Dcp

13 April 2016

ARUP

Our ref CHS
13 April 2016

13 Fitzroy Street
London
W1T 4BQ
United Kingdom

t +44 20 7636 1531
d +44 20 7755 4933
f +44 20 775 2121

hilary.shields@arup.com
arup.com

Development Management
Planning Services
London Borough of Camden
Town Hall
Argyle Street
London WC1H 8ND

For the attention of Shane O'Donnell

Dear Sir,

59 Maresfield Gardens- Audit of Revised Basement Impact Assessment December 2012

In November 2015 we were appointed to comment on a new BIA dated March 2015 for 59 Maresfield Gardens.

We have been asked to confirm that:

1. The submission contains a Basement Impact Assessment, which has been prepared in accordance with the processes and procedures set out in the Arup report/Camden Planning Guidance 4 2013.
2. The methodologies have been appropriate to the scale of the proposals and the nature of the site
3. The conclusions have been arrived at based on all necessary and reasonable evidence and considerations, in a reliable, transparent manner, by suitably qualified professionals, with sufficient attention paid to risk assessment and use of conservative engineering values/estimates
4. The conclusions are sufficiently robust and accurate and are accompanied by sufficiently detailed amelioration/mitigation measures to ensure that the grant of planning permission would accord with DP27, in respect of
    a. maintaining the structural stability of the building and any neighbouring properties
    b. avoiding adversely affecting drainage and run-off or causing other damage to the water environment and
    c. avoiding cumulative impacts on structural stability or the water environment in the local area

We have been asked to comment on whether this report:

5. Raises any reasonable concerns about the technical content or considerations of the submission which should be addressed by the applicant by way of further submission, *prior* to planning permission being granted. In this case it would need to be apparent that the submission is so deficient in some respect that the three conclusions (points 4a-c above) cannot be guaranteed without the provision of further information at this stage.

6. Raises any relevant and reasonable considerations in respect of the structural integrity or condition of the road and the neighbouring properties which may be unknown or unaccounted for by the submission or which would benefit from particular construction measures or methodologies in respect of the development *following* a grant of permission for the development.

In January 2016 we sent a series of questions by email to Camden for forwarding to the applicant, which are attached at the back of this letter. These were addressed by email from Martin Cooper of GEA to Hilary Shields dated 16th March 2016, also attached.

Following the email response of 16th March 2016, we find that the BIA, together with the attached email response, are sufficient to satisfy the requirements for the grant of planning permission in accordance with DP27, in respect of:

- maintaining the structural stability of the building and any neighbouring properties
- avoiding adversely affecting drainage and run-off or causing other damage to the water environment and
- avoiding cumulative impacts on structural stability or the water environment in the local area

Additional comments are as given below. They do not change our conclusion above.

There is the potential for a small increase in groundwater level beneath the swimming pool and for a small decrease in groundwater level below the footings of 57 Maresfield Gardens. As a result, there is the potential for some minor additional movement to the adjacent structures which may occur following construction. In our opinion this should be acknowledged and covered in party wall agreements.

There are temporary works required for the ramp and to support the driveway to be designed. The stability of these and adjacent structures will need to be checked by the Contractor prior to the Works.

Our conclusion relates only to the basement configuration and construction sequence proposed. If there are significant changes to these during detailed design then another review would need to be conducted.

Our review is an audit of the information contained in the BIA and does not constitute a third party check on the calculations.

Note that we were asked to comment against CPG4 2013. CPG4 was updated in 2015 so that it now adds:

- BIA to provide mitigation measures where any risk of damage is identified of Burland Category “very slight” or higher.

- Preferred approach is for a basement not to extend beyond the footprint of original building and to be no deeper than 1 full storey below ground level. Larger schemes require more justification

The BIA does not address the new requirements of CPG4 2105.

Yours sincerely

C H Shields

Hilary Shields
Senior Geotechnical Engineer
BA Cantab MSc DIC CEng MICE

Hilary Shields

Subject: FW: RE: Follow Up Independent Verification-59 Maresefield Gardens - Overude invoice 000395403

From: Hilary Shields
Sent: 31 January 2016 21:07
To: 'O'Donnell, Shane'
Subject: RE: RE: Follow Up Independent Verification-59 Maresefield Gardens - Overude invoice 000395403

Dear Shane

Please can you pass these comments on to the applicant. I am happy to continue to review the responses before writing our report to Camden.

1. The BIA talks about a heave void beneath the basement slab. There is no thickness given for this heave void and it is not shown on the Elliot Wood drawings. This will lead to extra dig. Also, the slab thickness is given as 300mm to be confirmed, so this too might lead to a deeper dig if the slab is thicker. Please consider the impact on the findings of the BIA.

2. The deeper dig for the swimming pool appears to extend significantly past the end wall of 57 Maresfield Gardens. However, there is no Wallap analysis for the deeper dig with the building surcharge. Please consider how this may affect the wall and ground movement assessment.

3. It seems that the 1.3m extra dig deeper dig for the swimming pool is proposed to be carried out in a battered back excavation. This will increase the length of 57 Maresfield Gardens affected by the deeper dig. In addition, it is not clear how the stair area will be formed and the dig for the stairs may create a berm in front of the formation level against 57 Maresfield Gardens which has not been considered. Please consider any impact of a battered dig for the swimming pool and stairs.

4. The deep chamber at the front wall has not been analysed in Wallap, perhaps because it will be carried out in a localised supported excavation, but some thought needs to be given to this. In addition, it should be shown on the architects drawings (not currently).

5. In the Wallap runs the surcharge on the formation on the passive side is 52.5kPa. It is not clear where this comes from, especially with the proposed heave void. Please explain.

