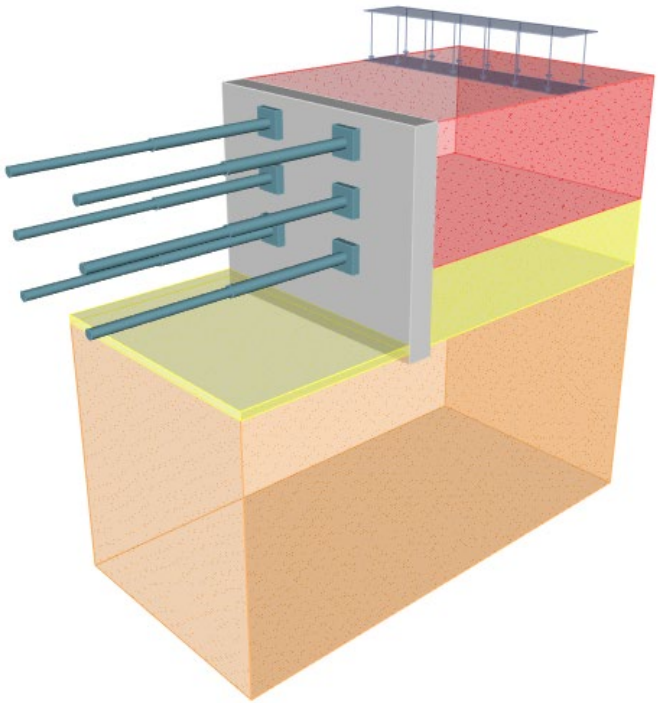
Ground and Project CONSULTANTS LTD

Report No. 60450

16 FROGNAL GARDENS
Ground Movement Assessment
December 2019



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Contents

1 Introduction

Ground and Project Consultants Ltd (GPCL) have been instructed by Croft Structural Engineers to carry out a Ground Movement Assessment for the proposed basement at 16 Frognal Gardens, Hampstead, London NW3 6UX.

The objectives of this report are to ascertain the expected ground movements and degree of any building damage for a building structure adjacent to the site. A Ground Investigation and Basement Impact Assessment has previously been carried out by Ground and Water Ltd and a previous structural assessment by Croft Structural Engineers.

The scope of this report and approach are as follows:

- Establish expected ground conditions at the site from previous reports;
- Develop an understanding of the proposals and their relationship to the adjacent structure at 18 Holly Walk;
- Carry out an assessment of ground movement following the principles and procedures set out in C760 “Guidance on Embedded Retaining Wall Design”;
- Carry out stability and ground movement assessment using Geo5 Sheeting Check software.

This report has been prepared by Jon Smithson, BSc, MSC, FGS, CGeol who is a chartered geologist with over 30 years’ experience.

2 Assessment of Ground Movement

2.1 Movement due to wall installation and excavation

An assessment of ground movements has been carried out for the adjacent house at 18 Holly Walk. Other properties are considered not to be at risk by Croft from the basement development as the properties are topographically lower so that the effective basement depth is minimal. The scope of this report is therefore limited to the assessment of ground movement and quantification of likely associated damage.

The magnitude of ground movements has been assessed for the excavation in front of the retaining structure, i.e. the basement wall.

Movement due to wall installation has been included at this stage. Although it is understood that the property will be underpinned, and as such a wall will not be installed into the ground, wall installation has been included to be conservative.

It is important to note that CIRIA report C760 is written for embedded retaining walls. Therefore, movement calculations for the excavation of soil and installation of underpins does not strictly apply to C760. There is no recognised method for calculating ground movements due to underpinned basements so C760 is used as a convenient and recognised approach.

To provide a comparison and to assess the stability of the basement during the construction phase analysis have been carried out using Geo5 “Sheeting Check” retaining wall software. The software allows input of progressive construction stages and the installation of props. Horizontal and vertical ground movements are calculated.

It is recognised that settlements are generally small where care and appropriate measures are taken in this type of basement construction.

Design drawings developed by Croft Structural Engineers have been reviewed and used to inform this assessment.

The following key assumptions have been made:

- The detailed design of the basement (and associated temporary works) has been carried out by an appropriately qualified and experienced structural engineer, to current professional standards and best practice;
- The maximum excavation depth is approximately 4.05m below ground level;
- The method of basement construction will be via underpinning;
- A high wall stiffness has been informed by the structural assessment by Croft Structural Engineers;
- The wall will be propped using stiff closely spaced (2m) props in the temporary case at three levels.
- In the permanent case the wall will always be propped at floor and ceiling level.

