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FOUNDATION ASPECTS OF THE EASTERN SCHELDT STORM-SURGE BARRIER

T. J. BOON[1]

ORIENTATION

Ultimately in 1985 a heavy civil-engineering construction, known as the 'storm-surge barrier' has te be completed in the estuary of the Oosterschelde (Eastern Scheldt). The barrier consists essentially of a number of concrete elements between (or in) which movable sluice gates are suspended. During storms these gates will be shut to protect the approximately 9 km wide estuary.

A difficulty is that the barrier must be built on the site originally approved for the dam in the Oosterschelde, thus in the three 25 to 35 m deep channels, the 'Roompot', the 'Schaar van Roggenplaat' and the 'Hammen', which together give a total width of approximately 3 km (Fig. 1). So it must be constructed in a dynamic situation of physical factors; of air, water and soil, of wind and storm, of waves and tides and of a shifting sandy sea-bed. The maximum current velocity is 1.5-2.0 m/s.

So it is desirable to limit the on-site construction activities in the open sea as far as possible. And so the study was directed on the prefabrication possibilities of the structure. After examination of the designs there remained two main alternatives:
(1) Caissons founded on a sill.
(2) Columns on foundation caissons.

CAISSONS FOUNDED ON A SILL

In the alternative 'caissons (50 x 53 m) founded on a sill', the sill is a filter construction built up in layers of stone, which are compacted and levelled (Fig. 2).

The soil underneath the sill (Holocene sand) must be compacted to secure the position during alternating loads due to wave attacks. Soil improvement had to be executed at those places, where this sand contains too much clay or silt. The main reason why this design has been abandoned are the uncertainties about a sufficient reliable construction of the sill. Too much siltation and sand infiltration during the execution gave uncertainties about the quality in the final situation because in a closed storm-surge barrier the sand would be washed out from the sill, causing displacements of the caissons.

COLUMNS OF FOUNDATION CAISSONS

The most characteristic of this design (Fig. 3) is the very deep foundation level. The area is 16 x 46 m and there are distances of 40 m. In the pre-design the piles were founded in the more compact Pleistocene sand layers. Soil investigation showed, however, that these Pleistocene sands on top did not have the quality that had been given to them in the first instance. On the other hand, calculations and tests on scale 1:10 brought about more insight in the behaviour of this foundation. The piles can shift and topple over and under horizontal load. Accordingly, as the piles become larger (founded deeper), the topple-over effect increases. It appeared that the deformation does not decrease accordingly as the pile was put deeper into the ground. Below an embedded depth of 10 to 12 m the deformations remain constant (Fig. 4).

To reduce the deformations further the area of the cross-section must be increased. This behaviour and the quality of the Pleistocene have contributed to the evaluation of the present design.

PIERS

Characteristics

The distances are 45 m and the foundation level is between the levels of caissons and columns on foundation caissons.

The piers (Fig. 5) will be embedded 8 to 12 m in a sill and will stand on a foundation bed consisting of fine granular material under which compacted sand layers are present, (Fig. 6). The deformation of the pier depends mainly (85%) on the frictional resistance on the foundation bed and stiffness of foundation bed and subsoil. 15% is contributed by the passive resistance of the sill.

[1]Rijkswaterstaat, Deltadienst, Postbus 5002, 4328 ZV BURGH-HAAMSTEDE, The Netherlands.