6. In the permanent condition it is stated that lateral stability is provided through RC shear walls. If there is a heave void then is the imbalance of lateral load from the road taken by the internal piles. Has this been considered?

7. Whilst the CIRIA profiles of settlement due to excavation must incorporate short term heave effects, since they are based on measured data, there is some deep seated short term to long term heave which would cause heave of the surrounding ground. If there is a heave void, the long term heave is less constrained and ought to be considered for the impact on neighbouring properties.

8. Originally, the deep basement application had 600mm diameter piles at 900 centres. This was stiffer than the current proposal for 450mm diameter piles at 600mm centres. Given that potential damage is falling into the slight category, and that dig may be slightly deeper than analysed, please consider whether this might still be an option for the current scheme.

9. There is the potential for a small increase in groundwater level beneath the swimming pool and for a small decrease in groundwater level below the footings of 57 Maresfield Gardens. As a result, there

is the potential for some minor additional movement to the adjacent structures which may occur following construction. In our opinion this should be acknowledged and covered in party wall agreements.

Regards

Hilary

Hilary Shields
Senior Engineer | Geotechnics & Tunnelling London

Arup
13 Fitzroy Street London W1T 4BQ United Kingdom
t +44 20 7636 1531 **d** +44 20 7755 4933
f +44 20 7755 2121
www.arup.com

Hilary Shields

From:	Martin Cooper <Martin@gea-ltd.co.uk>
Sent:	16 March 2016 14:57
To:	Hilary Shields
Cc:	Mark Renshaw; Edd Rushton (EddR@lom-fdp.com); stephen.alder@jacksoncoles.co.uk; Steve Branch
Subject:	59 Maresfield Gardens - BIA
Attachments:	59 Maresfield Gdns Scheme 4 South Wall_SLS Pool.pdf

Dear Hilary

With apologies for the delay in responding following our conversation a week or two ago, we've discussed the points you raised with the design team and our responses are set out below point by point.

Please feel free to call me directly if you would like to discuss further but we hope that they will satisfy your concerns.

Kind regards

Martin

Please can you pass these comments on to the applicant. I am happy to continue to review the responses before writing our report to Camden.

1. The BIA talks about a heave void beneath the basement slab. There is no thickness given for this heave void and it is not shown on the Elliot Wood drawings. This will lead to extra dig. Also, the slab thickness is given as 300mm to be confirmed, so this too might lead to a deeper dig if the slab is thicker. Please consider the impact on the findings of the BIA.
   There is a single mention of potential heave protection that was not deleted from the latest issue of the BIA. Elliott Wood have confirmed that there is to be no heave protection and any heave forces will be transferred through the slab into the piled foundations. The piles will be suitably reinforced against the tension that would occur in the short term before the building load is applied to the piles and which, in the long term would off-set any tension forces. At this stage the preliminary designs have indicated that a 300 mm slab should be sufficient even for the potential heave forces mainly on account of the relatively short spans.

2. The deeper dig for the swimming pool appears to extend significantly past the end wall of 57 Maresfield Gardens. However, there is no Wallap analysis for the deeper dig with the building surcharge. Please consider how this may affect the wall and ground movement assessment.
   A new Wallap analysis has been undertaken for the South wall with the deeper excavation for the pool whilst still supporting the adjacent No 57 Maresfield Gardens. This run is appended and has indicated no increase in pile depth but an increase in maximum bending moment from 65 kNm per pile to 124 kNm per pile. There is a slight increase in the maximum deflection from 10 mm to 12 mm but the movements remain within those in the movement curves adopted within the XDisp analysis. There is therefore no change to the predicted damage category.

3. It seems that the 1.3m extra dig deeper dig for the swimming pool is proposed to be carried out in a battered back excavation. This will increase the length of 57 Maresfield Gardens affected by the deeper dig. In addition, it is not clear how the stair area will be formed and the dig for the stairs may

create a berm in front of the formation level against 57 Maresfield Gardens which has not been considered. Please consider any impact of a battered dig for the swimming pool and stairs.
The Wallap analysis for the pool in No 2 above represents the deepest case analysed and the design for those piles will also be adopted for the section of wall behind the berm used to reduce the level in that area.

4. The deep chamber at the front wall has not been analysed in Wallap, perhaps because it will be carried out in a localised supported excavation, but some thought needs to be given to this. In addition, it should be shown on the architects drawings (not currently).
The exact location of the deep chamber has yet to be finalised but Elliott Wood have confirmed that wherever it is placed, the basement slab will have been cast, with a box-out or similar and additional reinforcement in the slab prior to the excavation of the chamber so that the piled wall will always be propped at basement level.

5. In the Wallap runs the surcharge on the formation on the passive side is 52.5kPa. It is not clear where this comes from, especially with the proposed heave void. Please explain.
The passive surcharge of 52.5 kPa represents the balancing water pressure for the 5.25 m excavation below groundwater level. There is no heave void.

6. In the permanent condition it is stated that lateral stability is provided through RC shear walls. If there is a heave void then is the imbalance of lateral load from the road taken by the internal piles. Has this been considered?
There is no heave void and the lateral load imbalance will be distributed through the piles.

7. Whilst the CIRIA profiles of settlement due to excavation must incorporate short term heave effects, since they are based on measured data, there is some deep seated short term to long term heave which would cause heave of the surrounding ground. If there is a heave void, the long term heave is less constrained and ought to be considered for the impact on neighbouring properties.
There is no heave void.

8. Originally, the deep basement application had 600mm diameter piles at 900 centres. This was stiffer than the current proposal for 450mm diameter piles at 600mm centres. Given that potential damage is falling into the slight category, and that dig may be slightly deeper than analysed, please consider whether this might still be an option for the current scheme.
The original scheme was for a further level of basement below the deepest level of this application and as we recall were for slightly deeper spans of the wall. The increased diameter has been considered for subsequent schemes but given the relatively modest plan area of the basement the loss in area was not acceptable to the client.

