TRANSNAV
http://www.transnav.eu
the International Journal
on Marine Navigation
and Safety of Sea Transportation
Volume 11
Number 3
September 2017
DOI: 10.12716/1001.11.03.03

Analysis of the Existing Parameters of the Ports Entrances in the World in Terms of Their Design

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ABSTRACT: This article aims to analyse the statistical parameters of waterways forming the entrance to the port and the construction of a model for determining the optimum parameters of the entrance to the port. It has been analyzed parameters of the entrances to the 100 selected global ports, based on the analysis it was examined the interdependence between certain parameters and the impact they have on the maximum size of the ship which can enter to the port. This analysis allowed to develop a model, which can possible to be applied to the entrance of initial port design.

1 INTRODUCTION

In designing of the entrance to the port a number of factors, which are sometimes mutually exclusive, e.g. the best access to the port, obtain through wider entrance, can cause that the entering wave will interfere with the operations which are being carried out in the port, should be taken into account. To ensure convenient navigation, harbour entrance should be situated from the direction of the open sea and should be as wide as possible. On the other hand, the narrower and more protected entrance is, the less wave energy and sediment carried by the wave from the seabed, which enter the port basin. It results in the achievement of more favourable conditions in the inner port. Additionally, according to PIANC guidelines, "*the width of the harbour entrance should be equal to or wider than the length overall (LOA) of the design ship to prevent the possibility of it becoming stranded across the entrance in the case of an incident*" [8]. Taking into account all these factors it is needed to find a compromise solution in which a balance is achieved [6].

It is recommended that the arrangement of entrance to the port is set up in such a way that ships entering the port have the prevailing wind from the bow or stern. Wind and waves from the side of the vessel create difficult conditions for keeping the ship on her course during the critical phases of entering the harbour basin. Therefore such an entrance to the port, which would allow for the frequent occurrence of such a situation, should be avoided.

In most cases there is a need for some concessions (as mentioned above). Location of the entrance on the area of breaking waves should be avoided, because of the difficulties that can arise during the ship's manoeuvres. The entrance to the port should be situated on the side from which the waving sea is the least frequent. In a situation when it is not possible to avoid the cross wind and wave, it is recommended to provide calm conditions at the entrance to the port by the extension of the windward breakwater outside the entrance area, at least the length equal to the maximum ship that can enter this port [4] .

The connection between selected parameters of entrances to the various ports in the world is

examined in this study. In addition the ports which can be entered by the vessels of length overall (LOA) minimum of 100m have been taken into account. The primary objective is to analyze the parameters of waterways forming the entrance to the port and the construction of the statistical model in order to determine the optimum dimensions of the entrance to the port in terms of the maximum size of vessel, which can enter the port.

The analysis developed a simple analytical model, which allows to determine the basic parameters of the entrance to the port, i.e. the width of the safe maneuvering area at the entrance to the port (d) in relation to the width of the entrance (D) and the maximum length of the ship, maximum draft of the ship (T) to available depth at the entrance to the port. It was also examined whether there is a correlation between the type of entrance to the harbour (arrangement of the breakwaters) and the type of water area by which the port is located.

Data analysis was performed using the simplest tools of linear regression in order to enhance its usefulness. Despite of the classification of ports, operating conditions vary widely. They also differ in the method of design aids to navigation and local regulations. All these factors cause significant variations in the parameters of the water ways. However, such comparisons have not been found in the literature and may be taken as a general guideline for the initial design of parameters of the waterway. The aim of this study is to create an initial empirical-statistical method (more simplified than PIANC or ROM), which application will be possible in the initial, often economic, analysis of the project.

