The Cockburn Lighthouse, Mozambique

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The Cockburn Lighthouse project, completed in December 1900, is a prime example of engineers' tenacity, and their willingness to face nerve-wracking conditions head-on.

INTRODUCTION

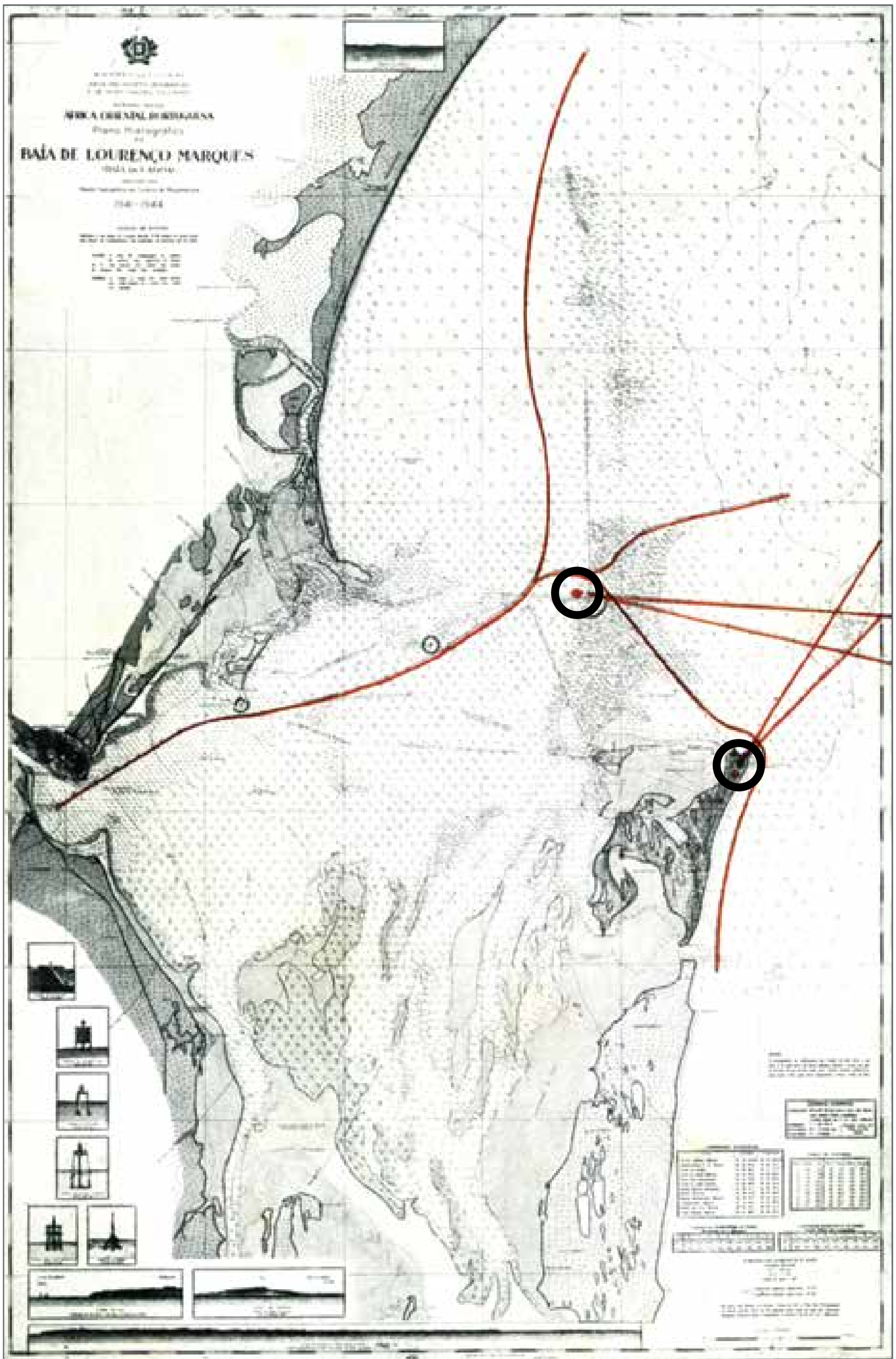
The construction of the Cockburn Lighthouse towards the end of the nineteenth century contributed hugely to the safe passage of ships visiting the harbour of Lourenço Marques (now Maputo) in Mozambique.

At the time, the construction of this lighthouse seemed virtually impossible, due to the relative scarcity of appropriate engineering equipment locally, combined with notoriously rough seas and the frequent exposure of the proposed lighthouse location to severe storms.