9. There is the potential for a small increase in groundwater level beneath the swimming pool and for a small decrease in groundwater level below the footings of 57 Maresfield Gardens. As a result, there is the potential for some minor additional movement to the adjacent structures which may occur following construction. In our opinion this should be acknowledged and covered in party wall agreements.
The groundwater impact assessment by Chord Environmental discussed in detail and identified no potential adverse impacts. However, it is acknowledged that this matter will need to be agreed within party wall agreements.

Regards

Hilary

Hilary Shields
Senior Engineer | Geotechnics & Tunnelling London

Arup
13 Fitzroy Street London W1T 4BQ United Kingdom
t +44 20 7636 1531 **d** +44 20 7755 4933
f +44 20 7755 2121
www.arup.com

Units: kN,m

INPUT DATA

SOIL PROFILE

Stratum no.	Elevation of top of stratum	Soil types: Active side	Soil types: Passive side
1	82.00	1 Made Ground / Alluv	1 Made Ground / Alluv
2	76.00	2 Claygate Beds	2 Claygate Beds
3	73.50	3 London Clay	3 London Clay

SOIL PROPERTIES

-- Soil type -- No. Description (Datum elev.)	Bulk density kN/m3	Young's Modulus Eh,kN/m2 (dEh/dy)	At rest coeff. Ko (dKo/dy)	Consol state. NC/OC (Nu)	Active limit Ka (Kac)	Passive limit Kp (Kpc)	Cohesion kN/m2 (dc/dy)
1 Made Ground / Alluv	17.00	12500	0.500	NC (0.490)	1.000 (2.570)	1.000 (2.571)	25.00u
2 Claygate .. (76.00)	18.00	37500 (3000)	1.000	OC (0.490)	1.000 (2.000)	1.000 (2.000)	75.00u (6.000)
3 London Clay (73.50)	19.00	45000 (2608)	1.000	OC (0.490)	1.000 (1.000)	1.000 (1.000)	90.00u (5.200)
4 MG /Alluv Drained	17.00	7500	0.500	NC (0.250)	0.324 (1.327)	3.601 (5.104)	0.0d
5 Claygate .. (76.00)	18.00	22500 (1800)	1.000	OC (0.200)	0.351 (1.391)	3.440 (5.233)	0.0d
6 London Cl.. (73.50)	19.00	27000 (1565)	1.000	OC (0.200)	0.337 (1.360)	3.440 (5.233)	0.0d

Additional soil parameters associated with Ka and Kp

------- Soil type ------- No. Description	--- parameters for Ka --- Soil friction angle	Wall adhesion coeff.	Back-fill angle	--- parameters for Kp --- Soil friction angle	Wall adhesion coeff.	Back-fill angle
1 Made Ground / Alluv	0.00	1.000	0.00	0.00	1.000	0.00
2 Claygate Beds	0.00	0.000	0.00	0.00	0.000	0.00
3 London Clay	0.00	-0.674	0.00	0.00	-0.674	0.00
4 MG /Alluv Drained	27.00	0.641	0.00	27.00	0.471	0.00
5 Claygate Drained	25.00	0.670	0.00	25.00	0.670	0.00
6 London Clay Drained	26.00	0.670	0.00	25.00	0.670	0.00

GROUND WATER CONDITIONS

Density of water = 10.00 kN/m3

	Active side	Passive side
Initial water table elevation	81.00	81.00

Automatic water pressure balancing at toe of wall : No

Water press. profile no.	Active side: Point no.	Elev. m	Piezo elev. m	Water press. kN/m2	Passive side: Point no.	Elev. m	Piezo elev. m	Water press. kN/m2	
1	1	81.00	81.00	0.0	1	80.60	80.60	0.0	MC
2	1	82.00	82.00	0.0	1	78.60	78.60	0.0	WC
3	1	81.00	81.00	0.0	1	77.50	77.50	0.0	MC
4	1	82.00	82.00	0.0	1	76.40	76.40	0.0	WC
5	1	81.00	81.00	0.0	1	74.45	74.45	0.0	MC
6	1	82.00	82.00	0.0	1	75.25	75.25	0.0	WC

WALL PROPERTIES

Type of structure = Fully Embedded Wall
Elevation of toe of wall = 72.00
Maximum finite element length = 0.60 m
Youngs modulus of wall E = 2.8000E+07 kN/m2
Moment of inertia of wall I = 3.3550E-03 m4/m run
E.I = 93940 kN.m2/m run
Yield Moment of wall = Not defined

STRUTS and ANCHORS

Strut/ anchor no.	Elev.	Strut spacing m	X-section area of strut sq.m	Youngs modulus kN/m2	Free length m	Inclin -ation (degs)	Pre- stress /strut kN	Tension allowed
1	84.40	3.00	0.010000	2.000E+08	2.00	0.00	0	No
2	81.10	3.00	0.010000	2.000E+08	4.00	0.00	0	No
3	78.00	3.00	0.010000	2.000E+08	4.00	0.00	0	No
4	74.70	1.00	0.350000	3.000E+07	1.00	0.00	0	No
5	79.50	3.00	0.100000	2.000E+08	4.00	0.00	0	No
6	78.95	1.00	0.250000	2.000E+08	1.00	0.00	0	No
7	81.75	1.00	0.250000	3.000E+07	1.00	0.00	0	No
8	84.40	1.00	0.250000	3.000E+07	1.00	0.00	0	No

