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Simulation of Bridge Passage in High Wind

Passage simulé sous un pont en cas de forts vents

Simulierung einer Brückendurchfahrt bei starkem Wind

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SUMMARY

Car-carriers (beam: 32 m) entering the harbour of Rotterdam have to pass a bridge with a minimum width of 47.2 m to reach the Brittanniehäven for the discharge and loading of cars. Because of their form, the car-carriers are very sensitive to beam winds. To find out whether the bridge can be passed in stronger winds at reduced risk, various types of manoeuvres in different winds were studied using a ship manoeuvring simulator. The results of the study indicate that sailing through the bridge in somewhat stronger beam winds may be possible under certain conditions.

RÉSUMÉ

Les navires transporteurs de voitures (largeur 32 m) entrant dans le port de Rotterdam doivent passer sous un pont d'une largeur minimale de 47,2 m afin de parvenir au Brittaniehäven où s'effectue le chargement et le déchargement des automobiles. Du fait de leur forme, les transporteurs sont très sensibles aux vents de travers. Pour juger de la possibilité de franchir le pont avec des vents assez forts, des études ont été menées avec des vents de force différente à l'aide d'un simulateur de manoeuvres de navire. Les résultats obtenus et les conditions nécassaires sont présentées.

ZUSAMMENFASSUNG

Autotransportschiffe (breiteste Stelle: 32 m), die in den Hafen von Rotterdam einfahren, müssen unter einer Brücke mit einer Mindestbreite von 47,2 m hindurchfahren, um den Britanniehaven zur Ent- und Beladung von Autos zu erreichen. Aufgrund ihrer Form sind die Autotransporter gegenüber Seitenwind sehr anfällig. Um herauszufinden, ob die Brücke bei stärkeren Winden mit verringertem Risiko passiert werden kann, wurden Manöver bei verschiedenen Windstärken mit Hilfe eines Simulators untersucht. Die Ergebnisse der Untersuchung zeigen, daß ein Passieren der Brücke bei etwas stärkeren Seitenwinden unter gewissen Voraussetzungen möglich sein kann.

1. INTRODUCTION

For several decades ships have outgrown their facilities. No matter how large harbours, locks, canals and bridges were built, it did not take long before ships were built large enough to stretch the capacity of their facilities to their limits. Although some harbours and canals can often be widened and deepened, there is not much stretching to do with a concrete lock or with a bridge. One is stuck with it for many decades. Even planners, who looked far enough into the future to build a tunnel instead of a bridge, saw dredgers scrape the top of their tunnel even before they retired.
The above description typically fits the Brittanniëhaven, which is located in the Europoort area of Rotterdam.
The design of the Brittanniëhaven was based on industrial sites North and South of the basin with the main emphasis on petrochemical activities.
The sea transport would consist of tank vessels of medium size.
The construction of the bridge to the north of the Brittanniëhaven, between the basin and the sea, was such that no particular problems could be expected.
However, in due time, the large sites north of the basin were restricted in use by regional authorities for environmental reasons.
As a consequence, the Port of Rotterdam had to shift the activities to those which were acceptable for the environmental authorities. Stevedoring facilities for conventional cargo and multi-purpose vessels were introduced.
This harbour, is a perfect place to discharge and load cars. The bridge through which the ships have to sail to reach this harbour, the Caland bridge,handles about all the truck and train traffic that serves the harbours and industries west of it.
It is the artery of Europort. Damage to this vital would result into economical disaster.
The dimensions of this important bridge are given in Chapter 2.
The critical ship for the bridge is a car carrier. These ships have a very high superstructure to contain the decks for up to 6000 cars. This makes these ships very sensitive to wind. The dimensions of the critical ship are given in Chapter 3. Because of their sensitivity to beam winds there is always the decision to be made between two choices: diverting the ship or to take the risk of passing the bridge. So the Municipal Harbour Authority of Rotterdam ordered MARIN to try and find a way of passing the bridge in stronger winds at reduced risk. This study was carried out by the Ship Handling Group of MARIN. Use was made of all the resources and data available in the nautical support department of the Rotterdam Port Authority.
In the Chapters 6 through 8 an account is given of the study and its results.

