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FLOATING BREAKWATER WAVE-ATTENUATION TESTS FOR EAST BAY MARINA OLYMPIA HARBOR, WASHINGTON

Hydraulic Model Investigation

by

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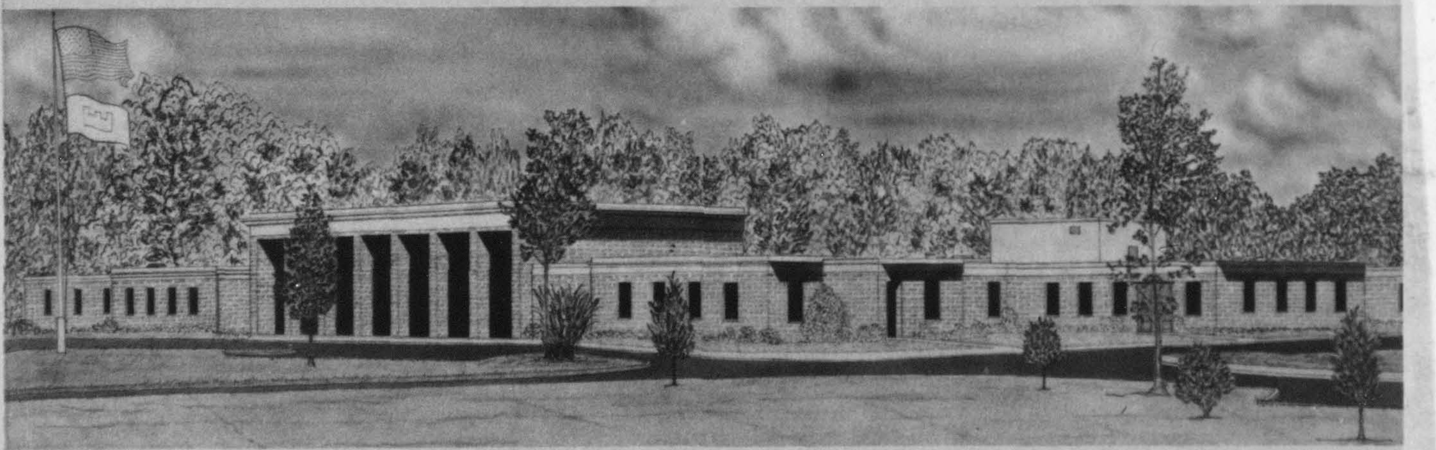
August 1979
Final Report



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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

An undistorted-scale hydraulic model study was conducted. Initially, two-dimensional (2-D) flume tests were employed to determine the wave-attenuating properties of four floating breakwater cross sections. Based on results of the 2-D tests and relative costs of the structures, the best plan was selected for three-dimensional (3-D) testing. The 3-D tests investigated the combined effects of angular wave attack, structure alignment, wave transmission, and wave diffraction around the exposed end of the breakwater system.

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The 2-D tests showed the transmission coefficient (C_t) to be strongly dependent on relative structure width (W/L) and weakly dependent on wave steepness (H/L). Results of the 3-D tests showed that maximum wave-height attenuation was achieved when incident wave crests were at a 15-degree angle relative to the center line of the breakwater. Also, 3-D test data showed that a large decrease in the water depth (from 25 ft to 10 ft) only produced a slight decrease in transmitted wave heights.

PREFACE

The model investigation reported herein was requested by the U. S. Army Engineer District, Seattle (NPS) in a letter to the U. S. Army Engineer Waterways Experiment Station (WES), dated 24 May 1977. Funding authorization was granted by NPS on Intra-Army order No. E-86-77-3066, dated 5 July 1977.

Model tests were conducted at WES during the period October 1977 to September 1978, under the general direction of Mr. H. B. Simmons, Chief of the Hydraulics Laboratory; Dr. R. W. Whalin, Chief of the Wave Dynamics Division; and Mr. D. D. Davidson, Chief of the Wave Research Branch. Tests were conducted by Mr. R. D. Carver, Research Hydraulic Engineer; Ms. J. I. Jones and Mr. W. G. DuBose, Engineering Technicians; and Mr. W. L. Reynolds, Electronics Technician. This report was prepared by Mr. Carver. Mr. Eric Nelson of NPS provided prototype information and coordinated plans for the model tests with Messrs. Davidson and Carver of WES.

Liaison was maintained during the course of the investigation by means of conferences, progress reports, and telephone conversations.

Commanders and Directors of WES during the conduct of this study and the preparation and publication of this report were COL John L. Cannon, CE, and COL Nelson P. Conover, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
feet	0.3048	metres
inches	25.4	millimetres
miles (U. S. statute)	1.609344	kilometres
pounds (mass)	0.4535924	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic metre

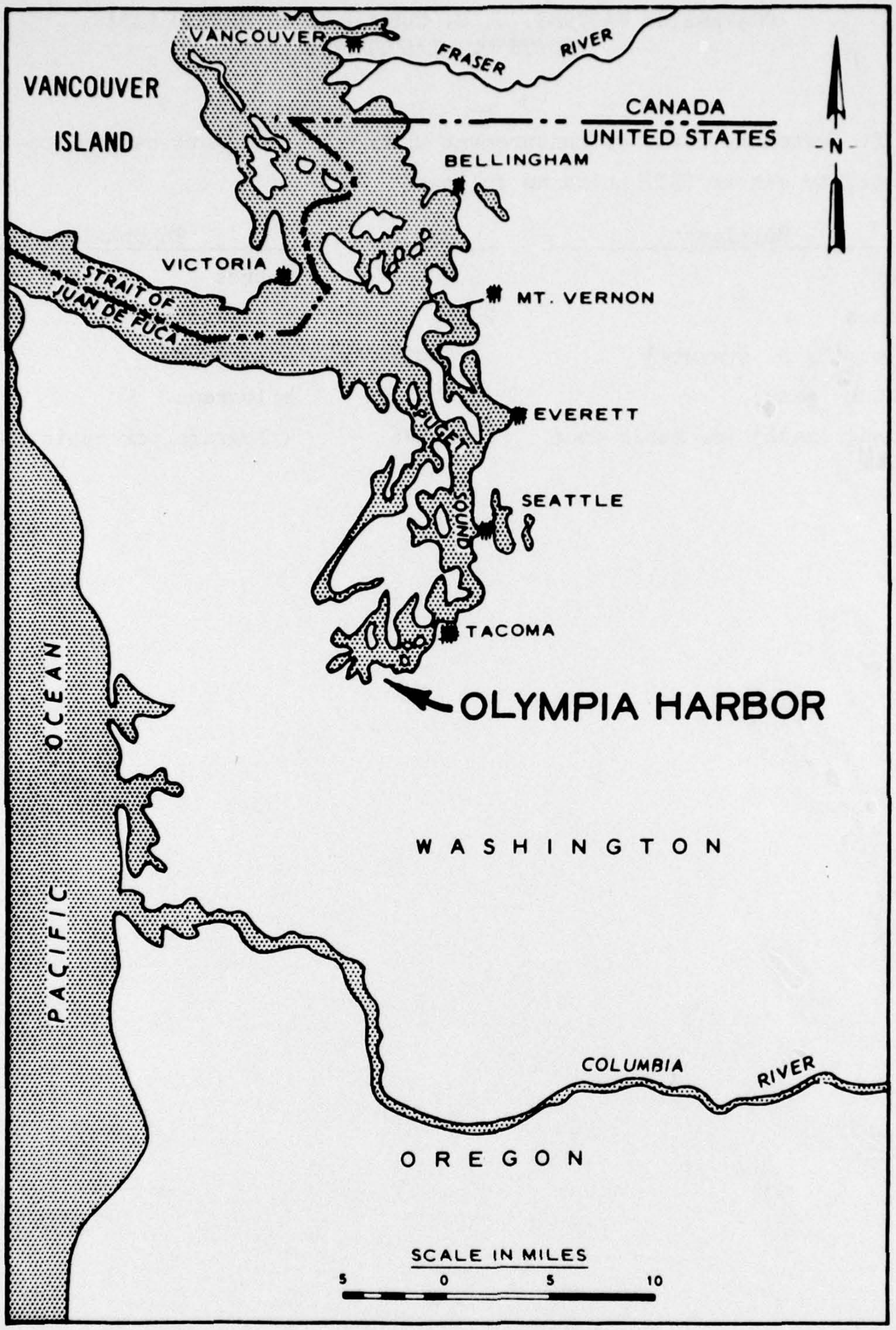

Figure 1. Location map

FLOATING BREAKWATER WAVE-ATTENUATION
TESTS FOR EAST BAY MARINA
OLYMPIA HARBOR, WASHINGTON

Hydraulic Model Investigation

PART I: INTRODUCTION

The Prototype

1. Olympia Harbor is located in the extreme southern reach of Puget Sound approximately 60 miles* southwest of Seattle, Washington (Figure 1). The harbor, which serves as both a shipping port and a pleasure boat haven, is not directly exposed to waves from the open ocean. It is proposed that a floating breakwater be used to protect a small-boat marina which is being developed within the eastern portion of the harbor (East Bay). According to data supplied by the U. S. Army Engineer District, Seattle, the proposed marina is exposed to short-period wind waves from the northwest clockwise to the north. The significant waves from the exposed directions range up to 2.8 sec in period and 2.0 ft in height.

2. Although model tests conducted at the U. S. Army Engineer Waterways Experiment Station (WES)[1,2] and the University of Washington[3] have provided data on the wave-attenuating capability of floating structures composed of tires or spheres, one type of twin-pontoon float, and one rectangular float, none of this information is directly applicable to the East Bay Marina design. Also, it was not thought that the wave-attenuating capabilities of the East Bay Marina structures could be analytically[4] predicted with sufficient accuracy. Therefore, it was decided that a site-specific hydraulic model study offered the best means

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* A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 3.

of accurately and reliably comparing the performance of potential floating breakwater plans.

Purpose and Approach of Model Study

3. The purpose of the study was twofold. Initially, it was desired to determine the wave-attenuating properties of four floating breakwater cross sections. This was to be accomplished by two-dimensional (2-D) flume tests for a selected range of wave conditions. Secondly, based on results of the 2-D tests and relative costs of the structures, the best plan was selected for three-dimensional (3-D) testing. The 3-D tests investigated the combined effects of angular wave attack, structure alignment, wave transmission, and wave diffraction around the exposed end of the breakwater system.

PART II: THE MODEL

Design of Model

4. Tests were conducted at an undistorted linear scale of 1:10, model to prototype. Scale selection was determined by the absolute size of model test sections, capabilities of the available wave generator, and depth of water at the structures. Based on Froude's model law[5] and the linear scale of 1:10, the following model-to-prototype relations were derived:

Characteristics	Dimensions	Model-to-Prototype Scale Relation
Length	L	$L_r = 1:10$
Area	L^2	$A_r = L_r^2 = 1:100$
Volume	L^3	$V_r = L_r^3 = 1:1000$
Time	T	$T_r = L_r^{1/2} = 1:3.16$
Weight	F	$W_r = L_r^3(64/62.4) = 1:1026$

Dimensions are in terms of force (F), length (L), and time (T).

5. All of the model test sections were designed and constructed so that centers of gravity and buoyancy, draft, mass moments of inertia, and water-plane moments of inertia properly simulated those of the proposed prototype structures. Although the prototype structures consist of basic units of polystyrene foam covered with a concrete shell and added ballast that are posttensioned together, the model breakwaters were necessarily constructed of marine plywood, galvanized-sheet steel, and Styrofoam to allow better reproduction of the floating and dynamic characteristics of the breakwaters. Model design calculations included all the major materials used in the prototype modules, i.e., concrete, polystyrene, and posttensioning steel, but ignored the anchor chain hardware connections and the bumper material between modules because their proposed weight would be negligible in the overall consideration (also their specific details had not been designed). Once the model

structures were constructed to the desired calculated dimensions, each structure floated within 0.10 ft prototype of the proposed prototype waterline. The specific weight of water used in the model $(\gamma_w)_m$ was 62.4 pcf, whereas that of sea water $(\gamma_w)_p$ is 64.0 pcf. This variation between model and prototype values was considered in all calculations involving dynamic reproduction of the prototype structures.

6. All plans were tested with 72-ft-long anchor chains. The prototype chain, weighing 14.2 lb/lin ft, was reproduced in the model by U. S. No. 1 double-link chain which had an approximate weight of 0.14 lb/lin ft.

Test Facilities and Equipment

7. Tests were conducted in a flat-bottomed wave basin which is approximately 56 ft wide and 90 ft long (Figure 2). A semiportable wall was used to create flume widths of 10 and 12.4 ft (2-D tests) and 35.5 ft (3-D tests). Fibrous wave absorber was placed in the ends of the flume to dissipate wave energy that might otherwise be reflected from the model walls.

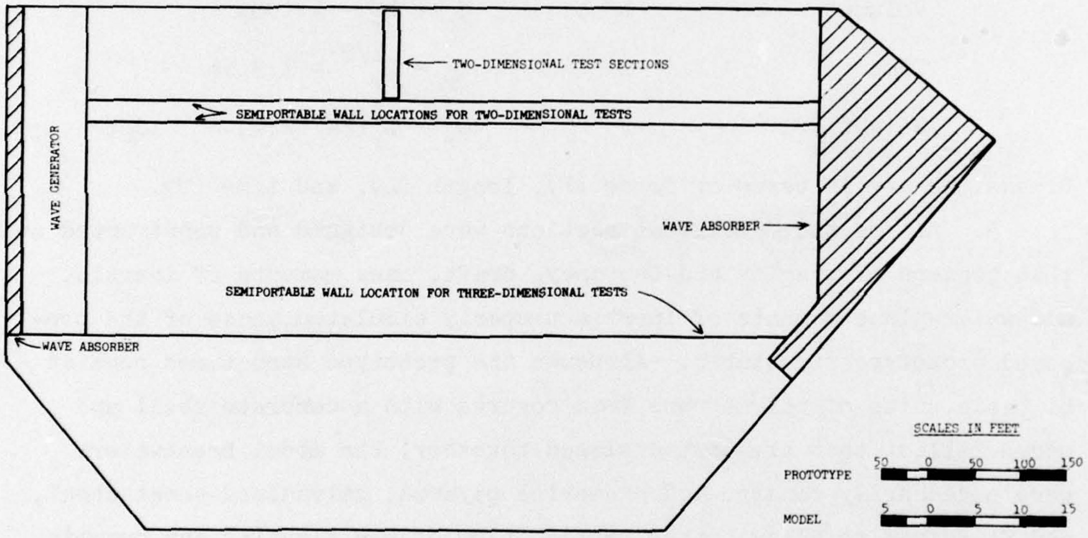

Figure 2. Model layout

8. Model waves were generated with a 35.5-ft-long,

horizontal-displacement wave generator. The horizontal movement of the plunger produced a periodic displacement of water incident to this motion. Test waves of the required characteristics were generated by varying the frequency and amplitude of the plunger motion.

9. An Automated Data Acquisition and Control System (ADACS), designed and fabricated at WES (Figure 3), was used to secure wave-height data at selected locations in the model. Basically, through the use of a minicomputer, ADACS recorded onto magnetic tape the electrical output of parallel-wire, resistance-type sensors that measured the change in water-surface elevation with respect to time. The magnetic tape output was then analyzed to obtain the required data.

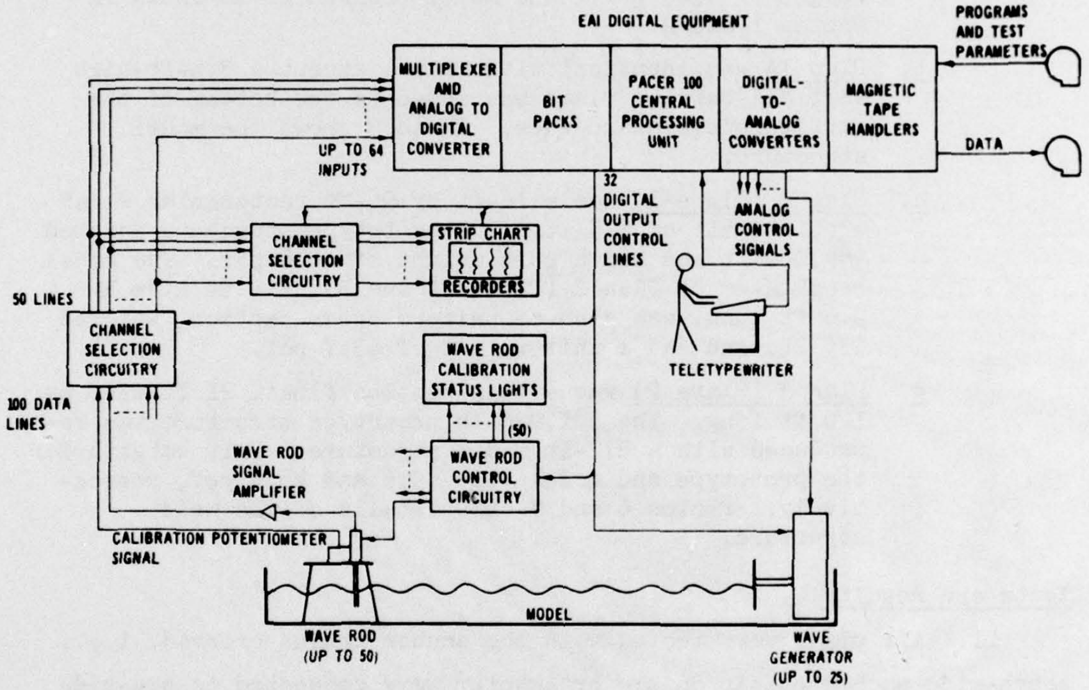

Figure 3. Automated Data Acquisition and Control System (ADACS)

PART III: TESTS AND RESULTS

Two-Dimensional Wave-Attenuation Tests

Plans tested

10. Three single-pontoon floats and one double-pontoon float were tested. Specific details of the various plans were as follows:

a. Plan 1 (Plate 1) was a 12-ft by 96-ft rectangular float with a draft of 3.5 ft. The prototype structure weighed 258,000 lb and had a unit weight of 44.8 pcf. Plan 1 was modeled with a uniform cross-sectional structure, 1.2 ft wide by 9.6 ft long, weighing 252 lb and having a unit weight of 43.7 pcf. The model breakwater is shown in Photos 1 and 2.

b. Plan 1A was identical with Plan 1 except a 3.5-ft-high vertical-barrier plate was added to the bottom of the structure's seaward face. Photo 3 shows the model structure.

c. Plan 2 (Plate 1) was a 16-ft by 96-ft rectangular float with a draft of 3.5 ft. The prototype structure weighed 344,000 lb and had a unit weight of 44.8 pcf. The model breakwater of Plan 2 (Photos 4 and 5), 1.6 ft wide by 9.6 ft long, was also of uniform cross section, weighed 335 lb, and had a unit weight of 43.7 pcf.

d. Plan 3 (Plate 2) was a twin-pontoon float, 21 ft wide by 120 ft long. The 381,226-lb prototype structure was reproduced with a 372-lb model structure. Unit weights for the prototype and model were 49.6 and 48.4 pcf, respectively. Photos 6 and 7 show details of the model structure.

Tests and results

11. All plans were tested with the anchor chains crossed, i.e., beach-side anchor points on the breakwater were connected to sea-side anchor points on the floor and sea-side anchor points on the breakwater were connected to beach-side anchor points on the floor (Plates 3 and 4). Plan 3 also was tested with the anchor chains uncrossed (Plate 5). Wave-attenuation tests were conducted in 25 ft of water (representative of high tide conditions), with wave periods of 2.5, 3.0, 3.5, 4.0, and 4.5 sec. Test waves ranged in height from 1.5 to 3.5 ft. Transmitted wave heights, which were measured at one wavelength behind the structures,

are presented in Table 1 and Photos 8-22 show the structures under wave attack for selected test conditions. Transmitted wave heights are plotted as a function of incident wave height in Plates 6-10.

12. Test results of Plans 1 and 1A afford some interesting comparisons. Based solely on the physical dimensions of the structure, it would probably be reasonable to assume that for the range of wave conditions tested, Plan 1A would exhibit a slight increase in performance relative to Plan 1. However, Plan 1A exhibited slightly higher transmitted values for the 2.5-sec wave period, slightly lower values for the 3.0-sec wave period, and almost the same values for the 3.5-sec wave period. The dynamic response of Plan 1A was significantly different from Plan 1. It was observed that for all wave conditions there was a decrease in roll and an increase in heave; consequently, the mechanism of wave transmission was fundamentally different, thus accounting for the variations in transmitted heights. As shown in Plate 7, the 3.0-sec wave period produced lower transmitted heights than the 2.5-sec wave period. Based on observations, this decrease seems to result from wave components generated by heave and sway motions being almost 180° out of phase and tending to cancel each other.

13. Since Plans 1 and 2 were both single-pontoon floats having widths of 12 ft (Plan 1) and 16 ft (Plan 2), it was expected that Plan 2 would generally yield somewhat lower transmitted wave heights than Plan 1. As evidenced in Table 1 and Plates 6 and 8, there is a consistent trend of Plan 2 exhibiting an increase in performance relative to Plan 1.

14. Referring to Table 1 and Plates 6-10, there are several points which merit discussion. Comparing Plan 3 test results, it is interesting to note that both anchoring arrangements gave almost identical values for the 2.5- and 3.0-sec wave periods; however, the crossed arrangement yielded slightly lower transmitted wave heights for the 3.5- and 4.0-sec wave periods and slightly higher transmitted wave heights for the 4.5-sec wave period. The differences observed should be representative of the prototype behavior; however, a precise explanation of the physical reasons for these differences is not available. It

appeared that the anchoring arrangement had a wave period dependent effect on the amount of roll experienced by the structure and, hence, a wave period dependent effect on transmitted wave heights. For all plans tested there was a consistent trend within wave periods for transmitted wave heights to increase with increasing incident wave height except for the responses of Plan 3 to the 3-sec wave period. Upon first inspection, results of the 3-sec period appear erroneous; however, repeat tests of Plan 3 (anchor chains uncrossed, Plate 10) show that the data trends are correct. Observations of Plan 3 for both anchoring arrangements show that for a 3-sec wave period an incident wave height of 1.5 ft produces a high degree of roll. However, as the incident wave height is increased to 2.0 and 2.5 ft, progressively larger amounts of water wash across the structure and damp its rotation. The end result is that the transmitted wave heights observed for all three incident wave heights are nearly the same.

Nondimensionalization of test results

15. Even though the test results as presented in the preceding section were adequate to evaluate and compare the plans tested, it should be informative to investigate dimensionless relations among the test variables. The wave-attenuating capability of a floating breakwater (i.e., ratio of transmitted to incident wave height (H_t/H_i) is most influenced by the angle of wave attack (β), width (W) and draft of the structure (D), water depth (d), incident wave height (H_i), and wavelength (L).

$$H_t = f(\beta , W , D , d , H_i , L)$$

For $\beta = 90°$ (2-D tests) the above relation reduces to

$$H_t = f(W , D , d , H_i , L)$$

Since the tests described herein were conducted in near deepwater conditions, H_t should be essentially independent of water depth. Also, draft (D) was invariant for each plan tested. Therefore, the functional relation for H_t reduces to

$$H_t = f(W , H_i , L)$$

One possible set of dimensionless Pi terms is

$$\pi_1 = H_t/H_i = C_t$$

$$\pi_2 = W/L$$

$$\pi_3 = H_i/L$$

Correlation of the test data has been attempted by the functional relation

$$\pi_1 = f(\pi_2 , \pi_3)$$

or

$$C_t = f(W/L , H_i/L)$$

16. Values of C_t , H_i/L , and W/L are given in Table 2. As shown in Table 2, for constant values of W/L there is very little change in C_t as H_i/L varies over a relatively wide range. Plots of C_t versus W/L are given in Plates 11-15. All these data show C_t to be strongly dependent upon W/L .

Natural Period Tests

17. At the conclusion of the 2-D tests, NPS requested that tests be conducted with the structures anchored in a still-water depth of 25 ft to determine the natural periods of roll, pitch, heave, and sway for Plans 1-3. As shown in Figure 4, the motions of the structures were defined as follows:

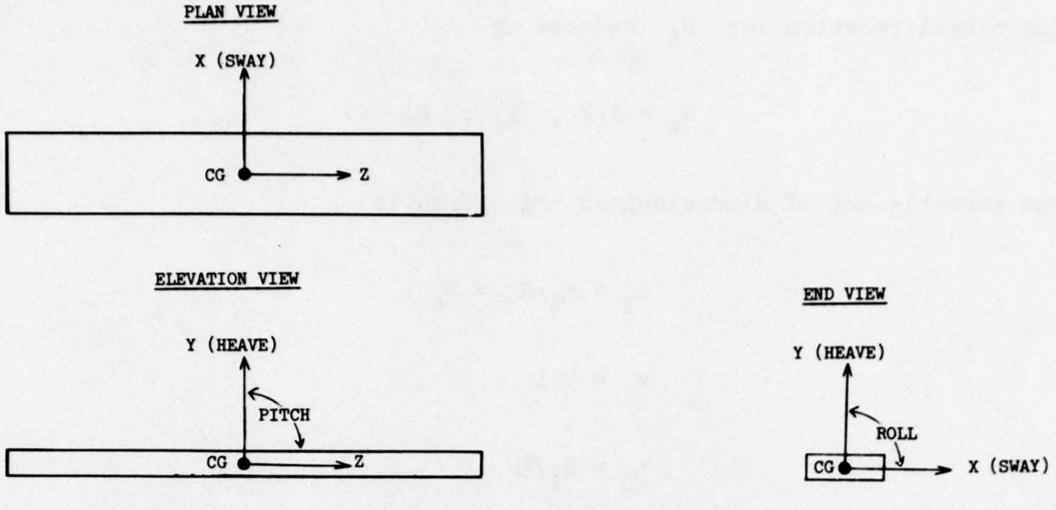

Figure 4. Definition sketch for motions of roll, pitch, heave, and sway

- a. Roll was defined as a rotation about the Z-axis in the X-Y plane.
- b. Pitch was defined as a rotation about the X-axis in the Y-Z plane.
- c. Heave was defined as a vertical motion along the Y-axis.
- d. Sway was defined as a translation in the X-Z plane along the X-axis.

18. In order to determine natural periods of roll and pitch, a torque was applied to produce rotation about the appropriate axis. The torque was then released and the unrestrained oscillations of the structures were measured. Natural periods of heave were determined by applying a uniformly distributed force in the negative Y-direction. Upon removing the force, the vertical oscillations of the structures were timed. Natural periods of sway were obtained by applying a force in the X-direction, sufficient to remove slack from the anchor chains. The force was then released and the periodic translations along the X-axis were timed. Results of these tests were as follows.

	Anchoring	Natural Period, sec, Prototype			
Plan	Arrangement	Roll	Pitch	Heave	Sway
1	Crossed	4.0	3.0	4.6	105
2	Crossed	3.7	3.7	5.8	118
3	Crossed	3.1	2.5	6.3	131
3	Uncrossed	3.1	2.5	6.3	132

Since model structures used in this study accurately reproduced the geometric and dynamic properties of the proposed prototype breakwaters, the natural period responses presented herein should accurately characterize prototype behavior.

Three-Dimensional Wave-Attenuation Tests

19. Based on results of the 2-D tests and relative costs of the plans investigated, NPS thought that with proper alignment of the structures, adequate and economical protection could be provided by Plan 1. Therefore, it was decided to initially test four configurations (alignments) of Plan 1 in the 25-ft depth, and based on results of these tests, two configurations would be selected for testing in a 10-ft depth. The 10-ft depth is representative of low tide conditions. To investigate the combined effects of transmission and diffraction, three modules of Plan 1 were used. Tests were conducted with the anchor chains crossed and the breakwater sections arranged in the following configurations: 60° linear (Plate 16), 75° linear (Plate 17), concave (Plate 18), and convex (Plate 19).

20. For all configurations, transmitted wave heights were measured directly behind the breakwaters (gages 1-3), in the vicinity of the proposed marina (gages 11 and 12), and at selected intermediate locations (gages 4-10). As shown in Plates 16-19, wave heights were not measured at the same flume locations for all configurations; however, the values obtained are directly comparable by gage number since for all configurations gages 1-3 are spaced at the same distances behind each breakwater section, gages 11 and 12 are in the same location relative to the proposed marina, and gages 4-10 are at the same relative intermediate locations with respect to the breakwater alignment.

Test results; d = 25 ft

21. Transmitted wave heights and coefficients of transmission for the 25-ft depth are presented in Table 3, and Photos 23-34 show the various configurations for selected incident wave conditions. Upon studying Table 3, it is apparent that no specific configuration yields consistently lower transmitted heights for all test conditions at all

gage locations. However, if attention is focused on the sheltered gages, i.e., gages 2, 3, 6, 7, 8, 11, and 12, the 75° linear configuration does yield consistently smaller transmission coefficients for the 2.5- and 3.5-sec waves (Table 4). This trend is particularly evident for the 3.5-sec waves, and it also applies when only gages 11 and 12 are considered (Table 5).

22. For the range of wave conditions tested, it appears that the 75° linear configuration is slightly better than the other three. However, depending upon the frequency of occurrence of various wave conditions and physical prototype constraints, any one of the four schemes tested might prove to be the best choice.

23. For all configurations and test conditions, no adverse motions of the structures were observed. Also, no violent motions of roll, pitch, heave, or sway were observed. The model sections did not simulate any type of bumper system; and even though the sections occasionally bumped each other, they were never observed to violently collide.

Test results; d = 10 ft

24. Based on test results from the 25-ft depth, it was decided to test the 75° linear and convex configurations in the 10-ft depth. Table 6 presents transmitted wave heights and coefficients of transmission. Also, the response of the configurations for selected incident wave conditions is depicted in Photos 35-40. As revealed in Table 6, neither configuration produced consistently lower transmitted heights for all test conditions at all gage locations; however, considering only the sheltered gages, the 75° linear configuration shows consistently lower average transmission coefficients for all three wave periods (Table 7). When only gages 11 and 12 are considered (Table 8), the 75° linear configuration shows a slight overall average advantage.

25. As compared with the 25-ft depth, the general trend toward slightly lower transmitted heights seems reasonable in that as the depth decreases, the relative draft of the breakwater increases and reduced transmission of wave energy is expected. As with the 25-ft depth, no violent motions of roll, pitch, heave, or sway were observed, nor were individual sections ever observed to violently collide.

