Notes

Here we present the methodology followed to design the dewatering system of a deep excavation developed in Barcelona.

Introduction

- The methodology followed for designing the dewatering system of a large excavation developed in the Barcelona.
- The excavation was required as assembly shaft of a tunnel boring machine for the construction of the High Speed Train tunnel in Barcelona.
- The excavation site was located in a densely populated area and errors in the dewatering system and/or excavation process may induce damage in near buildings.
- The excavation was developed combining the cut and cover method with pumping wells
- A close historical building (Torre del Fang) must to be preserved.

Location of the study site

Notes

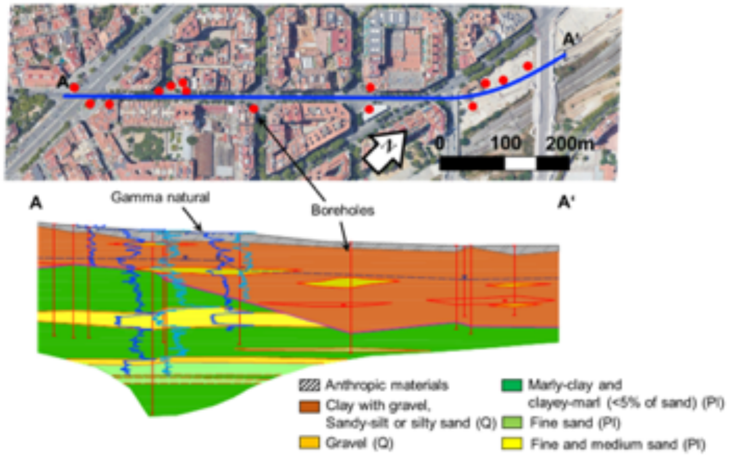
The excavation was developed using the cut and cover method combined with pumping wells and was required to construct the assembly shaft of the tunnel boring machine for drilling the high speed train tunnel in Barcelona.

The excavation was developed in a densely populated area and was close to a historical building. Therefore, the dewatering system had to be designed carefully to avoid large soil displacements.

