MR 76-9
(AD-A028 274)

Wave Attenuation by Artificial Seaweed

by
John Ahrens

MISCELLANEOUS REPORT NO. 76-9
JUNE 1976

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER MR 76-9	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) WAVE ATTENUATION BY ARTIFICIAL SEAWEED		5. TYPE OF REPORT & PERIOD COVERED Miscellaneous Report
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) John Ahrens		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Department of the Army Coastal Engineering Research Center (CERRE-SP) Kingman Building, Fort Belvoir, Virginia 22060		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS F31236
11. CONTROLLING OFFICE NAME AND ADDRESS Department of the Army Coastal Engineering Research Center Kingman Building, Fort Belvoir, Virginia 22060		12. REPORT DATE June 1976
		13. NUMBER OF PAGES ~~13~~ 12 p
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Artificial seaweed
Shore protection
Wave attenuation
Waves

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

A series of wave tank tests was conducted at the U.S. Army Coastal Engineering Research Center (CERC) to determine the ability of a field of low specific gravity artificial seaweed to attenuate wave action. Wave gages were located on both sides of the seaweed field to measure wave attenuation. The field consisted of seven rows of seaweed with the rows spaced 3 meters (10 feet) apart. Ten distinct wave conditions were tested using periods ranging from 2.6 to 8.2 seconds and wave heights from 0.24 to 1.1 meters

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(0.8 to 3.6 feet). The stillwater depth for all tests was 2.4 meters (8 feet). There was a measureable level of wave attenuation for only the shortest period, 2.6 seconds. For the 2.6-second period, the reduction in wave height on passing through the seaweed field was about 12 percent.

PREFACE

This report is published to provide coastal engineers with the results of a series of wave tank tests of artificial seaweed's ability to attenuate wave action. The work was carried out under the coastal processes program of the U.S. Army Coastal Engineering Research Center (CERC).

The report was prepared by John P. Ahrens, Coastal Structures Branch, under the general supervision of Dr. Robert M. Sorensen, Chief, Coastal Structures Branch, Research Division.

The author acknowledges the numerous contributions by Mr. George Simmons in setting up and conducting the tests, and by Dr. Robert M. Sorensen for the many suggestions which improved the report.

Comments on this publication are invited.

Approved for publication in accordance with Public Law 166, 79th Congress, approved 31 July 1945, as supplemented by Public Law 172, 88th Congress, approved 7 November 1963.

Wilson P. Andrews

WILSON P. ANDREWS
LTC, Corps of Engineers
Commander and Director

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WAVE ATTENUATION BY ARTIFICIAL SEAWEED

by

John Ahrens

I. INTRODUCTION

This report discusses the wave tank testing of a low specific gravity artificial seaweed field and its ability to attenuate wave action. Field testing of the seaweed's potential to prevent scour or trap sand has previously been evaluated. Additional information on tests and applications of artificial seaweed is found in Rankin and Cogan (1965), Wicker (1966), Brashears and Bartnell (1967), Nicolon of Holland (1972), and Bakker, et al. (1973).

II. TEST SETUP, CONDITIONS, AND PROCEDURES

The artificial seaweed was tested at the Coastal Engineering Research Center (CERC) in the large wave tank, 6.1 meters (20 feet) deep, 4.6 meters (15 feet) wide, and 194 meters (635 feet) long (see Coastal Engineering Research Center, 1971 for a description of the tank). A riprapped wave absorber slope occupied 46 meters (150 feet) of tank length during the testing. Waves were generated by a piston-type wavemaker.

Each seaweed unit (Fig. 1) was composed of a large number of slender fronds made of stretched polypropylene foam strands (Fig. 2). The unit was 2 meters (6.5 feet) wide, about 2.1 meters (7 feet) long, and bound by horizontal stitching at 25-centimeter (10 inches) intervals. The fronds had a specific gravity between 0.1 and 0.2, and were attached to a black nylon bag which could be filled with weighting material to anchor the unit. The seaweed unit was secured in the tank by running a heavy aluminum strap through the nylon bag and bolting the strap to the floor. When the tank was filled each unit formed an inverted curtain extending about 2.3 meters (7.5 feet) above the tank floor.

The artificial seaweed field was formed by seven rows of seaweed, each row consisting of two seaweed units, spaced 3 meters (10 feet) apart along the wave tank. Figures 3 and 4 show a cutaway view along the tank and a cross-sectional view of the tank through the seaweed field, respectively.

