e-maritime

MARCH 2021 COASTAL ROAD IN RÉUNION BIDSTON LIGHTHOUSE

LIST OF CONTENTS

Front Cover: The **Spreader Beam** designed for placing the Anti-scour protection for the New Coastal Road in Réunion

Photo Credit: Région Réunion, J. Balleydier

Back Cover: Bidston Lighthouse and Observatory, February 2016

By kind permission of Ray McBride

International, online magazine about ports, docks, vessels and maritime equipment. Peer-reviewed.

It is published at www.e-maritime.cz. Open Access.
Release on: 30 March, 30 June and 30 November

September Issue is released jointly with the magazine e-mosty: "BIM / Vessels and Maritime Equipment", published on 20 September at www.e-mosty.cz with open access.

Number: 01/2021, March. Year: III.
ISSN: 2571-3914

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Dear Readers

In the first article, we provide an overview of a project of **New Coastal Road (Nouvelle Route du Littorial) in Réunion**. *The road has replaced the near-shore existing road RN1 between the two cities of Saint Denis and La Possession. Since the original road frequently underwent extreme natural, geological and marine events, it was decided to build a new one out at sea, further away from the cliff. We bring information on the project, its history, companies involved, design and construction.*

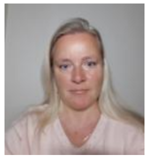
The next article of this issue was prepared by **Paula Rinaudo and Jose Vicente Rajadell from Rúbrica Engineering**. *They describe the spreader beam which was designed for placing the anti-scour protection of the piers of the New Coastal Road in Réunion. They provide technical description of the beam and an overview of its design requirements. They also describe the equipment and its operation. At the time of writing, all half mattresses have been successfully installed and no significant issues were found on the structure or systems during the operations. Rúbrica Engineerings´s team and suppliers took a great part in the achievement of their installation.*

The last article of this issue was prepared by **David Stork** *and it brings information about* **Bidston Lighthouse**. *It is located on the Wirral, across the River Mersey from Liverpool in England. It is known as the world's most inland lighthouse. This article describes what led to its construction and its subsequent history as a lighthouse. In addition to discussing the lighthouses, their optics and their keepers, the signal station that was located on the site and probably set up prior to the lighthouse being built is discussed. Also briefly described is the development of tide tables in the UK as this was greatly helped by William Hutchinson, a significant character in the story of Bidston and the Port of Liverpool in its formative days. Finally, there is a brief discussion of Bidston Observatory located on the same site.*

I would like to **thank all authors, people and companies** *that have cooperated on preparation of this issue;* **David Stork for reviewing this issue**, **Richard Martin for the language check**. *We would also like to thank* **Inma Gómez of Rúbrica Maritime** *and* **Tristan Lecomte of Vinci Construction / Grands Projets** *for their cooperation and assistance.*

Magdaléna Sobotková

Chief Editor



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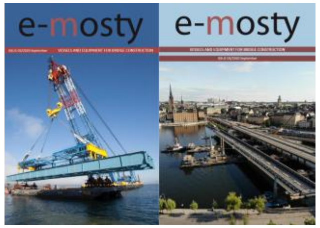
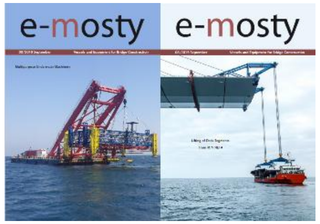




ISSN: E-MOSTY 2336-8179

NEW COASTAL ROAD - NOUVELLE ROUTE DU LITTORAL RÉUNION

Magdaléna Sobotková

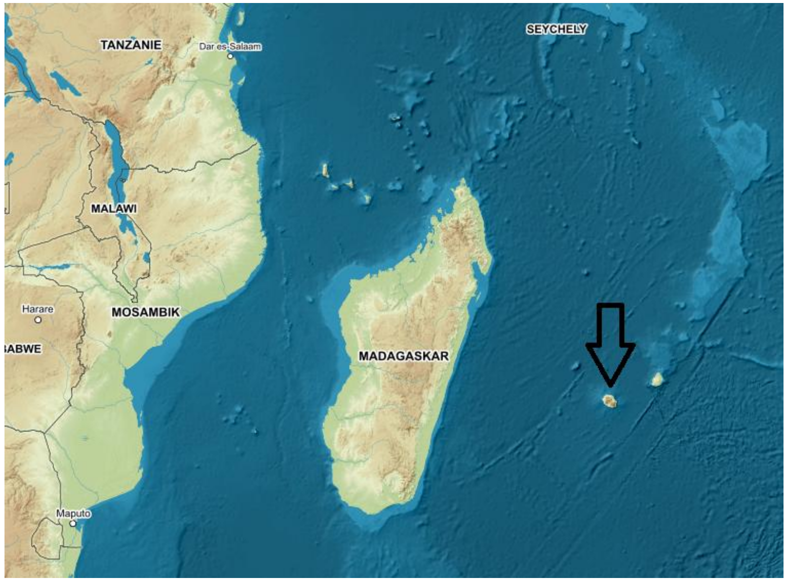
INTRODUCTION

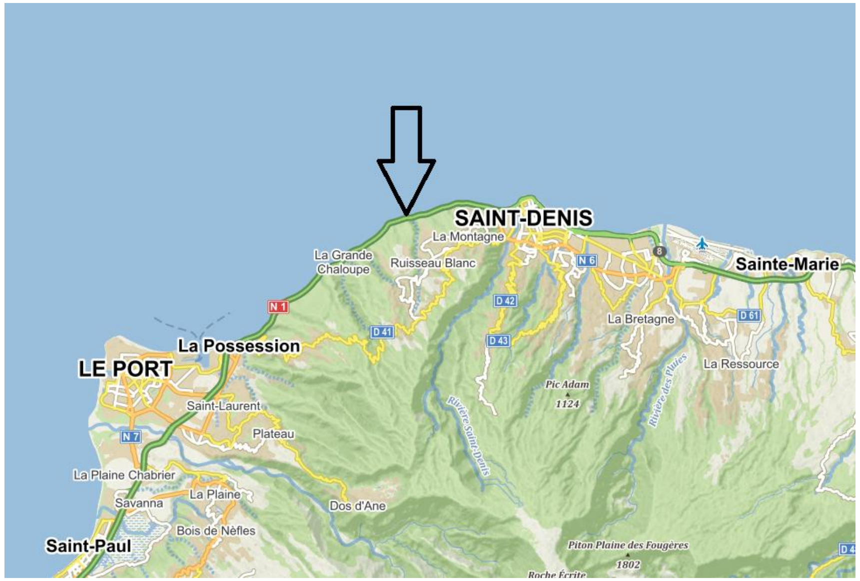
The RN1 (main road) is located between Saint-Denis and La Possession. Saint-Denis de la Réunion is the administrative capital of the French overseas department and region of Réunion in the Indian Ocean. The road connecting the two towns is also called Route du Littoral (Coastal Road).

It is the strategic road linking the commercial port (town of Le Port) to the administrative town of the island and the Roland Garros international airport, see Figures 1 and 2.

Every day it is used by an average 60,000 vehicles.

Since it frequently undergoes extreme natural, geological and marine events, the road needed to be replaced by a new road built out at sea, further away from the cliff. Its dimensions have been designed to resist a hundred-year swell event.





Figures 1 and 2: Location of Reunion Island and Nouvelle Route du Littoral on the map.

Source: www.mapy.cz

HISTORY OF THE PROJECT

The Regional Council started working on the project of construction of the New Coastal Road (NCR) at the end of 2013.

The main challenge of the new road was primarily to put an end to a constantly unsafe situation for the thousands of drivers who everyday use this major road on Réunion Island.

The importance of this strategic link for the island´s economy made it essential to construct a completely safe new road.

The coastal road, which is located between the sea and the cliff face, was constantly subject to multiple natural hazards (rockslides, rain floods, flooding due to high tides); as a result, access to the road was often limited or suspended, with intensive maintenance required, and fatal car accidents occurred fairly regularly.

For years, the Regional Council, supported by the French State, put up 450,000m² of nets, with the aim of reducing the risks, but these were inefficient against major rock falls, such as the dramatic one that cost the lives of two Reunion Island road users on 24th March 2006.

All the experts working on the problem concluded that it was impossible to foresee or anticipate these phenomena, which was why it was decided that the existing road could not serve as safe infrastructure.

The choice of a road partially out at sea was made in 1999, and then confirmed in 2006. 20 years of studies, expertise, enquiries and public debates confirmed the need for a new infrastructure.

The experts also stated that this solution responds to the different challenges of the road, not only technically, but also financially and environmentally.

The NCR is also supposed to play a major role in the transition towards developing a system of modern and efficient public transport, thanks to the possibility of integrating buses, light railed transport as well as a cycle lane and thus encourage the inhabitants to use environmentally friendly means of transport.

Figure 3: Aerial View of the New Coastal Road

Photo Credit: Vinci Construction

THE MAIN STAGES OF PREPARATORY WORKS AND START OF THE CONSTRUCTION

2013/2014

- Investigation of special (unique) environmental areas linked to disturbances of protected species (mainly sea birds and marine mammals);
- Two public enquiries concerning use to be made of the public maritime zone (DPM) and work affecting the marine environment;
- Announcing results of tender for construction work (call for tender end of 2012, representing almost €1.2 billion);
- Administrative authorisation concerning water policy and work on DPM (Administrative documents);
- Provision of special environmental areas for protected species (decrees issued by Prefecture and Ministry);
- Start of preparatory work (access to construction site) and signature of contracts for construction of large-scale maritime structures;
- Construction work lot N°2 (dike at La Possession supporting the junction of the RD41 road) and lot N° 4 (viaduct of Grande Chaloupe);

2015

- Start of construction of large-scale maritime structures (dikes/ viaducts), after a preparatory period of approximately one year for mobilisation of the equipment (for example offshore platforms). The construction of large-scale maritime structures was planned to take approximately four years;

2016 – 2020

- Construction and completion of the structure

THE PROJECT

The new coastal road is designed to replace RN1; it is being built above the sea 80 to 300m from shore in order to avoid possible natural hazards.

Given its open marine location, the infrastructure is exposed to particularly harsh weather and sea conditions (cyclones and extremely high tides) as well as sensitive and variable geotechnical conditions.

In addition, the project must comply with very stringent environmental requirements, especially with regard to marine wildlife.

The construction of the project began towards the end of 2013; viaduct construction works are now complete. The project is estimated to cost EUR 1.66bn.

THE CHARACTERISTICS OF THE PROJECT

- Approximate length: 12,500m (from kilometric point PR 1.02 to PR 13.5 on the existing road);
- Speed limit: 90km/h;
- Type of road: 2 lanes in each direction + verges + a planned lane for future TCSP (Bus Network), plus bicycle lanes;
- Combination of dikes and maritime viaducts;
- Complete interchange with the RD41 (Route de la Montagne) in La Possession;
- Complete interchange in La Grande Chaloupe;
- Road with no toll:

The 5,400m long viaduct which is part of the 12,500m long project is being constructed along the coastline from Saint-Denis to La Grande Chaloupe. It stands between 20m and 30m above sea level and is located 70m away from the coast. The elevated highway is 30m wide with a dual three-lane configuration capable of accommodating buses, cars, pedestrians and bicycles. This is a unique project in terms of its length and width (at 5,400m, it is France's longest viaduct of its kind).

The 3,600m long highway between La Grande Chaloupe and La Possession is a dual three-lane road. The La Possession interchange is expected to form the other part of the new link road.

COMPANIES INVOLVED

The engineering, procurement, construction and management (EPCM) contract for the new coastal highway project was awarded to EGIS. The contract also covered the structural designs for the road. The highway was developed by a consortium led by GTOI (a subsidiary of Colas) and includes VINCI Construction subsidiary SBTPC and VINCI Construction Terrassement.

The construction of the new coastal road was divided into several work packages. One of the two main work packages was the full-service construction of a viaduct between Saint-Denis and La Grande Chaloupe. This contract was awarded to the VINCI Construction Grand Projects consortium for the construction of the 5,400m viaduct.

The viaduct was constructed by VINCI Construction, Dodin Campenon Bernard, Bouygues Travaux Publics and Demathieu & Bard.

DHI was subcontracted by EGIS to carry out the physical hydraulic model tests required to support the structures.

CHRYSO provided admixture for environmental exposure class concrete which offers the durability guarantee of 100 years minimum through its EnviroMix® approach for the project.

The 16 cranes used for the project were supplied by contractors Vinci Construction Grand Projects, Bouygues TP and Grues Levages Investissements (GLI).

Engen was awarded a contract to provide fuel for the project. The rock and aggregate required for the project were provided by Comarco.

The other contractors involved in the project were HEBETEC Engineering, Mecap and APP Consultoria Powerproject & TILOS & Ecodomus.

DESIGN OF THE VIADUCT

The coastal viaduct is 5,400m long. It has 50 supports; 48 piers out at sea and two supports on the dikes, referred to as "abutments" (one at the Grande Chaloupe end and the other at the St. Denis end).

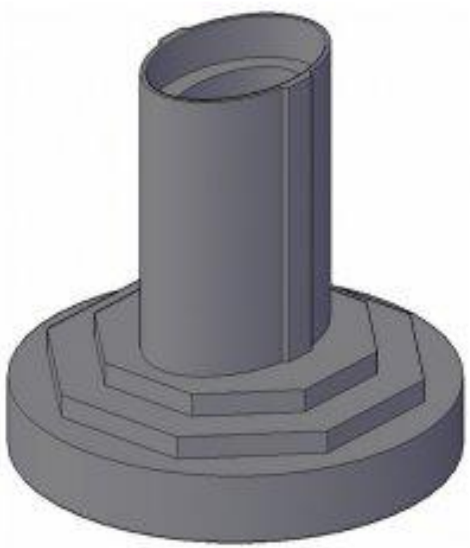


Figure 4: The lower section of a pier

Each pier of the viaduct is composed of these prefabricated parts:

- The lower section, called the base plate, consists of the base section which rests on the seabed, and a part of the bridge pier section of varying height which will reach about 3 m above sea level, see Figure 4.
- The upper section, called the pier head, consists of a part of the bridge pier section of varying height and the column section upon which the deck comes to rest, see Figure 5.

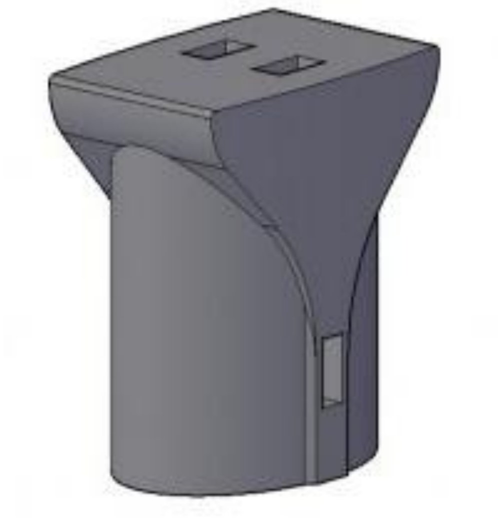


Figure 5: Upper section of a pier

A zero pier segment is then placed on top of the two pier parts; it corresponds to initial sections of the deck of each pier. The bridge segments that form the deck are connected to it.

The total height of the bridge piers varies from 24 to 38m. The pier base plates rest between 12 and 15m below sea level, between 3 and 8 m beneath the ocean bed.

CONSTRUCTION

The 5,400m long offshore viaduct was constructed using prefabricated reinforced concrete sections to avoid tides and to minimize work at sea. Two production sites were set up in the harbour zone:

- Port Est, with direct access to the sea, which served for prefabrication of the bridge piers;
- Rear Port Zone, for prefabrication of the segments for the deck.

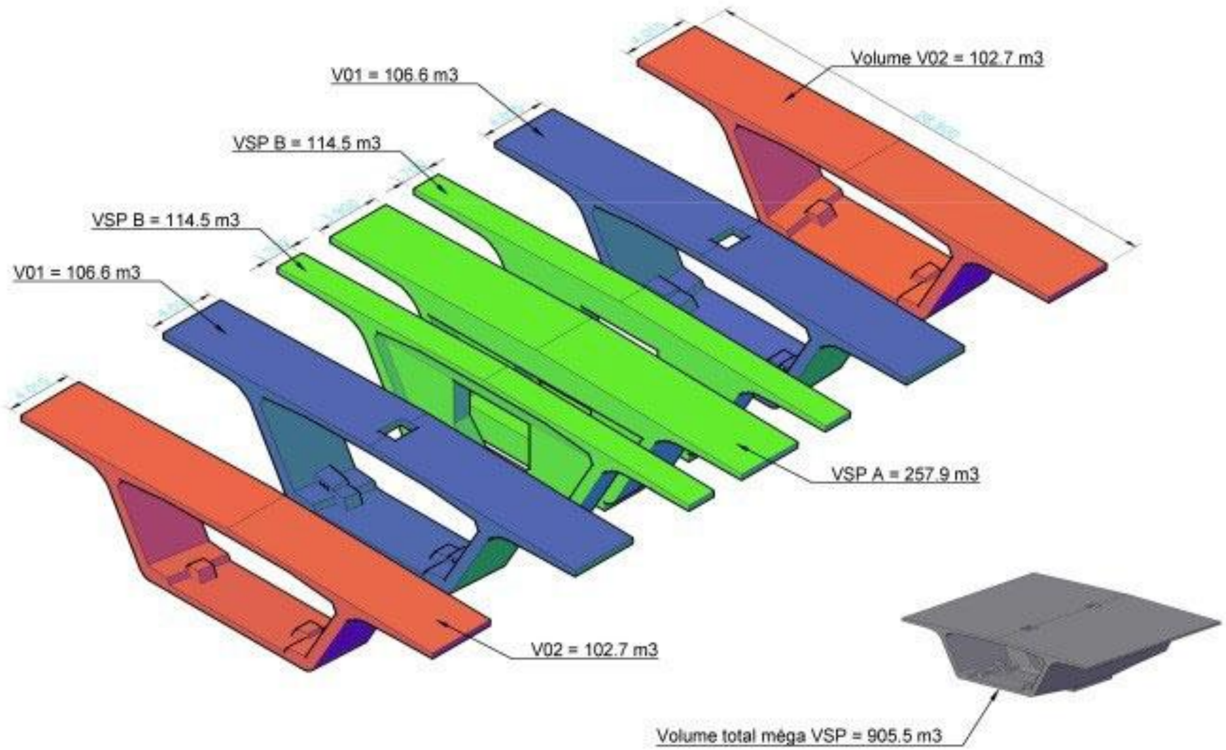


Figure 6: Bridge segments

The production and handling capacities to accommodate the size of the prefabricated components had to be adapted to this complex task.