PART IV: CONCLUSIONS

26\. Based on the test results and observations presented herein, it is concluded that:

a. For the 2-D wave-attenuation tests:

(1) Plan 3 exhibited the best wave attenuation of all plans tested.

(2) Uncrossing the anchor chains on Plan 3 had a negligible effect for the 2.5- and 3.0-sec wave periods; however, slightly higher transmitted heights were observed for the 3.5- and 4.0-sec wave periods and slightly lower values were obtained for the 4.5-sec wave period.

(3) Adding a vertical barrier plate to Plan 1 (Plan 1A) had little effect on wave-attenuation characteristics and, therefore, appears to be of questionable benefit in reducing transmitted energy.

(4) C_t was found to be strongly dependent on W/L and weakly dependent on H/L.

b. For the 3-D wave-attenuation tests:

(1) The 75° linear configuration appears to provide the best overall protection; however, the frequency of occurrence of various wave conditions, as well as possible constraints on the layout of harbor facilities, should be given consideration in selecting the optimum plan for construction.

(2) Relative to the 25-ft depth, the 10-ft depth generally resulted in slightly lower transmitted wave heights.

(3) For all configurations tested, individual breakwater sections were never observed to violently collide.

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Table 1

Transmitted Wave Heights

Two-Dimensional Tests of Plans 1, 1A, 2, and 3

Test Wave		Transmitted Wave Height, ft				
Period, sec	Height, ft	Plan 1	Plan 1A	Plan 2	Plan 3	Plan 3*
2.5	1.5	0.7	0.8	0.6	0.4	0.4
	2.0	0.9	1.1	0.8	0.4	0.4
	2.5	1.0	1.3	0.9	0.6	0.5
3.0	1.5	0.7	0.6	0.6	0.8	0.8
	2.0	1.0	0.9	0.8	0.7	0.8
	2.5	1.4	1.2	1.0	0.7	0.7
3.5	1.5	1.2	1.1	1.0	0.8	0.9
	2.0	1.6	1.6	1.3	1.0	1.0
	2.5	1.9	2.1	1.6	1.1	1.4
	3.0	2.3	2.4	2.0	1.4	1.6
4.0	2.0		1.8	1.6	1.5	1.6
	2.5		2.1	2.0	1.8	2.0
	3.0		2.6	2.4	2.1	2.3
	3.5		2.9	2.9	2.4	2.7
4.5	2.0				1.9	1.7
	2.5				2.3	2.1
	3.0				2.7	2.5
	3.5				3.2	3.0

---

* Tests conducted with anchor chains uncrossed.

Table 2

Two-Dimensional Tests of Plans 1, 1A, 2, and 3

Values of C_t, H_i/L, and W/L

T, sec	H_i, ft	H_t, ft	C_t	H_i/L	W/L
Plan 1					
2.5	1.5	0.7	0.47	0.047	0.38
	2.0	0.9	0.45	0.063	0.38
	2.5	1.0	0.40	0.078	0.38
3.0	1.5	0.7	0.47	0.033	0.26
	2.0	1.0	0.50	0.043	0.26
	2.5	1.4	0.56	0.054	0.26
3.5	1.5	1.2	0.80	0.024	0.19
	2.0	1.6	0.80	0.032	0.19
	2.5	1.9	0.76	0.040	0.19
	3.0	2.3	0.77	0.048	0.19
Plan 1A					
2.5	1.5	0.8	0.53	0.047	0.38
	2.0	1.1	0.55	0.063	0.38
	2.5	1.3	0.52	0.078	0.38
3.0	1.5	0.6	0.40	0.033	0.26
	2.0	0.9	0.45	0.043	0.26
	2.5	1.2	0.48	0.054	0.26
3.5	1.5	1.1	0.73	0.024	0.19
	2.0	1.6	0.80	0.032	0.19
	2.5	2.1	0.84	0.040	0.19
	3.0	2.4	0.80	0.048	0.19
4.0	2.0	1.8	0.90	0.025	0.15
	2.5	2.1	0.84	0.031	0.15
	3.0	2.6	0.87	0.038	0.15
	3.5	2.9	0.83	0.044	0.15
Plan 2					
2.5	1.5	0.6	0.40	0.047	0.50
	2.0	0.8	0.40	0.063	0.50
	2.5	0.9	0.36	0.078	0.50

(Continued)

(Sheet 1 of 3)

Table 2 (Continued)

T, sec	H_i, ft	H_t, ft	C_t	H_i/L	W/L
Plan 2 (Continued)					
3.0	1.5	0.6	0.40	0.033	0.35
	2.0	0.8	0.40	0.043	0.35
	2.5	1.0	0.40	0.054	0.35
3.5	1.5	1.0	0.67	0.024	0.26
	2.0	1.3	0.65	0.032	0.26
	2.5	1.6	0.64	0.040	0.26
	3.0	2.0	0.67	0.048	0.26
4.0	2.0	1.6	0.80	0.025	0.20
	2.5	2.0	0.80	0.031	0.20
	3.0	2.4	0.80	0.038	0.20
	3.5	2.9	0.83	0.044	0.20
Plan 3; Anchor Chains Crossed					
2.5	1.5	0.4	0.27	0.047	0.66
	2.0	0.4	0.20	0.063	0.66
	2.5	0.6	0.24	0.078	0.66
3.0	1.5	0.8	0.53	0.033	0.46
	2.0	0.7	0.35	0.043	0.46
	2.5	0.7	0.28	0.054	0.46
3.5	1.5	0.8	0.53	0.024	0.34
	2.0	1.0	0.50	0.032	0.34
	2.5	1.1	0.44	0.040	0.34
	3.0	1.4	0.47	0.048	0.34
4.0	2.0	1.5	0.75	0.025	0.26
	2.5	1.8	0.72	0.031	0.26
	3.0	2.1	0.70	0.038	0.26
	3.5	2.4	0.69	0.044	0.26
4.5	2.0	1.9	0.95	0.021	0.22
	2.5	2.3	0.92	0.026	0.22
	3.0	2.7	0.90	0.031	0.22
	3.5	3.2	0.91	0.036	0.22

(Continued)

(Sheet 2 of 3)

Table 2 (Concluded)

T, sec	H_i, ft	H_t, ft	C_t	H_i/L	W/L
Plan 3; Anchor Chains Uncrossed					
2.5	1.5	0.4	0.27	0.047	0.66
	2.0	0.4	0.20	0.063	0.66
	2.5	0.5	0.20	0.078	0.66
3.0	1.5	0.8	0.53	0.033	0.46
	2.0	0.8	0.40	0.043	0.46
	2.5	0.7	0.28	0.054	0.46
3.5	1.5	0.9	0.60	0.024	0.34
	2.0	1.0	0.50	0.032	0.34
	2.5	1.4	0.56	0.040	0.34
	3.0	1.6	0.53	0.048	0.34
4.0	2.0	1.6	0.80	0.025	0.26
	2.5	2.0	0.80	0.031	0.26
	3.0	2.3	0.77	0.038	0.26
	3.5	2.7	0.77	0.044	0.26
4.5	2.0	1.7	0.85	0.021	0.22
	2.5	2.1	0.84	0.026	0.22
	3.0	2.5	0.83	0.031	0.22
	3.5	3.0	0.86	0.036	0.22

(Sheet 3 of 3)

Table 3

Three-Dimensional Tests of Plan 1

Values of H_t and C_t; d = 25 ft

Gage Number	Configuration							
	60° Linear		75° Linear		Concave		Convex	
	H_t, ft	C_t	H_t, ft	C_t	H_t, ft	C_t	H_t, ft	C_t
T = 2.5 sec; H_i = 1.5 ft								
1	1.1	0.73	0.5	0.33	1.1	0.73	0.5	0.33
2	0.5	0.33	0.4	0.27	0.6	0.40	0.9	0.60
3	0.4	0.27	0.2	0.13	0.3	0.20	0.4	0.27
4	0.9	0.60	0.8	0.53	0.8	0.53	0.3	0.20
5	0.4	0.27	0.4	0.27	0.3	0.20	0.9	0.60
6	0.5	0.33	0.5	0.33	0.3	0.20	0.4	0.27
7	0.3	0.20	0.6	0.40	0.5	0.33	0.6	0.40
8	0.3	0.20	0.2	0.13	0.3	0.20	0.4	0.27
9	0.8	0.53	1.4	0.93	0.9	0.60	1.0	0.67
10	0.6	0.40	0.4	0.27	0.5	0.33	0.8	0.53
11	0.7	0.47	0.5	0.33	0.7	0.47	0.4	0.27
12	0.6	0.40	0.3	0.20	0.3	0.20	0.5	0.33
T = 2.5 sec; H_i = 2.0 ft								
1	1.2	0.60	0.6	0.30	1.3	0.65	0.9	0.45
2	0.6	0.30	0.5	0.25	0.7	0.35	1.1	0.55
3	0.8	0.40	0.4	0.20	0.5	0.25	0.3	0.15
4	1.4	0.70	1.1	0.55	1.2	0.60	0.6	0.30
5	0.3	0.15	0.6	0.30	0.6	0.30	1.2	0.60
6	0.7	0.35	0.4	0.20	0.3	0.15	0.5	0.25
7	0.5	0.25	0.7	0.35	0.8	0.40	0.6	0.30
8	0.6	0.30	0.2	0.10	0.5	0.25	0.3	0.15
9	1.1	0.55	1.8	0.90	1.2	0.60	1.2	0.60
10	1.0	0.50	0.5	0.25	0.8	0.40	1.2	0.60
11	0.6	0.30	0.9	0.45	1.0	0.50	0.7	0.35
12	0.7	0.35	0.5	0.25	0.5	0.25	0.9	0.45
T = 2.5 sec; H_i = 2.5 ft								
1	1.2	0.48	0.7	0.28	1.6	0.64	1.3	0.52
2	0.7	0.28	0.8	0.32	0.8	0.32	1.2	0.48
3	0.7	0.28	0.4	0.16	0.7	0.28	0.5	0.20

(Continued)

Note: Gage locations are shown in Plates 16-19. (Sheet 1 of 5)

Table 3 (Continued)

Gage Number	Configuration							
	60° Linear		75° Linear		Concave		Convex	
	H_t, ft	C_t	H_t, ft	C_t	H_t, ft	C_t	H_t, ft	C_t
T = 2.5 sec; H_i = 2.5 ft (Continued)								
4	2.1	0.84	1.5	0.60	1.9	0.76	0.9	0.36
5	0.5	0.20	1.2	0.48	0.6	0.24	1.3	0.52
6	0.7	0.28	0.5	0.20	0.5	0.20	0.4	0.16
7	0.6	0.24	0.8	0.32	0.9	0.36	0.9	0.36
8	0.8	0.32	0.5	0.20	0.8	0.32	0.5	0.20
9	1.6	0.64	2.4	0.96	1.7	0.68	1.7	0.68
10	1.2	0.48	0.8	0.32	1.0	0.40	1.4	0.56
11	0.7	0.28	1.0	0.40	1.1	0.44	1.0	0.40
12	0.8	0.32	0.7	0.28	0.7	0.28	1.2	0.48
T = 3.0 sec; H_i = 1.5 ft								
1	0.7	0.47	0.5	0.33	1.2	0.80	0.8	0.53
2	0.7	0.47	0.5	0.33	1.2	0.80	0.7	0.47
3	0.6	0.40	0.4	0.27	0.8	0.53	0.5	0.33
4	1.5	1.00	1.0	0.67	1.6	1.07	0.8	0.53
5	0.6	0.40	0.4	0.27	0.4	0.27	0.8	0.53
6	0.6	0.40	0.6	0.40	0.8	0.53	0.4	0.27
7	0.5	0.33	0.6	0.40	0.4	0.27	0.5	0.33
8	0.7	0.47	0.8	0.53	1.0	0.67	0.6	0.40
9	1.0	0.67	1.2	0.80	0.8	0.53	1.3	0.87
10	0.7	0.47	0.4	0.27	0.8	0.53	0.8	0.53
11	0.5	0.33	0.6	0.40	0.7	0.47	0.7	0.47
12	0.7	0.47	0.9	0.60	0.6	0.40	0.8	0.53
T = 3.0 sec; H_i = 2.0 ft								
1	1.0	0.50	0.8	0.40	1.5	0.75	1.2	0.60
2	0.8	0.40	0.9	0.45	1.5	0.75	1.0	0.50
3	0.6	0.30	0.9	0.45	1.2	0.60	0.7	0.35
4	1.9	0.95	1.6	0.80	1.9	0.95	0.9	0.45
5	0.7	0.35	0.8	0.40	0.5	0.25	1.2	0.60
6	0.7	0.35	1.1	0.55	1.1	0.55	0.9	0.45
7	0.7	0.35	0.8	0.40	0.5	0.25	0.9	0.45
8	0.9	0.45	1.1	0.55	1.0	0.50	0.9	0.45
9	1.5	0.75	1.6	0.80	1.2	0.60	1.7	0.85

(Continued)

Table 3 (Continued)

	Configuration							
	60° Linear		75° Linear		Concave		Convex	
Gage Number	H_t, ft	C_t	H_t, ft	C_t	H_t, ft	C_t	H_t, ft	C_t
			T = 3.0 sec; H_i = 2.0 ft (Continued)					
10	1.1	0.55	0.8	0.40	1.0	0.50	1.2	0.60
11	0.7	0.35	0.9	0.45	1.0	0.50	1.2	0.60
12	0.9	0.45	1.1	0.55	0.7	0.35	1.2	0.60
			T = 3.0 sec; H_i = 2.5 ft					
1	1.1	0.44	1.0	0.40	1.7	0.68	1.2	0.48
2	1.1	0.44	1.1	0.44	1.7	0.68	1.4	0.56
3	0.7	0.28	1.0	0.40	1.6	0.64	1.1	0.44
4	2.3	0.92	2.2	0.88	2.4	0.96	1.6	0.64
5	0.9	0.36	1.1	0.44	0.7	0.28	1.5	0.60
6	1.2	0.48	1.4	0.56	1.3	0.52	1.3	0.52
7	1.0	0.40	1.1	0.44	0.8	0.32	0.9	0.36
8	0.9	0.36	1.2	0.48	1.2	0.48	1.2	0.48
9	2.0	0.80	2.2	0.88	1.7	0.68	2.1	0.84
10	1.5	0.60	1.2	0.48	1.2	0.48	1.6	0.64
11	0.9	0.36	1.2	0.48	1.2	0.48	1.6	0.64
12	1.0	0.40	1.2	0.48	1.0	0.40	1.4	0.56
			T = 3.5 sec; H_i = 1.5 ft					
1	0.9	0.60	1.2	0.80	1.3	0.87	1.2	0.80
2	1.0	0.67	1.3	0.87	1.3	0.87	1.4	0.93
3	1.1	0.73	0.8	0.53	1.3	0.87	1.1	0.73
4	1.3	0.87	1.2	0.80	1.3	0.87	1.5	1.00
5	1.3	0.87	0.9	0.60	1.0	0.67	1.1	0.73
6	1.0	0.67	1.2	0.80	1.2	0.80	1.3	0.87
7	1.2	0.80	1.0	0.67	1.3	0.87	1.2	0.80
8	1.1	0.73	0.8	0.53	1.2	0.80	1.3	0.87
9	1.3	0.87	1.6	1.07	1.4	0.93	1.2	0.80
10	1.2	0.80	0.8	0.53	1.3	0.87	1.3	0.87
11	1.2	0.80	0.9	0.60	1.1	0.73	1.0	0.67
12	1.2	0.80	0.7	0.47	1.3	0.87	1.1	0.73

(Continued)

Table 3 (Continued)

Gage Number	Configuration							
	60° Linear		75° Linear		Concave		Convex	
	H_t, ft	C_t	H_t, ft	C_t	H_t, ft	C_t	H_t, ft	C_t
$T = 3.5$ sec; $H_i = 2.0$ ft								
1	1.2	0.60	1.5	0.75	1.6	0.80	1.6	0.80
2	1.3	0.65	1.6	0.80	1.8	0.90	1.8	0.90
3	1.4	0.70	1.3	0.65	1.8	0.90	1.4	0.70
4	1.7	0.85	1.7	0.85	1.7	0.85	2.0	1.00
5	1.7	0.85	1.4	0.70	1.4	0.70	1.4	0.70
6	1.4	0.70	1.6	0.80	1.6	0.80	1.6	0.80
7	1.6	0.80	1.4	0.70	1.8	0.90	1.6	0.80
8	1.4	0.70	1.3	0.65	1.5	0.75	1.5	0.75
9	1.8	0.90	2.1	1.05	1.9	0.95	1.6	0.80
10	1.5	0.75	1.2	0.60	1.7	0.85	1.8	0.90
11	1.6	0.80	1.5	0.75	1.4	0.70	1.4	0.70
12	1.5	0.75	1.3	0.65	1.7	0.85	1.5	0.75
$T = 3.5$ sec; $H_i = 2.5$ ft								
1	1.7	0.68	1.8	0.72	1.9	0.76	2.0	0.80
2	1.7	0.68	1.9	0.76	2.3	0.92	2.2	0.88
3	1.8	0.72	1.2	0.48	2.3	0.92	1.7	0.68
4	2.0	0.80	1.9	0.76	2.1	0.84	2.5	1.00
5	2.1	0.84	1.4	0.56	1.7	0.68	1.7	0.68
6	1.9	0.76	1.7	0.68	2.0	0.80	2.2	0.88
7	2.0	0.80	1.5	0.60	2.2	0.88	2.0	0.80
8	2.1	0.84	1.3	0.52	1.9	0.76	1.8	0.72
9	2.4	0.96	2.7	1.08	2.3	0.92	2.1	0.84
10	1.8	0.72	1.5	0.60	2.0	0.80	2.2	0.88
11	1.9	0.76	1.7	0.68	1.8	0.72	1.9	0.76
12	1.8	0.72	1.5	0.60	2.1	0.84	1.8	0.72
$T = 3.5$ sec; $H_i = 3.0$ ft								
1	2.0	0.67	2.0	0.67	2.4	0.80	2.3	0.77
2	2.0	0.67	2.2	0.73	2.8	0.93	2.5	0.83
3	2.2	0.73	1.6	0.53	2.8	0.93	2.0	0.67
4	2.4	0.80	2.4	0.80	2.6	0.87	3.0	1.00
5	2.5	0.83	1.6	0.53	2.1	0.70	2.0	0.67
6	2.3	0.77	1.9	0.63	2.4	0.80	2.4	0.80

(Continued)

Table 3 (Concluded)

Gage Number	60° Linear		75° Linear		Concave		Convex	
	H_t, ft	C_t	H_t, ft	C_t	H_t, ft	C_t	H_t, ft	C_t
$T = 3.5$ sec; $H_i = 3.0$ ft (Continued)								
7	2.4	0.80	1.9	0.63	2.6	0.87	2.3	0.77
8	2.3	0.77	1.4	0.47	2.3	0.77	2.2	0.73
9	2.8	0.93	3.1	1.03	2.8	0.93	2.5	0.83
10	2.3	0.77	1.9	0.63	2.5	0.83	2.4	0.80
11	2.2	0.73	2.0	0.67	2.1	0.70	2.2	0.73
12	2.2	0.73	1.9	0.63	2.6	0.87	2.1	0.70

(Sheet 5 of 5)

Table 4

Three-Dimensional Tests of Plan 1

Values of H_t and C_t Obtained by Averaging Results of Gages 2, 3, 6, 7, 8, 11, and 12; d = 25 ft

Test Wave		Configuration							
		60° Linear		75° Linear		Concave		Convex	
Period sec	Height ft	H_t, ft	C_t	H_t, ft	C_t	H_t, ft	C_t	H_t, ft	C_t
2.5	1.5	0.5	0.33	0.4	0.27	0.4	0.27	0.5	0.33
	2.0	0.6	0.30	0.5	0.25	0.6	0.30	0.6	0.30
	2.5	0.7	0.28	0.7	0.28	0.8	0.32	0.8	0.32
Average C_t			0.30		0.27		0.30		0.32
3.0	1.5	0.6	0.40	0.6	0.40	0.8	0.53	0.6	0.40
	2.0	0.8	0.40	1.0	0.50	1.0	0.50	1.0	0.50
	2.5	1.0	0.40	1.2	0.48	1.3	0.52	1.3	0.52
Average C_t			0.40		0.46		0.52		0.47
3.5	1.5	1.1	0.73	1.0	0.67	1.2	0.80	1.2	0.80
	2.0	1.5	0.75	1.4	0.70	1.7	0.85	1.5	0.75
	2.5	1.9	0.76	1.5	0.60	2.1	0.84	1.9	0.76
	3.0	2.2	0.73	1.8	0.60	2.5	0.83	2.2	0.73
Average C_t			0.74		0.64		0.83		0.76
Average C_t for all periods			0.48		0.46		0.55		0.52

Note: Gage locations are shown in Plates 16-19.

Table 5

Three-Dimensional Tests of Plan 1

Values of C_t Obtained by Averaging Results of Gages 11 and 12; d = 25 ft

Test Wave		Configuration			
		60° Linear	75° Linear	Concave	Convex
Period sec	Height ft	C_t	C_t	C_t	C_t
2.5	1.5	0.44	0.27	0.34	0.30
	2.0	0.33	0.35	0.38	0.40
	2.5	0.30	0.34	0.36	0.44
Average C_t		0.36	0.32	0.36	0.38
3.0	1.5	0.40	0.50	0.44	0.50
	2.0	0.40	0.50	0.43	0.60
	2.5	0.38	0.48	0.44	0.60
Average C_t		0.39	0.49	0.44	0.57
3.5	1.5	0.80	0.54	0.80	0.70
	2.0	0.78	0.70	0.78	0.73
	2.5	0.74	0.64	0.78	0.74
	3.0	0.73	0.65	0.79	0.72
Average C_t		0.76	0.63	0.79	0.72
Average C_t for all periods		0.50	0.48	0.53	0.56

Note: Gage locations are shown in Plates 16-19.

Table 6

Three-Dimensional Tests of Plan 1

Values of H_t and C_t; d = 10 ft

Gage Number	Configuration			
	75° Linear		Convex	
	H_t, ft	C_t	H_t, ft	C_t
T = 2.5 sec; H_i = 1.5 ft				
1	0.5	0.33	0.6	0.40
2	0.4	0.27	0.9	0.60
3	0.3	0.20	0.3	0.20
4	0.8	0.53	0.4	0.27
5	0.4	0.27	1.0	0.67
6	0.4	0.27	0.7	0.47
7	0.6	0.40	0.3	0.20
8	0.3	0.20	0.2	0.13
9	1.1	0.73	0.7	0.47
10	0.5	0.33	0.9	0.60
11	0.6	0.40	0.3	0.20
12	0.5	0.33	0.4	0.27
T = 2.5 sec; H_i = 2.0 ft				
1	0.7	0.35	0.9	0.45
2	0.5	0.25	1.4	0.70
3	0.5	0.25	0.4	0.20
4	1.0	0.50	0.8	0.40
5	0.7	0.35	1.4	0.70
6	0.5	0.25	0.9	0.45
7	0.8	0.40	0.6	0.30
8	0.4	0.20	0.4	0.20
9	1.8	0.90	1.0	0.50
10	0.4	0.20	1.2	0.60
11	0.8	0.40	0.8	0.40
12	0.7	0.35	0.8	0.40
T = 2.5 sec; H_i = 2.5 ft				
1	1.0	0.40	1.2	0.48
2	0.6	0.24	1.7	0.68
3	0.8	0.32	0.6	0.24
4	1.6	0.64	1.1	0.44
5	1.2	0.48	2.1	0.84
6	0.6	0.24	0.8	0.32
7	0.9	0.36	1.2	0.48
8	0.4	0.16	0.5	0.20
9	2.7	1.08	1.4	0.56
10	1.2	0.48	1.7	0.68
11	1.3	0.52	1.0	0.40
12	0.7	0.28	1.2	0.48
T = 3.0 sec; H_i = 1.5 ft				
1	0.4	0.27	0.9	0.60
2	0.5	0.33	0.4	0.27
3	0.3	0.20	0.4	0.27
4	0.8	0.53	0.5	0.33
5	0.5	0.33	0.7	0.47
6	0.6	0.40	0.4	0.27
7	0.6	0.40	0.6	0.40
8	0.4	0.27	0.8	0.53
9	1.3	0.87	1.0	0.67
10	0.6	0.40	0.3	0.20
11	0.6	0.40	0.8	0.53
12	0.8	0.53	0.6	0.40
T = 3.0 sec; H_i = 2.0 ft				
1	0.8	0.40	1.3	0.65
2	0.8	0.40	0.9	0.45
3	0.5	0.25	0.6	0.30
4	1.0	0.50	1.0	0.50
5	0.9	0.45	1.2	0.60
6	0.9	0.45	0.7	0.35
7	0.7	0.35	0.7	0.35
8	0.6	0.30	0.8	0.40
9	1.8	0.90	1.5	0.75
10	0.6	0.30	0.5	0.25
11	0.9	0.45	1.2	0.60
12	0.9	0.45	0.8	0.40

(Continued)

Table 6 (Concluded)

Gage Number	Configuration			
	75° Linear		Convex	
	H_t, ft	C_t	H_t, ft	C_t
T = 3.0 sec; H_i = 2.5 ft				
1	0.7	0.28	1.7	0.68
2	1.1	0.44	1.4	0.56
3	0.8	0.32	0.7	0.28
4	1.7	0.68	1.2	0.48
5	1.2	0.48	1.4	0.56
6	1.1	0.44	1.2	0.48
7	0.9	0.36	1.0	0.40
8	0.8	0.32	1.1	0.44
9	2.4	0.96	1.9	0.76
10	0.9	0.36	0.8	0.32
11	1.1	0.44	1.6	0.64
12	1.1	0.44	1.0	0.40
T = 3.5 sec; H_i = 1.5 ft				
1	0.6	0.40	0.8	0.53
2	0.8	0.53	1.1	0.73
3	0.7	0.47	0.7	0.47
4	1.2	0.80	1.4	0.93
5	0.9	0.60	1.0	0.67
6	1.1	0.73	1.0	0.67
7	0.5	0.33	0.9	0.60
8	0.9	0.60	0.9	0.60
9	1.3	0.87	1.4	0.93
10	0.9	0.60	0.8	0.53
11	0.8	0.53	0.8	0.53
12	0.9	0.60	0.8	0.53
T = 3.5 sec; H_i = 2.0 ft				
1	0.9	0.45	1.3	0.65
2	1.1	0.55	1.5	0.75
3	1.0	0.50	1.0	0.50
4	1.7	0.85	1.8	0.90
5	1.3	0.65	1.3	0.65
6	1.3	0.65	1.2	0.60
7	0.7	0.35	1.1	0.55
T = 3.5 sec; H_i = 2.0 ft (Continued)				
8	1.1	0.55	1.1	0.55
9	1.7	0.85	1.8	0.90
10	1.2	0.60	1.0	0.50
11	1.1	0.55	1.1	0.55
12	1.1	0.55	1.0	0.50
T = 3.5 sec; H_i = 2.5 ft				
1	1.3	0.52	1.3	0.52
2	1.4	0.56	2.0	0.80
3	1.3	0.52	1.2	0.48
4	2.2	0.88	2.0	0.80
5	1.5	0.60	1.6	0.64
6	1.7	0.68	1.6	0.64
7	1.0	0.40	1.4	0.56
8	1.3	0.52	1.2	0.48
9	2.1	0.84	2.2	0.88
10	1.4	0.56	1.2	0.48
11	1.4	0.56	1.5	0.60
12	1.2	0.48	1.2	0.48
T = 3.5 sec; H_i = 3.0 ft				
1	1.6	0.53	1.5	0.50
2	1.7	0.57	2.5	0.83
3	1.6	0.53	1.6	0.53
4	2.6	0.87	2.5	0.83
5	1.8	0.60	2.0	0.67
6	1.8	0.60	1.9	0.63
7	1.1	0.37	1.6	0.53
8	1.5	0.50	1.5	0.50
9	2.6	0.87	2.5	0.83
10	1.8	0.60	1.7	0.57
11	1.5	0.50	1.9	0.63
12	1.5	0.50	1.4	0.47

Note: Gage locations are shown in Plates 17 and 19.

Table 7

Three-Dimensional Tests of Plan 1

Values of H_t and C_t Obtained by Averaging Results of Gages 2, 3, 6, 7, 8, 11, and 12; d = 10 ft

Test Wave		Configuration			
		75° Linear		Convex	
Period sec	Height ft	H_t, ft	C_t	H_t, ft	C_t
2.5	1.5	0.4	0.27	0.4	0.27
	2.0	0.6	0.30	0.8	0.40
	2.5	0.8	0.32	1.0	0.40
Average C_t			0.30		0.36
3.0	1.5	0.5	0.33	0.6	0.40
	2.0	0.8	0.40	0.8	0.40
	2.5	1.0	0.40	1.1	0.44
Average C_t			0.38		0.41
3.5	1.5	0.8	0.53	0.9	0.60
	2.0	1.1	0.55	1.1	0.55
	2.5	1.3	0.52	1.4	0.56
	3.0	1.5	0.50	1.8	0.60
Average C_t			0.53		0.58
Average C_t for all periods			0.40		0.45

Note: Gage locations are shown in Plates 17 and 19.

Table 8

Three-Dimensional Tests of Plan 1

Values of C_t Obtained by Averaging Results of Gages 11 and 12; d = 10 ft

Test Wave Period sec	Test Wave Height ft	Configuration 75° Linear, C_t	Configuration Convex, C_t
2.5	1.5	0.40	0.27
	2.0	0.40	0.40
	2.5	0.40	0.44
Average C_t		0.40	0.37
3.0	1.5	0.47	0.47
	2.0	0.45	0.50
	2.5	0.44	0.52
Average C_t		0.45	0.50
3.5	1.5	0.60	0.53
	2.0	0.55	0.55
	2.5	0.52	0.56
	3.0	0.50	0.57
Average C_t		0.54	0.55
Average C_t for all periods		0.46	0.47

Note: Gage locations are shown in Plates 17 and 19.

