ZEEBRUGGE
PORT EXPANSION

Royal Inauguration

JULY 1985

ZEEBRUGGE PORT EXPANSION

Royal Inauguration

Editor
Bill Reid

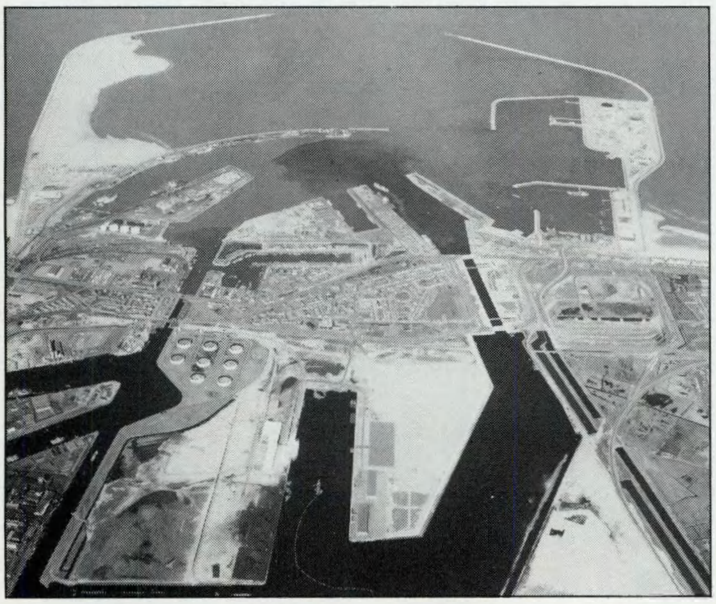
Deputy Editor
Richard Fleming

Advertisement Director
Roy Barr

Group Advertisement Director
John Kennedy

Managing Director
Paul R. Michael

Group Production Manager
Colin A. Edwards



Front Cover: This aerial view of the enlarged Port of Zeebrugge shows the massive scale of the $1.7bn expansion project.

A SUPPLEMENT TO

Dredging + Port Construction

THE JOURNAL OF WORLD PORT DEVELOPMENT

Industrial & Marine Publications Ltd
Queensway House
2 Queensway
Redhill
Surrey RH1 1QS
England
Telephone: (0737) 68611
Telex: 948669 TOPJNL G

"Dredging + Port Construction" is a monthly publication aimed at all those concerned with the port development industry worldwide.

CONSTRUCTION

OPERATIONS

A LANDMARK IN MARITIME DEVELOPMENT

Throughout all ages, harbours have been important to the economic prosperity and the welfare of a country or a region. Indeed, in the world of commerce, the sea is a vital link between the continents.

The history of Bruges bears testimony to this inescapable fact. Times of direct communication with the sea or lack of such went together, respectively, with a high degree of prosperity or depression.

But the development of a harbour and its infrastructure these days is influenced predominantly by world-wide trends in seaborne transportation of cargoes and not by the needs of its local environment.

Official opening of the new port of Zeebrugge on July 20, 1985 by His Majesty King Baudouin will surely become acknowledged, therefore, not only as a landmark in the history of Bruges and Belgium, but also in the annals of international maritime development.

It became clearly evident in the 1960s that an increase in the volume of goods handled and, more so especially, the evolution in navigtion, transport and cargo handling techniques necessitated a radical re-appraisal of the port's facilities.

Seaports with deep water and the potential for vast infrastructural development appear to be essential for the maintenance of an international competitive position. In Zeebrugge it has been possible to adapt the existing harbour to these standards.

Against the backcloth of the current world recession, every contribution to an economic revival and to an incease in employment is important. Expectations are that this new harbour will make a significant contribution.

The construction of a deep-sea port at Zeebrugge has not only aroused considerable economic interest, but it has also constituted an exciting technical and scientific challenge. Over the last 10 years, moreover, the port has been the scene of the country's biggest industrial and engineering activity.

It has also projected far and wide an appreciative awareness of Belgian expertise and innovatory skills in civil engineering and, more specifically, in the field of hydraulic engineering.

Extensive studies preceded the implementation of these massive and complex works, most of which have had to be carried out in open water. A new outer harbour has now been created, which is connected with the inner harbour via a sea lock.

Finally, I think that such a gigantic and difficult project is also important in the history of mankind. It is a tribute to human knowledge and ingenuity and, in this particular instance, to the capabilities of the planners, organisers and all those who have been involved.

L. Olivier

Louis Olivier
Minister of Public Works

Port of Zeebrugge expands into the future

by Ir. R. Simoen, Inspector General of the Ministry of Public Works, Ostend and Ir. J. P. Korbee, General Advisor to the Board of L. L. & N. De Meyer N.V.

More than 100 years ago, in 1881, His Majesty King Leopold II of Belgium made this statement: "Nations achieving high performances have perceived their need for easy and reliable accesses to the sea. We do not have such an access, yet we need it. We have a maritime border more than 60 km long; let us make use of it.

"On our coast, we need at least one harbour equipped with the best facilities, accessible at all times for ships of all tonnages. Modern science can make such construction possible".

In this way, His Majesty took a decisive stand in a dispute, which started in 1866, for and against a deep-sea port in Belgium, situated near Bruges. In 1885, the dispute was settled; parliament approved the decision for the construction of "Bruges Seaport".

On July 23, 1907, King Leopold II officially inaugurated the Zeebrugge Port. This comprised a 2.5 km harbour dam which extended into the "ever-tricky" North Sea, a sea lock and an inner port in Bruges itself. This port functioned adequately for 50 years until the 1956 Suez crisis, which triggered off a revolutionary and rapid increase in ship sizes. The new era of large bulk carriers dictated the need for a dramatic expansion in port facilities, greater depths of water in harbours and their approach channels, and improved cargo handling techniques to facilitate faster turn-round times.

In the early 1970s it became clearly evident that an outer port had to be built at Zeebrugge to meet present and future traffic demands. At that time, however, the Government had no engineering staff with experience of building a structure in the North Sea. This type of work is totally different to that involved in the construction of bridges, quay walls, roads, buildings, tunnels, locks etc ... as marine engineers are well aware. But major decisions are normally taken by politicians and not by technical experts.

In 1973, the Government commissioned a syndicate to undertake a study of the impact on the 64 km stretch of Belgian coast that would result from any works deemed necessary for the import or production of LNG, coal, ore and electricity. The Symarinfra syndicate, as it was called, consisted of two ministerial departments and L. L. & N. De Meyer of Ghent, a consulting contractor with experience of working in the North Sea. De Meyer called in HAECON N.V., consulting engineers of Ghent, for expert advice. The study was published in 1974.

Frame-contract

In 1975, the frame-contract formula was selected by the Government for study/design and execution of the seaward expansion of the outer port at Zeebrugge. The decision was influenced by the success of this formula on similar maritime projects in The Netherlands.

Dutch experience had proved that it is almost impossible to formulate in advance a "cut and dried" study for projects which extend far beyond the coastline and impinge on the existing sea regime with its tidal currents. It is also difficult to pre-determine the effects of such projects on the behaviour of beaches and the seabed.

However, the preparatory study was directed towards obtaining the fullest possible information about the known or assumed behaviour of the sea and the seabed. But surprises always occur because not all of the sea's reactions can be predicted in advance, in spite of the extensive knowledge and modern modelling techniques available from technical institutes and research laboratories. This requires rapid adaptations of the design and execution plans during the construction period without incurring costly delays or protracted discussions on claims.

The frame-contract, which defines general but strict rules and limits for quality control, timing and prices, makes constant consultation possible between Government and the contractors responsible for design. Accordingly, studies and construction plans can be either amended or even changed as and when the need arises during the course of the project to ensure the utmost efficiency and completion on schedule.

In 1976, the Government invited tenders from international contractors on the basis of the frame-contract formula. In September of that year a contract was awarded to a group of contractors brought together by De Meyer, each of whom are specialists in their own particular fields. The group is called Tijdelikje Vereniging Zeebouw-Zeezand TV-Z2. The studies for this joint venture were carried out under the leadership of consulting engineers HAECON N.V.

After nine years, this giant and complex project is in the final

Facts and Figures

The Zeebrugge port expansion project comprises:

- **a new inner harbour of 1,300 ha, including docks, quay walls and extensive handling and storage facilities**
- **a new sea lock for ships of up to 125,000 d.w.t.**
- **a new outer harbour to ensure safe access to the new sea lock and an area of about 550 ha which could be used eventually as a further extension to the port.**

Dimensions of the new outer harbour were governed by the need to accommodate the following types of vessels:

- **fully laden ships of 125,000 d.w.t.**
- **partly loaded tankers of 300,000 d.w.t.**
- **third and fourth generation container ships**
- **an LNG tanker of 125,000 m^3**

Design and construction was entrusted to a consortium of eight leading contractors known as Zeebouw-Zeezand:

- **L. L. & N. De Meyer**
- **Francois-C.F.E. N.V.**
- **Franki N.V.**
- **S.B.B.M. Six Construct N.V.**
- **Jan De Nul N.V.**
- **Dredging International N.V.**
- **Overseas Decloedt & Fils N.V.**
- **Royal Boskalis Westminster N.V.**

Client: Ministry of Public Works, Coastal Division.
Leading consultant for the studies: HAECON N.V.

Quarried stone is the most important material for construction of the breakwaters. It is supplied in different grades by a large number of quarries.

The daily supply is about 8,000t, arriving in two to three 1,100t trains, two barges and a fleet of 100 trucks. Some 50 concrete blocks are made on-site each day.

Completion of the two outer breakwaters is scheduled for the end of 1985.

Total quantities:

Dredged sand	**±60m m^3**
Hydraulic fill and reclamation	**± 72m m^3**
Sea gravel	**± 7m tonnes**
Willow mattresses	**± 1.1m m^2**
Quarried stone	**±10.6m tonnes**
Concrete blocks	**± 60,000**

stages of completion. Not a single delay has occurred during the progression of works through all the different phases. Furthermore, not a single claim has been lodged by the contractors.

There can be few, indeed if any, dredging and port construction projects throughout the world, particularly of such magnitude as Zeebrugge, that can lay claim to such a record. In addition, the sea certainly did not behave as a lovely lady . . . positively bad tempered on many occasions!

Project details

A 1,300 ha inner port area has been created. A sea lock which is navigable by ships of up to 125,000 d.w.t. has been built and a new, extended outer harbour is nearly finished.

Design of the outer harbour is such that ships can safely complete their voyage "dead slow" at the entrance of the lock. Consequently, a minimal sailing length has been created to allow vessels to "put on their brakes" between entering the port and entering the lock.

The breakwaters have been constructed in a curved configuration to form the outer port. A 50 ha transport zone in which all "dry" port activities will be concentrated is currently under construction.

Large-scale rehabilitation of the beach, east of the Port of Zeebrugge, has had to be carried out. Storms over many years had eroded it to a dangerous state with a consequent threat to the boulevard and adjacent buildings.

Four years of extensive studies were necessary to establish the outline and the construction details of what now must appear to be a logical and simple concept.

Descriptions of the various works involved in the execution of this interesting port project are given in subsequent articles.

Construction of the two main breakwaters in the North Sea was one of the major challenges faced by the Zeebouw-Zeezand consortium.

The scale of the outer port construction project at Zeebrugge is particularly evident in this striking aerial picture.

East Coast rehabilitation

by Ir. P. Kerckaert, Chief Engineer–Director Coastal Department, Ministry of Public Works
Ir. C. F. Rietveld, Assistant General Manager, Zeebouw–Zeezand J.V.
Ir. P. De Candt, Project Engineer, HAECON N.V., and
Ing. A. Noordam, Project Manager, Zeezand J.V.

The beaches on the coast east of Zeebrugge harbour have been badly eroded over the years. As this part of the Belgian coastline is an intensively used holiday resort, a beach rehabilitation scheme was required in conjunction with the port extension. Extensive prototype surveys supplied data for hydraulic and mathematical models to quantify alternative solutions. These solutions consist of a beach nourishment, whether or not supported by coastal defence works.

Between December 1977 and March 1979, trailing-suction hopper dredgers removed some 9m m^3 from selected borrow areas in open sea and dumped the sand in protected waters in front of cutter suction dredgers. These subsequently pumped the material over a maximum distance of 11 km, using up to five booster stations. The east coast now has beaches over 100 m wide, where before at high tide no beach was left at all.

Surveys of the restored beach have to be compared with the study results which indicate the further measures that will have to be taken. A comparison of the revenue derived from the tourist trade and project costs shows the latter to be relatively inexpensive.

Beach nourishment plant on the beach at Knokke-Heist; the whole operation proved to be a considerable tourist attraction.

Zeebrugge harbour is situated on the north-east coast of Belgium, some 10 km from the Dutch border. It is located in a morphologically complex coastal region known as the Flemish Banks, on the seaward side of the Westerscheldt estuary. The morphology of this region is primarily determined by its relatively high current velocities (up to about 2 m/sec at Spring tide) and the very fine sand and silt.

Material transport is thus considerable, and morphological instability rapidly ensues from changes in the hydraulic regime. The initial harbour of Zeebrugge was protected by a vertical breakwater more than 2 km in length which was constructed between 1897 and 1906.

In 1976, the Belgian Government awarded the turn-key contract for the harbour extension at Zeebrugge to the joint venture group T.V. Zeebouw–Zeezand. The contract included the planning and design of functional coastal protection for that section of the north-east coast.

The design phase established the optimal extension length of the new outer harbour to be about 3.5 km from the coast into the sea. This would naturally bring changes in the hydraulic regime, with repercussions on the morphology of the coastal region concerned.

Provisional analyses of the problem had led to the conclusion that natural restoration of the beach was out of the question, so that this would have to be accomplished artificially by means of beach nourishment, whether or not supported by other measures such as groynes and filling up the Appelzak.

Design

The study was aimed at investigating the probable consequences of harbour extension on the coastal region east of the harbour, followed by formulation of measures required for maintaining the replenished beach. Different transport phenomena were considered to calculate the coastal erosion: tidal transport, on-offshore transport, eolean and longshore transport. The morphological effect of the modified tidal currents resulting from extension of the harbour proved to be most significant.

Tidal transport phenomena were calculated for the nearshore area (outside the breaker zone). The tidal currents for each alternative were deduced from physical and hydraulic mathematical models. The object of calculating sediment transport due to tidal currents was to analyse, for each alternative, what the consequences of the adopted measure would be for the coastal region concerned in terms of sedimentation and erosion.

Beach regression due to erosion by tidal currents was calculated to be as follows (sedimentation not included):

— initial situation:
250,000 m^3/yr, or about 25 m^3/'/yr
— new outer harbour:
300,000 m^3/yr, or about 30 m^3/'/yr
— new outer harbour plus one groyne:
500,000 m^3/yr, or about 50 m^3/'/yr.

Wind erosion

On the beach, wind erosion will become more significant than it used to be because the replenishment has enlarged the beach by more than 100 m out to sea, thereby creating a large dry sand area.

Sediment transport by the wind was calculated using Bagnold's formula for sand in desert areas,

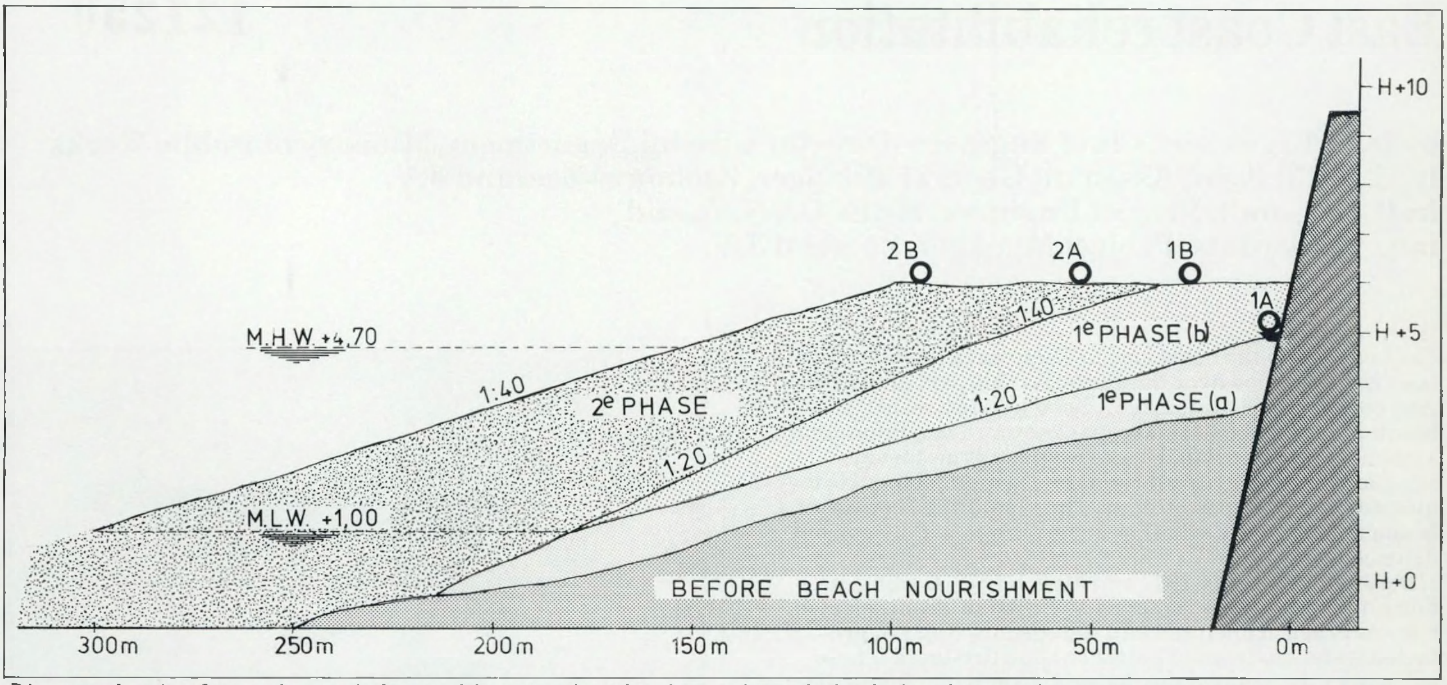


Diagram showing first and second phases of the execution plan for sand supply for the beach nourishment programme.

i.e. with a moisture content of 0 per cent. Terwindt has undertaken research into the relationship between the moisture content on the beach and the minimum shear velocity needed to initiate sand transport by wind on Dutch beaches. From this, sand transport by wind has been determined under various moisture conditions.

By combining these data with climatological data, a wind erosion loss of 80,000 m^3/yr was finally calculated for the coastal region concerned. Most wind losses proceed inland (perpendicular to the coastline) and are a nuisance to the commercial premises along the seafront. Measures have therefore been sought to reduce these losses by means of Osier hedges and wooden screens.

In studying erosion problems a choice always has to be made between a "hard" defence — by means of groynes, for example, which are supposed to combat erosion — and a "soft" defence, implying that erosion losses are replenished at regular intervals by materials equivalent to the amount lost. The selection of one method in preference to the other is a matter of economics.

Sediment transport calculations showed that a total annual coastal erosion of around 800,000 m^3 must be anticipated.

Beach nourishment

The beach nourishment works were carried out within the framework of extensions to the outer harbour of Zeebrugge. This means that a number of data were obtainable from drillings made earlier to determine the new navigation route. This greatly assisted the search for suitable borrow locations for the 8m m^3 plus of sand required as beach fill.

For economic reasons, it was decided to deepen a 5 km long stretch of the navigation channel to the Westerscheldt, north of the "Wandelaar" sandbank, at about 20 km sailing distance from Zeebrugge. In the first 2 m below the existing bottom, which varied between H −12 m and H −15 m, sand layers were encountered with a mean grain diameter of D_{50} between 225 and 325 micron, a quality meeting all the requirements laid down for the beach improvement.

In view of the location of this borrow area, the use of large sea-going trailing-suction hopper dredgers was an obvious choice. They not only enabled work to be continued under bad weather conditions for a comparatively long time, but they did not inconvenience shipping in any way.

The trailer dredgers deposited their loads in a special dumping pit. From there, working continuously, a powerful cutter suction dredger and booster station pumped the sand along the beach.

To provide an initial protection and restoration for a 5 km long section of the sea wall, it was decided to pump in about 2.6m m^3 of sand in the first phase. Subsequently in a second phase, about 5.8m m^3 of sand was supplied, this time distributed over the entire length of the 8 km long beach.

In December 1977, the approach to the new sea lock had been dredged far enough to permit the commencement of sea sand supplies. The dumping pit was divided into two adjoining sections, each measuring 350 × 80 m, so that the cutter suction dredger could remain continuously at work. While one section was being dredged to about H −15 m, the other was being filled to about H −8 m. The cutter suction dredger needed about 10 days, on average, to process one fully dumped section.

The trailing-suction dredgers had to be of appropriate size for the capacity of the cutter dredger, thus the hopper capacity of the vessels used for this operation varied between 5,000 and 7,000 m^3 of sand. Fully loaded, they had a draught of 8–10 m and were able to dump their loads at all times, irrespective of the state of tide.

The average working cycle of each trailer dredger was about four hours per load: 1.5 hours dredging time, two hours sailing time, and 10–15 min dumping time. Most of the sand was dredged by the trailer dredgers *Pacifique* and *Antwerpen IV*.

At the end of 1977 the cutter dredger *Mercator* had excavated the lock approach and started the first phase of sea sand supplies. Initially, the sand was pumped over a distance of more than 6,000 m via a pipeline of 800 mm diameter. Three 2,500 hp diesel booster stations were set to work astern of the dredger at 500, 1,300 and 3,400 m respectively.

The first was a floating station near the end of the 500 m long floating pipeline, while the other two were situated on different parts of the beach above the high water line. Special attention had to be given to provide provide sufficient clear water for the diesel engines and gland pumps. Finally, a system of drain tubes, entrenched in the beach between low and high water level, was chosen.

To bridge the greater pumping distances (between 8,000 and 11,000 m) two more booster stations were used, some 5,400 m and 6,600 m astern of the cutter dredger. Two 2,000 hp electro-boosters were set up on the already partly replenished beach right opposite the centre of the seaside resort of Knokke-Heist. They operated on the municipal electricity network. Electric propulsion was chosen to comply with the strict regulations governing noise abatement in this built-up and much frequented tourist zone.

In July 1978, the most distant point for beach reclamation was reached, involving a maximum pumping distance of 11,000 m. This marked the end of the first phase, during which a volume of 2.6m m^3 of sand had been deposited over a length of 5 km, i.e. 520 m^3 per running metre.

In addition to the cutter dredger *Brabo*, which was equipped with a 1,600 hp submersible pump and two 1,600 hp pressure pumps, all five boosters were also in operation. This meant that more than 16,000 hp was being employed to pump an average mix concentration of 20–25 per cent in the 11,000 m long pipeline of 800 mm diameter at a velocity of 4.5–5 m/sec.

After that, working back again, the second phase of beach nourishment was implemented, during which 5.8m m^3 of sand was distributed as evenly as possible over 8 km of beach, i.e. an average of 725 m^3 per running metre. During this part of the operation the boosters were gradually withdrawn from service, and in March 1979 the beach improvement project was completed.

Throughout the execution of this project, the plant worked 24 hours a day, five days a week, from Monday to Saturday morning inclusive. The necessary repair and maintenance jobs were done at the weekends.

As previously mentioned, erosion of the beach at Knokke had been theoretically evaluated at 800,000 m^3 per year, consisting of 300,000 m^3 per year by tidal currents, 420,000 m^3 by wave action and 80,000 m^3 by wind erosion. Evaluation of these theoretical quantities after six years of observations revealed that the real losses are much lower than expected.

Nevertheless, some additional supply of 1m m^3 of sand will be needed in 1985 at the most exposed areas of the beach of Knokke. The job will probably be carried out by Jan de Nul's new 27,000 hp sea-going, self-propelled cutter section dredger *Leonardo Da Vinci,* currently under construction at IHC Smit in Kinderdijk, The Netherlands, and scheduled for commissioning in October.

Beach activities

The entire length of the main pipeline was entrenched to a depth of 1 m so that only the pipes actually spouting sand were in view over a short stretch of the beach. In effect, the operation turned out to be a tourist attraction since the good quality of the sand made it possible for people on the beach to make immediate use of the sand that had been deposited the previous day.

During the first phase, two pipes supplied sand all along the sea wall to a width of 30 m and a level of H +6 m. Under low water conditions the first pipeline was used, which had been laid on concrete blocks specially placed at H +5 m level over 12 m along the face of the sea wall. Under high water conditions the second pipe, lying somewhat to the rear and 25 m from the sea wall, simultaneously pumped sand over the first pipe, which later continued to function as the main pipeline.

