Unusual Geotechnical Solutions at the Leixões Cruise Terminal

Solutions Géotechniques Inusuelles au Terminal de Croisières de Leixões

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ABSTRACT: The aim of this paper is to present the main design and execution criteria related with both cofferdam and foundations solutions, using soil-cement panels, micropiles and bored piles in several applications, at the new Leixões Cruise Terminal, located at the Leixões Port, in Portugal. The Terminal building is being built with one basement on a marine environment, over very difficult geological and geotechnical conditions, which demanded the use of some unusual and integrated geotechnical solutions.

RÉSUMÉ : Dans cet article sont présentés les principaux critères de conception et d'exécution associés aux solutions des parois de soutènement et des fondations, utilisant panneaux de sol - cément, micropieux et pieux forés, pour le nouveaux Terminal de Croisières du Port de Leixões, au Portugal. Le bâtiment, avec un plancher au-dessous du niveau de l'eau est placé dans une ambiance maritime. Ce scénario complexe a demandé l'utilisation de quelques solutions géotechniques peu communes et intégrées.

KEYWORDS: cutter soil mixing, piles, micropiles.

1 INTRODUCTION

The construction of the new Cruise Terminal at Leixões, at the North of Portugal, as a consequence to the constant increase of the cruise traffic, was a challenge from both the geotechnical and structural point of views, mainly due to very difficult and unusual conditions, ranging from the geological and geotechnical scenario to the existent and under operation Leixões Port infrastructures, mainly the South break water, as well as the existent boarding deck (Figures 1 and 2).

Figure 1. Site location.

According to the Terminal Project it was necessary to build one basement bellow the water table, including several earth retaining structures in order to allow the excavation works on dry conditions leading to a global cofferdam effect. For this purpose soil - cement panels, using CSM technology, reinforced with steel profiles, micropiles (both for foundation and cut off effect) and the existent sheet piles were used. Also pointed out are the adopted special foundations of a very complex structure, including bored piles and micropiles (Figure 3).

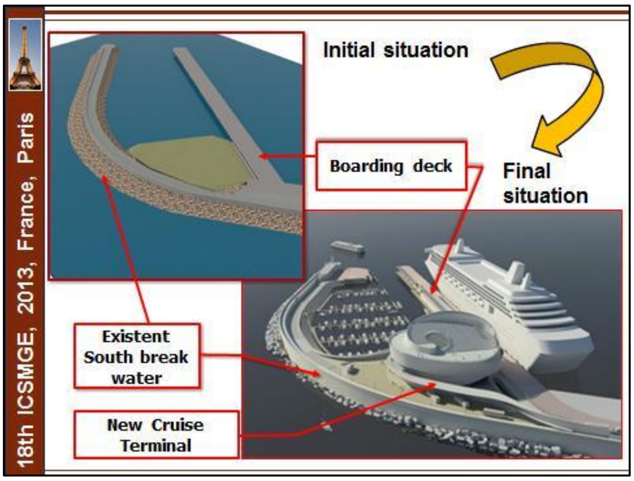

Figure 2. Existent and final situations.

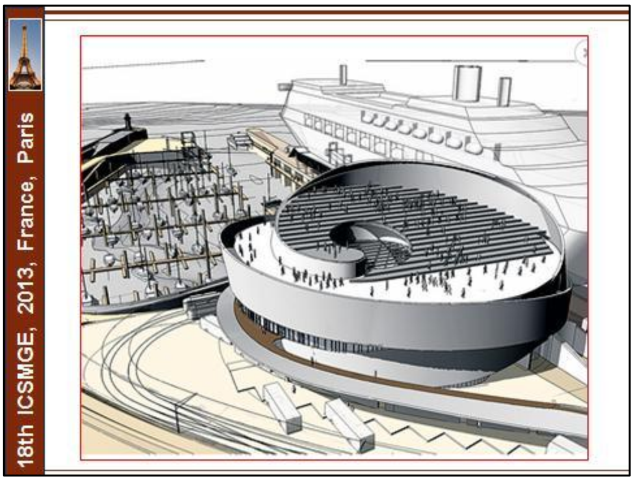

Figure 3. Perspective of the Cruise Terminal building.

