Group Assignment CIEM2000

1. Introduction

This assignment is meant for groups of 3 students. Please sign up for a group in BrightSpace. The final report for the overall assignment must be submitted before **April 19th, 2024, 18:00h**, in the CIEM2000 Assignments section on Brightspace. Intermediate formative assessment will be given after submitting a preliminary report related to the Sections:

- 1 to 4, not later than **January 8th, 2024, 18:00h**
- 5, not later than **February 9th, 2024, 18:00h**.
- 6 and 7, not later than **April 5th, 2024, 18:00h**

Feedback on the numerical modelling part will be given during the respective sessions in the last week of Q3.
After having processed all feedback, the final report needs to be submitted, not later than **April 19th, 2024, 18:00h**.

Grading
The Assignment will count for 25% of your final mark for the whole module. The grading of the Assignment will be based on the final report. The overall mark for the Assignment is the average of the sub-marks from each Assignment component (4,5,6,7,8). Hence, it makes sense to submit preliminary versions of your report (provided you meet the above deadlines) and benefit from the feedback to improve your final report grade.
The overall mark must be sufficient (> 5.8); not necessarily for the individual components.
In the case of an insufficient overall mark on the final report, an updated report needs to be submitted by the end of Q4, not later than **June 21st, 2024, 18:00**.

2. Project Description

In Rotterdam, close to highway A20, at location 51°57'54.2"N 4°34'55.6"E (51.965044, 4.582112), a new development will take place in which an apartment building is constructed with an underground car park next to it. The site is currently occupied by a building of the City of Rotterdam, which will be demolished. The underground car park is meant to have 3 stories and the apartment building will have 4 stories (ground floor + 3 levels).

The site was developed about 60 years ago, when an anthropogenic (man-made) soil layer of 3 m was placed on top of the natural soft soil layers. Reclamation started in 1960, following the time schedule described in Section 4.

3. Project Data

3.1 Location

The location of the site is shown in Figures 1 and 2.

Figure 1. Street view of the construction location

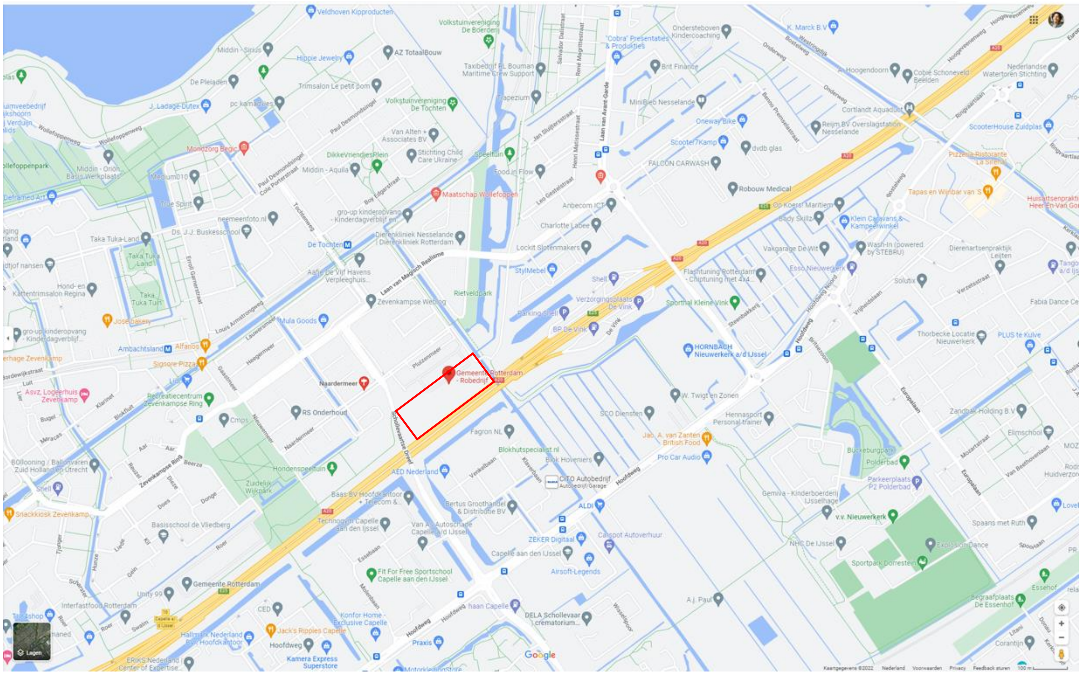

Figure 2. Location map

The dimensions of the underground car park are:

- Length 60 m (inner distance between walls)
- Width 20 m (inner distance between walls)
- 3 stories deep; the deepest level of the car park equals NAP -14m

The dimensions of the apartment block (frame structure) are:

- Length 60 m
- Width 15 m
- 4 stories high; equivalent vertical load of 40 kPa

The location of the car park is parallel to the highway. The apartment block is situated North of and parallel to the car park, with a distance of 5 m between them.

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The existing building on the location will be demolished before the construction works.

3.2 Soil Investigation

- You can find CPT's and boreholes on Dinoloket (https://www.dinoloket.nl/). Most important CPTs have already been downloaded for you (see BrightSpace). You can identify (at least) four different soil layers, among which a soft organic layer.
- Data for the soft organic layer are given in the text (Section 4).
- For the other layers, we will elaborate (some of) the soil properties and parameters in the unit Testing & Modelling of Soil Behaviour based on CPT data, the use of correlations and Table 2b from the Dutch Eurocode 7. See last 2 pages of this document.
- Feel free to use other sources as well, if necessary or desired.