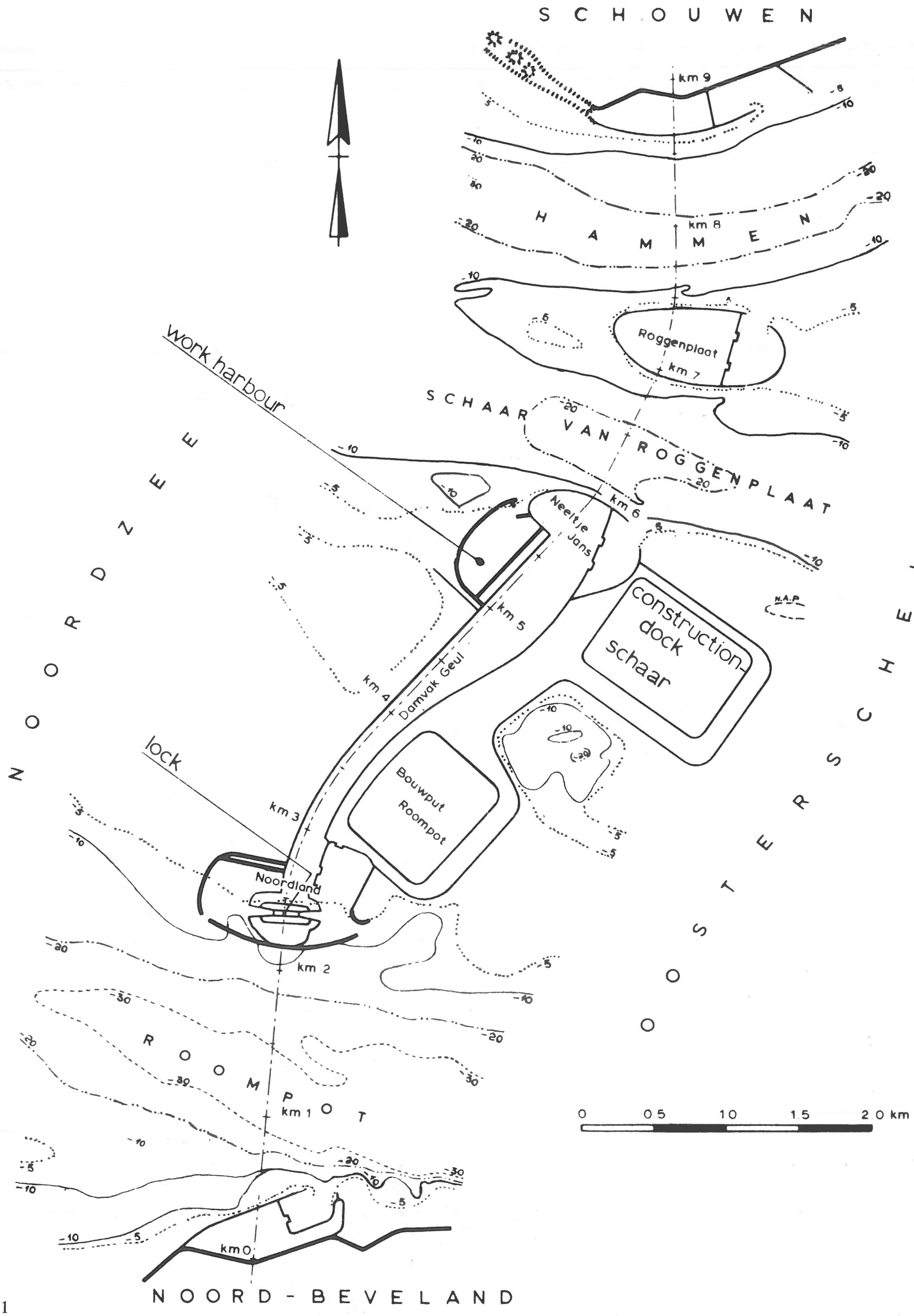

Fig. 1
The mouth of the Eastern Scheldt with work islands (present situation).