Geological characterization

Borehole logging + Gamma Natural Ray log

General cross-section

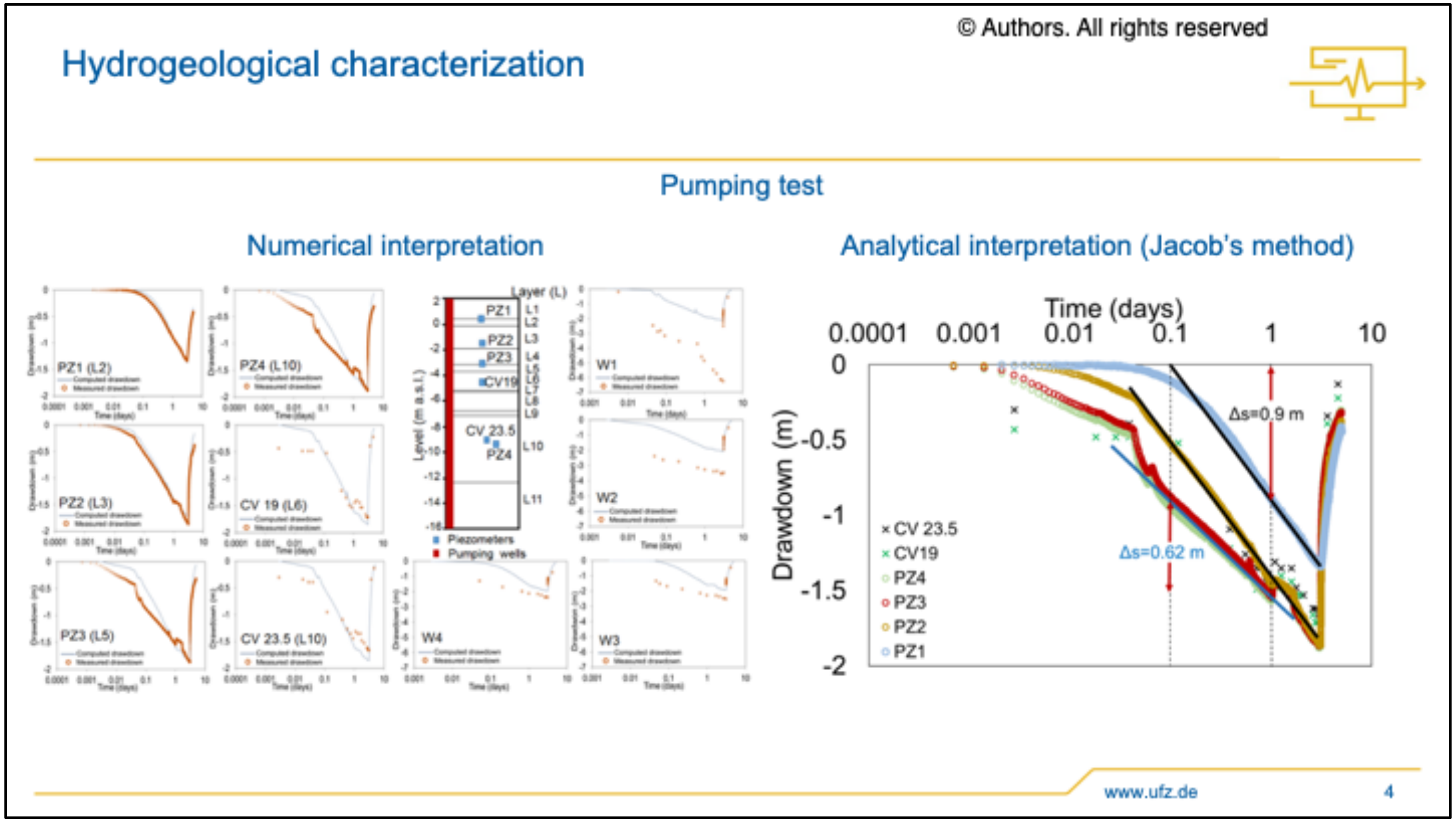


Detailed layers below the water table

Layer	Period	Top (m a.s.l)	Bottom (m a.s.l)	Description	Piezometer
L1	Quaternary	2	0.45	Silty-clay with sand and poor proportion of fine gravel	
L2		0.45	-0.1	Silty-clay with medium gravel (25-30%)	PZ1
L3		-0.1	-1.95	Clayey-sand (fine) with fine gravel (25-30%)	PZ2
L4		-1.95	-3.15	Clayey-sand (very fine) with few gravel (5%)	
L5		-3.15	-3.7	Fine-medium sand with some clay (5%)	PZ3
L6		-3.7	-5.15	Medium-coarse sand with some clays (5%) and medium gravel	CV19
L7		-5.15	-5.35	Medium-fine gravel with a sandy-calyey matrix	
L8		-5.35	-6.75	Sand (medium to coarse) and gravel	
L9		-6.75	-7.15	Medium to coarse gravel	
L10		-7.15	-12.35	Heterometric gravel with salty matrix (5%)	PZ4 - CV23
L11	Neogen (Pliocene)	-12.35	-	Marly-clay	

Notes

The first step consisted in characterise geologically the soil using borehole logging and Gamma Natural Ray log. The combination of both techniques allowed differentiating different geological layers. Specifically, 11 geological layers were differentiate from the water table up to a deep and thick low hydraulic conductivity formation (i.e., Pliocene marls).



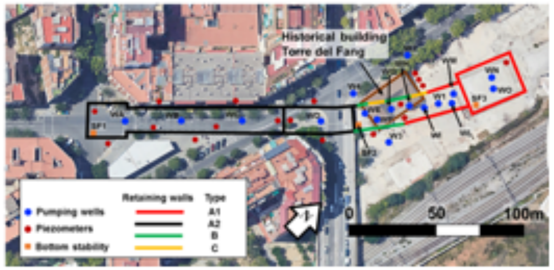
Notes

Six piezometers screened at different depths were designed considering the geological characterisation. The objective was the groundwater response at different layers to a previous pumping developed in the site. The previous pumping, during which 4 pumping wells were used, was used as a pumping test to characterize hydrogeologically the site. The pumping test was interpreted numerically and analytically. The numerical interpretation provided the parameters of each layer while the analytical interpretation allow validating the numerical results by comparing the effective hydraulic conductivity. On the left, you can see the fitting between observed and computed drawdown, which was acceptable. On the right you can see the interpretation of the pumping test by using the Jacob's method.

Dewatering system

- The excavation (in the model) is subdivided in areas depending on the excavation depth and the presence of perpendicular diaphragm walls that isolate different parts of the excavation.
- The head is prescribed 2 meters below the maximum excavation depth and the required pumping rate is computed.
- Wells are distributed homogeneously. Their number depend on the required pumping rate.
- Bottom stability was computed at different points far from the pumping wells to ensure that the safety factor ($SF = \frac{\sigma_V}{P_W}$) was higher than 1.2.