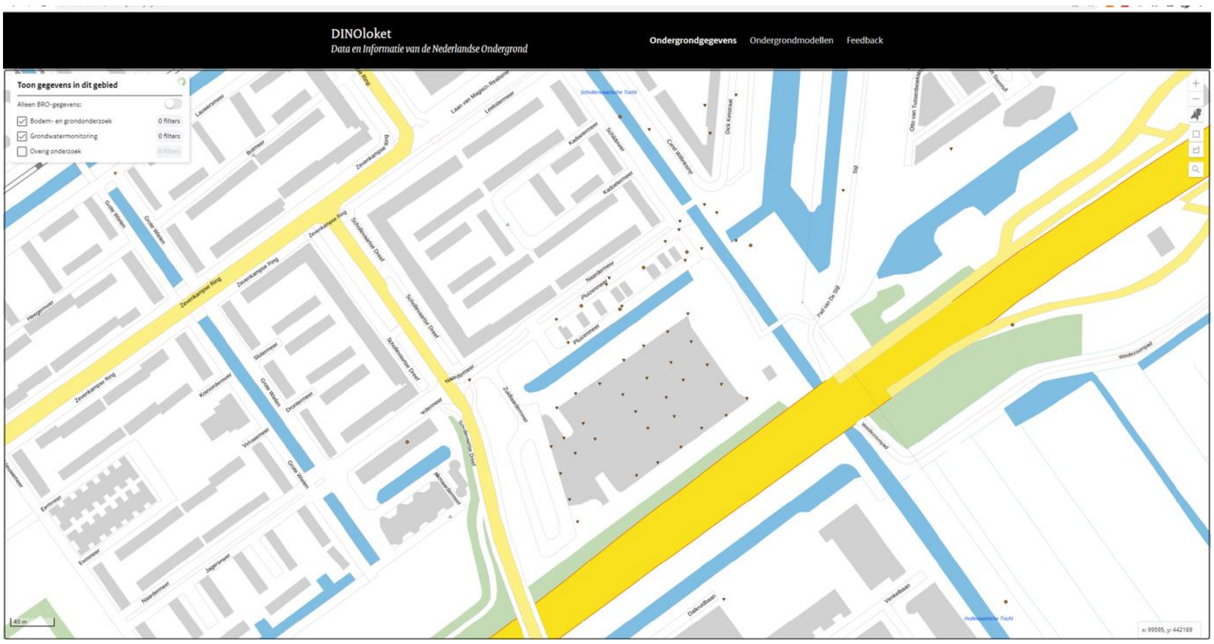

Figure 3. Detailed plan view of the location site

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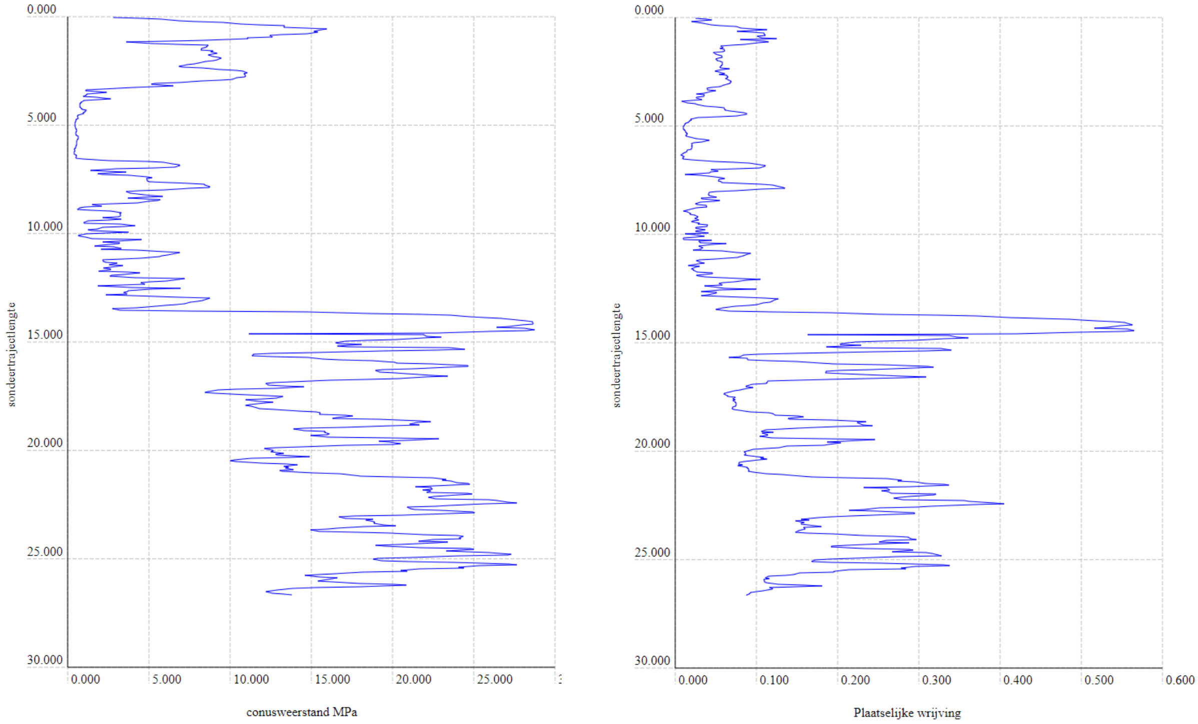