Gages were located on both sides of the seaweed field to measure wave attenuation (Fig. 3). A 1.5-meter-long (5 feet) capacitance-type wave gage with continuous resolution was located at the seaward tank station 522. A 3-meter-long (10 feet) step-resistance gage with sensitive elements 3 centimeters (0.1 foot) apart (Williams, 1969) was located at the landward tank station 442. Output from the two gages was recorded on a dual-channel pen and ink strip chart. The step-resistance wave gage is essentially a self-calibrating gage. The capacitance gage was statically calibrated before each data run and checked after each run to ensure that it maintained its calibration.

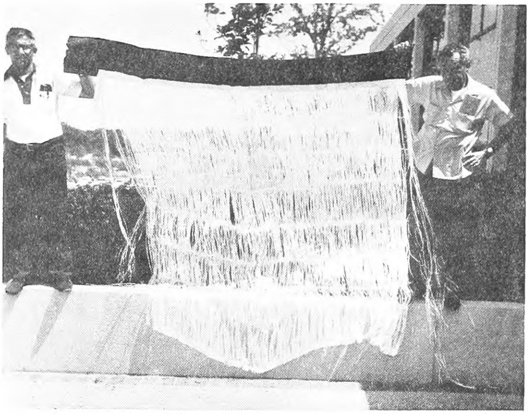

Figure 1. One seaweed unit.

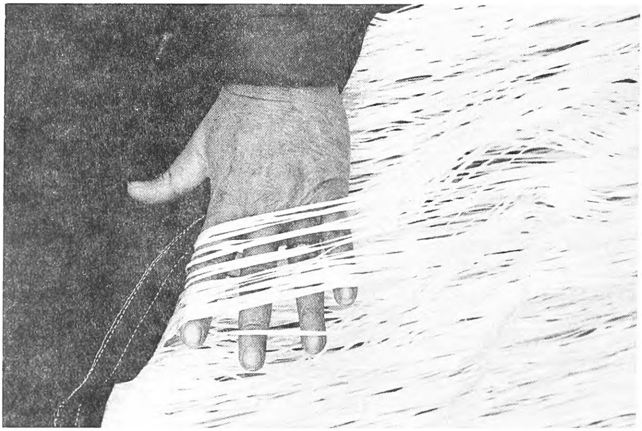

Figure 2. Closeup view of seaweed fronds.

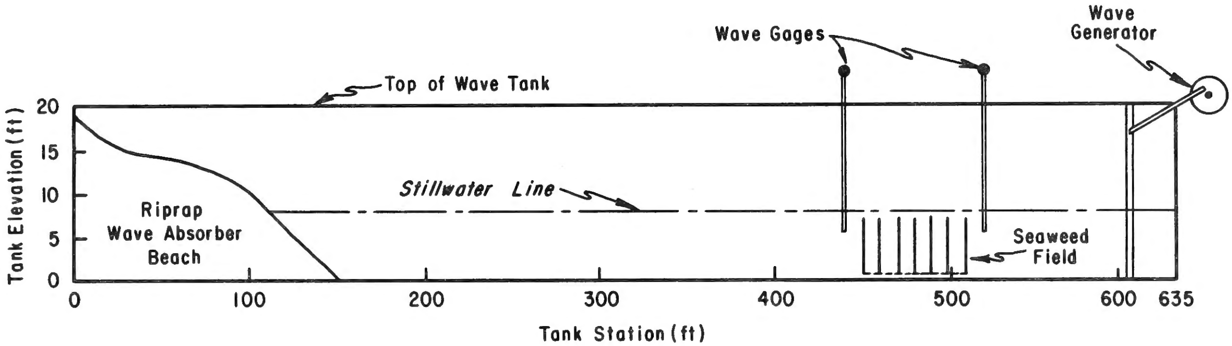

Figure 3. Test setup in large wave tank.