SURCHARGE LOADS

Surch -arge no.	Elev.	Distance from wall	Length parallel to wall	Width perpend. to wall	Surcharge ----- kN/m2 ----- Near edge	Far edge	Equiv. soil type	Partial factor/ Category
1	81.50	1.30(A)	0.50	20.00	100.00	=	N/A	1.00 P/U
2	81.50	0.80(A)	20.00	0.50	80.00	=	N/A	1.00 P/U
3	82.00	0.00(A)	20.00	20.00	5.00	=	N/A	1.00 Var
4	74.45	-0.00(P)	8.00	10.00	65.50	=	N/A	1.00 -

Note: A = Active side, P = Passive side
Limit State Categories P/U = Permanent Unfavourable
P/F = Permanent Favourable
Var = Variable (unfavourable)

CONSTRUCTION STAGES

Construction stage no.	Stage description
1	Apply surcharge no.1 at elevation 81.50
2	Apply surcharge no.2 at elevation 81.50
3	Apply surcharge no.3 at elevation 82.00
4	Apply water pressure profile no.1 (Mod. Conserv.)
5	Excavate to elevation 80.60 on PASSIVE side
6	Install strut or anchor no.2 at elevation 81.10
7	Apply water pressure profile no.3 (Mod. Conserv.) No analysis at this stage
8	Excavate to elevation 77.50 on PASSIVE side
9	Install strut or anchor no.3 at elevation 78.00
10	Apply water pressure profile no.5 (Mod. Conserv.)
11	Excavate to elevation 74.45 on PASSIVE side
12	Install strut or anchor no.4 at elevation 74.70
13	Apply surcharge no.4 at elevation 74.45
14	Install strut or anchor no.5 at elevation 79.50
15	Remove strut or anchor no.3 at elevation 78.00
16	Install strut or anchor no.6 at elevation 78.95
17	Remove strut or anchor no.5 at elevation 79.50
18	Install strut or anchor no.7 at elevation 81.75
19	Remove strut or anchor no.2 at elevation 81.10
20	Change properties of soil type 1 to soil type 4 Ko pressures will be reset
21	Change properties of soil type 2 to soil type 5 Ko pressures will be reset
22	Change properties of soil type 3 to soil type 6 Ko pressures will be reset

FACTORS OF SAFETY and ANALYSIS OPTIONS

Limit State options: Serviceability Limit State
All loads and soil strengths are unfactored

Stability analysis:
Method of analysis - Strength Factor method
Factor on soil strength for calculating wall depth = 1.00

Parameters for undrained strata:
Minimum equivalent fluid density = 5.00 kN/m3
Maximum depth of water filled tension crack = 0.00 m

Bending moment and displacement calculation:
Method - Subgrade reaction model using Influence Coefficients
Open Tension Crack analysis? - No
Non-linear Modulus Parameter (L) = 20.00 m

Boundary conditions:
Length of wall (normal to plane of analysis) = 6.00 m

Width of excavation on active side of wall = 20.00 m
Width of excavation on passive side of wall = 10.00 m

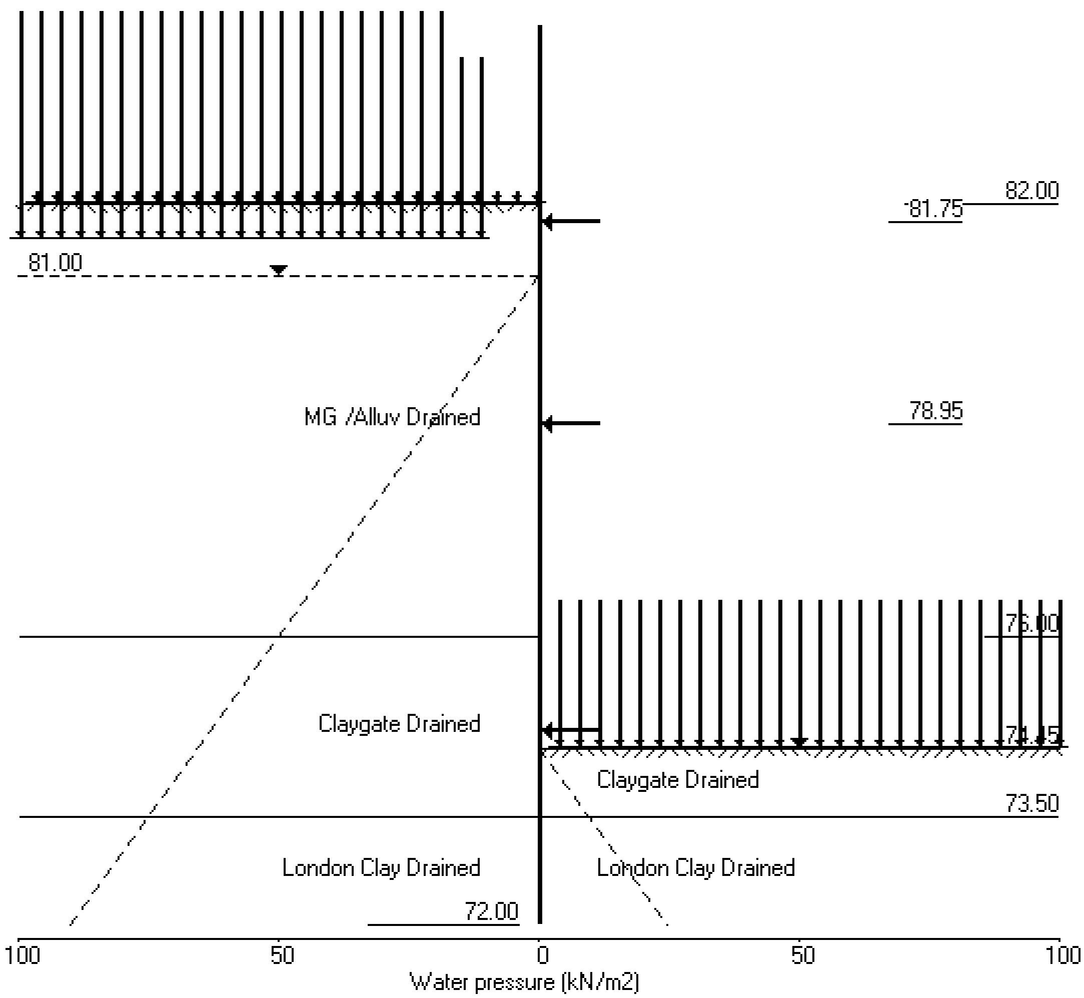
Distance to rigid boundary on active side = 20.00 m
Distance to rigid boundary on passive side = 20.00 m

