CHAPTER 4 WAVE CALMNESS STUDY

4.1 Introduction and Planning Concepts

4.1.1 Planning Concepts

This chapter deals with necessary information related the wave calmness condition of the proposed terminal. Using the study results of this chapter, Chapter 2 presented the general layout of terminal. This chapter thus deals with the verification of navigational safety and with the workability of the terminals.

The study is rather limited to the South Port, since the feasibility study is undertaken for the Barge Terminal and Grain Terminal.

4.1.2 Study Layout

Among two terminals, the barge terminal can be installed within the present layout under minimum modification. It locates at the western end of South Port. While the new grain terminal should be built in the newly reclaimed pier at the South Pier No.3. This pier locates the far-east basin of the South closing with the port entrance. Thus, wave calmness at the front basin of the new terminal should be the item to be verified. Wave calmness along the south channel also be checked accordingly.

Original South Pier S3 is planned by MOT as a rectangle of 260 m width by 500 m length. Its area is approximately 13.0 ha which is sufficient for two units of two million ton grain terminal. Thus, the first choice for new grain terminal is the use of the original layout (Alternative L220), even though it is formulated with only partial boundary quay wall.

Note: Construction of a quay wall structure planned 1260m long (500 m + 500 m + 260 m). However it was suspended when a subsection of 860m quay wall (500 m + 260 m + 100 m) was completed

Other than this MOT original layout, the master plan proposed Alternative L400 providing a wide slip development scheme between the S2 and S3. This new arrangement aims at providing ship maneuvering space enough for the large ocean-going vessels including Panamax type of 65,000tons. Taking these two different schemes, the study team prepared the grain terminal development alternative.There are two alternatives: namely,

Alternative L220 Alternative L400 The former alternative is MOT's original layout for S3 which has 220 m width slip and 260m section generating 13 ha area of reclaimed land. The latter alternative is a modified layout with a 400m width of slip with 80m land section. Alternative L220 can be constructed at ten % lower cost than Alternative L400 since it makes full utilization of the suspended quay wall construction.

Refer to Figure 4.1.1A.L220 for the Alternative L220. Refer to Figure 4.1.1.B.L400 for the Alternative L400.

Advantage of Plan L400 is to provide an enough space to the safety maundering of the large ocean-going vessels. Advantage of Plan220 is the construction economy, or ten % less cost than those of L400.

Plan L400 has another technical privilege that it can built its silo bins on the good soil condition area. According to the elevation data of bearing stratum of earth, the Pier S3 locates the worse location. Elevation of the stratum (Limestone) is generally observed –35m or deeper. While the southern part of this pier rests on the shallow limestone layer, -25m or higher. Shallow hard stratum generally means better condition due to lower possibility of existence of soft layers which may be cause the settlement.

This indicates there were old valley under the Piers, S1, S2 and S3. It is reported that the canal was excavated on the soft layers such as old submerged valley. Thus this submerged valley is continuing from the canal entrance towards the east to offshore site. It is also reported that heavy structures at the S1 were affected by irregular settlement due to soil consolidation under the heavy weight.

As seen in PART III Chapter 2, Alternative L400 was finally selected for the area of new grain terminal.

4.1.3 Simulation

As shown in Section 4.3, a separate wave calmness simulation study has been conducted. This study focuses on the wave condition analysis in accordance with wave calmness. Refer to Appendix IIIA, which indicates wave intensity at an observation point.

Wave calmness at an observation point varies with the wave characteristics and the protection works like a breakwater. In order to estimate wave penetration into berthing areas, possible breakwater alignments were given as alternative aspects, to be constructed at the South.



Figure 4.1.1.A General Layout of South Channel and Terminals: Alternative L220



Figure 4.1.1.B General Layout of South Channel and Terminals: Alternative L400

4.2 Navigation Safety and Consideration

This section deals with a supplemental discussion of the navigational safety of the proposed terminals in the south. Conclusion on this aspects was provided in Chapter 2 evaluating study results of this chapter.

