A NEW ACCESS CHANNEL AND TURNING BASIN FOR THE PORT OF LOMÉ (TOGO) - FROM DESIGN GUIDELINES TO SIMULATOR TRAINING

Un nouveau chenal d’accès et bassin d’évitage pour le port de Lomé (Togo) – Des directives de conception à l’entrainement sur simulateur

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ABSTRACT

The development of a new, state-of-the-art container terminal in the port of Lomé (Togo) introduces large-scale transshipment to West Africa, along with the requirement of the capability to receive container ships with a capacity of up to 14,000 TEU. A new dock of about 1,000 m by 200 m has been constructed. On behalf of Lomé Container Terminal and for account of the Togolese State and the Port Autonome de Lomé (PAL), the Maritime Technology Division of Ghent University and Flanders Hydraulics Research have been asked by Terminal Investment Limited to determine the main dimensions and layout of a new approach channel and the required characteristics of assisting tugs, and to formulate recommendations on navigational aids for safe and smooth operations. The paper gives an overview of the contributions of Ghent University and Flanders Hydraulics Research to the project, starting from the design phase by using guidelines and real time manoeuvring simulations to training sessions for the Togolese pilots. In a first phase of the project, the approach channel (width, depth and bend radius) and the turning basin (diameter and depth) in the port were determined by means of a selection of concept and detailed design guidelines and calculation methods. Real time simulations have been carried out in a second and a third phase of the project by Flemish coastal pilots who are experienced with Ultra Large Container Vessels (ULCVs) calling at the port of Zeebrugge. These were witnessed and validated by the seniormost Togolese pilots who attended the final real time simulations. As a result of the study, recommendations were formulated about characteristics of the approach channel, the turning basin and the dock. Additionally, procedures about the use of tugs, recommended speed ranges and helpful navigational aids were proposed. After the study three training campaigns were organized for the Togolese pilots in Flanders which consisted of a simulator training and a practical part in which they accompanied the Flemish pilots during their work on ULCVs on the Belgian coast.

KEY WORDS

channel design, port accessibility

RESUME

Un terminal de conteneurs ultra moderne est construit dans le port de Lomé (Togo) et introduit le transbordement à grande échelle pour l’Afrique de l’Ouest. Un nouveau bassin (environ 1,000 m x 200 m) est construit et donne accès aux porte-conteneurs de 14,000 TEU. Pour le compte de la République Togolaise et du Port Autonome de Lomé (PAL), par l’intermédiaire de Lomé Container Terminal, Terminal Investment Limited a fait appel à la Division de Technologie Maritime de l’Université de Gand et au Laboratoire de Recherches Hydrauliques flamand afin de déterminer les dimensions principales et l’agencement d’un nouveau chenal d’accès, de déterminer les besoins en terme d’assistance et de remorquage des navires et de formuler des recommandations relatives à l’aide à la navigation permettant d’assurer le bon déroulement et la sécurité des opérations. Cet article présente un résumé de la collaboration de l’Université de
MOTS-CLEFS
conception d’un chenal d’accès, accessibilité d’un port

1 INTRODUCTION

The development of a new, state-of-the-art container terminal in the port of Lomé (capital of Togo) introduces large-scale transshipment to West Africa, along with the requirement of the capability to receive container ships with a capacity of up to 14,000 TEU. A new dock of about 1,000 m by 200 m has been constructed. Figure 1 shows Togo in the world, the port of Lomé before expansion and the port during expansion (Google Earth images).

In a first phase of the project, the approach channel and the turning basin in the port were determined by means of a selection of concept and detailed design guidelines and calculation methods. A real time simulator with a (2D) bird’s eye view was used in the second phase to evaluate the output of the concept design phase. Full mission bridge simulations making use of a virtual 3D environment were performed in the third phase of the project.

After the study three training campaigns were organized for the Togolese pilots in Flanders. Each campaign consisted of two days of simulator training, while the other days the Togolese pilots observed their Flemish colleagues during their work on ULCVs. A simplified simulator with a 2D bird’s eye view simulation environment has also been installed in Togo and can be used as a training tool by the local pilots.