2 DIVISION OF ENTRANCES

When designing the port entrance general layout of the port must be taken into account. Additional terms are the relations between the port entrance with the remaining infrastructure (breakwaters, quays, areas of depth, etc.), maneuvering areas (fairways, anchorage, etc.) as well as the design of the elements forming the entrance to the port. In addition following conditions must be considered [3], [4], [6], [5]:

- the expected traffic density, maximum ships that can be handled in the port;
- ensuring adequate water circulation between the port area and the open sea to prevent contamination of water in the port basin;
- reducing the height and the energy of wave entering the port;
- minimize downtime ships appearing on the entrance to the port, due to the conditions prevailing in the area (e.g. the strong currents, tides), and adopted the shape of the entrance to the harbor (breakwaters at the entrance);
- dynamic shore regime, because the construction of any artificial transverse structures occurring from the shore into the sea, introduces disorder into the team factors that create this regime. Every transverse obstacle creates accumulate on their windward side and increased erosion on its leeward side. The impact of the regime on the port includes: sanding of port entrance or dangerous undercutting of the construction of the port. The arrangement of breakwaters shall be designed in such a manner, that the cost of dredging the entrance to maintain proper depth is as low as possible;
- any subsequent in port development and limitations to the entrance arrangement used in this subject, which can occur.

Typical breakwaters systems forming the entrance to the port and their functions are presented in the Fig. 1. Type No. 1 shows a system of breakwaters used in the case of a large sector of waves and a small sedimentation caused by the wave. The entrance is protected by a vast outer breakwater to provide good conditions for ship maneuvering. Type No. 2 presents the arrangement of breakwaters used in case of strong waves from a single-sector. Type No. 3 shows the layout of breakwaters used in the case of a large sector of waves and significant transport of sediment from the seabed. The equalization of the external breakwater is made to minimize vortices and consequent deposition of transported sediment in the inner basin. The inner breakwater is necessary to protect the area of the port. This is a potential area of sedimentation and erosion. Type No.4 presents the harbor protected by a separate island breakwater. Type No. 5 shows the arrangement of breakwaters ensuring the protection of the entrance to the port located at the bay or estuary, keeping the navigable channel and providing appropriate conditions for maneuvering.

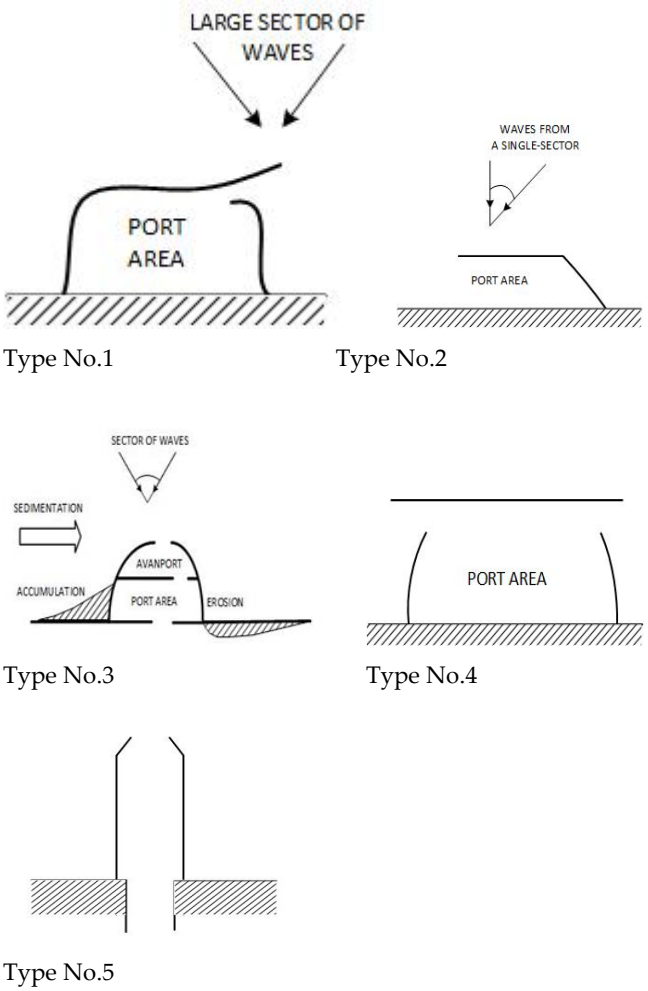

Figure 1. Typical breakwaters systems.

