Western Scheldt Tunnel/Bridge Project

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SUMMARY

The Western Scheldt is the main gateway to the Belgian ports of Antwerp (Antwerpen) and Ghent (Gent) and the Dutch ports of Flushing (Vlissingen) and Terneuzen. In 1988, over 70,000 vessels sailed along this river.

The Province of Zeeland is eager to build a fixed link across the Western Scheldt to replace two ferry services. There are two main options for the design of this link, a bridge-tunnel combination or a bored tunnel. The latter will have no influence on shipping traffic on the Western Scheldt. The first option, however, will have an influence on navigation. This influence is minimised by prescribing strict limiting conditions for the design and construction.

RESUME

LE PROJET DE PONT/TUNNEL DE L'ESCAUT OCCIDENTAL

L'Escaut Occidental constitue la voie d'accès principale aux ports belges d'Anvers (Antwerpen) et de Gand (Gent) et aux port néerlandais de Flessingue (Vlissingen) et de Terneuzen. En 1988, plus de 70.000 navires ont emprunté ce bras de l'Escaut.

La Province de Zélande souhaite remplacer les deux services de ferries reliant les rives de l'Escaut Occidental par une liaison fixe. Celle-ci peut se concevoir de deux façons principalement: soit un pont combiné à un tunnel, soit un tunnel foré. Ce dernier n'exercerait aucune influence sur la navigation, tandis que le premier en aurait une, limitée cependant par l'observation de contraintes de conception et de construction strictes.

1 Introduction

Traditionally, because of its island geography, the road infrastructure of the Province of Zeeland ran east to west. This was all changed by the Delta Works. Thanks to the routes on the Delta dams and the Zeeland Bridge, north-south relations were vastly improved. Today, the only exceptions remain the Vlissingen-Breskens and Kruiningen-Perkpolder ferry services across the Western Scheldt. As part of the national main road network, these services form the link between Zeeuws-Vlaanderen and Central Zeeland. More than ever before, the Western Scheldt is forming a barrier to road traffic.

Although the ferry services operate well, they do have their limits. In the early hours of the morning, in the evenings and on weekends there is only one departure every hour. At night there are no crossings, which necessitates a diversion via Antwerp. In the summer months, waiting times often rise to between 1 and 2 hours and, quite apart from the inconvenience, this traffic situation represents a direct obstacle to the optimum development of economic and social relationships.

Both State and Province finance the major part of the running costs of the ferry services. The other part is financed by the fees payed by the users. The State is also responsible for the maintenance (f.e. dredging) of the harbours used by the ferries. For the State alone, the total annual costs for the ferry services, including harbour maintenance, exceeds the amount of 40 million guilders. Building a fixed link would eventually decrease the costs for both State and Province.

Due to its important role as a shipping route to the Belgian ports of Antwerp and Ghent as well as the Dutch ports of Flushing and Terneuzen, the Western Scheldt cannot be blocked off, so the question of building a permanent cross-river connection has been the subject of continuous discussion over the last few decades.

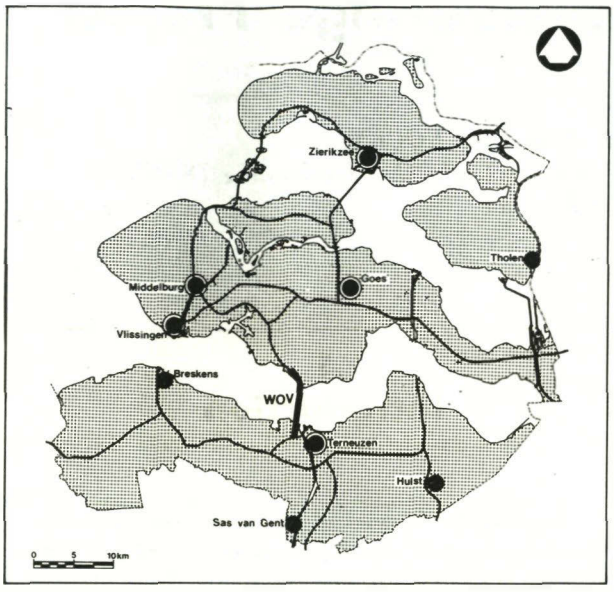

Figure 1
Road infrastructure in the Province of Zeeland, with the location of the new Western Scheldt Crossing (WOV)
Infrastructure routière dans la Province de Zélande et emplacement de la Traversée de l'Escaut Occidental (WOV)

The construction of the intended Western Scheldt cross-river connection (WOV) would both improve the current situation and create new opportunities (see Fig 1).

