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29 Barrie House, St Edmunds's Terrace, London NW8 7QH

Basement Impact Assessment Audit

For

London Borough of Camden

Project Number: 12727-47
Revision: F1

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1.0 NON-TECHNICAL SUMMARY

1.1. CampbellReith was instructed by London Borough of Camden, (LBC) to carry out an audit on the Basement Impact Assessment submitted as part of the Planning Submission documentation for 29 Barrie House, St Edmund's Terrace, London, NW8 7QH (planning reference 2018/0645/P). The basement is considered to fall within Category B as defined by the Terms of Reference.

1.2. The Audit reviewed the Basement Impact Assessment for potential impact on land stability and local ground and surface water conditions arising from basement development in accordance with LBC's policies and technical procedures.

1.3. CampbellReith was able to access LBC's Planning Portal and gain access to the latest revision of submitted documentation and reviewed it against an agreed audit check list.

1.4. The Basement Impact Assessment (BIA) and Structural Strategy Report (SSR) have been prepared by well-known firms of engineering consultants using individuals who possess suitable qualifications.

1.5. Relevant information screening and scoping as defined and required in the LBC Planning Guidance document 'Basement and Lightwells (CPG4)' has been provided.

1.6. It has been identified that the basement proposal neither involved a listed building nor was adjacent to listed buildings.

1.7. The proposed scheme involves the demolition of the existing two storey building, construction of part four, part five storey residential block forming the extension to 8-storey block of flats and construction of basement to both blocks.

1.8. The basement walls are proposed to be formed using piling methods, with concrete floors and liner walls. This is acceptable as an appropriate structural form for the proposed basement in respect of the identified ground conditions.

1.9. A proposed construction methodology are to be provided in the form of a Basement Construction Plan (BCP).

1.10. Outline structural calculations for the basement retaining wall structure have been provided.

1.11. An appropriate site investigation has been carried out, including investigation of ground water levels.

1.12. The ground conditions have been identified as a shallow depth of made ground overlying London Clay. Ground water was observed at relatively shallow depth below ground level.

1.13. The basement is to be found below the anticipated ground water level, however an appropriate construction method has been proposed to account for this.

1.14. The damage category calculated for the flats within Barrie house has been calculated as Burland category 1 via a formal ground movement assessment.

1.15. The damage category for the neighbouring properties has been calculated as a worst-case of Burland damage category 1 via a formal ground movement assessment.

1.16. The site is within of the Environment Agencies Inner Source Protection Zone 1 (SPZ), relating to the Barrow Hill reservoir however, it is accepted that the development will not impact on the ground water flows.

1.17. An appropriate SUDs Assessment has been provided including adequate drainage system strategy proposal.

1.18. It is accepted that nearby rail assets are outside of the zone of influence of the proposed site.

1.19. It is accepted that the surrounding slopes to the development site are stable.

1.20. It is accepted that the development will not impact on the wider hydrogeology of the area and is not in an area subject to flooding.

1.21. It can be confirmed that the proposal conforms to the requirements of CPG Basements.

2.0 INTRODUCTION

2.1. CampbellReith was instructed by London Borough of Camden (LBC) on 06/02/2018 to carry out a Category B Audit on the Basement Impact Assessment (BIA) submitted as part of the Planning Submission documentation for 29 Barrie House, St Edmund's Terrace, London, NW8 7QH, planning ref: 2018/0645/P.

2.2. The Audit was carried out in accordance with the Terms of Reference set by LBC. It reviewed the Basement Impact Assessment for potential impact on land stability and local ground and surface water conditions arising from basement development.

2.3. A BIA is required for all planning applications with basements in Camden in general accordance with policies and technical procedures contained within

- Guidance for Subterranean Development (GSD). Issue 01. November 2010. Ove Arup & Partners.
- Camden Planning Guidance (CPG) 4: Basements and Lightwells.
- Camden Development Policy (DP) 27: Basements and Lightwells.
- Camden Development Policy (DP) 23: Water.
- Local Plan Policy A5 Basements.

2.4. The BIA should demonstrate that schemes:

a) maintain the structural stability of the building and neighbouring properties;

b) avoid adversely affecting drainage and run off or causing other damage to the water environment;

c) avoid cumulative impacts upon structural stability or the water environment in the local area, and;

evaluate the impacts of the proposed basement considering the issues of hydrology, hydrogeology and land stability via the process described by the GSD and to make recommendations for the detailed design.

2.5. LBC's Audit Instruction described the planning proposal as *"It is proposed develop the site adjacent to the existing residential tower block at Barrie House 29 St Edmunds Terrace. The site is currently occupied by a car park and an unoccupied 2 storey masonry structure in the western corner. Included in the proposal is a basement structure below the footprint of the proposed block, which is the focus of this Basement Impact Assessment as part of the planning application pack. Redevelopment of existing two-storey porter's lodge and surface level car park*

to construct a part four, part five storey extension (lower ground, ground and 3 storey's) to Barrie House including excavation of a basement level, to provide 9 self-contained residential flats, cycle parking, refuse and recycling stores, hard and soft landscaping and relocated off-street car parking spaces."

The Audit Instruction also confirmed 29 Barrie House, St Edmund's Terrace involved, or was a neighbour to, listed buildings.

2.6. CampbellReith accessed LBC's Planning Portal on 14/02/2018 and gained access to the following relevant documents for audit purposes:

- Basement Impact Assessment Part 1-9 Rev.1 – February 2018, parmarbrook
- Location Plan – October 2017, prepared by Marek Wojciechowski Architects
- Existing, Demolition and Proposed Application Drawings – November 2017, prepared by Marek Wojciechowski Architects
- Design and Access Statement Part 1-6 - November 2017, Marek Wojciechowski Architects
- Planning Statement - February 2018, Montagu Evans
- Landscape Proposal – December 2017, Exterior Architecture
- Construction Management Plan – December 2017, RPS
- Sustainability Assessment – Final Issue dated 04/01/2018, motion
- Daylight and Sunlight Report – 21 December 2017, malcolm hollis
- Draft Construction Management Plan (inc. Pro Forma) – December 2017, RPS
- Noise Level Survey – 18 December 2017, EMTEC
- Arboricultural Report – 2 January 2018 (1-38-4326), John Cromar's Arboricultural Campany Limited
- Planning Comments – where pertinent to scope of audit

2.7. Following the D1 issue of this audit the following further information was downloaded and considered;

- Basement Impact Assessment Part 1-9 Rev.2 – May 2018, parmarbrook

2.8. Following the D2 issue of this audit the following further information was provided via email on 13/07/18 and has been included in appendix 3 of this report;

- Secant pile retaining wall design – C0, parmarbrook

3.0 BASEMENT IMPACT ASSESSMENT AUDIT CHECK LIST

Item	Yes/No/NA	Comment
Are BIA Author(s) credentials satisfactory?	Yes	
Is data required by Cl.233 of the GSD presented?	Yes	
Does the description of the proposed development include all aspects of temporary and permanent works which might impact upon geology, hydrogeology and hydrology?	Yes	
Are suitable plan/maps included?	Yes	Referral to the EA maps has been made and commentary is sufficient. Responded to screening question adequately.
Do the plans/maps show the whole of the relevant area of study and do they show it in sufficient detail?	Yes	
Land Stability Screening: Have appropriate data sources been consulted? Is justification provided for 'No' answers?	Yes	A justification statement is generally provided for 'no' answer.
Hydrogeology Screening: Have appropriate data sources been consulted? Is justification provided for 'No' answers?	Yes	A justification statement is generally provided for 'no' answer.
Hydrology Screening: Have appropriate data sources been consulted? Is justification provided for 'No' answers?	Yes	A justification statement is generally provided for 'no' answer.
Is a conceptual model presented?	Yes	
Land Stability Scoping Provided? Is scoping consistent with screening outcome?	Yes	Impact Assessment with ground movement assessment has been identified and scoping is consistent with screening.

Item	Yes/No/NA	Comment
Hydrogeology Scoping Provided? Is scoping consistent with screening outcome?	No	All Hydrogeology Screening answers were No and justification has been provided.
Hydrology Scoping Provided? Is scoping consistent with screening outcome?	Yes	Further ground water monitoring has been identified and scoping is consistent with screening outcome.
Is factual ground investigation data provided?	Yes	
Is monitoring data presented?	Yes	Ground water level has been monitored
Is the ground investigation informed by a desk study?	Yes	
Has a site walkover been undertaken?	Yes	A site walkover was undertaken by a CGL Engineer on 6th December 2017.
Is the presence/absence of adjacent or nearby basements confirmed?	Yes	
Is a geotechnical interpretation presented?	Yes	
Does the geotechnical interpretation include information on retaining wall design?	Yes	Factors for retaining wall design have been provided but Structural calculations for retaining wall to be provided.
Are reports on other investigations required by screening and scoping presented?	Yes	Ground movement assessment has been provided and ground water monitoring has been identified
Are the baseline conditions described, based on the GSD?	Yes	
Do the base line conditions consider adjacent or nearby basements?	Yes	
Is an Impact Assessment provided?	Yes	
Are estimates of ground movement and structural impact presented?	Yes	Ground movement assessment
Is the Impact Assessment appropriate to the matters identified by	Yes	

Item	Yes/No/NA	Comment
screen and scoping?		
Has the need for mitigation been considered and are appropriate mitigation methods incorporated in the scheme?	Yes	
Has the need for monitoring during construction been considered?	Yes	
Have the residual (after mitigation) impacts been clearly identified?	Yes	
Has the scheme demonstrated that the structural stability of the building and neighbouring properties and infrastructure will be maintained?	Yes	
Has the scheme avoided adversely affecting drainage and run-off or causing other damage to the water environment?	Yes	SUDs Assessment has been provided
Has the scheme avoided cumulative impacts upon structural stability or the water environment in the local area?	Yes	
Does report state that damage to surrounding buildings will be no worse than Burland Category 1?	Yes	Worst case damage category of 1 has been calculated
Are non-technical summaries provided?	Yes	Non-technical summary has been provided in BIA part 5 Section 10

4.0 DISCUSSION

4.1. The Basement Impact Assessment (BIA) has been carried out by a well-known firm of engineering consultants, Card Geotechnics Limited (CGL) and the individuals concerned in its production have suitable qualifications in geology as required by CPG4.

4.2. Consulting Structural Engineers, parmarbrook, have produced supplementary information to support the structural design and construction of the basement proposal.

4.3. The BIA Audit Instruction confirmed that the site is not situated in a conservation area and that there are no listed building neighbouring the site.

4.4. The BIA submissions include land Stability, Hydrogeology and Hydrology screening and scoping, relevant site investigations and impact assessment as defined and required in the LBC Planning Guidance document 'Basement and Lightwells (CPG4).

4.5. The existing Site is located within the Primrose Hill area of London and consists of a 1950's 8-storey detached residential tower block named Barrie House with a single storey basement Plant Room beneath part of its footprint, a hardstanding car park and an unoccupied 2 storey masonry structure named Porter's Lodge.

4.6. The site generally slopes from north-eastern to south-western corner with approximately 6.6m difference and covers approximately area of 0.2ha. It is bounded by St. Edmund's Terrace to the South and Broxwood Way to the West. There is 'Kingsland' residential estate to the north and 'Regent Heights' which is a seven storey residential block of flats to the East.

4.7. The proposed scheme involves the demolition of the existing 2 storey caretaker's flat in the far western corner of the site, then construction of part four, part five storey residential block which will form part of the extension to Barrie House. Both the proposed block, and the approximately half of the existing tower block will include a new basement level, with the existing plant room at basement level extended beneath the existing block.

4.8. A site specific ground investigation was conducted in September 2012, comprising three trial pits (to investigate existing foundations), three window sample boreholes and one cable percussion borehole to a depth of 7.5mbgl. Two return ground water monitoring visits were undertaken in December 2017.

4.9. The form of construction of the basement to the proposed tower block consists of underpinning three of the existing shallow pad foundations, and the construction of with an L shaped retaining wall to the perimeter of the existing structure which is not below existing load bearing structure. The pad foundations around the existing portion of basement are indicated as being

at a level below the required basement formation level, and are not indicated as requiring underpinning. A new ground bearing RC basement slab is proposed to form the extended basement slab level.

4.10. London Clay was encountered beneath the made ground (in BH1 & WS2) at 0.5-1.13mbgl and directly below the foundation concrete (in WS1 to WS3), to the full depth of the borehole (maximum 7.5mbgl in BH1). The stratum generally comprised brown weathered mottled orange clay with occasional grey gleying and scattered selenite crystals. The London Clay is generally overlaid by Made Ground which was present above all foundation pads, comprising a topsoil layer followed by brown clay with occasional to some building rubble. In the area of the existing pad foundations(WS2) a 1m thick layer of soft to firm clay with occasional flint gravel and dark brown sand and silt lenses was observed from the level of the top of the pad foundation (1.1mbgl). Borehole BH1, in the car park area, encountered 0.5m thick layer of made ground comprising asphalt surfacing and at the depth of 0.35m becoming grey/brown clay with some ash and clinker.

4.11. Groundwater was noted within the Made Ground at levels between 42.7mOD (1.9mbgl) and 44.78mOD (0.82mbgl). The groundwater levels were generally consistent at each of the window sample locations, however the groundwater level at borehole WS2 was approximately 1m lower than the groundwater level at borehole WS1. It was noted that as pipes had no cover and that some of the water could be standing water that has entered during rainfall. However, the observed groundwater levels indicate that groundwater is likely to be encountered during the excavation of the proposed basement and as such ground water control measures will be required. Additionally, sump pumping was suggested to be used while the excavation processes.

4.12. The basement structure to the new building is proposed to be formed from a 450mm diameter secant piled wall to the perimeter, with 250mm thick RC liner wall. A 600mm thick RC raft slab is to support internal load bearing walls and columns, and a RC ground slab is proposed to bear onto and provide a permanent prop to the head of the piled wall in the permanent case. The proposed superstructure is proposed as an in-situ reinforced concrete frame.

4.13. The underpinning to the three pad foundations to the existing structure is indicated as being carried out in either nine or four horizontal sections, depending on the size of the pad, and two vertical stages. It is indicated that access to carry out the underpinning will be obtained from both external with the contiguous piling to the proposed structure being installed prior to allow for local excavations to take place, and from beneath the existing building via cutting through the existing basement wall and excavating beneath the existing suspended slab. While a detailed scheme of temporary works is not provided for the basement construction to the existing building, it is noted that lateral restraint is to be provided to the underpinning at all times during construction.

4.14. Due to the sensitive nature of carrying out underpinning to an existing multi storey building, and the potential sensitivity of a 1950's framed structure to ground movements, it is required that further details of the proposed construction methodology are to be provided in the form of a Basement Construction Plan (BCP). The BCP is to contain the following;

- Detailed construction method of all underpinning works associated with the existing multi storey building.
- Sequence of underpinning construction, including how access to form each underpin is to be gained, and details of any temporary works excavations beneath the existing building.
- Details of temporary works/propping to stabilise both the underpinning in the temporary case, and any temporary excavations.
- Bearing pressure calculations in the temporary case, with justification of the acceptability of bearing pressures for the duration required for the temporary case.

4.15. Construction of the basement to the new building is proposed to take place alongside that of the basement to the existing building, with contiguous piling carried out initially, the underpinning works carried out to the existing building, and then the excavation within the secant piled wall and construction of the proposed liner wall, raft slab, and internal load bearing elements. While a detailed temporary works scheme are not provided for the construction of the basement to the proposed building, it is indicated that lateral propping is to be provided to the contiguous piled wall in the temporary case until both the basement and ground slabs have been constructed, therefore permanently propping the piled wall. It is accepted that feasibility of the safe construction of the basement to the proposed building has been demonstrated.

4.16. An interpretive geotechnical report has been produced that provides geotechnical design parameters for shallow foundations, retaining walls, and piled foundations based on the site specific investigations. The geotechnical interpretation of the soil has been presented specifying bearing pressure calculation in the permanent case.

4.17. The new structure will be set at a formation depth at approximately 4.75m below existing ground floor level, and therefore in the London Clay. The stratum has been confirmed as having good load bearing characteristics appropriate for an RC raft slab, with a safe maximum bearing pressure of 200kN/m2. The excavation of the basement will result in a maximum unloading of approximately 102 kN/m2. As there is a risk of heave in the ground and hydrostatic uplift the basement slab will be designed accordingly during the detailed stage.

4.18. Given the ground conditions, shape and form of the building it is proposed to found the building on a raft slab, which will be tied into the piled perimeter walls. At this stage it is envisaged this will be in the order of 600mm thick, including 450mm piles and a 250mm liner wall. The depth of embedment of the contiguous piles has been modelled as being equal to the excavation depth of 5.15m, therefore the pile lengths have been assumed as 10.3m.

4.19. Outline structural calculations for the basement retaining walls have been provided which adequately demonstrate the structural feasibility of the structural proposal.

4.20. EA mappings indicates the site is within Flood Zone 1, and therefore has a 'low' risk of surface water flooding. It is noted that the site did not experience flooding in the significant flooding events in 1975 and 2002.

4.21. The Environment Agency Maps shows the site is within of the Environment Agencies Inner Source Protection Zone 1 (SPZ), relating to the Barrow Hill reservoir. The London Clay strata is described as being approximately 50m thick beneath the site, which creates an impermeable barrier between the principle aquifer that is located within the chalk beneath the London clay, and the development which is located within the top few meters of the clay. While piling is proposed, it is accepted that the London Clay is of adequate thickness to allow for typical depths of piling without causing penetration through the entire thickness of The London Clay.

4.22. It is accepted the site has a very low flooding risk from surface water and sewers, reservoirs and fluvial/tidal watercourses.

4.23. A ground movement assessment has been produced with horizontal displacements calculated following the method as described in CIRIA 760 for secant piled wall construction, and vertical displacements calculated using PDISP which takes into account heave due to unloading of the soil beneath the basement. The basement walls has been considered as being of 'high stiffness', therefore benefitting from a high level prop in both the permanent and temporary cases. The ground movement assessment also considers the flats within Barrie House itself, with a section taken through the building and a maximum differential vertical displacement and angular distortion calculated. Horizontal movements have been ignored for the damage assessment of Barrie House due to the underpinning proposed which will take the formation level to the depth to a lower level.

4.24. The damage category assessment concludes a worst-case damage category to the surrounding buildings of 1, including a damage category of 1 for the flats within Barrie House. It is accepted that reasonable assumptions have been made in the method used, and that assuming good workmanship and appropriately designed temporary works this damage assessment can be considered to be of appropriate accuracy.

4.25. A discrepancy was noted between the ParmaBrook BIA and CGL's ground movement assessment, with the BIA stating that damage to neighbouring buildings would not exceed category 2 following mitigation measures. It is assumed that this is an error given the detailed GMA discussion is carried out in CGLs report.

4.26. A construction monitoring scheme is proposed to be carried out throughout the construction stage to demonstrate that movements are within those predicted by the CGL analysis. Monitoring will be carried out by the contractors or their representatives using targets and methods agreed with party wall surveyors prior to the beginning of construction. The site is within 5m of Broxwood Way, however the basement development on site will be over 15m from Broxwood Way and therefore will not affect the property. The movement monitoring strategy should be updated following the revising of the GMA.

4.27. The maximum slope on site is marginally over 1 in 5 or 11.3^{O} to the west / south west of the existing apartment block. The slope stability was assessed in the Soil Consultants report 2 and a factor of safety of 1.45 was found for the slope stability indicating the overall stability is acceptable. Also, no signs of deep-seated failure were observed on site.

4.28. It is accepted that nearby rail assets are outside of the zone of influence of the proposed site.

4.29. An outline works programme covering key phases of work and approximate durations has been presented.

4.30. A schedule of closed queries and the requirement of the BCP are included in Appendix 2. It can be confirmed that the proposal conforms to the requirements of CPG Basements.

5.0 CONCLUSIONS

5.1. The Basement Impact Assessment (BIA) has been carried out by a well-known firm of engineering consultants, and the individuals concerned in its production have suitable qualifications in geology as required by CPG4.

5.2. The BIA submissions include Land Stability, Hydrogeology and Hydrology screening and scoping, relevant site investigations and impact assessments as defined and required in the LBC Planning Guidance document 'Basement and Lightwells (CPG4)'.

5.3. The BIA Audit Instruction confirmed that the site is not situated in a conservation area and that there are no listed building neighbouring the site.

5.4. The proposed scheme involves the demolition of the existing 2 storey caretaker's building, construction of part four, part five storey residential block forming the extension to 8-storey Barrie House and basement construction to both blocks.

5.5. The basement to the existing residential block is to be formed with an L-shaped RC retaining wall to the perimeter of the building with underpinned internal shallow pad foundations and RC ground bearing slab. The basement to the proposed new building is to be formed of the perimeter secant piled wall, with RC liner wall and RC raft slab. The proposed block basement excavation is to be 4.75mbgl in depth, and the new block basement up to 2.1mbgl.

5.6. A site specific ground investigation has been carried out, which consist of three trial pits, three window sample boreholes and one cable percussion borehole. A brief period of ground water monitoring was undertaken.

5.7. The ground conditions have been identified as a shallow depth of made ground overlying London Clay. Ground water was not consistent and was observed between 1.9 and 0.82mbgl. It is likely that the ground water table will be encountered during basement foundation excavation and ground water control measures will be required.

5.8. A bottom up construction sequence is proposed with temporary propping described as being provided to the secant piled walls at all times until the permanent RC box is constructed. This is acceptable as an appropriate method of construction.

5.9. An interpretive geotechnical report has been produced that provides geotechnical design parameters for shallow foundations, retaining walls, RC raft slab and piled foundations based on the site specific site investigations. The new structure will be set in the London Clay and as there is a risk of heave in the ground and hydrostatic uplift the basement slab will be designed accordingly during the detailed stage.

5.10. Due to the sensitive nature of carrying out underpinning to an existing multi storey building, it is required that further details of the proposed construction methodology are to be provided in the form of a Basement Construction Plan (BCP).

5.11. Outline structural calculations for the basement retaining wall structure have been provided.

5.12. A ground movement assessment has been produced generally following the method as described in CIRIA 760. A worst-case damage category for the neighbouring buildings been concluded as Burland category 1. The damage category to the flats within Barrie house have been calculated as having a damage category of 1.

5.13. A construction monitoring scheme is proposed to be carried out throughout the construction stage to demonstrate that movements are within those predicted in the GMA.

5.14. The site is within of the Environment Agencies Inner Source Protection Zone 1 (SPZ), relating to the Barrow Hill reservoir however, it is accepted that the London Clay is of adequate thickness to allow for typical depths of piling for the development without causing penetration through the entire thickness of The London Clay.

5.15. SUDs Assessment has been provided. Permeable paving and attenuation system has been proposed as part of the rain water management. It is recommended that the proposed additional flow to the combined drainage system to be checked with Thames Water.

5.16. It is accepted that nearby rail assets are outside of the zone of influence of the proposed site.

5.17. It is accepted that the surrounding slopes to the development site are stable.

5.18. It is accepted the site has a very low flooding risk from surface water and sewers, reservoirs and fluvial/tidal watercourses.

5.19. It is accepted that the development will not impact on the wider hydrogeology of the area and is not in an area subject to flooding.

Appendix 1: Residents' Consultation Comments

Residents' Consultation Comments

Surname	Address	Date	Issue raised	Response
Liyang Li and Will Chaffin	Flat 12, Barrie House, 29 St. Edmunds	04/03/2018	Concern was raised regarding deep excavation to Barrie House	The applicant has submitted a construction methodology adequate to the proposed excavation and basement construction.
Group of residents	Flat No. 5 - Gaurav Jain Flat No. 17 - Armine Ishkanian and Vitali Flat No. 20 - Anita Robbins-Berke and David Berke Flat No. 3 - Suvarna Shirsat Flat No. 11 - Luke Sonoda Flat No. 21 - Elizabeth Elster Flat No. 12 - Liyang Li and Will Chaffin Flat No. 14 - David Atkinson and Joanna Kaliszewska Flat No. 7 - Alain Gherson Flat No. 16 - Mr. &Mrs.Gupte Flat No. 4 -Tischa Stossler	Feb/March 2018	No Basement Impact Assessment for basement directly under the block of flats. Slope stability Stability of the building during excavation and construction of the basement caused by possible mains water pipeline leak located nearby.	An appropriate ground movement assessment has now been produced that assesses the damage category to Barrie House as 1. The applicant has demonstrated adequately slope stability assessment which shows no further concerns. The applicant has demonstrated stability assessment adequate to the proposed development.

Appendix 2: Audit Query Tracker

Audit Query Tracker

Query No	Subject	Query	Status	Date closed out
1	Stability	Preliminary design calculations for the secant piled retaining wall, RC retaining walls and underpinning to demonstrate feasibility of proposal.	Closed	19/07/18
2	Stability	Predicted movement values to be resubmitted based on secant piled wall construction method as proposed. Currently calculations account for contiguous piled wall installation. Or evidence of mitigation measures proposed to indicate that the values adopted are realistic	Closed	12/07/18
3	Stability	In relation to the basement formation beneath the existing multi storey block; • Detailed construction method statement • Detailed temporary works design	To be provided in a Basement Construction Plan	N/A
4	Stability	Basement Impact Assessment to be provided for the flats within Barrie House	Closed	12/07/18

Appendix 3: Supplementary Supporting Documents

Retaining wall calculations

parmarbrook

SECANT PILED RETAINING WALL DESIGN

FOR TEMPORARY AND PERMANENT CONDITIONS

AT

BARRIE HOUSE

29 ST EDMUND'S TERRACE

CAMDEN

LONDON, NW8

Initial Issue	C0	Design Calculations for Comment / Approval	8th June 2018
Stage	**Revision**	**Comments**	**Date**

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1.0 INTRODUCTION

As part of the redevelopment of a site at Barrie House, 29 St Edmund's Terrace, Camden, London NW8, it is proposed to construct a new up to five storey residential development, including a single level basement below. The site is currently occupied by a car park and a two storey masonry structure.

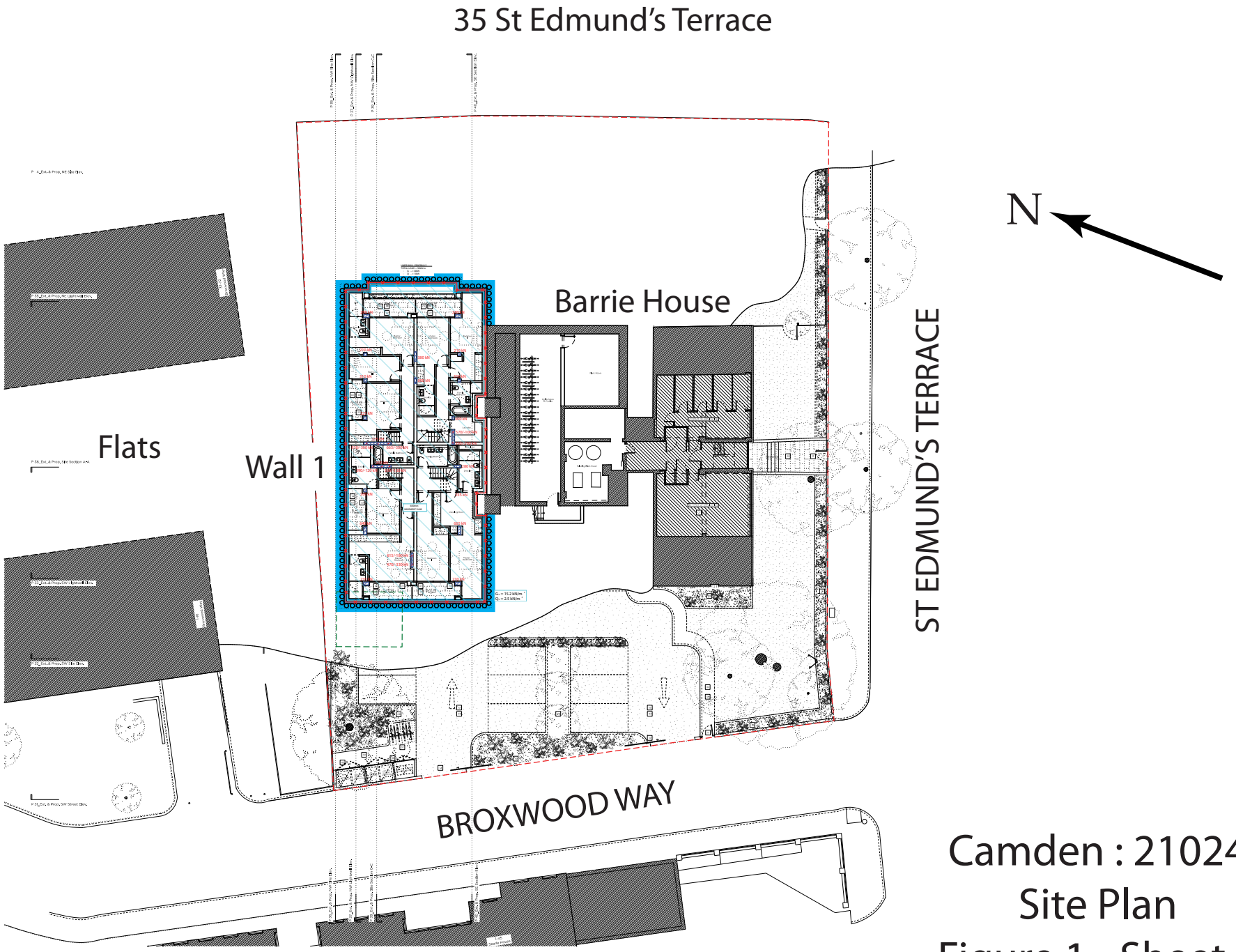
The site can be located by National Grid Reference TQ 27497 83580 and lies off the East side of Broxwood Way, which provides the site access. The Southern boundary adjoins the existing Barrie House block, while the Northern boundary adjoins blocks of flats on Broxwood Way. The Eastern boundary adjoins the gardens and multi-storey block of number 35 St Edmund's Terrace.

To allow construction of the proposed basement a secant piled wall is proposed around all sides of the basement except part of the section on the southern side adjacent to the existing Barrie House, which will be supported by underpins or other means.

The plan positions of the new basement and the proposed retaining wall are shown on the site plan, given on Figure 1 – see page 4. This also shows the sections taken for the design.

These calculations cover the design of the temporary / permanent piled retaining wall only.

The calculations have been carried out by Piledesigns Limited on behalf of Parmarbrook.



Camden : 21024
Site Plan
Figure 1 - Sheet 4

2.0 INFORMATION PROVIDED

2.1 General and Structural Arrangements for the Proposed Development

Details of the proposed retaining wall has been taken from the relevant drawings provided, which are from Parmarbrook, Structural Engineers for the project, under their project no: 1805. Further clarification has been provided following verbal and email communication with the Engineer.

The main retaining wall drawings can be summarised as follows:

PAR-ZZ-LG-DR-S-0090-D1 revision P01: General Arrangement – Lower Ground Floor
PAR-ZZ-00-DR-S-0100-D1 revision P01: General Arrangement – Ground Floor
PB-SK001 revision 2: Proposed Structural Layout and Basement Loading

The drawings provided are "PRELIMINARY" and "CONTRACT ISSUE" drawings showing details of the secant pile scheme should be received before piling commences on site.

The piling platform level has been taken as 46.0mAD (approximate existing ground level).

One wall section has been identified for this analysis, labelled Wall 1. The section has been indicated on Figure 1, and has been chosen to represent the general soil and structural criteria for the site.

Wall 1 covers all sides of the basement except the section of the Southern side adjacent to the existing Barrie House, for which the Lower Ground Floor structural slab level is given as 41.3mAD. With a 600mm slab and 50mm of blinding concrete, the SLS dig level has been taken as 40.65mAD. A further allowance of 500mm for possible (unplanned) over-dig has been taken for the ULS case. A general surcharge of 10kN/m² has been taken behind the wall for the temporary and permanent conditions.

2.2 Ground Conditions

Ground conditions have been taken from a Site Investigation Report carried out by Soil Consultants; report reference: 9241/OT/JRCB, dated 7th November 2012. The investigation contains the records of one Cable Percussion and three Window Sample boreholes, taken to a maximum depth of 7.5m.

