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Hydraulic engineering works for the benefit of navigation in the new Rotterdam harbours.

1. Introduction

The completion of the new harbours west of Rotterdam known as the Europoort complex has made it necessary to extend the navigational aids in the area. The outer harbour, which reaches far out into the North Sea, has a central entrance which is divided upstream into two lanes by a midstream dam, the channel giving access to the older part of the port of Rotterdam being on the north side of this and that giving access to Europoort on the south side.

The location of the access channel has had to be indicated by a new central line of lights for the benefit of deep-draft shipping. As ships have to be able to take their bearings from a great distance the two light-line lighthouses are very tall.

The heads of the northern and southern moles are some 5 kilometres off the coastline and must be provided with a harbour light for safety reasons. Placed on the moles, these lights will have to stand up to heavy buffeting from the stormy waters of the North Sea. For this reason they had to be placed well above the water. The construction of the moles makes it impossible to reach the towers via the moles themselves or by ship. The maintenance engineers have to be taken there by helicopter.

The radar installations along the fairway from Hook of Holland to Rotterdam have to be adapted, and observation of the multifarious shipping movements off the harbour entrance requires a radar station out at sea.

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The installations which are to be built are shown in Figure 1.

2. The towers of the 112° central light line

Indication of the axis of a channel is a good aid to navigation. This can be done by erecting two beacons, the front one lower than the rear one, both being in line with the axis of the channel. For improved visibility the beacons are now lit day and night. The visibility of the light line depends on a great number of factors. In addition to the skill of the observer and the aids he has, there is the distance between the two lights, the rigidity of the towers, the size of the source of light and atmospheric conditions. The range of visibility also depends on the height of, and difference in height between, the two towers and the candlepower of the lights they support.

The central light line for the new, combined harbour mouth indicates the position of the channel which has been dredged out in recent years to extend the harbour mouth for deep-draft shipping. The distance for which this line must be utilizable is 11 km for a total required visibility of 15 km. Tests have shown that the towers should be 1100 metres apart and should differ in height by at least 15 metres. So as not to be obstructed by the bridge, funnel and suchlike of unladen ships the lower tower needed to be 30 metres above the water. The towers are octagonal, giving them a certain relief which improves their visibility. For the same purpose, alternate panels have been painted white and black. Because of its position at the end of the midstream dam, the lower tower needed to be made more easily identifiable when visibility was bad, so it was fitted with a number of fog lights.

Both light-line towers are situated in the open sea. The western one is particularly exposed to heavy buffeting from the waves. Tests in the Hydraulics Laboratory at Delft showed that the towers would be subjected to a quasi-static wave load of 750 tf. The wave uprush reaches a height of 12 metres above mean sea level.

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The towers had to be designed with due regard for the difficulties presented by conditions at the site. At the time of construction the protective moles had not yet been completed and the wave attack then may have been greater than it will be ultimately.

The midstream dam was also unfinished. In view of this, the work of erecting the towers was highly sensitive to changes in weather conditions and ultra-rapid construction methods had to be employed. This was achieved by pre-constructing large components elsewhere in such a way that they could be put together with the least possible delay.

The foundation of each tower was a hollow prestressed concrete pile with an external diameter of 4.25 m and 0.30 m walls to bear the heavy load. Similar piles had been used for the foundations of the Zeeland bridge. They can be sunk in position in about 10 hours (figure 2a).

The midstream dam in which the towers are incorporated was completed when the foundation piles were in position (figure 2b).

The towers themselves were erected when the dam had been finished and was still accessible in good weather (figure 2c).

To erect the structures as rapidly and safely as possible they were built of prefabricated concrete sections 4.60 metres high. The surfaces of the fillets to be joined together were mortised. The fillets could be joined separately either to each other or to the foundation pile. The great advantage of this was that the construction work could be interrupted without endangering the whole project in the event of a sudden storm. Any shuttering erected on the site would have been washed away time and again.

The concrete sections each weighed 50 tons or more and were already installed with such vital elements as stairs, platforms, ventilation and lift shafts, lamp sockets etc. A 165-ton mobile crane was used to hoist the sections into place (figure 3).

The joining surfaces were brought into line by matching trapeziform joints. Before being eased into their final position the joining surfaces of both sections were covered with epoxy resin adhesive. The last element to be filled was the concrete

- platform -

platform carrying the lamp house. It took only two days to build one tower.

3. The harbour lights at the ends of the moles

For safety reasons the entrance to a harbour or harbour area should be well marked. This is often done with beacons which are also on at night. It is therefore essential in the present context to mark the ends of the moles at the entrance to the Rotterdam harbour area with beacons. The heavy traffic passing through the harbour mouth night and day and the size of the ships call for fairly elevated lights.

