Proceedings of the XVIII ECSMGE 2024
GEOTECHNICAL ENGINEERING CHALLENGES
TO MEET CURRENT AND EMERGING NEEDS OF SOCIETY

ISBN 978-1-032-54816-6
DOI 10.1201/9781003431749-492

ECSMGE 24
XVIII EUROPEAN CONFERENCE
ON SOIL MECHANICS AND
GEOTECHNICAL ENGINEERING

Special foundations at the cycle-pedestrian bridge over the Trancão river, Portugal

Fondations spéciales du pont cyclable-piéton sur la rivière Trancão, Portugal

A. Pinto*
JETsj, Geotecnia, Lisbon, Portugal

A. Rodrigues, P. Santos
RODIO, Lisbon, Portugal

C. Caxias
ANP Systems GmbH, Lisbon, Portugal

**apinto@jetsj.com*

ABSTRACT: This paper describes the special foundations solutions adopted at the cycle-pedestrian bridge built over the Trancão River, connecting Lisbon to Loures. The bridge structure is a laminated wood deck, supported by steel cables, with a 65m central main span. Considering the very low resistance and high deformability of the superficial alluvial layers, it was necessary to design a deep foundation solution, resting at the Miocene bedrock. Reflecting the local geological scenario, as well as the restraints related with the use of heavy equipment at the riverbanks, the foundation solution consists of micropiles, vertical and inclined, executed using the self-drilling methodology, associated with the execution of 500mm diameter mini jet grouting columns, ranging from about 30 to 20m. The main quality control / quality assurance (QC/QA) results, including two full scale tension load tests, are presented.

RÉSUMÉ: Cet article décrit les solutions de fondations spéciales adoptées pour le pont cyclable-piéton construit sur la rivière Trancão, reliant Lisbonne à Loures. La structure du pont est un tablier en bois lamellé collé, soutenu par des câbles en acier, avec une travée centrale de 65 m. Compte tenu de la très faible résistance et de la déformabilité élevée des couches alluviales superficielles, il était nécessaire de concevoir une solution de fondation profonde, reposant sur le substratum rocheux du Miocène. Compte tenu du scénario géologique local, en plus des contraintes liées à l'utilisation d'équipements lourds sur les berges, la solution de fondation consiste en des micropieux, verticaux et inclinés, exécutés selon la méthodologie de auto forage, associés à l'exécution de mini colonnes de jet grouting de 500 mm de diamètre, allant de 30 à 20 m. Les principaux résultats du contrôle de la qualité e du contrôle de l'exécution (CQ/QA), bien aussi que deux tests de charge de traction à grande échelle, sont présentés.

Keywords: Jet grouting; micropiles.

1 INTRODUCTION

The new cycle and pedestrian bridge over the Trancão river was built before the World Youth Day 2023 (WYD), with the main objective to connect the paths already existent at both banks of the Trancão river (Loures at North and Lisbon at South).

With this purpose, a three span (28m+65m+28m, 121m overall length) cable stayed bridge, with laminated wood deck, steel towers and cables, resting over reinforced concrete columns and abutments, was built. At Loures and Lisbon sides, respectively, access ramps with 82m and 70m were built, the last one parallel to the Trancão river (Figures 1 and 2).

Figure 1. Bridge location (Google maps, without a scale).

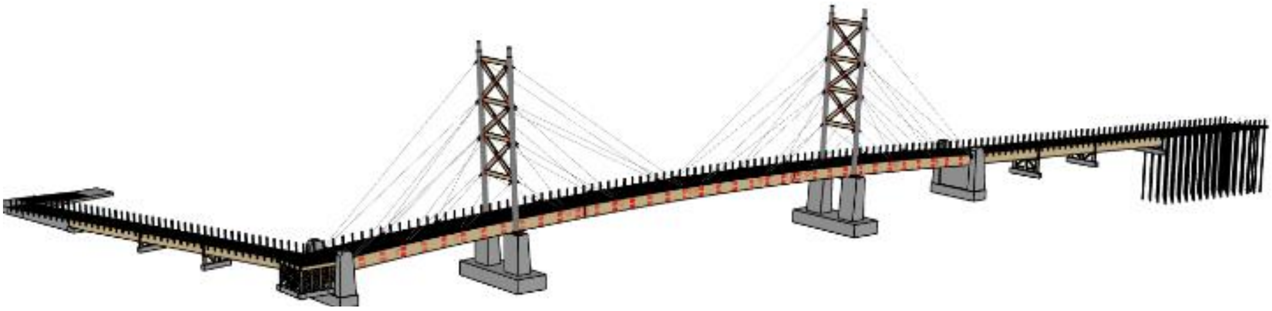

Figure 2. Bridge 3D view (JETsj project).

2 GEOLOGICAL CONSTRAINS

The geological investigation campaign included the execution of four boreholes and allowed the confirmation of the ground geotechnical zones (ZG). It was possible to confirm, from the surface, the existence of 2.5m heterogeneous landfills (ZG1), resting over very soft alluvial (Tagus River basin) materials with overall thickness ranging from 14 to 22m, with N_{SPT} blows not bigger than 2 and undrained shear strength (Su) not bigger than 20kPa (ZG2).