For the purposes of the calculations, the width and height of 18 Holly Walk have been estimated to be as follows:

Distance from Basement (m)	Basement Depth (m)	Building Height (m)	Building Length (m)
3.14	4.05	7.5	14.8

It is assumed that the soils are competent soils from the ground investigation. The ground conditions comprised Head (high strength sandy gravelly clay with silt and sand pockets) to 1.7m bgl, overlying Bagshot Formation (medium strength sandy silt clay with clayey sand and silt bands and pockets). Groundwater was encountered at 6m bgl during drilling and was not recorded during monitoring (>5m bgl).

The following ground movements have been calculated in relation to ground movements, using figure 6.15 in C760.

Maximum Vertical Deflection Δ (mm) at 18 Holly Walk	Maximum Horizontal Movement dh (mm) at 18 Holly Walk	Building Damage Assessment
4.0	6.1	1 Very Slight

This assumes that the wall is propped high and at lower levels during construction and therefore a high stiffness can be assumed. It is understood that there will be adequate propping in the temporary case to justify this assumption and in the permanent case the structure will provide adequate support to the retaining walls and act as a high-level prop.

There are a number of key points to note in using this assessment:

- Most ground movement will occur during excavation of the basement and construction so the adequacy of temporary support will be critical in limiting ground movements;
- The speed of propping and support is key to limiting ground movements and limiting unpropped wall heights;
- Good workmanship will contribute to minimising ground movements;
- The calculation assumes the wall is in competent soil;
- Larger movements will be expected where soft or loose soils are encountered at, above and below formation.

Ground movement can be minimised by adopting a number of measures, including:

- Ensuring that adequate propping is in place at all times during construction;
- Installation of the first (stiff) support quickly and early in the construction sequence;
- Avoidance of ground loss through the gaps between the piles (if used);
- Avoid leaving ground unsupported;
- Minimise deterioration of the central soil mass by the use of blinding/ covering with a waterproof membrane;

- Avoid overbreak;
- Control and appropriate design and selection of dewatering to minimise fines removal and drawdown.

It must be noted that the movements are calculated values based on the findings and methods of CIRIA C760. Larger movements may be generated if anyone or any combination of the above recommendations and/or assumptions are not heeded or if ground conditions are different from those anticipated by the investigation. Computer analysis suggests that ground movements are highly sensitive to prop and wall stiffness, so the use of stiff props both in the temporary and permanent cases is essential.

The actual magnitude of these movements will depend upon a number of factors described above and the nature of the ground expected may give rise to larger movements.

2.2 GEO5 Sheeting Check Analysis

Further assessment of the basement construction has been carried out using "Sheeting Check" developed by GEO5.

Undrained analysis has been performed, with a series of construction stages, involved excavation propping further excavation, propping and so forth. The "Temporary Works Scheme Design" drawing has been used to inform this sequence.

The analysis serves as a preliminary check on global and internal stability. These are satisfactory for scenarios in the undrained condition.

The assessment includes for line load from the house.

In addition, the analysis suggests the following ground movements, which are comparable to those developed using C760.

Maximum Vertical Movement (mm)	Distance from the wall (m)	Maximum Horizontal Movement (mm)
8.5	1.62	9.8

The output sheets are provided below.

Deviation in the model from early propping demonstrates its importance in that if props are installed late then more ground movement occurs.

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Project	Frognal Gardens		
Project No.	60450		
Calc Title	Ground Movement Assessment at 18 Holly Walk		
Date	18 December 2019	**Rev**	0

House Details, Background Data and Assumptions

Calculations based on C760 Pg155,

Building	**18 Holly Walk**
Ground Level (m AD)	11.7
Basement Depth (m)	4.05
Basement Floor level (m AD)	7.6
Effective Basement Depth (m)	4.05
Wall Depth (m)	4.05
Length (m)	14.8
Height (m)	7.5
Distance (m)	3.1
Far Side (m)	17.9

Movement Calculations for Wall Installation

Horizontal

Distance from wall/wall depth (m)	Distance (m)	Movement/ Wall Depth (%)	Horizontal Movement (mm)	Relevance to Adjacent Properties
0.0	0.0	0.080	3.24	
0.1	0.4	0.070	2.84	
0.2	0.8	0.075	3.04	
0.3	1.2	0.060	2.43	
0.4	1.6	0.050	2.03	
0.5	2.0	0.044	1.78	
0.6	2.4	0.040	1.62	
0.7	2.8	0.035	1.42	
0.8	3.2	0.030	1.22	NS 18 HW
0.9	3.6	0.020	0.81	
1.0	4.1	0.018	0.73	
1.1	4.5	0.015	0.61	
1.2	4.9	0.012	0.49	
1.3	5.3	0.010	0.41	
1.4	5.7	0.005	0.20	
1.5	6.1	0.000	0.00	FS 18 HW