The lights have to be set in the ends of the moles. The body of the moles is made up of stones of varying sizes covered with concrete blocks each weighing 50 tons. As the moles only rise 2 metres above mean sea level and the ends are situated 5 kilometres off the coast, it is impossible to reach the latter by travelling along the moles. The towers are set in the rough stonework of the pier in seas with an almost permanent heavy swell, so it is also virtually impossible to reach them by ship. It was largely these limiting factors that determined the method of construction and final appearance of the harbour lights.

It was realized that the only way to reach the lights for maintenance work would be by helicopter, and a landing platform had to be provided for the purpose on top of each tower. The platform had to be virtually horizontal. The preliminary investigation was based on two possible methods; one of these was similar to that used for the light-line towers described above. As the towers would be subject to exceedingly heavy buffeting from the waves the idea of extending them at the bottom on three sides was considered, the extension to rest on three heavy concrete piles of the same type as those used for the light-line towers. The mole would be completed with stones and concrete blocks after the towers had been put in position. One disadvantage of this construction was that the towers would have been rigid, but embedded in the body of the mole which would be shifted by soil movements and wave buffeting. The stresses thus

- set -

set up would have been so great that this plan was rejected.

The alternative was to use a wide caisson, which would be part of the body of the dam, as the foundation of the tower. The upper side of the caisson was to be level with the top of the dam and the sides were to be shored up with stone and concrete blocks. This method, which is soon to be employed, is shown diagrammatically in figure 4. and 5.

Subsoil movement must also be expected here, and even stratified movement in view of the profile of the subsoil. The caisson will be moved along at the same time and the foundation will tilt. Neither the tower nor the helicopter platform can be allowed to tilt and this is the reason why the present design incorporates a device to correct movements out of the vertical. By hinging the tower to the upper side of the caisson and using horizontal piston jacks it will be possible to move the tower horizontally in relation to the foundation construction and effect a correction of 1:25. This is sufficient to offset any soil movement. The tower in its caisson will contain a concrete machine room, high enough to be out of reach of the waves. This will be connected with the platform, which will be made of steel. For air traffic safety reasons the harbour light will be located underneath the platform.

The tower will be made of prestressed concrete, the tension cables also running through the machine room. The tower will contain a number of rooms needed in connection with the operation of the light.

The caisson is a reinforced concrete structure. The Dutch Department of Water Control and Public Works (Rijkswaterstaat) has had much experience of caissons of this type in recent years in connection with the Delta Plan; its engineers know a great deal about the overall stability and the moving and sinking into position of such structures. The bottom is designed to achieve the greatest stability with the minimum diameter. The upper half of the caisson is clad in wood to protect it against the abrasion by the enormous concrete blocks expected during the first few years.

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The designers constantly had to bear in mind the fact that each of the components of the harbour lights would have to be made in a special construction harbour or dock. The parts will have to be put together and the equipment prepared for operation in the shelter of the harbour area of Hook of Holland. Consequently, on-site work at the ends of the moles out at sea will be cut to a minimum. This is also one of the fruits of the experience gained in recent years in carrying out large hydraulic engineering projects along the Dutch coast. Work at sea must be minimized, and the work that has to be done must be as simple and quick as possible in order to take the fullest possible advantage of the sporadic periods of good weather and calm seas.

Both caissons will be built on a pontoon able to carry almost 10,000 tons. This can be done in an established construction yard where transport, cranes, concrete construction equipment and specialized manpower are to hand.

This is better than constructing a temporary cofferdam which would have to be filled in again later and where all the necessary installations would only be temporary. The pontoon method will also make it possible to transport the caisson safely by sea from the construction yard to Hook of Holland. It would be impossible to float the caisson along canals and rivers owing to its weight and the resultant depth of draft. The caissons, towers, engine rooms and landing platforms are being put together and installed with lights, diesel generators, oil tanks, nautaphones and emergency accommodation for inspection staff in the Europoort harbour area.

When work on the moles has progressed far enough and other conditions are favourable the harbour light will be towed to its position. The distance to be covered is only 10 kilometres. With a freeboard of 3 metres and a metacentric height of at least 1 metre this manoeuvre should be quite safe. By letting in water through valves the whole harbour light construction will sink onto a previously prepared gravel bed. When the ballast compartments of the caisson have been filled with gravel and broken

- stone -

stone the harbour light will be firmly fixed in place and the mole will then be completed.