A lighthouse was direly needed at the dangerous entrance to the Lourenço Marques bay (between 1894 and 1900 ten ships and their crews had been wrecked in this stretch of sea).

The British Admiralty had started surveying the east coast of Africa in 1822 already, and this survey included the entrance to the bay of Lourenço Marques (later complemented by a Portuguese Navy survey). Various sandbanks were identified at the entrance to the bay, and these were named after British Navy officers who had taken part in the survey. The largest of these sandbanks was named Cockburn. It was approximately triangularly shaped, with two south vertices on the islands of Inhaca and Elephants, and a very dangerous north vertex marked by a seven-ton buoy.

Between these dangerous sandbanks a number of channels, varying in depths between 6.4 m and 7.3 m, allowed access to the 37 km long bay of Lourenço Marques which, if properly buoyed, would allow ships to navigate in safety without the risk of running aground on sandbanks during low tides.



Location of the Cockburn Lighthouse (north, circled) and Inhaca Island Lighthouse (south, circled) in relation to the main shipping routes (red lines) to the Lourenço Marques (now Maputo) harbour (extreme left)

INVITING TENDERS

From around 1882 the local government recommended the installation of a set of lighhouses at the entrance of the bay which would allow safe entry and exit through either the south canal or the north canal.

During Admiral Ivens Ferraz's administration, in 1896, tenders were called for the design and construction of a lighthouse on the dangerous north vertex of the Cockburn sandbank. The Cockburn Lighthouse would complete the set of lighhouses already installed elsewhere.

Four companies responded to the tender invitation and, according to their investigations, the following were the main characteristics of the new lighthouse site:

- Average depths measured in a number of hydrographic surveys at astronomical tides:
  - At lowest tide – 6.3 metres
  - At highest tide – 9.3 metres
- The nature of the ground verified by a geotechnical investigation carried out by the French civil engineer E F Tissot, who at the time practised privately in Lourenço Marques, indicated shifting sands down to a depth of 8 m below the seabed. (However, it was later determined that this survey, despite having been done at the site indicated by the Lourenço Marques Captaincy, had in fact been done a distance away from the final lighthouse site.)
- Tidal current velocities of 5 to 6 miles per hour were measured by a tachymeter during astronomical tides.

The preferred proposal, submitted by the French firm Schneider & Co to the amount of £6 000, was signed into a contract in November 1896 between the appointed Commission and the firm's local (Johannesburg and Lourenço Marques) representatives, L Grunberg & Sam.

The contract was for the fabrication of the lighthouse infrastructure in double-helix steel piles, from the foundation up to the lantern, and its assembly on site at the north vertex of the Cockburn sandbank. The contract included the supply and installation of the lantern manufactured by the French firm Harbier & Bénard of Paris. The proposal anticipated the sinking of piles in the sandbank soil to a planned depth of 8 m below the sea floor, which obviously is undulated because of the continuous and alternating movement of the loose sand layers that cover it. In practice, later, the piles refused at 3.5 m, because of the increasing compactness of the fine clayey sand layers. A shortening of the piles was then authorised, with each pile being composed of a lower and higher stage, respectively 3.27 m and 6.36 m long, connected by a laminated steel sleeve of 0.71 m in diameter.

The complexity of the task was described by the conctractor in a letter addressed to the Lourenço Marques District Governor. He described the enormous difficulties, the great dangers faced and the disasters suffered during four fruitless attempts to launch each of the four scaffolds, which had been built one after the other, and of which only the third was placed on site and stayed over the sandbank for a month before being overturned and destroyed by the sea, the other three sinking during transport. Besides the material losses suffered, the contractor described the great life risks incurred by his men, directed by two foremen with 15 years' experience in the erection of lighthouses, who eventually considered it impossible to erect this lighthouse on the sandbank due to the invincible difficulties that they were encountering. During the Commision's meeting of August 1898, the contract was therefore rescinded at the request of the contractor.

At that same meeting, a proposal was received from the English firm Bell & Wilson, who had completed marine works at the Melbourne harbour in Australia and who, for that reason, was considered capable of carrying out the difficult and dangerous task of erecting the lighthouse steelwork. Their proposal to the amount of £4 320 was accepted by the Commission. However, this English firm later also requested the contract to be rescinded after two failed attempts to place a scaffold that would allow the erection of the lighthouse steelwork on the Cockburn sandbank.

THE RIGHT ENGINEER FOR THE TASK

Due to increasing pressure from local commercial firms for the lighthouse to be erected, it was decided to look for an engineer who was competent, capable and experienced in marine work to direct another attempt at constructing the lighthouse.