The paper gives an overview of the contributions of the Maritime Technology Division of Ghent University and Flanders Hydraulics Research to the project from an early design phase to the start of the operations at the terminal.
2 DESIGN PARAMETERS

In this section a general overview is given about the design parameters and the boundary conditions of the project.

At the start of the study it was clear that the new dock and terminals would be developed in the western part of the harbour, see Figure 1. The width of the dock, the location and the dimensions of the turning basin and the characteristics of the access channel were subject of the study.

A map with a partial survey of the bathymetry was provided by the client. The depth in the channel and the port had to be defined. A simple water level analysis was made based on a measurement campaign in the period from 18/07/2013 to 13/09/2013 in Lomé and showed that in that period the water level was never below -50 cm ZP (local reference) and always below +150 cm ZP. In about 90% of time the water level was between -10 cm ZP and +120 cm ZP.

A wind distribution of the observed wind speeds between 1959 and 1998 in Lomé indicated that the vast majority of the observations, blowing from SSW and SW direction, does not exceed 14.15 m/s (= 27.4 knots, 7 Beaufort). For a wind speed of 14.15 m/s the probability of exceedance is 0.44 %. For a wind speed of 11.15 m/s (6 Beaufort) the probability of exceedance is 1.22 %.

The waves predominantly come from S and SW. A significant wave height of 3 m is rarely exceeded. Based on previous studies made available, waves coming from 165 degrees and 195 degrees have a significant wave height of 3.02 m and 3.45 m respectively with a return period of 0.1 and 1 years. Likewise, a significant wave height of 2.75 m has a probability of exceedance of 2.16 % and a significant wave height of 3.25 m has a probability of exceedance of 0.63 %.

The current runs from west to east and, based on the information initially available, the speed could reach values up to 0.8 m/s.

A pipeline is located east of the port and has an orientation of 330° clockwise from north. Because of safety reasons, a minimal distance had to be guaranteed between an ultra large container vessel and the pipeline.

A 14,000 TEU container vessel, type MSC Beatrice, was used as a design vessel. It has a length overall of 366 m, a beam of 51.3 m and a design draft of 14.5 m (summer draft of 15.6 m).

Tugs are of importance during the in- and outbound manoeuvres. The two strongest tugs (both of the conventional type) available in the harbour were built in 1985 and 2010 and have a maximal bollard pull of about 25 tons and 65 tons, respectively. The required tug assistance had to be studied as well.

3 PHASE 1: DESKTOP STUDY

In a first phase of the project, the approach channel (width, depth and bend radius) and the turning basin (diameter and depth) in the port were determined by means of a selection of concept and detailed design guidelines and calculation methods.

3.1 Design parameters

The centre line of the access channel was supposed to be located at a distance of at least 200 m from the pipeline. Both the pipeline and the outer section had the same orientation. It was proposed that the vessels use an access channel which consists of a straight outer section, a bend and a straight port entrance section, as shown in Figure 2. The outer section runs parallel to the pipeline at an angle of 330.3°. The port entrance section runs parallel to the original southern breakwater at an angle of 275.2°. The bend therefore has an angle of 55.1°.
3.2 Determining dimensions of access channel, turning basin and dock

3.2.1 Channel characteristics

Different scenarios have been calculated based on the recommendations of ROM [ROM, 2003], PIANC [PIANC WG49, 2011] and Japanese [Ohtsu, 2006] channel design guidelines. The first recommends a bend radius between 5 and 10 times the design vessel whereas PIANC advices, with an under keel clearance of 20 %, a turning radius of 7 times the length of the vessel. The smaller the bend radius the longer the port entrance section.

According to ROM guidelines concerning vessel speeds which can be used for defining channel width and depth, it was decided to use vessel speeds of 11 knots and 7 knots in the calculations for the outer section and the port entrance section, respectively. The channel is developed for one-way traffic. In Table 1 an overview is given of the recommended water depth and width of the access channel. A distinction is made between the outer section (OS) and the inner section (IS). For calculating the water depth, heel due to wind was taken into account. Table 1 illustrates that the results of the diverse concept design methods are very divergent and sometimes contradictory. Especially the required water depth suggested by the PIANC concept design method appears to be very conservative.