4.2.1 Channel Alignment

A navigation channel is defined as any stretch of waterway that links the berths of a port to the open sea. The channel would normally terminate at its inner end with a turning and/or port basin which allows the vessels space for stopping and turning maneuvers.

PIANC suggests that channel alignment should be assessed with regard to:

- (a) The shortest channel length,
- (b) Conditions/basins, etc. at either end of the channel,
- (c) The need to avoid obstacles or accretion areas which are difficult or expensive to remove or require excessive (and hence costly) maintenance dredging,
- (d) Prevailing winds, currents and waves,
- (e) Avoiding bends close to the port entrances,
- (f) The edge of the channel should be so shaped that ships passing along it do not cause disturbance or damage.

Straight channel legs are preferable to curved ones.

4.2.2 Width of South Channel

A ship navigating in the channel is affecting by (1) natural forces namely wavw, wind and current and (2) vessel traffics. One of important natural influence other than wavw is current forces.

A ship will generally not be able to navigate a channel in a position parallel to the channel axis or leading line. The forces acting on the ship, caused by cross currents and wind, would necessitate steering under a certain angle – the drift angle – in order to follow this leading line. This way a state of equilibrium is reached between the external momentum and forces, and those coming from resistance and rudder. It is so possible to determine this drift angle for varying circumstances by means of model tests.

In a confined water area it turns out that under the above-mentioned external conditions, the ship also needs a compensating rudder angle to keep on average on a straight course. Especially for channel-axis navigation when sailing under the crosscurrents action, relatively large rudder angles will need to correct and preclude a further drifting from the straight track.

When considering the traffic volume in 2010, the south channel could be planned as a one-way channel which might also manage the forecast number of calling vessels.

The channel width would depend on the size of the ships to be catered for and on the physical conditions of the site. Based on the research and experience so far, the required channel width seems to depend particularly on the environmental conditions. They cover such as crosscurrents and cross-current gradients (variation of these cross currents per unit length of channel), waves and swell, wind and visibility. The accuracy of information regarding the ship's position and the easy "readability" of this information by navigators are also decisive information.

One of the particular navigational conditions at the proposed terminal is mixed vessel traffics between the large ocean-going vessels in 65,000tons and the light barges in 2,000tons. It is estimated that there are four to five trips of barges calling the proposed grain terminal.

Basic alignment including the width of channel should be verified by these conditions, Refer to Chapter 2.

4.2.3 Depth of Approach Channel and Port Basin

Chapter 2 will provide with specific idea of channel dimension. This subsection deals with the basic consideration in the water depth under the fairway. It can be said that the existing water depth is mostly enough, thus there is no requirement of deepening the existing fairway.

The required under-keel clearance (UKC) and safety margins are schematically shown **Figure 4.2.1**.



Figure 4.2.1 Definition of Under-Keel Clearance

This figure is a simplification of the actual conditions.

Generally, the necessary UKC can be determined from the following factors:

- a. Draft,
- b. The resultant vertical movements of the vessel caused by the swell and waves, i.e. pitching, rolling and heaving,
- c. The tendency of nearly parallel sinking with a slight trim by the head that is in known as squat, which appears when sailing shallow waters,
- d. Tidal level and water density,
- e. Safety margin, the Net UKC, depends on bottom type, (muddy, sandy or rocky).

A simpler way to allow for squat, draft and sounding uncertainties (and also to give a margin for safety) is to set a minimum value on water/draft ratio. In many parts of the world a value of 1.10 has become accepted although a value of 1.15 can also be found.