Dredging plant used on beach project

Name	Dredger Type	Owner
Pacifique	hopper (9,260 m^3)	Decloedt
Antwerpen IV	hopper (4,800 m^3)	Dredging Int.
Brabo	cutter (6,585 hp)	Dredging Int.
Mercator	cutter (6,515 hp)	Jan de Nul
3 booster sta.	diesel (each 2,500 hp)	Decloedt
3 booster sta.	electro (each 2,000 hp)	Boskalis

This process was adopted because spouting underwater always creates a steeper face. Thus the pipe on the sea wall, working under low water conditions, produced a comparatively gentle slope, while the second pipe, lying further out to sea, spouted a relatively steep slope under high water conditions. As a result, the toe of the beach being replenished always formed at approximately the same place, sand losses were curtailed, but a sufficiently wide beach was created.

During the second phase, two other pipelines about 40 m apart deposited sand along a following strip of beach, so that a 100 m wide beach was finally realised, at a level of H +6 m. At the request of the municipality at Knokke-Heist, a 25 m wide strip was nourished to H +7 m for a distance of 2,000 m along the sea wall. This is the busiest part of the beach and ensures that the adjacent properties will be safe at any high water.

Total costs for this project amounted to approximately Bfr2,000m, which equates to Bfr250,000 per running metre of beach, or about Bfr1,500 per m_2 of beach above the high water line.

Beach observation

Design of the beach nourishment project incorporated the follow-up implementation of a well defined beach observation programme. This should enable adequate protective measures to be taken if these prove necessary.

Following completion of the beach nourishment works the whole area has been regularly surveyed by sounding the area below low water and by photogrammetric and terrestrial surveys above low water. Each month a selection of representative profiles is measured on the coastline from the sea wall down to the low water line (terrestrial surveys). The other surveys are carried out twice a year, in Spring and in Autumn.

A comparison of the costs incurred in beach replenishment and the revenue derived from the tourist show the works to be relatively inexpensive. About 3 m tourists stay overnight each year and a similar number are day visitors. Assuming they spend, respectively, an average of Bfr1,500 and Bfr300, the total revenue is Bfr5,400m/yr.

Maintenance cost for the beach is, therefore:

164,000 m^3/yr × Bfr270/ m^3 = Bfr45m/yr

or:

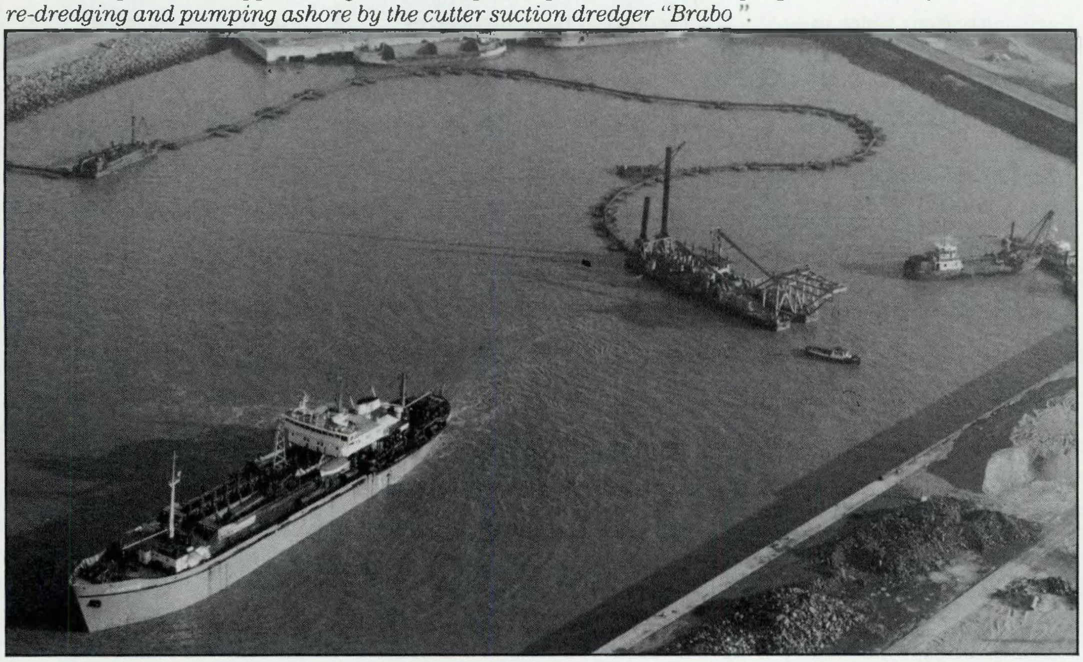
$\frac{45}{5,400} \times 100$ per cent = 1 per cent of what the tourists spend, or expressed per tourist:

$\frac{45m}{(3 + 3)m}$ = Bfr 7.5/tourist/day.

This comes out at less than the price of a beer (Bfr30).

At the end of 1985 an additional 1m m^3 of sand will be supplied to the most heavily eroded beach areas as a first phase of a maintenance programme since the main beach restoration project in 1979.

The trailing-suction hopper dredger "Atlantique" is pictured here dumping its sand load for re-dredging and pumping ashore by the cutter suction dredger "Brabo".



HYDRO SOIL SERVICES

In open sea conditions and less protected environment (tidal rivers, lakes,...), self elevating platforms are best employed as a stable working base for reliable testing, accurate positioning and all kinds of civil construction works.

During the construction works of the new outer harbour of Zeebrugge, a variety of works were executed from small jack-up platforms by HYDRO SOIL SERVICES.

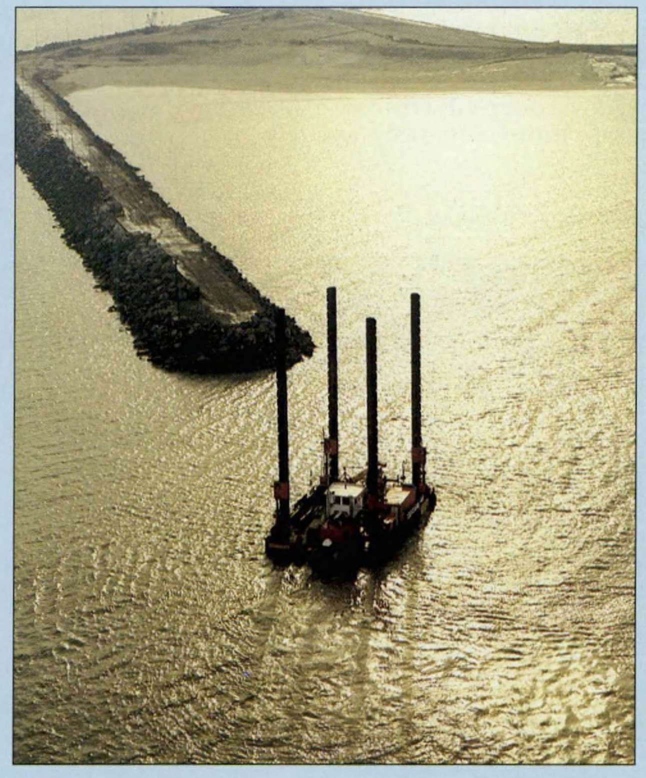
Because of the heterogeneous structure of the seabed, an extensive programme of soil investigations was carried out including cone penetration tests, pore pressure readings, exploratory borings, etc.
These tests were executed nearshore as well as in open sea.

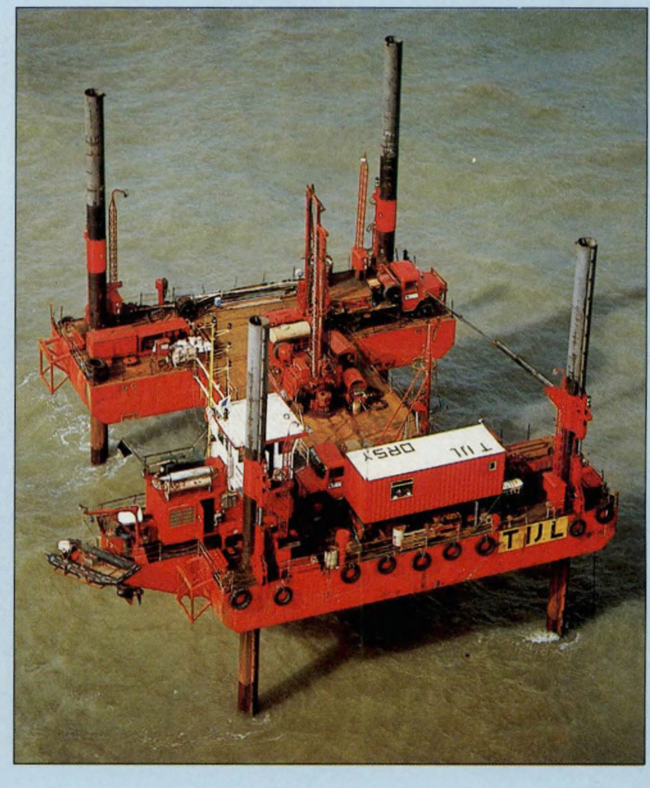
In order to provide the harbour of Zeebrugge with deep access channels, some old shipwrecks have to be removed. In order to examine the possibility to 'bury' these wrecks partially or completely beneath the channel or harbour bed, a soil investigation programme combined with a geotechnical interpretation of the tests results is necesarry.

A first application was succesfully undertaken by HYDRO SOIL SERVICES during the wreck removal works of the british destroyer MAORI.

The breakwaters of the new harbour are of the rubble mound type, constructed on a sand foundation.
The quality of this sand was evaluated by CPT tests.
When the used evaluation criteria were not fulfilled, deep compaction was carried out. Taking into account the offshore marine conditions, HYDRO SOIL SERVICES proposed a new technique of underwater compaction using small explosive charges lowered into the ground by wash-boring.
As a result a high and homogeneous densification was obtained using small equipment.

Other services offered by HYDRO SOIL SERVICES to the construction industry include hydrografic surveys, marine mineral and gas exploration, general laboratory services, rock drilling and blasting underwater, restoration of harbour structures and demolishing of concrete underwater.





Address: Scheldedijk 30
B-2730 Zwijndrecht Belgium

Phone: 32-3/252.65.26
Telex: 31839 Telefax: (03) 2526831

Breakwaters and civil construction works

by Ir. L. van Damme, Principal Engineer, Coastal Department, Ministry of Public Works
Ir. D. J. Vandenbossche, Technical Director, HAECON N.V.
Ir. N. Pille, Technical Department, Zeezand J.V.
Ir. C. F. W. Rietveld, Assistant General Manager, Zeebouw–Zeezand J.V.
Ing. J. Lemmers, Technical Department, Zeebouw J.V.
Ing. M. Lauwers, Superintendent, Zeebouw J.V.

The extension of the outer port of Zeebrugge is protected by two breakwaters, each about 4 km in length. After establishing the design conditions, comparative studies were carried out for different types of breakwaters of which the rubble mound type proved to be the best solution.

The design of the armour layer resulted in a flat semicube armour unit to provide a safe and economic structure. One of the important features of the breakwater construction was the dredging in open sea of unsuitable top soils by self-propelled, sea-going cutter suction dredgers. The trenches were filled with sand of a good quality and protected against erosion. Where necessary, this foundation was compacted from a self-elevating platform using vibration needles or explosives.

The toe construction of the breakwaters consists of willow mattresses and beams of heavy quarry stone. The dam core is built with quarry run or heavier grades of stone and covered by protective layers of stone and concrete armour units. Within the harbour area several civil construction works complete the project, the most important of these being a jetty for L.N.G. carriers of up to 125,000 m^3, quay walls, pavements, pipeline ducts and navigation aids.

The extension of the port, in other words the distance that the breakwaters protrude into the sea and the shape of the breakwater layout, was designed in compliance with the following criteria:

- the eastern and western limits were formed by the urban areas of Knokke-Heist and Zeebrugge, and their beaches which attract an extremely remunerative tourist trade.
- the existing "Pas van het Zand" channel as well as previous decisions locating the sea lock and the link between outer and inner harbour, together determined the original orientation of the shipping routes to and from the inner harbour.
- the northern limit was fixed according to the generally expressed requirement that any changes to tidal currents in the Western Scheldt Estuary were to be of a limited nature.
- inward and outward bound shipping manoeuvres were to be guaranteed in the increasing cross-current conditions and velocity profiles. Sufficient manoeuvring areas for inward and outward bound ships were to be provided.
- at the entrance to the new sea lock a maximum design wave was imposed to safeguard lock operation. For wind forces up to Force 7 the maximum significant wave height had to be less than 0.70 m.
- the outer harbour should provide sufficient sheltered port area for the location of tidal basins and harbour infrastructure to handle general cargo, containers, an L.N.G. plant, roll-on/roll-off terminals and other facilities.
- the stringent time schedule requirements for the L.N.G. terminal had to be taken into account.

A comprehensive hydraulic study was carried out on several hydraulic and wave diffraction models, both mathematical and physical. The required nautical studies made use of measurements on trial navigation runs, as well as ship manoeuvring simulation both on a mathematical real-time simulator and on physical models and calculations. The erosion and sedimentation problems were assessed using comprehensive sedimentation field studies, e.g. radioactive tracer measurements and mathematical and physical modelling.

Finally, the so-called "1750-G" concept was retained and finally approved by Government for implementation.

Design conditions

The bottom depth in the alignment of the outer harbour breakwater ranges between Z−5.00 m and Z−7.00 m (chart datum Z = mean low water spring +0.08 m). The tide has amplitudes of 4.40 m at mean spring tide to 2.80 m at mean neap tide. The meterological set-up is to a maximum to 2.45 m in the defined design period.

The tidal currents at the final breakwater alignment will be 1.2 m/sec to 2 m/sec at spring flood tide and 1 m/sec to 1.6 m/sec at spring ebb tide. The soil conditions in the Zeebrugge area are rather complex. A comprehensive geological and geotechnical survey was undertaken with boreholes, static cone penetration tests and continuous seismic profiling.

The synthetically recorded geological profile showed a rather pronounced separation between the tertiary sediments and the quarternary cover layers with, as a main feature, the cuesta of the Bartonian clay formation with dips of up to 30 per cent. The less resistant bottom "sandwich" layers, consisting of alternate thin layers of soft clay and sand, mainly 4–6 m in thickness, cover a considerable deposit of fairly dense to densely packed quarternary sand in the western breakwater. In the eastern breakwater the deposit of quarternary sand is up to 15 m thick on the tertiary Bartonian clay deposit. This tertiary layer rises towards the sandwich cover layer at the head of the eastern breakwater.

From 1958–71, waves were systematically measured by shipborne wave recorders on board the lightship *Westhinder*, stationed some 40 km from Zeebrugge. Since 1977, wave riders have been continuously recording at several locations in the Zeebrugge area. The transmitted data was analysed and synthesised by computer to provide the relevant wave parameters and statistics.

The preliminary and final designs were based on the wave climate derived from the *Westhinder* data by refraction analyses, which covered different approaches, wave periods and water levels.

The design wave height conditions are summarised in the following table. By defining these conditions the risk of the design wave height being exceeded has been estimated to be 10 per cent during the 50 year lifetime and depreciation write-off period of the main structures. For shorter exposure periods (max. 3–5 years) an average yearly exceedance frequency of 10 per cent has been taken.

After evaluation of technical feasibility, costs, risks and con-

Design wave height conditions for outer harbour breakwater NW/NE

Design wave height H_s(m)	6.10
Design sea level (m)	Z+6.85
Accepted damage (per cent)	0.5
Probability of exceedance (per cent)	10
Lifetime or exposure time (years)	50

struction aspects the rubble mound breakwater was selected. The caisson type breakwater was judged to be more risky due to the very high standards required for the foundation, the design wave climate and expected siltation during construction. In addition, a technically equivalent design was some 30 per cent more expensive.

The detailed design specified a foundation bed which involved soil replacement by dredging the unsuitable top soils and the dumping of selected sea sand as backfill. To ensure stability, the dumped sand had to reach a static cone resistance value of 4 MN/m^2. Where these values were not obtained, artificial compaction was carried out.

Hydraulic and sedimentation studies carried out to define the phases of construction works indicated that erosion of the foundation bed could be expected in front of the breakwater structure. To prevent this a detailed programme of bottom protection was designed consisting of, respectively, a layer of gravel, fascine mattresses and stone filter layers.

Lateral berms of heavy quarry stone (1–3 t and 3–6 t grade) support the armour layers of the breakwaters. The berms are founded on mattresses which extend 30–50 m seawards to protect the toe against scouring. A wave carpet at a level of Z −6.00 m limits the wave action on the armour to the design wave height defined by the original seabed of Z −7.00 m.

Soil replacement

Over large lengths of the breakwaters at Zeebrugge the bearing capacity of the surface layers was insufficient. A soil replacement design was assessed, both technically and economically, by evaluating the alternative of a breakwater built directly on the existing seabed, where the overall stability is provided by rubble stone equilibrium on both sides.

Where the cross-section and layout of the trench was complicated by sharp curves, difficult slopes and changing depths, the top layer of loose sands and soft clays was dredged by large seagoing, self-propelled cutter section dredgers. Elsewhere, the trenches were dredged by trailing-suction hopper dredgers.

The cutter suction dredgers used on the soil replacement project had to work some 1,000 m away from the shore in unprotected waters. In this part of the North Sea during winter, wind forces of 100–130 km/hr, wave heights of 4 m and current speeds of up to 2.5 m/sec are frequently prevalent.

In these circumstances, only fully seaworthy, self-propelled cutter suction dredgers (Class "Deep Sea Dredge") can be used. From April–December 1978, the first part of the project was carried out by the 16,100 hp self-propelled cutter suction dredger *Vlaanderen XIX*, owned by Decloedt. This vessel dredged the temporary and definitive access channels to the harbour and removed the bad layers under the inner protection dams.

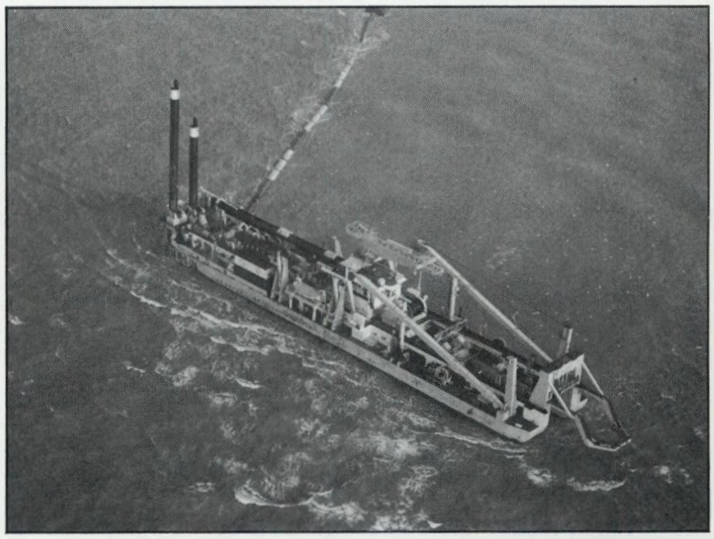
During the summer of 1979, Boskalis Westminster's 19,250 hp self-propelled cutter suction dredger *Oranje* completed the ground improvement under the eastern breakwater of the L.N.G. terminal.

Work schedules compelled the removal of unsuitable soil layers under the L.N.G terminal to be carried out in the inhospitable conditions of winter during December 1979 to January 1980. The working area was located some 1,500 m offshore without the protection of the existing harbour mole against north-westerly and northerly storms. Jan de Nul's 20,088 hp self-propelled cutter suction dredger *Marco Polo* executed this part of the operation.

Five years of experience at Zeebrugge have proved that dredging in open sea conditions with cutter suction dredgers is still a challenge for any existing vessel. Consequently, substantial quantities of bad soils were removed by trailing-suction hopper dredgers in places where the cross-section and slopes of a trench were not too complicated.

It is generally known that soil replacement by dredging and refilling a trench leaves a transitional layer at the bottom. Special precautions had to be taken to minimise the extent and thickness of that layer. In addition, a supplementary amount of mud in a dredged trench at Zeebrugge results from waves and strong tidal currents.

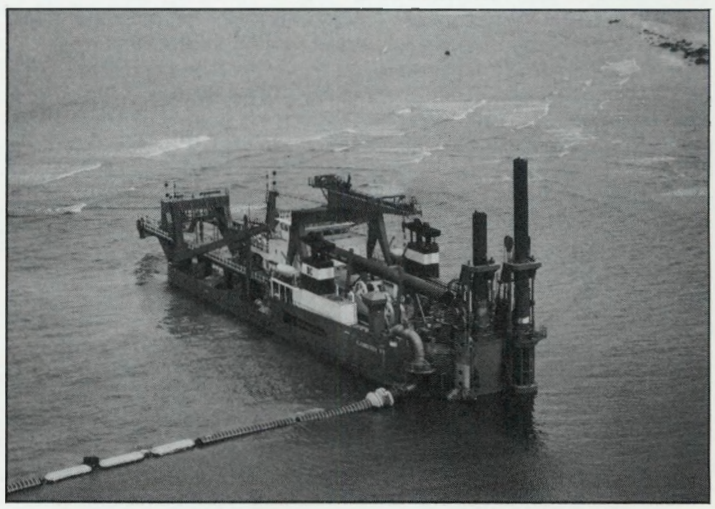
To minimise the sedimentation in a dredged trench, immediately after a lenght of 150–250 m had been prepared, sand was dumped by a fleet of trailing-suction hopper dredgers in the 2,000–5,000 m^3 category, such as *Schelde II,*

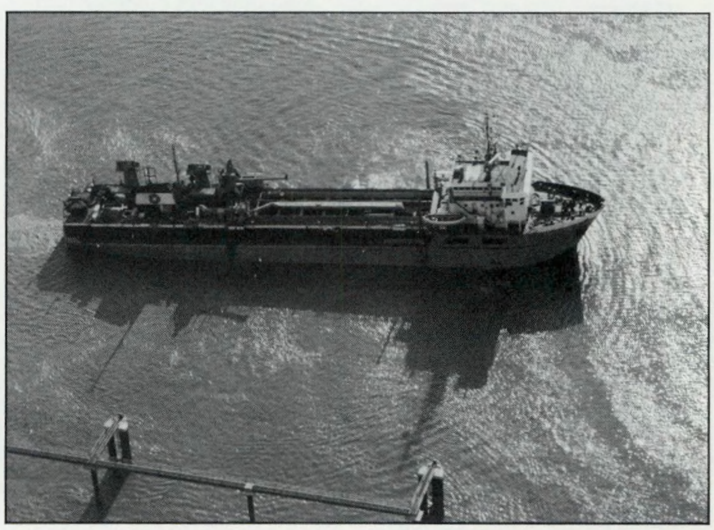


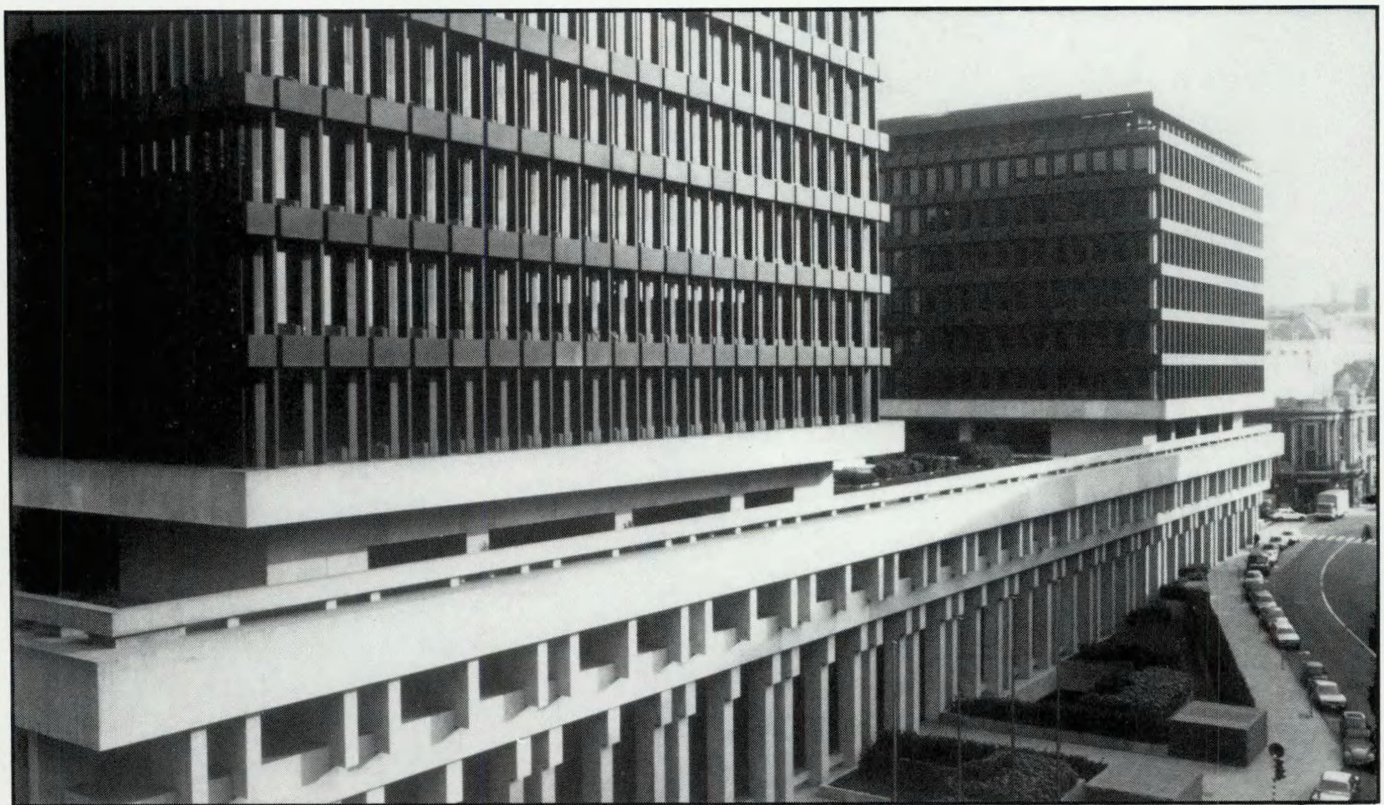
Top: Jan de Nuls' self-propelled sea-going cutter suction dredger "Marco Polo" (20,088 hp) at work in protected waters removing bad soil layers under the northern breakwater of the L.N.G. terminal.