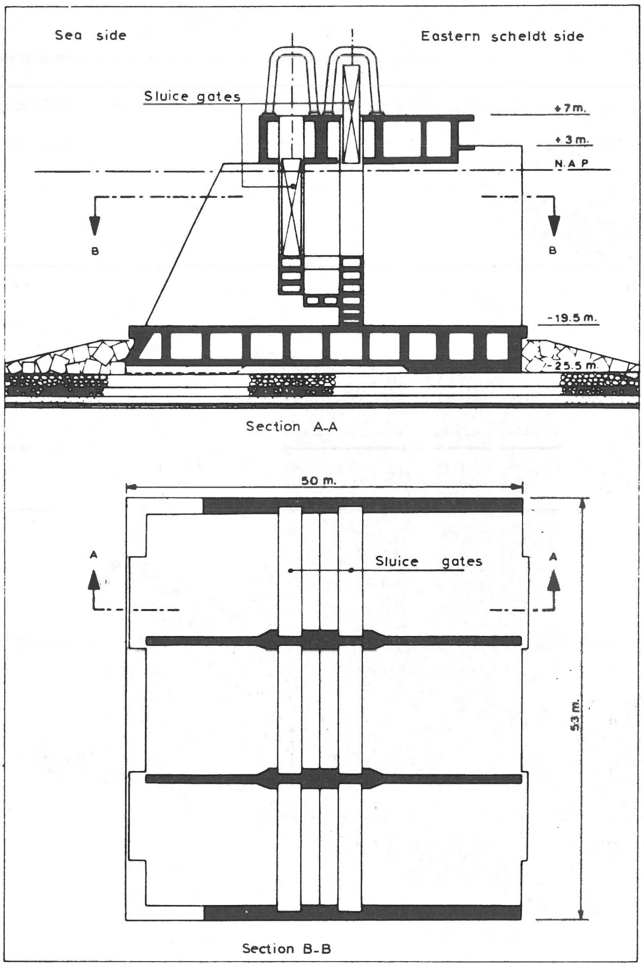

Fig. 2
Caissons on sill.

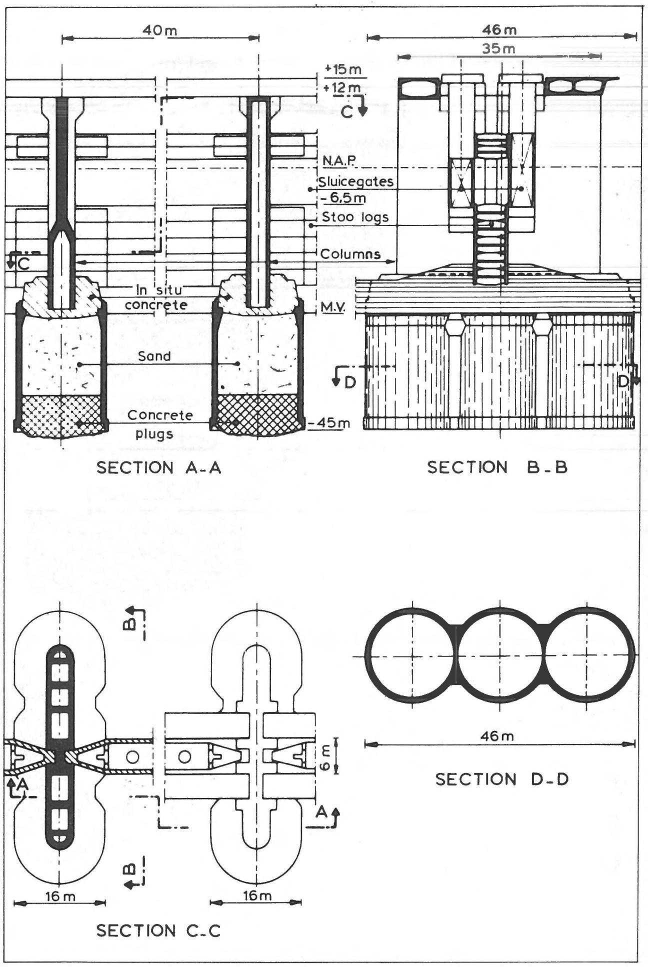

Fig. 3
Columns on foundation caissons.

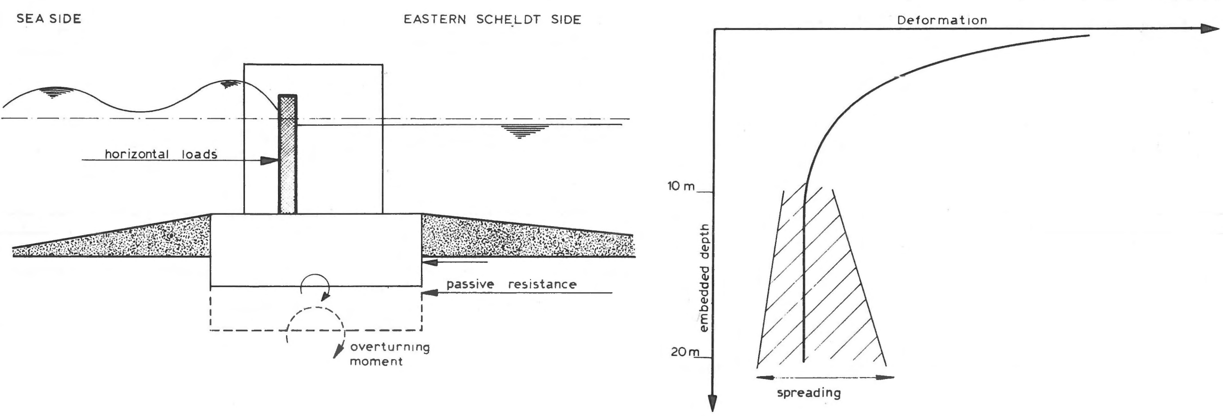

Fig. 4
Deformation characteristics.