Europe Maritime Pilot Association (EMPA) has made recommendation on the UKC of calling vessels at Rotterdam, Antwerp and Amsterdam as follows:

UKC at open sea passage	20% or more of the draft
UKC at off port fairway	15% or more of the draft
UKC at port inside	10% or more of the draft

Maximum draft of the largest vessel expected in 2010 is 12.4 meters by the grain carrier of 65,000tons. Therefore an appropriate UKC at the channel should be dredged to -13.6 m to keep 10 % of the draft. The existing water depth around the S34 pier site is deeper than -15m, thus actually no technical problems.

4.2.4 Turning Basin in the South Port

Immediately after the port entrance, the navigable width of the channel should be increased. Vessels usually have to go here for more complicated maneuvers than in the offshore approach channel.

The basic maneuver is turning the vessel and the space required to do this turn generally is a circle with a diameter of four times the ship's length where there is no assistance from tugs. Where some tugs assistance is available, a circle of half this size may be considered as adequate. These are only average figures whereas the actual required area will additionally depend on wind, wave and current conditions in any particular case.

The maximum Grain Bulk Carrier length as seen for the year 2010 is estimated as 254m and the vessels will be assisted by tugs. Therefore, the minimum diameter of turning basin would be 500m.

4.3 Wave Calmness Study

4.3.1 Introduction

One of the important aspects in the port planning is that all the vessels in the port should be provided with a good and protected maneuvering route and berthing place to have smooth cargo handling operation. The non-operating days (or down time), caused by heavy waves or whatever else, should be limited to low level. A modern port should have an annual down time of less than a week.

A longer down time than the acceptable at the Port of Constantza, would make the shipping companies and the operators face excess expenditures. A long down time might even affect the price of imports and exports or the decision of a foreign investor to open a new business in Romania or to redirect the investment to other ports.

4.3.2 Present Channel and Berthing Basin

The Constantza Port is well protected by the two breakwaters namely the North Breakwater and South Breakwater. A main channel runs along the North Breakwater. There is second channel leading to the South Port area, including South S1 Pier.

There is a connecting channel between the North and South areas used for barges.

When an ocean-going vessel calls at the Pier S1, it would move through the existing channel and would have to turn its head twice before arriving at Pier S1. When it runs along this direction, the waves might affect its ability to maneuver. Refer to Figure 4.3.1.

It is assumed that the cargo handling operation at the east side of Pier S2 will be affected by waves.

In case of a river barge, it mainly maneuvers within the so-called "River Basin ". Due to the wave problem, it will however have to go through the connecting channel up to the North Port area. This simply indicates that wave intensity in the port area under present conditions has some influence on vessel maneuvering.

Since this port is large with an area of almost 5000ha, one of its advantages is space for future development. Counter to this is accelerating the wave generation in the port basin due to existing long fetch distance.

It is also noted that the present channel alignment does not always meet the requirements for vessels calling at the South Port.





4.3.3 Purpose of Study

One of the port's important functions is to provide vessels with a safe and calm channel and basin system to maintain smooth vessel maneuvering.

The Short Term Development Plan includes two new terminals, namely, the Barge Terminal and the Grain Terminal. The purpose of the study is to quantitatively verify the physical schemes, as well as the wave occurrence probability that is over the Limit Wave Height.

In the event that the scheme does not meet with the international standards in terms of wave calmness, the plan should be modified so as to meet the requirements.

Thus final purpose of this study is:

- 1) To estimate Workability of the Terminals, by means of the estimation of down time
- 2) To know how the shape of breakwater affects down time

This study aims at verifying the planned North Breakwater Extension by MOT. Thus, this section does not intend in any means to undertake breakwaters design.

4.3.4 Simulation Method

The wave calmness simulation has been conducted by PCI as belonging to the Study Team in Japan under the following conditions:

- 1) Using Computers
- 2) Applying random wave action
- 3) Two step analysis, Preliminary and Final
- 4) Application : "offshore wave "

Combining of the two waves, namely "offshore wave " and " In-port wave2" was carried out by " Square Equal Method "

 $Ha^{2} = H1^{2} + H2^{2}$

Where;	Ha: Combined wave height	m
	H1: Incidental wave by off-shore wave	m
	H2: In-port generated wave	m

In-port wave has been estimated separately and combined.