An important step towards achieving this objective was taken after the conclusion of exhaustive discussions between the national government, the province, the municipalities and other interested parties about the choice of the route. On 1 March 1991, the States General of the Province of Zeeland fixed the route and six days later the Minister of Transport, Public Works and Water Management approved the choice.

The choice of the route was preceded by thorough studies, the findings of which are laid down in the Route Memorandum/Environmental Effect Report (Province of Zeeland, January 1990). This document describes:

- the current situation and autonomous developments,
- the various alternative solutions for the WOV,
- the effects of constructing the WOV, for each alternative, on the area between the A 58 on Zuid-Beveland and the N 61 in Zeeuws-Vlaanderen and on the connecting roads for the ferry services. This also includes the effects on the nautical function of the Western Scheldt.

This memorandum, together with its supplements, represents the most important set of background documents for the technical assessment plan drawn up by the Province of Zeeland and other government bodies, such as the Directorate-General for Public Works and Water Management, Division Zeeland and the Civil Engineering Division.

The assessment plan, consisting of a preliminary design for the entire cross-river connection, with the approach roads and the connecting and interconnecting roads, is available as a reference design for the candidates for the design and construction. The insights into the specific character of the chosen route, acquired whilst drawing up this preliminary design, have been translated into requirements, as laid down in the memorandum "Limiting Conditions". The results of investigations and studies are contained in the memorandum "Basic Information".

The defined route outside the dykes joins the lands to the west of the lock complex at Terneuzen in Zeeuws-Vlaanderen to those to the west of the village of Ellewoutsdijk on Zuid-Beveland (Figure 2).

At the time of writing this article (November 1992), two Combinations of contractors were in the process of designing the connection. The two groups are:

1. Kombinatie Middelplaat Westerschelde

   This group is formed by several Dutch, German and Belgian contractors and consultants.

2. Kombinatie Krupp/Bilfinger + Berger Bau AG

   This group also comprises several Dutch consultants.

The Combinations will present their designs by the end of 1992.

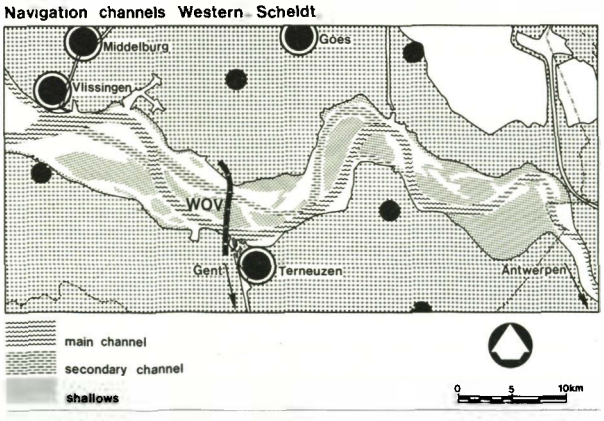

Figure 2
Situation of the Western Scheldt Crossing (WOV) and the navigation channels
Emplacement de la Traversée de l'Escaut Occidental (WOV) et des chenaux de navigation

2
Nautical Aspects of the Western Scheldt Route

At the chosen site, the Western Scheldt is approximately 5 km wide and includes two important fairways. The main fairway for seagoing vessels is the Pas van Terneuzen (on the Zeeuws-Vlaanderen side). The Pas van Terneuzen is approximately 1,600 m wide, and the actual fairway is 600 m wide. To the north, the Pas runs into the Middelplaat, an area of shallows some 2,200 m across. In turn, the Middelplaat runs into the Everingen, a secondary fairway approximately 1 kilometre wide, on the Zuid-Beveland side, used primarily by inland shipping and small seagoing vessels.