Table 1: Overview of the recommended depth and width in outer section (OS) and inner section (IS)

<table>
<thead>
<tr>
<th>Water depth (h)</th>
<th>Width (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[h/T] [m]</td>
</tr>
<tr>
<td>OS</td>
<td>IS</td>
</tr>
<tr>
<td>PIANC (concept design)</td>
<td>1.28</td>
</tr>
<tr>
<td>ROM (for Hs = 3 m)</td>
<td>1.18</td>
</tr>
<tr>
<td>Japan</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2: Example of an approach scenario with bend radius equal to 7 times the ship’s length
3.2.2 Turning basin

A first estimation of the dimensions of a turning basin was made based on recommendations of the US Army Corps of Engineers [US Army Corps of Engineers, 2008]. The minimal diameter of the turning basin should be at least 20% larger than the length overall of the design vessel.

3.2.3 Required dock width

According to ROM, the minimal width should be 291 m for a dock with only mooring vessels at one side. Additionally, a desktop simulation with wind and moored vessels carried out by FHR showed that a width of 250 m could be feasible.

3.3 Tug assistance and aids of navigation

The desktop simulation also resulted in a first estimation of the required tug assistance during port manoeuvres. The results of the calculations and simulations have been discussed with expert pilots of the Flemish Pilotage (DABL), who also provided recommendations with regard to the required aids of navigation. Buoys and leading lights were proposed accordingly.

3.4 Results of phase 1

Based on guidelines and recommendations in combination with an expert input of Flemish pilots it was proposed to study three scenarios in the second phase. A distinction was made between a scenario with a bend with radius 5 and 7 times the ship’s length. In a third scenario the ship could turn in a basin located outside the port, followed by entering astern with tug assistance.

It was proposed to start Phase 2 with a channel depth over draught ratio of 1.2, a channel width of 200 m, a turning basin with a diameter of 1.2L (440 m) inside the harbour or 1.5L (550 m) outside. The dock width of 250 m was recommended and had to be validated under various environmental conditions and the number and the power of the tugs had to be checked as well. Additionally recommendations were given about lighted leading lines at the centreline of the straight sections in the channel and the dock, completed with locations of buoys.

4 PHASE 2: BIRD’S EYE VIEW SIMULATION

A real time simulator with a (2D) bird’s eye view (see Figure 3) was used in the second phase to evaluate the output of the concept design phase.

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**Figure 3:** Basic simulator with bird’s eye view
4.1 Simulations

4.1.1 Input

As a design vessel from the simulator database, a container carrier with a length over all of 381 m and a breadth of 51.6 m was considered at drafts of 13.1 and 15.5 m. Simulator ship models at FHR are available for under keel clearances between 20% and 100% of the draft.

It was preferred to swing in the harbour, since this area is more protected in comparison to the sea so that only simulations with the turning basin in the harbour were performed. A decision of the client to guarantee a distance of 500 m between the pipeline and the fairway, which is generally observed in the maritime world, resulted in bend radii which were significantly smaller than the proposed radii of phase 1. A layout with a port entrance (PE) section of 1,000 m and a section of 1,300 m were implemented. The bend radius of scenario PE1000 equals 3.93L and for scenario PE1300 this was only 2.36L. In contrast to the proposal during phase 1 to simulate with a channel width of 200 m, the channel width was set to 250 m in phase 2. It was foreseen to navigate with under keel clearances of 20% which resulted in two different channel depths due to the differences in draft. A uniform current profile was applied during the simulations from southwest to northeast, with a current velocity of 0.6, 1.0 or 1.4 knots. South and southwesterly winds of Beaufort 4 and 6 have been tested and ASD tugs with a maximal bollard pull of 65 tons were made available.

4.1.2 Execution

Simulations were executed by Flemish coastal pilots who are experienced with Ultra Large Container Vessels (ULCV) calling at the port of Zeebrugge (Belgium). The combination of their experience in a similar environment with the output of the simulations data led to an adjustment of the results of the first design phase.

4.1.3 Analysis

Both inbound and outbound manoeuvres have been investigated. The analysis of the simulation runs was based on plots of the trajectory of the ship, an analysis of kinematical (velocities) and control (engine/propeller, rudder, bow thruster) parameters, an analysis of tug assistance, and graphs with time dependence of run parameters. All this was completed with feedback by the pilots. The tug assistance was evaluated based on histograms for the thrust.

