REPORT

MODEL STUDY OF THE PALMAS DEL MAR MARINA PUERTO RICO

NEA Hydraulic Laboratory
Reykjavík, Iceland

September 1973

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THE NATIONAL ENERGY AUTHORITY
HYDRAULIC LABORATORY
IN REYKJAVÍK

Report on a model study of

PALMAS DEL MAR MARINA

THE PALMAS DEL MAR COMPANY,
SAN JUAN, PUERTO RICO

Principal Investigator　　　　Director of Laboratory

September 1st 1973.

SUMMARY

This report describes a model study, undertaken at the NEA Hydraulic Laboratory in Reykjavík, of Palmas Del Mar Marina, Puerto Rico.

The purose of the model study was to determine the hydraulic optimal performance of the harbour. The model scale was 1:45.

Three main alternatives were tested for waves from two directions and for three wave heights and periods.

Two separate tests were performed on the south boundary and also on the width of the channel to the inner harbour.

The possibility for possible surge action in the outer harbour was studied to some extent in the model.

The layout with modifications shown in the conclusion (section 6) gives satisfactory wave conditions in the harbour. However, during periods of very low frequency it may not be possible to use the pier head.

C O N T E N T S

L I S T O F T A B L E S

L I S T O F S H E E T S

L I S T O F P H O T O S

I. INTRODUCTION.

It was decided to perform a hydraulic model experiment on the Marina planned at Palmas Del Mar.

The contract between the Pālmas Del Mar Company and NEA Hydraulic Laboratory in Reykjavík was signed and received at Reykjåvík on January 23rd 1973.

The scope of the model experiment was to investigate:

A. The configuration of the entrance.
   - A(1) Width.
   - A(2) Shape of an entrance.
   - A(3) Location of tip of breakwater considering safe navigation.

B. The location of the pier head in the outer harbour.

C. The South breakwater and it´s relative importance for the wave action in the outer harbour.

D. The south boundary of natural rock formation, and it´s importance as an energy absorber.

E. The entrance to the inner harbour, width and configuration.

F. Wave action in the port of the inner harbour in the immediate vicinity of the entrance channel.

G. Dregding limits in the harbour.

H. Furthermore to evaluate the possibility for seiche action.

Waves listed in Table 1 should be tested (Report of Aug. 1972, by Dr. P. Bruun).

BASIC MATERIAL DELIVERED BY THE SPONSOR INCLUDES:

a) Marine Core, Palmas Del Mar, Chart-Map revised by Dr. P. Bruun in Febr. 1973 as final for model.

b) Detailed layout of marina.

c) Cross section of the north breakwater.

d) Report of August 1972 by P. Bruun incl. information about wave action.

2. MODEL SCALE AND HYDRAULIC SIMILITUDE.

According to the harbour size and wave action the model scale of 1:45 was found most suitable.

In hydraulic models on wave action the gravity force is the main force. Other forces, such as fluid friction, surface tension, and like, are neglected. This fact means that Froude´s law is used. The most important ratios are:

Geometrcial scale		=	1:45
Velocity scale	$(1:45)^{1/2}$	=	1:6.71
Time scale	$(1:45)^{1/2}$	=	1:6.71
Area scale	$1:45^2$	=	1:2020
Volume scale	$1:45^3$	=	1:91000

3. MODEL CONSTRUCTION AND EXPERIMENTAL TECHNIQUE.

Regarding construction of the model see Layout of Model, DWG no 1 which is based on the Marina Cove, Palmas Del Mar, Chart-Map, revised by Dr. P. Bruun in Febr. 1973.

The coordinates and contours of the marina cove were modelled on the floor of the Laboratory in scale 1:45 and marked with steel-pins. A concrete wall was built around the model area. The bottom of the model was made of sand with a 2 centimeter (cm) thick concrete layer to the final elevation. The bottom of the model outside the entrance was mostly made of gravel.

Shorelines and coordinates were painted on the bottom. All shores inside the harbour were made of stones of approx. 2 cm in diameter and with a slope of 1:1.5 and the height of the shores were approximately 3.3 cm above M.S.L. (5 ft in prototype).

The north breakwater, a concrete crip rock filled in the prototype, was made of galvanized iron sheets and plywood. It was built in 3-4 sections to get the right length and angles. The north breakwater was filled with stones of approx. 3 cm in diameter. A cross section of the breakwater is shown in Sheet No 1.

Piles made of plywood, 0.8 x 0.8 cm (10 x 10 in. in prototype) were installed in the channel to the inner harbour and along the shore between the channel and the synchrolift 13 cm apart (20 ft in prototype).

The trestle pier and the pier head were made of plywood. They were 11 cm and 20 cm wide (16 ft and 30 ft in prototype), both on 0.8 x 0.8 cm piles 13 cm apart (10 x 10 in. piles 20 ft apart in prototype). The deck of the trestle pier and the pier head was 3.3 cm above M.S.L. (5 ft in prototype).

The trench for the synchrolift was made of plywood and had vertical walls all around. The depth in the trench was 14 ft. The synchrolift in the trench was protected by a short breakwater with a wharf on the inside. The synchrolift with the protective wall is shown in Sheet No 2.

Wind waves are three dimensional with a spectrum of wave heights, periods and directions. A sea state, in practice, is described by the significant wave height and by the period and the predominant wave direction. The significant wave height is defined as the average wave height of the highest one third of all the waves present in the wave train.

In the model the wave generator produces a regular wave. The practice accepted for comparison of irregular waves in the prototype with regular wave in the Laboratory is to set the significant wave height and period in the prototype equal to the regular wave in the model.

