

FIRST CONCRETE GRAVITY BASE STRUCTURE FOR DUTCH SEAS

On June 13, 1992, NAM's concrete gravity base production and storage platform left the construction site in the Verolme dry dock near Rotterdam, to be towed to a location 220 km North of Den Helder, where it was installed on the seabed. In the summer of 1993, after placement of the steel topsides, the offshore platform will commence production of the oil and gas reserves in the F3 block of the Dutch Continental Shelf.

The project was realized by Hollandsche Beton- en Waterbouw bv, and Van Hattum en Blankvoort b.v., as an "EPCI" contract, entailing engineering, procurement, construction and installation.

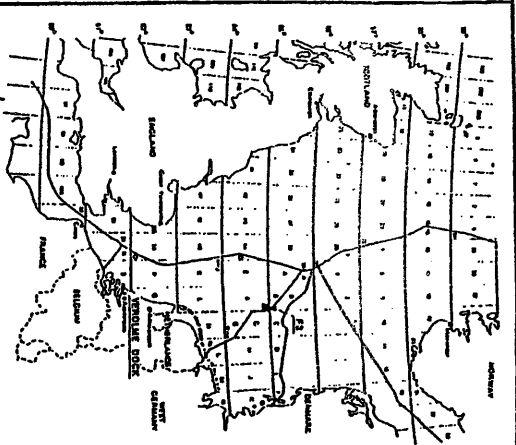
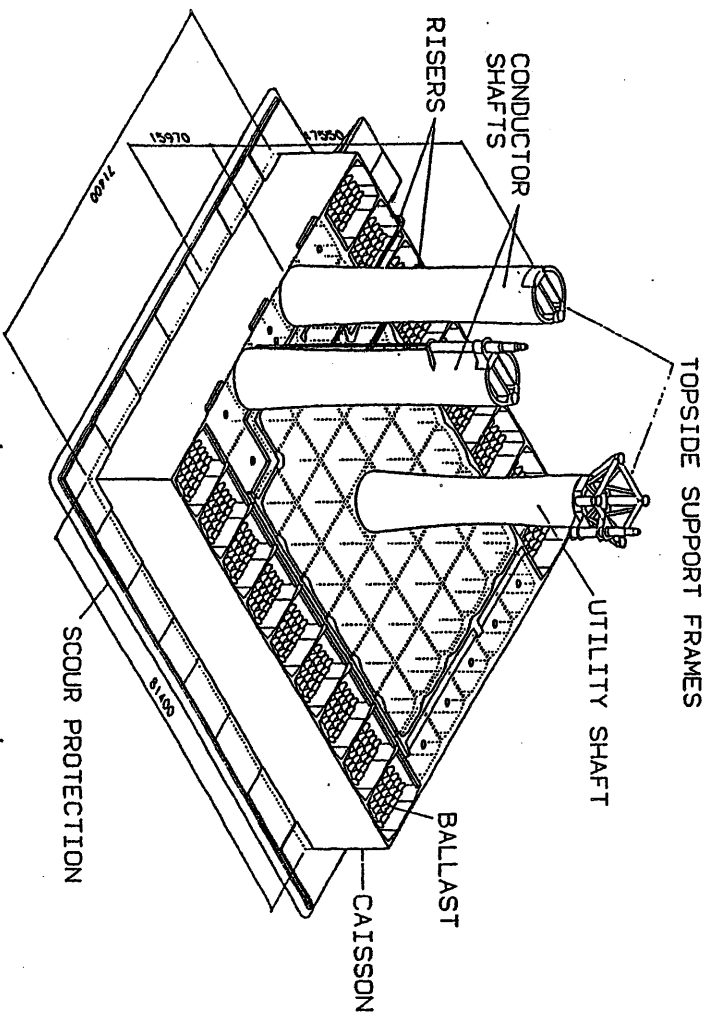
A construction period of eleven months, following the detailed design, which started six months earlier, closely, imposed high managerial and organizational demands.

This gravity base platform, as commissioned by NAM, is the first concrete platform in the Dutch Sector of the North Sea. Concrete was considered to be the most suitable building material in this particular case, due to the fact that the platform is planned for both production and storage.

The facility consists of a concrete caisson of 71 metres (short side) x 81 metres (long side), with a height of 15 metres, and is divided into 63 cells (see fig. 1). Three shafts rise from the caisson, each with a height of 50 m - two on the shorter side of the Gravity Base Structure (conductor shafts) and one in the middle of the caisson (the so-called utility shaft). The cell below the utility shaft contains the equipment for seagoing transport, installation on the seabed and oil transport into and out of the caisson during the operational phase.

