Aveiro, PORTUGAL

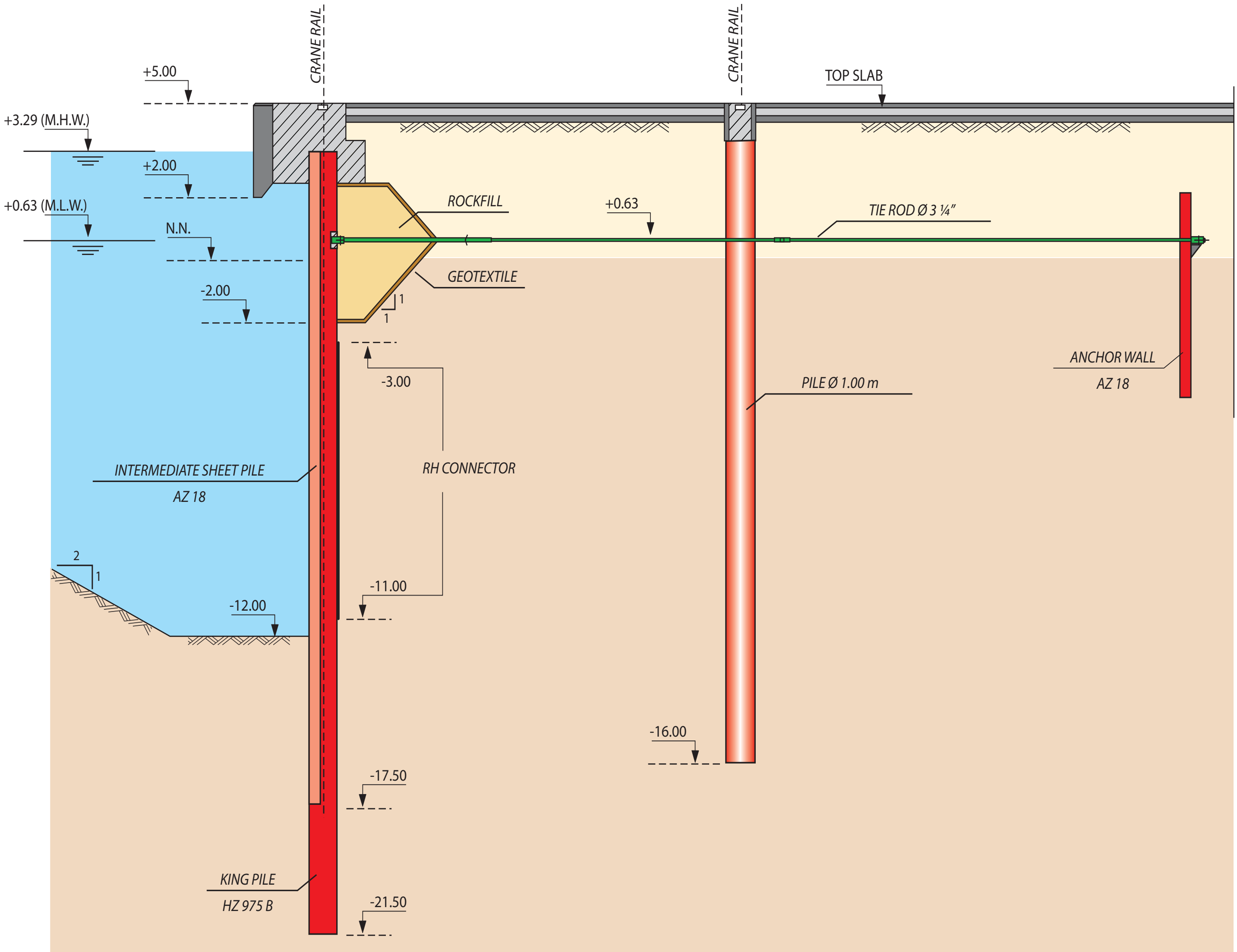
New solid bulk terminal

Aveiro is located about 300 km north of Lisbon, Portugal's capital, and roughly 65 km south of Porto, the country's second-largest city. In the 16^{th} century, the city acquired prosperity through cod fishing. At the end of the century, strong storms caused Aveiro's harbour to silt up. In 1808, the passage from the lagoon to the sea was reopened.