The waves were produced by a pneumatic wave generator, see photo 7. The wave period was checked with a stop watch. Wave heights were measured with two resistance meters and all measurements were registered by a strip chart recorder. The equipments used for wave recording are shown on photo 8.

The incident wave height was measured by recording the wave height at ten points over one wave length in the propagation direction. From these ten points the average wave height was calculated and used as incident wave height.

4. WAVE ACTION OUTSIDE THE HARBOUR

The report of August 1972 by Dr. P. Bruun includes information about wave action.

There are two main wave directions in the deep water outside the harbour, SE and E. Waves from SE are only slightly affected by refraction but waves from E may have turned approximately 20 to 25 degrees toward north of west.

After preliminary tests it was decided to investigate two directions of approach, E 20° S and SE.

According to the contract, waves listed in Table 1 of the above mentioned report should be tested, but after the preliminary tests swell action was omitted according to an agreement with Dr. P. Bruun.

For these two wave directions the following wave characteristics outside the harbour were investigated:

TABLE 1. Wave characteristics investigated in the model tests.

Prototype			Model (1:45)	
Height M	Height FT	Period sec	Height cm	Period sec
1,8	6,0	6,0	4,1	0,89
2,4	8,0	8,0	5,4	1,19
3,0	10,0	10,0	6,8	1,49

5. MODEL TESTS.

5.1 Configuration of entrance.

Wave action in the entracne is a function of wave action outside the entrance. The width of the entrance is related to the size of boats and the wave action entering the harbour. Most of the boats are from 20 ft to 70 ft and it is anticipated that the largest boats will be Hydrofoils of about 80 ft.

For these boats the most satisfactory width of the entrance will be 150 ft to 200 ft considering navigation and penetration of wave energy into the harbour.

In the preliminary tests on the entrance, the following parameters were investigated:

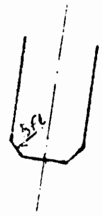
a) entrance widths from 150 ft to 190 ft
b) orientation of the north breakwater
c) orientation of the tip of north breakwater
d) expansion of the cut in the rock reef south of the entrance
e) the south breakwater

The orientation of the north breakwater shown in the Marina Cove, Palmas Del Mar, Chart-Map, was N 40°E. To decrease reflection toward the entrance it is recommened to turn the breakwater five degrees anticlockwise so the orientation of the main breakwater will be N 35°E. For the same reason the outermost part of the breakwater should be turned 25° to 30° degrees. The new orientation of the tip of the breakwater will then be N 10°E to N5°E. The length of the tip varied from 80 ft to 105 ft. The tip would extend to 20 to 21 ft depth.

Two alternatives of breakwater heads were tested, a circular head with a radius of 12.5 ft and a rounded head with a radius of 5 ft.

The circular head reflected waves into the entrance and caused "wash" of the waves into the harbour.

With the rounded head the wave situation at the entrance was satisfactory with no "wash" and very little reflection toward the entrance. It is, therefore, recommended to build the head rounded with a radius about 5 ft or with corners cut off as shown:



The cut in the rock reef was made vertical according to the plan revised by Dr. P. Bruun.

The orientation of the original cut was E 27° S as shown in drawing DWG No. 1. Comparing this cut to an expanded cut of maximum 55 ft and with direction of E 20°S (shown with red line in drawing DEG No. 1) notable reduction of the wave heights in the outer marina was obtained with the same entrance width (150 ft).

Omitting the south breakwater the waves break on the south reef creating currents along the south shore. This current increases the wave heights in the outer harbour. Therefore, it is recommended to build the rubble mound breakwater on the south side of the cut.

5.2 Experimental Result on Test A, B and C

According to the preliminary tests the following series of tests were performed

TEST A. Breakwater orientation N 35°E. Orientation of tip N 8°E, 80 ft long. Expansion of cut in rock reef. Entrance width 150 ft. Bottom width of channel to inner harbour 150 ft.

TEST B. Breakwater orientation N 35°E. Orientation of tip N 8°E, 105 ft long. Original cut in rock reef. Entrance width 150 ft. Bottom width of channel to inner harbour 150 ft.

TEST C. Breakwater orientation N 35°E. Orientation of tip N 8°E, 105 ft long. Expansion of cut in rock reef. Entrance width 190 ft. Bottom width to inner harbour 150 ft.

The layout of TEST A, B and C are shown on DWG No. 1. and the areas where wave heights were measured are shown in Sheet No 3.

Outside the entrance (area A) there are four measure points, two of them about one wavelength from the entrance and two others about half a wavelength from the entrance. Inside the entrance (area E and F) there are three measure points.

Around the pier head (area G, H and I) there are three measure points, two of them in front of the pier head and one inside in each area.

In the middle of the outer harbour (area J, K, L) there are two measure points.

In front of the entrance to the inner harbour (area U) there are two measure points.

In front of the synchrolift (area T) there are two measure points.

In the immediate vicinity of the entrance channel in the inner harbour (area X) there are three measure points.

In all other areas in the harbour there is one measure point.

The experimental results are given in Sheets No. 4-21 for TESTS A, B and C.

To get a better overall view the average wave height and a standard deviation for each area were calculated and indicated in Tables 2 to 4 for each TEST. Table 5 to 7 give the same data for each wave period.

Comparison between the three tests may be summerized as follows:

TEST A.

Entrance width 150 ft.
Expansion of cut in rock reef.

Sheets No. 4 and 5.

Wave period 6 sec.
Wave height 1.8 m outside harbour.

