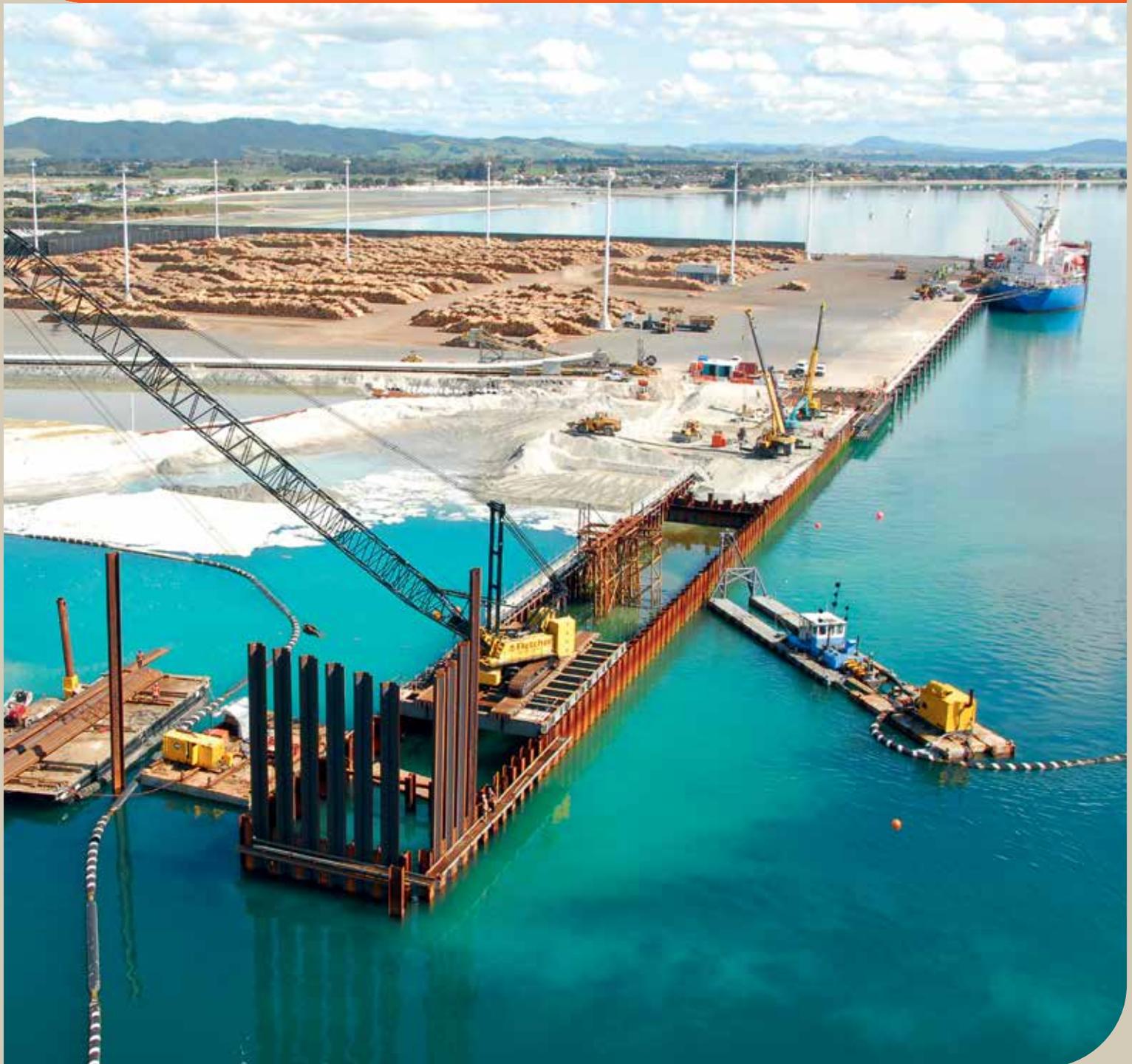




Foundation Solutions for Projects Harbour Construction

Innovative steel sheet pile solutions for modern ports



Harbour Construction

Innovative steel sheet pile solutions for modern ports



Contents

Introduction		5
Project locations		6- 7
Canada	Voisey's Bay, Labrador	8
Canada	Shippagan, New Brunswick	12
USA	Seattle, Washington	15
USA	Elizabeth, New Jersey	17
USA	Norfolk, Virginia	21
Cuba	Havana	25
Chile	Mejillones	30
Portugal	Aveiro	36
Spain	Cadiz	42
France	Calais	45
Belgium	Antwerp	52
Denmark	Aarhus	54
Denmark	Prøvestenen, Copenhagen	61
Germany	Hamburg (Altenwerder)	66
Germany	Hamburg (Predöhlkai)	70
Italy	La Spezia	78
Turkey	Mersin	86
Senegal	Ziguinchor	92
India	Visakhapatnam	96
Russia	Nakhodka	102
Philippines	General Santos	104
Taiwan	Kaohsiung	110
Taiwan	Anping	114
Taiwan	Taipei	118
New Zealand	Marsden Point	124



ArcelorMittal has over one-hundred-year tradition in the development and production of steel sheet piles. Through innovation since 1911, the U- and Z-shaped piles today form one of the most advanced solutions for constructing and deepening quay walls.

Global traffic continues to increase steadily and so does the size of the container vessels. This expansion places a considerable strain on the infrastructure of the ports they call, and the ports need to invest massively to meet the requirements of the new ship generations. Steel sheet piles offer a sustainable and cost-effective solution for modern ports, be it for increasing the dredging depth by simply installing a sheet pile wall in front of an existing structure, or to build a brand-new quay wall. The straightforward and fast installation allow the new structure to be operational within a short period of time. Additionally, the installation works only require a reduced workforce and equipment.

ArcelorMittal's research team develops new sheet piles and accessories so that we can continue offering the best products on the market and meet the ever-changing requirements of the dynamic shipping and logistics industry. The latest developments include the AZ-800 range, the 750 mm wide U-piles and the unmatched HZ-M king piles with a section depth of up to 1 100 mm designed specifically for quay walls with draughts of 20 m and more.

Today the construction industry needs to be more resilient and sustainable. New projects must be designed with a low environmental impact over its whole life cycle if we want to achieve carbon neutrality by 2050, the target imposed by the governments in 2015. Steel is a perfect material to illustrate "circular economy": it can be recovered at 100%, and reused several times before being 100% recycled.

This brochure gives an overview of waterfront projects using different types of steel sheet pile solutions. Owing to numerous advantages such as its intrinsic quality, sustainability, execution speed, ... sheet piling structures have become increasingly popular all over the world.



Seattle

Voisey's Bay

Shippagan
Port Elizabeth
Norfolk

Havana

Mejillones

Ziguinchor

Prøvestenen
Aarhus
Hamburg
Antwerp
Calais
La Spezia
Aveiro
Cadiz



Mersin

Nakhodka

Taipei

Kaohsiung

Anping

General Santos

Visakhapatnam

Marsden Point

Voisey's Bay | Labrador | Canada

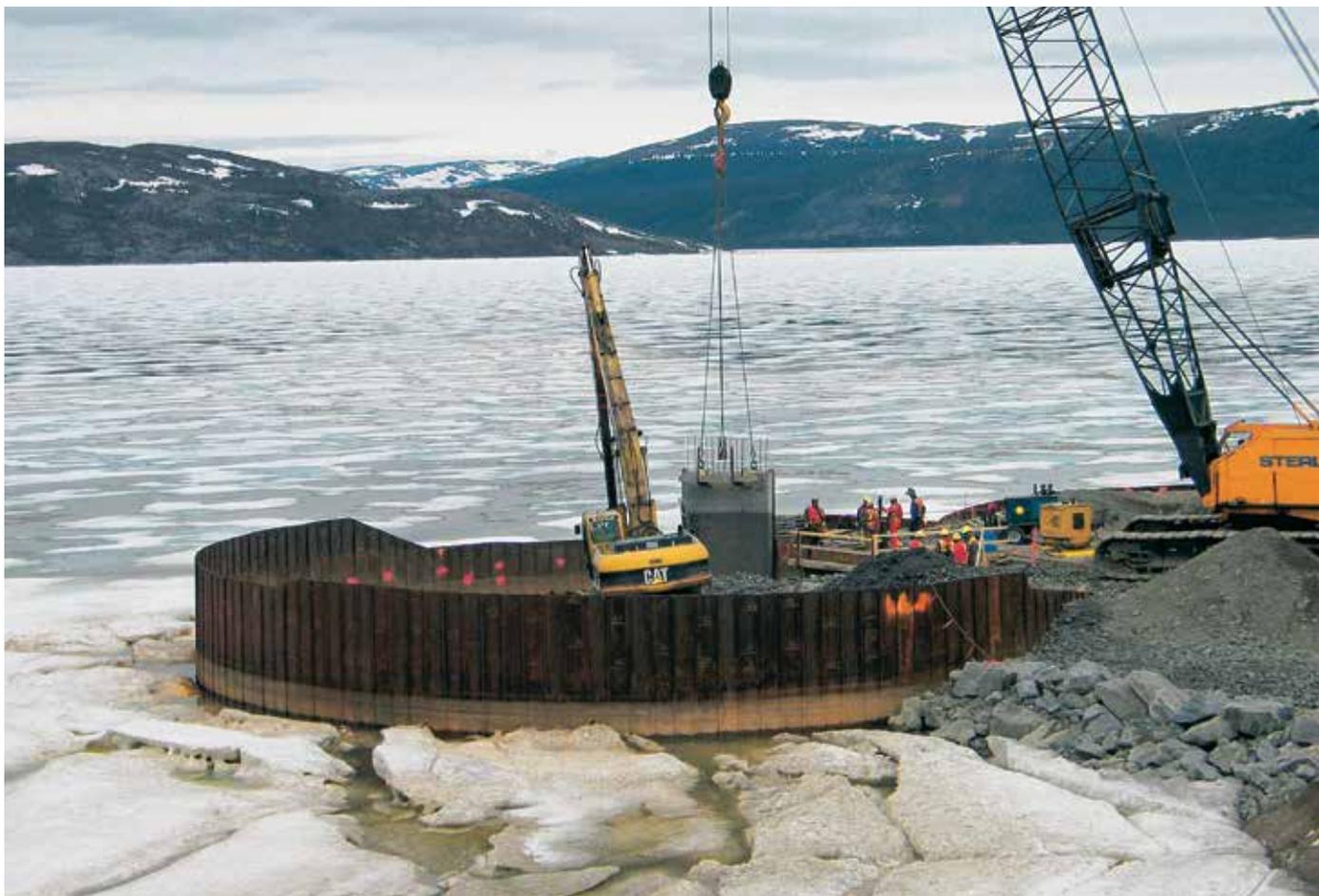
> Construction of permanent port facilities



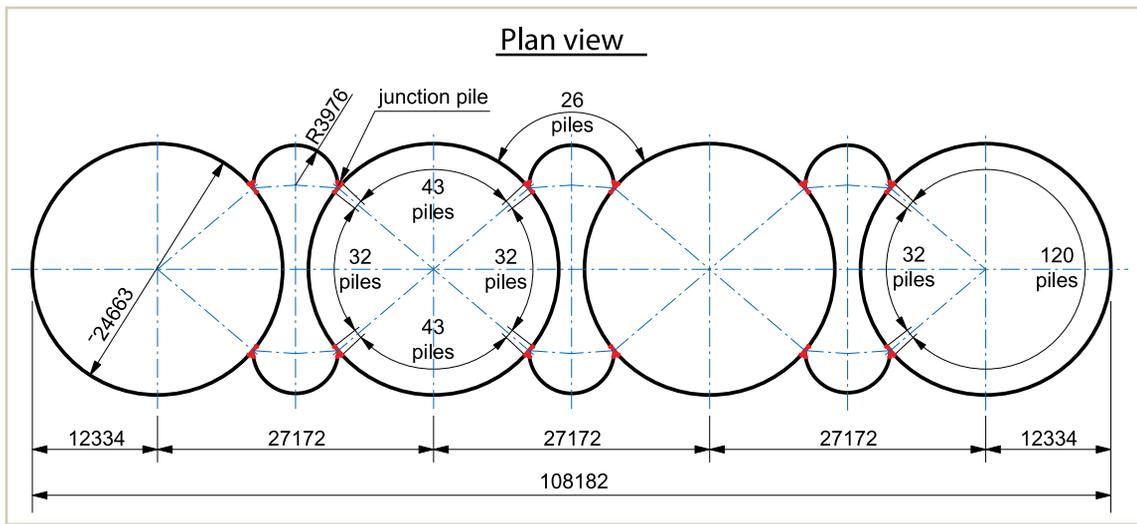
Supply ship docking at the sheet pile wharf in Voisey's Bay.

Voisey's Bay is situated in a remote area on the north-east coast of Labrador, in the Canadian Arctic. One of the richest nickel-copper-cobalt finds in the world, the Voisey's Bay deposit was discovered in 1993, some 350 km north of Happy Valley-Goose Bay.

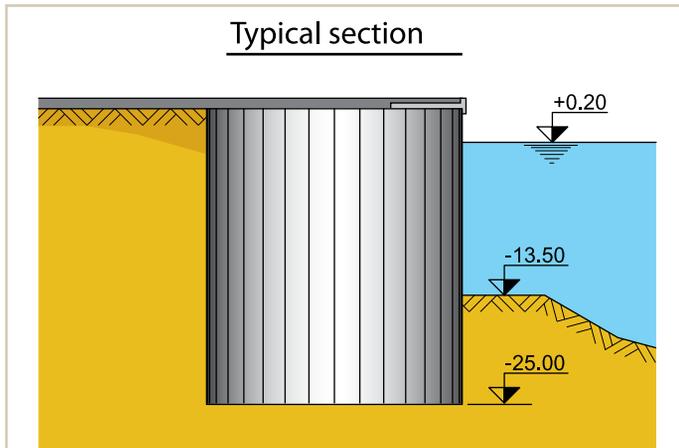
The Voisey's Bay Nickel Company (VBNC) built an integrated mine at the site which is now in operation. A harbour was required in order to import mine consumables and export the nickel concentrate. Construction of the wharf in nearby Anaktalak Bay began in summer 2004, and the main structure was completed in December 2004, with some ancillary work completed in late spring 2005. The new deep-sea wharf received its first ship on schedule in November 2005.



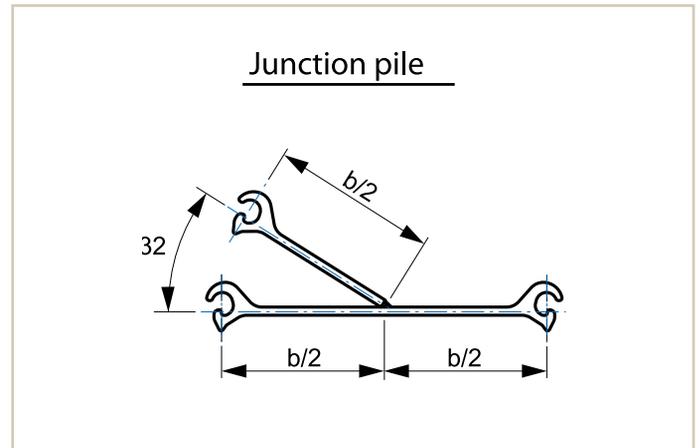
The design of the sheet pile cells had to take account of ice loads.



The wharf consists of four cells and six connecting arcs.



Cross-section of the AS 500 sheet pile cell.



The junction piles were produced by one of ArcelorMittal's subcontractors.

The dock has an approximately 100-metre berthing face with a minimum draught of 13.5 metres. Westmar Consultants Inc. (marine structural design) and Jacques Whitford (geotechnical design) jointly submitted the design for a new deep-sea wharf in Anaktalak Bay in order to accommodate up to six supply ships and concentrate carriers per month.

A circular steel sheet pile gravity structure was selected as the main structure. Individual sheet pile cells were driven into the predominantly dense sand/gravel soil. Since the AS 500 sheet pile system does not require embedment into lower soil layers for statical reasons, it is a standard solution for extremely hard soil conditions. The design of the wharf was particularly challenging due to the fact that its construction had to be completed within one short ice-free season. Several geotechnical boreholes were not completed before the installation of the first sheet piles.

The geology of the Anaktalak Bay site can be simplified into three distinct soil layers overlying bedrock. The surface is characterised by a significant zone of soft to firm clay overlying a sandy layer containing cobbles and boulders. The rockfill for the cells and the backfill consist of well-graded angular material. Dredging of the very soft sediments had to be avoided. This led to the development of a state-of-the-art instrumentation plan to continuously monitor stability during construction. A set of

curved precast concrete ice impact panels with a reinforced cope beam system supplemented the strength of the main structure. A variety of failure mechanisms (overturning, sliding, interlock failure, as well as horizontal and vertical shear failure) were analysed in the design of the sheet pile structure. Ice loads were an essential design consideration due to extreme winters with temperatures dropping as low as -40°C (-40°F). Special ice-impact beams were installed to take the horizontal loads.

The face of the marginal wharf is made up of four AS 500 cells joined together with six arcs. The sheet pile cells forming the face of the wharf also act as a retaining structure for backfill material. Scour protection was placed in front of the cells and the sheet piles were driven into it. Once the cells were placed, the area behind the wharf was backfilled with dredged soil.

For the construction of the four cells and six arcs, the following numbers of sheet piles were delivered by ArcelorMittal's Canadian agent, Skyline Canada:

- 680 straight-web sheet piles,
- 72 straight-web sheet piles bent by 7° ,
- 12 straight-web junction sheet piles.



The sheet piles were installed with the help of a template.



Piles were driven with barge-mounted equipment.

Each main cell made of 150 AS 500 straight-web sheet piles and 4 junction piles has a diameter of 24.7 m. Each of the six arcs is made of 14 normal AS 500 piles and 12 bent piles in alternate positions. Secometal, a subcontractor of ArcelorMittal, fabricated the bent piles. All the AS 500 sheet piles are 26.7 m long and 12.7 mm thick. The piles have a guaranteed minimum interlock strength of 5,500 kN per running metre of interlock. Skyline Canada additionally delivered 19 spare piles including single, bent and junction piles. The new wharf design received an Award of Engineering Excellence from the Consulting Engineers of British Columbia in 2006.

Owner:

Voisey's Bay Nickel Company (VBNC)

Contractor:

IKC-Borealis

Designer:

Westmar Consultants Inc and Jacques Whitford

Sheet piles:

AS 500-12.7

Pile length:

26.7 m

Steel grade:

S 355 GP

Total quantity of sheet piles:

1,640 metric tons

General installation procedure for AS 500 cells

Step 1

- Installation of template and supporting piles
- Temporary positioning of top/lower platform as high/low as possible above/below water level

Step 2

- Positioning of four or more isolated sheet piles (usually the special junction piles)
- Verification of verticality, then fixing by tack welding to upper platform
- Threading of adjacent sheet piles

Step 3

- Closing of cells between special junction piles
- Threading of arc piles (2 or 4)

Step 4

- Driving of piles using staggered driving method after closing of the cell

Step 5

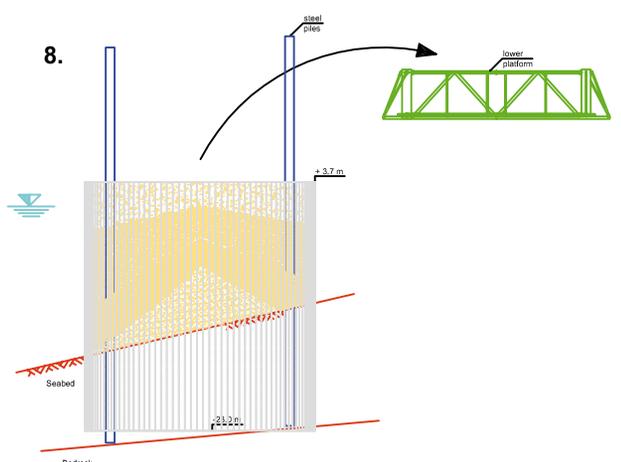
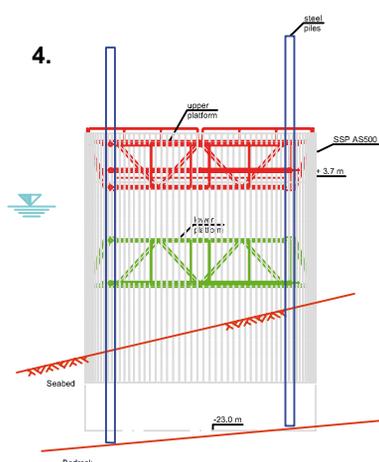
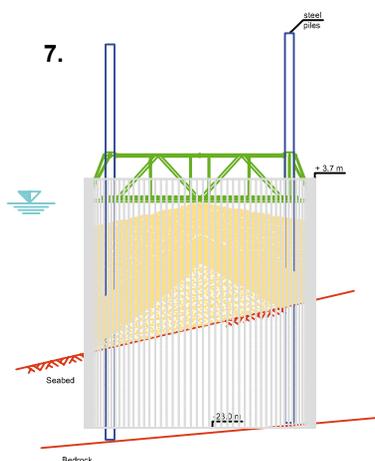
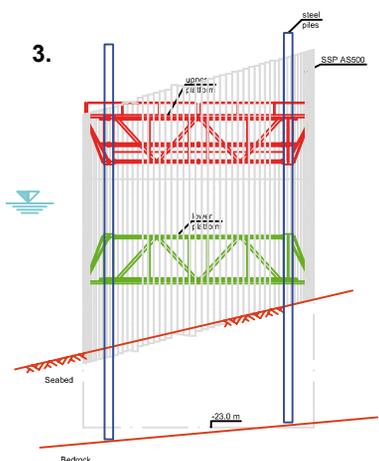
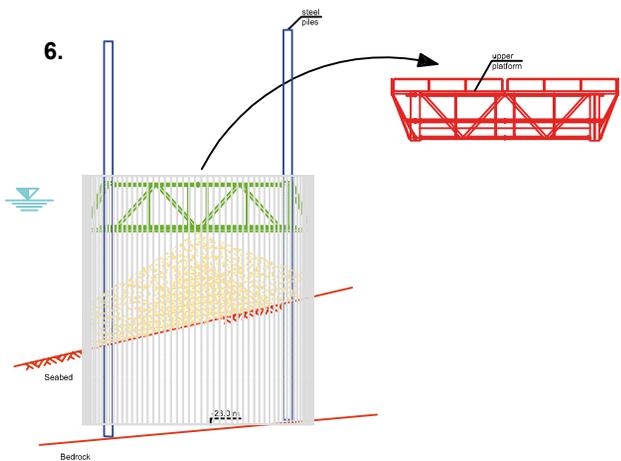
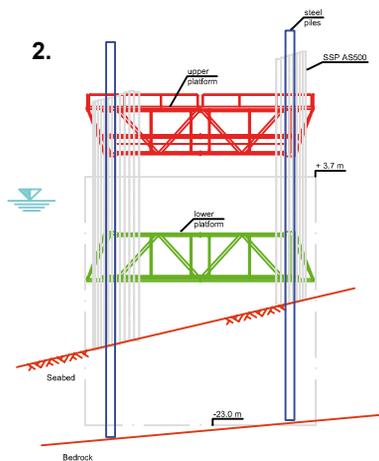
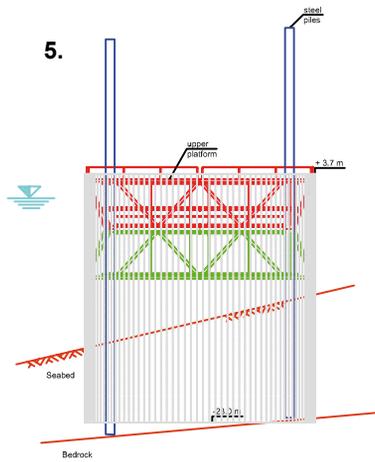
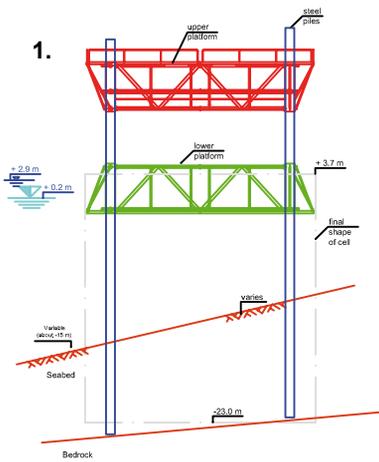
- Lowering of upper platform and driving of piles to design level

Step 6 & 7

- Filling of the cell
- Raising/Removal of platforms at appropriate times

Step 8

- Backfilling to the top of the cell
- Extraction of supporting piles



Shippagan | New Brunswick | Canada

> Rehabilitation of an existing wharf

The existing “Old North Wharf” in Shippagan in the Canadian province of New Brunswick, where the St. Lawrence meets the Atlantic Ocean, was scheduled for reconstruction. Due to the ever-increasing size of vessels, the dredge depth had to be increased in order to meet the requirements of the present fishing industry.

Soil investigation was assigned to AMEC Earth and Environmental Ltd who drilled five boreholes on the Old North Wharf property with a track-mounted diamond drill. The boreholes reached a depth of 7.5 m to 17.7 m below the harbour bottom. The results of the investigations showed that the site is characterised by a two- to four-metre-thick layer of compact to dense silty sand with gravel, which overlies bedrock. The SPT-values (Standard Penetration Test) for the sand with gravel range from 20 to over 100 blows per 0.3-metre penetration. The bedrock with a strength comparable to pre-consolidated clay can be classified as extremely weak according to the Canadian Foundation Manual.

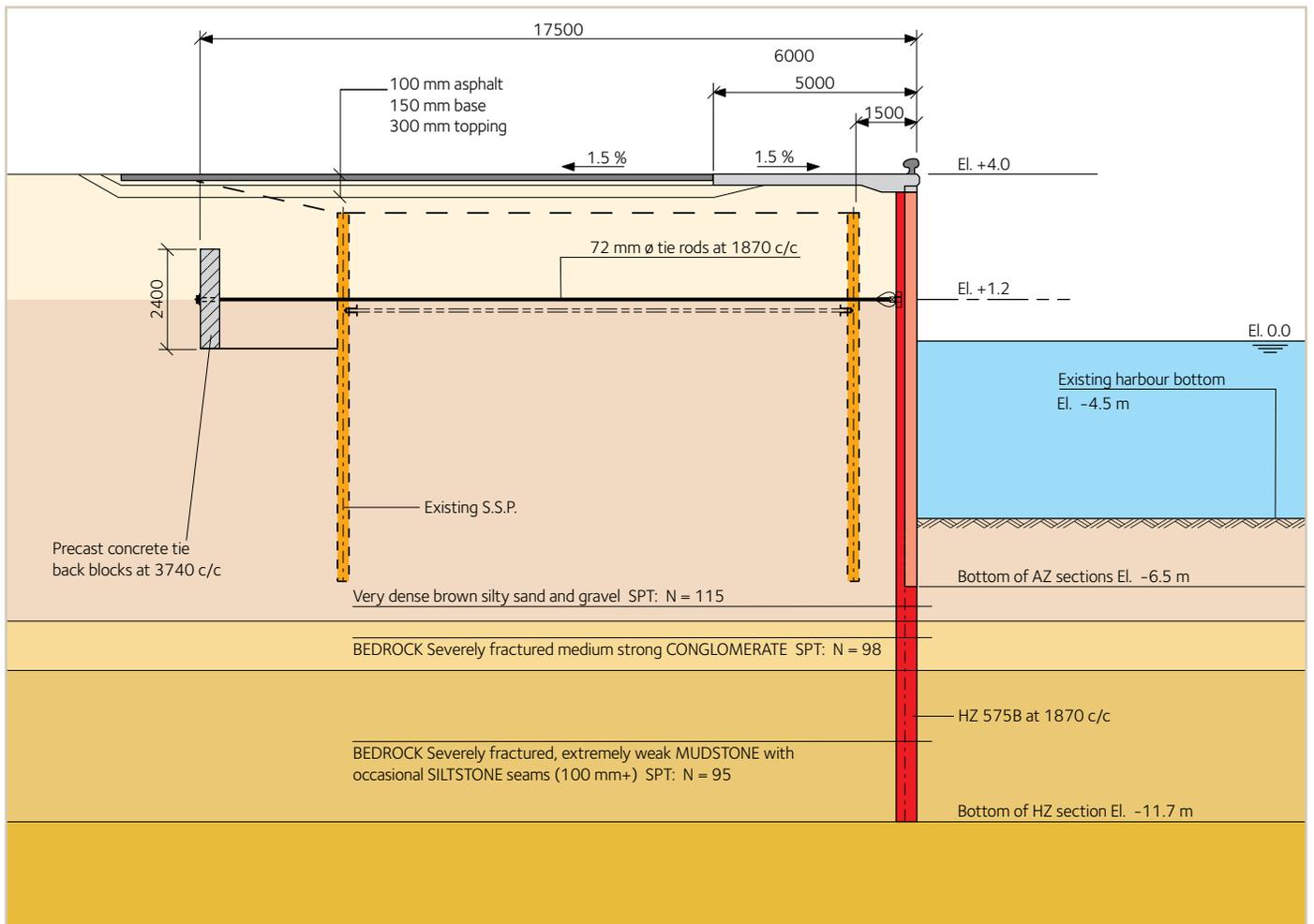
The proposed project comprised construction of a new quay wall, backfilling, and finishing of the deck.

The owner (Public Works and Government Services, Canada) and the consulting engineer (Eastern Designers & Company Limited) both opted for a steel sheet pile solution. Several construction methods were analysed. Due to site conditions, i.e. shallow bedrock levels, and the expected lifetime of the wharf, the sheet pile solution turned out to be the most economical option. Difficult soil conditions with sandstone, mudstone, siltstone and bedrock led to the choice of an HZ/AZ combined-wall system. Construction was scheduled to begin in July 2002 and was expected to last twelve months. The first step of the project was the removal of the existing concrete wharf deck, cope wall, wood fenders, guide rails and related hardware.

Then the HZ 575 king piles and the AZ 13 intermediary sheet piles were driven 1.5 m in front of the existing structure. The space between the new and existing wharves was backfilled with dredge material. The demolished concrete deck of the old quay made way for dredged sand that was piled up to an elevation of +3.5 m behind the newly installed combined sheet pile wall. The shoreline area between the North and South wharves was also closed with a sheet pile structure.



Shippagan harbour showing the old and new north wharves on either side of the inner dock.



Cross-section showing the existing and the new sheet pile wall.



New sheet pile wall installed 1.5 m in front of the existing wall.

A Delmag D19-32 diesel impact hammer was placed on the existing wharf to drive the steel sheet piles through the top soil layers and into the hard mudstone. Pre-drilling was not necessary despite tough soil conditions. Special “driving shoes” produced by APF in New Jersey, USA protected the HZ piles from damage during the driving process. The contractor Comeau & Savoie Construction Ltd built a two-level template in their workshop to facilitate the installation of combined sheet pile walls. The design of the template was based on conceptual drawings supplied by ArcelorMittal adapted to accommodate the driving shoes.

The installation of the sheet piles proceeded smoothly and was executed in accordance with recommendations of ArcelorMittal’s Canadian office Skyline Canada. Despite encountering hard driving conditions, only three HZ beams could not be driven to the desired depth. The embedment length of those king piles was reduced and the AZ sheet piles were driven until they encountered the rock layer. The contractor was able to drive five HZ king piles and five AZ sheet piles during a typical shift of ten hours. All driving was completed within seven weeks. After the installation of the combined-wall system, the contractor proceeded with placement of the concrete tie-back blocks, installation of the tie rods, backfilling between existing and new structures and, finally, installation of a concrete and asphalt wharf deck.

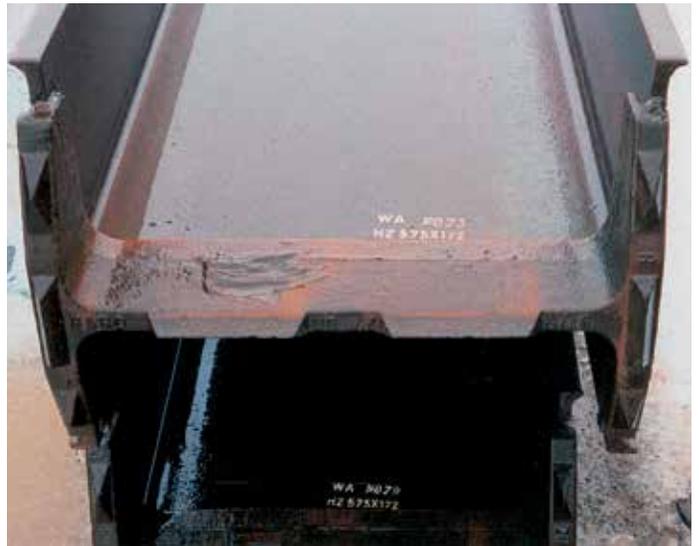
Skyline Canada delivered a complete solution to the contractor, including steel sheet piles and tie rods. The eye tie rods were produced by Anker Schroeder from Dortmund, Germany. The 3.75-inch tie rods are made of S 355 JO steel according to DIN EN 10025. Each tie rod linked an HZ king pile to the concrete tie-back blocks.



Eight guiding shoes – four per template level – guide each HZ king pile.



The two-level template ensures the king piles are correctly positioned for driving.



Driving shoes protect the pile toe from damage when hard soil layers are expected during driving.



Owner:

Public Works and Government Services,
Canada

Contractor:

Comeau & Savoie Construction Ltd

Designer:

Eastern Designers & Company Limited

Sheet pile system:

HZ 575 B -12/AZ13 and
HZ 575 C -12/AZ 13

Length of HZ king piles:

15.75 m / 17.55 m

Length of AZ sheet piles:

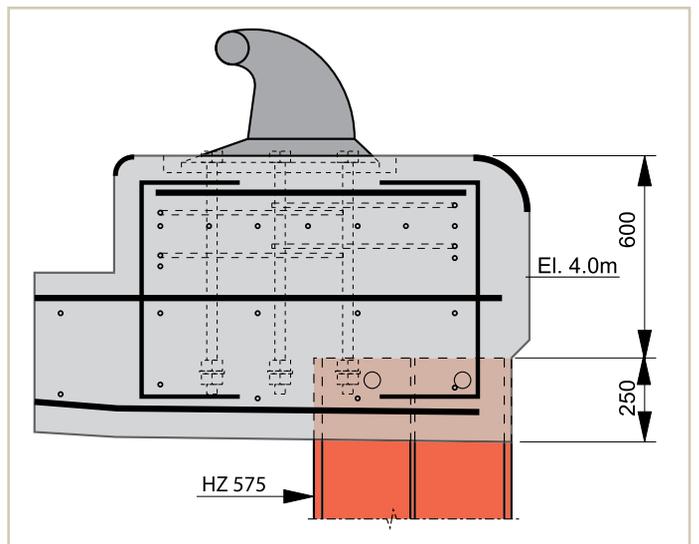
10.55 m / 11.55 m

Steel grade:

CSA Gr 350 W, except HZ connectors
S 430 GP

Total quantity of sheet piles:

800 metric tons



Steel sheet pile – capping beam connection detail with bollard.

Seattle | Washington | USA

> Deepening of Pier 36

The Port of Seattle's Pier 36 belongs to the United States Coast Guard (USCG). The deepening project called for demolition of the old pier, a deck-on-pile structure. Underneath the existing pier the ground sloped down to the bottom of the harbour. The top part of the slope was faced with riprap (sand, gravel and crushed rock) with a concrete cover. Concrete and timber bulkheads had been installed to stabilise the old pier. The lower part of the slope was mud. In order to accommodate the new Coast Guard's vessels, it was decided to develop a new, deeper quay by 2003.

The cross-section shows the existing mud layer reaching up to a level of approximately -3 m (equivalent to -10 feet). Removing the stone revetment beneath the old pier would have implied high costs. It was therefore decided to dredge the mud down to the depth of 12 m necessary for the docking of the Coast Guard's vessels. An underwater cantilever sheet pile wall was chosen to hold back the rocky top part of the slope. A new deck on piles was constructed behind the sheet pile wall. The deck is made of precast concrete panels resting on precast concrete piles. The inclination of the rock slope was slightly changed to incorporate the timber bulkhead. Since Seattle is situated in an active seismic zone, earthquake loads were considered for the design of the new facility at Pier 36.

The first step in the construction of the new quay was the driving of the underwater steel sheet pile wall at the end of the rocky slope. The contractor, M.A. Segale Inc., fabricated his own template for the installation of the HZ 975 D - 24 / AZ 19

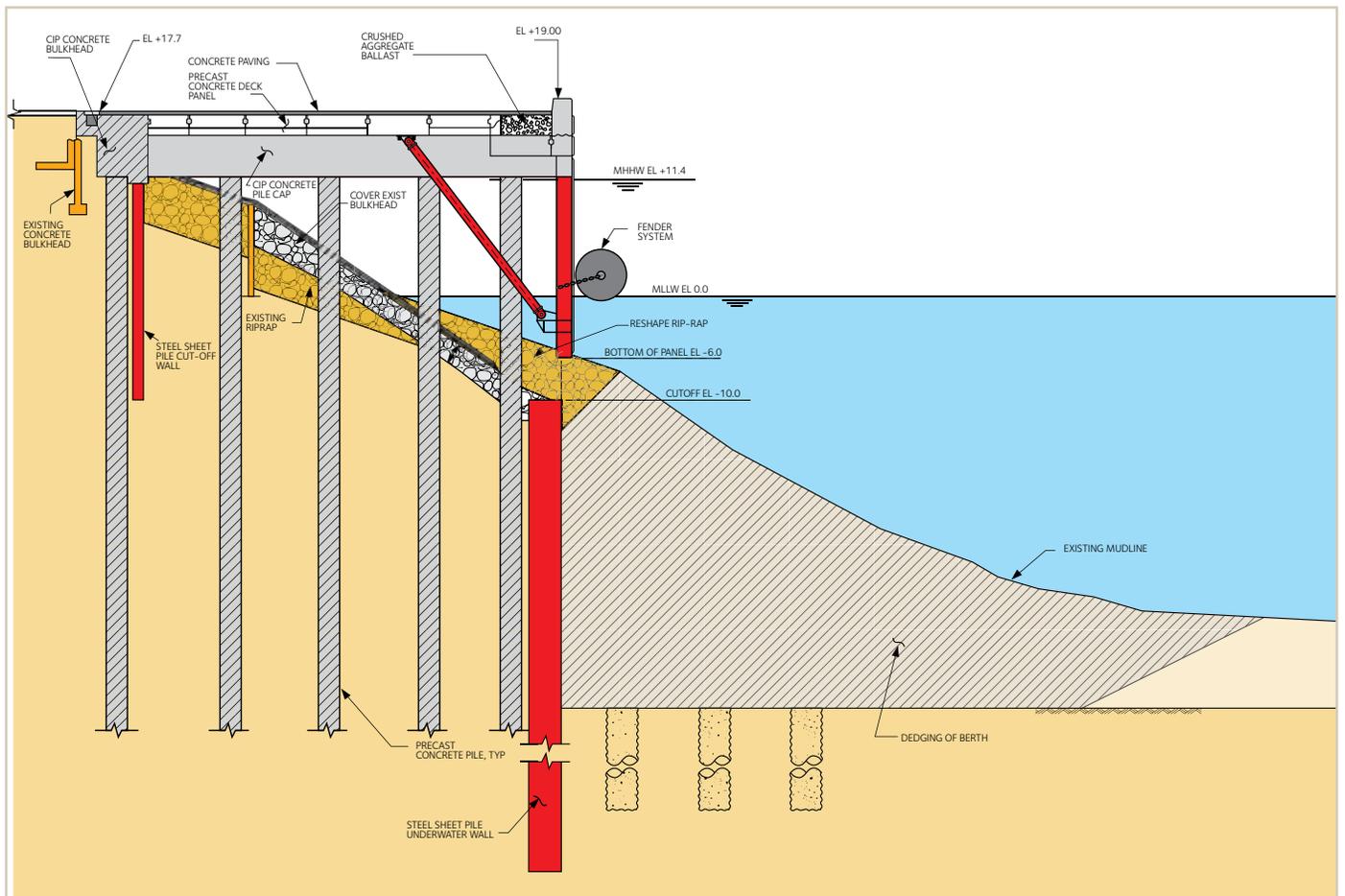


combined-wall system. A total of 1,315 t of sheet piles in a high steel grade were delivered to the site.

The steel sheet piles were equipped with a cathodic protection system with sacrificial anodes. Cathodic protection is a means of protecting steel structures by preventing the corrosion process. The sacrificial anodes were fixed to Pier 36's underwater steel sheet piles. The more electrically negative metal of the anodes corrodes first; it is therefore necessary to supervise the anode from time to time, depending on the site conditions and the lifetime of the structure.



Seattle's Pier 36 had to be deepened to accommodate the US Coast Guard's new vessels.



The underwater sheet pile wall made costly removal of the existing rocky slope unnecessary. [Elevations in feet].

A steel anode sled with three sacrificial aluminium-zinc-indium anodes designed for use in seawater and saline mud was installed on the USCG pier, together with test stations with corrosion monitoring equipment. A number of tests that measured base potential, electrical continuity, and anode potentials ensured proper functioning of the system.

Cathodic protection is effective for sheet piles in permanent contact with an electrolyte e.g. water. When properly designed and maintained, cathodic protection is a highly effective means of providing protection, leading to negligible corrosion rates in the order of 0.01 mm/year.



The steel sheet pile wall that stabilised the structure was installed from a barge.

Owner:
United States Coast Guard

Designer:
BERGER/ABAM Engineers Inc.

Contractor:
M.A. Segale Inc.

