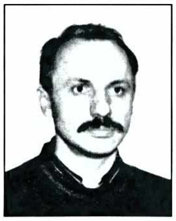

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Application of shiphandling simulation to harbour and waterway design

Part II*

SUMMARY

The paper describes the problem of aiding the harbour layout design through computer simulation of ship motion. The key aspect of this support relies on treatment of the ship and the commanding pilot as a stochastic sensor testing the given harbour layout under varying environmental conditions. The role and effectiveness of the ship motion simulation in the harbour design are discussed in reference to other existing harbour design support methods.

The paper presents an example of the simulation experiment which was used for the selection of the harbour layout during planning of the expansion of Port of Callao, Peru. Such example may be used as a pattern for nautical analyses with the application of shiphandling simulation technology. The paper also evaluates the degree of fulfilment of the simulation objectives and points out the areas for further research.

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AN EXAMPLE OF REALIZATION OF A SIMULATION EXPERIMENT FOR THE HARBOUR LAYOUT ASSESSMENT

The simulation analysis used to assess the layout of a part of the Port of Callao (Peru), conducted by the author in 1997 at Yusen Marine Science Inc. (YMS), Tokyo, is presented. This example may serve as a pattern for organizing and conducting such analyses as relatively few information sources in this respect are available [12].

The planned expansion of the Port of Callao comprised construction of the grain terminal and adjacent container terminal. The analysis of the requirements for the new terminals, prepared by civil engineers who considered the layout from the view point of land operations and construction related issues, led to the formulation of three versions of the harbour layout project. The designers were interested in the nautical evaluation of the proposed solutions, expecting it to be an additional criterion in the rational selection of the ultimate design.