Satisfactory conditions apart from some reflection and edging of waves at pier head which is considered being a result of the regularity of the wave action. It will not occur if vessels are berthed along the pier. The wave height decreases notably behind the pier head so it will be practical to move the pier head 60 ft back.

Sheets No. 6 and 7.

Wave period 8 sec.
Wave height 2.4 m outside harbour.

Satisfactory conditions with the same remarks as made above for 6 sec waves. It is however still recommended to move the pier head 60 ft back, and consider the possibility of not using the front of the head during such very low frequency situations (of the order of 2%). A local peak may occur at the entrance to the inner harbour but there is little penetration into the inner harbour.

Sheets No. 8 and 9.

Wave period 10 sec.
Wave height 3.0 m outside harbour.

The situation is comparable to the situation with 8 sec waves and the frequency is very low (about 1%).

TEST B.

Entrance width 150 ft.
Original cut in rock reef.

Sheets No. 10 and 11.

Wave period 6 sec.
Wave height 1.8 m outside harbour.

Conditions are not satisfactory at the pier head and almost all wave heights exceed those of sheets No. 4 and 5. The situation is unsatisfactory for waves from SE.

Sheets No. 12 and 13.

Wave period 8 sec.
Wave height 2.4 m outside harbour.

Conditions are less satisfactory at the pier head and in most parts of the harbour basin, apart from the area inside the south breakwater where the original cut in the rock reef improves the situation in the south harbour and in the channel for SE.

Sheets No. 14 and 15.

Wave period 10 sec.
Wave height 3.0 m outside harbour.

Conditions are less satisfactory at the pier head and in most parts of the harbour basin, apart from the area inside the south breakwater where the original cut in rock reef improves the situation in the south harbour.

TEST C.

Entrance width 190 ft.
Expansion of cut in rock reef.

Sheets No 16 and 17.

Wave period 6 sec.
Wave height 1.8 m outside harbour.

Sheets No 18 and 19.

Wave period 8 sec.
Wave height 2.4 m outside harbour.

Sheets No 20 and 21.

Wave period 10 sec.
Wave height 3.0 m outside harbour

The situation for waveheights 1,8 m and period of 6 sec is the most frequent of these three situations.
Comparison of the three tests show that TEST A is most satisfactory. Moving the pier head in TEST A about 60 ft back wave heights in front of the pier head are acceptable.

5.3 Energy absorption at the South Boundary

A tentative evaluation was made for TESTS A, B and C.

TEST B: In Test B (original cut of rock reef and entrance width 150 ft), without south breakwater waves break on the reef creating currents along the shore including relatively strong currents perpendicular to the entrance to the inner harbour. At the synchrolift a local surge occurs.

A small rubble mound at the entrance to the inner harbour (shown in red in Sheet No 3) reduces this current as well as the local surge.

Building a south breakwater on the reef also reduces currents as well as surge, and eliminates the need for a small breakwater at the entrance.

TEST A and C: There is not need for the small rubble mound extending from the south side of the inner entrance.

A comparison of a vertical and sloping cut was made by placing a rubble mound with a slope of 1:2 in the cut as shown in Sheet No. 22. The rock size was of approx. 2 cm in diameter. For reasons of navigation, however, such design of the cut may be less desirable. These tests were run for TEST A only.

Measure points are shown in Sheet No. 22. Where there are several measure points in each area the average value was used.

The comparison of wave action for vertical and sloping cuts (1:2) is given in Table 8.

When waves propagate parallel to the vertical cut they tend to be normal to the cut and the wave heights increase as the waves proceed. When the waves propagate along the sloping cut they tend to turn up on the cut and wave heights decrease as they proceed along it.

As shown in Table 8 wave heights for all periods and both directions are acceptable outside the entrance to the inner harbour, at the entrance to the synchrolift, and in the channel to the inner harbour as well as inside the channel.

In front of the pier head, however, wave heights increase compared to vertical cut for 8 sec and 10 sec. For 6 sec they are equal or less.

Due to the undesirable effects on navigation of a slope, outside the vertical cut, this slope is not recommended.

It is possible, however, to dredge the cut with a slope of 1:2 from the end of the small breakwater at the synchrolift to about 60 ft west of the south breakwater, as shown in Sheet No. 23. The wave action at the pier head will not increase in the prototype.

5.4 Entrance to the Inner Harbour.

Wave penetration to the inner harbour is a function of wave height outside the entrance and the direction of the waves. The direction of the waves again is a function of the wave period. For 6 sec waves, wave direction almost follows a straight line to the inner basin. For 8 and 10 sec waves, waves almost propagate towards NW and turn towards the north slope of the channel. Due to the small angle of approach very little reflection occurs.

A preliminary test with vertical side walls in the channel cuased increase of wave heights in the channel. It was therefore decided not to test the vertical boundary further.

The slopes of the inner channel were then provided with a rubble mound slope of 1:1.5 assuming a wharf on piles spaced 20 ft in the prototype.

To investigate the influence of entrance width on wave action in the inner harbour, 200 ft bottom width was compared to 150 ft bottom width, with and without rubble mound in the cut.

The measure points are shown in Sheet No. 22.

Table 9 shows the results for 200 ft and for 150 ft bottom width. As shown in the Table, wave heights in the inner harbour are within acceptable limits, also for the 200 ft bottom width entrance. In almost all cases however the maximum wave height may exceed the average wave height with 0.10 m to 0.20 m.

Due to the fact that waves in the prototype are three-dimensional, while the wave generator produces regular wave generator produces regular wave with a fixed wave height, wave period and direction in each test, some disturbances may occur in the prototype due to the formation of local peaks. Although the tests show that the wave heights inside the channel are acceptable for 200 ft bottom width it is recommended to build the channel not wider than 175 ft.