3 THE MODEL FOR DETERMINING THE OPTIMUM PARAMETERS OF THE ENTRANCE TO THE PORT

To carry out the analysis of entrance parameters the database of 100 selected ports was created. The basic criterion for the selection of the port was a system of breakwaters forming the entrance according to the division described in Chapter 1. Next criterion is the location of the port, which is apportioned as follows:
- ocean - the ocean and the open sea,
- closed area - Mediterranean sea,
- area partially open - coastal sea and located between islands,
- bays.

The study does not take into account the natural harbors, which entrances are not protected by the breakwaters.

For analyzing of the entrance parameters following elements were checked:
- d - the width of safe maneuvering area at the entrance,
- D –the width of entry measured between the breakwaters forming the entrance [m],
- h - the depth in the entrance measured during HW.

There have also been taken into account the maximum size of the ship, which may enter the port, specified by the port regulations:
- B - breadth of the ship [m],
- T - draft of the ship [m].

All data are summarized in the Tab. 1, an excerpt of which is shown below.

4 ANALYSIS OF THE DATA COLLECTED

The parameters used for the statistical analysis were taken based on data obtained from the navigation paper charts, electronic charts (ECDIS), navigation charts database available on www.navionics.com, database of ports on the www.findaport.com and the publication "Guide to Port Entry". Fig. 2 presents the example of the port of Rio Grande do Sul and the method of sizing the entrance to the port.

Tab. 2 shows a percentage breakdown of the entrance, depending on the location of the port. There is no significant connection between the type and the location of the port.

Table 2.Percentage breakdown of entrance depending on the location of the port.

TYPELOCATION	Area Partially Open	Closed Area	Ocean	Bay
1	25%	28%	25%	17%
2	15%	16%	25%	21%
3	30%	25%	13%	16%
4	15%	19%	4%	29%
5	15%	12%	33%	17%

Figure 2. The method of sizing of the entrance to the port.

Analysis of width of the maneuvering area at the port entrance (d) depending on the width of the entrance (D) is shown in the Fig. 2 and the Pearson's correlation coefficient is 0.6, which means a high correlation. Coefficient of determination is 36%.

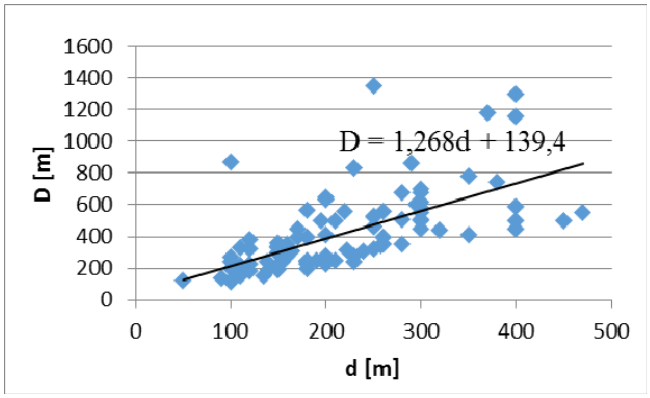

Figure 3. Analysis of width of the maneuvering area at the port entrance (d) depending on the width of the entrance (D).

The Pearson's correlation coefficient between the width of the maneuvering area at the entrance to the port (d) and the breadth of the vessel (B) is 0.3 and this is a positive correlation. Coefficient of determination is 9%.Analysis is shown in the Fig. 4.

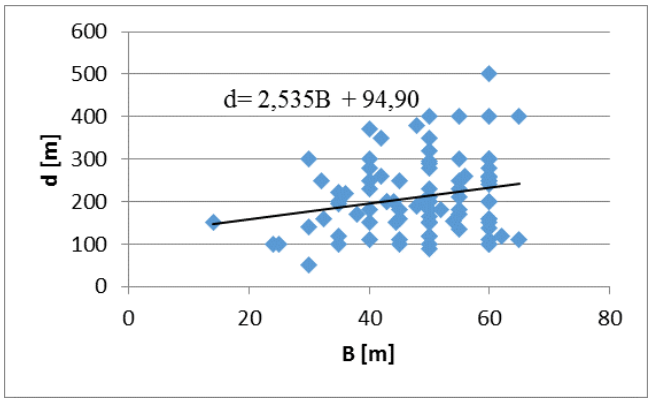

Figure 4. Analysis of the width of the maneuvering area at the entrance to the port (d) depending on the breadth of the vessel (B)

Table 1. Database of 100 selected ports.