4. The radar tower out at sea

The modernization of the radar installations in the Rotterdam harbour area has made it desirable to incorporate in the system a station situated far out at sea. The tower to carry the radar equipment will not be set in place for some years. However a preliminary design is already being worked out and tested. A particularly important matter that is being investigated is the wave attack on the towers. The wave spectrum actually measured at sea is being used in the model tests, which are being carried out in the Hydraulics Laboratory at Delft. The preliminary design for the tower is shown in figure 6.

Once again, the idea is to place the tower in a caisson. There is an engine room at the top of the tower and the roof serves as a helicopter platform, an essential facility because the tower will be operated by remote control and maintenance engineers will only be able to reach it by helicopter. The radar tower proper is at one edge of the platform and rises well above it in order to minimize shadow effects.

The sandy bed in the whole area in which the tower affects wave movement will have to be ballasted with gravel. As the bottom may also settle unevenly here, the tower will also be adjustable in relation to its caisson foundation. Many years later, when the subsoil has become consolidated, the space between the tower and the caisson surround will be filled up with concrete mortar.

As the buffeting the tower will receive is a crucial factor affecting its stability, the structure should be made as slim as possible where it is exposed to the waves; indeed, the preliminary design shows a tower that is relatively slim to a great depth, and the stabilizing caisson body is relatively shallow and its upper surface is a considerable distance below the surface.

Before the preconstructed tower, completed in a protected harbour area, can be floated out to the site, the walls of the

- caisson -

caisson will have to be raised with temporary concrete panels that will protrude well above the water when the caisson has been sunk. This method has proved very effective on many occasions when completing dikes as part of the Delta project. It has also been adopted in Sweden in recent years for the erection of lighthouses, with good results.

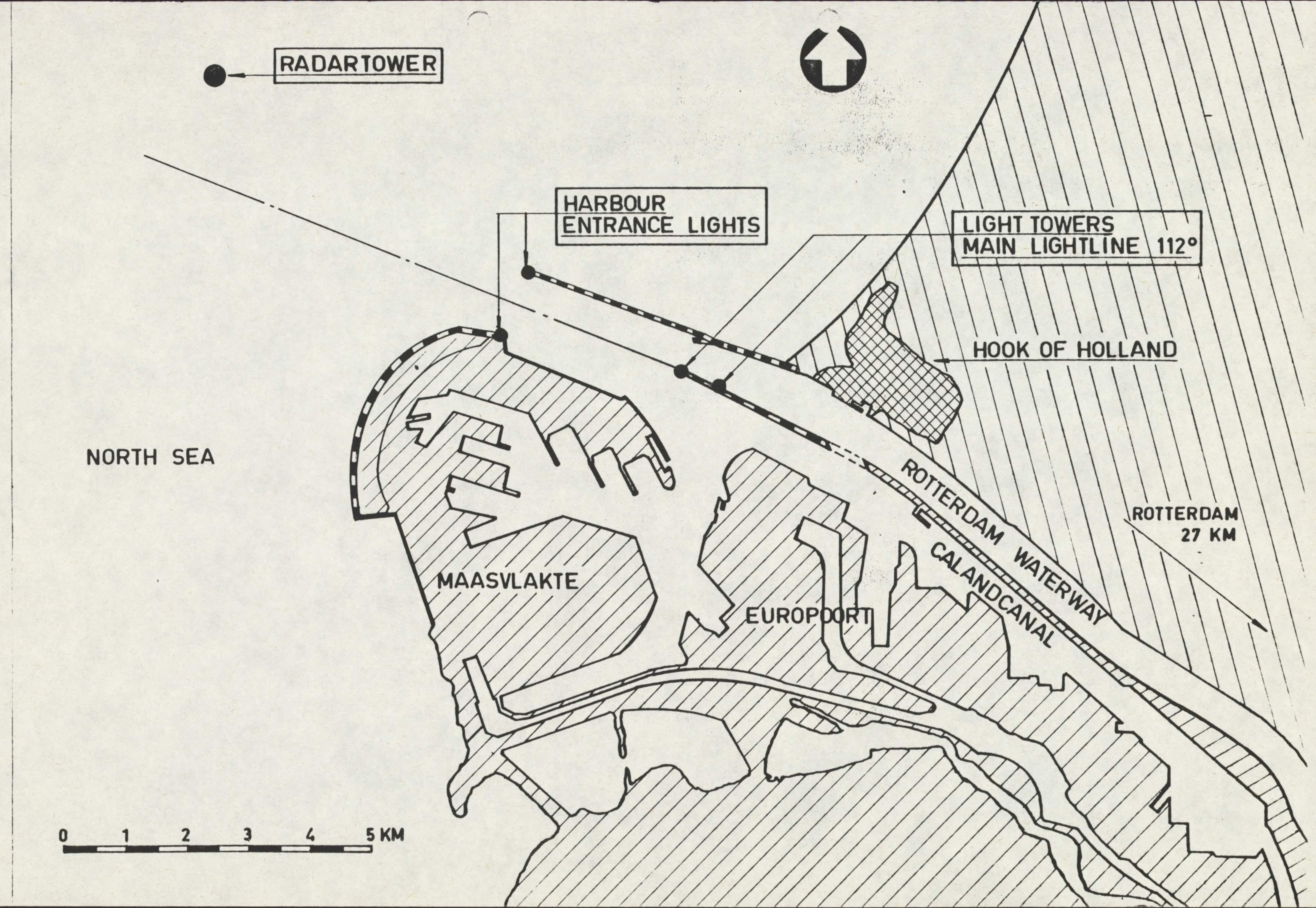
Once the caisson has been sunk, the temporary wall sections are pulled off by tugs and left on the sea floor. The caisson is then ballasted with sand and stone. The stone must act as a filter but may not allow any sand to be washed away, and the upper layer must be heavy enough to remain in position despite heavy wave attack.