The two production plants featured an extensive set of specific tools. For instance, the segment production site was equipped with a 350t gantry to move parts and components.

The plant also included concrete production units (one of which supplied the neighbouring pier production plant), a system to treat the water used to clean concrete mixer trucks, a cooling system for aggregate materials, and mixers.

In addition, there was an ice-production unit with an output capacity of 45t a day to help control the temperature of the concrete even during the most intense heat waves. The whole production was environmentally friendly and met strict requirements in this regards.

The prefabrication method of construction presented the following advantages:

- It ensures a maximum amount of work is carried out ashore on the 2 prefabrication sites, in optimal conditions of work and safety;
- It minimizes operations at sea, which can be very constraining, notably with respect to meteorological conditions. The possibility of working or not depends on predetermined criteria such as wave height, wind speed, type of activity, equipment used, etc.

On the other hand, this method requires considerable means to transport the prefabricated sections.

The prefabricated segments were then brought to the site using specific means of transport:

- Approximately 48 prefabricated bridge piers were transported to the construction site brought in and installed by the ´Zourite´ barge.
- Seven segments which form the deck portion over each pier were transported using a barge and installed along with the pier heads. Each segment weighs up to 2,400t;
- The 1,386 continuous segments, weighing up to 670t, that form the rest of the deck of the viaduct were manufactured at a production plant at a rate of three or four a day and transported at night on the original coastal road.

They were installed using a launching gantry.

The gantry was 278m long and 28m tall and it was custom-built for the project by CIMOLAI, the detail specification see below.

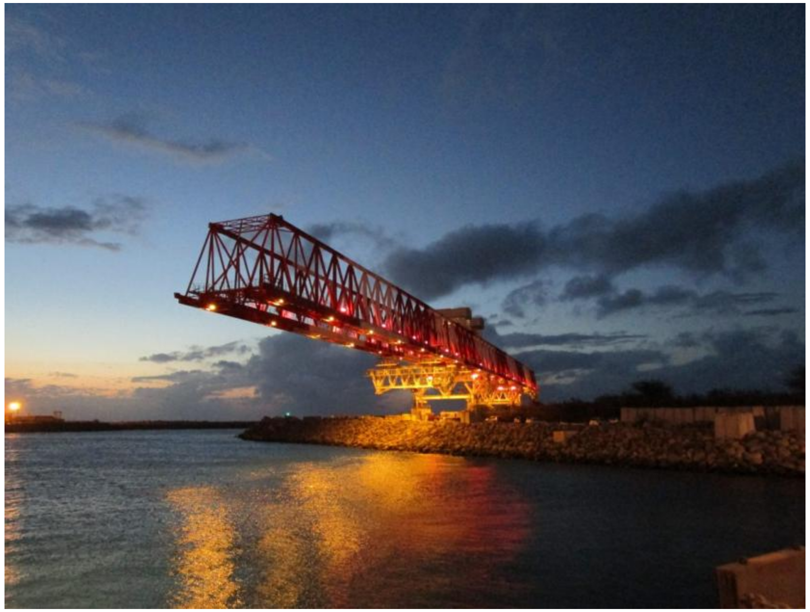
The elements were placed by the gantry and assembled on either side of the pier voussoirs.

The beam moved from Grande Chaloupe to Saint-Denis.

Figure 7: Three trucks 35m in length, 5m in width and equipped with 216 wheels were used for transport of the segments

Segment launching gantry SLG 320 – Technical Specification

Total length: 280m
Maximum launching: 123.5m
Number of main winch trolleys: 2
Maximum capacity of each main winch trolley: 308t
Maximum weight of the element positioned with two main winch trolleys: 550t
Number of hanging elements at span end: 5
Total weight of hanging elements at span end: 1372.2t
Total weight of the hanging elements during cantilever construction: 22
Number of elements launched daily: 4



Figures 8 – 11: Segment Launching Gantry SLG 320   Photo Credit: CIMOLAI

<u>For each bridge pier, the construction sequence was as follows:</u>

- Prior to installation, a hole is excavated at the required position, in order to provide ground conditions with the suitable load bearing characteristics. The bottom of the hole is covered with a layer of 1m thick granular foundation in order to have a base which is as regular as possible;
- The base plate (lower part of the bridge pier) is then transported onto 'Zourite' from the prefabrication plant in Port Est;
- 'Zourite' carries it across and sets down the base plate. It is positioned very precisely, thanks to both the gantry and to the adjustment systems fixed on the bridge pier.
  The base plate is positioned 40cm above the granular foundation, to allow grouting between the underside of the base and the top of the granular layer. This grout makes it possible to have a perfect contact between the base and the ground;
- Zourite then returns to Port Est to load the bridge pier head (upper section of the bridge pier), as well as the deck section to be loaded on top of the bridge pier (mega bridge pier voussoir or abutment voussoir, as appropriate);
- A reinforced concrete central section between the two parts of the bridge pier is then constructed to fix the two elements, hence the need for a concrete mixer on board. The upper section of the deck is fixed to the bridge pier by means of pre-stressed cables.

Figure 12: Launching gantry during installation Photo Credit: CIMOLAI

Figure 13: Deck segment lifting and installation

After this, the launching gantry rests on top of the elements already in place at sea in order to assemble the deck voussoirs.

These segments were transported on land along the existing coastal road diverted to one side.

BEARINGS

84 high pressure pot bearings and 28 standard pot bearings were used for the structure. The largest bearing is designed with a maximum vertical load of 121,000kN (ULS) and longitudinal movement of +/-400mm.

The total weight of the delivered bearings is estimated to be 1,100tons, with the heaviest bearing weighing 18tons.

All bearings have been equipped with a high-pressure pads and vertical load measuring sensors featuring digital displays that provide real-time data.

In addition, the installed bearings have a lifting capacity of 30mm, which is achieved by the injection of a special hardening material.

MAJOR VESSELS AND EQUIPMENT USED FOR CONSTRUCTION

- Barge ´Zourite´: It is a 107m long, 44m wide vessel, equipped with a gantry with lifting capacity up to 4,800t. It is self-propelled and thanks to its 8 legs, it can be stationed at sea. It enabled installation of each bridge pier. It is also equipped with a concrete mixer, built specially for the project. The crew of the barge is made up of six marine personnel (2 officers, 1 boatswain, 1 oiler and 2 sailors) and 15 construction staff working on board to carry out

Figure 14: One of the installed RESTON® Pot Lift-Control bearings
Photo Credit: mageba

Figure 15: Barge ´Zourite´. Photo Credit: Région Réunion, J. Bayllédier

the construction work at sea, notably the concreting for the joints between the upper and lower sections of the piers;

- 1 pontoon for improving the condition of the sea-bed and laying down the anti-scouring mats. This will be brought in from the NEPTUNE shipyard in Holland;
- 1 technical assistance vessel (SSE multicat) for supplies (water, fuel, spare parts etc.);
- 3 vessels for transporting staff (Actamarine);
- The fleet of the sub-contractor SDI (Société de Dragage Internationale : International Dredging Company);
- The Pinocchio dredger (hydraulic excavator on pontoon);
- Two separable barges for disposal of materials out at sea (self-powered, 60m in length and with a shaft of 1000m^3);
- An assistance multicat and a bathymetric launch (for measuring the topography of the sea bed);
- Two Potain MD 485 B M20s, two MDT 368 As, an MD 560 B, a Potain K5/50C, a Manitowoc 12000E-1 crawler crane, seven Grove all-terrain cranes and two Grove rough-terrain cranes are being deployed in the construction of Reunion Island new coastal road.

Figures 16 and 17: Complete Viaduct, Photo Credit: VINCI Construction

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DESIGN, FABRICATION AND ERECTION OF ANTI-SCOURING MATTRESS CONNECTION STRUCTURE - NOUVELLE ROUTE DU LITTORAL

Paula Rinaudo, Jose Vicente Rajadell, Rúbrica Engineering

1. INTRODUCTION

The « Nouvelle route du littoral » (NRL) project consists of building a new coastal road (replacing the near-shore existing road RN1), between the two cities of Saint Denis and La Possession located on Reunion Island.

The existing coastal road is extremely sensitive to unforeseen events, particularly when it is partly closed.

Accidents or breakdowns significantly increase traffic jams, which are recurring incidents at the western approach to Saint Denis (up to 10km of traffic jams in the morning).

The main aim of the new road is primarily to put an end to a constantly unsafe situation for thousands of users.

The viaduct between Saint Denis and La Grande Chaloupe is 5,409m long, set on maritime piers in open sea (60 to 200m from the shore coast), in water depths of 8/11m.

Figure 1: Nouvelle route du littoral [1]

The width of the viaduct is 28.9m and the length of the standard span is 120m. When completed it will be the largest maritime viaduct in France.

The deck is a single pre-stressed concrete box girder of a variable depth. It is supported by 48 piers in the sea and 2 abutments connecting with the embankments towards the shoreline.

Each pier is composed of 3 precast elements:

- A circular base foundation (external diameter 20 and 23m) from seabed to +3.00NGR
- A pile head from +3.00NGR to cope beam
- Segments on piers to which future span segments of the bridge will be connected.

The piers are swept by ocean swell which can be massive when hit by tropical cyclones. To counter the effect of constant wash-out on the viaduct's 48 piers, huge circular scour protection mats were designed and laid up. They are made of woven propylene geotextile, providing a substrate overlaid by 528 concrete blocks poured into separate blocks which are held together by the geotextile at the block base, where it solidifies into the interstices of the fabric.

This forms a mass of sufficient flexibility, extent and tonnage to compact the seabed over a wide area. Feasibility was tested and validated in trial conditions under water.

Each mattress is 50m in diameter, and when overlaid by the concrete blocks weighs 1,600 metric tons on land.

It was decided to pre-fabricate them on land and then lay them in halves on the seabed. To proceed, three main tools have been developed.

First, 800ton, 912m² half-mattresses are prefabricated on a special immersion platform supported by four underwater telescopically retracting legs resting on the harbour seabed.

The mattresses are then equipped with an outstanding large spreader beam, which is the object of the study of this article.

Then the anti-scouring half-disks are lifted and taken to site with specially developed pontoon, equipped with four large lifting devices.

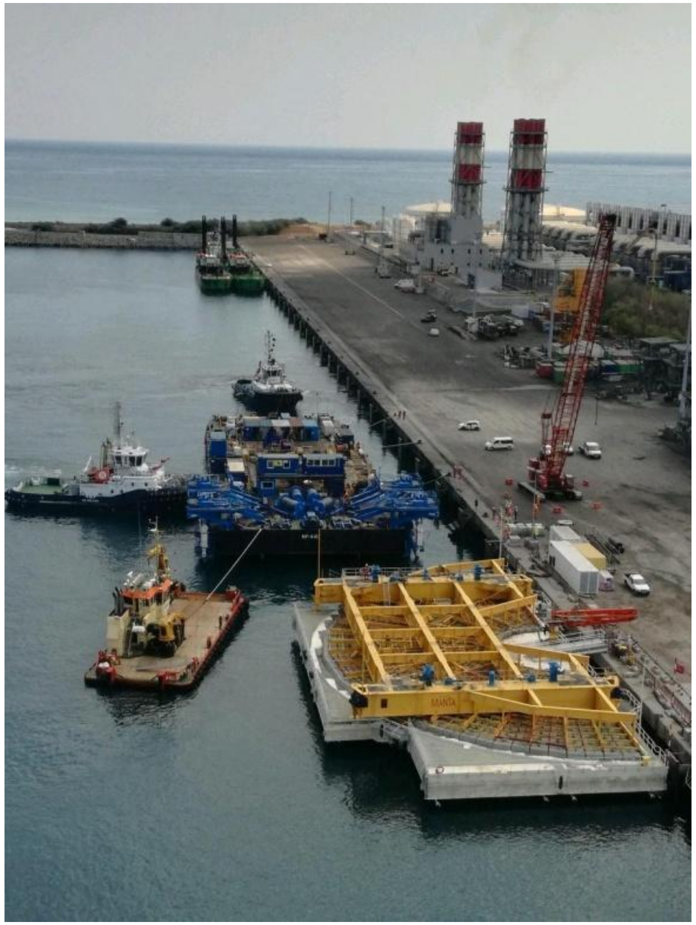
The **Spreader Beam (SB)** designed for placing the Anti-scour protection has three main elements: the main frame, the secondary structure and the bearing points automatic release system. The structure has three different configurations 0, -15^0 and 15^0.

The submerged weight of a half mattress is 476 tons (800 tons in the air) and the self-weight of the spreader beam is 286 tons.

Figure 2: Precast of the concrete half mattress (912m^2) on the submersible platform at the port [2]

An automatic release system for disconnecting the mattress from the spreader beam has been developed.

This system has 496 hydraulic cylinders designed and manufactured for sea water conditions.



The connection between the precast concrete block and each automatic releasing system is done by reusable slings which are connected on each precast concrete block during its pouring.

A submersible platform is used to construct the half mattress on it whilst it is in its floating condition.

This article presents the main challenges of the project during design, fabrication and erection phases.

2. SPREADER BEAM DESIGN REQUIREMENTS

The mattress is constructed at Le Port Saint Denis. The spreader beam is connected underneath pontoon NP440 to connect to the half mattress on the submersible platform and transported it to site.

Once the pontoon is in position, the half mattress has to be lowered into position around the circular foundation base.

On completion of this operation the spreader beam is released from the half mattress by the automatic release system and is lifted clear of the mattress for transport back to back to Le Port, where mattresses are constructed.

← Figure 3: The pontoon alongside the berth at the port

The cycle for the fabrication and installation for each anti-scouring half mattress is:

1. Construction of the precast concrete blocks that make up the half mattress on the submersible platform at the construction site.
2. Platform submerges with the mattress.
3. Place the spreader beam on the platform and release the spreader beam from the lifting structure.
4. Platform is raised up with the mattress and spreader beam.
5. Connect the slings between the half mattress and the spreader beam connection points.
6. Submerge the platform with the half mattress and spreader beam connected.
7. Connect the spreader beam to the underside of pontoon NP440.
8. Tow the pontoon to the foundation support position with the half mattress hanging from the spreader beam.
9. Lower the spreader beam and half mattress into the desired position. Adjust position using the spreader beam winches and anchor points.
10. Release the mattress from the spreader beam.
11. Lift the spreader beam and transport back to the construction site.

Figure 4: Platform submerging. Mattress and spreader beam connected

Figure 5: Pontoon near the circular foundation ready to lower the half mattress into position

This procedure had to be repeated 96 times.

For the spreader beam a design life of 3 years was required, the time for the project to be completed.

The equipment is exposed to a marine and tropical environment. It was therefore very important to provide the proper protective coating.

The half mattress has an external diameter of 50.5m and an area of 912m^2.

The spreader beam has to be able to adapt to two possible mattresses inside diameters (12 and 14m).

Each half mattress is composed of 528 concrete blocks. Each concrete block has to be manually attached to the spreader beam on the platform by slings.

The operation to release the blocks is by hydraulic cylinders.

The hydraulic release system includes a hydraulic fuse element that limits the load on each point to 32KN. The design of the hydraulic release system was one of the key points of the project design.

For final positioning the system is provided with 4 subsea winches of 10t capacity.

The spreader beam has to be able to adapt to the possible configurations of the alignment between the longitudinal axis of the NP440 and the symmetry axis of the mattress.

This alignment is 0º in most of cases. However, +/- 15º is also possible.

Therefore, the spreader beam has 3 possible coupling configurations to the pontoon.

The main design goals were:

- Keep the structure as light as possible;
- Keep the complete system within the allowed height;
- Minimize the horizontal resistance forces during towing operations;
- Design a sling fastening system to ensure efficient operation and safe condition for the work force;
- Simplify the erecting method.