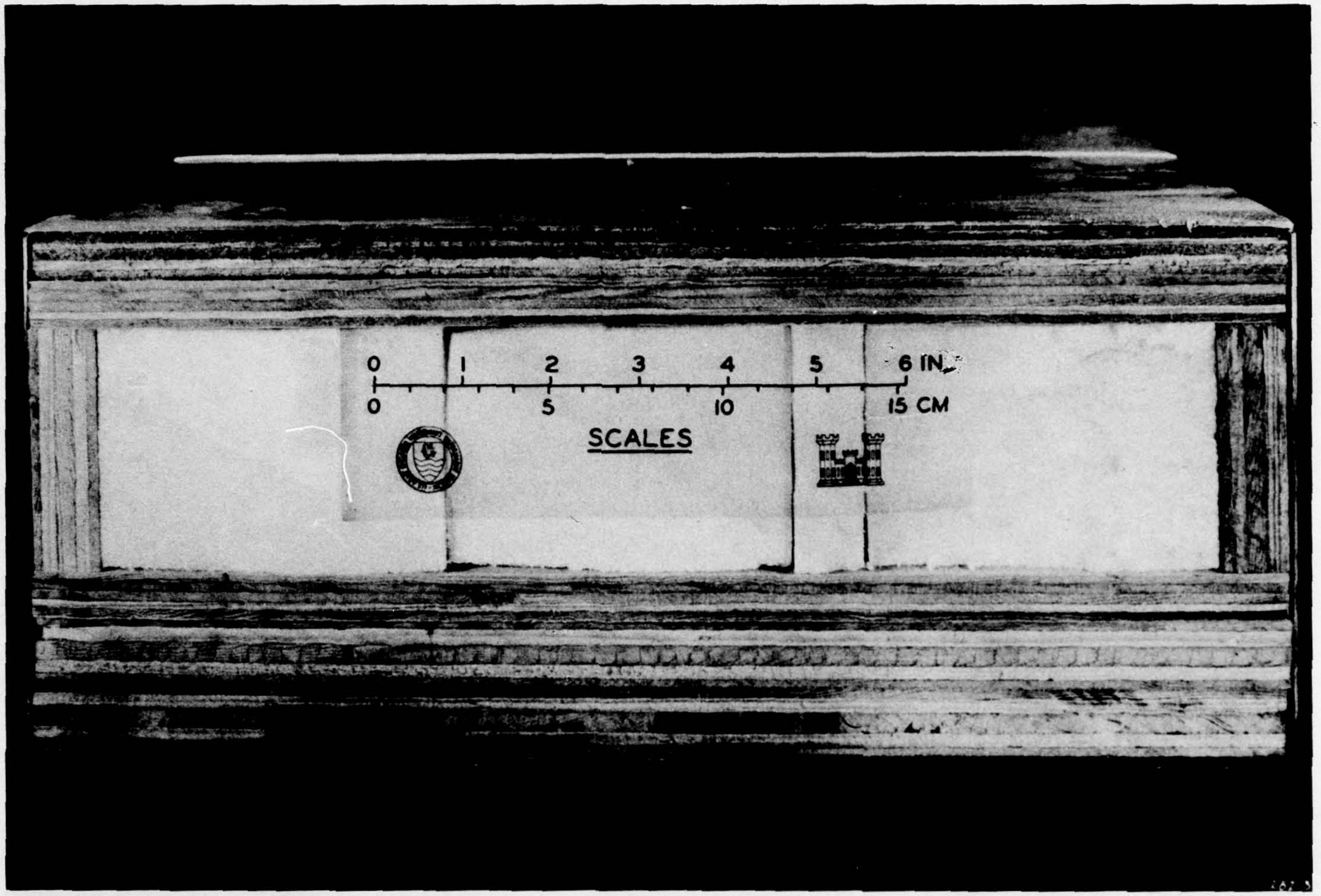


Photo 1. End view of Plan 1

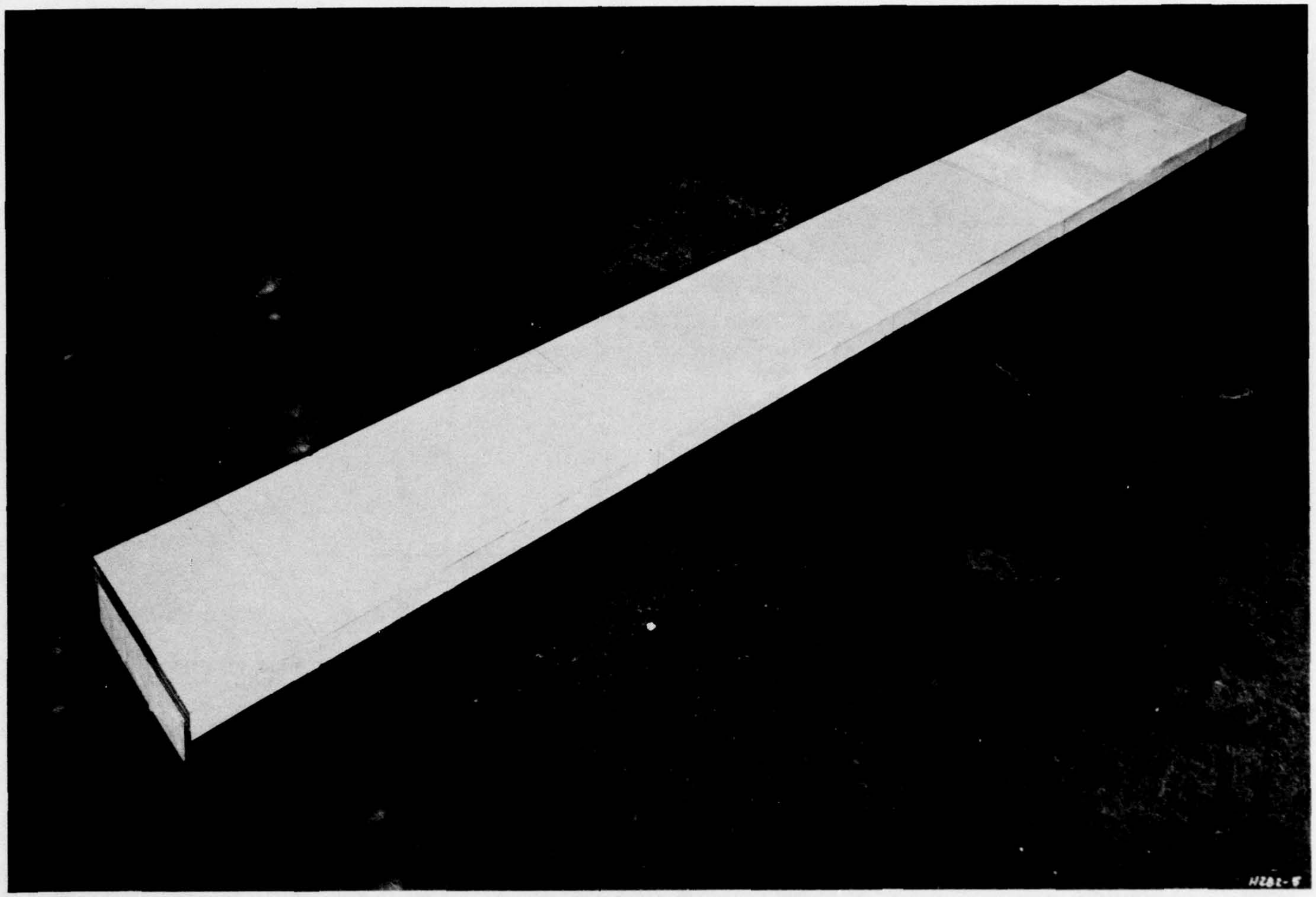


Photo 2. Perspective view of Plan 1

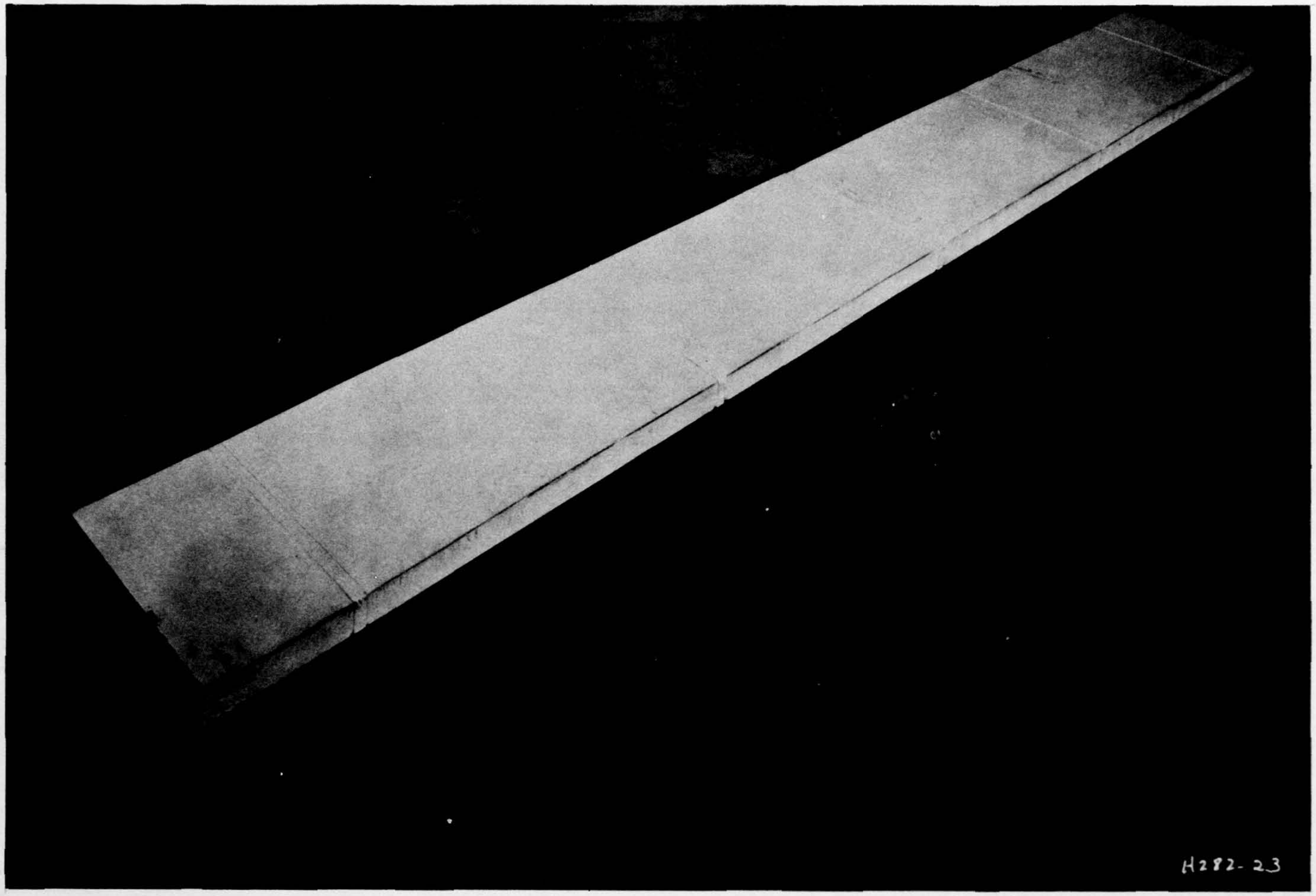


Photo 3. Perspective view of Plan 1A

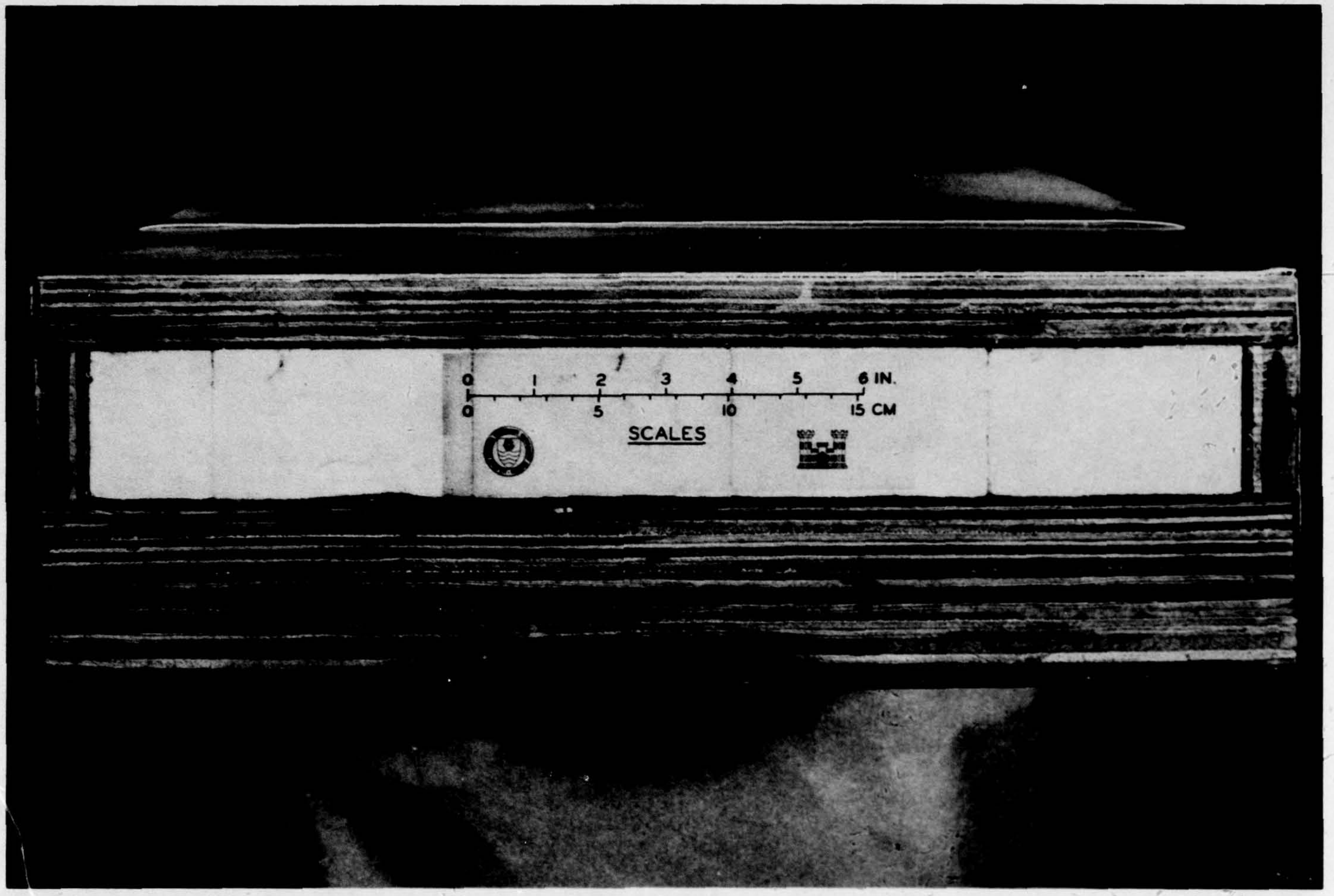


Photo 4. End view of Plan 2

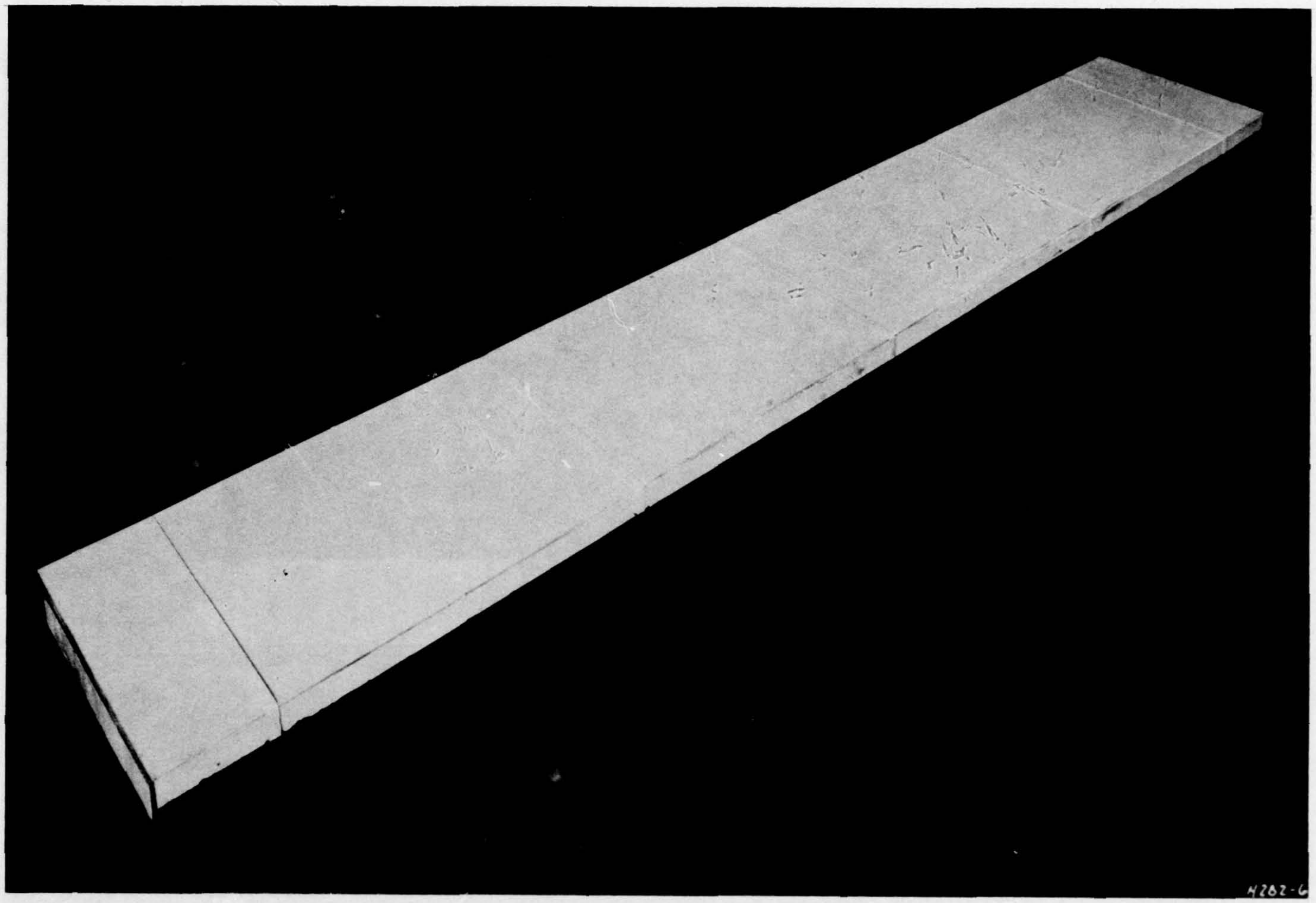


Photo 5. Perspective view of Plan 2

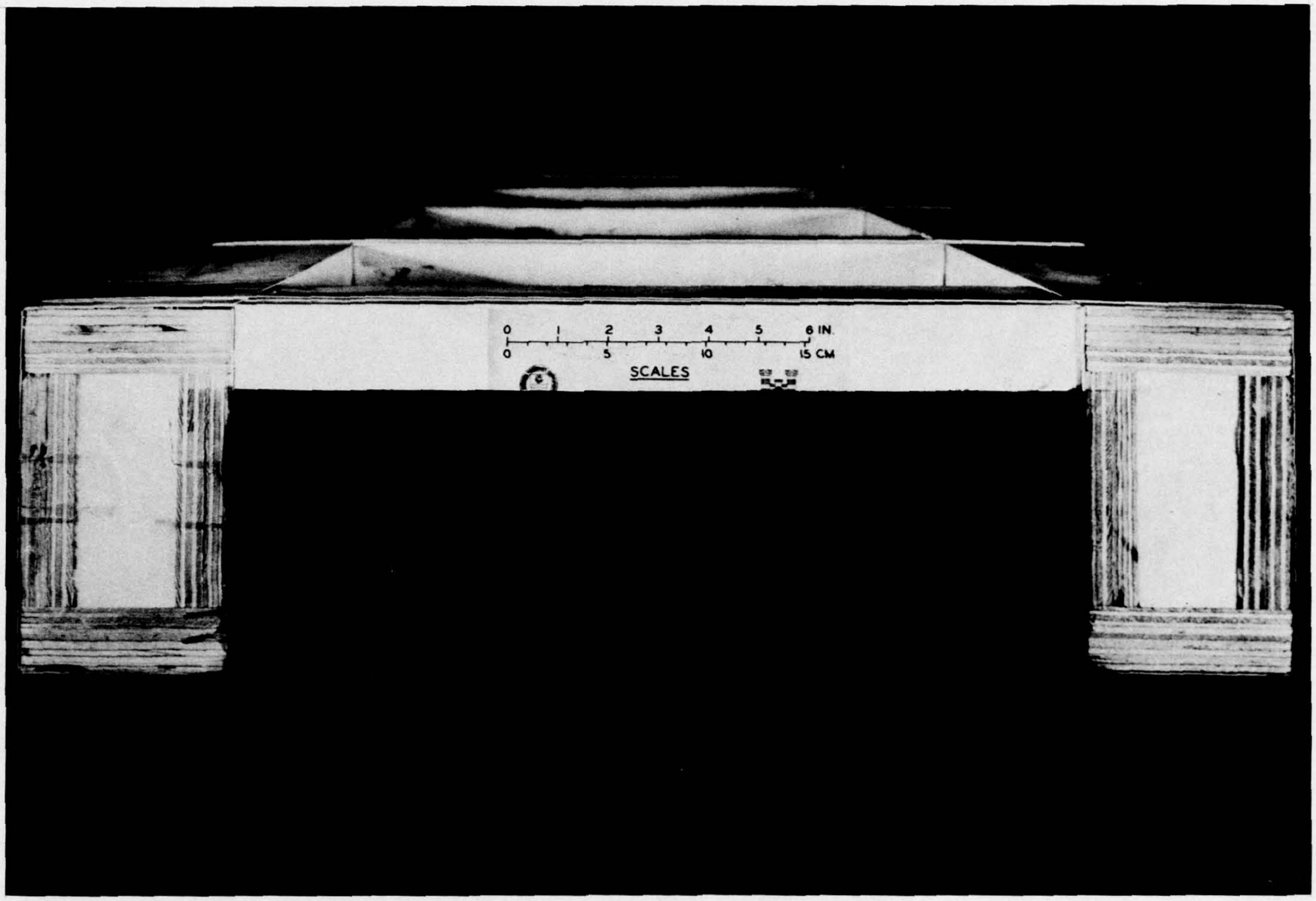


Photo 6. End view of Plan 3

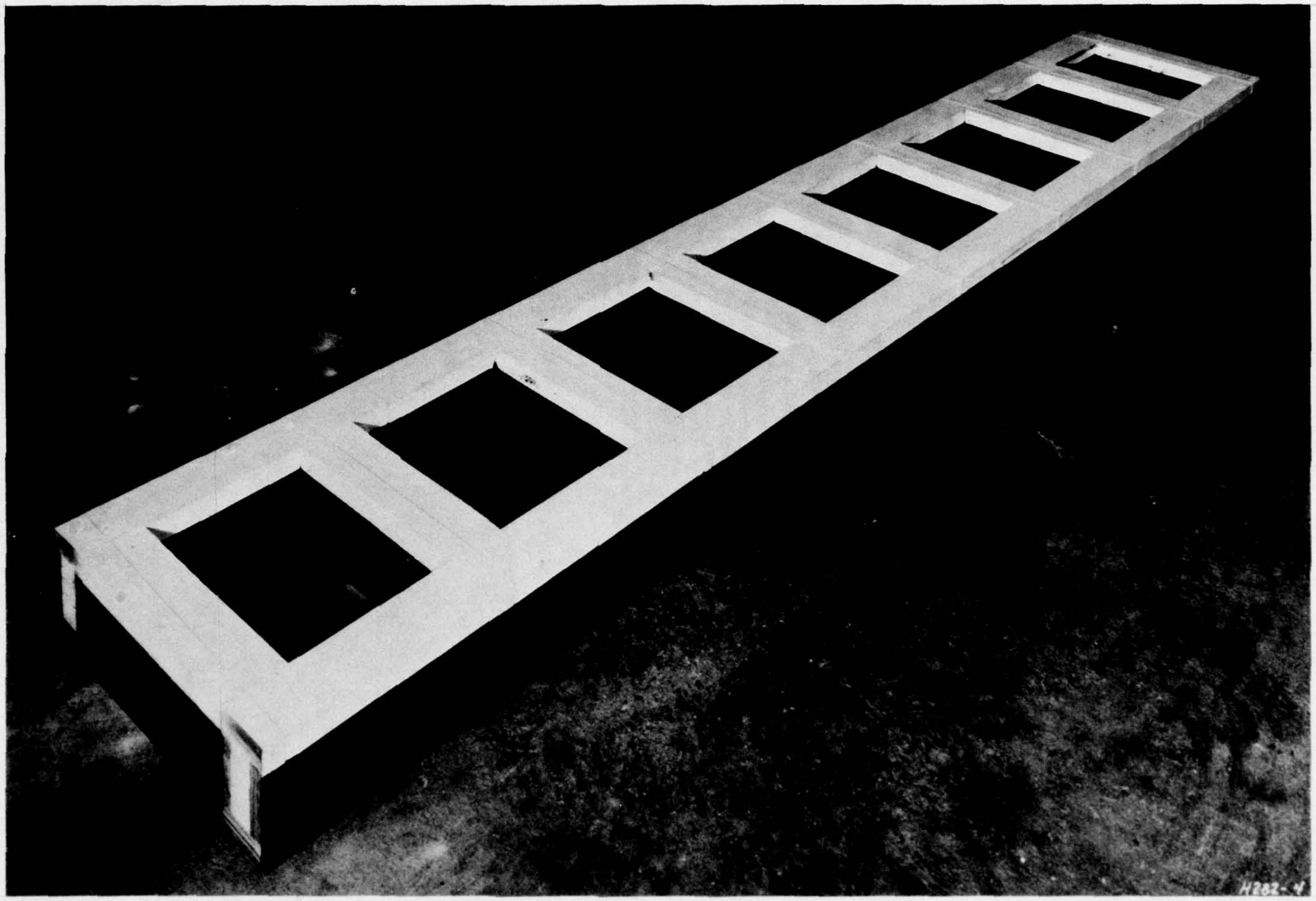


Photo 7. Perspective view of Plan 3

Photo 8. Overhead view of Plan 1 under attack of 2.5-sec, 2.0-ft waves

Photo 9. Overhead view of Plan 1 under attack of 3.0-sec, 2.0-ft waves

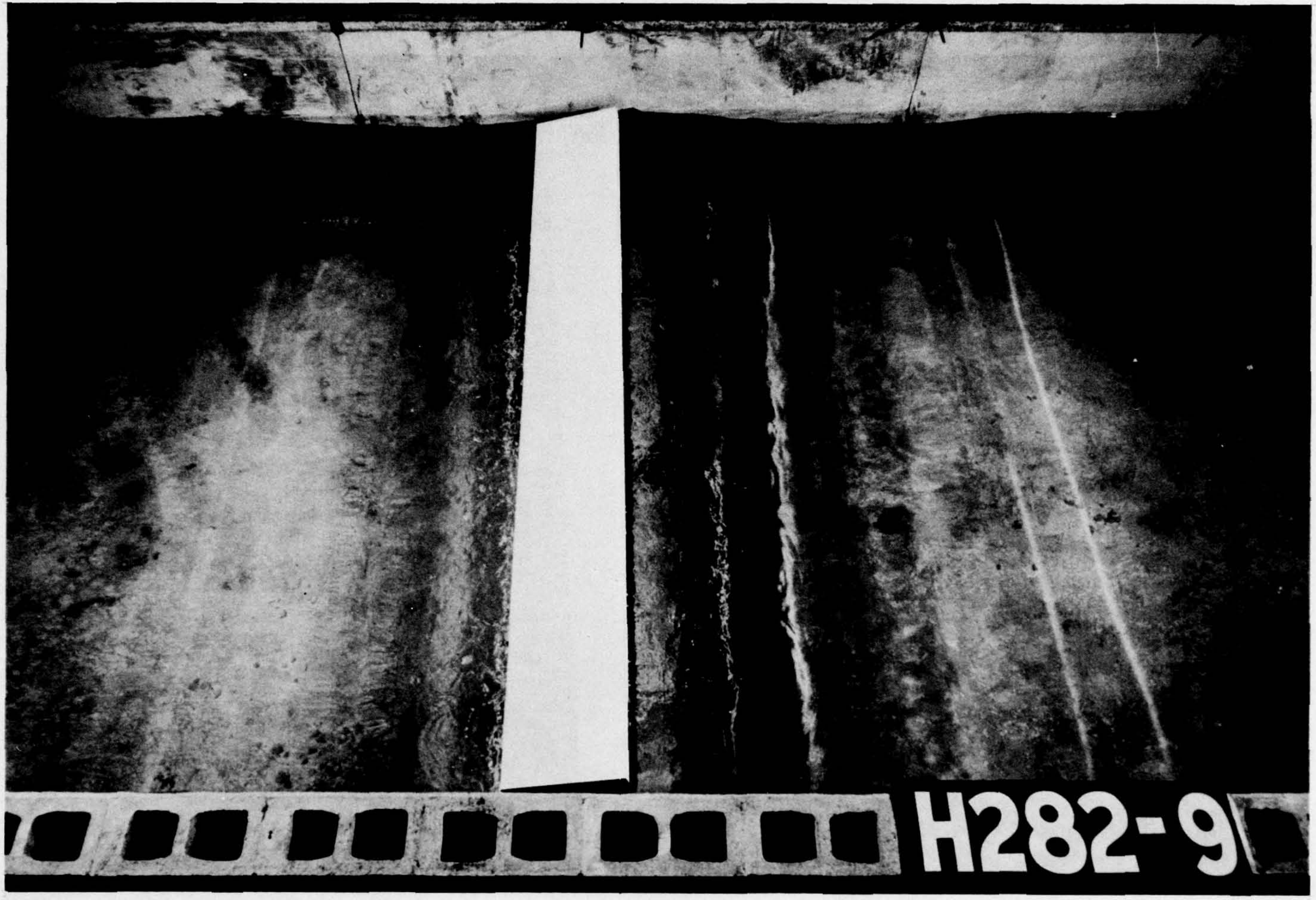


Photo 10. Overhead view of Plan 1 under attack of 3.5-sec, 2.5-ft waves

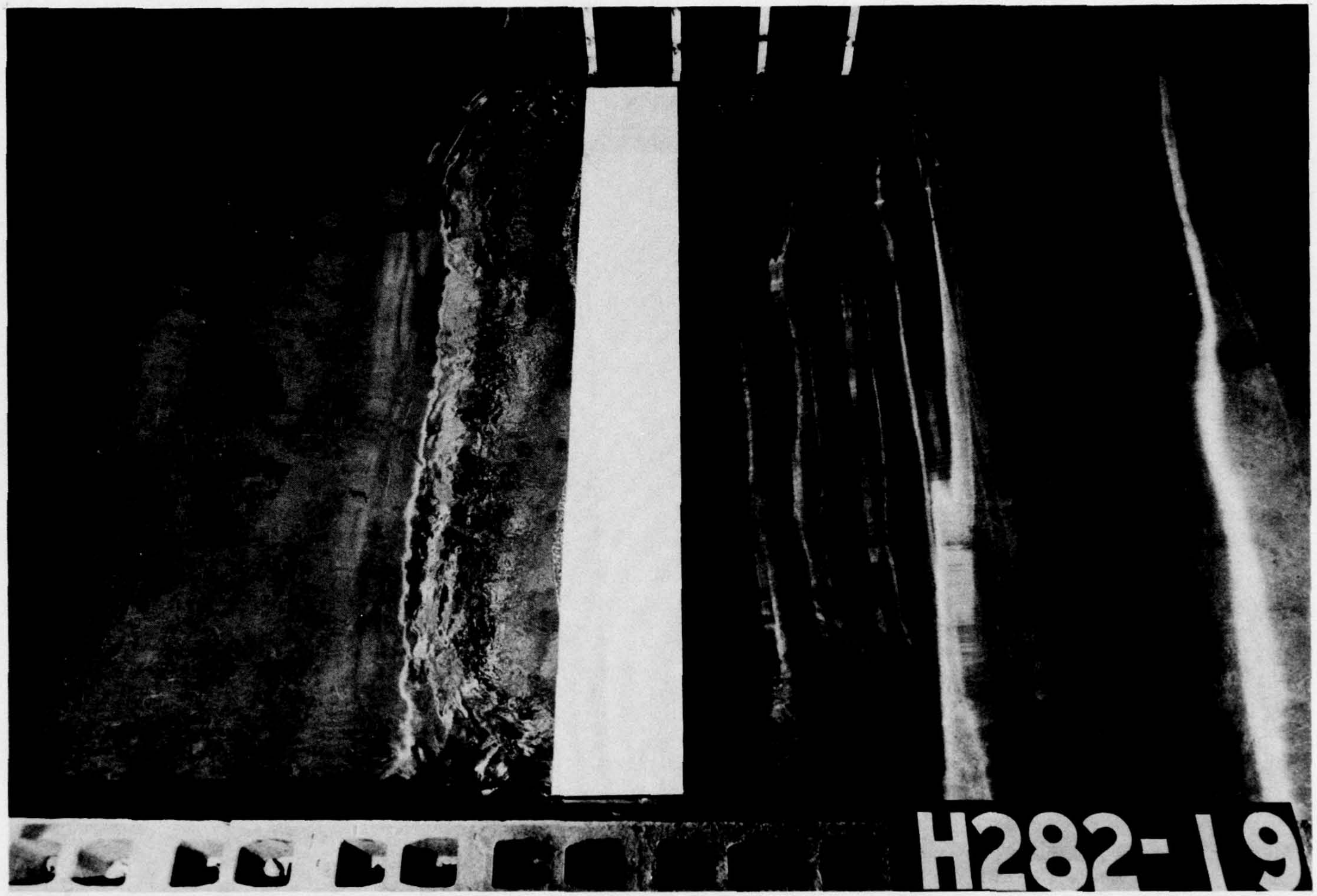


Photo 11. Overhead view of Plan 1A under attack of 2.5-sec, 2.0-ft waves

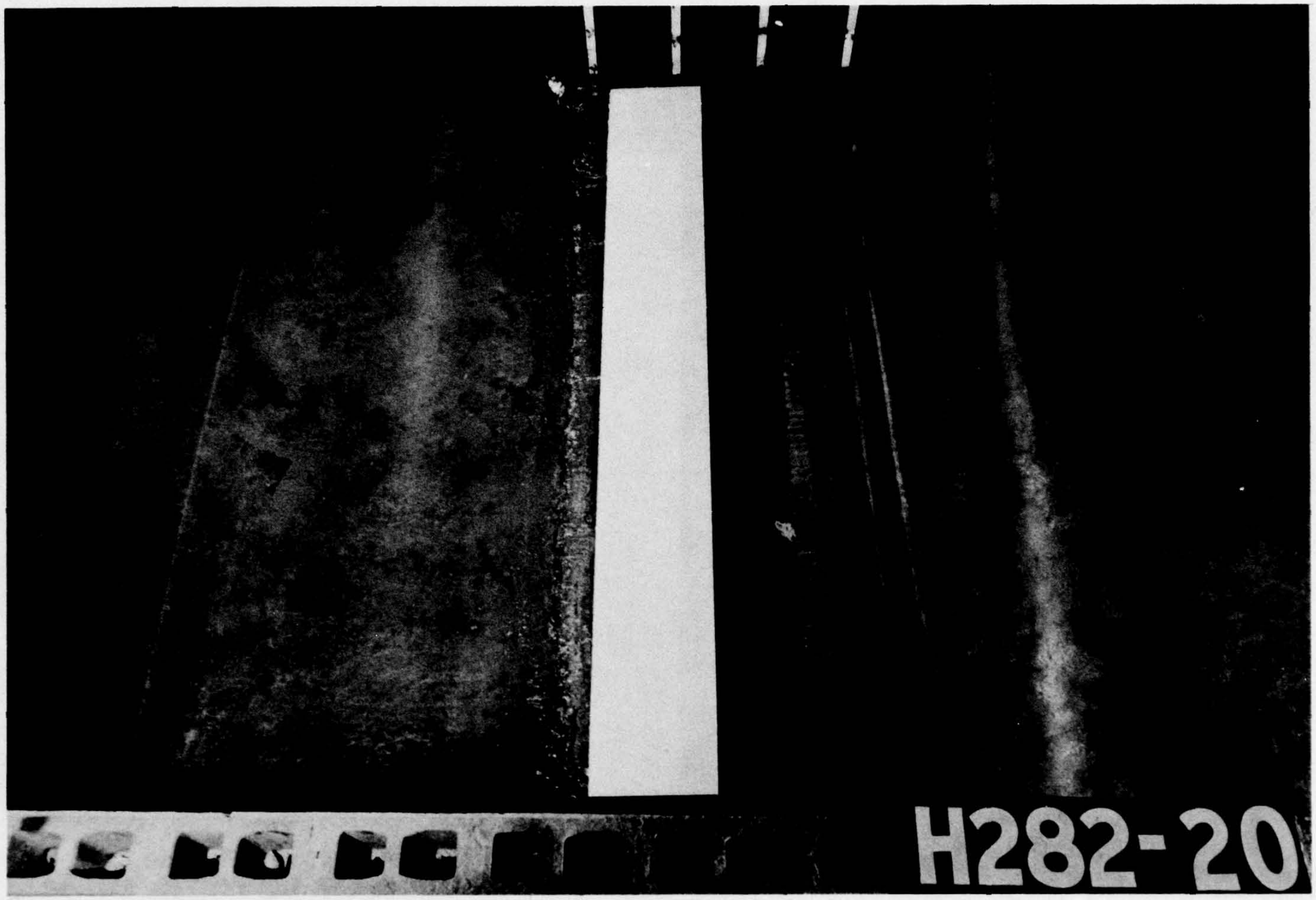


Photo 12. Overhead view of Plan 1A under attack of 3.0-sec, 2.0-ft waves

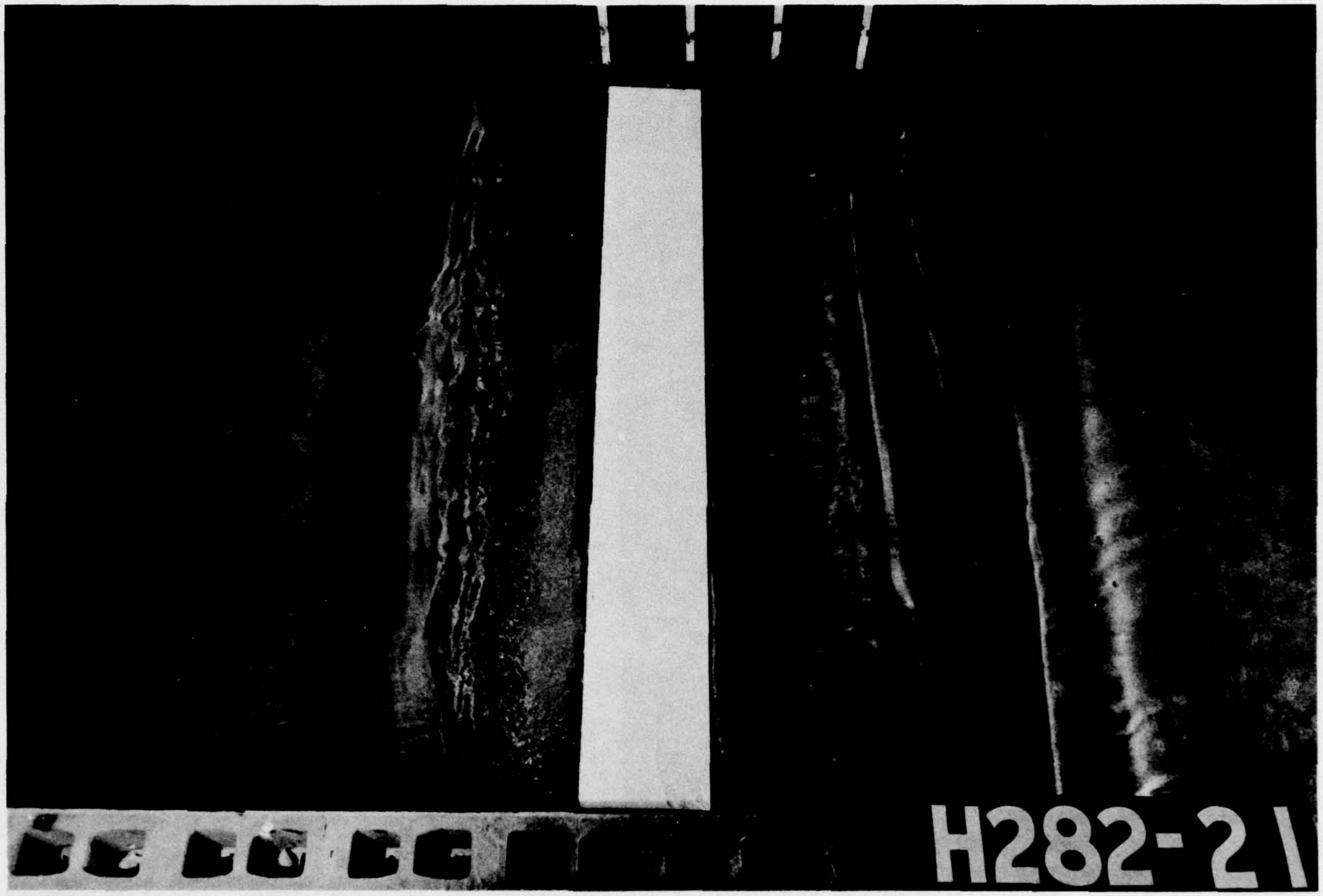


Photo 13. Overhead view of Plan 1A under attack of 3.5-sec, 2.5-ft waves

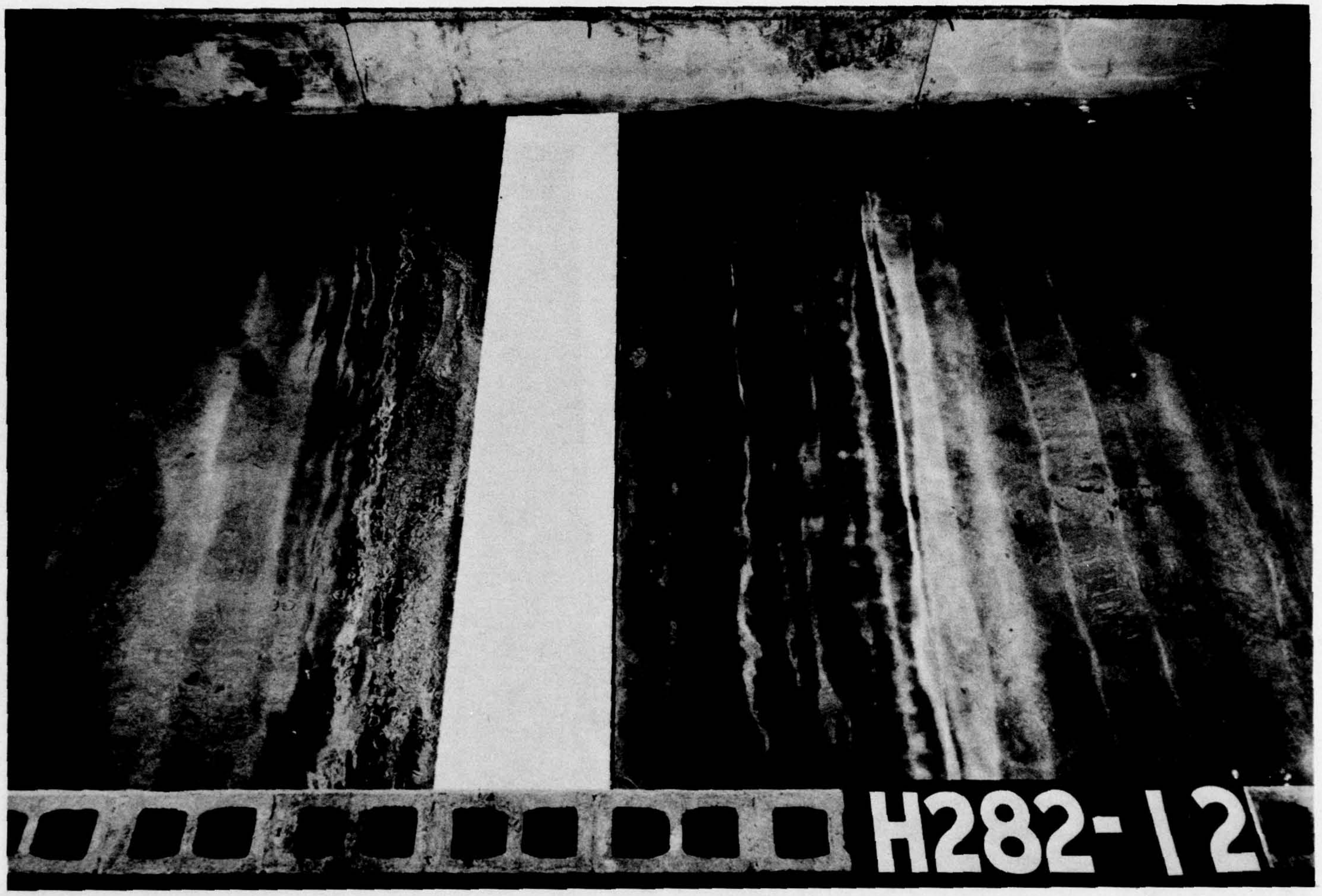