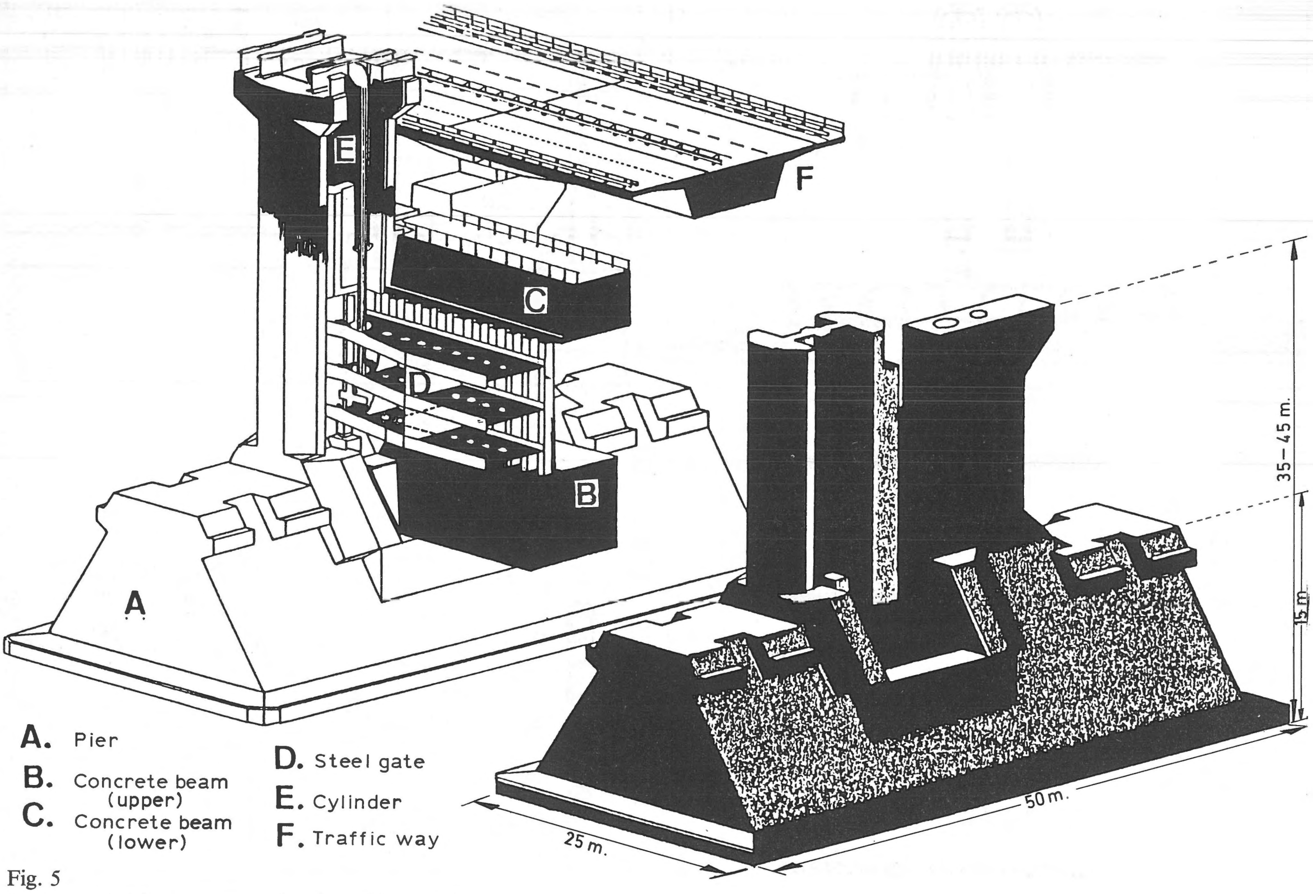

Fig. 5
Eastern Scheldt storm-surge barrier without sill.