Middle: Decloedt's self-propelled sea-going cutter suction dredger "Vlaaneren XIX" (16,300 hp) dredging the entrance channel to the work harbour.

Bottom: Dredging International's trailer-suction hopper dredger "Schelde II" (3,200 m^3) removing bad soil layers in the foundation of the western breakwater.







Maas, *Beachway* and *Sanderus*. In order to reduce the cost of building the superstructure of the breakwaters, sand was dumped as high as possible. This was only possible by using trailer dredgers with sliding bottom doors and split hopper trailers such as Dredging International's *Pantagruele* and Jan de Nuel's *Galilei*.

The controlled dumping of the sand was executed without any mooring. High accuracy in positioning was obtained by using trailing-suction hopper dredgers equipped with bow thrusters and sufficient propulsion power.

Special attention was given to the electronic positioning and surveying system. Nine Decca Trisponder DMU 540 distance measuring units were purchased to achieve accurate positioning up to 0.5 m. These receivers measured the distances to a number of fixed stations on shore. A built-in computer converted the measured distances into UTM co-ordinates, while a track plotter provided a continuous display of the vessel's position on a map.

All soundings were made onboard the specially adapted hydrographic vessel *Jacqueline*, equipped with an identical DMU 540 positioning unit and an Atlas Deso 20 echo sounder. A cassette unit onboard registered all position, depth and tidal data on a continuous basis. On shore, the data collected by the survey vessel was processed by a cassette unit which read the recorded data, applied the tidal corrections and transferred the corrected data on discs. Finally, a 64 K-byte computer system processed the inserted data into depth charts, profiles, dredged quantities etc.

Sea gravel

The loss of sand in refilled trenches through the erosive forces of tidal current was limited by placing a covering layer of about 1 m of unscreened sea gravel. The gravel was dredged on the French coast near Wissant and Dieppe by Dredging International's trailing-suction hopper dredgers *Maas* and *Schelde II*.

These vessels meet many special requirements for dredging gravel at great depths, such as an underwater dredge pump and a booster jet in the suction pipe. Spreading of the gravel on top of the trenches was done in several layers at sailing speeds of two knots in strokes of about 300 m length and 15 m width.

In the area of the L.N.G. breakwater, where the soft and loose top soil layers were dredged by the maintenance service of the existing harbour, sand was dumped immediately on the seabed over a height of about 5 m. On both sides the sand was protected with dumped gravel banks. The gravel was dredged by Jan de Nul's trailing-suction hopper dredger *Sanderus* off the south coast of England near the Isle of Wight.

Compaction in depth based on vertical vibration was applied by a patented vibration probe, which comprised three steel plates welded together with the cross-section of a three-pronged star, hence the name "Starprofile". The probe was hung in a vibrator block and lowered into the dumped sand by a crane mounted on a jack-up platform. The energy of the vertically vibrating probe was transferred to the soil mainly through a series of ribs working as individual pounders.

Crew transport to the self-elevating platform "Launcelot" in bad weather conditions; the "Launcelot" was equipped with an NCK heavy duty crane (capacity 80 t at 30 m radius) and two 120 t crawler cranes for compaction.

The vibrating probe penetrated to a depth of about 2 m into the natural layers underneath the bottom of a filled trench. The distance between the compaction centres on a triangular pattern was determined by the results of CPT tests carried out before compaction, and the cone resistance to be obtained in the dumped sand after compaction. Compaction works at Zeebrugge were performed by the self-elevating platforms *Dirk*, *Launcelot* and *Zeebouwer*.

Although deep compaction with the vibration probe produced satisfactory results, a programme was introduced in 1983 to examine the feasibility of *in situ* densification by using explosives from the jack-up platform *Tijl*. The impact of an explosive charge causes momentary liquefaction of loose saturated sands which subsequently adopt a more dense, stable structure under the weight of the overburden and increased drainage.

To reduce the amount of quarry stones in the centre of the breakwater, sea gravel was dumped as high as possible by two 660 m^3 self-propelled, sea-going split hopper barges. The sea gravel for this operation was dredged by the specially equipped gravel dredger *Deepstone* off the east coast of England in the Thames and Humber estuaries and near the Lowestoft and Wash areas.

This dredger is equipped with a screen installation which supplies average loads of 7,500t screened gravel with a sand content of less than 30 per cent. A filter installaion in the well of the vessel drains the load, which is delivered ashore by a travelling deck grab and a 2,000 t/hr conveyor belt.

The gravel was offloaded by the *Deepstone* in the new work harbour. As no quay wall was available, an unloading facility with a capacity of 2,000 t/hr had to be constructed. A 122 m long unloading belt conveyed the gravel to a level of 20 m above ground level,

The "Sanderus" dredged sea gravel for the L.N.G. breakwater off the south coast of England near the Isle of Wight.

Dredging plant used on foundation works

Sea-going, self-propelled cutter suction dredgers

Name	Total output	Owner
Marco Polo	20,088 hp	Jan de Nul
Oranje	19,900 hp	Boskalis
Vlaanderen XIX	16,500 hp	Decloedt

Trailing-suction hopper dredgers

Name	Hopper capacity	Owner
Sanderus	5,338 m^3	Jan de Nul
Beachway	3,051 m^3	Boskalis
Maas	3,000 m^3	Dredging Int.
Schelde II	3,200 m^3	Dredging Int.

Split hopper trailer dredgers

Name	Hopper capacity	Owner
Krankeloon	2,700 m^3	Dredging Int.
Galilei	2,339 m^3	Jan de Nul
Pantagruele	2,000 m^3	Dredging Int.

Self-propelled split hopper barges

Name	Hopper capacity	Owner
Zeezand I	660 m^3	Zeezand T.V.
Zeezand II	660 m^3	Zeezand T.V.

Self-elevating platforms

Name	Dimensions	Owner
Launcelot	40 × 40 m	Boskalis
Dirk	23.50 × 40 m	Boskalis
Zeebouwer	20 × 42.60 m	Zeebouw T.V.
Tijl	20 × 25 m (self-propelled)	Dredging Int. + Smet N.V.

The self-propelled jack-up platform "Tijl" was employed during compaction works carried out by explosives; equipped with three jetting rigs, the platform was moved in parallel lines to minimise anchor movements.

where it was spread over a length of 120 m by a stock belt fitted with a tripper installation.

Total stock capacity was about 100,000t of gravel. Special attention was given to the foundations of the conveyor installation. As bad soil layers had not been removed under the reclaimed stock area, it was calculated that settlements of about 1 m could be expected at the foundations. For this reason, an isostatic construction had to be accepted, fitted with rotating couplings on each point of support. As supports in the stock pile, a tube section was chosen instead of framework to minimise the forces imposed by the gravel sliding down.

A 600 t/hr conveyor belt installation was built 200 m south of the unloading belt to load the split hopper barges. The gravel was rehandled from the stock pile by one or two wheel loaders and dumped on to a 110 m long conveyor belt.

Most of the gravel was dumped in the centre of the breakwaters without any mooring by the two 660 m^3 self-propelled, sea-going split hopper barges *Zeezand I* and *Zeezand II*. To enable accurate dumping these vessels are equipped with twin rudder propellers and a powerful bow thruster.

Compaction

To control the quality of the soil replacement, CPT tests type M4 were performed at regular distances in the corresponding areas. Although precautions were taken to minimise the quantity of mud at the bottom of the trench before dumping the sand, it was seen from the results of the CPT tests that this could not be completely prevented.

In each diagram a thin layer with relatively small cone resistance could be distinguished at the bottom of the previously dredged trench, indicating the presence of a thin layer of silty or clayey sand. Generally, however, from a depth of about 1 or 2 m underneath the top of the dumped sand layer, the cone resistance reached values of about 6-10 MN/m^2, or even more. The design criteria of quality of the dumped sand were made bearing in mind that liquefaction of this sand foundation of the breakwaters was not admitted. Handling these criteria for density control compaction was necessary over a length of about 25 per cent of the breakwaters, where soil replacement had been chosen.

A blasting programme was carried out in the foundation layers at the extremity of the north-western breakwaters. The jack-up platform *Tijl* was equipped with three jetting rigs and the platform was moved in parallel lanes to minimise movements of its anchors. The charge holes were jetted in parallel lines at distances of 7.5 m and the explosive charges were placed at depths of 4.5 m and 9 m below the seabed.

Blasting was executed in a triangular pattern whereby the charges at the corners of a triangle were detonated at least four hours after detonation of the charges of the adjacent triangle. When all the charges had been detonated, the platform was moved to an adjacent lane. In this way the same volume of soil was influenced by different blasts at varying times.

A total surface area of about 14,000 m^2 was compacted over a period of 15 days. Compaction was carried out over a thickness layer of about 11 m using about 15.3 g Blastogel per m^3 of soil. In the compacted area, 242 borings with a total length of 2,180 m were made in water depths varying between 8–13 m, and 2,300 kg of explosives were detonated.

Breakwater construction

Construction of the breakwaters has involved the use of low-cost materials so far as this has been technically feasible, and with due regard to life-span stability under the most extreme of weather and sea conditions. Sand and gravel have only a limited resistance to tidal, current and wave action, but can be used up to a certain level.

At Zeebrugge, it was found that sand could be used up to a level of LLWS −3 to −4 m, provided that a protection of gravel was dumped on top of it within two weeks. The gravel at this level was sufficiently stable to hold on until a protection of willow mattresses or quarry run was placed on it. The bottom protection of willow mattresses had to be stable because they formed part of the final construction.

By programming the successive operations within the pre-defined time limits it has been possible to build 15–20 per cent of the body of the breakwaters with sand and gravel. But the superstructure of the breakwaters had to be constructed with more resistant materials, covered with heavy stone on the harbour side and concrete blocks on the seaward end.

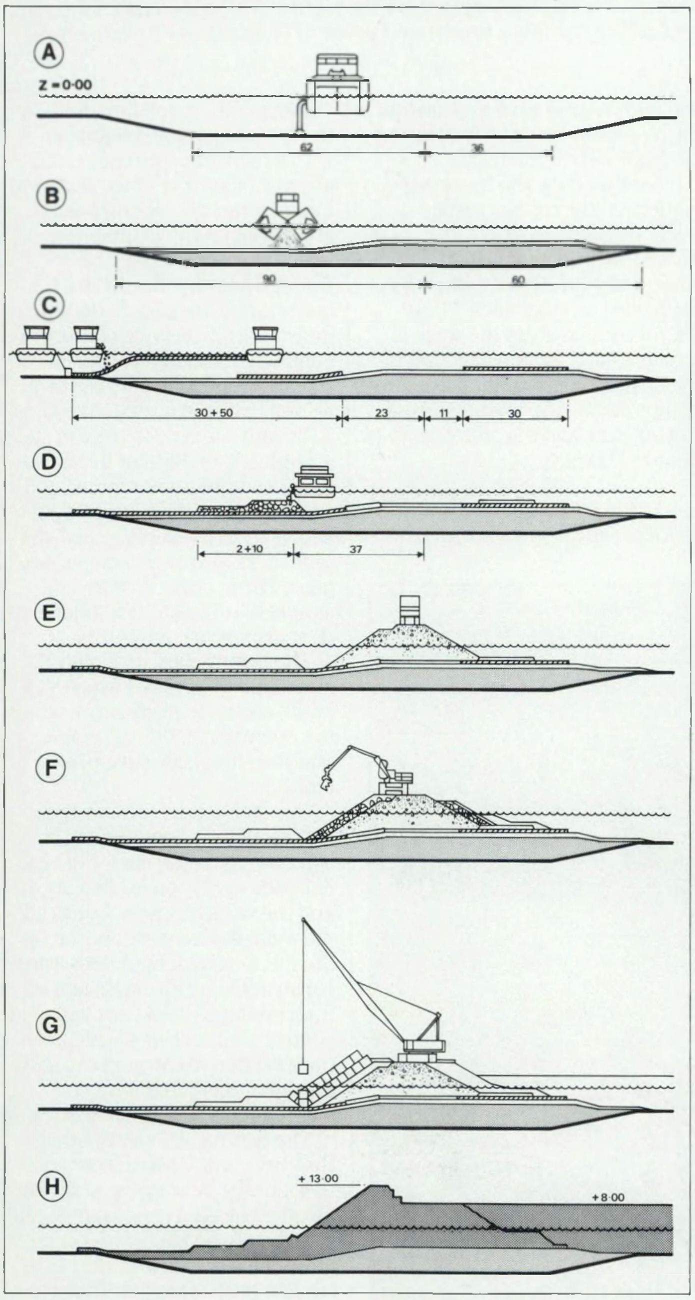
The progressive construction of breakwaters in open sea is largely dependent on weather conditions. In this case, where the

construction materials or protective measures varied in accordance with these conditions, a reliable weather and wave forecast was essential. To this end, the Ministry of Public Works, Coastal Service, Ostend, in co-operation with the Meteo Wing of the Belgian Air Force, set up a special on-site Meteorological Forecasting Service.

Twice-daily weather forecasts were provided, together with a correlated wave prediction. Directional wind force/wave height correlation graphs were prepared by the consultant on the basis of wind and wave data measured in prototype. This enabled the contractors' site managers and surveyors to predict the amount of time that could be spent on the various phases of constructing the breakwaters.

The meteorological service was also equipped with an on-line wave analysis computer which processed data received from the wave-rider buoy located on the work site. This supplied information to forecasters and site managers about wave generation and height in respect of wind force and direction.

Diagram showing construction phases for the breakwaters; (A) dredging of unsuitable topsoil; (B) dumping of sand and a cover layer of gravel; (C) sinking of mattresses; (D) dumping of berms for toe protection; (E) dumping of core of quarry run; (F) placing of secondary 1/3 t cover layer; (G) placing of 20-30 t concrete blocks; and (H) finishing crown and eventual reclamation.



Willow mattresses

Willow mattresses, ballasted with various grades of stone, provide the protection against erosion and scour on both sides of the breakwaters. These mattresses are well-proven in north-west Europe for the capability to follow scour at and under their edges without disintegrating.

Another advantage of importance for the Zeebrugge project was the relative thin nature of the construction as compared with a stone filter of several layers of successively coarser grades. As the sea is shallow, approximately LLWS −6 m, a more costly filter construction would have been required for the heavier top layer of stone.

The mattresses are constructed on a slope by first laying out a fabric of polypropylene. Ends of cord are interwoven in this fabric to secure the bundles of willow. Dimensions of the mattresses had a standard width of 30 m and a length of 50 m commensurate with those of the stone-dumping barges. The mattresses were towed to the site at high tide and sunk to the seabed by the barges with stone in a fashion rather similar to sprinkling sugar on a cake. After being placed into position the mattresses were bedded down still further with heavier grades of stone varying between 1,000–3,100 kg/m^2, dependent on the exposure of wave attack. The area between the sunken mattresses were covered with a layer of 1 m quarry run of 200–300 kg to protect the underlying gravel.

The last phase of the operation involved the sinking of berms which form the toe protection for

S.A.UCO N.V. of Ghent supplied sea-mattresses to protect the outer harbour breakwaters against toe scour. Photo shows the sinking of a mattress in progress. A large wave-breaking "carpet" was specified to be constructed towards the seaward end of both breakwaters wherever the seabed was between 2.50 and 7.00 m below low water level. The scour protection mattress was designed to be geotextile based, constructed primarily of willow fascine and overlaid by quarrystone layers extending right up to 3,000 and 6,000 kg rocks on the toe slopes.

The outer armour protecting the core has a slope of 34 deg and on top of this the head of the breakwater is filled with heavy quarry stones weighing between 1,000 and 3,000 kg. The outsides of the breakwaters are covered with concrete cube armour units weighing 30,000 kg with a concrete density of 2,300 kg/m^3. The crest elevation is 13 m above low water level.

The following inventory indicates the average weekly quantities of materials that were handled during construction of the breakwaters:

Supply of quarry stone by road	20,500 t
Supply of quarry stone by rail	16,500 t
Supply of quarry stone by ship	4,000 t
Supply of cement	1,000 t
Supply of concrete aggregates	8,000 t
Supply of willow	2,000 m^3
Manufacturing and sinking of willow mattresses	4,500 m^2
Stone dumping by barges	17,000 t
Quarry stone in the superstructure	24,000 t
Manufacturing and placing of concrete blocks	300 units

The total quantities involved in construction of the breakwaters are, approximately:

Willow mattresses	1.1m m^2
Quarry stone	11 m tonnes
Concrete blocks	60,000 units

Manufacturing in progress for the willow mattresses, provided for protection against erosion and scour of both sides of breakwaters.

the cover layers of the breakwaters. These berms weighed 1–3 t on the harbour side and 3–6 t on the seaward side and were placed into position by stone dumping barges of a heavier and sturdier construction than those used on the mattress sinking operation.

Completion of the underwater works was followed by construction in the "dry" of the cores for the breakwaters. The stone was supplied by dump trucks of 40 t capacity. The secondary layers consist mostly of 1/3 t stone on the seaward side and form an intermediate filter between the core and the concrete blocks of the cover layer. These stones were placed into position by a Poclain 600 hydraulic crane. The concrete blocks for the cover layer range between 20 t for the less exposed areas and up to 30 t for the breakwater heads. These were positioned by a heavy-duty crawler crane.

L.N.G. jetty

This jetty has a dual function. It will provide a berth for the 125,000 d.w.t. tanker *Methania* which will bring in the liquid gas, and also serve as a connection for the pipe racks between the loading platform and the mainland.

The unloading and the service platforms which have, respectively, dimensions of 47 m × 40.50 m and 69 m × 20 m, consist of a prestressed deck supported on steel piles. These platforms constitute the work space needed for construction of the unloading installations such as pipe racks, operation and control building and the "nitrogaindewaere" facility.

Independent dolphins, built in front of the jetty and equipped with a fender construction, will absorb the energy of the berthing tanker. Special mooring points are placed on the dolphins to ensure a safe mooring of the vessel. To bridge the distance between the mainland and the unloading and service platform a connection has been established.

This connection consists of an access road and a service road, both with a length of 188.5 m and a width of 9 m. Both of these roads comprise a reinforced concrete roadway built on steel piles and, next to the service road, the pipe racks also founded on steep piles. These projects were assigned in 1983 to two independent groups of contractors.

The layout consists mainly of steel foundation piles which support a concrete platform on which the operation buildings, cranes and the pipe racks have been built.

Generally there are two types of steel piles — longitudinal or spiral welded. The choice of type depends mostly on availability and the wall thickness. Longitudinal welded piles were chosen for the L.N.G. jetty. These piles were constructed by Firma Begemac, Federal Republic of Germany. To control the theoretical calculations related to carrying capacity, tension forces, flexibility, and reality, a test pile was driven.

The test results showed that the curve and tension were positive, but the bearing capacity was insufficient. As a consequence, all piles had to be filled with concrete after being driven and after the silt had been removed. To protect

Construction of the front of the eastern breakwater, with dredging of unsuitable topsoil being undertaken by the "Oranje".

the piles against corrosion two types of anti-corrosion systems were used: a protective coating and cathodic protection.

During the driving of the pile supporting structure, the cross beams and the capitals were prefabricated. The cross beams are a part of the connecting grid and form a support for the prestressed I-beams. When a certain number of piles had been driven and filled with concrete, the prefabricated cross beams with a maximum weight of 45 t were placed.

At the beginning of these works, some slight problems were encountered in holding the beams in the right direction because they were constantly moved by the wind and waves. This problem was solved by connecting the piles with each other by a metal structure which was removed after the joints had been connected. All the piles were provided with a reinforced concrete capital, each of 7 t weight and 3 m × 3 m.

When the piles had been driven and the capitals were in position, the piles were filled with concrete. The prefabricated cross beams were then placed. In the cap of the pile, which was provided with seven anchors, a group of 20 casings with a section of 8.5 cm and a length of 2.7 m was placed and filled with concrete up to the level of the capital. The casings were carefully connected with each other by muffs and the reinforcement was placed in position, finalised by concreting of the connection points.

Prefabricated reinforced concrete plates were used as casings for the open sides of the joints. Following placement of the prefabricated beams and the concreting of all the connecting points and after the concrete had a pressure force of 40 N/mm^2, the whole structure was prestressed in transversal and longitudinal directions.

Dolphins

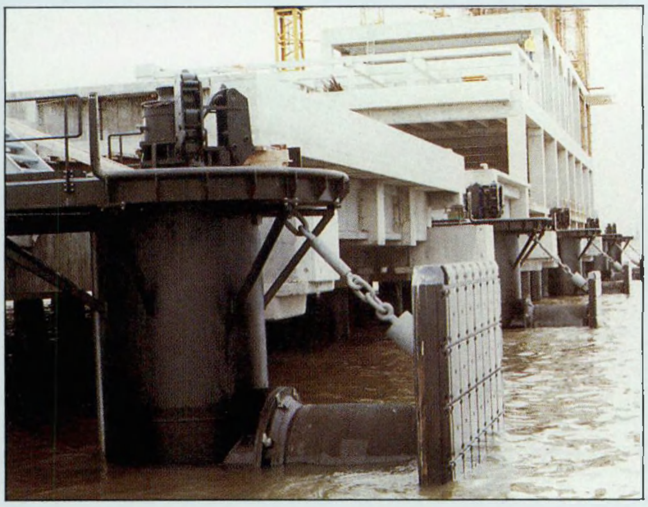
Independent breasting and mooring dolphins were placed to absorb the energy of the berthing tanker and to take the static wave and wind forces by moored conditions of the vessel.

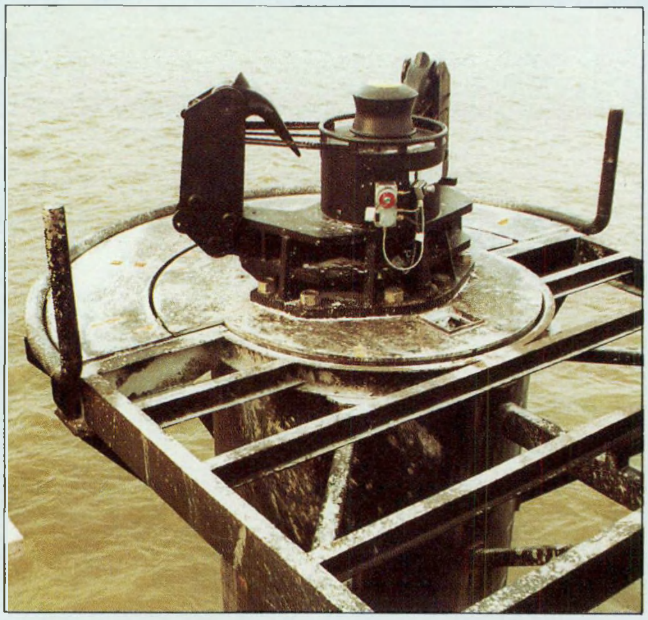
The piles have a diameter of

Begemac N.V. of Antwerp supplied longitudinally welded steel pilings with an outside diameter of 914.3 × 14 mm wall thickness and in different lengths of between 25,050 and 28,790 mm for the LNG terminal (as shown in the photo). The company also supplied longitudinally welded tubular steel dolphins with a diameter of 2,200 mm and in different wall thicknesses of between 25 and 58 mm.