That engineer was found in the person of Portuguese Army Engineer, Colonel José Maria de Vasconcellos e Sá, who was at the time the director of the Lourenço Marques Harbour Works.

After the annulment of the previous two contracts, the materials that had not been used were taken over by the Lourenço Marques Harbour Works, who transported it from where the English firm had left it, to the beach below Ponta Vermelha in Lourenço Marques, where it was catalogued and repaired. It was then noticed that six important cast-iron parts, weighing about 300 kg each, and which were the six periphery tower column caps for the lighthouse seating, were missing. The caps were ordered from the French firm Schneider & Co, and arrived in Lourenço Marques in October 1900.

Engineer De Vasconcellos e Sá conducted various investigations, and then planned and managed the execution of the project in a logical manner, as described briefly below.

Where to construct the scaffold

The Cockburn site was exposed to the worst winds possible – the northeast monsoons from October to March, and the southwest monsoons from April to September. During the April to September period, severe storms happened frequently, and with such swiftness and violence, that it was not possible to forecast them timely to avoid their consequences. The months of April and September were considered as transition times between monsoons.

When these winds blew so hard in the bay mouth, the towering waves drew two distinct lines of violent surf at the converging edges of the sandbank groups. The closest land, but deserted, was Elephants Island at a distance of 9 km, and Port Melville, which was only a shelter place, 11 km away. It was clear that Lourenço Marques itself, at a distance of 37 km from the lighthouse site, was the most practical location to construct the scaffold and resolve any material difficulties.

Seabed undulations and levels

Data of the seabed undulations and levels was necessary for the design of the works scaffold. These undulations vary greatly due to sand movement resulting from tidal currents and agitation during storms.

It was imperative that the undulations should never put the scaffold out of plumb to the extent that it collided with the lighthouse tower steelwork, which would be erected within the scaffold frame.

Fortunately, with the wise measures taken, the level difference between the lowest and highest sides of the scaffold deck, just after its placement, did not exceed 0.79 m. To obtain this result, it was necessary to find, through accurate surveying, an area of seabottom surface as close as possible to the northern vertex of the sandbank which, at the suitable time, would be marked by a buoy visible only during lowest low tides, located at the centre of a triangular area defined by another three buoys of the same type, visible during all tidal conditions.

A small 'plateau' area was found where the depths varied between 5.4 m and 6.3 m, with level differences of no more than 0.9 m between two points spaced 12 m to 15 m apart.

It was in this limited area that the lighthouse scaffold would be erected, albeit at a slight inclination. This compromise would, however, not affect its stability during the construction of the lighthouse.

Geotechnical survey

The first geotechnical test was carried out by the French civil engineer Tissot, as mentioned above. This test was done with great difficulty after various attempts during several hours of calm seas over the Cockburn sandbank, which allowed the introduction into the seabed of a simple auger which reached a depth of 10 m below seabed. The need for further tests would be decided after the scaffold had been placed over the lighthouse site.

The completed scaffold on its launching runway, March 1900

Tidal conditions

The average astronomical tidal range observed in various places around this sandbank before the erection of the lighthouse was 3.6 m. The same tidal range was measured on the scaffold legs at the construction site. The astronomical tidal current velocities, measured by tachymeter 1.8 m below the sea surface, was six miles per hour. The duration of calm waters between consecutive tides lasted for about one hour, which was the only time when work by divers could be performed. This circumstance made the erection works, which required diving services, greatly time-consuming.

Wave forces

It was not easy to measure this force because it would be necessary to install an adequate dynamometer at any fixed point along the closest shore, such as at the shores of Inhaca Island. Recourse to existing data for the Scotland coast in the North Sea (where the wave pressures

