CHAPTER 108

DISCONTINUOUS COMPOSITE WAVE ABSORBER STUDIES

Anthony R. Fallon
Research Engineer
Chevron Oil Field Research Company
La Habra, California

An experimental study was conducted to determine the energy dissipation characteristics of a discontinuous wave absorber consisting of an impervious lower slope and a stone-filled upper slope. The purpose was to determine the wave energy absorption as a function of the incident wave parameters and the wave absorber geometry. Parameters varied were wavelength, wave height, lower and upper absorber slopes, berm depth and width, and stone size. For virtually all test conditions, a minimum wave reflection was found when the discontinuity (berm) depth was at one-quarter to one-half the water depth below the water surface. The overall wave absorption increased under the following conditions: an increase in horizontal berm width of up to five layers of stone; a decrease in the angle of the upper (stone-filled) slope when the berm depth is below one-fifth the water depth; and a decrease in the angle of the lower (impervious) slope when the berm depth is above one-half the water depth. The results should be useful where water wave reflections must be minimal and space is limited, such as in harbor walls or for hydraulic models.

INTRODUCTION

The purpose of this study was to experimentally determine wave reflection as a function of wave absorber parameters. The absorber consisted of a stone-filled upper slope and an impervious lower slope. The series of over 400 wave absorber tests was run at the Look Laboratory of the Department of Ocean Engineering at the University of Hawaii. The author conducted the tests as a Master of Science thesis research project (Fallon, 1970). This paper presents the significant results.

TESTING PROCEDURE

The experimental configuration is shown schematically in Figure 1. Tests were conducted in a 48 ft-long x 9 in-wide x 13 in-high plexiglass flume. The wave generator was a paddle hinged at the top. Wave reflection was measured by moving the three wave gages (suspended from a trolley) slowly through a partial standing wave set up in front of the wave absorber test section. The resistance gages each measured a node and a loop (anti-node) as they moved through the standing wave. The oscillograph records (Figure 2) were used to determine a reflection coefficient based on linear wave theory. The reflection coefficient (R) is defined as:

$$R = \frac{HL-HN}{HL+HN}$$

where HL is the loop height and HN is the node height. The reflection coefficients for each gage were then averaged to obtain a representative reflection coefficient.

Computer simulations of the testing procedure were run to determine the error resulting in using the moving probe method for determining reflection coefficients. For R near unity, or a high probe velocity relative to the wave celerity, a large error resulted that was biased toward low values of R. However, when the reflection coefficient was less than 50%, as was the case in nearly all the test conditions run, this error was found to be less than 5%.

The wave absorber section is shown schematically in Figure 3. It consisted of an impervious lower slope (A) and a stone-filled upper slope (B), both of which were varied from 18° to 90°. Previous investigators have found that the reflection coefficient could vary with the stone placement. Therefore, to insure consistent absorber characteristics the stones were hand sorted, and flat or oblong stones were rejected. The stones were 1/2" and 3/4" in diameter and the void ratio for these stones was approximately 50%. The berm width (W) was varied from 0 (no stone) to 14 times the stone diameter. The berm depth (Z), found to be a very sensitive parameter, was varied in small increments; from 9 to 17 different values were used for each test condition. The relative berm depth (Z/D), where D is the water depth, was varied from 0 (all impervious slope) to 1.0 (all stone-filled slope). The water depth was 4 inches.

The nature of the apparatus limited the test wave characteristics. The ratio of wavelength to depth (L/D) was varied from 9 (in most tests) to 24. Relatively flat waves were used; their steepness (H/L) was varied from 0.004 to 0.012, 0.008 being used for most.

RESULTS

The primary result of these tests was the determination of the reflection coefficient variation as a function of the berm depth. This is illustrated in Figure 4 for an upper slope of 18° and a lower slope of 34°. The reflection coefficient decreases with increasing berm depth (that is, with extension of the rocks below the surface) reaching a minimum at about Z/D = 0.45. There the reflection coefficient levels off or even begins to rise for a further increase in the berm depth. This trend was observed in virtually all tests with a minimum reflection coefficient at Z/D values from 0.25 to 0.5. A point of minimum reflection was observed in the configuration with no stones and only the geometric discontinuity present (Figure 5). It also occurred when the upper slope was rock-filled and at the same angle as the impervious lower slope. Figure 6 shows such results, for slopes of 18 degrees.

The effect of changing the berm width, which can be considered a measure of the number of layers of stones used, is illustrated in Figure 7. The reflection coefficient is plotted versus berm depth for various berm widths. The berm width is expressed in the dimensionless parameter W/d, which is the berm width divided by the average stone diameter (d). There is little wave absorption gained by increasing the berm width beyond five stone-diameters for the conditions tested.

The effect of changing the upper absorber slope is shown in Figure 8. When Z/D is less than 0.2, the angle of the upper slope has little effect on R. However, for Z/D greater than 0.2, R increases with an increase in the upper slope angle, as might be expected.