2 MAIN CONDITIONS

2.1 Geological and geotechnical conditions

The local geological conditions were homogeneous, but very complex. The excavation works intersected, from the surface, level +5,0m, sandy and silty materials, correspondent to the hydraulic embankment created for working platform purpose. The embankment fill is resting over the bed rock, weathered schist, as previously to the construction of the embankment the existent alluvial material was dredged (Figures 4 and 5).

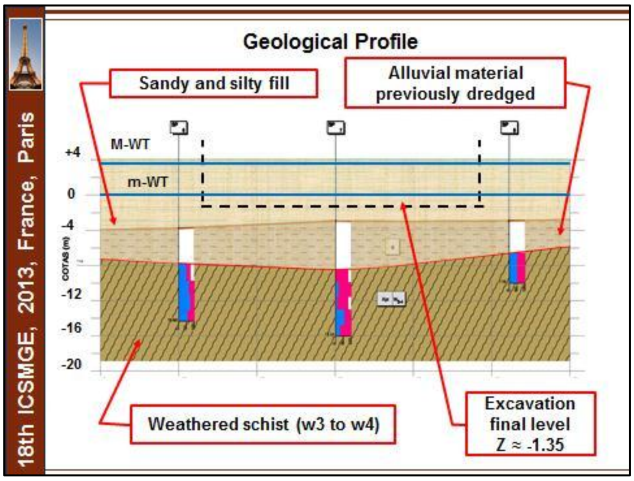

Figure 4. Geological profile.

The water table level ranged from +4,0m to -0,25m according to the Atlantic Ocean tide (Figure 5).

Main Geotechnical Parameters

Geotechnical Zone	Ground	γ [kN/m³]	E [kPa]	ϕ [º]	c′ [kPa]
ZG1	Sandy and silty fill	16	15.000	20	5
ZG2	Break water stones (rip rap)	22	60.000	25	10
ZG3	Schist	20	120.000	50	100

Water level ranged from +4,0m (high tide) to -0,25m (low tide)

Figure 5. Adopted geotechnical parameters.

2.2 Other conditions

The main neighbourhood conditions included the existent infrastructures, under operation, mainly: the South side break water, accommodating several infrastructures, and the East side cruises boarding deck, a reinforced concrete slab supported by reinforced concrete bored piles. When the embankment was constructed, a sheet pile wall was installed at the boarding border face, in order to improve the hydraulic embankment confinement (Figure 6).

The South side cofferdam walls, as well as of the South side special foundations had to intersect the break water rip rap (8kN to 130kN). This situation was confirmed as an important issue mainly for the execution of the cofferdam walls, as well as for the construction of the bored piles.

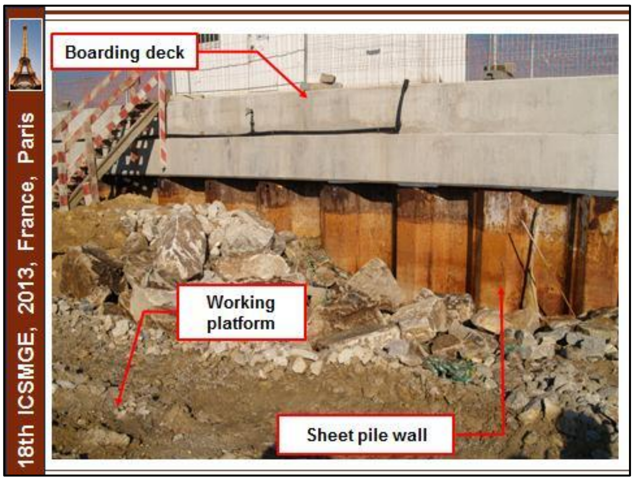

Figure 6. Main neighbourhood conditions: boarding deck.