Vertical

Distance from wall/wall depth (m)	Distance (m)	Movement/ Wall Depth (%)	Vertical Movement (mm)	Relevance to Adjacent Properties
0.0	0.0	0.050	2.0	
0.1	0.4	0.048	1.9	
0.2	0.8	0.046	1.9	
0.3	1.2	0.042	1.7	
0.4	1.6	0.040	1.6	
0.5	2.0	0.037	1.5	
0.6	2.4	0.035	1.4	
0.7	2.8	0.032	1.3	
0.8	3.2	0.029	1.2	NS 18 HW
0.9	3.6	0.027	1.1	
1.0	4.1	0.025	1.0	
1.1	4.5	0.023	0.9	
1.2	4.9	0.020	0.8	
1.3	5.3	0.018	0.7	
1.4	5.7	0.016	0.6	
1.5	6.1	0.014	0.6	
1.6	6.5	0.011	0.4	
1.7	6.9	0.009	0.4	
1.8	7.3	0.007	0.3	
1.9	7.7	0.004	0.2	
2.0	8.1	0.000	0.0	FS 18 HW

Deflection Ratio

	18 Holly Walk
Delta	1.2
dh	1.2

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Assumptions

Calculations based on C760 Fig. 6.15 assume system stiffness =1000, FOS against base heave >3. zero at 3 x excavation depth as Fig. 6.11 a) and b)

High Stiffness	0.0075

Movement Calculations for Excavation

Horizontal **Distance from wall/excavation depth (m)**	**Distance (m)**	**Horizontal Movement/ Wall Depth (%)**	**Horizontal Movement (mm)**	**Relevance to adjacent properties**
0.0	0.0	0.15	6.1	
0.2	0.8	0.1425	5.8	
0.4	1.6	0.135	5.5	
0.6	2.4	0.1275	5.2	
0.8	3.2	0.12	4.9	NS
1.0	4.1	0.1125	4.6	
1.2	4.9	0.105	4.3	
1.4	5.7	0.0975	3.9	
1.6	6.5	0.09	3.6	
1.8	7.3	0.0825	3.3	
2.0	8.1	0.075	3.0	
2.2	8.9	0.0675	2.7	
2.4	9.7	0.06	2.4	
2.6	10.5	0.0525	2.1	
2.8	11.3	0.045	1.8	
3.0	12.2	0.0375	1.5	
3.2	13.0	0.03	1.2	
3.4	13.8	0.0225	0.9	
3.6	14.6	0.015	0.6	
3.8	15.4	0.0075	0.3	
4.0	16.2	0	0.0	FS

Vertical **Distance from wall/excavation (m) depth**	**Distance (m)**	**Settlement/ Excavation Depth (%)**	**Settlement (mm)**	**Relevance to adjacent properties**
0.0	0	0.040	1.62	
0.2	0.81	0.050	2.03	
0.4	1.62	0.070	2.84	
0.6	2.43	0.080	3.24	
0.8	3.24	0.070	2.84	NS
1.0	4.05	0.070	2.84	
1.2	4.86	0.060	2.43	
1.4	5.67	0.060	2.43	
1.6	6.48	0.050	2.03	
1.8	7.29	0.040	1.62	
2.0	8.1	0.035	1.42	
2.2	8.91	0.030	1.22	
2.4	9.72	0.025	1.01	
2.6	10.53	0.020	0.81	
2.8	11.34	0.015	0.61	
3.0	12.15	0.010	0.41	
3.2	12.96	0.005	0.20	
3.4	13.77	0.000	0.00	FS