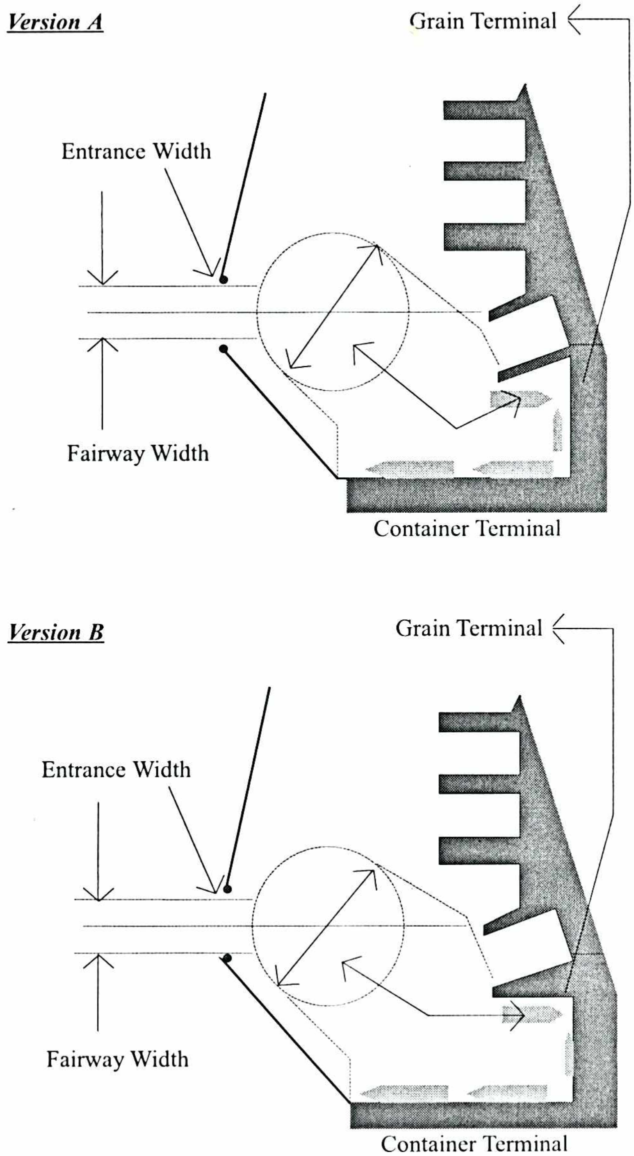


***Fig.6.** Two studied versions of the layout fragment of the Port of Callao*

The proposed design versions differred in the distance between the quays of the grain and container terminals as well as the relative orientation of these quays. Two of the designs differred only in the distance between the grain and container quays, so they were considered as belonging to the same class of solutions ; ultimately the design with the smaller distance between the quays was chosen for further simulation studies as the representative of the solution class. Fig.6 shows the two studied versions of the designed harbour layout. It indicates the manoeuvring problems and harbour parameters requiring studies.

The principal design questions asked by harbour designers and the ones formulated during the analysis and simulation experiment were as follows :

- ➢ Is the width of the harbour approach fairwater sufficient for the dimensioning ships ?
- ➢ Is the width of the harbour entrance sufficient ?
- ➢ Is the size of the turning basin-located inside the harbour-sufficient for stopping and turning manoeuvres of a ship ?
- ➢ Is the location of the designed quays relatively to each other and to the approach axis acceptable from the nautical viewpoint ?
- ➢ Are the powering, type and number of the tugs planned for servicing the dimensioning ships sufficient ?
- ➢ Is the existing system of the navigation aids (buoys, leading marks, harbour control tower) sufficient ?

The realization of the conducted analysis was divided into the following stages (also shown in Fig.7) :

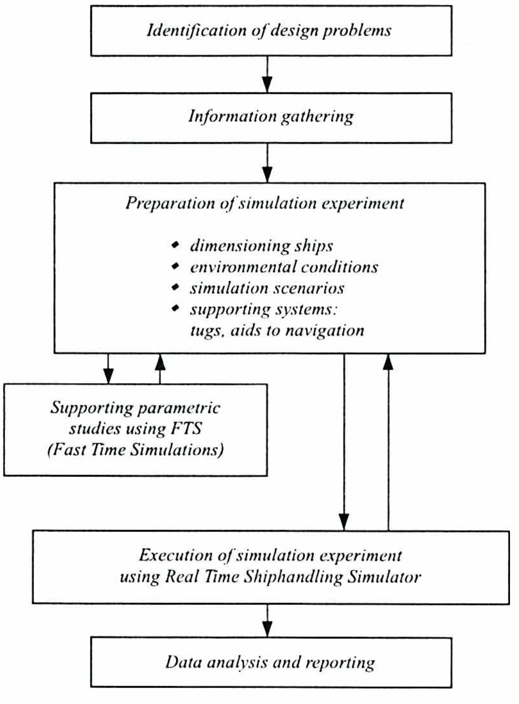


Fig. 7. The flowchart of the nautical analysis performed during the Callao Project

Stage 1
Gathering information about the project

The designers supplied the following data :

- ✓ data about wave breakers and quays, actual data about the harbour approach fairway
- ✓ information about the project, significant from the viewpoint of nautical operations, for example, the number and size of quays, alignment of ships at quays
- ✓ the design harbour layouts to be studied
- ✓ size and types of ships planned to service the designed quays.

The analysts studied the local conditions, particularly the following :

- ⇨ temporal and spatial distributions of the wind
- ⇨ wave distributions outside the harbour
- ⇨ distributions of sea currents and tides
- ⇨ depths
- ⇨ conditions of moving the ship into and out of the harbour
- ⇨ availability of tugs and methods of their work.

During a site visit the analysts collected or verified the following information :

- piloting procedures
- the influence of visibility changes on the piloting procedures
- conditions of moving the ship into and out of the harbour
- availability of tugs and methods of their work
- communication procedures between the pilot and the tug operators or operators of the harbour traffic control tower
- visual scenery; a number of the photos required for modelling of simulator 3D graphics were taken.

