Innovative Solution of King Post Walls combined with CSM Panels

Solution Innovante de Parois Berlinoise combinée avec des Panneaux de CSM

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ABSTRACT: The aim of this paper is to present the main design and execution criteria related with the innovative solution of earth retaining walls combining the King Post Walls (Berlin) with the CSM (Cutter Soil Mixing) panel's technology. A case study where the solution was applied is presented, confirming the solution excellent overall performance.

RÉSUMÉ : Dans cet article sont présentés les critères principaux de conception et d'exécution de la solution innovante qui combine des parois de soutènement (Berlinoise) avec de panneaux de CSM (Cutter Soil Mixing). Un cas d´étude avec ce type de solution est présenté, confirmant l'excellente performance globale de la solution.

KEYWORDS: cutter soil mixing, Berlin wall

1 INTRODUCTION

The traditional and widespread King Post Walls (Berlin) technology has some disadvantages, mainly the excavation schedule as well as the confinement reduction of the supported soil during the excavations works, mainly in cohesionless soils (Figure 1). In order to overcome this disadvantage, the Berlin solution can be combined with the CSM technology, which acts as a preliminary treatment of the supported soil.

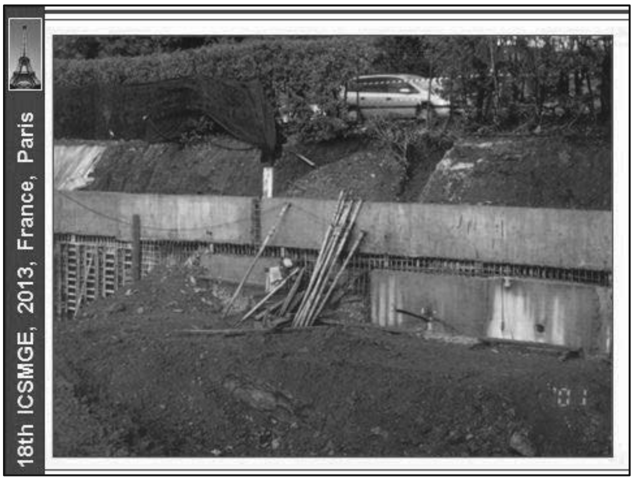


Figure 1. View of the confinement reduction of the supported soil during the excavation works using the Berlin Wall technology.

As an example of this combined solution the case of the enlargement of a railway platform, in order to accommodate the new infrastructures at the connection between two main railway lines in Lisbon, Portugal, is presented (Gomes Correia et al., 2013), following previous works using the CSM technology (Pinto A. et al., 2011). For this purpose it was necessary to perform several excavations with 13m of maximum depth. Due to neighbourhood conditions, three retaining structures (M1, M2 and M3) were built using the combination of Berlin wall with the CSM technology. In this paper the case of the M3 wall is presented, with 13m height and about 66m wide (Figure 2).

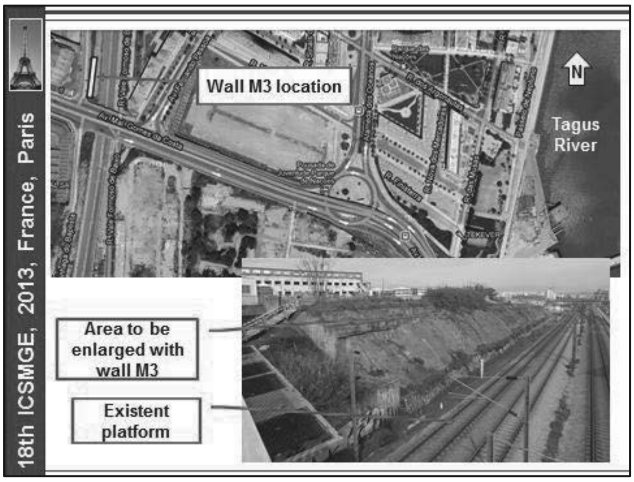


Figure 2. Wall M3 location.