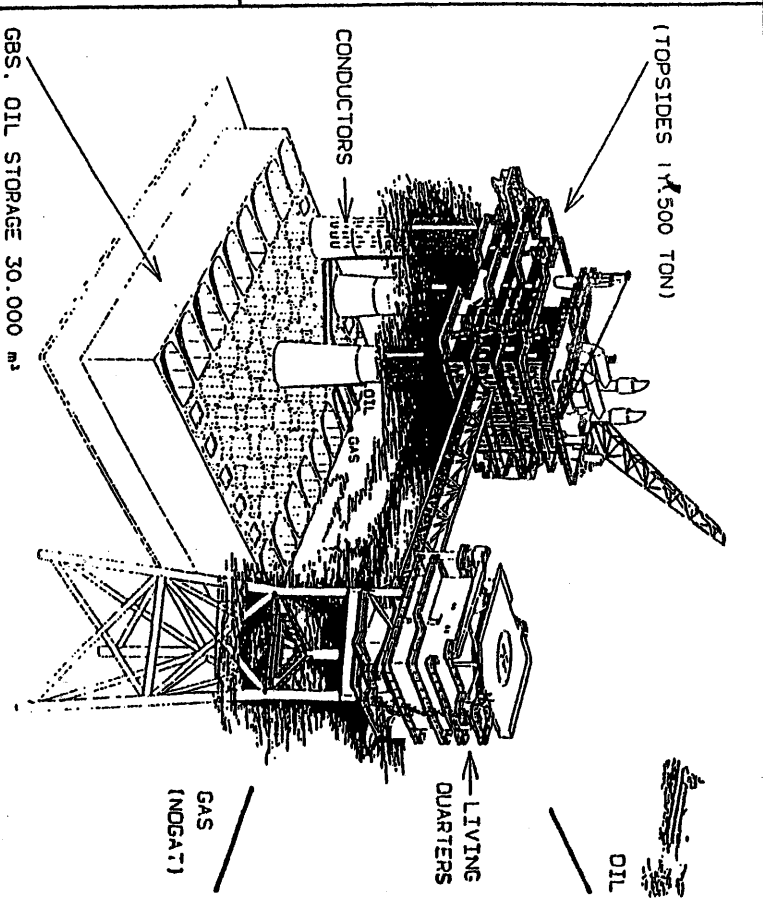
It is this concrete construction, complete with installations, pipelines, etc., which has been constructed in the Verolme dry dock, towed out to sea and installed at the F3 location (see fig. 2). After installation (see fig. 3) in a water depth of approximately 42 metres, the wells to the underlying oil/gas reservoir will be drilled through the conductor shafts. Thereafter, during summer 1993, the topsides (super structure) will be installed on top of the three shafts.

A separate steel jacket, bearing the living quarters for personnel, will be installed on top of the three shafts.