Figure 4. Representative CPT profile from field investigation carried out in 1989 (CPT000000149495)

a) Cone resistance [MPa] *b) Sleeve friction [MPa]*

3.3 Water Levels

In Rotterdam, the waterlevel in the city can be found on:

http://www.gis.rotterdam.nl/Gisweb2/Default.aspx?context=MIJNPROJECT.1091#

[Prowat 2000 Peilbuis 136573-3 (rotterdam.nl)]()
[Prowat 2000 Peilbuis 136573-1 (rotterdam.nl)]()

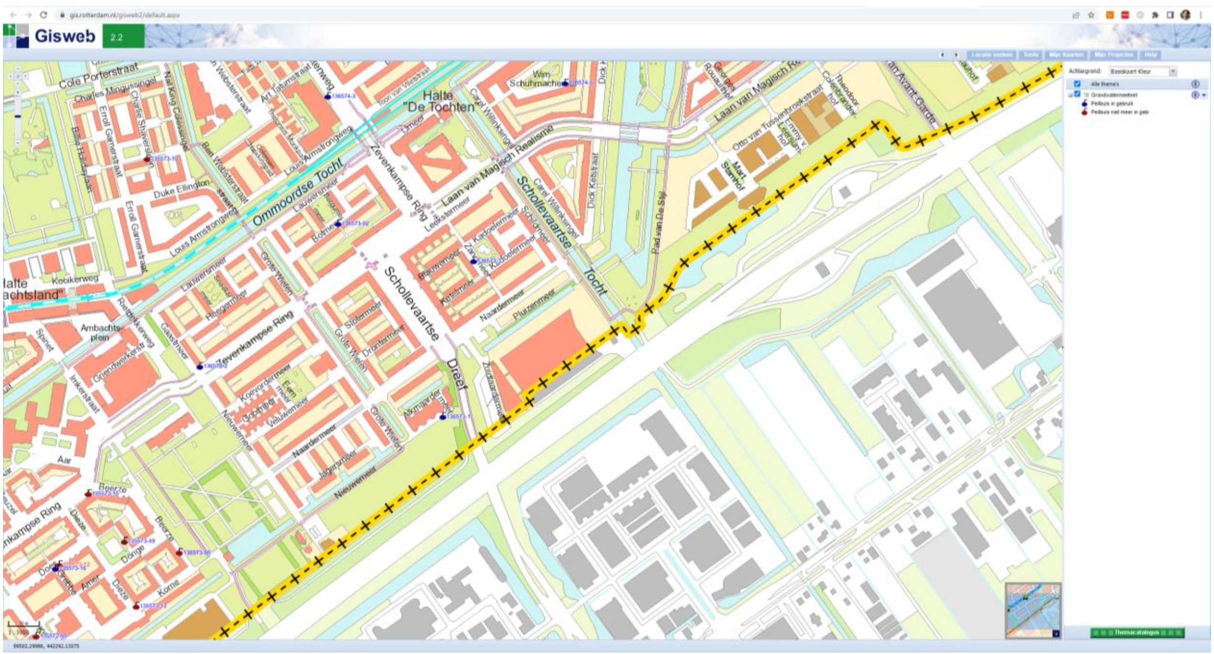

Figure 5 Interface water table GIS

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You are expected to deliver results on the following topics:

4. Site reclamation (related to unit Theory & Modelling of Geo-Processes)
5. Parameter determination (related to Testing & Modelling of Soil Behaviour)
6. Foundation design (related to Foundations & Excavations)
7. Excavation design (related to Foundations & Excavations)
8. Numerical modelling (integrated CIEM2000 topic)

4. Site reclamation

The site was developed in the 1960's, when an anthropogenic sand layer of three meters was placed on top of the natural soft soil layer for land reclamation. The original stratigraphy of the site before the land reclamation is reported in Figure 5(a) and consisted of a 5 m thick, soft organic layer with a subsoil underneath. The ground surface was at -6.5 m NAP and the piezometric surface at -6 m NAP, which means the area was a lake.