4.2 Results of phase 2

The shorter the port entrance section, the larger the bend radius which makes manoeuvring in the bend more comfortable. The longer the port entrance section, the longer the time to line up which makes the preparing for stopping and swinging easier.

The simulations have clearly shown that both examined bend radii of 2.36 L and 3.93 L (with L = 366 m) give turning manoeuvres at 20% under keel clearance that are taken safely and smoothly with moderate rudder action and propeller rate. Based on all the trajectory plots it was observed that widening of the bend was necessary. It could also be concluded that controlling the speed in the access channel is very important. Using the relation

\[ \text{rot}_{\text{rpm}} = \frac{3}{\pi} \frac{1}{R_{\text{mile}}} V_{\text{ks}} \approx \frac{V_{\text{ks}}}{R_{\text{mile}}} \]  

(1)

between the vessel’s speed \( V \), the radius \( R \) of the bend and the rate of turn (\text{rot}) during the manoeuvre seemed also very helpful. In (1) the rate of turn is expressed in degrees per minute, the speed in knots and the radius in mile.

The required water depth has been re-calculated using the ROM guidelines but with the values calculated by the seakeeping software Seaway to account for the maximum wave response. The resulting vertical motions of the design vessel appeared to be larger than when estimated with the ROM guidelines. The recommended depth to draft ratio in the outer section, the bend and the port entrance section was 1.22, 1.22 and 1.19, respectively, yielding water depths of 19.0 m, 19.0 m and 18.4 m, respectively, for a draft of
15.5 m. However, a reduction to a gross under keel clearance of 20% or a depth of 18.6 m could be justified, taking account of the severe wave conditions (i.e. with a significant wave height of 3 m), the other operational issues related to the wave induced motions (pilot tender, tugs) and the margins included in the calculation method. For these sections the assumption of a 20% under keel clearance can be justified.

5 PHASE 3: REAL TIME SIMULATION ON A FULL MISSION SIMULATOR

5.1 Simulations

Full mission bridge simulations making use of a virtual 3D environment were performed in the third phase of the project (Figure 4).

In comparison with the layout of phase 2, some adaptations were implemented: e.g. the width of the bend in the access channel was widened from 250 m to 300 m, the width between the breakwaters was reduced to about 210 m and the port entrance section and the bend radius were both set to 1,150 m. A turning basin was created with a depth of 17.8 m and a diameter of 500 m (1.36 L). Because the southern side of the dock would not be developed in the short term, it was decided to simulate with and without moored vessels (breadth 51.3 m) on the northern quay. If a vessel was moored it had to be passed.

Most of the runs were executed by Flemish coastal pilots, in the presence of a delegation of Togolese pilots who also participated in the simulations for validation and initial training purposes. In comparison with the second phase, the number of runs with wind force 6 was reduced because of the very small probability of exceedance of this wind condition.

Figure 4: Left: simulations with Togolese en Flemish pilots at FHR; Right: 3D-visuals of the environment

5.2 Results of phase 3

The third phase resulted in final recommendations concerning layout and dimensions of the access channel and the turning basin, navigational aids and tug assistance. Recommended procedures (e.g. speeds, rate of turn values) were formulated as well.

For the inbound manoeuvre, the passing of the current line (see Figure 5) and the entering of the 180 m wide (full depth) dock astern by passing a moored vessel could be seen as the most difficult parts of the manoeuvre. Simulations showed that these kind of manoeuvres are feasible but at least two ASD tugs with a bollard pull of 65 tons are required. To be able to cross the current line in a safe way, the assistance of a pulling aft tug is strongly recommended before the ship crosses the current line. Because of the drop of the current the yawing moment to port resulted very often in a lateral deviation of the ship towards the southern breakwater. It was advised to reduce the speed of the vessel by using the aft tug. A reduced speed gives the possibility to give a kick ahead if necessary. The speed of the vessel at different points was analysed and advices in terms of speed ranges at the start of the bend, at the end of the bend and at the current line were formulated. For an outbound manoeuvre it was recommended to hold the speed below a certain value because of the presence of bank effects while leaving the dock.
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It was also advised to move the proposed turning basin about 50 m to the west and to widen the dock if ships with a beam of 51 m have to pass each other. This could be solved by changing the southern slope to create more space for the tugs. At least one ‘non-conventional tug’ is necessary to assist in pulling mode at the stern of the vessel in the access channel. The use of a portable pilot unit (PPU) can be seen as a very helpful tool for the pilot to get more accurate details about the ship’s position and motion.

