

The construction of the Matola Dolphins: Maputo Harbour, Mozambique

BRIEF DESCRIPTION OF THE PORT OF MAPUTO

The Port of Maputo, situated in Maputo Bay in Mozambique, comprises two sections:

- The Gorjão Quay, designated by Maputo Cargo Terminals – this quay, which has 13 berths, is adjacent to the city and has an extension of 3.3 km.
- The Matola Section, designated by Maputo Bulk Terminals – this quay is situated upstream of the estuary where three rivers join (the Tembe, Umbelúzi and Matola Rivers).

The Matola Section of the harbour started in the 1930s with the construction of the LÍngamo Oil Terminal and

today comprises, going from upstream to downstream, the Cereal Terminal, the Mozal Jetty, the old LÍngamo Oil Terminal (unused today), the dolphin berthing posts which include the present Oil Terminal, the Coal Terminal and two berthing dolphins (which were never used) placed downstream from the Coal Terminal. The LÍngamo Oil Terminal was deactivated after the construction of the present Coal Terminal, which had initially been built for the export of iron ore from Swaziland, but was changed to a coal terminal after the Swaziland iron ore mine became extinct.

Before the construction of the present Coal Terminal, the Matola Section was

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Aerial view showing the present oil terminal (upstream) and the present Matola Coal Terminal (downstream)

used by oil tankers, and by vessels carrying mainly timber. After the construction of the Iron Ore/Coal Terminal the oil tankers used the new quay. The timber carriers dropped anchor in the estuary, and the timber was offloaded to barges that were towed to the wall built in the meantime between the LÍngamo Oil Jetty and the new Iron Ore/Coal Terminal, with an extension of about 850 m. The barges berthed at the wall, where they were offloaded to timber warehouses from where the timber was exported by rail to neighbouring countries.

This area of the port is narrow and shallow, which limited access to ships not longer than 200 m in order to allow safe manoeuvrability.

From time to time the Matola section is subjected to violent storms, which, when coinciding with strong low-tide currents, presented a danger to the timber vessels anchored in the estuary. Also, the increase in the size of the ships accessing this area, led the Mozambique Railways and Harbours (CFM) to improve shipping safety conditions, particularly for the timber carriers, hence the decision to construct three dolphin berthing posts, placed between the old LÍngamo Oil Jetty and the present Coal Terminal, in front of the barge berthing wall. The three berthing posts would comprise six berthing dolphins and three mooring dolphins, with one of the berthing dolphins converted and strengthened from an existing mooring dolphin.

Since then two new terminals have been built upstream of the dolphin berthing posts, namely the Cereal Terminal Jetty, which is upstream of the new Mozal Aluminium Terminal. The old Oil Terminal, situated between the Cereal Terminal and the Mozal Jetty, is now derelict.

THE MATOLA DOLPHIN BERTHING POSTS

The berthing dolphins are disposed along a straight line, which became the berthing line, at regular spacing. The berthing line is defined by the downstream corner of the old Oil Terminal and the upstream corner of the Coal Terminal quay, on the water side, and the three mooring dolphins are disposed also along a straight line, parallel and about 10 m behind the berthing line. With this option, besides considerations of economy, the barge traffic between the timber carriers and

the barge berthing wall was maintained and facilitated by the considerable reduction in the travelling distance between the ship anchored about 500 m away from the barge berth. A new quay was then considered between the old Oil Jetty and the Coal Terminal quay, running over and using the dolphins as berthing and mooring structures.

Beginning from upstream to downstream, these berthing posts were designated Berthing Posts No 1, No 2 and No 3. Posts No 1 and No 2 would be designed to receive the timber carriers and oil tankers in ballast, and Post No 3, which would be a dedicated oil terminal, would be used by oil tankers and ore carriers in ballast, waiting for a place at the Iron Ore/Coal Terminal quay.

The dolphin berthing posts were planned for ore carriers displacing up to 80 000 tdw (ton dead weight), oil tankers displacing up to 40 000 tdw and timber carriers displacing up to 20 000 tdw.

