Computer assisted analysis of Aviles Port extension: hydraulic conditions, navigation and training of pilots
J.R. Iribarren & J.M. Montero

Port Research Program, CEPYC-CEDEX,
Antonio Lopez, 81. 28026 Madrid, Spain

Abstract

This paper describes the analysis of the design and operational conditions of Raices Quay Extension (Port of Aviles, Spain) using computer based methods. During the development of this project, wave climate and wave propagation conditions were defined, current field was compared before and after dredging the channel and ship entrance manoeuvres were reproduced in a real-time simulator. As a result of the study, nautical recommendations aimed for better operational conditions and safety were elaborated.

Introduction

The Port of Aviles is located in the North Coast of Spain, facing the Atlantic. It is an important fishing port but aluminum and iron ore, fertilizers, scrap metals and steel products are also relevant due to the local chemical and heavy industries. The port lies along a tidal entrance some 10 km long subject to a maximum tidal range of 4.50 m.

The entrance channel, 1500 m long and 8 m deep, is partially protected from the prevailing NW winter wind and waves, but the entrance approach is rather difficult during severe wave storms.

Raices Quay, one of the main quays of the port, is being extended 250 m in order to receive fully laden Panamax bulkcarriers. At the same time, the access channel and the manoeuvring area will be dredged to -9 m in order to permit the safe access of these ships.

This paper describes the analysis of the design and operational conditions of this new structure using computer based methods. The following
aspects were covered during the development of the project:

- Wave climate characteristics in the area
- Wave propagation towards the channel entrance
- Current field before and after dredging
- Real-time simulation of ship manoeuvres
- Training of local pilots operating with larger ships

Figure 1. General layout of the Port of Aviles

The results of such study are collected in a series of nautical recommendations aimed at improving operational conditions and safety. The application of a real-time simulator for the analysis of the new structures and the training phase of local pilots will be especially emphasized in the paper.

Ship dimensions

The design ship for the new quay is a Panamax 48000 DWT bulkcarrier. Table 1 shows the main dimensions of such a ship:
Table 1. Ship dimensions

<table>
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<th>Description of the entrance manoeuvre</th>
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<td>The entrance starts approximately 1 mile away from the channel entrance to the Northwest. The ship makes a Southeast course with engine dead slow, sailing some 5 knots. During this approach phase, the influence of following waves from the N or NW is predominant, hampering the steering control of the ship. Therefore, entering the narrow mouth of the channel, 160 m total width, becomes quite a difficult task.</td>
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<td>The second phase is the straight segment of the channel, where wave height decreases very quickly. The main difficulty here is to keep the track in a narrow channel, where the ship is subject to suction forces from the near banks. Moreover, because of the deep draught of the vessel, the manoeuvre must start with a water level at least 3 m above MLWL. This could mean two hours before high water for maximum tides, so stern current up to 30 cm/s will reduce control on the ship.</td>
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<td>A 75 degrees amplitude bend comes afterwards, so the ship's speed should be kept sufficiently low in the previous segment to allow a safe course change. Cross winds, either from the W (winter) or the NE (summer) impose an additional difficulty to the manoeuvre.</td>
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The final segment is a straight wider area (up to 400 m), were the ship is to be stopped in a limited length. Then it can be docked either bow in or out. If bow in, there might be problems to turn the ballasted ship out in heavy winds. If bow out, it will be necessary to turn the fully laden ship in the available space, with the help of four tugs (1700 HP, two 1200 HP and 700 HP) giving a total of 66 tons bollard pull.

Wave climate

Visual wave data from the NCDC (Ashville, North Carolina, USA) were used to define the wave climate in the area. The frequency for each direction was computed as well as the wave height distribution for each direction. Waverider buoy data measured in a near location were also available.

Two wave directions were considered for the simulations, because of the orientation of the coastline: North and Northwest. For each wave direction an associated wind direction was selected (NE and W). Afterwards, two weather conditions were defined: "normal" and "hard", corresponding to wave heights with 50% and 10% annual exceedance probability. Standard wind speeds were chosen linked to the wave conditions (3 and 20 knots). All in all, four different weather conditions were used during the simulations, combining wave directions with wind speeds.

Wave propagation

The wave conditions selected in the previous chapter were propagated from deep water towards the port and inside the channel using two numerical models (REFDIF10, CEPYC-CEDEX 1990 and MIKE21, DHI), in order to determine the wave characteristics in the approaching area.

Figure 4 shows the position of the wavefronts for waves from the North with a period T=14 s. Figure 5 shows the wave penetration coefficients obtained for the same wave condition. Wave heights and directions obtained using REFDIF10 and MIKE21 were used in further phases of the study.
Current field

Current velocities (speed and direction) were measured in the Port in five sections of the channel, namely the entrance, the first straight segment, the bend, the stopping area and the manoeuvring area. The measurements were taken in a 1.50 m tide from three hours before high water to three hours after it, in order to accurately define the entrance conditions.