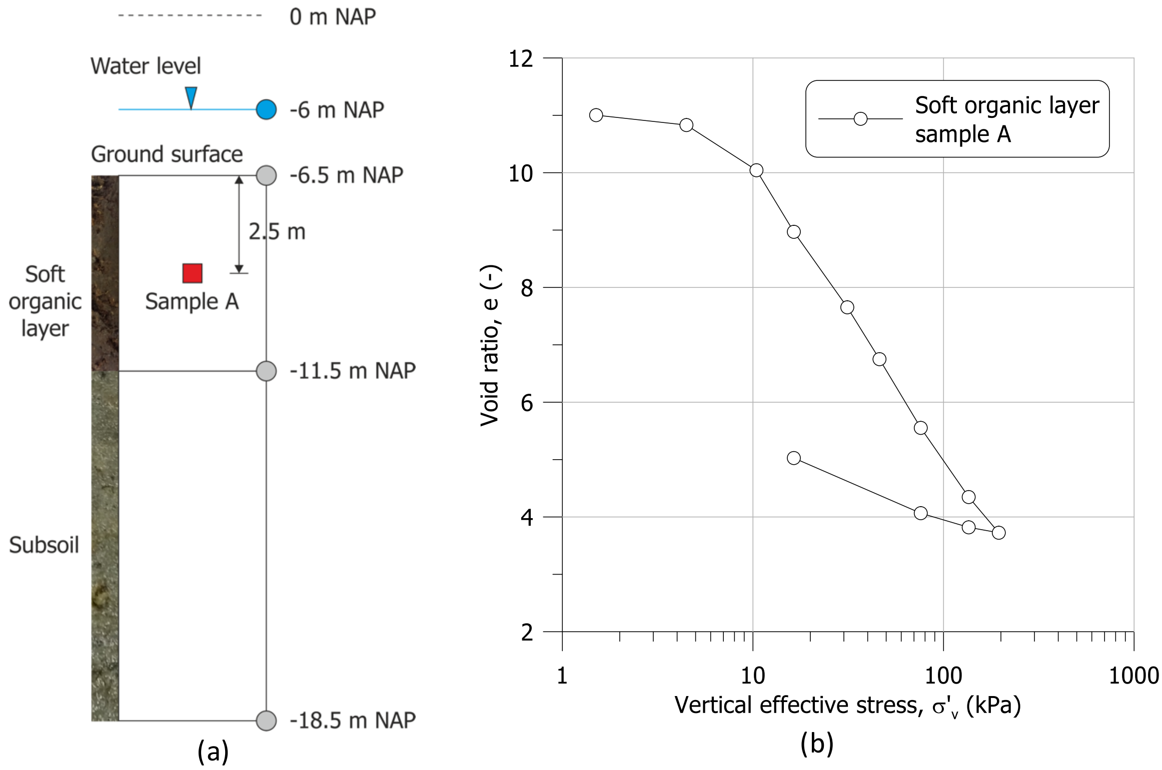

Figure 5. Original stratigraphy before land reclamation (a) and results of the oedometer test from sample A retrieved from the soft organic layer

An experimental campaign was carried out before land reclamation to characterise the response of the foundation soft organic layer. One sample (sample A in Figure 5(a)) was brought to the laboratory for incremental loading oedometer test. The compression curve is displayed in Figure 56(b) and the laboratory data are reported in Table 1 in terms of vertical effective stress, σ'_v, void ratio, e, and coefficient of consolidation, c_v. The evolution of the coefficient of consolidation during the incremental loading stages is displayed in Figure 6. The unit weight of the soft organic layer is γ = 12 kN/m^3.

Table 1. Experimental data from oedometer test on sample A retrieved from the soft organic layer

Vertical effective stress σ'_v (kPa)	Void ratio e (-)	Coefficient of consolidation c_v (m^2/s)
1.5	11.00	
4.5	10.83	$3.44 \cdot 10^{-5}$
10.4	10.04	$6.70 \cdot 10^{-6}$
16.4	8.97	$3.73 \cdot 10^{-7}$
31.3	7.65	$1.70 \cdot 10^{-7}$
46.1	6.75	$7.57 \cdot 10^{-8}$
75.9	5.55	$5.06 \cdot 10^{-8}$
135.4	4.35	$3.14 \cdot 10^{-8}$
195.0	3.72	$1.30 \cdot 10^{-8}$
135.4	3.82	
75.9	4.07	
16.4	5.03	

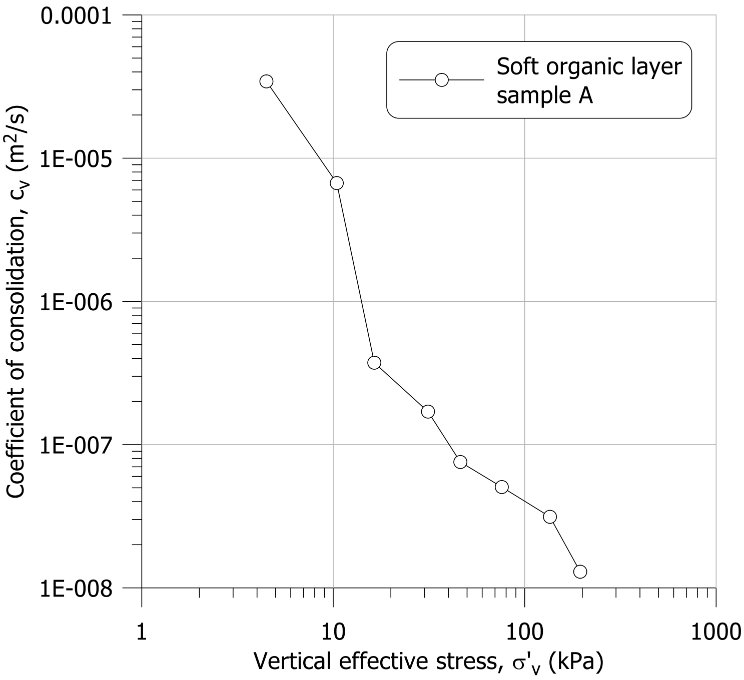

Figure 6. Coefficient of consolidation during the incremental loading stages on sample A retrieved from the soft organic layer

For land reclamation, three meters of sand (unit weight γ = 20 kN/m^3) were placed on top of the soft organic layer in three stages. The time sequence of the land reclamation works is reported in Figure 7.