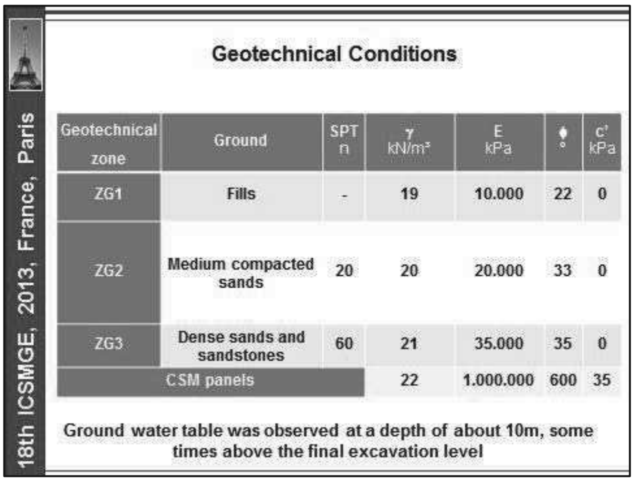
2 MAIN CONDITIONS

2.1 *Geological and geotechnical conditions*

The local geological conditions were heterogeneous. The excavation works intersected, from the surface, heterogeneous landfills and Miocene medium dense to dense sands and sandstones. The ground water table was located about 5m above the final excavation level (Figures 3 and 6).

2.2 *Other conditions*

The main neighbourhood conditions included the existent railway lines (under operation and connecting the two Portuguese main cities), several industrial and sensitive buildings, located behind the walls, as well as the important viaduct of the Marechal Gomes da Costa Avenue, over the railway lines, pointing out the importance to control the walls deformation during and after the excavation works (Figure 4).



Geotechnical Conditions

Geotechnical zone	Ground	SPT n	γ kN/m³	E kPa	ϕ' °	c' kPa
ZG1	Fills	-	19	10.000	22	0
ZG2	Medium compacted sands	20	20	20.000	33	0
ZG3	Dense sands and sandstones	60	21	35.000	35	0
CSM panels			22	1.000.000	600	35

Ground water table was observed at a depth of about 10m, some times above the final excavation level

Figure 3. Main geotechnical conditions.

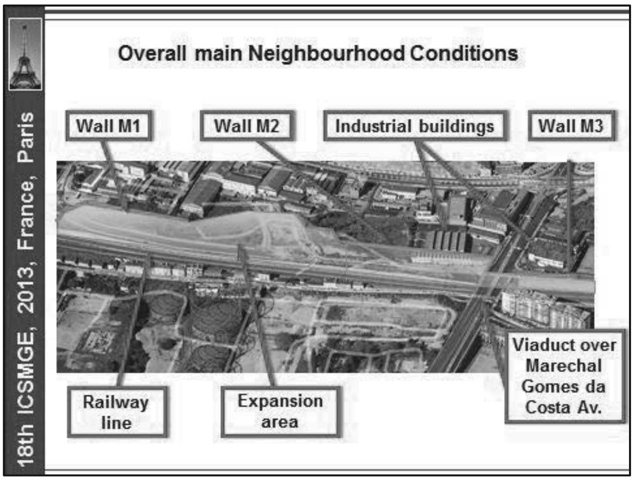


Figure 4. Overall main neighbourhood conditions.

3 ADOPTED SOLUTION

In order to allow the excavation works minimizing the ground loss of confinement effect, soil - cement panels with a maximum depth of about 18m and a cross section of 2,4 x 0,5m^2, including 0,20m of overlapping, were preliminarly built using the CSM technology. The panels were reinforced with vertical IPE240 hot rolled steel profiles (Euronorm 19-57), spaced in average 1,1m, in order to resist to the earth and ground water pressures, as well as to assure a better control of the retaining structure deformations (Figure 5).

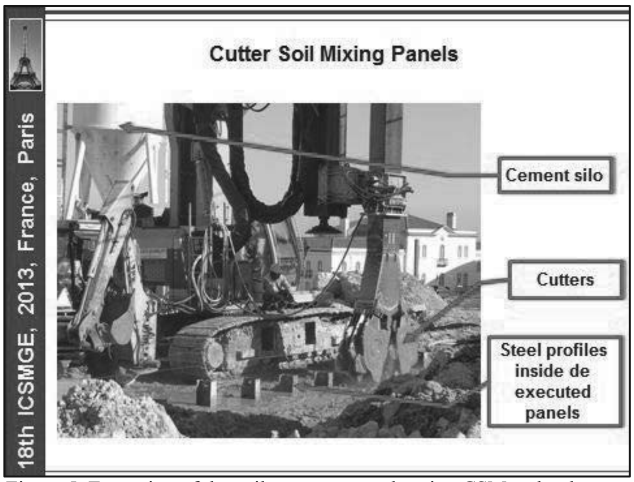


Figure 5. Execution of the soil - cement panels using CSM technology.