In a second stage, the current was reproduced by means of MIKE21 model for a complete tide cycle in three different conditions: a) Present situation with 1.50 m tidal range (the situation in which the measurements were taken, for calibration and comparison purposes). b) Present situation with 4.00 m tidal range. c) After dredging the channel and manoeuvring area with 4.00 m tidal range (future operational conditions). Figure 6 shows the results of this model in the third case, two hours before high water. The use of this model permitted the assessment of the influence of the planned dredging in the current pattern.
Real-time simulation of the manoeuvre

The entrance manoeuvre was reproduced in CEPYC-CEDEX ship simulator. The simulations were performed by an experienced pilot using the bridge instruments (radar, gyro compass, rate-of-turn indicator, Doppler log, rudder indicator, engine rpm indicator, wind speed and direction indicator and echo sounder) as well as an outside view 100 degrees horizontal amplitude.

A total of 50 different manoeuvres were performed, concentrating in the entrance of a fully laden ship in bad weather conditions. Most of the runs were aimed at docking bow out, thus requiring the ship to turn in front of the new quay. Nevertheless, some "bow in" manoeuvres were also simulated, altogether with the corresponding departure manoeuvres (ballasted ship).

During the test runs it appeared that the approach to the channel in following waves was the most critical phase of the manoeuvre. It is impossible to use tugs there, so the ship must use its own power to steer towards the channel under the drift and yaw forces of waves. At the same time, the speed must be kept sufficiently low while making the turn in order to enter the channel with reasonable safety. Two different approach routes were tested (from the West and from the Northwest) with the aim of keeping the ship exactly in the direction of waves, thus reducing the drift forces to a minimum.

Figure 7. Bridge mock-up of CEPYC-CEDEX simulator

The speed along the channel is also an important parameter: If too much power is used in the approach, the ship will come into the channel quite fast (more than 5.5 knots). The bank suction forces will then be very high and therefore difficult to counteract. Moreover, the bend will be hard to negotiate if too much speed is used. On some of the simulations, trials were made to stop the engine or even give astern, in order to reduce speed in the straight
segment. This is always a risk, because of the possibility of loosing control of the ship or even having a black-out in the engine, but it seemed rather useful in most cases.

The stopping distance was found acceptable for such large ships if the bend is passed properly. The last part of the bend showed to be a difficult point as well, especially in cross NE wind, so the passage should be planned and controlled from the very beginning.

The ship could be turned in the available area using the tug formation mentioned above. In general, one of the tugs could be removed, with the only result of slightly slowing the turn, but it is more safe to keep four tugboats available in case anything unforeseen happens. Two different strategies were tested for the turn, namely dragging the ship backwards to the quay after turning in the center wide area of the basin and pivoting the ship around its bow just in front of the berth. The latter was much faster, but there is a greater risk of grounding in the Southern limit of the manoeuvring area.

**Training of local pilots**

Three out of four local pilots from the Port of Aviles visited CEPYC-CEDEX for several days in order to familiarize with the conditions in the new Raices Extension Quay. They were given a presentation including a description of the simulator, the new quay and the ship and a detailed analysis of the simulator runs performed by a neutral pilot.

They had the opportunity to discuss the results of the simulations done so far and analyze the alternative strategies proposed, comparing them with their present performance. Finally, they came to the bridge and were able to sail the new larger ship themselves in their "future" home port.

Several lessons were learned during these sessions: First of all, the simulator and the model were extremely realistic to them, and they felt quite close to reality in most aspects, including stress and fatigue. Moreover, some details of the model could be corrected thanks to their cooperation, making the model more accurate (special wind effects, visual references, selection of paramount parameters, etc.). The initial strategy was compared with their usual way of sailing and some alternative actions were proposed. And, of course, they acquired a lot of experience in the future conditions in a compressed time schedule, handling a larger ship than those calling the port nowadays.

**Conclusions**

The development of this study permitted a more accurate assessment of the quality of the project itself, because it involved a more complete evaluation of
all factors involved. The use of numerical models such as wave propagation and current models gives very detailed information about the hydraulic conditions of the site, both in present and future situations. Nevertheless, the connection with reality should never be forgotten, so field measurements are unavoidable as the basis for further analysis.

The use of a ship manoeuvring simulator has demonstrated to have several outstanding advantages: An interactive real-time model is used, so perception and human behaviour factors can be included in the study; Pilots and captains play an important role in the design process, so both parts (port engineers and mariners) can elaborate a more complete overview of the problems; The results are more precise than those obtained using rules of thumb and more specific conditions (weather, current, waves, tugs, etc.) can be analyzed; Accurate entrance rules for specific ports can be developed based on the results of the simulation, concerning environmental conditions. Downtime can then be evaluated; Risk analysis for the manoeuvres is possible using statistical methods developed for this purpose.

The main feature of a port extension study performed using a simulator is the interactive process between men, the ship and the environment. The second big advantage is the cooperation between port engineers on one side and pilots or captains on the other. High quality, economical and efficient projects can then be developed.

It is the aim of CEPYC-CEDEX and the Port Authority of Aviles to carry out a verification of the model results monitoring the real tracks of ships along the channel. These field measurements will not only permit a more realistic calibration of the models used but also estimate the operational conditions of the Port more accordingly.

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