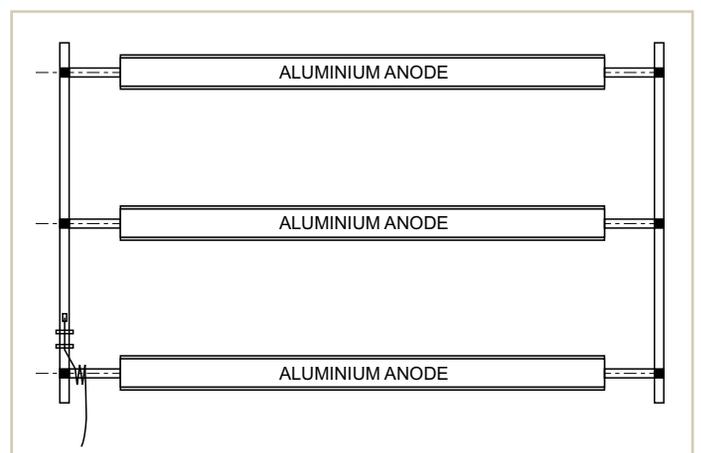
Sheet piles:
HZ 975 D - 24/AZ 19

Length of HZ king piles:
36.3 m

Length of AZ sheet piles:
30.2 m

Steel grade:
ASTM A572 Grade 60

Total quantity of sheet piles:
1,315 metric tons



The pier's cathodic protection system prevents corrosion problems.

Port Elizabeth | New Jersey | USA

> Deepening of existing container terminal

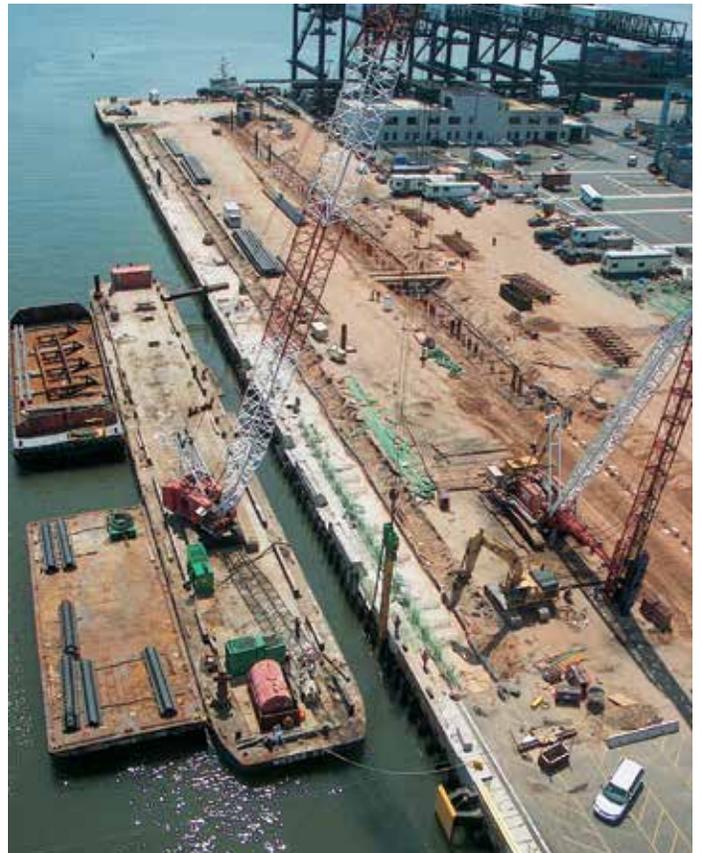
Port Elizabeth is located close to Newark International Airport and a stone's throw from New York City. The Port Authority of New York & New Jersey recently decided to upgrade the thirty-year-old wharf structures at the Elizabeth Marine Terminal to handle the next generation of container vessels. A five-phase plan was created to overhaul the old wharf structures at Berths 82 through 98 by increasing crane and mooring loads as well as the water depth at the wharf face. Another vital point was to equip the wharf with cranes reaching up to 18 containers wide, thus enabling the latest generation of Super Post-Panamax vessels to be handled. In parallel with the terminal upgrading project, the Army Corps of Engineers currently plans massive dredging operations to deepen the harbour bed to 15.2 m to accommodate the most modern container ships.

The \$650-million terminal redevelopment programme was sequenced in five phases to ensure that construction will not disrupt on-going container operations at existing terminals. Approximately 350 m of wharf are upgraded during each 9- to 12-month phase. The project was launched in January 2002 and is scheduled to be completed by 2009.

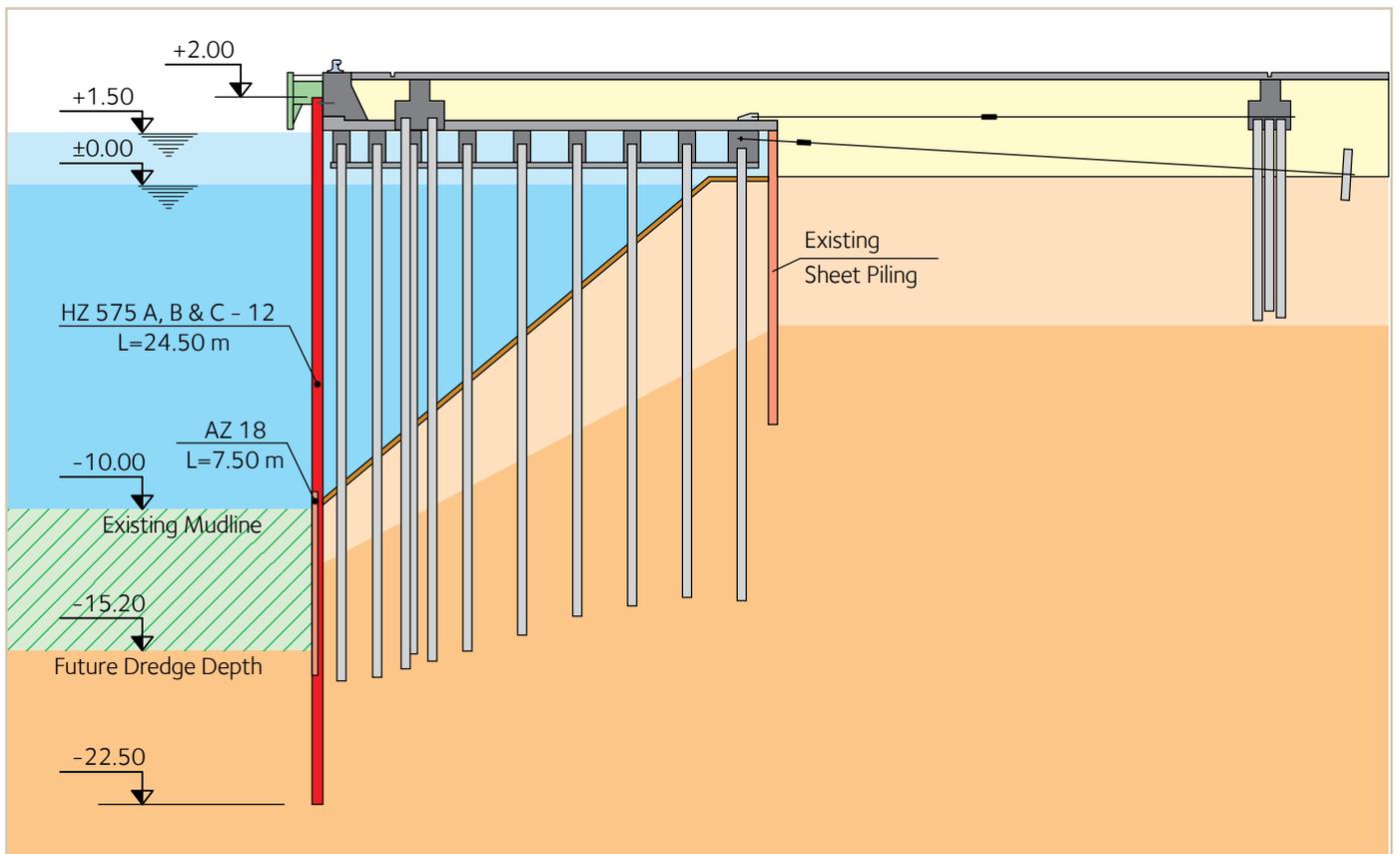
It encompasses the following points:

- Installation of an HZ/AZ combined sheet pile cut-off wall along the face of the wharf to enable the water depth to be increased to -15.2 m,
- Removal of the existing crane rail support beams and installation of new piles and beams to support the increased crane loads,
- Replacement of the existing timber fender system with a new system capable of resisting the berthing energy of 150,000-DWT vessels,
- Upgrading of the existing electric systems for increased crane power demands.

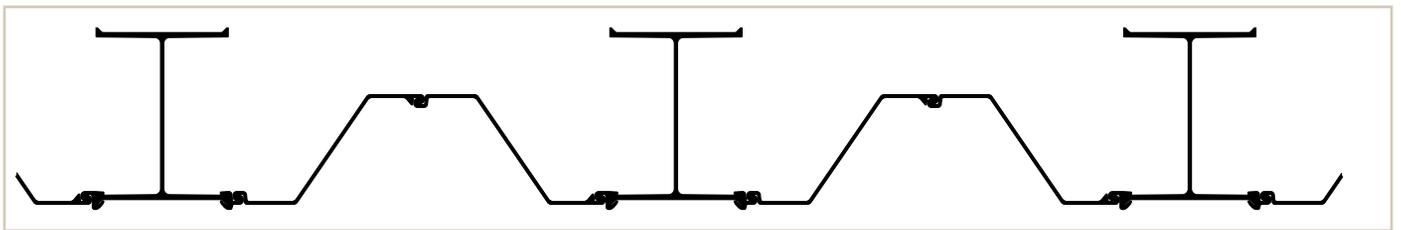
The modernisation of the 1,830-m wharf is a typical example of a cost-efficient terminal-deepening solution. The wharf structures were constructed in the early 1970's to serve general cargo operations. With the coming of containerised cargo, the terminal was equipped with container cranes.



The water depth of the Elizabeth Marine Terminal was increased from 10 m to 15.2 m.



A cut-off HZ/AZ combined sheet pile wall was driven in front of the existing terminal.



HZ 575 king piles / AZ 18 intermediary sheet pile combined wall.

The wharf and cranes were able to serve Panamax container vessels with a draught of up to 12.2 m. The main part of Berths 82 through 98 coincides with the typical Port Elizabeth/Port Newark cross-section: a 15.2-m-wide low-level-platform consisting of a 30-cm concrete deck slab supported by timber piles. Tie rods attached to a deadman system provide the lateral stability of the wharf structure. The crane rail beams are supported by timber and steel piles.

The first step in the design of wharf improvement, inspection of the existing wharf, showed that all the elements of the existing structure were in good condition. The design office appointed for the project, Han Padron Associates, determined that combining the new construction with the existing wharf structures was the optimum and most economical improvement alternative.

Construction time was considerably reduced by choosing to improve the existing structure rather than completely demolishing and replacing the wharf. Provision was also made in the design for new supporting piles for the crane rails. The advantage of the cut-off sheet pile wall chosen is the ability to retain the existing mudline elevation beneath the wharf while permitting the area in front of the toe wall to be dredged to the desired depth.

Since requirements for earthquake design were not included in the building codes at the time the existing wharf was built,

a seismic analysis had to be performed to ensure that the upgraded structure complies with current codes. After evaluating the wharf's stability under static and seismic loading conditions, the project team chose a coated HZ/AZ combined-wall system along the face of the wharf as the most cost-efficient solution. Several of the wharf improvement elements were governed by the seismic loading, including the size of the HZ king piles and anchor bolts.

The assessments of the structural upgrades depend on geotechnical conditions. The general geological profile of the site consists of hydraulic fill above soft and loose silt and clays overlying dense sand and gravel and underlain by sandstone and shale bedrock.

The principal concern regarding overall global stability after the planned dredging works was a slip-circle type of failure. Slope-stability analyses of the riprap slope determined that the tips of the HZ king piles needed to be driven into the dense sand and gravel layers in order to achieve sufficient stability. Driving the king piles through these denser layers also resulted in the optimum wall design with maximum passive pressure on the wall.

To transform the existing terminal of the 1970's into a state-of-the-art container terminal accommodating 6,600-TEU vessels the following cut-off combined sheet pile wall was installed at the wharf face: HZ 575 king piles with AZ 18 intermediary sheet



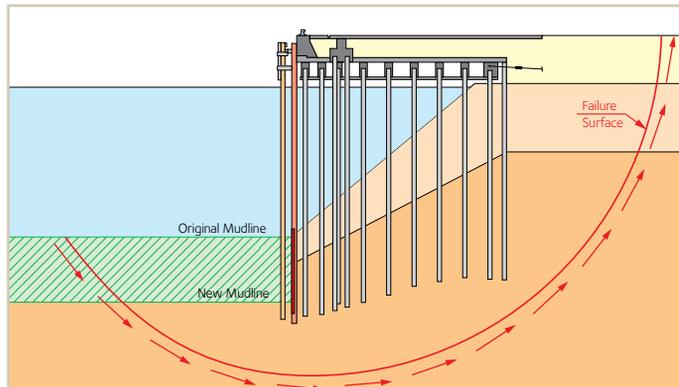
King-pile driving with two-layer template.



A special beam transmitted the vibration energy to the underwater AZ-piles.



The installation equipment was not submerged.



Slip-circle type of failure was of concern with respect to the stability of the new wharf.

piles. The sheet pile wall permitted dredging of the harbour bed to -15.2 m while maintaining the stability of the slope beneath the relieving platform. Soil and static analyses showed that it was necessary to anchor the top of the king piles. The HZ piles were anchored into the concrete fascia wall to reduce bending moment, deformations and embedment depth of the king piles in comparison to a cantilever solution.

Driving works were simplified considerably due to the fact that the heads of the king piles remained above the water line. A two-level driving template equipped with supporting consoles was set on the existing quay wall. A quayside crane lifted the king piles brought in by barge and lowered them into the driving guide. The template was equipped with neoprene shields to protect the coating system of the sheet piles. A vibratory hammer first drove the HZ piles until refusal; an impact hammer then drove them to the design depth. Since the design called for the king piles to be attached to the existing quay wall, the head of the piles remained 2 m above the waterline. Underwater driving was thus not necessary for the installation of the HZ piles.

Owner:
APMT NORTH AMERICA

Designer:
Han Padron Associates, New York

Sheet pile system:
HZ 575 A, B & C -12 / AZ18

Length of HZ king piles:
23.0 m / 24.5 m

Length of AZ sheet piles:
7.5 m

Steel grade:
Grade 50 (yield strength: 355 N/mm²)

HZ connectors:
S 430 GP

Total quantity of sheet piles:
2,440 metric tons



The heads of the HZ king piles remained above the water line, which facilitated their installation...



...and provided an ideal support for the fenders of the terminal.

Furthermore, the king piles were used as support for the combined fender and panel system that provides the necessary standoff between ship and toe wall.

The king piles also acted as a guiding frame for the installation of the intermediary sheet piles. The contractor did not want to submerge the vibratory hammer and thus opted for a special beam that transmitted the vibration energy from the installation equipment to the AZ piles throughout the driving process to design depth. The underwater AZ sheet piles prevent soil erosion due to the turbulence caused by ships' screws.

Projects similar to the terminal deepening described above have been carried out in numerous ports all over the world. Many marine container terminals in operation today were originally built to accommodate Panamax size vessels (draught up to 12 m). In order to remain competitive, ports are now forced to accommodate Post-Panamax ships. Quay walls constructed in the 1970s have to be modernised to receive these large vessels. A very quick and cost-efficient solution for upgrading wharves is to install stabilising steel sheet pile walls in front of the existing wharf to permit deepening operations. HZ/AZ combined sheet pile systems were also used for the following projects in Port of Elizabeth:

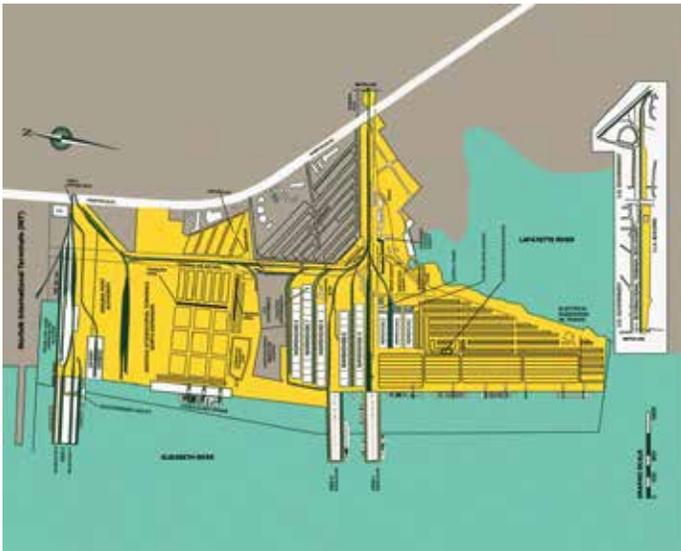
- P&O Container Terminal, Port of Newark, delivery: 2001
4,630 t HZ 775 B - 12 / AZ 18 $L_{HZ} = 25 - 30$ m,
 $L_{AZ} = 13.5 - 16$ m
- APMT NORTH AMERICA Marine Terminal, Phase 1,
Port of Elizabeth, delivery: 2002
1,350 t HZ 575 B&C - 12 / AZ 18 $L_{HZ} = 24.5$ m,
 $L_{AZ} = 7.5$ m
- APMT NORTH AMERICA Marine Terminal, Phase 2,
Port of Elizabeth, delivery: 2003
1,090 t HZ 575 A&B - 12 / AZ 18 $L_{HZ} = 23$ m,
 $L_{AZ} = 7.5$ m
- Maher Terminals, Modernisation of berth 75 - 78,
Port of Elizabeth, delivery: 2003
2,260 t HZ 775 C - 12 / AZ 18



Neoprene shields attached to the template protected the coating system during installation.

Norfolk | Virginia | USA

> NIT South Wharf Renovation Project, Port of Virginia



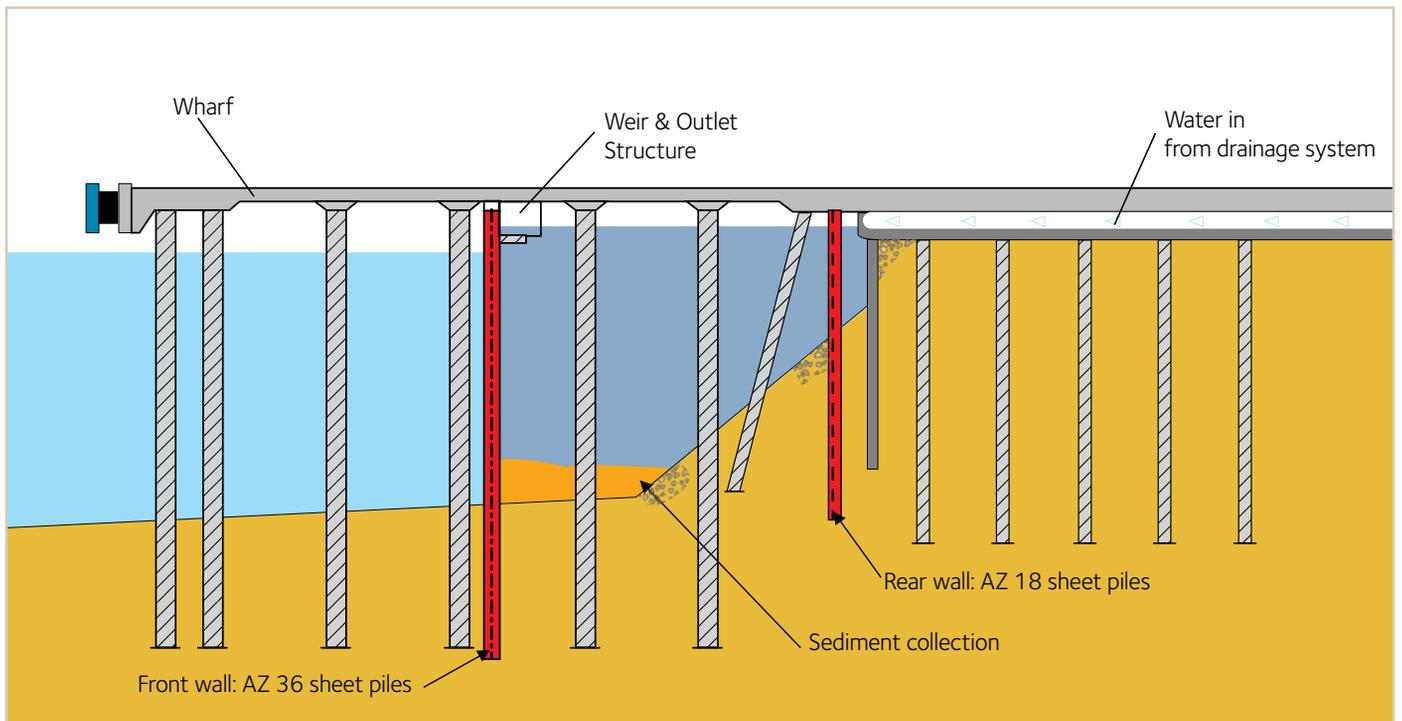
The new terminal is built on the Elizabeth river, some 29 km from the Atlantic Ocean.

In recent years, the Port of Virginia on the East Coast of the United States has registered explosive growth in Asian cargo. This growth has led to ambitious terminal renovation and expansion projects to accommodate the increasing volume of cargo. Northeast Asia, primarily China, accounts for up to one third of U.S. container traffic with yearly growth rates in the range of 10 - 15%. As ports on the U.S. West Coast reach their maximum capacity, the rise in container traffic is also being felt on the U.S. East Coast.

The Port of Virginia, one of the world's largest natural ice-free harbours is located 29 km from the Atlantic Ocean. The port's annual shipping volume reached 1.98 million TEU in 2005 – a growth of roughly 10% compared to the previous year. In order to accommodate both increasing cargo volumes and the increasing size of cargo ships, the Virginia Port Authority [to whom we credit the pictures shown] decided to renovate Norfolk International Terminal's (NIT's) South Terminal. The Port of Virginia boasts a 15-metre-deep inbound channel that will ultimately be dredged to 18 metres, making it the deepest on the U.S. East Coast. This new access channel will allow deep-draught Suez Class container ships (10 - 12,000 TEU vessels) to call at the port.



The NIT south wharf was renovated using two rows of steel sheet piles.



Cross-section of the expanded terminal with the stormwater detention basin set between two rows of AZ sheet piles.

Launched in 2002, the renovation of the port's largest container cargo terminal included the replacement of 1,290 metres of marginal wharf with a state-of-the-art structure designed specifically for containerised cargo operations. Eight 30.5-m-gauge post-Panamax cranes were installed to cope with the increased cargo. The container yard was also reconfigured to improve its efficiency.

The NIT South Wharf Renovation project involved replacing and widening the wharf by installing precast concrete piles, a steel sheet pile wall and an innovative under-wharf stormwater detention system. The wharf construction and landside renovations were completed in stages to keep three of the terminal's four container berths operational throughout the renovation project.

Consulting engineers Moffatt & Nichol designed the renovation of the South Wharf, including the stormwater treatment measures required by state and federal environmental

regulations. An under-wharf detention basin system formed by a front and a rear sheet pile wall was installed. This basin eliminated the need for a conventional treatment pond while maximising the land area available for cargo operations.

A vital goal of the project's stormwater detention measures was to create a highly impervious basin. At a width of 630 mm, the AZ 36 sheet piles were suitable not only to take up the statical loads, but also to contain stormwater. The watertightness of the system was further increased by the following measures:

- Particularly high watertightness of the Larssen interlock due to its tight shape,
- The number of permeable interlocks was halved by welding the middle interlocks,
- Large sheet pile width (1,260-mm double piles), and
- Filling of the non-welded interlocks with a Roxan sealing system.



Installation of the basin's impervious sheet pile wall.



Supporting piles for the front side of NIT's new South Wharf.



The AZ double piles were brought in by barge.



Installation by land-based crane equipped with vibratory hammer.



The AZ 36 sheet piles take the static loads and act as an impervious water barrier.

The Roxan system is based on a urethane-prepolymer product. Its volume doubles after 24 hours of exposure to water. The contractor has to avoid having driving-process interruptions of more than two hours during installation, otherwise he risks damaging the partly swollen sealing system. Contrary to bituminous sealing products, Roxan exhibits excellent durability properties in mineral oil, crude oil or petroleum and is thus ideal for containing stormwater. The sheet piles were delivered from ArcelorMittal in Luxembourg to their U.S. sales agency Skyline Steel who applied the sealing system in their shop in Savannah, Georgia. The piles were then taken by truck to the project site in Norfolk, Virginia.

A coating system was applied to the AZ sheet piles in Skyline's shop to counter all corrosion risks caused by the water contained in the stormwater detention basin. The sheet piles were made of Marine Steel Grade A690, which has approximately two to three times greater resistance to seawater 'splash zone' corrosion than ordinary carbon steel compliant with the U.S. ASTM A690 standard.

The AZ 36 and the AZ 18 sheet piles were driven in front of the existing wharf as double piles, using a vibratory hammer. The wharf itself is a deck-on-pile structure partly incorporating the detention basin and extending the terminal approximately 30 m into the Elizabeth River.



Overview of the construction site.



A template ensures the straightness of the sheet pile walls.



A hole was cut into the piles to pass the rebar tie rods.



A waling system evenly distributes anchor forces into the sheet pile wall.

Owner:
The Virginia Port Authority (VPA)

Design Engineer:
Moffatt & Nichol

Contractor:
Tidewater Skanska, Inc.

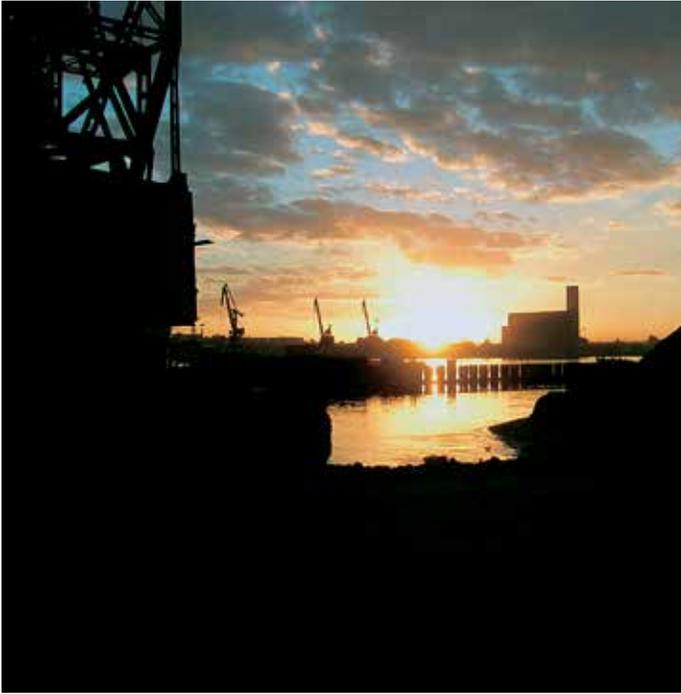
Sheet pile system:
AZ 36, AZ 18

Steel grade:
Grade ASTM A690

Total quantity of sheet piles:
3,950 metric tons

Havana | Cuba

> Container terminal extension

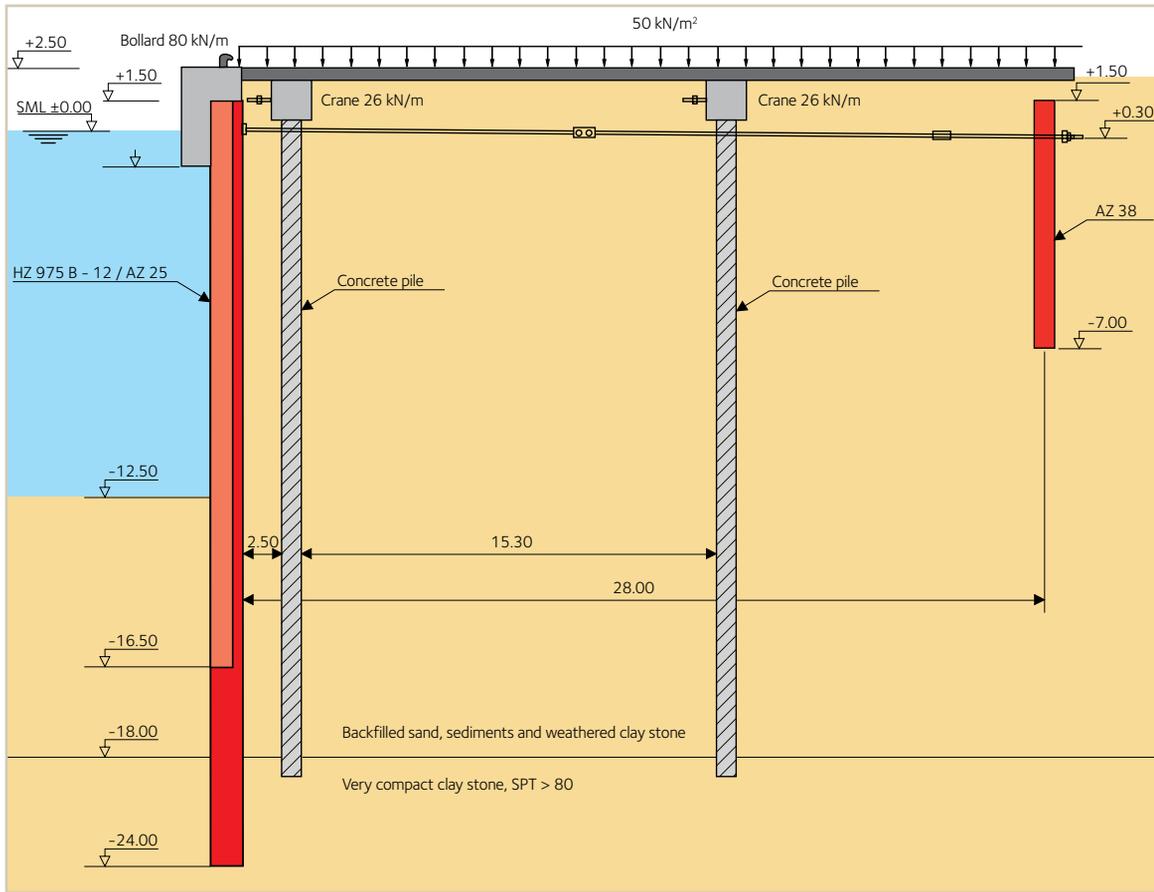


The Caribbean island of Cuba is currently experiencing an economic boom. Global economic ties, especially with individual European nations, continue to flourish. Construction of the Havana Container Terminal (Terminal de Contenedores de Habana - TCH) is a typical example of Cuba's recent development: The project started in 1990 as a Cuban-Soviet project until the collapse of the former Soviet Union. In 1993, the Transport Ministry bidded out the concession for the container terminal.

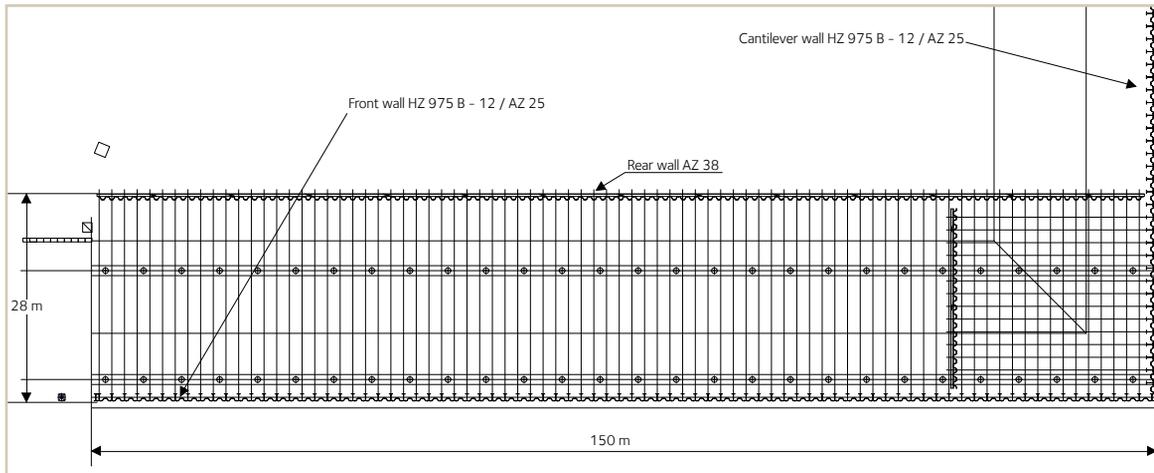
Being Cuba's only container terminal, TCH was approved for a fifteen-year project in 1996. Only four years later, the goals of the fifteen-year plan were reached; the first container vessel called at the terminal as early as 1998. In phase one, an initial investment of \$14 million upgraded the terminal and enabled it to receive 150,000 containers per year. In phase two, after an investment of \$16.8 million, the annual traffic can now attain 300,000 TEU. Growth is so significant that a further \$7.5 million is to be invested to further increase the container-handling capacity of the TCH.



Cuba's booming economy called for a new container terminal.



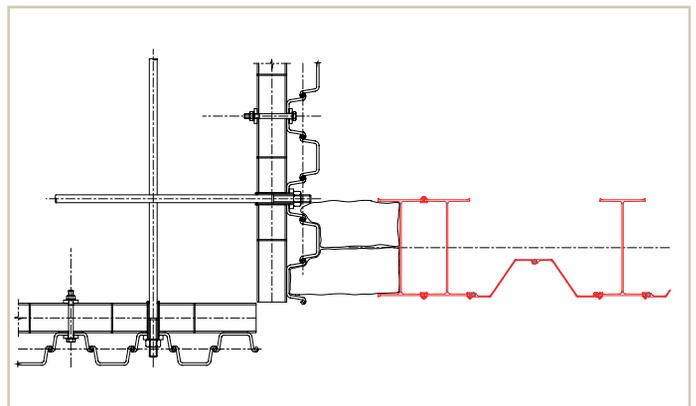
Cross-section: combined HZ/AZ main wall anchored with an AZ 38 wall.



L-shaped combined sheet pile quay wall consisting of a tie-back front wall and a cantilever return wall.

COLUMNA LITOLÓGICA		SONDEO 5		
COTA	ESCALA ANTRICAL SIMBOLOG. ESTRATO	DESCRIPCIÓN	IV. RECUPERACIÓN	
			Nº DE GOLPES / 30 cm	RECUPERACIÓN DE LA MUESTRA %
0			0	0
2			0	0
4		AGUA	0	0
5.90			0	0
6		SEDIMENTO EN ESTADO FLUIDO. EL MUESTREADOR FENETRO POR PESO SIN RECUPERACION DE MATERIAL ALGUNO.	0	0
10.35		ARCILLA LIMOSA DE COLOR GRIS OSCURO, DE CONSISTENCIA BLANCA, CON INTENSO COLOR FETIDO, PRESENTE.	0	0
11.80		ARCILLA LIMOSA DE COLOR GRIS OSCURO, HASTA GRIS VERDOSA, DE CONSISTENCIA FIRME AHASTA DURA, SIN COLOR CARACTERÍSTICO.	0	0
14			0	0
17.0			0	0
18			0	0
20			0	0
22		ARGILTA DE COLOR GRIS VERDOSA, DE CONSISTENCIA DURA A MUY DURA, CON FRAGMENTOS DE LA PROPIA ARGILTA E INTERCALACIONES DE ARENICA.	0	0
24			0	0
26		A PARTIR DE LOS 27.00 m EN ESTADO SEMIRROCO, FISURADA.	0	0
28			0	0
30			0	0
32.0			0	0

Boreholes were drilled to evaluate the soil conditions.



Connection detail: existing Larssen wall / new combined wall.

The port's latest proposed investment is for a 150-m extension of the existing container terminal quay wall. In addition to the materials, most of the special technologies and services were not easily available in Cuba. The quay wall was thus supplied as a complete solution by the Bauer Group, a German company specialised in geotechnical and foundation construction worldwide as well as in the sale of foundation construction equipment. The package included the supply and installation of a combined sheet pile wall together with the tie rods. The sheet piles were produced by ArcelorMittal's "Mill 2", in Belval, Luxembourg. The remaining civil works such as backfill and concrete structures were performed by the Constructions Division of the Cuban Ministry for Transport.

The new quay wall had to be connected to an existing wall made of Larssen 5 piles produced in Russia. These heavy 420-mm piles have a section modulus of $3,000 \text{ cm}^3/\text{m}$ and a weight of 238 kg/m^2 . They have a huge weight disadvantage compared to modern piles and are therefore far less economical. The superior width of today's piles allows faster driving progress enabling the contractor to complete quay walls more rapidly.

To meet the requirements of the permanently growing dimensions of vessels, the new quay wall is designed with a water depth of 12.5 m. Apart from the geometry of the future construction, soil analyses are a vital point in the design of quay walls. The results showed that the geology in the area consists of sediments overlaying claystone which is completely weathered in the upper four to five metres. Very compact claystone with SPT values (Standard Penetration Test) of 80 to 120 blows per 30 cm penetration is prevalent below -18.0 m.

The extension of the container terminal consists in the construction of an L-shaped sheet pile wall. The shorter side of the L-shape is a combined wall composed of 25.5 m HZ 975 B king piles and 18 m AZ 25 intermediary piles, partly cantilever and partly anchored to an AZ 38 wall. For the longer side of the L-shape, an HZ 975 B-12/AZ 25 solution with HZ king piles with a web height of 975 mm as load-carrying elements and AZ 25 sheet piles as intermediary soil-retaining elements was chosen. The HZ king piles, delivered in S 390 GP steel grade, were driven to a depth of 24 m, whereas for the AZ infill elements in steel grade S 270 GP a shallower depth was sufficient to ensure wall stability. The front wall is attached to the anchor wall with a single layer of 28-metre tie rods. The tie-back wall is made of 8.5-metre AZ 38 double piles in steel grade S 430 GP.

A small number of spare piles were delivered from Luxembourg to the site in Havana to prevent a standstill of the construction site as a result of any possible damage to piles during transport or installation.

The new and existing walls were connected with two concrete blocks. These blocks fitted into the valley of the Larssen pile at one end and in between the flanges of an HZ caisson at the other.



Driving of steel sheet piles with barge-mounted equipment.



Driving of HZ king piles at the corner of the L-shaped wall.



The area behind the quay wall was backfilled with dredged sand.

The execution of the project can be divided into two main phases: the off-shore works and the finishing works on land. The combined sheet pile wall was installed with a locally hired floating crane. A Bauer base carrier equipped with a vibratory hammer was used for the initial installation of the HZ piles. A hydraulic hammer drove the piles to their final depth. A template was used as a guiding frame to ensure the exact positioning of the king piles. To finalise the container quay wall, the double sheet piles forming the anchor wall were installed with a simple service crane mounted on a second floating pontoon in places where land-based installation was difficult. Due to the high accuracy during installation of the HZ piles, the sheet piles fitted perfectly into the gaps between the king piles so that a small hammer was sufficient for the driving of the final metres into the compact soil strata.



Bauer's pile-driving equipment: impact hammer and vibratory hammer.



Precise positioning of the HZ king piles was guaranteed using a double-level template.



A locally hired floating crane assisted the installation of the combined sheet pile wall.



The AZ piles were inserted between the HZ piles then driven to design depth.

Owner:

TCH S.A. Terminal de Contenedores, Cuba

Contractor:

Bauer Spezialtiefbau GmbH, Germany

Steel grade:

S 430 GP, S 390 GP, S 270 GP

Sheet piles:

870 t HZ 975 B, 410 t AZ 25, 320 t AZ 38

Total quantity of sheet piles:

1,600 metric tons



The complete solution provided includes front wall, tie rods, and anchor wall.

After the completion of the combined wall the main equipment was set-up on land to install major parts of the anchor wall. Backfilling of the new quay area proceeded simultaneously. The sheet piles forming the anchor wall were driven into the backfilled soil. This facilitated attachment of the tie rods that connect the king piles of the front wall with the AZ anchor wall. A continuous waler beam transferred the anchor loads uniformly into the anchor wall assuring the stability of the system whilst minimising deformation of the main wall.



The HZ piles were driven by vibratory hammer until refusal, then taken down to design depth by impact driving.



Several sheet piles were installed from a barge; others were driven with land-based equipment.



Mejillones | Chile

> Breakwater and quay construction

The port of Mejillones is situated 1,440 km north of Chile's capital, Santiago, on the Pacific Ocean coastline, not far from the town of Antofagasta. The history of the town is directly linked to the mineral of sodium nitrate. In 1831 a small port for the shipment of nitrate was built in Mejillones.

In 1995, an earthquake seriously damaged the harbour installations of the town of Antofagasta, revealing the vulnerability of the exporters using this port. The local mineral industries were in need of an earthquake-proof harbour. Studies showed that the most efficient solution would be to build a new harbour 65 km north of Antofagasta, in the bay of Mejillones.

The masterplan of the "Complejo Portuario de Mejillones S.A." called for construction of joint terminals for different types of cargo in accordance with demand. Construction started in November 2001. Contractor Belfi S.A. completed the construction of Terminal 1 by October 2003. The total budget of the project is estimated at \$120 million. The annual amount of cargo handled by Puerto Angamos exceeds three million metric tons.



In accordance with the requirements of the mineral industry, the new port was designed considering seismic loads.



Port of Mejillones, Chile © Puerto Angamos



The breakwater consists of sheet pile cells assembled with straight-web sections, whereas bending-moment-resisting sheet piles were used to build the terminal walls.



Terminal 1 is composed of different parts:

The breakwater was built using eight circular cells 24 m in diameter and 24 m in height. The 200-metre structure is made of high-tensile-steel sheet piles: AS 500 straight-web sections.

The 31.1-metre sheet piles were provided in steel grade S 390 GP. ArcelorMittal's straight-web sections have a width of 500 mm; there are currently five different thicknesses (9.5 mm to 12.7 mm) available. For the project in Mejillones, a steel thickness of 12 mm was chosen. The interlock of the AS 500-12.0 section is able to transmit tensile force of up to 5,000 kN/m.

A circular template was used for the installation of the cells. The sheet piles were driven from a jack-up barge. A total of 3,100 metric tons of AS 500 sections were used for the construction of the port's breakwater. The straight-web sections and the junction sections were fabricated in Luxembourg and delivered to the jobsite in Chile ready for installation.

