, α = 0.45

Force = (wall stem + toe + retaining soil × 1.1) × 0.45 + Passive pressure

= (13.4 kN/m + 12.6 kN/m + 35 kN/m × 1.1) × 0.45 + 13.4 kN/m

= 29.0 + 13.4

= 42.4 kN/m

37.8 < 42.4 ∴ Wall does not slide

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Part of structure	Basement wall C		
Date	04.07.2017	Job number	J2889
Engineer	Checked by	Checked date	Sheet number
GW			10

Reinforcement design

Wall thickness = 250mm
Cover, mm = 50 mm
Cover, dev = 10 mm
Horizontal bars ϕ_x = 10 mm } assumptions
Vertical bars ϕ_y = 16 mm }

$M = 66.9$ kNm/m

$$k_o = \frac{66.9 \times 10^6}{1000mm \times 250mm^2 \times 30\ N/mm^2} = 0.03568$$

$$Z = (250 - 50 - 10 - 10 - \frac{16}{2}) \times \left(0.5 + \sqrt{0.25 - \frac{0.03568}{1.134}}\right) = 166.4\ mm$$

$$A_{s,req} = \frac{66.9 \times 10^6}{0.87 \times 500\ N/mm^2 \times 166.4mm} = 924\ mm^2/m$$

H16 @ 200mm c/s provides 1206 mm^2/m

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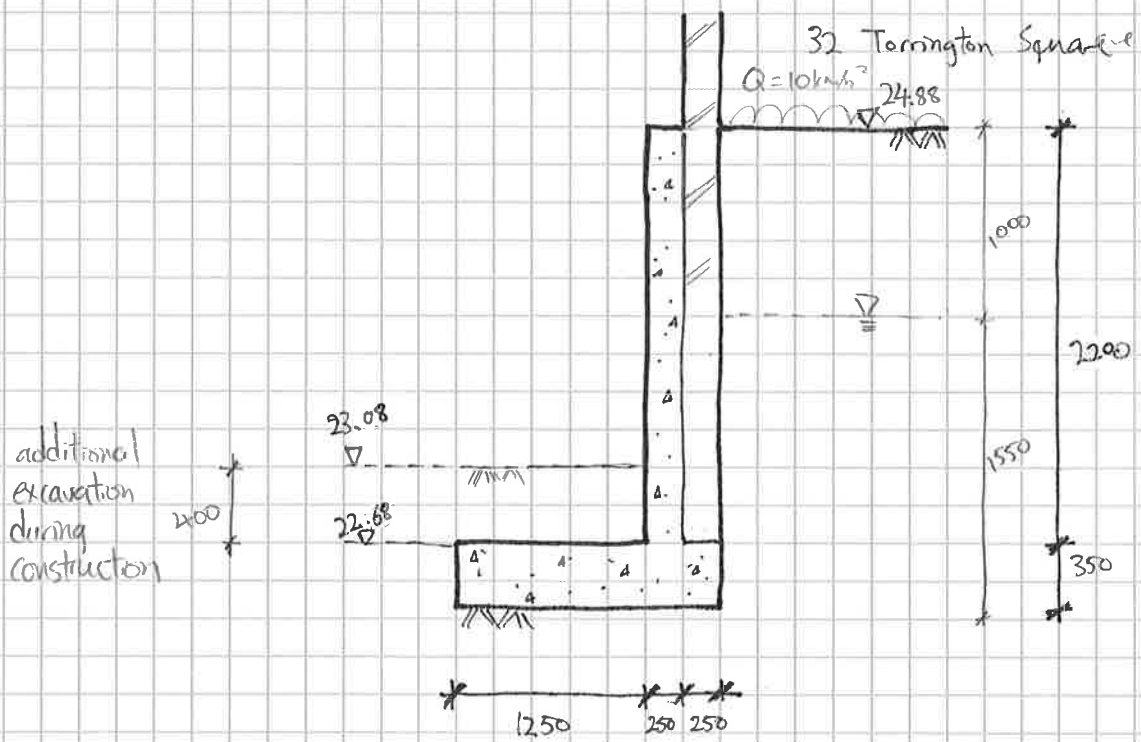
Project	Torrington Square		
Part of structure	Retaining wall D		
Date	11.07.2017	Job number	J2889
Engineer	Checked by	Checked date	Sheet number
GW			1

Retaining wall adjacent to 32 Torrington Square at the rear



Assumptions:

Soil properties: Gravel

Friction angle, ϕ = 30°

Cover, min = 50mm
Cover, dev = 10mm

Horizontal bars, ϕ_h = 10mm
Vertical bars, ϕ_v = 16mm

$$K_a = \frac{1-\sin\phi}{1+\sin\phi}$$

$$= \frac{1-\sin 30}{1+\sin 30}$$

$$= 0.33 \approx \frac{1}{3}$$

$$K_p = \frac{1}{K_a}$$

$$= 3.0$$

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Project	Torrington Square		
Part of structure	Retaining wall D		
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Engineer	Checked by	Checked date	Sheet number
GW			2

Acting Pressure

$P_S = K_a \times 20\,kN/m^3 \times \frac{1.0m^2}{2}$

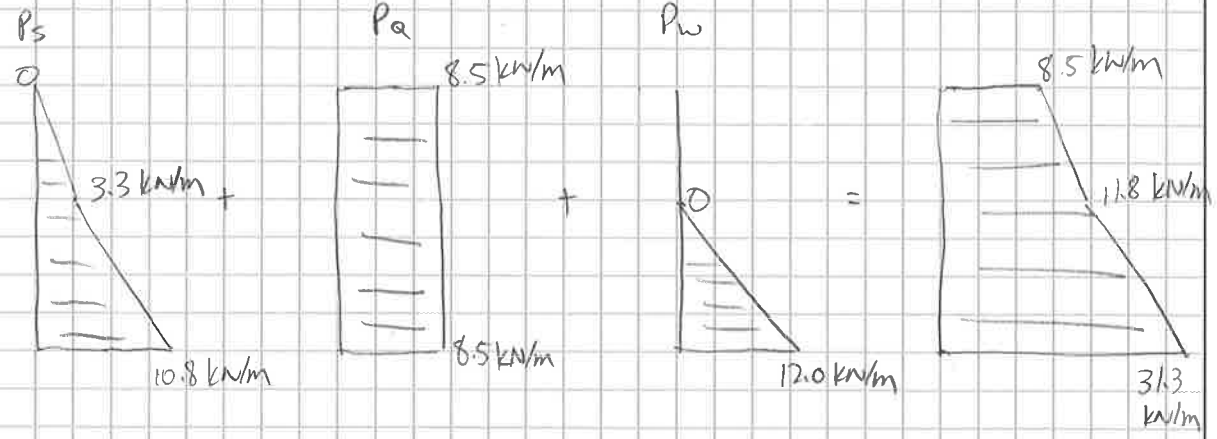
$= 0.33 \times 20 \times \frac{1.0m^2}{2}$ (above water level) $= 3.3\ kN/m$

$P_S = 0.33 \times (20-10) \times \frac{2.55m^2}{2}$ (below water level) $= 10.8\ kN/m$

$P_Q = K_a \times Q \times H$

$= 0.33 \times 10\,kN/m^2 \times 2.55m = 8.5\ kN/m$

$P_W = 10\,kN/m^3 \times \frac{(2.55-1.0)^2}{2} = 12.0\ kN/m$



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Project	Torrington Square		
Part of structure	Retaining Wall D		
Date	11.07.2017	Job number	J2889
Engineer	Checked by	Checked date	Sheet number
GW			3

Passive pressure

Self weight of stem:

$= 24 kN/m^3 \times 0.25m (w) \times 2.2m (h)$ $= 13.2$ kN/m

Self weight of heel:

$= 24 kN/m^3 \times 0.35m (thk) \times 1.75m (l)$ $= 19.3$ kN/m

Dead load of brick party wall + underpinning (assumed whole wall as brick)

$= 20 kN/m^3 \times 0.25m (thk) \times 2.2m (l)$ $= 11.0$ kN/m

The additional excavation will be backfilled after construction so the 400mm excavation + 350 mm soil can be utilised as passive force