3 ADOPTED SOLUTIONS

3.1 Global cofferdam

In order to allow the excavation works on dry conditions, three main retaining structures solutions were adopted (Figure 7).

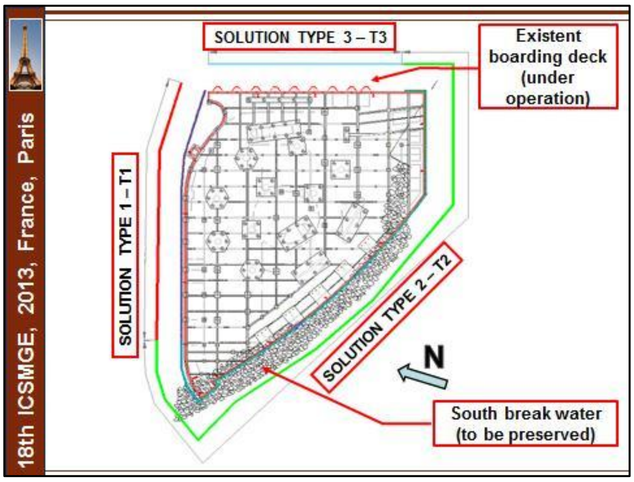

Figure 7. Adopted solutions for the global cofferdam.

<u>Solution type 1 (T1)</u>: soil - cement panels with a cross section of 2,4 x 0,5m^2, including 0,20m of overlapping and 1m of embedment at the bed rock, performed using the CSM technology (Figures 8 to 11), taking into account the experience obtained on previous works (Pinto et al., 2011).

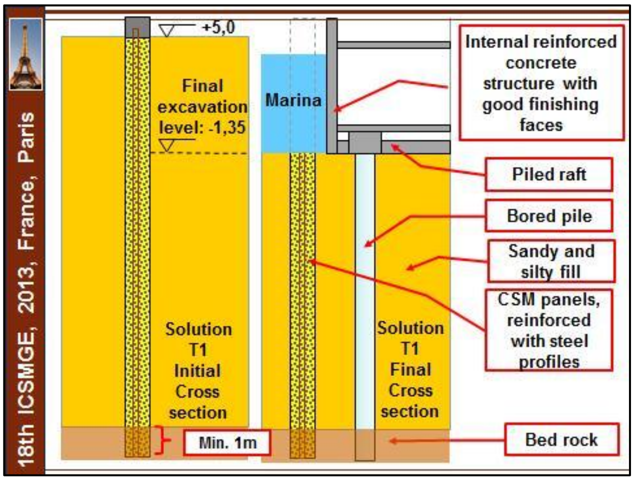

Figure 8. Solution T1 – initial and final cross section.

The soil - cement panels, with UCS resistance not lesser than 4MPa, were reinforced with vertical IPE330 steel profiles (Euronorm 19-57), spaced 0,55m in average, in order to resist to the earth and water pressures, as well as to ensure a better control of the deformations. The steel profiles were placed inside the panels, before the cement started the curing process and capped by a reinforced concrete beam (Figure 8 to 11).

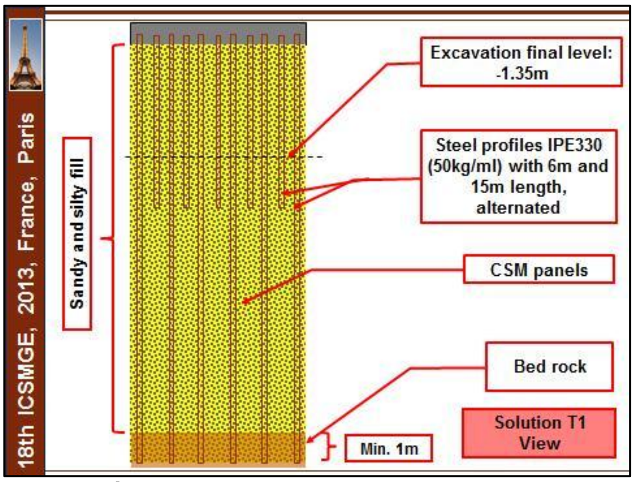

Figure 9. Solution T1 – view.