The steel profiles were placed inside the soil - cement panels, before the cement started the curing process, and were braced by four or three levels of permanent ground anchors, applied at the reinforced concrete capping beam, as well as at the distribution beams (Figures 6, 7 and 8).

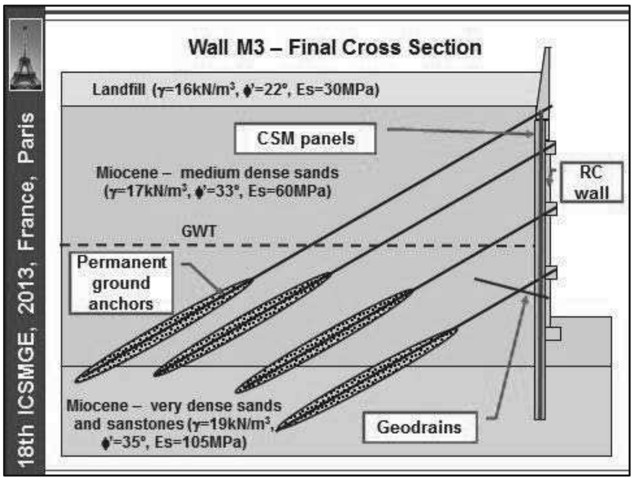


Figure 6. Final cross section of the wall M3.

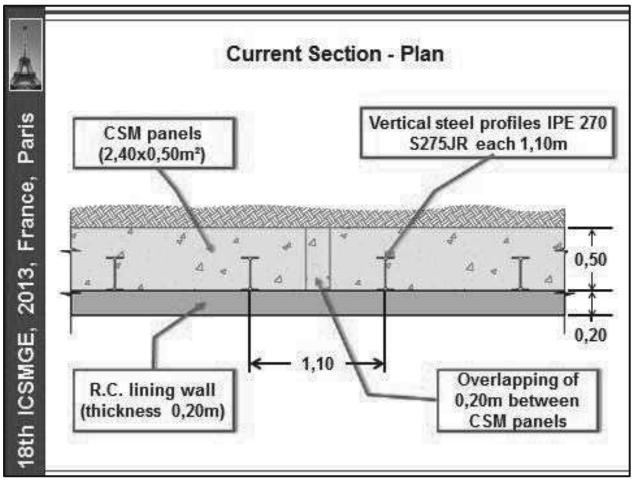


Figure 7. Plan of the wall M3 current section.

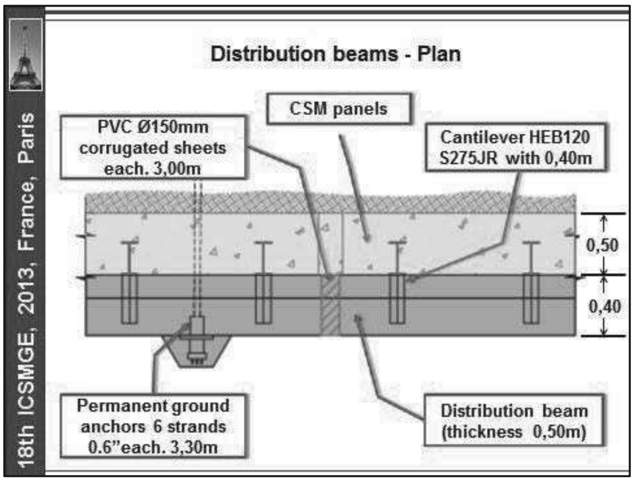


Figure 8. Plan of the wall M3 at the distribution beams section.

As already stated, according to the innovative solution combining the Berlin wall with the CSM technology, the soil - cement panels were designed in order to be integrated on the final earth retaining solution, including the 0,2m thickness lining reinforced concrete (RC) wall and beams (capping and distribution), and also to minimize the water inflow to the excavation platform (Figure 7, 8 and 9). The preliminary ground improvement effect due to the soil - cement panels allowed the execution of the excavation works without any restrictions, with big advantages on the excavation works schedule, as well as on the RC wall finishing face (Figure 9).