Stage 2
Preparation of the simulation experiment

The dimensioning ships were selected according to the design data provided by harbour planners, as follows :

- ✶ Bulk carrier (of about 70 000 DWT, Lpp = 240 m)
- ✶ Post-Panamax container carrier (of about 6000 TEU capacity, Lpp = 300 m)
- ✶ Panamax container carrier (of about 3000 TEU capacity, Lpp = 247 m).

The smaller container ship was incorporated into the study on the request of a customer. However, the Post-Panamax ship was the main dimensioning ship for the container terminal, planned for such ships. The mathematical models of each of the dimensioning ships were prepared and tested by using proprietary databases.

Hydro-meteorological conditions for the experiments was selected by using the collected data. The wind force of 10% of the strongest winds occurring in the region, as well as the strongest recorded sea currents flowing across the harbour approach fairway were assumed. Islands protect the harbour approach area, so moderate waves only were used in this study.

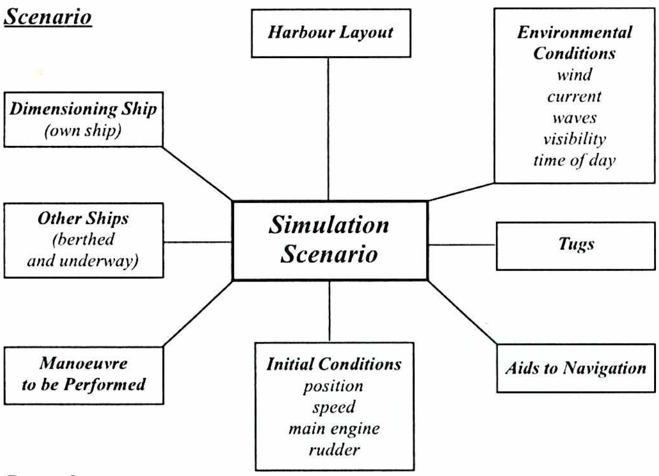
It was established that the entrance manoeuvres of such large ships were to be performed at daytime only. Moreover the analysts decided that some experiments would be conducted at a restricted visibility as fog may rapidly cover the Callao area.

The simulation studies by means of an autopilot-controlled simulator FTS (Fast-Time Simulation) were used to evaluate the influence of wind and currents on the required width of the harbour approach fairway for the ships sailing with different speeds. The same method was used to study the size of the area required for stopping the ship by tugs and main engine operations. The preliminary assessment of the tug powering required for turning the ships in the turning basin and for lateral moving the ships into the quay proximity during berthing manoeuvres was performed by using the FTS as well.

Next, the analyst team prepared a set of scenarios for the experiments to be conducted on the visual real-time shiphandling simulator. In an exemplary experiment scenario the following parameters were specified :

- the harbour layout
- the hydro-meteorological conditions: wind speed and direction, current distribution, waves, visibility, time of the day
- the presence of other ships outside the harbour and at the quays
- the dimensioning ship
- the set of tugs
- the manoeuvre to be executed (entrance or departure), the starting and final destination points
- the initial conditions of the simulation : position, velocities, main engine and rudder settings.

The analysts provided for more harbour entrance manoeuvres as such manoeuvres are inherently less safe due to the increased influence of hydro-meteorological factors acting on a ship slowly moving within a restricted fairway. Reducing the ship's speed and ultimate stopping the ship within a limited area inside the harbour was also necessary. The nautical analysis and discussion of the proposed harbour layout designs indicated that more problems were to be expected during the bulk carrier entrance manoeuvres to the harbour characterized by the non-parallel placement of the grain and container quays. Therefore the analysts provided for more experiments on this layout to investigate the hypothesis and acquire objective data for supporting or rejecting it. The analysts assumed that all quays-except one where the manoeuvring ship had to berth-would be occupied. Such situation constrains the area available for the manoeuvring ship and represents the most unfavourable (statically) nautical condition inside the harbour.