5.5 Dredging.

The largest vessels anticipated to enter the harbour are Hydrofoils, about 80 ft long. It is therefore no need for dredging of the outermost part of the outer harbour and along the north breakwater where the Hydrofoils will berth. The expansion of the rock reef shown (with red line) in drawing DGW No. 2 is recommended to reduce wave heights in the outer harbour. It is also recommended to make the slope everywhere in the dredged areas at least 1:10 to avoid increase of local waves. The model tests showed that the 17 to 18 ft deep depression in the middle of the outer basin causes an increasing wave height at the boundaries of the depression. It is, therefore, recommended to fill the depression to about 14 ft depth. Sheet No. 23 shows the recommended dredging plan.

5.6 Long period waves.

Periodical horizontal movements of ships moored in harbours is called surge action. The first sign of surge action is rythmical stretchings and slackenings of mooring cables resulting in periodical displacements of the ship. During heavy surge action it may not be possible to keep the vessels in position by strong mooring cables.

Surge action in harbours is caused by long waves penetrating from the open sea, such as meteorological disturbances including steep pressure gradients. It may also be caused by surf beat which are waves with period of about 1 to 3 min and a height varying from few cm to several dm. Meteorological disturbances may cause waves with periods varying from 3 to 100 min and heights from 5 cm to 100 cm. Waves of periods 60 to 150 sec undoubtedly occur in the open sea during storms as a result of wind gustiness. These waves are "hidden" in the short period wave trains.

Long waves in harbours may demonstrate themselves in tow ways. Firstly, after the long waves have entered the harbour they may be reflected from the boundaries over and over again, possibly causing resonance waves. Secondly if resonance occurs between harbour geometry and the long waves from the sea, these waves may be amplified causing harbour seiches.

With respect to conditions in the outer harbour the fundmental node will occur in the entrance. The theoretical period is about 92 sec. The first harmonic will have nodes outside as well as inside the pier head with the theoretical period of 46 sec. In the model it was possible to produce a slow variation of the water table in the harbour at 90 to 100 sec with a relatively strong current at the entrance.
It was also possible to produce the first harmonic at 40 to 50 sec but the current was very weak. The possibility of surge action in the harbour due to the first harmonic is small because long waves in the open sea with periods of 40 to 50 sec are rare. It is, however, possible that surge action may occur along the pier head at very low frequency situations. One must then consider the possibility of not using the pier head.

6. CONCLUSION.

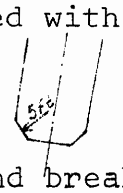
Following is a summation of conclusions drawn from the results of the tests performed.

Of the three main tests, TEST A, B and C, TEST A gives the most satisfactory condition in the harbour. The following modifications therefore are recommended for consideration:

1) Expansion of the cut in the rock reef in TEST A.

2) To decrease reflection towards the entrance the north-breakwater should be turned to N35°E.

3) For the same reason the tip should be turned to N8°E. The length of the tip is about 80 ft. The head of the tip is rounded with a radius of about 5 ft.



4) A rubble mound breakwater should be built on the south side of the entrance extending to the cut.

5) The entrance width should be about 150 ft.

6) The cut at the entrance should be almost vertical to a point about 60 ft west of the south breakwater.

7) The cut should be dredged with a slope of 1:2 from the end of the small breakwater at the synchrolift to about 60 ft west of the south breakwater.

8) The pier head should be moved about 60 ft back, considering the possibility of not using the front of the head during very low frequency situations.

9) Although the model tests show an acceptable penetration of wave energy to the inner harbour with a 200 ft channel a width of 175 ft is recommended, due to the possibility of penetration of irregular waves in the

prototype. The sides of the channel should be covered by a 1:1.5 rubble mound.

10) To avoid local increase of wave action in the harbour all slopes should be dredged to about 1:10 slope. The depression in the middle of the outer harbour should be filled up to about 14 to 15 ft.

11) It is possible that surge action may happen, mainly along the pier head during very low frequency situations. One must therefore consider the possibility of not using the pier head during such situations.

TESTA A TABLE 2

EXPERIMENTAL RESULTS
AN AVERAGE WAVE HEIGHT AND STANDART DEVIATION

(IN METERS)