SUMMARY

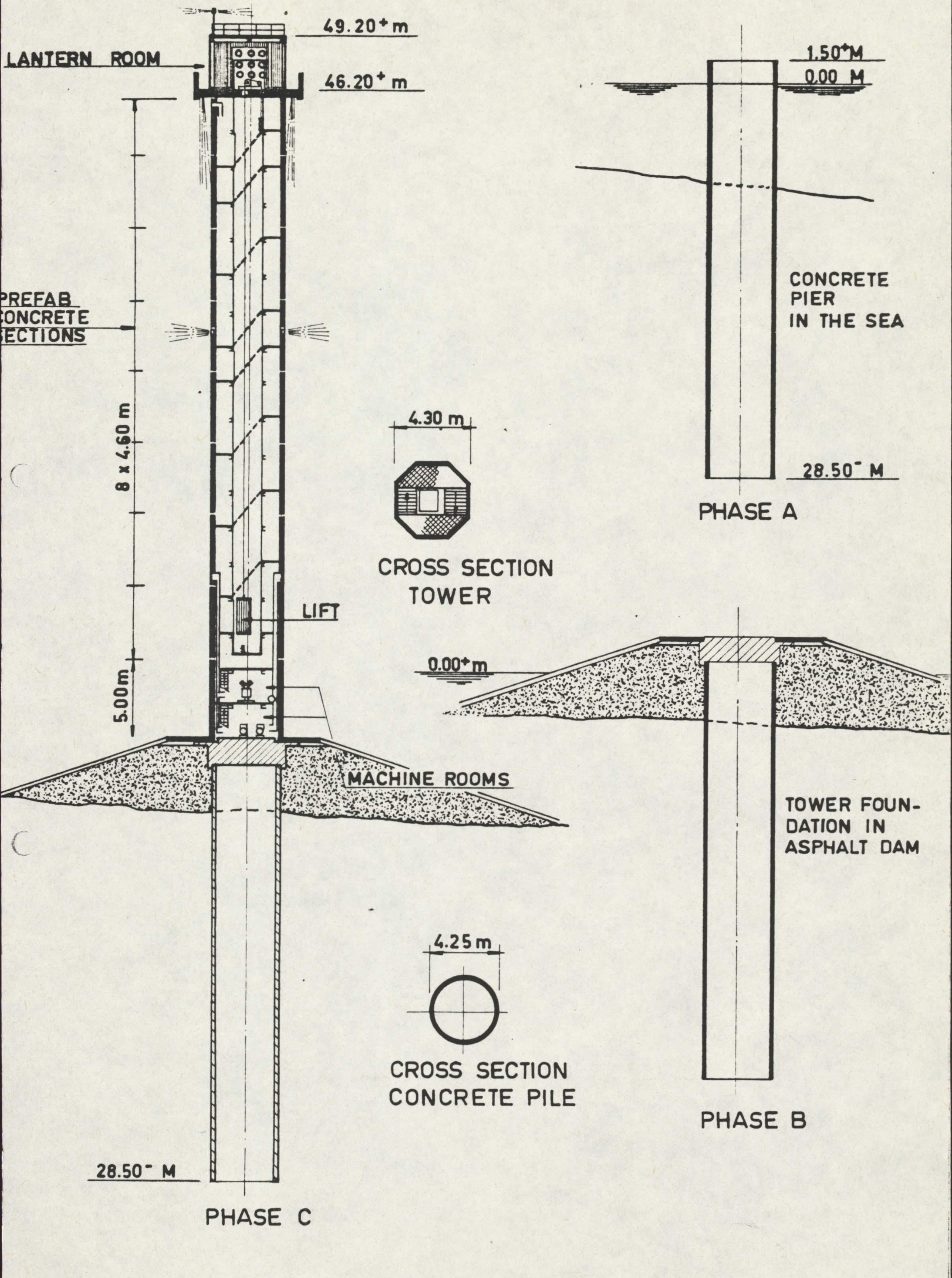
The completion of the new harbours west of Rotterdam, known as the Europoort complex has made it necessary to extend the navigation aids in the area.