Photo 14. Overhead view of Plan 2 under attack of 2.5-sec, 2.0-ft waves

Photo 15. Overhead view of Plan 2 under attack of 3.0-sec, 2.0-ft waves

Photo 16. Overhead view of Plan 2 under attack of 3.5-sec, 2.5-ft waves

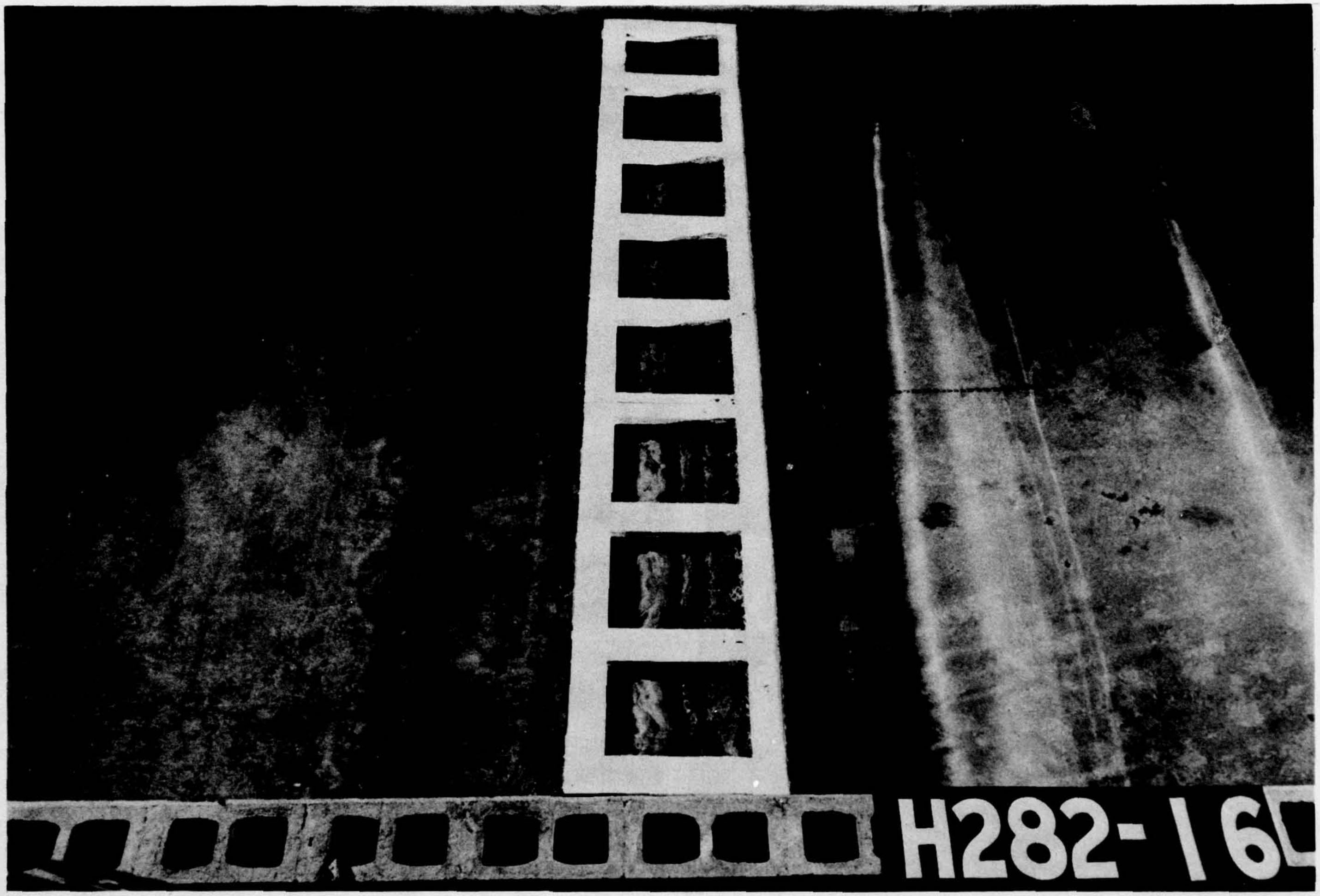


Photo 17. Overhead view of Plan 3 under attack of 2.5-sec, 2.0-ft waves with anchor chains crossed

Photo 18. Overhead view of Plan 3 under attack of 3.0-sec, 2.0-ft waves with anchor chains crossed

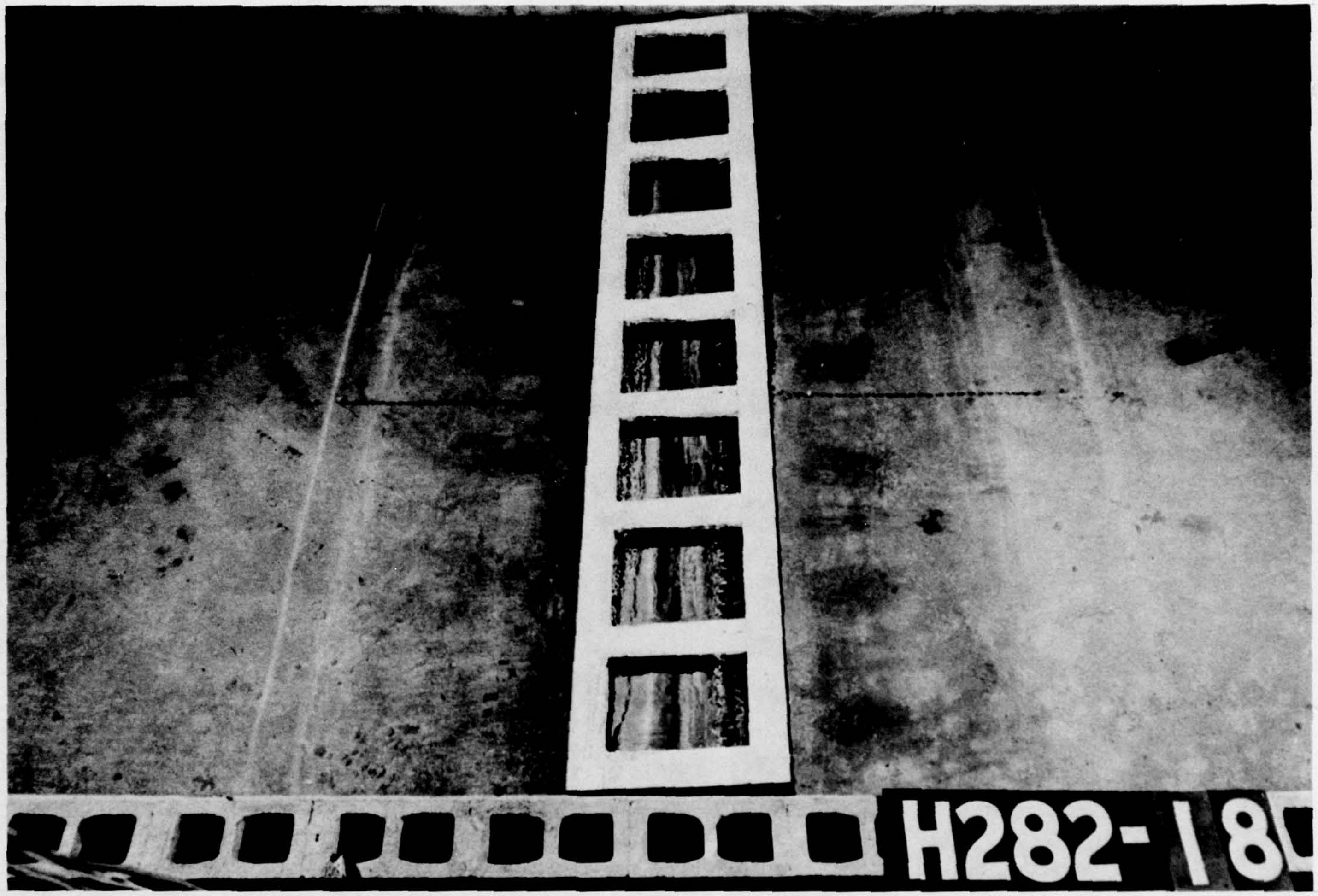


Photo 19. Overhead view of Plan 3 under attack of 3.5-sec, 2.5-ft waves with anchor chains crossed

Photo 20. Overhead view of Plan 3 under attack of 2.5-sec, 2.0-ft waves with anchor chains uncrossed

Photo 21. Overhead view of Plan 3 under attack of 3.0-sec, 2.0-ft waves with anchor chains uncrossed

Photo 22. Overhead view of Plan 3 under attack of 3.5-sec, 2.5-ft waves with anchor chains uncrossed

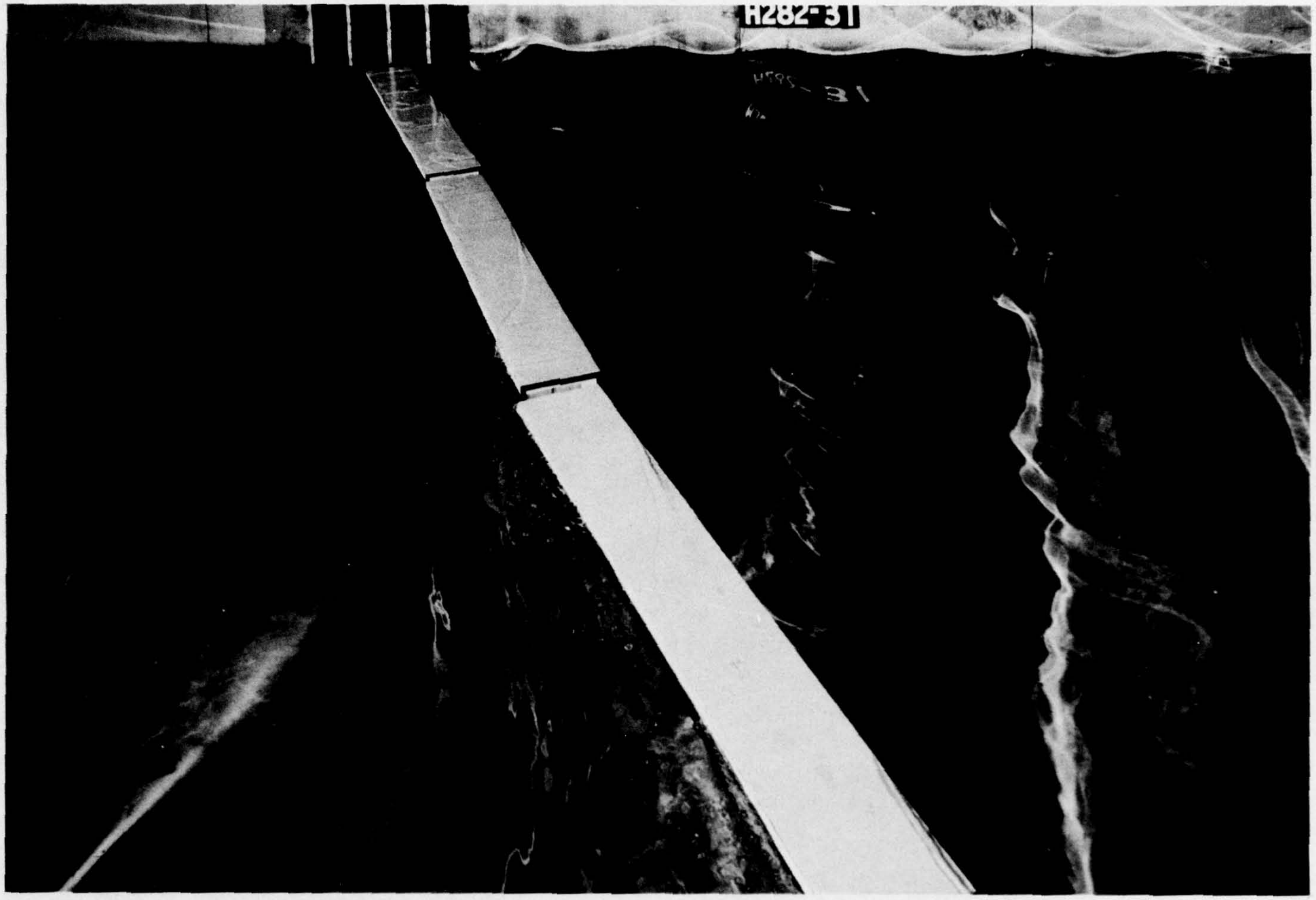


Photo 23. Overhead view of Plan 1 in the 60° linear configuration under attack of 2.5-sec, 2.0-ft waves in a water depth of 25 ft

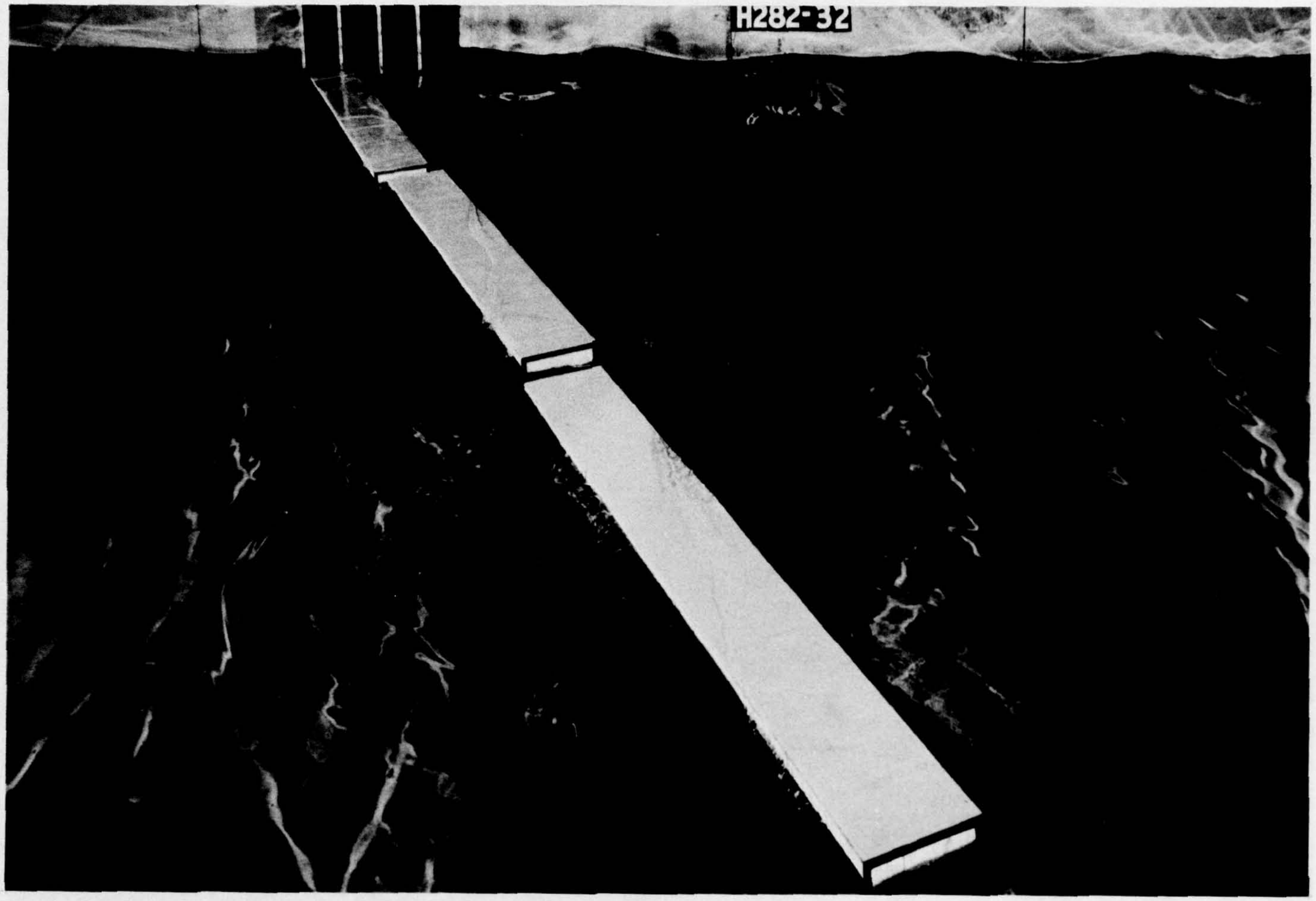


Photo 24. Overhead view of Plan 1 in the 60° linear configuration under attack of 3.0-sec, 2.0-ft waves in a water depth of 25 ft