5.3 Additional simulation scenarios

In addition two additional “intermediate” scenarios were also studied and verified through full mission bridge simulations. These scenarios were intended to verify the impact of an intermediate layout of the basin where a temporary constructive bund at the dock entrance restricted the basin width. These scenarios took into account different vessel lengths, based on the existing vessel call sizes and reduced waterdepths with the intention to better define the operational limits during the constructive phase of the development of the terminal.

In addition, Svašek Hydraulics studied the sediment transport along the coastline and its impact on the development of the Lomé Container Terminal, see [Les, 2013]. One of the objectives of that study was the investigation of the currents and more specific the predictability of currents in the harbour entrance and approach channel. It was concluded that the current velocities along the coastline for Togo are driven by ocean currents (up to 0.2 m/s), tidal currents (around 0.1 and 0.2 m/s) and longshore currents induced by wave breaking (0.7 m/s to 1.0 m/s). The current runs from west to east. Svašek Hydraulics calculated current profiles with significant wave heights of 1.0 m, 1.3 m and 1.8 m. The original simplified uniform current profiles have been replaced by the calculated profiles in the simulator.

6 TRAINING

After the study three training campaigns were organized for the Togolese pilots in Flanders. Each campaign consisted of two days of simulator training, while the other days the Togolese pilots accompanied their Flemish colleagues during their work on ULCVs on the Belgian coast. During the simulator trainings Flemish pilots demonstrated and assisted the Togolese pilots.

Later, a simplified desktop simulator with a 2D bird’s eye view simulation environment (see Figure 6) has been installed in Togo which can be used as a training tool by the local pilots.
Figure 6: Desktop simulator installed in Togo, used for training purposes

7 CONCLUSIONS

A new dock of about 1,000 m by 200 m accommodates a new state-of-the-art container terminal in the port of Lomé. On behalf of Lomé Container Terminal and for account of the Togolese State and the Port Autonome de Lomé (PAL), the Maritime Technology Division of Ghent University and Flanders Hydraulics Research have been asked by Terminal Investment Limited to determine the main dimensions and layout of a new approach channel and the required characteristics of assisting tugs, and to formulate recommendations on navigational aids for safe and smooth operations.

In the first phase of the study the approach channel and the turning basin in the port were determined by means of a selection of concept and detailed design guidelines and calculation methods. Different scenarios have been proposed which could be used as an input for the second phase. In this phase real time manoeuvring simulations have been carried out by Flemish coastal pilots in a two dimensional simulation environment. The design of the access channel was modified and different approach channels with a difference in bend radius were verified. Full mission bridge simulations making use of a virtual 3D environment were performed in the third phase of the project by Flemish coastal pilots.

For the accessibility of the port it can be concluded that the success or failure of a manoeuvre is strongly connected to the speed and the rate of turn in the bend of the channel. Additionally the way of anticipating for passing the current line is of importance. Controlling these parameters can be done with the assistance of a pulling tug and can be simplified by using a portable pilot unit (PPU). At least three tugs with a maximal bollard pull of 65 tons should be available in the port to be able to welcome ultra large container vessels under most prevailing conditions. Advices about navigational aids like buoys and leading lights were formulated as well.

Both guidelines and real time simulations are used in a complementary way. Guidelines and recommendations can be used for the design of a channel, a turning basin or a dock. By using real time simulations these dimensions can be verified and advices about navigational aids, tug requirements and speed recommendations can be formulated. Simulations with experienced pilots in combination with the analysis of recorded parameters result in advices about a design.
8 REFERENCES

Inros Lackner AG (2010), Wave study for the new dock in the port of Lomé - Final version