Lightline towers, harbour light at the end of the moles and a radar tower are belonging to these aids.

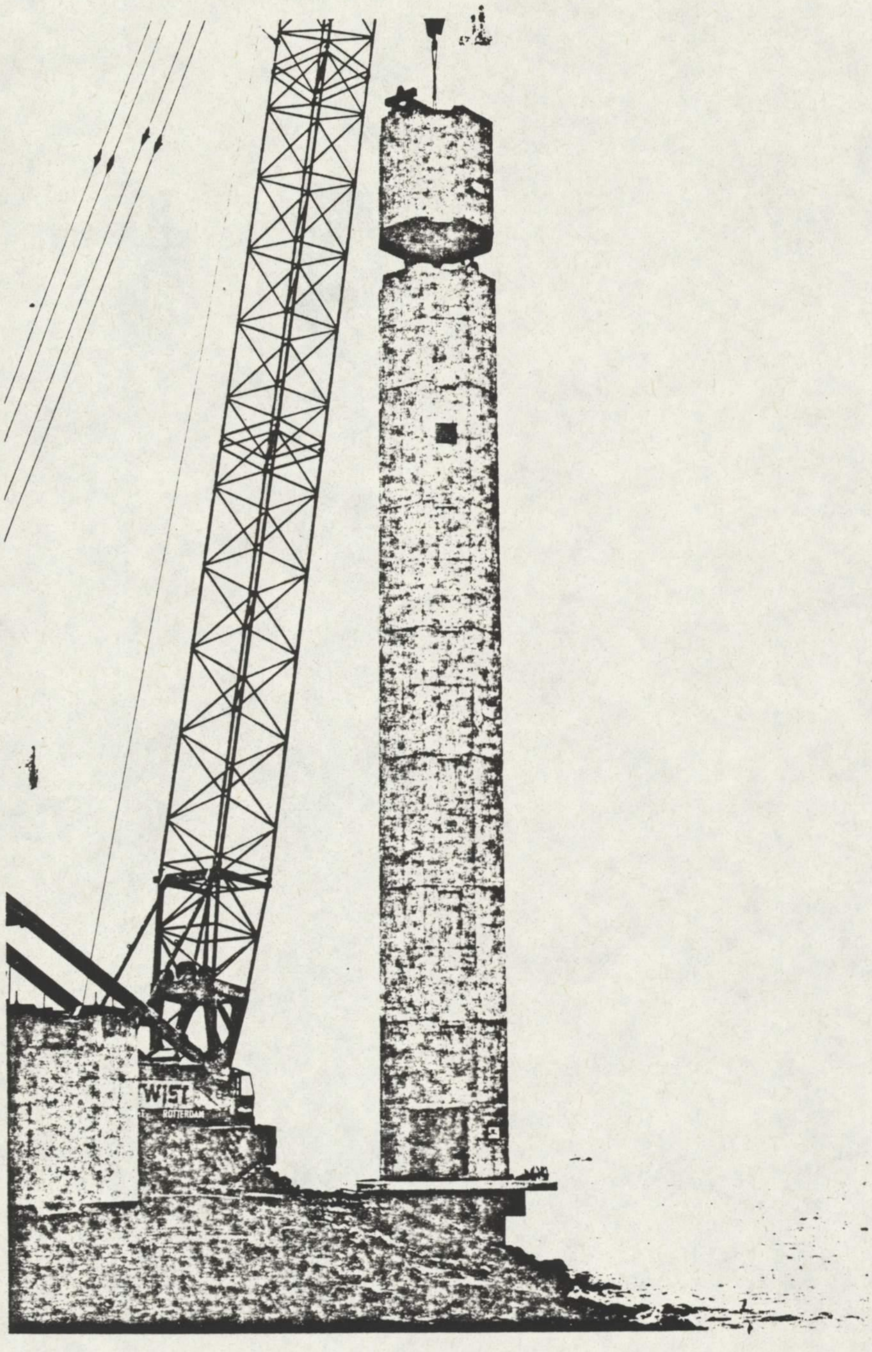
Seeing that the total member of workable days a year in the open sea for traditional building-methods is not more than 10, a design, based upon sea circumstances is necessary. That will say, a design, whereby the construction as complete as possible is made on a sheltered building place and the operation time at sea is short.