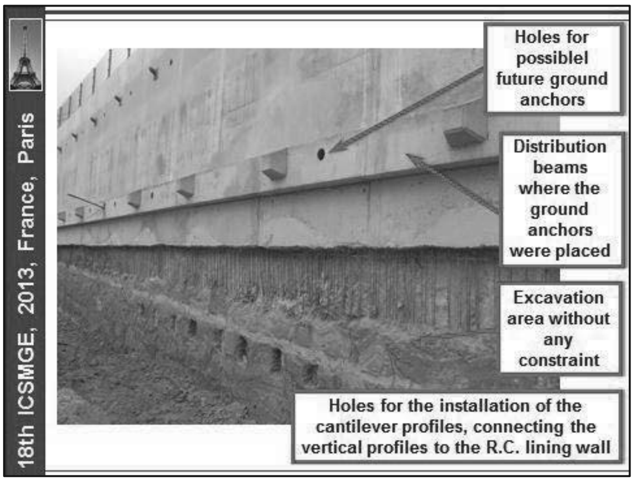


Figure 9. Plan of the wall M3 at the distribution beams section.

The combination of the soil - cement panels with the lining RC wall allowed the construction of a safe and economical solution, overcoming the main disadvantages of the Berlin wall solution (initial solution proposed for the same Project) and spreading the solution application field to almost every kind of geological and geotechnical scenarios, as well as to complex and sensitive neighbourhood conditions.

4 MAIN CONSTRUCTION PHASES

One of the main advantages of the adopted solution was the possibility to reduce the excavation works overall schedule and also to decrease the loss of confinement of the excavated soil and, consequently, to decrease the wall and the neighborhoud structures and infrastructures deformations.

The main construction phases are presented on the Figures 10 to 15. As already stated, it should be pointed out the big advantage of the full width excavation, in each level, only possible due to the soil – cement panels ground improvement effect, leading to a big optimization of the construction overall schedule. Due to the versatility of the CSM technology, it should also be pointed out the possibility to apply this solution to almost every kind of geological and geotechnical scenarios, ranging from heterogeneous landfills and soft soils to medium weathered rocks, like the sandstones intersected on present site.

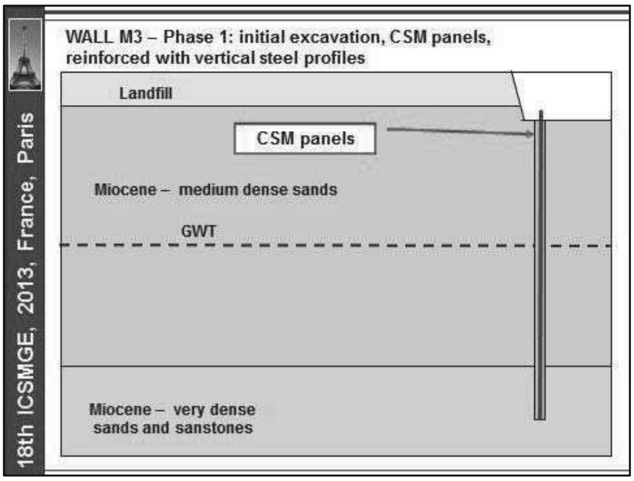


Figure 10. Phase 1.

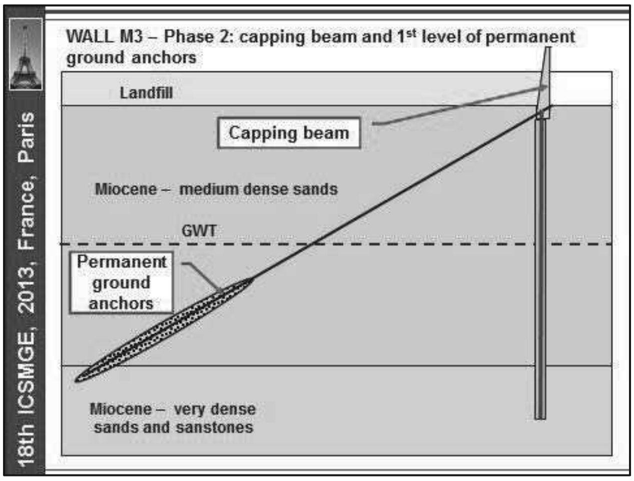


Figure 11. Phase 2.