Procedures

- the way of informing the pilot about the **objectives and the conditions** of planned simulation run
- the way of **debriefing and commenting the results** of a simulation run
- the **criteria of terminating** a simulation run
- the **method of analysis and presentation** of preliminary results of the simula-tions

Fig.8. Preparation of simulation experiment

The analyst team prepared two sets of tugs : the first set modelled the tugs presently available at Callao, and the second set composed of stronger tugs having their power determined during the experiment preparations. They expected that the existing set of tugs would be insufficient for safe support of the pilot, therefore they prepared means for improving such situation.

The analysts prepared the experiment realization procedures, namely :

- the way of informing the pilot about the objectives and conditions of the planned simulation run
- the way of debriefing and commenting its results
- the criteria of terminating the simulation run
- the method of analysis and presentation of its preliminary results.

They also prepared the information materials for all participants of the simulation experiment. The preparation process of the simulation experiment is shown in Fig.8.

Stage 3
Conducting of the simulation experiment by using a visual real-time shiphandling simulator

The objective of the experiment was to select a safer design from the layouts submitted for the evaluation. The customers also expected comments regarding such nautical aspects as navigation aids, tug powering, qualification level of pilots and tug masters.

The simulation analysis was ordered by a civil engineering construction company which carried out the design and the construction work on behalf and under supervision of the Peruvian Government. Representatives of the following bodies participated in the simulation experiment :

- Peruvian Ministry of Transport
- The administration of Port of Callao
- The technical branch of the harbour construction and service in Peru
- The company carrying out the design and construction of the new terminals at Port of Callao.

The chief pilot of Port of Callao was that performing the manoeuvres. The quartermaster, main engine telegraph operator and tug operator were YMS employees. The person responsible for the analysis and the experiment (i.e. the author) observed progress of the experiment on the simulator bridge.

After familiarizing with the simulation run scenario the pilot planned the execution of the manoeuvres according to his judgement. The simulation run was executed after a short preparation. When the run terminated its results were printed, sometimes parts of the simulation were replayed, and the analyst conducting the experiment asked the pilot about comments regarding the just executed manoeuvres. During the experiments the analysts observed the following quantities :

- ship positions, trajectories together with their swept paths, headings
- ship velocities (linear and angular)
- helm commands and the way and circumstances of using them
- main engine commands and the way and circumstances of using them
- applied power, the way and circumstances of using the tugs
- the distances to the navigation area limits
- the distances to other ships berthed in the harbour.

To aid the analysis the analysts introduced a set of control lines crossing the navigation area where the ship manoeuvred. The control lines were placed on the harbour approach fairway, at the harbour entrance, at the turning basin entrance and exit, and at the head of the grain quay - as shown in Fig.9. The analysts determined the distributions of the observed quantities on the control lines. Each pair of neighbouring control lines marked the boundaries of a navigation area segment. The analysts chose the location of navigation area segments, being guided by the expected stationary control strategy to be used by the pilot, so to be able to analyze the observed manoeuvring quantities in a uniform way. The control strategies adopted for the analyses of the experiment results were: keeping the course and trajectory, stopping, turning and berthing the ship.

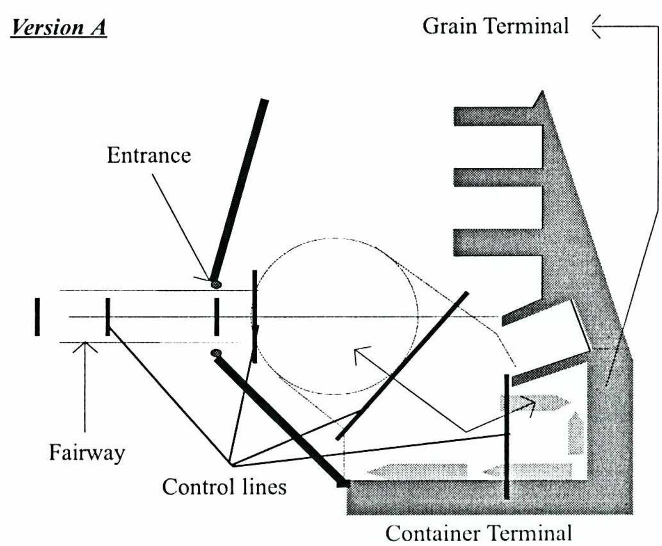


Fig.9. Localization of control lines within the navigation area

Stage 4
Analysis of the data and results of simulation experiments; presentation of findings of the study

After executing the experiment the analysts performed the preliminary analysis of its results. They presented the analysis and its preliminary findings to the participants of the experiment. During the presentation the participants asked additional questions and formulated the problems which were to be addressed during the complete analysis of the simulation experiment results.