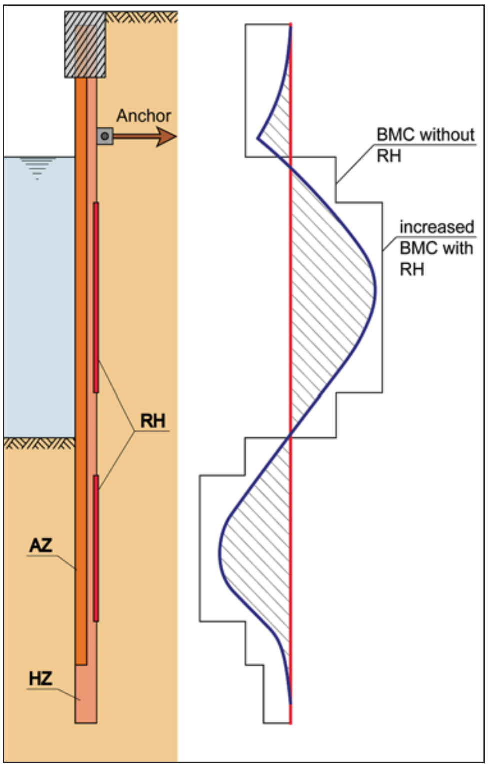
Today, Aveiro is an important fishing and commercial harbour. Operating 24 hours a day and enjoying optimum natural conditions as a sea shipping port, Aveiro is ideally situated to serve the vast economic areas of central Portugal and Spain. Aveiro Commercial Harbour comprises approximately 1,700 m of quays (north, south and roro terminals) and three wharves for liquid bulk (petroleum products, chemicals and wine).

The Harbour Authority APA – Administração do Porto de Aveiro –, aimed to build an environmentally sound port with the highest standards of safety and efficiency with a specialised infrastructure for trading bulk goods. For the period 2000 - 2006, the European Union allocated € 3.7 billion for investment in the Portuguese maritime-port sector, with a view to upgrading infrastructures and to making Portugal an integral part of the trans-European transport network.

The two parts of Aveiro's new terminal have a combined length of 750 m



The state-of-the-art terminal consists of an anchored HZ/AZ sheet pile system



A particularly economical solution was provided with the help of RH connectors

The sheet pile wall was later topped with a concrete capping beam

In 2005, cargo handled in the port of Aveiro was up 6% compared to 2004. This was the biggest rise of all Portuguese ports. The port of Aveiro handles over 3 million metric tons of cargo annually. Dredging works for the solid bulk and liquid bulk terminals were launched recently by the Port Authority of Aveiro.

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A two-level-template ensured straightness during installation

Due to the template the space between the king piles precisely fits one AZ pile

The sheet piles were vibratory-driven until refusal

Geological tests showed that the coastline features dunes consisting of medium and coarse sand made up of quartz, feldspar, and calcium fragments. Horizontal ground acceleration due to seismic activity in the region of Aveiro Harbour can reach up to 0.1 g.

Two solid-bulk quays with a water depth of 12 m were built in the port of Aveiro. The first quay is 450 m long and is used for shipping agricultural produce. The second 300-m quay is used for handling other bulk cargo, mainly cement and clinker.

The quay wall of the solid-bulk terminal consists of an HZ 975 B - 14 / AZ 18 combined-wall system. The 25.9-m HZ king piles are made of high-yield-strength steel (grade S 430 GP). The steel of the 20.9-m AZ 18 intermediate sheet pile elements has a yield strength of 355 N/mm². A total of 4,500 metric tons of steel sheet piles was delivered from Luxembourg to the site in Portugal.

Crane loads rest on the front sheet pile wall and on concrete columns

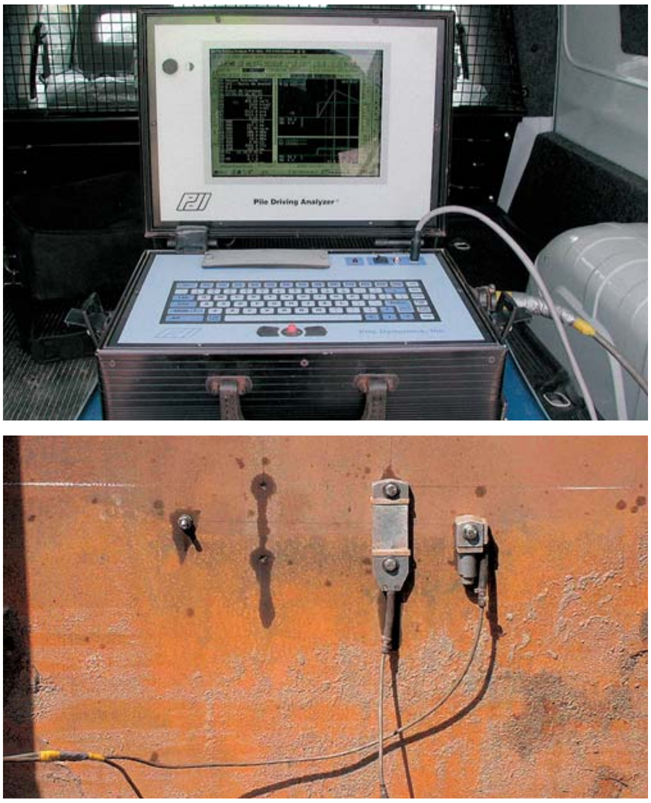
RH connectors were placed at the back of the HZ king piles, at the location of maximum moment. These connectors locally increase the section modulus in order to guarantee the necessary stability along the full length of the pile while using a minimum amount of steel. The saving in steel makes this combined-wall system a particularly economical solution.

The anchor wall is situated 31 m behind the main wall. By holding back the top of the main wall, the anchor wall not only limits deflections, but also considerably decreases the maximum moment in the front wall, allowing a lighter section to be chosen. The anchor wall consists of AZ 18 profiles in steel grade S 355 GP with a length of 6.5 m.