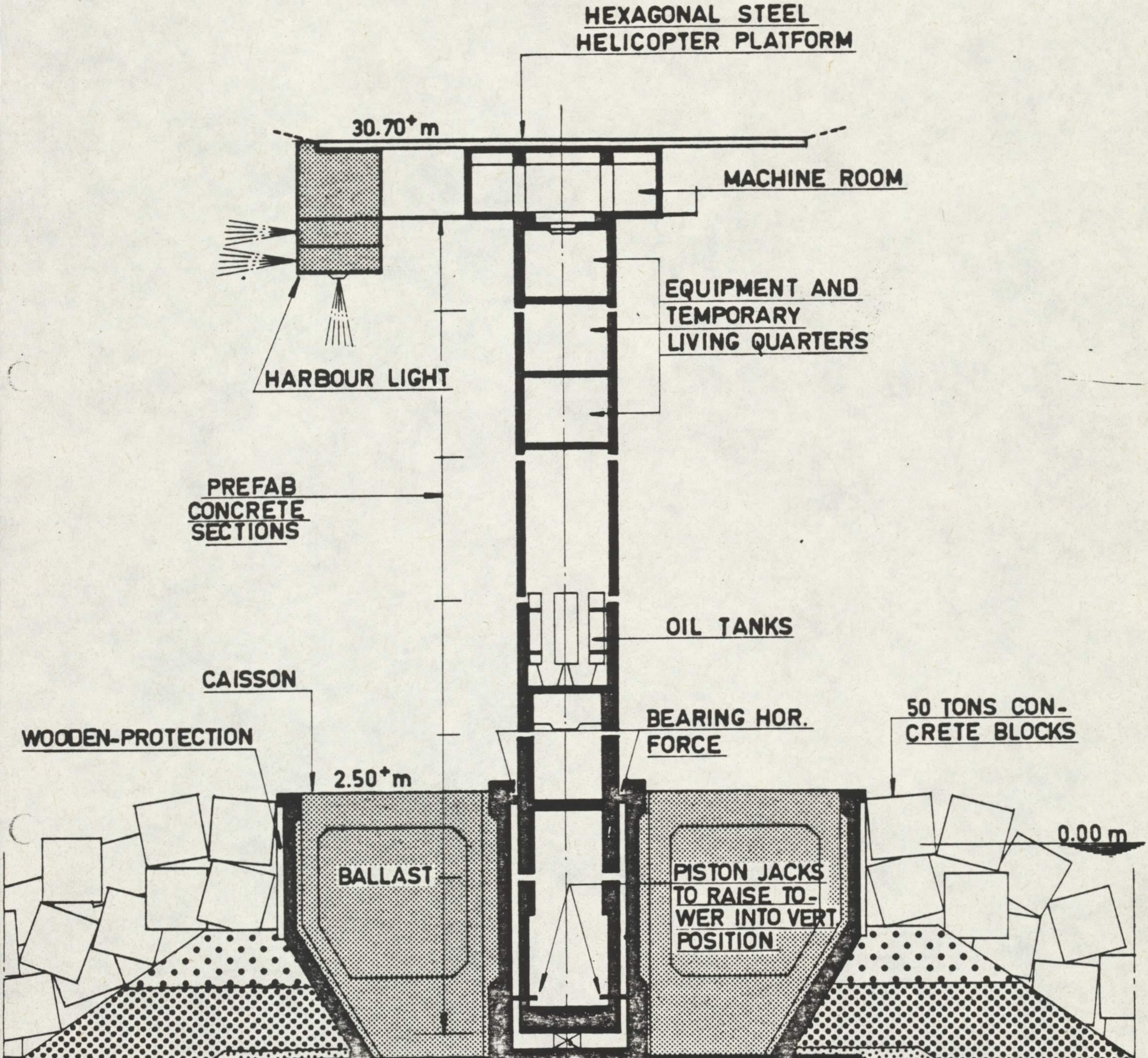


RADARTOWER
HARBOUR ENTRANCE LIGHTS
LIGHT TOWERS MAIN LIGHTLINE 112°
HOOK OF HOLLAND
NORTH SEA
ROTTERDAM WATERWAY
CALANDCANAL
ROTTERDAM 27 KM
MAASVLAKTE
EUROPOORT
0 1 2 3 4 5 KM

