Visakhapatnam, INDIA

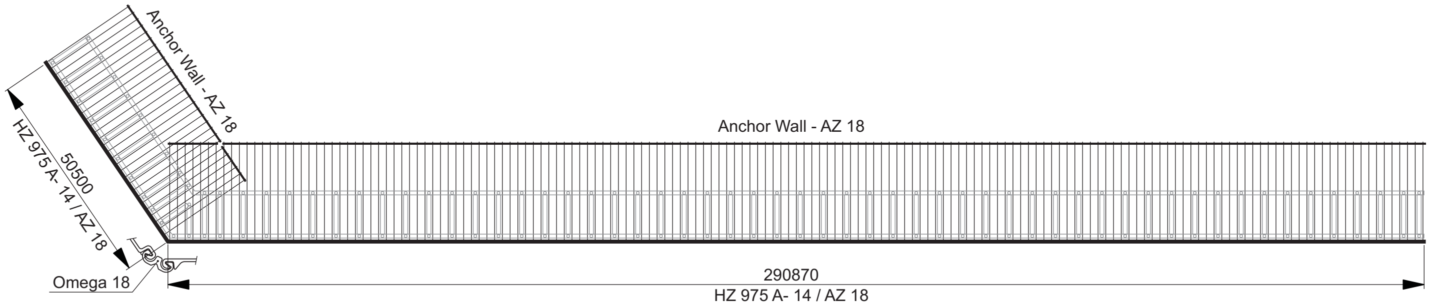
Extension of Berth WQ-7

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.

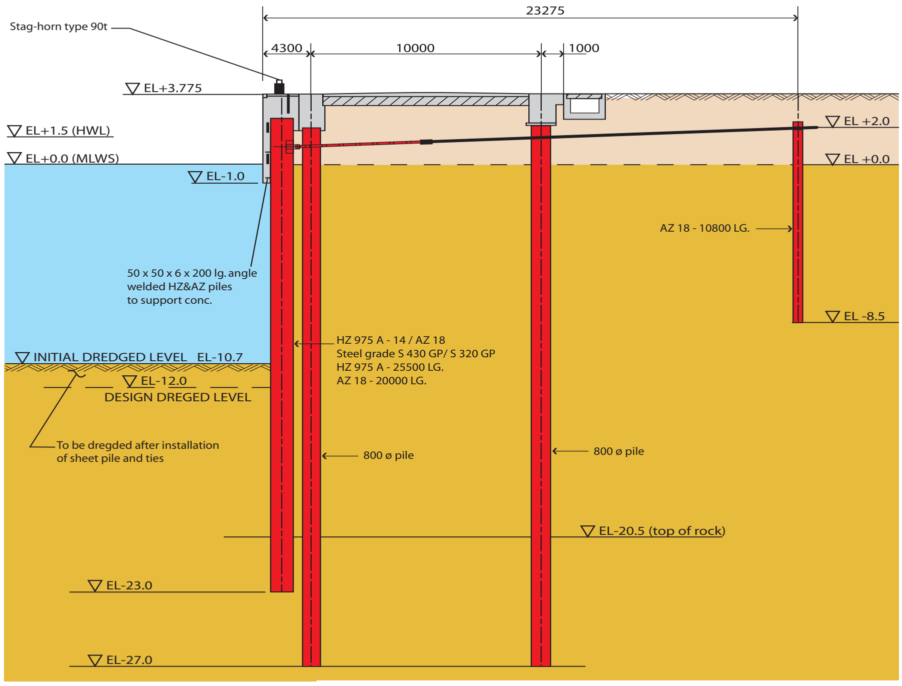
About 90% of India's foreign trade passes through one of the ports situated along its 6,000-km coastline. Eleven major ports – Calcutta, Chennai (Madras), Cochin, Haldia, Kandla, Mangalore, Mormugao, Mumbai (Bombay), Paradip, Tuticorin and Visakhapatnam – are managed by the government controlled Port Trusts. Together, they have been handling approximately 230 million metric tons of cargo per year. A development plan has just been completed to raise

Visakhapatnam Port is one of India's largest harbours

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



The two segments of the quay wall have a combined length of 340 m



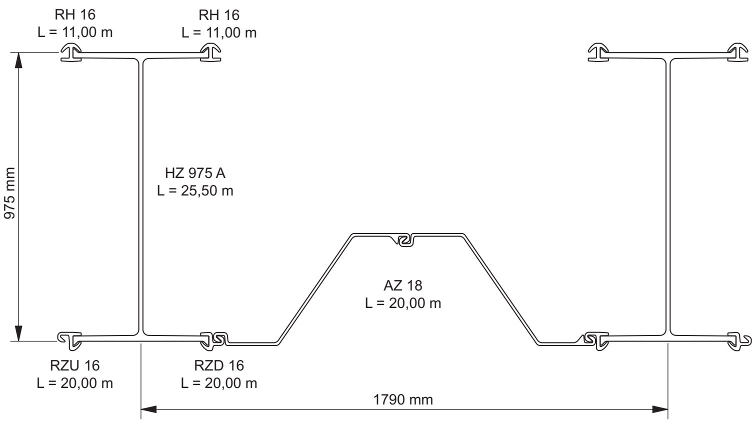
The HZ 975 A - 14 / AZ 18 main wall is installed 23 m in front of the AZ 18 anchor wall

capacity by a further 170 million metric tons.