OUTPUT OPTIONS

Stage no.	Stage description	Output options: Displacement Bending mom. Shear force	Active, Passive pressures	Graph. output
1	Apply surcharge no.1 at elev. 81.50	No	No	No
2	Apply surcharge no.2 at elev. 81.50	No	No	No
3	Apply surcharge no.3 at elev. 82.00	No	No	No
4	Apply water pressure profile no.1	No	No	No
5	Excav. to elev. 80.60 on PASSIVE side	No	No	No
6	Install strut no.2 at elev. 81.10	No	No	No
7	Apply water pressure profile no.3	No	No	No
8	Excav. to elev. 77.50 on PASSIVE side	No	No	No
9	Install strut no.3 at elev. 78.00	No	No	No
10	Apply water pressure profile no.5	No	No	No
11	Excav. to elev. 74.45 on PASSIVE side	No	No	No
12	Install strut no.4 at elev. 74.70	No	No	No
13	Apply surcharge no.4 at elev. 74.45	No	No	No
14	Install strut no.5 at elev. 79.50	No	No	No
15	Remove strut no.3 at elev. 78.00	No	No	No
16	Install strut no.6 at elev. 78.95	No	No	No
17	Remove strut no.5 at elev. 79.50	No	No	No
18	Install strut no.7 at elev. 81.75	No	No	No
19	Remove strut no.2 at elev. 81.10	No	No	No
20	Change soil type 1 to soil type 4	No	No	No
21	Change soil type 2 to soil type 5	No	No	No
22	Change soil type 3 to soil type 6	Yes	No	Yes
*	Summary output	Yes	-	Yes

Units: kN,m

Stage No.22 Change soil type 3 to soil type 6



Units: kN,m

Stage No. 22 Change properties of soil type 3 to soil type 6
Ko pressures will be reset

STABILITY ANALYSIS of Fully Embedded Wall according to Strength Factor method
Factor of safety on soil strength

Stage No.	--- G.L. --- Act.	Pass.	Strut Elev.	FoS for toe elev. = 72.00: Factor of Safety	Moment equilib. at elev.	Toe elev. for FoS = 1.000: Toe elev.	Wall Penetr -ation
22	82.00	74.45		More than one strut			

BENDING MOMENT and DISPLACEMENT ANALYSIS of Fully Embedded Wall
Analysis options
Length of wall perpendicular to section = 6.00m
Subgrade reaction model - Boussinesq Influence coefficients
Soil deformations are elastic until the active or passive limit is reached
Open Tension Crack analysis - No

Rigid boundaries: Active side 20.00 from wall
Passive side 20.00 from wall

Limit State: Serviceability Limit State
Calculated Bending Moments and Strut Forces are to be multiplied by a factor of 1.35 to obtain values for structural design. See summary for factored values.

Node no.	Y coord	Nett pressure kN/m2	Wall disp. m	Wall rotation rad.	Shear force kN/m	Bending moment kN.m/m	Strut forces kN/m
1	82.00	17.59	0.007	-1.02E-03	0.0	-0.0	
2	81.75	19.41	0.007	-1.02E-03	4.6	0.7	17.1
		19.41	0.007	-1.02E-03	-12.4	0.7	
3	81.50	11.37	0.007	-1.02E-03	-8.6	-1.8	
4	81.10	11.60	0.007	-1.01E-03	-4.0	-4.1	
5	81.00	13.35	0.008	-1.00E-03	-2.7	-4.4	
6	80.60	22.79	0.008	-9.89E-04	4.5	-4.2	
7	80.05	33.43	0.009	-9.86E-04	19.9	3.1	
8	79.50	41.45	0.009	-1.05E-03	40.5	19.9	
9	78.95	48.19	0.010	-1.25E-03	65.2	48.8	214.5
		48.19	0.010	-1.25E-03	-149.3	48.8	
10	78.47	53.61	0.010	-1.33E-03	-125.1	-16.5	
11	78.00	58.89	0.011	-1.11E-03	-98.4	-69.7	
12	77.50	64.50	0.011	-6.35E-04	-67.5	-111.3	
13	77.15	68.53	0.012	-1.84E-04	-44.3	-131.1	
14	76.80	72.67	0.011	3.24E-04	-19.5	-142.3	
15	76.40	77.56	0.011	9.35E-04	10.5	-144.3	
16	76.00	82.62	0.011	1.52E-03	42.5	-133.9	
		118.17	0.011	1.52E-03	42.5	-133.9	
17	75.68	123.53	0.010	1.95E-03	81.8	-113.9	
18	75.35	128.97	0.009	2.29E-03	122.9	-80.8	
19	75.03	134.39	0.009	2.49E-03	165.6	-34.2	
20	74.70	139.56	0.008	2.50E-03	210.2	27.5	223.3
		139.56	0.008	2.50E-03	-13.1	27.5	
21	74.45	142.97	0.007	2.42E-03	22.2	28.5	
		-58.27	0.007	2.42E-03	22.2	28.5	
22	73.97	-40.45	0.006	2.27E-03	-1.3	31.9	
23	73.50	-22.74	0.005	2.12E-03	-16.3	26.1	
		-6.55	0.005	2.12E-03	-16.3	26.1	