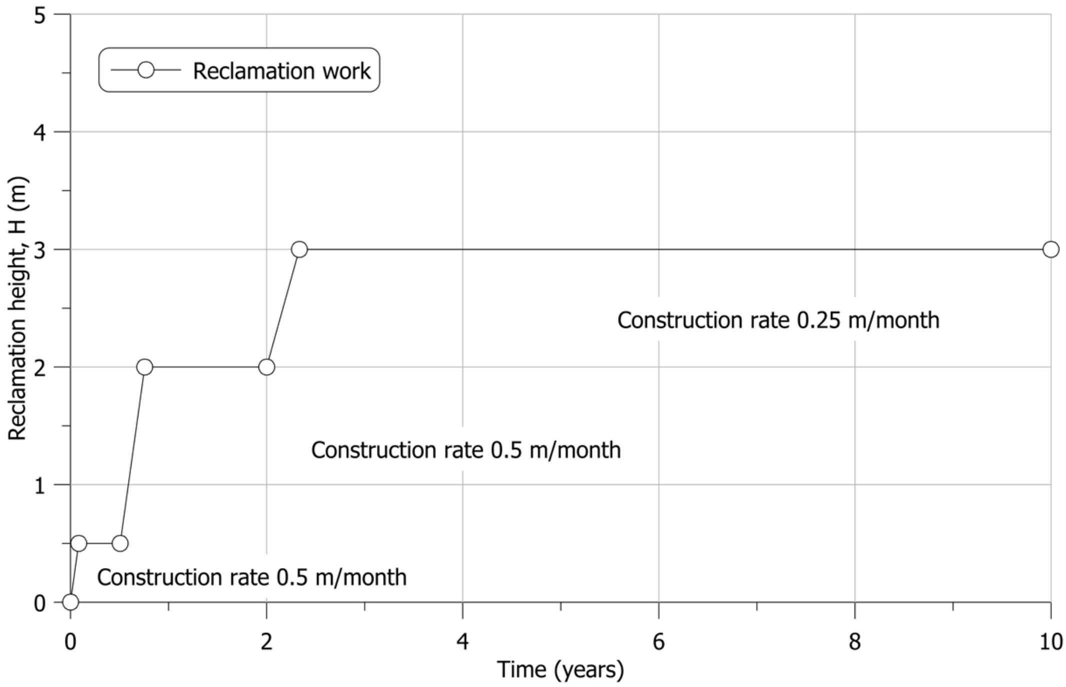

Figure 7. Time sequence of the land reclamation works

Note: in the final configuration, two meters of sand will be 'under water' and the last meter will be 'above the water level'.

Questions

a) With reference to the original and current stratigraphy based on the CPT profile, report your assumptions on the definition of the drainage conditions for the soft organic layer.

b) Estimate the excess pore water pressure at a point located 2.5 m below the ground level, (i.e. at a depth of 2.5 from the top of the soft organic layer) over eight years after the start of the reclamation works, assuming incompressible water.

c) Calculate the total settlement starting from the beginning of the construction, and for a total period of time of eight years.

d) Answer again questions a) and b) assuming that the fluid contains gas, giving a ratio of the solid skeleton compressibility to the soil compressibility η=0.8.

e) Compare the final soil profile you obtained with the available CPT data and comment on the result.

Report your reasoning path, intermediate calculations and assumptions you made to answer the questions.

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5. Parameter determination

This part is based on the unit Testing & Modelling of Soil Behaviour (T&MoSB).
Here, we will elaborate the parameters that are later needed for the numerical modelling of the case study. Some time is reserved for this during the lectures of T&MoSB. For a proper planning of activities, **it is important to complete the parameter determination by the end of Q2** and deliver your report by February 9th,2024, to receive feedback and have this ready for the numerical modelling part in Q3.
For the parameter determination, perform the following tasks after completing the previous tasks up to Section 4:

a) Considering the situation to date, make a geotechnical cross section (identifying <u>different soil layers</u>) at the location of the car park and apartment block. Assume unit weights and determine the initial stress profile in terms of total stresses, pore pressures and effective stresses.

b) For all layers, determine characteristic values of <u>soil parameters</u>. Present all parameters in a table; see example below.

c) <u>For all soil layers</u>, assume the Hardening Soil Small Strain (HSsmall) model as a representative constitutive model and determine all <u>model parameters</u> in preparation of the numerical modelling of the excavation. The numerical modelling and analysis itself is considered in Section 8. Present all parameters in a table.

The properties of the soft organic layer shall be (mostly) determined from the results obtained in Section 4. The properties of the other layers can be determined using the CPT data and Table 2b of the Dutch version of EuroCode 7, or by using parameter correlations with the CPT parameters. If there are sand layers involved, you may refer to Brinkgreve et al., 2010 (NUMGE 2010; available on BrightSpace) after having estimated the relative density (Dr) from the CPT data.

Table 1: Example of table with soil parameters of all layers

Soil description	γ_{sat} [kN/m³]	c [kPa]	φ [°]	Dr (only for sand) [%]	Other parameter you might need

<u>Remarks:</u>

γ_{sat} : saturated unit weight
c : cohesion
φ : internal friction angle
….. : ….