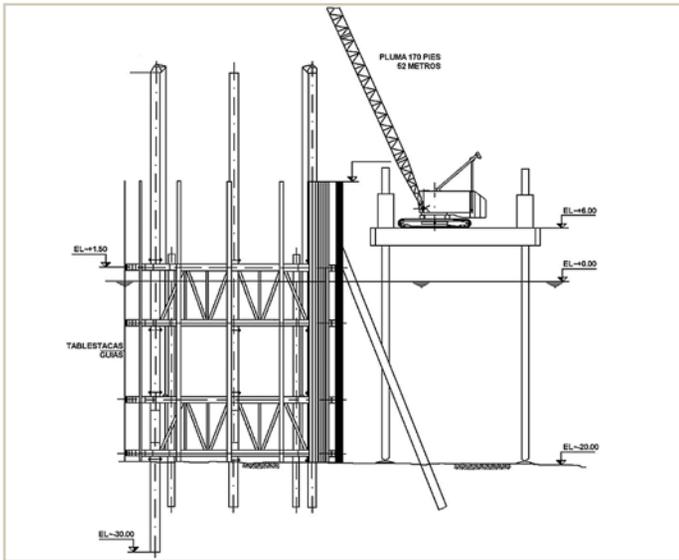
The construction of Puerto Angamos was a first for templates of such size Chile. The contractor used a 200-ton crane on a jack-up platform and a two-level template of roughly 120 t to build each cell composed of 152 AS 500 sheet piles. All the cells were constructed using the same template.



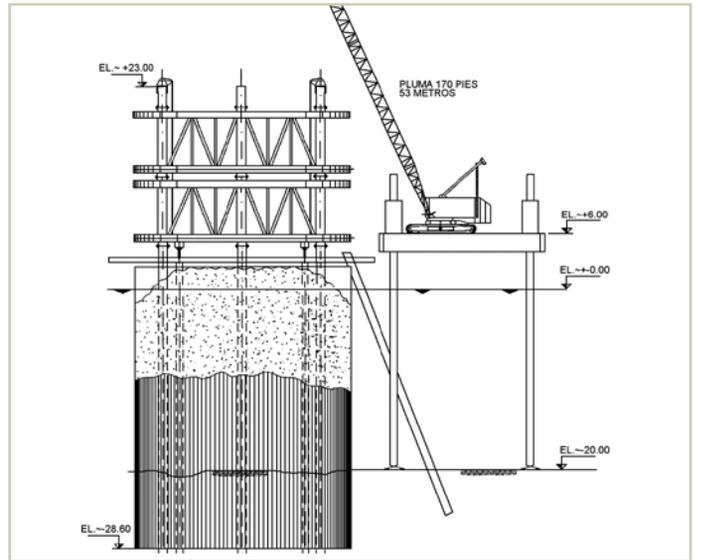
The breakwater is composed of eight cells with a diameter of 24 m.



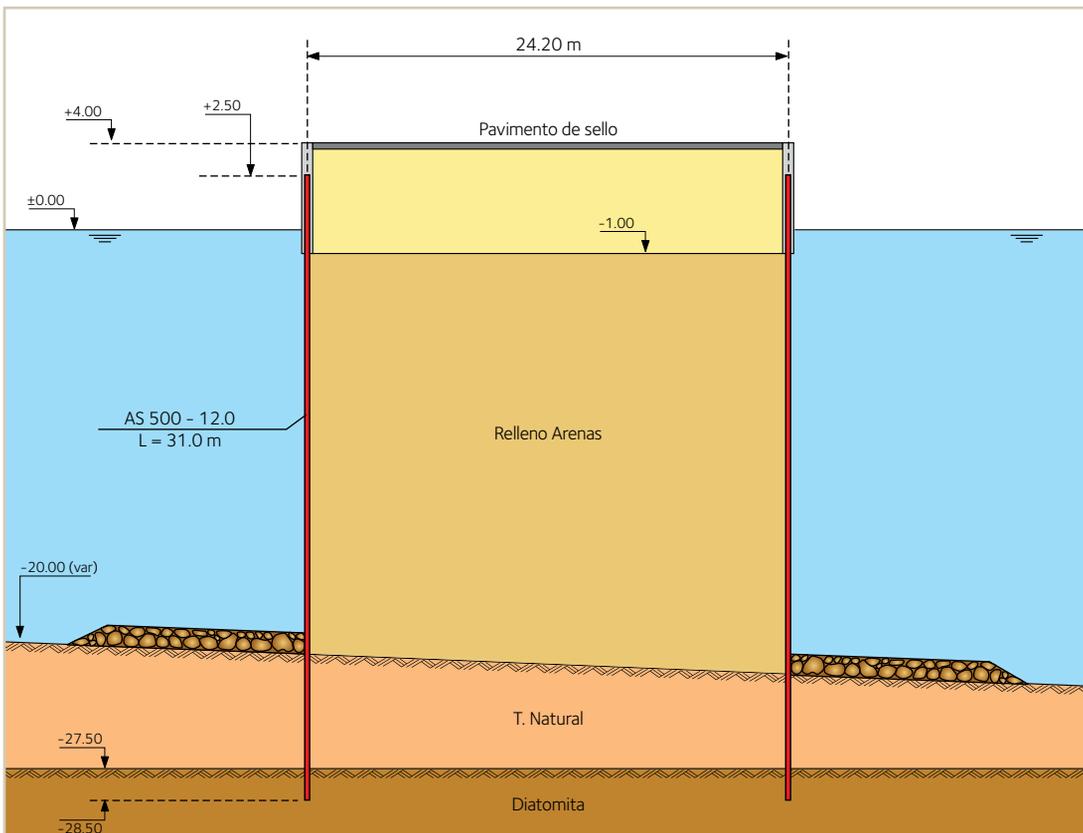
The straight-web sections were installed with the help of a template to form the breakwater cells.



A barge-mounted crane lifted the sheet piles into the template.



Removal of the template and filling of the cells.



The self-stable cells protect the quay area from waves.



The filled cells are capable of supporting the construction plant.

Quays 1 and 2 are deck-on-pile structures. They are designed for ships up to 50,000 DWT and a length of 225 m. The deck foundation consists of 296 vertical and battered steel piles.

The 620-metre wall of Quay 3 was built using bending-moment-resisting sheet piles. A high-strength HZ/AZ combined wall was installed in Puerto Angamos. The quay wall consists of HZ king piles that carry the main loads and AZ sheet piles that act as infill elements also called intermediary sheet piles. The HZ piles were anchored using steel tie rods provided by Anker Schroeder from Germany.

The chosen sheet pile system varies with the rising water depth. The 115-mm-diameter tie rods were supplied in three parts due to their considerable overall length. The individual pieces were joined together by two turnbuckles providing a flexible, moment-free system.



Sheet pile cells are usually filled with locally available sand.



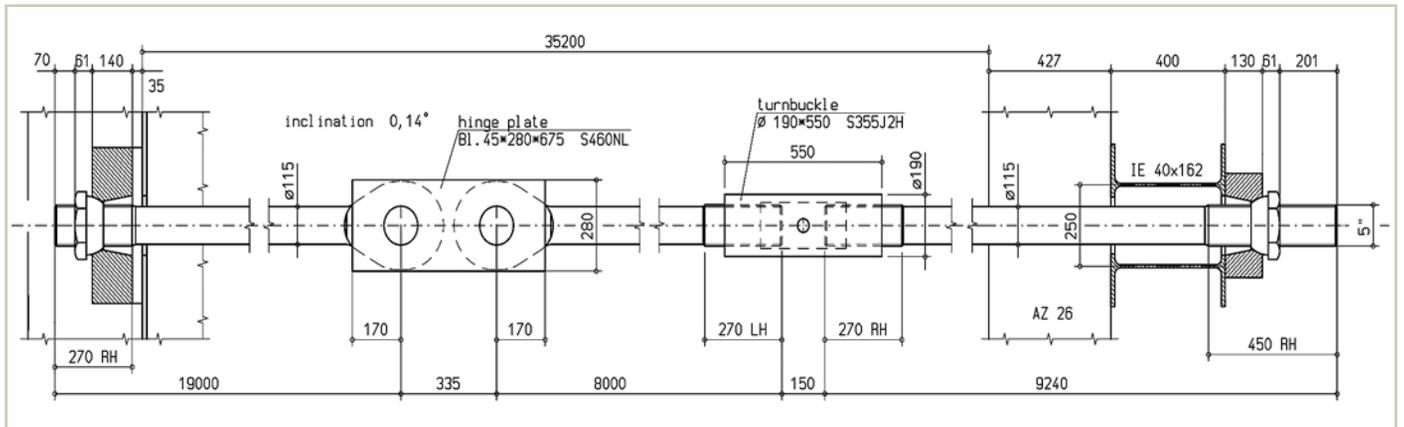
Concrete ring beams protect the cells.



An anchored combined sheet pile wall was chosen as the optimum solution for the quay wall.



A concrete capping beam supports fenders and bollards.



The steel tie rod is in three parts to facilitate transportation.

Owner:
Complejo Portuario de Mejillones S.A.

Contractor & Engineering:
Belfi S.A.

Steel grade:
S 390 GP

Sheet piles:

AS 500 – 12	3,100 t
HZ 575 A – 14	100 t
HZ 575 B – 24	480 t
HZ 775 A – 24	1,500 t
HZ 975 A – 24	1,700 t
AZ 13	620 t
AZ 26	700 t

Total quantity of sheet piles:
8,200 metric tons



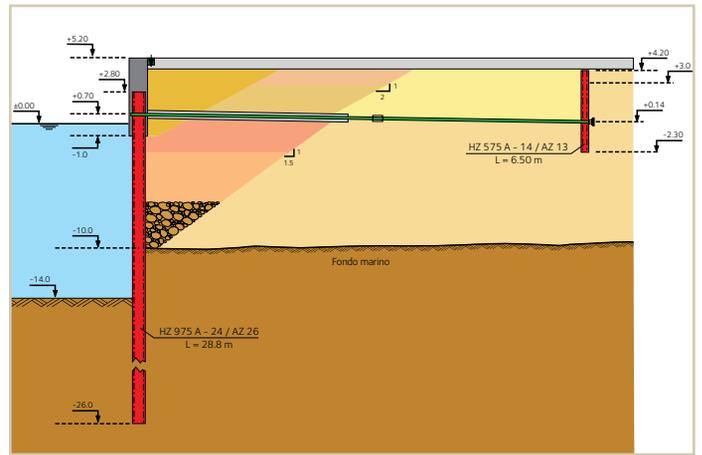
First vessel docking at the new port constructed in less than two years.



A jack-up barge and a template were used to install the HZ/AZ system.

A special template fitting all HZ beams was built to facilitate the installation. Special care had to be taken over the design of this template because it was to fit HZ beams with heights of 575 mm, 775 mm and 975 mm.

Contractor Belfi S.A. used a 100-ton crane to install the steel sheet piles. The crane was mounted with a vibratory hammer for driving of both the straight-web sections and the combined wall. The HZ/AZ system was vibratory-driven until refusal. The vibratory hammer was then replaced by Delmag D-22 and D-30 impact hammers for driving the final metres.



Typical cross-section of the HZ/AZ system adapted to the varying water depth.

The main challenge for the contractor was the completion of the Puerto Angamos' quays in only 22 months. Eighteen cranes and two jack-up platforms were used simultaneously to stick to the tight time schedule. The workforce reached up to 1,400 employees at peak construction times.

The contractor implemented a quality assurance plan for the construction of this important project based on the NCh-ISO 9002 standard. More than 11,000 inspection reports confirmed the outstanding quality of the Puerto Angamos project.



Completed in record time, the port is mainly used by the mineral industry.

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 16th 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 ro-ro 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

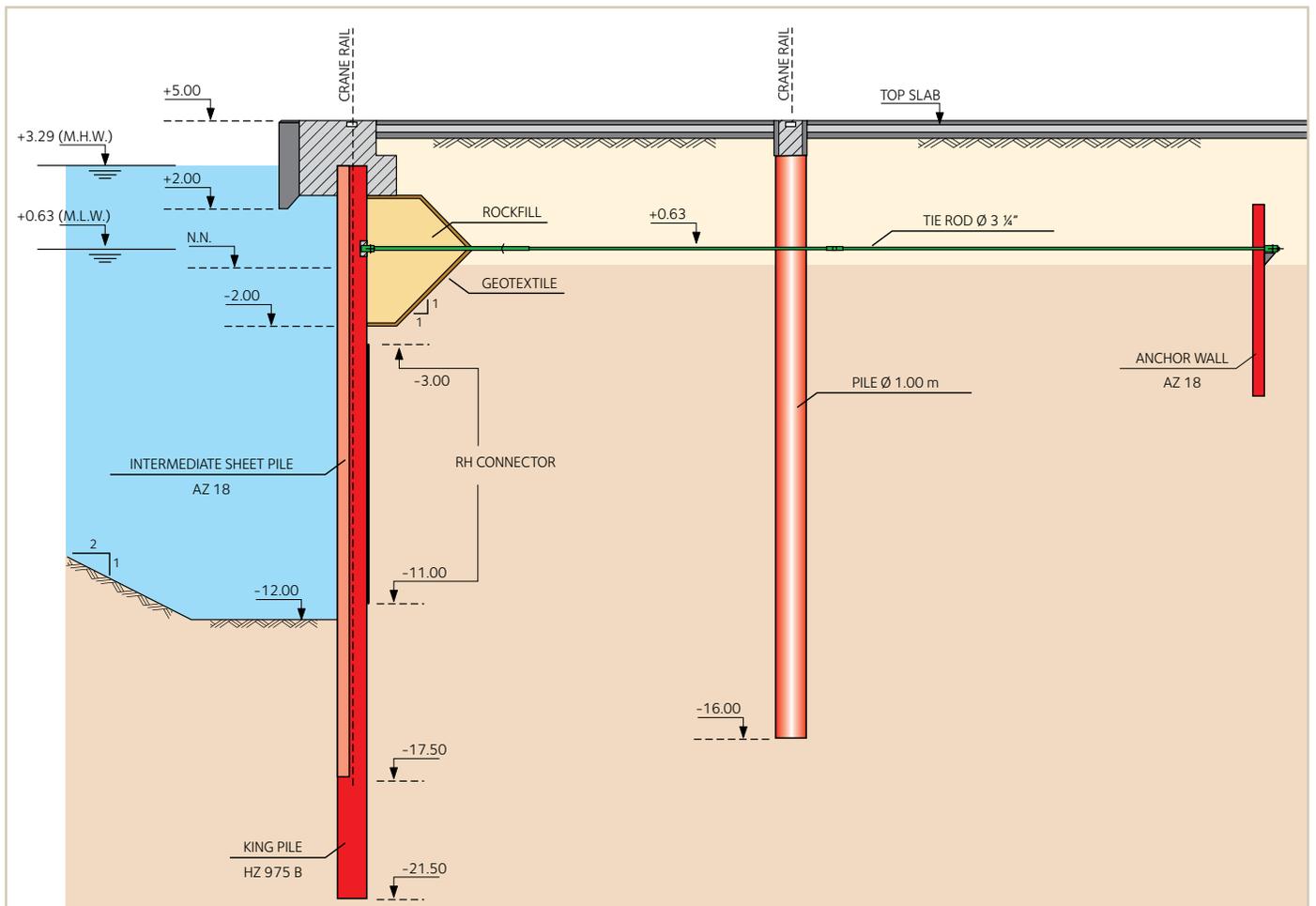
infrastructure for trading bulk goods. For the period 2000 – 2006, the European Union allocated € 3.7 billion for investment in the Portuguese maritime-port sector, with a view to upgrading infrastructures and to making Portugal an integral part of the trans-European transport network.

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.

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.



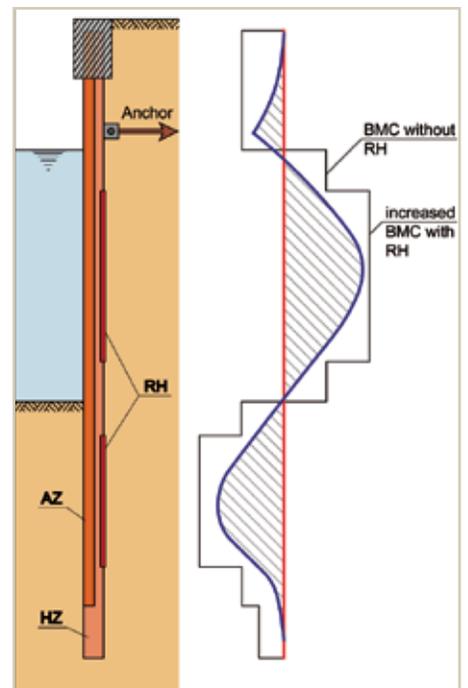
The two parts of Aveiro's new terminal have a combined length of 750 m.



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



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



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

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.



A two-level-template ensured straightness during installation.



The sheet piles were vibratory-driven until refusal.



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

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 ArcelorMittal. They have a length of 31 m, a diameter of 70 mm, and a thread of $3\frac{1}{4}$ ". 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.



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



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, bearing plates, spacers, fixing bolts, and splicing plates with corresponding nuts was delivered by ArcelorMittal 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.



Tie rod/sheet pile wall connection details.

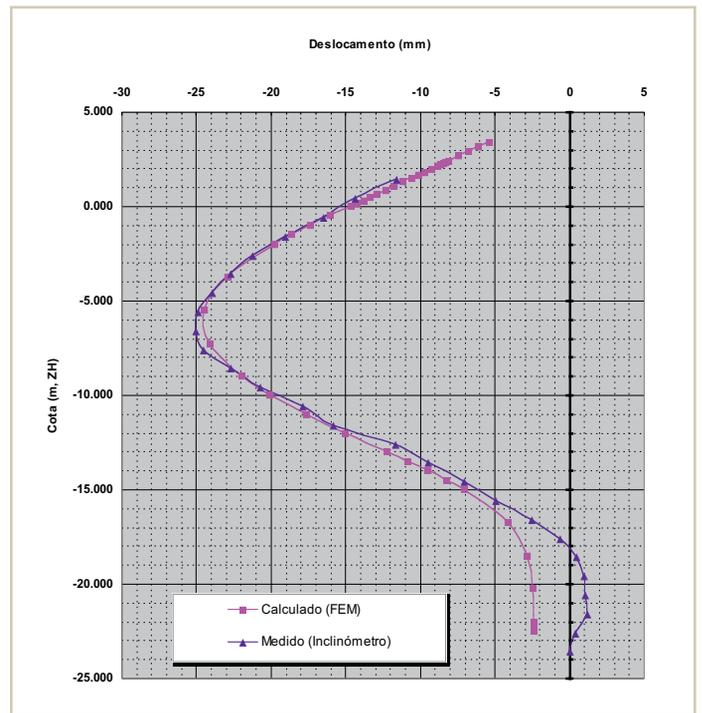
Steel sheet pile solutions are characterised by their great flexibility. The corner section of the main wall consisted of ordinary AZ 18 intermediate elements attached to HZ piles by connectors. Most assignments such as welding or tie-rod installation can be executed by a small workforce in a minimum 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 confirmed the vertical bearing capacity of 1,800 kN.



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 values indicate a vertical king pile bearing capacity exceeding the required 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



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.

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 ArcelorMittal, the new solid-bulk terminal boosts the economy of the region.

Cadiz | Spain

> Extension of existing quay

Cabezuela quay in Bay of Cadiz Harbour originally handled only bulk goods. The Harbour Authority – Autoridad Portuaria de la Bahía de Cadiz – decided to extend the quay in order to increase its bulk handling capacity, thus attracting more shipping lines to the port. The northern end of the wall was extended by 117 m during the first phase of the development project. Construction works for the first phase began in March 1999. The existing “Muelle de la Cabezuela” quay wall built in 1989 is 495 m long. It consists of 17 reinforced concrete caissons founded on rock and gravel 14 m below sea level.

Soil conditions with sufficient resistance to support the caissons were encountered only at great depths towards the north side of the existing quay. Adopting the caisson solution for the extension would have involved high costs due to the deep foundation required. The owner therefore rejected this solution and was looking for more economical construction methods. Deck-on-pile and sheet pile solutions were studied and compared.

Because of advantageous technical and financial aspects, easy installation within short timeframes and minimum environmental impacts, the decision fell in favour of the sheet pile wall.

The great height of the quay wall led to important loads that called for a high-strength-steel sheet pile solution. ArcelorMittal's combined-wall system proved to be the ideal structural element for the 20-m-high Cabezuela quay wall. The HZ/AZ solution incorporates two types of sheet piles: HZ king piles that act as a structural support and AZ sheet piles acting as intermediary infill elements. 31-m HZ 975 D king piles combined in pairs were used for this project together with 24-m AZ 18 sheet piles.

An anchor wall made of AZ 36 sheet piles was installed 36 m behind the main quay wall to limit deflections and to increase the loadbearing capacity. The two walls were connected by tie rods with a diameter of 4.5” placed one metre above water level to facilitate installation.



Economic advantages led to a sheet-pile-based extension of the concrete quay.



The driving template was placed on the embankment.



Tie rods were installed above the water line to facilitate the installation.



A finger quay formed the north end of the Cabezuela quay.



The quay extension required 1,600 metric tons of sheet piles.



Once the sheet pile wall was installed, the area behind it was backfilled.



The connection between old and new quay consists of a steel plate welded to the first sheet pile.



The wall's corner consists of AZ 18 piles that were also used as intermediary piles.

Owner:

Autoridad Portuaria de la Bahía de Cadiz

Consulting engineer:

CEDEX, Alatec Haskoning

Main contractor: NECSO

Piling contractor: Piacentini (Italy)

Sheet pile system: HZ 975 D - 24 / AZ 18

Length of sheet piles: HZ 31 m, AZ 24 m

Steel grade: S 430 GP

Total quantity of sheet piles:

1,600 metric tons

Calais | France

> New passenger berth



The new Berth 9 is equipped with larger ramps and is able to handle bigger ships.

The Port of Calais is situated on France's North Sea coast, at the point closest to England (22 nautical miles). Calais, together with the Port of Dover, provides the main maritime link between the UK and Western Europe.

The two ports find themselves in the unique global position of taking first and second place in port classifications in terms of passenger transport. Handling an average of 65 car ferry departures per day and up to 20 million passengers per year, Calais is also France's fourth largest mercantile port with 38 million metric tons of goods handled annually.

The opening of the Channel Tunnel in 1994-1995 prompted shipping companies to review their operations in order to tackle this new competitor head-on: the frequency of crossings has been increased and embarkment procedures have been improved.



The ports of Calais and Dover are the world's busiest passenger ports.



The existing PU 25 quay wall allowed the new wall to be driven in the dry.



The old anchor wall had to be removed before the piles for the new Berth 9 were driven.



The rocks forming the old harbour bed were removed by a crane mounted on a barge.



Bentonite and other filling materials prevented the possibility of the very fine sand washing out through the interlocks.

The Port of Calais comprised seven ferry berths in 1994. Berth 5, the first berth to be built (commissioned in 1975), in the outer harbour, featured two single-lane links for loading and unloading docking passenger ferries. Initially designed for vessels 168 m long and 6 m deep, it became unsuitable for modern cross-Channel traffic.

For operational and strategic reasons, it was impossible to interrupt traffic through Berth 5. In 1995, the operator of the port—the Chamber of Commerce and Industry of Calais—therefore decided to build a new Berth 8. As soon as it had

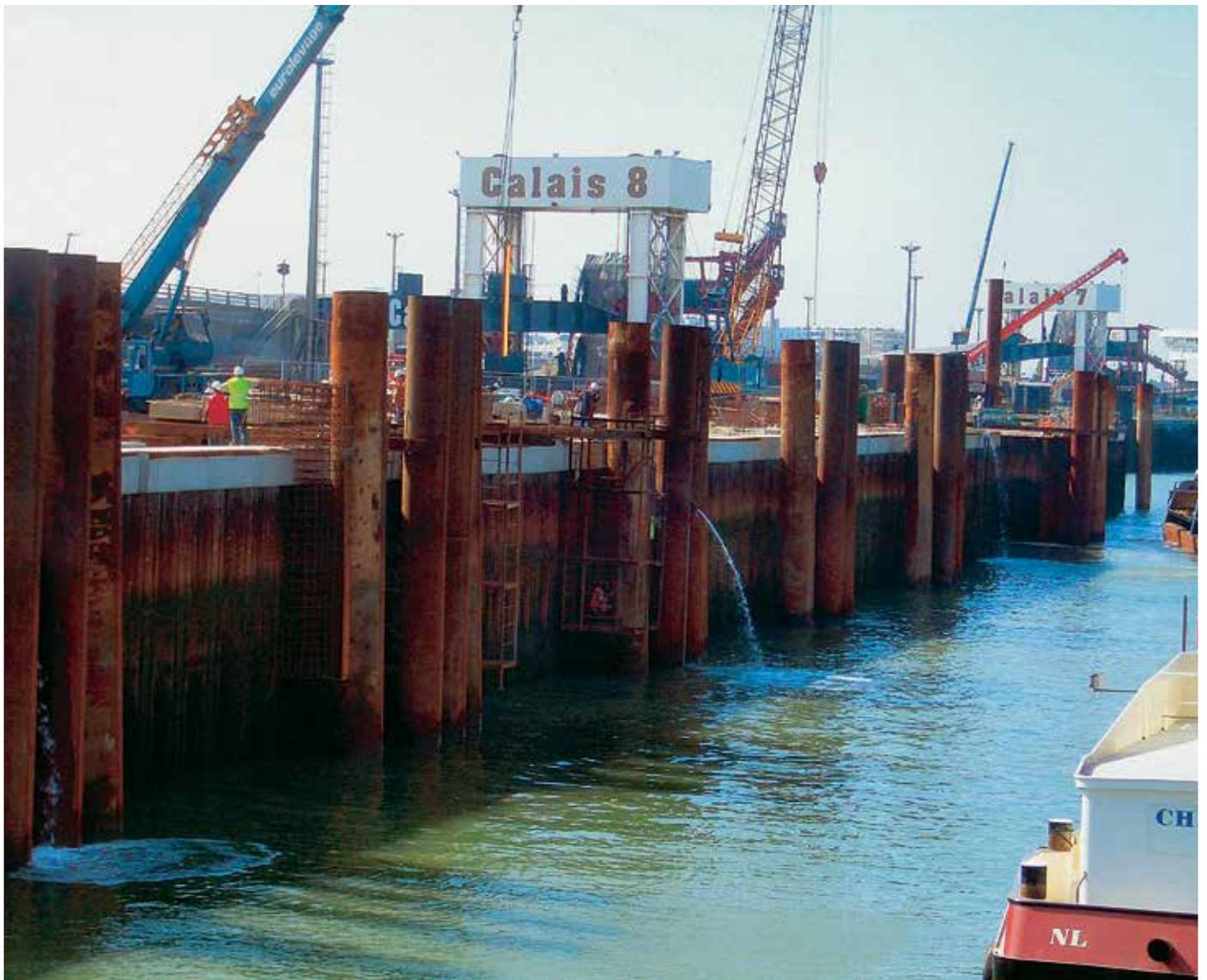
been commissioned, it was possible to start upgrading Berth 5 to a length of 200 m and a dredge level of -8 m. Due to the increased capacity of the latest generation ferries and the requirements to optimise turnaround time, two levels with two lanes each were provided to deal with the roll-on/roll-off traffic at the new berths. Both Berth 5 (HZ 775 B, 26/11 combination) and Berth 8 (PU 32) were constructed using steel sheet piles provided by ArcelorMittal from Luxembourg.



A bentonite trench facilitated driving so that a simple template was sufficient.



Vibratory driving of the 21.6-m AZ 12 intermediary piles.



The steel tubes driven in front of the quay wall act as fenders.



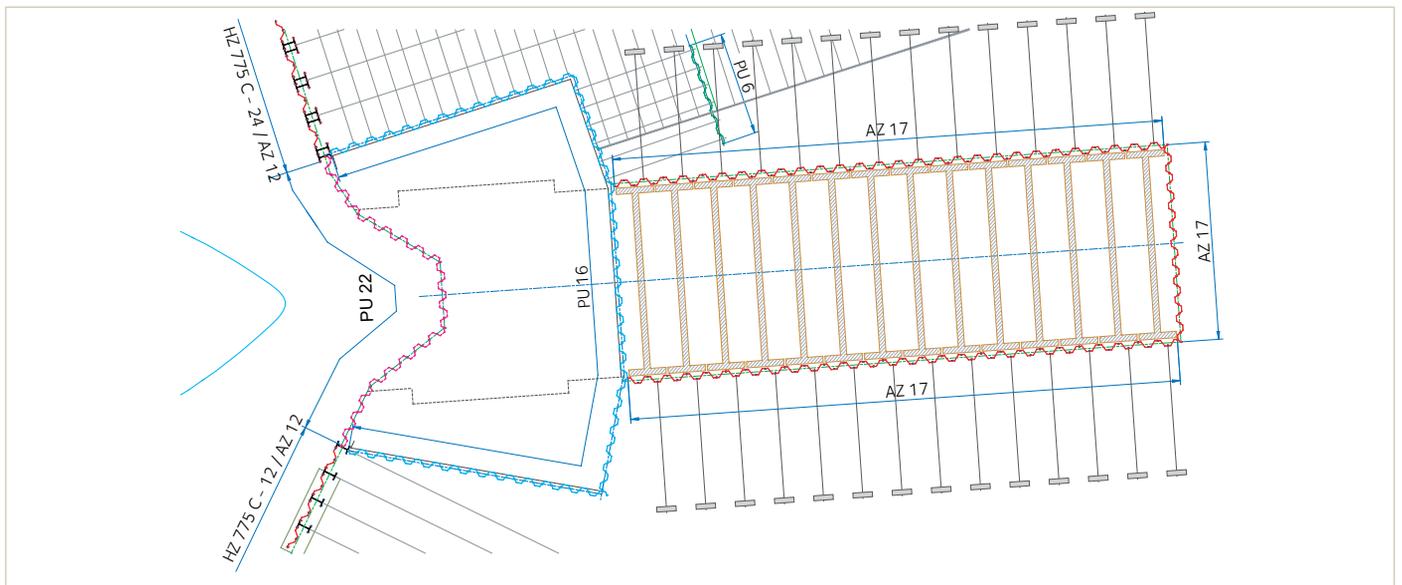
HZ 775 C -26 / AZ 12 quay wall offering a water depth of 8.5 m.

The 100-million-euro investment project for the port launched in 2004 was scheduled for completion by 2006. With its new 180-m car-ferry terminal, Berth 9 is at the heart of Calais' redevelopment project. It was operational at the end of 2005, after a construction time of just over a year. The new pier completes the current range of 4 large-sized and one small berth. Another smaller part of the project is the construction of a new Ro/Ro berth for catamarans and roll-on/roll-off vessels.

The new Berth 9 with a water depth of 8.5 m is built right next to Berth 8. The existing structure at the location of the new berth had to be removed. With a water depth of merely four metres, it was no longer suitable for modern ferries. To allow docking of passenger vessels, the new structure had to be L-shaped. The existing straight berth comprised a PU 25

main wall (top: +9.0 m, tip: -16.1 m) and a PU 16 anchor wall (top: +4.7 m, tip: +0.9 m). Rocks of different sizes had been placed on the waterside in front of the main sheet pile wall. The existing structure facilitated construction of the new Berth 9: the old main wall acted as protection from the sea, enabling the contractor to work in the dry. After removing the backfill material behind the old PU 25 piles, the exposed anchor wall and tie rods were removed easily.

French contractor Spie Batignolles then proceeded with the installation of the new L-shaped combined-wall system. The longer side of the L forms the wall alongside the ferry and is 174 m long. The following sheet piles were installed: 93 HZ king piles with length of 26 m and 92 AZ 12 intermediary piles with a length of 21.6 m.



Berth 9 features a two-level ramp for faster loading and unloading of the Ro/Ro vessels.



The 35 x 14 m sheet pile trench accommodates the lower access ramp.

The design of the sheet pile wall provided by ArcelorMittal's technical team showed that an HZ 775 C-12 solution made of HZ king piles with a height of 775 mm and AZ 12 intermediary sheet piles fulfils the static requirements. More details can be seen in cross-section A-A.

The shorter side of the L-shaped structure measures roughly 48 m and comprises the ramp as well as a sheet pile wall on either side of the ramp. An HZ 775 C-26 solution, as shown in cross-section B-B, formed the quay's front wall.

All HZ king piles were ordered in high-strength steel S 430 GP. AZ 12 sheet piles were used for the anchor wall and as intermediary elements for the main quay wall. The AZ piles of the front wall mainly have a load distributing function; which is why a lower steel grade (S 240 GP) was chosen. The AZ 12 piles in steel grade S 355 GP forming the anchor walls are 2.2 m and 4.5 m long respectively.

There is no special corrosion-protection system in the Port of Calais. It was decided to use an extra thickness that will be allowed to corrode away during the lifetime of the sheet pile structure. The following corrosion reserves were chosen: 1.75 mm on the sea side and 0.25 mm on the soil side of the piles.

In November 2003 several boreholes were drilled to a depth of 35 m to investigate soil conditions. The geological properties such as internal friction angle, cohesion and density coefficients that are necessary for the elasto-plastic design of the sheet pile wall were analysed by pressuremeter, penetration and laboratory testing. For the design of the foundation piles, toe resistance and lateral friction were also evaluated.

The results of the geological investigation revealed three different types of soil:

1. +9 m to -5 m: soft backfilled sand with shells, friction angle: 36°, density: 17.5 kN/m³.
2. -5 m to -20 m: compact "Flandrian sand", friction angle: 37°, density: 19 kN/m³.
3. Below -20 m: silty "Flandrian clay", friction angle: 10°, cohesion: 25-50 kPa.

Operator:

Chamber of Commerce and Industry of Calais

Contractor:

Spie Batignolles

Steel grade:

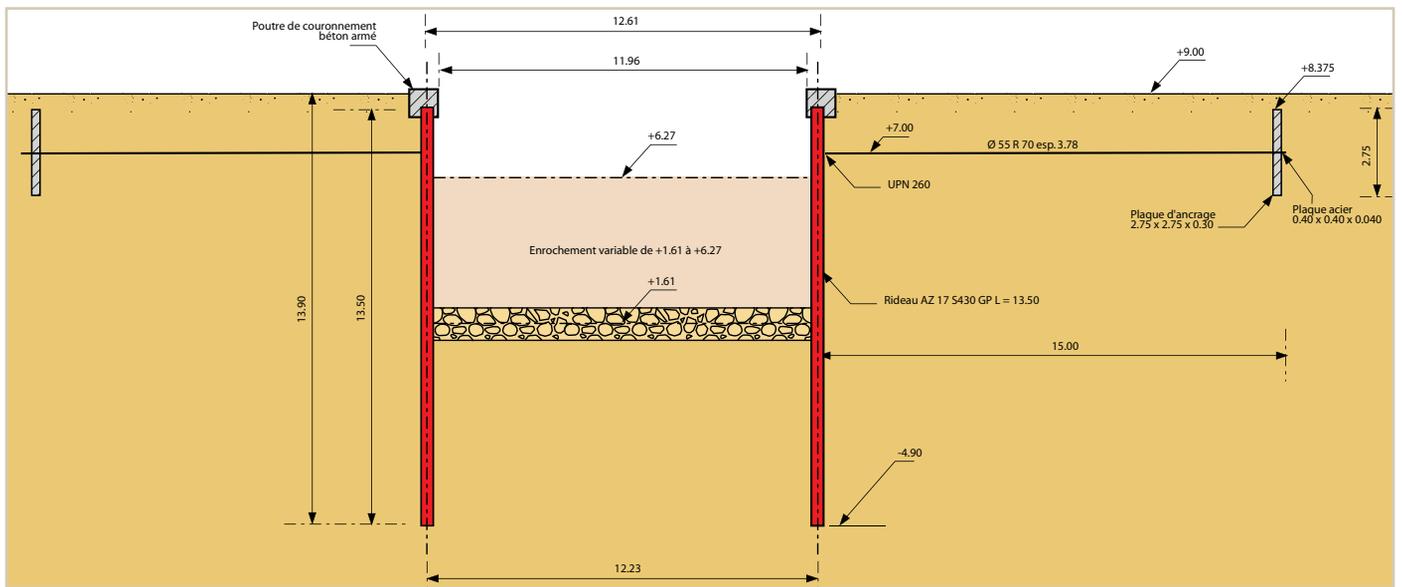
HZ & AZ 17: S 430 GP, AZ 12: S 240 GP

Sheet piles:

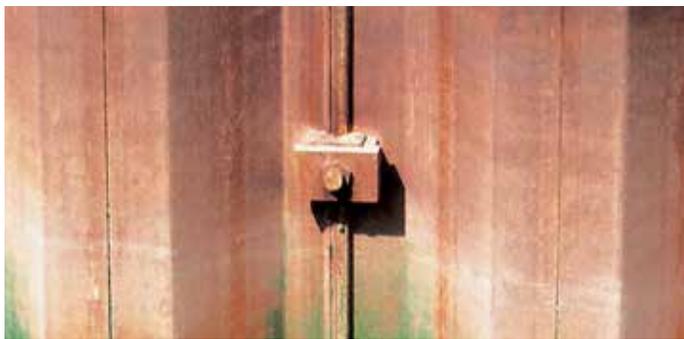
HZ 775 C-12 / AZ 12, HZ 775 C-26 / AZ 12, AZ 17, PU 22, PU 16, PU 6

Total quantity of sheet piles:

1,500 metric tons



ArcelorMittal supplied AZ 17 sheet piles in six different lengths for the trench.



Junction tie rod / AZ 17 sheet pile.

The combined-wall sheet piles were driven into a trench filled with bentonite cement to prevent the fine sand particles washing out through the pile interlocks. Above the top of the trench, the sheet piles were filled with a bituminous material called Beltan, adding to the impervious quality of the steel wall. This unconventional way of installing the piles also had the positive effect of considerably facilitating driving through the hard sand layer. The trench was 1.22 m wide and reached a depth of -16.4 m. This alternative installation method allowed very precise placement of the steel sheet piles without need for an elaborate template.



Lower access ramp of neighbouring Berth 8.

A high-strength (yield strength: 500 N/mm²) steel tie rod connects the two sheet pile walls. Common round steel tie rods have a weak point: the reduced cross section at the thread. In order to provide tie rods with tensile strength corresponding to the shaft diameter, the anchors' ends were upset. These upset tie rods thus combine reduced weight, easier handling and lower costs. The Berth 9 project used upset tie rods with a shaft diameter of 85 mm upset to 105 mm at the thread. They were equipped with T-shaped connectors, bolts and eyes at the front end. The anchors connect both sheet pile walls over a length of 28.5 m. The horizontal tie rods were attached to the AZ 12 anchor wall with the help of a waling made of two UPN beams.

Being exposed to tidal variations ranging from +0.30 m to +7.30 m, the deck of Berth 9 offers an elevation of +9.0 m to enable year-round operation. A water depth of eleven metres was assumed for the design of the quay. A 2.5-m-thick, 42-m-wide bed of rockfill was placed in front of the main sheet pile wall to serve as scouring protection deemed necessary due to numerous ship movements.



Upper access ramp under construction.

A special 14-m-wide trench with sheet pile walls was built for the placement of the steel access ramp. AZ 17 sheet piles were driven on both sides of the 35-m-long inclined trench. The piles were supplied in a variety of lengths: 11.5 m, 10.5 m, 9.5 m, 8.5 m, and 7.5 m for the side walls; 6.3 m for the return wall. The AZ piles were anchored to concrete plates. The two-level ramp allows fast car and truck access to the ferries, optimising docking times in the Port of Calais.

Antwerp | Belgium

> Deurganckdock Container Terminal



Deurganckdock

To meet exponential growth of container traffic in the Port of Antwerp, an expansion programme was finalised in January 1998. It includes a new tidal container dock on the left bank of the river Scheldt some 60 km inland from the North Sea. Once finished, the new facility – Deurganckdock – will double the harbour’s container handling capacity.

Works at Deurganckdock are being carried out in three phases. Terminals with quay lengths of

1,250 m, 1,750 m and 2,200 m are planned. For the design of the quay wall, an extensive soil investigation programme was carried out, and indicated the presence of 8 different soil layers. The quay wall consists of an L-shaped reinforced concrete wall. The horizontal “footing” of the quay wall is up to 26 m wide. A sheet pile wall is driven behind and in front of the footing which supports the 23.5 m vertical wall.

Before the earthworks started, the groundwater level was lowered by means of dewatering pumps in order to execute the construction works in a dry excavation. The excavation proceeded in several steps to reach a depth of -18 m, with different slopes.

Steel sheet piles were driven on both sides of the foot of the quay to ensure the stability of the structure. By connecting them to the footing of the quay wall, erosion of soil from beneath the quay wall was prevented. After driving of the sheet piles, the excavation was deepened to -21 m. A 70 mm layer of dry concrete was placed to obtain a clean foundation surface. Different types of AZ sheet piles were used: some 5,300 metric tons of AZ 19, AZ 26 and AZ 36 for permanent applications and 700 metric tons of AZ 26 and AZ 36 profiles as temporary supporting piles.

Once concreting of the footing of the quay wall was finished, works on the vertical part of wall started. The next step consisted in backfilling the excavation behind the quay wall with sand to +8.8 m. When the first 1,650 m of the quay wall were ready, the soil was then raised to the level of the future terminal sites with the help of cutter dredgers.



Over 6,000 t of steel sheet piles were used for the foundation of the quay walls.



The AZ sheet piles were installed with a diesel hammer.

At the entrance of Deurganckdock, the terminal walls open towards the river Scheldt. In contrast to the L-shaped quay, this entrance wall is an anchored structure. MV piles were used to take the horizontal loads of this retaining wall. MV piles consist of steel bearing piles wrapped with a grout envelope during installation enabling them to carry very high tensile forces. The steel pile displaces soil during the driving process. The volume

created by the displaced soil is progressively filled with grout that provides an excellent connection between displaced soil and the steel element. ArcelorMittal offers a range of special wide-flange piles that are used throughout the world as HP piles for deep foundations of various structures.