Working method (Fig. 7)

(1) Trenches are dredged by means of a dustpan dredger at places where the subsoil is not sufficiently compact and contains too much silt.
(2) Fill up a soil improvement by clean sand.
(3) Compaction until max. 40 m minus average sea level (N.A.P.). This method is based on vertical vibrations, which are generated by a vibrator and transferred to the subsoil by means of a special resonator. There are four vibrators in line at equal distance of 6 m (Fig. 8). The area to be compacted has a width of approximately 80 m and a depth of 8 to 10 m.
(4) To lay a foundation mattress on the sand upon which the pier is placed.
(5) Build up the sill and undergrout completely the bed-plate of the pier.

DESCRIPTION OF THE FOUNDATION MATTRESS

The most important requirements for the foundation bed were (1) sufficient sliding resistance and (2) holding the sand of the subsoil when hydraulic gradients occur (statical and dynamical).

This makes high demands upon the filter properties of this material which led to a construction with 3 layers, viz. from bottom to top (see Fig. 6, detail B): coarse-grained sand 0.3 - 2 mm; fine gravel 2 - 8 mm; and gravel 8 - 40 mm.

For reasons of technical execution one decided to build these layers in a mattress with a thickness of 0.32 m, a width of 50 m and a length of 200 m. This method gives the best security to lay down undisturbed filters and to prevent sand transport under the mattress.

The mattress consists of:
(1) a bearer on the bottom, which must have a design strength of 800 kN/m width. This bearer will be manufactured either of polyester fabric or polypropylene fabric reinforced by steel wires.
(2) in between the filter layers a continuous synthetic cloth is placed to prevent mixing of these layers during the transport of the mattress.
(3) in every filter layer vertical partition walls are placed to prevent sagging of the materials when the mattress is in a vertical position during sinking operations.
(4) the bottom and top fabrics are kept together by a pre-arranged pattern of vertical steel pins.