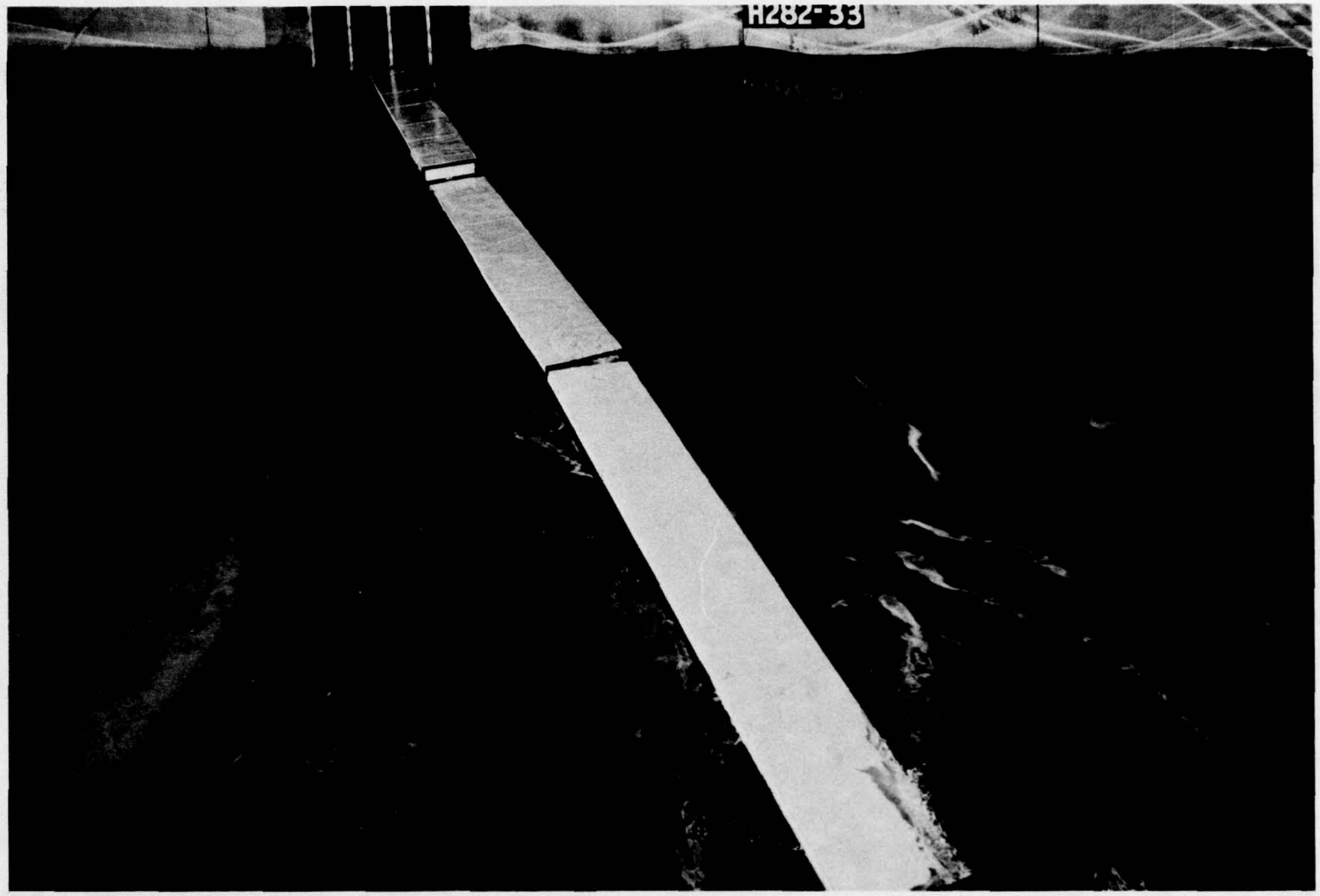


Photo 25. Overhead view of Plan 1 in the 60° linear configuration under attack of 3.5-sec, 2.5-ft waves in a water depth of 25 ft

Photo 26. Overhead view of Plan 1 in the 75° linear configuration under attack of 2.5-sec, 2.0-ft waves in a water depth of 25 ft

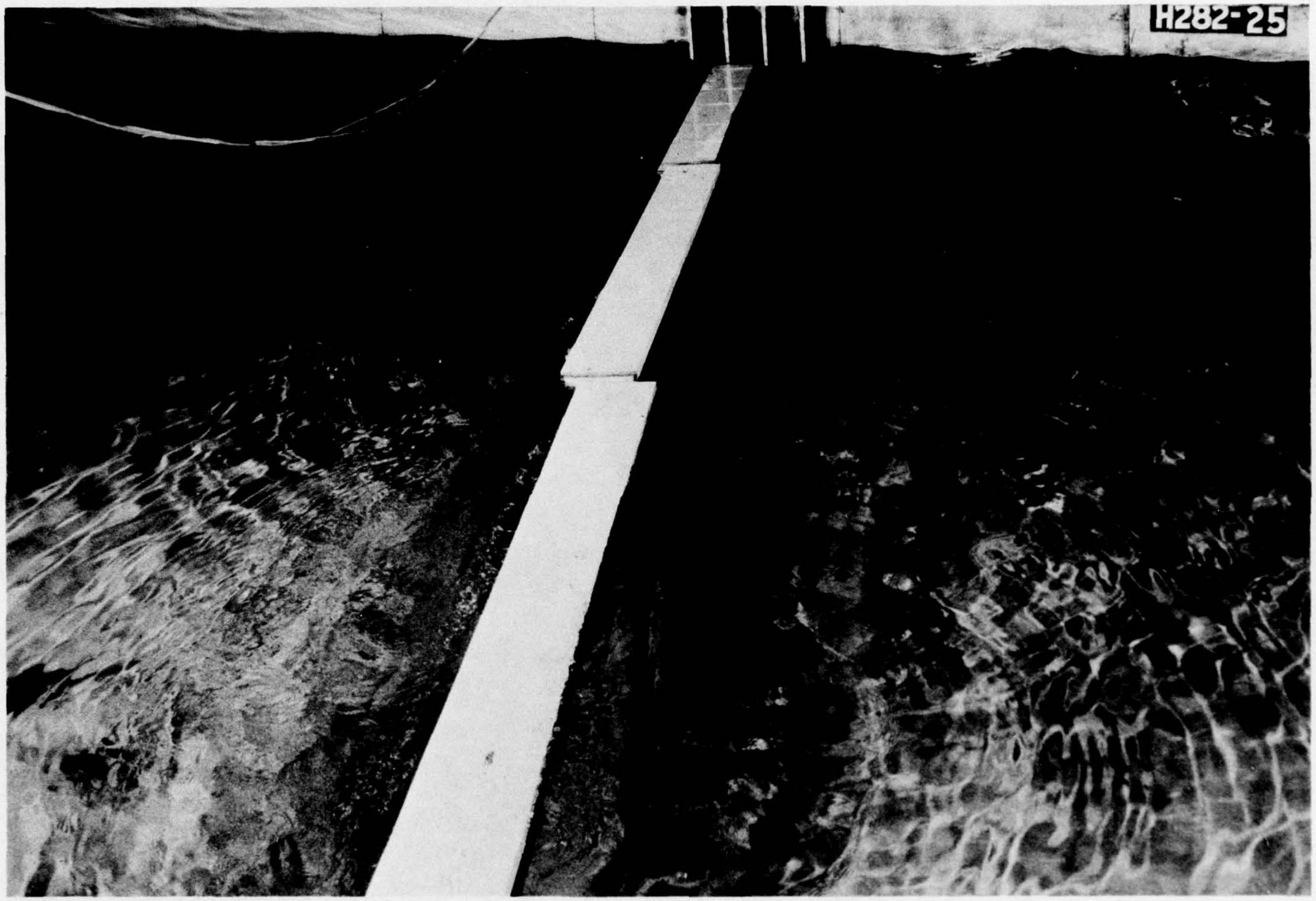


Photo 27. Overhead view of Plan 1 in the 75° linear configuration under attack of 3.0-sec, 2.0-ft waves in a water depth of 25 ft

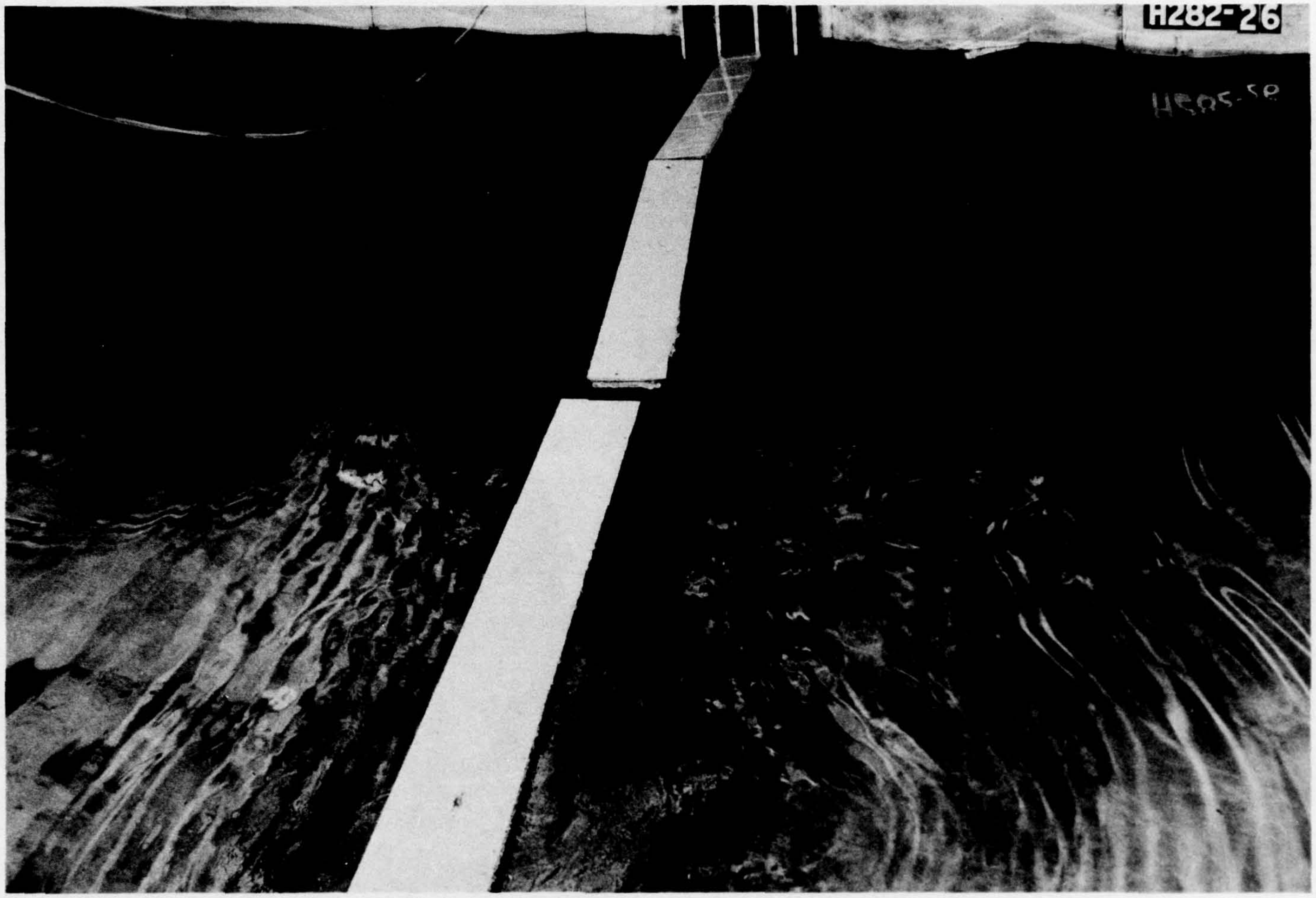


Photo 28. Overhead view of Plan 1 in the 75° linear configuration under attack of 3.5-sec, 2.5-ft waves in a water depth of 25 ft

Photo 29. Overhead view of Plan 1 in the concave configuration under attack of 2.5-sec, 2.0-ft waves in a water depth of 25 ft

Photo 30. Overhead view of Plan 1 in the concave configuration under attack of 3.0-sec, 2.0-ft waves in a water depth of 25 ft

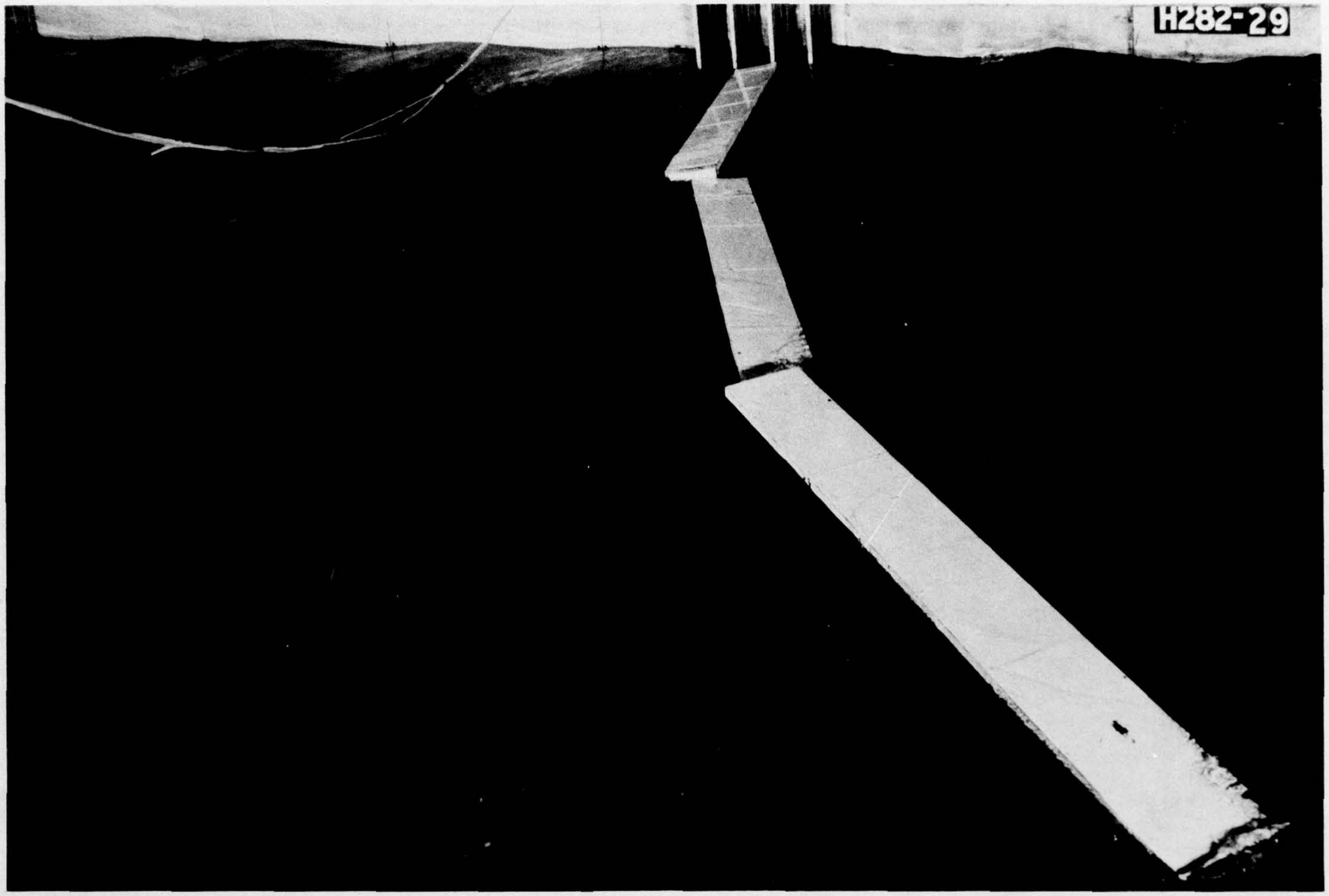


Photo 31. Overhead view of Plan 1 in the concave configuration under attack of 3.5-sec, 2.5-ft waves in a water depth of 25 ft

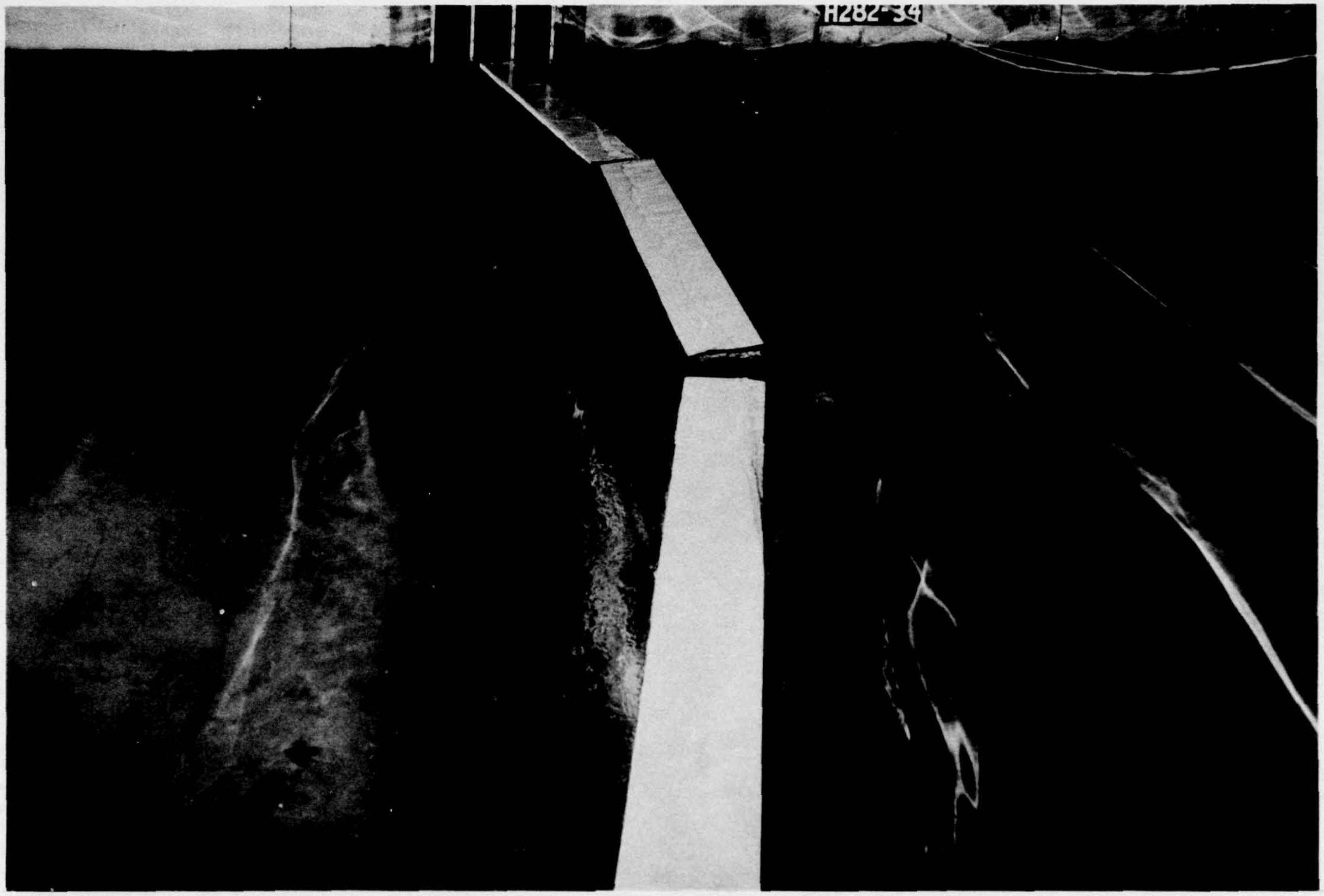


Photo 32. Overhead view of Plan 1 in the convex configuration under attack of 2.5-sec, 2.0-ft waves in a water depth of 25 ft

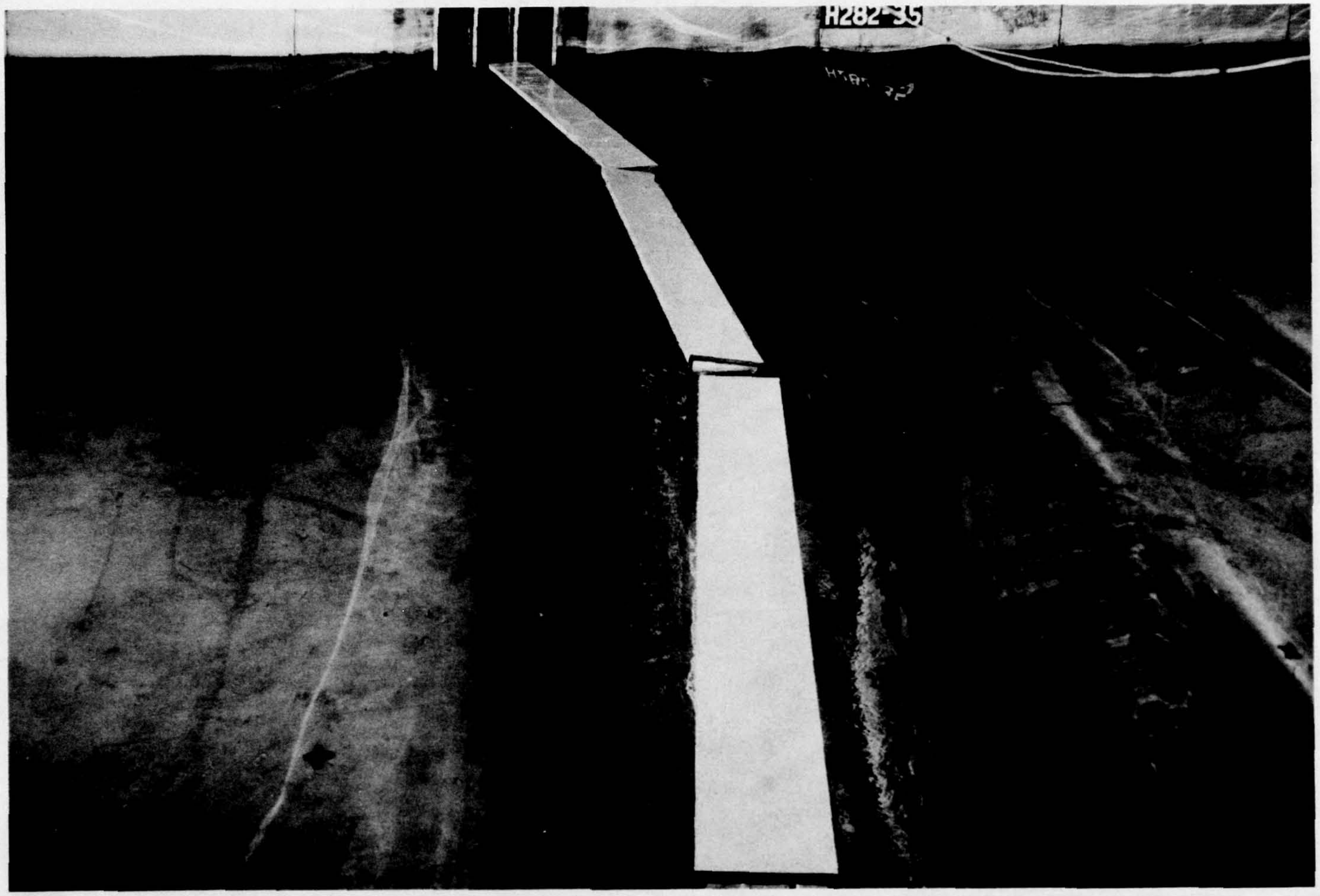


Photo 33. Overhead view of Plan 1 in the convex configuration under attack of 3.0-sec, 2.0-ft waves in a water depth of 25 ft

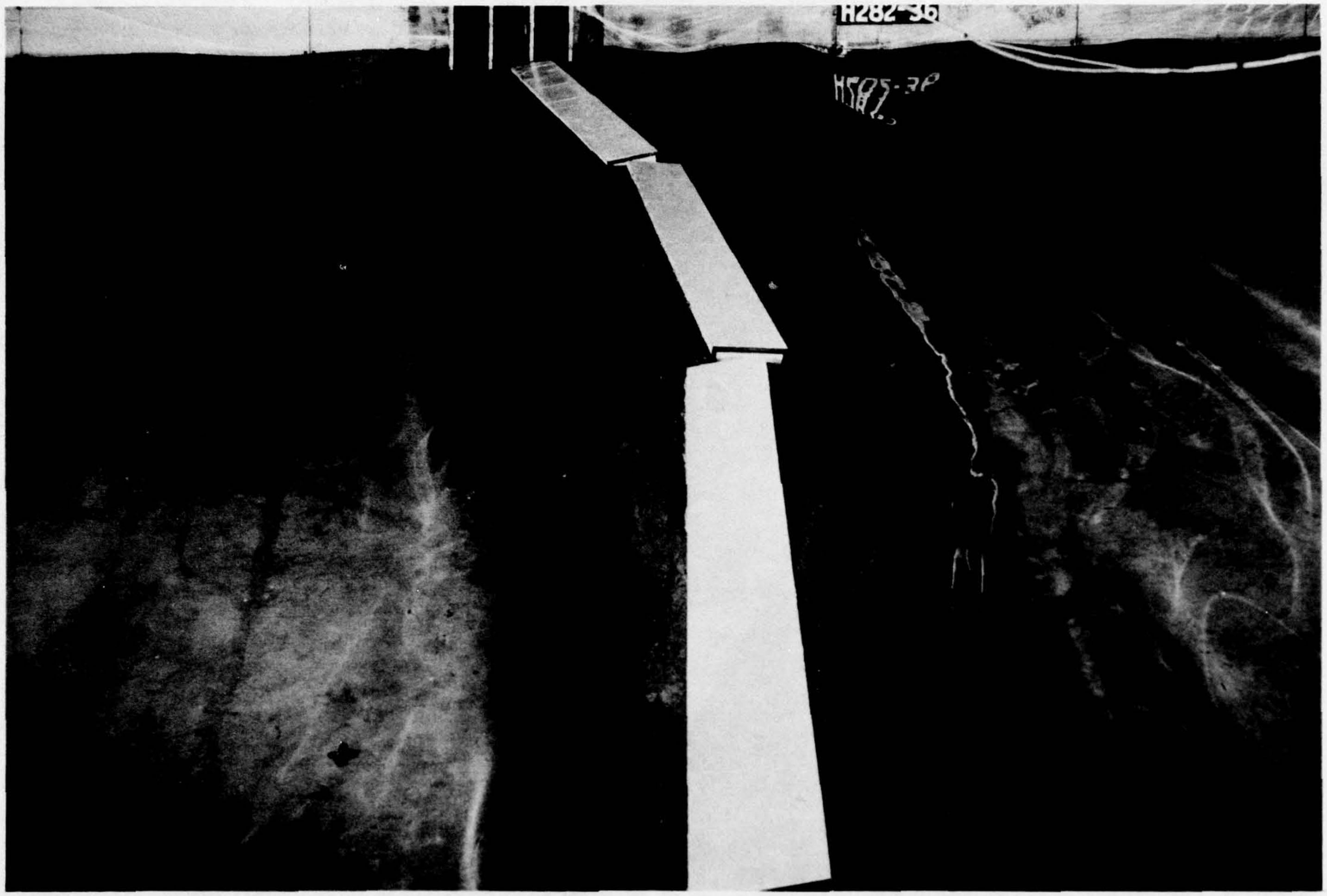


Photo 34. Overhead view of Plan 1 in the convex configuration under attack of 3.5-sec, 2.5-ft waves in a water depth of 25 ft

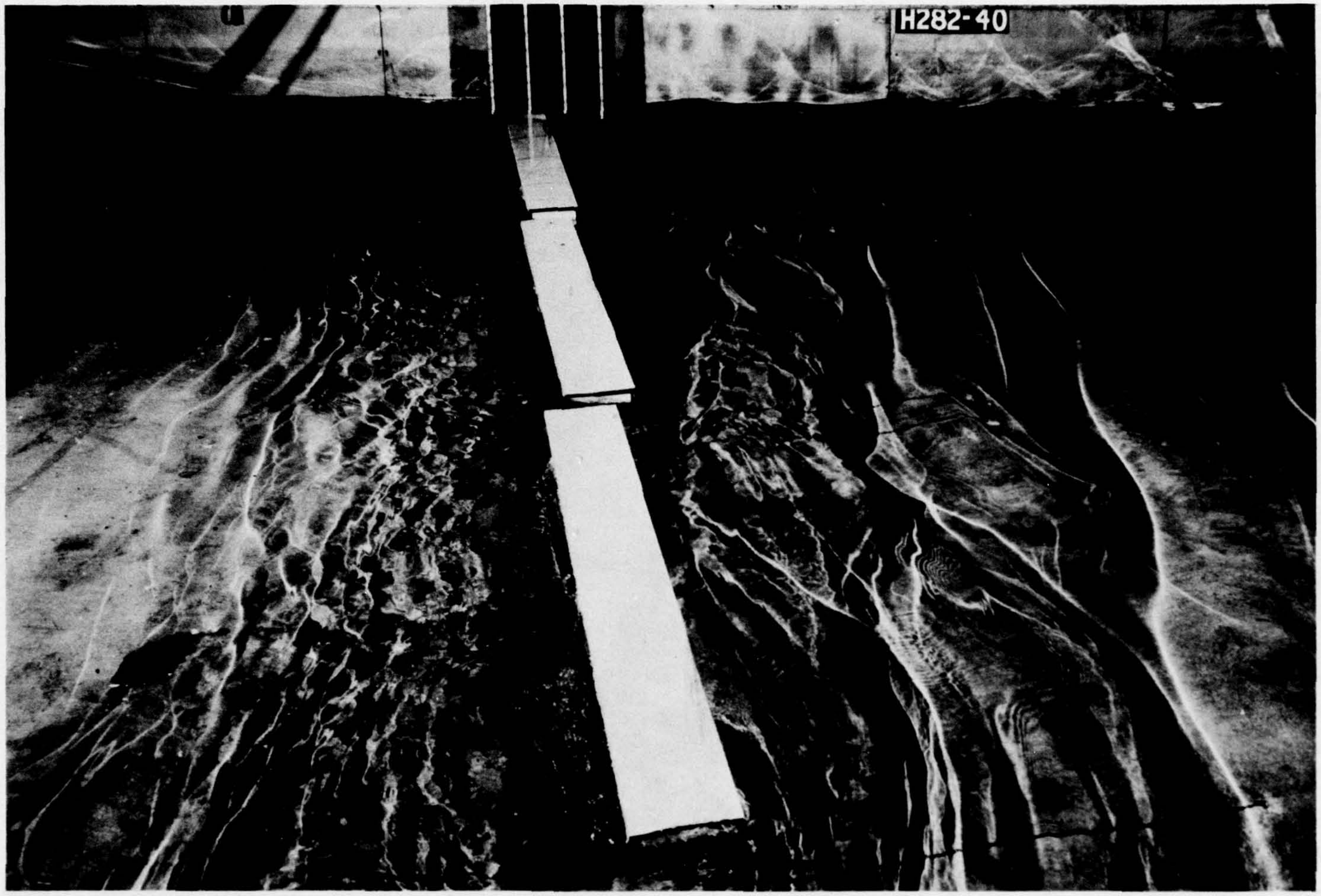


Photo 35. Overhead view of Plan 1 in the 75° linear configuration under attack of 2.5-sec, 2.0-ft waves in a water depth of 10 ft