Table 2: Example of table with HSsmall parameters

Model parameter	Layer 1	Layer 2	...	Layer n	Unit
Drained or undrained?					-

γ_{unsat}					kN/m^3
γ_{sat}					kN/m^3
E50ref					kN/m^2
Eoedref					kN/m^2
Eurref					kN/m^2
...					

6. Foundation

For the foundation of the apartment block:

a) To design the foundation of the apartment block, consider the soil properties as determined in the previous Sections and determine any missing soil parameters to design a shallow foundation of the apartment building.
b) Examine the feasibility of using a shallow foundation option for the building. You can choose the method you wish to employ to determine the best estimate of the foundation bearing capacity and settlement under working load. Report on the calculation approach and risks associated with choosing a shallow foundation.
c) Compare the behaviour of a full-displacement (driven precast piles) and a screw-injection pile type at the site. Estimate the length of the pile, propose a pile layout and estimate the expected settlement at working load.
d) Evaluate which type of foundation is most applicable in this situation.

7. Excavation

For the design of the deep excavation:

a) Determine the missing soil parameters for a D-SheetPiling analysis (both characteristic and design values).

b) Consider the different possible and reasonable methods for creating the deep excavation. Considering the depth of the car park of to be NAP – 14 m, then the excavation should be deeper to account for floor thickness and other possible construction details. Take at least the following issues into account:
   - Construction risks: include executional aspects of installing the retaining structure: Consider at least the influence of installation and removal of the retaining structures on the neighbouring structures; vibrations and deformations and the risks to the structure itself; The surrounding area is sensitive to vibrations and settlements, and lowering of the phreatic water table or the hydraulic head outside your excavation is not allowed.
   - Construction time.
   - Construction costs.

   Motivate your selection of the most suitable construction method <u>for this case specifically</u> based on the abovementioned criteria.

All construction parts of the excavation should be taken into account, not just the walls.

c) Consider the failure mechanisms of the retaining structure

Summarize the failure mechanisms to be checked for the relevant stages; make a sketch of them for your excavation specific. Please don't describe the mechanisms themselves; that has already been done in the reader and in CUR166.

d) Specify all construction stages to be analysed.

e) Design the retaining structure of the shaft

Make a detailed design of the deep excavation according to CUR166/NEN9997-1 with the help of the D-Sheetpiling-program. The reader gives most of the details that you need. Check all the necessary steps of the CUR166 system as given in CUR166 or NEN99997 Chapter 9.7 and 9.8.

Check with a manual calculation the lateral effective stress at a depth of NAP – 16 m as given by D-sheetpiling output, at the passive and the active side of the retaining structure. Perform the check only for the construction phase just after excavating the deep excavation to the maximum depth; in other words: make clear that the printed lateral effective stresses are in harmony with the printed lateral deflections of the sheet and are a result of your specifications in the input of D-sheetpiling.

f) Design anchor or strut plan

Make a design of an anchor system. Consider at least:

- the load on the anchors and their resistance (capacity);
- the level and length of the grout element
- the centre-to-centre distance (horizontal spacing) of the anchors;
- the dimensions of the waling.

If you are using struts, make a design of the strut plan instead, with similar topics.

g) Predict settlements in surroundings

Check the deformations of the apartment block with simple methods from the reader. Predict if any damage to the apartment building is likely to occur and what measures you could take if this is the case. Include all relevant construction stages.

8. Numerical modelling

In addition to your D-Sheetpiling analysis, you are asked to create a numerical model of the situation and perform a numerical analysis in the finite element software PLAXIS. An example of how to model an excavation can be found in Chapter 3 of the PLAXIS Tutorial Manual (Submerged construction of an excavation). We will do this exercise in class (in the A-module, Numerical Modelling in Geotechnical Engineering) to get familiar with the software. Although the exercise only takes an hour to finish, creating a numerical model from scratch takes significantly more time and requires preparation! Do not underestimate this and make sure you prepare the details of your numerical model before the computer

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sessions in the unit Foundations & Excavations in the last week of Q3. To prepare your numerical model, answer for yourself the following questions:

- Where to put the vertical model boundaries (how far away from the excavation and apartment building)? Where to put the bottom boundary? What boundary conditions to apply? Make a sketch of your model with these details.
- How to model the pore water pressure distribution? Put a water level in your model.
- How to model dewatering of the excavation pit? Does this affect the pore pressure distribution in the surrounding soil?
- (Note: The Tutorial example only considers submerged excavation. De-activating soil elements still leaves the water active!)
- How to model the retaining wall and concrete floor of the car park? Using volume elements (like a 'soil layer') with Linear Elastic properties, or using plate elements? The apartment building may be schematized as a horizontal beam (plate) at the depth of the foundation, represented by a distributed weight or load of 40 kPa.
- Use the model parameters as determined in Section 5 for all layers.
- Consider the use of interface elements to model soil-structure interaction (at least between the walls and the soil). What is an appropriate wall friction (modelled as interface strength reduction factor, Rinter) for each layer?
- How to translate the properties of the structural components to the required input parameters?
- Considering the default element type in PLAXIS (15-node triangle), how coarse/fine should the mesh be? Should there be local refinements?
- Which calculation phases (representative of the various construction stages) should be defined?