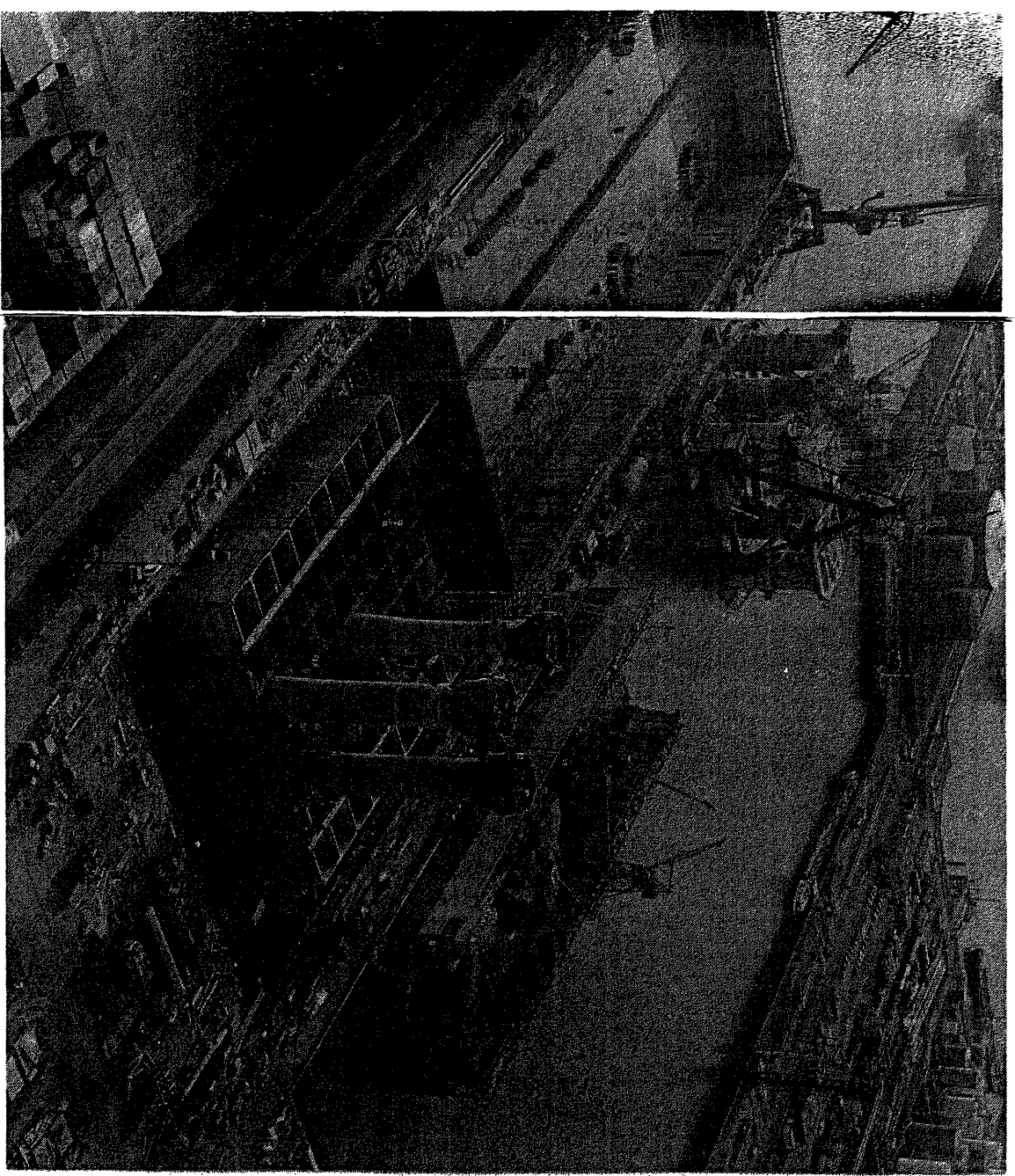
2 Location of the F3 field in the North Sea

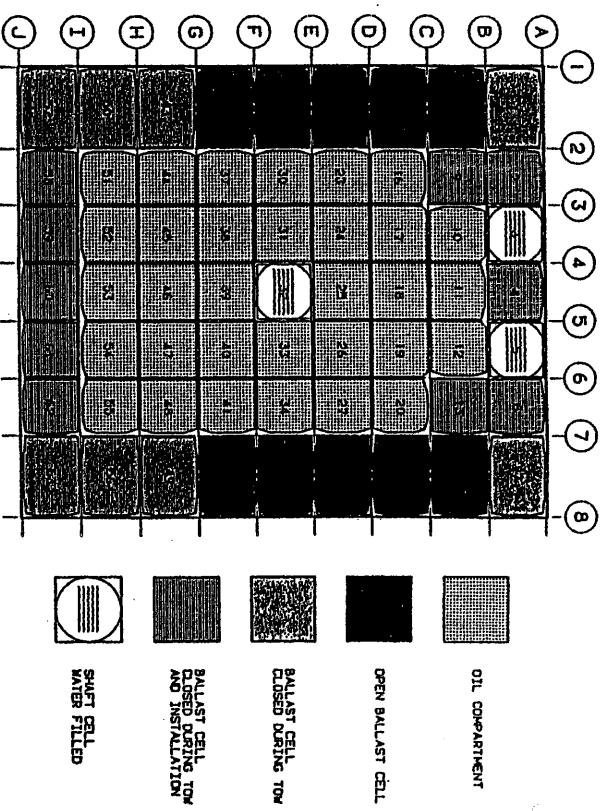
3 Production and storage platform in operation