In 1988, 73,200 vessels, excluding pleasure craft, sailed along the Western Scheldt. The 46,400 seagoing vessels had a total combined tonnage of approximately 558 million tons (dwt). The combined weight of the 26,800 inland vessels which sailed the river was approximately 22 million tons (data based on counts in ports and locks).

The intensive level of shipping on the Western Scheldt is one of the reasons for the strict requirements placed on that part of the project that has to be executed on the river. The purpose of these requirements is to serve safety and workability, as well as to avoid or limit blockages for shipping as far as possible.

Characteristic dimensions of seagoing ships sailing in the Pas van Terneuzen are

Ship type	Dead-weight tonnage	Length over all (LOA)	Width	Draught
Bulk carrier	200,000 ton	300 m	50 m	6 m
Containership	73,000 ton	275 m	39 m	11 m
Multipurpose ship	45,000 ton	97 m	32 m	10 m

Characteristic dimensions of ships sailing on the Everingen are:

Ship type	Ton-nage	Length over all (LOA)	Width	Draught
Seagoing ship	20,000 DWT	185 m	25 m	5 m
Push navigation with 6-barge units	18,000 ton*	192 m	35 m	4 m
Tanker	3,000 ton*	100 m	11 m	4 m

* Carrying capacity of inland shipping in metric tons.

The Treaty of 1839 between the Netherlands and Belgium guarantees free passage to the port of Antwerp. This treaty has become effective as well for the port of Ghent.

That treaty influenced the nautical requirements for the project for a great deal. The following limiting conditions apply to the Pas van Terneuzen, the main fairway:

- Minimum required width of the fairway: 750 m at NAP (Normal Amsterdam Level) -20.5 m;
- Unlimited navigational clearance over the entire width of the fairway.

Figure 3 shows the cross section of the Western Scheldt with the two navigation channels, the Pas van Terneuzen (south) and the Everingen (north).

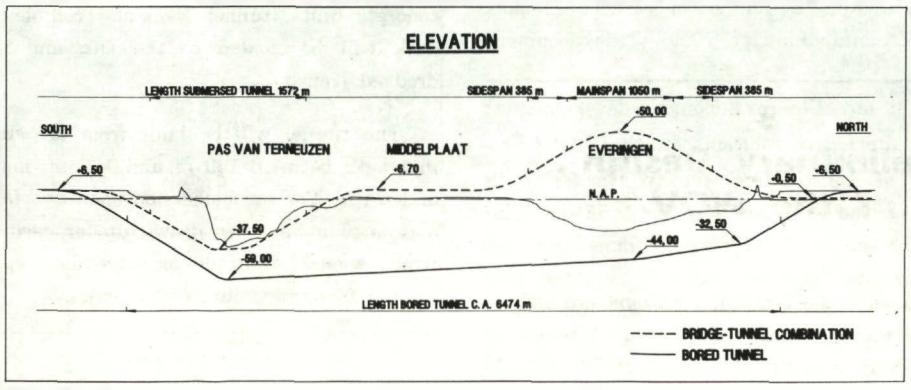

Figure 3

Cross-section of the Western Scheldt, with the length profiles of the tunnel-bridge and bored tunnel solutions. Section transversale de l'Escaut Occidental comportant les profils longitudinaux des alternatives du pont-tunnel et du tunnel foré.

During the construction phase, navigation in the Pas van Terneuzen may be limited to a certain level. If necessary, the passage width may be narrowed to 300 m. The navigational clearance is not to be affected.

Complete blocking of the Pas van Terneuzen is only allowed during the submersion of tunnel elements. Such a complete blocking may last for 34 hours; within this period two flood-tides are allowed for. The building-company has to plan the submersion of the tunnel elements six months ahead. In this period, port authorities and shipowners can take the necessary precautions.