Required drawdown



Distribution of pumping wells

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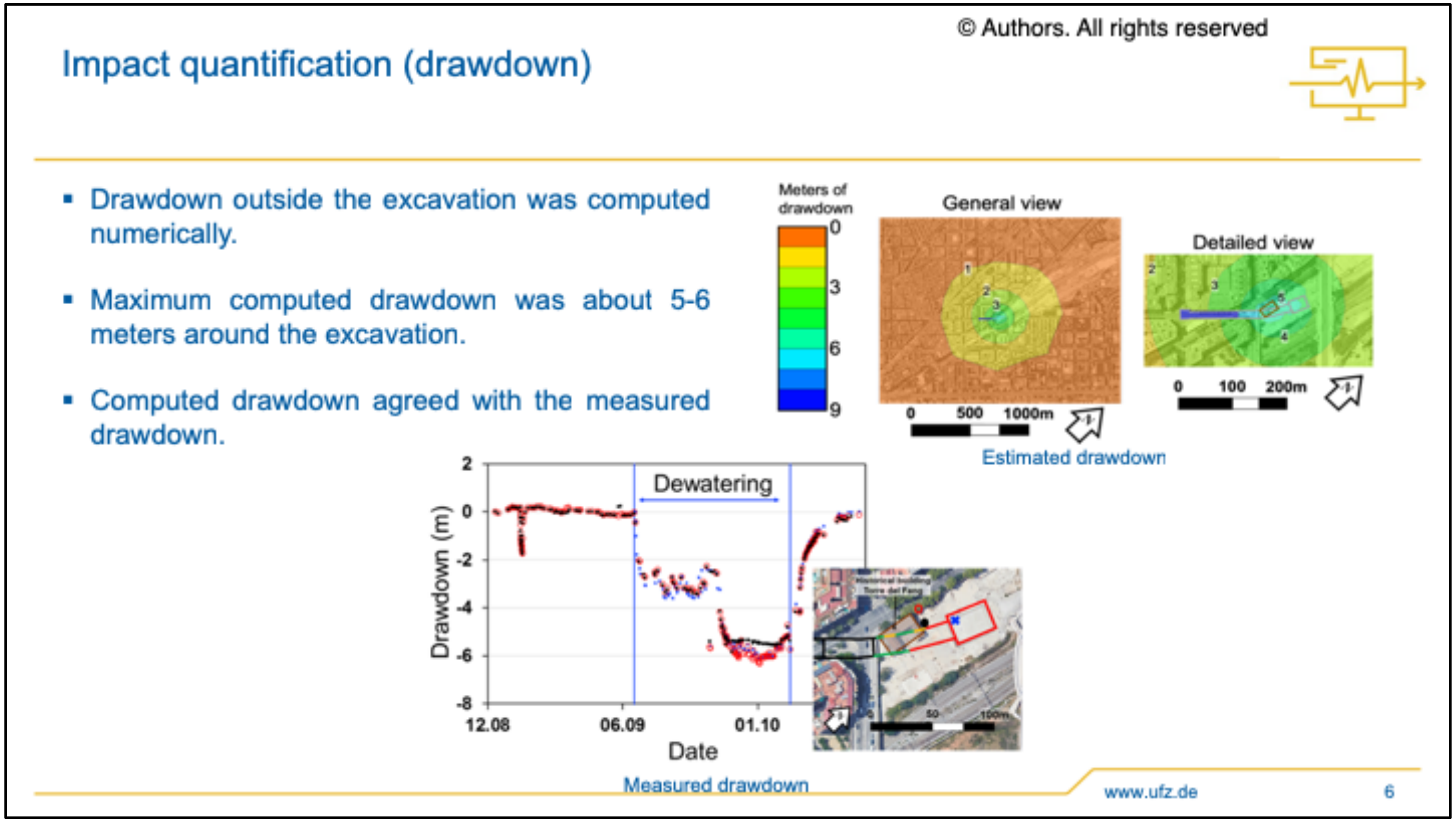
After, a numerical model of the site including the diaphragm walls was developed. This numerical model allowed calculating the total pumping rate to ensure dry a safe conditions during the excavation.

The total pumping rate was calculated by prescribing the head two meters below the excavation bottom. Given the characteristics of the diaphragm walls and the excavation, it was possible to differentiate four isolated zones. Therefore, an individual pumping rate was calculated for each one.

Subsequently, a number of pumping wells was distributed homogenously inside each zone according to the needed pumping rate.

Finally, the safety factor against bottom uplift or liquefaction was calculated at different locations. These locations were located far from the pumping wells that is where the bottom stability could be more compromised. The safety factor was calculated considering the water pressure, which was obtained numerically, and the weight of the soil.



Notes

The next step consisted in computing the impacts of the dewatering outside the excavation.