Following the complete analysis, the analysts wrote the final report which was subsequently presented to the customers. For the presentation the analyst team also prepared the videotape which showed selected fragments of the experiment illustrating the key findings and conclusions. The video record was generated with the use of the simulator's graphics system, and subsequently supplemented by visualizing data and comments to facilitate the information transfer.

The analysts studied all data collected during the simulation experiment runs to discover regularities and draw conclusions based on these observations, namely :

- *The required widths of the approach fairway and harbour entrance* - corresponding to various probability levels of crossing the navigation area boundaries. They were evaluated by using the distributions of the swept path at the control lines placed on the approach fairway and within the fairway segments.
- *The evaluation of the execution of the control strategies within various segments of the approach fairway and in harbour entrance proximity.* It was carried out by using the distributions of the ship heading and deviation of the ship position from the fairway axis, being functions of the distance from the harbour entrance.
- *The area occupied by ships during stopping inside the harbour.* It was analyzed by using the area location and size, considering the amount of the energy used for stopping (represented by control commands for the output power of tugs and ship's main engine and the distances from quays and other berthed ships. The ship turning manoeuvres performed in the turning basin were similarly evaluated.
- *The sequences of transferring the bulk carrier from the turning basin to the grain quay.* They were analyzed by using the heading angles of the manoeuvre phases, velocities during the phases, distances from quays and berthed ships, tug usage and time of manoeuvring.
- *Adequacy of the tug power and navigation aiding system within the harbour.* It was analyzed by using the time of berthing to and unberthing from quays with the tug assistance, as well as the time required for turning the ships with tugs; during the turning the area required for the manoeuvre was also analyzed.

The analyses led to the following conclusions :

- The harbour layout in which the grain quay is parallel to the container terminal quays is preferable from the point of view of the nautical operations.
- The area of the planned turning basin is sufficient for stopping and turning the dimensioning ships.
- 100 m width of the harbour approach fairway is sufficient for one-way traffic.
- Widening the harbour entrance is not required because an improvement of the accuracy in guiding the ship along the fairwater axis while approaching the harbour entrance was observed during the experiments.
- Manoeuvring of large ships requires using more powerful and manoeuvrable tugs than those currently present at the harbour. (This suggestion cannot be basically justified without data provided by the simulation experiment).
- The present navigation aiding system is sufficient.

Additional comments resulting from the observations were as follows :

- It is desirable to train pilots and tug masters before commencing the service of ships comparable in size to the dimensioning ships used during the experiments.
- As the harbour is used both for military and civil purposes the traffic control of all ship movements is an important factor resulted from the limitations of manoeuvrability of large vessels recognized by traffic controllers.

The customers appreciated the conducted study and the participants of the simulation highly valued the fact of co-operating in its accomplishment.

The example of the Callao study contains a set of preparation actions, procedures and assessments which may be used as the basis for developing simulation patterns to be applied in aiding future harbour designs.

THE DEGREE OF ACCOMPLISHING THE OBJECTIVES OF SIMULATION ANALYSES

Judging the existing experience from the simulation use for harbour designing one may state that the properly organized process of a simulation experiment and analysis can meet the expectations of the customer ordering such analysis. This may help the designers to decide to use such a tool for solving a specific harbour design problem.