The lesser nautical limiting conditions, valid for the northern secondary fairway, the Everingen, are:

- The minimum passage width perpendicular to the channel, in the case of a single opening, must be 400 m and, with two openings, 2 x 250 m at NAP -10.0 m. For the time being, the navigational clearance above the fairway(s) has been set at NAP +43 m. A lower clearance is still the subject of discussion with the Belgian authorities.
- It is not allowed to situate objects within 800 m of the easternmost mooring location of the Everingen.

During construction the Everingen is **not** to be blocked. A minimum passage width of 200 m is allowed with a headway of NAP +43 m.

In 1990, a radar system which controls navigation on the Western Scheldt was introduced. This system will play an important role during the construction phase in directing regular navigation as well as extra navigation for measurements, dredging, submersion processes, etc. Bridges and dams may influence the performance of the radar system in the construction phase and after completion. Additional radar-sensors may have to be placed on the WOV-route to ensure the method of double radar coverage. A high-quality performance of the radar system depends on this method.

3 Preliminary Design of the WOV.

At the moment, the two Combinations are still in the process of making competing designs. A presentation of their designs is therefore not possible yet. As the preliminary design has produced the basic information and requirements for the designs of the Combinations, it might be interesting to take a brief look at this pre-design. The preliminary design for the assessment plan provides two solutions for the cross-river connection:

1. a tunnel, dam-construction and bridge
2. a completely bored tunnel.

The preliminary design solution 1 consists of five sub-projects:

1. A tunnel below the Pas van Terneuzen, including entrances;
2. A bridge over the Everingen;
3. A dam-construction on the Middelplaat, an area of shallows in the middle of the Western Scheldt, and a dam-construction at the land end of the bridge on Zuid-Beveland;
4. Approach roads, both on Zuid-Beveland and in Zeeuws-Vlaanderen;
5. A dry dock and finishing quay in the Vlissingen-Oost industrial area.

The preliminary draft solution 2 consists of two sub-projects:

1. A bored tunnel under the entire Western Scheldt, including entrances;
2. Approach roads on both Zuid-Beveland and Zeeuws-Vlaanderen.

3.1. SOLUTION 1.

TUNNEL

Particularly because of the requirement of unlimited navigational clearance, the cross-river connection in the Pas van Terneuzen will be in the form of a tunnel.

Various variants have been examined for the preliminary design of both the tunnel and the entrances.

For the closed tunnel section, a tried and tested method with which a great deal of experience has already been gained, has been chosen. Individual concrete units (tunnel elements) completed in a dry dock will be floated to the site and sunk into a dredged trench.

The tunnel will be built from ten units, varying in length between 139 m and 162 m, making a total of 1574 m. For the immersion operation (at neap tide), a time plan has been drawn up for each tunnel unit, which ensures that the blockage for shipping will be limited to a maximum of 34 hours.

DAM.

The relative height of the Middelplaat makes the choice of a dam-construction as connection between the tunnel and the bridge almost self-evident.

The dam-construction, more than 2 km long, runs approximately north-south and is situated outside the fairways. The ground level at the site of the dam-construction over its longest length varies between NAP and NAP +1 m. The Middelplaat area is very even, and is not crossed by channels.

During the construction phase, the dam-construction will serve both as transport route for construction traffic and as worksite.

The geometry of the dam body and the type and dimensions of the slope covering are highly mutually-dependent. Employing a shallower slope angle will lead to a lower crest level and, possibly, to a lighter protective structure.

From the point of view of landscaping, preference would be given to a slope geometry which as far as possible matches the traditional dyke profile along the Western Scheldt.

The construction of the dam on the Middelplaat calls for the supply, storage and processing of large quantities of material. Facilities will also be necessary for the transportation of staff and (heavy) equipment. These factors call for the construction of a work dock on the Middelplaat. This dock will also be employed for the execution of all other hydraulic engineering projects in the Everingen and the Pas van Terneuzen, since no suitable facilities for these activities are available in the immediate vicinity.

BRIDGES.

The pre-design indicates five bridge variants over the Everingen, ranging from a maximum of 5 to a minimum of 2 bridge piers. From a technical point of view, these designs comply with the requirements and are therefore equal. From a nautical point of view, the solutions with 2 piers result in smaller chances of ships colliding with piers. The 2 piers are located far outside the fairway and can only be reached by relatively small vessels. The calculated impact forces on the piers depend upon the number of piers; they vary from 110 MN (2 piers) to 150 MN (5 piers).