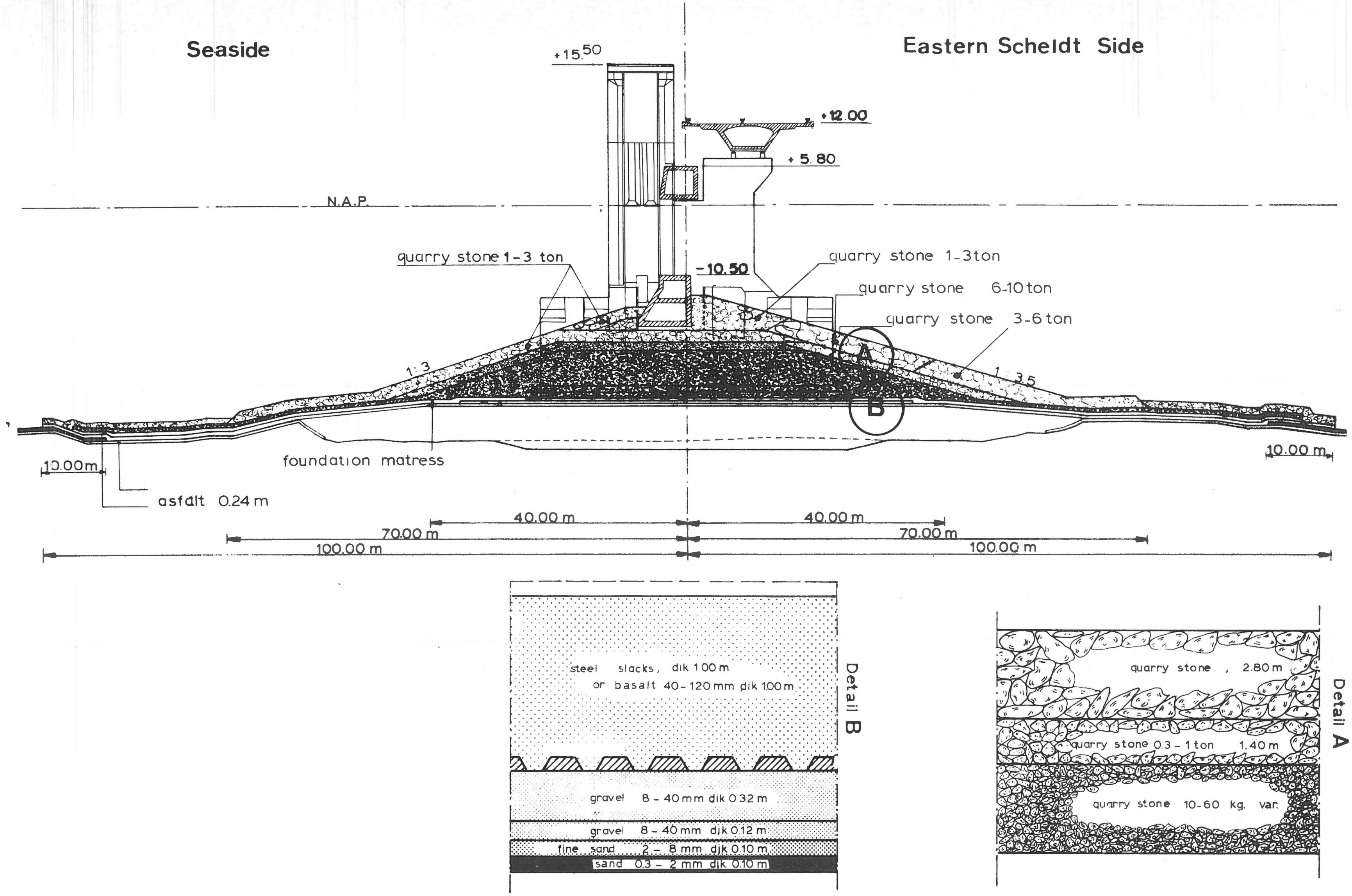

Fig. 6
Cross section of pier, sill and foundation mattress.