The boreholes showed the ground conditions to comprise Made Ground over London Clay. The Made Ground generally comprised topsoil and clay over soft to firm clay with rubble, clinker and gravel. The London Clay was noted as soft to stiff brown clay with selenite crystals.

A summary of the borehole results is presented in Table 1.

Table 1: Borehole Results

Borehole No	Location	Ground Level (mAD)	Level of London Clay (mAD)	Ground water levels in boreholes (mAD)
BH1	North side	46.0	45.50	-
WS1	NW corner	45.6	43.85	44.65
WS2	SW corner	44.6	42.50	41.10
WS3	SE corner	45.3	43.68	-

A plot of SPT ‘N’ values and Shear Strengths against level is presented in Figure 2 – see sheet 7.

The Hand Vane readings have had a reduction factor of 0.8 applied.

For the purpose of the retaining wall design the Made Ground has been taken to a level of 43.75mAD, with the London Clay taken to depth.

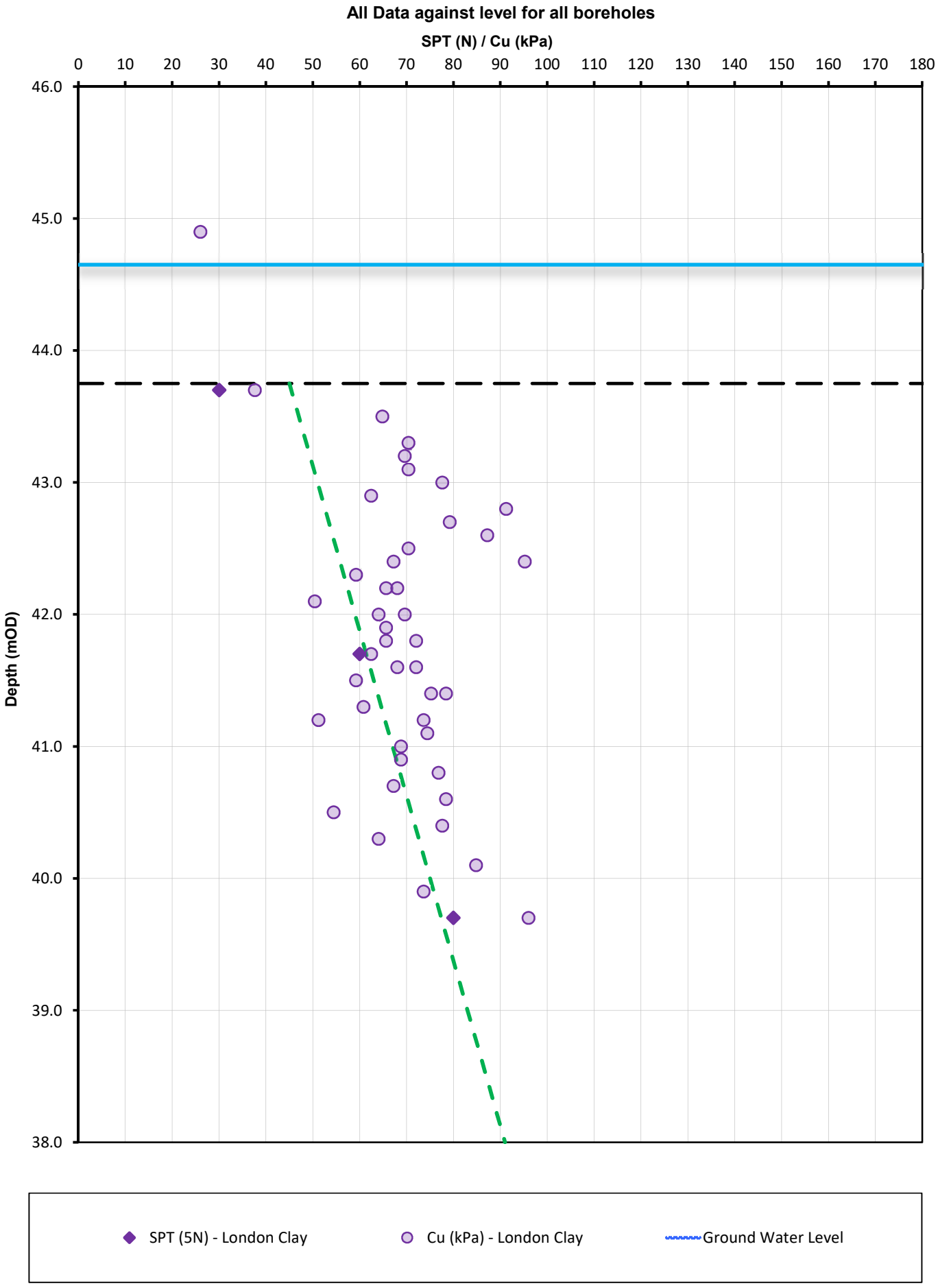
A design line in the London Clay has been taken as a shear strength of 45kN/m² at a level of 43.75mAD and increasing at a rate of 8kN/m² per metre depth.

Groundwater was recorded in the boreholes during the drilling at a highest level of 44.65mAD.

The assumed soil profile and design parameters should be checked during initial piling operations and any variations notified to the designer.

PILEDESIGNS
GEOTECHNICAL EXPERTISE

Project Name:	Barrie House, 29 St Edmund's Terrace, Camde			**Date:**	08/06/2018
Projet No:	21024	**Drawn by:**	DBS	**Rev:**	C0



3.0 DESIGN PARAMETERS

3.1 Geotechnical

The pile design calculations have been based on the information provided. The soil parameters employed have generally been taken from the soils information provided and checked against published data and other ground investigation reports in the area. The analysis has considered drained conditions for the Made Ground and undrained conditions for the London Clay when applied to the temporary condition. For the permanent condition all soil types have been changed to the drained condition where applicable.

The sections shown on Figures 3 and 4 on sheets 10 and 11 show the typical soil profile used in the analysis and the soil parameters for the drained and undrained conditions.

Groundwater for the temporary condition has been taken at a level of 44.65mAD. For the permanent condition groundwater has been taken at the underside of the basement on the passive side and approximate ground level on the active side.

3.2 Construction Sequence

Wall 1

- Carry out piling from the assumed piling platform level (46.0mAD)
- Excavate for and construct Capping Beam (after adequate curing of the piles)
- After adequate curing of the Capping Beam install temporary propping at Capping Beam level (44.0mAD)
- Excavate to Lower Ground Floor slab formation level (40.65mAD)
- Construct Lower Ground Floor RC slab, structural walls and Ground Floor slab
- After adequate curing of the slabs and walls remove temporary propping
- Apply long term parameters to piles and soils
- Apply high water check

3.3 Structural Design Parameters

The male secant bored pile retaining wall piles will be constructed using Auger Bored piling techniques with a minimum C30/37 designed concrete pump mix and ‘B’ (500N/mm²) grade main reinforcement bars with helical shear links. A minimum of 75mm cover to the main reinforcement will be provided by propriety spacers.

The main structural design parameters used in the retaining wall analysis have been summarized in Table 2, for 450mm diameter piles at approximately 600mm centres.

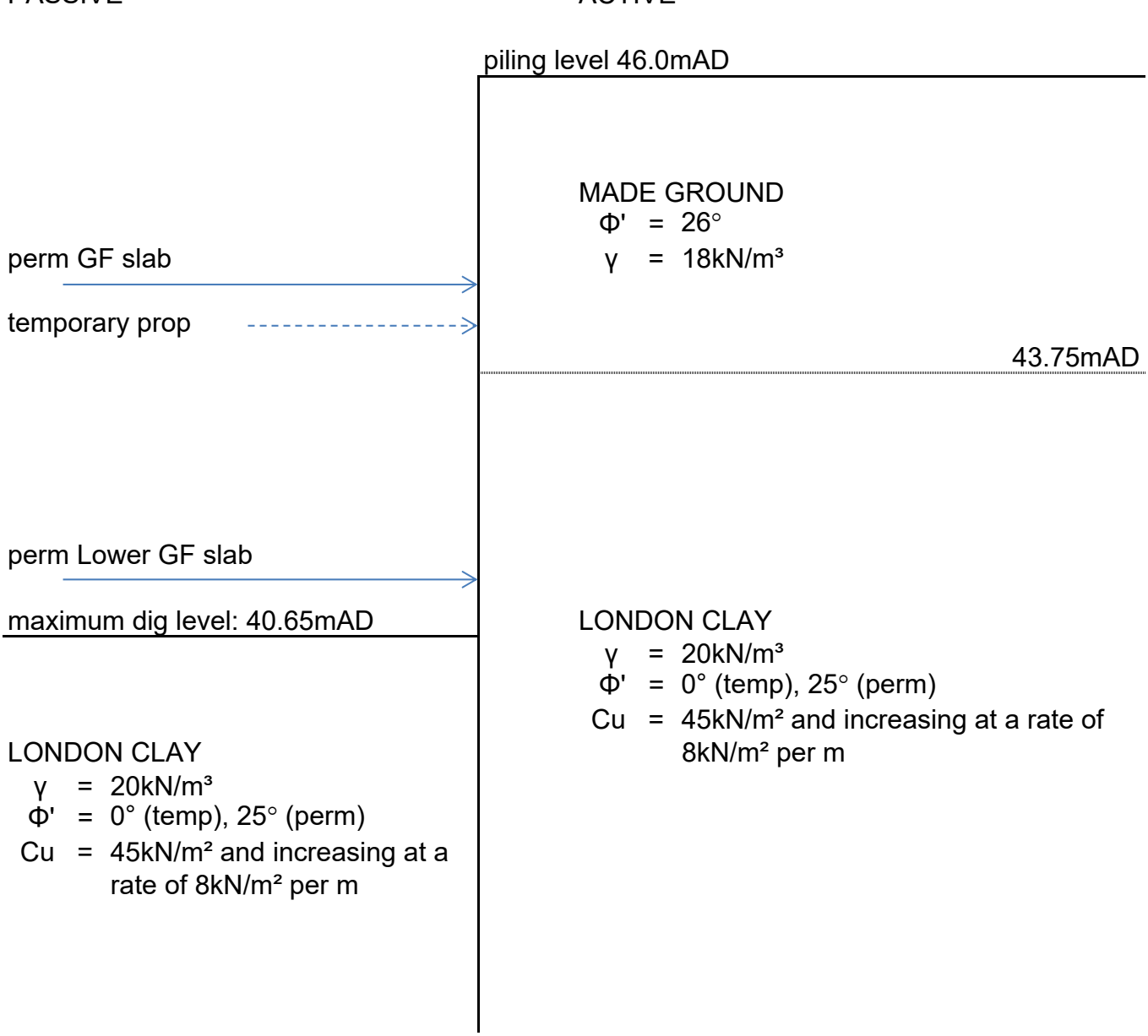
Table 2 – Main Structural Design Parameters

Material	Short Term Parameters	Long Term Parameters
Concrete 450mm diameter	E = 1.96 x 10^{+7} kN/m² I = 3.35 x 10^{-3} m^4/m run E.I = 65754 kN.m² / m run	E = 1.40 x 10^{+7} kN/m² I = 3.35 x 10^{-3} m^4/m run E.I = 46967.5 kN.m² / m run
Steel	E = 2.05 x 10^{+8} kN/m²	E = 2.05 x 10^{+8} kN/m²

Notes:
Short term EI = 70% of the initial value.
Long term EI = 50% of the initial value.

TYPICAL SECTION FOR SLS CONDITIONS - Figure 3

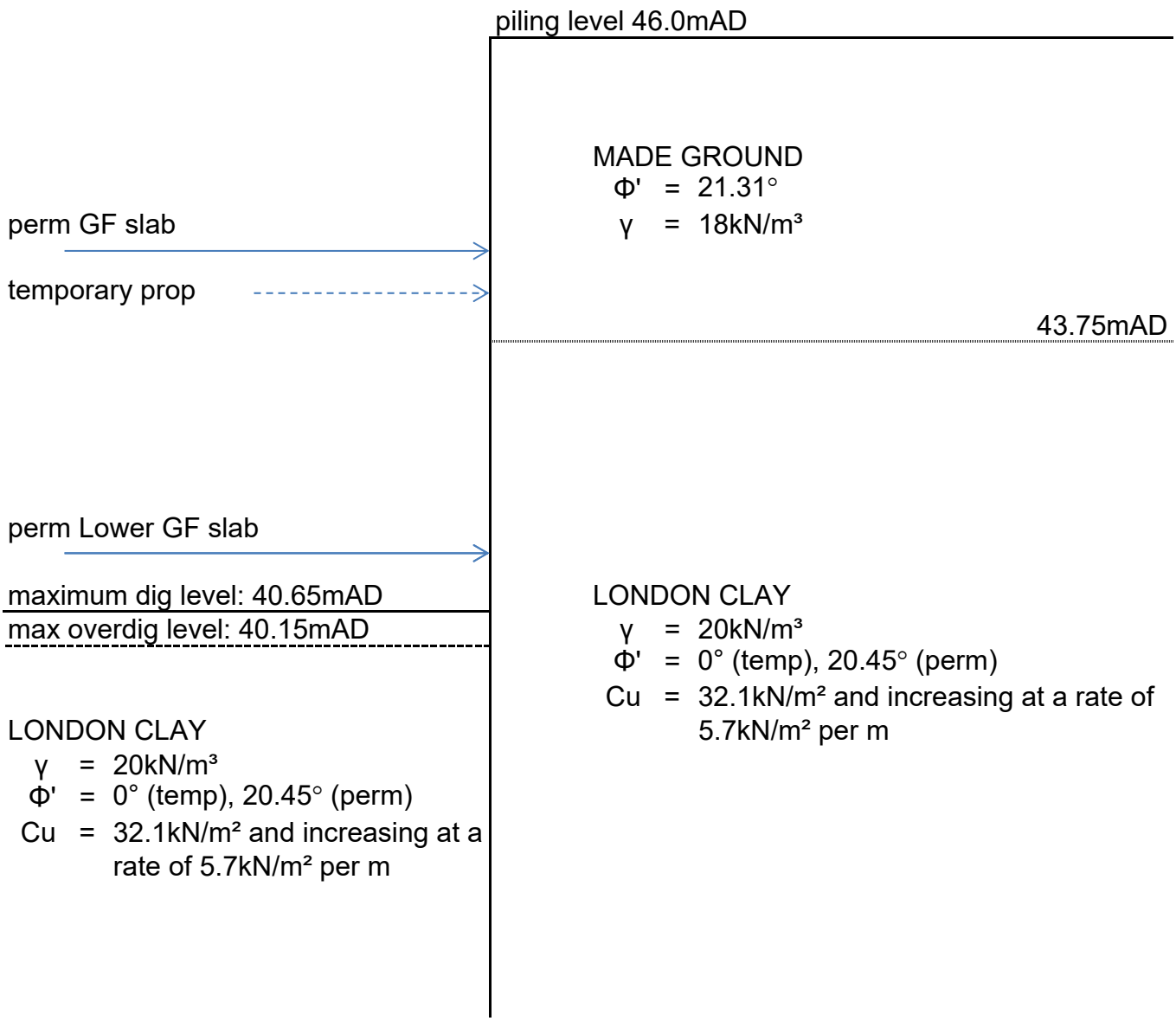
General surcharge of 10kN/m² allowed



A typical initial water level of 44.65mAD has been taken on the active and passive sides for the temporary condition. For the permanent condition water has been taken at the underside of the Lower GF slab on the passive side and to ground level on the active side.

TYPICAL SECTION FOR ULS CONDITIONS - Figure 4

General surcharge of 10kN/m² allowed



A typical initial water level of 44.65mAD has been taken on the active and passive sides for the temporary condition. For the permanent condition water has been taken at the underside of the Lower GF slab on the passive side and to ground level on the active side.

3.4 Retaining Wall and Propping Geometry

Wall 1 will act as a propped cantilever in the temporary condition and be propped by the Lower Ground Floor and Ground Floor slabs in the permanent condition.

Table 3 presents the structural and geometrical properties of the propping that has been used in the design of the retaining wall.

Table 3: Assumed details of horizontal propping

Wall no / Prop no (Perm/Temp)	Prop Elevation (mAD)	Prop Spacing (m)	Prop Sectional area (m^2)	Prop Young's modulus (kN/m^2)	Prop free length (m)
1 / 1 (Temp) Capping Beam level	44.00	5.0	0.015	$2.05 \times 10^{+8}$	5.00
1 / 2 (Perm) – Lower Ground Floor slab	41.00	1.0	0.60	$1.40 \times 10^{+7}$	5.00
1 / 3 (Perm) – Ground Floor slab	44.45	1.0	0.20	$1.40 \times 10^{+7}$	5.00

Prop levels taken as the approximate midpoint of the structural slabs.

It is understood that where there are openings in the Ground Floor slab then the Capping Beam will be designed to provide the propping at these positions.

Should the construction sequence or propping system be changed from that assumed then the retaining wall design will require to be reassessed which could result in changes to the pile length and / or reinforcement.

4.0 DESIGN METHODOLOGY

4.1 Geotechnical Analysis for Secant Bored Pile Retaining Wall

The retaining wall analysis has been carried out using the computer program 'WALLAP' Version 6.06 developed by Geosolve.

The design has been carried out using the 'Strength Factor' approach with partial factors in accordance with BS EN 1997-1: 2004 Eurocode 7 and to the approach as prescribed in the UK National Annex of BS EN 1997–1. Using this approach three runs for each section may be carried out and these are typically referenced as:-

SLS	service limit state
ULS-comb 1	ultimate limit state – structural (STR)
ULS-comb 2	ultimate limit state – geotechnical (GEO)

With respect to the above the wall design is checked in its ultimate state by applying partial factors and carrying out two separate checks (combinations), as shown in Table 4 which have been taken from Tables NA.A1. (B) and (C) of the UK National Annex to BA EN 1990+A1; 2005 for the actions and Table A. NA.4 of the National annex to BS EN 1997-1: 2004 for the soil parameters.

Both represent ultimate conditions with combination 1 the structural ultimate case (ULS-STR), and combination 2 the geotechnical ultimate case (ULS-GEO). Combination 1 applies partial factors to actions (A) - (temporary/permanent actions, Gk, and variable actions, Qk) while soil parameters (M1) and pile resistances (R1) are kept un-factored (R1 & M1 = 1.0). Combination

2 applies partial factors to the soil parameters (M2) and partial factors of smaller magnitude to the variable actions (A). For both these cases the design is mainly to verify that the proposed embedment length i.e. reinforced pile length / toe level, provides a nominal factor of safety against failure. Bending and shear forces are unfactored in any subsequent structural calculations for ULS-comb 2, but factored by 1.35 for ULS-comb 1. An allowance for overdig within both ultimate cases is included and taken as up to a maximum of 10% of the retained height (or 0.5m whichever is the lesser).

Table 4 Partial factors adopted for design (Retaining Wall Earth Pressures).

	Notation	Partial Factor		
		SLS	DA1 Comb. 1	DA1 Comb. 2
ACTIONS: (A)				
Permanent Action (Unfavourable)	G_k	1.0	1.35 (A1)	1.0 (A2)
Variable Action (Unfavourable)	Q_k	1.0	1.50 (A1)	1.3 (A2)
SOIL FACTORS: (M)				
Effective angle of shearing resistance	tan Ø'	1.0	1.0 (M1)	1.25 (M2)
Effective cohesion	C'	1.0	1.0 (M1)	1.25 (M2)
Undrained shear strength	C_u	1.0	1.0 (M1)	1.40 (M2)
RESISTANCES: (R)				
Earth resistance	γ_{Re}	1.0	1.0 (R1)	1.0 (R1)

Notes – factors given above apply to Actions which refer to unfavourable conditions

- Combination 1 (ULS-STR): A1 + M1 + R1.
- Combination 2 (ULS–GEO): A2 + M2 + R1.

A further analysis is included which represents SLS conditions and usually carried out to determine wall deflections. The analysis assumes moderately conservative soil parameters, with a partial factor (M2) taken as 1.0 and no allowance for overdig. This calculation also provides bending moments and shear forces which are factored up by 1.35 in any subsequent structural calculations. The results from this analysis are provided per metre run and therefore amended to the particular pile diameter and spacing.

The input and output data from the WALLAP analyses are presented in Appendix A. The Ultimate Limit State (ULS) conditions employ factored soil parameters as required for the (ULS–GEO), DA1 Combination 2 conditions.

Calculated wall displacements and corresponding program outputs may be considered to be an upper bound estimate of long-term movements, due to the following factors:

(a) Geotechnical parameters, pile stiffness and surcharges are considered to be reasonably conservative values. A more accurate assessment of wall displacements would require the input of 'actual' parameters to be obtained from more sophisticated laboratory testing.

(b) The computer program does not consider the beneficial effects of structural elements such as a capping beam.

(c) The computer program is a two-dimensional analysis program and does not consider the beneficial effects of geometrical features such as internal or external wall corners which increase its overall stiffness.

(d) The computer program uses a Winkler spring analysis to determine the wall displacements, in which springs are used to represent a continuum and there is no

transfer of shear stresses between springs. In general, the application of this concept leads to an overestimation of structural deformations; hence the resulting displacements may be over-predicted.

The results of the WALLAP analysis are given in Appendix A. These are summarised in Tables 5, 6 and 7 and given below. Table 5 provides the results of the stability analysis from WALLAP and calculated deflections. It includes varying sets of bending moments and shear forces. Reinforcement calculations are based on the worst case bending moments and shear values determined from the un-factored ULS-comb 2 and factored SLS and ULS-comb 1 results. Table 6 details the temporary and permanent prop forces and Table 7 shows the details of the sections with the proposed pile length.

The estimated actual deflections should be in the region of 50 to 70% of the calculated figures and a typical figure for actual deflection may be taken as 60%.

4.2 Individual Pile Section Structural Analysis

Reinforcement requirements have been analysed for the shear forces and bending moments indicated within the WALLAP outputs (Appendix A) and summarized in the wall schedule, (Table 7). Using the Oasys ADCOL software, all bending moments and shear force calculations have been carried out in accordance with the requirements of BS EN 1992, Eurocode No. 2 ‘Design of Concrete Structures’.

The results of the ADCOL analyses are given in Appendix B. For all cases the concrete grade has been taken as a minimum C30/37 and a worst case axial load of 0kN compression.

Location: **CAMDEN - Barrie House, 29 St Edmund's Ter.**

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TABLE 5 - Results of Retaining Wall Analysis (Wall 1)

Sections Ref	Case	Pile diameter	Pile spacing (approx)	Calculated deflection	Estimated deflection	Bending Moments			Shear			Ultimate Design Values per pile at spacing given	
						Maximum	Factor	Ultimate	Maximum	Factor	Ultimate	Moment	Shear
	Temp / Perm	mm	mm	mm	mm	kN.m/m		kN.m/m	kN/m		kN/m	kN.m	kN
SLS	T/P	450	600	7	4	54.0	1.35	72.9	88.0	1.35	118.8	43.7	71.3
ULS1	T/P	450	600			57.0	1.35	77.0	87.0	1.35	117.5	46.2	70.5
ULS2	T/P	450	600			53.1	1.00	53.1	97.7	1.00	97.7	31.9	58.6
										Max	450	**46.2**	**71.3**

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Location: **CAMDEN - Barrie House, 29 St Edmund's Ter.**

TABLE 6 - Details of Prop Forces

Wall Ref	Strut Ref	Type	Level	SLS Results Prop Force unfactored	ULS Results Prop Force unfactored	
					ULS1	ULS2
			mAD	kN/m run	kN/m run	
1	1	Temp	44.00	69.0	74.0	80.1
	2	LGF slab	41.00	120.0	116.0	144.2
	3	GF slab	44.45	94.0	98.0	100.0

Location: **CAMDEN - Barrie House, 29 St Edmund's Ter.**

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TABLE 7 - Details of Retaining Wall Piles

Wall Section	Pile diameter	Pile spacing	Assumed Piling Level	RW Pile Length	RW Pile Toe Level	Reinforcement					
						Main Bars					Helical
						No		size		length	size @ spacing
	mm	mm	mAD	m	mAD			mm		m	mm @ mm
1	450	600	46.000	10.0	36.000	5	*	B16	*	10.0	B8 @ 225

4.3 Retaining Wall Axial Load Carrying Capacity

The retaining wall piles may be required to carry axial compression loads.

For piles in a retaining wall a reduction factor is usually applicable due to the close centres of the piles within the wall. This factor is applies to the shaft resistance only. For the 450mm diameter piles at a spacing of 600mm, take the surface area per metre depth as 1.2m², i.e. the wall is considered as a straight sided section, (2 * 0.6m pile spacing). Relating this value to the surface area of an isolated 450mm diameter pile (1.414m²/m), the reduction factor for shaft friction is determined to be 0.85. No reduction factor is applicable to the end bearing since the base surface area per metre per pile in the wall (0.27m²) is larger than the base area of a single pile (0.159m²).

Axial Design

The design has been carried out in general in accordance with Eurocode (BS EN 1997-1:2004) with reference made to the UK National Annex. This is an ultimate limit state design approach with partial factors applied to actions (A), materials (M) and resistances (R). Pile lengths have been determined to satisfy a structural check (STR), with partial factors only applied to actions, and a geotechnical check (GEO), with partial factors applied to both actions and resistances. These are in accordance with the Eurocode Design Approach 1 and referred to as combinations DA1-1 and DA1-2 respectively.

An explanation of the appropriate partial factors as usually derived for these combinations is indicated below.

Design Approach 1 - Combination - 1

Taken as A1 + M1 + R1

With partial factors of 1.0 applied to both M1 and R1

For A1 a factor of 1.35 has been applied to the permanent loads and 1.5 applied to the variable loads.

Design Approach 1 - Combination - 2

Taken as A2 + M1 + R4

For A2 a factor of 1.0 has been applied to the permanent loads and 1.3 applied to the variable loads.

For M1 all factors have been taken as unity.

Partial factors for R4 relate mainly to testing and also pile type, with factors applied to both shaft adhesion and end bearing for the latter. For this site it is understood that no pile testing is proposed.

Partial factors for GEO limit state from Table A.NA.8 as follows:

1.6 applied to shaft resistance and 2.0 to the base resistance with a model factor of 1.4 applied to both. The above factors apply without any explicit verification testing.

Vertical Design

Assumed soil profile

PPL	to	40.6mAD	DISCOUNTED
40.6mAD	to	--- mAD	LONDON CLAY

Groundwater taken as 44.65mAD.

Design A – Discounted level 40.6mAD – Retaining Wall

Shaft Adhesion

In DISCOUNTED SOIL Density taken as 18kN/m³
Discounted for positive skin friction

In LONDON CLAY Density taken as 20kN/m³
with shear strength as 45kN/m² at a level of 43.75mAD and increasing at a rate of 8.0kN/m² per metre depth
See Figure 2 for SPT plot against depth
Use 0.5 shear strength

End Bearing

In LONDON CLAY For unit end bearing use 9 * shear strength with shear strength values as given above.

Factor of Safety

Shaft resistance (compression), FOS	1.6
End resistance, FOS	2.0

For EC7 approach also with model factor of 1.4 applied to both

The above calculations have been carried out using the OASYS Pile program, version 19.6 which allows the appropriate partial factors to be applied to the soil parameters. The results are given in Appendix C1. Perusal of the appropriate actions shows that design approach case 2 (DA1-2) dictates and the calculated results for the 450mm diameter retaining wall piles are shown in Table 8 below. Permanent / variable load split assumed as 70% / 30%.

Table 8 (450mm diameter Retaining Wall piles)

Wall No / Column Ref	PPL (mAD)	Discount Level (mAD)	Perm Load (kN)	Var Load (kN)	SLS (kN)	DA1-1 (kN)	DA1-2 (kN)	Pile Length (m)
1	46.0	40.6	105	45	150	209	164	10.0

Appendix C1: Design A – Discounted level 40.6mAD – Retaining Wall piles

Concrete C30/37 minimum

5.0 SUMMARY OF RESULTS AND GENERAL COMMENTS

Summary results of the various wall analyses are presented in Table 5. Temporary and permanent prop forces are presented in Table 6. The pile summary schedule indicating pile lengths and reinforcement is presented in Table 7.

The detailed retaining wall analysis comprising the computer print outs are presented in Appendix A.

Reinforcement calculations comprising the computer printouts from the ADCOL design software and the Helical check are presented in Appendix B.

Axial capacity calculations comprising the computer printouts from the PILE design software are presented in Appendix C.

APPENDIX A

Ref No	Description
1-ULS1	WALLAP analysis for wall section 1, moments and embedment.
1-ULS2	WALLAP analysis for wall section 1, moments and embedment.
1-SLS	WALLAP analysis for wall section 1, moments and deflection.

WALLAP

1-ULS1

Units: kN,m

INPUT DATA

SOIL PROFILE

Stratum no.	Elevation of top of stratum	Soil types Left side	Right side
1	46.00	1 Made Ground dr	1 Made Ground dr
2	43.75	2 London Clay und	2 London Clay und

SOIL PROPERTIES (Unfactored SLS soil strengths)

No.	Soil type -- 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 dr	18.00	10000	0.562	OC (0.250)	0.323 (0.000)	3.647 (0.000)	
2	London Cl.. (43.75)	20.00	27000 (4800)	1.000	OC (0.490)	1.000 (2.000)	1.000 (2.000)	45.00u (8.000)
3	London Cl.. (43.75)	20.00	20790 (3696)	1.000	OC (0.200)	0.351 (1.391)	3.253 (4.831)	0.0d
4	Not defined							
5	Backfill dr	20.00	30000	0.500	OC (0.250)	0.217 (0.000)	6.535 (0.000)	
6	Concrete dr	24.00	40000	0.500	OC (0.200)	0.140 (0.000)	13.89 (0.000)	

Additional soil parameters associated with Ka and Kp

No.	Soil type 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 dr	27.00	0.670	0.00	27.00	0.500	0.00
2	London Clay und	0.00	0.000	0.00	0.00	0.000	0.00
3	London Clay dr	25.00	0.670	0.00	25.00	0.500	0.00
4	Not defined						
5	Backfill dr	36.00	0.670	0.00	36.00	0.500	0.00
6	Concrete dr	45.00	0.670	0.00	45.00	0.500	0.00

GROUND WATER CONDITIONS

Density of water = 9.810 kN/m3

	Left side	Right side
Initial water table elevation	44.65	44.65

Automatic water pressure balancing at toe of wall : Yes

Water press. profile no.	Left side Point no.	Elev. m	Piezo elev. m	Water press. kN/m2	Right side Point no.	Elev. m	Piezo elev. m	Water press. kN/m2	
1	1	44.65	44.65	0.0	1	40.00	40.00	0.0	MC+WC
2	1	46.00	46.00	0.0	1	40.65	40.65	0.0	MC+WC
					2	40.65	46.00	52.5	

WALL PROPERTIES

Type of structure = Fully Embedded Wall
Elevation of toe of wall = 36.00
Maximum finite element length = 0.60 m
Youngs modulus of wall E = 1.9600E+07 kN/m2
Moment of inertia of wall I = 3.3548E-03 m4/m run
E.I = 65754 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	44.00	5.00	0.015000	2.050E+08	5.00	0.00	0	No
2	41.00	1.00	0.600000	1.400E+07	5.00	0.00	0	No
3	44.45	1.00	0.200000	1.400E+07	5.00	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	46.00	0.50(L)	10.00	10.00	10.00	=	N/A	1.10 Var
2	40.65	-0.00(R)	10.00	10.00	53.00	=	N/A	1.00 P/F

Note: L = Left side, R = Right 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 46.00
2	Apply water pressure profile no.1 (Mod. Conserv.)
3	Excavate to elevation 43.50 on RIGHT side
4	Install strut or anchor no.1 at elevation 44.00
5	Excavate to elevation 40.15 on RIGHT side
6	Fill to elevation 40.65 on RIGHT side with soil type 1
7	Install strut or anchor no.2 at elevation 41.00
8	Install strut or anchor no.3 at elevation 44.45
9	Remove strut or anchor no.1 at elevation 44.00
10	Change EI of wall to 46968 kN.m2/m run Yield moment not defined Allow wall to relax with new modulus value
11	Change properties of soil type 2 to soil type 3 No analysis at this stage Ko pressures will not be reset
12	Apply surcharge no.2 at elevation 40.65 No analysis at this stage
13	Apply water pressure profile no.2 (Mod. Conserv.)