N.V. Mitsui & Co. Europe (Benelux) S.A. supplied and installed under a turn-key contract five Bridgestone fenders SUC H 2250 × 1 × 1 mounted on a monopile system for the LNG terminal (as seen in the photo). The tanker's berthing energy is absorbed by a combination of super cell fender and a mono flexible pipe-pile.

The cell fender is a cylindrical elastomeric section with steel mounting plate permanently bonded to the main column during vulcanisation. Under axial loading, the contoured profile of the cylinder buckles radially. This controlled, multi-directional dispersion of energy combines the high absorptive efficiency of the buckling columns with the strength-extending characteristics of a stable geometric shape high energy absorption and low reaction force as distinguished features.





To cope with high safety standards, the Belgian Ministry of Public works decided to provide the Zeebrugge LNG jetty with an up-to-date mooring installation, supplied by N.V. Steditek Belgium. Each of the 12 dolphins (as seen in photo) is equipped with a number of Quick Release Mooring Hooks.

These hooks are designed to withstand a 150t loading, and they are able to release the LNG tanker's mooring lines under a tensile force of up to 125t. In the event of an emergency, the hooks can be released either manually or by remote control. To facilitate remote release, the hooks are equipped with a specially designed, solid state controlled electrical actuator, mounted in an explosion-proof enclosure.

For mooring line handling, each dolphin is also provided with a capstan motor assembly. The Quick Release Mooring Hook Support serves not only to support the mooring hooks but is also for the high performance winch.

Picture showing the east stock area with its graded piles of stone, the work harbour for use by the various contractors, and the start of the work on the L.N.G. terminal area.

General view of the final stages of construction of the L.N.G. jetty, with construction of some of the storage tanks of the L.N.G. terminal visible in the background.

2.20 m, a length of 40 m, and a weight of 87 t. They have a variable wall thickness and consist of high quality steel to make them as flexible as possible. Each pile had to be prefabricated in a conditioned environment to ensure the correct welding conditions for the high quality steel plates which had thicknesses up to 54 mm.

When the piles had been driven, two structural elements were added to the dolphins: the fender including the support and fender panel and the dolphin platforms for the mooring equipment. Both parts were prefabricated. The fender is connected to the piles by a frame of horizontal and vertical plates and stiffeners for the supporting plate of the fender.

The prefabricated dolphin platform for the mooring equipment consists of a frame of beams covered by a steel plate of 50 mm thickness. The mooring force is taken by a quick release mooring unit anchored by eight anchor bolts M80. L = 1.8 m. The quick release mooring units are equipped with double-triple and quadruple hook assemblies.

These are equipped with an integral power capstan, provided with an explosion-proof protected electric remote control system, and completely integrated into the mooring assembly. A remote controlled electric release mechanism is provided. This enables one operator in a central control station to release any or all of the hooks in the system.

Work harbour

A work harbour was built to provide facilities for handling gravel and quarry stone and also shelter for the floating plant of the contractors' consortium. Bituminous sand breakwaters protected a dock wherein a 530 m long quay wall was used to load the quarried stones, along with a jetty for dredgers and an assortment of other craft involved in the project. A bridge was also built over the coastal road to connect the work harbour with the stone yard.

The quay wall, built on a substratum composed principally of sand layer, was designed to receive ships of up to 5,000 d.w.t. The concrete structure of the quay wall rested on reinforced concrete piles and steel sheet piles. The concrete piles were sunk into the ground and had a diameter of 54 cm, the compression piles had a bearing capacity of 150 t and the tension piles took up to 32 t.

Access channel and reclamation

by Ir. P. Kerckaert, Chief Engineer-Director, Coastal Department, Ministry of Public Works
Ir. D. J. Vandenbossche, Technical Director, HAECON N.V.
Ir. C. F. W. Rietveld, Assistant General Manager, Zeebouw–Zeeland J.V.
Ir. N. Pille, Technical Department, Zeezand J.V.
Ir. P. Jacob, Project Manager, Bergingswerken J.V.

Design of the access channel to the Port of Zeebrugge included a study of various routes and the ultimate depth and width. The choice was influenced by minimal navigation hazards, the more suitable dredged materials for reclamation and the number of wrecks that had to be removed.

The cross-section was designed for an L.N.G. tanker of 125,000 m^3 and the attendant safety requirements. Approximately 30m m^3 had to be dredged, most of which was reclaimed to provide a harbour area within the new outer port. The dredging was executed by trailing-suction hopper dredgers which deposited their loads in protected dumping areas in front of cutter suction dredgers which, in turn, pumped the sand to the reclamation areas. Several wrecks also had to be removed.

The following elements were taken into account for determining the route of the access channel:
- the nautical qualities or disadvantages of three proposed routes
- the costs of capital dredging
- the costs of maintenance dredging
- the balance of the sand extracted from the channel and the quantities needed for reclamation in the outer harbour
- the costs for the removal of wrecks within the chosen channel route
- the "dredgeability" of the soil to be removed.

Site investigations were carried out comprising soundings, soil sampling, vibro cores and boreholes and an overall wreck survey. After this, cost estimates were prepared for dredging and wreck removal in three alternative routes and for various depths. An important parameter was the quantity of sand which could be used for reclamation in the outer harbour.

The Pas van het Zand, i.e. the access channel from the Scheur to Zeebrugge, was selected as being the most economical and best navigable route.

Channel depth

The keel clearance (k.c.) had to fulfill two criteria. First, during normal, good weather conditions and a channel depth meeting the design depth, there had to be sufficient keel clearance to allow the vessel normal manoeuvrability. This value of the k.c. can be described as the required net k.c.

Second, during bad weather conditions and/or deviations of the design depth in the channel, the chance of the ship touching the bottom had to be acceptably small. The required k.c. and channel depth were calculated for an LNG carrier. It should be stressed that the results of these calculations are not valid for other types of vessels such as bulk carriers or container ships because of the very strict safety margins applied to LNG traffic.

Draught of the vessel is 11 m. According to PIANC recommendations and other studies it was found that for ship speeds up to about 8 knots a reasonable estimate for squat could be derived from the formula:

$$Z = \frac{V^2}{2g}, \text{ in which}$$

Z = squat in m
V = ship speed in m/sec
g = acceleration of gravity = 9.8 m/sec^2.

As the maximum ship speed in the channel will not exceed 7 knots, the squat will be approximately 0.6 m.

As the LNG carrier will only sail in the channel during rising tide and when the cross current is less than 1 knot, the lowest water level during Spring tide is 1.05 m above datum. The limitation of the acceptable cross current to 1 knot is one of the strict safety measures for LNG traffic. For other traffic considerably higher cross current velocities are accepted.

Due to meterological influences the water level may be reduced by 0.4 m with a probability of 12 times a year. It was not considered necessary to regard lower frequencies as the influence of this effect is small in relation to others. The lowest tidal level during the ship's entrance was taken as 1.05–0.40 = 0.65 m above datum. A net keel clearance of 1.2 m for the LNG carrier was regarded as sufficient to provide normal manoeuvrability.

During bad weather conditions a ship may suffer wave induced motions which lead to an increased draught. This phenomenon can be described in a statistical way, once the response functions of a ship to wave motion are known. Given the wave characteristics it is possible to calculate the probability of a ship's movements. These calculations were undertaken for three types of vessels — LNG, third generation container ships and VLCCs — by Marine Structure Consultants B.V.

Due to heavy siltation in the channel, it has to be accepted that in spite of continuous dredging the minimum channel depth might be less than required and also sometimes more. The variations of channel depth between soundings were also calculated.

In this particular instance it was found that in 1 per cent of the soundings the channel depth was 1 m less than required. Thus the chance of encountering a channel depth of 1 m less than expected is 0.01 ($p_d = 0.01$). The total chance of touching bottom also depends on the chance of a ship navigating the channel (p_s). Assuming that all three phenomena (waves, shoaling and traffic) are independent, the combined chance P can be found by multiplying the three individual chances.

Thus
$P_x > x_1 = p_v \times p_d \times p_s$,
x being the sum of ship's motion, with chance p_v and shoaling with chance p_d.

In this way a frequency curve can be drawn. To determine the design value for x an acceptable value for P has to be chosen. Another way of approach is to introduce the available keel clearance in good weather conditions into the graph and find the chance of touching bottom. If this chance is acceptable there is no need to deepen the channel for bad weather conditions.

Following the last method of reasoning, the available keel clearance is:

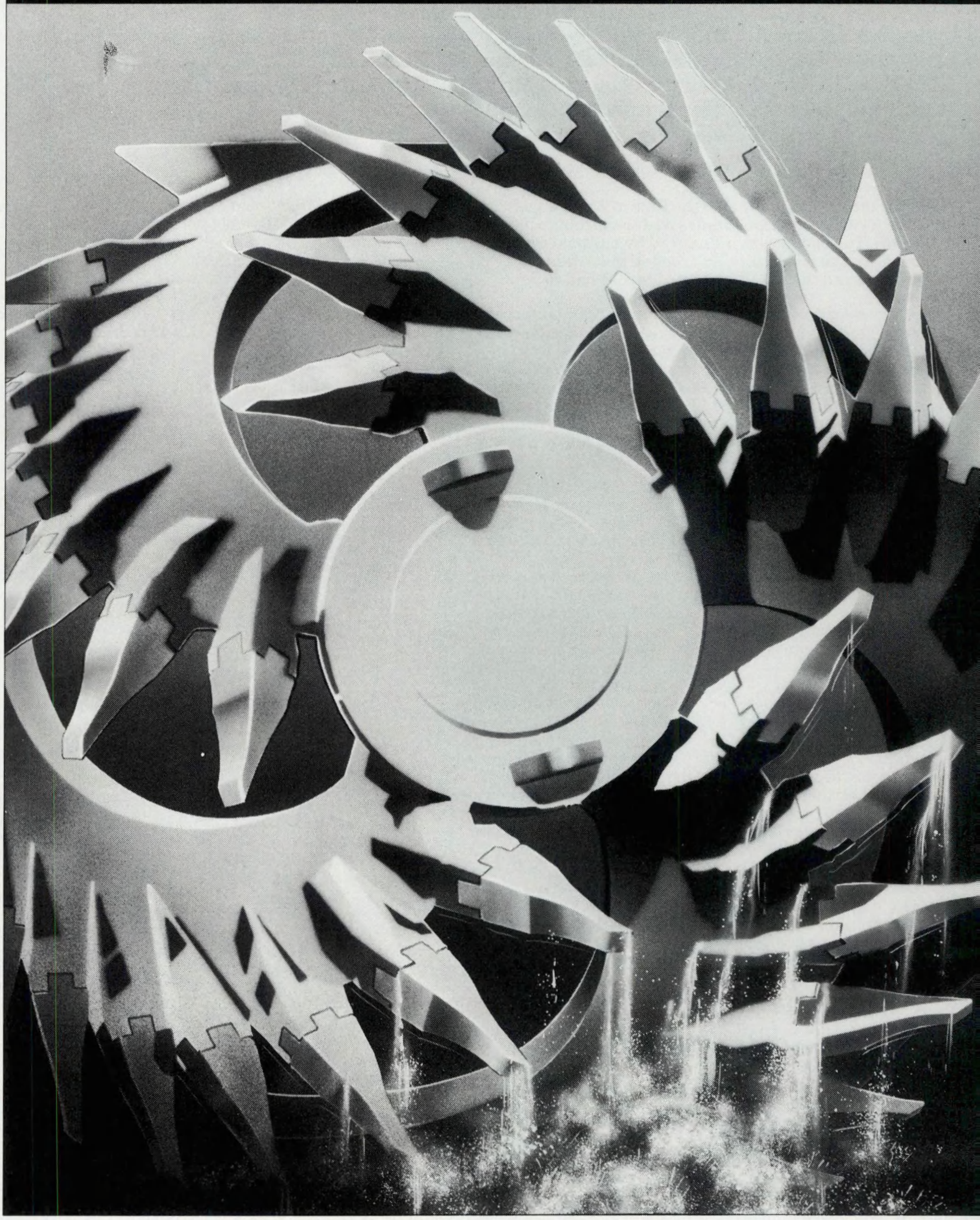
Channel depth	12.50 m
Tidal level	+ 1.05 m
Water depth	= 13.55 m
Ship's draught	− 11.00 m
Squat	− 0.60 m
Accuracy of soundings	− 0.30 m
Available keel clearance	= 1.65 m

The conclusion was that for this particular channel the normal conditions were decisive and the design channel depth was fixed at 12.5 m below datum. In the same way for the LNG carrier with its specific safety margins, the channel depth in the Scheur was designed at 13.4 m below datum.

Channel width

A distinction had first to be made between the Scheur and Pas van het Zand channel sections. The Scheur channel not only serves the entrance to Zeebrugge, but it is also the principal access route to the Western Scheldt and the major ports of Antwerp, Ghent and Vlissingen. This has to be a two-way channel for the biggest ships and hazardous cargo ships carrying LNG or LPG.

THE CON



TINUING SUCTION STORY.

(AGAIN AND AGAIN AND AGAIN.)

At IHC Holland, we're rather fond of the 'Continuing suction story'. For as the world's largest dredger builders, it's a story that says a great deal about us, too.

How, for instance, the unrivalled IHC Holland experience in this field has resulted in supplying well over 650 cutter suction dredgers to all parts of the world.

How IHC is able to provide ex-stock dredgers with machinery outputs varying from 150 kW up to 2,500 kW all built from standard components for early delivery and at an economic price. Or construct a custom built vessel, of any size, demountable or oceangoing, to suit any specific requirement on time and at a price that fits your budget. Plus the extensive backing of training facilities, spare parts and after sales service.

It's an enviable record. And one that explains why IHC Holland has already been asked to build more cutter suction dredgers than any other company in the world.

But the story doesn't end there. For today, with the world's most up to date dredger building yards, at Sliedrecht and Kinderdijk, supported by a highly sophisticated research and development wing, IHC Holland is better placed than ever to lead the world into new eras of dredging technology.

For more information on today's most advanced cutter suction dredgers or any other IHC product and service or to receive our authoritative quarterly magazine 'Ports and Dredging', contact IHC Holland, P.O. Box 208, 3350 AE Papendrecht, Holland. Telephone (0) 78 15 88 11, Telex 29456.

Congratulations!

What better example of the reliability of IHC Holland products than the 'Marco Polo', one of the most powerful self-propelled cutter suction dredgers in the world.

IHC

IHC HOLLAND *WE HAVE THE SOLUTIONS.*

In the case of the three mile long Pas van het Zand, however, it had to be determined whether it was economically feasible to provide a two-way channel for all ship sizes. A study was carried out which calculated the eventual down-time for second and third generation container ships, large bulk carriers and the LNG vessel *Methania* if only one-way traffic was chosen.

At the time these calculations were carried out VLCCs called regularly at Zeebrugge. Following closure of the Texaco refinery, this traffic has stopped, but it has been replaced since then by bulk carriers of similar size in the coal and ore trade. However, the conclusions are still valid. It was subsequently decided that there was no need for a two-way channel until possibly the 1990s and so the width of the Pas van het Zand has been designed for one-way traffic.

Final channel width design for the LNG carrier was:

Pas van het Zand — one-way traffic, 300 m width at a depth of LLWS — 12.5 m.

Scheur — two-way traffic, 750 m width at a depth of LLWS — 13.4 m.

Seaward of the Scheur — two-way traffic, 900 m width at a depth of LLWS — 13.6 m.

Dredging

As the design for the Zeebrugge outer harbour consists of breakwaters being built as far as 3,000 m out from the coastline in water depths of 5–7 m below low tide, it was possible to keep dredging quantities for the creation of new docks in the outer harbour to a minimum. Moreover, the quantities of sand required for reclamation could be dredged in conjunction with deepening of the access channels.

Work started in 1977 by dredging the entrance channel to the new sea lock which was under construction at that time. The entrance channel served temporarily as a protected dumping pit for the beach nourishment project and was dredged by the cutter suction dredger *Mercator*.

Meanwhile, a working zone had to be created east of the harbour for construction of the southern quay wall of the work harbour. In addition, construction areas for the prefabrication of 25 t concrete blocks and for the stocking of sea-dredged gravel were needed. These areas were reclaimed by the cutter suction dredger *Brabo*. The sand was dredged in the existing and future channels by the trailing-suction hopper dredgers *Antwerpen IV* and *Atlantique*.

In June 1980, the breakwaters of the LNG terminal were advanced sufficiently to permit a start to be made on reclamation of the 40 ha area for the future LNG installations. In total, almost 10m m^3 of sand were dredged by the cutter section dredger *Brabo*. The sand was won in navigation channels to Zeebrugge and Antwerp and dumped in front of the cutter dredger by the trailing-suction hopper dredger *Sanderus*.

From June 1982, some 9m m^3 of sand were needed as inner protection of the western breakwater. As the ara between the new outer western breakwater and the existing harbour mole was scheduled to be reclaimed in the near future for port facilities, heavy quarry stone protection was not foreseen as inner slope protection.

The first part of the job was done by the cutter suction dredger *Ortelius*. Sand was supplied by Decloedt's trailing-suction split hopper dredger *Vlaanderen XX* and Dredging International's trailer dredger *Rupel* by deepening the Scheur-west access channel. From the end of 1983 the entrance channel to the new sea lock could not be

With construction of the L.N.G. terminal breakwaters sufficiently advanced, work began in June 1980 on reclamation of the 40 ha L.N.G. terminal site.

Decloedt's split hopper trailer dredger "Vlaanderen XX", with a capacity of 5,145 m^3, is pictured here in the process of dumping its sand load in the initial dumping pit at the entrance to the sea lock.

Soils that could not be used for reclamation were loaded by Dredging International's backhoe dredger "Big Boss" into 1,000 m³ split hopper barges.

used anymore as a dumping pit because the lock then became operational. A new protected dumping pit was subsequently dredged south of the LNG breakwater which was then almost finished.

As the top layers consisted of mud and clay, these soils could not be used for reclamation and were loaded into 1,000 m³ self-propelled split hopper barges by Dredging International's self-propelled backhoe dredger *Big Boss*. When finished, the dumping pit was continuously refilled with coarse sand from the access channels by the trailing dredgers *Pacifique* and *Rupel*.

The cutter dredger *Brabo* pumped this sand to the western area by means of three diesel booster stations each of 2,500 hp. In May 1985 the western outer breakwater was finished sufficiently to permit a protected dumping pit to be dredged much closer to the reclaim area.

Wreck removal

It was known from existing charts that several wrecks and obstacles were on the seabed of the channel route. On 26 June 1981, the joint venture T.V. Bergingswerken, including the dredging contractors Dredging International, Decloedt and Jan De Nul, successfully submitted a tender to the Belgian Ministry of Transport for the clearing of an unknown wreck, No. 108, located off the Port of Zeebrugge between the buoys *Scheur 5* and *Scheur 6*.

An extensive study was subsequently implemented, including a team of divers and an examination of the wreck using sonar. Choosing the method of execution depended on the characteristics of the soil under and around the wreck, and so an analysis of the seabed was planned. The divers carried out the first investigations to locate and describe the state of the wreck during September 1981.

When the status of the wreck had been determined, the joint venture commissioned two subcontractors, Smet Boring N.V. and the Rijksinstituut of Grondmechanika to perform four borings and 12 static cone penetration tests. These tests were carried out from the self-elevating platform *Tijl*, located near the wreck at about 10 km from the coast.

With the help of divers, it was possible to bring a screw from the wreck to the surface. The wreck was then identified as the British destroyer *Maori*, Class 1, built in 1909 and sunk off Zeebrugge in 1915.

During 1961–62, the wreck had been levelled by explosives. This left part of it about 1 m above the seabed and the remainder was buried in sand. Two phases were involved in removal of the wreck:

Phase 1 — As the wreck was deeply embedded in the sand it was proposed to start freeing it by using a fixed-point suction dredger equipped with a specially designed jetting device.

Phase 2 — When the wreck was sufficiently freed, it was proposed to use a salvage ship equipped with a mast of 50 t capacity load and a hydraulic grab. This vessel could load 1,500 t on deck.

Decloedt's cutter suction dredger *Vlaanderen XVII* was mobilised in May 1982. It was adapted to carry a jet and a flexible suction tube, the suction nozzle of which could reach to the −20 m mark. Phase 1 was completed in early August 1982. The wreck was completely freed, and a basin, the bottom of which reached the −20 m mark, was

Jan de Nul's trailer-suction hopper dredger "Sanderus" dumping sand for re-dredging and pumping to the western breakwater area by the cutter dredger "Ortelius".


Jan De Nul N.V.
PO Box 40
Belgium
Tel: 53/76 05 11 Telex: b 12 340 de nul b
GALILEI 2000
Dredging of the approach channel to Jiuzhou Harbour in the People's Republic of China – 1985.

The following equipment was used for dredging of the access channels, reclamation and wreck removal:

Dredging of the access channels

Name	Type	Owner
Vlaanderen XVIII	trailing hopper (11,300 m^3)	Decloedt (maint. contract)
Pacifique	trailing hopper (9,250 m^3)	Decloedt
Rupel	trailing hopper (7,200 m^3)	Dredging Int.
Sanderus	trailing hopper (5,338 m^3)	Jan de Nul
Vlaanderen XX	split hopper (5,145 m^3)	Decloedt
Atlantique	trailing hopper (4,392 m^3)	Dredging Int.

Dredging of docks and reclamation

Name	Type	Owner
Brabo	cutter dredger (6,585 hp)	Dredging Int.
Ortelius	cutter dredger (6,925 hp)	Jan de Nul
Mercator	cutter dredger (6.515 hp)	Jan de Nul
Big Boss	self-propelled backhoe dredger (2,778 hp)	Dredging Int.

Wreck removal

Name	Type	Owner
Norma	salvage vessel (400 t sheerlegs)	Dredging Int. Decloedt, Jan de Nul and Herbosch Kiere
Vlaanderen XVII	stationary suction hopper dredger	Decloedt

dredged all around the wreck. About 300,000 m^3 of sand were removed during this operation.

The derrick ship *Norma*, jointly owned by Dredging International, Decloedt and Jan De Nul, was mobilised to remove the bow and the stern of the *Maori*. The *Norma* is a self-propelled vessel that can load 1,500 t on deck. It was equipped with a mast of 50 t capacity load fitted with a special hydraulic grab, designed by Dredging International.

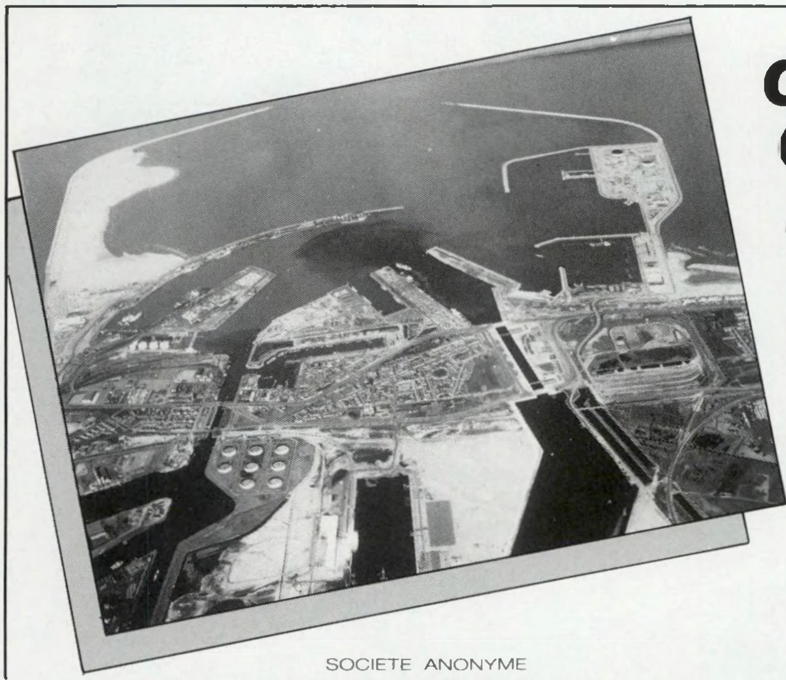
It lifted the complete wreck up to the −17.50 m mark. It was then blasted whereby it broke up into pieces of 45 t. On October 15, the Bergingswerken joint venture handed over the area free of all fragments of wreckage to the Administration.