Steel MV piles take the tensile forces of the entrance walls.

Owner:

Ministry of the Flemish Community, LIN, AWZ, Maritieme Toegang

Contractor:

Consortium comprising Cordeel, Aertssen, CFE & Van Laere and Dredging Int'l

Driving company:

Soetaert

Permanent sheet piles:

440 t AZ 19; 2,300 t AZ 26; 2,600 t AZ 36

Temporary sheet piles:

540 t AZ 26; 200 t AZ 36

Aarhus | Denmark

> Extension of CT East



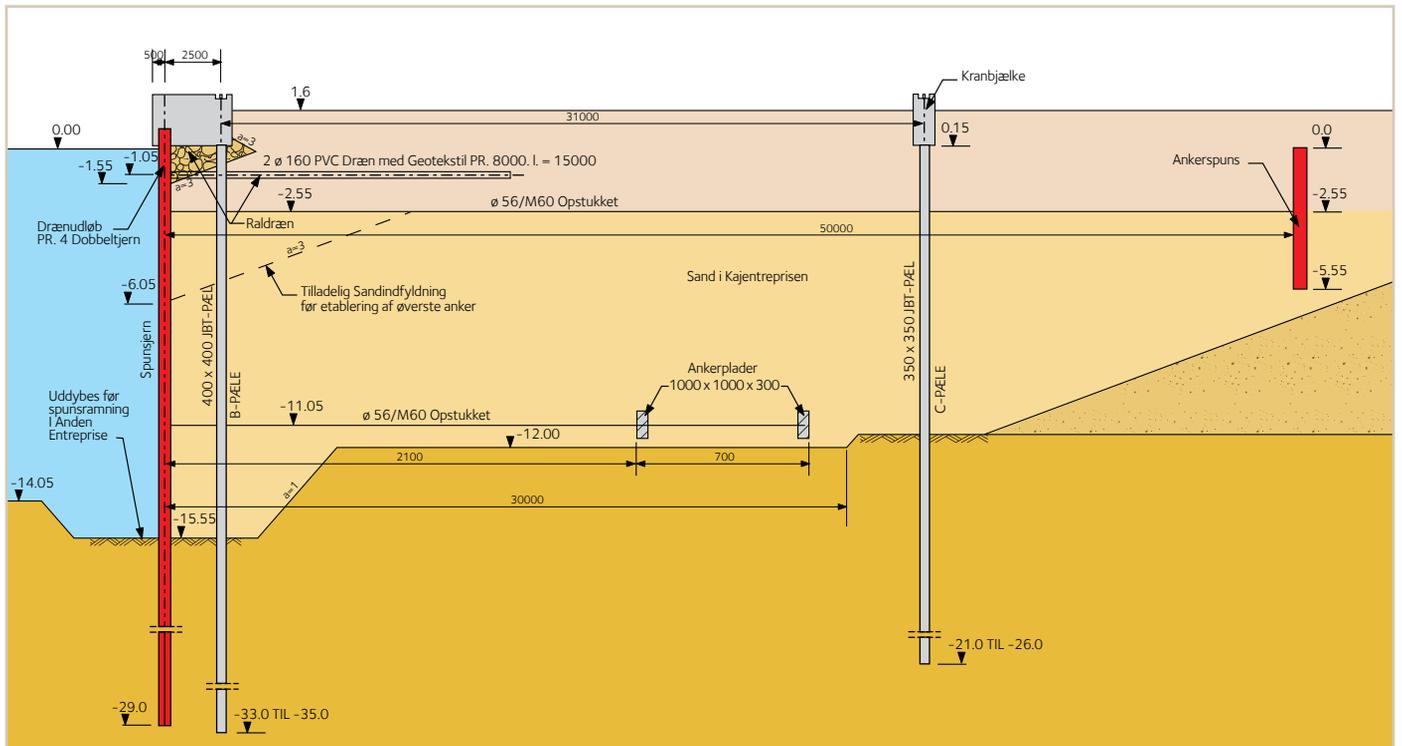
Aarhus is Denmark's major container port.

Aarhus is located on the east coast of Jutland, Denmark's peninsula north of Germany. The town with its 300,000 inhabitants is home to the country's largest container port handling almost 500,000 TEU each year. Covering a land area of 227 hectares, the port offers a total quay length of 13.5 km. Aarhus has a market share of 63% of the total number of containers handled by Danish ports.

The port is ideally located in relation to the home market – not far from the centres of consumption and production in Denmark. Nature has provided the port of Aarhus with a range of significant advantages, for example a natural water depth to match the requirements of large, ocean-going container ships. In addition, there are no natural hindrances such as large waves and winter ice that can hamper vessels calling at the port. Apart from the seaport, Aarhus has major shipbuilding and petroleum-refining industries; other manufacturing activities include machinery, transportation equipment, processed food and beer.



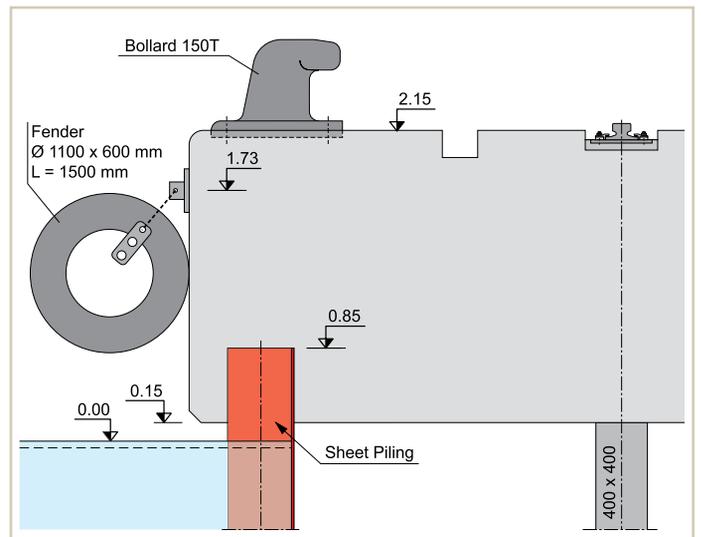
The extension project will increase the annual cargo-handling capacity to 20 million metric tons.



Two levels of tie rods were chosen due to poor soil conditions leading to the positive side-effect of reducing maximum bending moments. A combined wall system was thus unnecessary. The underwater installation of tie rods by divers was a complex task however.



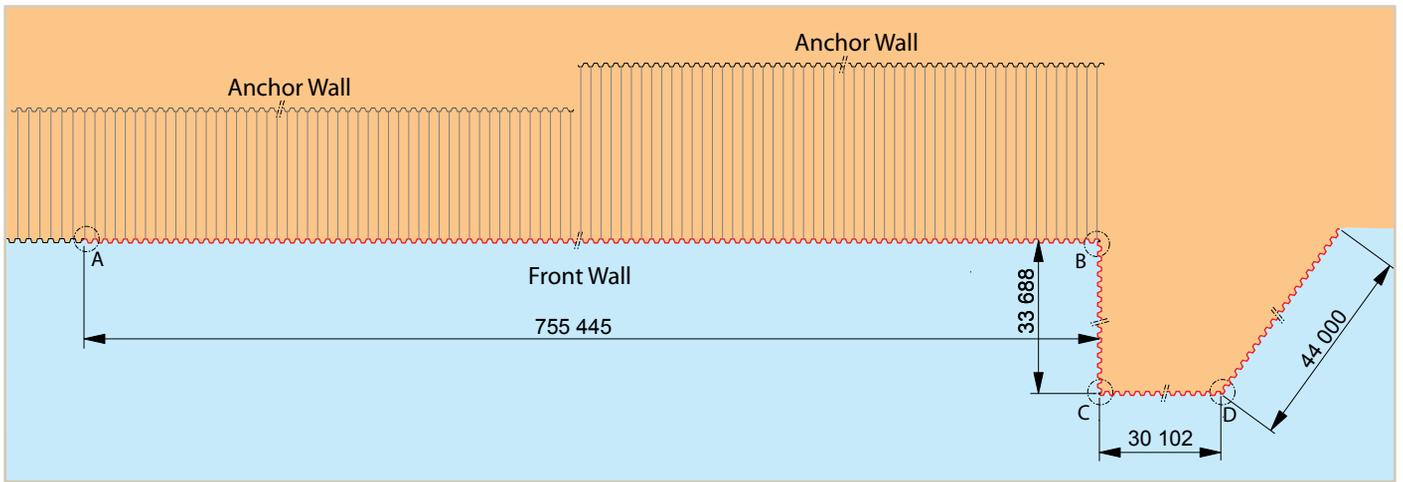
Some 3.5 Mm³ of sand were placed behind the sheet pile wall to create the new CT East.



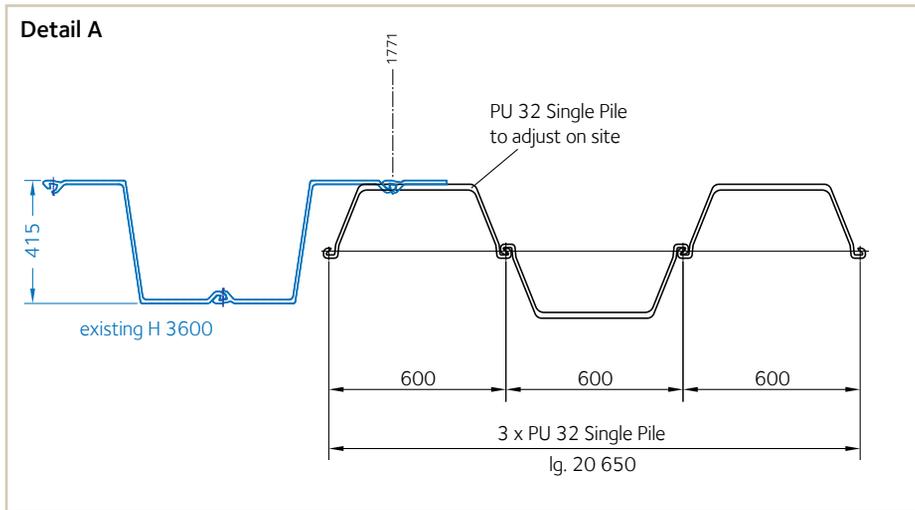
Concrete capping beam showing fender, bollard, crane rail and top of sheet pile.

The all-purpose port has its own towage, pilot and mooring service which is available 24 hours a day, 365 days a year. Approximately 8,000 ships including some 25 cruise ships dock annually at the port of Aarhus carrying a total of 10 million metric tons of goods. Almost 5 million metric tons of cargo are handled via the two container terminals North and East and via the ferry services. The turnover of oil products amounts to almost 2 million metric tons. The last 3 million metric tons include bulk cargo such as animal feed and coal.

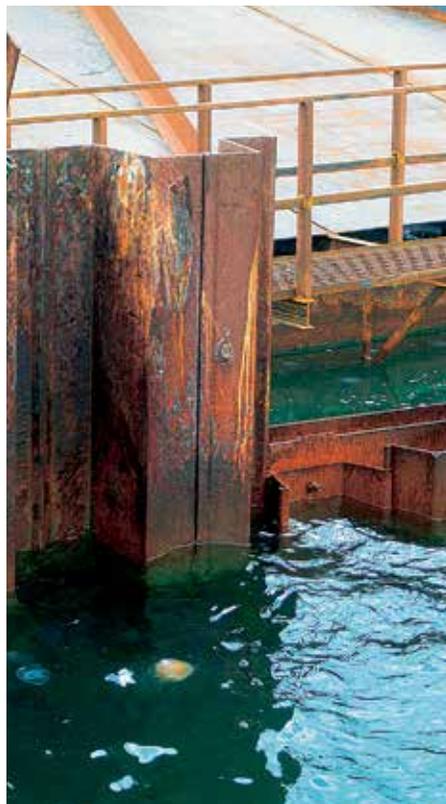
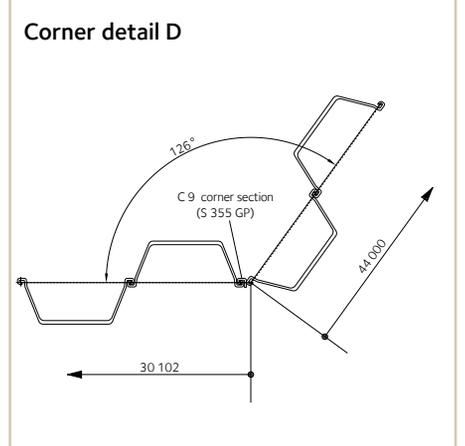
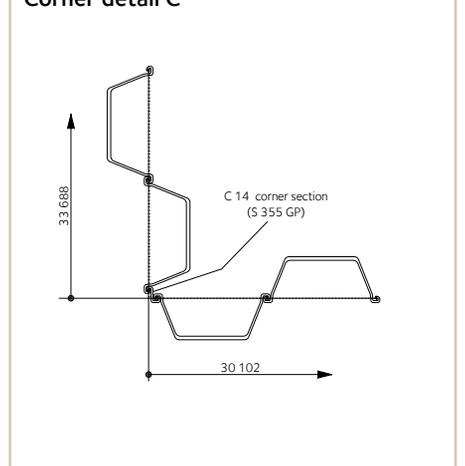
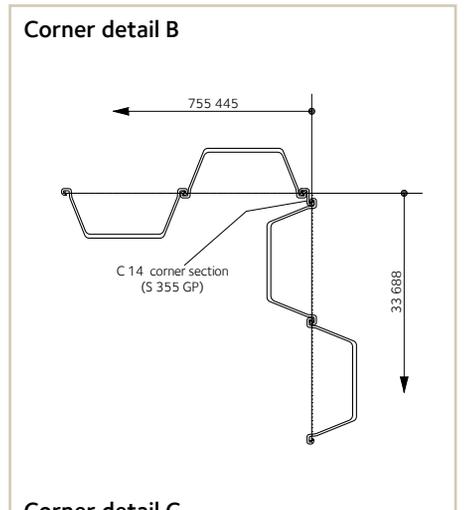
The Port of Aarhus is a municipal autonomous port led by a Board of Governors of seven members with the Mayor of Aarhus as chairman. Ocean-going container ships call at the port to load cargo arriving via smaller feeder ships from countries located around the Baltic Sea. The relatively new EU membership of the Baltic states will result in a market increase in the volume of exports and imports in coming years.



Layout of the new sheet pile quay wall of Container Terminal East.



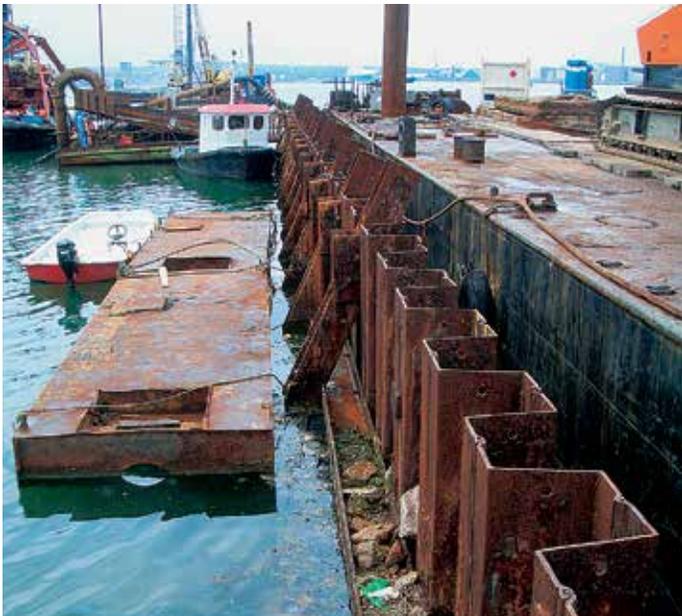
The existing sheet piles were connected to the new PU 32 sheet piles by a single pile that was adjusted on site.



Detail A: End of capping beam of the old CT East. The existing sheet piles of CT East continued a few metres beyond the capping beam.



The construction equipment was mounted on barges to build the quay wall.



The new quay wall was temporarily fixed with inclined piles.



A steel beam was fixed to the main wall as waling.

The port has already established a position for itself as an important Baltic hub. Regular services have been established to other large European and Asian ports. Numerous road and rail connections in addition to modern computer management systems that control reception, delivery and storage of containers mark the efficiency of the Port of Aarhus.

Due to ever increasing trading volume, there is already significant pressure on the European highway network and on the West European container ports. To relieve traffic problems, the EU has declared that sea transport must be promoted. Being close to the new markets around the Baltic Sea, the Port of Aarhus is a solution for fast and efficient cargo transportation avoiding the congested road networks.

The Port of Aarhus is investing its financial profits in the maintenance of the port infrastructure and the development of harbour facilities to make space for even more vessels. In 1995 the port reached its maximum capacities and a programme for extension of the existing quays was decided. Expansion began in 1998 and will be spread out over 25 years. When the extension operation is completed, the port area will have doubled. The annual cargo-handling capacity will increase to approximately 20 million metric tons. The projected maximum water depth is 15.5 m alongside the quays. The budget for the expansion project is estimated to exceed 250 million euros.

The two existing container terminals in the Port of Aarhus are Denmark's largest and busiest offering a water depth of up to 14 m. Each year, 1,500 ships call at Container Terminal North and at the new Container Terminal East to load and unload approximately 500,000 containers. Container Terminal North is equipped with five gantry container cranes, each with a lifting capacity of up to 40 metric tons, while Container Terminal East is equipped with 3 post-Panamax cranes with a lifting capacity of up to 90 metric tons. Each crane can lift an average of 35 containers per hour. The terminals have room for container ships or roll-on/roll-off ships. The terminals are complemented by modern facilities for cooling and refrigerating containers.



Storage area for sheet piles.



Barge-mounted crane for installation of sheet piles.



The sheet piles and the beams were transported to the installation site by barge.



Large areas had to be backfilled to complete the new CT.

The existing part of Container Terminal East came into use by APM Terminals in April 2001. CT East currently offers a quay length of 500 m, a water depth of 14 m and has a storage area of 200,000 square metres that can accommodate up to 6,400 containers. It is equipped with Ro/Ro facilities, railway tracks, office and warehouse facilities and repair and service companies. Efficient cargo handling is assured by straddle carriers, reach stackers and trucks in cooperation with computer reporting and logistics systems.

The projected new quay will add almost 300,000 square metres of harbour area to the existing terminal. The budget for the expansion of CT East designed to accommodate container vessels carrying up to 7,000 TEU was limited to 65 million euros.

For the extension of the terminal, the sheet pile wall of the existing part of the terminal will be prolonged to reach a total quay length of 1,300 m. The new structure is planned as a multiuse terminal. An anchored wall consisting of ArcelorMittal's PU sheet piles was chosen by NIRAS Portconsult and by the technical department of the port. NIRAS Portconsult is a Danish consulting company carrying out assignments worldwide in the fields of port planning and engineering as well as in soil engineering.

Due to poor soil conditions, it was necessary to install two levels of tie rods for the construction of the new quay. To limit the weight and thus the costs of the steel solution, a high-strength steel grade with yield strength of 430 N/mm² was chosen. PU 32 profiles were used for the main wall, PU 22 profiles for the anchor wall. The soil conditions vary considerably along the quay wall comprising weak to stiff clay layers. The sheet pile solution was adapted to these changing conditions: the length of the PU 32 sheet piles of the main wall of the terminal varied from 20.65 to 31 m. The sheet piles were vibratory driven and temporarily fixed with inclined beams by Danish contractor MT Højgaard. The next step consisted in backfilling the area behind the PU 32 wall to -12 m with sand brought in by a dredger from the Bay of Aarhus. The lower tie rod was then installed on top of the backfilled sand at a depth of eleven metres. The tie rod consists of a 28 m steel bar with a diameter of 56 or 63 mm, depending on the soil characteristics present. Two reinforced concrete deadmen, one at the end of the tie rod, the second 7 m from the end, transfer the anchor's traction forces into the backfilled soil. A crane lifted the tie rods with the two 300-mm-thick concrete plates from a barge and lowered them to the design depth. Divers fixed the tie rods to the main sheet pile wall. A hole to fit the tie rod was burnt in the sheet piles prior to installation to facilitate the underwater works.

The dredger then backfilled the area behind the front sheet pile wall until a water depth of three metres was reached. The 1,200-mm-wide PU 22 double piles of the anchor wall were installed with a vibratory hammer. The upper tie rod connects both sheet pile walls at a depth of -2.55 m. All top tie rods have a diameter of 56 mm and are made of high-strength steel (yield strength: 460 N/mm²).



The tie rod consists of a 28 m steel bar, 56 or 63 mm in diameter.



Reinforced concrete deadmen 1,000 x 1,000 x 300 mm.



The crane lifted the tie rod together with the deadmen into position at a depth of eleven metres. Sand was pumped from a dredger to refill the area behind the sheet pile wall.

The first 450 m of the extension uses 20.65-m-long PU 32 double piles. The anchor wall made up of 7-m PU 22 profiles is placed 30 m behind the main wall. The next 345.6 m to the corner of the structure consists of PU 32 profiles with lengths of 25.65, 29.65 or 31 m depending on soil conditions. At a distance of 50 m, 5.5-m-long PU 22 profiles anchored the structure. A corner at the west end of the quay wall was designed to accommodate Ro/Ro vessels.

The foundation for the crane rails was separated from the quay-wall structure because of poor soil conditions. The Port of Aarhus purchased five super-post-Panamax cranes with an outreach of 60 m to serve even the largest container vessels. The loads of the crane rails are carried by reinforced concrete piles with a sectional area of 400 x 400 mm. Due to the enormous loads of super-post-Panamax cranes, the piles were driven as much as 35 m into the weak soil.

The Port of Aarhus has long and very satisfying experience with cathodic protection systems. Several steel sheet pile quays in Aarhus are considerably more than 50 years old. The anodes protecting those structures have been replaced every five to eight years. The port authorities decided to rely on sacrificial zinc anodes as corrosion protection for the new quay. The expected lifetime of the new structure exceeds 50 years. Visual inspections by divers are scheduled every two years to check the actual condition of the anodes.

Although the tidal variations in the Port of Aarhus are in the range of only one metre, a drainage system consisting of rocks was installed behind the main wall. This system reduces the water pressure on the sheet pile wall and allows a more economical section to be chosen. A concrete platform overlying a layer of compacted sand and stones mixed with cement was installed on top of the backfilled sand behind the PU 32 quay wall. Asphalt finishing was not suitable as there are severe risks of the material being damaged, especially in warm weather conditions. A slope of 0.5% ensures rainwater drains from the container handling area. Completion of the new terminal currently under construction is scheduled for mid 2007.



Nearly 4,000 metric tons of PU 32 profiles in different lengths had to be installed to complete the 1,170 m main wall.



Existing part of Container Terminal East.

The port's long-term extension plan is situated on the right side of the white line. The red line marks the new port area which was finished in 2001.



Owner:
Port of Aarhus, Denmark

Designer:
Technical Department of the Port of Aarhus
and NIRAS Portconsult

Contractor:
MT Højgaard, Denmark

Steel grade:
S 430 GP

Sheet piles:
3,930 t PU 32 double piles
690 t PU 22 double piles

Total quantity of sheet piles:
4,620 metric tons



The new terminal will feature super-post-Panamax cranes and a water depth of 15.5 m.

Prøvestenen | Copenhagen | Denmark

> Construction of a new harbour & soil enclosure



The double-wall cofferdam was installed in open water.

Prøvestenen is located in the Danish capital in Copenhagen, whose name historically means “the merchants’ harbour”. The entire Öresund region has always been the obvious connection between Sweden and Denmark as well as between the Baltic Sea region and Western Europe, where a steady increase in cargo volume is anticipated. The region where the famous Öresund Bridge was built is an established logistics centre which includes Copenhagen Malmö Port (CMP). Created in 2001, the two harbours of Copenhagen Malmö Port are 26 kilometres apart. CMP’s vision is to become the leading harbour in the region. The port currently offers a maximum water depth of 13.5 m, a combined quay length of 16.5 km including two container and ten ferry terminals as well as oil tanks with a volume of two million cubic metres.



Different types of steel sheet piles were used for the cofferdam that functioned as a soil enclosure and harbour wall.



The sheet pile cofferdam forms an impervious barrier for the contaminated soil.

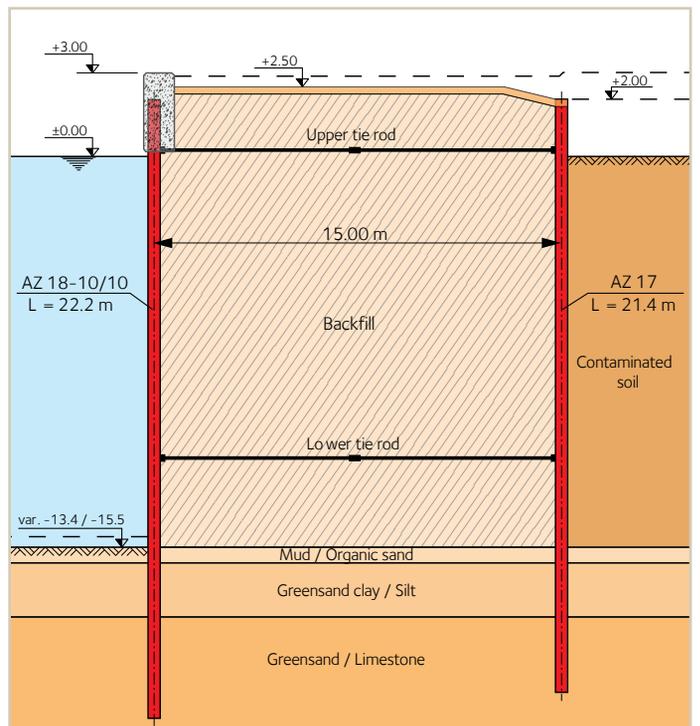
CMP is the biggest dry-bulk harbour in the region and will enhance its position with investments in docking facilities. A development company owned by Port of Copenhagen and the Copenhagen municipality was established in 2001. It was to invest €8 million in the development of Prøvestenen over a 5-year period. The so-called "Fuel Island Prøvestenen" also plays an important role for the local petroleum industry. Construction of the new dry-bulk area in the southern part of Prøvestenen started in May 2002, including a 650-metre quay that will expand the bulk area by 180,000 m².

When the expansion of Prøvestenen was completed in 2004, the dry-bulk activities in the other port areas were scaled down and moved to the new area where the water depth of 13.5 m can accommodate large vessels. The reclaimed area on which the Prøvestenen project was built is located close to the Öresund bridge linking Denmark and Sweden.

The harbour was not the main reason for building the cofferdam in Prøvestenen. The structure was primarily designed as a dumping place for contaminated soil. As a side effect the impervious sheet pile cofferdam forms a quay wall that will serve as a temporary docking place to relieve congestion from nearby ports.

Different types of sheet piles were used for the construction. The total amount of sheet piles was delivered to Prøvestenen in batches, in accordance with the needs at the construction site. Deliveries took place from 2001 until 2003, either by ship or by truck from the mills in Luxembourg.

The water at the south side of the reclaimed area is shallower (design water depth = 4 m). Therefore 9.4-m-long AZ 13-10/10 sheet piles were sufficient for this side of the new quay. The AZ 13-10/10 wall was tied back to concrete anchor plates. A berm was built up along the other part of the south quay. PU 8 sheet piles were driven into this berm with an excavator-mounted vibratory hammer.



The cofferdam consists of AZ 18-10/10 sheet piles on the water side and AZ 17 sections on the land side.



The PU 8 piles were driven into a berm by an excavator-mounted vibratory hammer.

The depth of Öresund Sound on the north side of the quay varies between 13.4 and 15.5 m. A double-wall cofferdam was chosen for this part of the construction. The cofferdam is made up of two sheet pile walls 15 m apart.

The wall facing the Öresund Sound consists of AZ 18-10/10 sections in S 390 GP steel grade with a length of 22.2 m and a section modulus of 1,870 cm³/m. The wall facing the reclaimed area comprises 21.4-m-long AZ 17 sections made of steel with a yield strength of 355 N/mm² and a section modulus of 1,665 cm³/m. The installation of these sheet piles in open water took place with the help of a vibratory hammer that was mounted on a barge. Z-type sheet piles were chosen for the deep-water side of the Prøvestenen quay because of their more economic section-modulus-to-weight ratio compared to U-type sheet piles.

The two walls are held together by two layers of tie rods. The top layer was installed the traditional way with a waling made of double U beams held in place by supporting brackets. The U beams were supplied in 12-metre lengths and joint together with waling joints and screws on site. The lower tie rod had to be installed underwater by divers. The conventional central attachment of the tie rod implied that the holes through which the tie rods pass had to be burnt through the middle interlock of the AZ sections. Furthermore a special supporting plate to bridge the central Larssen interlock is needed. In order not to lose the economic advantage of the AZ sheet piles, ArcelorMittal worked out a means of installing the tie rods next to the central interlocks. The principle of this solution combines the static advantages of the AZ piles with the simple anchoring of U-shaped sheet piles. Off-centre attachment of the tie rods means that ordinary supporting plates are sufficient and that the more difficult boring through the middle interlock does not have to be carried out by the divers. Both material and installation costs are thus considerably reduced.



Several barges facilitated the installation of the two cofferdam walls.



The crane, vibratory hammer and sheet piles were loaded on a barge.



The conventional top tie-rod system includes a waling.



Workshop installation of the waterswelling sealing system.



Most of the sheet piles were brought to Prøvestenen by ship.



Horizontal beams were used as a driving template.



Top steel tie rods of the cofferdam.



Model of the lower off-centre tie rod.

Owner:
Udviklingsselskabet Prøvestenen

Contractor:
Skanska

Consulting engineer:
Moe & Brodsgaard a/s

Sheet pile systems:
PU 8, AZ 13-10/10, AZ 17, AZ 18-10/10

Steel grade:
AZ 18-10/10 in S 390 GP,
all other sheet piles in S 355 GP

Total quantity of sheet piles:
4,500 metric tons

The installation of a double-wall cofferdam implies the filling of the inner wall area with dredged material. The interlocks of the AZ 18-10/10 front wall were sealed. There are several systems available from ArcelorMittal to ensure the watertightness of Larsen interlocks. The simplest system, a bituminous filler, was rejected in this case due to the fact that the nearby petrochemical facilities may have a negative impact on the durability of the bituminous filling system. As contaminated soil was used as backfill material behind the double-wall cofferdam, the sheet pile walls had to form an impervious enclosure to protect the waters of the Öresund region.



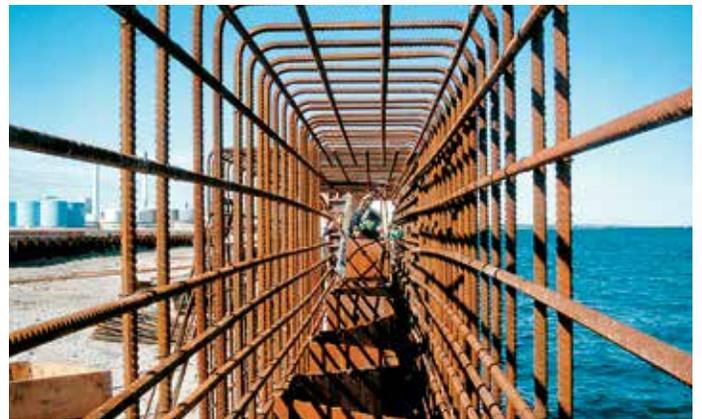
The cofferdam was filled with dredged sand.

The contractor for the Prøvestenen project decided to use a waterswelling product – the Roxan sealing system. Roxan is a urethane prepolymer with waterswelling properties that increases its volume by 100% when in contact with water. The product starts to expand in water after a contact time of two hours and reaches its maximum volume after 24 hours of exposure. It can resist water pressures of up to 25 m.

The system possesses excellent durability for each type of environment. ArcelorMittal supplied the sheet piles together with the sealing system in the interlock. The Roxan system is preferably installed in a workshop with special tools under clean and dry conditions.



The structure is also an enclosure for dumping soil.



Reinforcement bars of the capping beam.



A capping beam fitted with fenders and bollards was placed on top of the sheet piles to finish off the construction.



Formwork for the concrete capping beam.

Hamburg | Germany

> Altenwerder Container Terminal

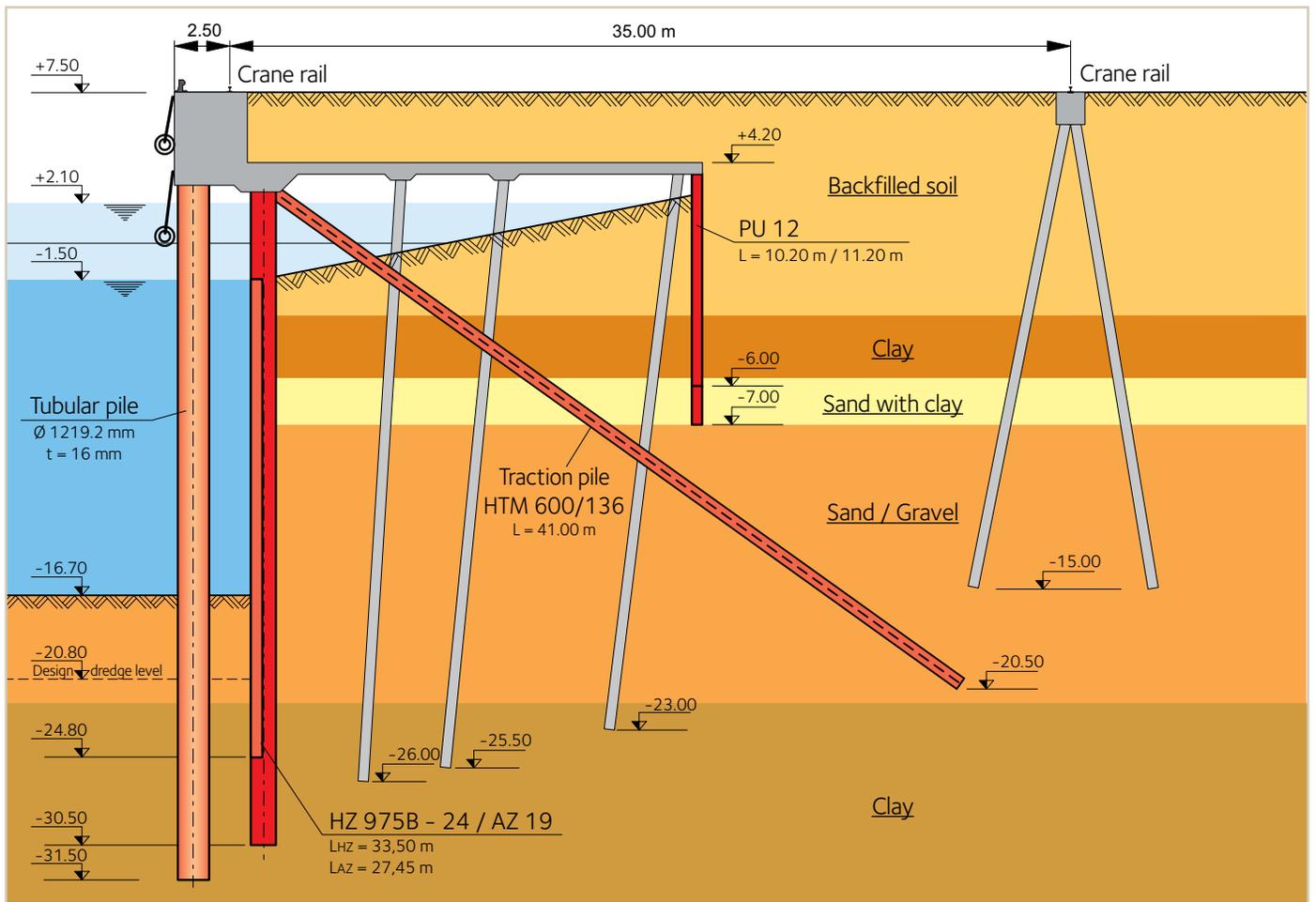
Hamburg, Germany's largest seaport, is also Europe's second largest container port and is among the top ten ports in the world. Due to the predicted increase of harbour transshipments, the port decided to annex the 250-hectare site of the former fishing village of Altenwerder in 1990. A new container terminal with state-of-the-art technology was to guarantee maximum efficiency in the handling of containers by 2003. The Altenwerder Container Terminal was designed to handle 1.9 million TEU per year.

The elevation of the top platform of the container terminal had to be incorporated into the port's flood protection scheme. For this reason the ground level of the Altenwerder site was raised to +7.50 m to allow continued operation despite frequent local floods. The dyke running directly along the waterway was relocated behind the site to make way for the new terminal. The next step consisted in deepening the shipping channel to permit even the largest container vessels to access their berths in all weather and river conditions.

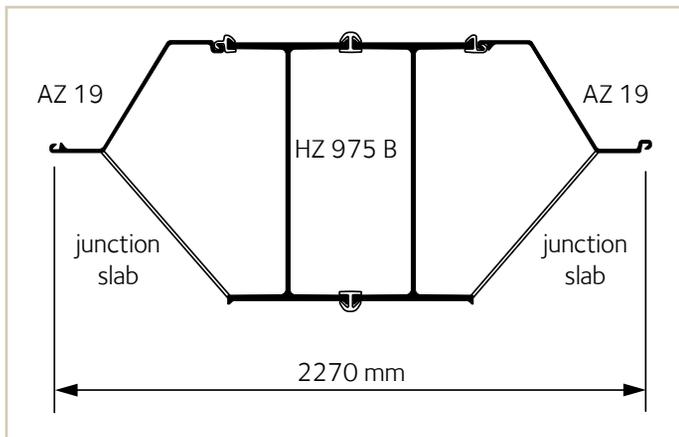
Following EU-wide tendering, the construction of the first section of the quay wall began in April 1999. Apart from predominantly economic factors, the essential criterion for contract award was the construction time. The decision eventually fell in favour of ArcelorMittal's HZ/AZ system, the most cost-effective solution. The expansion of the port calls for construction of four large container-vessel berths with a total quay length of 1,400 m and a water depth of 16.70 m.



The new Altenwerder CT will handle 1.9 million TEU per year.



With a quay-wall height of more than 24 m, the new container terminal can receive super-post-Panamax class vessels.



The double king piles and the intermediary piles were delivered to the site as joined elements.

The basic features of the cross-section include the following elements:

- Low-level superstructure slab with pile foundation (to reduce soil pressure),
- Sheet pile wall set back by 4 m (to minimise scouring),
- Open cross-section (to reduce water pressure),
- Anchor piles (to provide stable anchorage and minimise deformation),
- Soil replacement (ice-age rock strata with boulders),
- Crane track on separate foundation (to reduce surcharges).

The difficult subsoil of the harbour floor in front of the quay wall bears the imprint of the ice age, with changing characteristics resulting in different design scenarios. A clay layer containing huge boulders had a major impact on the choice of installation method.

The unconventional installation method called for replacement of the soil layers above El. -25.3 m instead of driving the sheet piles through the different layers of sand, gravel, pebbles and boulders. The steel elements were placed and driven to final depth in a 1.20-m-wide bentonite-supported trench. Cement was added to the suspension to prevent flushing out of the prevalent extremely fine sand particles. The required vibration energy was considerably reduced by choosing this alternative installation method which implied a much lower likelihood of possible negative impacts on existing structures nearby.



Tubes placed in front of the sheet pile wall act as fenders.



The 47-m tailor-made HTM 600/136 anchor piles were driven with a hydraulic impact hammer.



The joined sheet pile elements where delivered just in time.



The low-level superstructure slab is placed on top of the two sheet pile walls, steel tension piles, fender tubes & concrete piles.

The quay wall of the first construction phase is 955 m long. It comprises two 350-m berths for container vessels and a 100-m feeder-vessel berth. Altenwerder boasts the highest quay wall in Germany with a top level at +7.50 m and a water depth of 16.70 m. The heart of the quay's cross-section is the HZ/AZ combined sheet pile system.

The container terminal's HZ/AZ system features double HZ 975 B king piles in steel grade S 390 GP with a length of up to 33.40 m as structural elements resisting both horizontal soil and water loads as well as vertical foundation loads. Additional plates were welded onto the king pile's toe in order to further increase their loadbearing capacity. The 27.45-m intermediary piles (AZ 19, steel grade S 240 GP) hold back the soil and distribute the loads into the king piles.

The elastic section modulus of the combined wall is 10,330 cm³/m. The HZ king piles and the AZ intermediary piles were joined together in the mill. The large resulting system width of 2,270 mm is of great benefit in terms of installation speed. Openings in the intermediary elements allow sand to be flushed out from below the quay platform. ArcelorMittal delivered all the piles just in time, thus minimising the required storage space.

The joined sheet pile elements each weigh approximately 22 t. They were threaded into the interlock of the previously installed pile and driven to design depth with an impact hammer. Excavation for the bentonite-filled trench and installation of the piles were carried out block by block. A loading trial on a separate king pile at the beginning of the construction works confirmed that the required load bearing capacities were achieved.



Due to difficult soil conditions, and as a means of reducing vibration, the sheet piles where driven in a bentonite-supported trench.

Owner:

Freie und Hansestadt Hamburg,
Hamburg Port Authority (HPA)

Contractor:

Hochtief AQ, NL Tief- und Ingenieurbau Nord,
Fr. Hoist GmbH & Co.

Sheet piles:

8,500 t double HZ 975 B king piles,
steel grade S 390 GP, L = 32.60 m - 33.40 m

1,500 t AZ 19 intermediate piles,
steel grade S 240 GP, L = 27.45 m

1,120 t PU 12 sheet piling apron,
steel grade 355 GP, L = 11.20 m

Bearing piles:

2,300 t HTM 600/136 anchor pile,
L = 45.5 - 47.2 m, steel grade S 355 J2G3

Total quantity of sheet piles:

11,120 metric tons (sheet piles)



A sheet pile wall finishes off the terminal at both ends.



After pouring, the concrete of the relieving platform was covered with a 3.3 m sand layer.



The heavy sheet pile elements were driven to a depth of 30.5 m with an impact hammer.