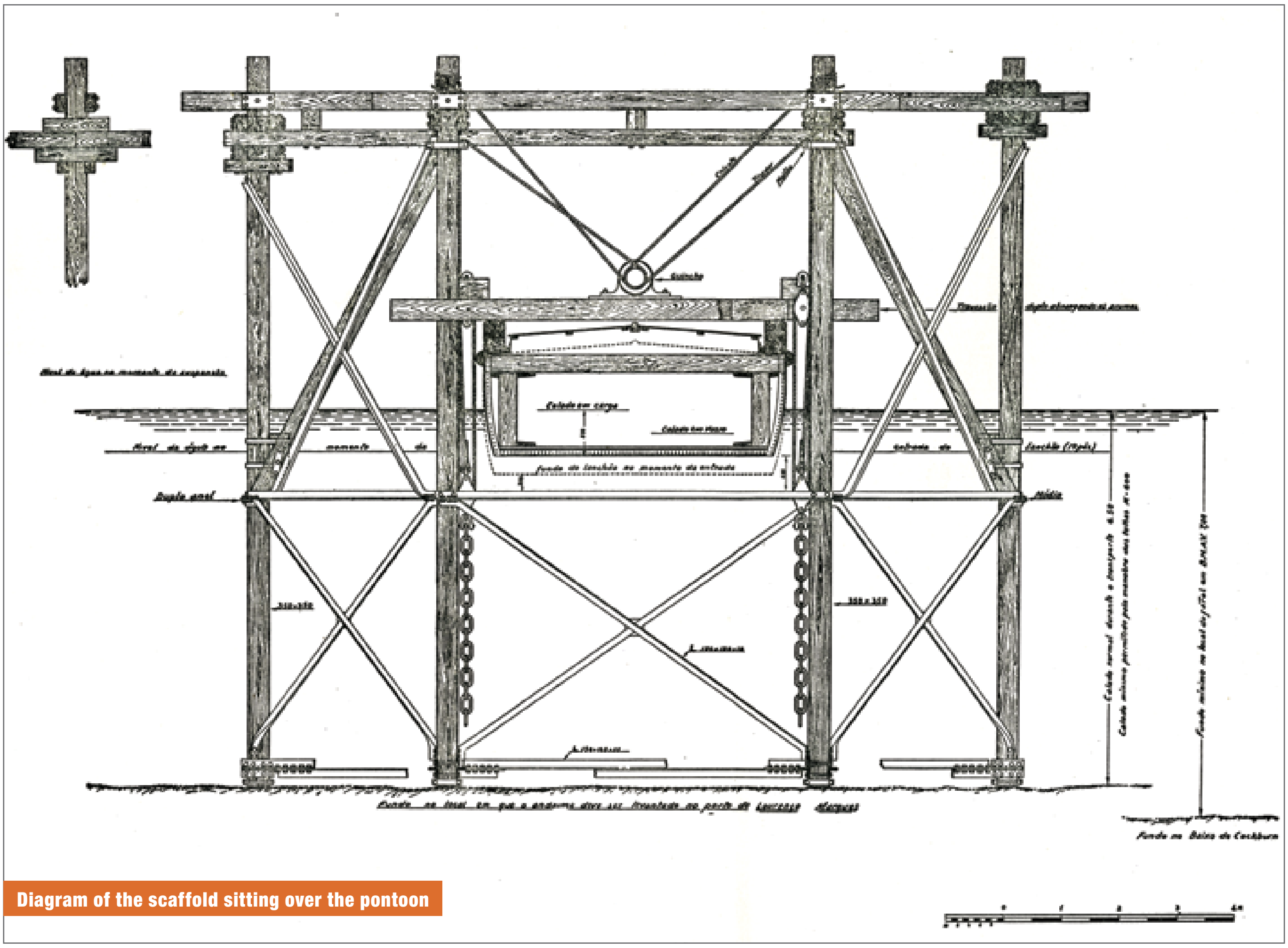


Diagram of the scaffold sitting over the pontoon reach extraordinary proportions) and observations done during storms at the base of the Skerryvore Lighthouse and the Bell Rock Lighthouse (respectively on the west and east coast of Scotland), indicated that the average pressure was not greater than 3 000 kg/m^2 which, in exceptional cases, could reach 30 000 kg/m^2.

The maximum wave action seemed to occur at an average calm sea depth, at the point considered, decreasing rapidly above or below this level. As the minimum depth at the Cockburn sandbank was below 7 m, a pressure of 6.0 ton/m^2, due to wave impact on the scaffold legs and bracings, was assumed for calculating the scaffold stability. For the scaffold overturning moment calculation, a height of 8.4 m was used, measured from the seabed to the scaffold middle height.

Scaffold materials

The first thing that had to be considered before starting on the actual scaffold design, was taking stock of the materials already available and how to use these to best advantage, as well as determining which of the required timber and steel sections could be found in the local market, and at which dimensions.

The Lourenço Marques market at the time was well furnished with "pitch pine" beams and other large wooden sections, but the same could not be said for the required steel sections. Fortunately the Mozambique Railways could supply the steel sections free of charge.

The wooden beams were floated from Matola to the Ponta Vermelha beach.

Scaffold height

The scaffold height was settled as 12 m, based on information gathered about the one previous scaffold attempt that did remain standing for a month before being destroyed in a storm.

A small increase in the height of the scaffold was briefly considered to prevent equipment being washed away by high waves during violent storms. However, such an increase would raise the centre of gravity of the system during the transporting of the scaffold, and this had to be avoided at all costs, in case bad weather was encountered during the voyage. Favouring the original height was the fact that the maximum wave height in stormy sea conditions rarely exceeded the tidal range or 3.4 m.