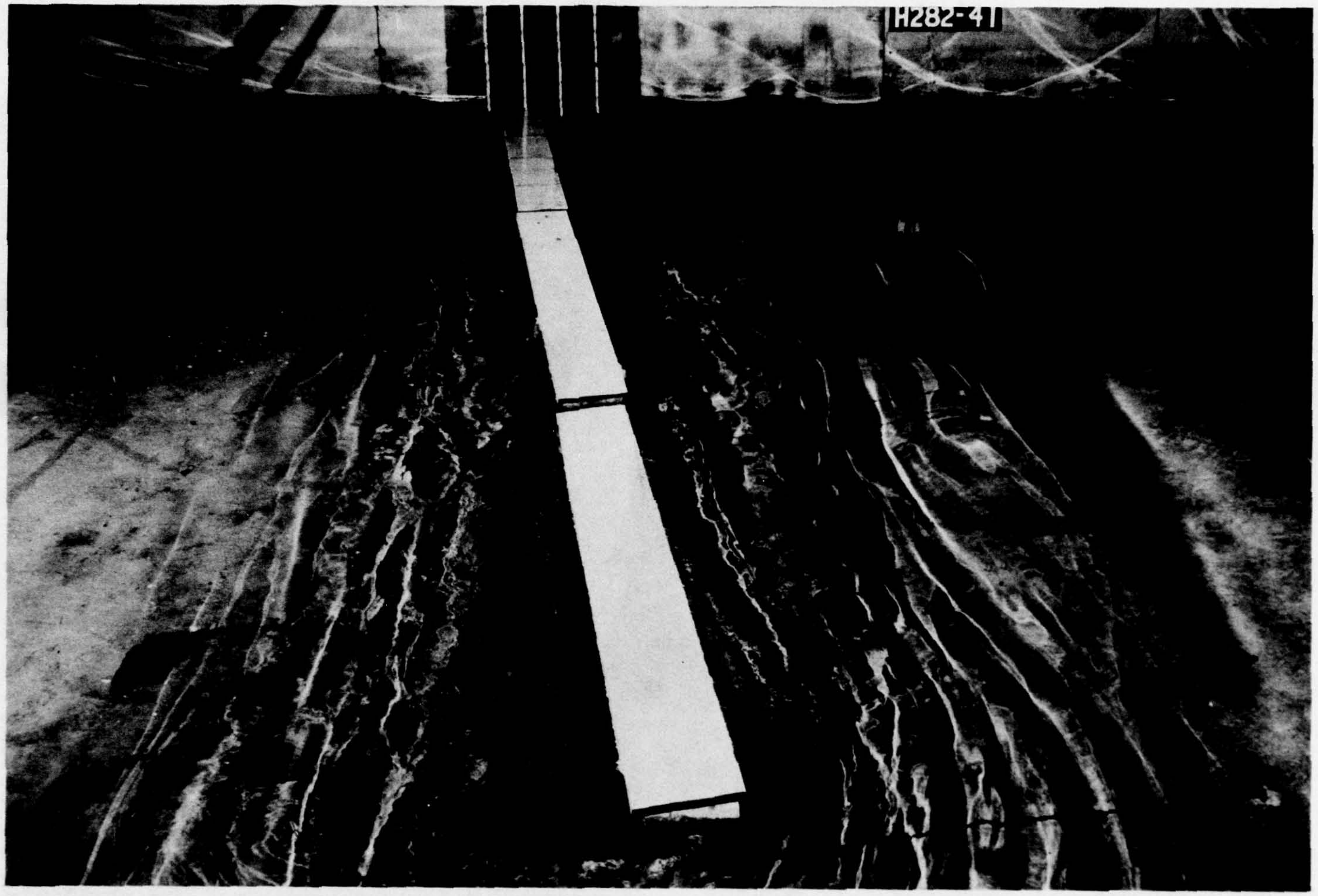


Photo 36. Overhead view of Plan 1 in the 75° linear configuration under attack of 3.0-sec, 2.0-ft waves in a water depth of 10 ft

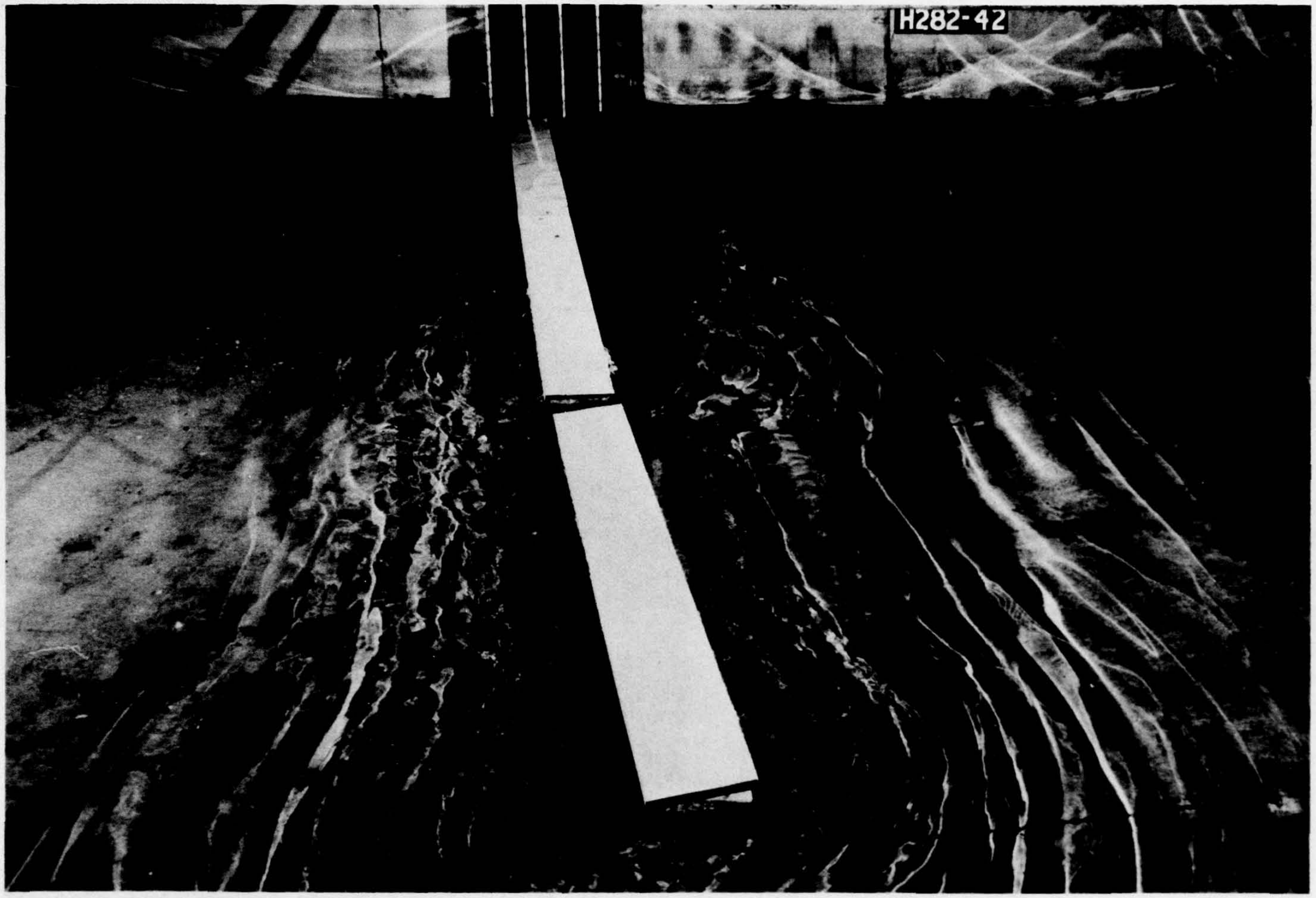


Photo 37. Overhead view of Plan 1 in the 75° linear configuration under attack of 3.5-sec, 2.5-ft waves in a water depth of 10 ft

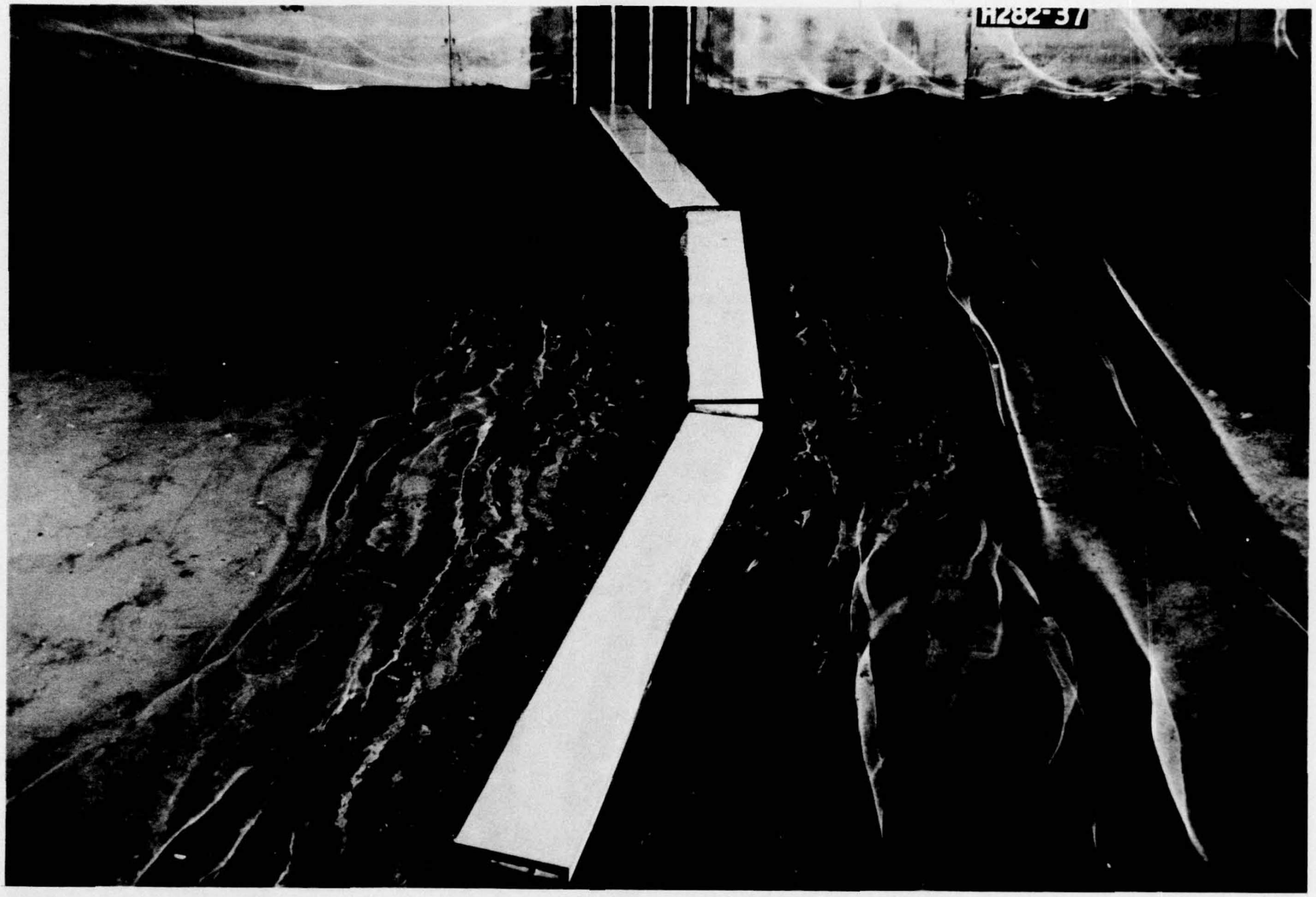


Photo 38. Overhead view of Plan 1 in the convex configuration under attack of 2.5-sec, 2.0-ft waves in a water depth of 10 ft

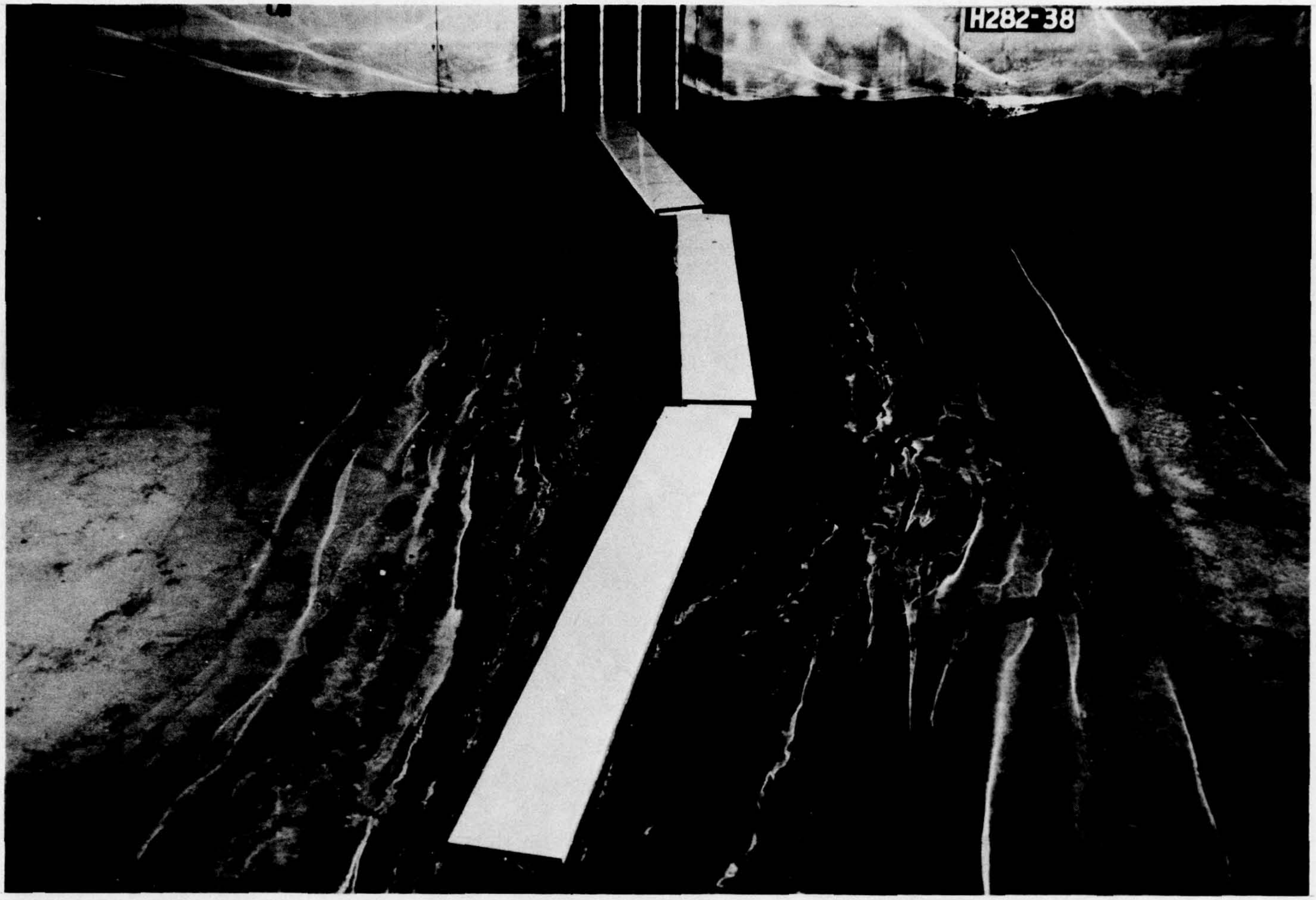


Photo 39. Overhead view of Plan 1 in the convex configuration under attack of 3.0-sec, 2.0-ft waves in a water depth of 10 ft

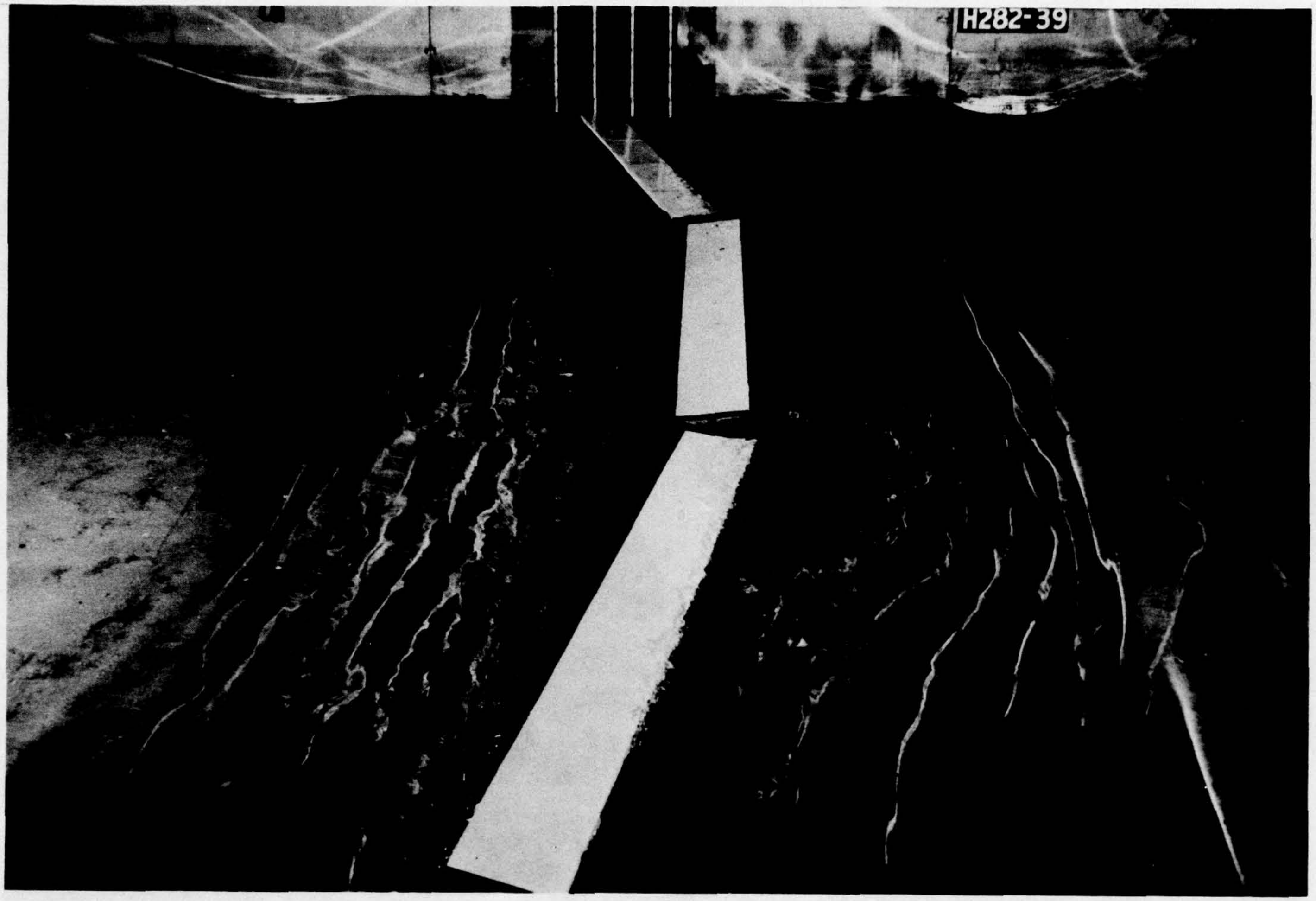
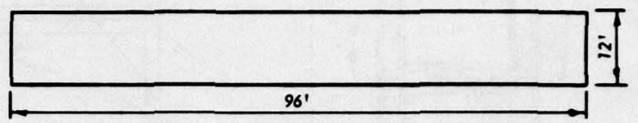
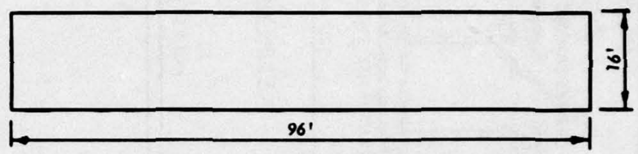


Photo 40. Overhead view of Plan 1 in the convex configuration under attack of 3.5-sec, 2.5-ft waves in a water depth of 10 ft



PLAN 1

96' × 12' RECTANGULAR MODULE COMPOSED OF
6 BASIC UNITS POSTTENSIONED TOGETHER

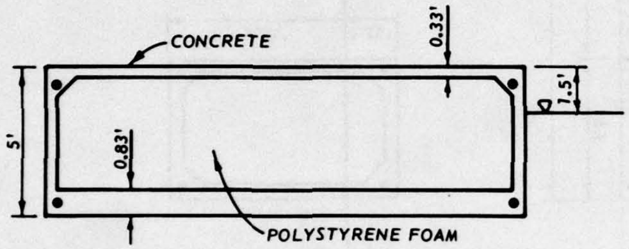


PLAN 2

96' × 16' RECTANGULAR MODULE COMPOSED OF
8 BASIC UNITS POSTTENSIONED TOGETHER

WEIGHTS AND UNIT WEIGHTS

CONFIGURATION	WEIGHT, LB	UNIT WEIGHT, PCF
PLAN 1	258,000	44.8
PLAN 2	344,000	44.8

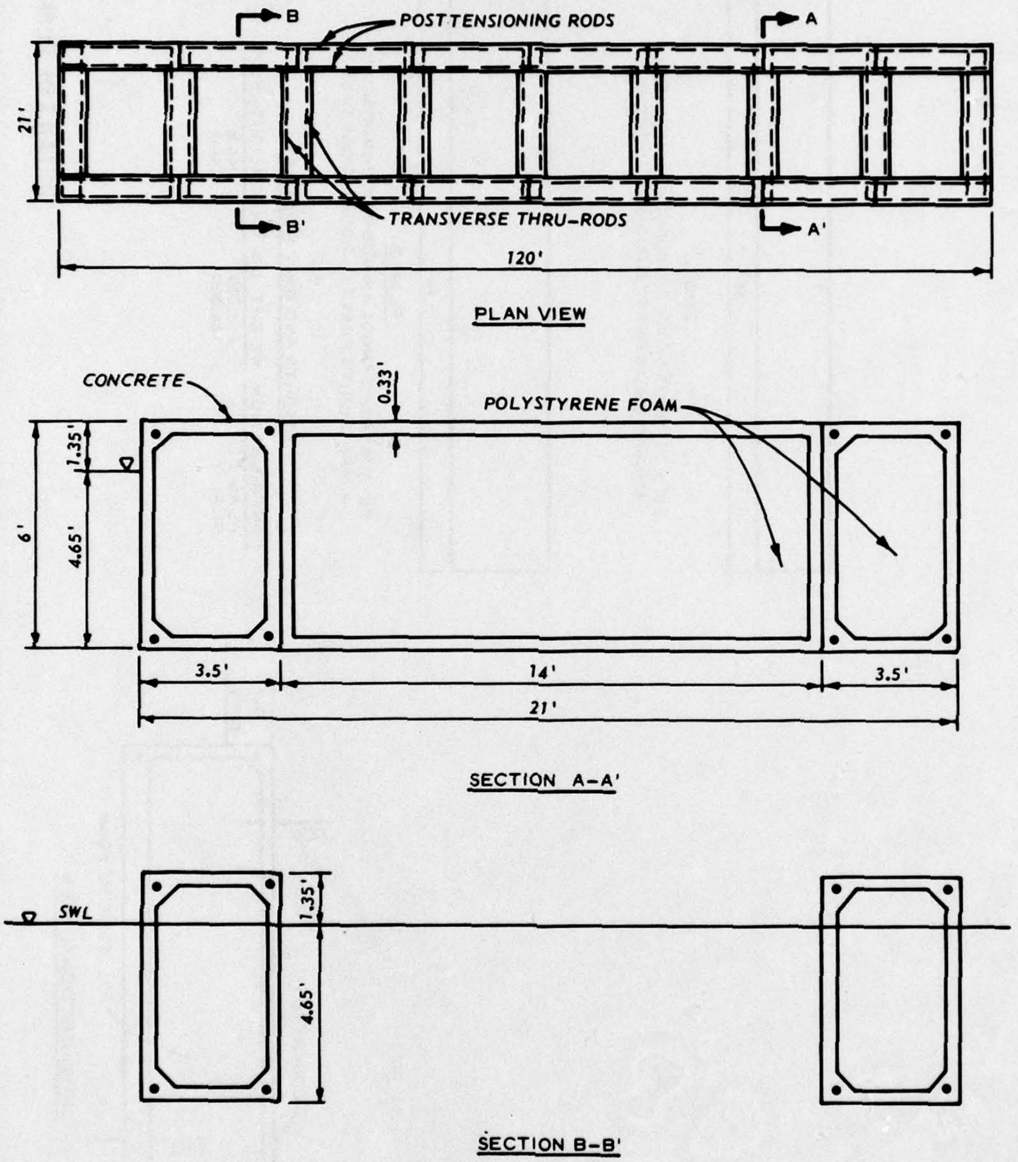


CROSS-SECTIONAL VIEW

DETAILS OF PLANS 1 AND 2

PLATE 1

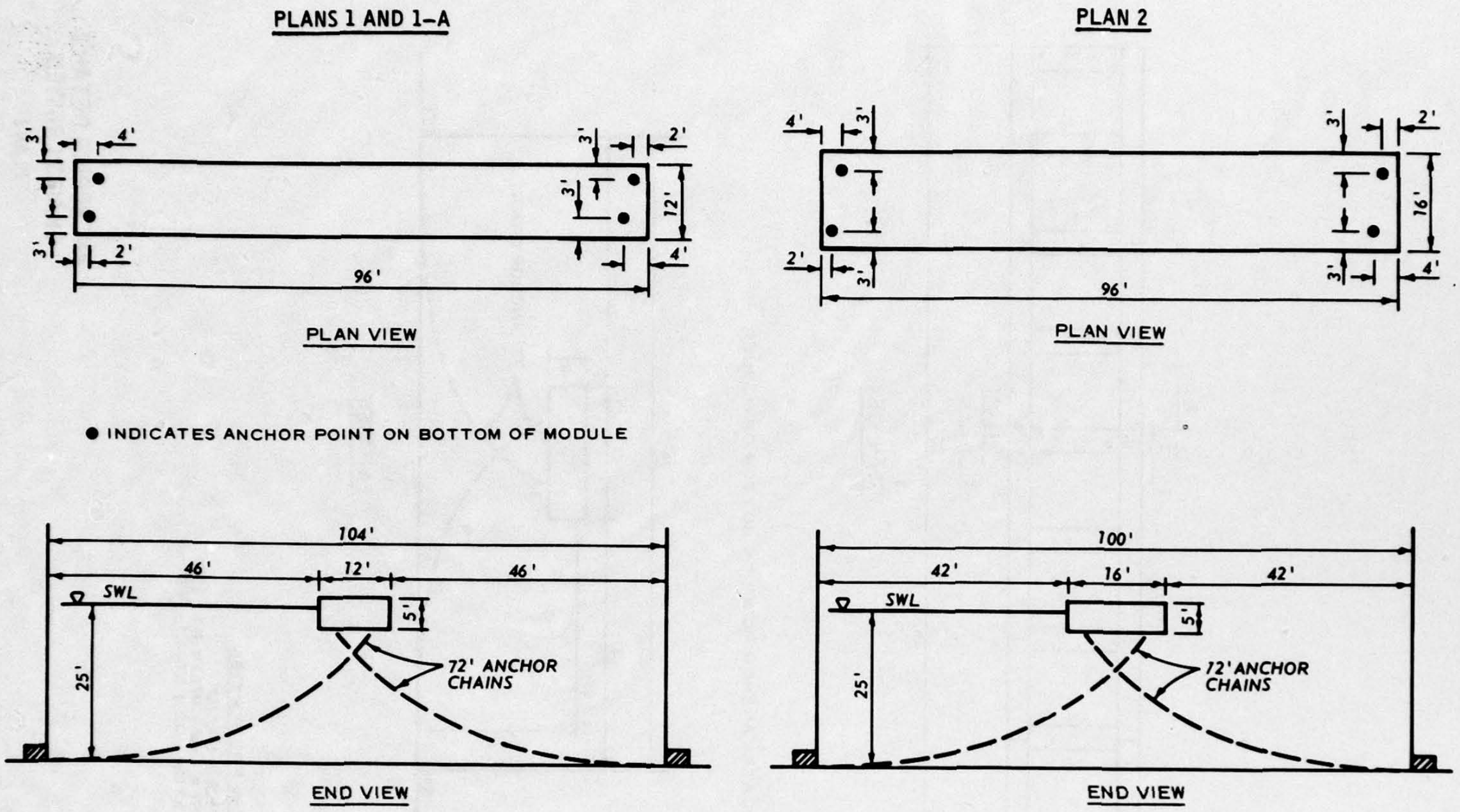
PLAN 3 (TWIN-PONTOON FLOAT)