The five variants are shown in Figure 4.

Variant A:
Linked concrete cable-stayed bridges.

The total length of this design with 5 bridge piers is 2,128 m. The 5 concrete cable-stayed bridges are 3 x 360 m and 2 x 340 m long, totalling 1,760 m. The chosen span length of 360 m per cable-stayed bridge equates to net lengths of 250 m perpendicular to the fairway for the passage width.

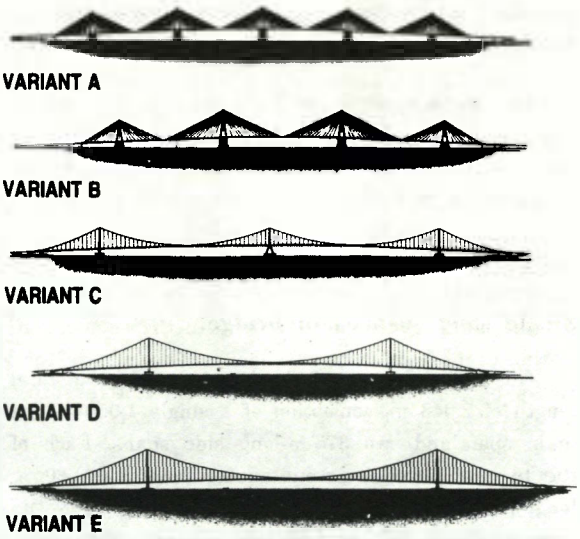

Figure 4
Designs for the bridge section of the tunnel-bridge crossing.
Variantes du pont de la traversée pont-tunnel.

Both of the 250-m passage openings are symmetrically projected in relation to the 5 cable-stayed bridges. This means that the existing fairway limit on the Zuid-Beveland side will have to be corrected by approximately 215 m to the north.

Variant B:
Linked steel cable-stayed bridges.

This variant, with 4 bridge piers, has a total length of 1,961 m. The three concrete spans on the Zeeuws-Vlaanderen side have a total length of 155 m. The 4 steel cable-stayed bridges have lengths of 2 x 500 m and 2 x 350 m, totalling 1,700 m. The concrete approach span on the Zuid-Beveland side is 106 m long. The 400-m passage opening is projected symmetrically in relation to the 4 cable-stayed bridges. This means that the existing fairway limit on the Zuid-Beveland side will have to be corrected by approximately 80 m to the north.

Variant C:
Linked steel suspension bridges.

This variant, with 3 bridge piers, consists of 2 linked steel suspension bridges with concrete anchor blocks and has a total length of 2,198 m. The symmetrical division into two main spans each 720 m long and two side spans each 255 m long was chosen to provide the optimum curve of forces in the main cables. Each of the two reinforced concrete anchor blocks are 80 m long and the concrete approach spans

are each 44 m long. The superstructure and the pylons consist entirely of steel structures.

The passage width on both sides of the central pylon is 250 m. In order to make this possible, the fairway limit on the Zuid-Beveland side will have to be corrected by 120 m to the north.

Variant D:
Single steel suspension bridge.

This variant, with 2 bridge piers, has a total length of 2,048 m, consisting of a single 1,050-m-long main span and two 375-m-long side spans. Each of the two reinforced concrete anchor blocks are 80 m long, and the approach spans are each 44 m long. The superstructure and the two pylons consist entirely of steel structures.

A completely symmetrical main support system was chosen. The passage width (in the central section of the main span) is 400 m.

Variant E:
Single steel suspension bridge.

This variant is a copy of variant D, the only differences residing in the length and the foundation of the two main piers.

Including anchor blocks and approach spans, the total length of this variant is approximately 2,580 m. The main span is 1,360 m long, and the two side spans measure 495 m. The two main piers have foundation pile constructions surrounded by artificial islands, to protect the piers against ship-collisions.