FACTORS OF SAFETY and ANALYSIS OPTIONS

Limit State options: ULS DA1 Combination 1
Water pressures : Moderately Conservative
Partial factor on C' = 1.000
Partial factor on Phi' = 1.000
Partial factor on Cu = 1.000
Partial factor on Soil Modulus = 1.000
Partial factor on Permanent Unfavourable loads = 1.000
Partial factor on Permanent Favourable loads = 1.000
Partial factor on Variable Unfavourable loads = 1.100
Design factor on calculated Bending Moments = 1.350

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) = 11.00 m

Boundary conditions:
Length of wall (normal to plane of analysis) = 50.00 m

Width of excavation on Left side of wall = 50.00 m
Width of excavation on Right side of wall = 50.00 m

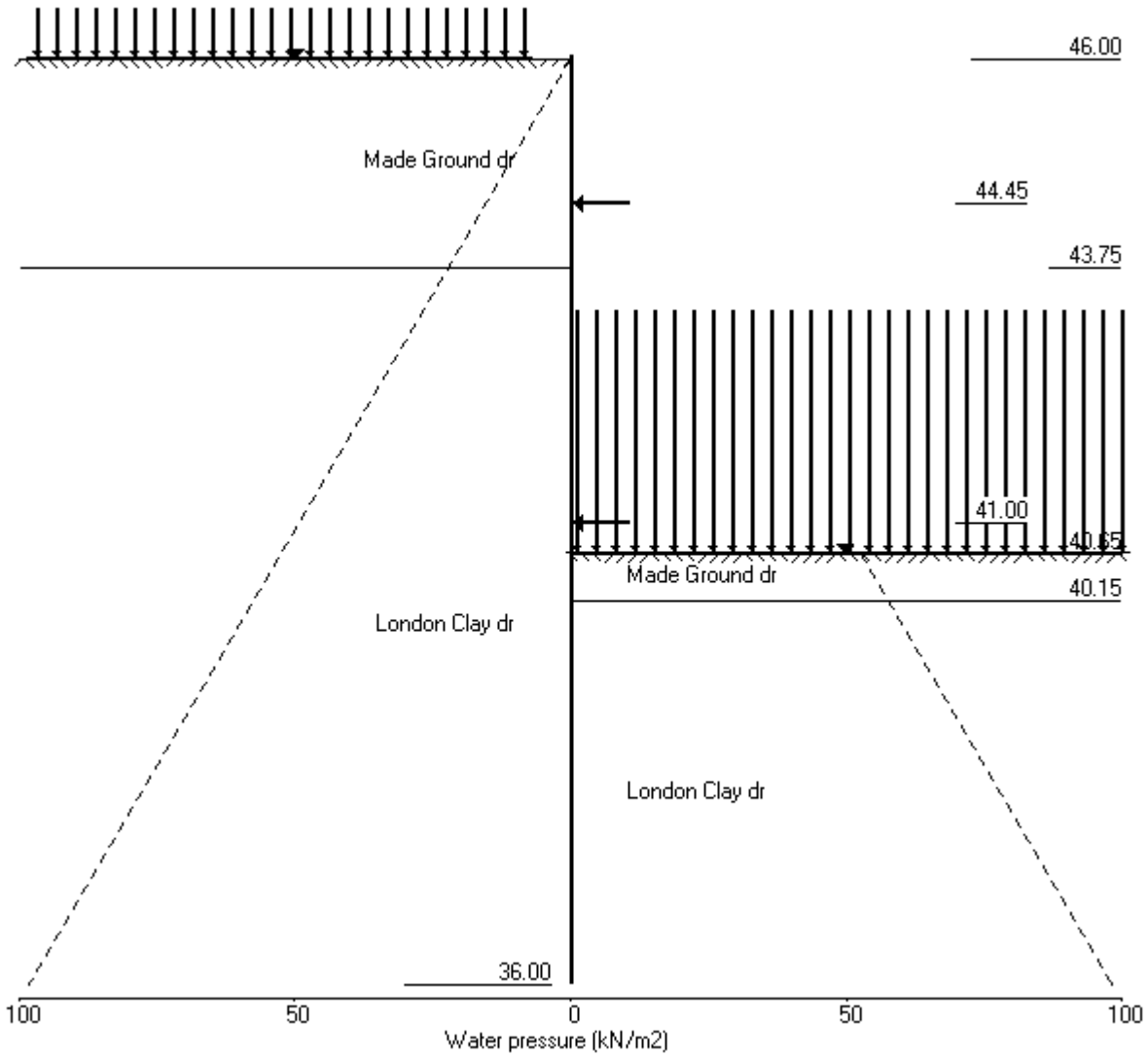
Distance to rigid boundary on Left side = 50.00 m
Distance to rigid boundary on Right side = 50.00 m

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. 46.00	Yes	Yes	Yes
2	Apply water pressure profile no.1	Yes	Yes	Yes
3	Excav. to elev. 43.50 on RIGHT side	No	No	No
4	Install strut no.1 at elev. 44.00	Yes	Yes	Yes
5	Excav. to elev. 40.15 on RIGHT side	Yes	Yes	Yes
6	Fill to elev. 40.65 on RIGHT side	Yes	Yes	Yes
7	Install strut no.2 at elev. 41.00	Yes	Yes	Yes
8	Install strut no.3 at elev. 44.45	Yes	Yes	Yes
9	Remove strut no.1 at elev. 44.00	Yes	Yes	Yes
10	Change EI of wall to 46968kN.m2/m run	Yes	Yes	Yes
11	Change soil type 2 to soil type 3	Yes	Yes	Yes
12	Apply surcharge no.2 at elev. 40.65	Yes	Yes	Yes
13	Apply water pressure profile no.2	Yes	Yes	Yes
*	Summary output	Yes	-	Yes

Units: kN,m

Stage No.13 Apply water pressure profile no.2 (Mod. Conserv.)



Units: kN,m

Stage No. 3 Excavate to elevation 43.50 on RIGHT side

BENDING MOMENT and DISPLACEMENT ANALYSIS of Fully Embedded Wall

Analysis options

Length of wall perpendicular to section = 50.00m
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: Left side 50.00 from wall
Right side 50.00 from wall

Limit State: ULS DA1 Combination 1

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	EI of wall kN.m2/m
1	46.00	0.00	0.007	1.44E-03	0.0	-0.0		65754
2	45.66	2.25	0.007	1.44E-03	0.4	0.1		65754
3	45.33	4.94	0.006	1.44E-03	1.6	0.4		65754
4	44.99	7.48	0.006	1.44E-03	3.7	1.3		65754
5	44.65	9.82	0.005	1.43E-03	6.6	3.0		65754
6	44.45	11.99	0.005	1.42E-03	8.8	4.5		65754
7	44.00	16.73	0.004	1.37E-03	15.3	9.8		65754
8	43.75	19.32	0.004	1.32E-03	19.8	14.2		65754
		11.25	0.004	1.32E-03	19.8	14.2		
9	43.50	13.78	0.003	1.26E-03	22.9	19.9		65754
		-33.64	0.003	1.26E-03	22.9	19.9		
10	43.05	-25.03	0.003	1.10E-03	9.7	26.8		65754
11	42.60	-16.91	0.002	9.12E-04	0.3	28.6		65754
12	42.00	-7.90	0.002	6.64E-04	-7.2	25.7		65754
13	41.50	-2.40	0.002	4.85E-04	-9.8	21.1		65754
14	41.00	1.25	0.002	3.44E-04	-10.1	16.0		65754
15	40.65	2.84	0.001	2.69E-04	-9.3	12.5		65754
16	40.15	4.01	0.001	1.90E-04	-7.6	8.2		65754
17	40.00	4.15	0.001	1.72E-04	-7.0	7.1		65754
18	39.50	3.92	0.001	1.30E-04	-5.0	4.1		65754
19	39.00	3.23	0.001	1.06E-04	-3.2	2.1		65754
20	38.40	2.19	0.001	9.42E-05	-1.6	0.7		65754
21	37.80	1.22	0.001	9.06E-05	-0.6	0.1		65754
22	37.20	0.47	0.001	9.02E-05	-0.1	-0.0		65754
23	36.60	-0.02	0.001	9.05E-05	0.1	-0.0		65754
24	36.00	-0.24	0.001	9.05E-05	0.0	-0.0		---

Node no.	Y coord	LEFT side: Water press. kN/m2	Effective stresses: Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2	Total earth pressure kN/m2	Coeff. of subgrade reaction kN/m3
1	46.00	0.00	0.00	0.00	0.00	0.00	0.00	3071
2	45.66	0.00	6.98	2.25	25.47	2.25	2.25a	3071
3	45.33	0.00	15.33	4.94	55.89	4.94	4.94a	3071
4	44.99	0.00	23.20	7.48	84.60	7.48	7.48a	3071
5	44.65	0.00	30.46	9.82	111.07	9.82	9.82a	3071
6	44.45	1.24	33.31	10.74	121.48	10.74	11.99a	3071
7	44.00	4.03	39.37	12.70	143.56	12.70	16.73a	3071
8	43.75	5.58	42.58	13.73	155.27	13.73	19.32a	3071
		Total> 48.16	11.25m	138.18	11.25	11.25a		11458

(continued)

Stage No.3 Excavate to elevation 43.50 on RIGHT side

LEFT side

Node no.	Y coord	Water press. kN/m2	Effective stresses: Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2	Total earth pressure kN/m2	Coeff. of subgrade reaction kN/m3
9	43.50	Total>	53.34	12.50m	147.36	13.78	13.78	11968
10	43.05	Total>	62.52	14.75m	163.74	26.66	26.66	12884
11	42.60	Total>	71.57	17.00m	179.99	39.26	39.26	13801
12	42.00	Total>	83.47	20.00m	201.50	55.16	55.16	15023
13	41.50	Total>	93.31	22.50m	219.34	67.45	67.45	16042
14	41.00	Total>	103.10	25.00m	237.13	78.88	78.88	17060
15	40.65	Total>	109.93	26.75m	249.56	86.43	86.43	17773
16	40.15	Total>	119.66	29.25m	267.30	96.70	96.70	18792
17	40.00	Total>	122.58	30.00m	272.61	99.69	99.69	19097
18	39.50	Total>	132.30	32.50m	290.34	109.45	109.45	20116
19	39.00	Total>	142.02	35.00m	308.05	119.00	119.00	21134
20	38.40	Total>	153.68	38.00m	329.32	130.36	130.36	22357
21	37.80	Total>	165.35	41.00m	350.59	141.77	141.77	23579
22	37.20	Total>	177.03	44.00m	371.87	153.28	153.28	24801
23	36.60	Total>	188.72	47.00m	393.17	164.92	164.92	26023
24	36.00	Total>	200.43	50.00m	414.48	176.70	176.70	27246

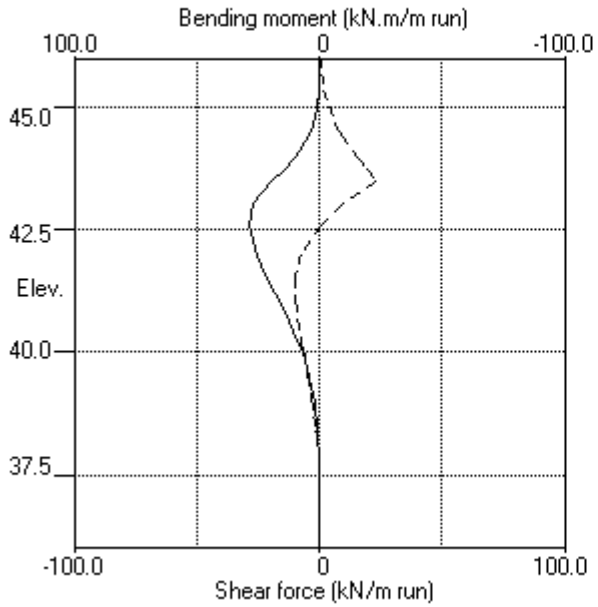
RIGHT side

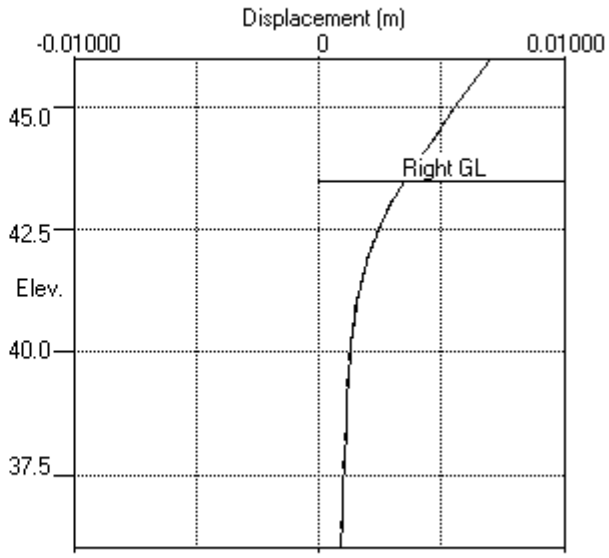
Node no.	Y coord	Water press. kN/m2	Effective stresses: Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2	Total earth pressure kN/m2	Coeff. of subgrade reaction kN/m3
1	46.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
2	45.66	0.00	0.00	0.00	0.00	0.00	0.00	0.0
3	45.33	0.00	0.00	0.00	0.00	0.00	0.00	0.0
4	44.99	0.00	0.00	0.00	0.00	0.00	0.00	0.0
5	44.65	0.00	0.00	0.00	0.00	0.00	0.00	0.0
6	44.45	0.00	0.00	0.00	0.00	0.00	0.00	0.0
7	44.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
8	43.75	0.00	0.00	0.00	0.00	0.00	0.00	0.0
9	43.50	0.00	0.00	0.00	0.00	0.00	0.00	0.0
		Total>	0.00	0.00	94.01	47.42	47.42	14351
10	43.05	Total>	9.00	2.25m	110.21	51.70	51.70	15450
11	42.60	Total>	18.00	4.50m	126.41	56.17	56.17	16549
12	42.00	Total>	30.00	7.50m	148.02	63.05	63.05	18015
13	41.50	Total>	40.00	10.00m	166.02	69.85	69.85	19236
14	41.00	Total>	50.00	12.50m	184.03	77.62	77.62	20457
15	40.65	Total>	57.00	14.25m	196.63	83.58	83.58	21312
16	40.15	Total>	67.01	16.75m	214.63	92.70	92.70	22533
17	40.00	Total>	70.01	17.50m	220.04	95.54	95.54	22900
18	39.50	Total>	80.01	20.00m	238.04	105.53	105.53	24121
19	39.00	Total>	90.01	22.50m	256.05	115.77	115.77	25342
20	38.40	Total>	102.02	25.50m	277.65	128.17	128.17	26808
21	37.80	Total>	114.03	28.50m	299.26	140.55	140.55	28274
22	37.20	Total>	126.04	31.50m	320.88	152.81	152.81	29739
23	36.60	Total>	138.05	34.50m	342.49	164.94	164.94	31205
24	36.00	Total>	150.06	37.50m	364.10	176.94	176.94	32670

Note: 11.25a Soil pressure at active limit
123.45p Soil pressure at passive limit

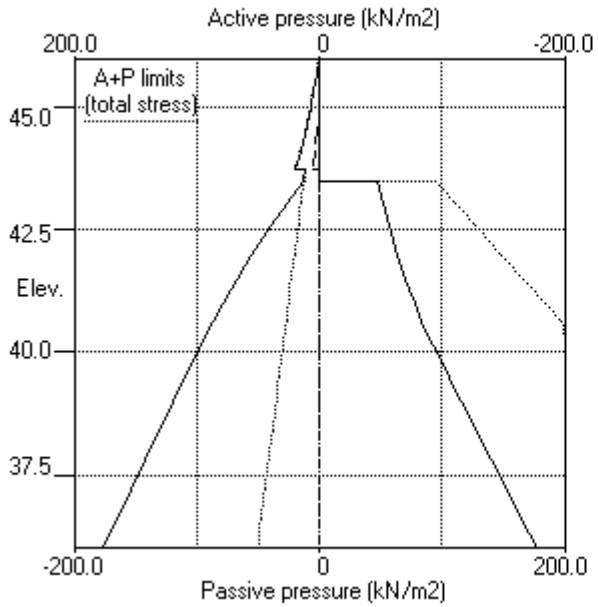
Units: kN,m

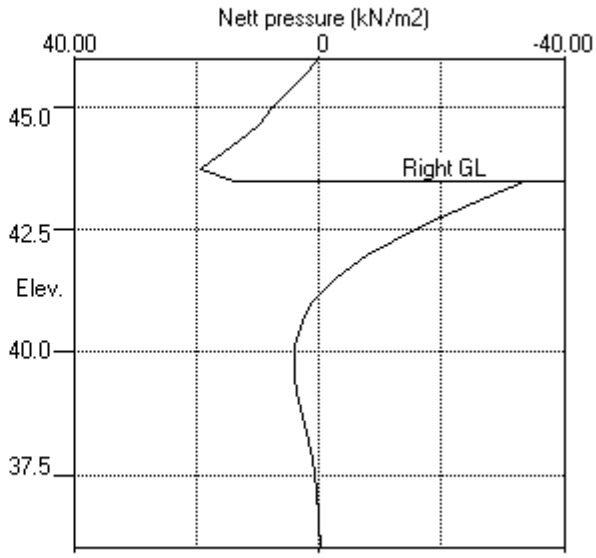
Stage No.3 Excav. to elev. 43.50 on RIGHT side





Stage No.3 Excav. to elev. 43.50 on RIGHT side





Units: kN,m

Stage No. 5 Excavate to elevation 40.15 on RIGHT side

BENDING MOMENT and DISPLACEMENT ANALYSIS of Fully Embedded Wall

Analysis options

Length of wall perpendicular to section = 50.00m
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: Left side 50.00 from wall
Right side 50.00 from wall

Limit State: ULS DA1 Combination 1

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	EI of wall kN.m2/m
1	46.00	0.00	0.004	-2.52E-04	0.0	-0.0		65754
2	45.66	16.07	0.004	-2.53E-04	2.7	0.1		65754
3	45.33	15.32	0.004	-2.58E-04	8.0	2.0		65754
4	44.99	14.40	0.004	-2.77E-04	13.0	5.6		65754
5	44.65	13.23	0.004	-3.19E-04	17.7	10.8		65754
6	44.45	13.28	0.005	-3.58E-04	20.3	14.7		65754
7	44.00	16.73	0.005	-4.95E-04	27.1	25.3	74.2	65754
		16.73	0.005	-4.95E-04	-47.1	25.3		
8	43.75	19.32	0.005	-5.70E-04	-42.6	14.1		65754
		11.25	0.005	-5.70E-04	-42.6	14.1		
9	43.50	12.50	0.005	-6.05E-04	-39.7	4.2		65754
10	43.05	14.75	0.005	-5.76E-04	-33.5	-12.6		65754
11	42.60	17.00	0.006	-4.42E-04	-26.4	-26.4		65754
12	42.00	20.00	0.006	-1.41E-04	-15.3	-39.6		65754
13	41.50	25.78	0.006	1.72E-04	-3.9	-43.0		65754
14	41.00	34.13	0.006	4.93E-04	11.1	-41.4		65754
15	40.65	41.00	0.005	6.96E-04	24.3	-35.2		65754
16	40.15	52.25	0.005	8.97E-04	47.6	-17.6		65754
		-39.84	0.005	8.97E-04	47.6	-17.6		
17	40.00	-38.10	0.005	9.30E-04	41.7	-10.9		65754
18	39.50	-31.17	0.004	9.52E-04	24.4	5.2		65754
19	39.00	-23.34	0.004	8.81E-04	10.8	13.5		65754
20	38.40	-14.30	0.003	7.48E-04	-0.5	15.7		65754
21	37.80	-6.40	0.003	6.18E-04	-6.7	12.8		65754
22	37.20	0.45	0.003	5.25E-04	-8.5	7.6		65754
23	36.60	6.95	0.002	4.79E-04	-6.3	2.5		65754
24	36.00	13.96	0.002	4.67E-04	0.0	0.0		---

At elev. 44.00 Strut force = 371.2 kN/strut = 74.2 kN/m run

Node no.	Y coord	LEFT side: Water press. kN/m2	Effective stresses: Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2	Total earth pressure kN/m2	Coeff. of subgrade reaction kN/m3
1	46.00	0.00	0.00	0.00	0.00	0.00	0.00	5990
2	45.66	0.00	6.98	2.25	25.47	16.07	16.07	5990
3	45.33	0.00	15.33	4.94	55.89	15.32	15.32	5990
4	44.99	0.00	23.20	7.48	84.60	14.40	14.40	5990
5	44.65	0.00	30.46	9.82	111.07	13.23	13.23	5990
6	44.45	1.24	33.31	10.74	121.48	12.04	13.28	5990
7	44.00	4.03	39.37	12.70	143.56	12.70	16.73a	1929

(continued)

Stage No.5 Excavate to elevation 40.15 on RIGHT side

LEFT side

Node no.	Y coord	Water press. kN/m2	Effective stresses: Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2	Total earth pressure kN/m2	Coeff. of subgrade reaction kN/m3
8	43.75	5.58	42.58	13.73	155.27	13.73	19.32a	1929
		Total>	48.16	11.25m	138.18	11.25	11.25a	7500
9	43.50	Total>	53.34	12.50m	147.36	12.50	12.50a	7833
10	43.05	Total>	62.52	14.75m	163.74	14.75	14.75a	8433
11	42.60	Total>	71.57	17.00m	179.99	17.00	17.00a	9033
12	42.00	Total>	83.47	20.00m	201.50	20.00	20.00a	9833
13	41.50	Total>	93.31	22.50m	219.34	25.78	25.78	10499
14	41.00	Total>	103.10	25.00m	237.13	34.13	34.13	11166
15	40.65	Total>	109.93	26.75m	249.56	41.00	41.00	11633
16	40.15	Total>	119.66	29.25m	267.30	52.25	52.25	12299
17	40.00	Total>	122.58	30.00m	272.61	55.89	55.89	12499
18	39.50	Total>	132.30	32.50m	290.34	68.59	68.59	13166
19	39.00	Total>	142.02	35.00m	308.05	81.64	81.64	13832
20	38.40	Total>	153.68	38.00m	329.32	97.14	97.14	14632
21	37.80	Total>	165.35	41.00m	350.59	112.18	112.18	15432
22	37.20	Total>	177.03	44.00m	371.87	126.82	126.82	16232
23	36.60	Total>	188.72	47.00m	393.17	141.33	141.33	17032
24	36.00	Total>	200.43	50.00m	414.48	156.08	156.08	17832

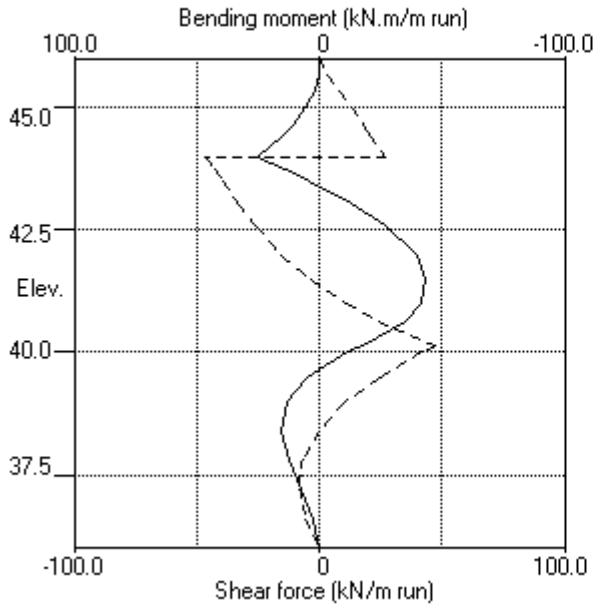
RIGHT side

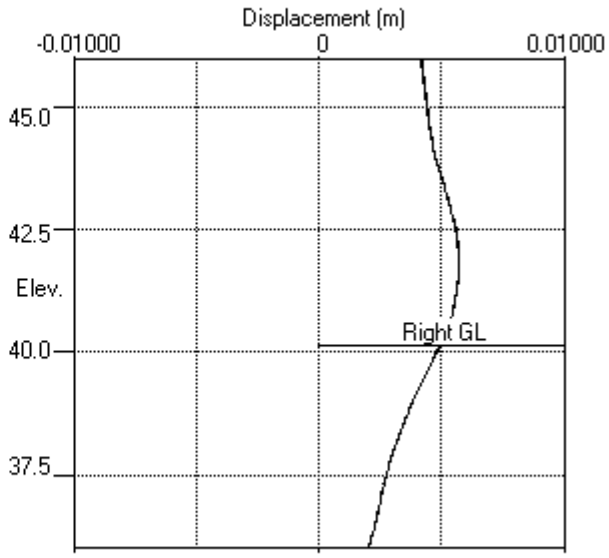
Node no.	Y coord	Water press. kN/m2	Effective stresses: Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2	Total earth pressure kN/m2	Coeff. of subgrade reaction kN/m3
1	46.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
2	45.66	0.00	0.00	0.00	0.00	0.00	0.00	0.0
3	45.33	0.00	0.00	0.00	0.00	0.00	0.00	0.0
4	44.99	0.00	0.00	0.00	0.00	0.00	0.00	0.0
5	44.65	0.00	0.00	0.00	0.00	0.00	0.00	0.0
6	44.45	0.00	0.00	0.00	0.00	0.00	0.00	0.0
7	44.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
8	43.75	0.00	0.00	0.00	0.00	0.00	0.00	0.0
9	43.50	0.00	0.00	0.00	0.00	0.00	0.00	0.0
10	43.05	0.00	0.00	0.00	0.00	0.00	0.00	0.0
11	42.60	0.00	0.00	0.00	0.00	0.00	0.00	0.0
12	42.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
13	41.50	0.00	0.00	0.00	0.00	0.00	0.00	0.0
14	41.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
15	40.65	0.00	0.00	0.00	0.00	0.00	0.00	0.0
16	40.15	0.00	0.00	0.00	0.00	0.00	0.00	0.0
		Total>	0.00	0.00	147.61	92.09	92.09	17642
17	40.00	Total>	3.00	0.75m	153.02	93.99	93.99	17929
18	39.50	Total>	13.00	3.25m	171.02	99.76	99.76	18885
19	39.00	Total>	23.00	5.75m	189.02	104.97	104.97	19842
20	38.40	Total>	35.00	8.75m	210.62	111.44	111.44	20989
21	37.80	Total>	47.00	11.75m	232.23	118.59	118.59	22137
22	37.20	Total>	59.01	14.75m	253.83	126.37	126.37	23284
23	36.60	Total>	71.02	17.75m	275.44	134.38	134.38	24432
24	36.00	Total>	83.03	20.75m	297.05	142.11	142.11	25579

Note: 20.00a Soil pressure at active limit
123.45p Soil pressure at passive limit

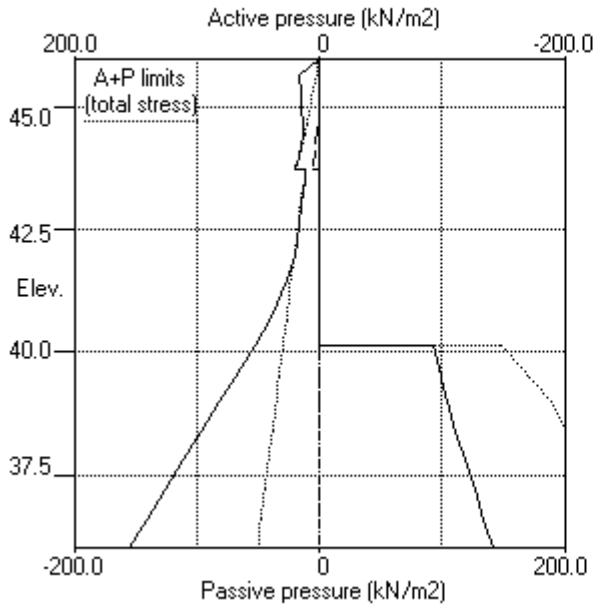
Units: kN,m

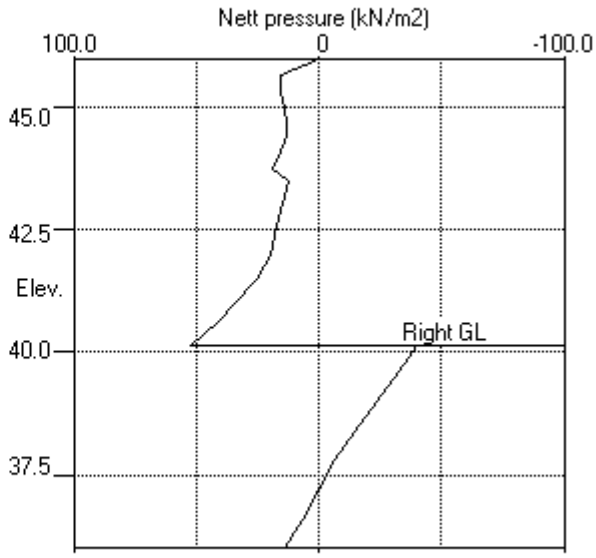
Stage No.5 Excav. to elev. 40.15 on RIGHT side





Stage No.5 Excav. to elev. 40.15 on RIGHT side





Units: kN,m

Stage No. 6 Fill to elevation 40.65 on RIGHT side with soil type 1

BENDING MOMENT and DISPLACEMENT ANALYSIS of Fully Embedded Wall

Analysis options

Length of wall perpendicular to section = 50.00m
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: Left side 50.00 from wall
Right side 50.00 from wall

Limit State: ULS DA1 Combination 1

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	EI of wall kN.m2/m
1	46.00	0.00	0.004	-2.24E-04	0.0	-0.0		65754
2	45.66	15.81	0.004	-2.24E-04	2.7	0.1		65754
3	45.33	15.11	0.004	-2.29E-04	7.9	1.9		65754
4	44.99	14.23	0.004	-2.48E-04	12.8	5.5		65754
5	44.65	13.12	0.005	-2.90E-04	17.5	10.7		65754
6	44.45	13.20	0.005	-3.28E-04	20.1	14.5		65754
7	44.00	16.73	0.005	-4.63E-04	26.8	25.0	74.5	65754
		16.73	0.005	-4.63E-04	-47.7	25.0		
8	43.75	19.33	0.005	-5.36E-04	-43.2	13.6		65754
		11.30	0.005	-5.36E-04	-43.2	13.6		
9	43.50	12.62	0.005	-5.69E-04	-40.2	3.6		65754
10	43.05	15.02	0.005	-5.35E-04	-34.0	-13.5		65754
11	42.60	17.47	0.005	-3.95E-04	-26.7	-27.4		65754
12	42.00	20.82	0.006	-8.56E-05	-15.2	-40.6		65754
13	41.50	26.97	0.006	2.35E-04	-3.2	-43.9		65754
14	41.00	35.76	0.005	5.61E-04	12.5	-41.8		65754
15	40.65	42.98	0.005	7.65E-04	26.2	-35.1		65754
16	40.15	51.86	0.005	9.61E-04	50.0	-16.4		65754
		-43.34	0.005	9.61E-04	50.0	-16.4		
17	40.00	-41.27	0.005	9.90E-04	43.6	-9.3		65754
18	39.50	-33.32	0.004	9.98E-04	25.0	7.3		65754
19	39.00	-24.61	0.004	9.11E-04	10.5	15.6		65754
20	38.40	-14.77	0.003	7.61E-04	-1.3	17.4		65754
21	37.80	-6.32	0.003	6.18E-04	-7.7	13.9		65754
22	37.20	0.89	0.002	5.17E-04	-9.3	8.1		65754
23	36.60	7.63	0.002	4.68E-04	-6.7	2.7		65754
24	36.00	14.82	0.002	4.55E-04	0.0	0.0		---

At elev. 44.00 Strut force = 372.5 kN/strut = 74.5 kN/m run

Node no.	Y coord	LEFT side ------- Effective stresses ------- Water press. kN/m2	Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2	Total earth pressure kN/m2	Coeff. of subgrade reaction kN/m3
1	46.00	0.00	0.00	0.00	0.00	0.00	0.00	5108
2	45.66	0.00	6.98	2.25	25.47	15.81	15.81	5108
3	45.33	0.00	15.33	4.94	55.89	15.11	15.11	5108
4	44.99	0.00	23.20	7.48	84.60	14.23	14.23	5108
5	44.65	0.00	30.46	9.82	111.07	13.12	13.12	5108
6	44.45	1.24	33.31	10.74	121.48	11.95	13.20	5108
7	44.00	4.03	39.37	12.70	143.56	12.70	16.73a	5108