Rubrica Engineering's scope was:

- Design and supply the spreader beam including all the electric and hydraulic systems and accessories;
- Develop erection method statements for the spreader beam;
- Transport spreader beam to site. The design must ensure that all components are able to be transported in 12m open top or high cube containers so that transport can be optimized;
- Manage on site assembly and commissioning;
- Provide operational support for the first 4 half mattress installations (2 pile base protection);
- Provide onsite training so that the NRL team can be autonomous.

Figure 6: Assembly of one of the main structure box beams

3. EQUIPMENT DESIGN AND DESCRIPTION

The complete equipment includes the spreader beam structure itself, the hydraulic system including the release component, hydraulic and electric systems.

STRUCTURE

The spreader beam structure is composed of the main structure and a secondary structure.

The mattress load transfers from the hanging point to the secondary structure. The secondary structure then transfers the load to the main structure and thence to the lifting structure.

The main structure is a frame formed by two lateral box beams 2.20m wide joined by welded I beams to give them the strength to take the vertical loads generated at the lifting points.

The couplings for the connection to the pontoon are placed on the upper part of the box beams.

The system has four telescopic legs to provide support and for positioning the main structure on the submersible platform. A hydraulically actuated pin for locking the leg in the extended position is provided.

The legs will support the total weight of the spreader as the slings will be let slack during the fastening operation.

To position and secure the location of the spreader beam onto the platform, a male coupling was installed.

The secondary structure is designed as a semi-circular frame with a profile similar to the half mattress profile.

The secondary structure is composed of radial beams and beams distributed in polygonal forming concentric rings.

The secondary structure is attached to the main structure by connections from the radial beams.

On the polygonal beams of the secondary structure the release system for each sling each block is located.

S355 Steel was used for the whole main structure and S275 for the secondary structure.

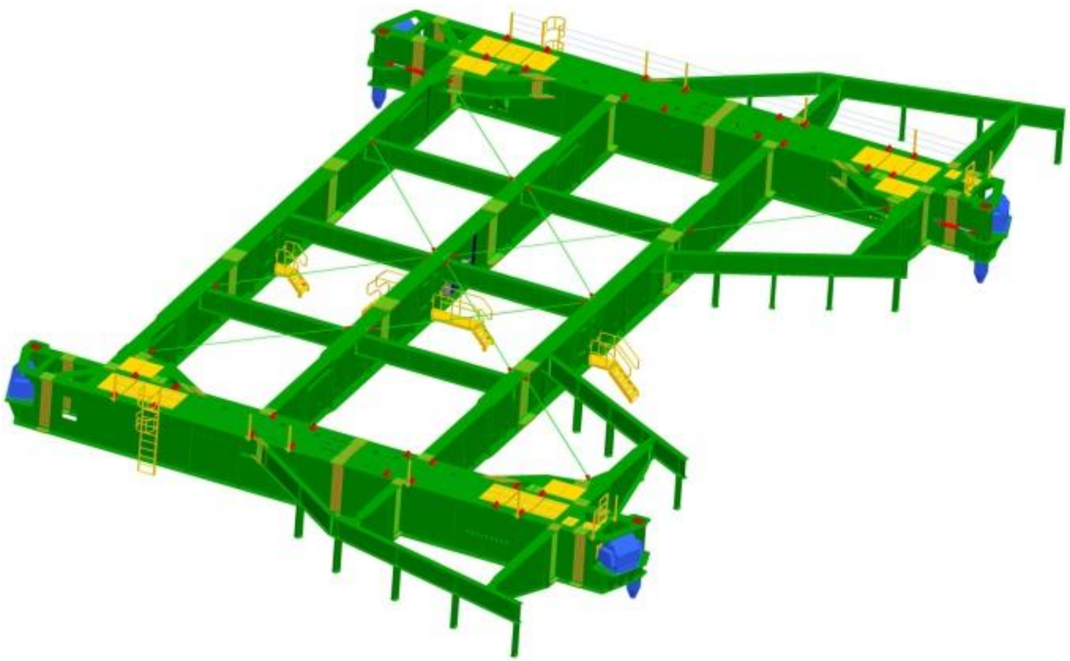


Figure 7: 3D model of the main spreader beam structure

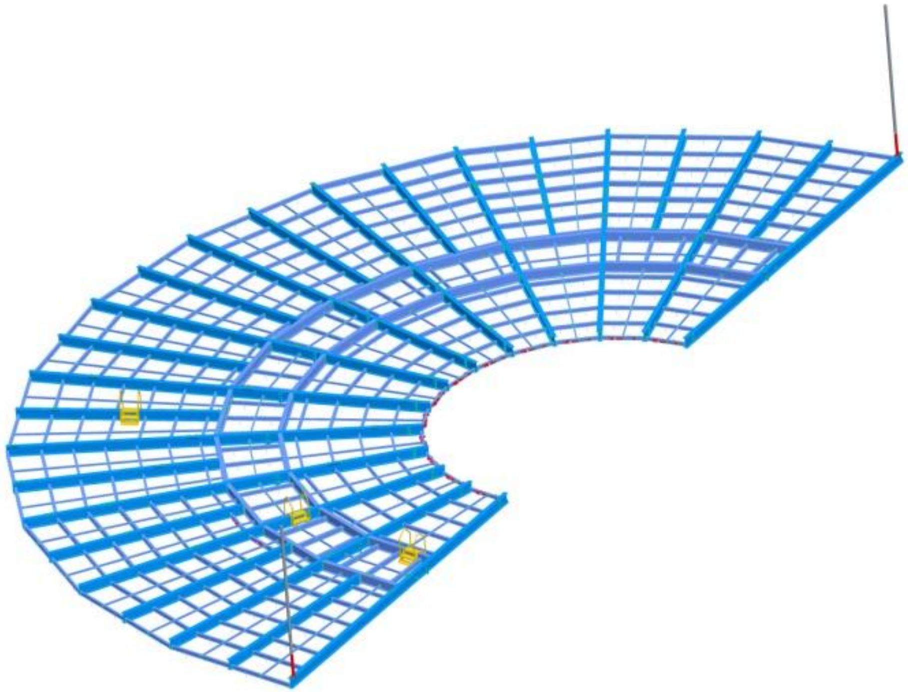


Figure 8: 3D model of the secondary structure

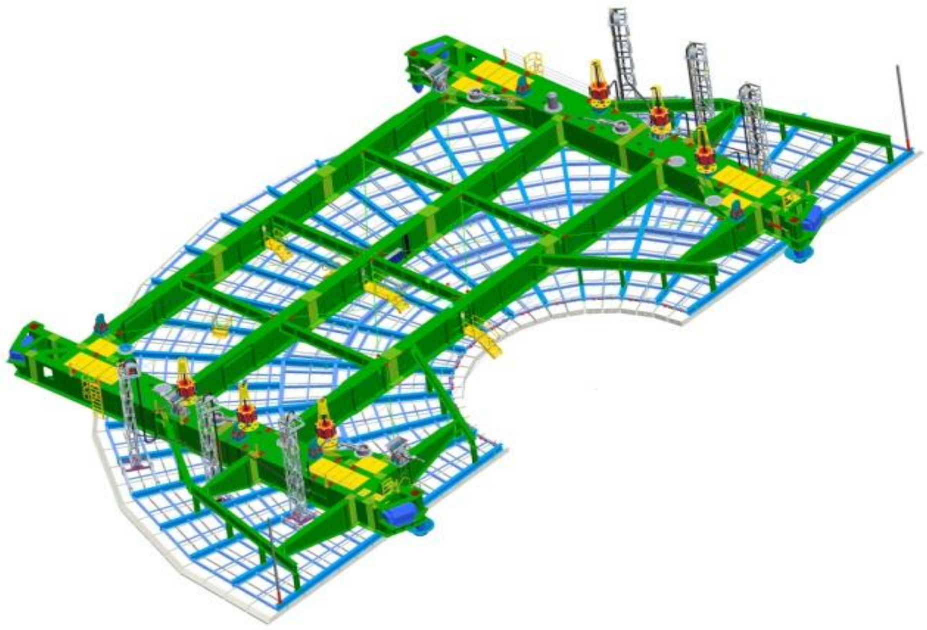


Figure 9: 3D digital model of the spreader beam structure

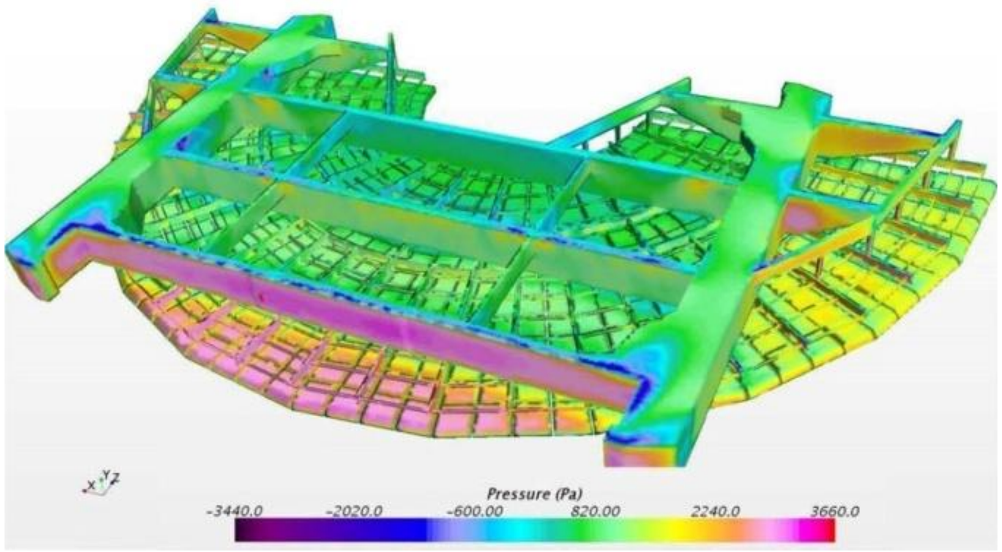


Figure 10: CFD Simulation

A 3D digital model was created for the design of the structure. The model was undertaken with industrial CAD software, LOD400.

Fabrication, assembly and operation drawings were generated from the model.

This enabled any modifications to the model to be easily updated on the drawings.

Weights and COG of the structures, substructures and elements were also obtained from the model.

Among other advantages of the model, it allows a check to be made for clashes and facilitate the input data of the calculation models.

<u>The following load conditions were considered on design:</u>

- Self-weight of the spreader beam structure was 261t. Submerged self-weight 228t;
- Variable loads:
  - Half mattress submerged weight 476t (surface load of 5.19kPa);
  - Half mattress submerged weight with towing loads 1,300t (great hydrodynamic forces up to 14kPa);
  - Local verification for the secondary beams with a force of 32kN.
- Pre-stress load: to prevent possible movement between the spreader and the pontoon during towing operation, a force of 370t was applied between the spreader beam upper connection points and the pontoon;
- Maximum towing speed 4 knots.

According to the equipment working cycle, the following loading and supports configurations were considered:

1. Rest configuration: equipment on the lifting platform supported on the four legs;
2. Towing with mattress: equipment submerged. Gravitational and towing load acting on the mattress and the spreader beam. Pre-stress load applied of 370t;
3. Unloading: equipment and mattress submerged hanging from the pontoon winches;
4. Towing without mattress: equipment submerged. Gravitational and towing load acting on the spreader beam. Pre-stress load of unloading situation.

To evaluate the towing load and its distribution on the spreader beam and mattress a CFD model was developed considering the 0º and 15º configurations and a pitch of 2º.

Several models were run during the calculation phases.

Bar models with the software Robot Structural Analysis 2018 (RSA) was used for the calculation of the loads on the main structure.

Then, those sections were verified with the software PIEM - considering the worst results of the bar models.

Plate models were done for local verifications. Models were done with the software: Idea Statica 8 and Creo simulate.

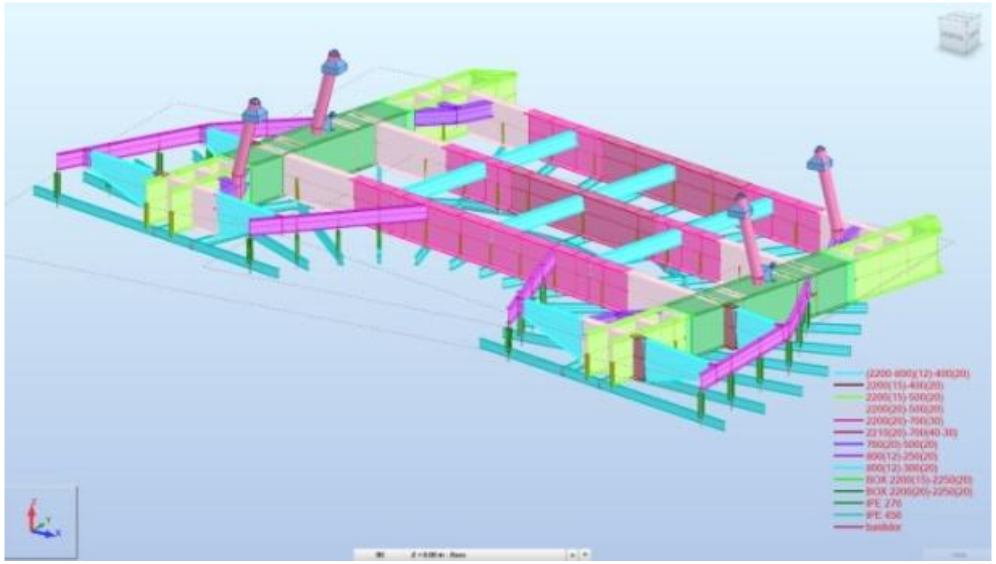


Figure 11: Beam model

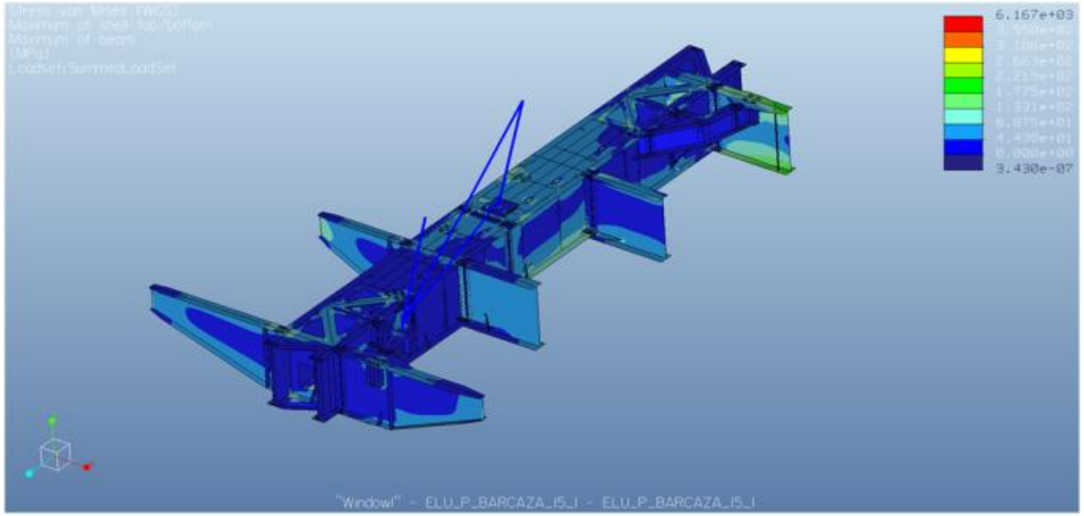


Figure 12: Plate model of local part of the structure

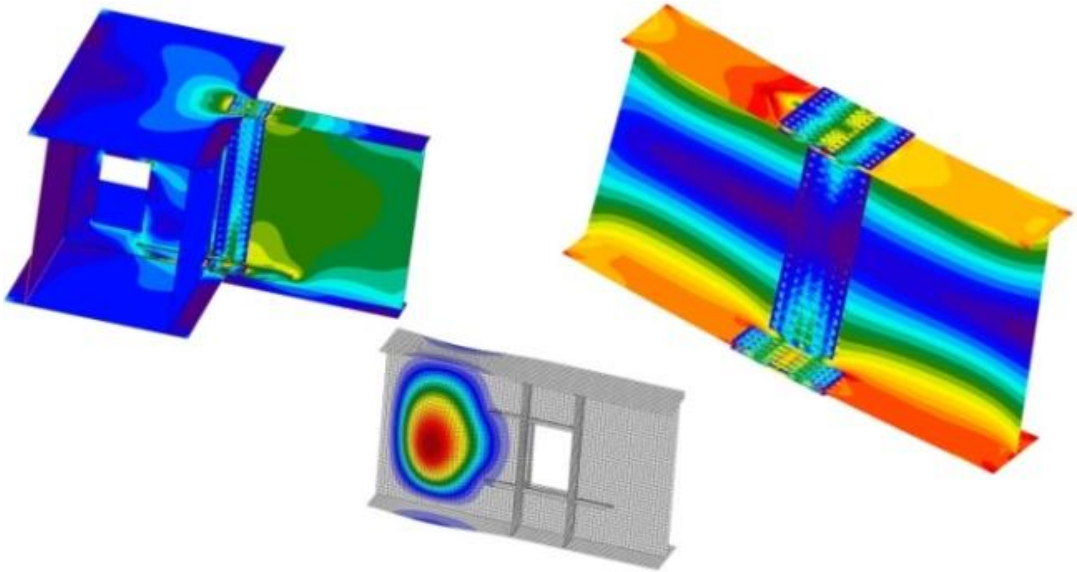


Figure 13: Joint, diaphragms and man footsteps models

Figure 14: Control panels and screen on the pontoon

SYSTEMS

Power systems are located on the barge. The electrical power is supplied to the Hydraulic Power Unit.