Also, a scaffold higher than 12 m would be impractical, because it would not have been possible to drive the piles to a depth of 10 m (at the time 8 m was still considered the correct depth), and because it would be necessary to extend the drilling bar from the piling machine.

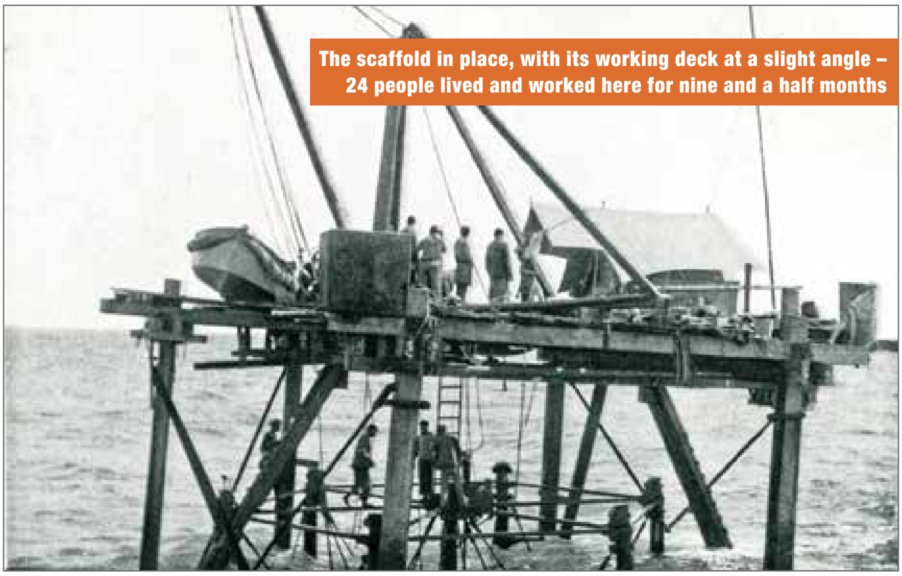
Scaffold characterisitics

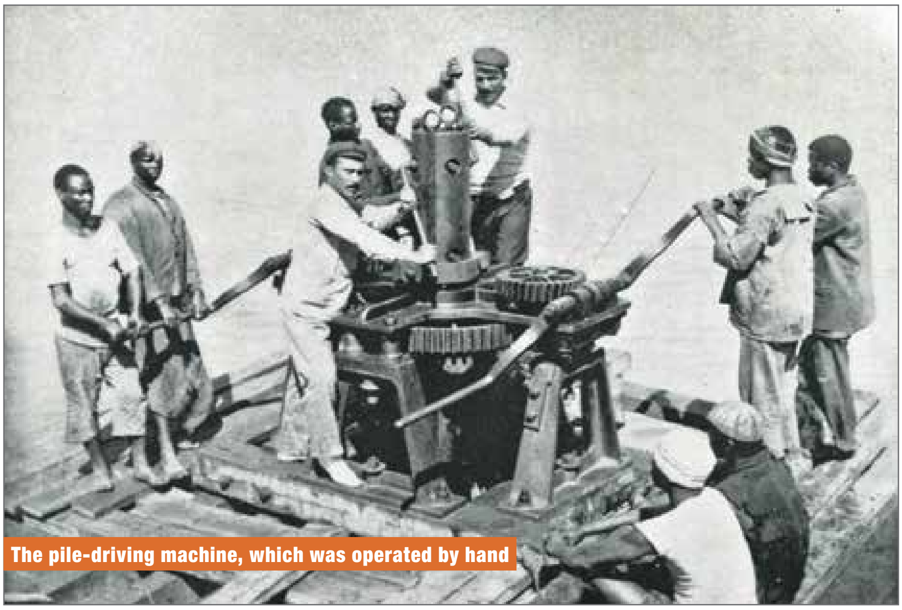
Considering all the challenges which had to be overcome to erect the lighthouse, the most important was producing a sturdy scaffold that would stand fast while serving as a work platform during the time needed for the pile-driving operations and the construction of the lighthouse. The two main characteristics required were the following:

- Guaranteed strength and stability were needed to withstand the constant exposure and the violent storms at the construction site during the many months it would take to erect the lighthouse (the scaffold stayed there for nine and half months).

- It had to be designed and constructed rigorously according to the shape and dimensions of the only vessel that could transport it to the construction site, and it had to leave enough free space, in all directions, to allow the erection of the lighthouse steel structure.