PORT	COUNTRY	TYPE	D [m]	D [m]	h [m]	LOCATION	B [m]	T [m]
Acajutla	Salvador	2	200	630	15.5	Ocean	43	15
Alexandria	Egypt	1	200	410	12.8	Closed Area	43	12
Algeciras	Spain	4	300	500	30	Bay	60	22.6
Algier	Algeria	4	110	180	22	Closed Area	60	10.5
Annaba	Algeria	2	190	250	14.1	Area Partially Open	48	12.5
Ashdod	Israel	2	250	1350	17.1	Closed Area	45	15.5
Barcelona	Spain	1	250	530	21.1	Closed Area	60	16.0
Bari	Italy	3	210	250	14.9	Area Partially Open	55	13

The Pearson's correlation coefficient between the depth of the entrance (h) and the draft of the vessel (T) is 0.7 and this is a positive correlation. Coefficient of determination is 49%. Analysis is shown in the Fig. 5.

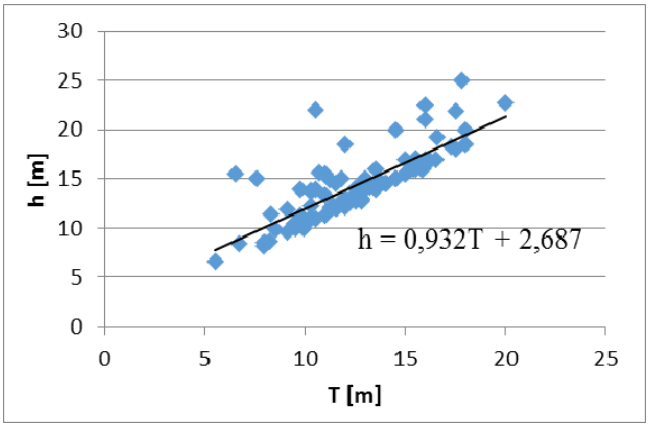

Figure 5. Analysis of the depth of the entrance (h) depending on draft of the vessel (T) .

4.1 *Using of method to determine the optimal parameters of the entrance to the port*

Created on the results of conducted statistical analysis on a sample of 100 global ports, it is possible to specify the method for determining the basic parameters of the port entrance on the stage of preliminary design. The actual parametres of the entrance are compared to the sample port with the parameters recommended using the developed method. It was assumed that the width of the entrance (D) and depth (h) are fixed in relation to the calculated value of the remaining parameters.

Tab. 3 shows the comparison of actual and recommended parameters of the entrance to the port of Rio Grande do Sul.

Table 3.Comparison of actual and recommended parametres of the entrance to the port of Rio Grande do Sul

	D [m]	d [m]	h [m]	B [m]	T [m]
Actual parameters	560	260	13	60	12.8
Recommended parameters	453	247	14.7	60	12.8

5 CONCLUSIONS

The aim of the study was the construction, analysis and verification of the model for determining the optimum parameters of the waterway at entrance to the port and its application to the initial design. Aim of the study was achieved by examining the relations between the various parameters which contributes to the entrance to the port. It has been found that there is no connections between the type of the entrance and the location of the port. While the dimensions of the entrance to the port have a significant impact on the maximum dimensions of a ship, that is, the wider and deeper entrance is, the bigger ship can enter the port. It also takes into account the connection between the actual width of the entrance to the port and the width of maneuvering area at the entrance. It has been also observed that these two values increase proportionally, i. e. if the entrance is wider then maneuvering area is also greater.

Based on the results of the statistical analysis conducted on a sample of 100 global ports, it is possible to specify the method for determining the basic parameters of the port entrance on the stage of preliminary design.

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