All the hydraulic system are controlled from a command cabin that allows the control of winches, operation of the release system and extend and retract the cylinders of the spreader beam legs.

There are four subsea cameras installed one on each winch. The cameras relay pictures to the command cabin screen.

Emergency buttons and warning were visualized also on the control screen. The complete description of the screen system is outside the scope of this article.

There is a connection box installed on the central part of the spreader beam with all electrohydraulic valves, sensors, connections, etc. This box is designed to operate when submerged or above the water.

There is a power supply cable and an ethernet cable that connect the main panel and the connection box. These cables have quick connection plugs enabling the spreader beam to be connected and disconnected for different operation stages.

4. CURRENT SITUATION

At the time of writing all half mattresses have been successfully installed.

As far as the authors are aware, no significant issues were found on the structure or systems during the operations.

Figure 15: Release system

Figure 16: Mattress submerged sling to spreader beam.

ACKNOWLEDGMENTS

Rúbrica Engineerings´s team and suppliers took a great part in the achievement of mattress installation.

RÚBRICA ENGINEERING´S TEAM INVOLVED IN THE PROJECT:

Pantecnia Consulting S.L.

TalleresPraferkloeckner metals

TalleresCasmon S.L.

IBERCISA Deck Machinery

EMS

SUPPLIERS:

Pantecnia Consulting S.L.

TalleresPraferkloeckner metals

TalleresCasmon S.L.

IBERCISA Deck Machinery

EMS

CRE Marine encapsulation Ltd.

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[1] © Région Réunion J. Balleydier

[2] ©Sebastien Marchal. www.bridgeweb.com, issue 95, p 70-71, 2019

http://www.nouvelleroutedulittoral.re/

A SHORT HISTORY OF BIDSTON LIGHTHOUSE AND ASSOCIATED FACILITIES

David Stork

INTRODUCTION

Lighthouses are recognised as essential for the safety of shipping around the world.

This article is about one in particular, Bidston Lighthouse which is located on the Wirral, across the River Mersey from Liverpool in England. It is known as the world's most inland lighthouse with coordinates 53° 24.066'N 3° 4.461'W.

This article describes what led to its construction and its subsequent history as a lighthouse. Figure 1 below is a photograph showing Bidston Lighthouse along with Bidston Observatory taken in February 2016.

In addition to discussing the lighthouses, their optics and their keepers, the signal station that was located on the site and probably set up prior to the lighthouse being built is discussed, as it is an integral part of the story.

Also briefly discussed is the development of tide tables in the UK as this was greatly helped by William Hutchinson, a significant character in the story of Bidston and the Port of Liverpool in its formative days.

Finally, there is a brief discussion of Bidston Observatory located on the same site.

This is very much a historical article which shows how we are still impacted by the events and technical developments of the 18th and 19th centuries, not just in the UK, but globally as well.

Although the story is set around Bidston it is hoped the reader can relate it to lighthouses and other developments in their part of the world.

↗ *Figure:1: Bidston Lighthouse and Observatory Feb 2016 (By kind permission of Ray McBride)*

March 2021

In writing this article I would like to acknowledge the considerable assistance of Dr Stephen Pickles, the present owner of the lighthouse, who explained the history of the lighthouse and passed on much advice, useful documents and illustrations.

Also, John & Diane Robinson for allowing me to use the information in their book 'Lighthouses of Liverpool Bay'. This is well worth a read if lighthouses are of interest to you. Other sources are acknowledged in the endnotes and the figures.

MERSEY LIGHTHOUSES

Until around the end of the 17th century Chester was the principal port in the north west of England but as the Port of Liverpool grew in importance there developed a considerable rivalry between the ports.

In 1644 a bill was presented to Parliament on behalf of the Port of Chester to build a lighthouse on the Cheshire shore to aid navigation into the Port.

At this time the Wirral was part of the county of Cheshire, unlike today when much of it is in Merseyside.

The Liverpool Town councillors, who were responsible for the port at that time, objected to this on the grounds that 'those lighthouses will be of no benefit to our mariners, but a hurt, and expose them to those dangers if they trust to them and also be great and unnecessary burden and charge to them'. [1]

At this time lighthouses were generally lit by open fires so what was behind this, apart from not wanting to help the Port of Chester, was a well-founded concern that 'wreckers' may light fires and that mariners would mistake these for the lighthouse and end up running aground resulting in the wreckers stealing the cargo from the vessels.

This concern was sufficient for Parliament to reject the bill.

The principal route into Liverpool was via the Horse Channel then into the Rock Channel. Hyle Lake was also used for anchoring whilst waiting to enter the Port of Liverpool.

Figure 2 is a chart of the River Mersey and River Dee by Grenville Collins from 1689 showing depths and various landmarks that mariners would have used to navigate into either the River Mersey or River Dee. It clearly shows sight lines using various landmarks.

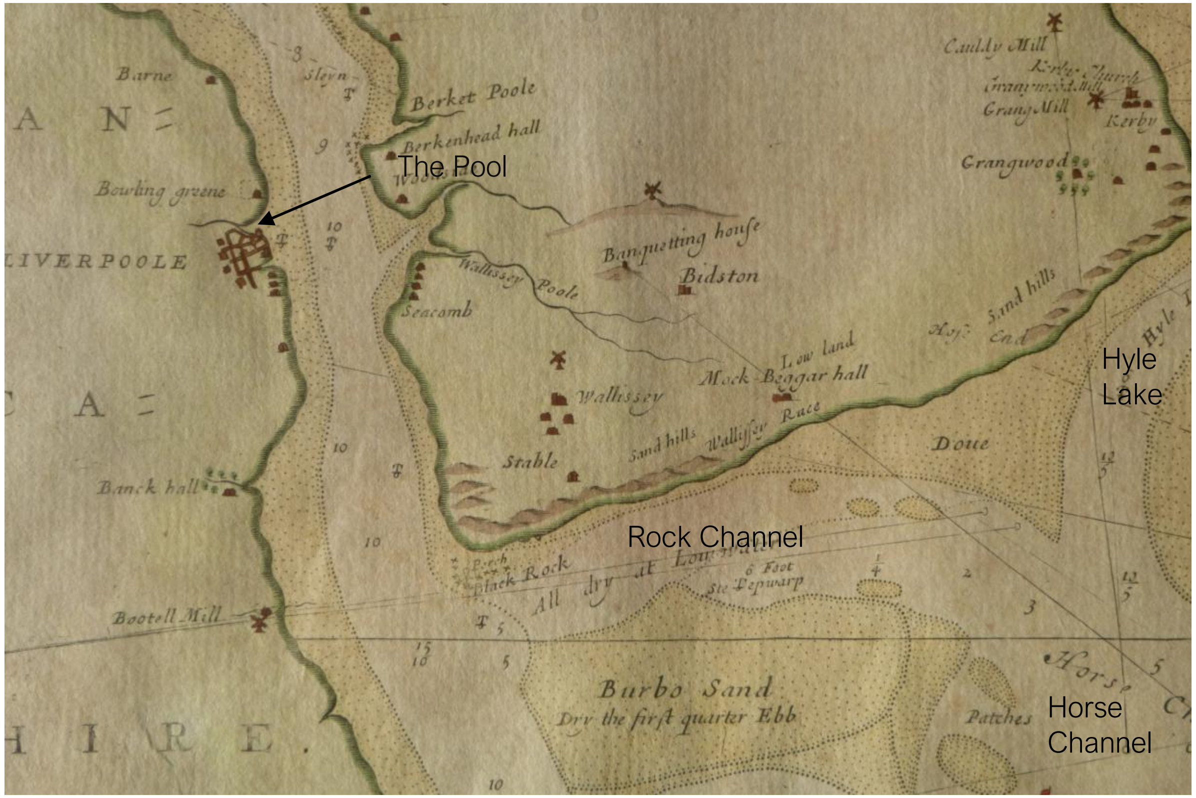


Figure 2: Extract of Captain Grenville Collins Chart of 1689 (By kind permission of Professor Christopher Michael)

Due to the variability of the sandbanks reliable navigation aids were required to help guide the ships transiting to Liverpool and Hyle Lake.

This chart is part of much larger chart of Liverpool Bay produced by Collins in his position as Hydrographer in Ordinary to King Charles II who appointed him to that position in 1682[2].

I have shown the position of Rock Channel, Hyle Lake and The Pool.

In those days Hyle Lake was an important anchorage as can be shown by the fact that this is where William III's navy was anchored and from where he embarked with his army for Ireland in 1690.

THE DEVELOPMENT OF THE PORT OF LIVERPOOL AND THE NEED FOR IMPROVED NAVIGATION

Sea trade in Liverpool was starting to build up at the start of the 18th century.

Cargo from ships was being unloaded in the Pool and also at Hyle Lake using shallow drafted lighters or the vessels lying aground and the cargo unloaded by cart at low water, both very inefficient operations so the port decided to build a new enclosed dock.

Following an act of Parliament in 1709 authorising new dock construction work began on the construction of the dock under the direction of Thomas Streer. When the dock opened in 1715 it was able to accommodate up to 100 ships and soon became very successful[3].

This was due in main to the easier access into the port, considerable time being saved by not having to navigate the River Dee, a notoriously difficult river to navigate due to its ever-changing sandbanks.

Besides the building of the dock to improve the safety of shipping, the 1709 act also authorised the installation of landmarks and buoys in the channels but these were never installed due to a shortage of sufficient funds.

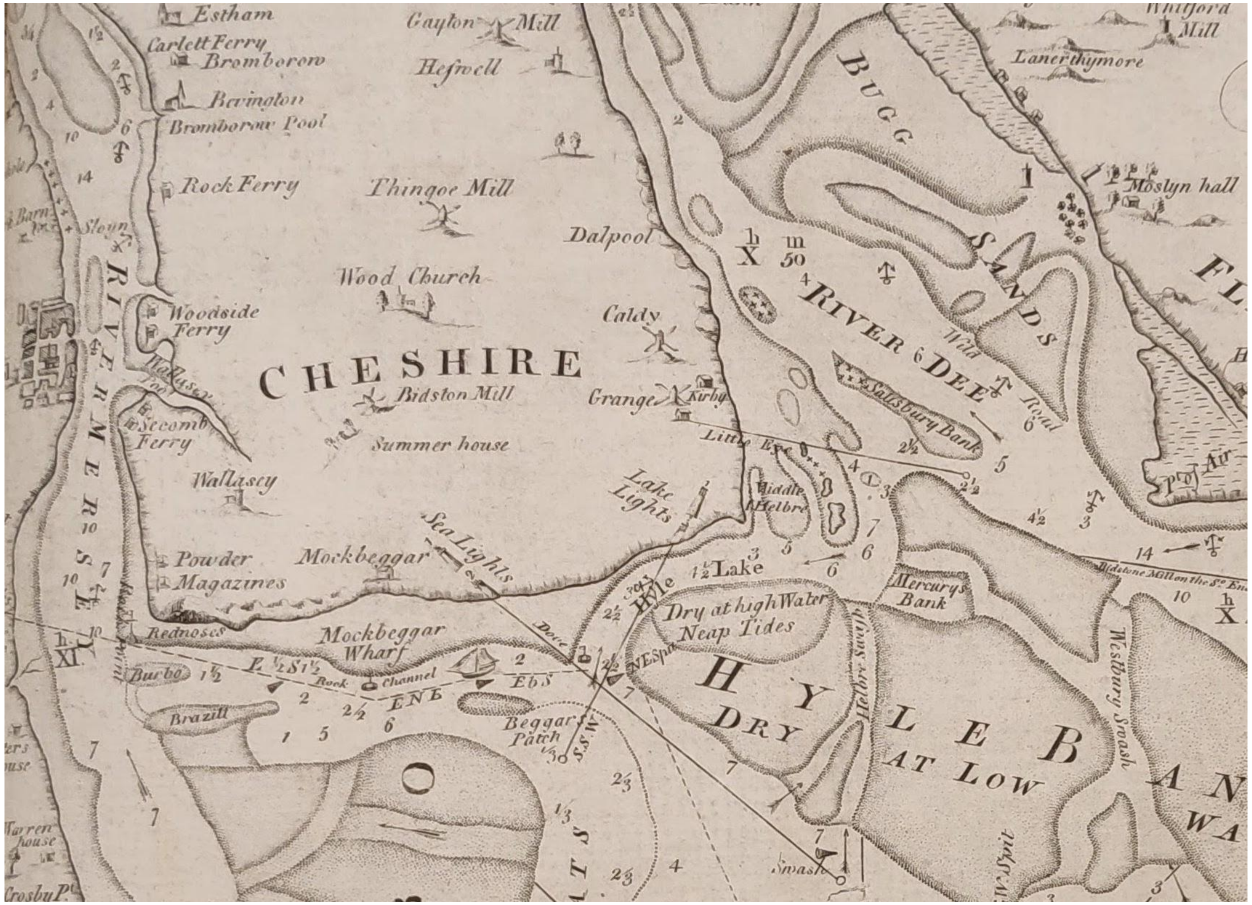


Figure 3: Details from Robert Williamson's chart, 1766
(By kind permission of Dr Stephen Pickles & Mersey Maritime Museum)

In fact, another act was passed in 1717 granting an extension of powers to Liverpool Corporation.

These authorised the completion of the dock work plus the marking of the Formby Channel with two landmarks and three buoys in or at the entrance of the channel and two buoys on the Hyle sandbank, one at the N.E. and the other at the N.W. spit of that bank, all to be completed by 25th December 1718.

There is however no record of these navigation aids ever being installed.[4]

By 1761 the merchants and ship owners were so concerned at the continued loss of ships, cargo and lives that they arranged for a bill to be put before Parliament to enable the ports further development including the building of lighthouses.

The Liverpool Dock Act, 1762, was passed which required, amongst other things, that four lights be erected on the Wirral to aid navigation. This time work was carried out and four lights were erected.

Two were built near Hyle Lake, an area now known as Hoylake. The other two were built near Mockbeggar Hall, now known as Leasowe, a remote area at that time.

Mockbeggar Hall, an octagonal, castellated tower, is around 1mile (1.6km) from the lights and the story goes that it got its name from the time a weary tramp went out of his way hoping to find food there only to discover it was deserted, no doubt a very disappointed man.

The two lighthouses got their name from this tower.

The two pairs of lights were known as the Lake Lights and Sea Lights respectively.[5] These can be seen on Figure 3, an extract from Robert Williamson's chart of 1766. As can be seen the lighthouses were constructed within 4 years.

The upper Sea Light was 101ft (30.79m) high and the lower Sea Light was 80ft (24.39m) high.

The Corporation's invitation to tender for erecting the Mockbeggar lighthouses was a little unusual as it required the contractors to make 500,000 common bricks and that they be made from clay near the land on which the lighthouses were to be located.

The geology of the sites included boulder clay about 4ft (1.2m) below ground level so there was abundant material available to manufacture the bricks. Figure 4 is a photograph taken in 2016 of what was originally the upper lighthouse.

Both sets of lights are what are known as 'leading lights'.

The purpose of the Lake Lights was for a vessel heading along the Horse Channel to gain entry to Hyle Lake so that when the two Lake lights were aligned this was the point when they would head along that line to gain safe entry into Hyle Lake.

Close to the entrance to the Lake the N.E. Spit of Hyle was situated, and it was moving eastward and thus affecting the channel into the Lake.

For this reason, the Lower Hyle Light was not made a permanent structure as it became necessary to move its position to confirm the location of the channel.

The position of this spit can be seen on Figure 2. This chart is from 1689 and it can also be seen that at that time there are no specific aids, only the landmarks that sailors used to help them navigate.

↖ *Figure 4: Mockbeggar (Leasowe) Lighthouse*
(By kind permission of Dr Stephen Pickles 2016)

As described above, the Sea lights consist of two lighthouses near Mockbeggar Hall. Their purpose was to guide ships through the Horse Channel.

When the two lights were aligned the vessel would follow this course until other lights were sighted, such as the Lake Lights showing where the vessel should alter course into Rock Channel, i.e., the lights led the vessel on a safe course.

BIDSTON LIGHTHOUSE AND TELEGRAPH STATION , WILLIAM HUTCHINSON

No article on Bidston Lighthouse would be complete without discussing William Hutchinson so let us step back a few years before the construction of the first Bidston lighthouse.

Hutchinson became an important figure in the development of the Port of Liverpool in the 2nd half of the 18th century. He was a native of Newcastle-upon -Tyne and a seaman by the late 1730s, serving on an East Indiaman trading to India and China.

After service in the British Royal Navy, he entered the employ of merchant and privateer Fortunatus Wright. Hutchinson was captured by the French in 1746, but escaped and by 1748 was master of the *St. George* and he captured a French ship, so returning the compliment!

A voyage in 1750 as captain of Wright's *Lowestoft* ended in shipwreck, and Hutchinson later claimed that only a timely rescue saved him from being eaten by the survivors in his lifeboat, as he had drawn the short straw.