In Figure 9 is illustrated the effect of lower absorber slope on R. The angle has little effect when Z/D is greater than 0.5. However, when Z/D is less than 0.5, R decreases significantly with an increase in lower absorber slope.

No correlation was found between wave absorption and stone size, possibly because (1) the range of sizes tested was rather small, and (2) the void ratios were all approximately the same for these sorted stones.

The general results related to incident wave parameters were that wave absorption increased with wave steepness but did not correlate with wave length.

Because these tests were conducted in a relatively small wave flume, it was desirable to compare the results with those for similar larger scale tests. Look Laboratory had conducted two-dimensional wave absorber tests of about four times this scale in 1969 as part of a hydraulic model testing program (Look Laboratory, 1969). The results are shown with comparable ones from the present series in Figure 10. Correlation is good, indicating that the results of the present study may be applied to larger-scale situations.

Based on the results of this experimental investigation a general "best design" can be suggested that will minimize the use of both the horizontal space and the number of stones required. An effective design would have (1) an upper (stone-filled) slope with a berm width five times the average stone diameter and the face inclined at an angle of 18°, (2) a berm depth of 1/2 the water depth, and (3) a nearly vertical lower (impervious) slope. Sea walls and harbor walls are possible applications for such a design. On a smaller scale, the walls of hydraulic models can be lined with this type of wave absorbers, as has been done at Look Laboratory.

REFERENCES

Fallon, Anthony R., Laboratory Studies of a Discontinuous Wave Absorber, M.S. Thesis; Ocean Engineering Department, University of Hawaii, December 1970.

Look Laboratory of Oceanographic Engineering, Study of Proposed Barbers Point Harbor, Hawaii, Technical Report No. 4, Center for Engineering Research, University of Hawaii, February 1969.

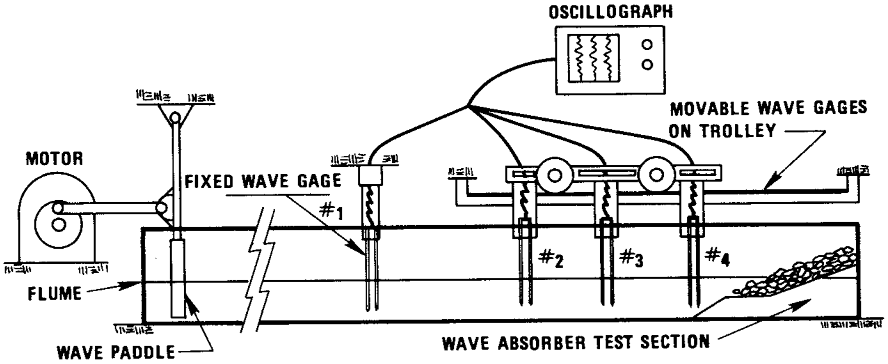


FIGURE 1

SCHEMATIC DIAGRAM OF WAVE ABSORBER TESTING APPARATUS.