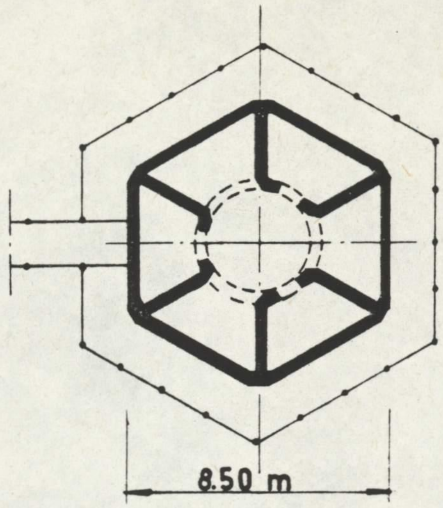


49.20+ m
LANTERN ROOM
46.20+ m
1.50+ M
0.00 M
PREFAB
CONCRETE
SECTIONS
8 x 4.60 m
CONCRETE
PIER
IN THE SEA
4.30 m
28.50- M
PHASE A
CROSS SECTION
TOWER
LIFT
0.00+ m
5.00 m
MACHINE ROOMS
TOWER FOUN-
DATION IN
ASPHALT DAM
4.25 m
CROSS SECTION
CONCRETE PILE
PHASE B
28.50- M
PHASE C

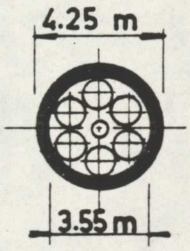

WIST



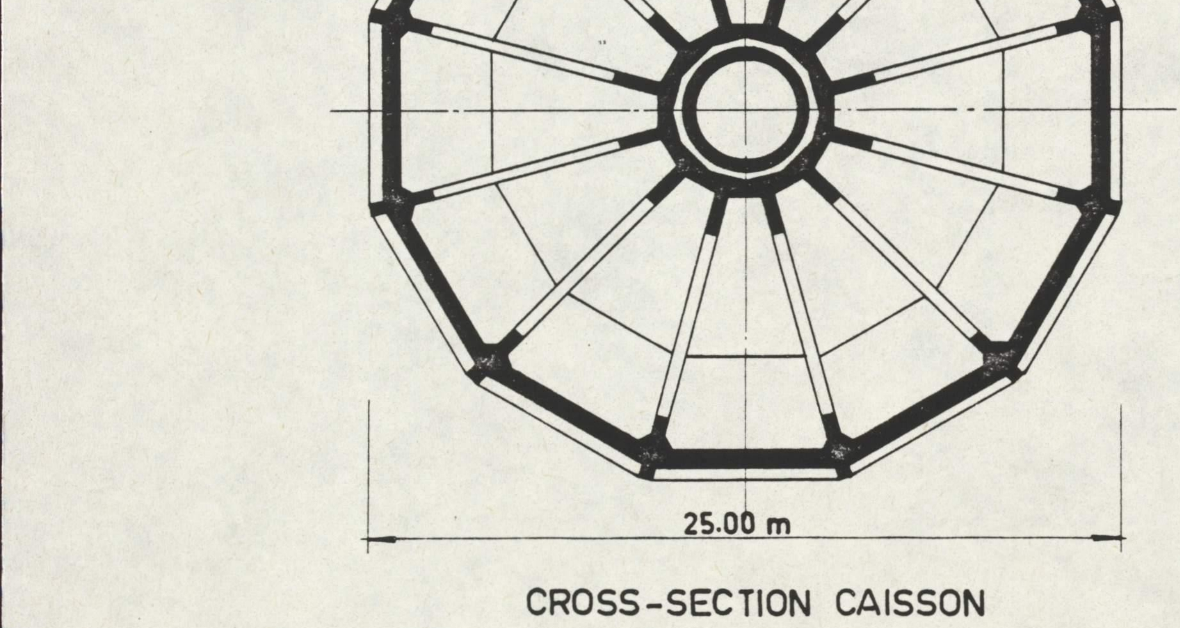
HEXAGONAL STEEL
HELICOPTER PLATFORM
30.70+ m
MACHINE ROOM
EQUIPMENT AND
TEMPORARY
LIVING QUARTERS
HARBOUR LIGHT
PREFAB
CONCRETE
SECTIONS
OIL TANKS
CAISSON
WOODEN-PROTECTION
BEARING HOR.
FORCE
50 TONS CON-
CRETE BLOCKS
2.50+ m
0.00 m
BALLAST
PISTON JACKS
TO RAISE TO-
WER INTO VERT
POSITION
BEARING VERT. FORCE
(HOR. MOTION POSSIBLE)
STONE AND GRAVEL