Elaborate (on scratch paper) the answers on the above questions prior to the computer sessions and don't forget to bring these to the class. These answers don't need to be written in your final report but are relevant for your numerical model such that you can use the planned computer sessions to create your model, run the calculations and capture the results. Don't try to make a perfect numerical analysis. In this stage, it is more important to go through the entire process of numerical modelling rather than obtaining the right results.

Your final report you should include:

Model and input data:

a) Finite element mesh, annotated with relevant dimensions
b) Table of model parameter sets for all layers (= Section 5) as well as structural components
c) Table of calculation phases
d) Initial effective stress field (principal stresses)

Results after full excavation and dewatering:

e) Deformed mesh and tilt of the apartment building foundation
f) Pore pressure distribution
g) Effective stress distribution (principal stresses)
h) Plots and/or table of structural forces in plates (walls), anchors/struts, (embedded) beams.
i) Comparison of wall forces with your results from D-Sheetpiling.
j) Conclude on the effects / influences of the excavation on the apartment building.

Don't write an essay. To reduce the amount of time for writing, just include the requested data and results in your report by 'copy' and 'paste' from PLAXIS or other software that you have used.

9. Report

Structure your report according to the different Sections in this assignment description. We strongly recommend delivering a preliminary version of the report, including Sections 1 – 5 by the end of Q2. If you submit Sections 1 to 4 before **January 8th,2024, 18:00h** and Section 5 before **February 9th ,2024,18:00h**, you will receive formative feedback on these parts.
By the end of **April 19th 18:00**, you must deliver your final report of max. 50 pages on this group assignment.

For all reports, make sure to include:

- table of contents + page numbers on each page
- (all assumptions made)
- soil parameters in table form
- sketches and drawings specific to your situation
- (detailed calculations in the annexes, summary in the main text)
- file in pdf, named according to your group number and indication ‘preliminary’ or ‘final’.

Please do NOT put names in the reports; just student numbers.

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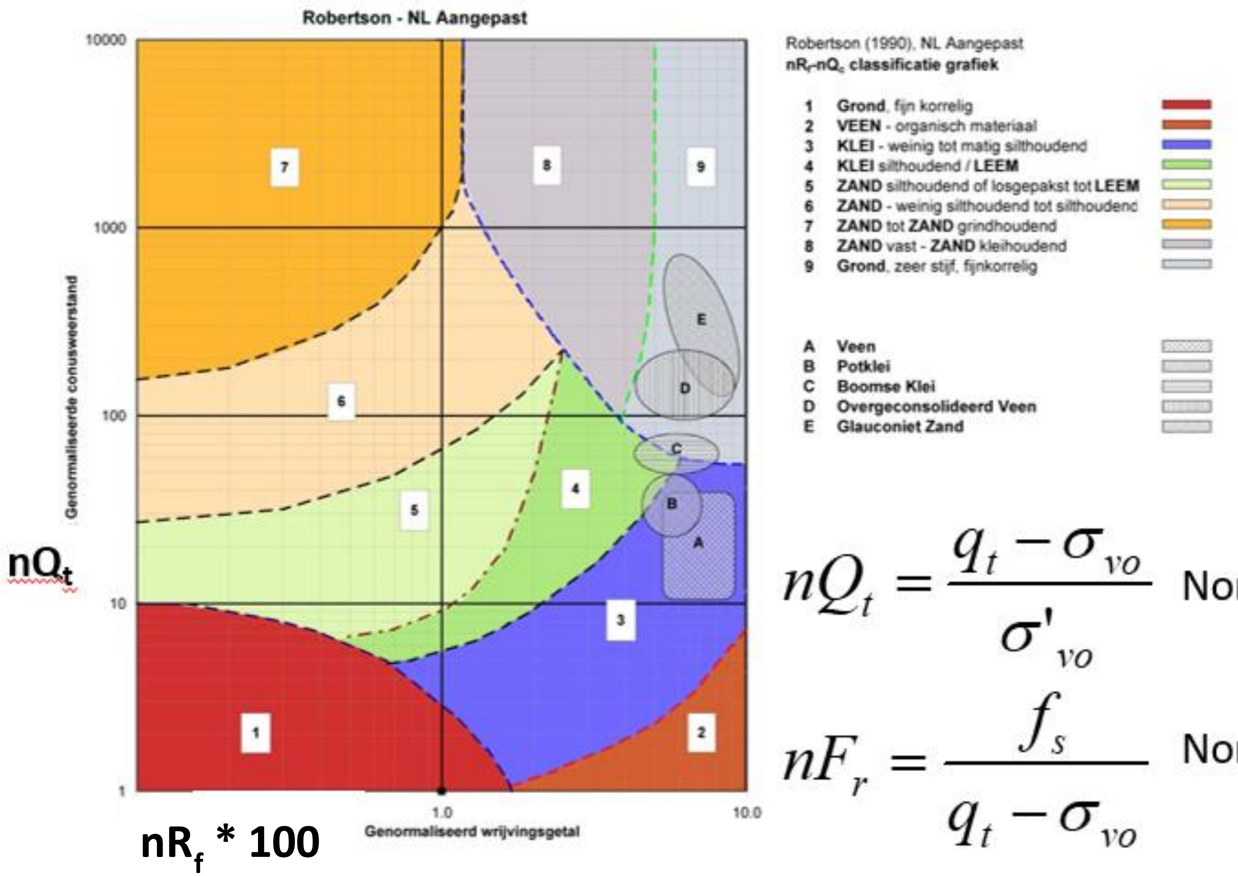
Table 2b from Eurocode 7