Posts No 1 and No 2 were designed for ships not longer than 180 m, with a maximum draught of 9.6 m, while Post No 3 was designed for ships not longer than 260 m, with a maximum draught of 11.7 m.

Between the berthing dolphins of Post No 3, a platform for four loading arms to connect to the ship manifold would be constructed, linked to the Iron Ore/Coal Terminal embankment by an access bridge 175 m long, bringing the pipelines from the nearby fuel tank farm and refinery.

Both the bridge and the platform are founded on vertical bored percussion piles.

Before the start of dolphin construction, a band 60 m wide between the old oil terminal and the Coal Terminal was dredged to bring the depth at Berthing Posts No 1 and No 2 to -10 m below chart datum, and -12 m below chart datum at Berthing Post No 3.

By providing these three berthing posts, the shipping manoeuvring and berthing safety conditions in this area were considerably improved.

The construction contract was extended later with the construction of two extra similar berthing dolphins, placed downstream of the Coal Terminal.

THE DESIGN SPECIFICATION FOR THE MATOLA DOLPHINS

The original design considered for the dolphins would entail the construction

of reinforced concrete cylinders, about 9 m in diameter, covered with a mass concrete cap about 1 m thick, where the bollards and quick-release hooks would be installed. The tallest cylinder would be about 17 m high, at Post No 3.

The successful tenderer, however, submitted an alternative design on steel caisson piles, linked by a reinforced concrete cap about 3 m deep where the bollards and quick-release hooks would be installed. The main reason for the alternative design submission was the concern about the long-term stability of the reinforced concrete cylinders.

The CFM's specification called for two berthing dolphins at Post No 3, capable of withstanding, with fenders, a berthing force of 450 metric tons, acting at level +3.5 m above chart datum, corresponding to a ship berthing at a velocity of 0.15 m/s, with a maximum approach angle of 10° about the berthing line. These dolphins were equipped with two bollards with a mooring rope tension capacity of 50 metric tons each.

The same specifications called for berthing dolphins at Posts No 1 and No 2 to be capable of withstanding, with fenders, a berthing force of 400 tons, acting at level +3.5 m above chart datum, corresponding to a ship berthing at a velocity of 0.15 m/s, with a maximum angle of approach of 10° about the berthing line. These dolphins were also equipped with two 50 metric ton bollards each. The Post No 1 upstream berthing dolphin, which was a mooring dolphin reinforced concrete cylinder, would be converted into a berthing dolphin, with the same specifications.

The berthing dolphins, being rigid, needed to be equipped with rubber fenders which had to take into account, besides the berthing ship force, the wind velocity, the tidal range and tidal currents, the angle to the berthing line of the approaching ship, the ship hull maximum allowable pressure, the ship hull curvature, and for smaller vessels, the possibility of hull projections.

The two new mooring dolphins were designed for a mooring rope pulling force of 200 metric tons, at an angle of 30°/45° about the berthing line.

All dolphins were provided with an access cat ladder.

The loading-arms platform had to withstand the pumping thrust from the pipeline liquid flow, of the order

of 60 metric tons, acting at level +5.5 m above chart datum.

DESIGN OF THE MATOLA DOLPHIN BERTHING POSTS

Two types of berthing dolphins existed at the Matola Section of Maputo Harbour.

One type consisted of an existing reinforced concrete cylinder about 9 m in diameter and 11 m tall, designed originally as a mooring dolphin and during this contract strengthened and converted into a berthing dolphin, capable of withstanding a berthing force of 400 tons.

The other type (the new berthing dolphins) was designed to withstand, with fenders, a berthing force of 450 tons, and consisted of bored piles inclined to 1 in 4 to the vertical. These piles were disposed in such a way that they could withstand the force normal to the berthing line and the torsion created by a ship berthing at an angle of 10° about the berthing line.

Each of these piles could also act as anchor in the estuary bottom, reaching depths of about 25 m below the estuary bottom. Two piles in the berthing dolphins of Post No 3 were tested to a tensile force of 110 metric tons.

The caissons were formed from Larssen profiles, and the steel had a percentage of copper in its composition to reduce the rate of corrosion in the marine environment.

