

**Zeitschrift:** IABSE structures = Constructions AIPC = IVBH Bauwerke  
**Band:** 5 (1981)  
**Heft:** C-19: Eastern Sheldt Strom Surge Barrier (the Netherlands)  
  
**Artikel:** Gates and operating machinery  
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**DOI:** <https://doi.org/10.5169/seals-16995>

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#### 4. Gates and operating machinery

##### Gates

The openings in the storm surge barrier in the Eastern Scheldt will be closed by means of a fixed element, the sill beams and upper beams, and a movable element, the gates (Fig. 1.).

The dimension and shape of the gates are determined by the centre-to-centre spacing of the piers, the flow cross-section through the barrier, and the load to be resisted by the gates. Allowing for the depth of bearing within the piers, the span of each gate is 41.3 m.

The piers are quite separate of one another and differences in angular rotation between any two adjacent piers due to unevenness and settlement of their foundations must therefore be taken into account. This means that the gates have to be of low torsional rigidity, which in turn means they have to be made of steel.

The height of the gates varies from 5.9 m in the shallow parts, to 11.9 m in deeper parts.

When closed, the gates have an "overlap" of 0.2 m with the upper beams and sill beams, ensuring that, even in the event of dimensional deviations, the gates will still mate properly with the beams though without actually touching them.

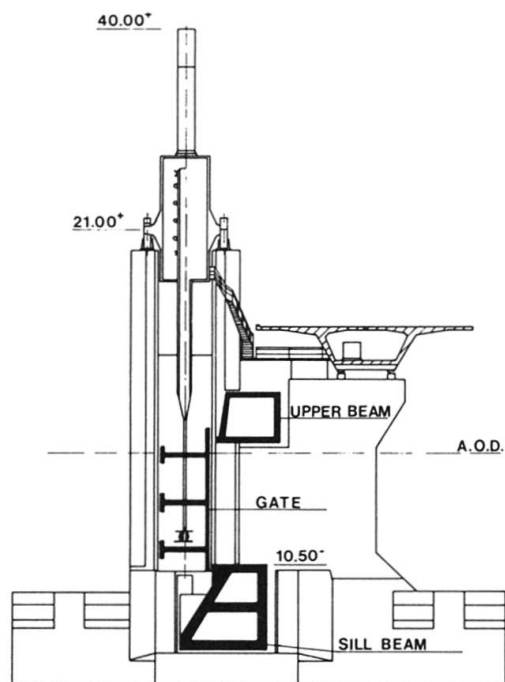


Fig. 1. Rack-and-pinion gate operating machinery

The water-retaining skin plating (Fig. 2) is on the "rear", i.e. the side facing the Eastern Scheldt and consists of shell-type units mounted vertically. Since these are subjected mainly to tensile stresses in consequence of wave loads and the loading from differences in water levels, relatively few stiffeners are needed, making this kind of plating less expensive than flat plating. An additional advantage is that there are apertures between the shell units and the horizontal girders which reduce the severity of the loading due to wave beating against the gate.

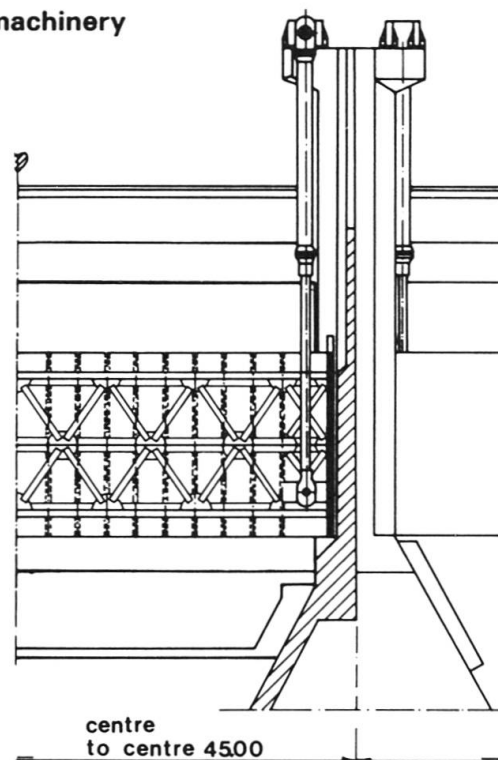


Fig. 2. View of gate in plan

The horizontal structure of each gate comprises two or three plate girders (the number depends on the height of the gate in question). In order to reduce loading due to vertical flow and wave action, the girders have holes in their webs. The latter are provided with the necessary stiffeners. The girders are also interconnected by vertical diaphragms. The vertical structure of the gate consists of a truss girder composed of tubular members. The chords of the truss are formed by the horizontal plate girders. The vertical loads are transmitted through the truss to the points of attachment of the gate-operating machinery. Together with the plate girders and the skin plating, the truss system forms a kind of box structure. In order to meet the basic requirement of low torsional rigidity, the truss is located as close to the skin plating as possible, so that the resulting resistance to torsion is relatively small.