MEASURE AREAS	T = 6 SEC H = 1.8 M				T = 8 SEC H = 2.4 M				T = 10 SEC H = 3.0 M			
	E 20°S		S E		E 20°S		S E		E 20°S		S E	
	$\bar{H}_m$	σ_m	$\bar{H}_m$	σ_m	$\bar{H}_m$	σ_m	$\bar{H}_m$	σ_m	$\bar{H}_m$	σ_m	$\bar{H}_m$	σ_m
A	1.62	0.35	1.29	0.75	2.92	0.18	2.10	0.52	2.58	0.53	2.90	0.59
B	1.40		0.55		2.95		1.60		2.00		2.15	
C	0.80		0.20		1.10		0.55		0.60		0.65	
D	0.20		0.15		0.20		0.25		0.20		0.25	
E	0.80	0.18	0.50	0.13	1.37	0.24	1.01	0.12	1.82	0.58	1.22	0.34
F	0.37	0.08	0.35	0	1.13	0.11	0.68	0.13	1.20	0.44	1.17	0.33
G	0.30	0.17	0.23	0.16	0.60	0.09	0.52	0.06	0.52	0.13	0.67	0.24
H	0.48	0.16	0.25	0.10	0.68	0.16	0.47	0.13	0.38	0.08	0.75	0.10
I	0.33	0.18	0.35	0.10	0.70	0.13	0.42	0.12	0.37	0.08	0.70	0.18
J	0.13	0.04	0.05	0	0.30	0	0.20	0.07	0.20		0.35	0.21
K	0.35		0.18	0.04	0.33	0.04	0.18	0.04	0.18	0.04	0.50	0.35
L	0.35		0.10		0.30	0.14	0.28	0.11	0.20		0.23	0.03
M	0.10		0.15		0.35		0.25		0.20		0.40	
N	0.20		0.15		0.25		0.15		0.20		0.15	
O	0.25		0.20		0.35		0.15		0.15		0.10	
P	0.10		0.10		0.10		0.10		0.05		0.20	
Q	0.15		0.15		0.15		0.15		0.15		0.20	
R	0.10		0.10		0.10		0.10		0.20		0.10	
S	0.20		0.20		0.25		0.25		0.10		0.65	
T	0.13	0.04	0.15		0.35		0.13	0.04	0.55	0.21	0.45	0.28
U	0.30		0.25	0.07	0.75	0.07	0.40	0.05	0.78	0.11	0.75	
V	0.35		0.20		0.25		0.15		0.35		0.25	
W	0.20		0.10		0.15		0.10		0.20		0.20	
X	0.10		0.05		0.12	0.03	0.20		0.20		0.10	
Y	0.05		0.05		0.05		0.05		0.05		0.10	
Z	0.05		0.05		0.10		0.10		0.20		0.15	
Ø	0.05		0.05		0.05		0.05		0.05		0.10	

MEASURE AREAS REFER TO SHEET NO 3.

EXPERIMENTAL RESULTS
AN AVERAGE WAVE HEIGHT AND STANDART DEVIATIONS
(IN METERS)

MEASURE AREAS	T = 6 SEC H = 1.8 M				T = 8 SEC H = 2.4 M				T = 10 SEC H = 3.0 M			
	E 20°S		S E		E 20°S		S E		E 20°S		S E	
	$\bar{H}_m$	σ_m	$\bar{H}_m$	σ_m	$\bar{H}_m$	σ_m	$\bar{H}_m$	σ_m	$\bar{H}_m$	σ_m	$\bar{H}_m$	σ_m
A	1.85	0.36	1.66	0.53	2.90	0.30	1.93	0.17	3.20	0.52	2.81	0.67
B	1.75		1.18		2.70		1.15		3.00		2.50	
C	0.30		0.67		0.60		0.85		0.65		0.65	
D	0.20		0.34		0.05		0.10		0.15		0.15	
E	1.25	0.18	0.90	0.10	1.40	0.26	0.57	0.18	1.48	0.25	0.85	0.09
F	0.75	0.13	0.56	0.17	0.90	0.30	0.38	0.13	0.95	0.49	0.48	0.08
G	0.85	0.10	0.58	0.08	0.92	0.33	0.62	0.20	1.03	0.33	0.90	0.27
H	0.48	0.11	0.52	0.23	0.75	0.05	0.55	0.10	0.82	0.23	0.87	0.26
I	0.48	0.11	0.60	0.13	0.90	0.35	0.62	0.28	0.58	0.19	0.80	0.21
J	0.23	0.04	0.17		0.40		0.40		0.28	0.11	0.55	0.21
K	0.33	0.18	0.34	0.07	0.30		0.23	0.11	0.30	0.14	0.70	0
L	0.30		0.20	0.04	0.45	0.17	0.25	0.07	0.50	0.21	0.60	0.07
M	0.20		0.07		0.55		0.30		0.10		0.15	
N	0.20		0.20		0.30		0.20		0.20		0.35	
O	0.15		0.22		0.30		0.20		0.10		0.40	
P	0.20		0.10		0.25		0.10		0.25		0.10	
Q	0.10		0.05		0.20		0.15		0.15		0.10	
R	0.20		0.06		0.20		0.10		0.35		0.24	
S	0.50		0.51		0.95		0.30		0.90		0.50	
T	0.27	0.11	0.20	0.12	0.30		0.10		0.30	0.21	0.25	0.21
U	0.53	0.04	0.34	0	0.68	0.04	0.15		0.70	0.14	0.45	0.07
V	0.45		0.11		0.45		0.10		0.25		0.25	
W	0.15		0.12		0.30		0.10		0.15		0.15	
X	0.15		0.05	0.02	0.30	0.15	0.08	0.02	0.23	0.03	0.18	0.03
Y	0.05		0.02		0.05		0.05		0.05		0.05	
Z	0.10		0.05		0.10		0.05		0.15		0.10	
Ø	0.05		0.02		0.05		0.05		0.10		0.05	

MEASURE AREAS REFER TO SHEET NO 3.

TESTA C   TABLE 4

EXPERIMENTAL RESULTS
A) AVERAGE WAVE HEIGHT AND STANDART DEVIATION
(IN METERS)