(continued)

Stage No.6 Fill to elevation 40.65 on RIGHT side with soil type 1

LEFT side

Node no.	Y coord	Water press. kN/m2	Effective stresses: Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2	Total earth pressure kN/m2	Coeff. of subgrade reaction kN/m3
8	43.75	5.58	42.58	13.73	155.27	13.75	19.33	1962
		Total>	48.16	11.25m	138.18	11.30	11.30	7612
9	43.50	Total>	53.34	12.50m	147.36	12.62	12.62	7950
10	43.05	Total>	62.52	14.75m	163.74	15.02	15.02	8559
11	42.60	Total>	71.57	17.00m	179.99	17.47	17.47	9168
12	42.00	Total>	83.47	20.00m	201.50	20.82	20.82	9980
13	41.50	Total>	93.31	22.50m	219.34	26.97	26.97	10657
14	41.00	Total>	103.10	25.00m	237.13	35.76	35.76	11333
15	40.65	Total>	109.93	26.75m	249.56	42.98	42.98	11807
16	40.15	Total>	119.66	29.25m	267.30	54.76	54.76	12484
17	40.00	Total>	122.58	30.00m	272.61	58.57	58.57	12687
18	39.50	Total>	132.30	32.50m	290.34	71.77	71.77	13363
19	39.00	Total>	142.02	35.00m	308.05	85.24	85.24	14040
20	38.40	Total>	153.68	38.00m	329.32	101.14	101.14	14852
21	37.80	Total>	165.35	41.00m	350.59	116.46	116.46	15664
22	37.20	Total>	177.03	44.00m	371.87	131.27	131.27	16476
23	36.60	Total>	188.72	47.00m	393.17	145.90	145.90	17288
24	36.00	Total>	200.43	50.00m	414.48	160.73	160.73	18100

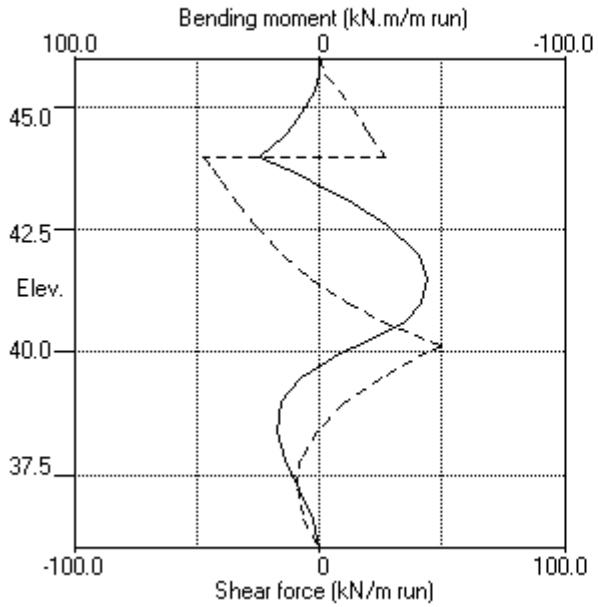
RIGHT side

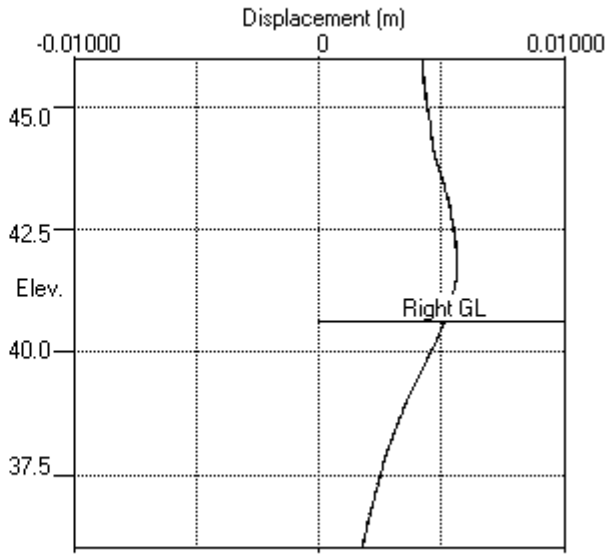
Node no.	Y coord	Water press. kN/m2	Effective stresses: Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2	Total earth pressure kN/m2	Coeff. of subgrade reaction kN/m3
1	46.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
2	45.66	0.00	0.00	0.00	0.00	0.00	0.00	0.0
3	45.33	0.00	0.00	0.00	0.00	0.00	0.00	0.0
4	44.99	0.00	0.00	0.00	0.00	0.00	0.00	0.0
5	44.65	0.00	0.00	0.00	0.00	0.00	0.00	0.0
6	44.45	0.00	0.00	0.00	0.00	0.00	0.00	0.0
7	44.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
8	43.75	0.00	0.00	0.00	0.00	0.00	0.00	0.0
9	43.50	0.00	0.00	0.00	0.00	0.00	0.00	0.0
10	43.05	0.00	0.00	0.00	0.00	0.00	0.00	0.0
11	42.60	0.00	0.00	0.00	0.00	0.00	0.00	0.0
12	42.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
13	41.50	0.00	0.00	0.00	0.00	0.00	0.00	0.0
14	41.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
15	40.65	0.00	0.00	0.00	0.00	0.00	0.00	0.0
		0.00	0.00	0.00	0.00	0.00	0.00	2062
16	40.15	0.00	9.00	2.90	32.82	2.90	2.90a	2062
		Total>	9.00	2.50m	156.62	98.10	98.10	13045
17	40.00	Total>	12.00	3.25m	162.02	99.84	99.84	13257
18	39.50	Total>	22.00	5.75m	180.02	105.08	105.08	13964
19	39.00	Total>	32.00	8.25m	198.02	109.85	109.85	14671
20	38.40	Total>	44.00	11.25m	219.63	115.91	115.91	15520
21	37.80	Total>	56.01	14.25m	241.23	122.77	122.77	16368
22	37.20	Total>	68.01	17.25m	262.84	130.37	130.37	17217
23	36.60	Total>	80.02	20.25m	284.45	138.26	138.26	18065
24	36.00	Total>	92.03	23.25m	306.06	145.91	145.91	18914

Note: 2.90a Soil pressure at active limit
123.45p Soil pressure at passive limit

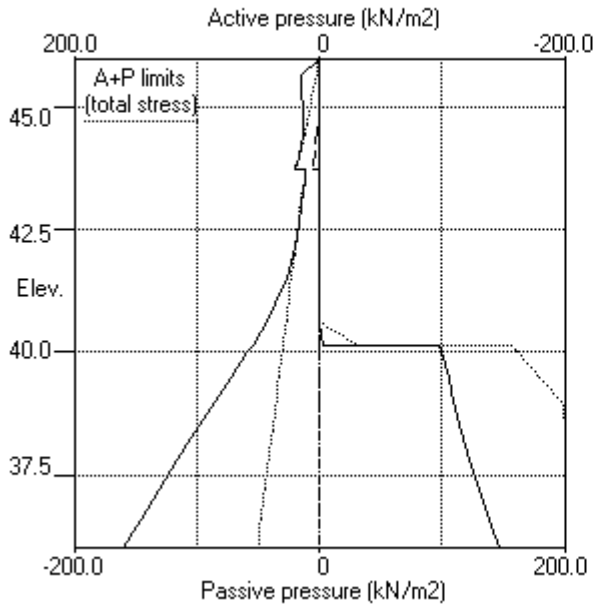
Units: kN,m

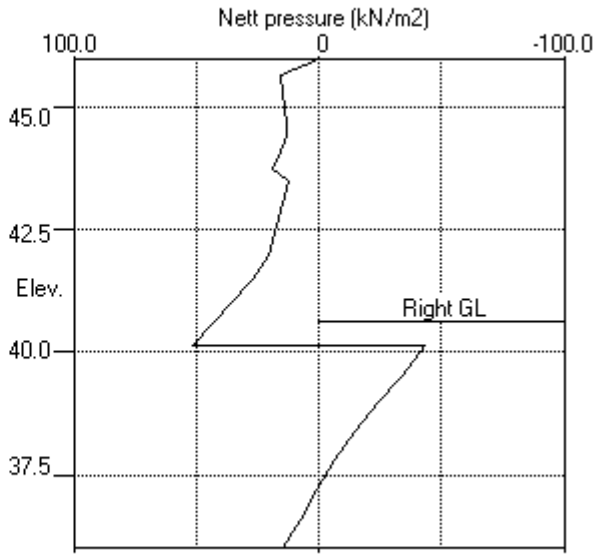
Stage No.6 Fill to elev. 40.65 on RIGHT side





Stage No.6 Fill to elev. 40.65 on RIGHT side





Units: kN,m

Stage No. 10 Change EI of wall to 46968 kN.m2/m run
Yield moment not defined
Allow wall to relax with new modulus value

BENDING MOMENT and DISPLACEMENT ANALYSIS of Fully Embedded Wall

Analysis options

Length of wall perpendicular to section = 50.00m
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: Left side 50.00 from wall
Right side 50.00 from wall

Limit State: ULS DA1 Combination 1

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	EI of wall kN.m2/m
1	46.00	0.00	0.004	-5.41E-04	0.0	-0.0		46968
2	45.66	18.01	0.004	-5.41E-04	3.0	0.1		46968
3	45.33	16.49	0.004	-5.50E-04	8.9	2.2		46968
4	44.99	14.79	0.004	-5.80E-04	14.1	6.2		46968
5	44.65	13.03	0.005	-6.44E-04	18.8	11.8		46968
6	44.45	12.88	0.005	-7.03E-04	21.4	15.8	60.0	46968
		12.88	0.005	-7.03E-04	-38.6	15.8		
7	44.00	16.73	0.005	-7.79E-04	-32.0	-0.4		46968
8	43.75	19.32	0.005	-7.59E-04	-27.4	-8.0		46968
		11.25	0.005	-7.59E-04	-27.4	-8.0		
9	43.50	12.50	0.005	-7.03E-04	-24.5	-14.3		46968
10	43.05	14.75	0.006	-5.24E-04	-18.3	-24.6		46968
11	42.60	17.00	0.006	-2.65E-04	-11.2	-31.9		46968
12	42.00	20.00	0.006	1.50E-04	-0.1	-36.3		46968
13	41.50	24.77	0.006	4.95E-04	11.1	-32.5		46968
14	41.00	35.49	0.005	7.71E-04	26.2	-23.8	26.3	46968
		35.49	0.005	7.71E-04	-0.2	-23.8		
15	40.65	43.78	0.005	9.22E-04	13.7	-21.0		46968
16	40.15	53.80	0.005	1.05E-03	38.1	-7.6		46968
		-39.46	0.005	1.05E-03	38.1	-7.6		
17	40.00	-36.86	0.004	1.07E-03	32.4	-2.1		46968
18	39.50	-27.69	0.004	1.02E-03	16.2	10.2		46968
19	39.00	-18.70	0.003	8.89E-04	4.6	15.3		46968
20	38.40	-9.57	0.003	7.02E-04	-3.8	15.0		46968
21	37.80	-2.59	0.003	5.45E-04	-7.5	11.0		46968
22	37.20	2.82	0.002	4.46E-04	-7.4	5.8		46968
23	36.60	7.38	0.002	4.04E-04	-4.3	1.6		46968
24	36.00	7.11	0.002	3.96E-04	0.0	0.0		---

At elev. 44.45 Strut force = 60.0 kN/strut = 60.0 kN/m run
At elev. 41.00 Strut force = 26.3 kN/strut = 26.3 kN/m run

(continued)

Stage No.10 Change EI of wall to 46968 kN.m2/m run
Yield moment not defined
Allow wall to relax with new modulus value

LEFT side

Node no.	Y coord	Water press. kN/m2	Effective stresses: Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2	Total earth pressure kN/m2	Coeff. of subgrade reaction kN/m3
1	46.00	0.00	0.00	0.00	0.00	0.00	0.00	4200
2	45.66	0.00	6.98	2.25	25.47	18.01	18.01	4200
3	45.33	0.00	15.33	4.94	55.89	16.49	16.49	4200
4	44.99	0.00	23.20	7.48	84.60	14.79	14.79	4200
5	44.65	0.00	30.46	9.82	111.07	13.03	13.03	4200
6	44.45	1.24	33.31	10.74	121.48	11.64	12.88	4200
7	44.00	4.03	39.37	12.70	143.56	12.70	16.73a	3201
8	43.75	5.58	42.58	13.73	155.27	13.73	19.32a	3201
		Total>	48.16	11.25m	138.18	11.25	11.25a	11915
9	43.50	Total>	53.34	12.50m	147.36	12.50	12.50a	12444
10	43.05	Total>	62.52	14.75m	163.74	14.75	14.75a	13398
11	42.60	Total>	71.57	17.00m	179.99	17.00	17.00a	14351
12	42.00	Total>	83.47	20.00m	201.50	20.00	20.00a	15622
13	41.50	Total>	93.31	22.50m	219.34	24.77	24.77	16681
14	41.00	Total>	103.10	25.00m	237.13	35.49	35.49	17740
15	40.65	Total>	109.93	26.75m	249.56	43.78	43.78	16344
16	40.15	Total>	119.66	29.25m	267.30	56.70	56.70	17281
17	40.00	Total>	122.58	30.00m	272.61	60.77	60.77	17562
18	39.50	Total>	132.30	32.50m	290.34	74.58	74.58	18499
19	39.00	Total>	142.02	35.00m	308.05	88.20	88.20	19435
20	38.40	Total>	153.68	38.00m	329.32	103.74	103.74	20559
21	37.80	Total>	165.35	41.00m	350.59	118.32	118.32	21683
22	37.20	Total>	177.03	44.00m	371.87	132.23	132.23	22807
23	36.60	Total>	188.72	47.00m	393.17	145.77	145.77	97161
24	36.00	Total>	200.43	50.00m	414.48	156.87	156.87	101725

RIGHT side

Node no.	Y coord	Water press. kN/m2	Effective stresses: Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2	Total earth pressure kN/m2	Coeff. of subgrade reaction kN/m3
1	46.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
2	45.66	0.00	0.00	0.00	0.00	0.00	0.00	0.0
3	45.33	0.00	0.00	0.00	0.00	0.00	0.00	0.0
4	44.99	0.00	0.00	0.00	0.00	0.00	0.00	0.0
5	44.65	0.00	0.00	0.00	0.00	0.00	0.00	0.0
6	44.45	0.00	0.00	0.00	0.00	0.00	0.00	0.0
7	44.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
8	43.75	0.00	0.00	0.00	0.00	0.00	0.00	0.0
9	43.50	0.00	0.00	0.00	0.00	0.00	0.00	0.0
10	43.05	0.00	0.00	0.00	0.00	0.00	0.00	0.0
11	42.60	0.00	0.00	0.00	0.00	0.00	0.00	0.0
12	42.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
13	41.50	0.00	0.00	0.00	0.00	0.00	0.00	0.0
14	41.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
15	40.65	0.00	0.00	0.00	0.00	0.00	0.00	0.0
		0.00	0.00	0.00	0.00	0.00	0.00	2807
16	40.15	0.00	9.00	2.90	32.82	2.90	2.90a	2807
		Total>	9.00	2.50m	156.62	96.16	96.16	17281
17	40.00	Total>	12.00	3.25m	162.02	97.63	97.63	17562
18	39.50	Total>	22.00	5.75m	180.02	102.27	102.27	18499
19	39.00	Total>	32.00	8.25m	198.02	106.90	106.90	19435

(continued)

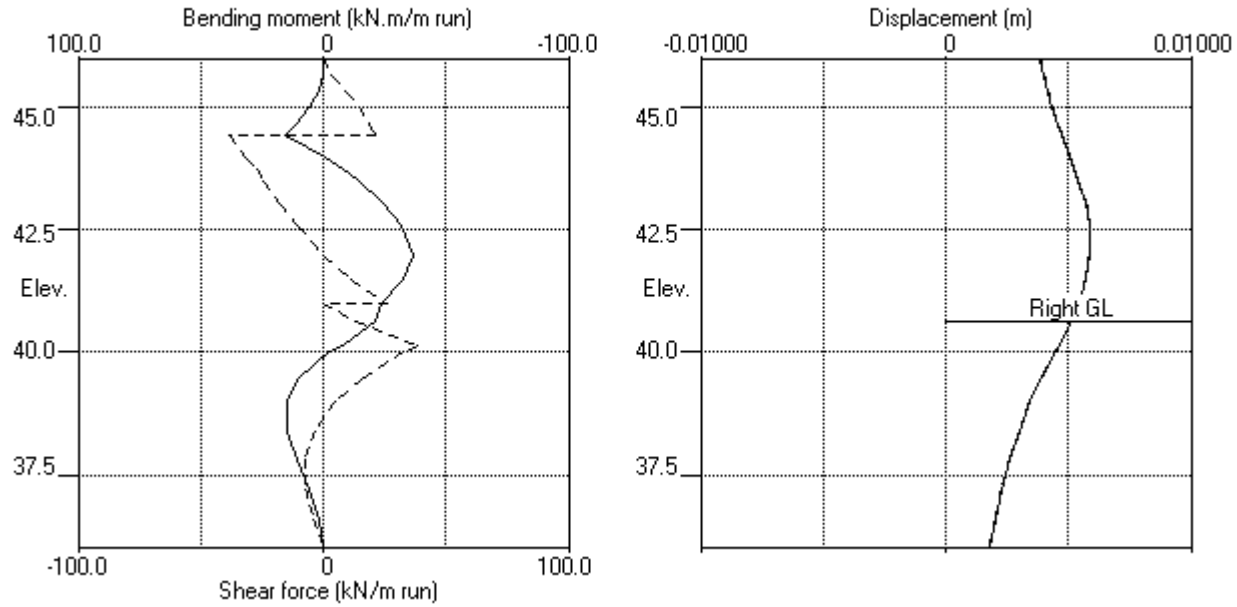
Stage No.10 Change EI of wall to 46968 kN.m2/m run
Yield moment not defined
Allow wall to relax with new modulus value

Node no.	Y coord	RIGHT side Water press. kN/m2	Effective stresses Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2	Total earth pressure kN/m2	Coeff. of subgrade reaction kN/m3
20	38.40	Total>	44.00	11.25m	219.63	113.31	113.31	20559
21	37.80	Total>	56.01	14.25m	241.23	120.91	120.91	21683
22	37.20	Total>	68.01	17.25m	262.84	129.41	129.41	22807
23	36.60	Total>	80.02	20.25m	284.45	138.39	138.39	97161
24	36.00	Total>	92.03	23.25m	306.06	149.76	149.76	101725

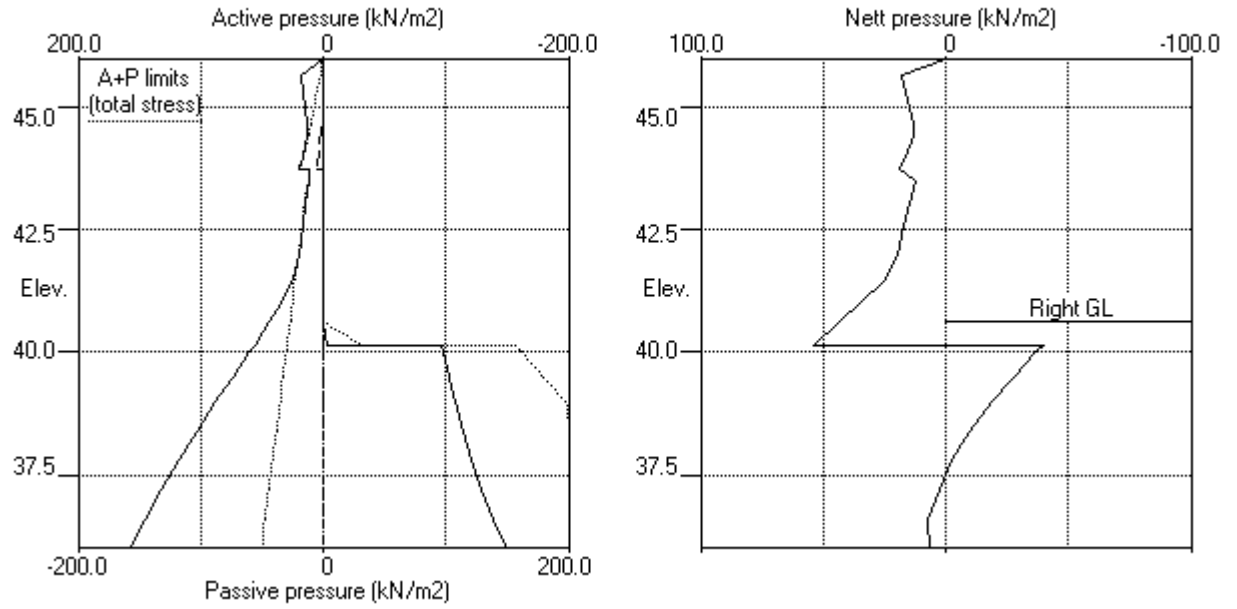
Note: 2.90a Soil pressure at active limit
123.45p Soil pressure at passive limit

Units: kN,m

Stage No.10 Change EI of wall to 46968kN.m2/m run



Stage No.10 Change EI of wall to 46968kN.m2/m run



Units: kN,m

Summary of results

BENDING MOMENT and DISPLACEMENT ANALYSIS of Fully Embedded Wall

Analysis options

Length of wall perpendicular to section = 50.00m
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: Left side 50.00 from wall
Right side 50.00 from wall

Limit State: ULS DA1 Combination 1

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		Bending moment Calculated		Bending moment Factored		Shear force Calculated		Shear force Factored	
		max.	min.	max.	min.	max.	min.	max.	min.	max.	min.
		m	m	kN.m/m		kN.m/m		kN/m	kN/m	kN/m	kN/m
1	46.00	0.007	0.000	0	-0	0	-0	0	0	0	0
2	45.66	0.007	0.000	0	0	0	0	3	-0	4	-0
3	45.33	0.006	0.000	2	-0	3	-0	10	-1	13	-1
4	44.99	0.006	0.000	7	-1	9	-1	17	-1	23	-1
5	44.65	0.005	0.000	14	-1	19	-1	25	-1	34	-2
6	44.45	0.005	0.000	19	-1	26	-2	29	-68	40	-92
7	44.00	0.005	0.000	25	-9	34	-12	27	-57	37	-77
8	43.75	0.006	0.000	14	-23	19	-31	20	-50	27	-67
9	43.50	0.006	0.000	20	-34	27	-46	23	-42	31	-56
10	43.05	0.006	0.000	27	-50	36	-67	10	-34	13	-46
11	42.60	0.006	0.000	29	-57	39	-77	1	-27	1	-36
12	42.00	0.006	0.000	26	-52	35	-71	25	-15	34	-21
13	41.50	0.006	0.000	21	-44	29	-59	54	-10	73	-13
14	41.00	0.006	0.000	16	-42	22	-56	87	-29	117	-39
15	40.65	0.005	0.000	13	-35	17	-48	26	-9	35	-13
16	40.15	0.005	0.000	8	-18	11	-24	50	-8	67	-10
17	40.00	0.005	0.000	7	-11	10	-15	44	-7	59	-9
18	39.50	0.004	0.000	10	0	14	0	25	-5	34	-7
19	39.00	0.004	0.000	17	0	22	0	11	-3	15	-4
20	38.40	0.003	0.000	17	0	23	0	3	-4	4	-5
21	37.80	0.003	0.000	14	0	19	0	0	-8	0	-11
22	37.20	0.003	0.000	8	-0	11	-0	0	-9	0	-13
23	36.60	0.002	0.000	3	-0	4	-0	0	-7	0	-9
24	36.00	0.002	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.	elev.	min.	elev.	max.	min.	max.	elev.	min.	elev.	max.	min.
	kN.m/m		kN.m/m		kN.m/m		kN/m		kN/m		kN/m	kN/m
1	0	39.00	-1	43.50	1	-2	1	41.50	-1	44.99	1	-1
2	0	38.40	-1	44.00	1	-2	1	43.75	-1	44.65	1	-2
3	29	42.60	-0	37.20	39	-0	23	43.50	-10	41.00	31	-14
4	No calculation at this stage											
5	25	44.00	-43	41.50	34	-58	48	40.15	-47	44.00	64	-64
6	25	44.00	-44	41.50	34	-59	50	40.15	-48	44.00	67	-64
7	No calculation at this stage											
8	No calculation at this stage											
9	17	38.40	-42	42.00	23	-57	45	40.15	-42	44.45	61	-56
10	16	44.45	-36	42.00	21	-49	38	40.15	-39	44.45	51	-52
11	No calculation at this stage											
12	No calculation at this stage											
13	19	44.45	-57	42.60	26	-77	87	41.00	-68	44.45	117	-92

Maximum and minimum displacement at each stage

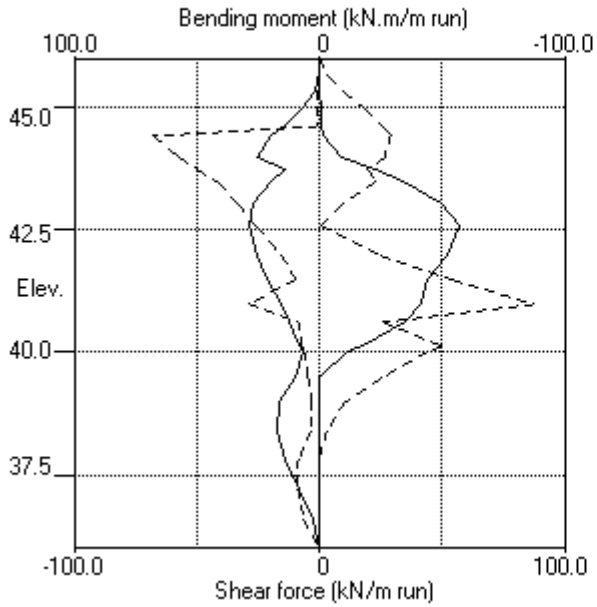
Stage no.	Displacement maximum m	elev.	minimum m	elev.	Stage description
1	0.001	46.00	0.000	46.00	Apply surcharge no.1 at elev. 46.00
2	0.001	46.00	0.000	46.00	Apply water pressure profile no.1
3	0.007	46.00	0.000	46.00	Excav. to elev. 43.50 on RIGHT side
4	No calculation at this stage				Install strut no.1 at elev. 44.00
5	0.006	42.00	0.000	46.00	Excav. to elev. 40.15 on RIGHT side
6	0.006	42.00	0.000	46.00	Fill to elev. 40.65 on RIGHT side
7	No calculation at this stage				Install strut no.2 at elev. 41.00
8	No calculation at this stage				Install strut no.3 at elev. 44.45
9	0.006	42.00	0.000	46.00	Remove strut no.1 at elev. 44.00
10	0.006	42.00	0.000	46.00	Change EI of wall to 46968kN.m2/m run
11	No calculation at this stage				Change soil type 2 to soil type 3
12	No calculation at this stage				Apply surcharge no.2 at elev. 40.65
13	0.006	42.60	0.000	46.00	Apply water pressure profile no.2

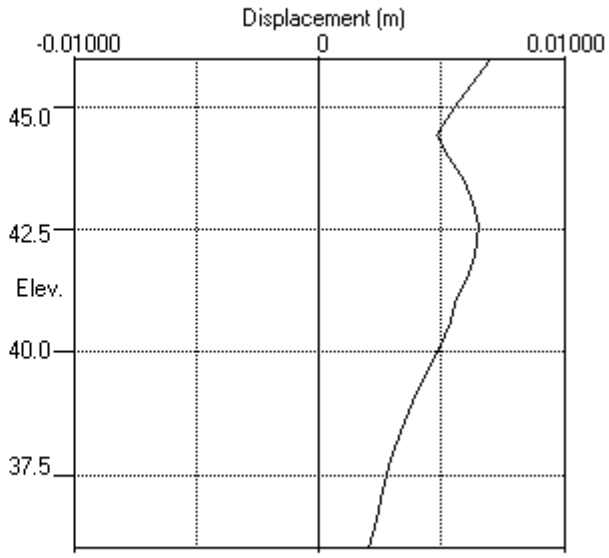
Strut forces at each stage (horizontal components)

Stage	Strut no. 1 at elev. 44.00			Strut no. 2 at elev. 41.00			Strut no. 3 at elev. 44.45		
	Calculated kN per m run	Calculated kN per strut	Factored kN per strut	Calculated kN per m run	Calculated kN per strut	Factored kN per strut	Calculated kN per m run	Calculated kN per strut	Factored kN per strut
5	74	371	501	---	---	---	---	---	---
6	74	372	503	---	---	---	---	---	---
9	---	---	---	16	16	22	63	63	85
10	---	---	---	26	26	36	60	60	81
13	---	---	---	116	116	156	98	98	132

Units: kN,m

Bending moment, shear force, displacement envelopes





WALLAP

1-ULS2

Units: kN,m

INPUT DATA

SOIL PROFILE

Stratum no.	Elevation of top of stratum	Soil types Left side	Right side
1	46.00	1 Made Ground dr	1 Made Ground dr
2	43.75	2 London Clay und	2 London Clay und

SOIL PROPERTIES (Unfactored SLS soil strengths)

-- 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 dr	18.00	10000	0.562	OC (0.250)	0.323 (0.000)	3.647 (0.000)	
2	London Cl.. (43.75)	20.00	27000 (4800)	1.000	OC (0.490)	1.000 (2.000)	1.000 (2.000)	45.00u (8.000)
3	London Cl.. (43.75)	20.00	20790 (3696)	1.000	OC (0.200)	0.351 (1.391)	3.253 (4.831)	0.0d
4	Not defined							
5	Backfill dr	20.00	30000	0.500	OC (0.250)	0.217 (0.000)	6.535 (0.000)	
6	Concrete dr	24.00	40000	0.500	OC (0.200)	0.140 (0.000)	13.89 (0.000)	

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 dr	27.00	0.670	0.00	27.00	0.500	0.00
2	London Clay und	0.00	0.000	0.00	0.00	0.000	0.00
3	London Clay dr	25.00	0.670	0.00	25.00	0.500	0.00
4	Not defined						
5	Backfill dr	36.00	0.670	0.00	36.00	0.500	0.00
6	Concrete dr	45.00	0.670	0.00	45.00	0.500	0.00

GROUND WATER CONDITIONS

Density of water = 9.810 kN/m3

	Left side	Right side
Initial water table elevation	44.65	44.65

Automatic water pressure balancing at toe of wall : Yes

Water press. profile no.	Left side Point no.	Elev. m	Piezo elev. m	Water press. kN/m2	Right side Point no.	Elev. m	Piezo elev. m	Water press. kN/m2	
1	1	44.65	44.65	0.0	1	40.00	40.00	0.0	MC+WC
2	1	46.00	46.00	0.0	1	40.65	40.65	0.0	MC+WC
					2	40.65	46.00	52.5	

WALL PROPERTIES

Type of structure = Fully Embedded Wall
Elevation of toe of wall = 36.00
Maximum finite element length = 0.60 m
Youngs modulus of wall E = 1.9600E+07 kN/m2
Moment of inertia of wall I = 3.3548E-03 m4/m run
E.I = 65754 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	44.00	5.00	0.015000	2.050E+08	5.00	0.00	0	No
2	41.00	1.00	0.600000	1.400E+07	5.00	0.00	0	No
3	44.45	1.00	0.200000	1.400E+07	5.00	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	46.00	0.50(L)	10.00	10.00	10.00	=	N/A	1.30 Var
2	40.65	-0.00(R)	10.00	10.00	53.00	=	N/A	1.00 P/F

Note: L = Left side, R = Right 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 46.00
2	Apply water pressure profile no.1 (Worst Cred.)
3	Excavate to elevation 43.50 on RIGHT side
4	Install strut or anchor no.1 at elevation 44.00
5	Excavate to elevation 40.15 on RIGHT side
6	Fill to elevation 40.65 on RIGHT side with soil type 1
7	Install strut or anchor no.2 at elevation 41.00
8	Install strut or anchor no.3 at elevation 44.45
9	Remove strut or anchor no.1 at elevation 44.00
10	Change EI of wall to 46968 kN.m2/m run Yield moment not defined Allow wall to relax with new modulus value
11	Change properties of soil type 2 to soil type 3 No analysis at this stage Ko pressures will not be reset
12	Apply surcharge no.2 at elevation 40.65 No analysis at this stage
13	Apply water pressure profile no.2 (Worst Cred.)