2. THE BRIDGE AND THE CHANNEL

The channel has a bottom width of 145 m and a depth of 13.5 m. The direction of the channel is 170 degrees.
The bridge is 42 m east of the centre line of the channel. The width of the bridge between the wooden fenders on either side is 47.2 m. These fenders protect the four pillars on which the bridge can be lifted to above mast height. Additionally these pillars are protected by solid concrete cylindrical dolphins on the four ends of the bridge. The length of the fenders is 87 m.

3. THE SHIP

The critical ship on which the study was focused was a car carrier of 200 m long and 32 m beam and a draft of about 7.5 m, with one right handed diesel driven propeller. The minimum manoeuvring speed was 6 knots at 35 RPM. One of the most

important dimensions, however, is the height of the ship of about 20 m above the water. The shape can, somewhat simply, be described as a normal freighter hull with a shoe-box shaped superstructure over nearly the whole length.
The lateral surface above water of 3900 m^2, is about 2.6 times the surface under water of 1500 m^2. It is the unfavourable relation between surface above and surface below water which makes the ship "crab" through a canal at an angle when the wind is abeam. This drift angle must be larger, the slower the ship sails. If the drift angle is not large enough, the ship will ultimately end up on the leeward shore or collide with the bridge fender. If the drift angle is large enough for the ship's centre of gravity to follow a channel's centre line or a line parallel with it, the swept path will be larger than the ship's beam. The swept path increases with the sine of the drift angle and the length of the ship. In the most favourable condition, without wind, when the drift angle is zero, the ship passes straight through. If she sails exactly on the centre line, there is only one quarter of a ship's beam spare on either side. This is already a rather small margin for aiming errors.

4. THE USE OF TUGS

If it is assumed that the ship has to pass through in line with the channel, tugs have to deliver the same lateral force as the wind, but in opposite direction. One tug forward and one tug aft on a line can deliver a considerable side force if both pull at close to straight angles. This can be done if the speed is low.
Because the bridge is so narrow, unfortunately, during the passage they cannot pull at right angles. They can pull only at very small angles when the ship is windward of the centre line. Then their lateral force is negligible. They can pull at a fairly large angle when the ship is on the centre line or to leeward of it.

5. THE MANOEUVRES

There are two ways the manoeuvre of passing the bridge in strong beam winds can be made: Fast and slow.
The fast way practically eliminates the benefits of tug assistance. By sailing fast, the lateral force by tugs is in fact traded in for the lateral force generated by a drift angle.
The higher the speed, the smaller the drift angle and consequently the swept path. Also the higher the speed the more accurate is the steering. However, if one thinks of the disastrous consequences of one misunderstood rudder order, a misjudgement of the pilot or some mechanical failure, the idea has to be abandoned immediately.
To avoid the chance of high speed collision with the bridge, one has to pass slowly. It is the only way to take maximum advantage of the tugs and avoid the chance of putting the bridge out of service for a long time.

6. THE NAUTICAL STUDY

It will be clear, from the description of the situation in the former chapters, that there was a potential threat of collision all along. However, through careful co-operation between harbour authorities, pilots, tug company and shippers such calamities could so far be avoided.
As a general rule, a beam wind of Bft 6 was the limiting condition for passing the bridge. Besides, even if the wind was less than Bft 6 at the time of arrival, but winds in excess of Bft 6 were forecast, the decision was taken to

head for an alternate basin to avoid the chance of being locked up behind the bridge for the duration of the strong wind.
Part 1 of the study involved on-the-spot observation of pilots, tugs, procedures in identical situations elsewhere, theoretical calculations and interviews. One of the results of this study was, that no drastic improvement was to be expected from expensive constructions like for instance a tunnel-shaped fence to guide ships through the bridge opening by leaning on the fence.
It was feared, that sharp edges like loading doors, scupper guards etc. would lead to excessive wear on the fenders. Instead, it was recommended to try to make better use of tugs. To achieve this, it was suggested, that the pilots give the tug masters better guidance then before, by introducing a simpler and shorter phraseology. In this way part of the initiative was actually diverted from tug master to pilot, who due to his location on the bridge, could overlook the general situation better than the tug masters from their locations.
It was further recommended that a small number of pilots be selected to pilot ships through the bridge and that these pilots be trained on a simulator for that specific job.
After internal discussions among the harbour's operations department and pilots, it was decided to design a research program that could be carried out on a manoeuvring simulator.