4.3.5 Technical Criteria

It is required to estimate the Workability (or down time) of the Port under clear conditions. In order to meet the international level, the following criteria were used in the analysis:

- Workability : 97.5 % workable: or Nine days in down-time, 2.5% x 365 days = 9 days
- 2) Limiting Wave Height: As shown in Table 4.3.1.

Type of Vessel	Size (DWT)	Limiting Wave Height (cm)
Barge	3,000.	30
General cargo	15,000 or less	40
	25,000 or more	60
Container	20,000 or less	30
	30,000 or more	40
Bulk	60,000	50
	80,000	75
	100,000	100

Table 4.3.1 Limiting Wave Height by Type of Vessel

4.3.6 Input Data and Layouts to Simulation Analysis

(1) Winds

In the Port of Constantza area the predominant wind is a N to NE wind in the winter time. The maximum 10-minute-average wind is from NE and the velocity is 8.7 m/s. The second important wind is coming from North with a velocity of 8.5 m/s.

When looking at the shape of the port, the longest fetch is E and NNW. However, the maximum velocity is 6.7 m/s from E and 4.9 m/s from the NW.

(2) Waves

The wave list, which was used to develop the existing North Breakwater construction, is available and was applied to this study.

(3) Water Depth

The water depth is based on the latest chats and sounding maps. According to the comparison between latest chart and old chart, there is just minor change. This indicates the seabed is stabilized.

(4) **Port Shape**

The shape of port is based on the latest map as provided by CPA.

(5) **Future Port Shape**

The future port shape has been developed based on the proposed Master Plan of Constantza Port. The modification thereof was carried out as to follow the latest development as mentioned in the Short Term Development Plan.

However, there is not much difference from the present Port Layout, since the change means only some land reclamation for the Proposed New Grain Terminal at the South Port Pier S3.

It is scheduled to improve the existing barge terminal by provision of quay wall and dolphins, however these will not have much affect to the existing port layout.

(6) Alignment of Breakwaters

The port is well protected by the breakwater. The extension works are continuing to the final alignment of the North breakwater.

The influence breakwaters are the North Breakwater, South Breakwater and South Groin of the Artificial Island. After considering the characteristics of each breakwater, three alternative plans have been prepared.

PLAN 1Existing ConditionPLAN 2 to 4Alternative Plans

Refer to Figure 4.3.2, and Figures 4.3.2a, 4.3.2b, 4.3.2c, and 4.3.2.d.

Figure 4.3.2 is a drawing that shows all the related parts of the wave calmness study including breakwater. Possible combination of protection works will be among:

- 1) North Breakwater: One km extension.
- 2) South Breakwater: One km extension.
- 3) Removal of the Mid-island Groins

Considering these three items, three breakwater alignment alternatives were prepared to select the better layout.

- PLAN 2: North Breakwater: One km extension to south.
- PLAN 3: South Breakwater: One km extension to north.
- PLAN4: South Breakwater: One km extension to north and Removal of the Mid-island Groins.



Figure 4.3.2 Possible Breakwater Combination in Alternative Plans



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Figure 4.3.2b Alternative Plan 2



Figure 4.3.2c Alternative Plan 3



4.3.7 Calculation of Wave Height

It is essential matter to estimate the wave height at every related point of the port. First of all square grid-mesh diagram in 100m x 100m was provided to observe the change of wave height. The wave height estimation was carried out by the following methods:

(1) Estimation of Wave Occurrence in the Port

Whenever the calmness of a port is expressed by the high wave occurrence, the ratio of the height excess is estimated as follows:

- 1. Calculating wave occurrence outside the port;
- 2. Selecting the calculation location inside the port
- 3. Calculating the wave height ratio inside the port for incident waves
- 4. Calculating the wave height inside the port taking into account different incident wave heights;
- 5. Calculating the cumulative ratio of wave height excess;
- 1. Calculation of wave occurrence outside the port

The wave occurrence data outside the port, would preferably be based on the actual measurement of the last 5 years. In case that the measured data is not available, it is hind-cast. In case of the port of Constantza, the result of the wave hind-cast between 1993 and 1997 were used. The results list the wave height as estimated at the water depth of -18m offshore the port and it is considered to be the same as the wave conditions at the port entrance.