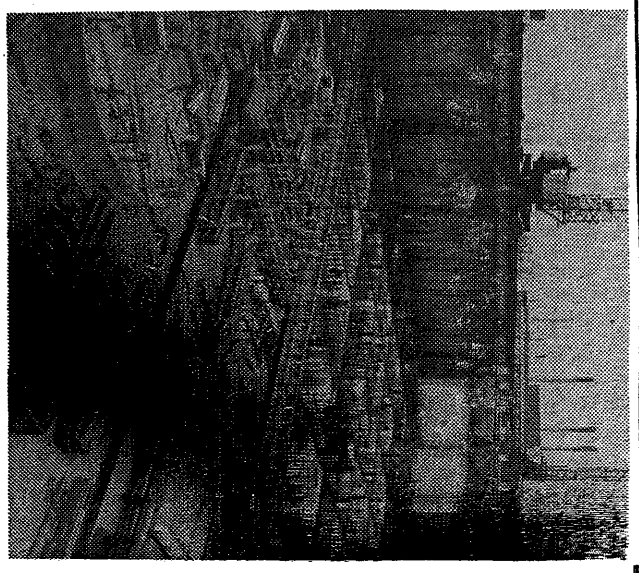
situated next to the GBS and will be interconnected via a walkway. A submerged pipeline, the "NOGAT pipeline", stretching from the F3 GBS location to Den Helder, will be used for the transportation of gas. An off-loading tower with berthing boom will be situated at a distance of two kilometres, connected to the GBS by a pipeline. The produced oil will be conveyed from this off-loading tower on a regular basis by a shuttle tanker. The outer cells on the long side of the caisson, are open compartments which, after placement of the GBS, will be filled with ballasting material.

Five closed cells, situated on the short side, function as water ballast compartments during the installation phase. These cells will also be filled with solid ballast material after placing the GBS on the seabed. The inner area of the GBS comprises 32 watertight compartments (with a total capacity of 30,000 m³) designed for the storage of oil (see fig. 5). Oil storage in the F3 GBS is not the usual oil-water displacement system, but the so-called dry cell storage system in which the oil is blanketed by an inert gas. The selection of this system is based on environmental requirements. It is the first GBS facility of its kind in the world.

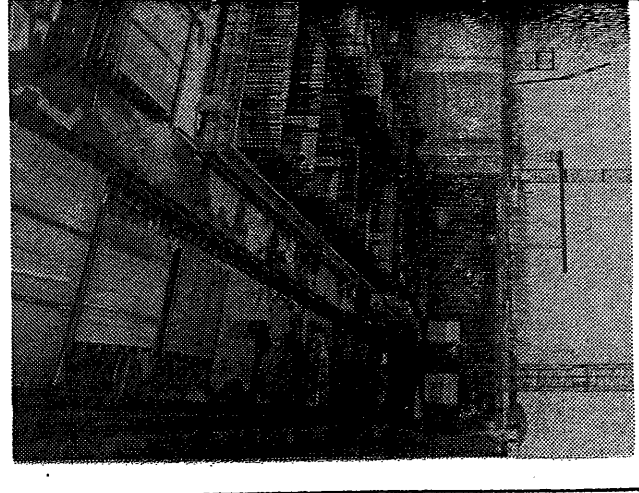




4 Horizontal cross section with different cell functions



Shipforming first wall sections



Construction of the base slab

Structural concrete, for the transfer of loadings into detailed design drawings. Structural steel, for the design of the transfer pieces on top of the concrete shafts, the fenders protecting the risers on the outside of the shafts and the attachment of these risers being subject to heavy wave and current loading to the shafts.

- Marine engineering, for all matters regarding tow and installation.
- Mechanical, Electrical and Instrumental engineering, for all systems required for installing and operating the GBS. These are the so called CMO (Contractors Mechanical Outfitting) and the MMO (Main mechanical Outfitting). Both systems required mainly pipes and pumping systems with their control and recording.

The CMO systems, required for ballasting during tow and installation, will eventually be used again after 40 years for retrieval of the structure. The five disciplines concerned were continuously involved in interface discussions, being of great importance to the progress. Right from the start, DNV was involved as checking and certifying authority as NAM had nominated DNV as subcontractor to the contractor. DNV had to approve the design and issue a certificate of supervision before the platform was allowed to start tow out and installation. For this reason all calculations and all construction drawings were submitted for approval.

Working according to DNV practice required an unusual amount of finite element analysis from the contractor up to a point of disputable detail. It became evident that a front end approach in structural engineering, paying much attention to shape, sizing and material selection as used by the contractor, gradually replaced an elaborate, back end approach of more and more detailed finite element analysis.

DESIGN AND CONSTRUCTION

The Bottomslab

The geotechnical concept for the foundation required a rib type slab. This choice was made in order to avoid direct contact of the bottomslab plates with the foundation (see fig. 6).