7. THE STUDY ON THE SIMULATOR

7.1. The experiment

The experiment was designed for 80 simulator runs; 40 arrivals and 40 departures; 20 were supposed to be made at Bft 5 and 7, 40 at Bft 6, because Bft 6 was considered the limiting and consequently the most important condition.
Because the westerly wind was the prevailing wind, 48 runs were made at westerly and 32 at easterly winds. The experiment was carried out by two groups of two active pilots.
Immediately following the completion of the main experiment eight additional runs were made with a bow thruster available.
Those runs were added to be compared with those eight runs of the main experiment, that were made under otherwise the same conditions.

7.2. Tug Deployment

Like in reality, two tugs of 30 ton bollard pull were fastened; one at the bow and one at the stern on an as short as possible line.
One 12 ton tug was standing by to leeward to push at the forward shoulder before the ship entered the bridge, another one was waiting to push as soon as the ship stuck her bow out at the other side. These 12 ton tugs had not been used in reality.

7.3. The Visual Scene

The position of the ship in relation of the bridge was made visible by showing a bird's eye view of the situation.
This digitally generated picture of the contours of ship and bridge was shown on a large cathode ray tube. The tug forces were seen as vectors.

7.4. The Execution of the Experiment

Because it was one of the aims of the experiment to find out if better results would be expected with more precise tug orders, it was agreed that tug masters

would only follow pilot's orders.
During the three training runs, which each pilot had to make before the real experiment, it already became clear that in no way the pilot could give the tug master all the orders as to direction and force. Although the pilots tried hard, tugs often got tangled up behind or on the bridge structure. Consequently, the tug masters had to be allowed at least to keep their vessels clear of the bridge and follow the pilot's orders as closely as possible. To approach the bridge slowly, it was necessary to do so with stopped engine and consequently total dependence on tugs. As had already become apparent from test runs and training runs, the low speed made the system very sensitive to changes in tug forces. The distribution of tug forces absorbed nearly all the pilots attention.
To relieve the pilot somewhat from this burden and save some of his mental capacity for other things, the actual passage had to be started from a more or less equilibrium position.
To achieve this, the ship was brought on the axis of the channel, with the strong wind an tug forces more or less in equilibrium and with as little as possible drift or yaw.
This more or less stable condition was, of course, disturbed when the forward tug itself had to move more forward to go through the bridge, thus sacrificing some lateral towing force. This loss was partly evened out by the bow getting some lee from the bridge or by the use of the stand-by pusher tug.
This stand-by tug had to be given the proper orders at the time the pilot had already started to mind engine and rudder to help clear the stern.
Especially immediately before and during the passage, the pilot had to mind too many things in too short a time. This was one of the main reasons why the runs with the Bft 7 beam wind were mostly unsuccessful.
As the majority of these manoeuvres resulted in a collision with parts of the bridge protection, it was decided to cancel the remainder of the Bft 7 runs and sail all those with Bft 4 instead. By doing this, in fact wind force Bft 4, 5 and 6 were investigated, instead of 5, 6 and 7 as originally planned.
After completion of the experiments it was decided, at the request of the pilot, to make four extra runs at Bft 7, with tug masters using their own judgement rather than waiting for pilot's orders. The results are described in Chapter 7.5.

7.5. The Results

The results are shown in Table 1 (Results per wind condition).

Table 1

Wind force in Bft	Wind Direction	Total Runs	Contact with bridge protection				
			No Contact			Contact	
			runs	% of total		light	hard
4	W	6	6	100	80		
	E	4	2	50			2
5	W	18	8	44	50	5	5
	E	12	7	58			5
6	W	22	6	27	39	2	14
	E	16	9	56		2	5
7	W	5					5
	E	1					1

Remark:

Hard contact means ship-bridge protection-contact at a lateral speed = 0.5 knots.

This does not necessarily cause damage, but will lead to heavy wear of timbers.

