Site overview showing marine structures and part of shed (on the right) during construction

Kwale Mineral Sands Export Facility
focus on the marine works

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Base Resources Limited from Australia appointed WSP in 2011 to assist with the development of their Kwale Mineral Sands project in Kenya. The Kwale Mine is located some 10 km from the coast and approximately 50 km south of Mombasa. The primary products of the mine are ilmenite, rutile and zircon. Zircon is exported in containers via the Port of Mombasa, while ilmenite and rutile are exported in bulk and required a dedicated export facility.

BACKGROUND

Base Resources Limited from Australia appointed WSP in 2011 to assist with the development of their Kwale Mineral Sands project in Kenya. The Kwale Mine is located some 10 km from the coast and approximately 50 km south of Mombasa. The primary products of the mine are ilmenite, rutile and zircon. Zircon is exported in containers via the Port of Mombasa, while ilmenite and rutile are exported in bulk and required a dedicated export facility. WSP was appointed to provide the engineering, procurement and construction management (EPCM) services for the new port facility.

The mine plans to export some 330 000 tonnes of material (consisting primarily of ilmenite and rutile) per year, through the new port facility. The site is located in Likoni on the southern bank of the river directly opposite the Port of Mombasa and directly adjacent to the existing ferry terminal.

The facility mainly comprises a storage shed for the mineral sands, an access trestle and load-out platform with breasting and mooring dolphins, and conveyors with a ship-loader. WSP put together a specialist consulting engineering team ensuring local representation, as well as specialist skills in the field of storage, transport and loading of mineral sands into the berthed bulk carrier. The project team that provided the consulting engineering services is as shown in Table 1.

After completing topographical, bathymetrical, geophysical and geotechnical surveys of the area, the layout and design of the facility were finalised, considering various design factors and

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Table 1: Project consulting team

EPCM project management	WSP
Structural engineering: • Marine-based • Land-based	 WSP WSP (preliminary design: Howard Humphreys, Kenya)
Civil engineering	WSP
Electrical engineering	Howard Humphreys (Kenya) reviewed by WSP
Ship-loader and conveyors	LNW/Syralco
Instrumentation, SCADA & PLC systems	LNW/Syralco

restrictions, including the client requirements and adhering to the port regulations of the Kenya Ports Authority.

The site was quite restricted and only about 13 300 m^2 in size. The facility and its operations were to be positioned between the new ferry terminal (currently under construction), an emergency slipway (currently not in operation, but to be refurbished), the shipping channel boundary, as well as a public road, residential area and school on the landside boundary. The site topography included a steep cliff of 6 m height from the landside to the beach.

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The final scope of works included the following:

- A storage shed with a capacity of 60 000 tonnes.
- A conveyor system and ship-loader with a loading capacity of 1 000 tonnes per hour.
- Two breasting dolphins and two mooring dolphins for the berthing of a maximum 57 000 DWT bulk vessel.
- A load-out platform with rails for the ship-loader, and fenders and bollards for the berthing of empty ferry vessels (from the adjacent ferry terminal) when the loading facility is not used.
- Access trestles with walkways and conveyor supports for access to the load-platform.

- Instrumentation, SCADA (Supervisory Control And Data Acquisition) and PLC (Programmable Logic Controller) systems.
- An administration building, maintenance workshop and a guard house.
- A fisherman's access ramp.
- A dedicated sub-station to address the risk of disruption to the operations due to regular power outages in Kenya.
- Roads, surfacing including pavements and grass, boundary walls, fencing and a sound barrier wall between the school and the facility.
- A 22 m long retaining wall (+9.65 m CD) with staircase providing access from the land to the beach (+3.8 m CD).
- Water tanks (collection of rainwater), sewage treatment plant, generators and fuel tanks.