The relieving platform was founded on concrete cast-in-situ piles. Tensile forces were transferred to 47-m anchor piles fixed to the superstructure with disc anchors. The steel anchor piles were spliced on site and driven with a hydraulic impact hammer at an angle of 1:1.3 into the soil below the platform. Due to the substantial tensile forces prevailing, ArcelorMittal supplied tailor-made HTM 600/136 sections. These piles are characterised by excellent durability due to low susceptibility to corrosion. Quay construction was completed with a rear sheet pile apron made of 11.2 m PU 12 sheet piles at the end of the relieving platform.

Tubular fenders were arranged below the head of the quay, in front of the sheet pile wall, at intervals of 3.59 m. The 30.8-m tubes were positioned by a crawler crane, vibrated with heavy vibratory hammers, then driven with an impact hammer to their final depth of 27.30 m. In order to increase the vertical bearing capacity, steel wings were welded onto the toes of the tubes. Other tubes were extended by up to four metres by on-site splicing. The water cushion between the tubes and the sheet piling reduces scouring at the base of the sheet piles caused by ships' propellers.

Construction works for the foundation (tubes, sheet piles and anchor piles) began in April 1999 and were completed by December 1999. The entire Altenwerder project was completed in spring 2001 using 16,500 metric tons of steel products supplied by ArcelorMittal.

Hamburg | Germany

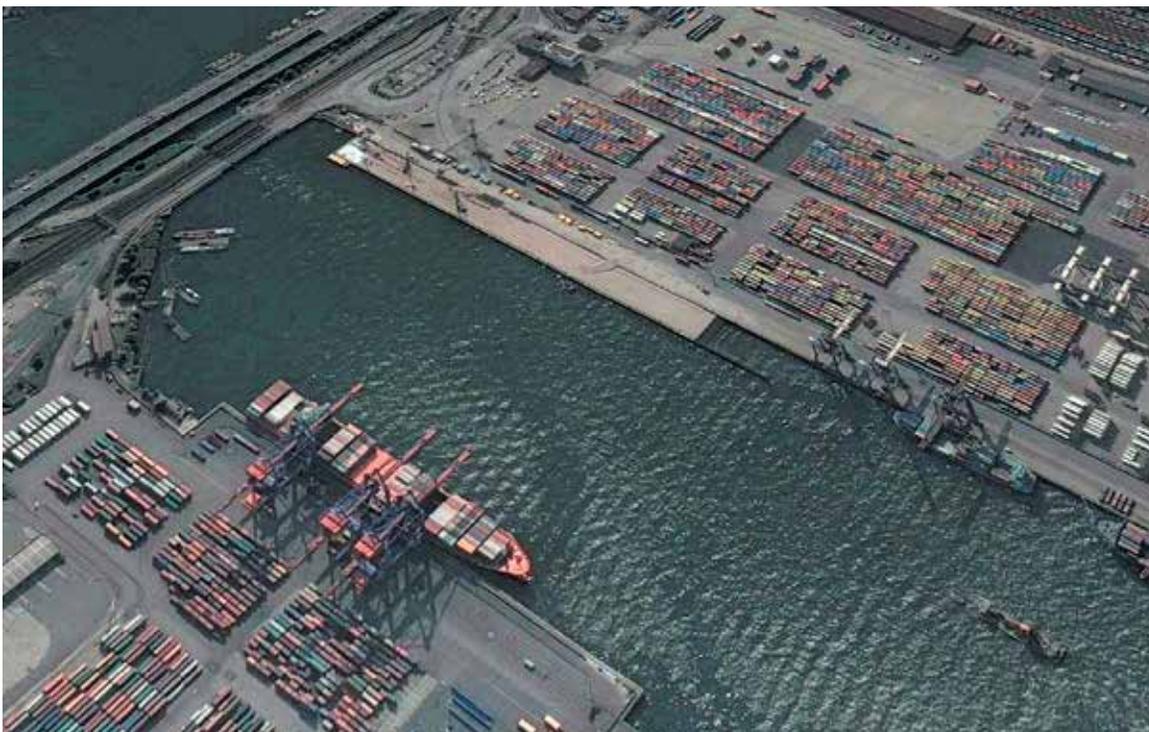
> Predöhlkai extension project – Berth 1

As one of the world's most important ports, Hamburg will handle an expected 14 million TEU by 2010. This represents a major rise from today's 8.5 million TEU container handling capacity. The European mega-port is currently confronted with a 15% yearly rise in container volume and close to 10% growth for total cargo throughput. It was therefore decided to increase the investment funds to approximately 1,000 million euros for enlargement of the following four facilities:

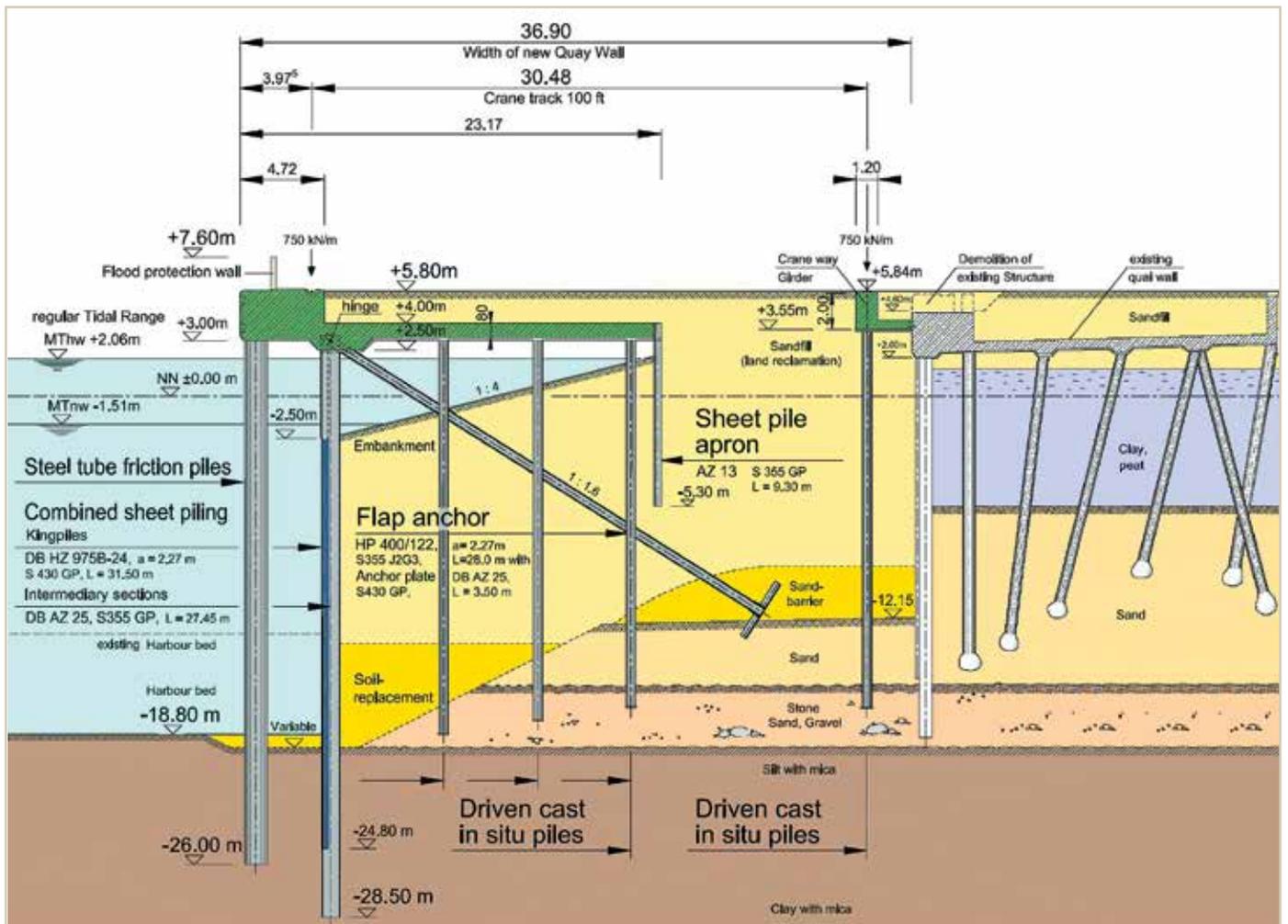
- **Burchardkai Container Terminal:**
Current quay length: 2,850 m. Current quay depth: 16.5 m.
Increase of capacity from 2.6 million TEU to 5 million TEU by area modification and modernisation of the storage system.
- **Altenwerder Container Terminal:**
Current quay length: 1,400 m. Current quay depth: 16.7 m.
It is planned to increase the capacity of the new container terminal built with steel sheet piles from 1.9 to 3 million TEU.
- **Tollerort Container Terminal:**
Current quay length: 395 m.
The expansion of the handling area will increase the container handling capacity by 0.8 million TEU to reach over 2 million TEU by 2011.



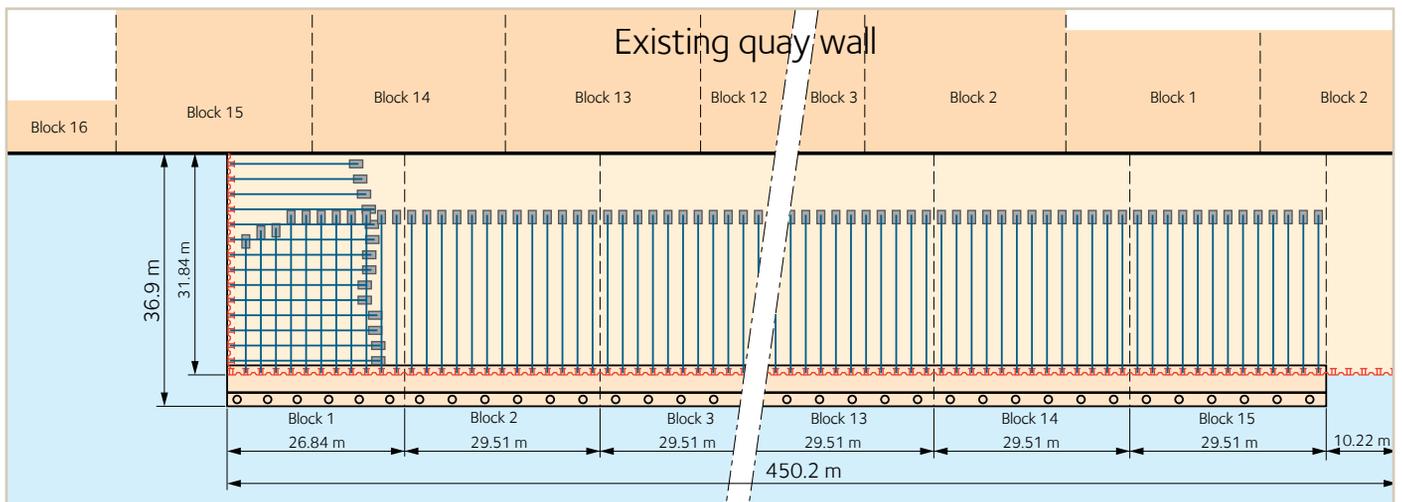
- **Eurogate Container Terminal – Predöhlkai:**
Current quay length: 2,100 m. Current quay depth: 18.8 m.
The extension of Berth 1 has just been completed; the development of Berth 2 to 3 is currently under way. The extension programme is scheduled for completion by 2008 and will extend the entire Predöhlkai quay length by 1,035 m.



By 2010 the Predöhlkai quay will be able to handle more than four million TEU per year.



The quay wall consists of a high-strength HZ 975 B - 24 / AZ 25 sheet pile solution.



Berth 1 is 450.2 m long and is 18.8 m deep.



The new sheet pile wall of Berth 1 was placed 36.9 m in front of the old quay wall.



The steel sheet pile wall was installed with the help of a jack-up platform.



A template guides the head of the double HZ king piles.



The pile toe was guided by a special sledge.



Installation proceeded smoothly as a result of two-level-guidance.

There are further plans for a westward expansion towards the river Elbe that will increase capacity from 2.6 to over 4 million TEU by 2010. The Eurogate project budget is 350 million euros.

The Eurogate Terminal was officially reopened in November 2005 when the first part of the modernisation programme was completed, after a construction time of 18 months. Boasting some of the biggest container cranes in Europe, the terminal is now ready to handle the world's largest container vessels. The modernisation of the 450-m-long Berth 1 included the construction of a new 24.6-m-high quay wall placed 37 m in front of the existing quay wall. Construction of the sheet pile wall was subdivided into 29.51-m-long sections. The first construction unit at the east end of the quay was 26.84 m long and was connected to the old construction at right angles. The western end of the quay is temporarily connected to Berth 2 which is currently being extended. The temporary wall used a combined sheet pile solution.

The entire Predöhlkai quay wall (Berth 1-3) in Waltershofer Hafen harbour will be built by placing a new offset sheet pile wall in front of the existing (sheet pile) quay wall. The Hamburg Port Authority has been using this method for numerous modernisation projects. The method, known as the "Hamburg solution", comprises a row of tubular fender piles and a half-open main sheet pile wall topped with a concrete capping beam and a flood protection wall. All installation works will be carried out from a jack-up platform. The sheet piles and anchors will be brought to the site by barge.

The soil investigations were completed prior to the start of the construction works. They showed that driving obstacles such as large stones are to be expected beneath the present harbour bed. It was therefore decided to replace the in situ soil layer: the sand was dredged, sieved and dumped. This proved to be a good idea as stones with a diameter more than 63 mm were extracted. At greater depths very hard silt and clay layers made driving extremely difficult but not impossible.

A high-strength combined steel sheet pile wall (HZ 975 B - 24/AZ 25) was chosen as a soil retaining structure. The main elements are double HZ 975 B king piles in a high steel grade. The double king piles at 2.27 m intervals were driven to depths ranging from 28.5 m to 29.5 m with a hydraulic hammer. Driving proceeded smoothly in the first sections with the IHC S-90 hydraulic hammer. From section 4 onwards, the cohesive values of the lower silt and clay layers proved to be too high for the hammer to drive the piles to the design depth. It was therefore decided to use an IHC S-280 hammer, the heaviest driving gear ever to be used in the port of Hamburg, delivering an energy of 280 kNm per blow with its 13.5-ton ram.

ArcelorMittal recommends installing combined walls with the "Pilgrim Step" driving method using a template with two guiding levels. The contractor chose an alternative method: a single template attached to a jack-up platform guides the top of the piles. The second guiding level is provided by a sledge that ensures the correct predefined distance between the king piles. Even though the "Pilgrim Step" driving method was not applied, the installation results were excellent.

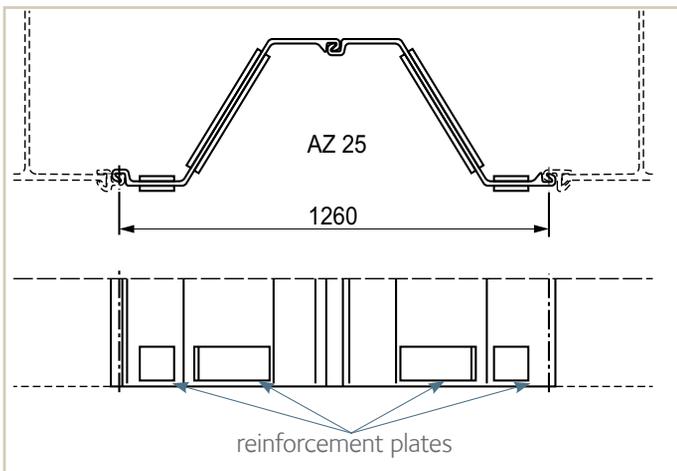


A crane lifted the sheet piles into the template.

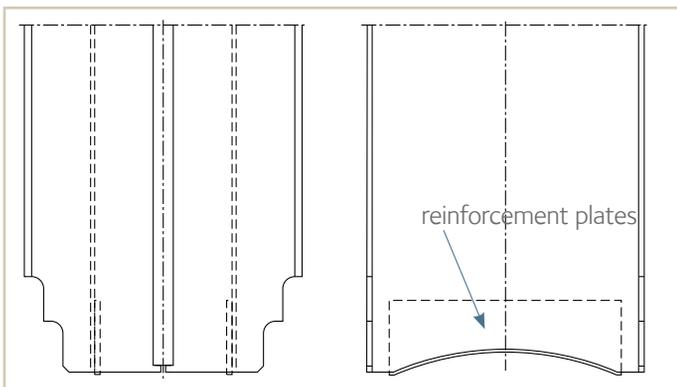


Because of the extreme soil conditions, pre-drilling was necessary to facilitate installation of the AZ piles.

Both HZ king piles and AZ intermediary piles were reinforced at the toe to cope with the hard soil. The webs of the HZ 975 double king piles were provided with 15 mm reinforcement plates and a concave cutout. The stepped cutouts of the flanges additionally reduced the driving resistance. Both sides of the AZ 25 double piles were reinforced with 15 mm steel plates. They were driven to a depth of 24.8 m in between the HZ king piles installed previously. Due to the difficult driving conditions it was decided to loosen the soil by pre-drilling to facilitate the installation of the lighter intermediary sections. A vibratory hammer was used to drive the AZ sheet piles until refusal, and an impact hammer then drove them to the design depth. The top part of every second AZ intermediary pile was cut to allow a wave chamber to form by natural erosion of the soil underneath the superstructure. The top 2.5 m of the interlocks of the concerned AZ piles concerned was cut off at the mill. This reduced welding torch cutting on site to a minimum.



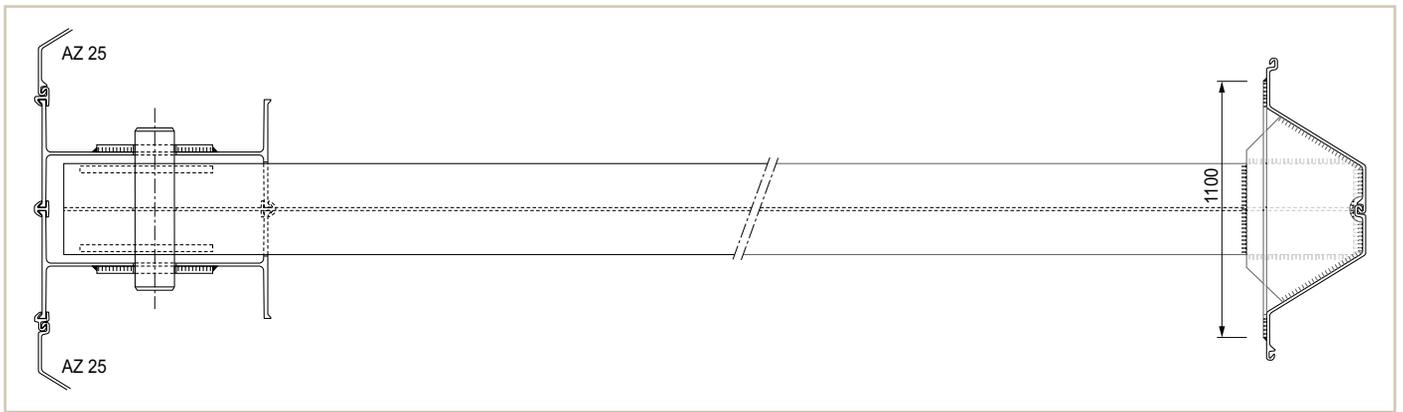
The toe of the double AZ pile was reinforced with 15-mm-thick steel plates.



The web and flanges of the king piles were cut to facilitate penetration into the hard soil.

The ingenious anchor system of Predöhlkai quay consists of pivoted 28 to 34-metre HP bearing piles attached to short double AZ sheet piles. This system is not only able to take high traction forces, but it can also be installed where very difficult driving conditions are to be expected. The preassembled anchors made up of HP 400/122 piles (steel grade S 355 J2G3) and stiffened AZ 25 double piles (steel grade S 430 GP) were delivered to the construction site by barge. A crane lifted the anchor into a horizontal position behind the quay wall. A joint connection attached the pivoted system to the wall. The vibratory hammer was attached to the anchor piles before the system was lowered to the harbour bed. Once the anchor reached an angle of 32°, the vibratory hammer was switched on to drive the sheet pile into the soil to ensure it did not move during backfilling. To facilitate installation of the anchors and to prevent jamming of the vibratory hammer, the top of the AZ piles was provided with two slots. The inclined anchor system functioned perfectly even in the east corner of the quay wall where the anchors of the main wall and side wall crossed each other.

To minimise scouring problems caused by ships' propellers, 1,220-mm-diameter steel tubes were placed in front of the quay wall. The entire area behind the new quay wall was backfilled with sand in later construction stages. The river sand from the Elbe River delivered by dredgers was piled up behind the main wall, securing the anchor system in position and allowing the concrete works on the top of the quay wall to be built in the dry.



Pivoted tension piles welded to AZ 25 sheet piles acted as anchors.



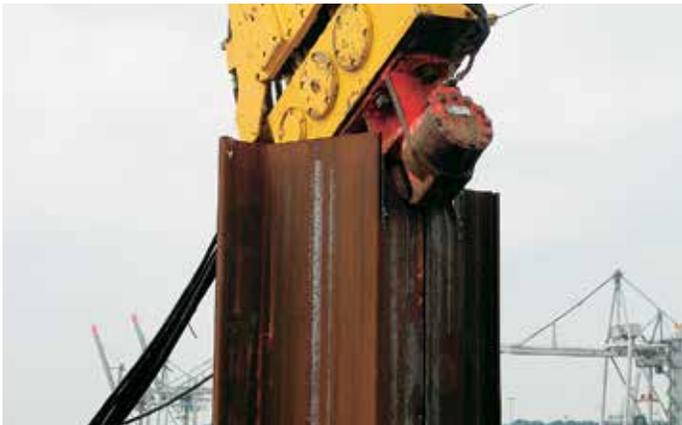
A crane lifted the preassembled anchors into position.



The vibratory hammer was attached to the sheet piles prior to installation of the anchors.



The entire anchorage system was lowered to the harbour bed with the vibratory hammer.



Two slots prevented jamming of the vibratory hammer.



At an angle of 32°, the vibratory hammer was switched on to securely position the anchor.



A 170-mm-diameter pin forms the pivot of the anchor system



The 3.5 m AZ 25 piles transfer tensile forces into the backfilled soil



Each HZ double king pile was fitted with an HP 400 x 122 tension pile.



The corner anchors had to be installed with great care as they crossed each other on different levels.



Steel tubes take vertical loads and minimise scouring.

The vertical loads of Predöhlkai Berth 1 are partly carried by steel systems – tubes and sheet pile wall – and partly by concrete piles towards the back of the quay. Three rows of concrete piles with diameters of 510 mm take the loads of the concrete superstructure. The superstructure fulfils a load relieving function, allowing economical design of the front sheet pile wall. AZ 13-10/10 sheet piles in steel grade S 355 GP were driven to -5.3 m at the back end of the concrete superstructure. These sheet piles have a soil retaining function. A row of concrete piles carries the loads of the rear crane rail situated just in front of the former quay wall.



The load-relieving concrete superstructure installed at elevation +3 m provides for economical design of the combined sheet pile wall.





The structural elements of the quay comprise sheet piles, steel tubes, tension anchors, concrete columns, and the load relieving-superstructure.

Overview: Construction phases 1 to 8 for Berth 1

- **Phase 1:**

An excavator mounted on a jack-up barge dredged the stony soil layer and placed it on a sieve. The sieved sand was transferred by conveyer belt onto a barge.

- **Phase 2:**

The barge was towed above the future location of the new sheet pile wall where it released the sand.

- **Phase 3:**

The HZ king piles were driven from the platform using a crane-mounted hydraulic hammer. The IHC S-90 hammer drove the piles to a depth of approximately 22 m. If extremely difficult driving conditions were expected, pre-drilling to a diameter of 360 mm was carried out. An IHC S-280 hydrohammer was used to drive the king piles to the final depth.

- **Phase 4:**

The soil was pre-drilled (diameter 600 mm) prior to installation of the intermediary AZ 25 sheet piles with a hydraulic-hammer.

- **Phase 5:**

The anchor was first lifted from a barge with a crane and placed in the joint connection, then vibrated into the harbour floor before placement of the backfill material. The steel scour-protection tubes were also installed during phase 5.

- **Phase 6:**

A hopper dredger carried river sand to backfill the area between the new and old quay walls.

- **Phase 7:**

The 510-mm-diameter concrete piles and the AZ 13-10/10 rear sheet pile wall were installed. Each concrete pile has a maximum bearing capacity of 2,500 kN.

- **Phase 8:**

The reinforced concrete superstructure was installed. "Windows" were cut from the lower side of the superstructure down to -2.5 m into the AZ piles to allow the wave chamber to form.

Owner:

Freie und Hansestadt Hamburg, Hamburg Port Authority (HPA)

Designer:

– KMT Ingenieurgesellschaft mbH, Hamburg
 – Hochtief Construction AG, Hamburg
 – F + Z Baugesellschaft mbH, Hamburg

Contractor:

– Hochtief Construction AG, Hamburg
 – F + Z Baugesellschaft mbH, Hamburg
 – Aug. Prien Bauunternehmung, Hamburg

Steel grade:

S 430 GP, S 355 GP

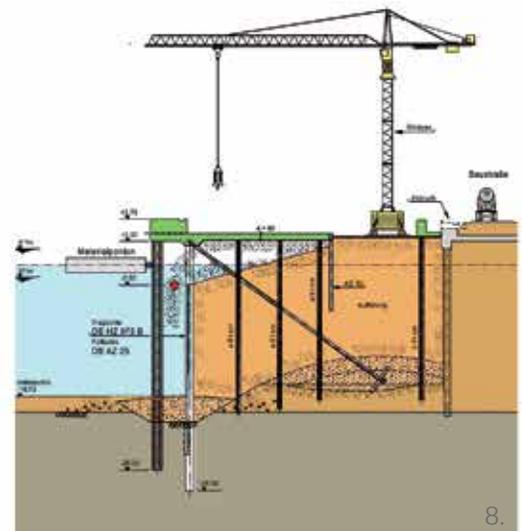
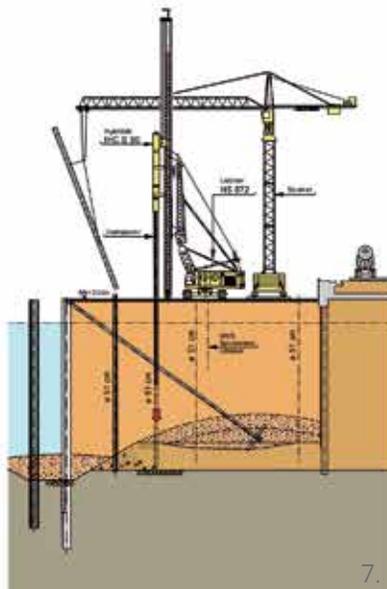
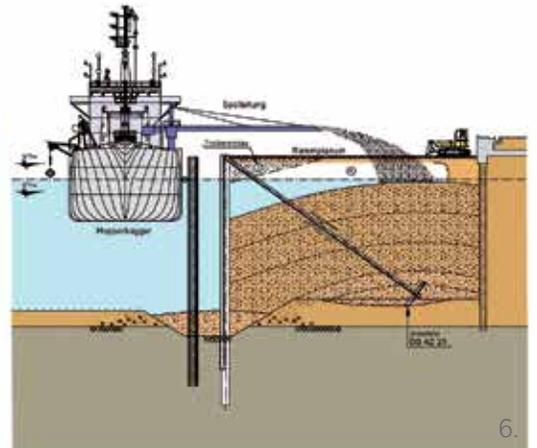
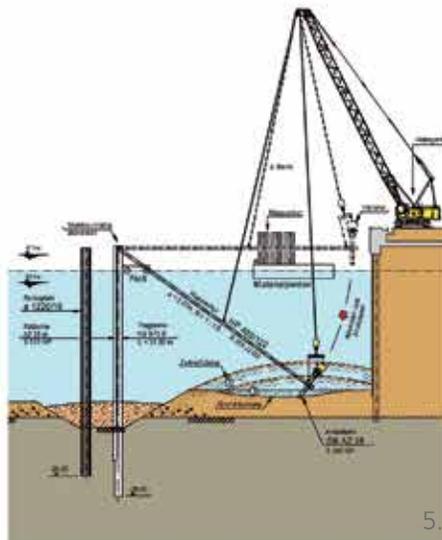
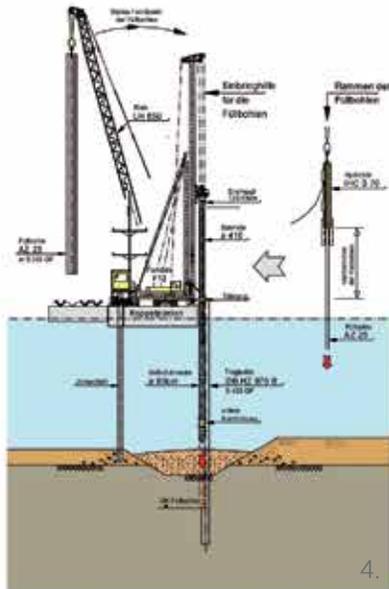
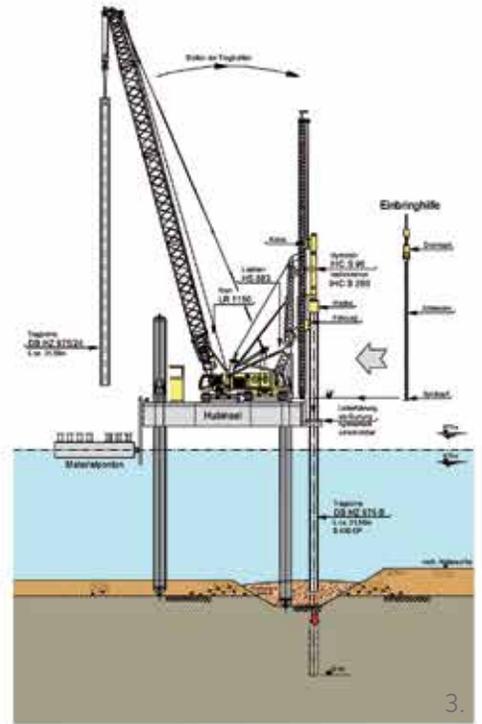
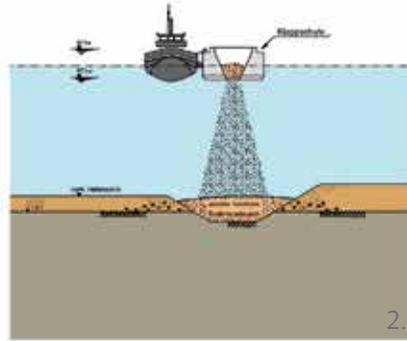
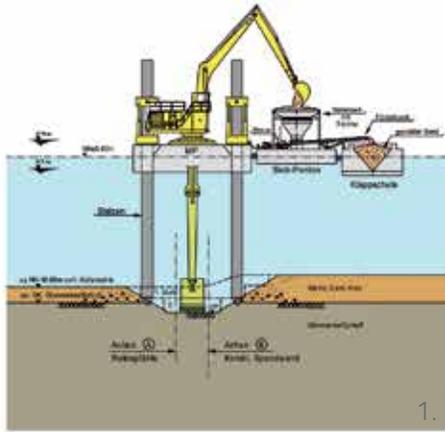
Sheet piles:

HZ 975 B – 24 / AZ 25
 3,740 t HZ 975 B – 1,470 t AZ 25 &
 AZ 13-10/10 – 910 t HP 400/122 anchors

Total quantity of sheet piles:

6,120 metric tons

Overview: Construction phases 1 to 8 for Berth 1



La Spezia | Italy

> Port expansion projects

The city of La Spezia is situated about half way between Genoa and Pisa, the part of the country with the largest concentration of harbours. Among these ports are the harbours of Genoa, Savona, Livorno and La Spezia which have a joint annual cargo handling capacity of more than 100 million metric tons. It is from here that the industrial north of Italy exports its products.

The origins of the Malaspina and Garibaldi quays date back to the end of the 19th century. The quay structures of the port suffered considerably during WW II. The port authority of La Spezia therefore had to invest heavily to rebuild the damaged structures.

Today the port offers a combined quay length of 5,300 m with draughts of up to 14.5 m to receive container ships of the latest generation. The different terminals in La Spezia handle all kinds of products: containers, coal, oil, cement, cereals, food oils etc. The port's container quays dispose of a total mooring length of 1,500 m. The Gottwald cranes with their 100-metric-ton lifting power serve the 260,000 m² container yards.

Following a study that predicted a rise in cargo traffic beyond the present capacities, a modernisation programme was launched in 1995, with the goal of expanding the Ravano, Malaspina and Garibaldi terminals. In 2004, the port of La Spezia handled slightly more than one million TEU, a rise of 3.4% compared to the previous year. The modernisation programme called for a total of 27,500 t of sheet piles to be installed in the following parts of the harbour:

1. GARIBALDI PIER: 9,000 t HZ/AZ combined wall

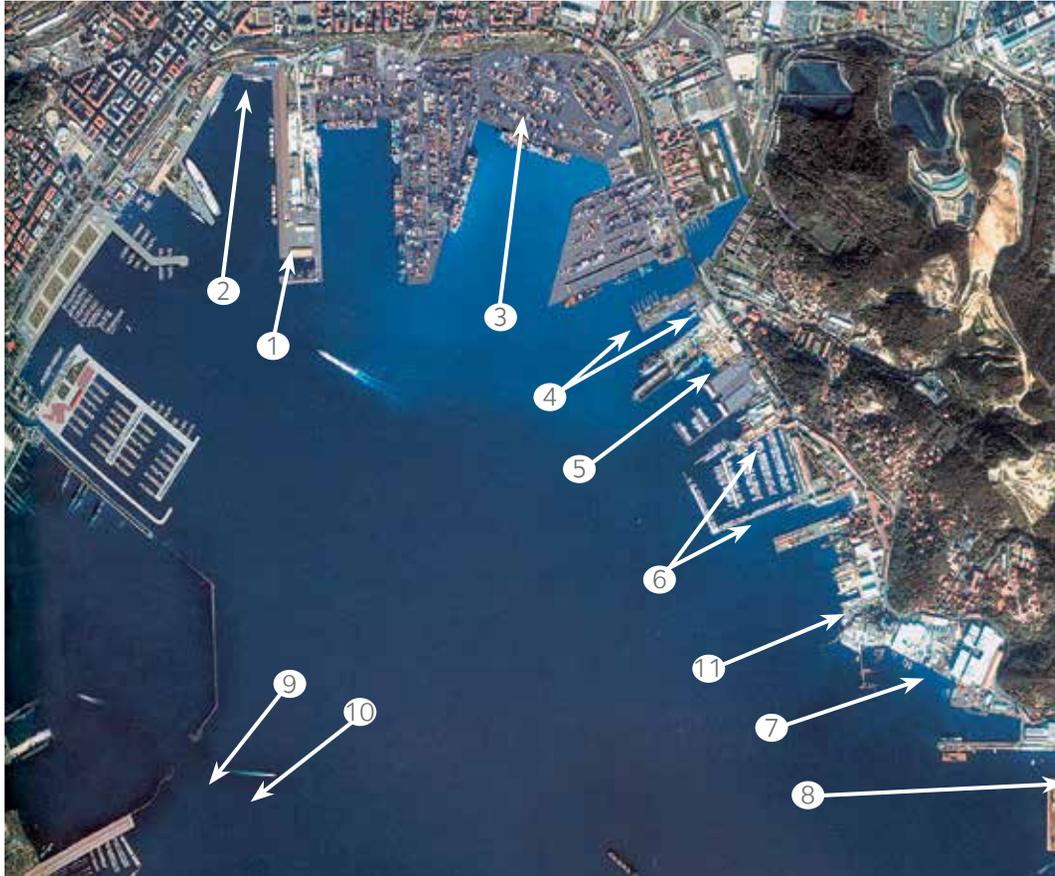
The effectiveness of the pier is guaranteed by three mooring spots totalling 510 m on the west side and two eastern mooring spots measuring 360 m. Garibaldi Pier offers a draught of up to twelve metres. Being the largest pier in the port of La Spezia, the crane park comprises several 12-t capacity quayside cranes as well as four mobile 100-t cranes. Together with the large cereal and cement silos, the 4,300 m² covered storage area handles various goods including forest products, coal, iron and steel products.



Due to the predicted rise in cargo volume, the port of La Spezia is currently upgrading several terminals.



La Spezia handles a large share of the container traffic engendere by the industries in northern Italy



27,500 t of sheet piles were used for eleven projects in La Spezia.

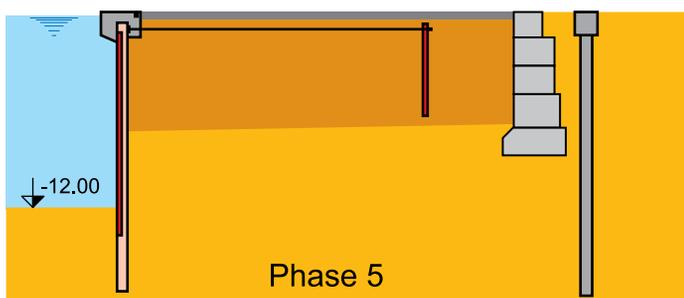
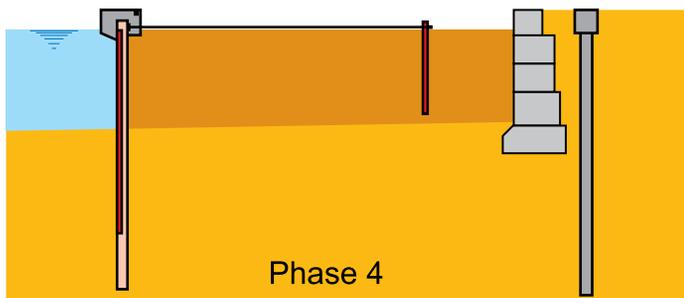
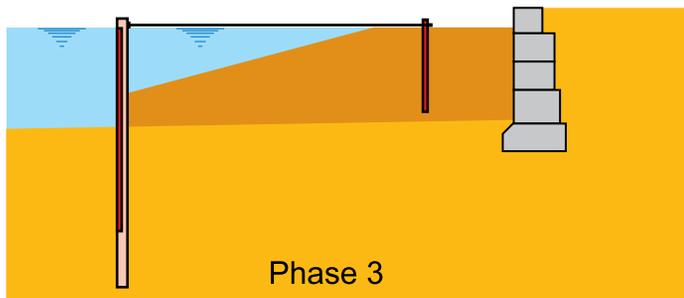
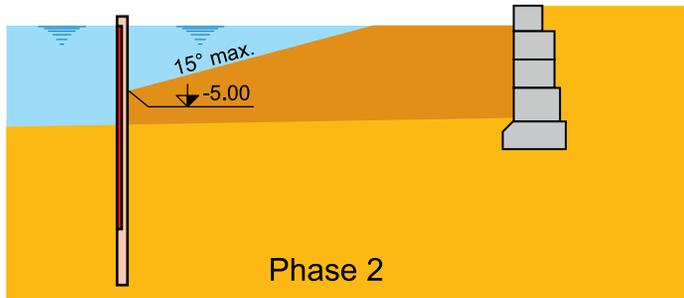
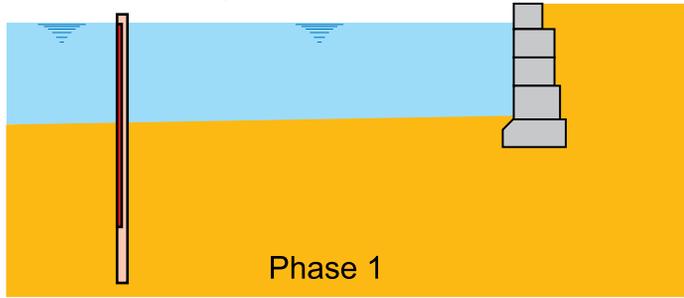
The draught of 12 m was achieved by placing a new sheet pile quay wall 40 m in front of the existing gravity wall. The combined steel sheet pile wall is U-shaped, thus forming three parts.

For the first part closest to the coast, an HZ 975 C - 12/ AZ 18 system with an elastic section modulus of 7,360 cm³/m was chosen as the main wall. The HZ king piles and the AZ intermediary piles were supplied in lengths of 24 m and 18 m.

After the installation of the steel sheet piles, the next phase of construction called for backfilling of the area between the new and existing quay walls. Along the rear wall, the backfill material had to rise from the harbour bed to a point level with the top of the previously installed main wall. Closer towards the main wall, the dredger installed the backfill material only until halfway to the top of the combined wall. This minimised the forces and the deformations of the combined wall which acted as cantilever wall before installation of the tie-rod system.

During the following construction phase, the 8-m AZ 26 sheet piles forming the rear anchor wall were driven. All the sheet piles used for the Garibaldi Pier project are made of high-strength steel (S 390 GP). The upset tie rods provided by Anker Schroeder from Dortmund, Germany were installed next. The anchors have a thread of 3.75", a diameter of 75 mm, a length of 25 m, and are connected every 1.79 m to the HZ beam at one end and to a UPN 400 waling at the other end. They were designed to take a working load of 839 kN.