Figure 5: William Hutchinson (1715-1801) - Liverpool Dock Master (By kind permission of Dr Stephen Pickles)

After time ashore in Liverpool, he later returned to privateering, captaining the 22-gun friga-te *Liverpool* (1757-8).

In 1759 Hutchinson was appointed Liverpool Dockmaster a position he held until 1793. He was responsible for a number of significant development's that improved navigation, helped develop the Port of Liverpool and improved the general wellbeing of mariners.

He would also have been heavily involved in the design and location of the new lighthouse's.

The list of his achievements whilst Dock Master is impressive:

- He helped revolutionise lighthouse optics, see below;
- He started keeping detailed tide, winds and atmospheric pressure records in 1764 and did this for some 25years. They were the earliest continuous set of tidal records in the United Kingdom.

  The first five years of this data contributed to the production of Holden's Tide Tables, which continued in use until the 1970s, see the discussion on tide tables below;
- Supported by Liverpool Dock Trustees he established Britain's first lifeboat station at Formby Point between 1771 and 1776;
- He also wrote a number of books. In 1777 he first published 'A Treatise on Practical Seamanship' which went through various editions and by 1794 was titled 'A Treatise on Naval Architecture'.

  It contained Hutchinson's advice and ideas on seamanship, ship design, and other maritime subjects, as well as autobiographical material;
- He helped set up the Liverpool Pilotage Service established under an act of Parliament in 1766;
- He founded the Liverpool Marine Society in 1789.

One of his most important endeavours, as it applies to Bidston Lighthouse, was to develop lighthouse optics. He had this to say in his Treatise.

'It is well known, from reason as well as experience, that an open coal fire light, exposed to all winds and weathers, cannot be made to burn and show a constant steady blaze to be seen at a sufficient distance with any certainty; for in storms of wind, when lights are most wanted, these open fires are made to burn furiously, and very soon away, so as to melt the very iron work about the grate; and in cold weather, when it snows, hails, or rains hard, the keepers of the lights, not caring to expose themselves to the bad weather, are apt to neglect the fire till it is too low, and then throw on a large quantity of coals at once, which darkens the light for a time, and till the fire burns up again; and in some weathers it must be difficult to make them burn with any brightness.

And when they are enclosed in a glazed close light-house, they are apt to smoke the windows greatly, nor do they afford so constant a blaze as oil lamps, with reflectors behind them, which we have adopted in Liverpool'.

He therefore understood the problems associated with how lighthouse lights were generated. He must have given a lot of thought on ways to improve these lights.

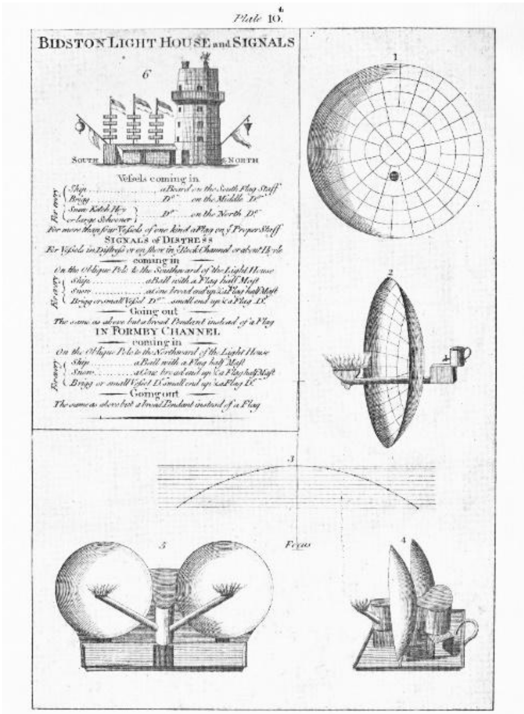
He developed the idea of a parabolic reflector combined with the use of an oil burner.

The story goes that his inspiration for the development of the reflector came whilst in a coffee house.

There, as a wager, a man claimed that he could read a newspaper from a distance of 10m in a darkened room by the light of a candle.

He achieved this by concentrating all the light into one direction using a bowl, lining the inside with a glass mosaic held in place with putty and won the wager.

Hutchinson developed the parabolic reflector, possibly using Bidston Hill to carry out his tests.



THE FIRST BIDSTON LIGHTHOUSE

The original lower sea light at Mockbeggar was undermined by wave action and collapsed into the sea in 1770. There was much discussion on the best option for a new lighthouse.

It was realised there was no point in replacing it in its original position as the same fate would almost certainly await it. As already discussed in 1763, Hutchinson was experimenting with oil lights and the parabolic reflector.

According to transcripts of some Liverpool Corporation Dock Committee minutes of 1763 there was a light built on Bidston Hill at that time.

The minutes state it was a wooden tower and we can surmise that this may have been where Hutchinson tested his parabolic reflector.

This may also have been where there was already a signal station that alerted ship owners to the arrival of their vessels so they could make ready for receiving the cargo, discussed later in this article.

It should be born in mind that there is limited information to corroborate this but it is logical for this location to be recognised as a location for the replacement lighthouse.

This solution was eventually decided upon – construction of a new hexagonal stone lighthouse which was opened in 1771.

↖ Figure 6: Page out of Hutchinson's Treatise showing the design of the light for Bidston (By kind permission of Dr Stephen Pickles)

Figures 7 and 8 show the location on William Morris's chart and a painting of the lighthouse respectively.

This became the upper Sea Light, the original upper Sea Light now becoming the lower Sea Light, the two Sea Lights maintaining the light signal that guided ships along the Horse Channel.

It is interesting to note that not everyone thought the siting of the lighthouse on Bidston Hill was a good idea.

Mr John Phillips of Liverpool, the designer of the first Smalls Lighthouse off the Pembroke Coast, disapproved of the lighthouse being built on Bidston because of its distance from the sea.

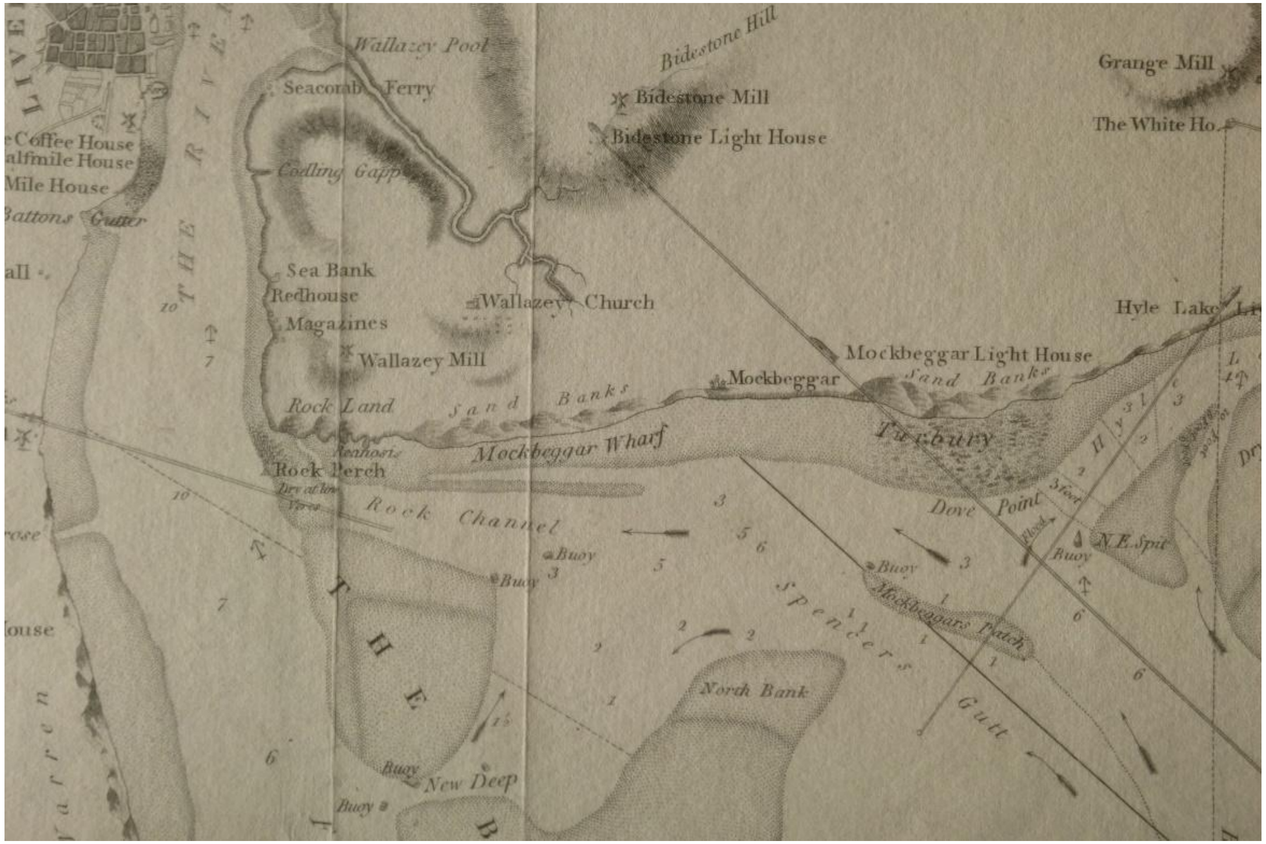


Figure 7: Location of Bidston Lighthouse - Part of William Morris chart of 1800
(By kind permission of Professor Christopher Michael)

His arguments were *'that every intention of a Lighthouse and Landmark is materially prevented, not to say defeated, by the situation, and I might add by the construction of the one on Bidston Hill, though the defects in construction may be dispensed with . . .*

The higher the elevation, the greater distance they can be seen, but the higher they are the more they are involved in an opacious[6] *atmosphere, in foggy and hazy weather; it is the safe, and not the great distance that is wanted ...*

It will be worse than trifling unless the tower on Bidston Hill is entirely demolished, and another built whereabout the old decayed one stands, or as near it as to retain all its advantages'.[7]

Clearly these were valid concerns but as Hutchinson had possibly tested his parabolic reflector there with no reported issues a decision was made to build the lighthouse on Bidston Hill.

Although this location provided the correct line of sight to give safe navigation for vessels, the 2.3mile (3.7km) distance from the coast was too far for coal fire lights to be effective.

The oil lights with parabolic reflectors developed by Hutchinson, and possibly already successfully tested at this location so it was decided to install this type of light in the lighthouse and to be protected from the weather in an enclosed room with glass windows.

Figure 8: Original Bidston Lighthouse (By kind permission of Mersey Maritime Museum and Art UK)

By the time the lighthouse was to be built a Mr Holden had improved the design and it was his design that was installed in the lighthouse and in all the other lights that the Corporation were responsible for.[8]

The lighthouse clearly generated some interest.

Joseph Cachin, a French Engineer who became responsible for expanding Cherbourg Harbour to become the world's largest during Napoleon's time, visited Bidston and made a drawing of the lighthouse complete with signals. It shows details of the oil burner and parabolic mirror, see Figure 9.

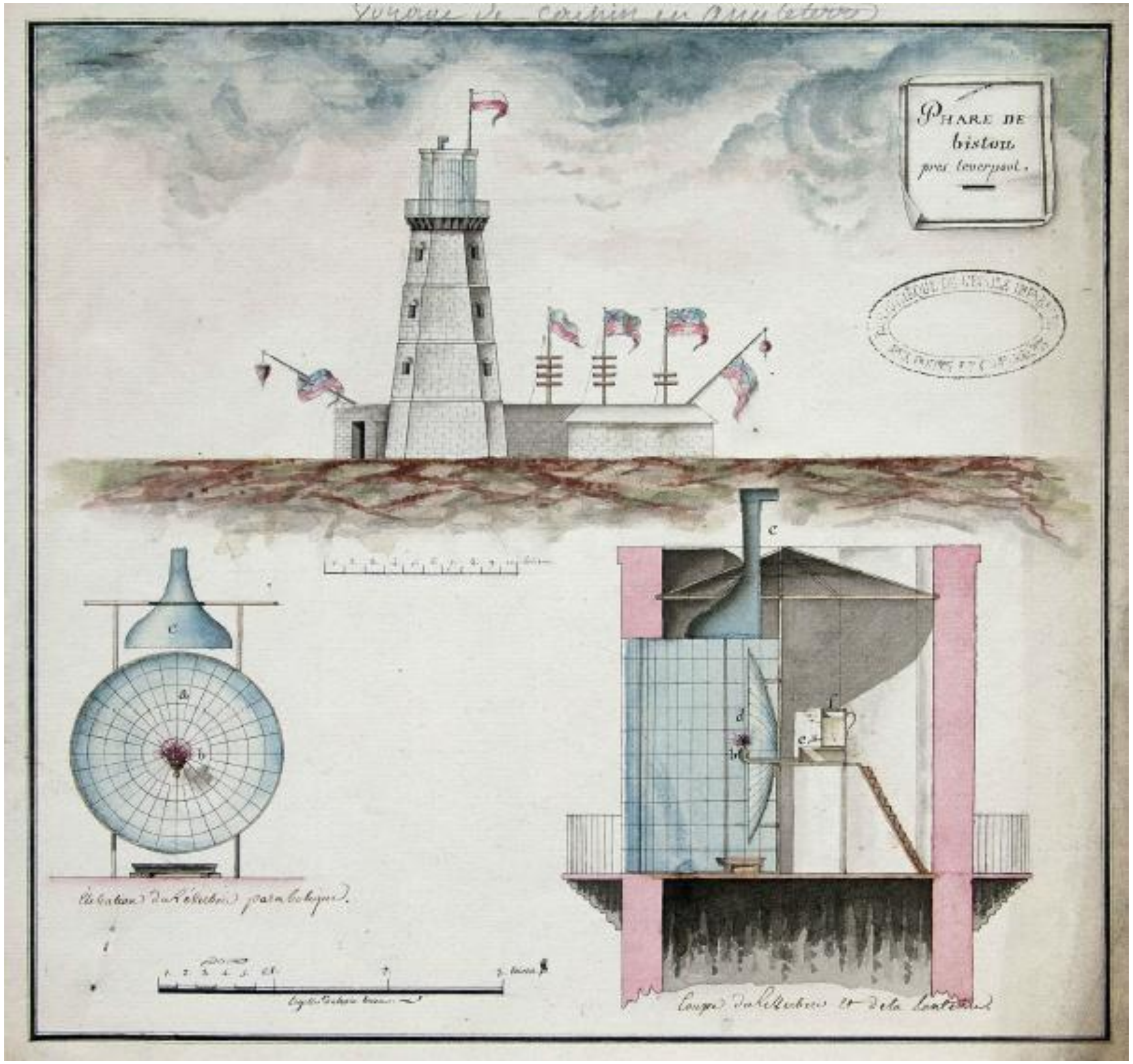


Figure 9: Phare de Bidston by Joseph Cachin 1785 (By kind permission of Ecole nationale des ponts et chausse'e)

Another great advantage of this site is that the foundations for the lighthouse would be on the very stable Helsby Sandstone Formation making construction much easier and providing much of the material for its construction.

Some wooden piling was required to support the accommodation buildings as the land sloped away where these were constructed. The building was 55ft (16.77m) high, half the height of the original upper Mockbeggar Sea Light, with an outside gallery running around the building at the lantern room level with access gained from the lantern room. The light was 244ft (74.4m) above half tide level.

The renowned Scottish Engineer Robert Stevenson, who by 1801 had built a number of lighthouses in Scotland, wanted to expand his knowledge and made a tour of English Lighthouses.

He visited Bidston Lighthouse and made the following observations: *'The lamp is lit by oil with one reflector of silvered glass, with no less than thirteen and a half feet diameter (4.12m) and its focus four feet (1.22m).*

This immense reflector is illuminated by one large cotton wick which consumes one gallon (4.55l) of oil in four hours'.

Interestingly he thought that *'I cannot see any good reason for expending such a quantity of oil for one reflector as the same quantity could answer for thirty reflectors of twenty inches (508mm) diameter, and I am confident that seven such reflectors would give an equal if not superior light'*. He also commented that the lighthouse was kept in good order.

The lighthouse was looked after by a number of lighthouse keepers which will be discussed below. The corporation, and then the Dock Trust setup by the Liverpool Dock Act of 1708, were responsible for the lighthouses and their upkeep.

In 1858 the Mersey Docks and Harbour Board was formed and took over the responsibility for the lighthouses. They held triennial inspections but that did not mean they were necessarily being kept in good order.

In 1861 the Royal Commission on Lights and Beacons commented on the poor condition of the reflectors. No improvements were made and the lighthouse became more and more dilapidated.

Although repairs were authorised in 1864 it was decided that it would be more cost effective to build a new lighthouse.

THE SECOND BIDSTON LIGHTHOUSE

The new lighthouse, along with new accommodation for the keepers, was built and the light lit in 1873.

The light shone every night for 40 years before it was finally extinguished on 9th October 1913.

It was no longer needed as the sand banks in the Horse Channel had shifted so much that it was no longer navigable. The Crosby Channel had by then become the main channel for vessels using Liverpool and Birkenhead Docks.

After it was decommissioned it fell into disrepair. The cottages were used as accommodation and offices.

It was restored as part of the millennium project in 2000. It is now privately owned but open to the public by on certain days or by appointment. Details can be found at www.bidstonlighthouse.org.uk, on Facebook at www.facebook.com/BidstonLighthouse or Twitter @BidstonLight.