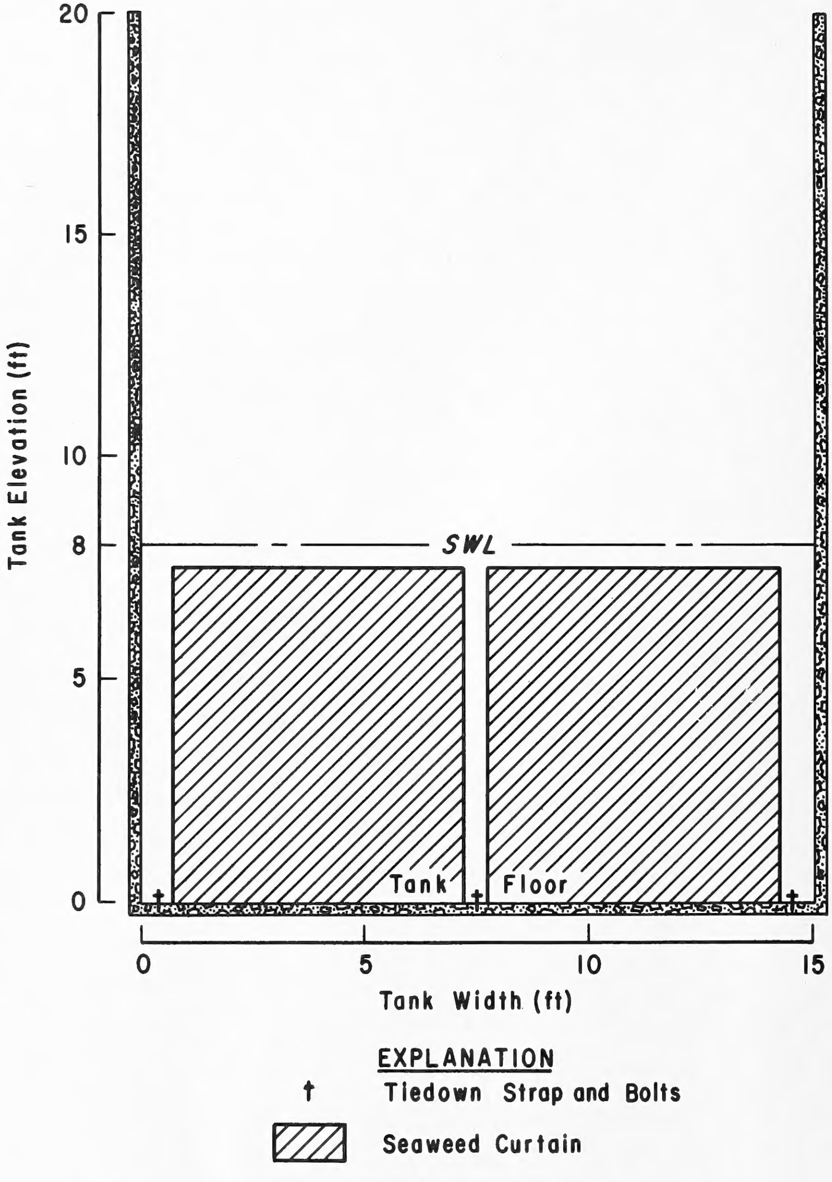

Figure 4. Cross section of tank at seaweed field.

A 2.4-meter (8 feet) stillwater depth, which was just sufficient to submerge the tops of the seaweed fronds (Fig. 4), was used for all conditions. Wave data were collected during runs of 10-minute durations. The 10 wave conditions tested are listed in Table 1. Generally, three runs were made at each wave condition so the reproducibility of conditions and results could be checked. The length of the data runs was chosen before the effectiveness of the wave absorber slope was noted. Standing-wave patterns on the tank wall indicated that there was considerable wave reflection from the absorber slope for wave periods of 6.2 and 8.2 seconds. The wave absorber had been designed for another study which used a stillwater depth of 4.6 meters and time restrictions on the use of the tank made it impossible to modify the absorber for the 2.4-meter water depth used in this study. Because of the wave reflection problem only the part of the wave record unaffected by reflection was used to calculate attenuation. Data runs were also made with the seaweed field out of the wave tank for all wave conditions to provide a control for the analysis.

III. DATA ANALYSIS AND RESULTS

Wave records were analyzed to see if wave energy had been lost in traveling through the seaweed field from the seaward to the landward gage. Since two different types of wave gages were used, the data runs with the seaweed out of the tank provided a method of eliminating systematic wave height measurement differences between the gages. The data runs with the seaweed out of the tank also allowed the analysis to eliminate inclusion of any losses of wave energy between the two gages due to the tank walls and floor. Table 2 shows how the wave height attenuation factor for wave condition 1 (Table 1) was computed.