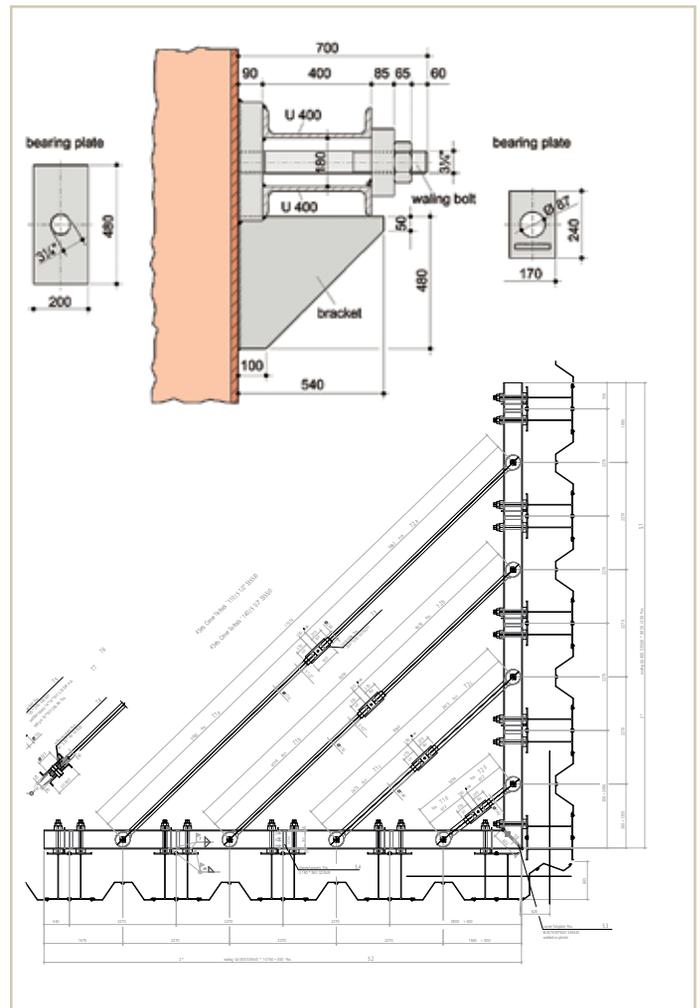
Construction phases



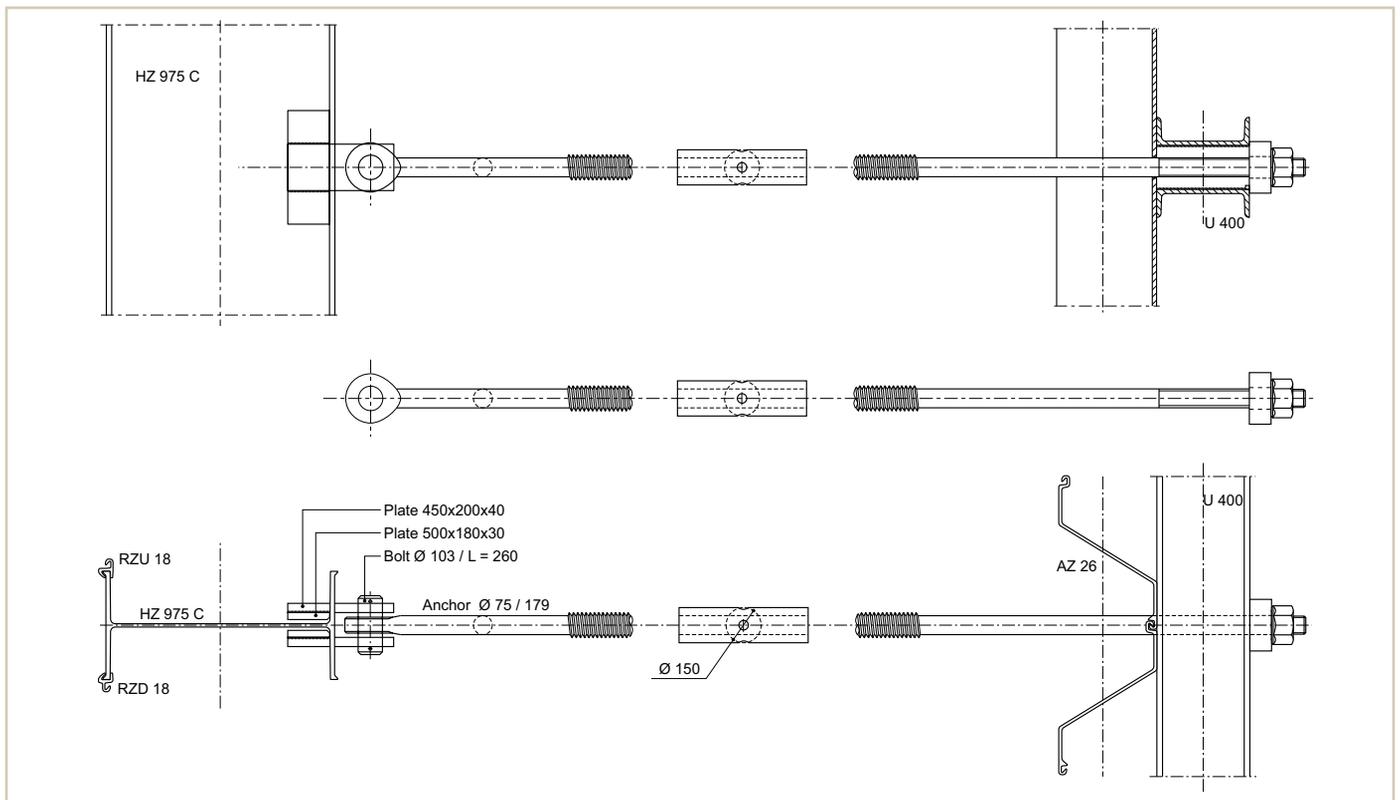
The new wall was placed 40 m in front of the existing structure.



The new U-shaped quay wall was built around the existing terminal.



Tie-rod system – Details of the quay wall corner.



Two different sets of upset tie rods were used, depending on the HZ/AZ system chosen.

Further from the shore, a stronger solution using the same high-strength steel grade was chosen for the second and third part: a HZ 975 B - 24/AZ 18 main wall with 27-m double HZ king piles and 22-m AZ 18 intermediary piles. The elastic section modulus of the chosen system amounts to 10,840 cm³/m. AZ 36 double piles nine metres long were installed as an anchor wall. Due to the larger system width of 2.27 m, stronger upset tie rods with a working load of 1,250 kN were required. The tie rods have a diameter of 90 mm, a thread of 4.5" and a length of 33 m.

Once all the tie rods were installed, the area behind the main sheet pile wall was backfilled. As a final step, the top slab with the capping beam was installed and the harbour bed was dredged to the required depth of 12 m.

2. MALASPINA QUAY: 1,800 t HZ/AZ combined wall

The 200-m multipurpose wharf with its depth of ten metres is equipped with four cranes and is used for handling Roll-on/Roll-off ships. Managed by the Compagnia Lavoratori Portuali, the wharf has a storage area of 2,500 m².

3. RAVANO PIER: 4,000 t HZ/AZ combined wall

This container terminal is managed by La Spezia Container Terminal (Contship Italy Group) and Terrestre Marittima. The terminal offers a berthing line of 300 m, a depth of 11 m, three rail tracks, and a 40,000 m² yard.

4. CANTIERI DEL GOLFO TERMINAL: 4,000 t HZ/AZ combined wall

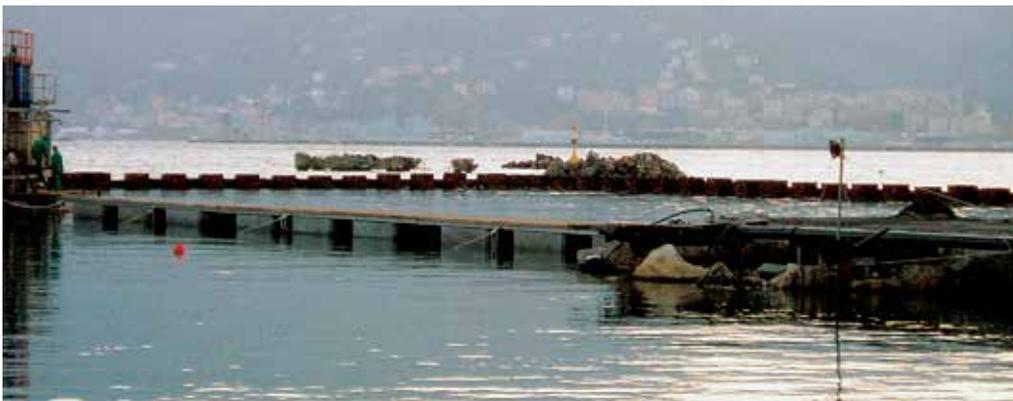
TARROS QUAY: 500 t HZ/AZ combined wall

Situated close to the Ravano quay, the 310 m Golfo Terminal with a depth of 12 m is specialised in Roll-on/Roll-off and container ships. The Tarros Terminal handles passenger traffic. The quays are equipped with seven Roll-on/Roll-off moorings.

5. IMMA maritime site: 500 t AZ sheet piles

6. PORTO LOTTI Marina: 3,500 t AZ sheet piles

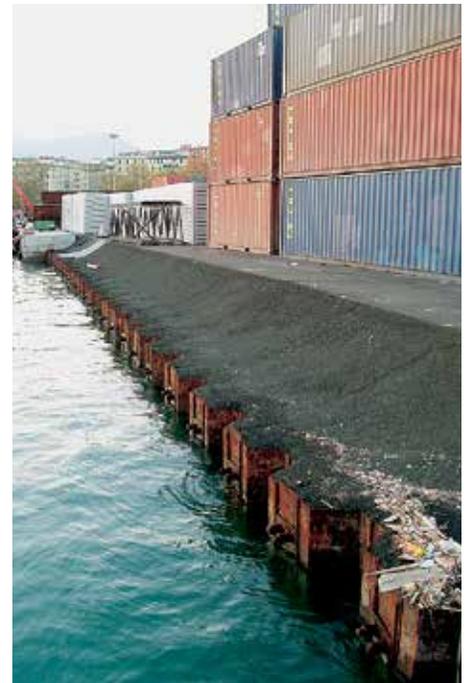
7. FERRARI maritime construction site: 250 t AZ sheet piles



With its draught of 12 m, Garibaldi Pier is the largest pier in La Spezia.



Malaspina Quay is a multipurpose wharf, mainly handling containers.

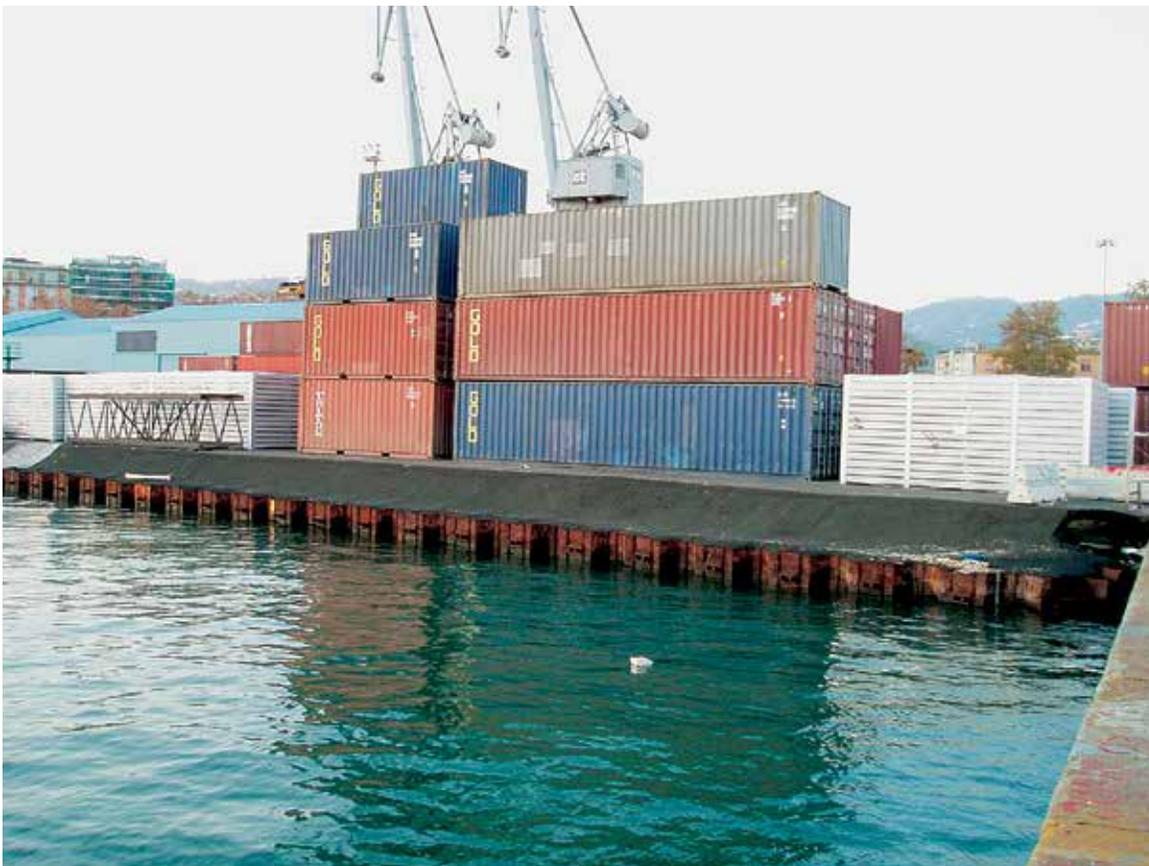


- 8. FINCANTIERI: 600 t AZ sheet piles**
- 9. VALDEMARO maritime construction site: 250 t AZ sheet piles**
- 10. GRAZIE Quay: 500 t AZ sheet piles**
- 11. FERRETTI Quay: 2,600 t AZ sheet piles**

The Ferretti Group is a world leader in the design and construction of luxury motor yachts and sporting boats. The group has invested 26 million euros in the construction of a

shipyard for the Northern Tyrrhenian Sea based in the port of La Spezia. Works on the new shipyard began in May 2003 and are scheduled for completion in 2006. Several existing structures were demolished to make way for new hangars, offices and a 400 m pier. The 15,000 m² boatyard in the eastern part of the port is currently in operation.

The new boat yard was built using Z-type sheet piles in steel grade S 390 GP. The main wall consists of AZ 36 piles; their lengths range from 19 to 24 m. Eight-metre-long AZ 18 piles



Thanks to the combined-wall system the new quay now offers a water depth of 10 m.



The owner of Ferretti Quay, the Ferretti group, designs and builds luxury motor yachts.

were installed as an anchor wall. A PTC vibratory hammer in combination with a template was used to drive the sheet piles. The 21 corners of the complex quay are formed by C9, C14 and Omega 18 connectors welded to special sheet piles. Some of the quay walls are 92 m long while others are only 7.5 m long.

All the AZ 36 and AZ 18 double sheet piles including the special sheet piles for the corners were delivered via train from the mill

in Luxembourg to the port of La Spezia. A sealing system was used for the Ferretti quay. The Roxan system used consists of a waterswelling product placed in the interlocks of the piles in a workshop in Luxembourg. The urethane prepolymer based Roxan system is extremely durable and can resist water pressures up to 25 m.



The new 400-m pier will be completed by 2006 using AZ 36 and AZ 18 sheet piles.



A template was used for the installation of the AZ piles.



2,600 t of 24-m AZ 36 and 8-m AZ 18 sheet piles were installed.

Garibaldi Quay

Owner: Condotte d'Acqua Spa

Steel grade: S 390 GP

Sheet piles:

- Main wall part 1: HZ 975 C, L = 24 m & AZ 18, L = 18 m
- Rear wall part 1: AZ 26, L = 8 m
- Main wall part 2 & 3: double HZ 975 B, L = 27 m & AZ 18, L = 22 m
- Rear wall part 2 & 3: AZ 36, L = 9 m

Total quantity of sheet piles:

9,000 metric tons

Ferretti Quay

Owner: Ferretti Group

Designer: Studio Manfroni e Associati

Contractor: Acmar (Ravenna)

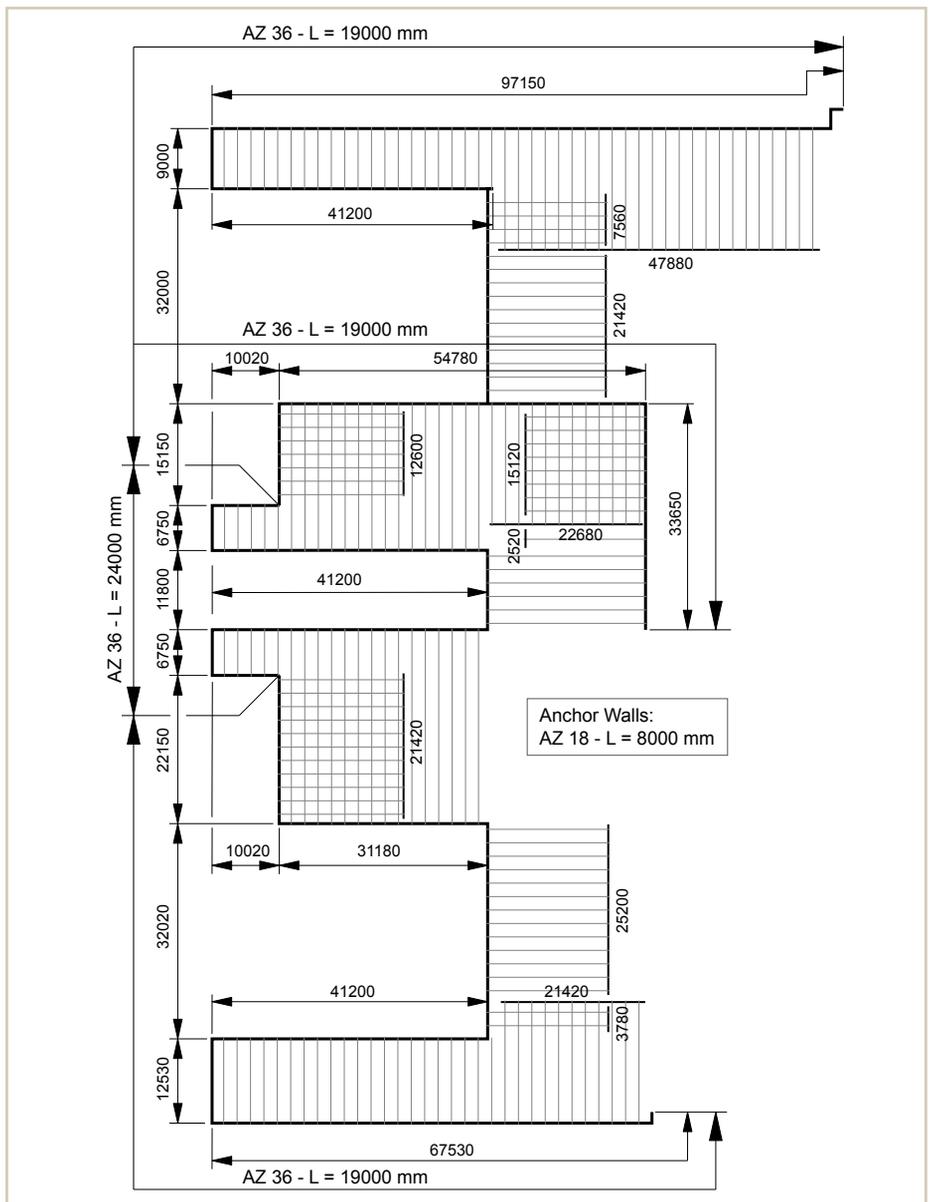
Steel grade: S 390 GP

Sheet piles:

AZ 36, L = 19 – 24 m AZ 18, L = 8 m

Total quantity of sheet piles:

2,600 metric tons



The complex quay layout includes numerous connectors forming 21 corners.



Installation proceeded smoothly with the PTC vibratory hammer and the driving template.



A sealing system, the waterswelling Roxan system, was inserted into the piles interlocks.

When installing sheet piles with the Roxan sealing product, the contractor must take care that the system does not swell before installation. Contact of Roxan-filled interlocks with water must be avoided during transport and storage. By placing the treated interlock to face downwards, unwanted swelling is generally avoided.

When installing the pile with the sealing product in the leading interlock, driving should not be interrupted for more than two hours. Otherwise the expanding sealing product may be torn off when driving resumes.

Mersin | Turkey

> Port extension project

Mersin is situated on the Mediterranean Sea, on the south-east coast of Turkey. Several international contracting companies were invited to bid for the upgrading of the Mersin Seaport of Debarcation. Closing date for the tender was September 2002. The entire project was completed by the end of 2005 after a construction time of two years.

To allow docking of large vessels and installation of new container cranes, both the existing wharf made of heavy underwater concrete blocks and the marshalling area, were modernised. The water depth was doubled to twelve metres. A steel sheet pile wall totalling 624 m in length was installed 12.2 m in front of the existing wharf. The area between the old and new part of the wharf was backfilled with rock. The steel sheet piles were driven into clay soil characterised by cohesive values ranging between 5 and 10 kN/m².

A steel solution was chosen for upgrading of the existing concrete solution partly because the project was constructed in an active seismic region. Being a ductile material, steel offers higher load reserves during earthquakes.

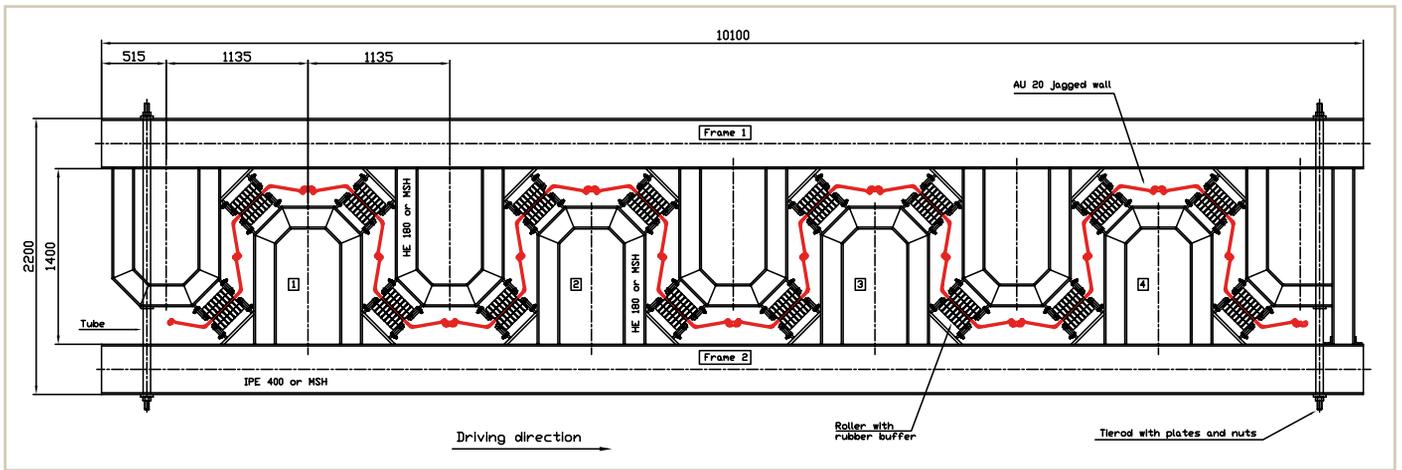
Purchase and installation of the steel sheet piles account for roughly 15% of the total project cost.

The following material was required (tender amounts):

- Wall area: 14,968 m²,
- Material quality: ASTM A690,
- Section modulus: 6,000 cm³/m,
- Thickness: 10 mm,
- Painting: 3 layers of epoxy coating.



The existing concrete structure was modernised with the help of a jagged sheet pile wall.



ArcelorMittal provided the contractor with drawings to assemble a template.



The contractor's template features two steel-tube guiding levels fitted with rubber fenders.



The rubber protectors prevent damage to the coating system during installation.



Vertical and inclined batter piles were also installed with the template.

The Omega 18 connector can be tack welded to the AU 20 double piles for handling reasons. In this case its contribution to the section modulus is disregarded. Appropriately designed welds contribute fully to the section modulus, however. The elastic section modulus reaches 7,395 cm³/m (6,365 cm³/m if connectors are tack welded) for a mass of 186.7 kg per square metre of wall. Each AU 20 double pile of the jagged wall contributes 1.135 m to the length of the quay wall.

543 AU 20 double piles in steel grade A690, representing a total of 2,535 metric tons, and 235 t of Omega 18 connectors in steel grade S 430 GP were used to build the 624 m main wall. "Marine" steel grade A690 is characterised by a resistance to seawater splash zone corrosion approximately two to three times greater than that of ordinary carbon steel. The main difference to ordinary steel is the high amount of copper (min 0.50%). This steel with a minimum yield strength of 345 N/mm² is mainly used in marine environments.

Şener Arda Construction is a Turkish contractor specialised in marine construction and piling work. Created in 1968, the company has completed numerous quays, jetties, harbours and breakwaters.

A suitable template is essential for the installation of a jagged wall. ArcelorMittal provided drawings for a template fitting the AU 20 double sheet piles and sent 2 engineers to supervise the installation procedures of the first steel sheet piles. The contractor built the template based on the design provided. The two guiding levels of the template are made of steel tubes fitted with special rubber fenders to prevent damage to the sheet pile coating system during driving.



Both the vibratory and the impact hammer were mounted on the specially designed rail-mounted rig.



The driving caps were provided by ArcelorMittal on a rental basis.



Quick-release shackles are a timesaving help used on numerous sites.

A specially designed rail-mounted rig system was used for the installation of the steel sheet piles and for the 24 inch (61 cm) steel tubes. The vertical piles were installed every 5 m, reaching a depth of 23.53 m. The inclined batter piles spaced at intervals of 2.5 m were driven to a depth of 32.42 m.

A vibratory hammer and an impact hammer were used as driving equipment. Installation proceeded conventionally: the vibratory hammer first drove the piles as far as possible into the soil, the impact hammer then drove the steel sheet piles to the design depth of 22.8 m. The panel-driving technique was used in order to ensure verticality and alignment of the sheet piles. Installation of a group or a "panel" of piles allows individual piles to remain above design depth in the event of obstructions in the soil, without interrupting driving operations. Refusal was defined by reaching an installation progress of just 2 to 3 mm per blow. Further driving at this penetration rate could cause damage to the piles and driving gear.



The installation rig used the existing concrete wharf for support.



The 624-m sheet pile wall will enlarge the mooring area.

A Japanese TVM-50 Toyoda vibratory hammer with the following characteristics was used:

- Weight: 3 t,
- Maximum centrifugal force: 420 kN,
- Maximum eccentric moment: 205 Nm,
- Frequency: 1,355 min⁻¹.

Şener Arda had two German diesel impact hammers available at the site: a Delmag D30 and a Delmag D46 equipped with rams weighing 3,000 and 4,600 kg. Their maximum explosion pressures average 1,050 and 1,650 kN, delivered at a frequency of 37 to 52 blows per minute. Weighing six metric tons, the Delmag D30 is limited to piles of up to eight metric tons, whereas the D46 can install piles of up to 15 metric tons. The optimum weight of the installation material ranges from two to nine metric tons for the D30. The required driving cap was supplied to the contractor as part of ArcelorMittal's services for the Mersin project.

At the far end of the wall, the contractor had to stop installation before reaching the target depth of 22.8 m because stiff clay slowed the driving progress below the set limit. The design of the jagged wall was revised to take account of the extremely stiff soil layer. Studies showed that the toe depth could be reduced by as much as 3 m because of the superior load-carrying capacities of the unexpectedly favourable soil values encountered at the end of the extension.

Owner:
TCDD Directorate

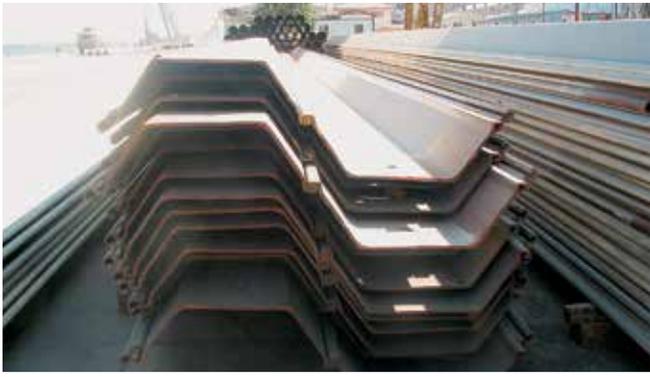
Contractor:
Şener Arda Construction Co. Inc.

Designer:
HES Engineering &
Unitek Engineering Consortium

Steel grade:
A690 & S 430 GP

Sheet piles:
2,535 t AU 20 double piles
235 t Omega 18 sections

Total quantity of sheet piles:
2,770 metric tons



The structural system consisted of a sheet-pile soil-retaining wall, steel crane-foundation piles, and deflection-restricting batter piles.



A three-layer coating system was applied on the waterside of the steel wall.



The AU 20 double piles were arranged into a jagged wall using Omega 18 connectors.

The AU 20 jagged wall was capped with a two-metre-thick reinforced concrete beam cast onto the sheet piles, the inclined steel piles that take horizontal loads, and the vertical steel piles that act as a foundation for the crane rails, and also securing the bollards, fenders and container-crane rails. A new pavement was installed behind the capping beam, on top of a 1.5-m layer of stabilising material overlying rockfill. Topping up the area between old and new construction, the rockfill extended to a depth of 12 m.

A coating system was applied on the water side of the steel sheet piles, over a depth of 16 m starting a metre below the pile head. A developed area of 18,656 m² had to be coated with the following three layers:

- Sigmarite sealer (50 µm),
- Sigmacover TCP Glassflake (450 µm),
- Sigmacover DTM coating (200 µm).

Ziguinchor | Senegal

> Quay reconstruction project

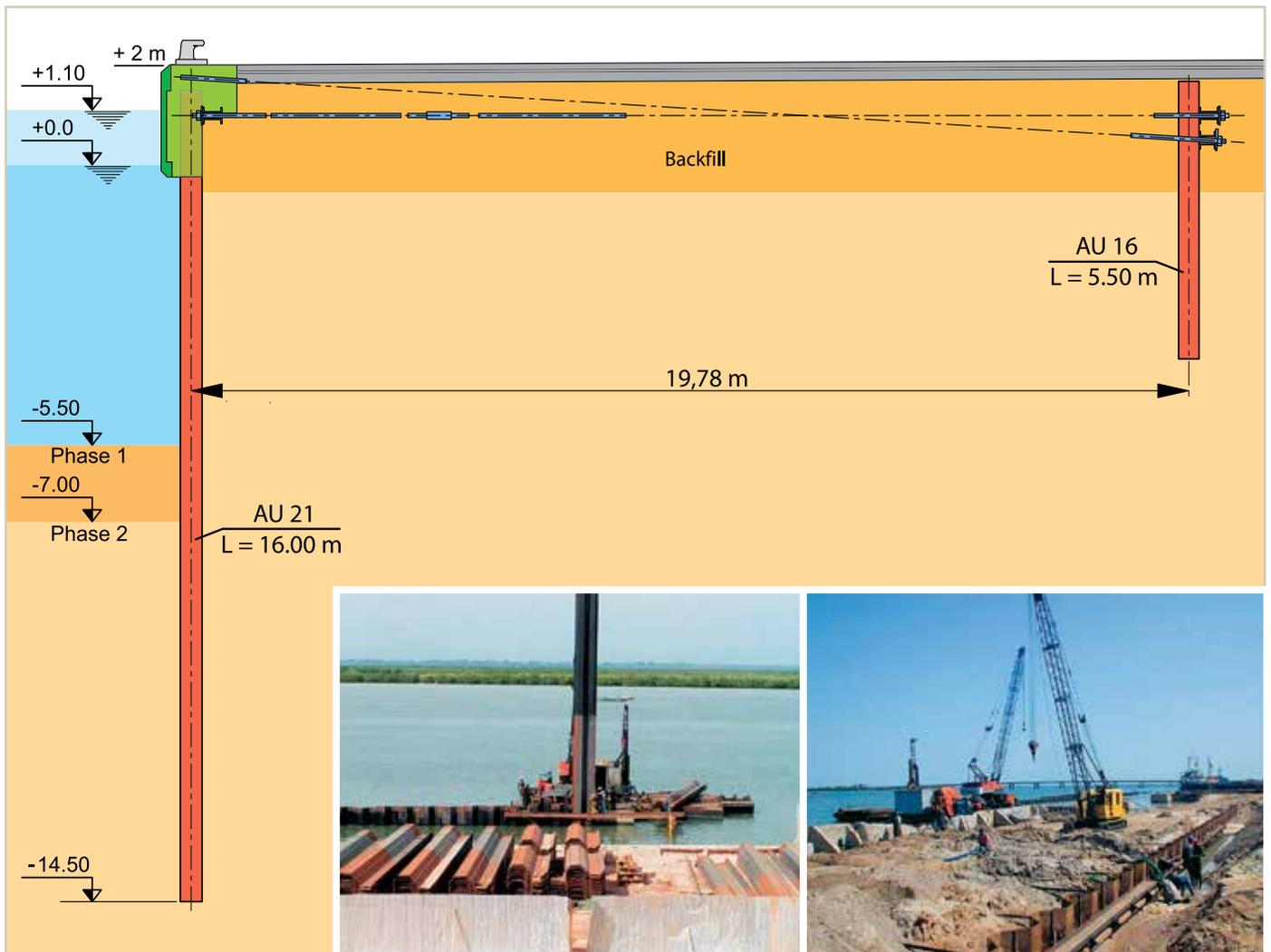


The coastal town of Ziguinchor is situated on the banks of the Casamance River in southern Senegal. Founded by the Portuguese in 1645, the prosperous trading post has an easy connection to the Atlantic Ocean, 70 km downriver. In addition to ferry passengers, the harbour handles local produce e.g. groundnut products, fish, rice, fruit and cotton as well as imports of petroleum products and capital goods.

With the assistance of different international organisations, chiefly the French Development Agency, the Senegalese Government undertook a vast development programme including the 5.3-million-euro rehabilitation of Ziguinchor Harbour whose fifty-year-old structures had seriously deteriorated over the years. The two-phase reconstruction operation concerned the passenger quay, the goods quay and the tanker berth.



The Senegalese river port of Ziguinchor is situated 70 km from the Atlantic Ocean.



The new quay wall was built with AU 21 sheet piles driven 20 m in front of the dilapidated structure.

The first phase began in August 2004 and lasted about 8 months. It involved the construction of an 80-m-long passenger quay wall directly in front of the existing wall with a 35-m-long return wall at the western end. It also included 31.5 m of goods quay and a 20-m-long roll-on roll-off berth. The goods quay is not aligned with the passenger quay but is located about twenty metres in front of and parallel to the old quay, enabling enlargement of the marshalling area reclaimed from the river.

The extension of the new goods quay was completed in July 2005 as part of the second phase. It included the construction of a 68-m-long return wall and backfilling of the new marshalling area. Once completed, the new quay had a total length of 265 m.

The soil conditions can be resumed as follows: soft to compact river mud overlying clayey sand. To ensure the stability of the structure, the soft mud was dredged before the sand backfill was placed. The river was deepened to 5.50 m to ensure sufficient water depth for vessels to dock.



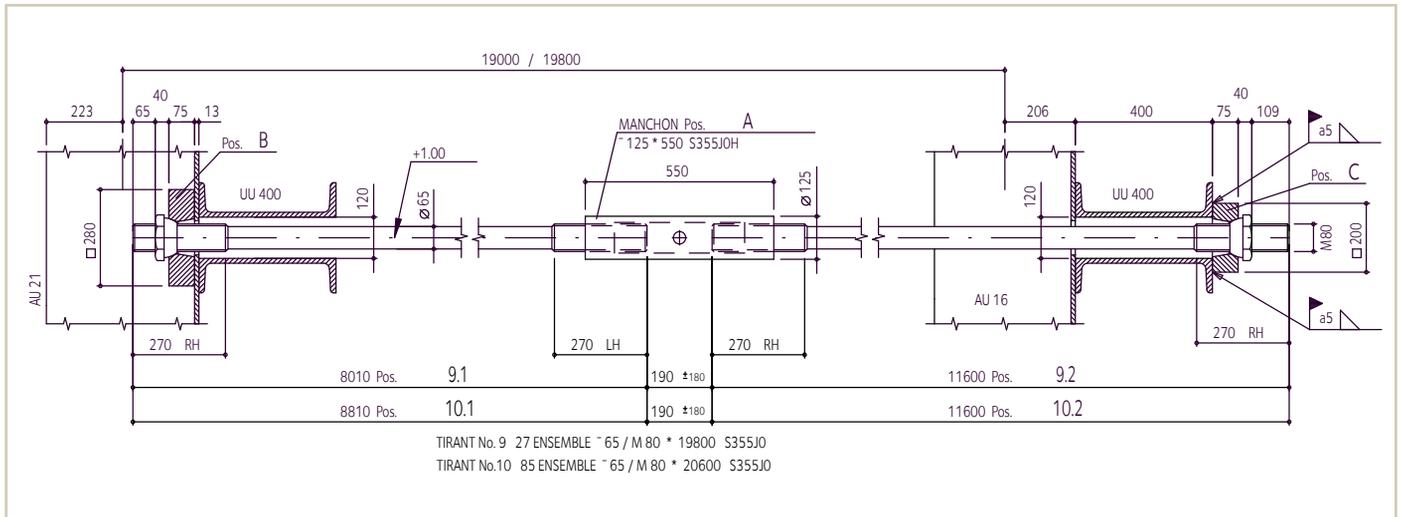
The reconstruction plans included passenger and cargo quays as well as the tanker berth.



Delmag diesel impact hammer.



190 tie rods in different lengths were supplied by Anker Schroeder.



The 65-mm-diameter tie rods have a working load of 680 kN.

Owner:

Senegalese Ministry of Infrastructures, Public Works, Road Transport, and Inland Waterways

Designer:

BCEOM

Contractor:

Eiffage Construction /
Fougerolle Sénégal consortium

Steel grade:

AU 21: S 430 GP, AU 16: S 270 GP

Sheet piles:

1,020 t AU 21, 270 t AU 16

Total quantity of sheet piles:

1,290 metric tons



Anker Schroeder provided the entire tie-back system.



Finished quay with bollard.



A three-layer coating system was applied to guarantee a long lifetime.

AU 21 steel sheet piles (rolled-up AU 20 piles) were chosen in response to the strongly felt need for maximum protection against corrosion through greater thickness. Because of the tropical climate this protection was further enhanced by special coating and cathodic protection. The shop-applied coating consists of a zinc-rich epoxy primer and two coats of coal-tar epoxy. It was applied to both sides of the immersed part of the main-wall sheet piles. The 750-mm-wide AU sheet piles have about 10% less developed surface area than 600-mm U piles, thereby reducing the coating area. This advantage of the AU sections is complemented by excellent driving performance and toughness resulting from the particularly favourable geometry of the web/flange interface.

The 16-m AU 21 sheet piles forming the main wall were driven into the clayey sand to a depth of 14.50 m. They were tied back at the top to an anchor wall made of 5.50-m AU 16 piles. The angles in the wall alignments were made using Omega 18 or Delta 13 connectors or junction piles with welded C9 corner sections that were provided by ArcelorMittal together with the steel sheet piles. The front quay wall was topped with a capping beam made of precast reinforced concrete elements.

The quay-wall anchor system consisted of 65-mm-diameter S 335 J0 steel grade tie rods with upset ends. 152 anchors in lengths of 19 to 30 m were supplied. They were attached to a waling made of 400-mm channel sections. 38 additional tie rods with a diameter of 58 mm and in lengths of 20 m to 22.50 m were installed at coping level, behind the bollards, to take up the pull forces exerted by moored vessels. All these components were supplied by ArcelorMittal's faithful partner for many years: Anker Schroeder from Dortmund, Germany.

The sheet piles, mostly supplied as double piles, were first driven with a Vibro Delmag rig placed on a barge, then impact driven with a Delmag D12 or D22 diesel hammer with a hanging leader.

The sheet piles produced in Luxembourg were transported by rail to the port of Antwerp, then by ship to Dakar where they were transferred to another ship bound for Ziguinchor. The passenger quay was completed in 2005, enabling the first ships to berth as specified from the outset.



Following a construction time of slightly more than one year, all quays were reopened at the end of 2005.

Visakhapatnam | India

> Extension of Berth WQ-7

In the early 1920s the Indian government decided to construct a harbour at Visakhapatnam on the east coast of India in order to provide a direct outlet for mineral and other products of the Central Provinces. The port serves a vast hinterland in the absence of any other sea port between Madras and Calcutta. In 1933, a heavy programme for dredging of the swamp near the town of Visakhapatnam was completed to form a sheltered harbour. The port was originally built as a monocommodity port for manganese ore exports, having only three berths with a combined cargo-handling capacity of 0.3 million metric tons. An unusual feature of the port are the old ships “Janus” and “Welledson” that were filled with stones then sunk towards the south of the entrance channel to form a breakwater.

About 90% of India’s foreign trade passes through one of the ports situated along its 6,000-km coastline. Eleven major

ports – Calcutta, Chennai (Madras), Cochin, Haldia, Kandla, Mangalore, Mormugao, Mumbai (Bombay), Paradip, Tuticorin and Visakhapatnam – are managed by the government controlled Port Trusts. Together, they have been handling approximately 230 million metric tons of cargo per year. A development plan has just been completed to raise capacity by a further 170 million metric tons.

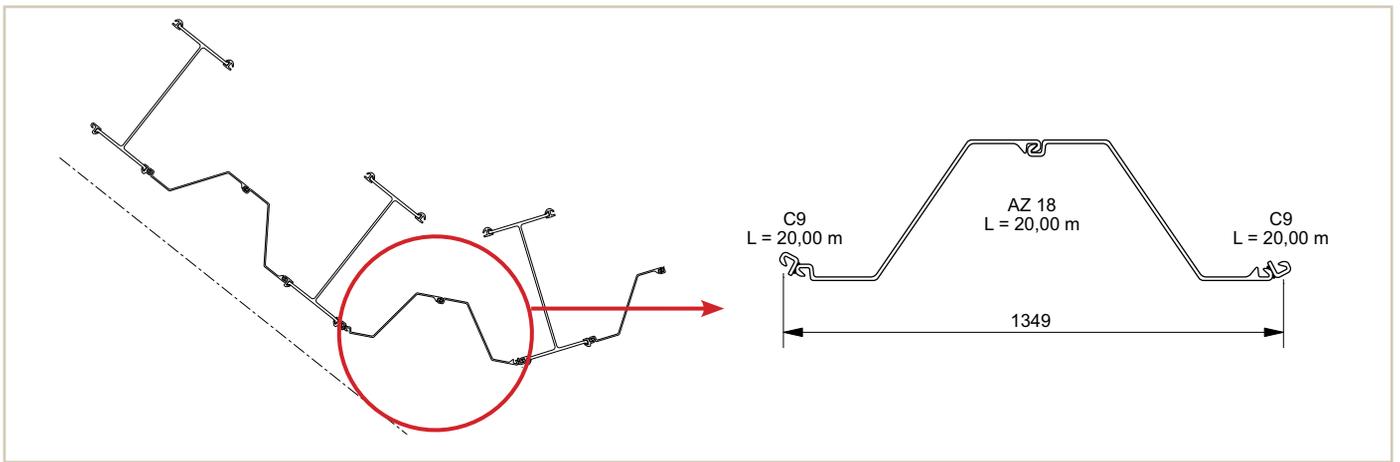
Visakhapatnam Port is today one of the largest harbours in India. It developed rapidly from a small mineral trading post into a major harbour handling bulk cargo, iron ore, petroleum oils and lubricants, coking coal and coke as well as container traffic. Visakhapatnam Port was under the control of the Bengal-Nagpur Railways at the time of its completion. The railway transported the mineral ore to the city of Visakhapatnam, home to one of the few ports on India’s eastern shoreline.