The lighthouse was designed by George Fosbery Lyster, FRSE (1821–1899) who had succeeded John Hartley as Engineer in Chief to the Mersey Docks and Harbour Board in 1861.

Figure 10 shows an initial design of the lighthouse. This is an early design as it shows a circular structure with a hexagonal ground floor.

It was eventually built as completely circular structure as can be seen in the photograph Figure 11 and ground floor plan Figure 12.

As with the first lighthouse the structure has an outside gallery around the lantern room for maintenance access. There is also accommodation for three keepers.

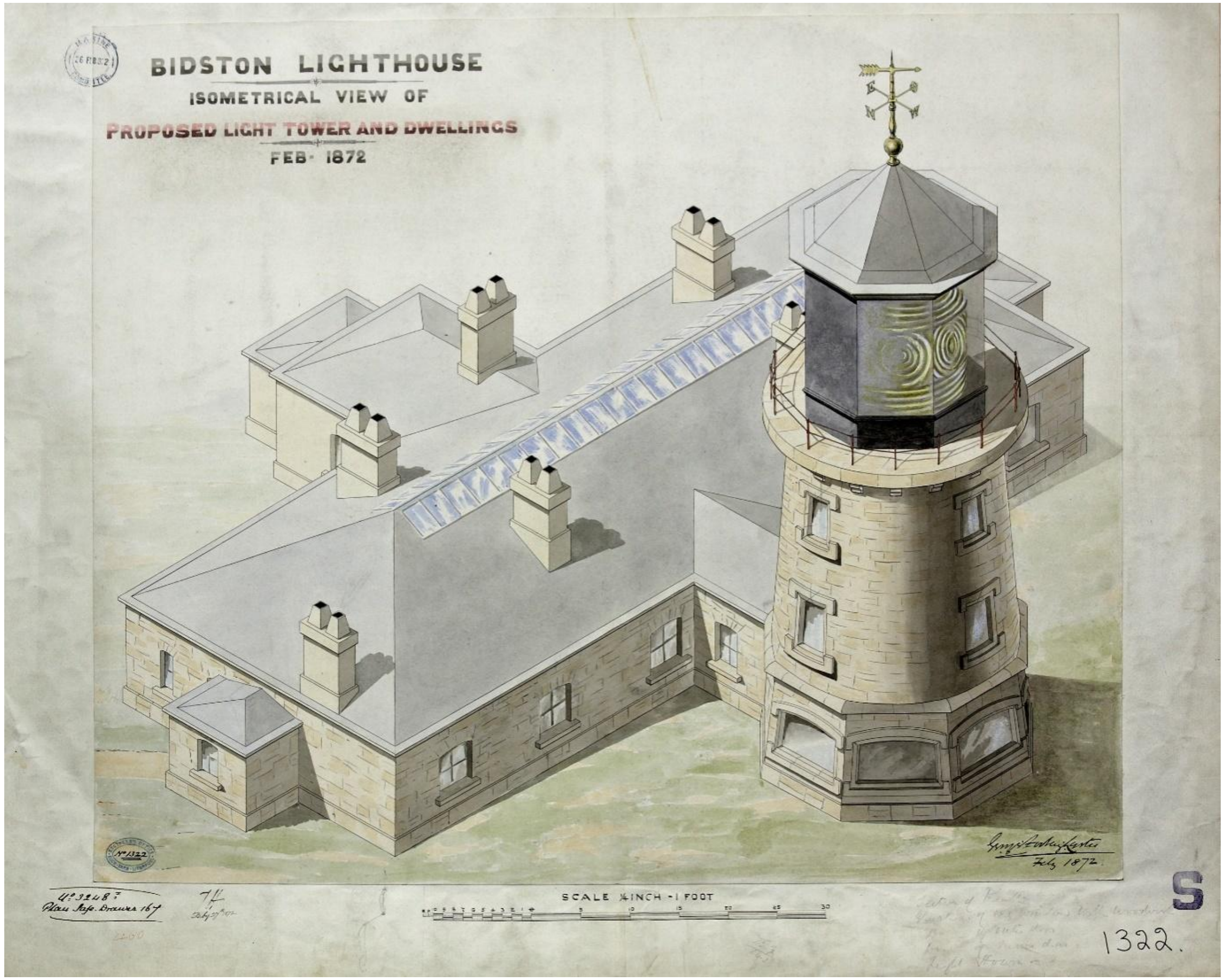


Figure 10: Isometrical View of the proposed new Lighthouse, 1872
(By kind permission of Dr Stephen Pickles, Peel Holdings and Mersey Maritime Museum)

This comprised two three-bedroom apartments either side of one bedroomed apartment with a living room but no kitchen. This was for the third keeper who would be a single man and eat with one of the other keepers and their families.

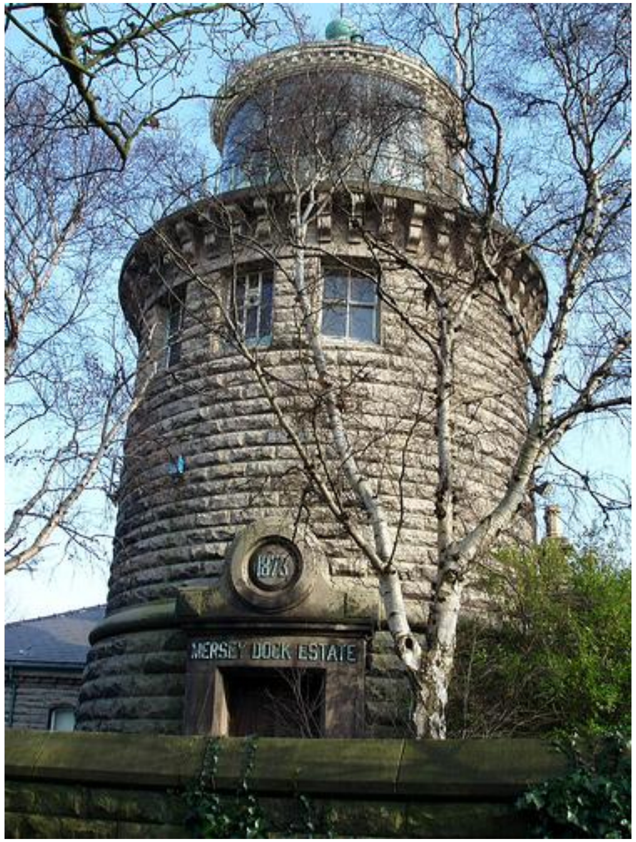


Figure 11: Bidston Lighthouse 2016
(By kind permission of Ray McBride)

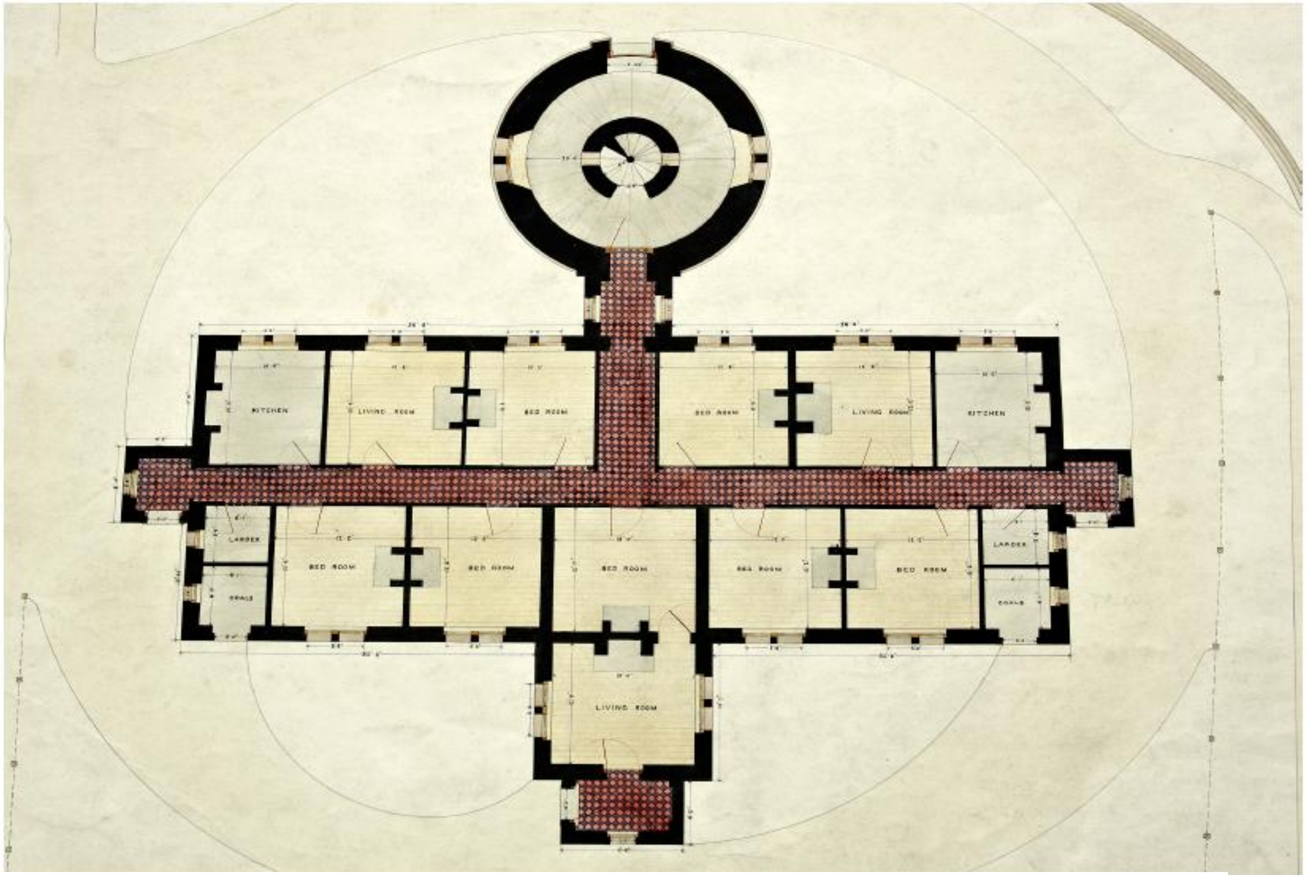


Figure 12: Ground floor plan
(By kind permission of Dr Stephen Pickles, Peel Holdings and Mersey Maritime Museum)

As with the first lighthouse the structure has an outside gallery around the lantern room for maintenance access. There is also accommodation for three keepers.

This comprised two three-bedroom apartments either side of one bedroomed apartment with a living room but no kitchen. This was for the third keeper who would be a single man and eat with one of the other keepers and their families.

As the location of the lighthouse was similar to the original the lighthouse itself did not require piles for foundations as it was built on the Sandstone rock.

As with the first lighthouse the accommodation would have required some deeper foundations to transfer the building loads to the rock level which was sloping away to the east. Figure 13 shows the location of foundations and their depths.

The lighthouse is constructed from the local sandstone over four floors with a circular outer solid wall and inner column constructed as a tube, all the internal walls are rendered and plastered.

This inner column carries the spiral stair case to the third floor. A circular void runs within this column from the second to the forth floor. A second circular void runs from the third floor to the forth floor.

The building is orientated with the cottages running in a north-south direction with the main entrance on the west side. The lamp is orientated so that it is visible in a NW by W direction in line with the Lower Sea light at Leasowe.

Figure 14 shows sections through the four floors of the lighthouse.

Ground Floor – the floor has an internal diameter of 20ft (6.1m) with 3ft 9in (1.43m) thick outer walls with two windows. The central circular column has a 6ft (1.82m) internal diameter with 1ft 6in (0.46m) walls. Each internal wall has a plaster render approximately 1.5in (75mm) thick.

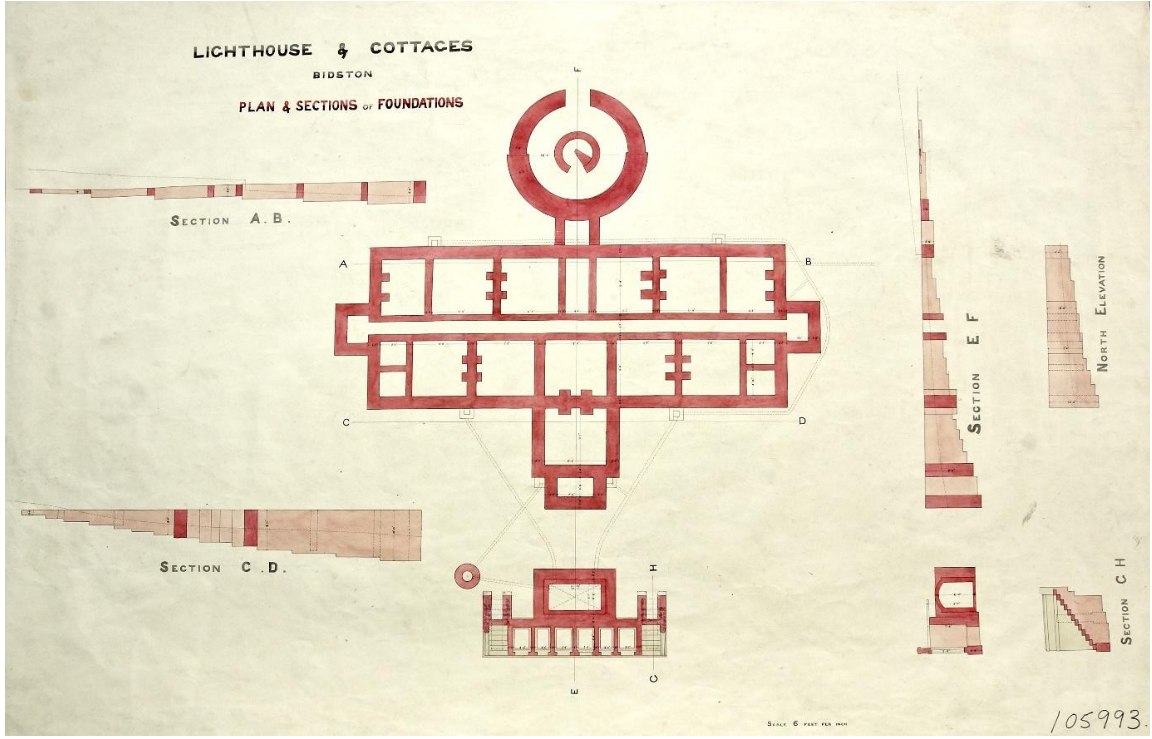


Figure 13: Plan & Sections of Foundations
(Courtesy of Dr Stephen Pickles, Peel Holdings and Mersey Maritime Museum)

The main entrance to the lighthouse is located on this floor on its west side. A doorway also leads through to the accommodation.

Access to the floors above is through a doorway in the central column leading to a spiral staircase and holes in the central column are provided to let daylight into the stairway.

Second or Oil Room Floor – this is where the oil would have been stored after being carried up in tin cans from the ground floor.

It was then pumped up to the lantern room via a pipe in the circular void in the central column.

The internal diameter of the room is 20ft (6.1m) with 3ft (0.92m) thick walls. The central column has an internal diameter of 6ft (1.82m) with walls of 1ft 6in (0.46m). Each internal wall has a plaster render approximately 1.5in (75mm) thick.

The working platform on which the oil would have been stored is 5ft 4in (1.63m) wide and as can be seen in the plan the west side the floor is strengthened to accommodate the oil tank.

Two windows were installed in the outside wall to let in daylight and the central column is provided with a hole to admit daylight.

Third or Signal Floor – this is where the electric telegraph was located. The internal diameter at this level has increased to 20ft 6in (6.25m) with 1ft (0.31m) thick walls.

The central column has an internal diameter of 6ft (1.82m) with 1ft (o.31m) thick walls. Holes are provided in the central column to let in daylight. The telegraph equipment is kept in a separate room on the north west side of the floor.

There are additional windows in the telegraph room to provide plenty of daylight. The spiral staircase ends at this level. Access to the lantern room is by wooden stairs from this floor.

Forth or Lantern Room and external gallery – this contains the lamp and the optics of which more later. It has an internal diameter of 18ft 9in (5.72) with 1ft 3in (0.38m) walls. The lamp and optics are supported by the internal column.

There is a door to the gallery which runs around the outside of the lantern room. This is 27ft 6in (8.38m) in diameter with a 3ft 8in (1.12m) wide walkway. The lighthouse is topped with a copper roof.