MEASURE AREAS	T = 6 SEC H = 1.8 M				T = 8 SEC H = 2.4 M				T = 10 SEC H = 3.0 M			
	E 20°S		S E		E 20°S		S E		E 20°S		S E	
	$\bar{H}_m$	σ_m	$\bar{H}_m$	σ_m	$\bar{H}_m$	σ_m	$\bar{H}_m$	σ_m	$\bar{H}_m$	σ_m	$\bar{H}_m$	σ_m
A	1.50	0.47	1.51	0.40	3.11	0.33	2.17	0.39	3.60	0.50	2.70	0.77
B	1.60		0.80		2.80		1.40		3.35		1.90	
C	0.40		0.56		0.95		0.85		0.80		0.40	
D	0.20		0.05		0.15		0.10		0.25		0.20	
E	1.30	0.18	0.71	0.17	1.65	0.10	1.65	0.39	2.37	0.70	1.23	0.14
F	0.72	0.10	0.62	0.15	1.52	0.40	0.75	0	1.70	0.34	0.95	0.09
G	0.50	0.13	0.52	0.12	1.02	0.20	0.78	0.10	0.93	0.23	0.93	0.38
H	0.63	0.25	0.42	0.18	1.17	0.14	0.65	0.18	0.85	0.18	0.47	0.26
I	0.60	0.10	0.40	0.10	1.02	0.19	0.60	0.15	0.65	0.28	0.76	0.16
J	0.15	0.07	0.50	0.16	0.58	0.18	0.65	0.07	0.48	0.18	0.38	0.04
K	0.35	0.14	0.42	0.04	0.25	0.14	0.33	0.04	0.58	0.04	0.48	0.25
L	0.23	0.17	0.18	0.08	0.65	0.28	0.38	0.11	0.40	0.21	0.33	0.11
M	0.20		0.12		0.20		0.20		0.15		0.15	
N	0.25		0.17		0.35		0.30		0.10		0.30	
O	0.40		0.23		0.45		0.10		0.35		0.25	
P	0.10		0.10		0.10		0.10		0.25		0.10	
Q	0.15		0.06		0.25		0.15		0.25		0.05	
R	0.10		0.17		0.15		0.15		0.70		0.30	
S	0.50		0.51		1.45		0.50		1.40		0.65	
T	0.20	0.07	0.31	0.04	0.70	0.07	0.33	0.04	0.70	0.35	0.38	0.18
U	0.45		0.40	0.08	1.32	0.11	0.60	0	1.17	0.18	0.48	0.11
V	0.45		0.28		0.55		0.35		0.60		0.35	
W	0.15		0.06		0.50		0.15		0.25		0.10	
X	0.10		0.05	0.01	0.42	0.08	0.18	0.03	0.35	0.10	0.22	0.03
Y	0.05		0.05		0.10		0.05		0.10		0.10	
Z	0.05		0.05		0.15		0.10		0.25		0.15	
Ø	0.05		0.05		0.05		0.05		0.05		0.10	

MEASURE AREAS REFER TO SHEET NO 3.

TEST A,B,C. TABLE 5

EXPERIMENTAL RESULTS FOR 6 SECONDS WAVES
AN AVERAGE WAVE HEIGHT AND STANDART DEVIATIONA

(IN METERS)

MEASURE AREAS	TEST A T = 6 SEC H = 1.8 M				TEST B T = 6 SEC H = 1.8 M				TEST C T = 6 SEC H = 1.8 M			
	E 20°S		S E		E 20°S		S E		E 20°S		S E	
	$\bar{H}$ m	σ m	$\bar{H}$ m	σ m	$\bar{H}$ m	σ m	$\bar{H}$ m	σ m	$\bar{H}$ m	σ m	$\bar{H}$ m	σ m
A	1.62	0.35	1.29	0.75	1.85	0.36	1.66	0.53	1.50	0.47	1.51	0.40
B	1.40		0.55		1.75		1.18		1.60		0.80	
C	0.80		0.20		0.30		0.67		0.40		0.56	
D	0.20		0.15		0.20		0.34		0.20		0.05	
E	0.80	0.18	0.50	0.13	1.25	0.18	0.90	0.10	1.30	0.18	0.71	0.17
F	0.37	0.08	0.35	0	0.75	0.13	0.56	0.17	0.72	0.10	0.62	0.15
G	0.30	0.17	0.23	0.16	0.85	0.10	0.58	0.08	0.50	0.13	0.52	0.12
H	0.48	0.16	0.25	0.10	0.48	0.11	0.52	0.23	0.63	0.25	0.42	0.18
I	0.33	0.18	0.35	0.10	0.48	0.11	0.60	0.13	0.60	0.10	0.40	0.10
J	0.13	0.04	0.05	0	0.23	0.04	0.17		0.15	0.07	0.50	0.16
K	0.35	0	0.18	0.04	0.33	0.18	0.34	0.07	0.35	0.14	0.42	0.04
L	0.35		0.10		0.30	0	0.20	0.04	0.23	[illegible]	0.18	0.08
M	0.10		0.15		0.20		0.07		0.20		0.12	
N	0.20		0.15		0.20		0.20		0.25		0.17	
O	0.25		0.20		0.15		0.22		0.40		0.23	
P	0.10		0.10		0.20		0.10		0.10		0.10	
Q	0.15		0.15		0.10		0.05		0.15		0.06	
R	0.10		0.10		0.20		0.06		0.10		0.17	
S	0.20		0.20		0.50		0.51		0.50		0.51	
T	0.13	0.04	0.15	0	0.27	0.11	0.20	0.12	0.20	0.07	0.31	0.04
U	0.30		0.25	0.07	0.53	0.04	0.34	0	0.45		0.40	0.08
V	0.35		0.20		0.45		0.11		0.45		0.28	
W	0,20		0.10		0.15		0.12		0.15		0.06	
X	0.10	0	0.05	0	0.15	0	0.05	0.02	0.10		0.05	0.01
Y	0.05		0.05		0.05		0.02		0.05		0.05	
Z	0.05		0.05		0.10		0.05		0.05		0.05	
Ø	0.05		0.05		0.05		0.02		0.05		0.05	

MEASURE AREAS REFER TO SHEET NO 3.