In 1984, a contract was awarded to the joint venture by the Belgian Government for the removal of a number of wrecks in the access channels to the Belgian sea ports. An A-frame was constructed on the *Norma* during the first half of 1985. The main hoisting capacity is 2 × 220 t, with an auxiliary hoist of 100 t and two salvage winches of 125 t. The sheerlegs will also be fitted with a special wreck grab of 100 d.w.t.

The first job is expected to be removal of the French roll-on roll-off vessel *Mont Louis*, which sank off the Belgian coast end-August 1984. The work will probably be carried out during the Summer of 1985.

Right: Part of the "Maori" wreck being cleared by the "Norma".

Below: The "Norma" is equipped with a 50 t derrick filled with a special hydraulic grab for wreck removal operations.



Inner harbour construction

In 1970, the Belgian Government decided to implement the first phase of a port expansion programme at Zeebrugge. This consisted of a new sea lock which provided access for ships of up to 125,000 d.w.t., and a new inner harbour with a total area of about 1,400 ha.

Work on the sea lock was started on 1 March 1972 by the joint venture SOGETRA-SBBM, Brussels. The final design was prepared by the design department of SBBM. The Ministry of Public Works, as client, was also responsible for the basic design and supervision of construction.

The lock was officially opened in April 1984, but it had been in use since November 1983. Its principal dimensions are:

Length overall	694 m
Width	57 m
Sill depth below low water level	15 m

The lock consists of two lock heads with a central lock chamber 500 m long. The chamber walls consist of high foundation quay walls on reinforced concrete and sheet piling. The draining floor of the lock chamber comprises perforated concrete elements placed contiguously on a filter layer consisting of gravel layer on a filter canvas of synthetic fibre .

Each lock head is equipped with two steel rolling doors so that there is always a reserve door available. These doors move sideways in chambers, which have a length of 64.50 m and a breadth of 11 m.

Each door chamber can function as a drydock for maintenance and repair of the rolling door. When a rolling door has to be set in drydock, the door chamber on the lock side is closed off by means of a caisson door.

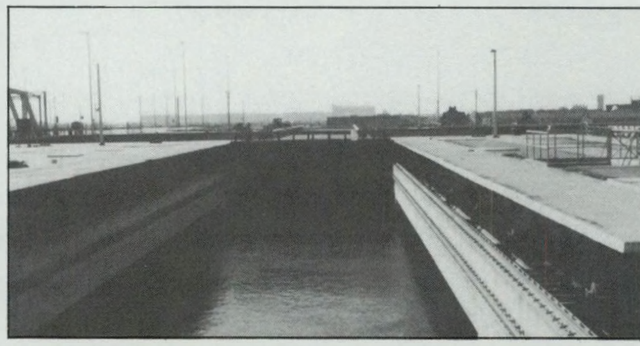
The doors are made of welded steel and are 58.60 m long, 10.90 m wide, and 24.30 m high. On the front side, the doors rest on an undercarriage that rolls on rails on the lock floor; on the rear side, the doors are hung on an upper-carriage that rolls on tracks on both sides of the top of the door chamber.

The emptying and filling of the lock chamber is effected by a series of five butterfly valves installed in each rolling door in pipes of 1.80 m diameter that connect both sides of the doors. The filling time of the lock chamber is approximately 40 min with a height differential of 4.50 m and about 35 min with a height differential of 3.50 m. A windmill with a power rating of 150 kW, was built to operate the lock's electro-mechanical equipment.

Other equipment on the lock consists of four steel bascule bridges, two on each lock head, which provide four lanes for the heavy coastal tourist traffic, and a feeding culvert that links the docks in the inner port with the seaward entry channel and keeps a constant water level in the docks.

The lock has been constructed on a site that was partially occupied by the Leopold and Schipdonk Canals. These two discharge canals were diverted in concrete culverts to the east of the new lock. At the mouth of these culverts, new electro-mechanical discharging sluices were installed.

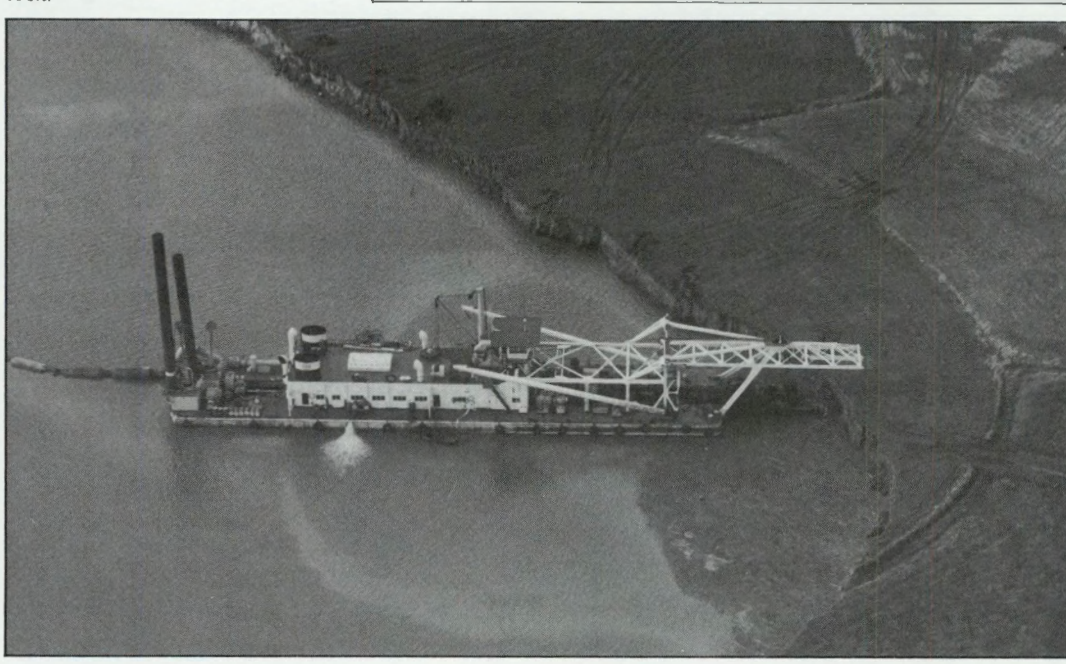
The entrance channel to the lock has a quay wall on the west



Gantry Railing Continental supplied Gantrail clips and pads (with special stainless steel reinforcement) for the fastening of type A120 rails on the gates in the main lock to the port. These gates are made of large box girder type caissons which move on heavy rails, tranverse to the longitudinal axis of the lock.

For each gate, there are two ground rail tracks on the bottom (under water level) and two rail tracks on the top (one on each side). In addition, there are lateral guiding rails fixed on the side walls. Photo shows the upper rail tracks and the guiding rail tracks on both sides of the channel in which the gate moves. There are in total 3,840 m of rail tracks (A120 type rail), for which the company supplied 3,840 m of MK6 pads and more than 10,000 clips.

Equipment was also supplied for the berths on both sides of the northern Insteekdok. On each side, there are two main rail lengths for the new gantry cranes, made of type A120 rails on a concrete foundation with a continuous sole plate, and Gantrail clips and pads. In addition, on each side an "in between" rail track has been installed on a ballast foundation, wooden sleepers, discontinuous sole plates and Gantrail clips and pads, to facilitate the use of existing cranes moved from the old "mole" to the new dock area.



The cutter suction dredger "Ortelius" dredging the connection dock between the inner harbour and the new sea lock.

side, which is called the Zweedse Kaai. The still level of the lock at 15 m under low water provides safe entry at half-tide sea level for ocean-going vessels with a draught of approximately 17.50 m.

The floor depth of 18 m under low tide at the Zweedse Kaai also gives such ships the possibility of being able to wait even at low tide to pass through the lock into the inner port.

Inner port

Approximately 1,400 ha of polder land lying between Zeebrugge and Dudzele and bordered by the Baudouin Canal on the west side and by the discharge canals, Schipdonk and Leopold, on the east, were appropriated for the new inner port.

Approximately 300 ha were allocated for installation of the connecting dock. The depth of the docks is 17.50 m under the normal dock level. In the new inner port area, the Baudouin Canal will be widened and deepened to a depth of 17.50 m under the normal dock level in order to function as a canal dock. Thus, all sectors of the inner port, both in the northern and in the southern part, will have access to deep water.

For the raising of these lands with a soil layer of approximately 3 m above the original polder level, soil has been used from the dock excavations. Gradually, the necessary roads and railways and the supplementary projects (bridges, culverts, etc.) will also be built in this sector.

An inlet basin of approximately 1,000 m long, 225–275 m wide, and with a water depth of 13.5 m has been constructed in the northern sector. On both sides of the inlet basin there are quay walls with a total length of 2,000 m, while at the northern end of the dock a ramp has been built for roll-on/roll-off ships. The northern sector is intended as a typical transhipment area (150 ha), complementary to the outer port. It became fully operational in early 1982.

The southern sector, i.e. the sector lying to the south of the connecting dock with the Baudouin Canal is intended for industries that will attract ship traffic via the new sea lock. It will be accessible via the projected deep-water dock (125,000–150,000 d.w.t.), with a 600 m long quay, 400 m wide and a water depth of 18.50 m. The angled slopes give a bottom width of 200 m. Go-ahead for the latter is still awaiting Governmental approval, but it is scheduled to be completed before 1989. The dock could later be extended to a total length of 2,000 m.

The first facility has been constructed in the southern sector. This is a peak-shaving plant of the N.V. Distrigaz in which, during periods of low gas consumption, a supply of natural gas is stored in liquid form. It is then revapourised in peak periods and distributed.

Inland connections

The present road link of Zeebrugge with the E5 motorway consists of a four-lane carriageway which bypasses the old city centre of Bruges. As port-bound road traffic demand will substantially increase, a separate motorway link with the E5 is planned.

Although the Baudouin Canal is accessible by ships of up to 8,000 d.w.t. and will be widened to 250 m over the first 5 km, the maximum size of vessels sailing inland between Bruges and Ghent is limited to 600 d.w.t. This is mainly due to the limitations of passage through the old locks and canals that encircle the city centre of Bruges.

Further details of Zeebrugge's hinterland connections and extensive plans for their improvement can be found on page 55.

A series of fenders was supplied by Sumitomo Rubber Industries Ltd. of Japan through their Brussels office for the new sea lock. This lock was built by a joint venture of SBBM Enterprises and SOGETRA to provide access for ships of up to 125,000 d.w.t. to the new docks in the inner harbour. Photo shows Pi-type 1250 H × 2750 L. fender.

Of the 133 fenders installed, 127 were Hyper Ace "V" profile type and the remainder were Pi-type. Pi-type fenders — four of 1,250 mm height × 2,750 mm length and two of 1,700 mm × 2,400 mm — were chosen for the entrance into the lock because these have a higher energy absorption and a lower friction coefficient on the rubbing surface than rotary type units.

Two cutter suction dredgers, the "Ortelius" and "Vlaanderen XIX" dredging the connection between the inner harbour and the existing Baudouin Canal.

1985 . . . HISTORICAL YEAR FOR THE PORT OF ZEEBRUGGE

I am very happy to see that such an important Journal as "Dredging + Port Construction" is publishing a special supplement on the Port of Zeebrugge.

Appropriately, this will mark the official inauguration of the new port expansion by His Majesty King Baudouin on July 20. This event will be accompanied by a whole range of activities and festivities that will go on until July 30.

I am particularly happy, therefore, to write this foreword for this special issue.

1985 is an exceptional year in the history of the City of Bruges. Certainly it is a unique year in the history of the Port of Bruges/Zeebrugge. Royal Inauguration of the new outer port, which gives access to ships drawing up to 16.8 m and provides new quays, transhipment wharves and warehouses, is the most important event since the port was opened in 1907.

Over the last 78 years many developments have been carried out in the Port of Bruges/Zeebrugge, but never before on such a vast magnitude of scale. Until recently, we had been restricted to the same port area and, more importantly, to the same sea lock with its limited dimensions (a width of less than 20 m), designed at the end of the 19th century.

In the meantime, however, large-scale development programmes had been carried out in the other major Belgian ports.

In 1985, the new sea lock which provides access for fully laden ships of up to 125,000 d.w.t. has become operational; so has the northern part of the new inner port with three new enterprises and the extension of one that was already in existence.

The new enterprises are:

— "Zeebrugse Behandelingsmaatschappij" (Z.B.M.)

— "Combined Terminal Operators" (C.T.O.)

— "Belgian New Fruit Wharf" (B.N.F.W.)

The SeaRo terminal occupies a few hectares for its Ford traffic. And in 1985, the large new breakwaters are going to be finished. These are the most impressive aspect of the expansion project, whereby the new outer port extends 3 km into the sea.

I would like to point out that all these works have been executed on schedule since they were started in 1976. But we must not pretend that the new port is ready and finished; quite a lot remains to be done.

In the new inner port, there are only 2,000 m of new quay walls currently available, and these do not have a depth of water that corresponds with the potential of the new Vandamme sea lock. We have to await the initiation of works on the first deep-water quay wall; also the construction of the projected industrial sites. And in the new outer port, the LNG terminal will not be ready before 1987.

Nevertheless, there is every reason for celebrating: the big features have been outlined, the new Port of Zeebrugge is now reality and the big "filling up" with everything that makes a modern port can start. It has, in fact, already started!

F. Traen
President
Port of Bruges/Zeebrugge

The Port of Zeebrugge: embarking on a new chapter in its development

by Richard Fleming, Deputy Editor, Dredging + Port Construction

With a total port area of 3,370 ha, the newly-expanded Port of Zeebrugge has come a long way since its initial opening by King Leopold II in July 1907. At that time, the new Port of Zeebrugge was constructed to meet the City of Bruges' wish for a new outlet to the sea to replace the silted-up link. Today, the Port of Zeebrugge is about to embark on a new chapter in its development history, and to assume a much wider rôle.

Since 1907, Belgian governments of all hues have recognised the tremendous potential offered by the Port of Zeebrugge, and indeed have on a number of occasions supported moves to upgrade the infrastructure of the port, often to the chagrin of the other two major Belgian ports of Antwerp and Ghent. This latest expansion at the Port of Zeebrugge, as detailed in previous articles within this special supplement, is but the latest example of government support for the port, and is by far the most ambitious and exciting.

In the last decade, the importance of the Port of Zeebrugge as a short-sea and deep-sea location has increased. As cargo handling methods have moved inexorably towards unitisation, so the Port of Zeebrugge has kept pace by encouraging the installation of appropriate terminal and handling facilities.

Table 1, which lists freight and passenger throughput figures for 1983 and 1984, shows the extent to which the previous dependence on short-sea traffic has matured to one of mutual inter-dependence with deep-sea traffic. 1984 freight volume stood at just over 12m tonnes, a creditable 16.5 per cent increase over the 1983 figure of 10.3m tonnes, and a higher than average growth for ports in the Le Havre-Hamburg range. Notable cargo sector increases were ro-ro services (up by 35.7 per cent), break bulk general cargo (+ 29.1 per cent) and coal/coke handling (+ 55.2 per cent).

Roll-on, roll-off services (both short-sea and deep-sea) still account for over 50 per cent of total Port of Zeebrugge throughput, but the opening of specialised dry bulk terminals as

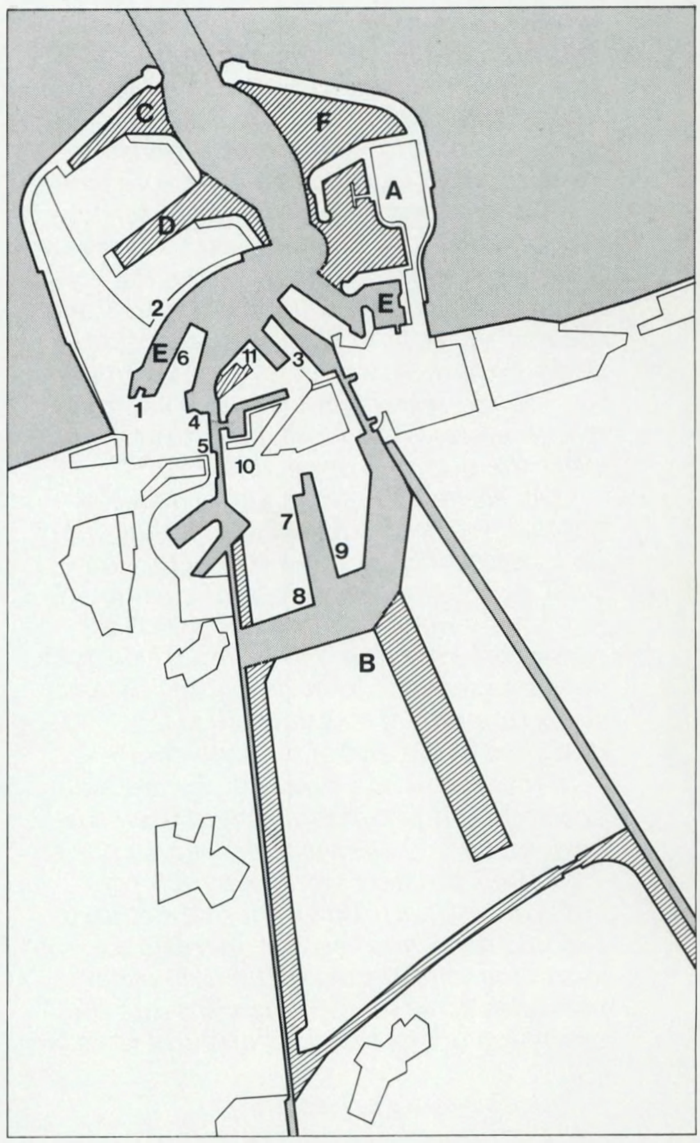


Figure 1: Map showing final outline of the Port of Zeebrugge and current location of main terminal facilities: (1) Townsend Thoresen; (2) North Sea Ferries; (3) Sea-Ro Terminal; (4) Train Ferry Terminal; (5) Shortsea Container Terminal; (6) Ocean Containerterminal Zeebrugge; (7) Combined Terminal Operators; (8) Zeebrugse Behandelingsmaatschappij; (9) Belgian New Fruit Wharf; (10) fishing port; and (11) navy base.

Facilities still under construction or planned include (A) Distrigaz L.N.G. terminal, (B) Seabulk terminal, (C) Wielingendok, (D) southern outer dock, (E) additional ro-ro facilities, and (F) off-shore bulk transhipment anchorage.

well as a multi-purpose facility in the last 18 months has broadened the base of the port, and has also had an appreciable impact on the 1984 throughput figures. These latter facilities can only have a greater impact in years to come, as the clientele is built up.

With the L.N.G. terminal due to come on stream in 1987, the liquid bulk products tonnage may once again approach the heights of the early 1970s, when the Texaco crude oil pipeline from Zeebrugge to the Ghent refinery was at its most active. Indeed, the Port of Zeebrugge has withstood very well the undeniable shock of the loss of the Texaco traffic, when the Ghent refinery was closed in 1982. To many, this proves the maturity of the Port of Zeebrugge — it has expanded its base to the extent that it is no longer dependent upon any one commodity area, but can offer an efficient service across the whole range of cargo handling requirement.

The Port of Zeebrugge is managed and operated by the N.V. Maatschappij van de Brugse Zeevaartinrichtingen (M.B.Z.), a semi-governmental body under the direction of the Minister of Public Works. This is a crucial difference between the Port of Zeebrugge and the Ports of Antwerp and Ghent, which are run on a municipal basis. The M.B.Z. is responsible for provision, where appropriate, of port infrastructure and for promotion of the port. Day-to-day operation of the individual terminals within the port is undertaken by the respective companies.

Moves are afoot to reflect the changed status of the Port of Zeebrugge, brought about by the expansion, through the creation of a new port authority body. Agreement on the shape and format of this new body has yet to


Zeebrugge
telephone: (050) 54 54 64
telex: 81 608 comto b.

Table 1: Freight and passenger throughput at the Port of Zeebrugge, 1983 and 1984

Traffic	1983 million tonnes	1983 per cent	1984 million tonnes	1984 per cent	per cent change 1983-1984
Freight traffic					
General cargo	7.308	71	9.061	76	+24.0
(ro-ro services)	(4.496)	(44)	(6.100)	(51)	(+35.7)
(container)	(2.111)	(21)	(2.155)	(18)	(+2.1)
(train ferry)	(0.443)	(4)	(0.473)	(4)	(+6.8)
(miscellaneous)	(0.258)	(2)	(0.333)	(3)	(+29.1)
Dry bulk materials	2.125	21	2.231	18	+ 5.0
(sand and gravel)	(1.641)	(16)	(1.558)	(13)	(−5.1)
(coal/coke)	(0.317)	(3)	(0.492)	(4)	(+55.2)
(miscellaneous)	(0.167)	(2)	(0.181)	(1)	(+8.4)
Liquid bulk products	0.872	8	0.709	6	−18.7
(refined products)	(0.675)	(7)	(0.578)	(5)	(−14.4)
(miscellaneous)	(0.197)	(2)	(0.131)	(1)	(−33.5)
Total	10.305	100	12.001	100	+16.5
Passenger traffic					
Individual transits	2.023m	100	2.096m	100	+3.6

Source: Maatschappij van de Brugse Zeevaartinrichtingen, Annual Report 1984.

be finalised, but it seems certain that a larger measure of autonomy will be granted.

The expansion of the Port of Zeebrugge has brought with it a re-appraisal of the port's rôle within the Le Havre-Hamburg range of ports. Whereas prior to the expansion, Zeebrugge might have been regarded by many as a medium-sized port, primarily for short-sea operations and only of secondary importance as far as deep-sea traffic was concerned, today the Port of Zeebrugge has much wider horizons.

The over-riding emphasis is still on serving the growing and lucrative short-sea trades to the United Kingdom, but there is, too, an increased desire and ability to service the handling requirements of deep-sea ro-ro, container and bulk shippers. With its coastal location, its convenient mid-range position and good inland transport links, the Port of Zeebrugge is very well placed to take advantage of its improved competitive status in all cargo handling sectors.

With the massive expansion of the Port of Zeebrugge now nearing completion, attention is turning to the commercial impact that the port, in its enlarged form, will have. With the competitive balance between ports in the Le Havre-Hamburg range delicate at the best of times, and with the inter-Belgian balance even more critical, the Port of Zeebrugge is poised to become a major force in the region. Inevitably, within the constraints of a sluggish world economy, ports can only gain additional business at the expense of others. It is too early to say, however, how the expansion of the Port of Zeebrugge will affect other ports.

This article details the way in which the M.B.Z., terminal operators and shipping lines alike have reacted to the challenge offered by expansion of the Port of Zeebrugge and to the enhanced competitive position *vis-à-vis* alternative operators at other ports. It is not the intention, however, to detail every activity within the Port of Zeebrugge. Readers who wish to learn more of specific services offered by the M.B.Z., individual terminal operators and shipping lines should refer in the first instance to the *Zeebrugge Port Information Handbook.*

Roll-on, roll-off services

Against a long-standing background as a significant Continental arrival and departure point for short-sea crossings to and from the United Kingdom, Zeebrugge has in recent years been able to further consolidate its leading position in this respect. The entry of the United Kingdom into the European Community above all provided the impetus for increased trade levels between the UK and its European partners, and introduction of additional freight and passenger roll-on, roll-off routes and services has been more than justified by demand patterns over recent years.

Twelve short-sea routes (ro-ro, container and train ferry) are currently operated out of Zeebrugge, all but one to ports in the UK, and details of these are given in Table 2. Among the range of Continental ports serving the short-sea ro-ro trades to the UK, Zeebrugge is perhaps best placed, being ideally located to serve both the south-east of the UK, with its good motorway links with the rest of the country, and the industrially more significant north, notwithstanding longer transit times. Figure 2 illustrates very well the geographic spread of UK ports served by ro-ro, container and train ferry services out of Zeebrugge.

Short-sea ro-ro freight and passenger traffic out of Zeebrugge in 1984 amounted to 6.1m tonnes, a notable increase of 35.7 per cent over the 1983 total of 4.5m tonnes, already in itself a record figure. Passenger volume increased more modestly, from 2.023m to 2.096m, a rise of 3.6 per cent.