FACTORS OF SAFETY and ANALYSIS OPTIONS

Limit State options: ULS DA1 Combination 2
Water pressures : Worst Credible
Partial factor on C' = 1.250
Partial factor on Phi' = 1.250
Partial factor on Cu = 1.400
Partial factor on Soil Modulus = 1.000
Partial factor on Permanent Unfavourable loads = 1.000
Partial factor on Permanent Favourable loads = 1.000
Partial factor on Variable Unfavourable loads = 1.300

Stability analysis:
Method of analysis - Strength Factor method
Overall 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) = 11.00 m

Boundary conditions:
Length of wall (normal to plane of analysis) = 50.00 m

Width of excavation on Left side of wall = 50.00 m
Width of excavation on Right side of wall = 50.00 m

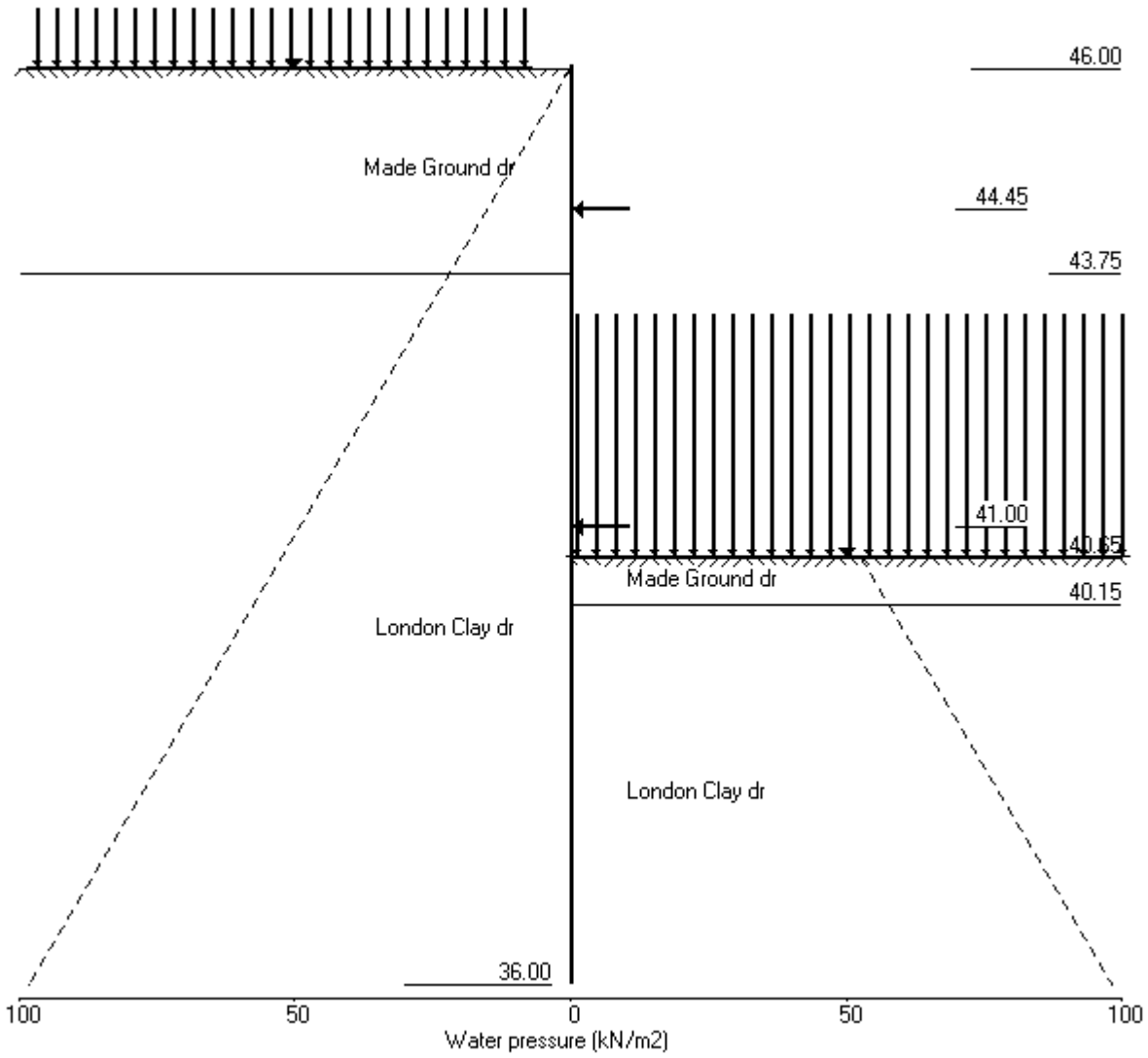
Distance to rigid boundary on Left side = 50.00 m
Distance to rigid boundary on Right side = 50.00 m

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. 46.00	Yes	Yes	Yes
2	Apply water pressure profile no.1	Yes	Yes	Yes
3	Excav. to elev. 43.50 on RIGHT side	No	No	No
4	Install strut no.1 at elev. 44.00	Yes	Yes	Yes
5	Excav. to elev. 40.15 on RIGHT side	Yes	Yes	Yes
6	Fill to elev. 40.65 on RIGHT side	Yes	Yes	Yes
7	Install strut no.2 at elev. 41.00	Yes	Yes	Yes
8	Install strut no.3 at elev. 44.45	Yes	Yes	Yes
9	Remove strut no.1 at elev. 44.00	Yes	Yes	Yes
10	Change EI of wall to 46968kN.m2/m run	Yes	Yes	Yes
11	Change soil type 2 to soil type 3	Yes	Yes	Yes
12	Apply surcharge no.2 at elev. 40.65	Yes	Yes	Yes
13	Apply water pressure profile no.2	Yes	Yes	Yes
*	Summary output	Yes	-	Yes

Units: kN,m

Stage No.13 Apply water pressure profile no.2 (Worst Cred.)



Units: kN,m

Stage No. 3 Excavate to elevation 43.50 on RIGHT side

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.	Overall FoS for toe elev. = 36.00 Factor of Safety	Moment equilib. at elev.	Toe elev. for FoS = 1.000 Toe elev.	Wall Penetr -ation	Direction of failure
3	46.00	43.50	Cant.	2.640	36.79	41.78	1.72	L to R

BENDING MOMENT and DISPLACEMENT ANALYSIS of Fully Embedded Wall
Analysis options
Length of wall perpendicular to section = 50.00m
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: Left side 50.00 from wall
Right side 50.00 from wall
Limit State: ULS DA1 Combination 2

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	EI of wall kN.m2/m
1	46.00	0.00	0.008	1.70E-03	0.0	0.0		65754
2	45.66	2.83	0.007	1.70E-03	0.5	0.1		65754
3	45.33	6.29	0.007	1.70E-03	2.0	0.5		65754
4	44.99	9.54	0.006	1.70E-03	4.7	1.6		65754
5	44.65	12.49	0.006	1.68E-03	8.4	3.8		65754
6	44.45	14.90	0.005	1.67E-03	11.1	5.7		65754
7	44.00	20.14	0.004	1.60E-03	19.0	12.4		65754
8	43.75	22.98	0.004	1.55E-03	24.4	17.8		65754
		11.25	0.004	1.55E-03	24.4	17.8		
9	43.50	12.50	0.004	1.47E-03	27.4	24.3		65754
		-42.10	0.004	1.47E-03	27.4	24.3		
10	43.05	-31.45	0.003	1.27E-03	10.8	33.6		65754
11	42.60	-20.72	0.003	1.03E-03	-0.9	35.3		65754
12	42.00	-9.07	0.002	7.35E-04	-9.8	31.1		65754
13	41.50	-2.16	0.002	5.22E-04	-12.6	25.0		65754
14	41.00	2.28	0.001	3.57E-04	-12.6	18.4		65754
15	40.65	4.10	0.001	2.70E-04	-11.5	14.1		65754
16	40.15	5.30	0.001	1.83E-04	-9.1	8.9		65754
17	40.00	5.41	0.001	1.64E-04	-8.3	7.6		65754
18	39.50	4.94	0.001	1.20E-04	-5.8	4.1		65754
19	39.00	3.96	0.001	9.78E-05	-3.5	1.8		65754
20	38.40	2.58	0.001	8.82E-05	-1.6	0.3		65754
21	37.80	1.35	0.001	8.73E-05	-0.4	-0.2		65754
22	37.20	0.42	0.001	8.90E-05	0.1	-0.2		65754
23	36.60	-0.19	0.001	9.01E-05	0.2	-0.1		65754
24	36.00	-0.51	0.001	9.04E-05	0.0	0.0		---

(continued)

Stage No.3 Excavate to elevation 43.50 on RIGHT side

LEFT side

Node no.	Y coord	Water press. kN/m2	Effective stresses: Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2	Total earth pressure kN/m2	Coeff. of subgrade reaction kN/m3
1	46.00	0.00	0.00	0.00	0.00	0.00	0.00	3203
2	45.66	0.00	7.15	2.83	19.93	2.83	2.83a	3203
3	45.33	0.00	15.90	6.29	44.34	6.29	6.29a	3203
4	44.99	0.00	24.10	9.54	67.19	9.54	9.54a	3203
5	44.65	0.00	31.57	12.49	88.03	12.49	12.49a	3203
6	44.45	1.24	34.52	13.66	96.24	13.66	14.90a	3203
7	44.00	4.03	40.71	16.11	113.50	16.11	20.14a	3203
8	43.75	5.58	43.97	17.40	122.58	17.40	22.98a	3203
		Total>	49.55	11.25m	113.85	11.25	11.25a	11920
9	43.50	Total>	54.77	12.50m	121.93	12.50	12.50a	12450
10	43.05	Total>	63.98	14.75m	136.29	25.65	25.65	13404
11	42.60	Total>	73.03	17.00m	150.48	39.26	39.26	14357
12	42.00	Total>	84.92	20.00m	169.23	56.16	56.16	15629
13	41.50	Total>	94.73	22.50m	184.76	68.97	68.97	16689
14	41.00	Total>	104.48	25.00m	200.22	80.66	80.66	17748
15	40.65	Total>	111.28	26.75m	211.02	88.28	88.28	18490
16	40.15	Total>	120.96	29.25m	226.42	98.53	98.53	19549
17	40.00	Total>	123.87	30.00m	231.04	101.49	101.49	19867
18	39.50	Total>	133.54	32.50m	246.43	111.12	111.12	20927
19	39.00	Total>	143.20	35.00m	261.81	120.53	120.53	21986
20	38.40	Total>	154.80	38.00m	280.27	131.73	131.73	23258
21	37.80	Total>	166.41	41.00m	298.73	143.01	143.01	24529
22	37.20	Total>	178.03	44.00m	317.21	154.43	154.43	25801
23	36.60	Total>	189.67	47.00m	335.71	166.01	166.01	27072
24	36.00	Total>	201.33	50.00m	354.23	177.72	177.72	28344

RIGHT side

Node no.	Y coord	Water press. kN/m2	Effective stresses: Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2	Total earth pressure kN/m2	Coeff. of subgrade reaction kN/m3
1	46.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
2	45.66	0.00	0.00	0.00	0.00	0.00	0.00	0.0
3	45.33	0.00	0.00	0.00	0.00	0.00	0.00	0.0
4	44.99	0.00	0.00	0.00	0.00	0.00	0.00	0.0
5	44.65	0.00	0.00	0.00	0.00	0.00	0.00	0.0
6	44.45	0.00	0.00	0.00	0.00	0.00	0.00	0.0
7	44.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
8	43.75	0.00	0.00	0.00	0.00	0.00	0.00	0.0
9	43.50	0.00	0.00	0.00	0.00	0.00	0.00	0.0
		Total>	0.00	0.00	67.15	54.60	54.60	15925
10	43.05	Total>	9.00	2.25m	81.29	57.10	57.10	17145
11	42.60	Total>	18.00	4.50m	95.44	59.98	59.98	18365
12	42.00	Total>	30.00	7.50m	114.30	65.23	65.23	19991
13	41.50	Total>	40.00	10.00m	130.02	71.12	71.12	21347
14	41.00	Total>	50.00	12.50m	145.74	78.39	78.39	22702
15	40.65	Total>	57.00	14.25m	156.74	84.17	84.17	23651
16	40.15	Total>	67.01	16.75m	172.46	93.23	93.23	25006
17	40.00	Total>	70.01	17.50m	177.17	96.08	96.08	25413
18	39.50	Total>	80.01	20.00m	192.89	106.18	106.18	26768
19	39.00	Total>	90.01	22.50m	208.61	116.57	116.57	28124
20	38.40	Total>	102.02	25.50m	227.48	129.15	129.15	29750
21	37.80	Total>	114.03	28.50m	246.34	141.66	141.66	31376
22	37.20	Total>	126.04	31.50m	265.21	154.01	154.01	33003

(continued)

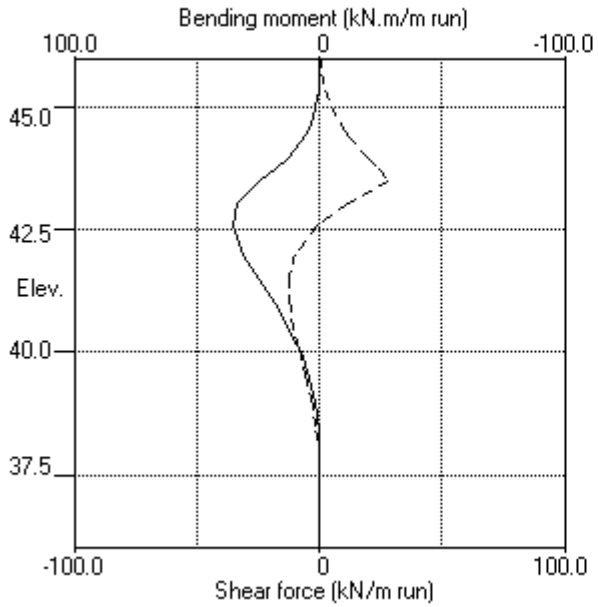
Stage No.3 Excavate to elevation 43.50 on RIGHT side

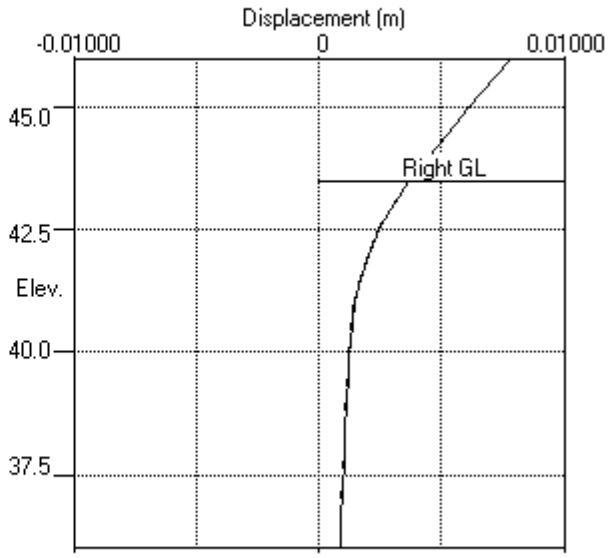
Node no.	Y coord	RIGHT side						
		Effective stresses				Total earth pressure	Coeff. of subgrade reaction
		Water press. kN/m2	Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2	kN/m2	kN/m3
23	36.60	Total>	138.05	34.50m	284.08	166.19	166.19	34629
24	36.00	Total>	150.06	37.50m	302.96	178.23	178.23	36256

Note: 12.50a Soil pressure at active limit
123.45p Soil pressure at passive limit

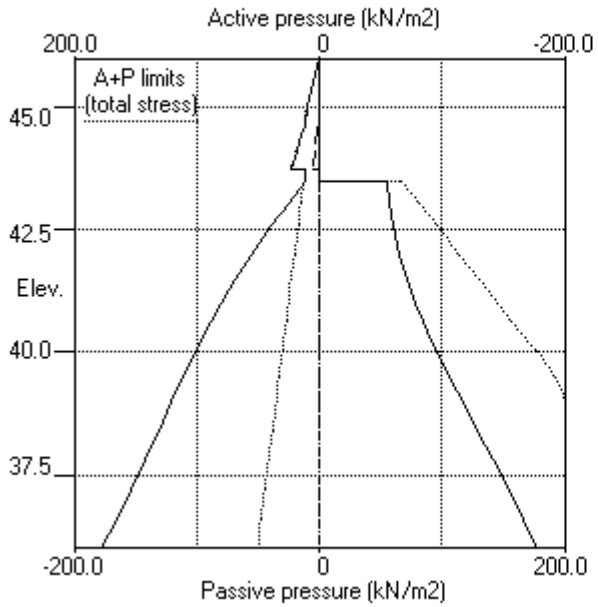
Units: kN,m

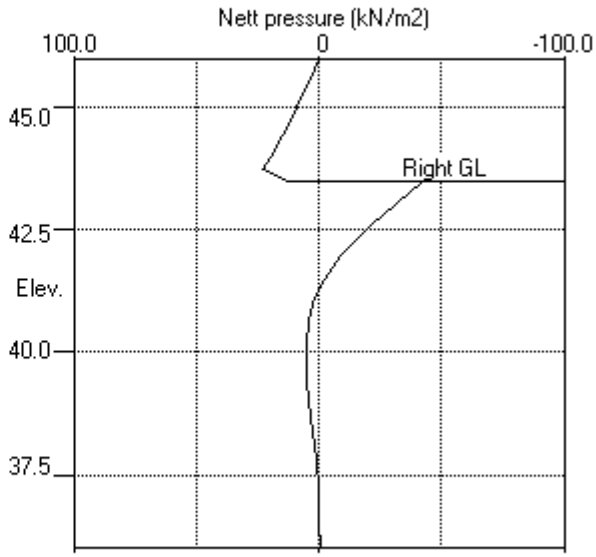
Stage No.3 Excav. to elev. 43.50 on RIGHT side





Stage No.3 Excav. to elev. 43.50 on RIGHT side





Units: kN,m

Stage No. 5 Excavate to elevation 40.15 on RIGHT side

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.	Overall FoS for toe elev. = 36.00 Factor of Safety	Moment equilib. at elev.	Toe elev. for FoS = 1.000 Toe elev.	Wall Penetr -ation	Direction of failure
5	46.00	40.15	44.00	1.973	n/a	39.70	0.45	L to R

BENDING MOMENT and DISPLACEMENT ANALYSIS of Fully Embedded Wall
Analysis options
Length of wall perpendicular to section = 50.00m
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: Left side 50.00 from wall
Right side 50.00 from wall
Limit State: ULS DA1 Combination 2

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	EI of wall kN.m2/m
1	46.00	0.00	0.005	-5.76E-05	0.0	0.0		65754
2	45.66	17.10	0.005	-5.78E-05	2.9	0.1		65754
3	45.33	16.97	0.005	-6.34E-05	8.6	2.1		65754
4	44.99	16.60	0.005	-8.44E-05	14.3	6.1		65754
5	44.65	15.90	0.005	-1.30E-04	19.8	11.9		65754
6	44.45	16.10	0.005	-1.73E-04	23.0	16.2		65754
7	44.00	20.14	0.005	-3.25E-04	31.1	28.3	79.8	65754
		20.14	0.005	-3.25E-04	-48.7	28.3		
8	43.75	22.98	0.005	-4.11E-04	-43.3	16.8		65754
		11.25	0.005	-4.11E-04	-43.3	16.8		
9	43.50	12.50	0.005	-4.55E-04	-40.3	6.4		65754
10	43.05	14.75	0.006	-4.44E-04	-34.2	-9.5		65754
11	42.60	17.00	0.006	-3.30E-04	-27.0	-23.7		65754
12	42.00	20.00	0.006	-5.15E-05	-15.9	-37.4		65754
13	41.50	25.98	0.006	2.47E-04	-4.5	-41.1		65754
14	41.00	34.75	0.006	5.54E-04	10.7	-39.8		65754
15	40.65	41.86	0.005	7.50E-04	24.1	-33.8		65754
16	40.15	53.37	0.005	9.40E-04	47.9	-16.1		65754
		-41.23	0.005	9.40E-04	47.9	-16.1		
17	40.00	-39.30	0.005	9.69E-04	41.9	-9.4		65754
18	39.50	-31.82	0.004	9.80E-04	24.1	6.6		65754
19	39.00	-23.59	0.004	8.99E-04	10.3	14.7		65754
20	38.40	-14.25	0.003	7.57E-04	-1.1	16.5		65754
21	37.80	-6.20	0.003	6.21E-04	-7.2	13.3		65754
22	37.20	0.72	0.003	5.24E-04	-8.9	7.8		65754
23	36.60	7.26	0.002	4.77E-04	-6.5	2.6		65754
24	36.00	14.30	0.002	4.65E-04	0.0	0.0		---

At elev. 44.00 Strut force = 399.1 kN/strut = 79.8 kN/m run

(continued)

Stage No.5 Excavate to elevation 40.15 on RIGHT side

LEFT side

Node no.	Y coord	Water press. kN/m2	Effective stresses: Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2	Total earth pressure kN/m2	Coeff. of subgrade reaction kN/m3
1	46.00	0.00	0.00	0.00	0.00	0.00	0.00	6024
2	45.66	0.00	7.15	2.83	19.93	17.10	17.10	6024
3	45.33	0.00	15.90	6.29	44.34	16.97	16.97	6024
4	44.99	0.00	24.10	9.54	67.19	16.60	16.60	6024
5	44.65	0.00	31.57	12.49	88.03	15.90	15.90	6024
6	44.45	1.24	34.52	13.66	96.24	14.86	16.10	6024
7	44.00	4.03	40.71	16.11	113.50	16.11	20.14a	1944
8	43.75	5.58	43.97	17.40	122.58	17.40	22.98a	1944
		Total>	49.55	11.25m	113.85	11.25	11.25a	7551
9	43.50	Total>	54.77	12.50m	121.93	12.50	12.50a	7887
10	43.05	Total>	63.98	14.75m	136.29	14.75	14.75a	8491
11	42.60	Total>	73.03	17.00m	150.48	17.00	17.00a	9095
12	42.00	Total>	84.92	20.00m	169.23	20.00	20.00a	9901
13	41.50	Total>	94.73	22.50m	184.76	25.98	25.98	10572
14	41.00	Total>	104.48	25.00m	200.22	34.75	34.75	11243
15	40.65	Total>	111.28	26.75m	211.02	41.86	41.86	11713
16	40.15	Total>	120.96	29.25m	226.42	53.37	53.37	12384
17	40.00	Total>	123.87	30.00m	231.04	57.08	57.08	12586
18	39.50	Total>	133.54	32.50m	246.43	69.94	69.94	13257
19	39.00	Total>	143.20	35.00m	261.81	83.10	83.10	13928
20	38.40	Total>	154.80	38.00m	280.27	98.66	98.66	14734
21	37.80	Total>	166.41	41.00m	298.73	113.72	113.72	15539
22	37.20	Total>	178.03	44.00m	317.21	128.33	128.33	16345
23	36.60	Total>	189.67	47.00m	335.71	142.82	142.82	17150
24	36.00	Total>	201.33	50.00m	354.23	157.53	157.53	17956

RIGHT side

Node no.	Y coord	Water press. kN/m2	Effective stresses: Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2	Total earth pressure kN/m2	Coeff. of subgrade reaction kN/m3
1	46.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
2	45.66	0.00	0.00	0.00	0.00	0.00	0.00	0.0
3	45.33	0.00	0.00	0.00	0.00	0.00	0.00	0.0
4	44.99	0.00	0.00	0.00	0.00	0.00	0.00	0.0
5	44.65	0.00	0.00	0.00	0.00	0.00	0.00	0.0
6	44.45	0.00	0.00	0.00	0.00	0.00	0.00	0.0
7	44.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
8	43.75	0.00	0.00	0.00	0.00	0.00	0.00	0.0
9	43.50	0.00	0.00	0.00	0.00	0.00	0.00	0.0
10	43.05	0.00	0.00	0.00	0.00	0.00	0.00	0.0
11	42.60	0.00	0.00	0.00	0.00	0.00	0.00	0.0
12	42.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
13	41.50	0.00	0.00	0.00	0.00	0.00	0.00	0.0
14	41.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
15	40.65	0.00	0.00	0.00	0.00	0.00	0.00	0.0
16	40.15	0.00	0.00	0.00	0.00	0.00	0.00	0.0
		Total>	0.00	0.00	105.44	94.60	94.60	18034
17	40.00	Total>	3.00	0.75m	110.15	96.38	96.38	18327
18	39.50	Total>	13.00	3.25m	125.87	101.76	101.76	19304
19	39.00	Total>	23.00	5.75m	141.59	106.69	106.69	20282
20	38.40	Total>	35.00	8.75m	160.45	112.92	112.92	21455
21	37.80	Total>	47.00	11.75m	179.31	119.92	119.92	22627
22	37.20	Total>	59.01	14.75m	198.17	127.61	127.61	23800

(continued)

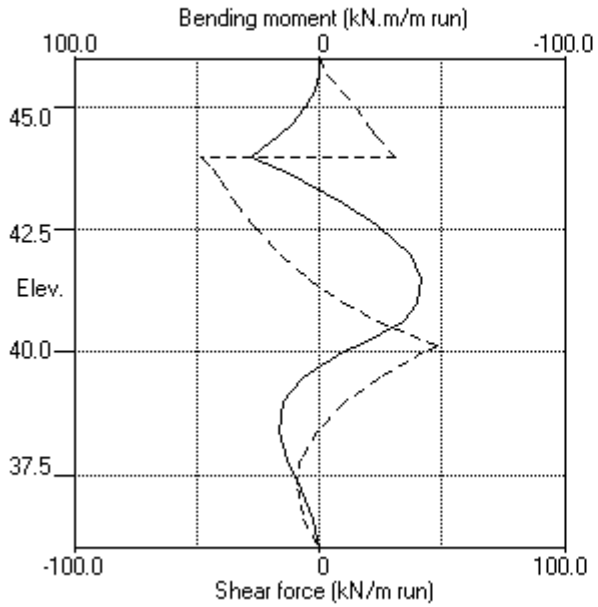
Stage No.5 Excavate to elevation 40.15 on RIGHT side

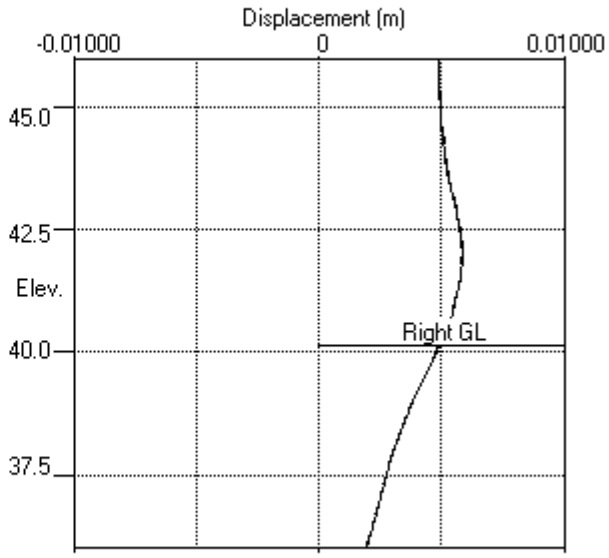
Node no.	Y coord	RIGHT side Water press. kN/m2	Effective stresses Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2	Total earth pressure kN/m2	Coeff. of subgrade reaction kN/m3
23	36.60	Total>	71.02	17.75m	217.04	135.56	135.56	24973
24	36.00	Total>	83.03	20.75m	235.91	143.23	143.23	26146

Note: 20.00a Soil pressure at active limit
123.45p Soil pressure at passive limit

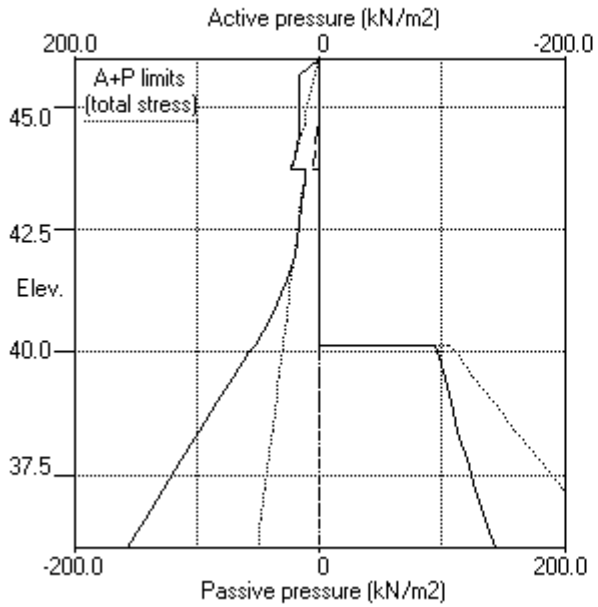
Units: kN,m

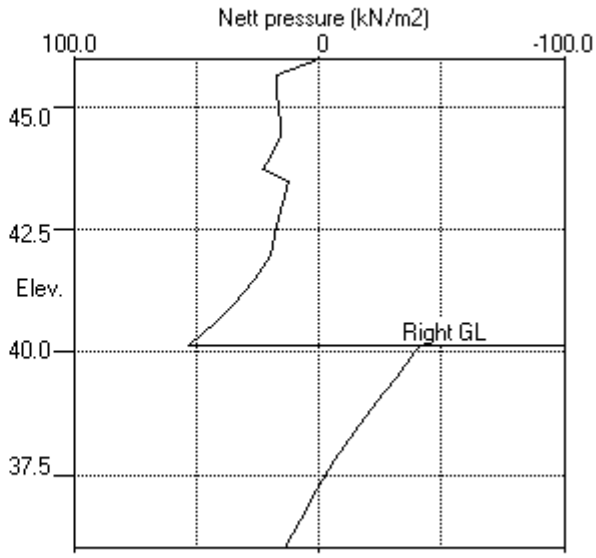
Stage No.5 Excav. to elev. 40.15 on RIGHT side





Stage No.5 Excav. to elev. 40.15 on RIGHT side





Units: kN,m

Stage No. 6 Fill to elevation 40.65 on RIGHT side with soil type 1

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.	Overall FoS for toe elev. = 36.00 Factor of Safety	Moment equilib. at elev.	Toe elev. for FoS = 1.000 Toe elev.	Wall Penetr -ation	Direction of failure
6	46.00	40.65	44.00	2.109	n/a	39.80	0.85	L to R

BENDING MOMENT and DISPLACEMENT ANALYSIS of Fully Embedded Wall

Analysis options

Length of wall perpendicular to section = 50.00m

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: Left side 50.00 from wall
Right side 50.00 from wall

Limit State: ULS DA1 Combination 2

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	EI of wall kN.m2/m
1	46.00	0.00	0.005	-2.81E-05	0.0	0.0		65754
2	45.66	16.83	0.005	-2.83E-05	2.8	0.1		65754
3	45.33	16.75	0.005	-3.38E-05	8.5	2.1		65754
4	44.99	16.44	0.005	-5.45E-05	14.1	6.0		65754
5	44.65	15.79	0.005	-9.99E-05	19.5	11.7		65754
6	44.45	16.02	0.005	-1.42E-04	22.7	16.0		65754
7	44.00	20.14	0.005	-2.92E-04	30.9	28.0	80.1	65754
		20.14	0.005	-2.92E-04	-49.2	28.0		
8	43.75	22.99	0.005	-3.76E-04	-43.8	16.3		65754
		11.30	0.005	-3.76E-04	-43.8	16.3		
9	43.50	12.62	0.005	-4.18E-04	-40.8	5.8		65754
10	43.05	15.03	0.005	-4.02E-04	-34.6	-10.4		65754
11	42.60	17.48	0.006	-2.83E-04	-27.3	-24.7		65754
12	42.00	20.83	0.006	5.02E-06	-15.8	-38.4		65754
13	41.50	27.19	0.006	3.10E-04	-3.8	-42.0		65754
14	41.00	36.41	0.005	6.23E-04	12.1	-40.2		65754
15	40.65	43.87	0.005	8.19E-04	26.2	-33.6		65754
16	40.15	52.36	0.005	1.00E-03	50.2	-14.8		65754
		-44.67	0.005	1.00E-03	50.2	-14.8		
17	40.00	-42.41	0.005	1.02E-03	43.7	-7.8		65754
18	39.50	-33.91	0.004	1.02E-03	24.6	8.7		65754
19	39.00	-24.82	0.004	9.28E-04	9.9	16.8		65754
20	38.40	-14.69	0.003	7.68E-04	-1.9	18.2		65754
21	37.80	-6.10	0.003	6.20E-04	-8.2	14.4		65754
22	37.20	1.17	0.002	5.16E-04	-9.7	8.4		65754
23	36.60	7.93	0.002	4.65E-04	-6.9	2.8		65754
24	36.00	15.13	0.002	4.52E-04	0.0	0.0		---