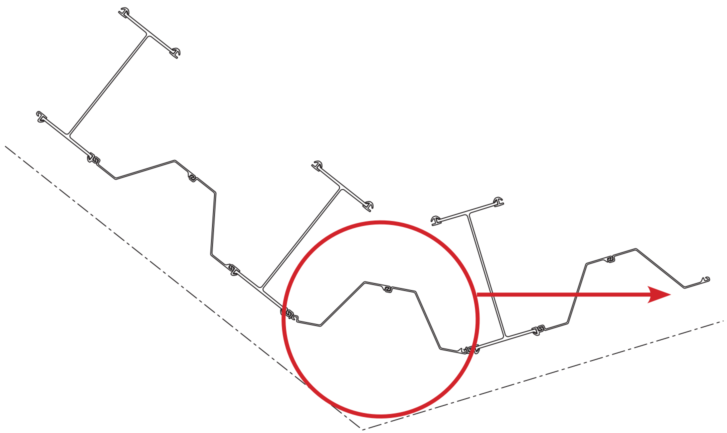
Visakhapatnam Port is today one of the largest harbours in India. It developed rapidly from a small mineral trading post into a major harbour handling bulk cargo, iron ore, petroleum oils and lubricants, coking coal and coke as well as container traffic. Visakhapatnam Port was under the control of the 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.

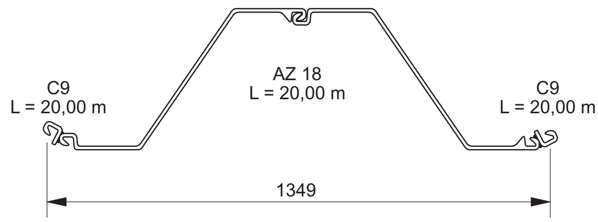
Visakhapatnam boasts the only port in the country to have exceeded the 50 million metric ton mark in 2004-2005, though with a low growth of 5%. The Indian government is considering increasing the port's cargo handling capacity to 70 million metric tons. The expansion will implement deepening of the outer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



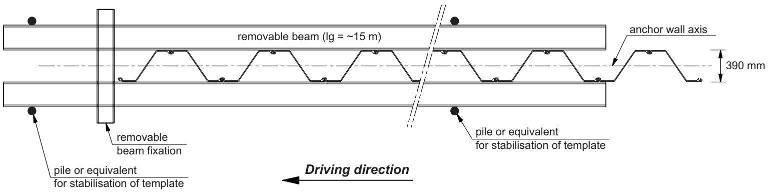
The combined wall was locally reinforced with RH sections



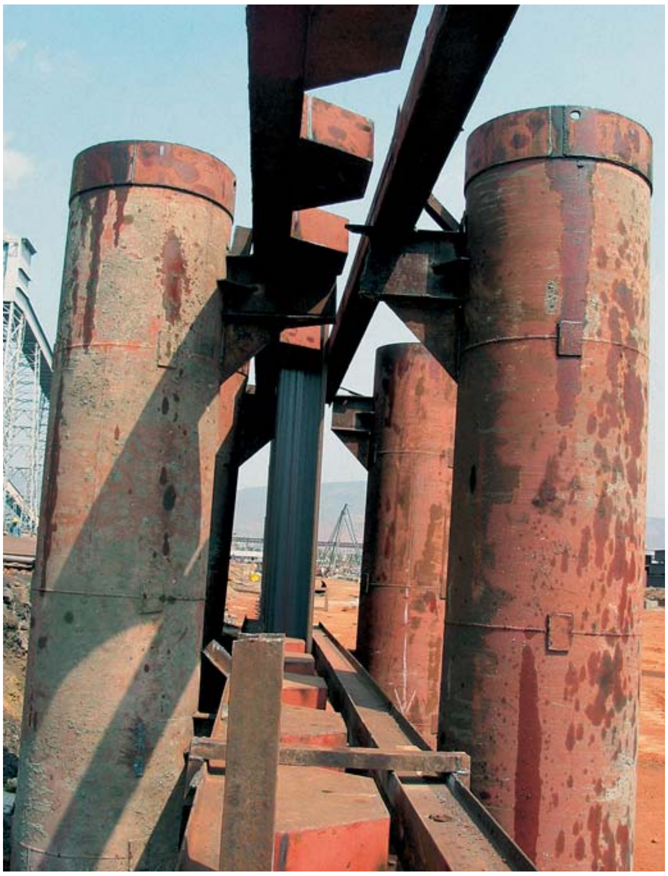


C9 connecters welded to an AZ 18 double pile formed the corner of the segmented quay wall

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



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

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.

Arcelor'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 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 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	
-17.00	-20.50	Brownish stiff clay	34
-20.50	-24.00	Highly weathered rock	> 50
-24.00	-27.38	Hard rock with fractures	> 50

Strong shackles were used to lift the king piles

Wooden spacers prevent damage to the stored AZ piles

The HZ 975 A – 14/AZ 18 sheet pile wall features a system width of 1,790 mm, a section modulus of 8,170 cm^3/m, and a weight of 225 kg/m^2. The king piles were designed in high-strength S 430 GP steel (minimum yield strength: 430 N/mm^2, minimum tensile strength: 510 N/mm^2, 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 (max%)	Mn (max%)	Si (max%)	P (max%)	S (max%)	N (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.


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

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

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

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

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 Arcelor'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 Arcelor.

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. ■