The set of dolphin piles was capped with a mass concrete pile cap of about 3 m deep.

The mooring dolphins consisted of piles bored into the estuary bottom at an angle of 1 in 4 to the vertical, and could also handle compression and tensile forces. In this case, too, each set of dolphin piles was capped with a mass concrete pile cap of about 3 m deep.

All the dolphin pile cap tops were at level +5 m above chart datum.

At the loading-arms platform, and in order to withstand the hydraulic thrust of the liquid flow, besides the vertical piles, two sets of inclined piles, each forming a tripod, were sunk from the completed platform deck.

CONSTRUCTION OF THE MATOLA DOLPHIN BERTHING POSTS

In the construction of the berthing posts, three types of piles were bored and/or driven.

For the loading-arms platform of Post No 3, and for the piers of the access

bridge to the platform, 350 mm diameter percussion vertical piles were sunk into the estuary sandstone bottom. A steel pipe served as permanent formwork for the reinforced concrete shaft. A percussion boring machine was installed on a U-shaped spud barge.

At the platform, two tripods of inclined percussion piles were bored into the ground, from the completed platform deck.

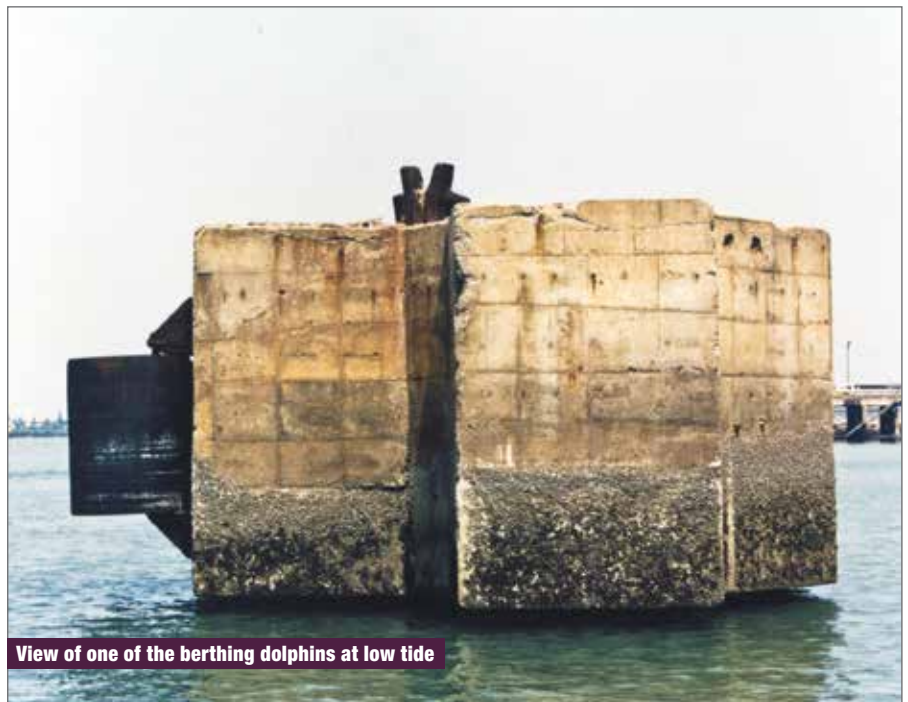
For all the new dolphins, bored piles inclined at 1 to 4 to the vertical were sunk into the estuary bottom.

The bored holes were 600 mm in diameter, enlarged at the bottom by six enlargements of 750 mm in diameter, 0.5 m long and interspaced by 0.5 m.