At elev. 44.00 Strut force = 400.4 kN/strut = 80.1 kN/m run

(continued)

Stage No.6 Fill to elevation 40.65 on RIGHT side with soil type 1

LEFT side

Node no.	Y coord	Water press. kN/m2	Effective stresses: Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2	Total earth pressure kN/m2	Coeff. of subgrade reaction kN/m3
1	46.00	0.00	0.00	0.00	0.00	0.00	0.00	5118
2	45.66	0.00	7.15	2.83	19.93	16.83	16.83	5118
3	45.33	0.00	15.90	6.29	44.34	16.75	16.75	5118
4	44.99	0.00	24.10	9.54	67.19	16.44	16.44	5118
5	44.65	0.00	31.57	12.49	88.03	15.79	15.79	5118
6	44.45	1.24	34.52	13.66	96.24	14.78	16.02	5118
7	44.00	4.03	40.71	16.11	113.50	16.11	20.14a	5118
8	43.75	5.58	43.97	17.40	122.58	17.41	22.99	1955
		Total>	49.55	11.25m	113.85	11.30	11.30	7590
9	43.50	Total>	54.77	12.50m	121.93	12.62	12.62	7928
10	43.05	Total>	63.98	14.75m	136.29	15.03	15.03	8535
11	42.60	Total>	73.03	17.00m	150.48	17.48	17.48	9142
12	42.00	Total>	84.92	20.00m	169.23	20.83	20.83	9952
13	41.50	Total>	94.73	22.50m	184.76	27.19	27.19	10626
14	41.00	Total>	104.48	25.00m	200.22	36.41	36.41	11301
15	40.65	Total>	111.28	26.75m	211.02	43.87	43.87	11773
16	40.15	Total>	120.96	29.25m	226.42	55.92	55.92	12448
17	40.00	Total>	123.87	30.00m	231.04	59.78	59.78	12650
18	39.50	Total>	133.54	32.50m	246.43	73.14	73.14	13325
19	39.00	Total>	143.20	35.00m	261.81	86.72	86.72	14000
20	38.40	Total>	154.80	38.00m	280.27	102.67	102.67	14809
21	37.80	Total>	166.41	41.00m	298.73	117.99	117.99	15619
22	37.20	Total>	178.03	44.00m	317.21	132.78	132.78	16429
23	36.60	Total>	189.67	47.00m	335.71	147.37	147.37	17238
24	36.00	Total>	201.33	50.00m	354.23	162.16	162.16	18048

RIGHT side

Node no.	Y coord	Water press. kN/m2	Effective stresses: Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2	Total earth pressure kN/m2	Coeff. of subgrade reaction kN/m3
1	46.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
2	45.66	0.00	0.00	0.00	0.00	0.00	0.00	0.0
3	45.33	0.00	0.00	0.00	0.00	0.00	0.00	0.0
4	44.99	0.00	0.00	0.00	0.00	0.00	0.00	0.0
5	44.65	0.00	0.00	0.00	0.00	0.00	0.00	0.0
6	44.45	0.00	0.00	0.00	0.00	0.00	0.00	0.0
7	44.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
8	43.75	0.00	0.00	0.00	0.00	0.00	0.00	0.0
9	43.50	0.00	0.00	0.00	0.00	0.00	0.00	0.0
10	43.05	0.00	0.00	0.00	0.00	0.00	0.00	0.0
11	42.60	0.00	0.00	0.00	0.00	0.00	0.00	0.0
12	42.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
13	41.50	0.00	0.00	0.00	0.00	0.00	0.00	0.0
14	41.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
15	40.65	0.00	0.00	0.00	0.00	0.00	0.00	0.0
		0.00	0.00	0.00	0.00	0.00	0.00	2062
16	40.15	0.00	9.00	3.56	25.09	3.56	3.56a	2062
		Total>	9.00	2.50m	114.44	100.58	100.58	13045
17	40.00	Total>	12.00	3.25m	119.16	102.19	102.19	13257
18	39.50	Total>	22.00	5.75m	134.87	107.05	107.05	13964
19	39.00	Total>	32.00	8.25m	150.59	111.54	111.54	14671
20	38.40	Total>	44.00	11.25m	169.45	117.36	117.36	15520
21	37.80	Total>	56.01	14.25m	188.31	124.09	124.09	16368

(continued)

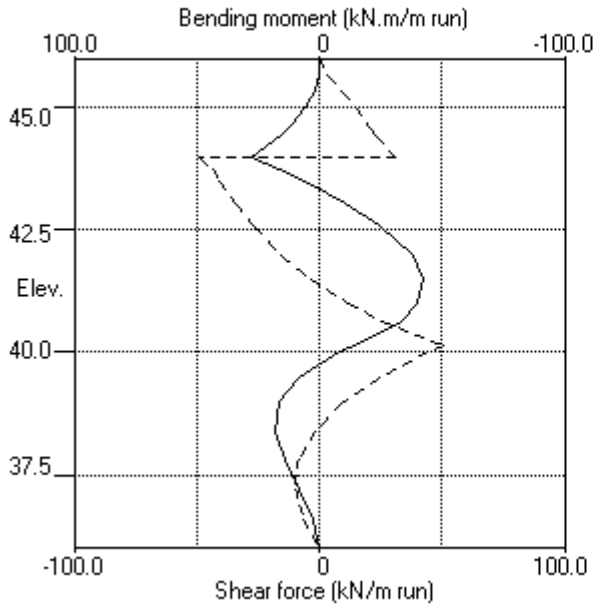
Stage No.6 Fill to elevation 40.65 on RIGHT side with soil type 1

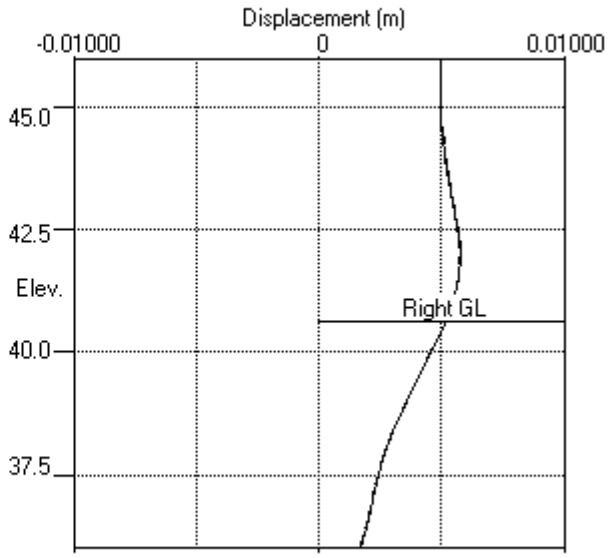
Node no.	Y coord	RIGHT side						
		Water press. kN/m2	Effective stresses Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2	Total earth pressure kN/m2	Coeff. of subgrade reaction kN/m3
22	37.20	Total>	68.01	17.25m	207.18	131.61	131.61	17217
23	36.60	Total>	80.02	20.25m	226.04	139.44	139.44	18065
24	36.00	Total>	92.03	23.25m	244.91	147.03	147.03	18914

Note: 3.56a Soil pressure at active limit
123.45p Soil pressure at passive limit

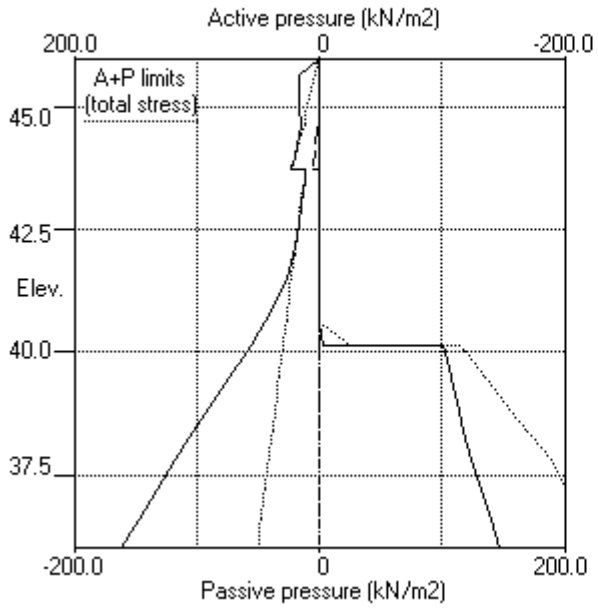
Units: kN,m

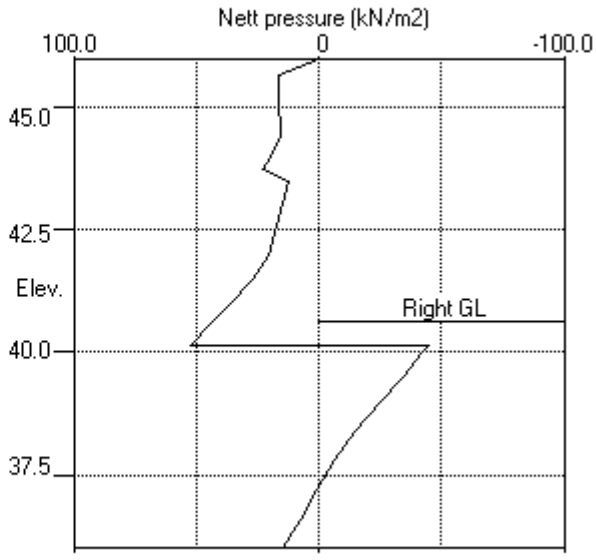
Stage No.6 Fill to elev. 40.65 on RIGHT side





Stage No.6 Fill to elev. 40.65 on RIGHT side





Units: kN,m

Stage No. 10 Change EI of wall to 46968 kN.m2/m run
Yield moment not defined
Allow wall to relax with new modulus value

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.	Overall FoS for toe elev. = 36.00 Factor of Safety	Moment equilib. at elev.	Toe elev. for FoS = 1.000 Toe elev.	Wall Penetr -ation	Direction of failure
10	46.00	40.65		More than one strut. No FoS calc.				

BENDING MOMENT and DISPLACEMENT ANALYSIS of Fully Embedded Wall
Analysis options
Length of wall perpendicular to section = 50.00m
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: Left side 50.00 from wall
Right side 50.00 from wall
Limit State: ULS DA1 Combination 2

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	EI of wall kN.m2/m
1	46.00	0.00	0.005	-3.60E-04	0.0	0.0		46968
2	45.66	19.15	0.005	-3.60E-04	3.2	0.1		46968
3	45.33	18.20	0.005	-3.69E-04	9.5	2.3		46968
4	44.99	17.01	0.005	-4.01E-04	15.5	6.7		46968
5	44.65	15.68	0.005	-4.71E-04	21.0	12.9		46968
6	44.45	15.68	0.005	-5.36E-04	24.1	17.4	65.0	46968
		15.68	0.005	-5.36E-04	-40.8	17.4		
7	44.00	20.14	0.005	-6.23E-04	-32.8	0.5		46968
8	43.75	22.98	0.006	-6.08E-04	-27.4	-7.2		46968
		11.25	0.006	-6.08E-04	-27.4	-7.2		
9	43.50	12.50	0.006	-5.55E-04	-24.4	-13.8		46968
10	43.05	14.75	0.006	-3.87E-04	-18.3	-22.9		46968
11	42.60	17.00	0.006	-1.43E-04	-11.1	-30.2		46968
12	42.00	20.00	0.006	2.52E-04	-0.0	-34.7		46968
13	41.50	24.91	0.006	5.82E-04	11.2	-30.8		46968
14	41.00	36.14	0.005	8.41E-04	26.5	-22.1	27.2	46968
		36.14	0.005	8.41E-04	-0.7	-22.1		
15	40.65	44.70	0.005	9.81E-04	13.4	-19.4		46968
16	40.15	54.36	0.005	1.10E-03	38.2	-6.1		46968
		-40.66	0.005	1.10E-03	38.2	-6.1		
17	40.00	-37.85	0.004	1.11E-03	32.3	-0.6		46968
18	39.50	-28.12	0.004	1.05E-03	15.8	11.5		46968
19	39.00	-18.77	0.003	9.04E-04	4.1	16.3		46968
20	38.40	-9.39	0.003	7.08E-04	-4.3	15.6		46968
21	37.80	-2.32	0.003	5.45E-04	-7.9	11.3		46968
22	37.20	3.10	0.002	4.44E-04	-7.6	5.9		46968
23	36.60	7.52	0.002	4.01E-04	-4.4	1.6		46968
24	36.00	7.28	0.002	3.92E-04	0.0	0.0		---

At elev. 44.45 Strut force = 65.0 kN/strut = 65.0 kN/m run
At elev. 41.00 Strut force = 27.2 kN/strut = 27.2 kN/m run

(continued)

Stage No.10 Change EI of wall to 46968 kN.m2/m run
Yield moment not defined
Allow wall to relax with new modulus value

LEFT side

Node no.	Y coord	Water press. kN/m2	Effective stresses: Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2	Total earth pressure kN/m2	Coeff. of subgrade reaction kN/m3
1	46.00	0.00	0.00	0.00	0.00	0.00	0.00	4205
2	45.66	0.00	7.15	2.83	19.93	19.15	19.15	4205
3	45.33	0.00	15.90	6.29	44.34	18.20	18.20	4205
4	44.99	0.00	24.10	9.54	67.19	17.01	17.01	4205
5	44.65	0.00	31.57	12.49	88.03	15.68	15.68	4205
6	44.45	1.24	34.52	13.66	96.24	14.44	15.68	4205
7	44.00	4.03	40.71	16.11	113.50	16.11	20.14a	3204
8	43.75	5.58	43.97	17.40	122.58	17.40	22.98a	3204
		Total>	49.55	11.25m	113.85	11.25	11.25a	11925
9	43.50	Total>	54.77	12.50m	121.93	12.50	12.50a	12455
10	43.05	Total>	63.98	14.75m	136.29	14.75	14.75a	13409
11	42.60	Total>	73.03	17.00m	150.48	17.00	17.00a	14363
12	42.00	Total>	84.92	20.00m	169.23	20.00	20.00a	15635
13	41.50	Total>	94.73	22.50m	184.76	24.91	24.91	16695
14	41.00	Total>	104.48	25.00m	200.22	36.14	36.14	17755
15	40.65	Total>	111.28	26.75m	211.02	44.70	44.70	16393
16	40.15	Total>	120.96	29.25m	226.42	57.92	57.92	17332
17	40.00	Total>	123.87	30.00m	231.04	62.06	62.06	17614
18	39.50	Total>	133.54	32.50m	246.43	76.04	76.04	18554
19	39.00	Total>	143.20	35.00m	261.81	89.75	89.75	19493
20	38.40	Total>	154.80	38.00m	280.27	105.32	105.32	20620
21	37.80	Total>	166.41	41.00m	298.73	119.88	119.88	21748
22	37.20	Total>	178.03	44.00m	317.21	133.74	133.74	22875
23	36.60	Total>	189.67	47.00m	335.71	147.17	147.17	94860
24	36.00	Total>	201.33	50.00m	354.23	158.24	158.24	99315

RIGHT side

Node no.	Y coord	Water press. kN/m2	Effective stresses: Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2	Total earth pressure kN/m2	Coeff. of subgrade reaction kN/m3
1	46.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
2	45.66	0.00	0.00	0.00	0.00	0.00	0.00	0.0
3	45.33	0.00	0.00	0.00	0.00	0.00	0.00	0.0
4	44.99	0.00	0.00	0.00	0.00	0.00	0.00	0.0
5	44.65	0.00	0.00	0.00	0.00	0.00	0.00	0.0
6	44.45	0.00	0.00	0.00	0.00	0.00	0.00	0.0
7	44.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
8	43.75	0.00	0.00	0.00	0.00	0.00	0.00	0.0
9	43.50	0.00	0.00	0.00	0.00	0.00	0.00	0.0
10	43.05	0.00	0.00	0.00	0.00	0.00	0.00	0.0
11	42.60	0.00	0.00	0.00	0.00	0.00	0.00	0.0
12	42.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
13	41.50	0.00	0.00	0.00	0.00	0.00	0.00	0.0
14	41.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
15	40.65	0.00	0.00	0.00	0.00	0.00	0.00	0.0
		0.00	0.00	0.00	0.00	0.00	0.00	2816
16	40.15	0.00	9.00	3.56	25.09	3.56	3.56a	2816
		Total>	9.00	2.50m	114.44	98.58	98.58	17332
17	40.00	Total>	12.00	3.25m	119.16	99.91	99.91	17614
18	39.50	Total>	22.00	5.75m	134.87	104.16	104.16	18554
19	39.00	Total>	32.00	8.25m	150.59	108.51	108.51	19493

(continued)

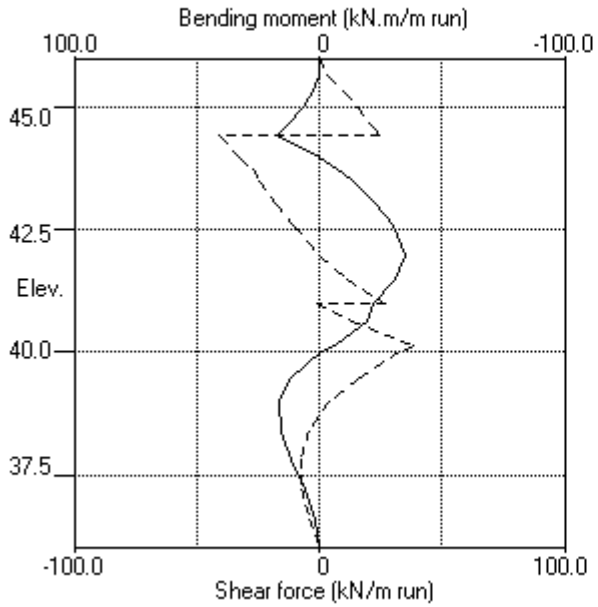
Stage No.10 Change EI of wall to 46968 kN.m2/m run
Yield moment not defined
Allow wall to relax with new modulus value

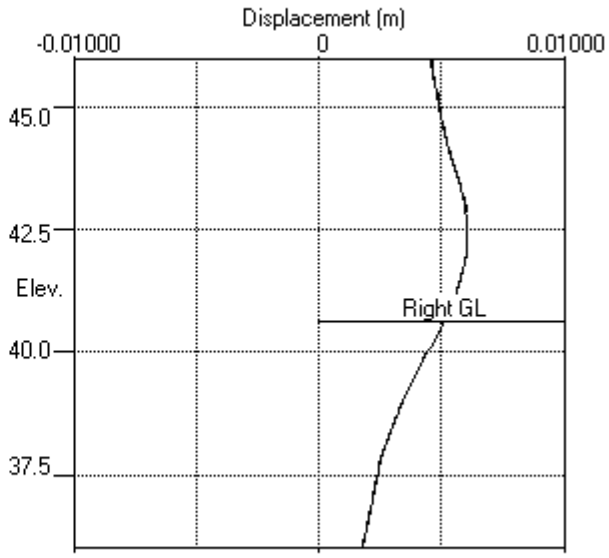
Node no.	Y coord	RIGHT side Water press. kN/m2	Effective stresses Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2	Total earth pressure kN/m2	Coeff. of subgrade reaction kN/m3
20	38.40	Total>	44.00	11.25m	169.45	114.71	114.71	20620
21	37.80	Total>	56.01	14.25m	188.31	122.20	122.20	21748
22	37.20	Total>	68.01	17.25m	207.18	130.64	130.64	22875
23	36.60	Total>	80.02	20.25m	226.04	139.64	139.64	94860
24	36.00	Total>	92.03	23.25m	244.91	150.95	150.95	99315

Note: 3.56a Soil pressure at active limit
123.45p Soil pressure at passive limit

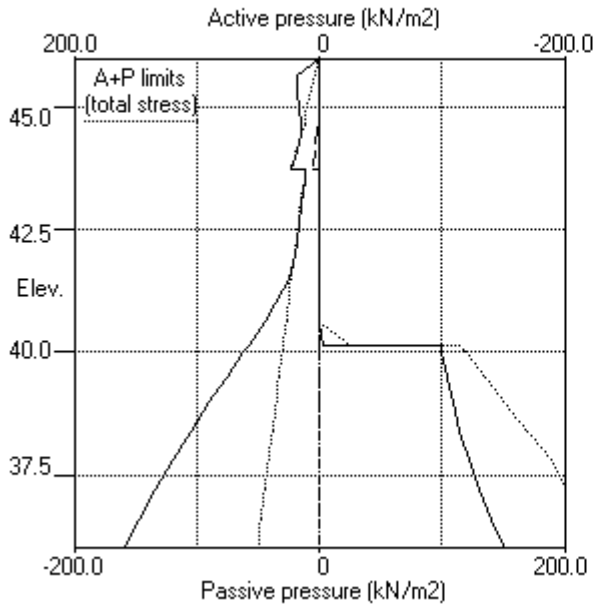
Units: kN,m

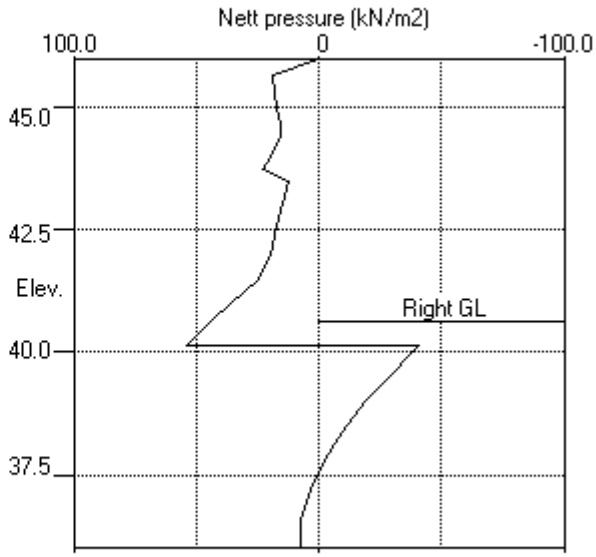
Stage No.10 Change EI of wall to 46968kN.m2/m run





Stage No.10 Change EI of wall to 46968kN.m2/m run





Units: kN,m

Summary of results

LIMIT STATE PARAMETERS

Limit State: ULS DA1 Combination 2
Water pressures : Worst Credible
Partial factor on C' = 1.250
Partial factor on Phi' = 1.250
Partial factor on Cu = 1.400
Partial factor on Soil Modulus = 1.000
Partial factor on Permanent Unfavourable loads = 1.000
Partial factor on Permanent Favourable loads = 1.000
Partial factor on Variable Unfavourable loads = 1.300

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.	Overall FoS for toe elev. = 36.00 Factor of Safety	Moment equilib. at elev.	Toe elev. for FoS = 1.000 Toe elev.	Wall Penetr -ation	Direction of failure
1	46.00	46.00	Cant.	Conditions not suitable for FoS calc.				
2	46.00	46.00	Cant.	Conditions not suitable for FoS calc.				
3	46.00	43.50	Cant.	2.640	36.79	41.78	1.72	L to R
4	46.00	43.50		No analysis at this stage				
5	46.00	40.15	44.00	1.973	n/a	39.70	0.45	L to R
6	46.00	40.65	44.00	2.109	n/a	39.80	0.85	L to R
7	46.00	40.65		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 = 50.00m
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: Left side 50.00 from wall
Right side 50.00 from wall

Limit State: ULS DA1 Combination 2

Bending moment, shear force and displacement envelopes

Node no.	Y coord	Displacement maximum m	Displacement minimum m	Bending moment maximum kN.m/m	Bending moment minimum kN.m/m	Shear force maximum kN/m	Shear force minimum kN/m
1	46.00	0.008	0.000	0.0	-0.0	0.0	0.0
2	45.66	0.007	0.000	0.1	-0.0	3.2	-0.3
3	45.33	0.007	0.000	2.3	-0.2	9.5	-0.8
4	44.99	0.006	0.000	6.7	-0.5	17.4	-1.2
5	44.65	0.006	0.000	13.8	-0.9	25.8	-1.2
6	44.45	0.005	0.000	19.5	-1.2	30.8	-69.2
7	44.00	0.006	0.000	28.3	-9.2	31.1	-56.8
8	43.75	0.006	0.000	17.8	-22.6	24.4	-48.9
9	43.50	0.006	0.000	24.3	-33.9	27.4	-40.8
10	43.05	0.006	0.000	33.6	-47.4	10.8	-34.6
11	42.60	0.007	0.000	35.3	-53.1	0.6	-27.3
12	42.00	0.006	0.000	31.1	-45.1	32.1	-15.9
13	41.50	0.006	0.000	25.0	-42.0	63.2	-12.6
14	41.00	0.006	0.000	19.5	-40.2	97.7	-46.5
15	40.65	0.005	0.000	14.1	-33.8	26.2	-20.2
16	40.15	0.005	0.000	8.9	-16.1	50.2	-9.1
17	40.00	0.005	0.000	7.6	-9.4	43.7	-8.3
18	39.50	0.004	0.000	11.5	-0.4	24.6	-5.8
19	39.00	0.004	0.000	17.9	-0.5	10.3	-3.5
20	38.40	0.004	0.000	18.2	-0.1	1.6	-4.3
21	37.80	0.003	0.000	14.4	-0.2	1.6	-8.6
22	37.20	0.003	0.000	8.4	-0.2	1.1	-9.7
23	36.60	0.002	0.000	2.8	-0.1	0.4	-6.9
24	36.00	0.002	0.000	0.0	0.0	0.0	0.0

Summary of results (continued)

Maximum and minimum bending moment and shear force at each stage

Stage	Bending moment				Shear force			
no.	maximum kN.m/m	elev.	minimum kN.m/m	elev.	maximum kN/m	elev.	minimum kN/m	elev.
1	0.6	39.00	-1.3	43.50	0.6	41.50	-0.9	44.99
2	0.5	39.00	-1.5	44.00	0.8	43.75	-1.2	44.65
3	35.3	42.60	-0.2	37.20	27.4	43.50	-12.6	41.50
4	No calculation at this stage							
5	28.3	44.00	-41.1	41.50	47.9	40.15	-48.7	44.00
6	28.0	44.00	-42.0	41.50	50.2	40.15	-49.2	44.00
7	No calculation at this stage							
8	No calculation at this stage							
9	18.2	38.40	-40.4	42.00	45.0	40.15	-43.8	44.45
10	17.4	44.45	-34.7	42.00	38.2	40.15	-40.8	44.45
11	No calculation at this stage							
12	No calculation at this stage							
13	19.5	44.45	-53.1	42.60	97.7	41.00	-69.2	44.45

Maximum and minimum displacement at each stage

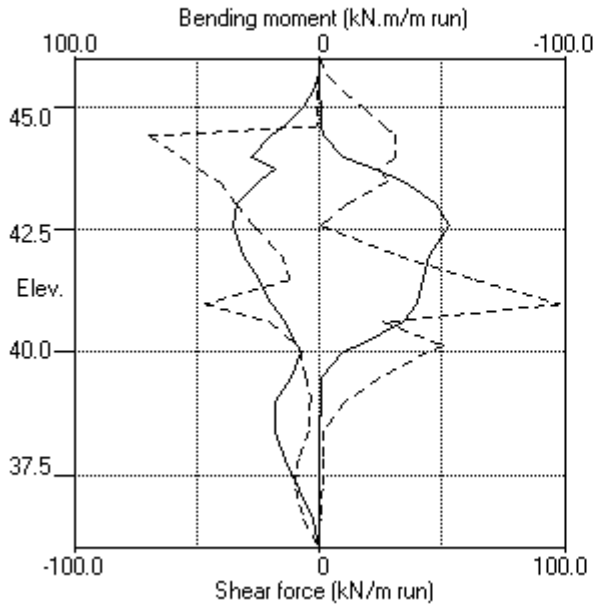
Stage	Displacement				Stage description
no.	maximum m	elev.	minimum m	elev.	
1	0.001	46.00	0.000	46.00	Apply surcharge no.1 at elev. 46.00
2	0.001	46.00	0.000	46.00	Apply water pressure profile no.1
3	0.008	46.00	0.000	46.00	Excav. to elev. 43.50 on RIGHT side
4	No calculation at this stage				Install strut no.1 at elev. 44.00
5	0.006	42.00	0.000	46.00	Excav. to elev. 40.15 on RIGHT side
6	0.006	42.00	0.000	46.00	Fill to elev. 40.65 on RIGHT side
7	No calculation at this stage				Install strut no.2 at elev. 41.00
8	No calculation at this stage				Install strut no.3 at elev. 44.45
9	0.006	42.60	0.000	46.00	Remove strut no.1 at elev. 44.00
10	0.006	42.60	0.000	46.00	Change EI of wall to 46968kN.m2/m run
11	No calculation at this stage				Change soil type 2 to soil type 3
12	No calculation at this stage				Apply surcharge no.2 at elev. 40.65
13	0.007	42.60	0.000	46.00	Apply water pressure profile no.2

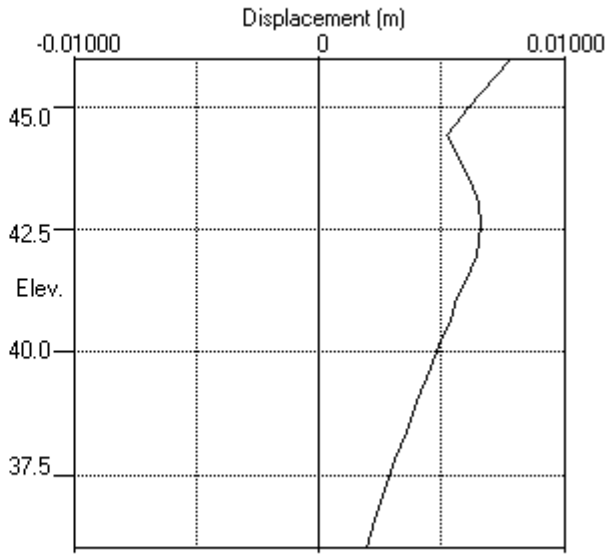
Strut forces at each stage (horizontal components)

Stage	Strut no. 1 at elev. 44.00		Strut no. 2 at elev. 41.00		Strut no. 3 at elev. 44.45	
no.	kN/m run	kN/strut	kN/m run	kN/strut	kN/m run	kN/strut
5	79.82	399.12	---	---	---	---
6	80.07	400.36	---	---	---	---
9	---	---	17.41	17.41	67.85	67.85
10	---	---	27.16	27.16	64.95	64.95
13	---	---	144.23	144.23	99.97	99.97

Units: kN,m

Bending moment, shear force, displacement envelopes





WALLAP

1-SLS

Units: kN,m

INPUT DATA

SOIL PROFILE

Stratum no.	Elevation of top of stratum	Soil types Left side	Soil types Right side
1	46.00	1 Made Ground dr	1 Made Ground dr
2	43.75	2 London Clay und	2 London Clay und

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 dr	18.00	10000	0.562	OC (0.250)	0.323 (0.000)	3.647 (0.000)	
2	London Cl.. (43.75)	20.00	27000 (4800)	1.000	OC (0.490)	1.000 (2.000)	1.000 (2.000)	45.00u (8.000)
3	London Cl.. (43.75)	20.00	20790 (3696)	1.000	OC (0.200)	0.351 (1.391)	3.253 (4.831)	0.0d
4	Not defined							
5	Backfill dr	20.00	30000	0.500	OC (0.250)	0.217 (0.000)	6.535 (0.000)	
6	Concrete dr	24.00	40000	0.500	OC (0.200)	0.140 (0.000)	13.89 (0.000)	

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 dr	27.00	0.670	0.00	27.00	0.500	0.00
2	London Clay und	0.00	0.000	0.00	0.00	0.000	0.00
3	London Clay dr	25.00	0.670	0.00	25.00	0.500	0.00
4	Not defined						
5	Backfill dr	36.00	0.670	0.00	36.00	0.500	0.00
6	Concrete dr	45.00	0.670	0.00	45.00	0.500	0.00

GROUND WATER CONDITIONS

Density of water = 9.810 kN/m3

	Left side	Right side
Initial water table elevation	44.65	44.65

Automatic water pressure balancing at toe of wall : Yes

Water press. profile no.	Left side Point no.	Elev. m	Piezo elev. m	Water press. kN/m2	Right side Point no.	Elev. m	Piezo elev. m	Water press. kN/m2	
1	1	44.65	44.65	0.0	1	40.00	40.00	0.0	MC+WC
2	1	46.00	46.00	0.0	1	40.65	40.65	0.0	MC+WC
					2	40.65	46.00	52.5	

WALL PROPERTIES

Type of structure = Fully Embedded Wall
Elevation of toe of wall = 36.00
Maximum finite element length = 0.60 m
Youngs modulus of wall E = 1.9600E+07 kN/m2
Moment of inertia of wall I = 3.3548E-03 m4/m run
E.I = 65754 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	44.00	5.00	0.015000	2.050E+08	5.00	0.00	0	No
2	41.00	1.00	0.600000	1.400E+07	5.00	0.00	0	No
3	44.45	1.00	0.200000	1.400E+07	5.00	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	46.00	0.50(L)	10.00	10.00	10.00	=	N/A	1.00 Var
2	40.65	-0.00(R)	10.00	10.00	53.00	=	N/A	1.00 P/F

Note: L = Left side, R = Right 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 46.00
2	Apply water pressure profile no.1 (Mod. Conserv.)
3	Excavate to elevation 43.50 on RIGHT side
4	Install strut or anchor no.1 at elevation 44.00
5	Excavate to elevation 40.65 on RIGHT side
6	Install strut or anchor no.2 at elevation 41.00
7	Install strut or anchor no.3 at elevation 44.45
8	Remove strut or anchor no.1 at elevation 44.00
9	Change EI of wall to 46968 kN.m2/m run Yield moment not defined Allow wall to relax with new modulus value
10	Change properties of soil type 2 to soil type 3 No analysis at this stage Ko pressures will not be reset
11	Apply surcharge no.2 at elevation 40.65 No analysis at this stage
12	Apply water pressure profile no.2 (Mod. Conserv.)