TEST A,B,C. TABLE

EXPERIMENTAL RESULTS FOR 8 SECONDS WAVES
AN AVERAGE WAVE HEIGHT AND STANDART DEVIATION
(IN METERS)

MEASURE AREAS	TEST A T = 8 SEC H = [illegible] M				TEST B T = 8 SEC H = [illegible] 4 M				TEST C T = 8 SEC H = [illegible].4 M			
	E 20°S		S E		E 20°S		S E		E 20°S		S E	
	$\bar{H}$ m	σ m	$\bar{H}$ m	σ m	$\bar{H}$ m	σ m	$\bar{H}$ m	σ m	$\bar{H}$ m	σ m	$\bar{H}$ m	σ m
A	2.92	0.18	2.10	0.52	2.90	0.30	1.93	0.17	3.11	0.33	2.17	0.39
B	2.95		1.60		2.70		1.15		2.80		1.40	
C	1.10		0.55		0.60		0.85		0.95		0.85	
D	0.20		0.25		0.05		0.10		0.15		0.10	
E	1.37	0.24	1.01	0.12	1.40	0.26	0.57	0.18	1.65	0.10	1.65	0.39
F	1.13	0.11	0.68	0.13	0.90	0.30	0.38	0.13	1.52	0.40	0.75	0
G	0.60	0.09	0.52	0.06	0.92	0.33	0.62	0.20	1.02	0.20	0.78	0.10
H	0.68	0.16	0.47	0.13	0.75	0.05	0.55	0.10	1.17	0.14	0.65	0.18
I	0.70	0.13	0.42	0.12	0.90	0.35	0.62	0.28	1.02	0.19	0.60	0.15
J	0.30	0	0.20	0.07	0.40	0	0.40	0	0.58	0.18	0.65	0.07
K	0.33	0.04	0.18	0.04	0.30	0	0.23	0.11	0.25	0.14	0.33	0.04
L	0.30	0.14	0.28	0.11	0.45	0.17	0.25	0.07	0.65	0.28	0.38	0.11
M	0.35		0.25		0.55		0.30		0.20		0.20	
N	0.25		0.15		0.30		0.20		0.35		0.30	
O	0.35		0.15		0.30		0.20		0.45		0.10	
P	0.10		0.10		0.25		0.10		0.10		0.10	
Q	0.15		0.15		0.20		0.15		0.25		0.15	
R	0.10		0.10		0.20		0.10		0.15		0.15	
S	0.25		0.25		0.95		0.30		1.45		0.50	
T	0.35	0	0.13	0.04	0.30	0	0.10	0	0.70	0.07	0.33	0.04
U	0.75	0.07	0.40	0.05	0.68	0.04	0.15	0	1.32	0.11	0.60	0
V	0.25		0.15		0.45		0.10		0.55		0.35	
W	0.15		0.10		0.30		0.10		0.50		0.15	
X	0.12	0.03	0.20	0	0.30	0.15	0.08	0.02	0.42	0.08	0.18	0.03
Y	0.05		0.05		0.05		0.05		0.10		0.05	
Z	0.10		0.10		0.10		0.05		0.15		0.10	
Ø	0.05		0.05		0.05		0.05		0.05		0.05	

MEASURE AREAS REFER TO SHEET NO 3.

TEST A,B,C. TABLE 7

EXPERIMENTAL.RESULTS FOR 10 SECONDS WAVES
AN AVERAGE WAVE HEIGHT AND STANDART DEVIATION
(IN METERS)

MEASURE AREAS	TEST A T = 10 SEC H = 3.0 M				TEST B T = 10 SEC H = 3.0 M				TEST C T = 10 SEC H = 3.0 M			
	E 20°S		S E		E 20°S		S E		E 20°S		S E	
	$\bar{H}_m$	σ_m	$\bar{H}_m$	σ_m	$\bar{H}_m$	σ_m	$\bar{H}_m$	σ_m	$\bar{H}_m$	σ_m	$\bar{H}_m$	σ_m
A	2.58	0.53	2.90	0.59	3.20	0.52	2.81	0.67	3.60	0.50	2.70	0.77
B	2.00		2.15		3.00		2.50		3.35		1.90	
C	0.60		0.65		0.65		0.65		0.80		0.40	
D	0.20		0.25		0.15		0.15		0.25		0.20	
E	1.82	0.58	1.22	0.34	1.48	0.25	0.85	0.09	2.37	0.70	1.23	0.14
F	1.20	0.44	1.17	0.33	0.95	0.49	0.48	0.08	1.70	0.34	0.95	0.09
G	0.52	0.13	0.67	0.24	1.03	0.33	0.90	0.27	0.93	0.23	0.93	0.38
H	0.38	0.08	0.75	0.10	0.82	0.23	0.87	0.26	0.85	0.18	0.47	0.26
I	0.37	0.08	0.70	0.18	0.58	0.19	0.80	0.21	0.65	0.28	0.76	0.16
J	0.20	0	0.35	0.21	0.28	0.11	0.55	0.21	0.48	0.18	0.38	0.04
K	0.18	0.04	0.50	0.35	0.30	0.14	0.70	0	0.58	0.04	0.48	0.25
L	0.20	0	0.23	0.03	0.50	0.21	0.60	0.07	0.40	0.21	0.33	0.11
M	0.20		0.40		0.10		0.15		0.15		0.15	
N	0.20		0.15		0.20		0.35		0.10		0.30	
O	0.15		0.10		0.10		0.40		0.35		0.25	
P	0.05		0.20		0.25		0.10		0.25		0.10	
Q	0.15		0.20		0.15		0.10		0.25		0.05	
R	0.20		0.10		0.35		0.24		0.70		0.30	
S	0.10		0.65		0.90		0.50		1.40		0.65	
T	0.55	0.21	0.45	0.28	0.30	0.21	0.25	0.21	0.70	0.35	0.38	0.18
U	0.78	0.11	0.75	0	0.70	0.14	0.45	0.07	1.17	0.18	0.48	0.11
V	0.35		0.25		0.25		0.25		0.60		0.35	
W	0.20		0.20		0.15		0.15		0.25		0.10	
X	0.20	0	0.10	0	0.23	0.03	0.18	0.03	0.35	0.10	0.22	0.03
Y	0.05		0.10		0.05		0.05		0.10		0.10	
Z	0.20		0.15		0.15		0.10		0.25		0.15	
Ø	0.05		0.10		0.10		0.05		0.05		0.10	