Visakhapatnam Port is one of India's largest harbours.



Local mineral production is the driving industry behind the port's development.



C9 connectors welded to an AZ 18 double pile formed the corner of the segmented quay wall.

Visakhapatnam boasts the only port in the country to have exceeded the 50 million metric ton mark in 2004-2005, though with a low growth of 5%. The Indian government is considering increasing the port's cargo handling capacity to 70 million metric tons. The expansion will implement deepening of the outer harbour, allowing bigger vessels to access the port.

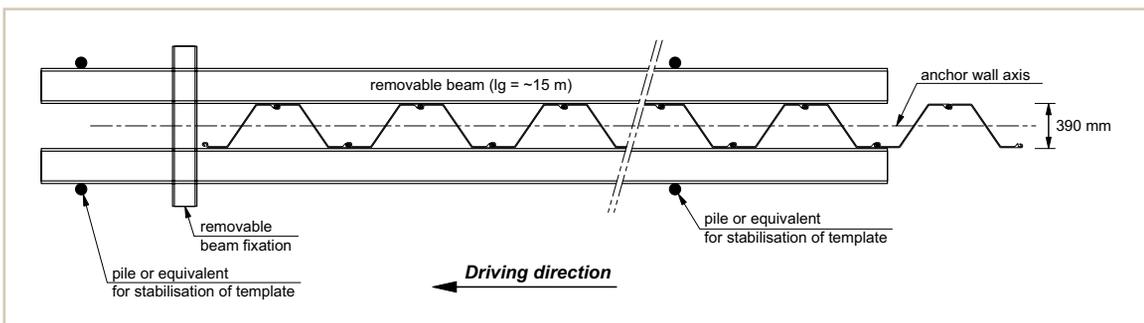
The Port of Visakhapatnam recently constructed and developed 22 berths, including two state-of-the-art ore berths, an off-shore oil tanker terminal, an LPG berth, and a container terminal, as well as four new multipurpose berths. Among these new constructions, Berth WQ-7 in the extended northern arm of the inner harbour was completed in April 2005 using 2,350 metric tons of steel sheet piles. The new berth can receive vessels up to 45,000 DWT.

Several exploratory boreholes were logged to investigate the characteristics of the site's soil layers which were incorporated into the design of the sheet pile wall. The result of the drilling can be resumed as follows: fill material overlying a layer of fine silty sand that reaches a depth of six metres. Below this, medium-density cohesive clay overlying very dense weathered rock with SPT values above 50 was encountered. The tidal levels in the port area vary between MHWN = +1.49 m and MLWS = +0.09 m. Loads due to high waves were not considered since the proposed site is well protected from the open sea.

ArcelorMittal's design team issued a preliminary design based on information supplied by the owner. According to these design calculations, the maximum bending moments will occur 5.5 m below the water level: 1,570 kNm/m for the normal case and 1,620 kNm/m for the seismic case.



The template was assembled in India, based on construction drawings supplied by ArcelorMittal.



A second driving template facilitated installation of the AZ 18 anchor wall.



Two-level templates ensure correct horizontal and vertical positioning of the sheet piles.



Strong shackles were used to lift the king piles.



Wooden spacers prevent damage to the stored AZ piles.



The contractor opted for the PTC 60HD heavy-duty vibratory hammer.



Power unit of the PTC hammer.

BORE LOG 3
J.J.SOIL INVESTIGATION & ENVIRON CONSULTANTS
10-51-8/1, KAILASMETTA UPLANDS
VISAKHAPATNAM - Bore hole 530 003

Project : Berth WQ - 7
 Location : Near HZ 183
 Bore hole No : 3
 Ground Water Table : -0,23

Ground R.L		Visual Description of Strata	N-value
From	To		
+2.00	+0.00	Reddish gravelly soil	
+0.00	-6.00	Fine sand with silt	
-8.00	-17.00	Blackish soft clay	34
-17.00	-20.50	Brownish stiff clay	> 50
-20.50	-24.00	Highly weathered rock	> 50
-24.00	-27.38	Hard rock with fractures	



Two crawler cranes lifted hammers and sheet piles into position.



The Indian designer Howe opted for an anchored HZ/AZ combined sheet pile quay wall.



Due to the presence of weathered rock an impact hammer was needed to fully drive the sheet piles.

The resulting forces lie well above the maximum design resisting moment of conventional sheet pile walls, reason for which the following combined-wall system was chosen for the construction of Berth WQ-7:

- 192 king piles HZ 975 A – 14, S 430 GP, L = 25.5 m,
- 191 intermediary piles AZ 18, S 320 GP, L = 20.0 m,
- 275 anchor piles AZ 18, S 320 GP, L = 10.8 m.

The HZ 975 A – 14/AZ 18 sheet pile wall features a system width of 1,790 mm, a section modulus of 8,170 cm³/m, and a weight of 225 kg/m². The king piles were designed in high-strength S 430 GP steel (minimum yield strength: 430 N/mm², minimum tensile strength: 510 N/mm², minimum elongation: 19%). The high-strength steel reduced material and transportation costs to a minimum. The section modulus of the HZ king piles was adapted to the maximum bending moments by adding RH sections to their flanges.

As a result, the designer was able to choose a rather light, locally strengthened king pile. Further savings were achieved in terms of steel grade and length reduction of the intermediary AZ 18 piles. The king piles in S 430 GP steel have the following chemical composition:

C	Mn	Si	P	S	N
(max%)	(max%)	(max%)	(max%)	(max%)	(max%)
0.27	1.70	0.60	0.05	0.05	0.011

The front sheet pile quay wall was tied back over a distance of 23 m to an AZ 18 anchor wall. The design bending moment of the anchor wall averages 230 kNm. The distance between the tie rods corresponds to the system width of the combined-wall system. Each 100-mm-diameter tie rod is subject to a design pull of 1,074 kN.

Owner:

Visakhapatnam Port Trust, Visakhapatnam

Designer:

Howe Private Ltd, New Delhi

Contractor:

Afcons Infrastructure Limited, Mumbai

Piling equipment:

- Hydraulic vibratory hammer: PTC 60HD
- Diesel impact hammer

Steel grade:

S 320 GP & S 430 GP

Sheet piles:

1,330 t HZ 975 A
1,020 t AZ 18

Total quantity of sheet piles:

2,350 metric tons



Designed for a lifetime of 50 years, the new Berth WQ-7 will boost the port's cargo-handling capacities.

Steps in construction of the quay wall:

- Driving of front main sheet pile wall (land-based work),
- Driving of anchor sheet pile wall (land-based work),
- Installation of steel tie rods connecting the two walls,
- Backfilling and pouring of reinforced concrete deck superstructure,
- Dredging to -12 m in front of main sheet pile wall,
- Connection of new berth to existing structure,
- Installation of pavement, drainage with culvert and electrical lighting.

The steel sheet piles were installed on-shore using a standard-frequency vibratory hammer. Vibratory hammers reduce the friction between soil and pile by applying vertical vibrations to the sheet pile. The vibrations are caused by rotating eccentric masses arranged in pairs to eliminate horizontal vibrations. The remaining vertical components add up, and the centrifugal force temporarily liquefies the soil in the vicinity of the sheet pile. The weight of the pile and the hammer create enough downward force for installation of the sheet pile wall. Preferably two hydraulically-operated clamps ensure secure attachment and proper transmission of the oscillating movement to the pile. Three technical parameters (eccentric moment, centrifugal force and frequency) are generally used to describe vibratory hammers. The frequency corresponds to the number of revolutions of the rotating masses per minute. The eccentric moment is equivalent to the product of the mass of the rotating masses [kg] and the distance [m] between the rotational axis and centre of gravity of the revolving weights. The generated centrifugal force (unit: kN) depends on the eccentric moment and on the frequency. Such hammers are especially advisable in non-cohesive water-saturated soils for driving of piles both above and under water.

The choice of vibratory hammer depends on the cross-section and weight of the pile, the penetration depth, and the soil characteristics. A PTC 60HD (heavy-duty vibratory hammer) was chosen to install the sheet pile wall at Berth WQ-7. The machine features a frequency of 1,650 rpm, an eccentric moment of 60 kgm and a maximum centrifugal force of 1,830 kN. The contractor, Afcons, opted for two crawler cranes with respective lifting powers of 40 and 70 metric tons to handle the seven-ton vibratory hammer, the sheet piles, and the template. Beyond the vibratory hammer's potential refusal point, the sheet piles were driven to design level using a diesel hammer.

The logs of three boreholes drilled at the driving site revealed the presence of weathered rock at an elevation of -20.5 m. Since the king piles had to be driven three metres beyond the rockhead, an impact hammer was essential in order to reach the design depth.

The layout drawings for the construction of the driving template were provided by ArcelorMittal's technical team. The necessary welding works were executed by an Indian subcontractor appointed by the main contractor Afcons. The template was levelled with the help of a theodolite. Technical assistance at the jobsite to support the installation of the combined wall was provided free of charge by ArcelorMittal.

The quay structures were designed for a lifetime of 50 years; therefore corrosion losses of 4 mm at the zone of permanent immersion on the water side and 1 mm on the land side were considered for the choice of the steel sheet pile section. An impressed-current cathodic protection system ensures that the required lifetime can be achieved.

Nakhodka | Russia

> Dry dock for offshore gravity base structures

The city of Nakhodka is situated in the far east of mainland Russia. The company Sakhalin Energy Investment Company Ltd. was established in 1994 to develop the Sakhalin II project, one of the largest integrated oil and gas projects in the world, including the Piltun-Asokhskoye oil field and the Lunskeye gas field. The venture called for the construction of two new production platforms founded on huge concrete gravity base structures installed in the fields in summer 2005. The beginning of year-round oil production for both platforms is scheduled for 2007; gas production is expected to get under way by 2008.

Since land transport of these enormous base structures weighing more than 100,000 metric tons was close to impossible, the investment company opted to build them in a dry dock. By later flooding this dock, the floatable offshore structures could easily be towed out to their destination in the open sea.

The dry docks were constructed with a 750-m sheet pile wall around all four sides of the rectangular excavation. 550 m of the surrounding sheet pile wall was built using AU 25 sheet piles; the remaining 200 m required the stronger PU 32 sections with a section modulus of 3,200 cm³/m. A slope with wells leads down to the bottom of the excavation. Three stages of wells lower the water level below the bottom of the dock, thus allowing construction to proceed in the dry.

The sheet piles used for the Sakhalin II development project were produced in Luxembourg and brought by train to their destination in Nakhodka. Each wagon was loaded with 40 to 45 t of steel sheet piles. Over 3,000 metric tons of sheet piles were required on the job site, in two different lengths: 24 and 29 m. The piles were cut into 12-m pieces to ease transportation. The contractor then spliced the sheet piles on site.



Huge construction projects were launched to exploit Sakhalin's natural resources.



A dry dock for offshore platforms was built using more than 3,000 metric tons of steel sheet piles.





The 750-m outer dock wall features AU 25 and PU 32 piles.

The following quantities of sheet piles were delivered:

- 1,940 t AU 25 in steel grade S 355 GP.
Pile length: 24 m (12 m + 12 m),
- 1,100 t PU 32 in steel grade S 355 GP.
Pile length: 29 m (12 m + 12 m + 5 m).

The contractor used a template and two different hammers (vibratory and impact hammer) to install the steel sheet piles. The soil conditions encountered are a relatively soft top layer with SPT values (Standard Penetration Test) ranging between 10 and 30 blows per 30 cm penetration overlying a high-density layer with SPT values from 60 to 90 blows. The U-piles were driven through the soft soil, to a depth of 15 m, with the vibratory hammer. The impact hammer was then used to drive the piles until refusal through the denser soil layers. All AU and PU piles were driven as double piles to speed up the installation process. Driving caps for the impact hammer were provided by ArcelorMittal free of charge for the duration of the works.

Description of the driving equipment:

- Vibrator hammer: ICE 815, eccentric moment: 46 kgm, nominal centrifugal force: 1,250 kN, maximum frequency: 1,600 rpm.
- Hydrohammer: IHC S70. Maximum energy per blow: 70 kNm, 50 blows per minute, Drop weight: 3.5 t.

The two offshore gravity base platform structures were completed after nearly ten months of uninterrupted concrete casting. The dry dock was then flooded and the two gigantic structures were towed to their respective offshore locations some 1,000 nautical miles from Nakhodka in July 2005.



Owner:

Sakhalin Energy Investment Company Limited

Contractor:

Quattrogemini Ltd, Finland

Sheet piles:

AU 25 and PU 32

Pile length:

24 m and 29 m

Steel grade:

S 355 GP

Total quantity of sheet piles:

3,040 metric tons

General Santos | Philippines

> Fishing quay expansion project

General Santos City in the southern part of the Philippines, 1,000 km south of the islands' capital Manila, was founded in July 1968. Some 26 years on, in 1994, construction began on the General Santos City Fish Port Complex (GSFPC), funded by the Overseas Economic Cooperation Fund (OECF) of Japan. It was completed just over four years later in March 1999. The port provides good trade access to major foreign markets in southeast Asia, Australia, continental Europe and the United States. The harbour features a 32,000-m² container yard equipped with modern container-handling facilities and additional provisions for holding livestock.

With annual production of 2.4 million metric tons, the 700-million-euro fishing industry accounts for 4% of the Philippines' gross national product. Considered the most modern fishing port in the country, General Santos is also the nation's second-largest fishing harbour. Fishing is the prime industry in the so-called "Tuna Capital" of the Philippines and is largely responsible for the city's economic boom. There are more than 50 commercial fishing companies located in General Santos, producing a collective volume of 8,000 metric tons of sashimi-grade tuna per month. General Santos City Fish Port Complex offers a 750-metre quay and a 300-metre wharf for 2,000-GT refrigerated carriers.



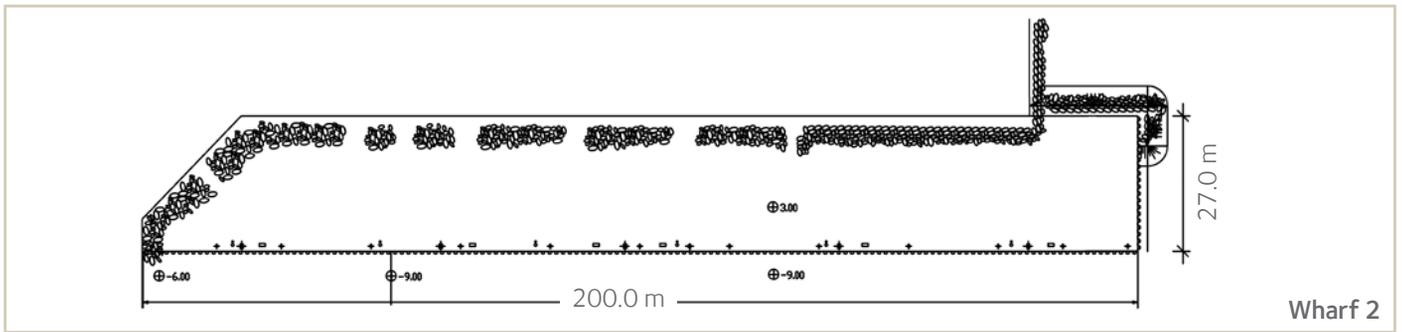
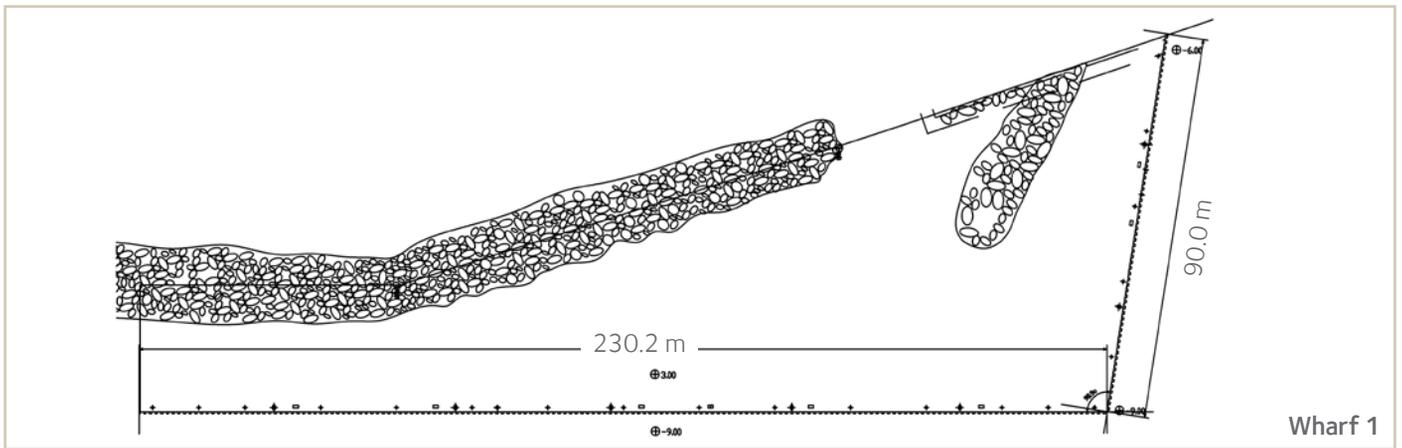
Tuna from General Santos.

Among the harbour's infrastructure are several refrigeration facilities, an ice producing plant, market halls, and fish container storage yards.

The Philippine Archipelago lies between two of the world's major tectonic plates, the Pacific Plate and the Eurasian Plate. Interactions and movements along the active faults cause strong earthquakes in the Philippines. General Santos City is situated about 20 km from the active Mindanao fault which is responsible for an average of six perceptible earthquakes per year. Important seismic loads had to be considered for the design of the expansion project.



Two AZ sheet pile quay walls were required by the growing tuna fishing industry.



The 2 new wharves offer a combined mooring length of over 500 m.

Steel solutions have an important advantage compared to concrete wharves; ductile steel can to a great degree absorb the energy input resulting from an earthquake's horizontal accelerations.

The tidal variations in the General Santos City Fish Port are not very substantial. The following tidal levels based on observations from nearby Davao Port were considered for the design of the sheet pile quays:

- Design high water level: 1.88 m (high tide accumulated frequency: 10%),
- Design low water level: -0.19 m (low tide accumulated frequency: 90%).

According to observations from the logs of 15 boreholes drilled at the site of the two new fishing quays, and to geotechnical tests, the strata structure in the area is relatively simple. The onshore area consists of made ground: medium to coarse sand ranging from +3.4 m to -3.2 m.

Further boreholes were drilled in the offshore area where the seafloor drops to a depth of -8.3 m. They showed a

homogeneous layer of medium to coarse sand mixed with a small amount of angular coral gravel down to a depth of -2.7 m. Further below, medium to high density silty clay with angular gravel continues to -42.6 m.

The project comprises the expansion of two wharves:

- Wharf 1: main wall length: 230 m, return wall length: 90 m,
- Wharf 2: main wall length: 200 m, return wall length: 27 m.

Wharf 1 is a new structure, whereas the second wharf is built in front of an existing wharf. This existing structure offers a water depth of just over one metre, far too shallow for the modern fishing vessels that dock and unload at General Santos.

Both wharves were built with Z-type steel sheet piles provided by ArcelorMittal from Luxembourg. Two different profiles were used: AZ 34 with a section modulus of 3,400 cm³/m and AZ 26 with a section modulus of 2,600 cm³/m. A high steel grade (S 430 GP) was used to provide an economical solution by optimising the weight of the sheet pile wall as far as possible.

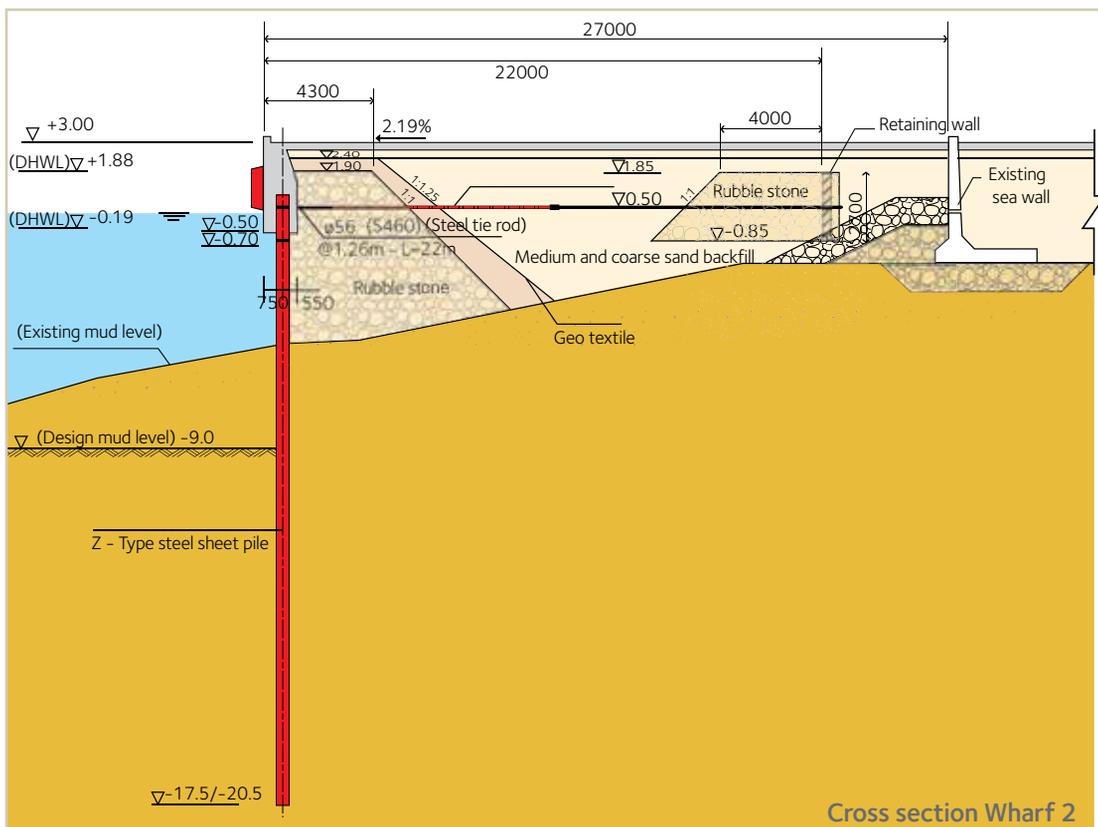
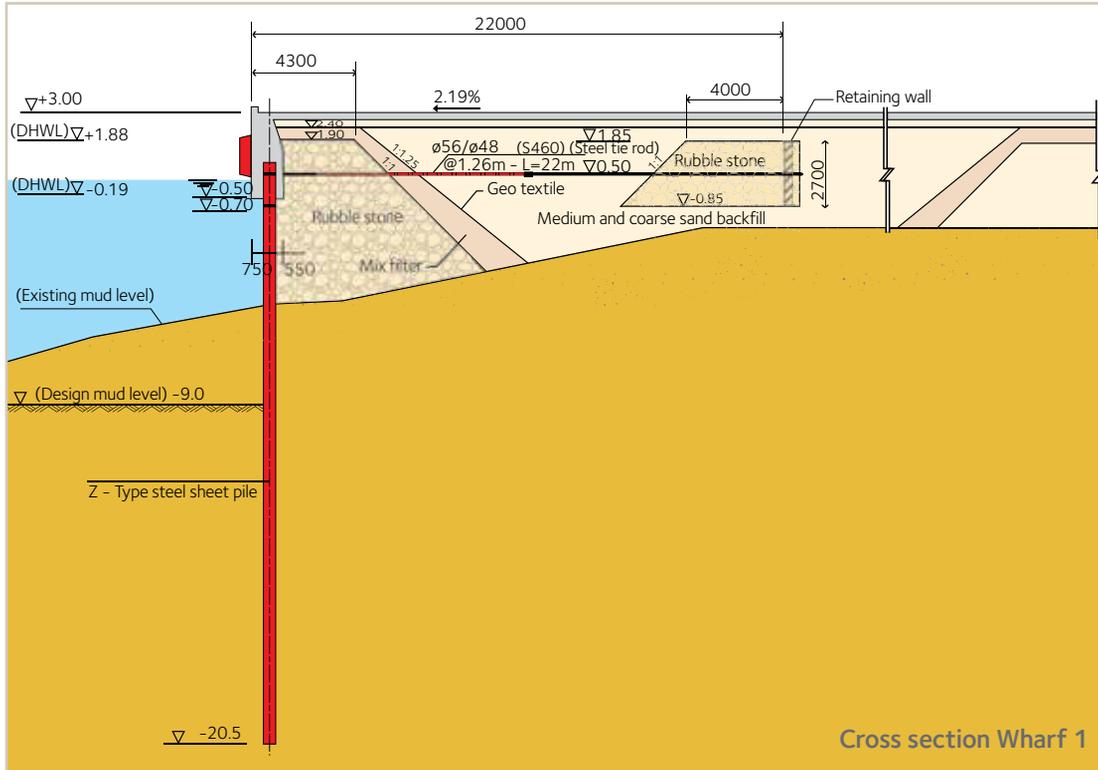


In a single delivery, all the sheet piles were shipped to the site where they were unloaded and stored.

The 380 AZ 34 double piles delivered are 21.5 m long; the 80 AZ 26 double piles are 18.5 m long. In order to connect the sheet pile walls made of 1,260-mm-wide double piles, two C9 and one Omega 18 corner sections were used. A total of 2,180 t of steel sheet piles were delivered by train from the rolling mill to Antwerp Harbour where they were loaded onto M/V Wilma heading directly to General Santos.

Both the main and return walls were connected to concrete anchor plates by 22-m tie rods. The German manufacturer Anker Schroeder provided 485 tie rods in high-strength steel S 460 N.

The weight of the tie-rod solution was further minimised by providing upset tie rods. Two different sizes of anchors were provided: M64 thread with a shaft diameter of 48 mm: 22 and 12 m. To allow both easy handling and transportation in containers, the tie rods were made of two pieces shorter than 12 m. The two separate anchor pieces were joined together by turnbuckles and tightened horizontally between the two walls. This is normally done above the water level to reduce the risk of corrosion. The turnbuckle also allows for correction of inaccuracies in the distance between the main and anchor walls.



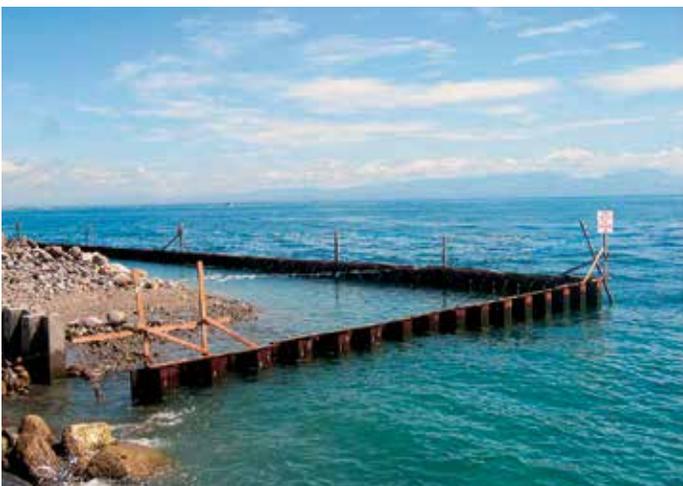
Modern fishing vessels can now dock at General Santos thanks to the water depth of 9 m.



AZ double piles up to 21.5 m long were installed with barge-based driving equipment.



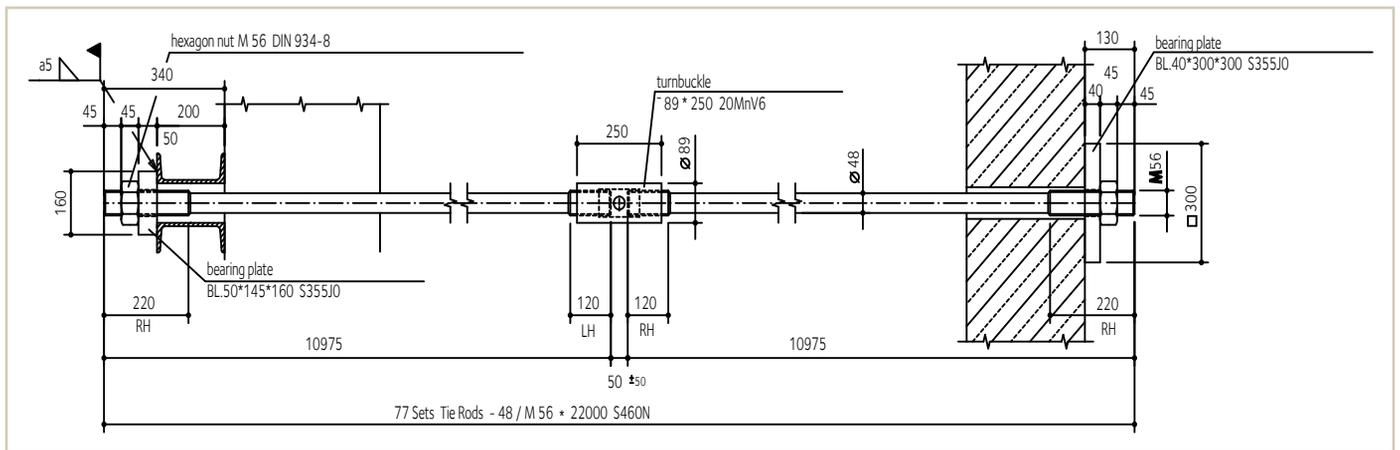
The two wharves were built using 380 AZ 34 double sheet piles as well as 80 AZ 26 double sheet piles.



The new steel quay wall of Wharf 2 was placed 27 m ahead of the existing concrete wall.



A vibratory hammer was used first; a diesel hammer then completed the installation process.



The 48 and 56 mm shaft diameter tie rods were provided by Anker Schroeder, Germany.



The tie rods consisted of several parts suitable for transportation in 40-foot containers.



The new quay walls required 485 high-strength-steel tie rods.

Owner:

Department of Agriculture, Philippine fishing development authorities

Contractor:

CAMC (China National Construction & Agricultural Machinery I/E Corp.)

Steel grade:

S 430 GP

Sheet piles:

1,890 t AZ 34, 290 t AZ 26

Total quantity of sheet piles:

2,180 metric tons



The area behind the AZ wall was backfilled carefully so as not to damage the tie rods.

The anchor sets including upset-end tie-rods (diameter 56 mm/ M64, total length = 22 m) with a working load of 615 kN were made up of the following pieces:

- 1 front upset-end tie-rod 56 mm/M64, RH-LH-thread, 10 350 / 120 / 250, S 460 N,
- 1 rear upset-end tie-rod 56 mm/M64, RH-RH-thread, 11 600 / 120 / 250, S 460 N,
- 1 turnbuckle, M64, length 250 mm, adjustment \pm 50 mm, 20 MnV6,
- 1 bearing plate on waling: 160 x 155 x 55 mm, S 355 J0,
- 1 bearing plate on concrete: 300 x 300 x 45 mm, S 355 J0,
- 2 x M64 hexagonal nuts according to DIN 934-8.

The steel sheet pile walls were installed the conventional way: a Japanese KN2-90 vibratory hammer drove the AZ piles until refusal. A second installation team followed with a Delmag D62 diesel hammer equipped with a 6.2-t ram to drive the piles to the design depth.



Extreme local seismic loading had to be considered when designing the new wharves.

Kaohsiung | Taiwan

> Deepening of Berths 65 and 66

There are currently seven international harbours in Taiwan playing important roles in economic development: Keelung, Kaohsiung, Hualien, Taichung, Suao, Anping, and Taipei. The port of Kaohsiung is Taiwan's leading international commercial port with Anping serving as its auxiliary harbour.

The deep-water port of Kaohsiung is the marine transit hub for East Asia and South Taiwan. Featuring a natural harbour and two access channels with depths of 11 and 16 metres, the 2,683-hectare port is capable of handling up to 100,000-DWT vessels. Kaohsiung currently has five container terminals and a total of 118 berths – including 26 container berths – which can accommodate 6,000-TEU post-Panamax container ships. Handling over 70% of Taiwan's container traffic and 60% of the country's total international trade volume, the harbour has been the world's third largest container port for many years, with a container throughput of 10 million TEU in 2006. Plans have been made to benefit from geographical advantages and nearby software and hardware facilities to speed up the development of Kaohsiung Harbour. To respond to the development of large vessels and to maximise the harbour's efficiency, several container wharves have been deepened, including the existing berths 65 (length: 244 m) and 66 (length: 440 m) that have been rebuilt as container wharves.



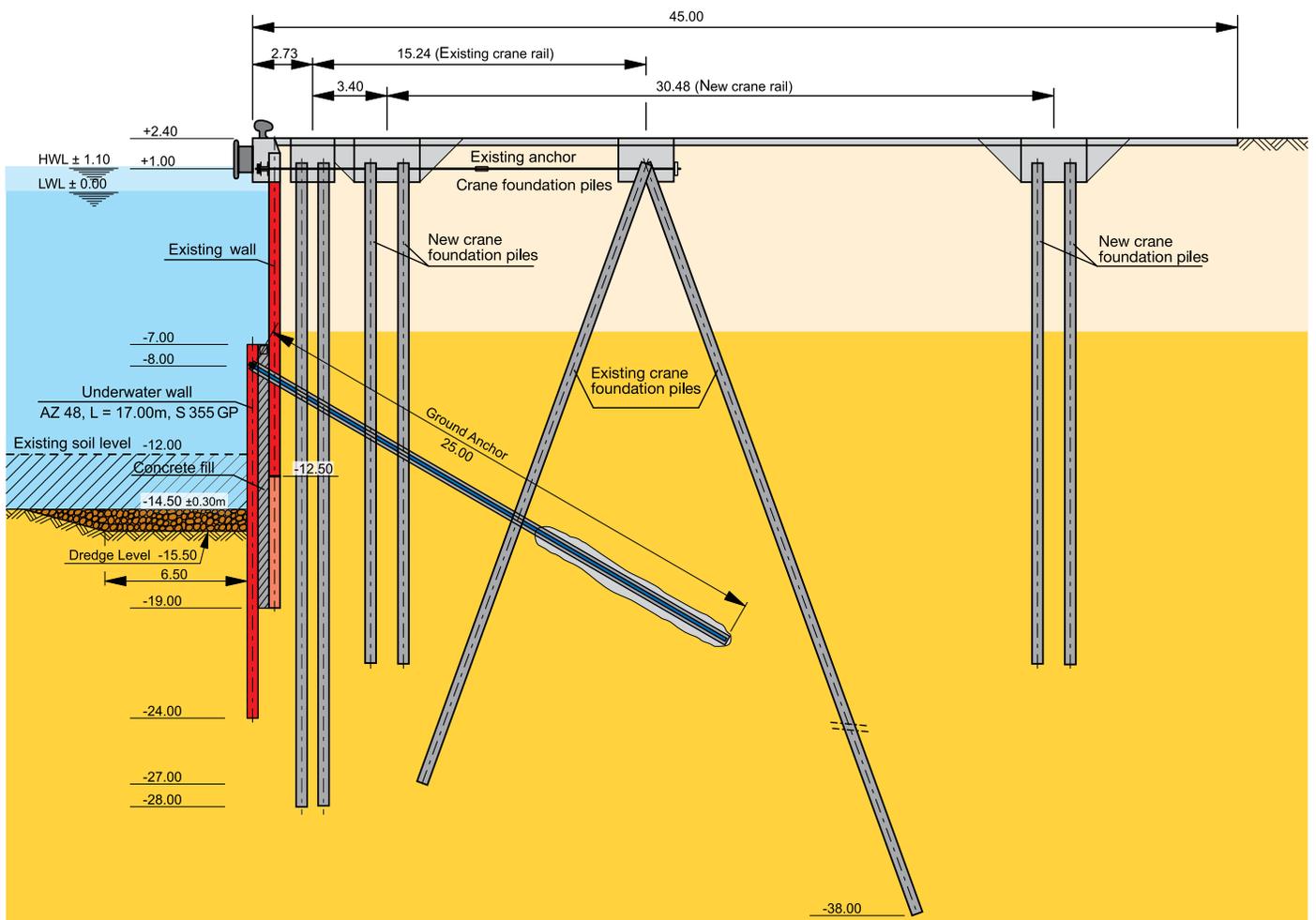
Kaohsiung features 5 container terminals and 118 berths.

Berths 65 and 66 are part of the Container Terminal No. 2. Due to the scheduled deepening from 12 to 14.50 metres, the existing quays had to be redesigned. The quay walls of the existing Berths 65 and 66 consist of a combined sheet pile wall featuring box piles as king elements and 500-mm U-piles as intermediary elements. The king elements (L = 20.5 m) and the intermediary elements (L = 13 m) are made of FSP VL sheet piles.

The Kaohsiung Harbour authorities disregarded the original concrete tender solution of the redesign because it exceeded the budget by 70%.



Handling 10 million TEU per year, Kaohsiung is one of the largest harbours in the world.



The most economical deepening solution involved installation of an underwater sheet pile wall forward of the quay.



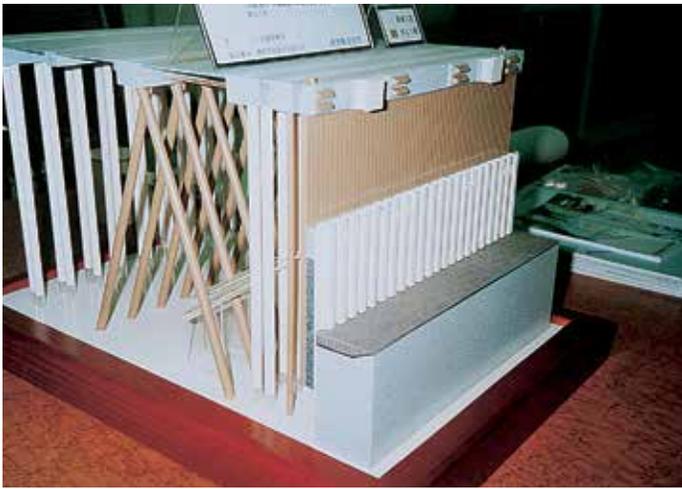
The existing structures were left in place.

It was therefore decided to opt for a high-strength steel sheet pile solution to deepen the quays. The new underwater sheet pile wall was to be placed in front of the toe of the existing quay wall.

Due to the substantial water depth of the new structure and seismic loads with horizontal ground accelerations of 0.11 g above and 0.22 g below the water level, bending moments were very high. The allowable deformation of the underwater sheet pile wall was strictly limited. In order to allow safe docking of vessels at the two deepened berths, the harbour authorities had to limit deflections so that ships would not strike the new wall.

A design study carried out by the ArcelorMittal's technical department showed a maximum moment of 1,014 kNm/m for the ultimate limit state and a maximum moment of 1,482 kNm/m for seismic conditions, assuming overdredging of 1.0 m. These loads stretch conventional steel sheet piles to their limit: only ArcelorMittal's AZ 48 with a section modulus of 4,800 cm³/m is capable of handling these moments.

The renovation of the 650-m quay calls for underwater installation of the AZ 48 sheet pile wall in front of the existing FSP VL box pile wall. The 17-m AZ 48 piles were driven into the harbour bed until their head reached a depth of seven metres. Cement grout and concrete were injected between the new and existing sheet piles.



The sheet pile wall reached from -7 to -24 m and was anchored with inclined anchors.



L-shaped plates were used to connect the sheet piles to the anchors.



Due to static requirements and the restricted allowable deformations, the new wall had to be anchored. Prestressed grouting anchors attached to the head of the sheet piles ensured the stability of the AZ 48 wall. The anchors were attached to every third sheet pile: the distance between anchors is thus $3 \times 0.58 \text{ m} = 1.74 \text{ m}$. The grouting anchors had to carry high loads which had to be transferred into deeper soils with high load-bearing capacities. The contractor opted for inclined anchors, for which a special connection system was developed. L-shaped plates were welded into holes cut into the AZ 48 piles. The 25-m tie rods were connected to the L-shaped plates and were held back by a 10-m-long grout section. They were installed half a metre from the top of the underwater sheet pile wall, at -7.5 m, with an inclination of 30 degrees. A total of 373 tie rods were required to hold back the 650-m quay wall. Each of them has a working load of 660 kN and an ultimate load of 2,490 kN. Following installation of the anchored underwater steel sheet pile wall, the harbour bed was dredged to -14.5 m. Deflections remain well within the set limits and safe operation of container traffic can thus be guaranteed.