$= kp \times 20 kN/m^3 \times \frac{0.75m^2}{2}$ $= 16.9$ kN/m

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Project	Torrington Square		
Part of structure	Retaining wall D		
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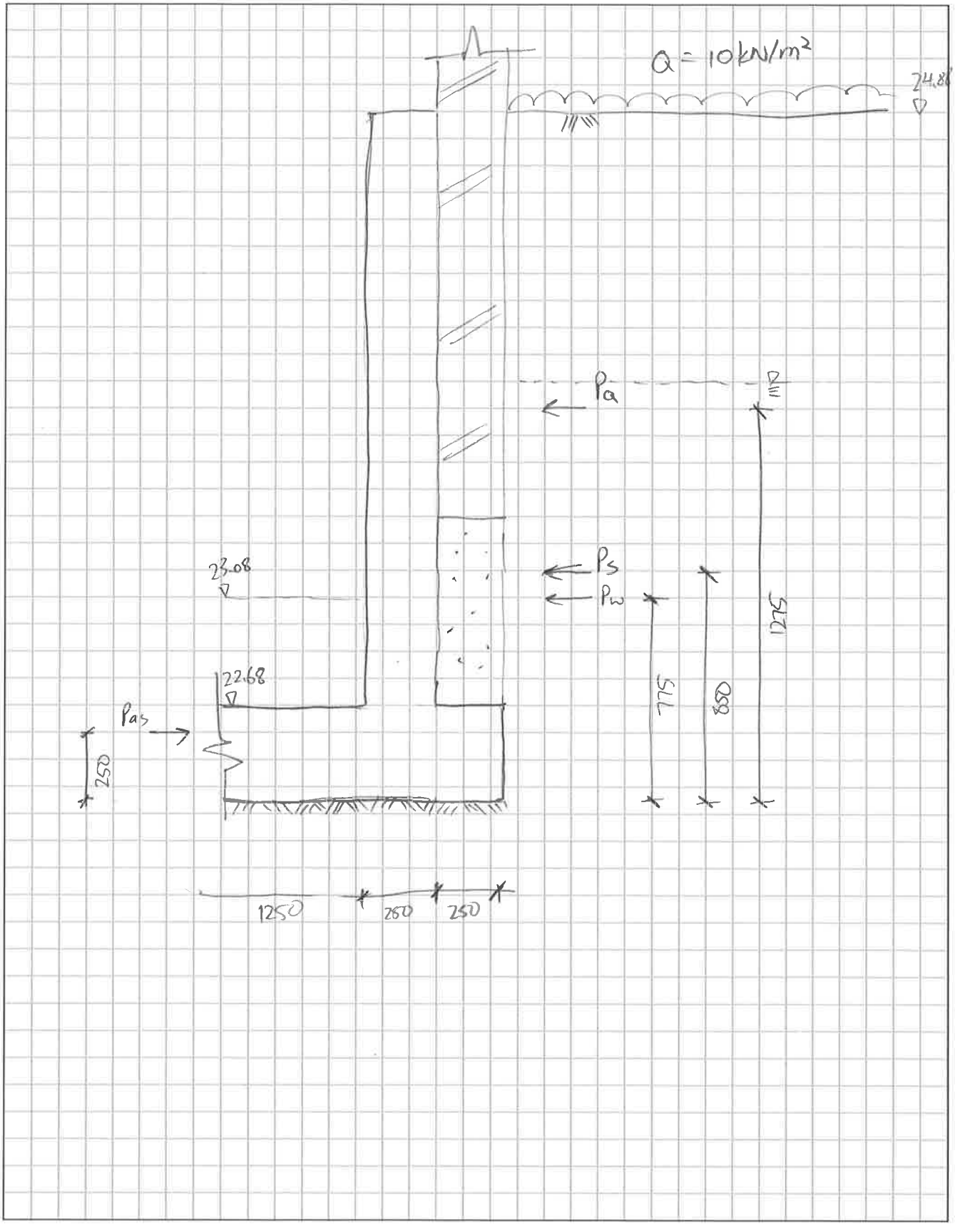
Engineer	Checked by	Checked date	Sheet number
GW			4



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Project	Torrington Square		
Part of structure	Retaining Wall D		
Date	11.07.2017	Job number	J2889
Engineer	Checked by	Checked date	Sheet number
GW			5

Acting moment

ULS case = 1.35 G_k + 1.50 Q_k + 1.0 water

Acting moment calculated in GSA 8.7 = 67.6 kNm/m

Returning moment

Wall stem : 13.2 kN/m × $(1.25_m + \frac{0.25_m}{2})$ = 18.2 kNm/m

Wall heel : 15.3 kN/m × $\frac{(1.75_m)}{2}$ = 13.4 kNm/m

Party wall : 11.0 kN/m × $(1.25_m + 0.25_m + \frac{0.25_m}{2})$ = 17.9 kNm/m

Retaining soil : 16.9 kN/m × $\frac{0.75_m}{3}$ = 4.2 kNm/m

A safety of 0.9 is applied to all returning moment :