The ribs, penetrating the bottom plate and located directly underneath the caisson walls, penetrate into the

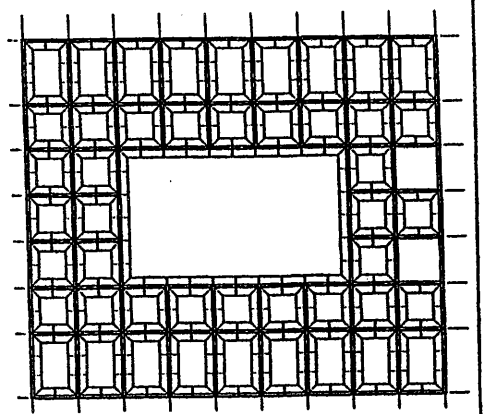
ing stage, such as placing the prefabricated roof plates and installation of pipeline systems. This latter stage continued up until June 13th, 1992 when the tow-out to the F3 location started.

Five specials

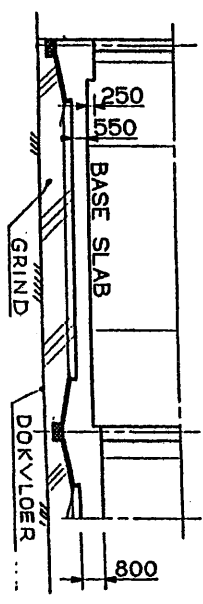
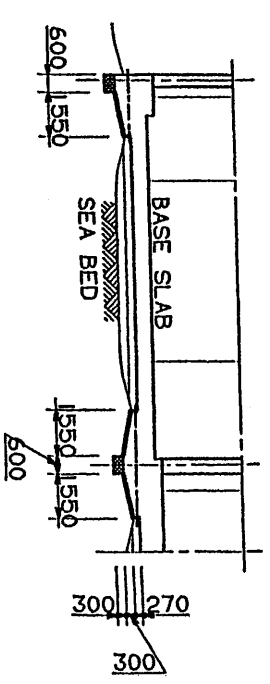
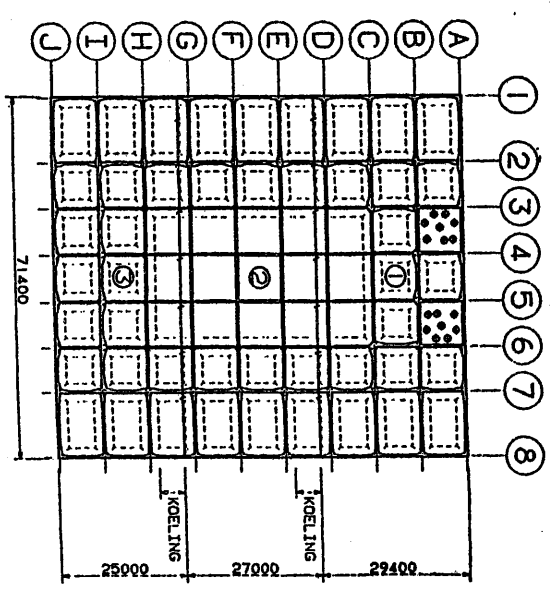
Designing the F3 GBS, five specific specialties were involved:

- Geotechnical engineering, for all foundation aspects

6 Scheme of the rib foundation beams



7 Construction of the base slab

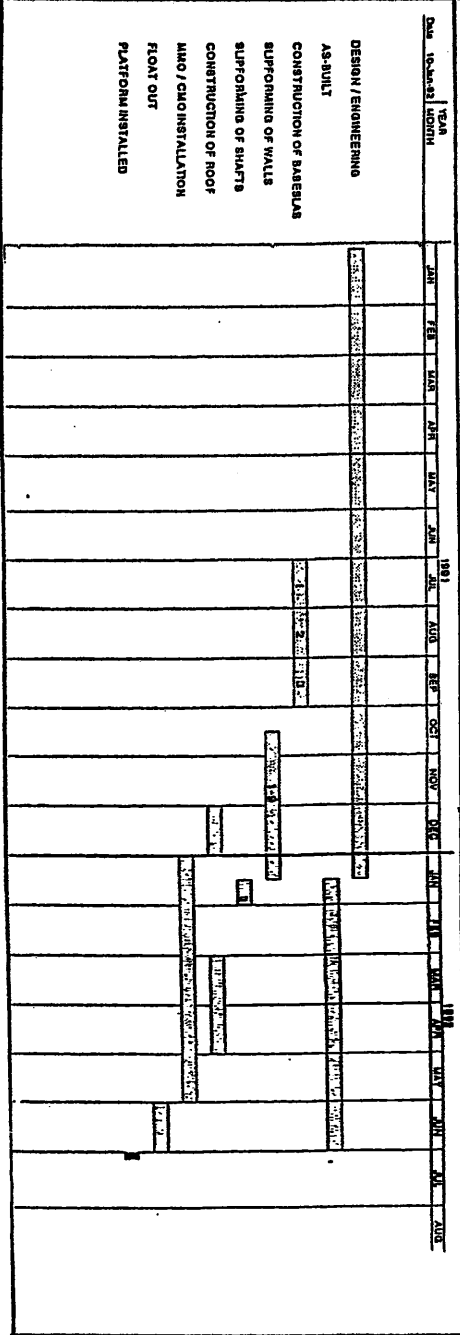


History

In May 1989, Delta Marine Consultants (DMC) and AVECO, being engineering consultants belonging to HBG and Volker Stevin respectively, started a feasibility study for NAM to investigate the feasibility of a GBS for the F3 production facility. The preferred base case at the time was a jacket type supported production platform with a floating storage vessel at a distance of 1 km, connected by a pipeline. The aim of the study was to whether a GBS, incorporating storage, was feasible in order to achieve a safer and effective production process.

The study was also used to investigate the influence of changes within the parameters of the functional requirements. The storage capacity had to vary from 20,000 to 40,000 m³, the

5 Construction schedule



number of shaft could be varied; the storage system could be oil-water displacement as well as dry cell storage; living modules could be on the platform or on a separate jacket; the conductors could be placed inside or outside the shafts.

A rectangular caisson proved to be the most suitable concept, providing practical formwork and straight prestressing cables. High strength concrete had been considered, but this material did not provide any benefits in this shallow water platform.

From the concepts developed, NAM chose a 30,000 m³ oil storage capacity, shaft protected conductors and living quarters separately supported. Based on this concept, four contractors were selected by NAM after an invitation to prequalify, to make a preliminary design incorporating their own possibilities and abilities. Det Norske Veritas, DNV, studied these designs and issued a quality assurance report addressing possible main problems in case these designs were to be detailed for actual construction. After this procedure, a formal tender followed, with the usual post tender negotiations involving some of the bidders.

The contract between the successful tenderers, the HBW-VSCI joint venture, was signed on the 27th December 1990, after which the detailed design commenced. (HBW is HBG operating company Hollandsche Beton-on Waterbouw; VSCI is Volker Stevin operating company Volker Stevin Construction International, later being replaced by Van Hattem en Blankvoort, its sister company). Site activities in the Verolme Dock started June 1991.

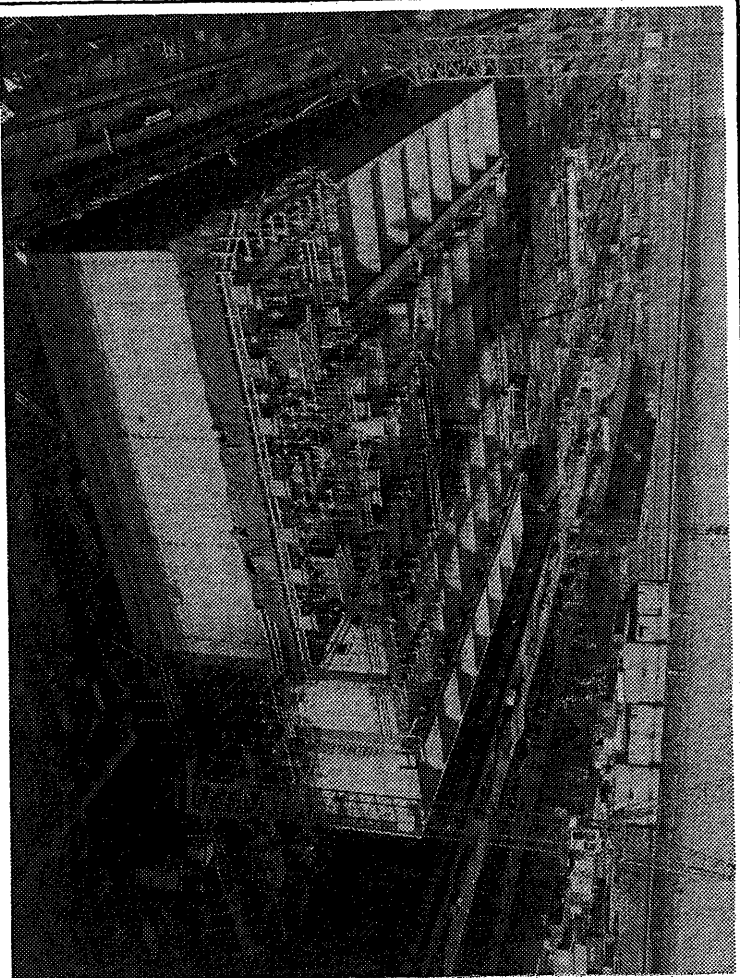
Figure 5 reflects the overall planning. The highest point of the beginning was reached in the beginning of February 1992, followed by the finish

seabed. They absorb an unevenness of up to 0.2 m of the seabed. After installation, a scour protection of dumped rock and protection mattresses round the caisson was installed.