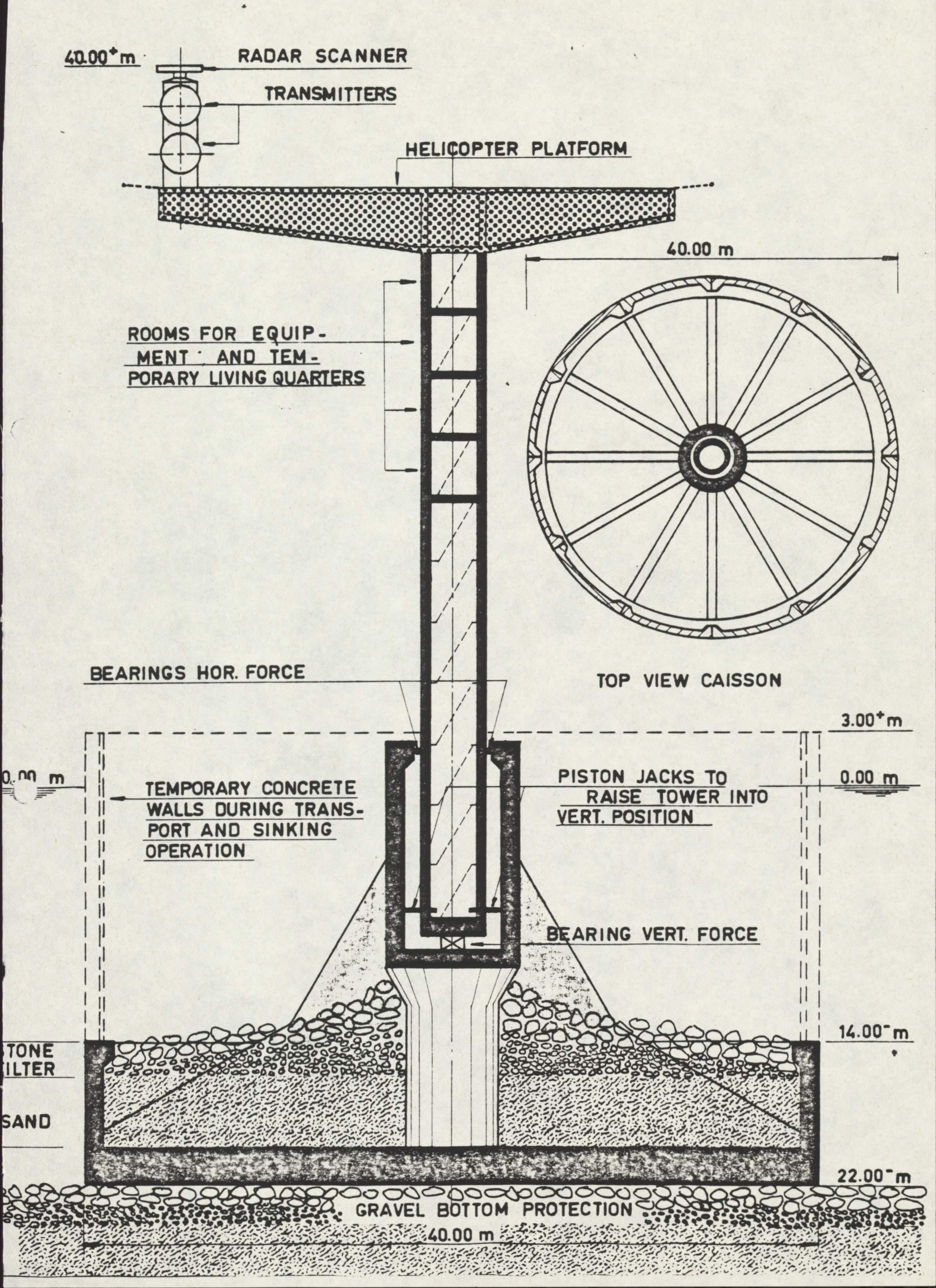
CROSS-SECTION MACHINE ROOM



CROSS-SECTION TOWER



CROSS-SECTION CAISSON


40.00+m
RADAR SCANNER
TRANSMITTERS
HELICOPTER PLATFORM
40.00 m
ROOMS FOR EQUIPMENT AND TEMPORARY LIVING QUARTERS
TOP VIEW CAISSON
BEARINGS HOR. FORCE
3.00+m
0.00 m
PISTON JACKS TO RAISE TOWER INTO VERT. POSITION
0.00 m
TEMPORARY CONCRETE WALLS DURING TRANSPORT AND SINKING OPERATION
BEARING VERT. FORCE
STONE FILTER
14.00-m
SAND
22.00-m
GRAVEL BOTTOM PROTECTION
40.00 m