As expected, the stronger the wind, the more frequent were the contacts of ship and bridge. If only Bft 5 and 6, the wind force at which the bulk of the runs were made, are considered, one sees that a higher percentage of contact were made with westerly winds than easterly winds.
For this there can be no other reason than that the bridge is off the centre at the east side of the channel. In other words, if a bridge is off centre it is easier to pass through it if it is on the windward side of the channel than if it is on the leeward side.
Table 1 also shows, that at Bft 5 in 50 per cent of all runs contact is made.
In reality ships contact approximately 0 per cent in Bft 5 wind. Clearly at Bft 5 the system of low speed, total tug reliance and total tug guidance, as used in the simulator, leads to more contacts than the system of rapid passage at a drift angle and minimal tug reliance, as used in reality.
However, at Bft 6, the latter system starts to become unacceptable due to either too large a drift angle or too high a speed or a combination of both, which could lead to heavy damage.
The system used in the simulation would indeed lead to more, but less severe contacts.
In general the tests consequently showed no advantage for the proposed system, if carried out by the average pilot. However, there are clear indications that the use of it by selected personnel could lead to better results.
It can be seen from Table 3, that for instance pilot number 2 scores 63 per cent of his manoeuvres without contact; twice the percentage of his colleagues numbers 1 and 4.

Table 2

RESULTS OF THE COMPARISON OF 8 RUNS WITH AND 8 RUNS WITHOUT BOW THRUSTER

Heading	Pilot Number	Without thr.		Without thr.	
		West	East	West	East
IN	1	x	0	x	x
	2	0	0	0	0
OUT	3	x	x	x	0
	4	x	0	0	0
Number of good runs		1	3	2	3

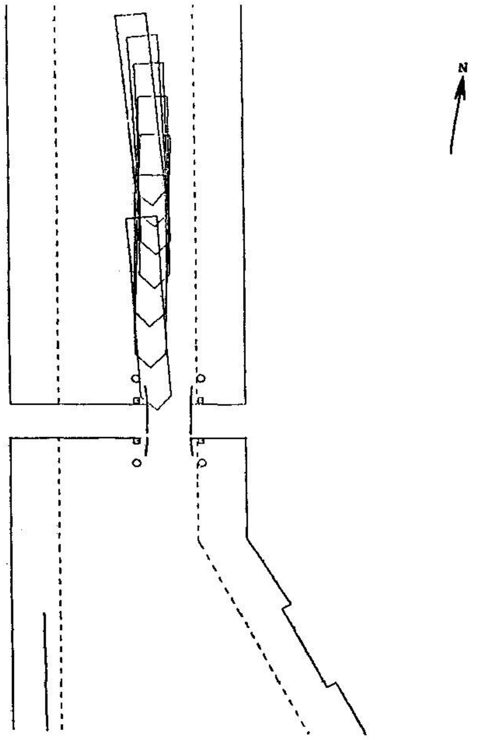
0 = no contact
x = contact at lateral speed 0.5 knots (refer to remark Table 1).

Table 3

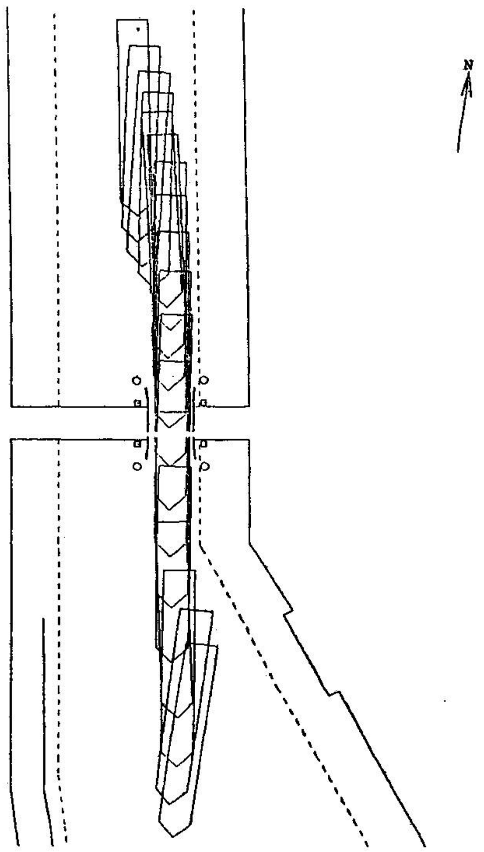
RESULT PER PILOT

Pilot Number	Total Runs	Contact with bridge protection			
		No contact		Light	Hard
1	19	6	32%	3	10
2	19	12	63%	3	4
3	15	7	47%	1	7
4	15	5	33%	3	7