In Table 2, the wave heights from stations 522 and 442 (cols. 2 and 3) are the average heights of five consecutive waves. These five waves were measured shortly after the generator was started for each data run when the wave conditions had stabilized at the station but before reflected waves from the absorber slope had reached the gage. For simplicity, waves in this category are referred to as *well-formed waves*. The ratio of the landward wave height to the seaward height for the seaweed-in and seaweed-out conditions is given in column 4. The paired values of the seaweed-in and seaweed-out conditions (col. 4) form the ratio which is the wave height attenuation factor (col. 5). There are nine equally valid ways the seaweed-in condition can pair up with the seaweed-out condition (col. 4); however, the average value of the wave height attenuation factor for the nine pairings will be the same as the average value in column 5. The average value of the wave height attenuation factor was tabulated for all wave conditions (Table 1, col. 4), and is considered the best estimate of the reduction in wave height caused by the seaweed field.

A wave height attenuation factor of 1 indicates no reduction in wave height for waves passing through the field due to the presence of the field.

Table 1. Test conditions and wave attenuation factors calculated from first five well-formed waves of each data run.

Wave condition no. (1)	Average seaward (sta. 522) wave height (ft) (2)	Wave period (s) (3)	Calculated wavelength (ft) (4)	Wave height attenuation factor[1] (5)	Wave energy attenuation factor[2] (6)	Square root of col. (6) (7)
1	2.6	2.6	32	0.875 0.878[3]	------ 0.791[4]	----- 0.889
2	1.5	4.3	64	0.965	0.978	0.989
3	3.1	4.5	66	1.016	0.952	0.976
4	1.1	6.2	96	0.967	0.989	0.994
5	2.3	6.2	96	0.986	1.021	1.010
6	3.7	6.2	96	0.996	1.071	1.035
7	0.7	8.2	128	1.019	0.998	0.999
8	1.6	8.2	128	1.013	0.885	0.941
9	2.6	8.2	128	1.040	1.128	1.062
10	3.5	8.2	128	1.002	0.967	0.983

[1]Calculated from trough to crest heights.

[2]Calculated from digitized wave records.

[3]Calculated from first 25 well-formed waves of each data run.

[4]Calculated from digitized records corresponding to first 25 well-formed waves of each data run.

Table 2. Example of wave height attenuation factor computations for a 2.6-second wave period.[1]

Data run designation (1)	Average wave height (ft) Seaward gage, sta. 522 (2)	Average wave height (ft) Landward gage, sta. 442 (3)	Ratio of landward-seaward gages (4)	Wave height attenuation factor = a/b (5)
1a[2]	2.70	2.34	0.867	0.841
1b[3]	2.60	2.68	1.031	
2a	2.63	2.32	0.882	0.829
2b	2.52	2.68	1.063	
3a	2.59	2.62	1.012	0.955
3b	2.51	2.66	1.060	
				Average 0.875

[1]Condition 1, Table 1.

[2]Seaweed in tank.

[3]Seaweed out of tank.

The example (Table 2) indicates that wave height is reduced 12.5 percent by the field for a 2.6-second wave period. Table 1 (col. 5) shows some wave height attenuation factors greater than 1 which implies a gain in wave height at the landward gage due to the presence of the field. Such a condition is impossible and indicates noise in the experiment.

To provide a check on the wave height attenuation factor calculations, the segment of the wave record from which the wave height was calculated was digitized at a rate of two times per second. From the digitized data the variance of the wave record was calculated; the variance is proportional to the wave energy. The variance of each wave record was treated the same as the wave height in Table 2 to give a wave energy attenuation factor for each condition (Table 1, col. 6). The square root of the wave energy attenuation factor (Table 1, col. 7) can be compared to the wave height attenuation factor as a method of judging the consistency of the two methods in evaluating wave attenuation due to the seaweed field. Both methods indicate that with the exception of the shortest wave period, there is little wave energy loss.

To further document the attenuation for the shortest period, T = 2.6 seconds, an analysis of a longer record length was conducted. Because of the slower group speed of this wave period a considerably greater record length and number of waves were unaffected by reflection from the absorber slope than for the longer period wave conditions. An analysis based on the first 25 stable waves unaffected by reflection gave a wave height attenuation factor of 0.878. The same segments of records used in the 25 wave analyses were digitized two times per second and gave a wave energy attenuation factor of 0.791 which corresponds to a wave height attenuation factor of 0.889 (Table 1, cols. 5, 6, and 7).

IV. CONCLUSION

This study shows that for the width of the field tested, the low specific gravity artificial seaweed is not effective in attenuating wave energy at wave periods commonly found in the ocean or other large bodies of water.

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