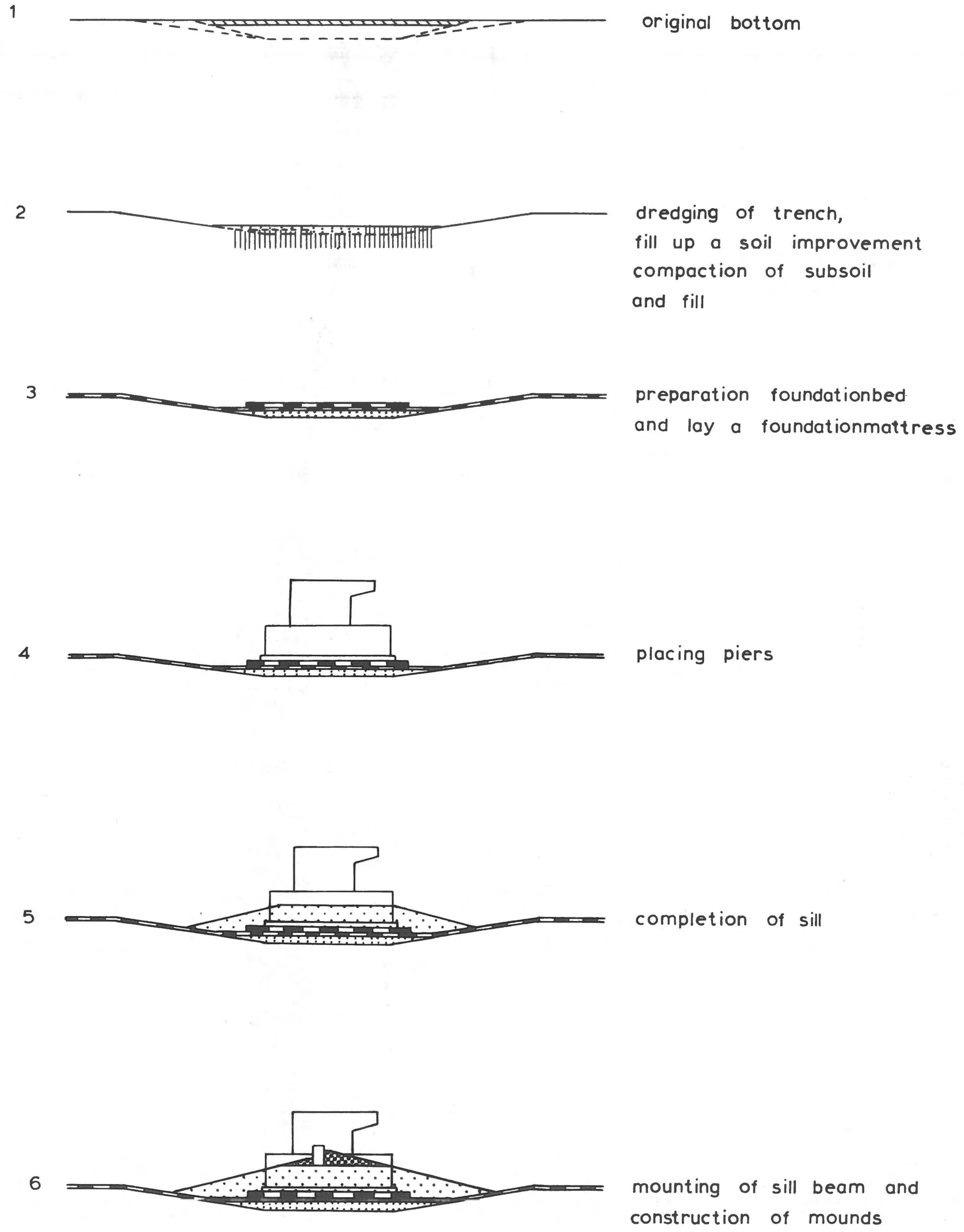

Fig. 7
Construction phases.

The mattress is manufactured in a factory, then wound on a drum and transported to the site in the channel. The mattress will be laid by a pontoon having a length of 60 m and a width of 90 m, called the *'Cardium'* (Fig. 9). This vessel is equipped with a dustpan suction mouth with a width of 45 m. With this mouth the bed is made on the right depth and also levelled out. Almost simultaneously with the dredging the mattress will be laid. A lot of experience has already been achieved in winding and sinking of much lighter mats for scour protection, viz. a concrete-block mat and a stone-asphalt mat on the Eastern Scheldt sea bed. There is experience with dustpan suction dredgers with a suction width of 10 m.

To prevent damage to the first filter mattress before or during placing the piers, a second mattress will be sunk at the size of 32 x 60 m having a thickness of 0.32 m (Fig. 10). This mattress it filled with gravel only and covered on top for an area of 60% with concrete blocks.

After sinking, each mattress is compacted to secure a good contact with the subsoil.

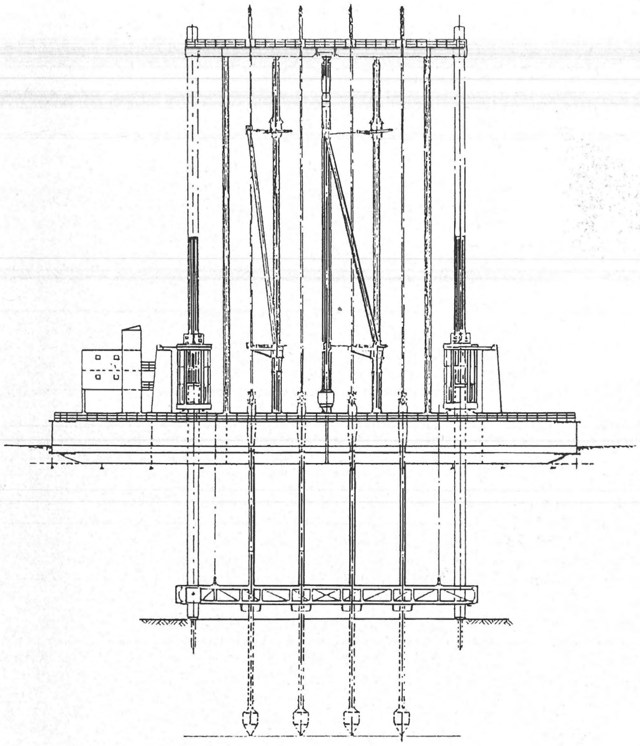

Fig. 8
Compaction pontoon.