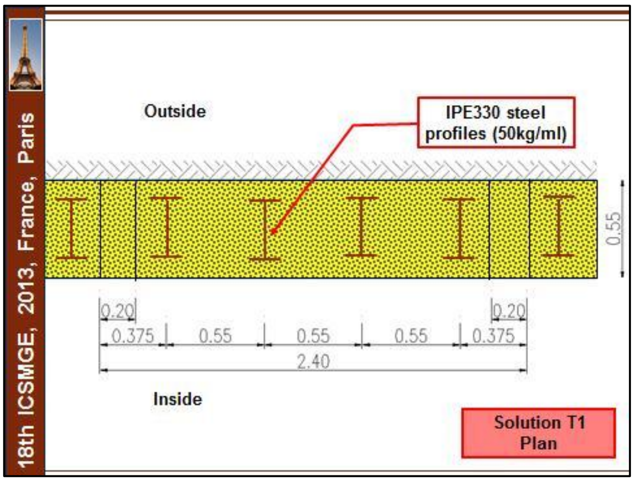

Figure 10. Solution T1 – plan.

The soil - cement panels will be demolished from the internal structure foundation level to the top, in order to allow the reinforced concrete (r.c.) wall with a very good finishing face, being visible from the adjacent marina, (Figure 12).

Figure 11. Solution T1 – view of soil-cement panels after excavation.

Solution type 2 (T2): soil - cement panels with a cross section of 2,4 x 0,5m^2, including 0,20m of overlapping on a height of approximately 6.5m, correspondent to the previous excavation depth, performed in order to replace the break water rip rap by a sandy fill. The panels were built using the CSM technology. Bellow the soil - cement panels the cofferdam cut off effect was assured through a curtain, performed using alternated slurry cement injections through steel tubes and micropiles N80 ϕ114,3x12mm, those also with foundation purposes and sealed 4m on the bed rock (Figures 12 to 15).

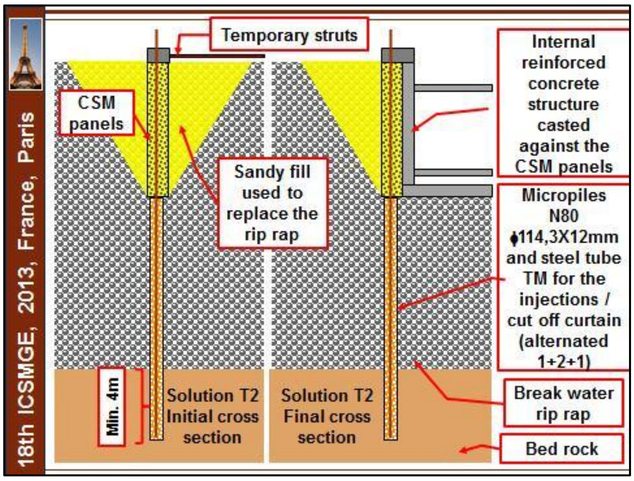

Figure 12. Solution T2 – initial and final cross section.