The scaffold on the pontoon, ready for the 50-hour voyage to the lighthouse site


The scaffold in place, with its working deck at a slight angle – 24 people lived and worked here for nine and a half months


The pile-driving machine, which was operated by hand

Transporting the scaffold using one vessel only

The scaffolds that had been built earlier by the French and English engineers were transported to the construction site suspended between two parallel vessels. This mode of transporting the scaffold did not seem to be successful.

Engineer De Vasconcellos e Sá's solution for transporting the scaffold consisted of using one vessel only, which would be positioned in the free space between the scaffold members, helped by two buoyancy tanks placed on either side of the scaffold. These buoyancy tanks would be discarded in case a storm happened while transporting the scaffold, as they would complicate manoeuvring during the storm. It must be noted that the distance from the Ponta Vermelha beach construction yard to the lighthouse site was about 40 km, which in reality became much longer due to the difficulties encountered during the voyage.

Description of the scaffold

As mentioned earlier, the sturdiness of the scaffold had to be such that it would remain stable during pile driving and while erecting the lighthouse, and would guarantee the safety of the workers who had to live there during the construction period. The scaffold had a hexagonal prism shape, 6.5 m in radius, and with a height of 12 m up to the deck level. The six columns constituted the edges of the prism. A dual-angle ring made from 120 x 120 x 12 steel angle sections connected the six scaffold columns, the external ring encircling the columns and the internal ring being encircled by the columns. The rigidity of the system was ensured by horizontal and vertical cross bracings.

The horizontal cross bracings were placed at the column lower ends and at the column top levels. The horizontal bracings at the column feet were constituted by 150 x 150 x 25 steel angle sections connecting the six columns, and were placed in such a manner to allow the symmetrical setting out of the six peripheral piles, in turn allowing, if necessary, a deviation of the lighthouse position.

The top horizontal bracings were made of wooden beams and wooden planks. The exclusive use of timber on the scaffold deck allowed the easy cutting or trimming of any obstructing deck member.

The vertical bracings were installed on the two parts in which the bottom horizontal ring, established 5 m above seabed, divided the scaffold height. In this manner the lower vertical bracing comprised two crossed diagonals at each face of the hexagonal prism, and the higher cross bracing comprised two diagonals also, placed on the hexagonal prim faces, except in two parallel faces, to allow the threading of the transport vessel. To compensate for the missing bracing in those two faces, two strong double wooden struts were placed perpendicularly to these two parallel faces, which, without hindering the erection of the lighthouse, also served as access ladders to the scaffold deck. These diagonal braces were made from 150 x 150 x 25 angle steel sections.

Scaffold stability

The accuracy of the careful calculations was confirmed during the 50 hours (half of which were in rough seas) that it took to safely transport the scaffold to the lighthouse site.

Once seated on the seabed, the scaffold had to withstand the dreadful high seas by its own weight and its careful construction.

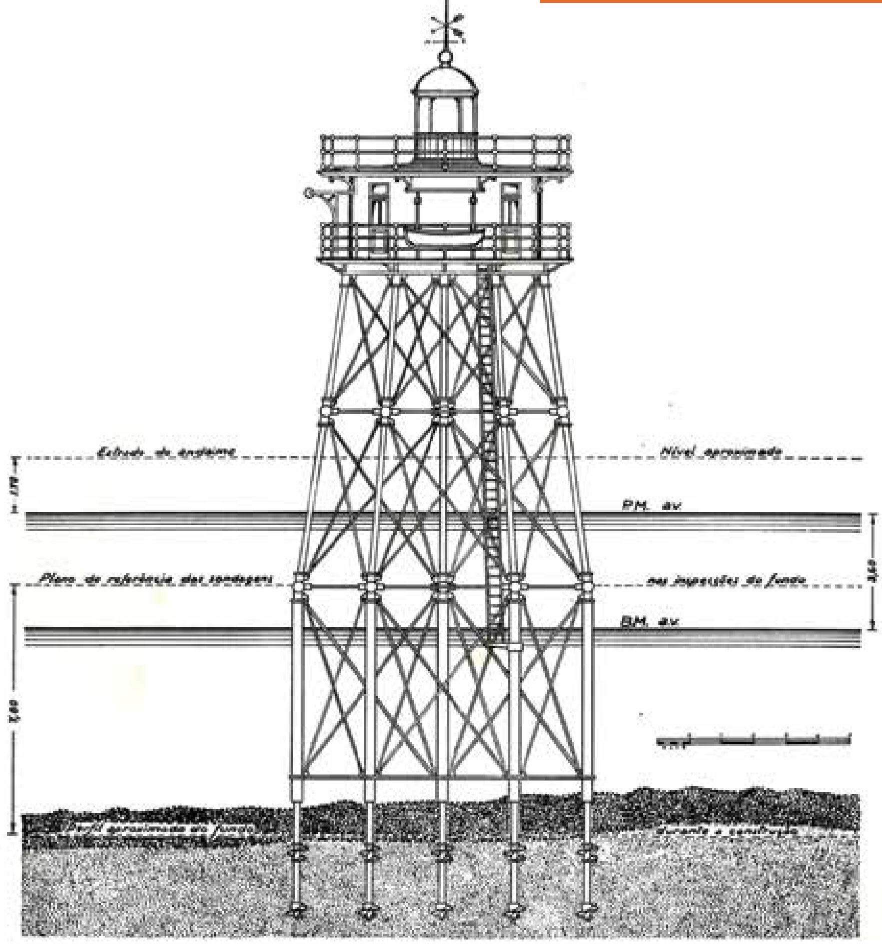
The calculations for its construction had taken into consideration the action of a storm coinciding with the highest high tide, and it was estimated that waves would not be higher than 3.6 m. Consideration was given to the maximum pressure by wave clashes with scaffold surfaces opposite to their direction, bearing in mind that the highest wave pressure would be concentrated at the average calm sea depth surface, reducing rapidly above and below that level.