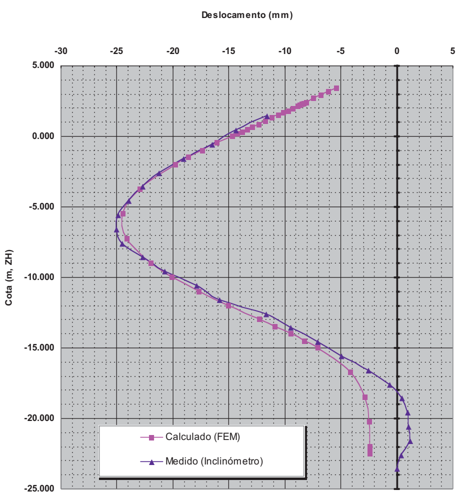
The high-strength tie rods made of steel with a yield strength of 460 N/mm^2 were provided by Anker Schroeder in cooperation with Arcelor. They have a length of 31 m, a diameter of 70 mm, and a thread of 3¼". They are made of two parts joined together by a turnbuckle. The turnbuckle has a dual role: it compensates variations in distance between main and anchor walls, and allows the tie rod to be straightened into a horizontal position. Welded T-shaped connectors attach the tie rods to the main wall.

The distance between two king piles is 1.79 m whereas the centres of the AZ 18 double piles of the anchor wall are 1.26 m apart. It was therefore necessary to install a waling system which also has the essential function of uniformly distributing the loads into the anchor wall. The complete package comprising the steel sheet piles and the entire tie-back system including tie rods, waling beams, brackets,

Tie rod/sheet pile wall connection details



Dynamic bearing tests confirmed the vertical bearing capacity of 1,800 kN



The test also showed that predicted and observed deflections match

Owner:
Administração do Porto de Aveiro

Contractor:
Somague, Irmãos Cavaco and SETH

Dynamic load tests:
PDI Engenharia (Brazil)

Geotechnical investigations and structure instrumentation:
Tecnasol FGE

Project designer:
J.M. Morim de Olivera and J.L. Rodrigues Rocha engineers

Sheet piles:
HZ 975 B - 14 / AZ 18

Pile length:
HZ: 25.9 m AZ: 20.9 m

Steel grade:
HZ: S 430 GP AZ: S 355 GP

Total quantity of sheet piles:
4,500 metric tons

bearing plates, spacers, fixing bolts, and splicing plates with corresponding nuts was delivered by Arcelor to the entire satisfaction of the customer.

A template was used to install the HZ king piles. This steel structure guides the sheet piles into the ground, ensuring they are correctly positioned both vertically and horizontally. The king piles were vibratory-driven to the top of the template, which was then repositioned to install the next HZ piles. An impact hammer was used to drive the last few metres. The installed HZ piles then served as a template for the AZ intermediate elements. The AZ double piles were vibratory-driven to design depth. The contractor opted for pre-drilling to ease AZ driving through a compact sand layer at a depth of 10 m.

Steel sheet pile solutions are characterised by their great flexibility. The corner section of the main wall consisted of ordinary AZ 18 intermediate elements attached to HZ piles by connectors. Most assignments such as welding or tie-rod installation can be executed by a small workforce in a minimum of time. One of the essential advantages of sheet pile systems in comparison to concrete solutions is the fact that the sheet piles are produced in a steel mill and are delivered ready for installation to the site. This guarantees consistently good quality of the construction material.

Dynamic bearing tests were carried out in order to ensure that the ground would provide the vertical bearing capacity required for the HZ 975 B piles to support the loads from the crane rails. In total, eight profiles were tested with the same equipment used for driving the piles: a hydraulic impact hammer with a 7,000 kg ram, deploying a maximum energy of 83 kNm. The results of the special deformation detectors and piezo-electric accelerometers applied back-to-back to the HZ piles were analysed. The measured

The steel structure was finished off with capping beam, fenders and bollards

Both the 450-m agricultural quay and the 300-m bulk quay were completed in 2005

values indicate a vertical king pile bearing capacity exceeding the required 1,800 kN.

The behaviour of the main and anchor walls was analysed using load cells attached to the tie rods and other measuring instruments installed inside inclinometer tubes next to the main wall. The readings obtained during dredging operations were compared to the predicted values. The geotechnical data was fed into a finite-element-method calculation program designed to simulate soil/structure interactions. The results showed that the predicted tie-rod force was confirmed and that the calculated and observed deflections matched. It was furthermore possible to validate the assumed geotechnical parameters and the calculation process.

The structure was completed with a concrete capping beam placed on top of the HZ king piles. It consists of cast-in-place monolithic sections, 21.48 m in length and 2.55 m in height. Concrete mountings were provided for fenders and mooring bollards.

The new terminal opened in 2005 and is among the most modern in the world. Thanks to the sheet pile - tie rod package delivered by Arcelor, the new solid-bulk terminal boosts the economy of the region. ■