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 = 1.50

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) = 11.00 m

Boundary conditions:
Length of wall (normal to plane of analysis) = 50.00 m

Width of excavation on Left side of wall = 50.00 m
Width of excavation on Right side of wall = 50.00 m

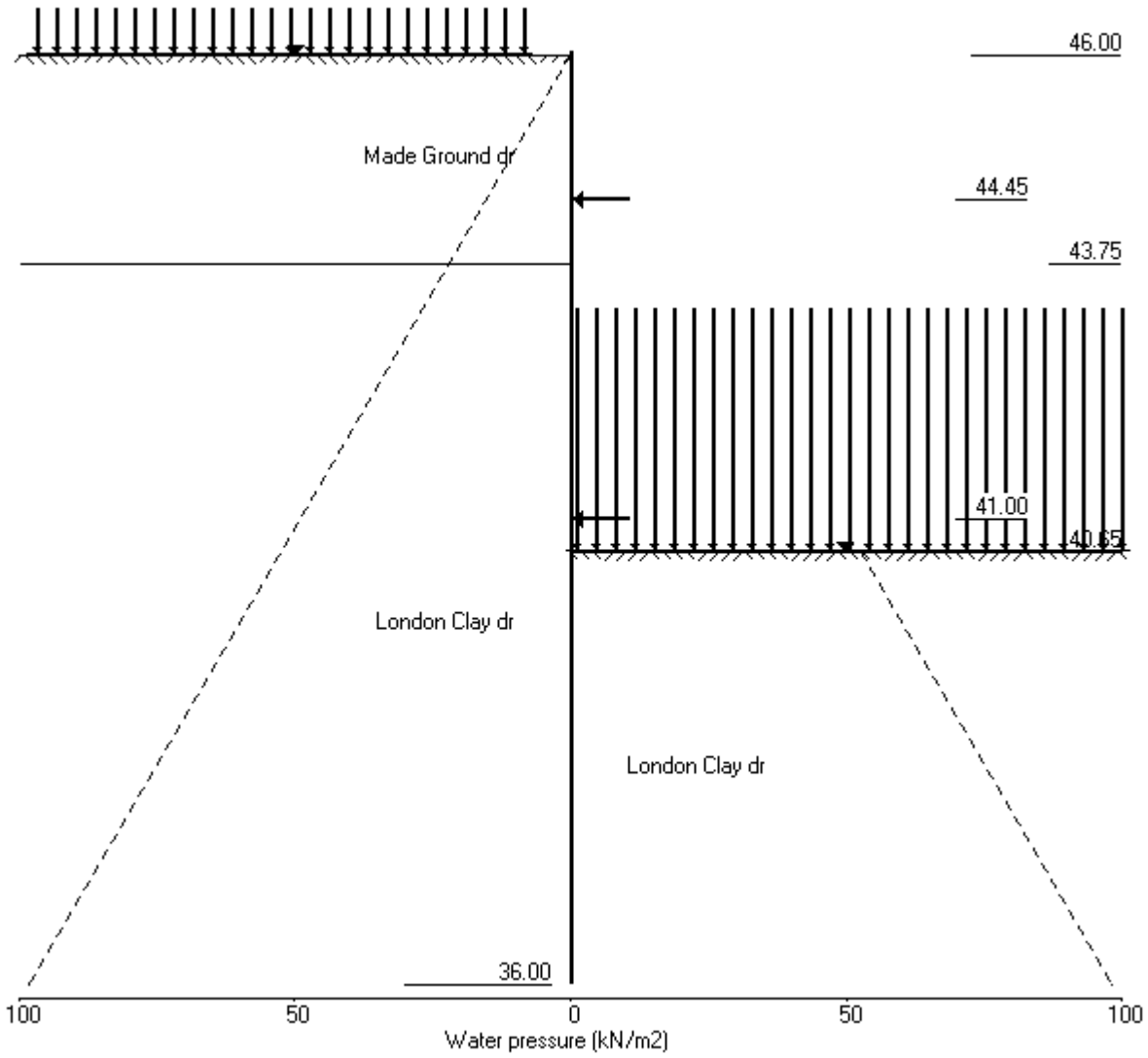
Distance to rigid boundary on Left side = 50.00 m
Distance to rigid boundary on Right side = 50.00 m

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. 46.00	Yes	Yes	Yes
2	Apply water pressure profile no.1	Yes	Yes	Yes
3	Excav. to elev. 43.50 on RIGHT side	No	No	No
4	Install strut no.1 at elev. 44.00	Yes	Yes	Yes
5	Excav. to elev. 40.65 on RIGHT side	Yes	Yes	Yes
6	Install strut no.2 at elev. 41.00	Yes	Yes	Yes
7	Install strut no.3 at elev. 44.45	Yes	Yes	Yes
8	Remove strut no.1 at elev. 44.00	Yes	Yes	Yes
9	Change EI of wall to 46968kN.m2/m run	Yes	Yes	Yes
10	Change soil type 2 to soil type 3	Yes	Yes	Yes
11	Apply surcharge no.2 at elev. 40.65	Yes	Yes	Yes
12	Apply water pressure profile no.2	Yes	Yes	Yes
*	Summary output	Yes	-	Yes

Units: kN,m

Stage No.12 Apply water pressure profile no.2 (Mod. Conserv.)



Units: kN,m

Stage No. 3 Excavate to elevation 43.50 on RIGHT side

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. = 36.00 Factor of Safety	Moment equilib. at elev.	Toe elev. for FoS = 1.500 Toe elev.	Wall Penetr -ation	Direction of failure
3	46.00	43.50	Cant.	3.814	36.79	41.54	1.96	L to R

BENDING MOMENT and DISPLACEMENT ANALYSIS of Fully Embedded Wall

Analysis options

Length of wall perpendicular to section = 50.00m

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: Left side 50.00 from wall
Right side 50.00 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	EI of wall kN.m2/m
1	46.00	0.00	0.007	1.42E-03	0.0	-0.0		65754
2	45.66	2.23	0.006	1.42E-03	0.4	0.1		65754
3	45.33	4.85	0.006	1.42E-03	1.6	0.4		65754
4	44.99	7.34	0.005	1.42E-03	3.6	1.2		65754
5	44.65	9.64	0.005	1.41E-03	6.5	2.9		65754
6	44.45	11.79	0.005	1.39E-03	8.6	4.4		65754
7	44.00	16.51	0.004	1.35E-03	15.0	9.7		65754
8	43.75	19.09	0.004	1.30E-03	19.5	14.0		65754
		11.25	0.004	1.30E-03	19.5	14.0		
9	43.50	13.63	0.003	1.24E-03	22.6	19.6		65754
		-33.04	0.003	1.24E-03	22.6	19.6		
10	43.05	-24.63	0.003	1.08E-03	9.6	26.4		65754
11	42.60	-16.67	0.002	8.98E-04	0.3	28.2		65754
12	42.00	-7.83	0.002	6.54E-04	-7.1	25.4		65754
13	41.50	-2.42	0.002	4.78E-04	-9.6	20.9		65754
14	41.00	1.19	0.002	3.39E-04	-9.9	15.8		65754
15	40.65	2.76	0.001	2.64E-04	-9.2	12.4		65754
16	40.33	3.64	0.001	2.10E-04	-8.2	9.5		65754
17	40.00	4.08	0.001	1.69E-04	-6.9	7.0		65754
18	39.50	3.86	0.001	1.27E-04	-5.0	4.1		65754
19	39.00	3.19	0.001	1.03E-04	-3.2	2.1		65754
20	38.40	2.17	0.001	9.12E-05	-1.6	0.7		65754
21	37.80	1.22	0.001	8.76E-05	-0.6	0.1		65754
22	37.20	0.47	0.001	8.73E-05	-0.1	-0.0		65754
23	36.60	-0.01	0.001	8.75E-05	0.1	-0.0		65754
24	36.00	-0.25	0.001	8.76E-05	0.0	-0.0		---

(continued)

Stage No.3 Excavate to elevation 43.50 on RIGHT side

LEFT side

Node no.	Y coord	Water press. kN/m2	Effective stresses: Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2	Total earth pressure kN/m2	Coeff. of subgrade reaction kN/m3
1	46.00	0.00	0.00	0.00	0.00	0.00	0.00	3060
2	45.66	0.00	6.90	2.23	25.17	2.23	2.23a	3060
3	45.33	0.00	15.04	4.85	54.84	4.85	4.85a	3060
4	44.99	0.00	22.75	7.34	82.95	7.34	7.34a	3060
5	44.65	0.00	29.90	9.64	109.03	9.64	9.64a	3060
6	44.45	1.24	32.71	10.55	119.27	10.55	11.79a	3060
7	44.00	4.03	38.69	12.48	141.11	12.48	16.51a	3060
8	43.75	5.58	41.88	13.51	152.73	13.51	19.09a	3060
		Total>	47.46	11.25m	137.46	11.25	11.25a	11423
9	43.50	Total>	52.63	12.50m	146.63	13.63	13.63	11930
10	43.05	Total>	61.79	14.75m	162.99	26.43	26.43	12844
11	42.60	Total>	70.83	17.00m	179.23	38.95	38.95	13758
12	42.00	Total>	82.75	20.00m	200.75	54.79	54.79	14976
13	41.50	Total>	92.60	22.50m	218.60	67.05	67.05	15992
14	41.00	Total>	102.41	25.00m	236.41	78.47	78.47	17007
15	40.65	Total>	109.25	26.75m	248.85	86.02	86.02	17718
16	40.33	Total>	115.60	28.37m	260.40	92.77	92.77	18378
17	40.00	Total>	121.94	30.00m	271.94	99.31	99.31	19038
18	39.50	Total>	131.68	32.50m	289.68	109.08	109.08	20053
19	39.00	Total>	141.42	35.00m	307.42	118.65	118.65	21068
20	38.40	Total>	153.12	38.00m	328.72	130.04	130.04	22287
21	37.80	Total>	164.81	41.00m	350.01	141.47	141.47	23505
22	37.20	Total>	176.52	44.00m	371.32	153.00	153.00	24724
23	36.60	Total>	188.25	47.00m	392.65	164.65	164.65	25942
24	36.00	Total>	199.98	50.00m	413.98	176.43	176.43	27161

RIGHT side

Node no.	Y coord	Water press. kN/m2	Effective stresses: Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2	Total earth pressure kN/m2	Coeff. of subgrade reaction kN/m3
1	46.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
2	45.66	0.00	0.00	0.00	0.00	0.00	0.00	0.0
3	45.33	0.00	0.00	0.00	0.00	0.00	0.00	0.0
4	44.99	0.00	0.00	0.00	0.00	0.00	0.00	0.0
5	44.65	0.00	0.00	0.00	0.00	0.00	0.00	0.0
6	44.45	0.00	0.00	0.00	0.00	0.00	0.00	0.0
7	44.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
8	43.75	0.00	0.00	0.00	0.00	0.00	0.00	0.0
9	43.50	0.00	0.00	0.00	0.00	0.00	0.00	0.0
		Total>	0.00	0.00	94.00	46.67	46.67	14247
10	43.05	Total>	9.00	2.25m	110.20	51.05	51.05	15338
11	42.60	Total>	18.00	4.50m	126.40	55.63	55.63	16430
12	42.00	Total>	30.00	7.50m	148.00	62.61	62.61	17885
13	41.50	Total>	40.00	10.00m	166.00	69.47	69.47	19097
14	41.00	Total>	50.00	12.50m	184.00	77.28	77.28	20310
15	40.65	Total>	57.00	14.25m	196.60	83.26	83.26	21159
16	40.33	Total>	63.50	15.87m	208.30	89.13	89.13	21947
17	40.00	Total>	70.01	17.50m	220.01	95.23	95.23	22735
18	39.50	Total>	80.01	20.00m	238.01	105.22	105.22	23947
19	39.00	Total>	90.01	22.50m	256.01	115.46	115.46	25160
20	38.40	Total>	102.02	25.50m	277.62	127.87	127.87	26615
21	37.80	Total>	114.03	28.50m	299.23	140.25	140.25	28070
22	37.20	Total>	126.04	31.50m	320.84	152.53	152.53	29525

(continued)

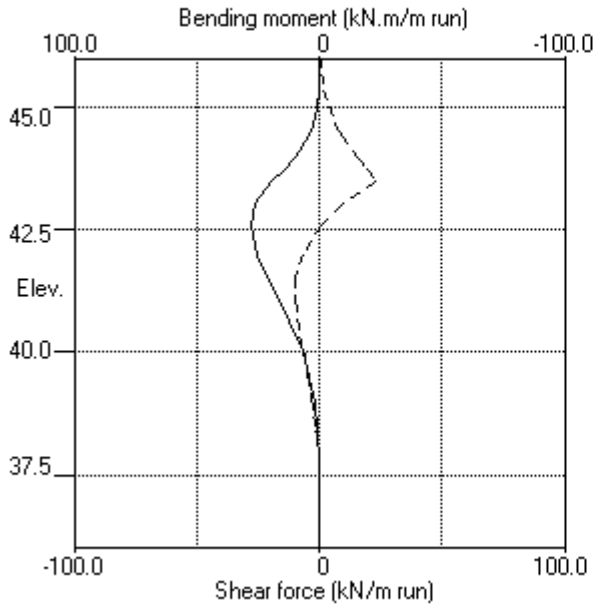
Stage No.3 Excavate to elevation 43.50 on RIGHT side

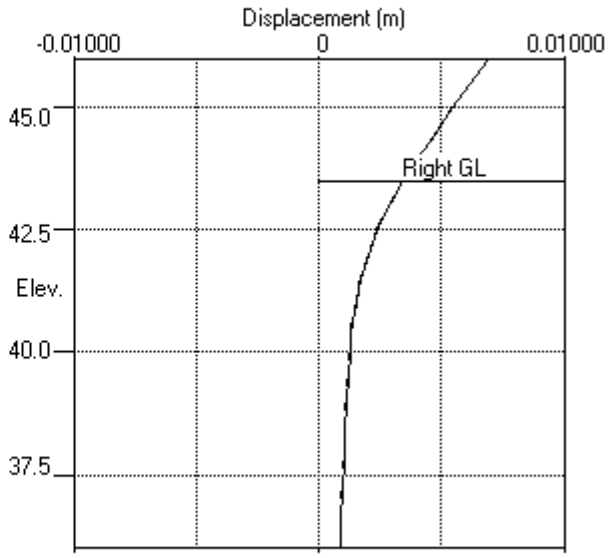
Node no.	Y coord	RIGHT side						
		Water press. kN/m2	Effective stresses Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2	Total earth pressure kN/m2	Coeff. of subgrade reaction kN/m3
23	36.60	Total>	138.05	34.50m	342.45	164.67	164.67	30980
24	36.00	Total>	150.06	37.50m	364.06	176.68	176.68	32435

Note: 11.25a Soil pressure at active limit
123.45p Soil pressure at passive limit

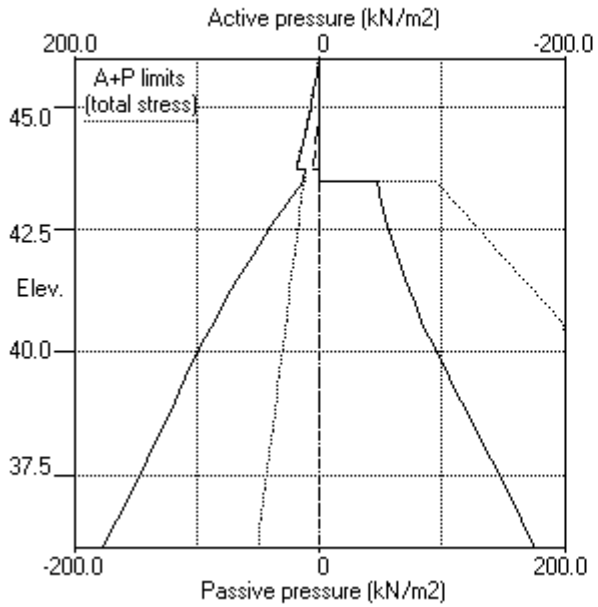
Units: kN,m

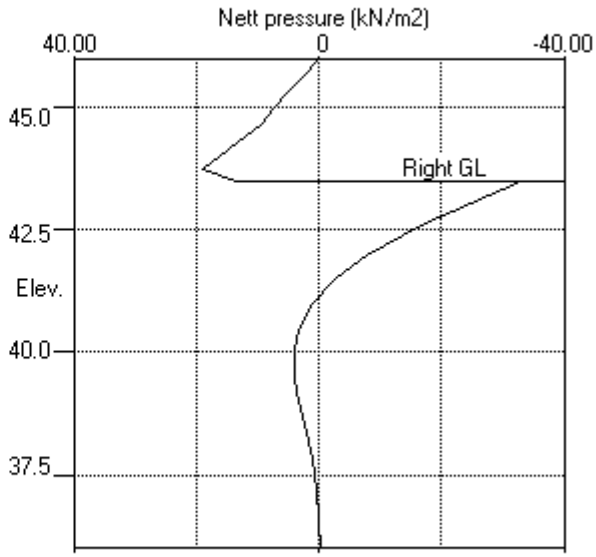
Stage No.3 Excav. to elev. 43.50 on RIGHT side





Stage No.3 Excav. to elev. 43.50 on RIGHT side





Units: kN,m

Stage No. 5 Excavate to elevation 40.65 on RIGHT side

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. = 36.00 Factor of Safety	Moment equilib. at elev.	Toe elev. for FoS = 1.500 Toe elev.	Wall Penetr -ation	Direction of failure
5	46.00	40.65	44.00	3.099	n/a	40.24	0.41	L to R

BENDING MOMENT and DISPLACEMENT ANALYSIS of Fully Embedded Wall

Analysis options

Length of wall perpendicular to section = 50.00m

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: Left side 50.00 from wall
Right side 50.00 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	EI of wall kN.m2/m
1	46.00	0.00	0.004	-4.82E-05	0.0	-0.0		65754
2	45.66	14.11	0.004	-4.84E-05	2.4	0.1		65754
3	45.33	13.71	0.004	-5.31E-05	7.1	1.7		65754
4	44.99	13.17	0.004	-7.03E-05	11.6	5.0		65754
5	44.65	12.40	0.005	-1.07E-04	15.9	9.7		65754
6	44.45	12.70	0.005	-1.42E-04	18.4	13.1		65754
7	44.00	16.51	0.005	-2.65E-04	25.0	22.9	68.9	65754
		16.51	0.005	-2.65E-04	-43.9	22.9		
8	43.75	19.09	0.005	-3.32E-04	-39.4	12.4		65754
		11.25	0.005	-3.32E-04	-39.4	12.4		
9	43.50	12.50	0.005	-3.62E-04	-36.5	3.3		65754
10	43.05	14.75	0.005	-3.32E-04	-30.3	-12.0		65754
11	42.60	17.00	0.005	-2.07E-04	-23.2	-24.4		65754
12	42.00	24.38	0.005	5.61E-05	-10.8	-33.5		65754
13	41.50	32.63	0.005	3.18E-04	3.5	-35.5		65754
14	41.00	42.09	0.005	5.65E-04	22.2	-29.4		65754
15	40.65	49.46	0.005	6.94E-04	38.2	-19.0		65754
		-27.72	0.005	6.94E-04	38.2	-19.0		
16	40.33	-25.56	0.004	7.60E-04	29.5	-8.0		65754
17	40.00	-22.69	0.004	7.80E-04	21.7	0.2		65754
18	39.50	-17.86	0.004	7.48E-04	11.5	8.2		65754
19	39.00	-12.92	0.003	6.72E-04	3.9	11.8		65754
20	38.40	-7.53	0.003	5.64E-04	-2.3	11.7		65754
21	37.80	-2.96	0.003	4.70E-04	-5.4	9.0		65754
22	37.20	1.01	0.002	4.06E-04	-6.0	5.1		65754
23	36.60	4.90	0.002	3.75E-04	-4.2	1.7		65754
24	36.00	9.24	0.002	3.67E-04	0.0	-0.0		---

At elev. 44.00 Strut force = 344.4 kN/strut = 68.9 kN/m run

(continued)

Stage No.5 Excavate to elevation 40.65 on RIGHT side

LEFT side

Node no.	Y coord	Water press. kN/m2	Effective stresses: Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2	Total earth pressure kN/m2	Coeff. of subgrade reaction kN/m3
1	46.00	0.00	0.00	0.00	0.00	0.00	0.00	6054
2	45.66	0.00	6.90	2.23	25.17	14.11	14.11	6054
3	45.33	0.00	15.04	4.85	54.84	13.71	13.71	6054
4	44.99	0.00	22.75	7.34	82.95	13.17	13.17	6054
5	44.65	0.00	29.90	9.64	109.03	12.40	12.40	6054
6	44.45	1.24	32.71	10.55	119.27	11.46	12.70	6054
7	44.00	4.03	38.69	12.48	141.11	12.48	16.51a	1890
8	43.75	5.58	41.88	13.51	152.73	13.51	19.09a	1890
		Total>	47.46	11.25m	137.46	11.25	11.25a	7369
9	43.50	Total>	52.63	12.50m	146.63	12.50	12.50a	7697
10	43.05	Total>	61.79	14.75m	162.99	14.75	14.75a	8286
11	42.60	Total>	70.83	17.00m	179.23	17.00	17.00a	8876
12	42.00	Total>	82.75	20.00m	200.75	24.38	24.38	9662
13	41.50	Total>	92.60	22.50m	218.60	32.63	32.63	10317
14	41.00	Total>	102.41	25.00m	236.41	42.09	42.09	10972
15	40.65	Total>	109.25	26.75m	248.85	49.46	49.46	11430
16	40.33	Total>	115.60	28.37m	260.40	56.75	56.75	11856
17	40.00	Total>	121.94	30.00m	271.94	64.34	64.34	12282
18	39.50	Total>	131.68	32.50m	289.68	76.28	76.28	12937
19	39.00	Total>	141.42	35.00m	307.42	88.25	88.25	13592
20	38.40	Total>	153.12	38.00m	328.72	102.39	102.39	14378
21	37.80	Total>	164.81	41.00m	350.01	116.18	116.18	15164
22	37.20	Total>	176.52	44.00m	371.32	129.73	129.73	15950
23	36.60	Total>	188.25	47.00m	392.65	143.26	143.26	16736
24	36.00	Total>	199.98	50.00m	413.98	157.00	157.00	17522

RIGHT side

Node no.	Y coord	Water press. kN/m2	Effective stresses: Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2	Total earth pressure kN/m2	Coeff. of subgrade reaction kN/m3
1	46.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
2	45.66	0.00	0.00	0.00	0.00	0.00	0.00	0.0
3	45.33	0.00	0.00	0.00	0.00	0.00	0.00	0.0
4	44.99	0.00	0.00	0.00	0.00	0.00	0.00	0.0
5	44.65	0.00	0.00	0.00	0.00	0.00	0.00	0.0
6	44.45	0.00	0.00	0.00	0.00	0.00	0.00	0.0
7	44.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
8	43.75	0.00	0.00	0.00	0.00	0.00	0.00	0.0
9	43.50	0.00	0.00	0.00	0.00	0.00	0.00	0.0
10	43.05	0.00	0.00	0.00	0.00	0.00	0.00	0.0
11	42.60	0.00	0.00	0.00	0.00	0.00	0.00	0.0
12	42.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
13	41.50	0.00	0.00	0.00	0.00	0.00	0.00	0.0
14	41.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
15	40.65	0.00	0.00	0.00	0.00	0.00	0.00	0.0
		Total>	0.00	0.00	139.60	77.18	77.18	15220
16	40.33	Total>	6.50	1.63m	151.30	82.31	82.31	15787
17	40.00	Total>	13.00	3.25m	163.00	87.03	87.03	16354
18	39.50	Total>	23.00	5.75m	181.00	94.13	94.13	17226
19	39.00	Total>	33.00	8.25m	199.00	101.17	101.17	18098
20	38.40	Total>	45.00	11.25m	220.60	109.92	109.92	19145
21	37.80	Total>	57.01	14.25m	242.21	119.14	119.14	20191
22	37.20	Total>	69.01	17.25m	263.81	128.72	128.72	21238

(continued)

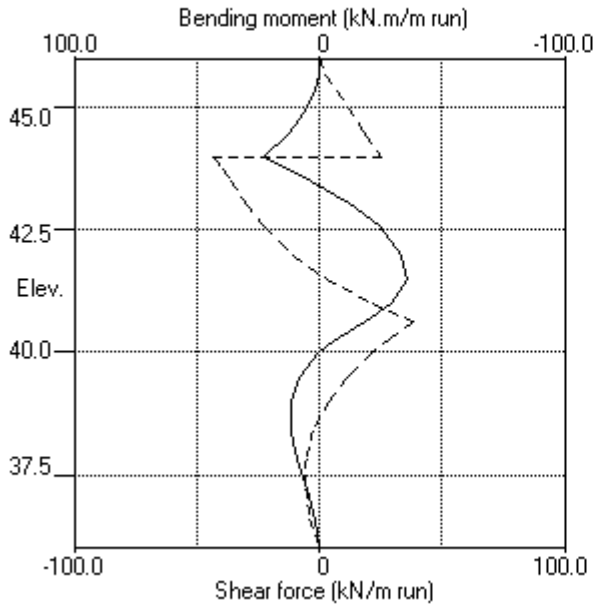
Stage No.5 Excavate to elevation 40.65 on RIGHT side

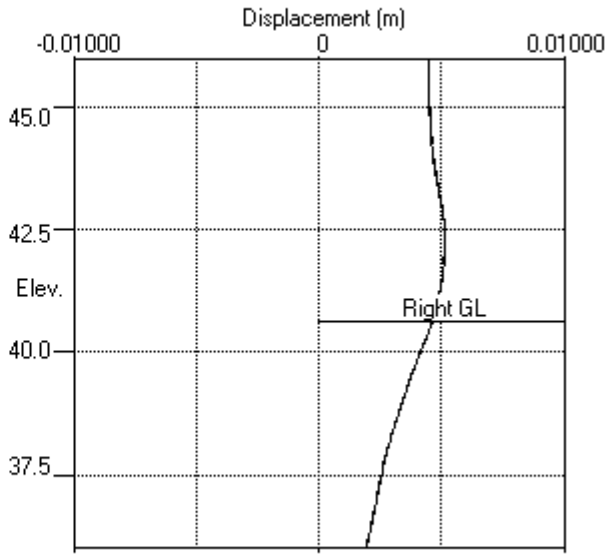
Node no.	Y coord	RIGHT side						
		Effective stresses				Total earth pressure	Coeff. of subgrade reaction
		Water press. kN/m2	Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2	kN/m2	kN/m3
23	36.60	Total>	81.02	20.25m	285.42	138.36	138.36	22285
24	36.00	Total>	93.03	23.25m	307.03	147.76	147.76	23331

Note: 17.00a Soil pressure at active limit
123.45p Soil pressure at passive limit

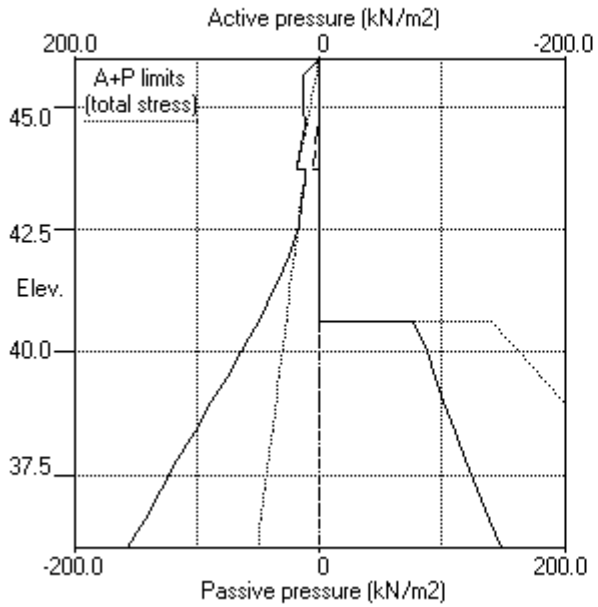
Units: kN,m

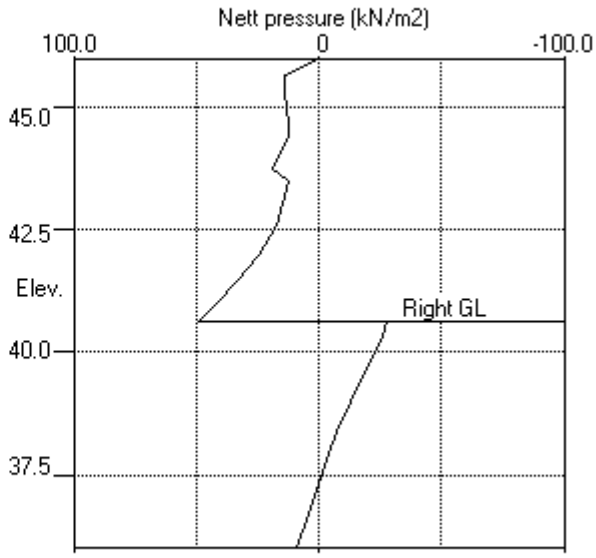
Stage No.5 Excav. to elev. 40.65 on RIGHT side





Stage No.5 Excav. to elev. 40.65 on RIGHT side





Units: kN,m

Stage No. 9 Change EI of wall to 46968 kN.m2/m run
Yield moment not defined
Allow wall to relax with new modulus value

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. = 36.00 Factor of Safety	Moment equilib. at elev.	Toe elev. for FoS = 1.500 Toe elev.	Wall Penetr -ation	Direction of failure
9	46.00	40.65		More than one strut. No FoS calc.				