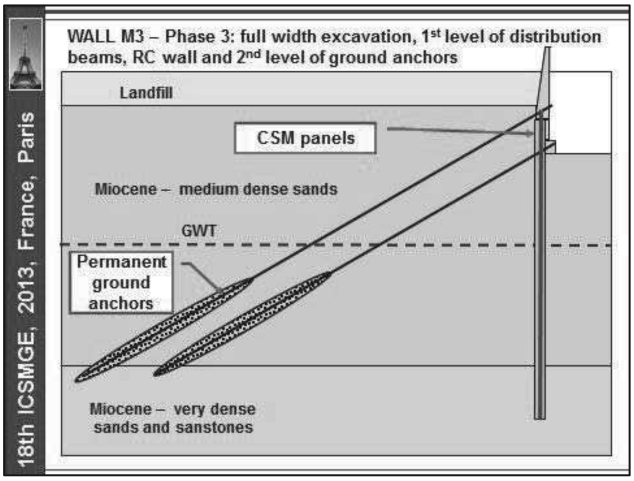


Figure 12. Phase 3.

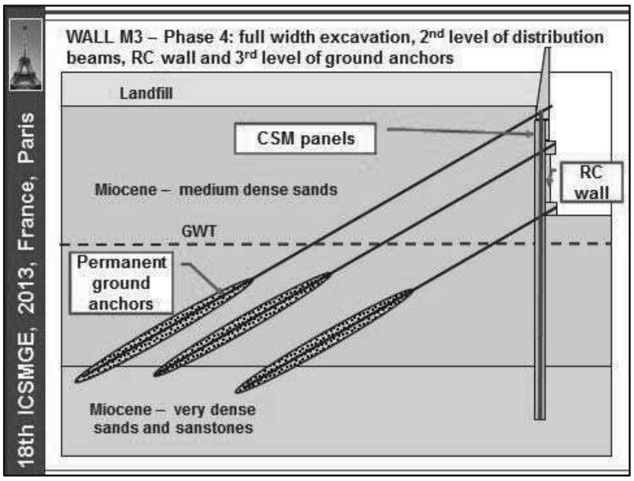


Figure 13. Phase 4.

A tight quality control and quality assurance of the main geotechnical works: soil – cement panels using CSM technology and permanent ground anchors, was implemented, including UCS tests on soil – cement cores and suitability and reception tests on permanent ground anchors (Gomes Correia et al., 2013).

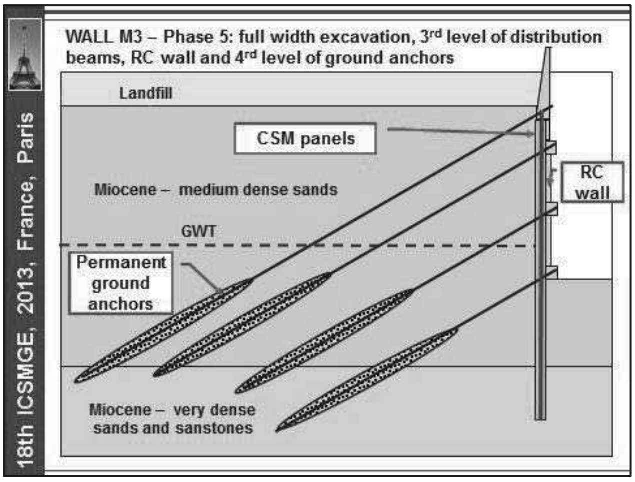


Figure 14. Phase 5.

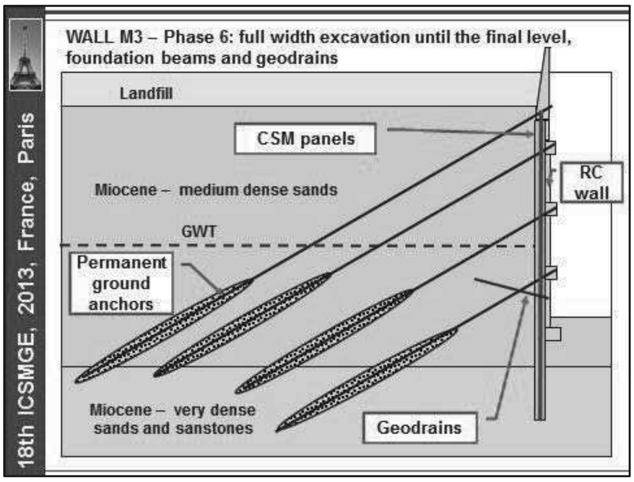


Figure 15. Phase 6.