(continued)

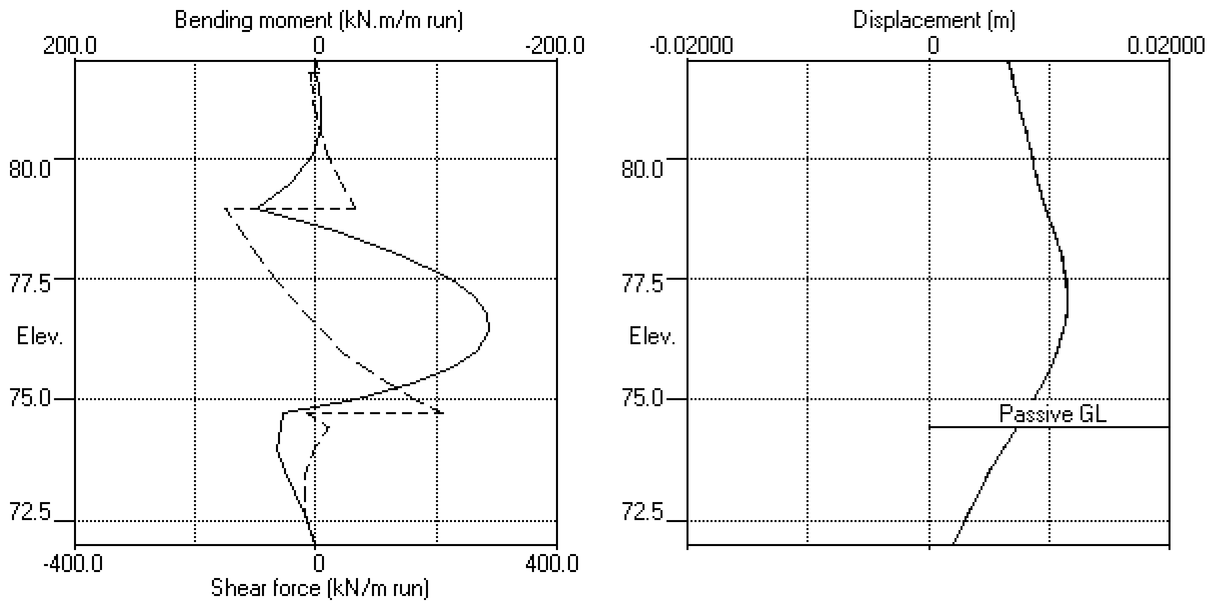
Stage No.22 Change properties of soil type 3 to soil type 6
Ko pressures will be reset

Node no.	Y coord	Nett pressure kN/m2	Wall disp. m	Wall rotation rad.	Shear force kN/m	Bending moment kN.m/m	Strut forces kN/m
24	73.05	-4.12	0.004	2.02E-03	-18.7	17.3	
25	72.60	12.25	0.003	1.96E-03	-16.8	9.5	
26	72.00	43.87	0.002	1.93E-03	0.0	-0.0	

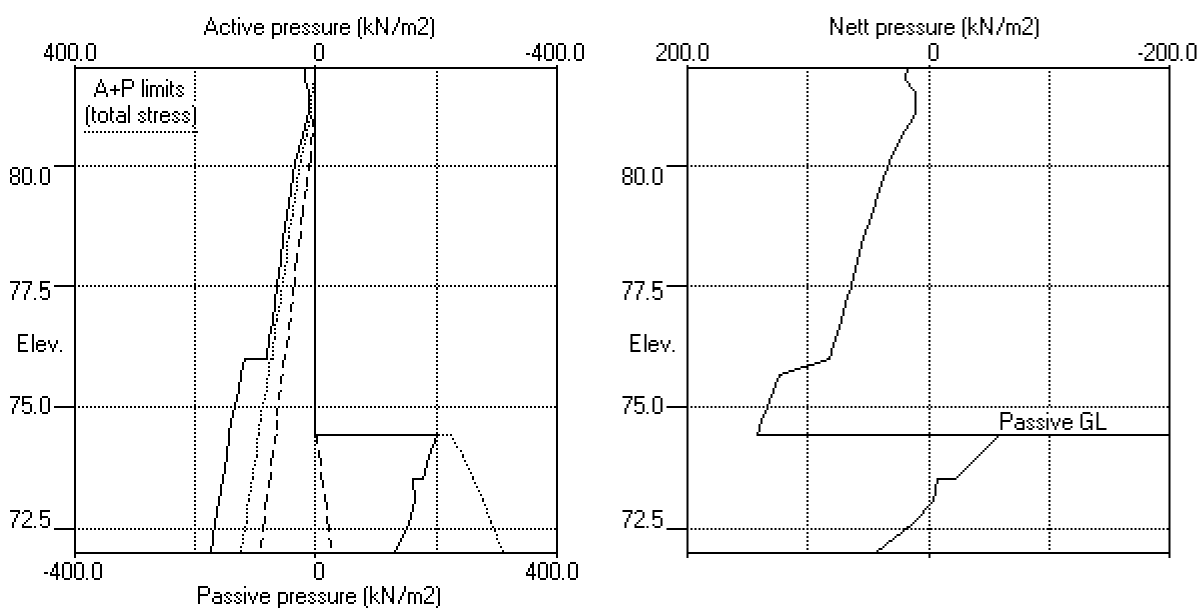
At elev. 81.75 Strut force = 17.1 kN/strut = 17.1 kN/m run
At elev. 78.95 Strut force = 214.5 kN/strut = 214.5 kN/m run
At elev. 74.70 Strut force = 223.3 kN/strut = 223.3 kN/m run