Under that layer, the Miocene loose sandy soils (ZG3) over the sandstone bedrock (ZG4) were found, the last one with very good resistance and deformation characteristics (Figure 3).

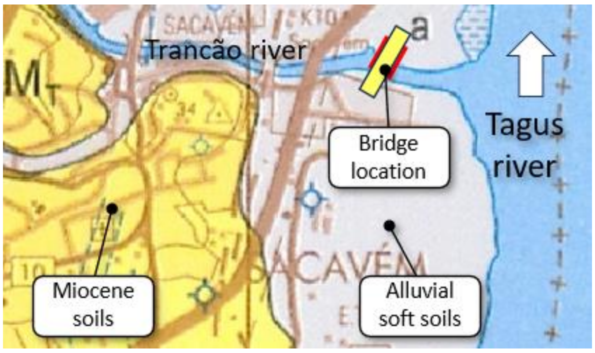

Figure 3. Geological scenario plan with bridge location (Portugal geological map, without a scale).

3 FOUNDATIONS SOLUTION

Considering the geological and geotechnical restraints, the compression and tension loads to be transmitted by the bridge to the ground, as well the restraints related with the use of heavy equipment at the riverbanks soft soils, the foundation solution consisted on micropiles ANP ϕH1600-76mm, ϕH0950-51mm and ϕH0550-38mm hollow steel bars with sacrificial grouting bits, vertical and inclined, executed using the upper – bottom self-drilling methodology, associated with the execution of 500mm diameter mini jet grouting columns at the ZG1, ZG2 and ZG3 geotechnical zones, ranging from about 30 to 20m (Figure 4).

Maximum jet grouting pressure was 200bar, compatible with the micropiles coupler's resistance. Due to the Atlantic Ocean proximity, leading to water chlorides, for durability reasons, pozzolanic cement with a consumption ratio of 160kg/m^3 was used.

The jet grouting columns had three main functions: i) increase the micropiles stiffness mainly against buckling; ii) increase the micropiles protection against corrosion; iii) reduce the micropiles overall length at the Miocene bedrock, particularly when the columns intersected the Miocene loose sands, at the South riverbank.

Figure 4. View of the micropiles hollow bars and bits.

The micropiles were capped by reinforced concrete caps, supporting the bridge columns and abutments. The loads were transmitted to the Miocene layer mainly by shaft resistance: i) at the South riverbank, starting at the loose sandy materials taking advantage of the 500mm jet grouting columns shaft resistance (qs); ii) at the North riverbank, at the Miocene bedrock, where the maximum diameter was only 250mm (Figure 5).

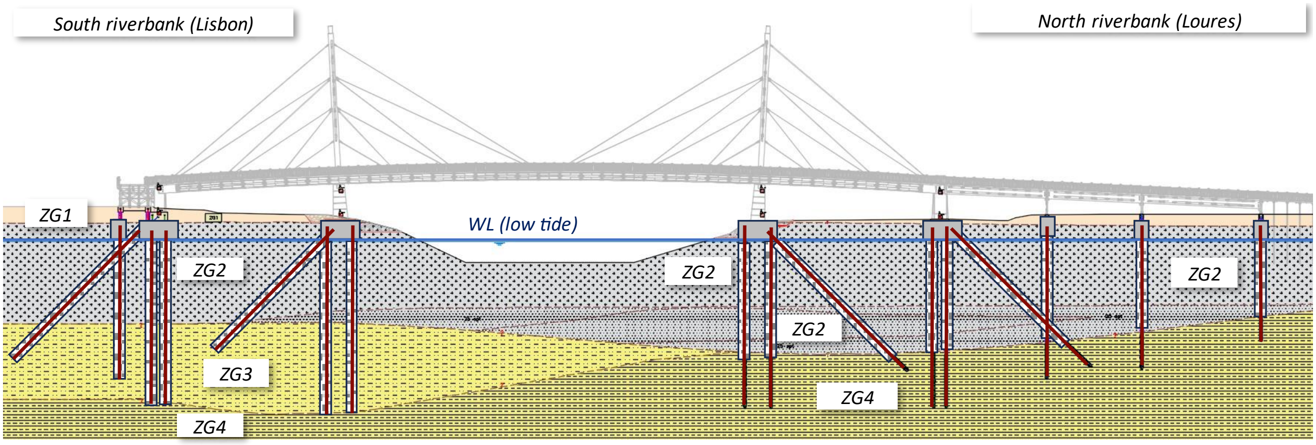

Figure 5. Bridge elevation with geotechnical zones (JETsj project, without a scale).

4 QUALITY CONTROL AND QUALITY ASSURANCE

4.1 Trial columns

Before the execution of the full-scale load tests, several jet grouting trial columns, with different cement consumption, were performed to check both the columns geometry and resistance at the very soft resistance alluvium layer (ZG2).