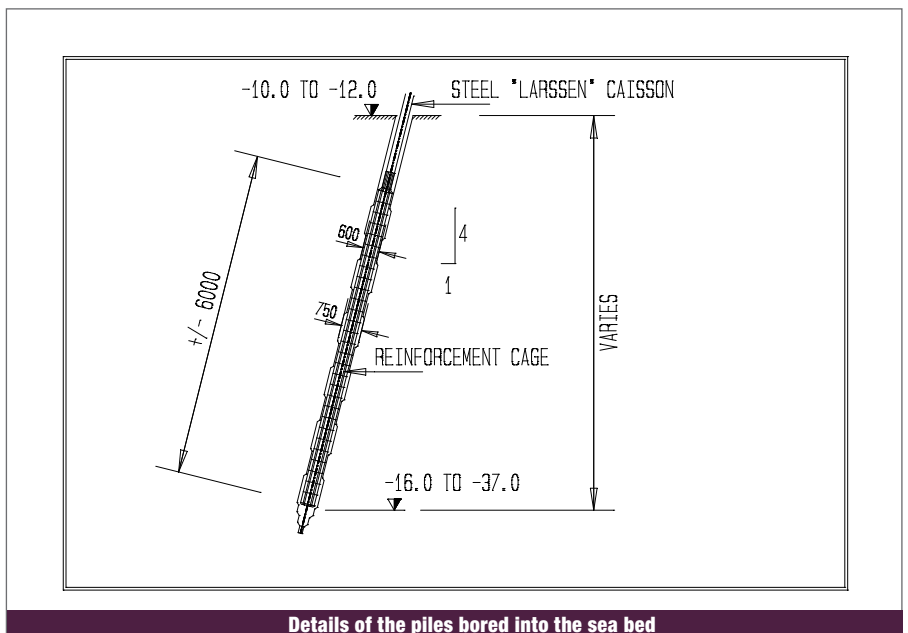
After the hole reached 6 m into the hard and solid sandstone layer, which in a number of piles could only be found at 25 m under the sea bed, a round-bar high-tensile reinforcement cage welded to a steel caisson was lowered into the hole and the concrete poured underwater from the working fixed-level platform, by means of a tremie.

The holes were cut into the sandstone estuary bottom by means of a reverse circulation boring machine weighing 15 tons, using sea water as the drilling medium.

The boring machine was installed on a jack-up platform, having to work from a fixed level as all the piles were inclined and had to be free from the



View of one of the berthing dolphins at low tide



Details of the piles bored into the sea bed

local tidal range between 3 m to 4 m. This platform could float with 50 metric tons of piling equipment and weighed about 200 tons.

A number of problems were encountered during hole boring for the installation of the dolphin piles, due to the lack of uniformity of the sandstone founding ground. The boring machine had to cross layers of sand where the hole had to be sleeved to prevent the collapse of its wall, and in other occasions had to cross layers of clay where the drill rate was very slow.

The boring tool was guided from the platform chariot to the sea bottom, by a guide pipe 650 mm in diameter, inclined at 1 to 4 to the vertical, supported on the highest end on the platform and sunk about 1 m into the estuary sea bed. This guide pipe was later recovered after the pile construction had been completed, and reused in the next pile.

The jack-up platform consisted of three steel caissons about 25 m long, joined to form a triangle and supported on three steel tube legs about 1 m in diameter and 25 m long at each corner of the triangle. The platform could be raised from or lowered into the water by a set of three pairs of 50 metric ton hydraulic jacks, each pair installed on the platform deck corners acting on each leg. The platform was fitted with a chariot where the piling rig was installed, allowing the piling rig to reach any point within the open triangular area defined by the platform caissons. The platform was equipped with mooring bollards and winches, placed at each corner of the triangle, which permitted anchoring and adjusting its position at each dolphin construction site.

To strengthen the existing reinforced concrete mooring dolphin and convert it into a berthing dolphin, nine steel caissons placed around the perimeter of the cylinder concrete cap at regular intervals were driven into the estuary bottom, at 45° by means of a diesel pile driver standing on the cylinder concrete cap.

This project was successfully completed in the early 1970s, but some of the dolphins in Posts No 1 and No 2 were later demolished to allow for the construction of the Mozal Jetty, or badly damaged by ships trying to berth at the dolphins from where the fenders had been removed. The two berthing dolphins placed downstream of the Coal Terminal were never used. ■



Jack-up floating platform carrying 50 tons of piling equipment, used in the construction of the Matola dolphins



Driving steel Larssen caissons at 45° to convert an existing mooring dolphin to a berthing dolphin, using a diesel pile driver