It was possible to apply this foundation system because of the evenness of the seabed at location. It showed advantages compared to a foundation composed of skirts and a grouted layer. In that case, being quite customary with deep water platforms, perimeter placed skirts penetrate into the seabed and the remaining space in between skirts and bottomslab is filled up with grout.

It has been considered to place a gravel bed before actually placing the GBS, but the geometrical shape and rheological characteristics of the seabed did not require such measures. Some improvement of the draining effect of the seabed has now been achieved by pressure relieve pipes within the ribs.

The total length of the ribs is 1200 m and excludes only ribs under the central oil storage compartment. Figure 6 shows the design of the rib type slab. The inclined parts reduce the penetration and the vertical 0.27 m jump reduces the chance that upward moving soil caused by rib penetration touches the bottom. Penetration has been predicted by calculating with a deviation of + and - 100 mm.

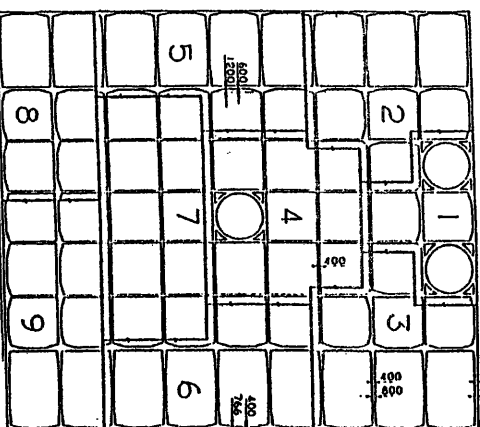


Slipforming caisson walls

Construction in the dry dock started by counter moulding this bottom shape with the aid of a gravel bed and prefabricated ribs (fig. 7). Additionally, the slab has been casted in three almost equal pours, of altogether 5800 m³ of concrete. Cooling occurred in certain areas of the slab to prevent cracks due to temperature shrinkage.

Walls and roofslab

Working out the detailed design, all load cases could be identified down to 40 different loadings, combined to a number of 462 different combinations. By postprocessing these, multiplied with the proper load and load combination factors, the resulting governing moments, shears and membrane forces were found for the detailing sizing of prestressing and



10 Scheme showing the nine different slipform sections

reinforcement.

After this, checks were being made on the following limit states:

SLS, Serviceability Limit State, with special care for cracks in walls surrounding the oil storage compartments, where a minimum compression zone of 20% of the cross section had to be maintained.

ULS, for Ultimate Limit State FLS, for Fatigue Limit State, being hardly critical in only quite special locations
PLS, for Progressive Limit State, being the result of special loadings, such as ship impact, earthquake loading, objects dropped on the caisson

roof etc.

The required finite element analysis has been carried out on subcontract basis by IHC-Gusto. The problem has been approached by first running a course model with 5 x 5 m size elements. Separate detailed runs have been carried out with a fine mesh of 0.8 x 0.8 m size for areas of complex nature. In most cases, these were found where steel embedments and transitions have to transfer their forces to the concrete structure (fig. 8 and 9).

The caisson walls with thicknesses of 400 mm to 600 mm were slipformed in 9 different sections. Three sets of slipform were used simultaneously, one for actual slipforming, one being prepared for the next pour and one being cleaned and transferred to a next location. Apart from some incidental delays, one section was able to start every week. Two 12 hour shifts worked from Monday morning to Saturday evening, completing 15 m of wall, with an average speed of 0.15m per hour.

Figures 11 and 12 show the amount of reinforcement and prestressing that had to be embedded. Because of the congestion of reinforcement and prestressing at the intersection of bottomslab and walls, this detail was changed at the connection of roofslab and walls, where the prestressing anchors were embedded in a cantilever as shown in fig.12. A total of

9800 m³ concrete was slipformed in the walls.