The record increase for 1984 in ro-ro traffic is accounted for by continued growth on the established ferry routes of Townsend Thoresen (Zeebrugge-Dover/Felixstowe) and North Sea Ferries (Zeebrugge-Hull), but also by the rapid impact of newcomers to Zeebrugge, such as the Kent Line service to Chatham and the Cobelfrêt link with Immingham.

The growth pattern in ro-ro services is such that both M.B.Z. as well as established terminal and vessel operators have plans for further expanding the level of service offered, both in terms of terminal facilities and ships deployed. Even this expansion is not expected to provide much of a breathing space, however, and M.B.Z. is already making provision for new ro-ro berths within the outer and inner harbour expansion.

Short-sea ro-ro services out of Zeebrugge are concentrated on three terminals — the M.B.Z. facilities operated by Townsend Thoresen, the North Sea Ferries terminal on the Leopold II mole, and the Sea-Ro Terminal facility on the Zweedse Kaai, just north of the Pierre Vandamme sealock. More recently, the Combined Terminal Operators facility on the northern Insteekdok has started serving short-sea ro-ro traffic with inauguration in January of the Searoads Ferries link with Tilbury.

The public ro-ro terminal, operated by Townsend Thoresen, is located between the entrance road to the Leopold II mole and the rail tracks to the O.C.Z. container terminal, and is equipped with two fixed ro-ro berths and one floating pontoon for emergency use.

The two fixed berths were constructed respectively in 1966 and 1974 specifically to serve the growing level of Townsend Thoresen sailings from Dover and Felixstowe. The length of the access bridges, from the fixed land support to the hoisting towers, is 54 m, with the bridges connected to berthed vessels by means of linkspans.

Maximum load capacity on the access bridges is 400 kg/m^2, allowing heavy articulated loads up to 60 t (on an axle load of 20 t over four wheels) to be handled. Vessels berth on both sides of a row of six 10 m diameter dolphins, ranged over a length of 145 m. There is no limitation on vessel length, but maximum beam, with the ship axis in line with the ramp axis, is restricted to 21.2 m. Vessels of up to 33 m beam can be

Table 2: Regular short-sea unit load services currently operated out of Zeebrugge

Route	Route operator	Terminal operator	Service frequency	Service type
Zeebrugge-Dover	Townsend Thoresen	Townsend Thoresen	6×daily	freight/passenger ro-ro
Zeebrugge-Dover	Townsend Thoresen	Townsend Thoresen	7×daily	freight ro-ro
Zeebrugge-Chatham	Kent Line	SeaRo	2×daily	freight ro-ro
Zeebrugge-Tilbury	Searoads Ferries Ltd.	Combined Terminal Operators	1×daily	freight ro-ro
Zeebrugge-Dagenham	Ugland Auto Liners	SeaRo	2×weekly	freight (car liner)
Zeebrugge-Harwich	British Rail	Train Ferry Terminal	20×fortnightly	train ferry
Zeebrugge-Harwich	Freightliner Ltd.	Shortsea Container Terminal	6×weekly	freight container
Zeebrugge-Felixstowe	Townsend Thoresen	Townsend Thoresen	3×daily	freight/passenger ro-ro
Zeebrugge-Immingham	Cobelfrêt	SeaRo	1×daily	freight ro-ro
Zeebrugge-Hull	North Sea Ferries	North Sea Ferries	1×daily	freight/passenger ro-ro
Zeebrugge-Hull	North Sea Ferries	North Sea Ferries	6×weekly	freight ro-ro
Zeebrugge-Oslo	Fred Olsen Liners	SeaRo	1×weekly	freight ro-ro

Source: M.B.Z.

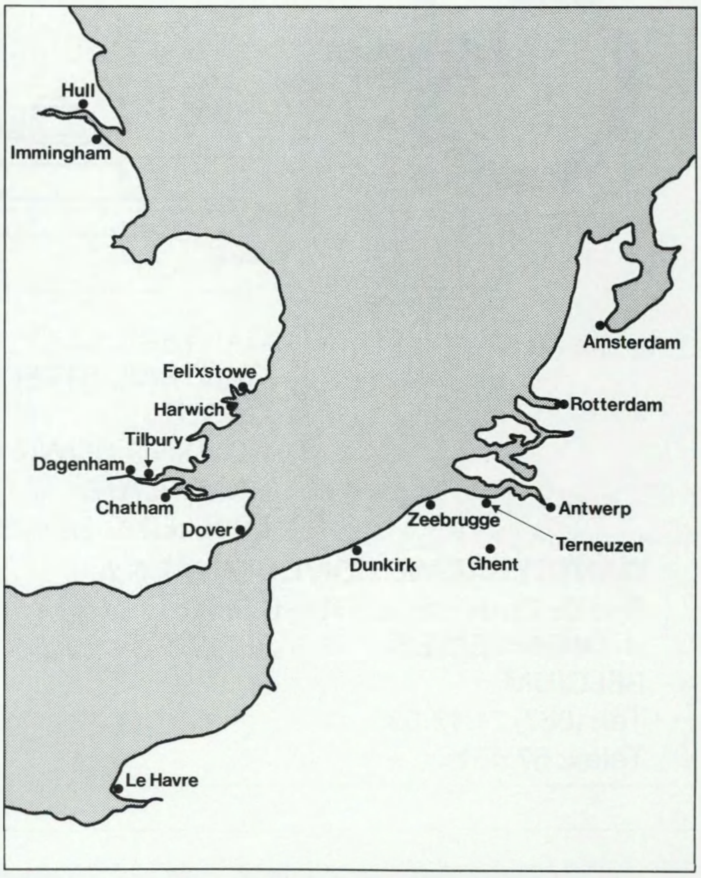


Figure 2: Map showing location of Zeebrugge and the geographical spread of short-sea ro-ro services to the UK.

accommodated if berthed out of axis.

The immediate terminal area has a capacity of 600 cars with total parking area comprising 5.9 ha (2,500 cars or 600 trailers). Handling of unaccompanied freight is undertaken with Douglas Tugmaster tractor units and fork-lift trucks.

The three-storey terminal building houses the full range of office accommodation for the companies concerned as well as customs and immigration facilities. There is also a large terminal area for passengers awaiting departure or for people waiting for arrivals.

Townsend Thoresen operates three separate services out of Zeebrugge — a freight/passenger service to Dover, operated six times daily by the ferries *Free Enterprise V, VI, VII,* and *VIII;* a freight-only service to Dover, running seven times daily and operated by the *European Clearway, European Trader* and *European Enterprise;* and a three times daily freight/passenger link to Felixstowe, operated by the *Viking Viscount* and *Viking Voyager.*

Townsend Thoresen has made solid progress on all three routes since starting ro-ro operations out of Zeebrugge (the Dover route was inaugurated in 1966, with Felixstowe following in 1974). Current investment plans include jumboisation of two of the freight/passenger ferries on the Dover route, the *Free Enterprise VI* and *Free Enterprise VII,* as well as provision of new double-deck ro-ro berths on the Leopold II mole, just south of the new North Sea Ferries terminal.

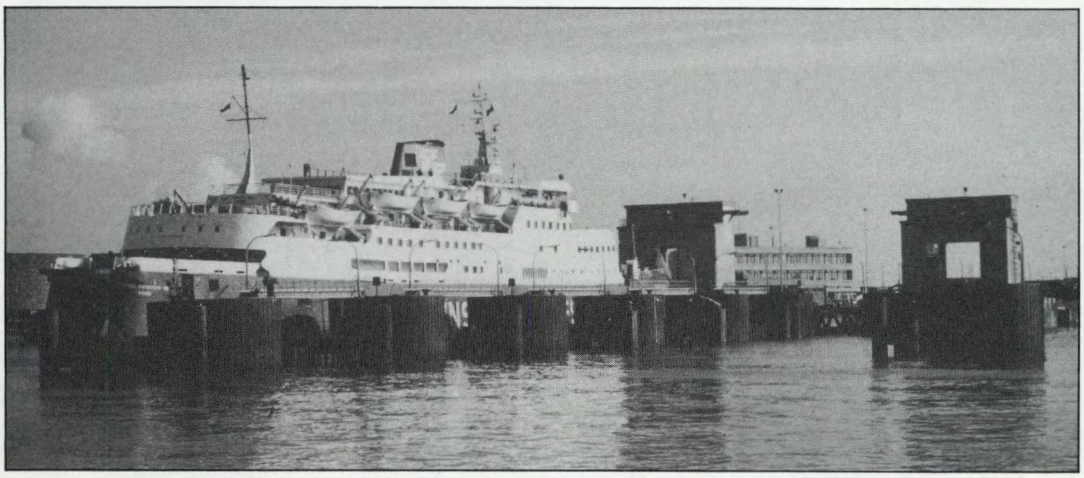
The jumboisation of the two ferries is being undertaken by Schichau Unterweser AG of Bremerhaven, Federal Republic of Germany, and involves fitting of a larger bow section to each vessel as well as the addition of a second full-length deck for freight vehicles (hence the need for double-deck loading/discharge facilities at Zeebrugge). The £15m work will increase the capacity of each of the two *Free Enterprise* vessels by 60 trailers. The existing passenger accommodation will remain unchanged. The new forebodies, hull numbers 2289 and 2290, were both launched in Bremerhaven on 18 May, and the two vessels are due for re-introduction into service on the Dover-Zeebrugge route in their new, converted form this October and in early 1986 respectively.

The enlarged vessels will substantially increase Townsend Thoresen's freight capacity on the Dover route, and will closely resemble the company's flagships, the trio of 8,000 d.w.t. Blue Riband vessels deployed on the Dover-Calais route.

Construction of the new ro-ro berths along the southern end of the Leopold II mole is expected to begin at the end of the year, and will feature the two-tier loading and discharge mentioned earlier. This will enable not only the enlarged *Free Enterprise VI* and *VII* to be handled more efficiently and speedily, but will also allow any newbuildings Townsend Thoresen may decide to introduce on to the Zeebrugge routes to be slotted in without substantial modifications being required to berthing arrangements.

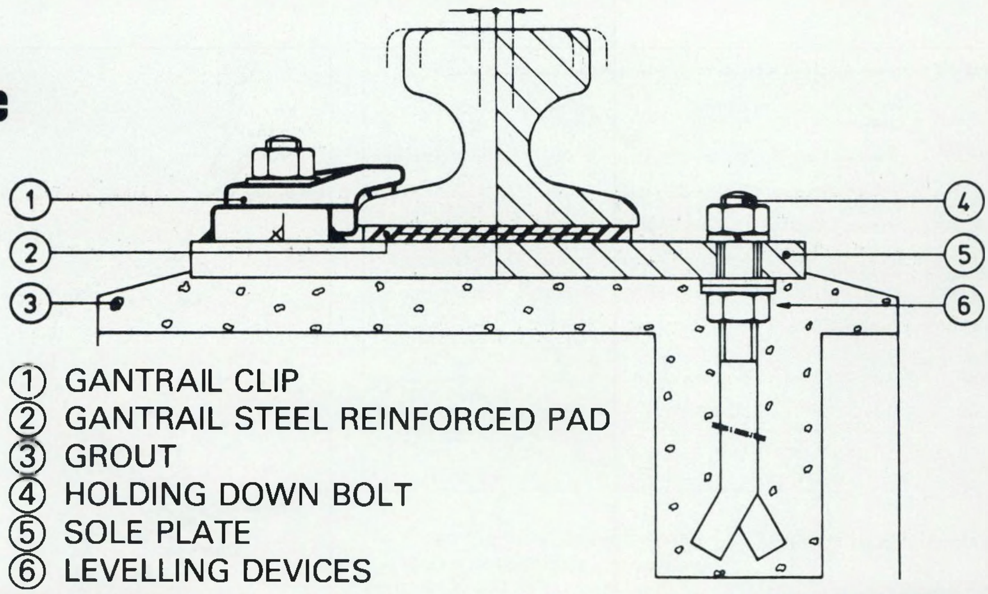
Townsend Thoresen, part of the European Ferries Group, has a considerable presence in the UK-Europe ro-ro market, with a total of seven routes and 24 ships. The company, which last year

One of Townsend Thoresen's four "Free Enterprise" vessels, two of which are to be jumboised, berthed at the M.B.Z. ro-ro facilities.



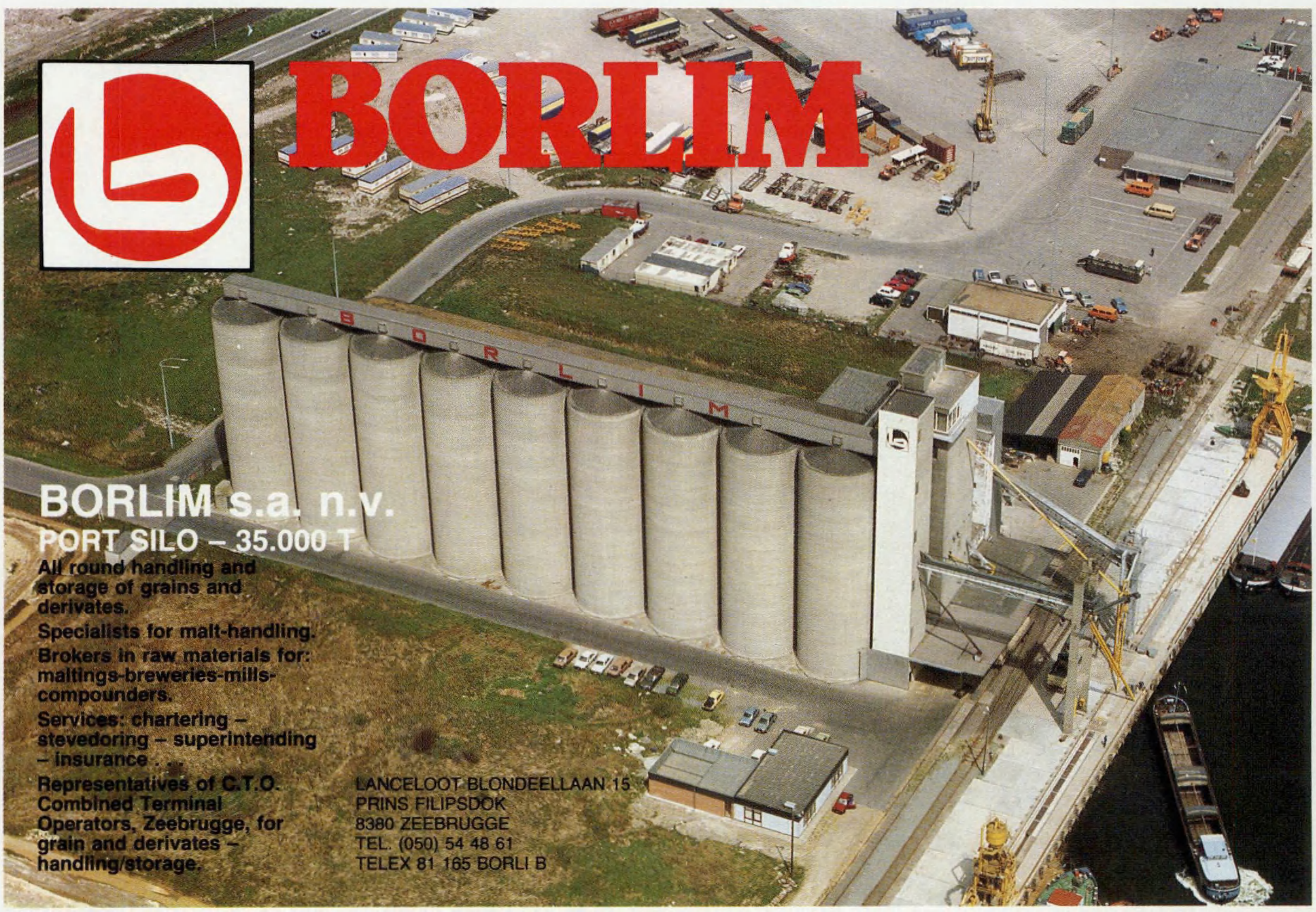
CRANE RAIL FASTENING TECHNIQUE

Lateral Adjustment



GANTRY RAILING CONTINENTAL S.A.
Rue du Commerce, 17B – B.P. 76
B-1400 NIVELLES
BELGIUM
Tél: (067) 21.13.63
Telex: 57.451

GANTRY GMBH
Pontsheide, 51
D-5100 AACHEN
W. GERMANY
Tel: (49) 24082075
Telex: 041/832972



acquired P & O Normandy's cross-Channel services, expects the popularity of its Zeebrugge routes from the UK to increase even further in years to come. Reasons cited for road hauliers increasingly favouring the Zeebrugge route are the good road links into the main European motorway network and the Sunday driving ban on Heavy Goods Vehicles in France. With its plans for increased shipping and terminal handling capacity, Townsend Thoresen is confident that it will be able to further consolidate its already large presence in Zeebrugge.

North Sea Ferries, a joint venture between P & O of the UK and Nedlloyd of The Netherlands, started its freight and passenger service from Zeebrugge to Hull in 1974 (a freight only service started in 1972). At that time it operated from the Prins Filipsdok, access to which is gained through the 1907 sealock. Initial service frequency was three overnight sailings a week in each direction, increased six months later to once daily with the introduction of a second multi-purpose ro-ro vessel on to the route. Current service frequency is one freight/passenger sailing daily overnight in each direction, operated by the *Norwind* and *Norwave*, and one freight-only service at a frequency of six days a week, operated by chartered-in tonnage in the form of the *Wuppertal* and *Fuldatal*.

North Sea Ferries' plans for the Zeebrugge-Hull route feature replacement of the *Norwind* and *Norwave* by the two vessels currently operating the Hull-Rotterdam route, the *Norstar* and *Norland*. These latter two vessels will be cascaded down from North Sea Ferries' Hull-Rotterdam route on commercial introduction of two new 31,000 g.r.t. ferries, ordered recently from Govan Shipbuilders of the UK and Nippon Kokan KK of Japan respectively. Introduction of the *Norland* and *Norstar* on to the Zeebrugge route in Spring 1987 will increase freight and passenger capacity considerably.

Although North Sea Ferries has been operating from its new ro-ro berths on the Leopold II mole since July 1984, it is only recently that construction work and outfitting of the new Bfr 200m terminal building there has been completed. The new terminal buiding, the first stone of which was laid in April 1984, provides transit accommodation for up to 1,500 passengers and houses full freight and passenger customs and immigration facilities as well as North Sea Ferries' booking and administrative offices.

North Sea Ferries' new terminal on the Leopold II mole is due to be inaugurated shortly; the two multi-purpose vessels on the Hull-Zeebrugge route, the "Norwind" and "Norwave", are to be replaced in Spring 1987.

North Sea Ferries decided to re-locate from the Prins Filipsdok in the inner harbour to the new site on the Leopold II mole for several reasons, not the least of which was the time delay (up to two hours) associated with transit through the 1907 sealock. Avoidance of this potential time delay not only reduces sailing time, with its fuel cost component, but also increases service reliability, thereby increasing product offering and customer confidence.

Additional factors in favour of re-location were that reclamation of the western outer harbour adjacent to the new terminal would provide additional trailer parking space, and also that the new terminal would be easier for intending customers to find (it is easy to under-estimate this latter point).

North Sea Ferries has now completely vacated the Prins Filipsdok site in favour of the new terminal, and the Prins Filipsdok ro-ro berth and parking area is now the subject of negotiations for use by other operators.

The new two-berth ro-ro linkspan on the Leopold II mole (length 104 m, width 23.2 m) was designed by Transport Efficiency B.V. of The Netherlands in co-operation with North Sea Ferries, and has proven to be completely reliable. Maximum load capacity is 180 t. The linkspan comprises two bridges, one of 30 m length, the other of 58 m. The design enables the linkspan not only to accommodate the high ramp hinges of the company's four multi-purpose ferries, but also any other ro-ro vessels wishing to use the North Sea Ferries linkspan. Spatial constraints also dictated to some extent the reduced length of the southern bridge on the linkspan.

With two vessels able to berth simultaneously, the new linkspan offers North Sea Ferries additional loading/discharge capacity and flexibility over the Prins Filipsdok site.

Ancillary handling equipment at North Sea Ferries comprises nine 50 t Douglas Tugmasters, one 30 t capacity mobile crane and three 7.5-30 t fork-lift trucks. A deep-freeze facility is also available for reefer trailers and containers.

North Sea Ferries anticipates that future demand on the Hull-Zeebrugge route will be more than adequately catered for by the introduction of the newer and larger *Norland* and *Norstar* from Spring 1987 (passenger capacity increased by 500 per cent, vehicle capacity by 250 per cent). There are no plans currently to extend the frequency beyond the overnight service, North Sea Ferries believing that this is a major contributory factor to the success of the route.

The third major ro-ro terminal in the Port of Zeebrugge is the Sea-Ro Terminal N.V. facility (SeaRo), with a main location on the Zweedse Kaai north of the Pierre Vandamme sealock. SeaRo was established in 1978 as a joint venture between M.B.Z., Belgisch-Engelse Vennootschap der Ferry-Boats and Ahlers and Mabesoone N.V. of Antwerp, and caters for both short-sea and deep-sea ro-ro traffic.

Several deep-sea and short-sea shipping services use the SeaRo facilities, the most notable being the Kent line (a joint venture between Norfolk Line and Cobelfrêt), which runs twice daily six days a week between Zeebrugge and Chatham, the daily Cobelfrêt service to Immingham and Fred Olsen Line's weekly service to various points in Norway. Ugland Car Liners transports Ford cars three times a week to Dagenham.

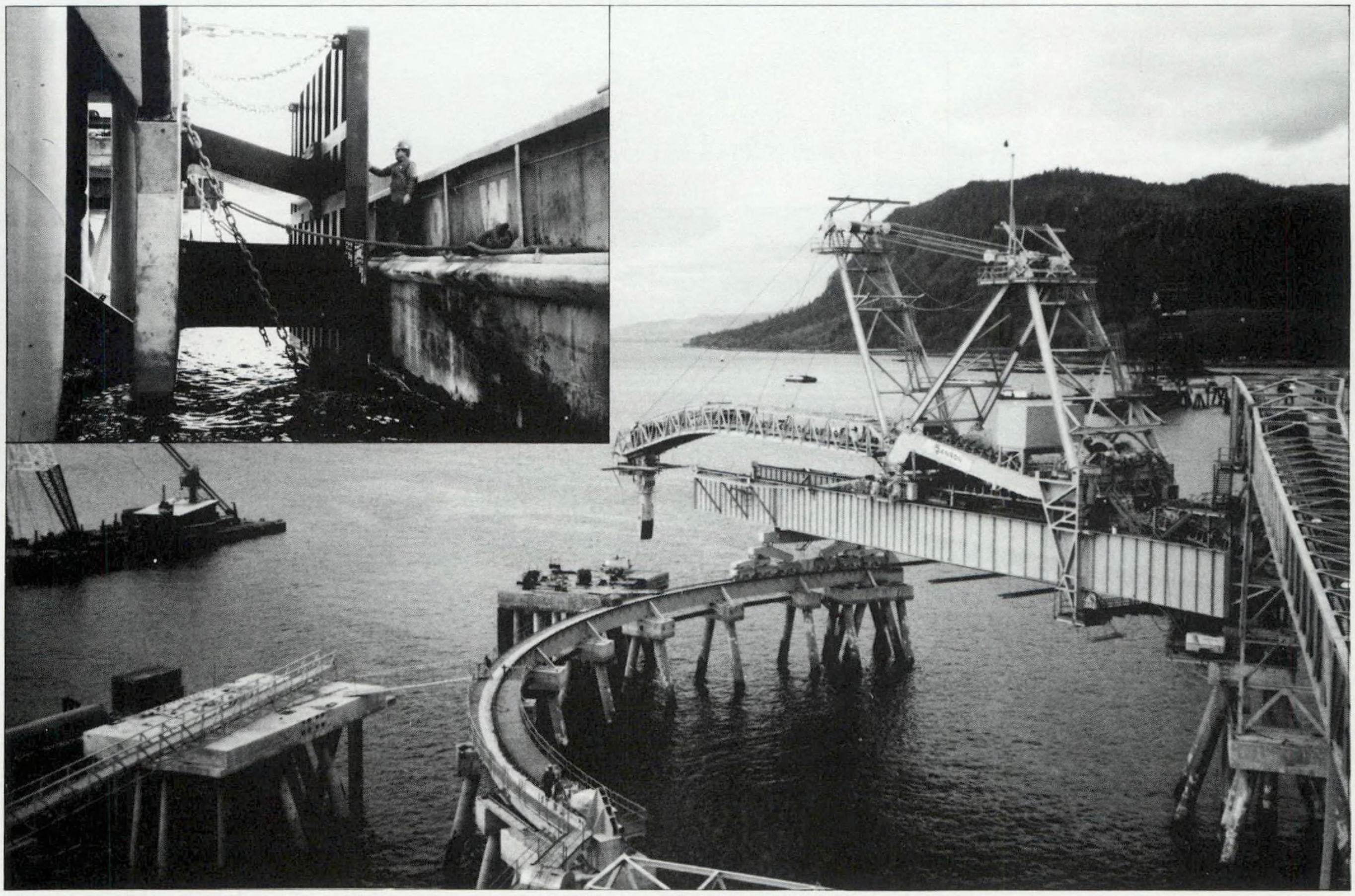
SeaRo moved to its present location on the Zweedse Kaai in 1983, and is now equipped with two linkspans, the second, MacGregor-Navire unit becoming operational last December. The Zweedse Kaai has a total quay length of 825 m and a quay width of 125 m. The 9 ha working area provides parking space for up to 800 trailers.