The columns resistance was evaluated trough unconfined compression strength (UCS) tests, performed trough cores collected from the columns at 28 days. At UCS tests both the columns unconfined compression resistance and Young's modulus were checked and compared with the design requests at 28 days: 3MPa and 1GPa, respectively (Figure 6).

Figure 6. Trial column view.

4.2 Tension full scale load tests

To confirm the design main assumptions, mainly the micropiles and jet grouting shaft resistance (qs), two suitability tension full scale load tests were performed, one in each riverbank, close from the bridge central columns.

The reaction structure was a reinforced concrete cap (2x2x1m^3) supported by four inclined self-drilling micropiles. The central tested micropile was reinforced with one ϕ35mm Gewi Plus S670/800 bar, protected by a smooth sheath at the landfill (ZG1) and alluvium (ZG2) layers, ensuring the unbonding length. A hollow plunged jack was used to apply a maximum load of 500kN to the micropile through the ϕ35mm bar (Figure 7). The maximum applied load was 1.67 times bigger than the maximum tension service load, approximately 350kN (Figures 8 and 9).

Figure 7. Full scale tension test: reaction structure view.

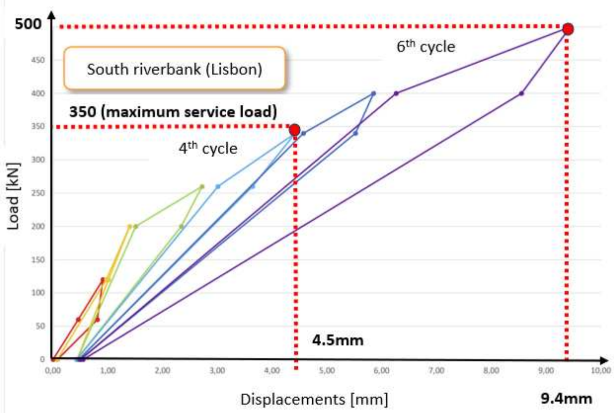

Figure 8. Load vs head displacements (South riverbank).

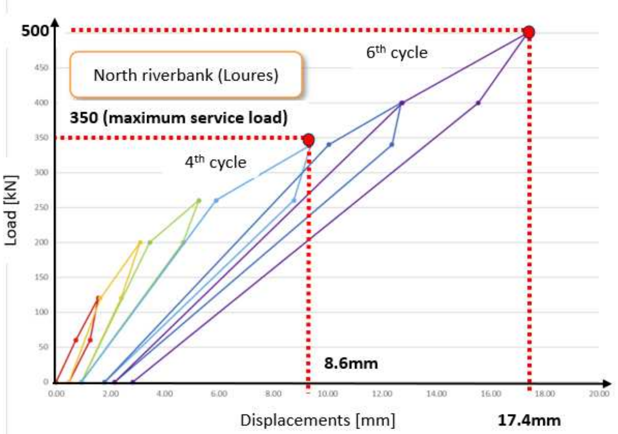

Figure 9. Load vs head displacements (North riverbank).

After 6 load and unload cycles the maximum displacements were 9.4mm and 17.4mm at, respectively, the South and North riverbank load tests. The plastic displacements were, respectively, 0.5mm and 2.5mm. The explanation for those differences could be related with the micropiles stiffness, as on the South riverbank the loaded micropile full length was inside a jet grouting column at the Miocene loose sandy soils (ZG3, with qs not lesser than 25kPa) and the alluvium (ZG2) thickness is lower (Figure 5).

Despite the tension loads at the micropiles are mainly due to wind and seismic loads, on both load tests the creep coefficient, for a minimum permanent load time of 30 minutes, was lesser than 1mm. The obtained results allow to confirm the suitability of the design and execution parameters.

4.3 Execution parameters recorder

All the jet grouting execution parameters were automaticallty recorded using a computer device and compared with the ones established based on the trial columns and suitability full scale load tests results.

5 DESIGN

The bridge foundations were designed using PLAXIS 2D, FEM stress-strain software. The shaft resistance values were initially estimated using reliable proposals (Bustamante, 2002) for jet grouting. The model was adjusted by back analysis after the full-scale load tests. According to the bridge monitoring, using prisms and topographic readings, since its opening to cycling and pedestrian traffic (Figure 10), the deck displacements have been in accordance with the estimated ones at the design stage.

Figure 10. Bridge view just before the YWD, August 2023 with the deck being reinforced for the pope's car crossing.

6 FINAL REMARKS

The presented case study allowed to confirm the advantages of foundation solutions using mini jet grouting columns combined with self-drilling micropiles in complex geological and geotechnical scenarios. As main advantages, compared with conventional solutions, can be pointed out: light, small and versatile equipment, minimum ground extraction, schedule prediction, and overall costs.

ACKNOWLEDGEMENTS

The authors are grateful to EMEL and Lisbon Municipality for the permission to present this paper.

REFERENCES

Bustamante, M (2002). Bearing capacity and integraty control of jet grouting columns. *Séminar Franco Tunisien: Pathologie des sols e des fondations*, Hammamet. Tunisia (in French).

INTERNATIONAL SOCIETY FOR SOIL MECHANICS AND GEOTECHNICAL ENGINEERING