MEASURE AREAS REFER TO SHEET NO 3.

COMPARISON OF WAVE ACTION FOR VERTICAL CUT AND FOR SLOPING CUT (1:2) TABLE 8

WAVE ACTION OUTSIDE HARBOUR		T = 6 SEC H = 1,8 M				T = 8 SEC H = 2,4 M				T = 10 SEC H = 3,0 M			
		E 20°S		S E		E 20°S		S E		E 20°S		S E	
		$\bar{H}$ (M)		$\bar{H}$ (M)		$\bar{H}$ (M)		$\bar{H}$ (M)		$\bar{H}$ (M)		$\bar{H}$ (M)	
MEASURE AREAS		VERTICAL CUT	SLOPING CUT	VERTICAL CUT	SLOPING CUT	VERTICAL CUT	SLOPING CUT	VERTICAL CUT	SLOPING CUT	VERTICAL CUT	SLOPING CUT	VERTICAL CUT	SLOPING CUT
In outer harbour	E_1	0,70	0,80	0,45	0,45	1,45	1,75	0,95	0,95	1,70	1,45	1,20	1,20
In outer harbour	F_1	0,40	0,65	0,35	0,35	1,15	0,95	0,75	0,75	1,05	0,75	1,20	1,20
In front of pier head	G_1	0,50	0,45	0,35	0,35	0,65	0,80	0,55	0,70	0,55	0,50	0,80	1,00
In front of pier head	H_1	0,60	0,45	0,35	0,35	0,60	0,80	0,40	0,45	0,45	0,45	0,75	0,90
In front of pier head	I_1	0,30	0,25	0,40	0,40	0,70	0,55	0,50	0,75	0,30	0,35	0,60	0,70
Outside syncrolift	T_1	0,15	0,10	0,15	0,10	0,35	0,15	0,15	0,10	0,55	0,15	0,45	0,25
60 ft outside channel	U_1	0,30	0,25	0,25	0,25	0,75	0,35	0,40	0,25	0,80	0,40	0,75	0,50
In channel, 150 ft from outer entrance	V_1	0,35	0,30	0,20	0,15	0,25	0,10	0,15	0,10	0,35	0,10	0,25	0,15
Immediate inside channel	X_1	0,10	0,10	0,05	0,05	0,10	0,05	0,20	0,10	0,20	0,10	0,10	0,05

MEASURE AREAS REFER TO SHEET NO 22

THE WAVE ENERGY PENETRATION INTO THE INNER HARBOUR AS
A FUNCTION OF THE CHANNEL WIDTH.

TABLE 9

WAVE ACTION OUTSIDE HARBOUR			T - 6 SEC H - 1,8 M				T 6 SEC H 2,4 M				T - 10 SEC H = 3,0 M			
			E 20^0S		S E		E 20^0S		S E		E 20^0S		S E	
CHANNEL WIDTH TO THE INNER HARBOUR			150 ft	200 ft	150 ft	200 ft	150 ft	200 ft	150 ft	200 ft	150 ft	200 ft	150 ft	200 ft
MEASURE AREAS			$\bar{H}$ M	$\bar{H}$ M	$\bar{H}$ M	$\bar{H}$ M	$\bar{H}$ M	$\bar{H}$ M	$\bar{H}$ M	$\bar{H}$ M	$\bar{H}$ M	$\bar{H}$ M	$\bar{H}$ M	$\bar{H}$ M
Immediate inside channel	X_1	VERT CUT	0,10	0,25	0,05	0,15	0,10	0,15	0,20	0,25	0,20	0,25	0,10	0,10
In channel 150 ft from outer entrance -	V_1	"	0,35	0,45	0,20	0,40	0,25	0,35	0,15	0,25	0,35	0,30	0,25	0,20
60 ft outside channel	U_1	"	0,30	0,35	0,25	0,30	0,75	1,00	0,40	0,55	0,60	0,70	0,75	0,75
Outside syncrolift	T_1	"	0,15	0,15	0,15	0,15	0,35	0,40	0,15	0,20	0,55	0,80	0,45	0,75
Immediate inside channel	X_1	STOP CUT	0,10	0,25	0,05	0,20	0,05	0,10	0,10	0,10	0,10	0,20	0,05	0,05
In channel 150 ft from outer entrance	V_1	"	0,30	0,35	0,15	0,25	0,10	0,20	0,10	0,15	0,10	0,20	0,15	0,15
60 ft outside channel	U_1	"	0,25	0,25	0,25	0,25	0,35	0,50	0,25	0,25	0,40	0,45	0,50	0,50
Outside syncrolift	T_1	"	0,10	0,10	0,10	0,15	0,15	0,20	0,10	0,10	0,15	0,45	0,25	0,40

MEASURE AREAS REFER TO SHEET NO 22