The horizontal forces and bending moments acting upon the gate are transmitted via the end post bearings to the piers. Because of the limited space for the vertical guideway in which the gate slides in the pier and because of the magnitude of the loads to be transmitted, the vertical bearings on each end post of the gate have sliding surfaces, as distinct from the runner wheels normally provided at the bearings of vertical gates. The sliding surfaces are on both the inner and outer bearings on the gate, because the loads due to water pressure and waves may act in either direction – towards the Eastern Scheldt or towards the North Sea – depending on the circumstances. The material forming the sliding surfaces mounted on the bearing attached to the gate, in combination with the material lining the gate guideway in the groove formed in the pier, must have a suitably low coefficient of friction, so that the force needed to move the gate subjected to water pressure and wave action up

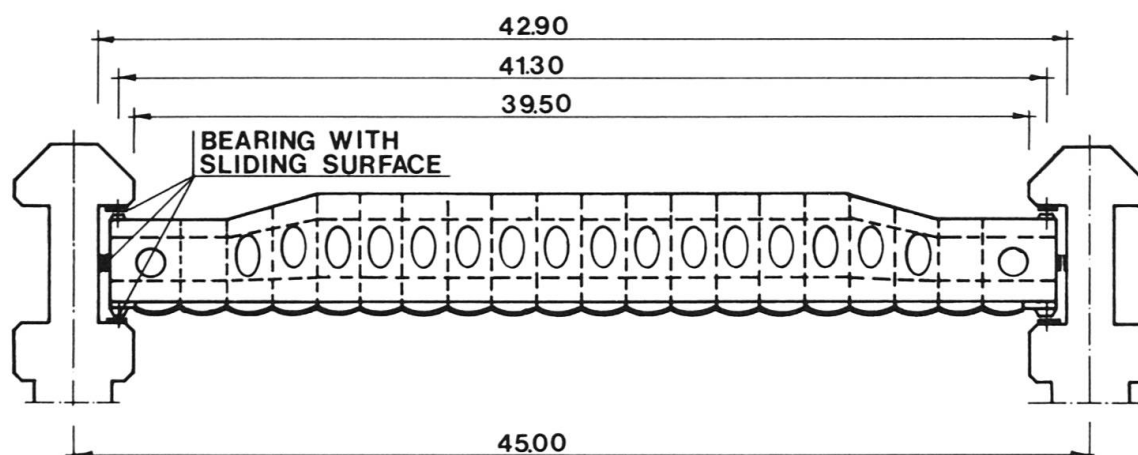


Fig. 3 Half elevation of gate with hydraulic operating machinery

or down is small. In order to prevent oscillation during gate movement (stick-slip), the difference between the static and the dynamic coefficient of friction must moreover be as small as possible.

### Gate-operating machinery

The gates are operated by machinery which is designed so that closure can be effected under the most unfavourable conditions foreseeable. The barrier superintendent has complete freedom to choose when he wants to close the gates and even if he were to misjudge the situation, he could still always be sure of closing them in an emergency.

On the other hand, in order that the machinery should not be unduly powerful and heavy, there are some restrictions – within ample limits – on the timing of operating connected with water pressure as a result of different water levels acting on the gates.

Closing the gates will take about one hour, opening them about two hours.

Since the gates lift vertically, they encounter friction forces when in motion, due to water pressure acting on them and to horizontal wave loading, thrusting the gates against their bearing faces. The operating machinery has to overcome this friction and to cope with the counteracting effects of vertical wave loading and suction forces. For a given difference in water level between the two faces of the gate, the dead weight of the latter is approximately in equilibrium with the frictional forces. Under such conditions it is important that the vertical loads exercised by the waves, which may alternately act upwards and downwards, must not toss the gate up and down. To prevent this, the operating machinery must be capable of developing a positive vertical restraining action.

Two types of machinery are currently being developed: one based on the use of hydraulic rams and one embodying rack-and-pinion gears. Substantial experience with both types is available, though not with installations of such size as those needed for the storm surge barrier. In making the final choice, the prime criteria – besides cost and planning – are reliability, ease of maintenance, manufacture and aesthetic quality.

With the hydraulic system (Fig. 3) each gate is moved by two double-acting hydraulic rams, pivoted and suspended from steel cross-members mounted on the

tops of the piers. The rams can pull the gates up and push them down, the latter operation being necessary under conditions where the frictional forces are greater than the dead weight of the gate. The rams are fed with oil under high pressure (up to about 200 bar) through pipelines which connect them to an hydraulic power unit.

Each unit serves the two rams of one gate and comprises electrically-powered hydraulic pumps, valves and other control elements, safety devices, filters, etc. In addition, it is equipped with a large tank in which hydraulic oil is stored. The whole assembly is accommodated in the bridge box girder which extends the full length of the barrier. The location ensures good accessibility, even under adverse weather conditions.

Arrangements will be made to enable a gate to be operated with hydraulic power supplied by the drive equipment of an adjacent gate in the event of its own power system failing. The dimensions of the hydraulic rams vary with the vertical dimensions of the gates. The largest rams have a stroke of about 12 m and an internal diameter of nearly 1 m.

In the rack-and-pinion system (Fig. 1), each gate – as with the hydraulic rams – has a driver at each end, comprising:

- a rack toothed on both sides, pivoting and attached to the gates;
- machinery for driving the rack, accommodated in a housing.

Depending on the size of the gate, each rack is driven by five to eight pinions distributed over the two toothed sides of the rack. The pinions are driven via gear units and a load-distributing device by two centrally mounted electric motors.

All the gate-operating components – pinions, gear units, electric drive equipment and the guides for the rack – are accommodated in one housing, which carries a chimney-shaped protective casing for the rack.

The drive unit as a whole is supported on the pier via two cradles provided with hinge-type rubber bearings. It is directly accessible by means of stairs and platform from the bridge box girder. All the principal drive components, together with the devices to ensure synchronized operation and end-position signalling, are accommodated in the bottom part of the housing.

(H. Van der Weyde and F. Remery)