The operations at the facility start with the trucks transporting the ilmenite and rutile from the mine, delivering it to the facility by entering the storage shed at one side, offloading and then exiting on the other side. Once sufficient volumes are in storage in the shed, the product is transported to the ship-loader via a conveyor system. The product is then loaded into the holds of the berthed bulk carrier via a travelling ship-loader, positioned on the load-out platform. The load-out platform was dimensioned for smaller vessels (approximately 20 000 DWT). In order to load all holds of larger vessels (approximately 30 000 to 57 000 DWT), these vessels need to be warped along the berth (moved ahead and astern along the berth by using winches on board the vessels).

THE MARINE WORKS

The marine structures include the access trestle and walkways that connect the facility on land with the load-out platform and the dolphins. The access trestles also provide support to the conveyor structures. The load-out platform was positioned to ensure adequate water depth for the design vessel and therefore dredging was not required on this project. On either side of the load-out platform one breasting dolphin and one mooring dolphin are located. The two breasting dolphins are connected to the load-out platform with walkways. The mooring dolphins are only accessible via boat. The top level of all the marine structures was kept the same level as that of the cope levels within the port, which is +5.40 m CD. The minimum riverbed depth at the platform and breasting dolphins is -13.50 m CD.

The conforming design of the various marine structures comprised tubular steel piles (vertical) founded into the riverbed and tied together with a reinforced concrete superstructure. The design accommodated the capability of local contractors, which meant that only vertical piles were used up to a maximum pile diameter of 1 m.

The construction of the marine facility was awarded to Stefanutti Stocks Marine, who included an alternative design offer based on larger diameter and raking piles for the berthing and mooring dolphins, as well as steel superstructures for the dolphins and access trestles. Their pile design incorporated diaphragms to reduce the penetration depths into the sandy and soft calcrete layers required when compared


Access trestles with conveyors fitted


Breasting dolphin piling


Load-out platform – precast deck slabs in position


Mooring dolphin piling

with the conforming design's open-ended piles. During construction two test piles were driven to confirm the driveability of these piles and ensure that the structure, as built, met the design criteria.

The access trestles comprise 22 number 760 mm diameter piles driven to an average penetration depth of 24 m, while the breasting dolphins comprise six number 1 300 mm diameter raking piles each, with an average penetration depth of 20 m, and the mooring dolphins comprise four number 900 mm diameter raking piles each with an average penetration of 21 m. The 1 200 mm diameter load-out platform piles (18 no) penetrated the riverbed by an average depth of 19 m. Corrosion protection for the headstocks and piles included a protective paint system, as well as cathodic protection. The piles were kept hollow, as the design life of the facility is only 20 years. This design life is based on the estimated life of the mine, which is 15 years.

The conveyor and ship-loader system necessitated strict deflection criteria (operating and out of operation) for the supporting marine structures, which resulted in the deflection criteria being the critical design criteria for the load-out platform design, especially considering the need for provision for empty ferry vessels berthing against this structure.

The superstructure for the access trestles and dolphins comprise steel headstocks, which also served as pile guide during piling for the dolphin structures. The void between the piles and tubular headstock members was filled with grout. Items such as handrails, bollards, access ladders, fenders and walkways were fitted to the headstocks. The

Access trestle – placing headstock

Concrete batching plant at night

headstocks were manufactured in South Africa and shipped to Kenya for installation.

The load-out platform superstructure comprises a combination of precast and in-situ reinforced concrete members to simplify construction over the water. All concrete was mixed at the batching plant on site. Readymix concrete would need to be transported from Mombasa city to site with the public Likoni ferry, hence the decision by the contractor to establish a batching plant on site.

The electrical supply to the ship-loader was earthed by providing electrical connection between the rails and the steel piles through the reinforced concrete. The load-out platform was fitted with rails, buffers and electricity for the ship-loader, bollards and fenders for berthing of the empty ferry vessels, hand rails, walkways and access ladders.

The firewater pipes, wash-down water pipes and electricity cables were fitted to the walkways to provide these services from land. The walkways were also fitted with general lighting. Two solar-powered navigation lights were fitted on the breasting dolphins.

The construction of the facility was completed towards the end of 2013. The first shipment of bulk ilmenite from the Likoni Port Facility took place on Monday 17 February 2014, while rutile and zircon were first shipped on 6 April 2014.

ACKNOWLEDGEMENT

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