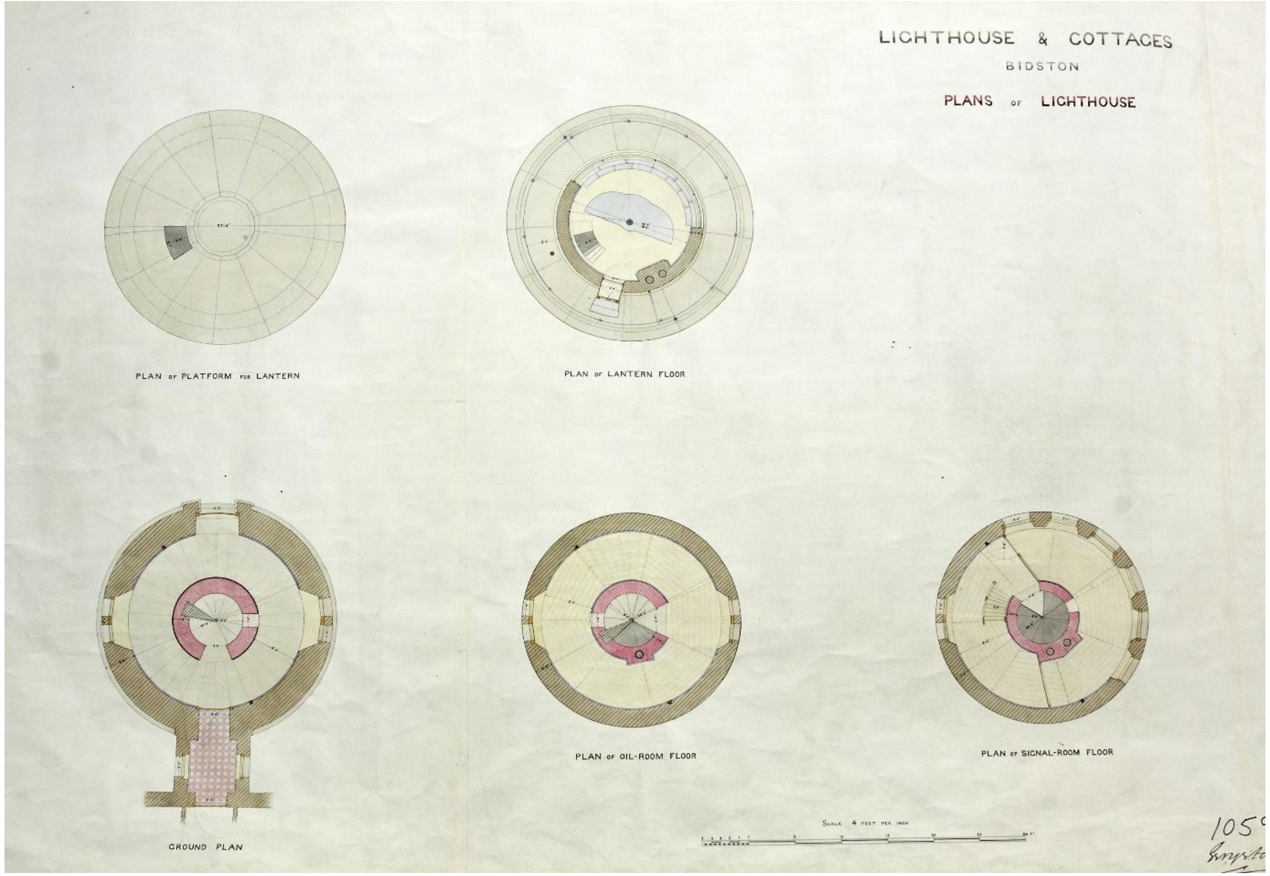


Figure 14: Sections through the lighthouse
(Courtesy of Dr Stephen Pickles, Peel Holdings and Mersey Maritime Museum)

THE LAMP AND OPTICS

Before discussing the type of lamp used at the new lighthouse, I will briefly review the development of lighthouse lamps.

Open fires of wood or other combustible material such as coal were originally used as the warning beacon on lighthouses and were in used up to around 1850.

As Hutchinson observed there were many problems with open fires due to the effect of the weather on the fires. When raining or windy the amount of light from the lighthouse, and therefore its effectiveness, was very variable.

A major improvement was to provide an enclosure with glass windows to protect the fire and give a more consistent and reliable light, though this created its own problems of the glass requiring regular cleaning to remove the smoke particles off the glass.

Another significant issue with open fires is that they could be mimicked by what were known as wreckers, people who lit fires to lure ships onto the shore so they could loot the cargo from the stricken ships.

The introduction from around 1500 of candles as an alternative to wood/coal fires was an important improvement as their light output was much better, they burned more constantly and cleaner and the smoke could more easily be extracted via chimneys.

They did still require the windows to be cleaned but not so regularly. Candles were used up to around 1800.

Oil lamps started to be used from around 1500. They used many different types of oil including whale oil and fish oil. These were very primitive at first but they underwent many improvements over the years until 1910.

Many inventive people have contributed to the development of the oil burners including Argand – the cylindrical wick with air fed into its centre, Lange – the development of the glass chimney, Carcel – the mechanism for an abundant supply of oil, Rumford – the development of multiple burners.

From 1857 the electric arc lamp came into use and was in regular use until 1920. From 1899 the electric incandescent lamp came into use.

The other major development in lighthouse lights is the optics. Optics had been developed for burning using the refractive properties of glass. They had not been developed for illumination.

Major problems of spherical aberration made the lenses produced so far unsuitable for producing light that could be used in a lighthouse. The major development of optics for use in lighthouses was made by Augustin Fresnel, a French mathematician and physicist.

In 1822 Fresnel described in, 'Memoire sur un nouveau systeme d'Eclairage des Phares' (Method on a new lighting system for lighthouses), a lens and afterwards he constructed a similar lens for lighthouse purposes, in which the centres of curvature of the different rings receded from the axis of the instrument according to the distances of those rings from the centre, so as practically to eliminate spherical aberration.

The only spherical surface being the central part. Over the following years lenses for lighthouses were developed to provide evermore precise light characteristics.[9]

OPTICS AND LIGHT FOR THE NEW LIGHTHOUSE

Before the replacement lighthouse was built at Bidston there was considerable debate about the type of light to be used for the new lighthouse and the optics. The source of the light could be oil, gas or electricity. There were three types of ways of distributing the light.

- Catoptric System created using only metallic reflectors;
- Dioptric System created using only an optical device; or
- Catadioptric System created using a combination of both.

At this time England only had two lighthouses powered by electricity and it was decided not use this due to its undue complication. Although gas lights had advantages it meant using a dioptric light and not the catoptric light that the existing lighthouse used.

This was made up of battery of lamps and reflectors so had a built-in fail-safe feature and it was also considerably cheaper.

Initially the Dock Board did not want to change the type of system, keeping with the catoptric system for the reasons given above.

Even so it was eventually decided to install a Chance Brothers dioptric oil light complete with a panoramic lantern glazing. It is perhaps surprising that the light cost more than the building of the lighthouse tower itself.

The tower cost £970 and the Chance Brothers oil light cost £1600. The lantern glazing cost a further £250. It did though show an element of visionary thinking to invest so much in this system.

Figure 15 is a photograph of the lens taken before being shipped to Bidston from Chance Brothers works in Birmingham. It had a range of 21Nm (38.9km) when seen from a ships deck.

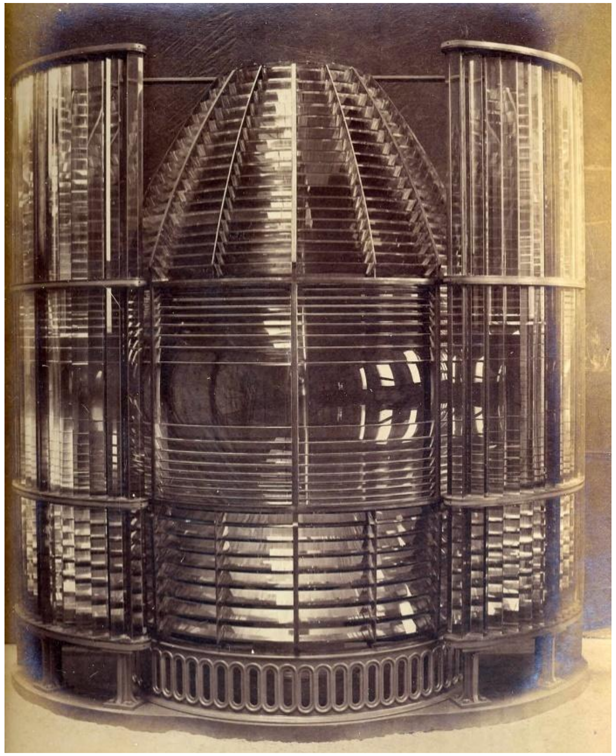


Figure 15: Chance Bros Dioptric Lens (Courtesy of Dr Stephen Pickles)

TIDE TABLES

Another of Hutchinson's contribution to navigation was to assist in the development of the first high quality, publicly accessible tide tables in the UK.

Two brothers, Richard & George Holden, had the idea of developing tide predictions to contribute to the safe navigation of ships using the Port of Liverpool.

Neither were scientists, Richard was a Liverpool Schoolmaster and George a curate on the Lancashire Yorkshire border.

They did though know people who could help with developing these ideas and Richard, who was a competent mathematician, was able to convert the ideas into practicable tables.

They met Hutchinson, and also importantly the Astronomer James Ferguson FRS. Hutchinson gave the Holdens his first five years of measurements of the (nearly) twice daily high tide levels at Liverpool.

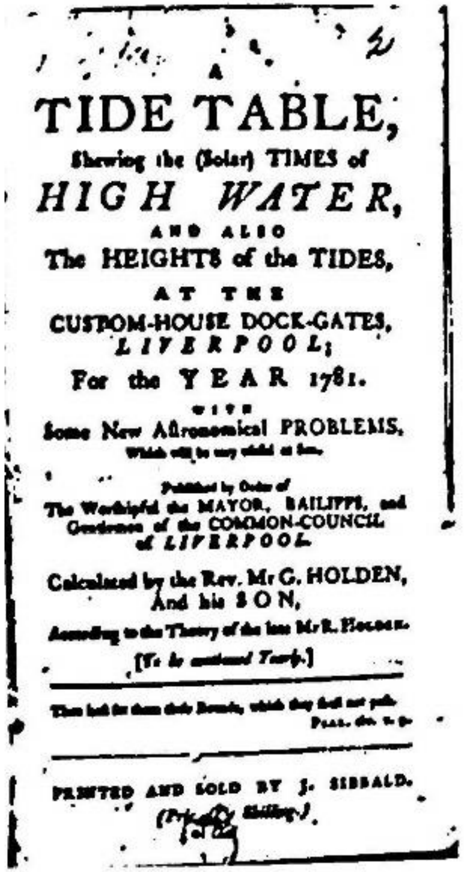
Ferguson knew of the work of the mathematician Daniel Bernoulli who had produced a tide table for Brest.

The final part of the jigsaw was the publication in 1767 of the Nautical Almanac under the direction of the 5th Astronomer Royal Neville Maskelyne. Although primarily used for navigation at sea it contained tables of lunar and solar parameters suitable for use in the Bernoulli method for forecasting tides.

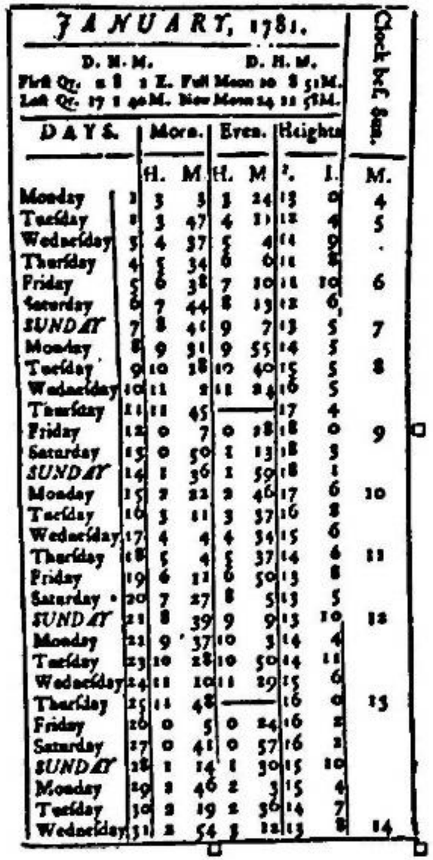
This was published each year and with the development of Holdens method this was all that was required to produce the tide tables every year.

In 1770 the brothers produced their first tide tables using data from Hutchinson and using the Bernoulli method learnt from Ferguson.

The Holden family went on to produce tide tables for almost 100 years. Holdens Almanack and Tide Tables was published by different owners for a further 100 years.[10]



A
TIDE TABLE,
Shewing the (Solar) TIMES of
HIGH WATER,
AND ALSO
The HEIGHTS of the TIDES,
AT THE
CUSTOM-HOUSE DOCK-GATES,
LIVERPOOL;
For the YEAR 1781.
WITH
Some New Astronomical PROBLEMS,
Published by Order of
The Worshipful the MAYOR, BAILIFFS, and
Gentlemen of the COMMON-COUNCIL
of LIVERPOOL.
Calculated by the Rev. Mr G. HOLDEN,
And his SON,
According to the Theory of the late Mr R. HOLDEN.
PRINTED AND SOLD BY J. SIBBALD.



JANUARY, 1781.

	D. H. M.		D. H. M.
First Qr.	2 8 1 E.	Full Moon	10 8 51 M.
Last Qr.	17 1 40 M.	New Moon	24 11 58 M.

DAYS.		Morn. H.	Morn. M	Even. H.	Even. M	Heights F.	Heights I.	Clock bef. Sun. M.
Monday	1	3	3	3	24	13	0	4
Tuesday	2	3	47	4	11	12	4	5
Wednesday	3	4	37	5	4	14	9	
Thursday	4	5	34	6	6	11	8	
Friday	5	6	38	7	10	11	10	6
Saturday	6	7	44	8	13	12	6	
SUNDAY	7	8	41	9	7	13	5	7
Monday	8	9	31	9	55	14	5	
Tuesday	9	10	18	10	40	15	5	8
Wednesday	10	11	2	11	24	16	5	
Thursday	11	11	45	—	—	17	4	
Friday	12	0	7	0	28	18	0	9
Saturday	13	0	50	1	13	18	3	
SUNDAY	14	1	36	1	59	18	1	
Monday	15	2	22	2	46	17	6	10
Tuesday	16	3	11	3	37	16	8	
Wednesday	17	4	4	4	34	15	6	
Thursday	18	5	4	5	37	14	6	11
Friday	19	6	11	6	50	13	8	
Saturday	20	7	27	8	5	13	5	
SUNDAY	21	8	39	9	9	13	10	12
Monday	22	9	37	10	3	14	4	
Tuesday	23	10	28	10	50	14	11	
Wednesday	24	11	10	11	29	15	6	
Thursday	25	11	48	—	—	16	0	13
Friday	26	0	5	0	24	16	2	
Saturday	27	0	41	0	57	16	2	
SUNDAY	28	1	14	1	30	15	10	
Monday	29	2	46	2	3	15	4	
Tuesday	30	2	19	2	36	14	7	
Wednesday	31	2	54	3	12	13	8	14

Figure 16: Pages out of Holdens Tide Table 1781 (By kind permission of The Liverpool Nautical Research Society)

LIGHTHOUSE KEEPERS

A Lighthouse is of no use without a keeper, at least up until lighthouses were automated. The keepers are an integral part of the story of Bidston so here is a brief history and as you will see there are some unusual aspects to the story.

The first keeper in 1873 was Mr Richard Wilding who had previously been a keeper at Leasowe.

He died in April 1797 aged 85. Wilding had married Elizabeth McCabe on July 4th 1779 and on his death the Dock Committee appointed her as the new keeper. She was the first female keeper appointed by Liverpool.

There were a number of conditions of employment, one being that she employs her Son in Law, Captain William Urmson as her Assistant.

Mrs Wilding died in 1800, aged 53, and the corporation appointed Captain Urmson as the next keeper. Mrs Wilding daughter from a previous marriage, Mary, married Captain Urmson and they had 4 children.

Unfortunately, Mary died before her mother in 1799. Captain Urmson eventually remarried and his wife helped him with lighthouse keeper duties as well as looking after the children.

Captain Urmson kept the lighthouse in good order as can be confirmed by comments made by Robert Stevenson when he visited where he said ‘this lighthouse is remarkably well taken care of being in every respect clean and in good order’.

This must have impressed the Dock Committee because he was asked to visit the other lighthouses at Leasowe and Hoylake at least once a week and be the other keepers Superior Officer.

As his children grew up, they began to help their father in the running of the lighthouse. In particular Jane and Catherine who were paid by the Dock Committee for their work.

Things were changing with the signalling station. A new electric telegraph system was to be introduced, as discussed below, which would be separate from the lighthouse.

In 1826 the Dock Trust needed a telegraph keeper and gave the job to William Urmson’s daughter Jane. In July 1828 Jane is reported as doing a good job by Lieutenant Watson (the instigator of the telegraph system).

In a report he could not avoid mentioning the very efficient manner which Bidston Station is worked which from its proximity to Liverpool handles many more signals than the other stations.

Captain William Urmson died aged 73 in 1835. As he had found his duties becoming increasingly onerous for some time his other daughters, Ann and Catherine, had taken over more and more of the keepers’ duties.

The Dock Trust therefore appointed Ann and Catherine as joint keepers. So, Ann, Jane and Catherine carried on what was now becoming a family tradition. This is all the more remarkable as they are all female, an unusual situation at that time.

Catherine married in 1841 and after that no longer helped at the lighthouse, Ann becoming the Lighthouse Keeper. She married a cousin, John Urmson, in 1841. Jane had already married Thomas Nichols in 1833.

Jane had one daughter, Mary Ann, who eventually became assistant telegraph keeper.

Mary Ann had died aged 26 in 1861 and when Jane and Thomas retired in 1861 the Dock Board appointed a James Adams as the new telegraph keeper with his daughter, Mary, assistant.