WEIGHT = 381,226 LB; UNIT WEIGHT = 49.6 PCF

DETAILS OF PLAN 3

PLATE 2

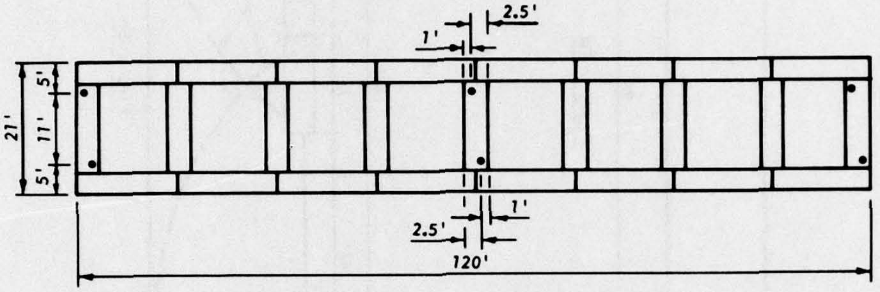


● INDICATES ANCHOR POINT ON BOTTOM OF MODULE

ANCHOR CHAIN PROPERTIES

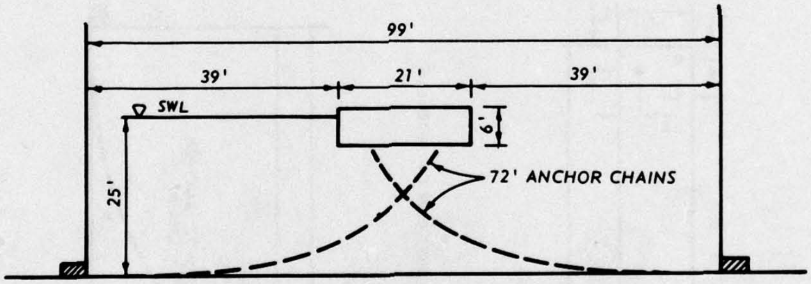
LINK DIAMETER = 1-3/16"
WEIGHT IN AIR = 14.2 LB/LIN FT
WEIGHT IN WATER = 12.3 LB/LIN FT

ANCHORING DETAILS
PLANS 1, 1A, AND 2



PLAN VIEW

● INDICATES ANCHOR POINT ON BOTTOM OF MODULE



END VIEW

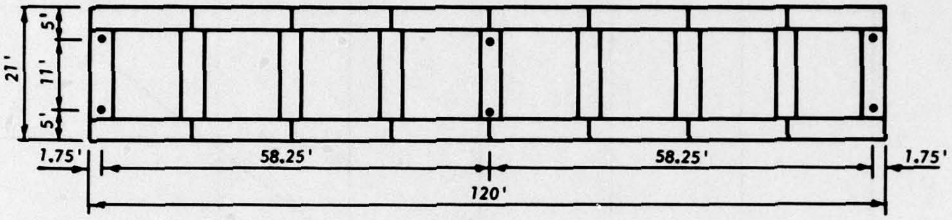
ANCHOR CHAIN PROPERTIES

LINK DIAMETER = 1-3/16"
WEIGHT IN AIR = 14.2 LB/LIN FT
WEIGHT IN WATER = 12.3 LB/LIN FT

ANCHORING DETAILS CHAINS CROSSED

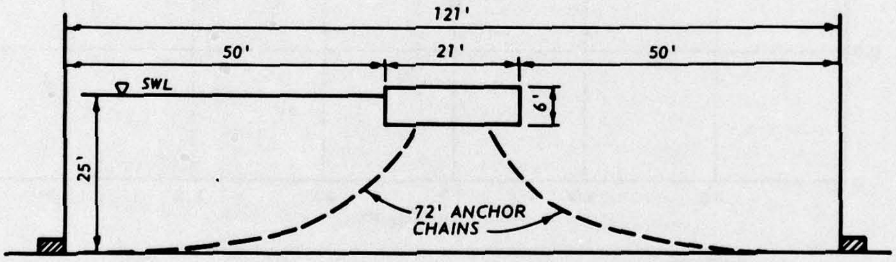
PLAN 3

PLATE 4



PLAN VIEW

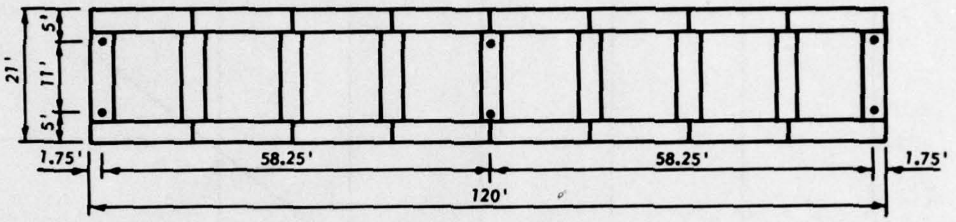
● INDICATES ANCHOR POINT ON BOTTOM OF MODULE



END VIEW

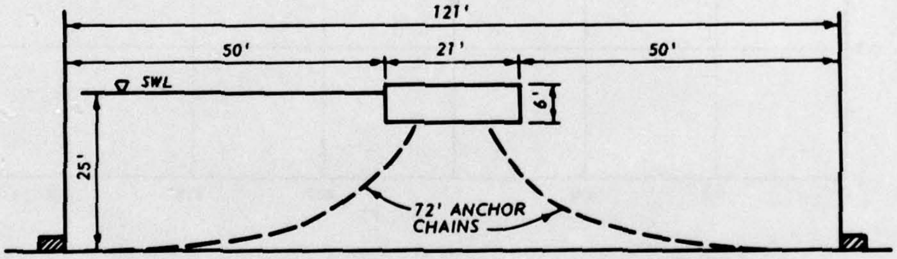
ANCHOR CHAIN PROPERTIES
LINK DIAMETER = 1-3/16"
WEIGHT IN AIR = 14.2 LB/LIN FT
WEIGHT IN WATER = 12.3 LB/LIN FT

ANCHORING DETAILS
CHAINS UNCROSSED
PLAN 3



PLAN VIEW

● INDICATES ANCHOR POINT ON BOTTOM OF MODULE

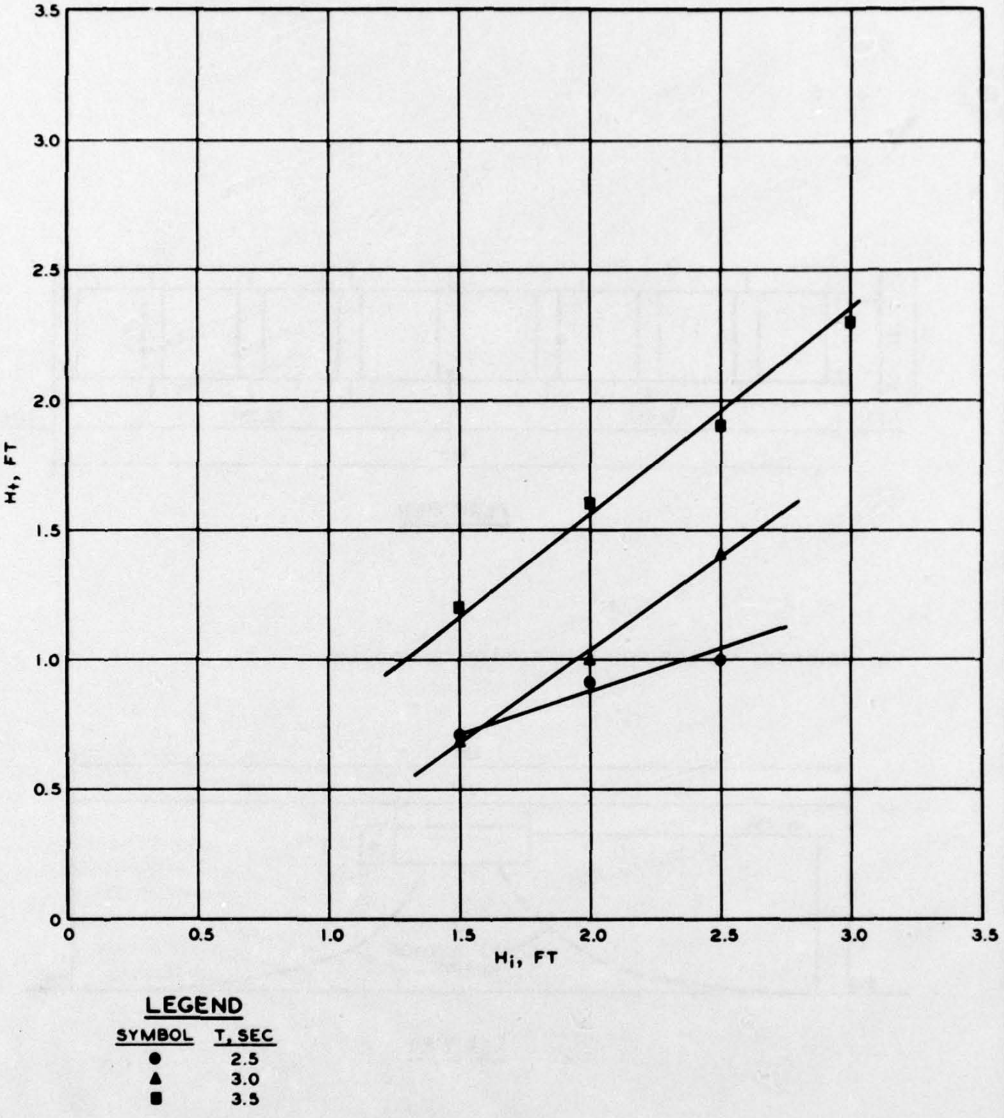


END VIEW

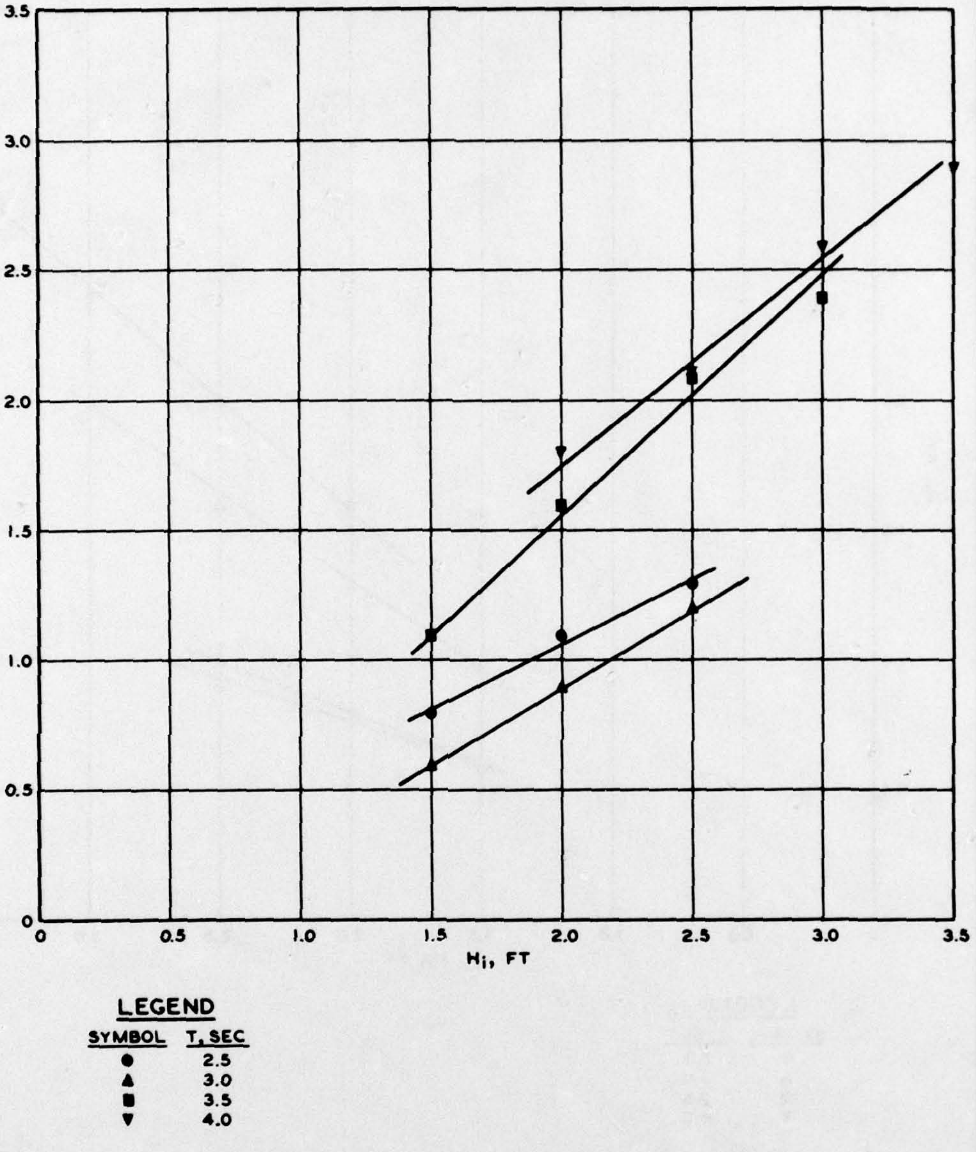
ANCHOR CHAIN PROPERTIES

LINK DIAMETER = 1-3/16"
WEIGHT IN AIR = 14.2 LB/LIN FT
WEIGHT IN WATER = 12.3 LB/LIN FT

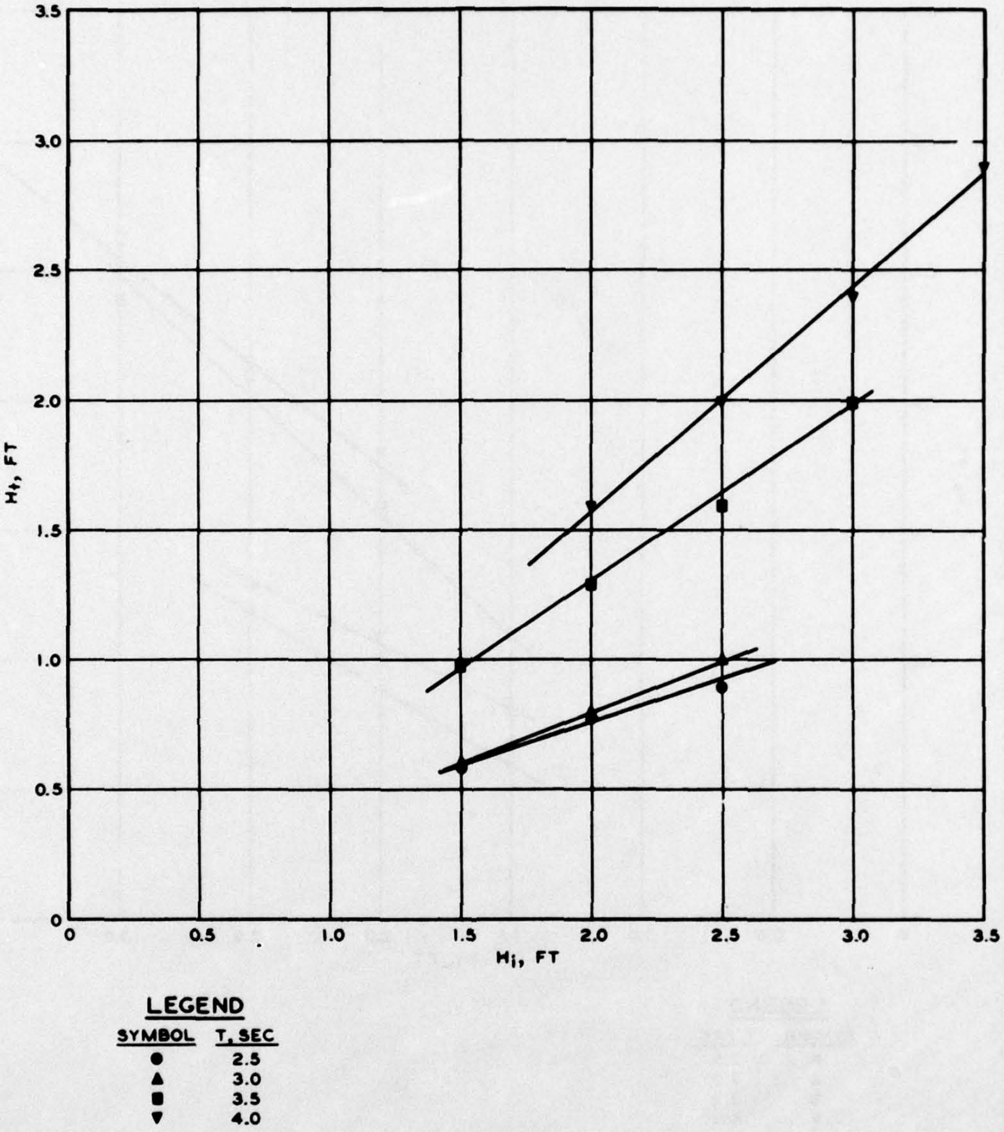
ANCHORING DETAILS
CHAINS UNCROSSED
PLAN 3



TRANSMITTED WAVE HEIGHT (H_t)
VERSUS INCIDENT WAVE HEIGHT (H_i)
PLAN 1

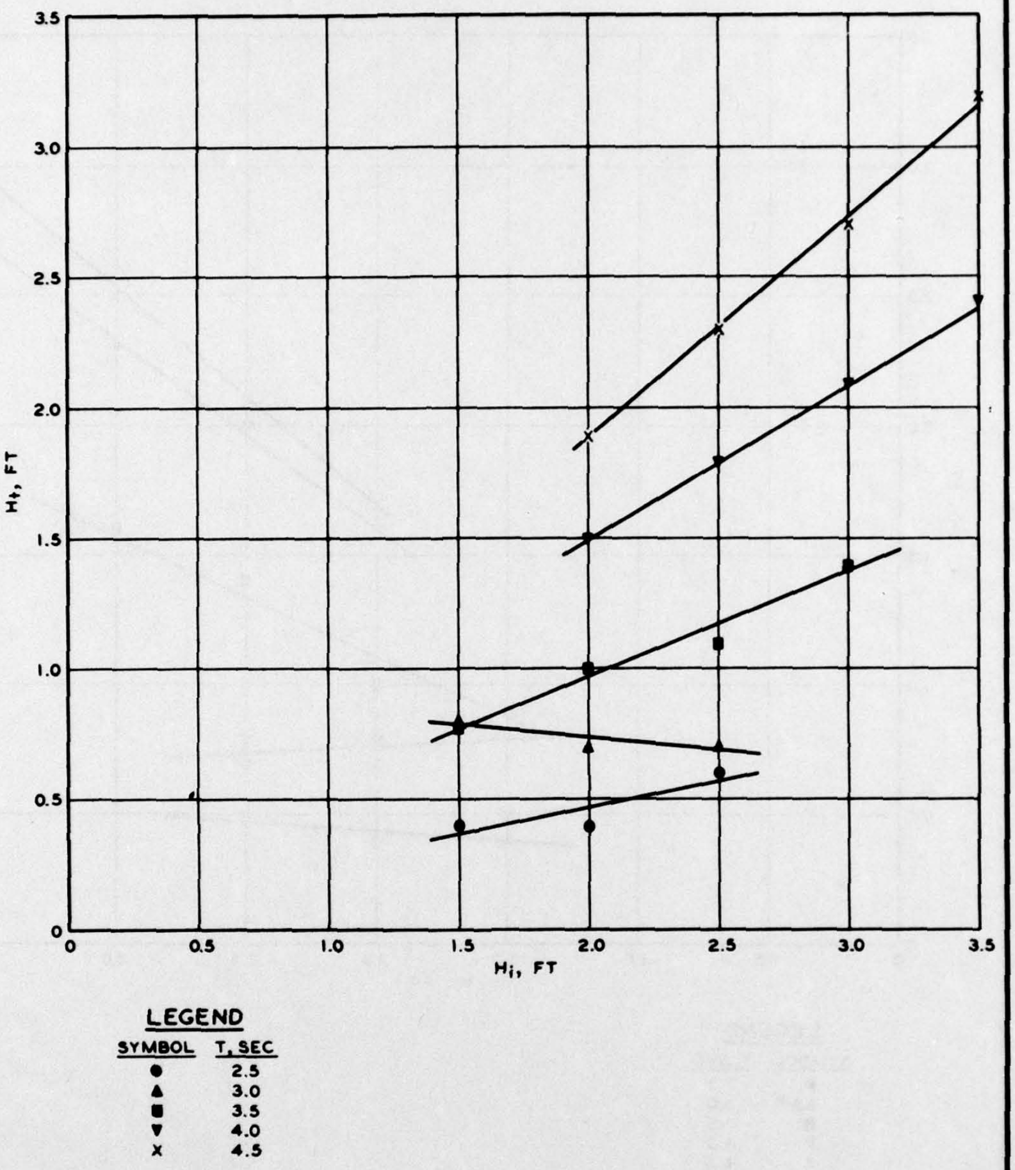


TRANSMITTED WAVE HEIGHT (H_t)
VERSUS INCIDENT WAVE HEIGHT (H_i)
PLAN IA



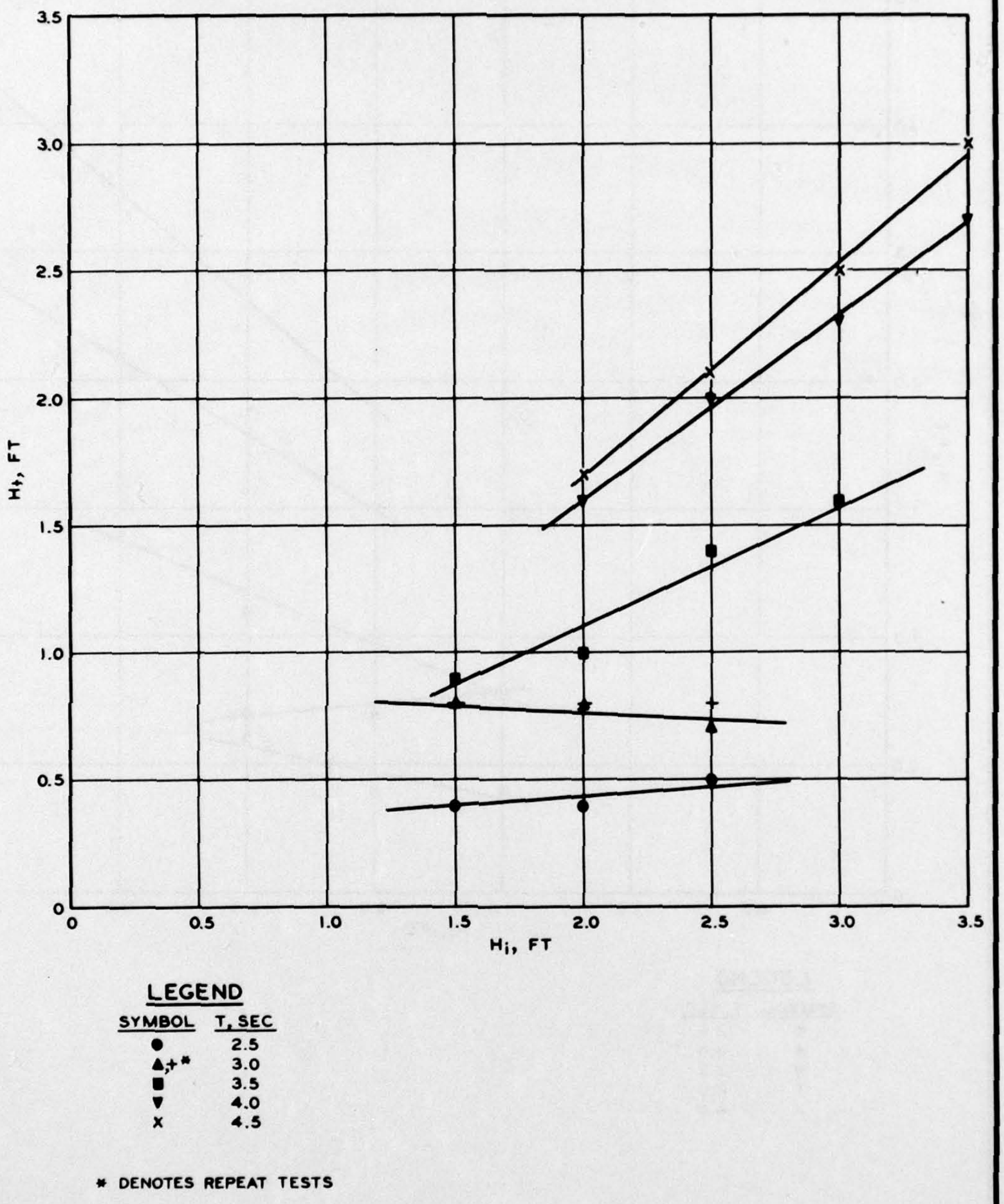
TRANSMITTED WAVE HEIGHT (H_t)
VERSUS INCIDENT WAVE HEIGHT (H_i)
PLAN 2

PLATE 8



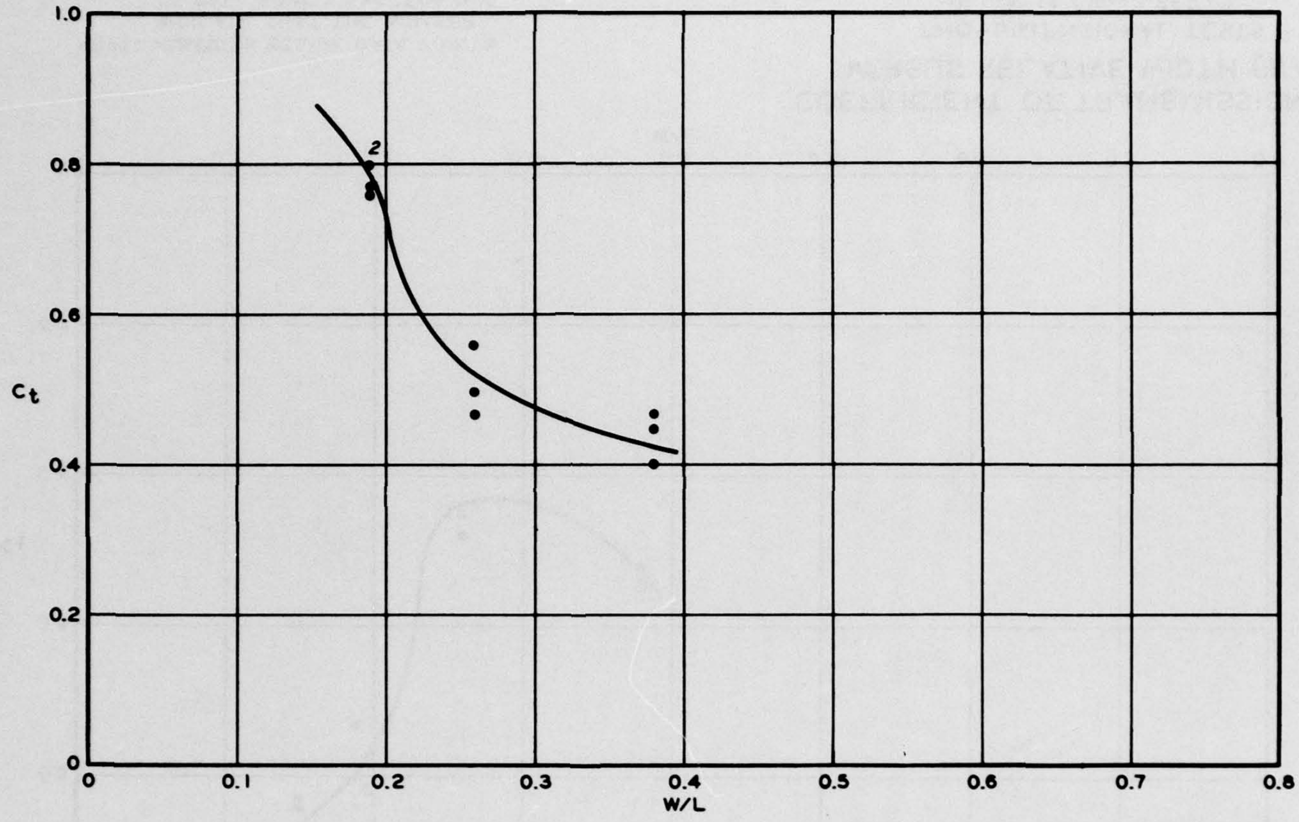
TRANSMITTED WAVE HEIGHT (H_t)
VERSUS INCIDENT WAVE HEIGHT (H_i)
PLAN 3
ANCHOR CHAINS CROSSED

PLATE 9



TRANSMITTED WAVE HEIGHT (H_t)
VERSUS INCIDENT WAVE HEIGHT (H_i)
PLAN 3
ANCHOR CHAINS UNCROSSED

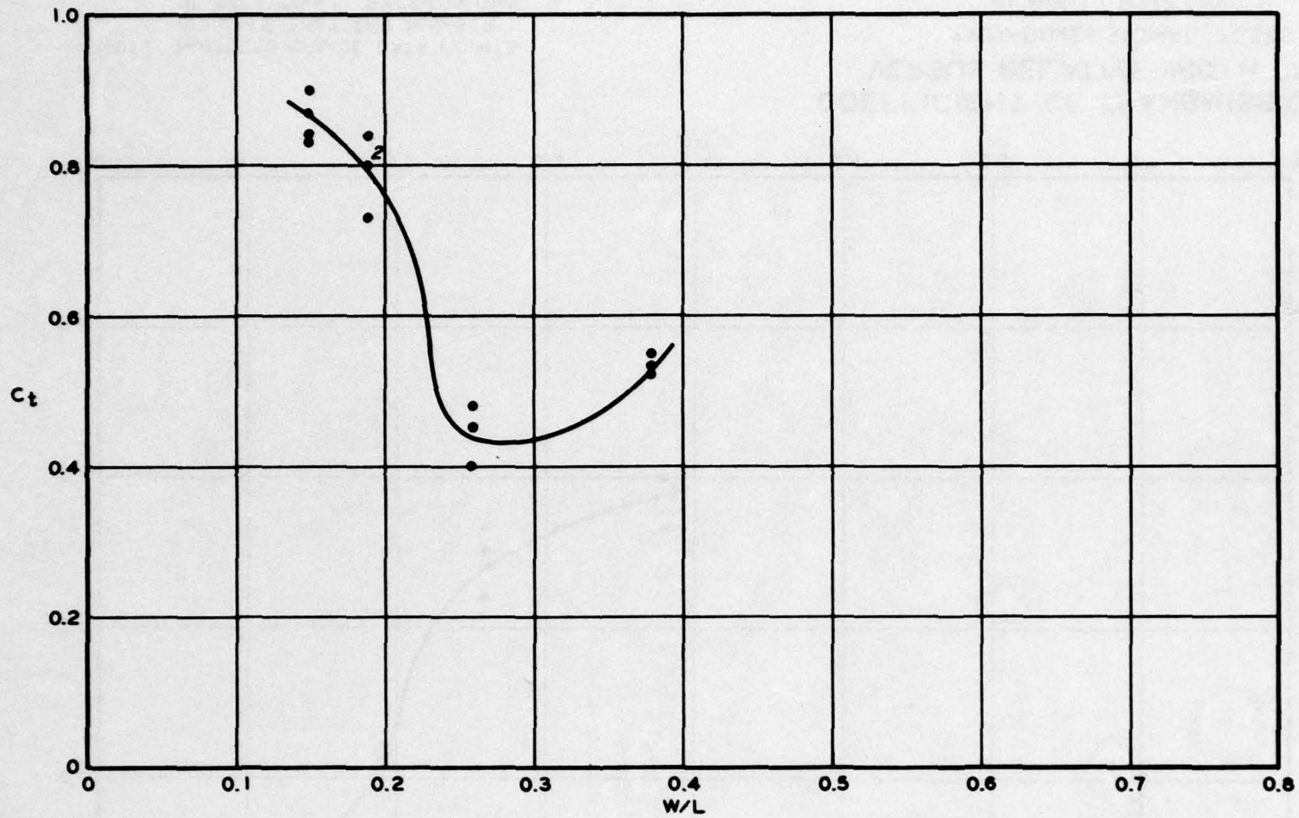
PLATE 10



NOTE: NUMBERS BESIDE DATA POINTS INDICATE THAT THE NUMBER OF DATA POINTS EXCEEDS ONE.