To calculate the loss of weight due to immersion, it was supposed that half of the scaffold at the moment of clash with the wave would be immersed up to the deck, and the other half immersed only till the level of the highest high tide. The wind action over the immersed part of the scaffold was ignored as insignificant compared with the pressure due to the waves generated by the same wind.

The total weight of the scaffold, loaded with the various materials and tools, was estimated to be 52 metric tons, taking into consideration the weight lost by the immersed part of the scaffold.

The calculations carried out to verify the stability of the scaffold against overturning by the waves, determined a safety factor of 1.92. Measurements, carried out by sextant in relation to three stable references with the centre of the Inhaca Island Lighthouse, confirmed this stability safety factor, and the scaffold indeed remained stable throughout the lighthouse construction period.

The Cockburn Lighthouse elevation



Scaffold construction

From the outset it was decided to construct the scaffold on a site close to the Lourenço Marques harbour, where it was possible to find all the materials and tools needed, instead of any of the islands inside the bay, as had happened with the previous contractors involved in this project. Hence the scaffold was constructed on the Ponta Vermelha beach, from where it was launched into the water, supported on two buoyancy tanks, dropping anchor at a particular place in the bay where the transport pontoon that would take the scaffold to site could be installed.

The scaffold was constructed to have a maximum draught of 6.3 m, which was shallower than the sea depth at site during lowest low tide.

Lighthouse construction

The scaffold was placed on site in April 1900.

Soon afterwards permanent accommodation for 24 workers, including two foremen, was prepared on the scaffold deck, together with provisions and kitchen implements. This deck would be the workers' home for nine and half months.

The piling rig was delivered to this platform by a 25 ton vessel, but the operation was only concluded after seven failed attempts, due to the prevailing sea conditions.

The piles (weighing 2 900 kg each) were transported from the Lourenço Marques harbour on a floating device constructed from two parallel sets of three wooden beams connected by a saddle where the pile was supported. The 'quaint' piles used on this project are probably not used frequently today.

Pile driving proceeded after the first pile-driving problems had been resolved, leading to a minor change in the setting out of the lighthouse, as had already been explained earlier in this article. By August 1900 all the piles had been installed.

The piling machine was of very simple design, and well fabricated. It was activated by two parallel, symmetric worm screws via a system of gears which transmitted to the pile the manual effort by two operators manning the two diametrically opposed worm screw crank handles.

With its feet firmly anchored in the seabed, the remaining lighthouse erection operations proceeded with the ease allowed by the sea and wind conditions, as well as by the availability of equipment.

The housing layout on top of the lighthouse comprised two bedrooms, a kitchen, a bathroom, and a storeroom for kerosene, cleaning articles and lantern spare parts.

To promote an agreeable temperature inside the house, an internal wooden lining around the housing perimeter was installed, leaving a gap between itself and the wall steel plate where cool air from below the housing floor could flow freely. The same approach was followed for the roof. The wooden ceiling comprised two spaces – in the lower space immedialtely above the ceiling, the airflow was from the perimeter wall, and in the higher space just below the roof steel plate, air entered from the housing eaves. These two air layers had a commom exit.

The lighthouse erection was completed by December 1900, when the first lighting trials commenced.