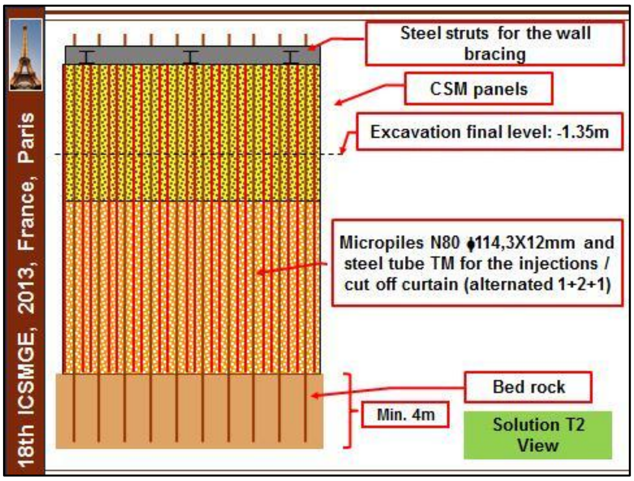

Figure 13. Solution T2 – view.

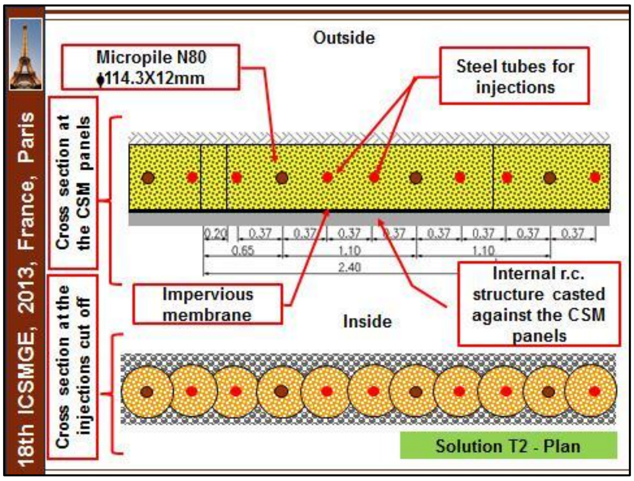

Figure 14. Solution T2 – plan.

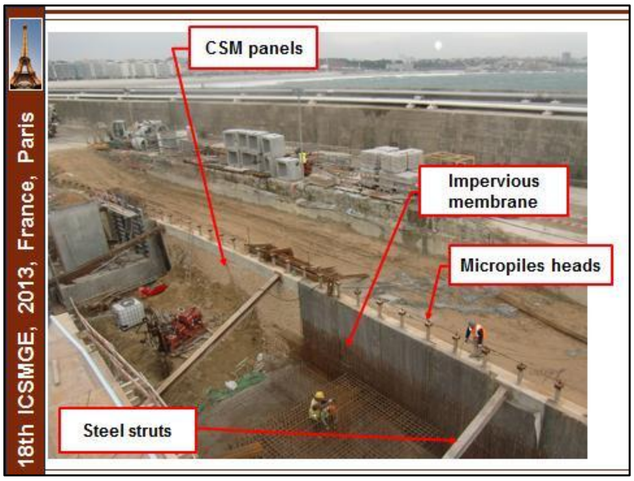

Figure 15. Solution T2 – soil - cement panels after excavation.

Solution type 3 (T3): the existent sheet pile wall was integrated on the global cofferdam, using a bracing system, steel ties, connected to the head of the boarding deck foundation piles (Figure 16).

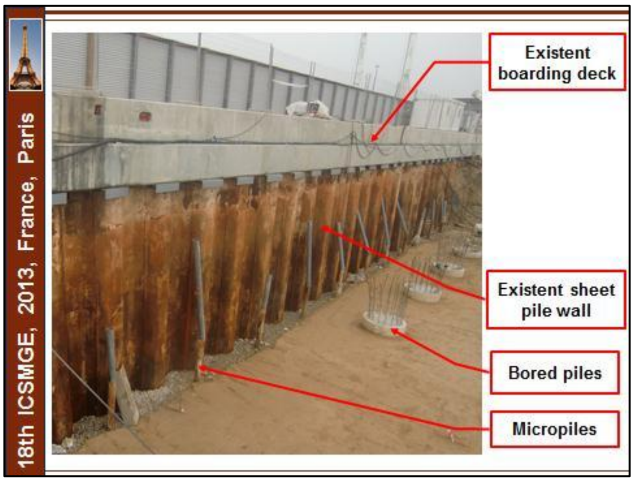

Figure 16. Solution T3 – view of the sheet pile wall after excavation.