2. The location selection for the calculation inside the port

The locations where the wave height exceedence is calculated are namely six points: i.e. four points in the basins and two points in front of the berths of the new grain terminal.

3. The wave height ratio calculation inside the port for the incident waves.

In this study the numerical calculation model was used. In the calculation, the **Takayama Model** was used. This model is intended to calculate the height distribution of the irregular waves that have a direction spectrum inside the port. It can also simulate multiple reflection and as well a secondary diffraction inside the port.

The result is shown as expressing the wave height ratio for the incident waves. The wave height ratio distribution as bearing incident waves from different directions are shown in the figures.

4. Calculation of wave height inside the port with different incident wave heights

From the above-mentioned figures, the wave height ratio at the calculation points are obtained. Thereafter by multiplying the values in (1) with different direction and different heights, the wave height inside the port is obtained.

5. Calculation of accumulative ratio of the wave height exceedence

By combining the (1) and (5) values, the wave height exceedence curve by each direction was drawn. From the graph, the working accumulative ratio of wave height exceedence is summarized in the table.

(2) Calculation of wind-induced wave inside the port

Since the port area inside the breakwater is large, it is assumed that the waves induced by strong winds inside the port could be high.

In order to calculate the height of the wind-induced wave, **SMB** method is used. The SMB method is used when the wind field does not move. The deep-water significant wave height and periods are calculated from the wind speed and duration or fetch with the formula. The result of this calculation is then shown in the diagram as shown in **Annex**. The smaller numbers for wave height and period as obtained using duration or fetch, are used as the estimated number.

In this study, it is assumed that the duration of wind is long enough and that the wave height and period is calculated only by wind velocity and fetch.

Figure 4.3.3 shows six wave observation points. Figure 4.3.4 indicates the wave reflection coefficient taking the existing structure into account.







Figure 4.3.4 Wave Reflection Coefficient

4.3.8 Summary of Wave Calmness Study

In order to select the possible breakwater layout, four alternative plans were provided, namely Plan 1, Plan 2, Plan 3 and Plan 4. Among this Plan 1 indicates the present condition in 2001. Remaining three plans are future breakwater alternatives. Plan2 is the scheduled one by MOT by means of 1km extension of the North Breakwater.

Four wave observation points were traced on the particular points at the present South approach channel and two points were set along the existing wet basin in front of the quays where the cargo handling will be undertaking. Wave arriving at these points defers by the alternative plan. If a larger decreasing in wave intensity than present condition is observed and if it is within acceptable annual downtime, such alternative is one of the possible layouts.

The downtime indicates the annual non-operational days of vessels at berth. It is proposed to set up this of 2.5% or less of 365 days since the port is only port to handle maritime cargoes in this nation.

Limiting waves are set forth by the berth usage. It is proposed of 0.3m for the barges and 0.5m for the ocean-going vessels. These figures were reduced to 0.2m and 0.4 m in the calculation only by the offshore waves, taking the effect of inner harbor waves.

Wave calmness study results were summarized and evaluated in order to select the better breakwater alignment for the future.