The versatility offered by the two floating linkspans means that SeaRo can switch linkspans to other locations to suit operational requirements, and the first unit has, in fact, now been transferred to the New York Kaai (the former Texaco quay on the Westerhoofd) to serve Kent Line and Fred Olsen traffic.

Traffic development at SeaRo has been one of ups and downs.

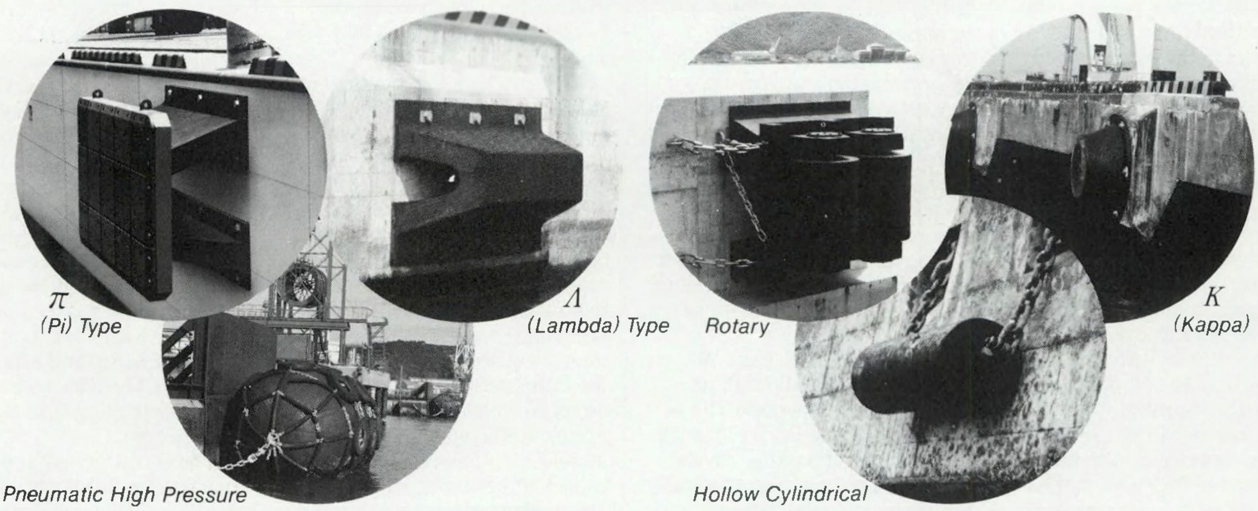
SUMITOMO RUBBER FENDER

IMPROVED OPERATIONS AROUND THE WORLD



Ridley Island Coal Terminal, Prince Rupert, Canada HPi-2500H for 250,000 DWT Coal Carrier

WIDE RANGE TO MEET ALL YOUR NEEDS



π (Pi) Type — *Λ (Lambda) Type* — *Rotary* — *K (Kappa) Type* — *Pneumatic High Pressure* — *Hollow Cylindrical*

SUMITOMO RUBBER INDUSTRIES, LTD.

Allied Products Division
Foreign Trade Department: 1-12, Akasaka 1-Chome, Minato-ku, Tokyo 107, Japan
Telephone: 03 (585) 0441 Telex: 2422919 SRITKO J
Cable: SUMIRUBBERIN TOKYO
Fax: (03) 585-0815

Representative in Europe
Sumitomo Rubber Industries, Ltd.
5/6 Square de Meeus, 1040 Bruxelles, Belgique
Tel: (02) 513-8130 Telex: 21038 "21038A SUMIT B"
Fax: (02) 513-3591

The company started well in 1979, but suffered from the bankruptcy of its premier customer, Roto Line, in 1982, and 1983 throughput was subsequently well below expectations. Since this brief setback, however, SeaRo has consolidated its position and recovered much lost ground with the introduction of the Fred Olsen Line and Cobelfrêt services to Norway and Immingham respectively. Throughput in 1984 amounted to 1.4m tonnes, compared to more than 0.3m tonnes in 1982, and 1985 is expected to see traffic levels break through the 2m tonnes barrier.

Both SeaRo floating linkspans are MacGregor designs. The first, dating from 1978, is an adaptation of the MacBridge (F) pontoon, designed to offset the disadvantages at the O.C.Z. terminal (which wished to cater for the growing trend towards combined lo-lo/ro-ro deep-sea vessels) of a high quay height and wide tidal variation. The 50 m × 33 m pontoon is supported by four columns resting on the seabed by means of chain-supported 160 t weights at each corner. Pontoon inclination can be achieved by trimming in the normal manner. The linkspan can be moved around the port to suitable locations by tugs simply by lifting the weights, and according to SeaRo this is the great advantage of floating linkspans (regardless of the lower capital cost), especially in Zeebrugge, where operational requirements change constantly.

The second linkspan, designed by MacGregor-Navire, became operational in December 1984 and is located at the southern end of the Zweedse Kaai near the sealock. Not only did the installation of the second linkspan greatly increase vessel handling capacity at SeaRo, but it also permitted a more efficient separation of deep-sea and short-sea ro-ro traffic.

The MacGregor-Navire linkspan was specially designed for corner site operation, but with a face angled at 116 deg. The unit can receive vessels with beams of 16-21 m, with axial ramps 5-16 m wide and can cope with threshold height variations of 1.5 m. Design loads are 88 t for the shore ramp and 120 t on the pontoon superstructure.

Structure dimensions are 30.4 m length, 19.5 m width for the 830 t pontoon, and 27.5 m length with width tapering from 18.5 m at the landing end to 7.0 m at the shore ramp end for the superstructure. Ramp length is 40 m and width 7 m. Maximum gradient of the linkspan at low water is nine per cent.

A major constraint at the Zweedse Kaai site has been the relatively limited parking area, and SeaRo has recently expanded the scope of its operations by providing for Ford car exports, mainly to Dagenham, to be handled from a 3 ha, 2,500 vehicle parking area linked to an intermediate pontoon on the east side of the northern Insteekdok. More recently, as already mentioned, Kent Line and Fred Olsen traffic has been transferred to the New York Kaai on the Westerhoofd.

Current indications are that SeaRo could transfer some operations to the contractor's work harbour, when M.B.Z. has equipped this, as anticipated, with two or three additional ro-ro berths. With 20 ha of water and 20 ha of land space, and water depths of 5 m and 8 m at low tide, the contractor's work harbour is well suited to conversion to a ro-ro terminal.

Ultimately, SeaRo may find itself in the healthy position of operating out of four different sites within the Port of Zeebrugge — the current location on the Zweedse Kaai, the New York Kaai, the northern Insteekdok and the contractor's work harbour. Who is to say that eventually SeaRo may not spread its wings even further?

Certainly, the demand, as both Townsend Thoresen and North Sea Ferries can also testify, for efficient ro-ro terminal and shipping services, especially to the UK, is there — it is simply a question of gearing resources properly to meet the demand.

Currently, demand for ro-ro service to the UK from Zeebrugge is such that it seems new routes are being opened every few months.

The immediate success of the Kent Line and Cobelfrêt services, both less than 18 months old, must give encouragement to other operators. Most recently, for example, Searoads Ferries Ltd. has started a daily freight-only service between Zeebrugge and Tilbury, although this has since suffered interruption.

The commissioning in Spring 1986 of the Dartford International Ferry Terminal, with excellent motorway links, will doubtless herald a further ro-ro service between Zeebrugge and Dartford.

Whether the market can sustain such growth has yet to be seen. If past growth patterns are maintained, there should be no problem, and ro-ro terminal operators and shipping lines alike can look ahead with confidence.

Capacity of Sea-Ro Terminal's Zweedse Kaai facility has recently been improved by installation of a MacGregor-Navire linkspan, seen here in the bottom right-hand corner; the first linkspan has since been re-located to the Westerhoofd.

Container terminals

Specialised container handling facilities at the Port of Zeebrugge are concentrated on two locations — the Ocean Containerterminal Zeebrugge (O.C.Z.) on the Westerhoofd for deep-sea traffic and the Shortsea Container Terminal (S.C.T), located on the west side of the access channel to the old sealock, and south of the Train Ferry Terminal for, as the name implies, short-sea traffic, mainly to the UK.

Container handling operations are also carried out at several of the multi-purpose facilities within the port, including M.B.Z. berths on the Leopold II mole and the new Combined Terminal Operators (C.T.O.) facility on the northern Insteekdok. Although these latter operations tend in the main to be of a small scale, this pattern may change early next year with installation of a container ship-to-shore gantry crane at the C.T.O. terminal.

Container traffic through the Port of Zeebrugge in 1984 amounted to 2.16m tonnes, a small rise of 2.3 per cent over 1983. Within this figure, however, was a decline of 8.7 per cent on deep-sea traffic, accounted for mainly by reductions in wool traffic from Australia. This drop was balanced by an increase of 10.7 per cent in short-sea volume, mainly to Harwich and Dagenham in the UK.

Both the O.C.Z. and S.C.T. container facilities are operated by Belgisch-Engelse Vennootschap der Ferry-Boats, a consortium comprising Société Nationale des Chemin de Fer Belges (S.N.C.B.), British Rail (B.R.), and since 1977, Compagnie Maritime Belges (C.M.B). There has been discussion of late of the future rôle British Rail will play in the Ferry-Boats consortium, and this is detailed further in the description of the Train Ferry Terminal. The involvement of Ferry-Boats in the two container terminals evolved during the 1970s as a consequence of the switch from break-bulk general cargo to containerisation, and of British Rail's decision to commence Freightliner containership operations between Zeebrugge and Harwich.

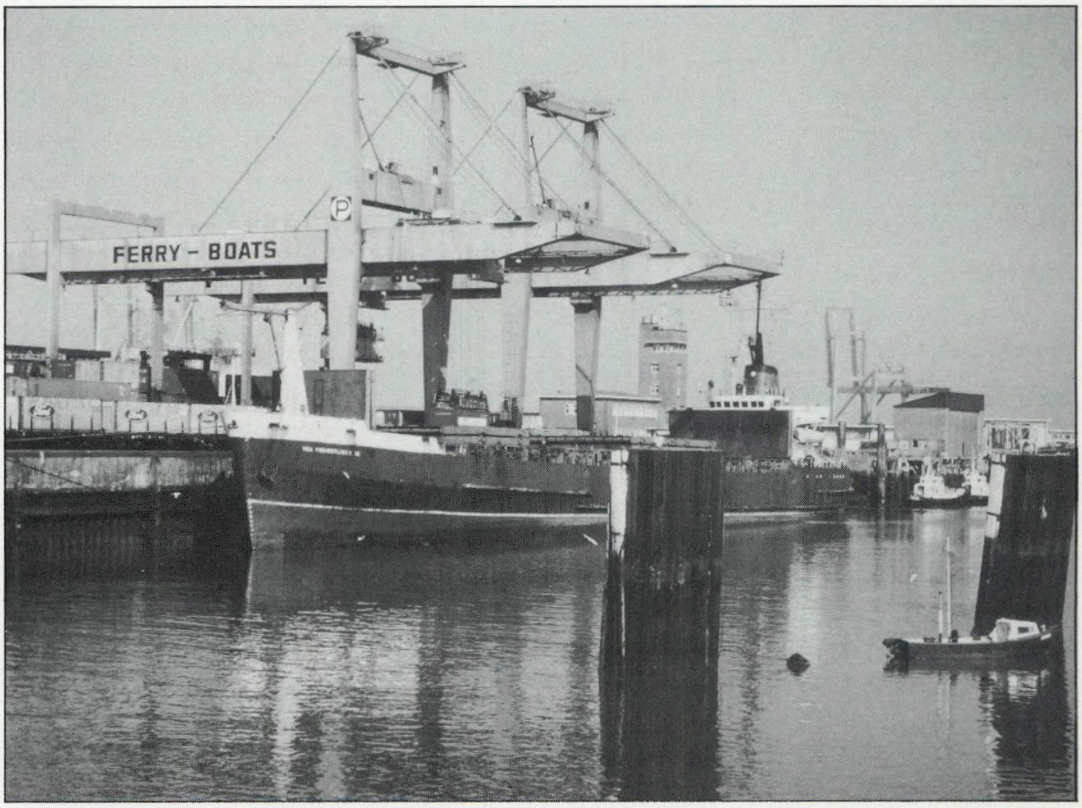
Both the O.C.Z. and S.C.T. terminals are laid out in a similar manner, with the gantry cranes straddling four rail tracks, permitting direct ship-rail-ship transloading and counteracting the relatively low level of container stacking area. The S.C.T. was the first of the two facilities to be constructed, in 1968, and as Mr. Hoornaert, manager for Ferry-Boats in Zeebrugge, says, the short quay length at the S.C.T. and insufficient deep water necessitated the construction of the O.C.Z. terminal in 1971 to handle the larger container vessels.

The S.C.T. has a quay frontage of 270 m, sufficient for two vessels to berth simultaneously, with a quay width of 53 m plus 26 m handling area. Alongside water depth is 7 m at low tide. The 5 ha terminal is equipped with two rail-mounted 30 t S.W.L. double head-beam Peiner gantry cranes with an outreach of 14 m beyond the quayside and three 30 t straddle carriers as well as an ASEA automatic remote rail wagon shunting device.

The main services to use the S.C.T. facility are the Freightliner Ltd. container service to Harwich (see box insert) and Ford, with shipment of containers from its Belgian and West German factories to its UK Dagenham plant. The main emphasis at the S.C.T. facility is on serving these two regular short-sea operators, and speed is of the essence.

The O.C.Z. terminal occupies an 18 ha site on the 20 ha Westerhoofd peninsular. Total quay length is 1,420 m with the main west quay having a length of 815 m allowing three vessels to berth simultaneously. Alongside water depth is 13 m at low tide, enabling third-generation containerships to berth. Ship-to-shore cargo transfer is by means of three container gantry cranes, two Munck units of 45 t S.W.L. capacity and one Boomse Metaalwerken machine, with an under spreader lifting capacity of 30 t. Maximum outreach is 37 m.

Again, all three gantry cranes are notable for high rail centres of 31.5 m and high headbeams (up to 104 m). Four rail tracks, reaching 755 m along the west quay, and two road lanes are straddled by the cranes. Movement of rail wagons for direct transfer of con-



The Shortsea Container Terminal serves the cross-Channel container trade; the facility's two Peiner gantry cranes are pictured here servicing the "Sea Freightliner II".

Deep-sea container traffic at the Port of Zeebrugge is catered for by the Ocean Containerterminal Zeebrugge, equipped with three ship-to-shore gantry cranes.

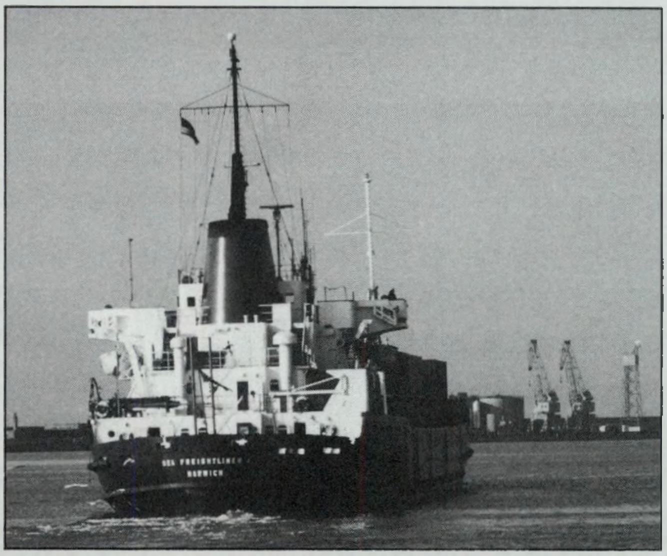
Freightliner establishes Zeebrugge office

Since assuming marketing and financial responsibility for the Harwich-Zeebrugge Sealink containership operation on 1 January 1983, Freightliner Ltd. (the container haulage subsidiary of British Railways Board) has achieved considerable traffic growth, with carryings this year expected to rise by at least 10 per cent to 70,000 boxes. Two cellular vessels are employed on the Harwich-Zeebrugge route, the *Sea Freightliner I and Sea Freightliner II*, each with a TEU capacity of 220. Normal service frequency is at least six times weekly in each direction.

By embarking on a marketing policy of actively seeking out new customers, both in the UK and in Europe, Freightliner has increased the customer base on the route to over 200. With a 20, 30 and 40 ft container fleet, the company is able to offer customers product flexibility. The recent introduction of the Freightliner Europe door-to-door service using Freightliner containers has been well received by the market on both sides of the Channel.

Competition for cross-Channel container traffic is fierce, with the various ro-ro operators especially looking to increase their share of this market. Competition is a considerable incentive, however, and to maintain and improve its position Freightliner recently decided to set up an office in Zeebrugge. This move will enable the company not only to deal with operational matters at the Zeebrugge end of the cross-Channel route, but also to ensure the rapid and efficient handling of Freightliner Europe door-to-door traffic.

Freightliner Ltd. is confident that the improvements it has made, and is continuing to make, to the Harwich-Zeebrugge containership route and to its European door-to-door network will enable it to further increase volume on the route, and to become an even more significant force in the European freight transport market.



"Sea Freightliner I" departing from Zeebrugge in the evening sun, with a full load of containers, bound for Harwich.

tainers is again undertaken with a remote control ASEA shunting device, controlled by the crane operator.

The stacking area behind the quay can accommodate up to 10,000 TEUs. Movement of containers around O.C.Z. is by means of 10 straddle carriers, six Valmet Oy machines and four Peiner units. O.C.Z. has recently taken delivery of a further straddle carrier from Valmet Oy. Fork-lift trucks, with capacities from 2 to 30 t, and tractors are also available for auxiliary handling duties.

The stacking area also accommodates the Consolidated Freight Station, which comprises 4,000 m^2 of covered sheds, with rail siding inside and outside, seven truckloading bays and seven container loading bays. A 1,000 m^2 canopy is also provided for stripping and revanning of containers and for handling of I.M.O. cargo.

Provision has been made too at O.C.Z. for proper servicing of reefer containers. A variety of systems is available for reefer containers to be maintained at the required temperature, including both mechanical chilling (Grenco wall type, 24 slots; Holima tower, 52 slots; clip-on points, 48 slots) and cryogenous (freeze-point, 48 slots; cryo clip-on, 20 slots) systems. A mobile liquid nitrogen unit is also available.

The O.C.Z. performance in 1984 was, as already stated, some 9 per cent down on 1983, due mainly to the continuing impact of the general world-wide recession. With the deep-sea services calling at Zeebrugge bound mainly for Africa and Australia/New Zealand, plus occasional callers bound elsewhere, it can be seen that the economic troubles of West African countries such as Nigeria would have a severe effect.

The increasing tendency, too, for container lines to reduce the number of European calls will increase the pressure on O.C.Z. to show that it can provide a superior service to competing terminals in the Le Havre-Hamburg range, and doubtlessly serious thought is now being given by M.B.Z. and Ferry-Boats to upgrading of the level of containership handling service offered by Zeebrugge.

It is currently intended that future development of container handling facilities in the Port of Zeebrugge will be concentrated on the new southern dock in the western outer harbour. This will not only offer deeper water (− 16 m), but will reduce vessel turnround time by virtue of improved berth access and faster container handling. Provision would be made for the new facility, no final decision on which has yet been taken, to service the latest fourth-generation container vessel fleet. This implies installation of high-outreach ship-to-shore gantry cranes and ancillary handling equipment.

Current projections for the new southern dock are for 2,400 m of quayside, a width of 300 m, and a low tide water depth of 16m. A slope at the western end of the dock would allow deep-sea ro-ro container vessels to be serviced. A significant limitation on this site, as with the existing O.C.Z. and S.C.T. terminals, would be the container stacking area, but again direct rail access at the quayside would be available, negating to a large extent the stacking constraint that would otherwise exist.

Train ferry link

The Train Ferry Terminal (T.F.T.) in the Port of Zeebrugge started operations in its present location in the outer harbour in 1924. Operated by Belgisch-Engelse Vennootschap der Ferry-Boats, the 4 ha T.F.T. comprises a single train ferry berth. Maximum vessel size on the berth is restricted to 163 m in length and 18.5 m beam. Water depth is −6.7 m at low water.

Until recently, the axle load on the two-track loading ramp was restricted generally to 20 t; work carried out in the last month, however, has enabled the maximum axle load to be raised to 22.5 t, to fit in with a general increase in European levels and permitting additional payload per wagon of up to 10 t.

The T.F.T. has been overshadowed somewhat by the pattern of development in the rival ro-ro sector, but nevertheless 1984 volume was up by nearly seven per cent to 473,225 t, despite a three-week service interruption in March 1984.

The T.F.T. currently services the two Sealink (UK) Ltd. train ferries employed on the Zeebrugge-Harwich route. The basic level of service is 20 sailings in each direction per fortnight, 13 with the *Speedlink Vanguard* (the larger of the two vessels) and seven with the *Cambridge Ferry*. Sailings of the *Cambridge Ferry*, the charter on which expires in 1986, could be increased if the traffic position warranted.

Financially, however, the two train ferry routes to the UK operated by Sealink (UK) Ltd. (now part of Sea Containers Ltd.) on a contract basis on behalf of British Rail are in a parlous state, the costs of the shipping provision alone not being met by current Continent-UK traffic levels.

While it is clear that this negative financial contribution cannot be sustained by the various parties for much longer, it is not at all clear how the situation is to be


SEA-RO TERMINAL NV
Zweedse Kaai
8380 Zeebrugge - Belgium
Tel. (050) 54 63 77
Telex 81.983

resolved.

As far as the long-term future of the Zeebrugge-Harwich train ferry service is concerned, much depends on the outcome of negotiations currently being held to reduce operating costs on the Dunkirk-Dover route, in the meantime on notice for closure by 2 November.

If the negotiations between the UK and French partners on the future of the Dunkirk-Dover route are successfully concluded, then it may at the same time be decided to upgrade that service by provision of a larger, more efficient multi-purpose vessel. This would necessitate installation of new berthing and handling facilities at Dover; switching of the Zeebrugge-Harwich service to Dover would increase the utilisation of these facilities, as well as improve the train ferry service from Zeebrugge by virtue of reduced sailing time (as opposed to Harwich) and faster turnrounds.

Use also of more modern multipurpose train ferries on the Zeebrugge-Harwich/Dover route(s) would require, too, new berthing and handling facilities at Zeebrugge, most likely directly to the north of the existing Train Ferry Terminal berth.

Dry bulk terminals

Historically the most significant dry bulk material handled at the Port of Zeebrugge has been sea-dredged sand and gravel, for use in the construction industry. Although sand and gravel throughput declined slightly in 1984 (down 5.1 per cent from 1.64m tonnes to 1.56m tonnes) this trade is expected to continue at around this level in the future (notwithstanding completion of the expansion work at the Port).

It is in the dry bulk sector that the most obvious signs so far of the expansion of the Port of Zeebrugge can be detected. Completion of the northern Insteekdok by contractor S.B.B.M. of Brussels, coupled with the opening of the large Pierre Vandamme sealock in November 1983, was followed closely by the establishment of two major dry bulk handling terminals — Zeebrugse Behandelingsmaatschappij (Z.B.M.) and Belgian New Fruit Wharf (B.N.F.W.), one on each side of the northern Insteekdok. The impact of these two new facilities has already been reflected in the Port of Zeebrugge's freight traffic figures for 1984, even though 1985 will be the first full year of operation.

Although it must be said that other ports in the Le Havre-Hamburg range, especially near neighbours Dunkirk, Antwerp and Rotterdam, are much better equipped for specialised large-scale handling of dry bulk materials, particularly coal and iron ore, nevertheless there would appear to be considerable potential for Zeebrugge to achieve substantial gains in this cargo handling sector. If this potential approaches realisation, then moves would be started to implement the Seabulk proposal for a state-of-the-art dry bulk handling terminal on the southern Insteekdok.