Hoofd-naam	Bijmengsel	Consis-tentie [b]	γ [c] kN/m³		γ_{sat} kN/m³		q_c [d] [g] MPa	C'_p		C'_s		$C_c/(1+e_0)$ [-]		C_α [f] [-]		$C_{sw}/(1+e_0)$ [e] [-]		E_{100} [f] MPa		φ' [f] Graden		c' kPa		c_u kPa	
grind	zwak siltig	los	17		19		15	500		∞		0,0046		0		0,0015		45		32,5		0			
		matig	18		20		25	1000		∞		0,0023		0		0,0008		75		35,0		0		n.v.t.	
		vast	19	20	21	22	30	1200	1400	∞		0,0019	0,0016	0		0,0006	0,0005	90	105	37,5	40,0	0			
	sterk siltig	los	18		20		10	400		∞		0,0058		0		0,0019		30		30,0		0			
		matig	19		21		15	600		∞		0,0038		0		0,0013		45		32,5		0		n.v.t.	
		vast	20	21	22	22,5	25	1000	1500	∞		0,0023	0,0015	0		0,0008	0,0005	75	110	35,0	40,0	0			
zand	schoon	los	17		19		5	200		∞		0,0115		0		0,0038		15		30,0		0			
		matig	18		20		15	600		∞		0,0038		0		0,0013		45		32,5		0		n.v.t.	
		vast	19	20	21	22	25	1000	1500	∞		0,0023	0,0015	0		0,0008	0,0005	75	110	35,0	40,0	0			
	zwak siltig, kleiig		18	19	20	21	12	450	650	∞		0,0051	0,0035	0		0,0017	0,0012	35	50	27,0	32,5	0		n.v.t.	
	sterk siltig, kleiig		18	19	20	21	8	200	400	∞		0,0115	0,0058	0		0,0038	0,0019	15	30	25,0	30,0	0		n.v.t.	
leem [e]	zwak zandig	slap	19		19		1	25		650		0,0920		0,0037		0,0307		2		27,5	30,0	0		50	
		matig	20		20		2	45		1300		0,0511		0,0020		0,0170		3		27,5	32,5	1		100	
		vast	21	22	21	22	3	70	100	1900	2500	0,0329	0,0230	0,0013	0,0009	0,0110	0,0077	5	7	27,5	35,0	2,5	3,8	200	300
	sterk zandig		19	20	19	20	2	45	70	1300	2000	0.0511	0,0329	0,0020	0,0013	0,0170	0,0110	3	5	27,5	35,0	0	1	50	100
klei	schoon	slap	14		14		0,5	7		80		0,3286		0,0131		0,1095		1		17,5		0		25	
		matig	17		17		1,0	15		160		0,1533		0,0061		0,0511		2		17,5		5		50	
		vast	19	20	19	20	2,0	25	30	320	500	0,0920	0,0767	0,0037	0,0031	0,0307	0,0256	4	10	17,5	25,0	13	15	100	200
	zwak zandig	slap	15		15		0,7	10		110		0,2300		0,0092		0,0767		1,5		22,5		0		40	
		matig	18		18		1,5	20		240		0,1150		0,0046		0,0383		3		22,5		5		80	
		vast	20	21	20	21	2,5	30	50	400	600	0,0767	0,0460	0,0031	0,0018	0,0256	0,0153	5	10	22,5	27,5	13	15	120	170
	sterk zandig	-	18	20	18	20	1,0	25	140	320	1680	0,0920	0,0164	0,0037	0,0007	0,0307	0,0055	2	5	27,5	32,5	0	1	0	10
	organisch	slap	13		13		0,2	7,5		30		0,3067		0,0153		0,1022		0,5		15,0		0	1	10	
		matig	15	16	15	16	0,5	10	15	40	60	0,2300	0,1533	0,0115	0,0077	0,0767	0,0511	1,0	2,0	15,0		0	1	25	30
veen	niet voorbelast	slap	10	12	10	12	0,1	5	7,5	20	30	0,4600	0,3067	0,0230	0,0153	0,1533	0,1022	0,2	0,5	15,0		1	2,5	10	20
	matig voorbelast	matig	12	13	12	13	0,2	7,5	10	30	40	0,3067	0,2300	0,0153	0,0115	0,1022	0,0767	0,5	1,0	15,0		2,5	5	20	30
variatiecoëfficiënt			0,05				–	0,25										0,10				0,20			

Classification graph Robertson [1990] modified for The Netherlands with results of Dutch Soils



Adjustments for the Dutch Soil Conditions

Area 4 and 5 are classified differently in order that loose sand layers and hallow clay layers are classified better

For q_c< 1. MPa and R_f > 5% the soils is classified as peat.

$$nQ_t = \frac{q_t - \sigma_{vo}}{\sigma'_{vo}}$$ Normalized Cone Resistance

$$nF_r = \frac{f_s}{q_t - \sigma_{vo}}$$ Normalized Friction Ratio

Where

nQ_t	= normalised cone resistance	nF_r	= normalised friction ratio
σ_{vo}	= total in situ vertical stress [kPa]	σ_{vo}'	= effective in situ vertical stress [kPa]
f_s	= measured sleeve friction [kPa]	q_t	= corrected cone resistance [kPa]. This is the value from the CPT.