5 DESIGN

All the soil - cement panels were design in order to achieve an unconfined compression resistance of at least 4,0MPa and a Young Modulus of 1GPa. Due to the soil and water chemical properties, pozolanic cement was adopted. For the design of the adopted solution FEM analysis was carried out, using Plaxis 2D software. The maximum estimated horizontal displacement was about 64mm due to the most critical seismic action (Figure 16).

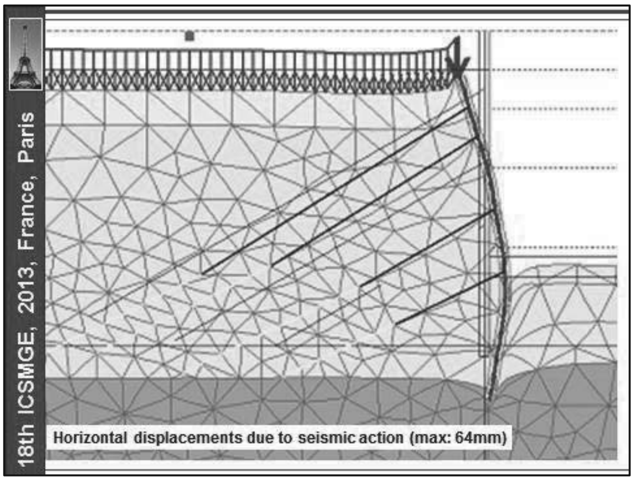


Figure 16. Horizontal displacements according to the FEM model.

6 MONITORING AND SURVEY PLAN

Considering the innovative aspects of the described solutions, a tight monitoring and survey plan was applied, taking into account the need to perform the construction in safe and economic conditions, for both the site and the neighbourhood conditions. In order to accomplish this goal the following equipment's /devices were installed: inclinometers (11un.), topographic targets (65un.) and ground anchors load cells (22un.). Measurements confirmed the excellent overall behavior of the adopted solution, confirming the importance of the previous confinement on the supported soil due to the soil – cement panels, leading, in general, to lower deformations than the ones predicted at the design stage, in spite of some anomalous movements, as presented on Figure 17.

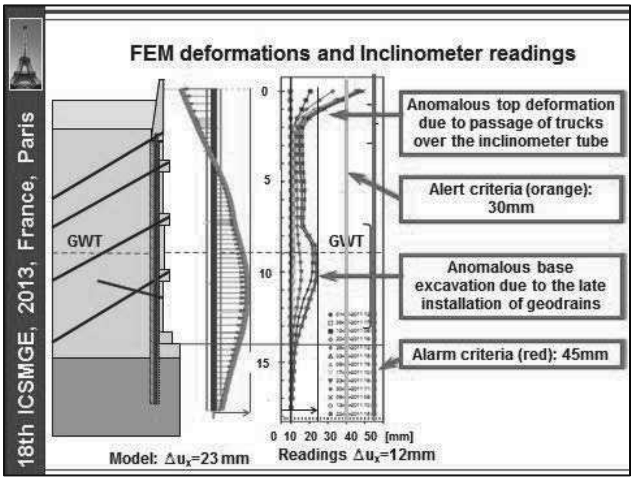


Figure 17. Comparison between predicted FEM deformations and inclinometer readings for static actions.

7 MAIN CONCLUSIONS

As main conclusions it is possible to point out the follwing advantages of the adopted solution:

- Good confinement of the excavated soils, due to the preliminary ground improvement effect of the soil - cement panels, allowing a very high and safe construction rate;
- Low deformations as confirmed by the monitoring.
- Good wall finishing face and water tightness.
- Environmental advantages associated to the CSM technology, minimizing the excavated ground volume.
- Application field to almost every kind of geological and geotechnical scenarios, as well as to complex and sensitive neighbourhood conditions.

8 ACKNOWLEDGEMENTS

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9 REFERENCES

Gomes Correia A., Tinoco J., Pinto A. and Tomásio R., 2013. An Anchored Retaining Wall in CSM. *Proc. 18th European Conference on Soil Mechanics and Geotechnical Engineering*, Paris, France.

Pinto A., Tomásio R., Pita X., Pereira A. and Peixoto A. 2011. Cutter Soil Mixing Solutions in Portugal on Hard Soils and Weak Rocks. *Proc. 15th European Conference on Soil Mechanics and Geotechnical Engineering*, September 2011, Athens, Greece, Part 2 – 3.3 – Ground Reinforcement, pp. 1037–1042.