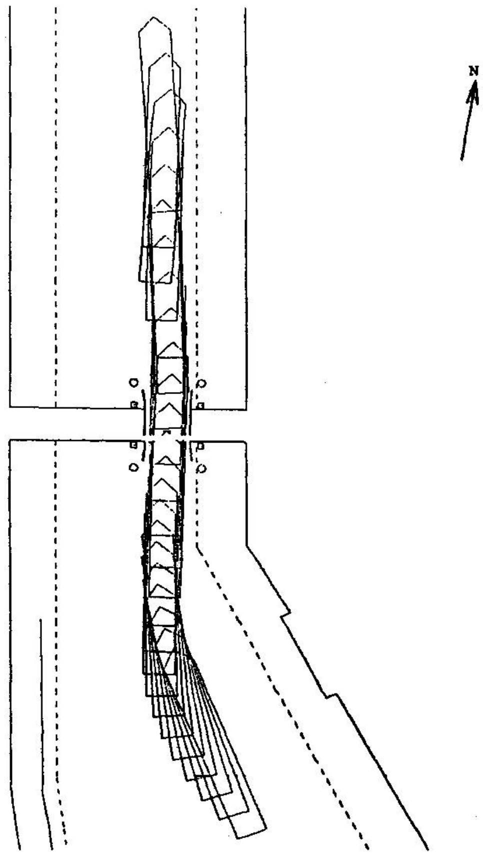
Remark: Refer to Table 1.



CALANDBRUG
Run: 1008 Time: 16.11 Date: 11-Apr-82 Plotted every 30 S
Wind: 5 Bft Wind direction: West



CALANDBRUG
Run: 7001 Time: 13.30 Date: 14-May-82 Plotted every 30 S
Wind: 7 Bft Wind direction: West



CALANDBRUG
Run: 7002 Time: 13.47 Date: 14-May-82 Plotted every 30 S
Wind: 7 Bft Wind direction: West

Table 2, which shows the results of the eight runs at Bft 6, with bow thruster confirms this.
Pilot No. 2 makes all four runs without contact, against No. 3 only one.
Comparing the eight runs made with the bow thruster with the eight runs without, the former showed better results, but not dramatically. The extra four runs, added at the end of the experiment were made in Bft 7 with bow thruster and tug masters using their own judgement without waiting for pilot's orders. These runs were remarkable successfully; only one light contact.
This improved result may be attributed to:

1. co-incidence
2. division of the task between pilot and tug masters
3. bow thruster
4. learning effects during the experiment

or a combination of these.

8. CONCLUSIONS

From the overall results of the study and the simulator tests it can be concluded that sailing through the bridge in somewhat stronger beam winds may be possible, provided the following conditions are met:

1. Change of existing sailing habits
2. Selection of a limited number of pilots with special skills in fast manoeuvring
3. Training of this group.

These three conditions are not easily fulfilled. It is not easy, especially for the older pilots to change their routine. Neither is it easy to convince mariners that the skills of one are of a different nature than those of others, although this can be proven by tests on simulators.
Besides, assigning special jobs to selected pilots requires adjustments in their roster, which may be a cause of discussion.
The third condition, training of the selected few is a matter of spending a relatively small amount of money on simulator training and a good deal of effort to convince pilots that their skills can be upgraded by training. But with a positive approach by management and staff, without doubt, good results can be reached. Still a bridge will always remain a bottle neck in a channel and, thus an obstruction to navigation. Nevertheless the Port of Rotterdam set-up a special working group of solving the described problem up to wind force 7 to 8 Bft. The results are not yet known at the moment of the printing of this paper.