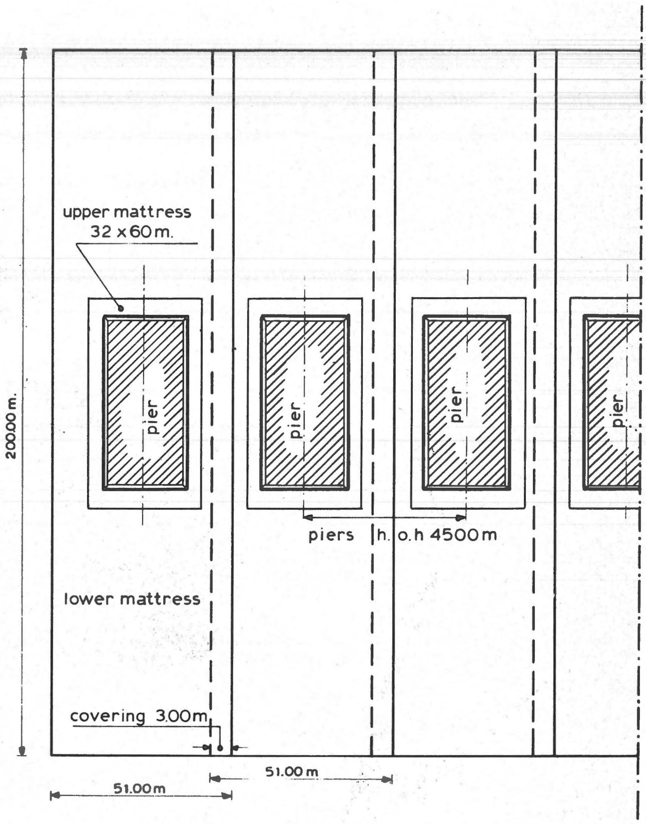

Fig. 10
Situation of upper and lower mattress.

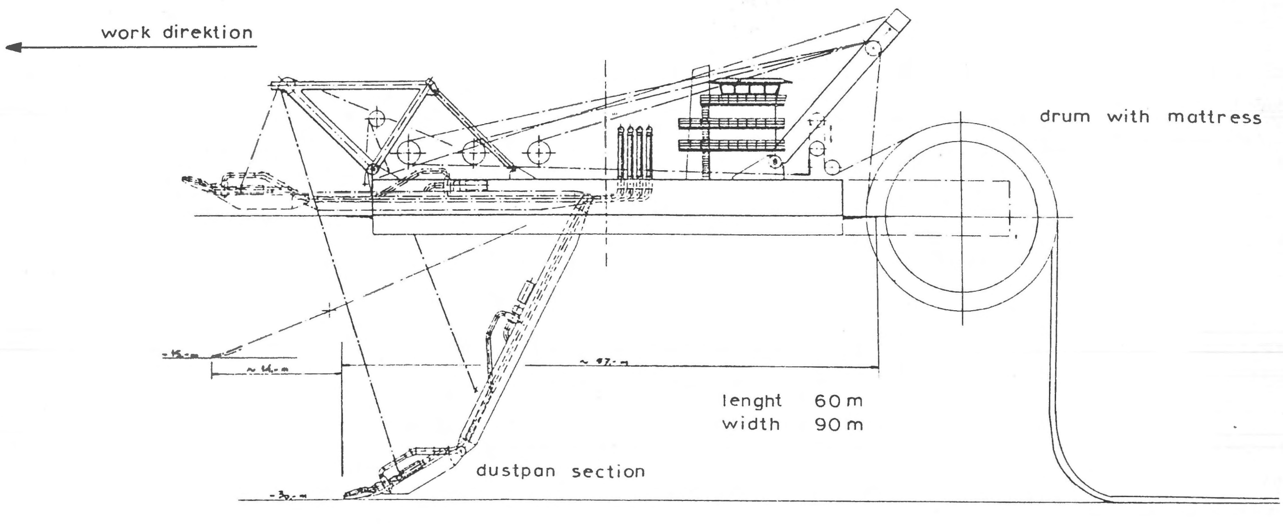

Fig. 9
Pontoon 'Cardium'.

Plate V
Air photograph of the three temporary islands in the Eastern Scheldt, used for construction of the storm-surge barrier. This plate is published on request of E. F. J. de Mulder (see next paper).