Deflection Ratio

	18 Holly Walk
Delta	2.84
dh	4.86

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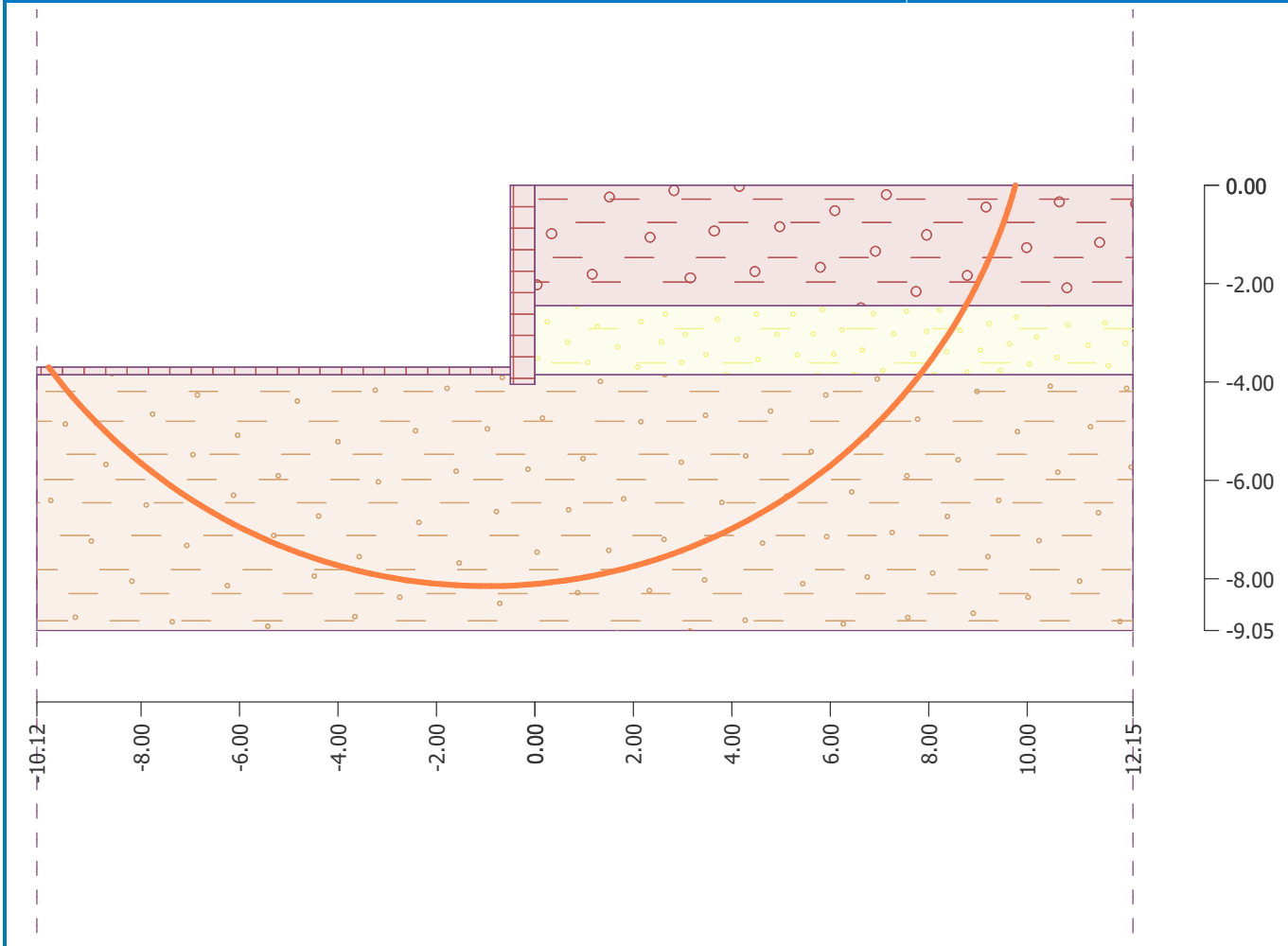
Combined for Wall Installation and Excavation

	18 Holly Walk
Delta	4.0
dh	6.1

Movement Assessment

18 Holly Walk			
Horiz Strain (%)	dh/L	0.04	
Deflection Ratio (%)	Delta/L	0.03	
From Graph Fig 6.27 c	Damage Category	1 Very Slight	
From Graph Fig 6.27 b	Try elim	0.075	upper limit of damage category Table 6.4
L/H	2.0	Therefore eh/elim	0.5
Reading off Fig 6.27 b for closest L/H curve this gives Delta/L/ elim		0.45	
L	14800		
Therefore Delta = L x Reading x elim			
Delta (mm)	4.995		
Delta for combined wall installation and excavation is less :Damage category is confirmed as	1 Very Slight		

Name :	Stage - analysis : 1 - 1



Head

Wall material

Bagshott Formation - granular

Bagshott Formation - cohesive

The slip surface after optimization.