3.2. SOLUTION 2.

Besides the variant with the immersed tunnel, dam-construction and bridge, a second preliminary design of a bored tunnel was drawn up later. Together with the favourable developments in the construction costs of bored tunnels, the following considerations played a role in this choice:

- No blockages of or restrictions to shipping during construction and use;
- No disruption of the morphological balance, since this solution entails no obstacles in the river;
- No damage to the environment and the landscape.

In order to gain the maximum from these advantages, a fully bored tunnel beneath the entire Western Scheldt was chosen.

The bored tunnel consists of two tubes with an outer diameter of 12.5 m and has a total length of some 6,500 m. The minimum depth of the ground cover is 12 m, in relation to the deepest expected bottom level; the deepest point of the bottom of the outer tunnel ring is approximately NAP -63 m.

3.3. PROJECT EXECUTION.

Apart from nautical influences, a further factor influencing the execution of solution no. 1 appears mainly in connection with the ground- and dredging works. In the hydraulic engineering projects alone, almost 14 million cubic metres of soil are involved. The risk of soil flows at certain points of the route also makes it necessary to execute a number of activities in stages.

Another important factor is the accessibility of the "bridge-under-construction", for example in relation to total construction time and costs. This aspect calls for a different approach for each bridge variant. The environmental requirements also place important limiting conditions on the execution methods and/or the order of execution of the project stages.

Unlike the bridge/tunnel combination, shipping plays no important role during the execution of the bored tunnel. Influencing factors are, however:

- Boring speed;
- Location of the factory manufacturing the tunnel units;
- Transport of tunnel units and removal of boring spoils;
- Harmonisation of the boring process with the civil- and electro-mechanical engineering project completion.

Based on the assumption that the tunnel will be bored from one side, using one machine per tunnel tube, the supply and removal lines are relatively long.

The processing of the approximately 1.8 million cubic metres of boring spoils that have to be removed calls for particular attention.

For both solutions a maximum construction time of approximately 5 years is assumed. Based on this schedule, the opening of an open road over or under open water might be expected in the year 2000.

How the link across the Western Scheldt eventually will look like depends upon the winning design. The costs of the winning design will be a crucial factor in the decision on proceeding with the project.

ZUSAMMENFASSUNG

KOMBINIERTES TUNNEL-/BRÜCKENBAUVORHABEN AN DER WESTER-SCHELDE

Die Wester-Schelde ist der Hauptzugang zu den belgischen Häfen Antwerpen und Gent sowie zu den niederländischen Häfen Vlissingen und Terneuzen. 1988 wurde dieser Fluß von über 70.000 Schiffen befahren.

Die Provinz Zeeland ist bestrebt, durch den Bau einer festen Verbindung über die Wester-Schelde die beiden dort befindlichen Fährbetriebe zu ersetzen. Für den Bau dieses Überganges kommen zwei Möglichkeiten in Betracht: eine Kombination von Brücke und Tunnel oder ein unterirdisch hergestellter Tunnel. Bei der letztgenannten Möglichkeit würde der Schiffsverkehr auf der Wester-Schelde nicht beeinflußt, bei der ersten wäre dies jedoch der Fall. Dieser Einfluß kann allerdings durch strenge Auflagen an Entwurf und Bau begrenzt werden.

RESUMEN

PROYECTO DE TUNEL/PUENTE PARA EL BRAZO OESTE DEL RIO SCHELDT

El brazo Oeste del Scheldt es la vía de acceso principal de los puertos belgas de Amberes y Gante y de los puertos holandeses de Vlissingen y Terneuzen. En 1988, más de 70.000 barcos navegaron por este río.

La provincia de Zeeland tiene el proyecto de construir un enlace fijo que cruce el brazo Oeste del Scheldt, en sustitución de dos servicios de transbordador. Hay dos opciones principales para el diseño de este enlace: una combinación de puente y túnel o un túnel cavado. La segunda solución no tendrá ningún efecto sobre el tráfico marítimo que transita el río. Sin embargo, la primera sí afectará la navegación. El efecto se reduce al mínimo imponiendo unos condicionantes estrictos para su diseño y construcción.