Wave Calmness at the Observation Points:

- (1) Channel to the South Piers (Point 41)
 PLAN 1 does not provide enough condition for both Ocean-going vessel and Barges.
 PLAN 2 does not provide enough condition for barges. However significant improvement would be obtained by this extension.
- (2) Channel to Point 22 (Point 21)
 PLAN 1 does not provide enough condition for both Ocean-going vessel and Barges.
 PLAN 2 does not provide enough condition for barges. However significant improvement would be obtained by this extension.
 PLAN 3 indicated better improvement than PLAN 2...
 PLAN 4 indicates improvement but less than PLAN 3.

(3) Berthing Points at South Pier (**Point 22 and Point 32**)

Anyway the calmness would indicate a sufficient condition. However the calmness near the northern pier tip shows a rather rough sea. This would be attributed to the rough sea at the south channel in PLANs 1 and 2.The barge maneuvering as crossing the channel seems too difficult under south-east winds as seen in PLANs 2, 3 and 4.

Comments to the breakwater arrangement are given as follows:

- (1) A breakwater extension will be required.
- (2) If the island groin can be removed, PLAN 4 looks better.
- (3) If not PLAN 4, PLAN 2 is the choice.
- (4) PLAN 3 will not recommended due to too much turning requirement to vessels.
- (5) Another alternative is a middle-joint scheme between PLAN 2 and PLAN 4. A 500m extension for each the North and South Breakwater.

Refer to Table 4.3.2 and Figure 4.3.5.

4.4 Conclusion and Recommendation

Although a further detailed study should be undertaken during the detailed design phase, the proposed site of Grain Terminal is considered as an acceptable location that allows ship maneuvering and safe operation.

It is proposed to pursue the extension of North Breakwater as scheduled. It is also recommended, however, to undertake a detailed study to make a comparison between PLAN 2 and PLAN 4.

			Ovservation Point at Specified Basin						
Alternative Plan	Check Conditions	Unit	P41	P21	P11	P01	P32	P22	Notes
			Near Entrance Channel	Turning Channel near S2/3	Channel near S1/2	End Channel at Barge Terminal	Basin S2/3,	Basin S2/3 Grain Terminal	
PLAN 1	0.2m for Barge	%	37.7	24.9	0.5	0	0	0.2	Present codition
	0.4m for Ocean Going V.	%	13.6	7.6	0	0	0	0	(No B/W Extension)
	Wave at 97.5% Workability	m	0.98	0.71	0.13	0.1	0.1	0.11	
PLAN 2	0.2m for Barge	%	8.6	9.7	0	0	0	0	North B/W 1km Extension
	0.4m for Ocean Going V.	%	2	2.1	0	0	0	0	
	Wave at 97.5% Workability	m	0.37	0.37	0.1	0.09	0.09	0.09	
PLAN 3	0.2m for Barge	%	0	0	0	0	0	0	South B/W 1km Extension
	0.4m for Ocean Going V.	%	0	0	0	0	0	0	
	Wave at 97.5% Workability	m	0.1	0.09	0.09	0.09	0.09	0.09	
PLAN 4	0.2m for Barge	%	0	0	0	0	0	0	South B/W 1km Extension
	0.4m for Ocean Going V.	%	0	0	0	0	0	0	and Removal of Island Groin
	Wave at 97.5% Workability	m	0.1	0.09	0.09	0.09	0.09	0.09	

Table 4.3.2 Non -Workable Probability (Downtime) at Observation Points by Breakwater Plan

Estimation of off-shore incidental wave to meet the Limit Wave Height, taking inner port wave.

 $H1^{2} + H2^{2} = Ha^{2}$

H1= Unknown H2= Given		Incidental Wave by wave from off-shore. Inner port wave by wind and others.
Ha= 0.3m	Limit wave height	Barge
Ha= 0.5m	Limit wave height	Ocean going vessel

Thus

H1^2= Ha^2-H2^2 H1=(Ha^2-H2^2)^0.5

> Hi= Hi=

Thus Limit wave height for barge and ocean going vessel are 20 cm and 40cm.







Figure 4.3.5 Downtime at Observation Points by Breakwater Plan