The following simulation analysis aspects support the above presented statement :

Simulations may be used in early and late phases of the design process to answer critical questions, even those arising in the course of the analysis being performed. The use of the simulations in the early phases of the harbour layout design may be particularly beneficial. The simulation analyses can also be applied to reviewing existing designs [7 to 9, 13 to 15].

The pilots participating in the real-time simulations accept their course and results. Moreover it is possible to create the environment and models which reflect the conditions of the pilot's work onboard a real ship. Therefore during interpretation of the simulation results less attention may be paid to the potential errors caused by conducting experiments in a model environment.

The simulation techniques make it possible to systematically and methodically study complex harbour layout problems, environmental conditions and harbour operation factors in a uniform and integrated manner [6,9 to 11]. The way of presenting the results of the simulation - particularly the real-time simulations - is visual; this is specially valuable for the persons participating in the design process.

The simulation process - in particular the simulation experiment - - improves communication among various participants of the decision-making and design processes. During the simulation process one may bring together various interest and lobbying groups to give them the opportunity of exchanging opinions and views. In effect, such optimization of the decision-making process may lead to the final formulation of the acceptable design solutions.

AREAS REQUIRING FURTHER RESEARCH AND DEVELOPMENT

Simulation analyses are often left out for the following reasons :

- Cost-and time-consuming preparations
- The lack of confidence in the simulation results
- The lack of awareness of suitability of such analyses in harbour design.

Therefore the results of application of a simulation method should be published together with its cost-profit analysis. Also, research efforts orientated at reducing the cost of preparation and conducting such analyses should be undertaken [1].

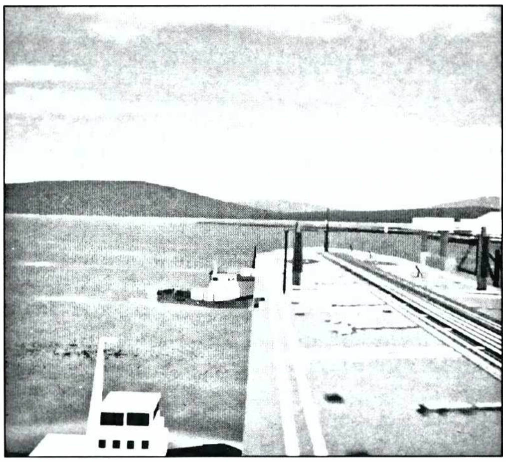
In particular there is a lack of agreement or common opinion among the groups of harbour designers and simulation analysts in the following subjects (although a very valuable research is reported in [11]) :

- Specification which particular simulation techniques should be used for a given class of design problems.
- Insufficiency of accurate mathematical models of ship motion in the case of harbour manoeuvres; therefore such models and methods of their verification should be developed.
- Lack of standard and objective methods of interpretation of the results of simulation experiments.
- Lack of a guidance regarding the required number of simulation experiments to be conducted for attaining the objectives of the experiment and analysis.
- Lack of indications which parameters should be selected for a given experiment to make interpretation of its results correct and answering the design problems indisputably.

Appraised by Bolesław Mazurkiewicz, Prof.,D.Sc.