3.2 Foundations

For the foundations of the Terminal building reinforced concrete bored piles (ϕ800mm and ϕ 1200mm) and steel micropiles N80 ϕ139,7x12mm were adopted. Micropiles were used also to resist to both light compression and tension loads, when the structure self-weight was not enough to equilibrate the hydrostatic pressures. Micropiles were designed against corrosion taking into account a sacrificial thickness. All the piles and micropiles were capped by a reinforced concrete raft, cast against an impervious membrane.

4 DESIGN

For the design of the adopted solutions, earth retaining structures and foundations, 2D, including axisymmetric, FEM analysis was carried out, using Plaxis software (Figure 17).

5 MONITORING AND SURVEY PLAN

A monitoring and survey plan was applied taking into account the need to perform the construction in safe and economic conditions, including inclinometers and topographic marks. Measurements confirmed the excellent overall behavior of the adopted solution, with the exception of a local area at solution T1, demanding the implementation of strengthening measures: inclined steel struts connecting the capping beams to the foundations piles (Figure 18).

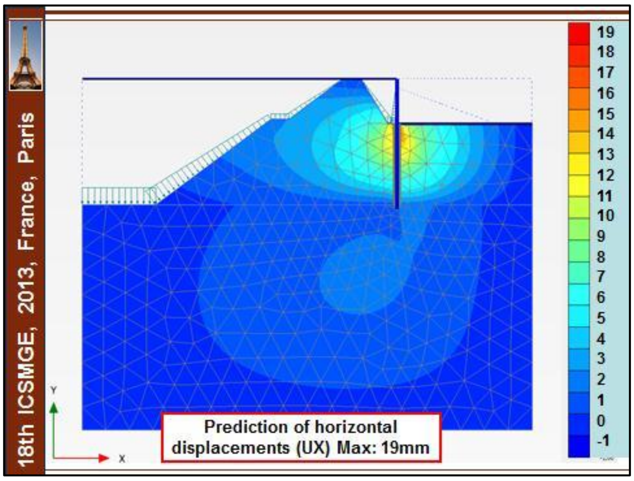

Figure 17. 2D FEM analysis for section T1.

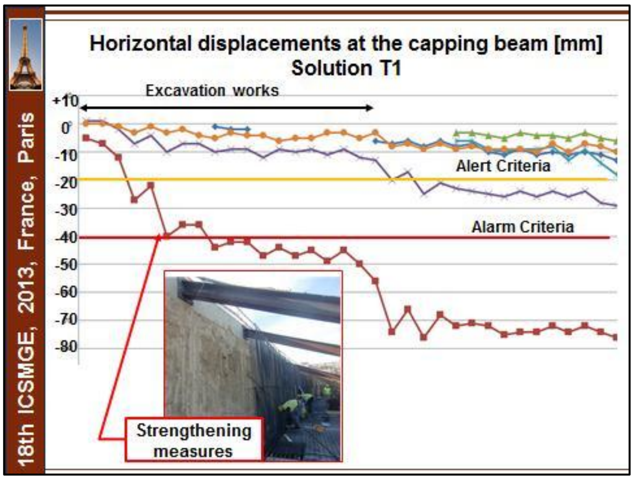

Figure 18. Horizontal displacents at topographic marks - solution T1.

6 MAIN CONCLUSIONS

Taking into account the complex scenario of the presented work, it is possible to point out the follwing points:

- Good water tightness, mainly due to the cofferdam effect assured by the embedment of the soil - cement panels at the bed rock, as well as due to the injections cut off curtain.
- Low deformations, confirmed by the monitoring results.
- Peripheral r.c. walls with very good finishing faces.

Also very important was the control of both costs and construction schedule.

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8 REFERENCES

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