Units: kN,m

Stage No.22 Change soil type 3 to soil type 6



Stage No.22 Change soil type 3 to soil type 6



Units: kN,m

Summary of results

LIMIT STATE PARAMETERS

Limit State: Serviceability Limit State

All loads and soil strengths are unfactored

STABILITY ANALYSIS of Fully Embedded Wall according to Strength Factor method

Factor of safety on soil strength

Stage No.	G.L. Act.	G.L. Pass.	Strut Elev.	FoS for toe elev. = 72.00: Factor of Safety	FoS for toe elev. = 72.00: Moment equilib. at elev.	Toe elev. for FoS = 1.000: Toe elev.	Toe elev. for FoS = 1.000: Wall Penetr -ation
1	82.00	82.00	Cant.	Conditions not suitable for FoS calc.			
2	82.00	82.00	Cant.	Conditions not suitable for FoS calc.			
3	82.00	82.00	Cant.	Conditions not suitable for FoS calc.			
4	82.00	82.00	Cant.	Conditions not suitable for FoS calc.			
5	82.00	80.60	Cant.	3.285	73.40	80.34	0.26
6	82.00	80.60		No analysis at this stage			
7	82.00	80.60		No analysis at this stage			
8	82.00	77.50	81.10	2.442	n/a	76.58	0.92
9	82.00	77.50		No analysis at this stage			

All remaining stages have more than one strut - FoS calculation n/a

Units: kN,m

Summary of results

BENDING MOMENT and DISPLACEMENT ANALYSIS of Fully Embedded Wall

Analysis options

Length of wall perpendicular to section = 6.00m
Subgrade reaction model - Boussinesq Influence coefficients
Soil deformations are elastic until the active or passive limit is reached
Open Tension Crack analysis - No

Rigid boundaries: Active side 20.00 from wall
Passive side 20.00 from wall

Limit State: Serviceability Limit State

Calculated Bending Moments and Strut Forces have been multiplied by a factor of 1.35 to obtain values for structural design.

Bending moment, shear force and displacement envelopes

Node no.	Y coord	Displacement max. m	Displacement min. m	Bending moment Calculated max. kN.m/m	Bending moment Calculated min. kN.m/m	Bending moment Factored max. kN.m/m	Bending moment Factored min. kN.m/m	Shear force Calculated max. kN/m	Shear force Calculated min. kN/m	Shear force Factored max. kN/m	Shear force Factored min. kN/m
1	82.00	0.008	0.000	0	-0	0	-0	0	0	0	0
2	81.75	0.008	0.000	1	-0	1	-0	6	-14	8	-20
3	81.50	0.008	0.000	3	-2	4	-3	10	-11	13	-14
4	81.10	0.008	0.000	8	-5	11	-7	13	-47	18	-64
5	81.00	0.008	0.000	8	-6	11	-8	3	-47	5	-63
6	80.60	0.008	0.000	10	-16	14	-21	7	-44	9	-60
7	80.05	0.009	0.000	16	-38	22	-51	22	-40	30	-54
8	79.50	0.009	0.000	25	-58	34	-78	43	-83	58	-112
9	78.95	0.010	0.000	54	-73	74	-98	67	-155	91	-209
10	78.47	0.010	0.000	0	-80	0	-108	14	-131	19	-176
11	78.00	0.011	0.000	0	-81	0	-110	29	-104	39	-140
12	77.50	0.011	0.000	0	-114	0	-154	25	-73	34	-99
13	77.15	0.012	0.000	0	-136	0	-183	33	-50	45	-68
14	76.80	0.012	0.000	0	-149	0	-201	43	-29	58	-39
15	76.40	0.011	0.000	4	-153	6	-207	56	-9	75	-12
16	76.00	0.011	0.000	12	-145	16	-196	71	0	95	0
17	75.68	0.010	0.000	18	-128	24	-172	82	0	110	0
18	75.35	0.010	0.000	26	-97	35	-131	123	0	166	0
19	75.03	0.009	0.000	33	-63	45	-85	166	0	224	0
20	74.70	0.008	0.000	36	-39	48	-53	210	-13	284	-18
21	74.45	0.007	0.000	36	-22	48	-30	103	-6	139	-9
22	73.97	0.007	0.000	32	0	43	0	42	-14	57	-19
23	73.50	0.006	0.000	29	0	40	0	6	-19	9	-25
24	73.05	0.005	0.000	24	0	32	0	0	-19	0	-26
25	72.60	0.004	0.000	13	0	18	0	0	-25	0	-33
26	72.00	0.003	0.000	0	-0	0	-0	0	-0	0	-0

Summary of results (continued)

Calculated Bending Moments and Strut Forces have been multiplied by a factor of 1.35 to obtain values for structural design.