Slope stability verification (Bishop)
Combination 1

Sum of active forces : F_a = 432.89 kN/m
Sum of passive forces : F_p = 2481.67 kN/m

Sliding moment : M_a = 4822.35 kNm/m
Resisting moment : M_p = 27645.75 kNm/m
Utilization : 17.4 %

Slope stability ACCEPTABLE

Combination 2

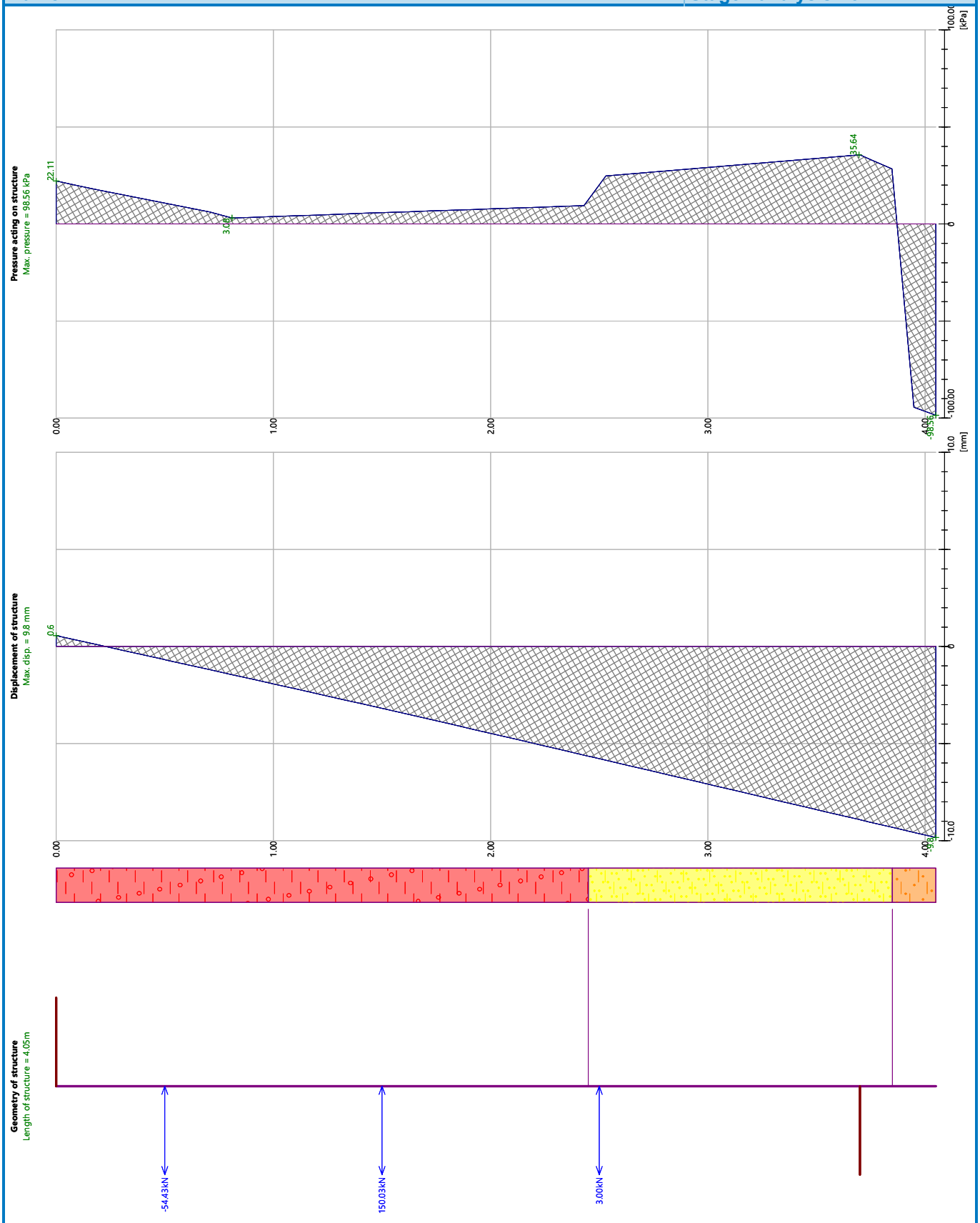
Sum of active forces : F_a = 318.25 kN/m
Sum of passive forces : F_p = 2235.67 kN/m

Sliding moment : M_a = 3892.23 kNm/m
Resisting moment : M_p = 27342.29 kNm/m
Utilization : 14.2 %

Slope stability ACCEPTABLE

Optimized slip surface for : Combination 1

Name :	Stage - analysis : 6 - 1



Name :	Stage - analysis : 6 - 1