Total = 0.9 × (18.2 + 13.4 + 17.9 + 4.2) = 48.3 kNm/m

Acting moment - Returning moment

= 67.6 kNm/m - 48.3 kNm/m = 19.3 kNm/m

∴ overturning moment remains - Pressure concentration check required for base

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Project	Torrington Square		
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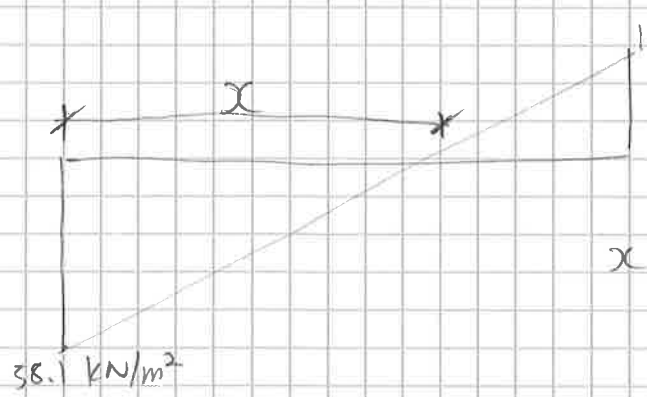
Engineer	Checked by	Checked date	Sheet number
GW			6

$$\sigma = \frac{N}{b} \pm \frac{6M}{b^2}$$

$$= \frac{0.9 \times (13.2 + 15.3 + 11.0)}{1.75\,m} \pm \frac{6 \times 19.3}{1.75\,m^2}$$

$$= 20.3 \pm 37.8 \qquad = -17.5\ kN/m^2 / 58.1\ kN/m^2$$



$$x = \frac{58.1}{58.1 + 17.5} \times 1.75\,m$$

$$= 1.34\,m$$

Revised bearing pressure to new bearing length

$$\sigma = \frac{N}{b} + \frac{6M}{b^2}$$

$$= \frac{0.9 \times (13.2 + 15.3 + 11.0)}{1.34\,m} + \frac{6 \times 19.3}{1.34\,m^2}$$

$$= 26.5 + 64.5 \qquad = 91.0\ kN/m^2$$

Allowable bearing pressure = 125 kN/m² > 91.0 kN/m²

∴ OKAY.

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Project	Torrington Square		
Part of structure	Retaining Wall D		
Date	11.07.2017	Job number	J2889
Engineer	Checked by	Checked date	Sheet number
GW			7

Sliding check:

Acting force:

$\gamma_{Gk} = 1.35$
$\gamma_{Qk} = 1.5$
$\gamma_w = 1.0$

ULS case $= 1.35\,G_k + 1.50\,Q_k + 1.0\,w_k$

$= 1.35 \times 10.8 + 1.5 \times 8.5 + 1.0 \times 12.0 = 39.3$ kN/m

Resisting force:

Coefficient of friction between concrete and soil $\alpha = 0.45$

Force = (wall stem + heel + brick wall) × 0.45 + Passive pressure

$= (13.2 + 15.3 + 11.0) \times 0.45 + 16.9 = 34.7$ kN/m

39.3 kN/m − 34.7 kN/m = 4.6 kN/m. $\frac{4.6}{34.7} = 13\%$.

This sliding design check is conservative. ∴ a 13% over capacity is deemed acceptable.

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Project	Torrington Square		
Part of structure	Retaining Wall D		
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Engineer	Checked by	Checked date	Sheet number
GW			8

Reinforcement design :

Wall thickness	= 250 mm	f_{ck}	= 30 N/mm²
Cover, mm	= 50 mm	f_{yk}	= 500 N/mm²
Cover, dw	= 10 mm		
ϕ_h	= 10 mm		
ϕ_v	= 16 mm		

M = 67.6 kNm/m

$$k_b = \frac{67.6 \times 10^6}{1000 \times 250^2 \times 30} = 0.0361$$

$$z = (250 - 50 - 10 - 10 - \tfrac{16}{2}) \times \left(0.5 + \sqrt{0.25 - \frac{0.0361}{1.134}}\right) = 166.3 \text{ mm}$$

$$A_{s,req} = \frac{67.6 \times 10^6}{0.87 \times 500 \times 166.3} = 934 \text{ mm}^2/\text{m}$$

H16 @ 200 mm c/s provides 1206 mm²/m