The lantern that was installed on top of the lighthouse could reach 10 miles (± 16 km). It was replaced in 1923 by a new lantern which increased its reach to 13 miles (± 21 km).

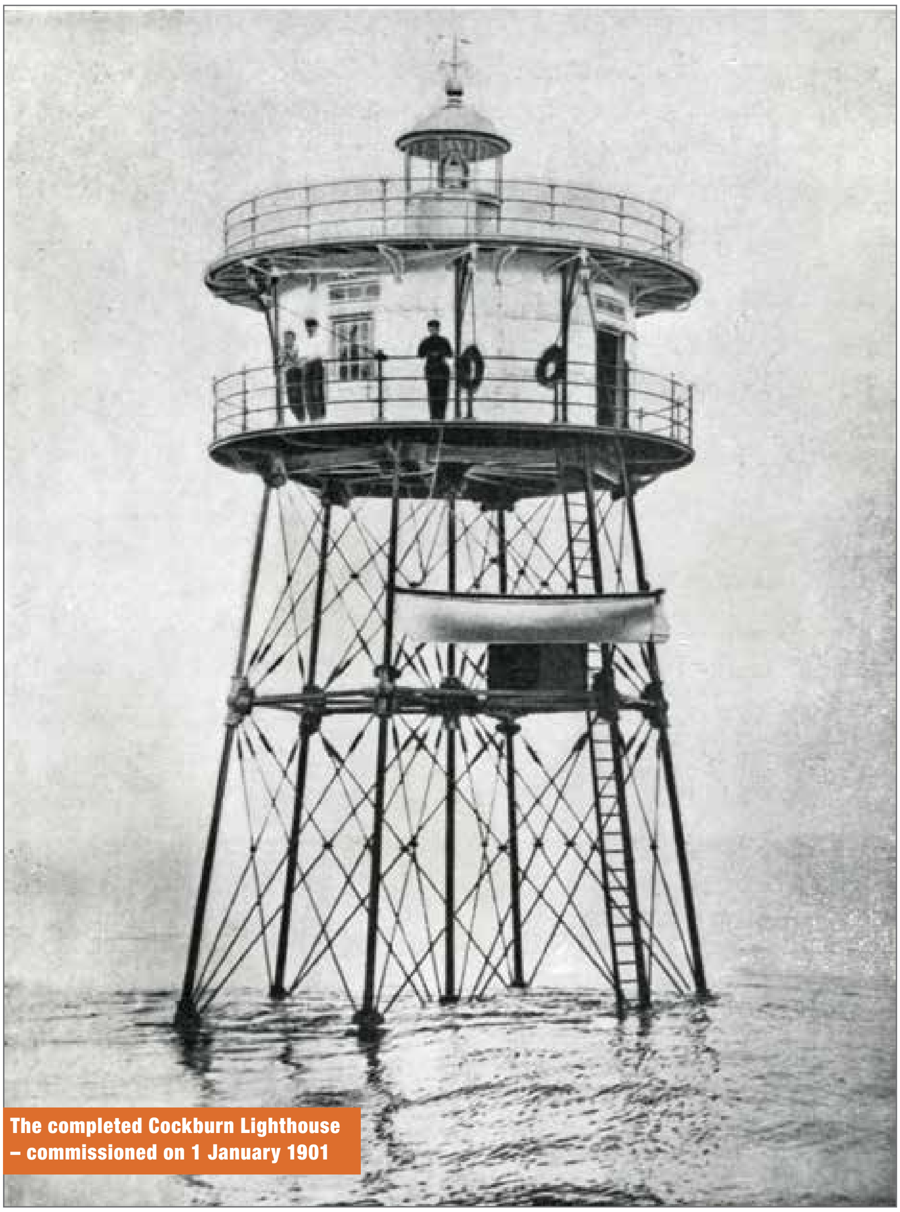
The dismantling of the sturdy scaffold started in January 1901, and was completed by February of the same year.

END OF AN ERA

The Cockburn Lighthouse was destroyed during Cyclone Claude, which ravaged the Mozambican southern coast in January 1966. The lighthouse had faithfully served the seafaring community for 65 years, requiring little maintenance during this time. After its demise, it was replaced by a buoy lighthouse which is still in operation.

REFERENCE / PHOTO CREDITS

História da Construção do Antigo Farol de "Cockburn" (History of the old Cockburn Lighthouse construction) by Army Engineer Colonel José Maria de Vasconcellos e Sá, 1951, Lisboa.



The completed Cockburn Lighthouse – commissioned on 1 January 1901

The Cockburn Lighthouse as seen from a tanker in stormy seas, November 1945