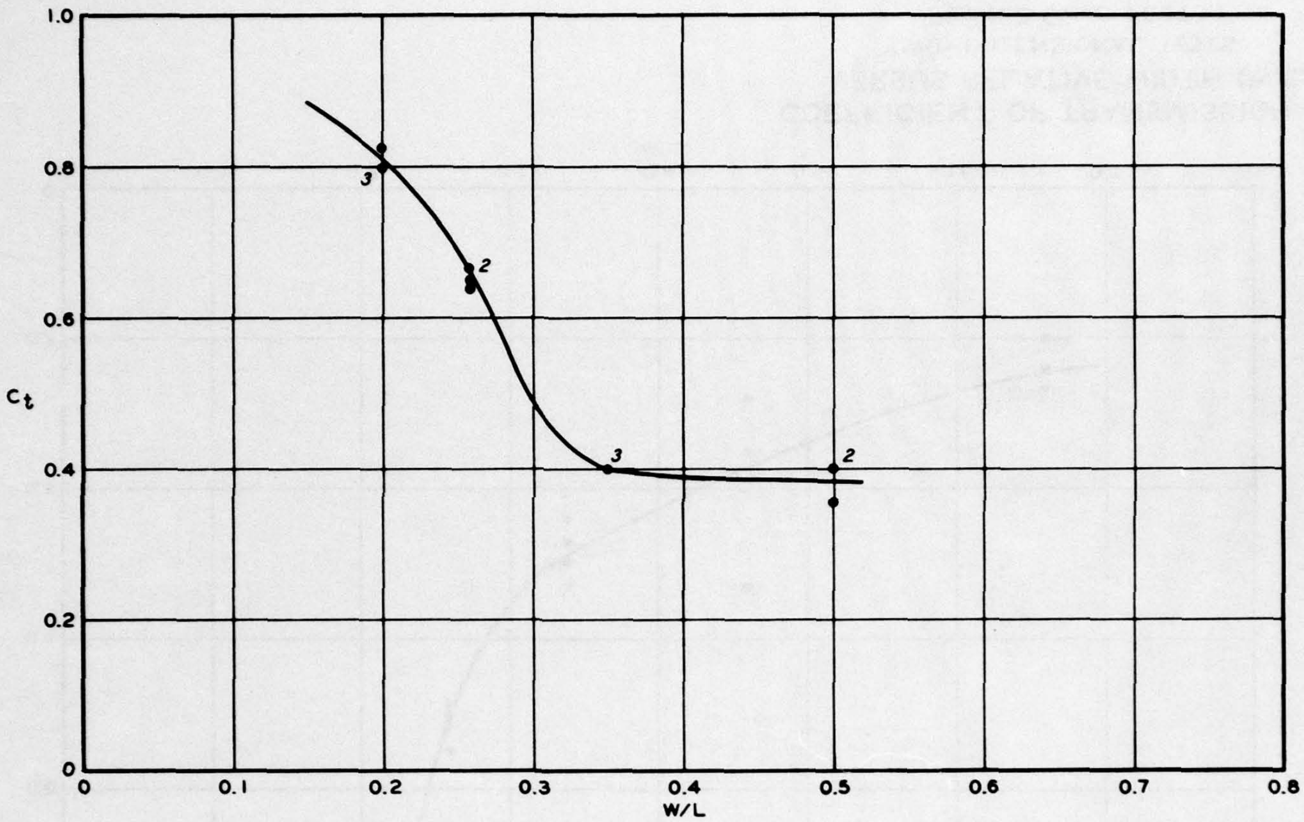
COEFFICIENT OF TRANSMISSION (C_t)
VERSUS RELATIVE WIDTH (W/L)
TWO-DIMENSIONAL TESTS
PLAN 1 (W=12 FEET)

PLATE 11



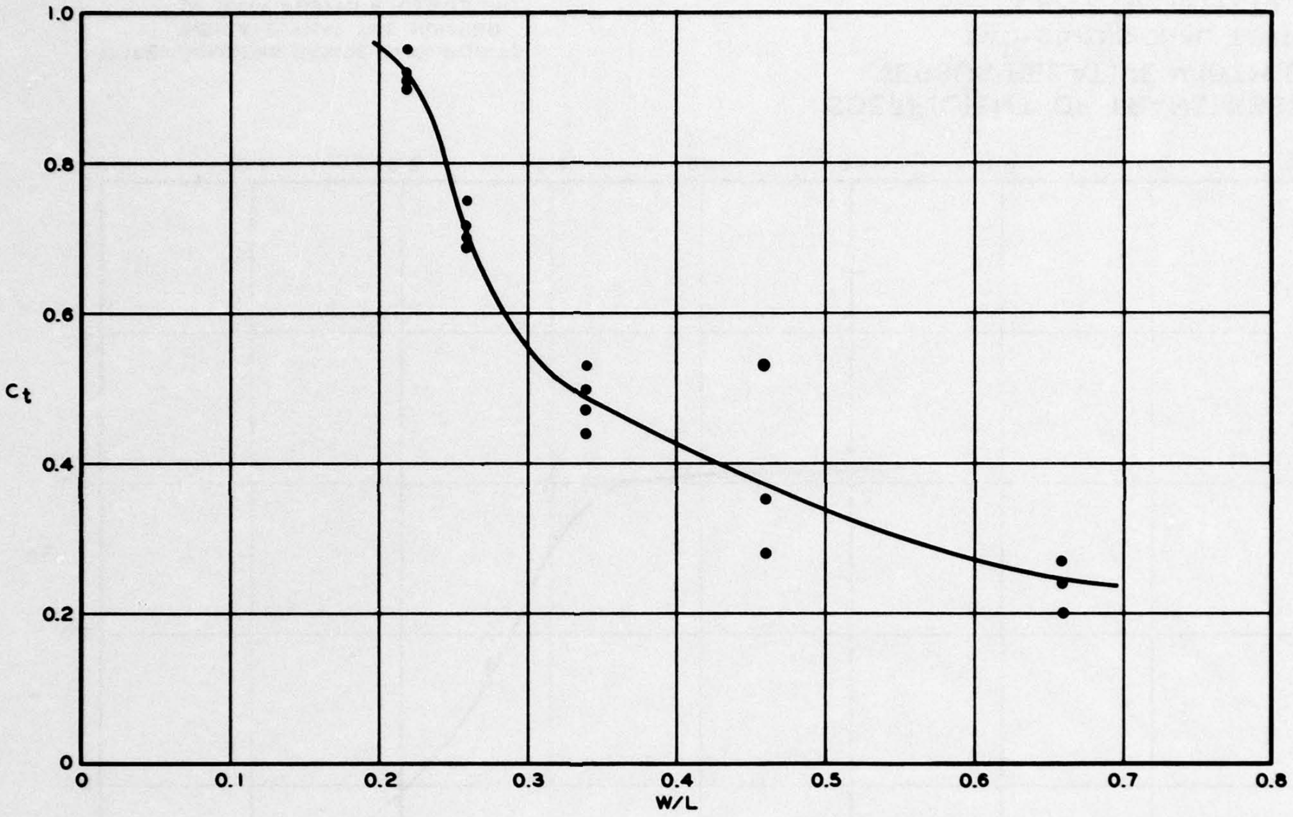
NOTE: NUMBERS BESIDE DATA POINTS
INDICATE THAT THE NUMBER
OF DATA POINTS EXCEEDS ONE.

COEFFICIENT OF TRANSMISSION (C_t)
VERSUS RELATIVE WIDTH (W/L)
TWO-DIMENSIONAL TESTS
PLAN 1A (W=12 FEET)



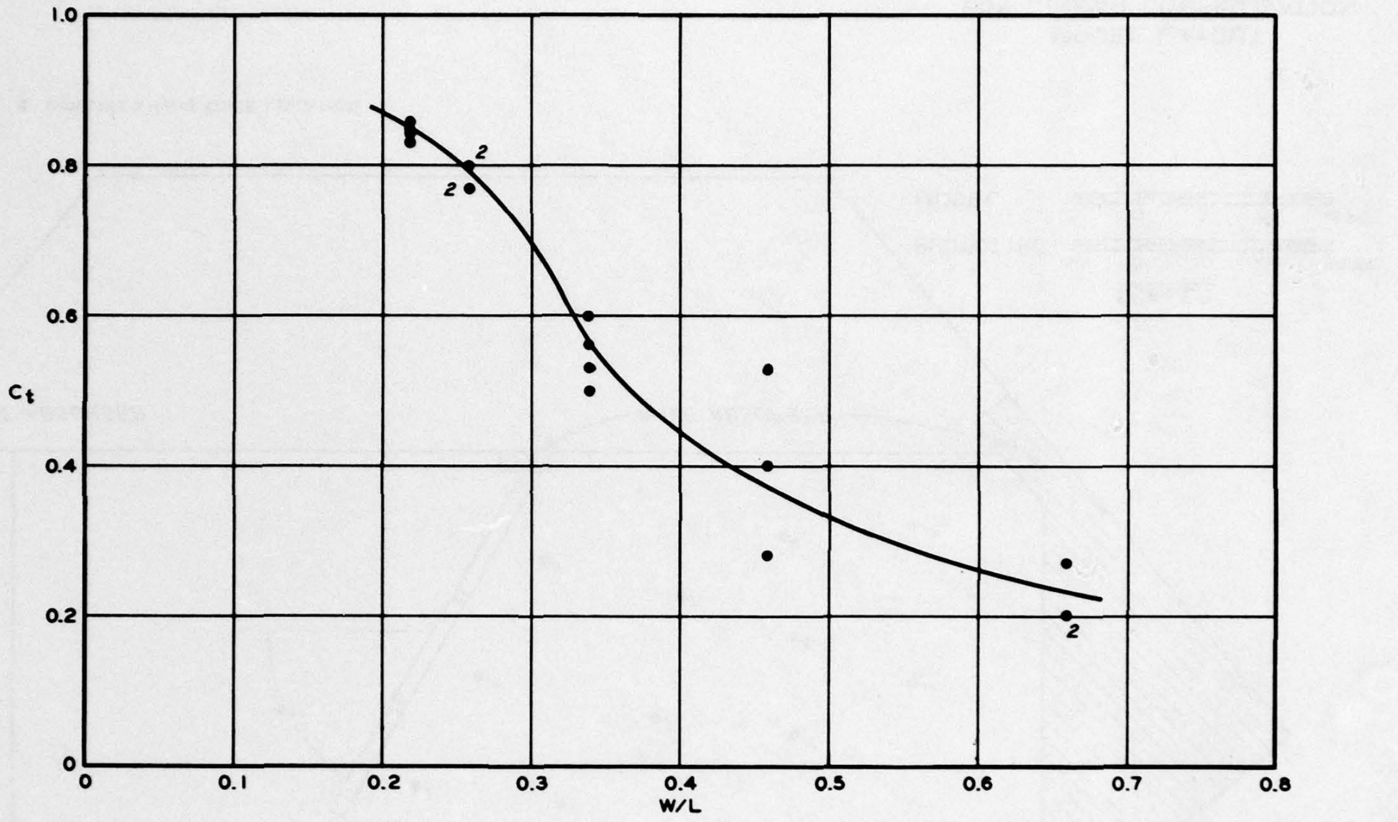
NOTE: NUMBERS BESIDE DATA POINTS
INDICATE THAT THE NUMBER
OF DATA POINTS EXCEEDS ONE.

COEFFICIENT OF TRANSMISSION (C_t)
VERSUS RELATIVE WIDTH (W/L)
TWO-DIMENSIONAL TESTS
PLAN 2 (W = 16 FEET)



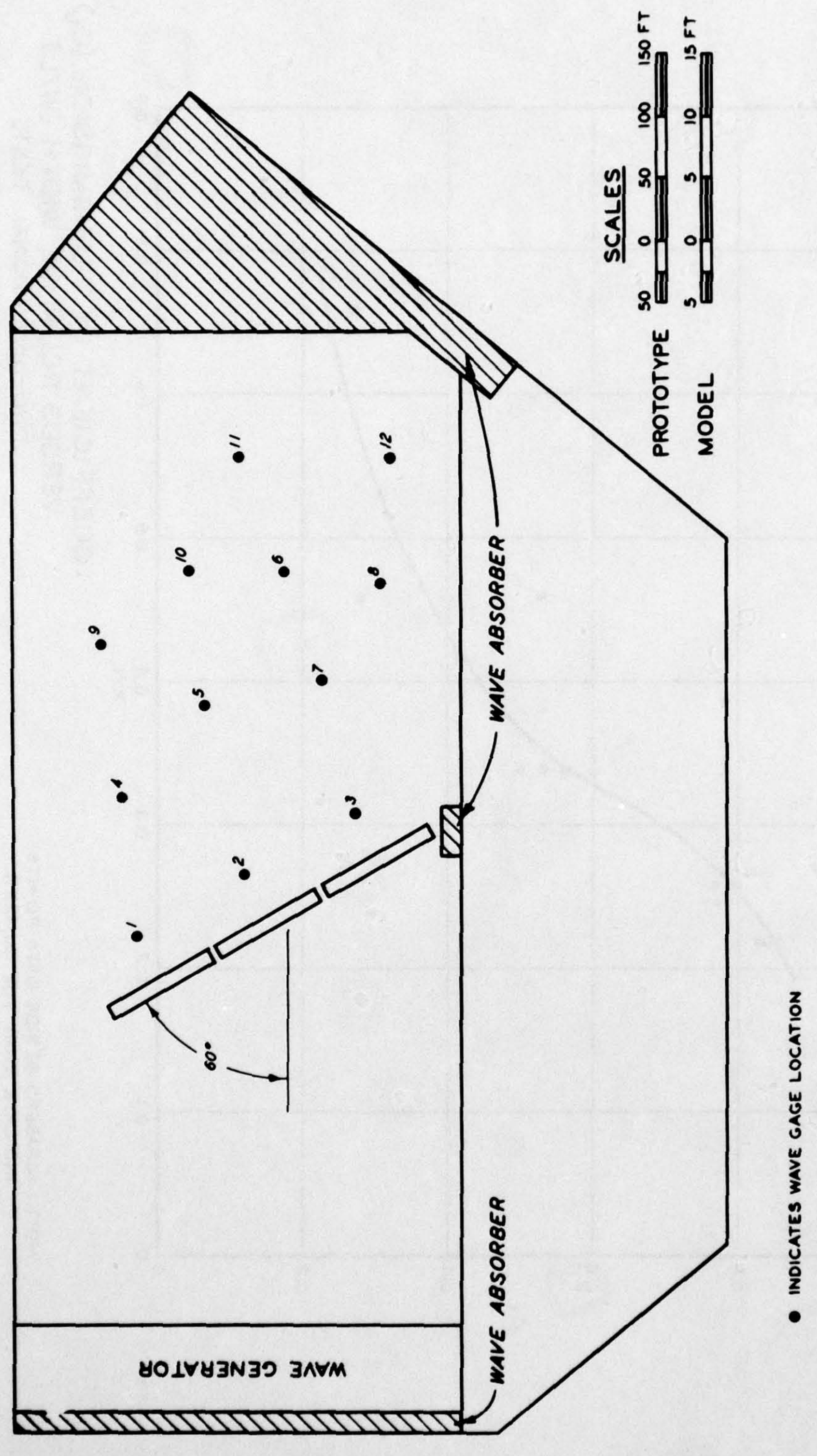
**COEFFICIENT OF TRANSMISSION (C_t)
VERSUS RELATIVE WIDTH (W/L)**
TWO-DIMENSIONAL TESTS
PLAN 3 (W=21 FEET)
ANCHOR CHAINS CROSSED

PLATE 14

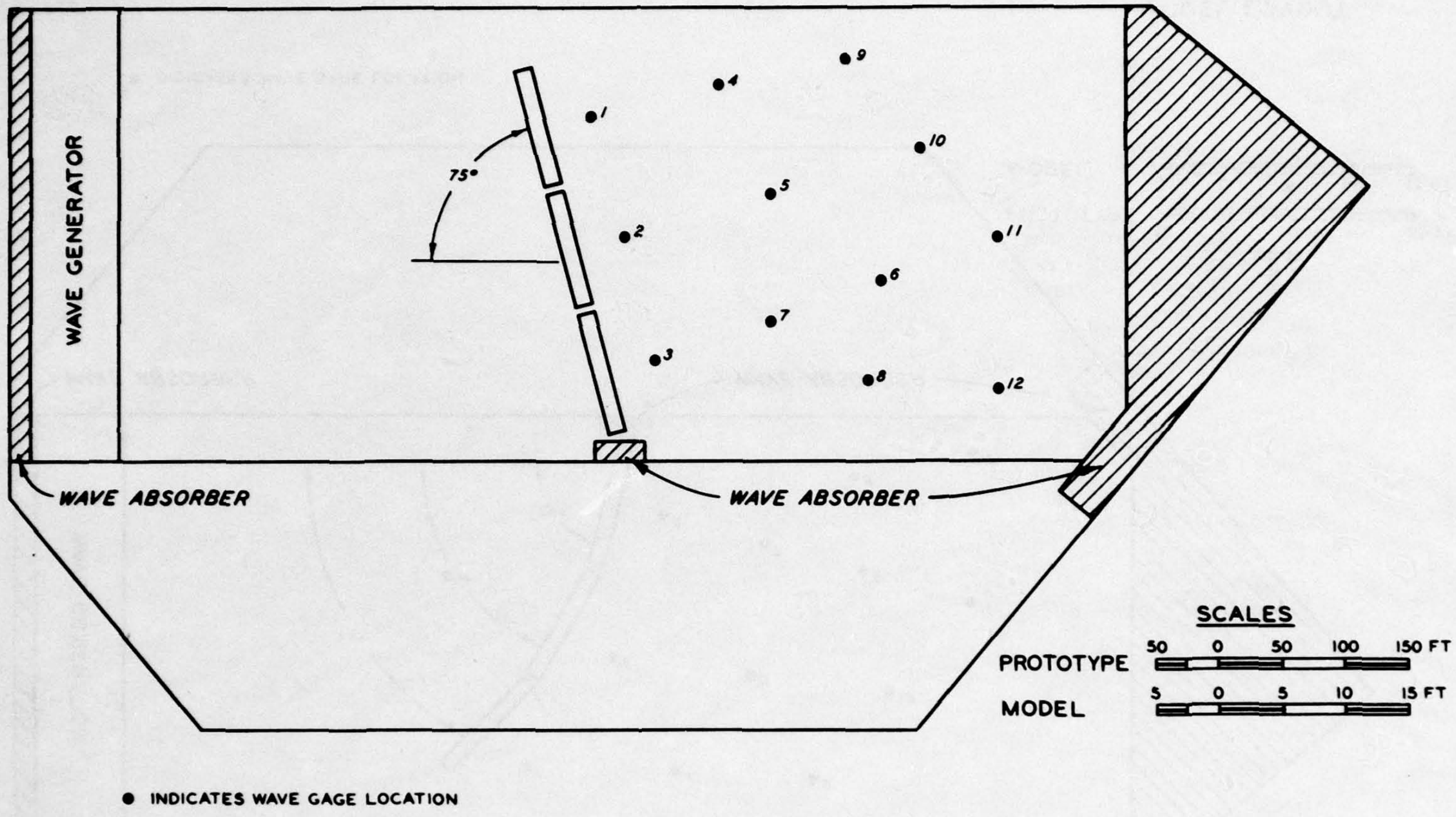


NOTE: NUMBERS BESIDE DATA POINTS
INDICATE THAT THE NUMBER
OF DATA POINTS EXCEEDS ONE

COEFFICIENT OF TRANSMISSION (C_t)
VERSUS RELATIVE WIDTH (W/L)
TWO-DIMENSIONAL TESTS
PLAN 3 (W=21 FEET)
ANCHOR CHAINS UNCROSSED

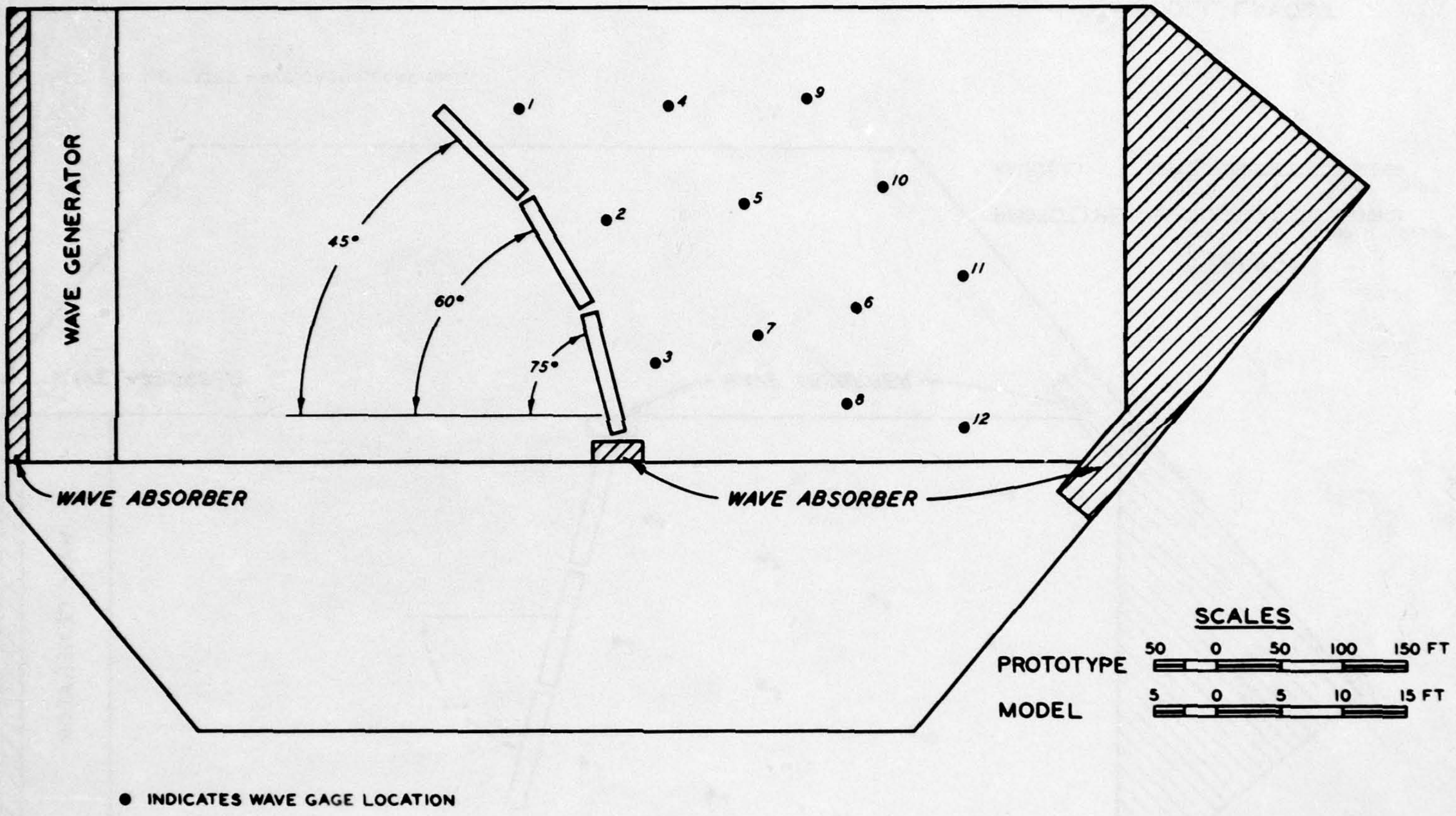


MODEL LAYOUT
60° LINEAR CONFIGURATION



MODEL LAYOUT
75° LINEAR CONFIGURATION

PLATE 17



MODEL LAYOUT
CONCAVE CONFIGURATION

AD-A075 779   ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG--ETC F/G 13/13
FLOATING BREAKWATER WAVE-ATTENUATION TESTS FOR EAST BAY MARINA,--ETC(U)
AUG 79 R D CARVER
UNCLASSIFIED WES-HL-79-13 NL

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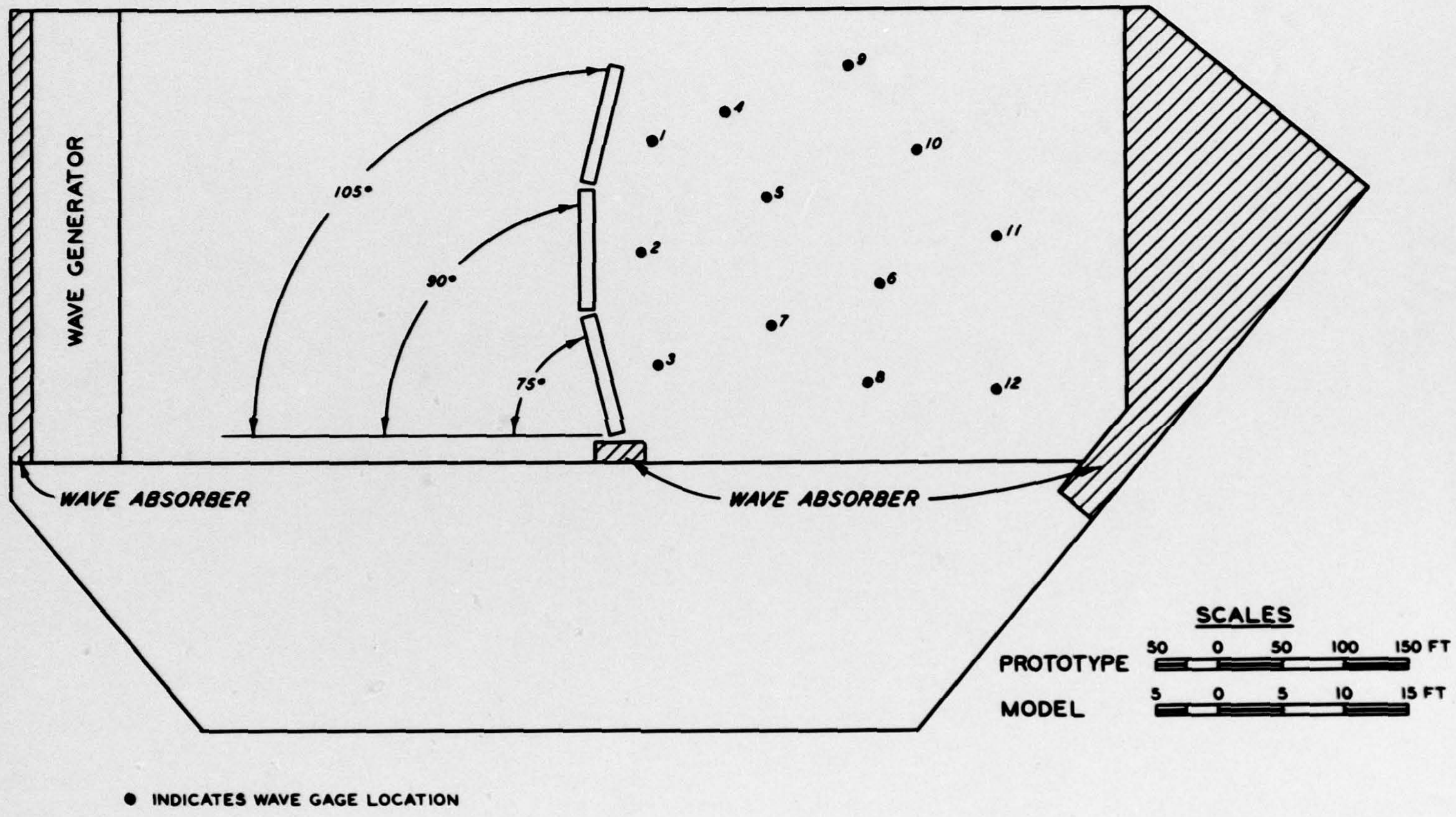

MODEL LAYOUT
CONVEX CONFIGURATION

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Carver, Robert D
Floating breakwater wave-attenuation tests for East Bay marina, Olympia Harbor, Washington; hydraulic model investigation / by Robert D. Carver. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1979.
18, [55] p., 19 leaves of plates : ill. ; 27 cm. (Technical report - U. S. Army Engineer Waterways Experiment Station ; HL-79-13)
Prepared for U. S. Army Engineer District, Seattle, Seattle, Washington.
References: p. 18.

1. Breakwaters. 2. East Bay, Wash. 3. Floating breakwaters. 4. Hydraulic models. 5. Marinas. 6. Olympia Harbor, Wash. 7. Water wave attenuation. I. United States. Army. Corps of Engineers. Seattle District. II. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Technical report ; HL-79-13.
TA7.W34 no.HL-79-13