In the storage area, on top of the cells that had to be closed, prefabricated concrete plates, with a weight of over 100 tons each, were placed. They were prefabricated by N-Coat and installed by the Smit-Tak 7 shearleg barge, being moored adjacent to the dry-dock in the harbour. The joints in between the prefabricated plates were poured after which the roof, containing 2700 m³ of concrete, was prestressed.

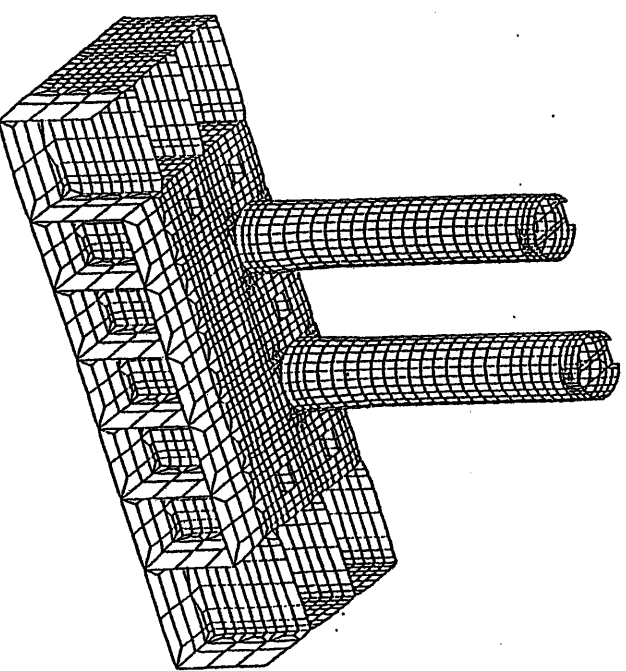
To protect the roof from objects, such as pipes and valves dropped from the deck during operations, a 0.75m thick layer of foamed concrete was poured on top of the roof. This layer has been slightly reinforced and anchored to the concrete roof. The layer has to absorb the impact of dropped objects in such a way, that the roofslab cannot be damaged.

The shafts

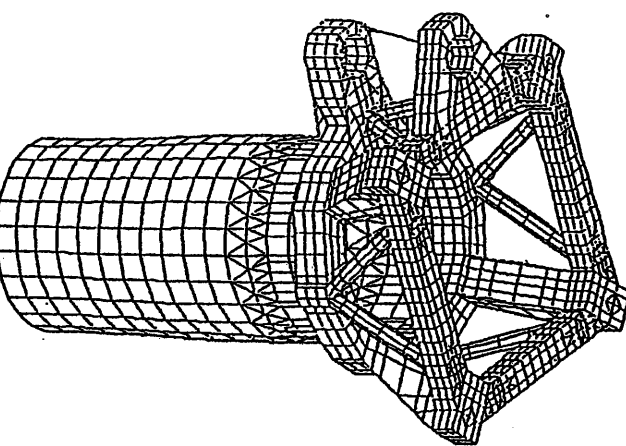
Especially the shafts were provided with a large number of embedments, classified as light, medium and heavy (fig. 14).

Light elements were selected as standard elements, the others were tailor made. For the heavy elements and their influence on the concrete structure, special calculations had to be made. This procedure required an extra line of calculating and detailing in the design team responsible for all

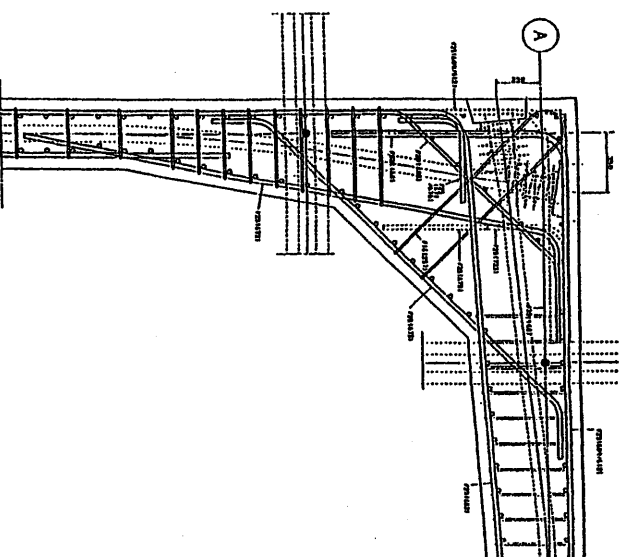
8 Finite element model for intersection of caisson with shafts



9 Finite element model for interface of utility shaft with deck support frame



11 Caisson cross section, showing prestressing details in outer corner



12 Cross section across roof and adjacent wall, showing the anchoring detail of the prestressing cables