Owner:
Kaohsiung Harbour authorities

Designer & Contractor:
HWA CHI Construction

Sheet piles:
AZ 48

Pile length:
17 m

Steel grade:
S 355 GP

Total quantity of sheet piles:
2,690 metric tons



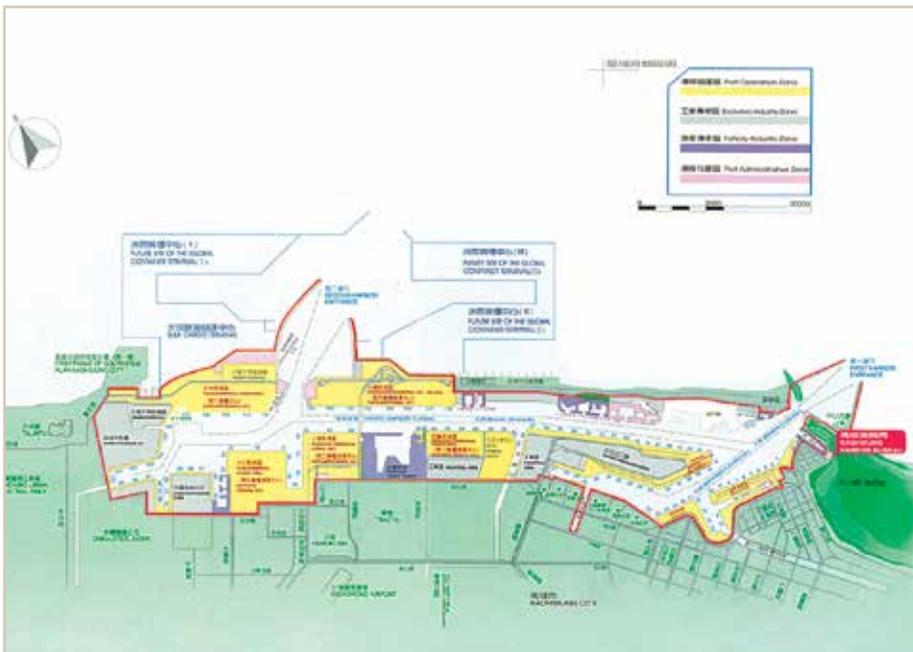
The deep excavation and seismic loads called for heavy-duty AZ 48 piles.



The piles were driven hard alongside the existing berths.



Belonging to CT 2, Berths 65 & 66 can handle vessels of up to 6,000 TEU.



Kaohsiung Port is promoted as an Asian-Pacific transshipment centre.

Anping | Taiwan

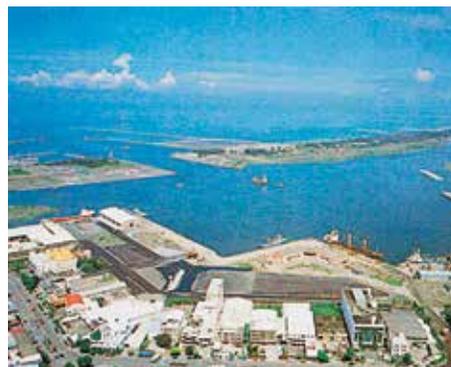
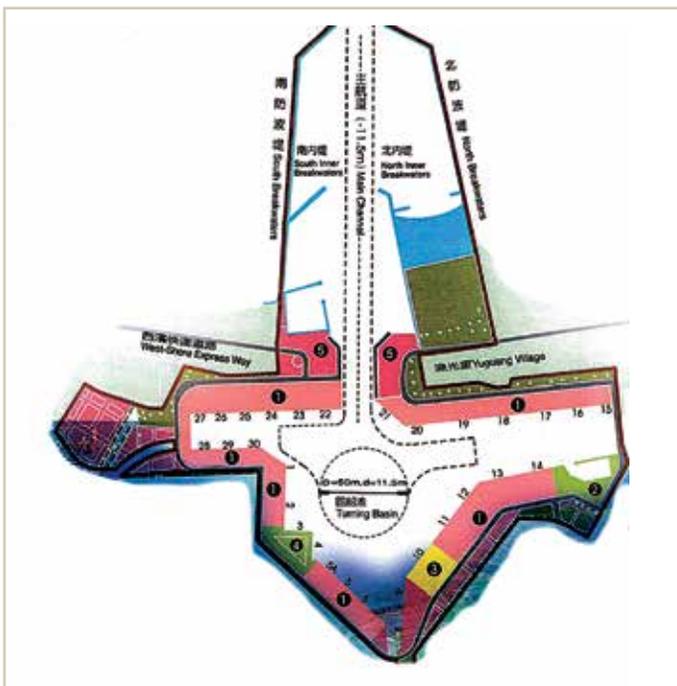
> Quay Construction

Anping, the most important auxiliary port of Kaohsiung Harbour, is situated on Taiwan's southwest coast some 40 km north of its mother port. The volume of cargo handled has been growing considerably in recent years as Anping has developed into a multi-functional harbour connecting east Asia, China, Hong Kong, and Taiwan's offshore islands. Due to its excellent geographical location and natural conditions, Anping used to be Taiwan's largest harbour, with origins dating back to the Ming dynasty. However, the importance of the harbour declined as a result of silting up.

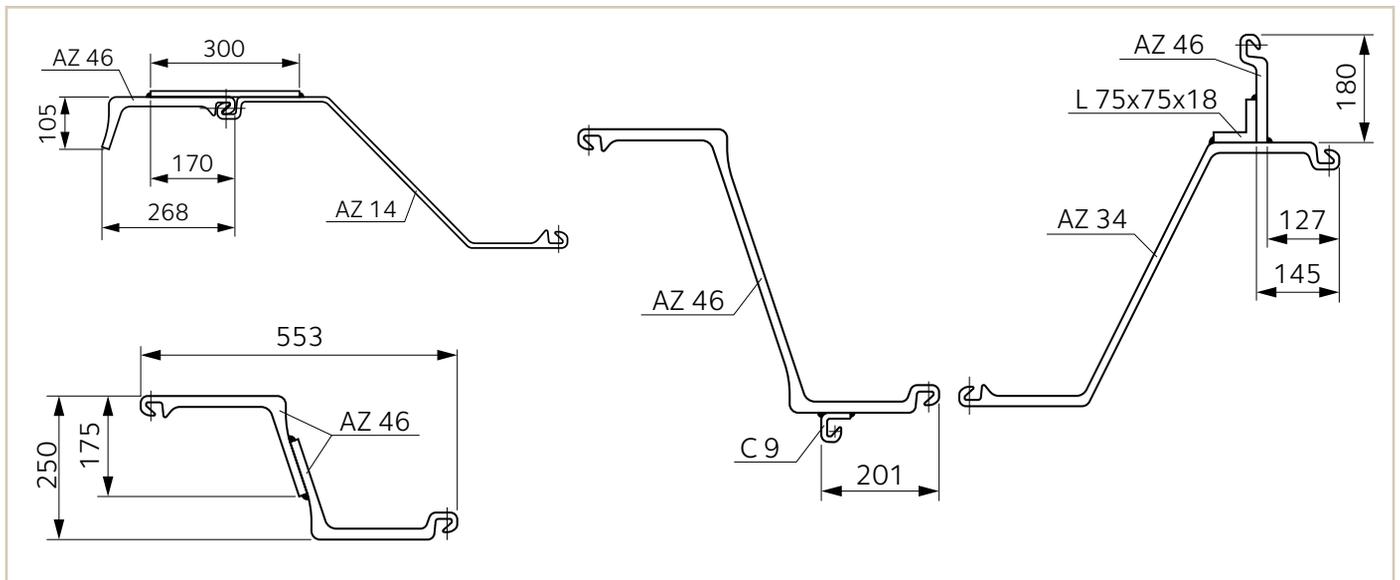
In more recent times the Kaohsiung Harbour Bureau started to rebuild Anping Port in order to improve local economic development. The port has been equipped with advanced port facilities and a tourist service centre transforming it into an international commercial harbour with growing international trading capacities. The depth of the navigation channel is 11.5 metres, the wharves of the harbour offer a water depth varying between 7.5 and 11 m. The combined wharf length totals 1,450 m for the deeper quays and 1,330 m for the shallower quays. After completion of the different expansion phases, Anping will have 32 wharves with a waterline of 5,566 m. The port will be able to handle vessels of up to 30,000 DWT, boosting its annual cargo capacity.



Anping Quay 1 - anchor wall.



Taiwan's Anping Port was expanded recently to accommodate larger vessels.



Several special piles were used to connect the different wall axes.



Several special piles and one PU pile were required to form the walls' corners and to attach the new quay wall to the existing structure. The following special piles were supplied by a subcontractor of ArcelorMittal and shipped to Taiwan together with the other sheet piles:

- AZ 46 single pile with C9 connector welded on,
- An oxycut AZ 46 single pile welded back together to obtain a reduced pile height of 250 mm,
- AZ 14 single pile interlocked with cut-off AZ 46. A plate was welded over the interlock to stabilise the cut-off AZ 46 sheet pile,
- AZ 34 single pile with additional Larsen interlock welded on.

The quay wall was installed using a jack-up barge on which the driving equipment was set up. Large parts of the parallel main and anchor walls were installed in open water some 52 m in front of the existing berths. Other parts of the quay allowed land-based installation of the steel sheet piles with a vibratory hammer. An impact hammer later drove the AZ piles to design depth, which was reached once the head of the piles passed the elevation of +1.2 m.

In contrast to most sheet pile construction sites, the contractor decided to install several AZ piles without the assistance of a driving template.

Owner:
Kaohsiung Harbour Bureau

Sheet piles:
AZ 46, AZ 34, AZ 14

Pile length:
23 m, 19 m, 13 m

Steel grade:
S 390 GP, S 355 GP, S 270 GP

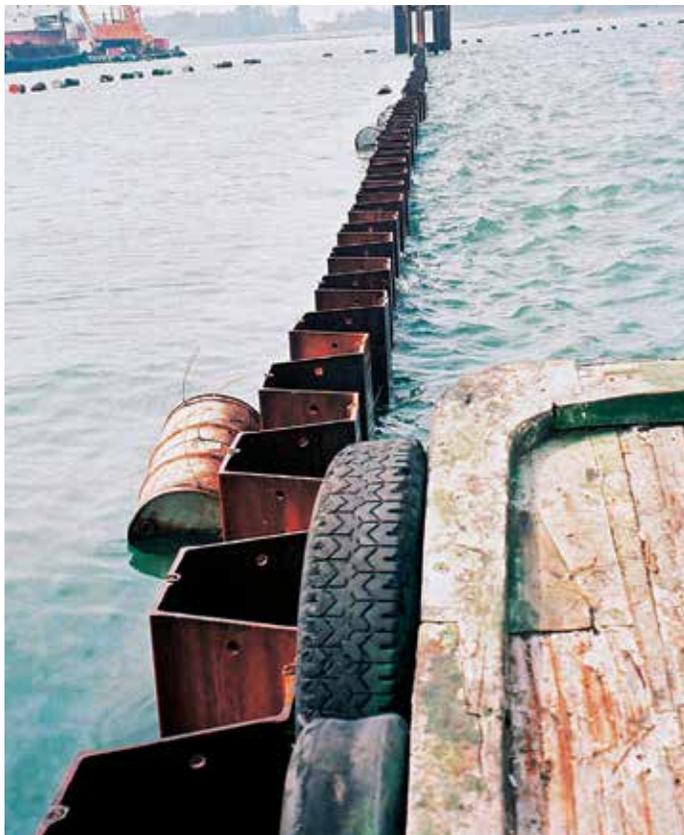
Total quantity of sheet piles:
2,500 metric tons



Welded on rebars prevent interlock rotation so as to precisely achieve the planned quay wall length.



The sheet piles were installed in open water using barge-mounted vibratory and impact hammers.



The installation team controlled the straightness of the wall axis optically.

Great care was taken to achieve the exact design length of the quay wall. The contractor welded rebars on the inside of the AZ 46 sheet piles to prevent rotation of the middle interlock which could have increased or reduced the width of the AZ 46 double piles. The target wall length was achieved by driving the quay wall in an optically controlled straight line. The contractor relied on the help of a driving guide for installation of the greater part of the 330-m quay wall, however.

The new infrastructure and facilities built under the “Anping Commercial Port Land Acquisition and First Stage Construction Plan” soon proved their worth. Implemented between July 1998 and September 2005, the project triggered strong growth in the cargo volumes handled: Anping handled 11.15 million metric tons of cargo volume in 2006, which represents growth of 66% compared to 2005.



With the new quays, the port was able to handle 11.15 million metric tons of cargo in 2006.



Taipei | Taiwan

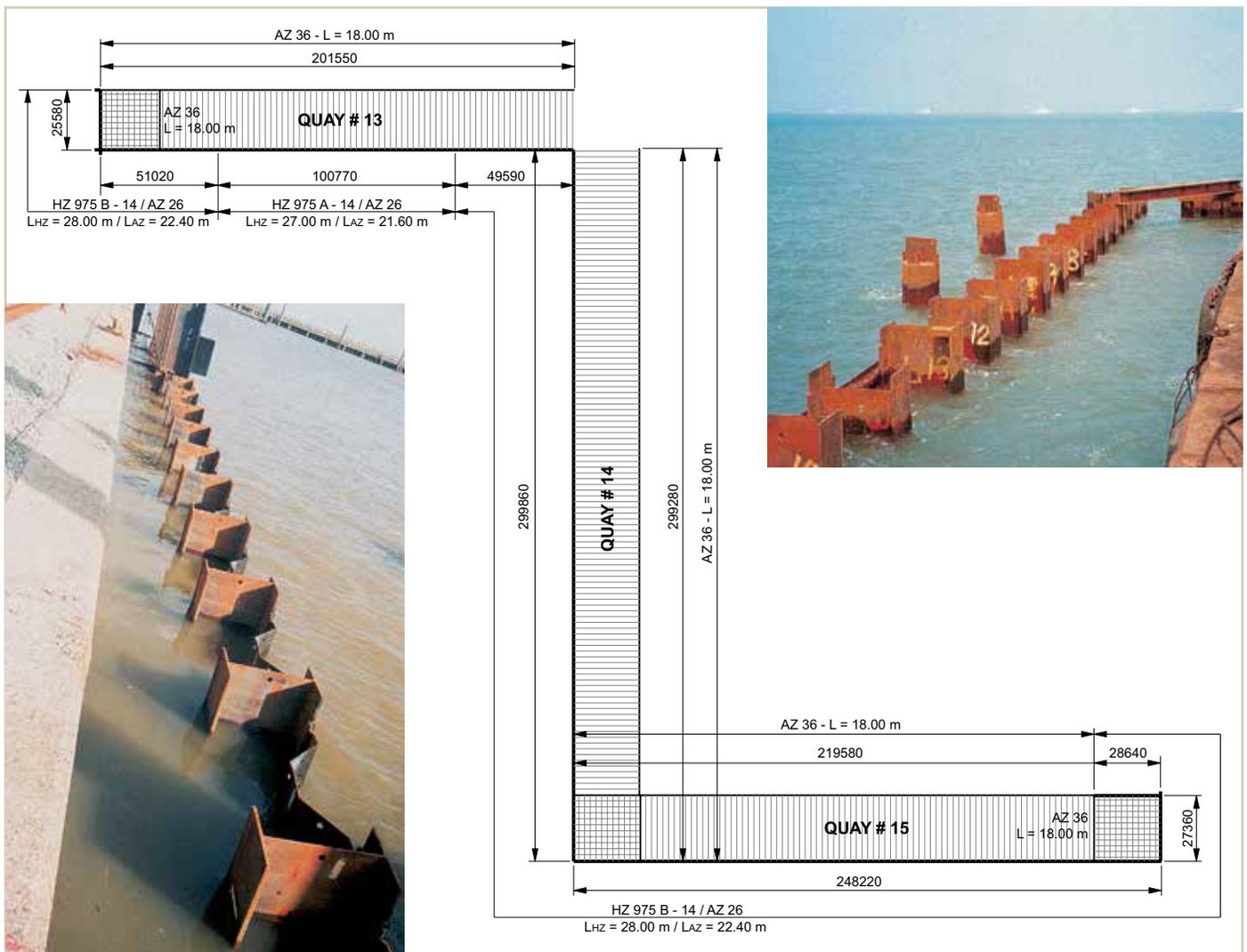
> Quays 13, 14 and 15



The owner of Quays 13, 14 and 15, the Formosa Plastics Corporation (FPC) is Taiwan's top petrochemicals company with an annual turnover of over US\$20 billion. FPC is one of the world's largest producers of PVC and is a member of the industrial giant Formosa Plastics Group. FPC is investing in petrochemicals, plastics, textiles, electronic materials, machinery, and power generation as well as in harbour operation and in the construction of marine and ground transportation. The company established Taiwan's first chemical tanker fleet in 1981. To meet the needs for transportation of chemicals and coals to their respective plants, the company possesses a fleet of 24 vessels including highly advanced chemical tankers, oil tankers, LPG ships, and cargo carriers.



Due to increasing traffic, Taipei Harbour is currently undergoing a three-phase expansion plan.



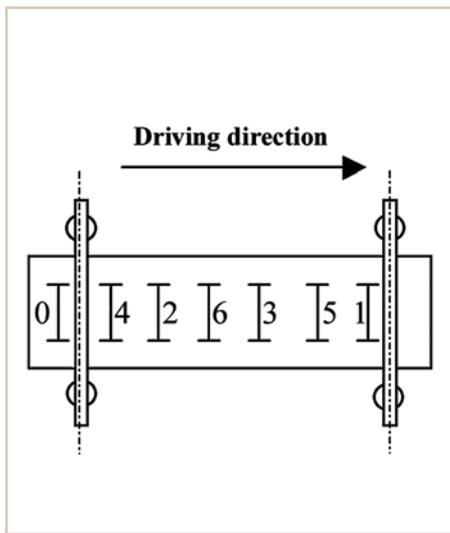
The Formosa Plastics Corporation required three new quays. Due to its advantageous installation speed, the choice fell in favour of the HZ/AZ combined-wall system.

Taipei serves as an auxiliary port for Keelung Harbour, one of Taiwan's seven international harbours. Taipei Port is located on the south bank of the Tamsui River in Taipei County, facing west onto the Taiwan strait. Exceptionally rich in natural resources, the port possesses a vast hinterland, spacious harbour areas with sufficient depths and an ideal geographical location near metropolitan Taipei.

The port of Taipei was designed as a multi-functional international port comprising terminals handling sand, gravel, cement, petroleum, containers, bulk and general cargo. Its total imports and exports exceeded 2.3 million metric tons in 2000. The Taipei Harbour Consortium (Yangming Marine Transport Corp., Evergreen Marine Corp. and Wan Hai Lines) plans to build a container warehousing and shipment centre at Taipei Harbour that will consist of 7 wharves featuring a total quay length of 2,355 m. With a depth of 14.5 m, the wharves will accommodate large container vessels with loading capacities of up to 5,000 TEU.

Since the primary purpose of the 3,102-hectare harbour is to relieve some of the ever increasing traffic Keelung is confronted with, Taipei Harbour has recently been undergoing a three-phase expansion of its facilities. The first phase began in January 1993, involving construction of a 70-hectare stacking yard and two nine-metre-deep berths totalling 340 m in length. Phase I was completed in 1998 with the reclamation of an 84-hectare area. The second phase, which involved the construction of 26 operation wharves including quays 13, 14 and 15 as well as 3,810-m-long outer breakwater, was finalised in 2002. The third and final phase is set to be completed by 2011.

Taipei is subject to high tidal fluctuations, the highest recorded level being at +3.82 m. The top of the new quay was therefore designed at +4 m to avoid flooding under extreme tidal conditions. The design of the sheet pile walls had to take the following tidal values into consideration: Mean High Water Level (MHWL) of +2.48 m and Mean Low Water Level (MLWL) of +0.55 m.



The "Pilgrim Step" driving sequence ensures that the piles encounter uniformly compacted soil during installation.



Two cranes, an ICE vibratory hammer and an impact hammer made up the installation equipment.



A two-level rigid template ensured the verticality of the king piles.



Driving was occasionally executed below the waterline because of substantial tidal variations.

The three wharves for the Formosa Plastics Corporation were built in 2001. The client's choice fell on ArcelorMittal's HZ/AZ combined sheet pile wall. Each of the three HZ/AZ quay walls was anchored to a tie-back wall to limit deflections of the wall's tip and to achieve an optimum moment distribution in the wall, synonym of an economically optimised layout. The existing soil harbour floor at -2.4 m was dredged to a depth of 15 m for each of the following quays:

Quay 13: Length 200 m

- Main wall:
- HZ 975 A / 14, L = 27 m & AZ 26, L = 21.6 m
 - HZ 975 B / 14, L = 28 m & AZ 26, L = 22.4 m

Anchor wall: • AZ 36, L = 18 m, distance to main wall: 25.3 m

Quay 14: Length 300 m

- Main wall:
- HZ 975 B / 14, L = 28 m & AZ 26, L = 22.4 m

Anchor wall: • AZ 36, L = 18 m, distance to main wall: 27.4 m

Quay 15: Length 250 m

- Main wall:
- HZ 975 A / 14, L = 27 m & AZ 26, L = 21.6 m
 - HZ 975 B / 14, L = 28 m & AZ 26, L = 22.4 m

Anchor wall: • AZ 36, L = 18 m, distance to main wall: 28.1 m

The HZ 975 A king beams were delivered in steel grade S 390 GP (yield strength: 390 N/mm²) and the HZ 975 B king beams in US Grade 60 (yield strength: 60 ksi = 414 N/mm²). The sheet piles were shipped to Taiwan in three batches from the mill in Luxembourg.

The three quay walls connect at angles of 90 degrees. A special solution had to be found for the intersecting anchor walls of Quay 14 and Quay 15. For this purpose, two AZ double piles were welded together to form a CAZ 36 box pile. Additional interlocks were welded onto the box pile to connect it to both anchor walls.



Two engineers from ArcelorMittal were dispatched to the site for assistance during the installation process.



The wall lengths of Quays 13, 14 & 15 are 150 m, 300 m & 250 m.



After installation of all the king piles, the AZ sheet piles were driven to El. -20 m.



The vibratory hammer was the ideal tool to install the AZ intermediary sheet piles.

Two engineers from ArcelorMittal travelled to Taiwan to provide assistance during the installation of the sheet pile walls. The contractor decided to set up the driving equipment on a barge that could move up and down in accordance with the tide. The installation gear consisted of a Kobelco crawler crane, a fixed crane, a vibratory hammer, and an impact hammer. Due to the substantial tidal fluctuations, the vibratory hammer occasionally had to work under water. This did not pose a challenge to the vibratory hammer because the separate power source remained above the waterline on the barge. The hammer used is characterised by a centrifugal force of 1,250 kN emitted at 1,600 rpm.

The driving template employed ensured that the high-section-modulus king piles were embedded into the ground straight, vertically, and at the required spacing. The 21-metric-ton template guided the piles at two levels 3.5 m apart. The lower level of the template was positioned close to the high water level at +2.48 m. Seven king piles spaced 1,790 mm apart fitted into the driving guide, which was fixed and levelled with the help of four tubes (length: 18 m, diameter: 800 mm, thickness: 20 mm). Tubular piles are the ideal support for templates during pitching and driving because they have identical static properties in all directions.



Two layers of tie rods connected main and anchor walls.



Two levels of load-distributing walings were installed.

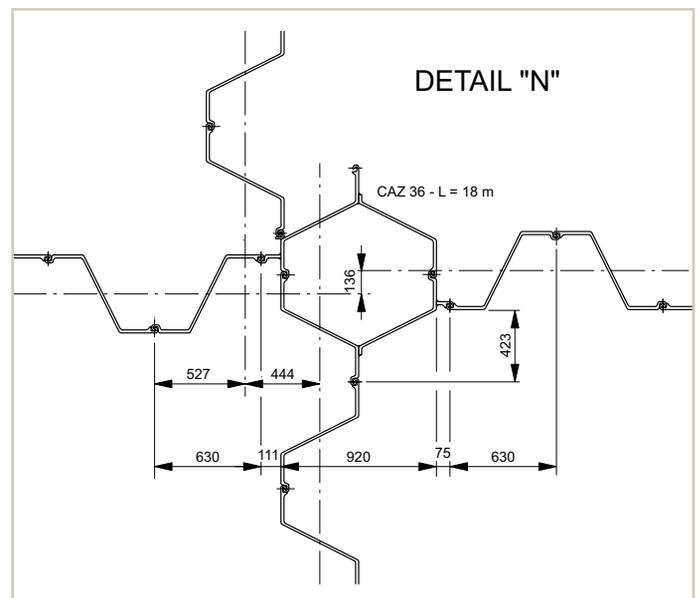


A CAZ 36 box pile with three interlocks welded on was used where the anchor walls intersect.

Boreholes drilled at the site showed SPT values ranging from 20 to 30 blows for the top soil layers, increasing to beyond 50 blows below El -23 m. The 8.5-t HZ king piles had to be driven into dense soil to El -25 m. The vibratory hammer turned out to be the ideal installation tool when driving through the upper layers of medium-density granular material. The lower clay layers however were so stiff that driving progress was barely perceptible. The contractor therefore switched to an impact hammer to proceed with the installation. Vibratory driving may cause cohesive soils to clump around the pile toe, considerably slowing down driving progress; hence impact hammers are advisable when faced with cohesive soils. The intermediary AZ sheet piles were vibratory driven until they reached the bottom of the medium-density soil layer at -20 m. The achieved verticality of the sheet piles was measured and turned out to be excellent.

To accomplish optimum driving results, a special driving sequence called the "Pilgrim Step" is advantageous: once all the king piles have been inserted into the template, the HZ pile driven previously being in position 0, driving then proceeds in the following order: 1 - 5 - 3 - 6 - 4 - 7 - 2. Driving one pile after the next (pitch and drive) could lead to problems with respect to the verticality of the sheet piles. Driving long elements can cause compaction of the soil at the pile toe which causes deviation of the following piles. An appropriate driving sequence avoids this problem. The driven piles should nevertheless be checked occasionally to ensure their correct vertical position.

The installation of the anchor walls began with driving of the special CAZ 36 box pile at the intersection of the anchor walls of Quays 14 and 15. The position of the sheet piles was checked at regular intervals. An interlock deviation of up to 5° allows for correction of driving inaccuracies without any need for special piles. When pile installation was complete, both the main and anchor walls were connected by two layers of tie rods. A waling was used to distribute the tensile force of the tie rods evenly into the sheet pile wall. The contractor used an excavator to backfill between the walls. A concrete capping beam and the top slab completed the three new quays.



The box pile was driven first, followed by the AZ 36 anchor walls of Quays 14 and 15.

Owner:
Formosa Plastics Corporation

Contractor:
Tian Tao, Taiwan

Steel grade:
S 320 GP, S 355 GP, S 390 GP, Grade 60

Sheet piles:
580 t HZ 975 A, L = 27 m
3,330 t HZ 975 B, L = 28 m
2,030 t AZ 26, L = 21.6 - 22.4 m
2,670 t AZ 36, L = 18 m

Total quantity of sheet piles:
8,610 metric tons



A large excavator was used to backfill the area between the main and anchor walls.



The installation and backfilling procedure proceeded on separate barges.



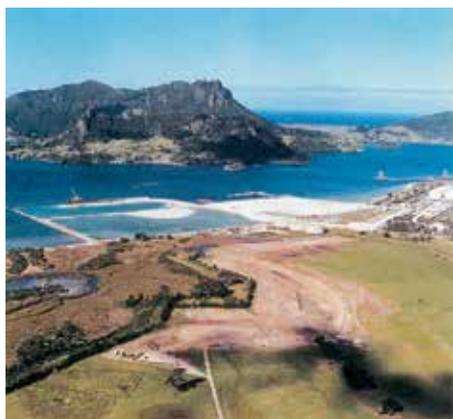
The 27.4-m return wall of Quay 15 consists of a combined wall with 14 HZ king piles.



Numbers of tie rods cross over each other to connect the main and return walls to their respective anchor walls.

Marsden Point | New Zealand

> Construction of new deepwater port

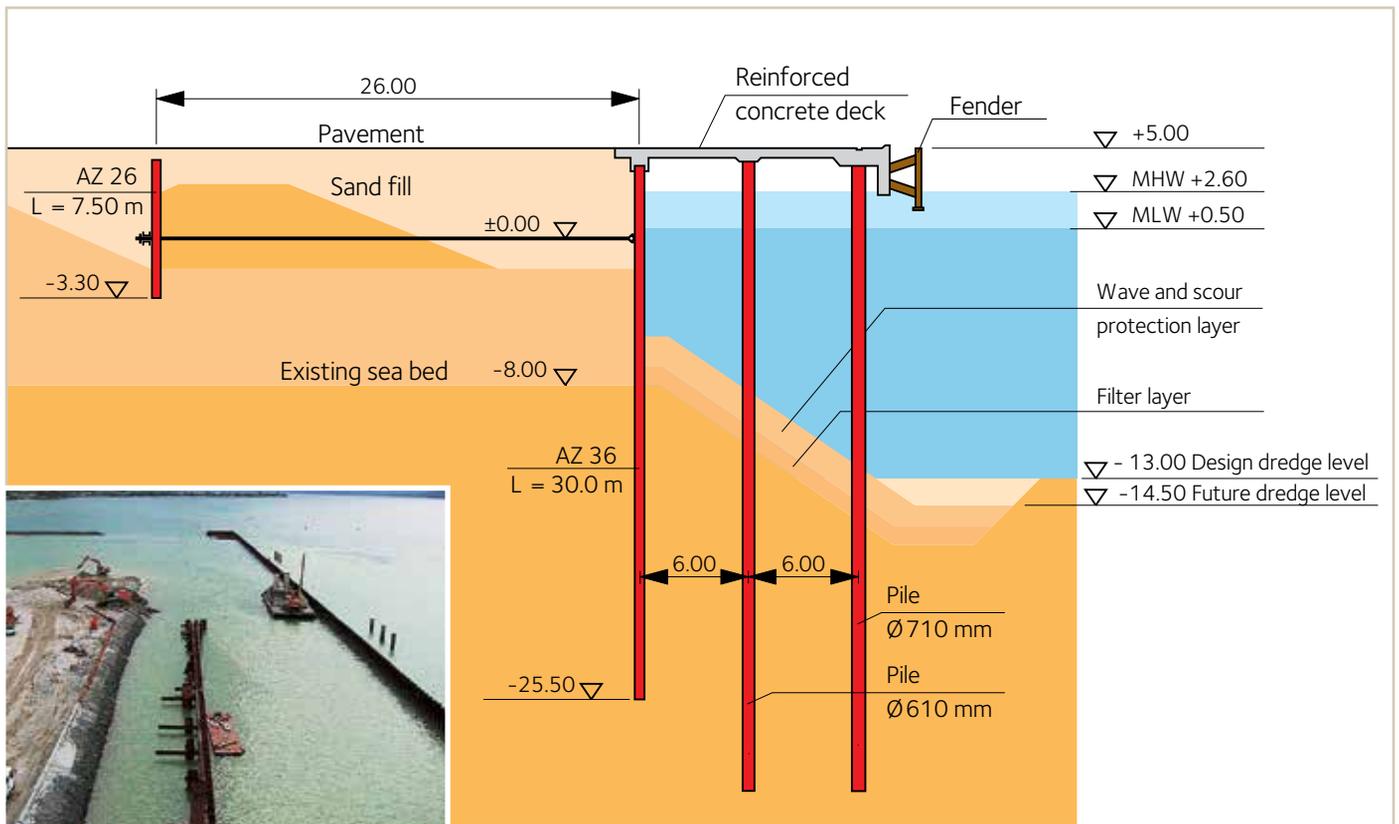


Marsden Point is situated on the northeast coast of New Zealand's North Island. It is here where the country's most modern and deepest port was constructed. Offering permanent shipping access and guaranteeing a continuous increase in traffic, the harbour is undoubtedly a key factor in the development of New Zealand's economy.

The idea of building a new port in this region goes back several decades. The Northland Port Corporation, which operates the nearby port of Whangarei, purchased the site in the 1960s when New Zealand's forestry was still in its infancy. With the passing of the years some 190,000 ha of pine forest reached maturity, resulting in sustained growth of exports of forest products from Whangarei. Exports were predicted to increase fourfold between 2000 and 2004. Port Whangarei, whose wharf structures were not designed to carry today's heavy handling equipment, is incapable of handling this growth.



The new deepwater port was completed in 2002 after a construction time of less than 2 years.



The originally planned HZ/AZ quay wall was replaced by a more economical AZ 36 wall.



The project's design lifetime of 50 years called for two layers of tar-free epoxy coating.

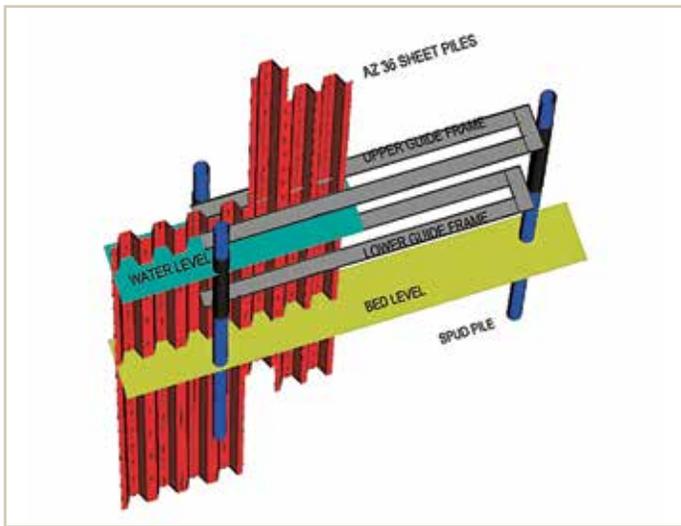


The main retaining wall was driven from a Flexifloat S-70 jack-up barge.

The port accepts draughts of merely nine metres, which is inconsistent with the evolution of modern shipping fleets. Furthermore this capacity can only be assured at the cost of regular dredging. More recently the port has faced a shortage of dumping sites for the dredged material. These arguments made the construction of a new deepwater port unavoidable.

Northport, a joint venture between Northland Port Corporation and Port of Tauranga, teamed up with Australasia's largest forest-products company, Carter Holt Harvey, for land operations at the planned new port. Following nearby construction of a very large laminated veneer lumber plant aimed principally at the export market, Carter Holt Harvey undertook a firm commitment to ship one million metric tons of wood and derivative products from the new port in its first five years of operation. A growing range of other exports were soon handled by the port. The annual cargo volume reached 2.8 million metric tons in 2005 including agricultural produce, fertilisers, cement and containers as well as wood.

Thorough studies concerning hydrographic and environmental aspects of the site had already been carried out in the 1970s. The area where the new port was built is situated between two inactive faults; its favourable geological conditions facilitated the construction works. The soil consists of alluvium, essentially sand, with rare peaty areas, all overlying deep greywacke and argillite bedrock. This meant not only that reclamation could go ahead without any preparatory dredging but also that the dredged soil from the turning basin could be used as backfill material: several million cubic metres of sand were placed behind a 1,700-m embankment standing between 3 and 16 metres high. The embankment was also built from readily available local materials, mainly sand, and was protected by heavy rocks. Consolidation of the structure was achieved by loading the top of the embankment up to a height of two metres with backfill material before levelling it off to build the pavement.



Proper alignment of the piles was achieved with a template.



Corrosion-protection tape was wrapped around the anchors.



The driving gear consisted of a vibratory hammer...



... and a hydraulic hammer.

Owner:

Northland Port Corporation,
Port of Tauranga and Carter Holt Harvey

Designer:

Beca Carter Hollings & Ferner Limited (BCHF)

Contractor:

Fletcher Construction Company Ltd

Steel grade:

S 430 GP

Sheet piles:

AZ 36, L = 30 m; AZ 26, L = 7.5 m

Total quantity of sheet piles:

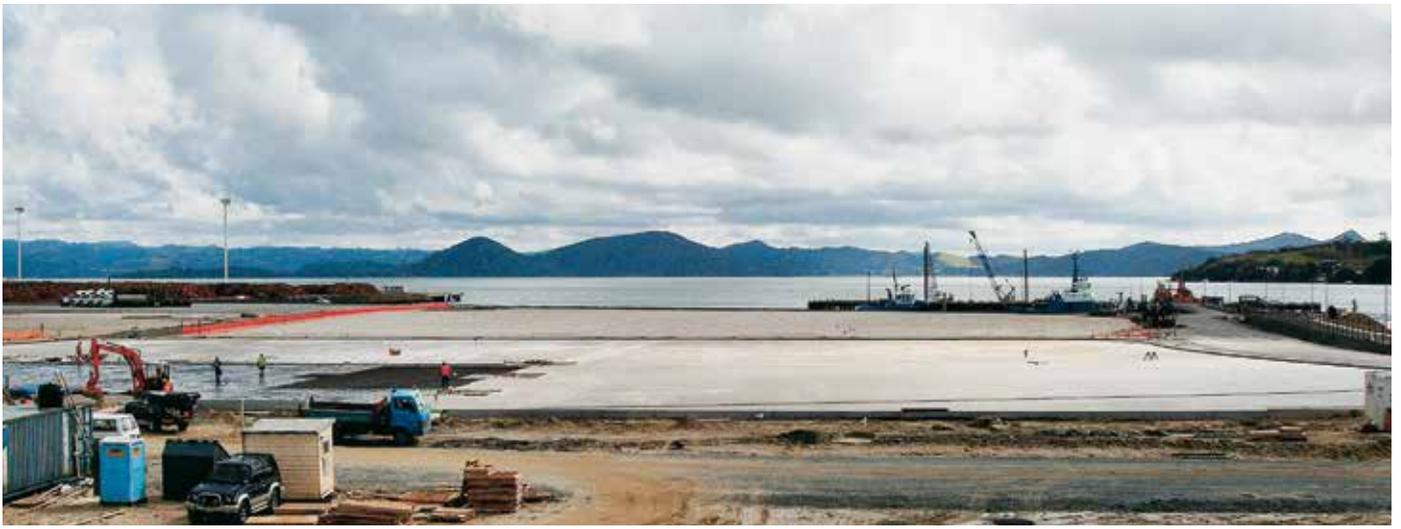
3,000 metric tons

Construction of the new deepwater port began in October 2000. Less than two years later, in June 2002, the first ship was able to dock at Northport. The second berth was completed only a few months after the first berth came into service. The project was built under a NZ\$ 30 million fixed-price design-and-build contract. The new port includes a 50-ha cargo-marshalling area (32 of which were to be on reclaimed land) and a 390-m wharf with two mooring spots able to handle 65,000-t bulk carriers with maximum lengths of 230 m and maximum draughts of 13 m. Fletcher Construction Company Ltd was the design-and-build contractor, with Beca Carter Hollings and Ferner the designer. Initially an HZ/AZ combined sheet pile wall was proposed for the retaining wall to both contain the adjacent reclamation and support the rear of the wharf deck. The deck consists of a cast-in-place reinforced-concrete flat slab supported on the seaward side by two rows of concrete-filled steel pipe piles. However, BCHF's final design substituted the combined sheet pile wall with a more cost-efficient AZ 36 wall. The design takes account of the high loads present (dead load of 85 kN/m, live load of 240 kN/m). The considerable width of the AZ piles chosen (1.26 m per double pile) is an advantage in terms of construction productivity. Although manufactured on the other side of the world, the 3,000 t of sheet piles used for the Northport project were supplied to the site within 3 months.

The 30-m-high main retaining wall made of AZ 36 sheet piles was driven 16 m into the prevalent sand, the lower five metres of which are of a very compact nature. Two 15-m-high retaining walls connect the main quay wall to the backfilled embankments. The AZ 36 sheet piles were anchored by 26-m tie rods to a 7.5-m-high deadman wall made of double AZ 26 sheet piles.

The main retaining wall and the deadman wall were connected by 60-mm-diameter steel tie rods provided by Anker Schroeder, consisting of two 13.45-m bars joined by a threaded coupler. Continuous steel-channel walers were bolted to the sheet piles by a team of divers who also installed the tie rods.

The site's geology and the depths involved meant there were no particular problems regarding pile driving. The main retaining wall was driven from a Flexifloat S-70 jack-up barge using a PTC 50 HL vibratory hammer operated with a P&H 5100 crane. In case of refusal prior to design penetration into the compact sand, a 9-t Junttan hydraulic hammer was used to complete the driving process.



Several exporting companies soon began to use the new port, making further expansion plans unavoidable.



The 390-m wharf was completed with retaining walls at each end.

A guide frame with two supporting levels 8 m apart guaranteed the required alignment. The template was held in place with steel tubes that were driven until refusal with the same driving gear that installed the sheet piles. Nine pairs of AZ 36 piles were inserted into the guide frame and driven in panels to ensure the required verticality was achieved. The deadman's AZ 26 sheet piles did not require driving: they were simply set up from the embankment and propped until enough sand had been placed on both sides.

With a design life of 50 years, special care was taken to provide adequate corrosion protection of the wall's most critical parts: the intertidal zone and the top of the immersion zone, which coincides with the level of the tie rods. The sheet piles were coated with two 175- μm layers of a tar-free epoxy coating known as Altra Tar. Once assembled, the tie rods were wrapped with Denso Ultraflex corrosion-protection tape, with heat-shrink sleeves around the couplers.

Right from the outset, plans were made for two further berths drawing 14.5 m. Construction of Berth No 3 started at the end of 2005 using a combined sheet pile solution delivered by ArcelorMittal.



Due to the success of the Northport project, ArcelorMittal also supplied the sheet piles for the 2005/2006 construction of the port's new Berth No 3.

Disclaimer:

The data and commentary contained within this steel sheet piling document is for general information purposes only. It is provided without warranty of any kind. ArcelorMittal Commercial RPS S.à r.l. shall not be held responsible for any errors, omissions or misuse of any of the enclosed information and hereby disclaims any and all liability resulting from the ability or inability to use the information contained within. Anyone making use of this material does so at his/her own risk. In no event will ArcelorMittal Commercial RPS S.à r.l. be held liable for any damages including lost profits, lost savings or other incidental or consequential damages arising from use of or inability to use the information contained within. Our sheet pile range is liable to change without notice.

Edition 2021 - Printed on FSC paper.

The FSC label certifies that the wood comes from forests or plantations that are managed in a responsible and sustainable way (the FSC principles promote the social, economical, environmental and cultural needs of today's and the next generations).
www.fsc.org

ArcelorMittal Commercial RPS S.à r.l.
Sheet Piling
66, rue de Luxembourg
L-4221 Esch-sur-Alzette (Luxembourg)
E sheetpiling@arcelormittal.com
sheetpiling.arcelormittal.com



Hotline: (+352) 5313 3105



ArcelorMittalSP



ArcelorMittal Sheet Piling (group)