Adams was well qualified for this role having been telegraph keeper of Puffin Island telegraph station from 1838-1852, then Point Lynas, both on the Isle of Anglesey, from 1852-1856 and returning to Puffin Island in 1856 until its closure in 1860.

Ann Urmson who had been in poor health for some time relied on her husband to help with running the lighthouse. Ann died aged 64 in 1869. After Jane died the Dock Board amalgamated the role of lighthouse and telegraph keeper.

James Adams was made keeper with two assistants, his daughter Mary and Janes husband John Urmson. John Urmson remained at the lighthouse until 1872.

When John Urmson retired it ended an era with the Urmson and Wildings family having kept the lights for 99 years, quite an achievement in those days for a largely female endeavour.

Ann's involvement had lasted more than 35 years making her the longest serving woman lighthouse keeper in Liverpool.

For the remaining time there was a working lighthouse at Bidston there were a total of 17 more keepers.

SIGNALLING STATION

The merchants expecting goods to be arriving and dock supervisors needed to know when their ship was coming.

For this purpose, a signalling station was built on Bidston Hill, possibly as early as 1763, the location being chosen due to its visibility from the docks and the visibility of vessels rounding Point of Ayre or sailing past Formby Point.

FLAGS

The original signalling method was by the use of flags to signal the arrival of a vessel.

Each company had its own flag. Figure 17 shows the flags with the owner of each flag is listed.

The painting shows the lighthouse and also a windmill that had been on the hill, possibly as early 1569.

At its peak there were 103 flag poles sited on the hill. The watchman who reported the signals to the dock Forman on Liverpool Docks was initially located on a warehouse in Chapel Street, then on the tower of St. Nicholas Church and lastly on Tower Buildings.

When a ship was sighted and identified the flag runners had 11minutes to raise the correct company flag and the correct cargo flag on the correct pole.

This was to give sufficient time between the ship being sighted for the dock Forman responsible for unloading the vessel to arrange for the labour to berth and unload the ship.

This meant the men would only be paid for actually undertaking work and not hanging about waiting for the ship to berth.

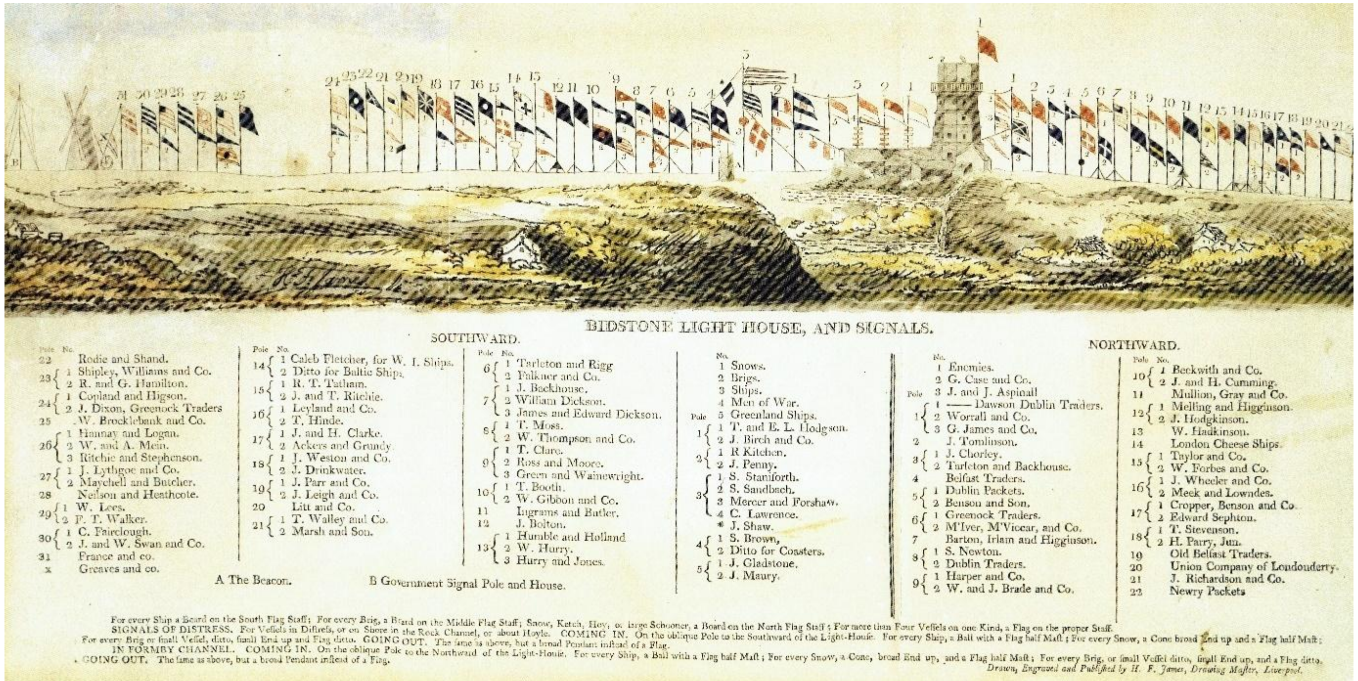


Figure 17: Bidston Lighthouse and Signals,1807 colour
(By kind permission of Williamson Art Gallery and Museum)

When the lighthouse was built, the lighthouse keeper became responsible for the operation of the signal station. As we have seen Richard Wilding was the first keeper.

In 1790 he complained that *'his distinguishing Public Signal Flags & Boards were much decayed and worn out'*. Because of their importance Mr Hutchinson immediately arranged for them to be refurbished.

Each flagpole was 30ft (9.14m) tall and made of Baltic Pine. The flag poles were set in holes, some of which can still be seen near the lighthouse, see Figure 18.

As described below a new telegraph system was to be installed but the signal flags were continued and even extended in 1826.

Figure 19: Surviving flagpole hole
(By kind permission of Dr Stephen Pickles)

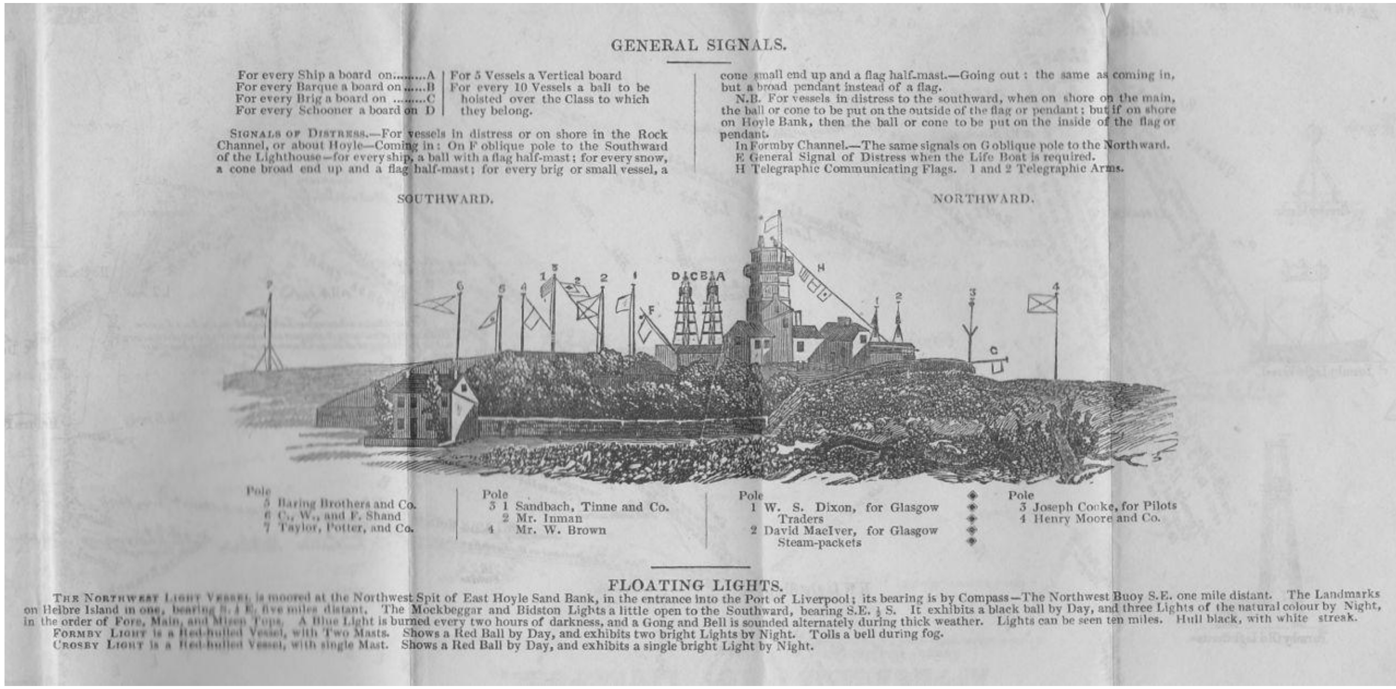
Figure 19 shows the lighthouse with the telegraph now consisting of two masts after upgrading in 1840. All but one set of poles were eventually removed in 1863 with the advent of the electric telegraph.

Only Mr Inman, Ship Owner, insisted on keeping his flag signals – he obviously did not trust modern technology!

OPTICAL TELEGRAPH

It was realised that a much more efficient method would be to signal the arrival of a vessel as it was passing the Isle of Anglesey.

This could be achieved by having telegraph stations located along the Welsh coastline with line of sight between each one to relay messages to Liverpool.



GENERAL SIGNALS.

For every Ship a board on.........A
For every Barque a board on ......B
For every Brig a board on C
For every Schooner a board on D

For 5 Vessels a Vertical board
For every 10 Vessels a ball to be hoisted over the Class to which they belong.

SIGNALS OF DISTRESS.—For vessels in distress or on shore in the Rock Channel, or about Hoyle—Coming in: On F oblique pole to the Southward of the Lighthouse—for every ship, a ball with a flag half-mast; for every snow, a cone broad end up and a flag half-mast; for every brig or small vessel, a cone small end up and a flag half-mast.—Going out: the same as coming in, but a broad pendant instead of a flag.

N.B. For vessels in distress to the southward, when on shore on the main, the ball or cone to be put on the outside of the flag or pendant; but if on shore on Hoyle Bank, then the ball or cone to be put on the inside of the flag or pendant.

In Formby Channel.—The same signals on G oblique pole to the Northward.

E General Signal of Distress when the Life Boat is required.

H Telegraphic Communicating Flags. 1 and 2 Telegraphic Arms.

SOUTHWARD. NORTHWARD.

Pole
5 Baring Brothers and Co.
6 C., W., and F. Shand
7 Taylor, Potter, and Co.

Pole
3 1 Sandbach, Tinne and Co.
2 Mr. Inman
4 Mr. W. Brown

Pole
1 W. S. Dixon, for Glasgow Traders
2 David MacIver, for Glasgow Steam-packets

Pole
3 Joseph Cooke, for Pilots
4 Henry Moore and Co.

FLOATING LIGHTS.

THE NORTHWEST LIGHT VESSEL is moored at the Northwest Spit of East Hoyle Sand Bank, in the entrance into the Port of Liverpool; its bearing is by Compass—The Northwest Buoy S.E. one mile distant. The Landmarks on Helbre Island in one, bearing S. ½ E. five miles distant. The Mockbeggar and Bidston Lights a little open to the Southward, bearing S.E. ½ S. It exhibits a black ball by Day, and three Lights of the natural colour by Night, in the order of Fore, Main, and Mizen Tops. A Blue Light is burned every two hours of darkness, and a Gong and Bell is sounded alternately during thick weather. Lights can be seen ten miles. Hull black, with white streak.

FORMBY LIGHT is a Red-hulled Vessel, with Two Masts. Shows a Red Ball by Day, and exhibits two bright Lights by Night. Tolls a bell during fog.

CROSBY LIGHT is a Red-hulled Vessel, with single Mast. Shows a Red Ball by Day, and exhibits a single bright Light by Night.

Figure 18: The Telegraph Station flags in decline, Holden's Almanack, 1858
(By kind permission of Dr Stephen Pickles)

A Liverpool to Holyhead telegraph was established by an Act of Parliament that had also authorised improvements to the docks. This was passed in June 1824.

It gave authority to the Liverpool Dock Trustees to 'establish a speedy Mode of Communication to the Ship-owners and Merchants at Liverpool of the arrival of Ships and Vessels off the Port of Liverpool or the Coast of Wales, by building, erecting and maintaining Signal Houses, Telegraphs or such other Modes of Communication as to them shall seem expedient, between Liverpool and Hoylake, or between Liverpool and the Isle of Anglesey'.

In 1825 the Trustees authorised Barnard Lindsay Watson to carry out a survey and provide costs. Watson identified that 11 stations would be required.

These were at Liverpool, Bidston, Hilbre Island, Voel Nant, Foryd, Llysfaen, Great Ormes Head, Puffin Island, Point Lynas, Carreglwyd, and Holyhead.

The signalling equipment being a ships mast about 50 feet high fitted with three pairs of moveable arms.

The top pair indicated 'hundreds,' the middle pair 'tens' and the bottom pair 'units.' Signalling was based on the transmission of numbers based on a Code produced by Watson.

On approaching Holyhead, an incoming ship would first transmit its number by means of signal flags and if any further information needed to be sent the appropriate signal would be sent from the ship.

These messages would then be relayed to Liverpool where the owners or their agents could arrange a berth and storage facilities for their goods or provide any additional services required by the vessel.

The first message passed over the completed line was on 5 November 1827.

The first ship to be reported was the *Napoleon* on 26 October 1827. The news of its safe arrival in England was taken back to its American owners by the *Josephine*.

This message travelled as far as Bidston, completing its journey by messenger as at the time the Liverpool station was unfinished.

The first message passed over the completed line on 5 November 1827 reported a change of wind direction at Holyhead from SW to W. Transmission time of this message was 5 minutes.[11]

Figure 20: Bidston Observatory
(By kind permission of Friends of Bidston Observatory)

Figure 21: The Doodson-Lege Tidal Predicting Machine
(By kind permission of The National Tidal & Sea Level Facility)

ELECTRIC TELEGRAPH

In 1850, Edwin Clarke approached the Liverpool Dock Trustees with regard to replacing the Semaphore with an electric telegraph.

It took until March 1855 before the Trustees agreed to consider it, when the Liverpool Mercantile Association began to lobby the Trustees.

The work was eventually undertaken and became the first electric telegraph in Britain to carry commercial and private messages.

Holyhead was linked to Point Lynas by landline; Point Lynas to Great Ormes Head by submarine cable; Great Ormes Head to Noel Vant, again by landline.

There was then a submarine cable to Hilbre Island; another submarine cable to the east bank of the River Dee; a landline to Bidston; and finally, a connection to Liverpool via a cable under the River Mersey.

The submarine cables were manufactured and laid by Glass Elliot & Co in 1858, using the chartered vessel *Resolute*. The line suffered from continuing technical problems, not least being severed when the anchors of the *Royal Charter* were dragged across it.

Ultimately, it was found impossible to maintain the cable between Point Lynas and the Great Orme and so it was replaced by a landline.[12]

BIDSTON OBSERVATORY

Although separate from the lighthouse it does sit right next to it so a short description of the building and its purpose is appropriate.

This beautiful grade-II listed building sits on the ridge of the hill and is visible from both Wales and Liverpool.

The Observatory was built in 1866 when Liverpool Observatory had to relocate due to the expansion of Waterloo Docks in the Port of Liverpool.

The building was built in 1866 to designs by Port of Liverpool Engineer in Chief George Fosbery Lyster.

It was constructed with the sandstone that the building would sit on, using the stone excavated during the construction of the cellars.

It had two domes, each dome contained a telescope - one used to calculate time, the other one known as his 'comet telescope'.

It was initially run by John Hartnup, an astronomer and director of the Liverpool Observatory, who was the first person to calculate the longitude of Liverpool. The work undertaken there includes:

- Chronometer Calibration. Mariners from all over the British Empire would send their chronometers to Bidston to be calibrated. An enormous ground floor room was the chronometer room with its walls covered in clocks. Up to 1,000 chronometers a year were calibrated. The observatory was built as space where you could bring chronometers and they would raise and lower their temperature to find out how they would work at sea;
- Setting the precise time every day for ships in the port by the firing of what was known as the one o'clock gun, the gun being fired by remote control from the observatory. The gun was fired for the last time on the 18th of July 1969;
- The research into time naturally evolved into tidal research. As we have already seen tidal predictions were originally carried out by the Holdens and successor companies.

  Eventually Tidal predictions were carried out at Bidston Observatory, the first carried out in 1924 initially by hand and then by early tide predicting machines. A famous name was involved in the design of the earlier tidal prediction machines, George Darwin, the second son of Charles Darwin.

In 1948-49 a past Director, Dr Arthur T. Doodson designed the Doodson-Légé Tide Predicting Machine, which was built by Légé & Co. of London. It was in daily use from then until the early 1960s, when it was superseded by the electronic computer.

At one time all of the world's tide times were calculated at Bidston. It was a smart machine, a couple of metres wide and covered in brass gears, pulleys and cogs, used to predict tide times.

It is now on display at the National Oceanographic Centre in Liverpool. It can be said to be effectively the first computer that could predict a year of tide times and height anywhere in the world.[13, 14, 15]

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