First, the drawdown was calculated numerically. On the right you can see the drawdown distribution in steady state assuming the maximum drawdown into the excavation. The maximum estimated drawdown was between 5 and 6 meters, which agreed with the drawdown measured during the excavation phase. On the figure below, you can see the measured drawdown during the excavation phase. The agreement between computed and observed drawdown proves the accuracy of the numerical model.

Impact quantification (settlements)

- Settlements outside the enclosure were computed analytically from the computed drawdown as:

$$\rho_i = \gamma_W s_i D_i \alpha_i,$$

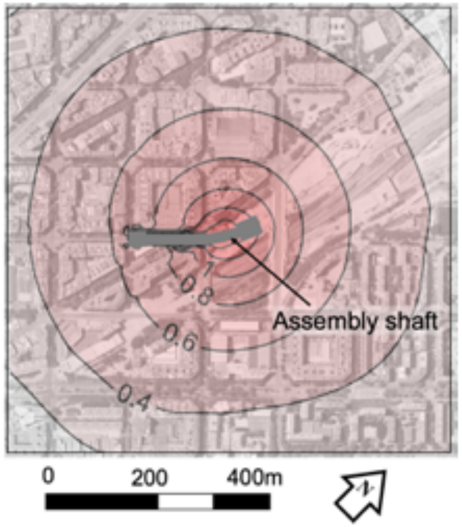
where ρ_i is the settlement of layer i, γ_W is the specific weight of the water, s_i is the drawdown at each layer i, which is expressed in meters of water column, D_i is the thickness of layer i and α_i is the soil compressibility

- The soil compressibility is deduced from the specific storage coefficient obtained during the pumping test since the aquifers is over-consolidated and behaves elastically, thus, considering the equation proposed by Jacob (1950):

$$S_i = \gamma_W \theta_i D_i \left(\beta + \frac{\alpha_i}{\theta_i}\right)$$

where θ_i and β are the porosity of layer i anc the water compressibility, respectively. Assuming that β is very small compared to α, it is possible to consider that $S_S = \alpha$

- Maximum computed settlements around the excavation were about 1.2 mm that agreed with the measured ones during the dewatering phase.



Estimated settlements

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After, using the computed drawdown, pumping settlements outside the enclosure were computed. Settlements were computed using the uppermost equation. In this equation, we know more or less all the parameters except the soil compressibility. Given that we didn't have information from laboratory tests we used the storage coefficient obtained from the pumping test interpretation to derive the soil compressibility. This was possible because the soil in this area is overconsolidated and behaves elastically. Therefore, if we consider the equation proposed by Jacob for elastic soils, we can assume that the soil compressibility is very similar to the specific storage coefficient.

On the right you can see the distribution of computed settlements around the excavation site.

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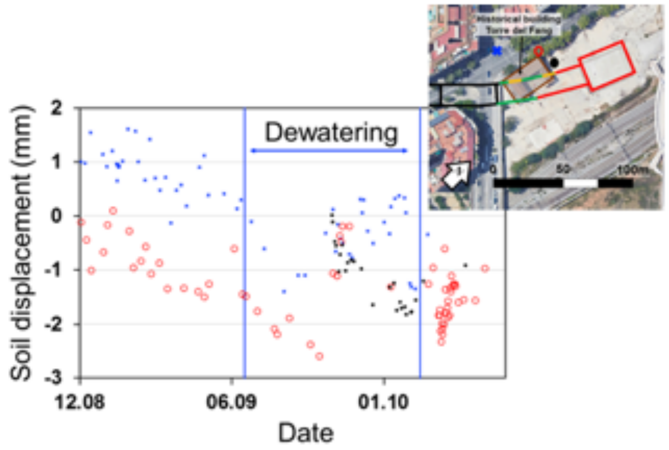

Measured settlements

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The computed settlements near the excavation site were about 1.2 mm that also agreed with the observed settlements during the dewatering as you can see in the figure on the right.

Conclusions

- The proposed methodology allowed designing an efficient and safe dewatering system
- Combination of numerical and "classical" analytical methods can help us to improve the interpretation of pumping tests.
- The bottom stability can be ensure by applying a simple approach.
- Settlements can be approximated using a straightforward methodology . Thus, without hydro-mechanical models that require more effort and parameters that usually are not well known

Notes

To conclude:

- The proposed methodology is useful to design efficient and safe dewatering systems.
- The combination of numerical methods and classical analytical solutions can help us to improve the interpretation of pumping tests.
- Bottom stability in excavations developed by the cut and cover method combined with pumping wells can be estimated using a simple approach
- And finally, soil displacements can be approximated using a relatively simple analytical methodology without using coupled hydromechanical models.

Questions?