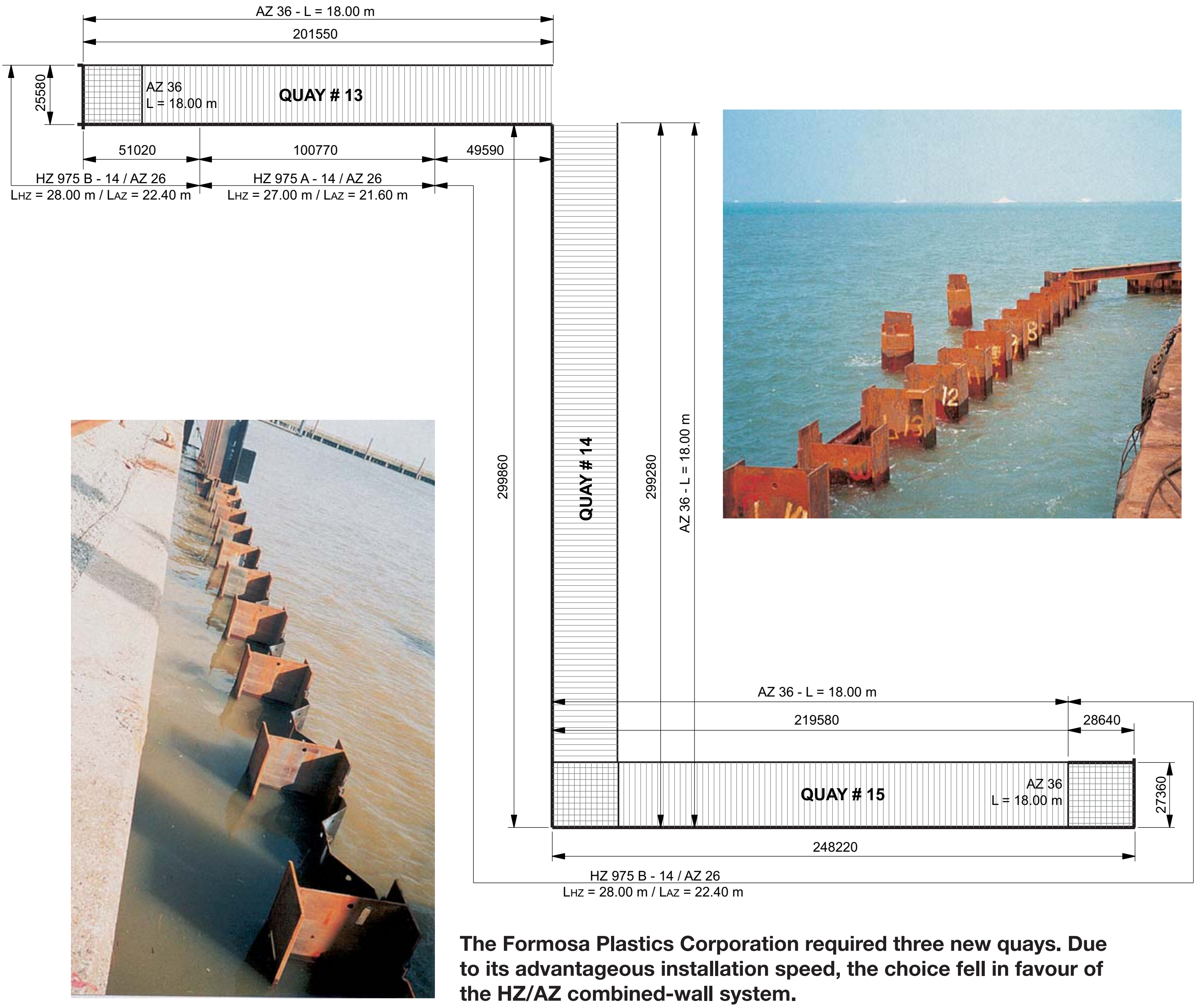
Taipei, TAIWAN

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.

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.

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



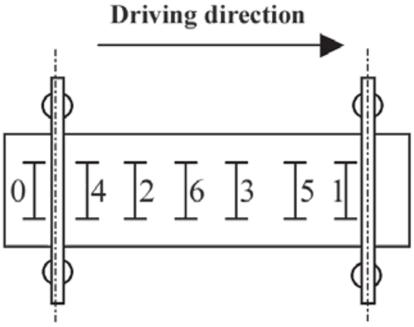
The Formosa Plastics Corporation required three new quays. Due to its advantageous installation speed, the choice fell in favour of the HZ/AZ combined-wall system.

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

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

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 three wharves for the Formosa Plastics Corporation were built in 2001. The client’s choice fell on Arcelor’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/mm^2) and the HZ 975 B king beams in US Grade 60 (yield strength: 60 psi = 414 N/mm^2). 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 Arcelor were dispatched to the site for assistance during the installation process

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

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

Two engineers from Arcelor 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.

Taipei Port, TAIWAN

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

Owner:
Formosa Plastics Corporation

Contractor:
Tian Tao, Taiwan

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

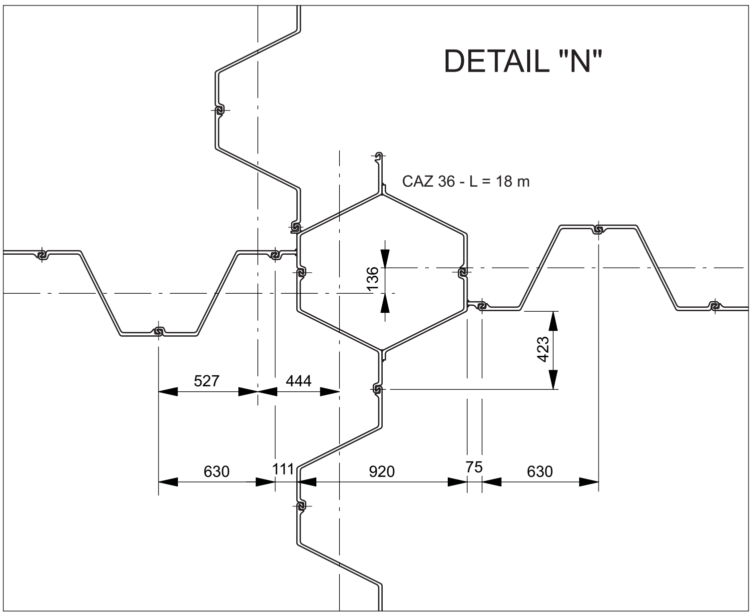
Sheet piles:
580 t HZ 975 A, L = 27 m
3,330 t HZ 975 B, L = 28 m
2,030 t AZ 26, L = 21.6 - 22.4 m
2,670 t AZ 36, L = 18 m

Total quantity of sheet piles:
8,610 metric tons

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



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

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

(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. ■