BENDING MOMENT and DISPLACEMENT ANALYSIS of Fully Embedded Wall
Analysis options
Length of wall perpendicular to section = 50.00m
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: Left side 50.00 from wall
Right side 50.00 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	EI of wall kN.m2/m
1	46.00	0.00	0.004	-3.52E-04	0.0	-0.0		46968
2	45.66	16.21	0.004	-3.52E-04	2.7	0.1		46968
3	45.33	15.04	0.004	-3.60E-04	8.0	2.0		46968
4	44.99	13.71	0.004	-3.87E-04	12.9	5.6		46968
5	44.65	12.33	0.005	-4.45E-04	17.3	10.7		46968
6	44.45	12.40	0.005	-4.99E-04	19.7	14.4	56.1	46968
		12.40	0.005	-4.99E-04	-36.4	14.4		
7	44.00	16.51	0.005	-5.66E-04	-29.9	-0.8		46968
8	43.75	19.09	0.005	-5.45E-04	-25.4	-7.8		46968
		11.25	0.005	-5.45E-04	-25.4	-7.8		
9	43.50	12.50	0.005	-4.91E-04	-22.4	-13.6		46968
10	43.05	14.75	0.005	-3.22E-04	-16.3	-22.8		46968
11	42.60	17.00	0.005	-8.27E-05	-9.2	-29.1		46968
12	42.00	20.63	0.005	2.80E-04	2.1	-30.1		46968
13	41.50	30.56	0.005	5.65E-04	14.9	-26.4		46968
14	41.00	41.87	0.005	7.68E-04	33.0	-14.9	21.8	46968
		41.87	0.005	7.68E-04	11.3	-14.9		
15	40.65	50.26	0.005	8.42E-04	27.4	-7.8		46968
		-26.13	0.005	8.42E-04	27.4	-7.8		
16	40.33	-22.52	0.004	8.62E-04	19.5	0.1		46968
17	40.00	-18.63	0.004	8.38E-04	12.8	5.7		46968
18	39.50	-13.03	0.004	7.52E-04	4.9	10.2		46968
19	39.00	-8.15	0.003	6.40E-04	-0.4	11.3		46968
20	38.40	-3.60	0.003	5.11E-04	-3.9	9.7		46968
21	37.80	-0.29	0.003	4.13E-04	-5.1	6.7		46968
22	37.20	2.31	0.002	3.54E-04	-4.5	3.4		46968
23	36.60	4.39	0.002	3.31E-04	-2.5	0.9		46968
24	36.00	3.86	0.002	3.26E-04	0.0	-0.0		---

At elev. 44.45 Strut force = 56.1 kN/strut = 56.1 kN/m run
At elev. 41.00 Strut force = 21.8 kN/strut = 21.8 kN/m run

(continued)

Stage No.9 Change EI of wall to 46968 kN.m2/m run
Yield moment not defined
Allow wall to relax with new modulus value

Node no.	Y coord	LEFT side						
			Effective stresses				Total earth pressure	Coeff. of subgrade reaction
		Water press. kN/m2	Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2		
1	46.00	0.00	0.00	0.00	0.00	0.00	0.00	4775
2	45.66	0.00	6.90	2.23	25.17	16.21	16.21	4775
3	45.33	0.00	15.04	4.85	54.84	15.04	15.04	4775
4	44.99	0.00	22.75	7.34	82.95	13.71	13.71	4775
5	44.65	0.00	29.90	9.64	109.03	12.33	12.33	4775
6	44.45	1.24	32.71	10.55	119.27	11.16	12.40	4775
7	44.00	4.03	38.69	12.48	141.11	12.48	16.51a	3182
8	43.75	5.58	41.88	13.51	152.73	13.51	19.09a	3182
		Total>	47.46	11.25m	137.46	11.25	11.25a	11849
9	43.50	Total>	52.63	12.50m	146.63	12.50	12.50a	12375
10	43.05	Total>	61.79	14.75m	162.99	14.75	14.75a	13323
11	42.60	Total>	70.83	17.00m	179.23	17.00	17.00a	14271
12	42.00	Total>	82.75	20.00m	200.75	20.63	20.63	15535
13	41.50	Total>	92.60	22.50m	218.60	30.56	30.56	16588
14	41.00	Total>	102.41	25.00m	236.41	41.87	41.87	17641
15	40.65	Total>	109.25	26.75m	248.85	50.26	50.26	16385
16	40.33	Total>	115.60	28.37m	260.40	58.28	58.28	16996
17	40.00	Total>	121.94	30.00m	271.94	66.37	66.37	17606
18	39.50	Total>	131.68	32.50m	289.68	78.69	78.69	18545
19	39.00	Total>	141.42	35.00m	307.42	90.63	90.63	19484
20	38.40	Total>	153.12	38.00m	328.72	104.35	104.35	20611
21	37.80	Total>	164.81	41.00m	350.01	117.51	117.51	21738
22	37.20	Total>	176.52	44.00m	371.32	130.38	130.38	22864
23	36.60	Total>	188.25	47.00m	392.65	143.01	143.01	89256
24	36.00	Total>	199.98	50.00m	413.98	154.31	154.31	93448

Node no.	Y coord	RIGHT side						
			Effective stresses				Total earth pressure	Coeff. of subgrade reaction
		Water press. kN/m2	Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2		
1	46.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
2	45.66	0.00	0.00	0.00	0.00	0.00	0.00	0.0
3	45.33	0.00	0.00	0.00	0.00	0.00	0.00	0.0
4	44.99	0.00	0.00	0.00	0.00	0.00	0.00	0.0
5	44.65	0.00	0.00	0.00	0.00	0.00	0.00	0.0
6	44.45	0.00	0.00	0.00	0.00	0.00	0.00	0.0
7	44.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
8	43.75	0.00	0.00	0.00	0.00	0.00	0.00	0.0
9	43.50	0.00	0.00	0.00	0.00	0.00	0.00	0.0
10	43.05	0.00	0.00	0.00	0.00	0.00	0.00	0.0
11	42.60	0.00	0.00	0.00	0.00	0.00	0.00	0.0
12	42.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
13	41.50	0.00	0.00	0.00	0.00	0.00	0.00	0.0
14	41.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
15	40.65	0.00	0.00	0.00	0.00	0.00	0.00	0.0
		Total>	0.00	0.00	139.60	76.38	76.38	16385
16	40.33	Total>	6.50	1.63m	151.30	80.79	80.79	16996
17	40.00	Total>	13.00	3.25m	163.00	84.99	84.99	17606
18	39.50	Total>	23.00	5.75m	181.00	91.72	91.72	18545
19	39.00	Total>	33.00	8.25m	199.00	98.79	98.79	19484
20	38.40	Total>	45.00	11.25m	220.60	107.95	107.95	20611

(continued)

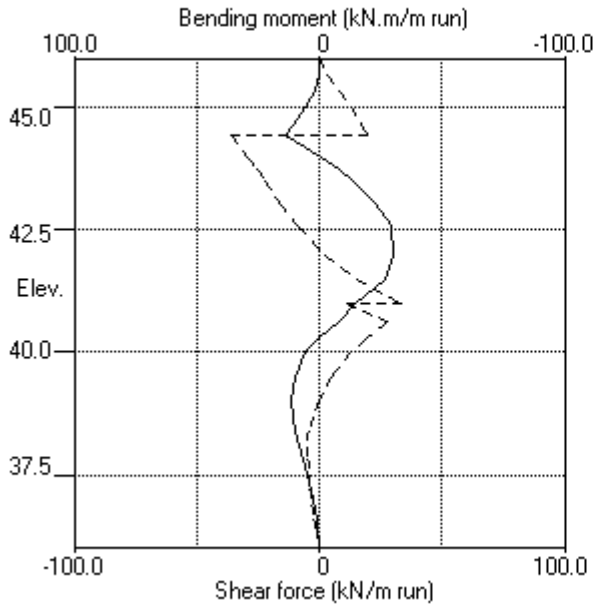
Stage No.9 Change EI of wall to 46968 kN.m2/m run
Yield moment not defined
Allow wall to relax with new modulus value

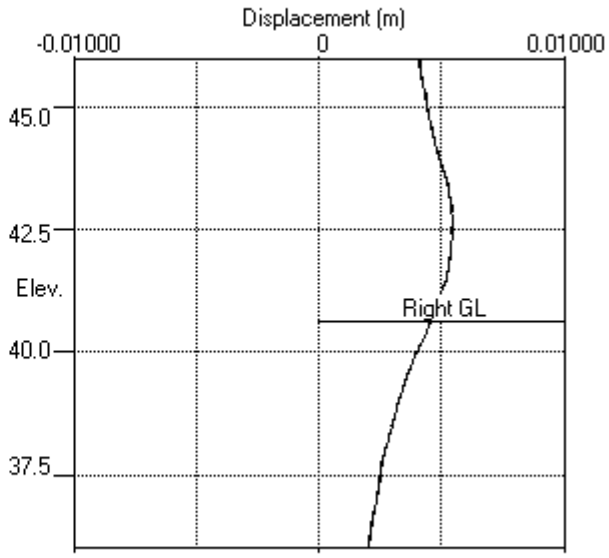
Node no.	Y coord	RIGHT side Water press. kN/m2	Effective stresses Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2	Total earth pressure kN/m2	Coeff. of subgrade reaction kN/m3
21	37.80	Total>	57.01	14.25m	242.21	117.80	117.80	21738
22	37.20	Total>	69.01	17.25m	263.81	128.07	128.07	22864
23	36.60	Total>	81.02	20.25m	285.42	138.62	138.62	89256
24	36.00	Total>	93.03	23.25m	307.03	150.45	150.45	93448

Note: 17.00a Soil pressure at active limit
123.45p Soil pressure at passive limit

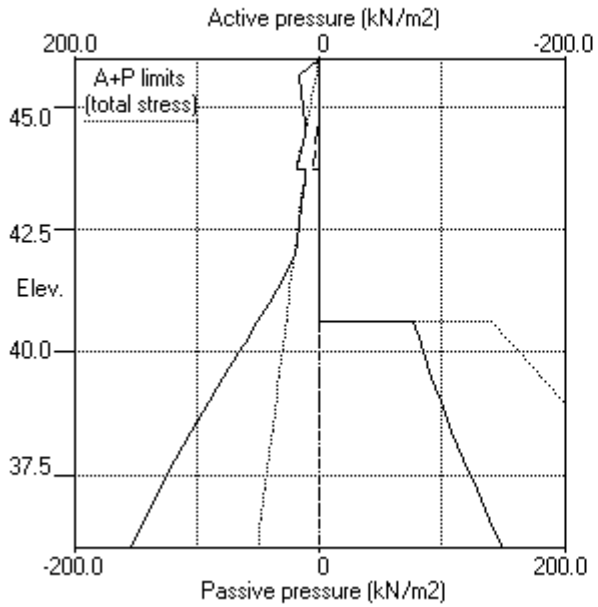
Units: kN,m

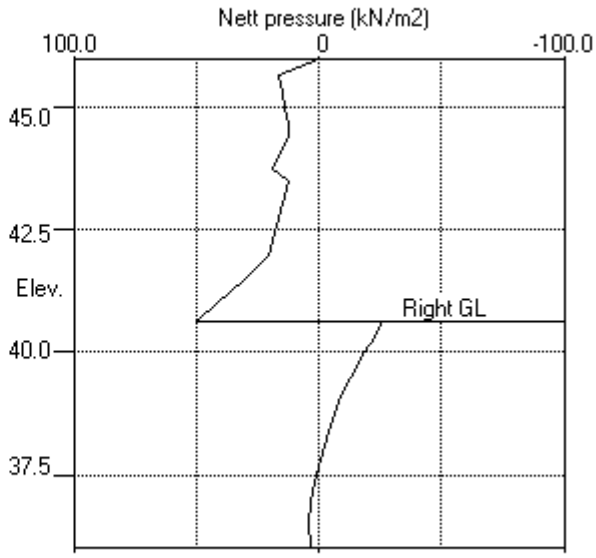
Stage No.9 Change EI of wall to 46968kN.m2/m run





Stage No.9 Change EI of wall to 46968kN.m2/m run





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.	Pass.	Strut Elev.	FoS for toe elev. = 36.00 Factor of Safety	Moment equilib. at elev.	Toe elev. for FoS = 1.500 Toe elev.	Wall Penetr -ation	Direction of failure
1	46.00	46.00	Cant.	Conditions not suitable for FoS calc.				
2	46.00	46.00	Cant.	Conditions not suitable for FoS calc.				
3	46.00	43.50	Cant.	3.814	36.79	41.54	1.96	L to R
4	46.00	43.50		No analysis at this stage				
5	46.00	40.65	44.00	3.099	n/a	40.24	0.41	L to R
6	46.00	40.65		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 = 50.00m
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: Left side 50.00 from wall
Right side 50.00 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		Bending moment Calculated		Bending moment Factored		Shear force Calculated		Shear force Factored	
		max.	min.	max.	min.	max.	min.	max.	min.	max.	min.
		m	m	kN.m/m		kN.m/m		kN/m	kN/m	kN/m	kN/m
1	46.00	0.007	0.000	0	-0	0	-0	0	0	0	0
2	45.66	0.006	0.000	0	0	0	0	3	-0	4	-0
3	45.33	0.006	0.000	2	-0	3	-0	9	-1	12	-1
4	44.99	0.005	0.000	7	-0	9	-1	17	-1	22	-1
5	44.65	0.005	0.000	13	-1	18	-1	24	-1	32	-1
6	44.45	0.005	0.000	19	-1	25	-1	28	-66	38	-89
7	44.00	0.005	0.000	23	-9	31	-12	25	-55	34	-74
8	43.75	0.005	0.000	14	-22	19	-29	19	-48	26	-64
9	43.50	0.006	0.000	20	-33	26	-44	23	-40	30	-53
10	43.05	0.006	0.000	26	-47	36	-64	10	-30	13	-41
11	42.60	0.006	0.000	28	-54	38	-72	1	-23	1	-31
12	42.00	0.006	0.000	25	-45	34	-61	27	-11	37	-15
13	41.50	0.005	0.000	21	-36	28	-48	56	-10	76	-13
14	41.00	0.005	0.000	16	-29	21	-40	88	-31	119	-42
15	40.65	0.005	0.000	12	-19	17	-26	38	-9	52	-12
16	40.33	0.004	0.000	10	-8	13	-11	30	-8	40	-11
17	40.00	0.004	0.000	7	0	10	0	22	-7	29	-9
18	39.50	0.004	0.000	10	0	14	0	12	-5	16	-7
19	39.00	0.003	0.000	13	0	17	0	5	-3	6	-4
20	38.40	0.003	0.000	12	0	16	0	2	-4	3	-5
21	37.80	0.003	0.000	10	0	13	0	0	-6	0	-8
22	37.20	0.002	0.000	6	-0	8	-0	0	-6	0	-8
23	36.60	0.002	0.000	2	-0	3	-0	0	-5	0	-7
24	36.00	0.002	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.	elev.	min.	elev.	max.	min.	max.	elev.	min.	elev.	max.	min.
	kN.m/m		kN.m/m		kN.m/m		kN/m		kN/m		kN/m	kN/m
1	0	39.00	-1	43.50	1	-1	1	41.50	-1	44.99	1	-1
2	0	38.40	-1	44.00	0	-2	1	43.75	-1	44.65	1	-1
3	28	42.60	-0	37.20	38	-0	23	43.50	-10	41.00	30	-13
4	No calculation at this stage											
5	23	44.00	-36	41.50	31	-48	38	40.65	-44	44.00	52	-59
6	No calculation at this stage											
7	No calculation at this stage											
8	14	44.45	-35	42.00	19	-47	33	40.65	-39	44.45	45	-52
9	14	44.45	-30	42.00	19	-41	33	41.00	-36	44.45	45	-49
10	No calculation at this stage											
11	No calculation at this stage											
12	19	44.45	-54	42.60	25	-72	88	41.00	-66	44.45	119	-89

Maximum and minimum displacement at each stage

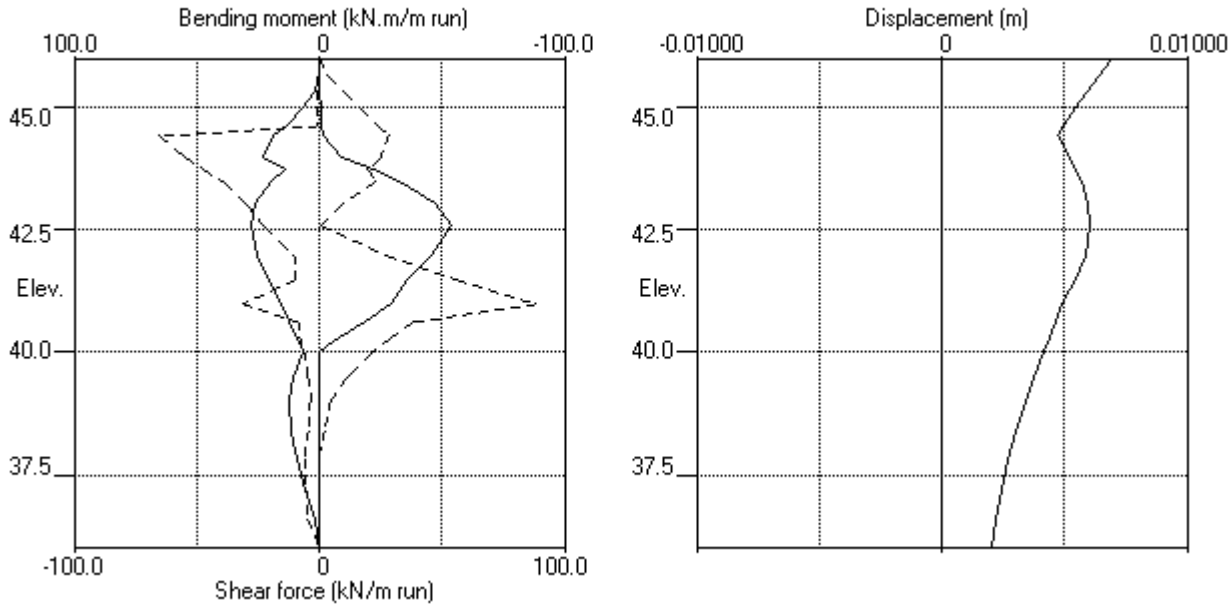
Stage no.	Displacement maximum m	elev.	minimum m	elev.	Stage description
1	0.000	46.00	0.000	46.00	Apply surcharge no.1 at elev. 46.00
2	0.001	46.00	0.000	46.00	Apply water pressure profile no.1
3	0.007	46.00	0.000	46.00	Excav. to elev. 43.50 on RIGHT side
4	No calculation at this stage				Install strut no.1 at elev. 44.00
5	0.005	42.00	0.000	46.00	Excav. to elev. 40.65 on RIGHT side
6	No calculation at this stage				Install strut no.2 at elev. 41.00
7	No calculation at this stage				Install strut no.3 at elev. 44.45
8	0.005	42.60	0.000	46.00	Remove strut no.1 at elev. 44.00
9	0.005	42.60	0.000	46.00	Change EI of wall to 46968kN.m2/m run
10	No calculation at this stage				Change soil type 2 to soil type 3
11	No calculation at this stage				Apply surcharge no.2 at elev. 40.65
12	0.006	42.60	0.000	46.00	Apply water pressure profile no.2

Strut forces at each stage (horizontal components)

Stage no.	Strut no. 1 at elev. 44.00			Strut no. 2 at elev. 41.00			Strut no. 3 at elev. 44.45		
	Calculated kN per m run	Calculated kN per strut	Factored kN per strut	Calculated kN per m run	Calculated kN per strut	Factored kN per strut	Calculated kN per m run	Calculated kN per strut	Factored kN per strut
5	69	344	465	---	---	---	---	---	---
8	---	---	---	15	15	20	58	58	79
9	---	---	---	22	22	29	56	56	76
12	---	---	---	120	120	162	94	94	127

Units: kN,m

Bending moment, shear force, displacement envelopes



APPENDIX B

Ref No	Description
B1	Results of “ADCOL” analysis for 450mm diameter wall piles with 5 x B16mm bars, 0kN compression load (Wall 1).
B2	Results of Helical Check for 450mm diameter wall piles with 5 x B16mm bars, B8mm helical @ 225mm centres, 75mm cover (Wall 1).

PILEDESIGNS
GEOTECHNICAL EXPERTISE

Camden - Barrie House, 29 St Edmund's Terrace
450mm diameter RW - 5x16mm cage
Moment Check

Job No.	Sheet No.	Rev.
21024	B1	

Drg. Ref.

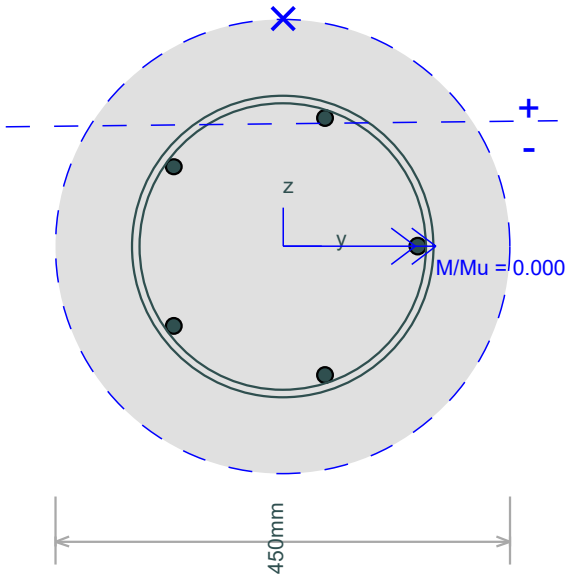
Made by	Date	Checked
DBS	08-Jun-2018	

Reinforcement Details

Bar Arrangement	1 ring(s)/5 bars per ring
Diameter of main bars	16mm
Area of reinforcement	1005.31mm²
Nominal Cover (outer)	75mm

Design Results

Analysis Case Name	Analysis Case 1
Axial Design Force	0kN
Axial Capacity	2844.53kN
Design Moment 'M'	0kNm
Ultimate Moment 'Mu'	69.2358kNm
Neutral Axis	— — —
Comp./Tens. Side	+/-
Governing Node/Bar	✕



Section 1

Analysis Case 1

Project	CAMDEN - Barrie House, 29 St Edmund's Terrace	Project No.		21024	Date	08/06/2018
Tilte	450mm Pile Shear Check - Wall 1	By	DBS	Check By		Page 1

REFERENCE

EC2 **Shear to EN 1992-1-1:2004 (EC2)** Circular Sections (Cast In-situ) using helical reinforcement

Pile section

pile dia d_{nom}	=	450	mm
design pile diameter	=	450	mm
Ac	=	159043	mm^2
4.4.1.3(4) cover c_{nom}	=	75	mm
main bar dia	=	16	mm
no. main bars	=	5	no.
helical dia.	=	8	mm
d	=	305	mm
f_{ck}	=	30	MPa
f_{yk}	=	500	MPa
Ult V_{Ed}	=	71.3	kN
Ult V_{Ed}	=	71.3	kN
factored actions N_{Ed}	=	0	kN

k_2 = 75 mm [NA.1 4.4.1.3 (4)]

γ_c = 1.5 (This is adjusted by K_f=1.1 [2.4.2.5 (2)] to give 1.65)

γ_c = 1.65 α_{cc} = 0.85 [NA.1 3.1.6 (1)}

γ_s = 1.15

SF factor 1

6.2.2 Check requirement for shear reinforcement

$V_{Rd,c} = [C_{Rd,c}k(100\rho_1 f_{ck})^{1/3}+k_1\sigma_{cp}]b_w d$

with minimum = $(v_{min}+k_1\sigma_{cp})b_w d$

$v_{min} = 0.035k^{3/2}f_{ck}^{1/2}$

0.4666

CRd,c = 0.18 / γc = 0.11

k = $1+(200/d)^{1/2}$ = 1.81 <=2.0

$\rho_1 = A_{sl}/b_w d$ = 0 <=0.02

$\sigma_{cp} = N_{ed}/A_c$ = 0 < $0.2f_{cd}$

k_1 = 0.15 [NA.1 6.2.2(1)]

$V_{Rd,c}$ = **60** kN

Is $V_{Rd,c} > V_{Ed}$ => **NO** Action: ***Design of shear reinforcement required***

6.2.3 Design Shear Reinforcement

Check concrete strut capacity at Cot θ = 2.5 :-

6.2.3 (3) exp 6.9 $V_{Rd,max} = \alpha_{cw}.b_w.z.v_1.f_{cd} / (Cot\theta+tan\theta)$ (6.9)

$V_{Rd,max}$ = **348** **kN**

cot θ = 2.5

tan θ = 0.4

α_{cw} = 1 [NA.1 6.2.3(3)]

z = 0.9d = 275 mm

v_1 = 0.6 (1-(fck/250) = 0.53 [6.6N]

Is $V_{Rd,c} > V_{Ed}$ => **YES** Action: ***Calculate link spacing***

Calculation for strut inclination:-

θ = $0.5.\sin^{-1}[(6.54*V_{Ed})/(b_w.d.(1-f_{ck}/250).f_{ck})$

θ = NA rad cot θ = 2.5 > 1.0

Calculate shear reinforcement spacing after Turmo et al (2008);-

$V_{Rd,s} = z.\cot\theta.(A_\Phi/0.5s).f_{ywd}.0.85$

$s = 2.([z.\cot\theta.A_\Phi.fywd.0.85]/V_{Rd,s})$

= **358** mm

A_Φ = 50.3 mm^2

f_{ywd} = 435 MPa

Provide	**8**	mm helical at nominal pitch	**225**	mm

Turo, J, *et al*. Shear truss analogy for concrete members of solid and hollow circular cross section. **Eng. Struc.** (2008)

APPENDIX C

Ref No	Description
C1	Results of “PILE” analysis for 450mm diameter retaining wall piles based on piling level of 46.0mAD and discounted level of 40.6mAD

Camden - Barrie House, 29 St Edmund's Terrace
450mm dia pile 40.6mAD discounted
vertical capacity

Notes

Piling Level 46.0mAD

Analysis Options

Design approach:	DA1(C1 + C2)
Pile type:	CFA
Model factor:	1.40
Partial factor on negative skin friction - Set A1:	1.00
Partial factor on negative skin friction - Set A2:	1.00
Serviceability verified by load tests (preliminary/working) carried out on more than 1% of constructed piles to loads not less than 1.5 times the representative load for which they are designed?	No
Resistance verified by a maintained load test taken to the calculated, unfactored, ultimate resistance?	No
Datum type	Elevation based
Effective stress profile	Calculated

Pile Properties

Pile type	Solid
Pile cross-section	Circular
Under-ream	No
Calculation profile	Single
Pile length	10.000 m

Cross-section	Number of cross sections	Top Diameter [m]	Second Diameter location [m]	Second Diameter [m]	Third Diameter location [m]	Third Diameter [m]
Cross-section 1	1	0.45000				

Undrained Materials - General Data

No.	Material description	Bulk unit weight [kN/m³]	Cu material factor	Top Cu [kPa]	Base Cu [kPa]
1	Discounted Soil	18.000	NA	0.0	0.0
2	London Clay 1	20.000	NA	70.200	115.00
3	London Clay 2	20.000	NA	115.00	115.00

Undrained Materials - Skin Friction Data

No.	Material description	Skin friction computation	Alpha	q_s Top [kPa]	q_s Base [kPa]	$q_{s,lim}$ Spec.	$q_{s,lim}$ Value [kPa]
1	Discounted Soil	Alpha specified	0.0	NA	NA	No	NA
2	London Clay 1	Alpha specified	0.50000	NA	NA	No	NA
3	London Clay 2	Alpha specified	0.50000	NA	NA	No	NA

Undrained Materials - End Bearing Data

No.	Material description	End bearing computation	Nc	q_b Top [kPa]	q_b Base [kPa]	$q_{b,lim}$ Spec.	$q_{b,lim}$ Value [kPa]
1	Discounted Soil	Nc specified	0.0	NA	NA	No	NA
2	London Clay 1	Nc specified	9.0000	NA	NA	No	NA
3	London Clay	Nc specified	9.0000	NA	NA	No	NA

No.	Material description	End bearing computation	Nc	q_b Top [kPa]	q_b Base [kPa]	$q_{b,lim}$ Spec. Value [kPa]
2						

Undrained Materials - Material Factors (Code Based)

No.	Material description	Qs factors M1	Qs factors M2	Nc factors M1	Nc factors M2	Qb factors M1	Qb factors M2
1	Discounted Soil	N.A.	N.A.	1.0000	1.0000	N.A.	N.A.
2	London Clay 1	N.A.	N.A.	1.0000	1.0000	N.A.	N.A.
3	London Clay 2	N.A.	N.A.	1.0000	1.0000	N.A.	N.A.

STAGE SPECIFIC DATA

Stage 0 : Initial Stage

Groundwater

No.	Level [m]	Pressure [kPa]	Unit weight of water [kN/m³]
1	44.650	0.0	9.8100

Soil Profiles

Soil Profile 1: Soil Profile 1

No.	Level [mOD]	Material description	Contributes to negative skin friction
1	46.000	Air/Void	No
2	41.300	Discounted Soil	No
3	40.600	London Clay 1	No
4	35.000	London Clay 2	No

Soil Profile - Groundwater Map

No.	Soil Profile	Groundwater
1	Soil Profile 1	Groundwater Profile 1

Stage specific warnings

1 - Stage 0 - The bottom most layer in Soil Profile 1 is assigned "Total stress" material. For this layer the cohesion is assumed to be constant at "Cu-Top", i.e cohesion specified at the top of this layer. The user specified value of cohesion at the bottom of this layer, "Cu-Bottom" is ignored. (Material Properties)

CAPACITY RESULTS

Partial Resistance Factors Used:

DA1 C1

Shaft resistance factor for set R1 (Compression):	1.00
Base resistance factor for set R1:	1.00
Shaft resistance factor for set R1 (Tension):	1.00

DA1 C2

Shaft resistance factor for set R4 (Compression):	1.60
Base resistance factor for set R4:	2.00
Shaft resistance factor for set R4 (Tension):	2.00
Model factor:	1.40

No.	Soil Profile	Groundwater

Stress Profiles

Soil Profile 1: Soil Profile 1

Level [mOD]	Density [kN/m³]	Undrained Cohesion [kPa]	Nq	Total vertical stress [kPa]	Porewater pressure [kPa]	Effective vertical stress [kPa]	Effective horizontal stress* [kPa]	Cumulative skin friction per unit perimeter [kN/m]
46.000	0.0	0.0	0.0	0.0	0.0	0.0	NA	0.0
44.650	9.8100	0.0	0.0	0.0	0.0	0.0	NA	0.0
41.300	9.8100	0.0	0.0	32.864	32.864	0.0	NA	0.0
41.300	18.000	0.0	N.A.	32.864	32.864	0.0	NA	0.0
40.600	18.000	0.0	N.A.	45.464	39.731	5.7330	NA	0.0
40.600	20.000	70.200	N.A.	45.464	39.731	5.7330	NA	0.0
36.000	20.000	107.00	N.A.	137.46	84.857	52.607	NA	203.78

* Effective horizontal stress not calculated for "Total Stress" materials and for Beta Method.

Cross-section 1 results:

Uniform pile with top shaft diameter = 0.45 m

Results - Compression

Soil Profile 1: Soil Profile 1

Level [mOD]	Pile length [m]	Ultimate base capacity (Q_b) [kN]	Cumulative external Friction (Q_s) [kN]	Negative skin friction (Q_{nsf}) [kN]	Net ultimate resistance [kN]	Design resistance DA1-C1 [kN]	Design resistance DA1-C2 [kN]	Combination with least resistance #	Factored load* DA1-C1 [kN]	Factored load* DA1-C2 [kN]
36.000	10.000	153.16	288.09	0.0	441.25	315.18	183.31	2	0.0(C)	0.0(C)

Limiting criteria :
1 : DA1 C1
2 : DA1 C2
*(C)-> Compression load, (T)-> Tension load
Note: Design resistance does not include any consideration of negative skin friction.

Nq Calculation Details

Soil Profile 1: Soil Profile 1 - Material Factor Set - 1

There are no pile toe levels in any drained material(with Berezantzev/Bolton option) in the given soil profile.

Soil Profile 1: Soil Profile 1 - Material Factor Set - 2

There are no pile toe levels in any drained material(with Berezantzev/Bolton option) in the given soil profile.

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