It is not without significance in many respects that both the Z.B.M. and B.N.F.W. terminals are subsidiaries of larger companies operating similar handling facilities in other Belgian ports. Z.B.M. is a subsidiary of Compagnie Belge de Manutention (C.B.M.), which operates a wide range of general cargo and bulk handling facilites in the Port of Ghent, while Belgian New Fruit Wharf operates a similar, but much larger fruit terminal in the Port of Antwerp.

The Z.B.M. facility became fully operational on 15 July 1984, and the first vessel to berth was the *Kedzieryn* with 5,500 t of Polish coal. The Z.B.M. terminal has a total quay length of 540 m, with an alongside water depth of 14.5 m. Quay width is 450 m, giving a total working area of 20 ha. Equipment provision includes one 28 t capacity rail-mounted level luffing crane, rated at 750 t/hr (max.) and supplied last year by Nieuwe Boomse Metaalwerken, three 8 t capacity × 32 m outreach Peiner dockside cranes and two 28 t Gottwald mobile cranes rated at 750 t/hr. The fixed craneage is provided by M.B.Z., as is one of the Gottwald mobiles, and is shared with the C.T.O. facility nearby.

At present, the Z.B.M. terminal handles mainly coal and coke, but there are plans to supplement this with iron ore and titanium ore. One constraint on operations is the limited consolidated storage area on site, although a total of 44,000 m^2 of pavement has already been laid. An example of the varied nature of coal handling at Z.B.M. is that in April the stockpile level stood at 187,500 t and comprised 22 different coal types. Movement of stock around the Z.B.M. site and to/from the quayside or within crane reach is carried out by wheeled front-end loaders and dozers, and Z.B.M. is shortly to take delivery of further Terex machines for this purpose. Two powerful screening plants are also available. Z.B.M. anticipates that 1985, its first full year of operation, will see throughput approaching the 2m tonnes mark.

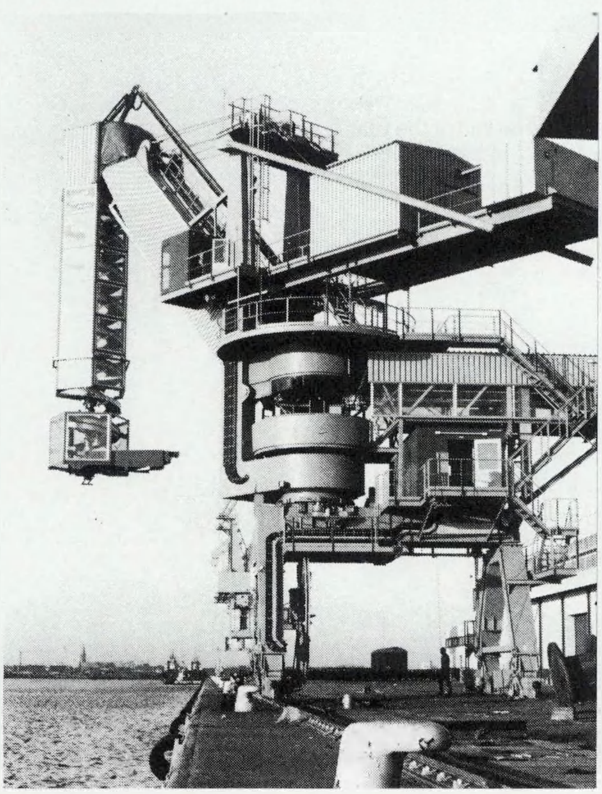
Eric Boonefaes, managing director of Lalemant Zeebrugge, which handles commercial transactions and marketing functions on behalf of Z.B.M., gives two main reasons for the decision to establish Z.B.M. in Zeebrugge. Firstly, he says, Zeebrugge's location directly on the coast gives the port an advantage in terms of sailing time and vessel access over competing ports in the region, while secondly the high productivity and good industrial relations record of the workforce in Zeebrugge was also an important factor.

Z.B.M. is concerned that it should be able to handle the largest vessels capable of transitting the Pierre Vandamme sealock (125,000 d.w.t.) and current intentions are that the company will move operations to the southern Insteekdok when this is completed. Water depth there is planned to be 18 m, and this will offer considerable competitive advantages over the present site, where vessel size is restricted by the 14.5 m water depth to 100,000 d.w.t. fully laden.

Much of Z.B.M.'s throughput is direct transhipment into coasters and barges. Although inland waterway connections out of Zeebrugge into the main European network are not good (although there are plans to upgrade these), growth is expected in estuarial traffic, in either coasters or reinforced barge-type vessels. Road and rail connections out of

Coal handling at the Zeebrugse Behandelingsmaatschappij facility is usually by means of this 750 t/hr Gottwald mobile crane; Z.B.M. expects to handle around 2m tonnes of coal, coke and ore in its first full year of operation.

New Technology for Shipunloaders Handling Cardboard Boxes

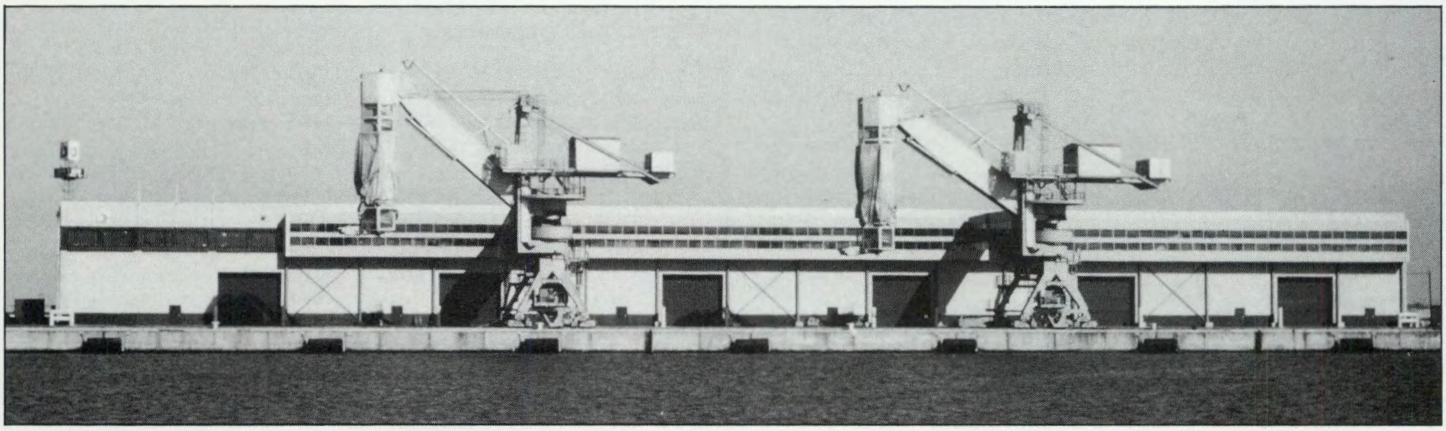


The new shipunloader at the port of Zeebrugge is used to unload cardboard boxes containing fruit from ocean-going vessels up to 25.000 dwt by means of spiral conveyors. The spiral conveyors consist of several fixed spiral sections and one mobile part as telescope for the height variation and slewing of the loading point in the ship's hatch. To make sure that the cardboard boxes are transported, the conveyor belts are provided with cams. At the mobile lower end of the spiral conveyor a tangential telescopic loading belt conveyor has been installed. It can be inclined downwards and upwards, thereby allowing three possibilities of movement for the adjustment of the loading point: lifting, lowering and slewing of the spiral as well as inclination of the loading conveyor so that all necessary positions in the ship's hatch can be reached. 3.800 cardboard boxes with a weight of 20 kg each can be handled per hour.

PWH

PHB Weserhütte
Aktiengesellschaft
P.O.Box 51 08 50
D-5000 Köln 51
Phone: (02 21) 36 75-0
Telex: 8 882 553

85/13 e



Equipment provision at the new Belgian New Fruit Wharf facility includes these two PWH continuous ship unloaders, each rated at up to 3,800 boxes/hr.

Z.B.M. are also used extensively, the N.V. Carcoke plant in the old part of the port being serviced by road, and steelmills in southern Belgium by 1,100 t trainsets.

The Belgian New Fruit Wharf (B.N.F.W.) terminal, located on the eastern side of the northern Insteekdok, received its first vessel in May 1984 but only became fully operational in July. With a 400 m quay length, a 14.5 m water depth and a 20 ha working area, the B.N.F.W. facility is equipped with a variety of handling plant, comprising two 8 t × 32 m outreach Peiner dockside cranes, two 3,800 boxes/hr PWH continuous ship unloaders and two Gottwald mobile cranes for auxiliary duties.

Two sheds give a full range of storage options. The first, 142.9 m long and 38 m wide, has an area of 5,430 m^2 and an overall free height of 10 m. Rail access into the shed has been provided.

The two rail-mounted ship unloaders, which were commissioned by PWH at the beginning of the year, each have a 22 kg box handling capacity of 3,800/hr, and are linked to palletising machines inside the shed. The machines are capable of handling vessels up to 25,000 d.w.t., and operate on a fixed spiral conveyor principle on vertical sections (supplied by Jonge Poerink of The Netherlands) with belt conveyors being employed on horizontal sections. Boxes are fed into the system by means of a slewing telescopic belt conveyor at the lower end of the spiral conveyor (thus giving access to all points of a vessel's hold); control is undertaken either from the operator's cabin or from a panel by the telescopic feeder conveyor.

The second shed, with dimensions of 143.9 m length and 38.3 m width, has an area of 5,506 m^2 and is fully insulated. Divided into two, one half of the shed has a free height of 10 m, while the other half is sub-divided into four different temperature-controlled compartments.

Belgian New Fruit Wharf operates similar facilities at its Antwerp terminal, where annual throughput is around 600,000 t. The Zeebrugge facility is expected to complement this with a further 150,000 t/yr, as well as give the company additional flexibility.

The N.V. Seabulk scheme to construct a major bulk handling facility on the southern Insteekdok has been under discussion for some years now, initial expectations of an early start having been dampened, mainly by the reduction in coal and iron ore imports into Europe in recent years. A decision on whether or not to proceed with this ambitious scheme is now expected in the near future.

If the Seabulk terminal proposal goes ahead in its original form, a 100 ha site would be prepared on the north-western corner of the southern Insteekdok. Total quay length would be 850 m, and water depth would be 18 m, enabling carriers of up to 130,000 d.w.t. to berth at the facility. Quay length could be extended, depending on demand.

Phase I of the Seabulk proposal provides for ground storage of 40 ha, and an annual transhipment capacity of 8m tonnes. Phase II would double storage and transhipment capacity. Initial quay length of 850 m would be divided into 600 m for discharge operations and 250 m for shiploading of vessels of up to 80,000 d.w.t.

Equipment provision would include two 2,000 t/hr gantry cranes and three stacker/reclaimers, with a stacking rate of 5,200 m^3/hr and a reclaimer capacity of 3,000 m^3/hr.

N.V. Seabulk, formed in July 1980, is a consortium of interests including the Port of Zeebrugge, Belgian Railways, N.V. Carcoke, the steel company Sidmar and the local regional development authority. Haecon N.V. carried out feasibility studies into the Seabulk proposal in 1981. At that time, total cost of the scheme (phases I and II) was estimated at 3,900m Belgian francs.

The 332,000 m^2 stockpile area was looked at especially carefully by Haecon because of the load put on the pavement structure and the subgrade (characterised by a variable and weak layered structure) by 14-16 m high iron ore stockpiles.

If it is decided to proceed with the Seabulk terminal project, work could begin by the end of the year and substantial dredging would be required to bring water depth down to the 18 m level. Completion could be expected some two years later.

Another option being examined for dry bulk transhipment is use of the lee of the eastern breakwater, north of the L.N.G. terminal, an area of some 88 ha, as an offshore lighterage facility.

Experience in the US with such schemes suggests that they can be more cost-effective and flexible than shore-based facilities. In this instance, material could be transhipped into ocean-going barges for onward transport to ports along the western Scheldt or the UK.

Multi-purpose facilities

Prior to the current expansion of the Port of Zeebrugge, general cargo handling operations (i.e. those that were either not unitised or of sufficient scale to be handled at the specialised terminals) were concentrated on the Leopold II mole, with its limited back-up quay width for storage and prehandling.

Commissioning, therefore, last year of the new Combined Terminal Operators (C.T.O.) facility on the west side of the northern Insteekdok as a multi-purpose general and bulk cargo handling terminal went a long way towards alleviating this situation.

C.T.O., a 100 per cent subsidiary of the Dutch transport group Van Ommeren, originally started up Zeebrugge operations with a shed on the Leopold II mole in December 1982, concentrating initially on discharge of bulk barley and subsequent bagging for shipment to Saudi Arabia.

The company's new location on the northern Insteekdok gives C.T.O. the ability to carry out a much wider range of handling functions, indicated by the flexibility offered by the innovative handling systems. The C.T.O. site occupies 18 ha, and quay length is ultimately to be 600 m, with an additional 50 m ro-ro berth to be completed by January 1986. Ro-ro operations are currently catered for by a 3,600 d.w.t. floating pontoon, with dimensions of 60 m length and 22 m width. M.B.Z. is currently putting the finishing touches to C.T.O.'s third berth, with a quay surface of 250 m length and 25 m width being laid at the northern end. Water depth is currently 13.5 m, being extended to 14.5 m.

The first two vessels to berth at the C.T.O. facility illustrate the wide cargo handling capability of the terminal. The m.v. *Darsser*

Ort, which came alongside on 3 May 1984, was loaded with pipe exports, while the m.v. *Cygnus Ace* six weeks later took on board 100 buses for Saudi Arabia.

As a multi-purpose terminal, the C.T.O. facility caters for three distinct kinds of cargo: bulk (grain); general cargo; and unitised cargo (both container and ro-ro).

Cargo handling equipment is varied. The 28 t Nieuwe Boomse Metaalwerken level luffing crane, three 8 t Peiner dockside cranes (transferred from the outer port and converted to 3,000 V electrical operation) and one Gottwald mobile crane are shared with the Zeebrugges Behandelingsmaatschappij (Z.B.M.) terminal nearby.

For bulk handling purposes, C.T.O. has also taken delivery from Geldof of Haselbeke of a 700 t/hr (hard grains, density 0.6) handling system, comprising a fixed and mobile belt conveyor network, grab discharge hopper, truck and rail wagon unloading pits, loading chute and a truck-mounted mobile shiploader (with a reach of 10 m and a 10 m height above quayside). Direct rail wagon to ship transfer has recently been introduced by commissioning of auxiliary conveyor sections to link the rail wagon discharge/truck loading system with the mobile shiploader. Ship unloading is undertaken by the dockside cranes.

For storage, C.T.O. has a general cargo warehouse of 6,000 m^2, linked by a 4,000 m^2 canopy to a 33,000 t flat silo for grain storage. The flat silo is divided into two ventilated compartments. Delivery of material into the silo is via overhead conveyors with trippers, while reclaim is via hoppers feeding underground conveyors. Movement of stock around the silo is with front-end loaders. 3,000 t/d bagging facilities (50 kg bags with a bulk density of 0.6) are also available.

C.T.O's investment plans include construction of a second 30,000 t flat silo and 6 × 1,000 t vertical bins, with conveyor connections into the main network. A 4,500 m^2 container freight station with rail connections is also planned. Four rail tracks have recently been laid at the rear of the existing sheds to supplement the three tracks on the quayside. A gantry crane for container handling and hook work is due to be installed alongside the existing craneage in Spring 1986. There is discussion, too, on installation of a pneumatic unloader, but current indications are that grab operation is preferred, as it maintains the versatility of the terminal.

With a 700 t/hr bulk handling system as well as conventional craneage, the Combined Terminal Operators facility can cater for a wide range of handling requirement.

Liquid bulk products

The closure of the Texaco refinery in Ghent in 1982, fed by a 47 km pipeline from Zeebrugge, was a serious blow for the Port of Zeebrugge and resulted in the loss of the great majority of its liquid bulk traffic. The decision, however, by the Belgian Government to concentrate imports of liquid natural gas (L.N.G.) on terminal facilities at Zeebrugge will lead to some measure of stability returning to liquid bulk handling at the port.

Construction of an L.N.G. terminal in the eastern outer harbour as part of the overall port expansion commenced some years ago. The Belgian Government specified that the L.N.G. terminal, for safety reasons, should be located at least 1.5 km from the nearest residential areas and well away from other cargo handling activity.

The L.N.G. terminal has been built on an artificial peninsular (completed in 1981). The berth has been constructed behind a protective breakwater, and this ensures that the risk of another vessel colliding with an L.N.G. carrier is excluded.

Construction of the L.N.G. jetty was detailed in a previous article within this supplement (see page 20). The jetty can accommodate L.N.G. carriers from 40-130,000 m^3 capacity, and minimum alongside water depth is 13 m. The 120 m long jetty, with a deck width of 20-40 m, is of reinforced concrete deck construction on steel tubular piles.

The initial L.N.G. contract signed between Distrigaz and Sonatrach of Algeria provided for import of 5bn m^3/yr over 20 years. The contract has since been renegotiated, due to lower energy demand in Belgium, and now provides for import of 2.5bn m^3/yr of L.N.G.

While there were doubts that this lower volume would enable the L.N.G. terminal project to proceed, international consultants Purvin & Gertz carried out a feasibility study and determined that the facility should be viable even with an annual import level of 1.5bn m^3. To take the reduced primary Belgian energy demand into account, however, it was decided to reduce the initial number of L.N.G. storage tanks at the terminal from four to three and to install only one of the planned two re-gasification lines.

The 40 ha terminal site currently under construction therefore comprises three 87,000 m^3 storage tanks, with a possible fourth and a second re-gasification line to be constructed at a later date. Current indications are that the L.N.G. terminal will be operational during 1987, with regular L.N.G. traffic from Algeria commencing then also.

Should the level of L.N.G. imports begin to approach terminal design capacity, there is the possibility of using a further section of the eastern outer harbour for expansion by provision of a second L.N.G. discharge jetty and two additional storage tanks. To keep expansion options open, a pipe-laying strip of 12.5 m and a single-carriageway road has been laid from the L.N.G. terminal to the north-eastern outer harbour.

Handling of other liquid bulk products at the Port of Zeebrugge has previously been concentrated on the Leopold II mole. Construction of the Wielingendok, in the north-western corner of the outer harbour, will enable these activities to be transferred away from the Leopold II mole with its busy ro-ro traffic.

The former Texaco pipeline from Zeebrugge to Ghent has now been adapted to carry coal gas, and will be used by N.V. Carcoke (with a coke plant alongside the Baudouin Canal) to serve customers in the chemical and metal

The Distrigaz L.N.G. terminal in the eastern outer harbour is due to commence commercial operation in 1987.

connected to the Ostend-Ghent Canal. Maximum vessel size on this waterway, however, is restricted to 900 t, although there are plans to increase this to 1,350 t. Capacity beyond Bruges is restricted by the labyrinth of old docks and canals that encircle the City of Bruges. There is little doubt that the poor inland waterway connections from Zeebrugge are a major hindrance to the development of the port.

Proposals to improve these links centre on widening of the Baudouin Canal over the first 5 km of its length from Zeebrugge, provision of a 4.2 km link across the southern perimeter of the inner port from the Baudouin Canal at Dudzele, and construction of the so-called North Canal.

The North Canal, when built, will link Zeebrugge with the main European inland waterway network. Initially water depth of 5 m would be provided, enabling 2,000 d.w.t. shipping or 3,000 t pushtow convoys to use the canal between Zeebrugge and Merendree, the junction with the Ostend-Ghent Canal. At a later date the canal would be extended to allow 10,000 t pushtow convoys to reach the Ghent-Terneuzen Canal near Zelzate.

industries at Evergem, on the Ghent-Terneuzen Canal.

Haecon N.V. carried out design work on the converted pipeline (diameter 500 mm, length 47 km) for Nationale Maatschappij der Pijpleidingen (N.M.P.), a state-owned company responsible for transport of products by pipeline.

N.V. Carcoke (licensed to use the converted pipeline) has been operating out of Zeebrugge since 1920, and were the recipients of coal shipped in the novel transport system introduced by Sea Containers Ltd. in 1982, involving the shipment of UK National Coal Board coal from the Kent coalfield to Zeebrugge in open-top bulk containers.

A new coke oven, with an annual capacity of 1.2m tonnes, is currently planned by Carcoke for installation near the N.V. Seabulk scheme, in which the company is a participant.

Hinterland connections

The excellent road and rail links from Zeebrugge into the respective main European networks have doubtlessly contributed significantly to the sustained growth of ro-ro and container traffic through the Port of Zeebrugge.

State road No. 905, a dual carriageway, presently links Zeebrugge with the E5 motorway south of Bruges, by-passing the town centre, while freight and passenger trains link into the Ostend-Köln main line at Bruges, with most other European destinations being accessible via Brussels.

To cater for the projected incease in road traffic, a separate motorway link from Zeebrugge to the E5 is planned. On the rail side no major infrastructural improvements are planned, line capacity being sufficient to cater for projected traffic increases. One advantage of the diversion of Bruges-Knokke/Heist traffic away from Zeebrugge (necessitated by construction of the Pierre Vandamme sealock and inner harbour) has been that rail activities at Zeebrugge, now a terminus, can be much more geared to port requirements.

The significance of rail for inland transport, especially for container traffic, can be gauged from the fact that of the 95,219 containers handled at the Short-sea Container Terminal in 1984, 78,604 (or over 82 per cent) arrived or departed by rail.

Current rail investment at Zeebrugge centres on provision of additional sidings on the west side of the northern Insteekdok, to the rear of the Combined Terminal Operators facility. Belgian National Railways believes the cargo handling activities constructed or planned for the outer and inner harbour will generate large volumes of rail-borne traffic in years to come, and is providing infrastructure accordingly.

The Port of Zeebrugge is currently handicapped, however, by the relatively poor inland waterway connections from Zeebrugge. The 12 km Baudouin Canal, with a minimum water depth of 7 m, links Zeebrugge with Bruges, in turn

Looking ahead

With the expansion work almost complete, it is clear that that the Port of Zeebrugge is a port with a future. That several major terminal operators have established subsidiary operations in the port testifies to this.

Expansion of the Port of Zeebrugge will enable Zeebrugge not only to do better at what it already excels, namely servicing of short-sea ro-ro operations, but also to diversify more into a wide range of cargo handling requirement and to cater for the special needs of deep-sea shipping. Expansion will enable the port to broaden its base.

Admittedly, the Port of Zeebrugge can not, as yet, be placed on a par with the Port of Rotterdam, nor does it have Rotterdam's natural inland waterway advantage. It can be safely predicted, however, that within the not too distant future the Port of Zeebrugge will become a significant force within the Le Havre-Hamburg range of ports and will generate a considerable impact on north European range port and shipping operations.

Belgium will have a seaport of which it can justifiably be proud.


Just some heavy references
U.S. Pipe, Oakland □ Universal Stevedoring, New York □ National Shipping Company of Saudi Arabia □ Arab Stevedoring Company, Alexandria □ Alexandria Port Authority □ OTT, Liverpool □ Black Sea Shipping Company, USSR □ Pays Stevedoring, Antwerpen □ Peinemann B.V., Rotterdam □ Holzmüller, Hamburg □ Afrika-Linie, Hamburg □ CGM, France □ Barber Blue Sea Line □ Aarhus Stevedoring Company □ Gothenburg Stevedoring Company □ Kuwait Gulf Link Transport Co. □ Kuching Port Authority, Malaysia □ Messina Lines, Italy □ BNS, Sweden □ HHLA, Hamburg □ Morflot, Soviet □ SNS, Algeria □ DSB, Denmark □ West African Terminals, UK □ Muara Port, Brunei □ Brandsma, Netherlands □ Zeebrugge Shipping and Bunkering □ Combined Terminal Operators CTO □ Townsend Thoresen □ North Sea Ferries □ Sea Ro Terminal.
Kalmar LMV
Box 308 S-341 00 Ljungby Sweden
Phone Int. +46 372 80740
Telex 52112 klmv s
PVBA Catracom
Kalmar-LMV
Goteborgweg 2 Bus 1
2030 Antwerpen
Tel 03/542 47 05
Tlx 73369 calift b
IEA
IEAU
USA
420217 4
4310
MAX.GROSS
TARE
MAX.CARGO
CU.CAP.
Kalmar LMV
42-1200 CS
090