Maximum and minimum bending moment and shear force at each stage

Stage	Bending moment						Shear force					
	Calculated				Factored		Calculated				Factored	
no.	max. kN.m/m	elev.	min. kN.m/m	elev.	max. kN.m/m	min.	max. kN/m	elev.	min. kN/m	elev.	max. kN/m	min. kN/m
1	1	74.45	-5	78.47	2	-6	3	76.00	-2	80.05	5	-3
2	7	74.70	-16	78.95	10	-22	12	76.00	-9	80.60	16	-12
3	10	74.70	-18	78.47	13	-24	15	76.00	-10	80.60	20	-13
4	10	74.70	-18	78.47	13	-24	15	76.00	-10	80.60	20	-13
5	22	75.03	-5	78.00	29	-7	22	76.00	-10	73.50	30	-14
6	No calculation at this stage											
7	No calculation at this stage											
8	36	74.70	-81	78.00	48	-110	71	76.00	-47	81.10	95	-64
9	No calculation at this stage											
10	36	74.70	-81	78.00	48	-109	70	76.00	-47	81.10	95	-64
11	8	73.50	-81	76.40	11	-109	66	74.45	-74	78.00	90	-100
12	No calculation at this stage											
13	16	73.50	-91	76.40	21	-123	84	74.45	-76	78.00	114	-102
14	No calculation at this stage											
15	25	79.50	-111	76.80	34	-150	92	74.45	-83	79.50	124	-112
16	No calculation at this stage											
17	23	73.50	-107	76.40	31	-144	90	74.45	-78	78.95	122	-105
18	No calculation at this stage											
19	23	73.50	-106	76.40	31	-143	90	74.45	-79	78.95	122	-107
20	45	78.95	-137	76.40	60	-184	103	74.45	-145	78.95	139	-195
21	54	78.95	-153	76.40	74	-207	203	74.70	-155	78.95	274	-209
22	49	78.95	-144	76.40	66	-195	210	74.70	-149	78.95	284	-202

Maximum and minimum displacement at each stage

Stage no.	Displacement maximum m	elev.	minimum m	elev.	Stage description
1	0.000	78.47	0.000	82.00	Apply surcharge no.1 at elev. 81.50
2	0.002	79.50	0.000	82.00	Apply surcharge no.2 at elev. 81.50
3	0.003	79.50	0.000	82.00	Apply surcharge no.3 at elev. 82.00
4	0.003	79.50	0.000	82.00	Apply water pressure profile no.1
5	0.008	82.00	0.000	82.00	Excav. to elev. 80.60 on PASSIVE side
6	No calculation at this stage				Install strut no.2 at elev. 81.10
7	No calculation at this stage				Apply water pressure profile no.3
8	0.009	78.47	0.000	82.00	Excav. to elev. 77.50 on PASSIVE side
9	No calculation at this stage				Install strut no.3 at elev. 78.00
10	0.009	78.47	0.000	82.00	Apply water pressure profile no.5
11	0.010	77.15	0.000	82.00	Excav. to elev. 74.45 on PASSIVE side
12	No calculation at this stage				Install strut no.4 at elev. 74.70
13	0.010	77.15	0.000	82.00	Apply surcharge no.4 at elev. 74.45
14	No calculation at this stage				Install strut no.5 at elev. 79.50
15	0.011	77.15	0.000	82.00	Remove strut no.3 at elev. 78.00
16	No calculation at this stage				Install strut no.6 at elev. 78.95
17	0.011	77.15	0.000	82.00	Remove strut no.5 at elev. 79.50
18	No calculation at this stage				Install strut no.7 at elev. 81.75
19	0.011	77.15	0.000	82.00	Remove strut no.2 at elev. 81.10
20	0.011	77.15	0.000	82.00	Change soil type 1 to soil type 4
21	0.012	77.15	0.000	82.00	Change soil type 2 to soil type 5
22	0.012	77.15	0.000	82.00	Change soil type 3 to soil type 6

Summary of results (continued)

Calculated Bending Moments and Strut Forces have been multiplied by a factor of 1.35 to obtain values for structural design.

Strut forces at each stage (horizontal components)

Stage no.	Strut no. 2 at elev. 81.10 Calculated kN per m run	Strut no. 2 Calculated kN per strut	Strut no. 2 Factored kN per strut	Strut no. 3 at elev. 78.00 Calculated kN per m run	Strut no. 3 Calculated kN per strut	Strut no. 3 Factored kN per strut	Strut no. 4 at elev. 74.70 Calculated kN per m run	Strut no. 4 Calculated kN per strut	Strut no. 4 Factored kN per strut
8	59	178	240	---	---	---	---	---	---
10	59	178	240	0	1	1	---	---	---
11	38	115	155	103	309	417	---	---	---
13	41	122	165	101	304	410	slack	slack	slack
15	11	32	43	---	---	---	slack	slack	slack
17	29	86	116	---	---	---	slack	slack	slack
19	---	---	---	---	---	---	slack	slack	slack
20	---	---	---	---	---	---	slack	slack	slack
21	---	---	---	---	---	---	201	201	271
22	---	---	---	---	---	---	223	223	301

Stage no.	----- Strut no. 5 ----- at elev. 79.50			----- Strut no. 6 ----- at elev. 78.95			----- Strut no. 7 ----- at elev. 81.75		
	--Calculated--		Factored	--Calculated--		Factored	--Calculated--		Factored
	kN per m run	kN per strut	kN per strut	kN per m run	kN per strut	kN per strut	kN per m run	kN per strut	kN per strut
15	104	311	419	---	---	---	---	---	---
17	---	---	---	89	89	120	---	---	---
19	---	---	---	97	97	132	20	20	28
20	---	---	---	208	208	281	18	18	25
21	---	---	---	222	222	300	15	15	20
22	---	---	---	214	214	290	17	17	23

* Indicates that the total force shown is the sum of the force in the strut plus a force applied at the same elevation which may represent temperature load or other forces which are part of the strut load. Force components are listed in the detailed results for individual stages.

```
GEOTECHNICAL & ENVIRONMENTAL ASSOCIATES                      | Sheet No.
Program: WALLAP  Version 6.05  Revision A45.B58.R48          | Job No. J11251D
                             Licensed from GEOSOLVE          | Made by :    MC
Data filename/Run ID: 59 Maresfield Gdns Scheme 4 South Wall_SLS Pool
59 Maresfield Gardens Scheme 4                               | Date:14-03-2016
South Wall SLS Poolside                                      | Checked :
-----------------------------------------------------------------------------
                                                    Units: kN,m
```