BIBLIOGRAPHY

1. Webster W.C., Editor : „Shiphandling Simulation - Application to Waterway Design". National Academy Press.1992
2. „Approach Channels - A Guide for Design"; Final Report for the Joint PIANC-IAPH Working Group II-30 in cooperation with IMPA and IALA. Supplement to Bulletin No. 95, June 1997
3. „Port Development - A Handbook for Planners in Developing Countries" 2nd Ed. Prepared by the secretariat of UNCTAD. United Nations, New York,1985
4. Drown D.D., Lowry I.J.: „A Categorisation and Evaluation System for Computer Based Ship Operation Training Simulators". Proceedings of MARSIM'93. St.John's, Canada,1993
5. Iribarren J.R., Montero J.M.: „Port Engineering Research Using A Manoeuvring Simulator". Proceedings of MARSIM'93. St.John's, Canada,1993
6. Nakamura S., et al.: „Procedures to Assess Manoeuvring Safety of Ships in Harbors". Proceedings of MARSIM'93. St.John's, Canada,1993
7. Woolnough E.W., Tasker R.L.: „Upgrading a Port Facility: How a Shiphandling Simulator Was Used to Determine the Requirements". Proceedings of MARSIM'93. St.John's, Canada,1993
8. Iribarren J.R., et al.: „Safety Analysis for the Port of Barcelona (flammable product basin) Using a Real Time Manoeuvring Simulator". Proceedings of MARSIM'96. Copenhagen, Denmark,1996
9. Laforce E., Vantorre M.: „Experimental Determination and Modelling of Restricted Water Effects on Bulkcarriers". Proceedings of MARSIM'96. Copenhagen, Denmark,1996
10. In Young Gong, et al.: „Development of Harbor Capability Assessment Simulation System by the Application of Fuzzy Algorithms". Proceedings of MARSIM'96. Copenhagen, Denmark,1996
11. Iribarren J.R.: „Determining the Horizontal Dimensions of Ship Manoeuvring Areas--General Recommendations and Simulator Studies". PIANC Publication. January 1999
12. Misiąg W.A.: „Shiphandling Simulations Applied for Nautical Analysis of Port of Callao Expansion Design". Proceedings of the Conference HYDRONAV'99--MANOEUVRING'99. Ostróda, Poland,1999
13. Hajduk J.: „The Analysis of Ships Manoeuvring Simulation Results at the Port of Gdańsk". Proceedings of the Conference HYDRONAV'99-MANOEUVRING'99. Ostróda, Poland,1999
14. Galor W.: „Selected Problems of High Speed Craft in Polish Ports". Proceedings of the Conference HYDRONAV'99-MANOEUVRING'99. Ostróda, Poland,1999
15. Gucma S.: „Ship's Manoeuvring Water Region - Methods of Determination". Proceedings of the Conference „MANOEUVRABILITY'95". Iława, Poland,1995



Forward view from port wing

Miscellanea

Technical University of Gdańsk
Marine Civil Engineering

Harbour engineering takes an important place in maritime economy and technology.

Technical University of Gdańsk, more precisely, the Department of Marine Civil Engineering, Faculty of Hydro and Environmental Engineering, educates specialists of the specialty.

Apart from the didactic activity the Department's staff, headed by Prof. Bolesław Mazurkiewicz, carries out extensive scientific research in the following main areas :

- problems of research, design, modernization and reconstruction of harbour hydrotechnic structures
- layout planning problems of the ports and port regions together with determining factors decisive of their correct technical exploitation
- design and construction problems of shipyard hydrotechnic facilities together with testing the existing structures and elaboration of modernizing projects (slipways, dry docks, hoists, lifts)
- problems of determining demands and solutions of the mooring and resilience facilities in ports and shipyards together with testing their performance and loads
- problems of research on and calculation of interaction of the mooring systems of the deep-sea platforms and floating objects (e.g. mooring-loading buoys)
- special problems dealing with sea-bed pipelines, a.o. research on hydrodynamic loads and stability of pipelines
- sea-shore protection problems together with research on effectiveness of various protection systems
- problems of investigation of demands and design of the dredging works in the areas of harbour and entrance waterways as well as those concerning mining of sea-bed resources
- testing and neutralization problems of the dredge winning as well as port and sea-bed sediments
- experimental and theoretical determination of the mechanical properties, stability and sedimentation of the solid wastes in the storage areas
- application of the kinematic element method to geomechanics with taking into account possible solving of 2D and 3D problems of slope stability, active and passive earth pressure as well as load-carrying capacity of the foundations placed in the vicinity of the slopes.

The scientific activity of the Department's staff also manifests it self in the co-operation with some foreign scientific institutions such as :

- Hannower University (Germany)
- Sankt Petersburg State Technical University (Russia)
- State Building Engineering and Architecture Academy of Odessa (the Ukraine)
- Maritime University of Odessa (the Ukraine).