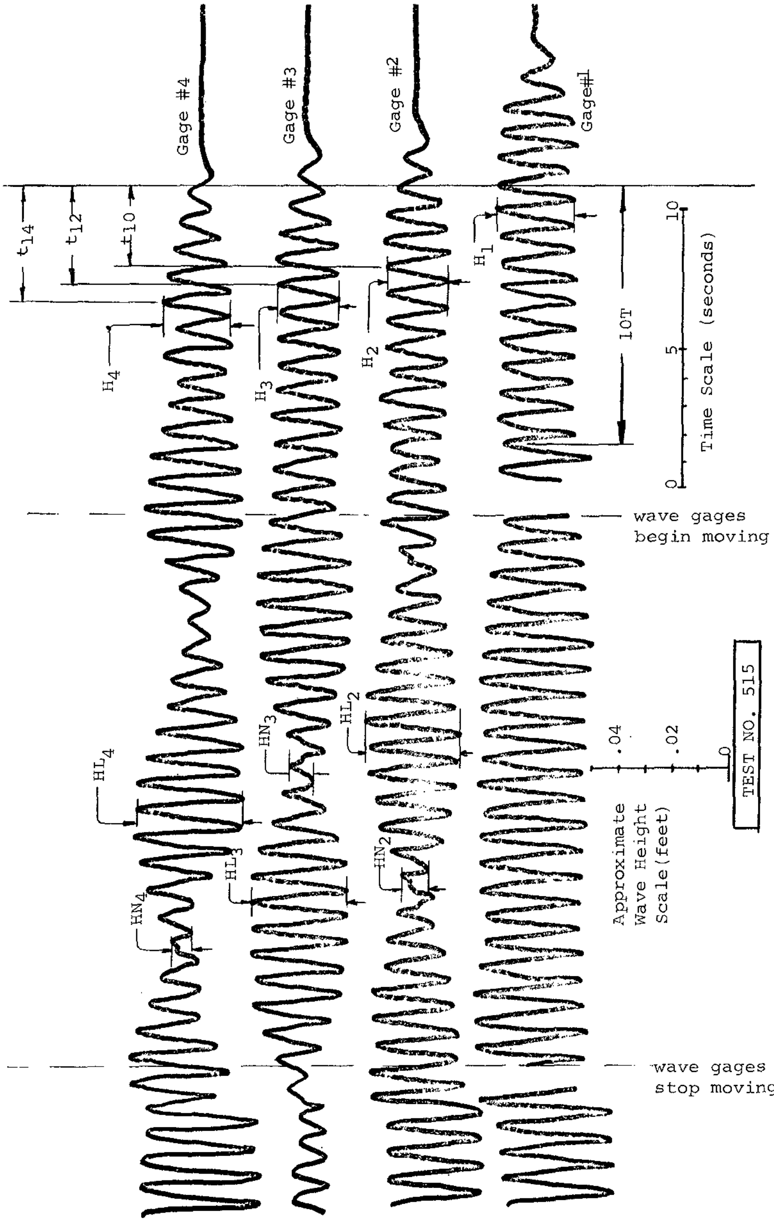


FIGURE 2

OSCILLOGRAPH RECORD FOR TEST No. 515

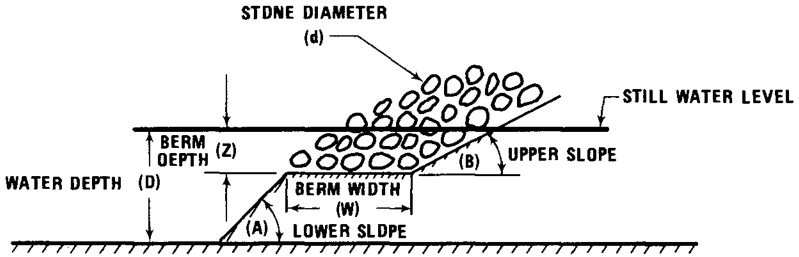
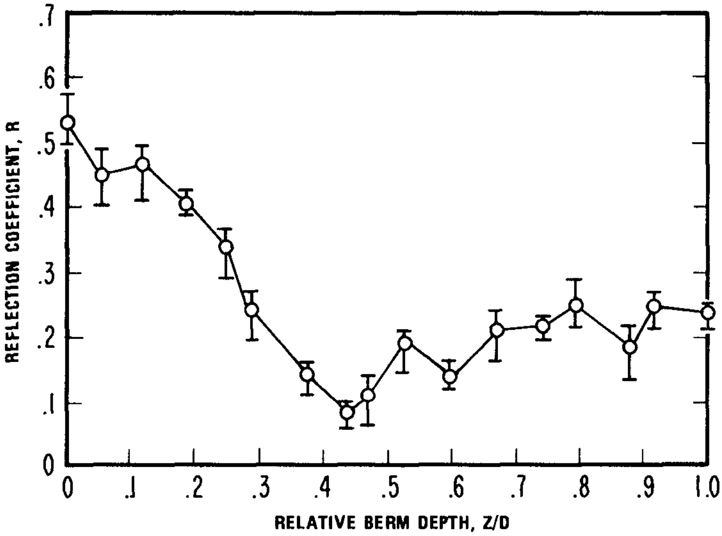


FIGURE 3

SCHEMATIC DIAGRAM OF WAVE ABSORBER TEST SECTION

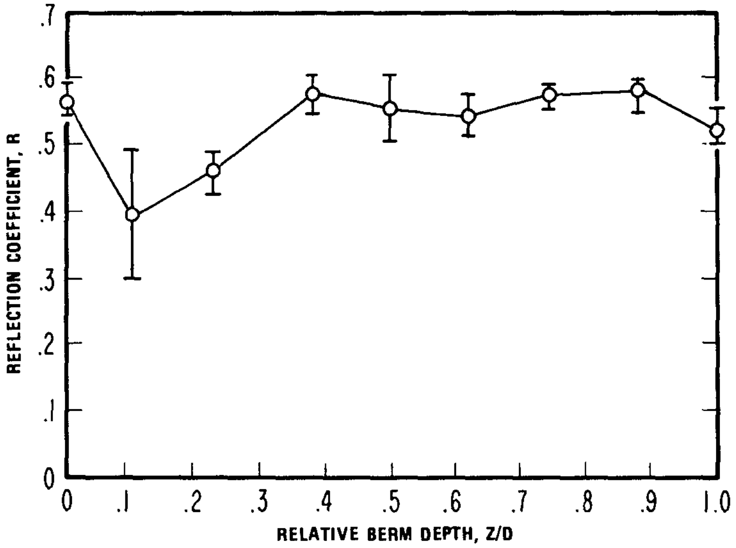


WAVELENGTH TO DEPTH RATIO L/D = 9
WAVE STEEPNESS H/L = .008

WATER DEPTH D = 4.0"
LOWER SLOPE A = 34°
UPPER SLOPE B = 18°
BERM WIDTH W = 6.0"

STONE DIAMETER d = 0.64"

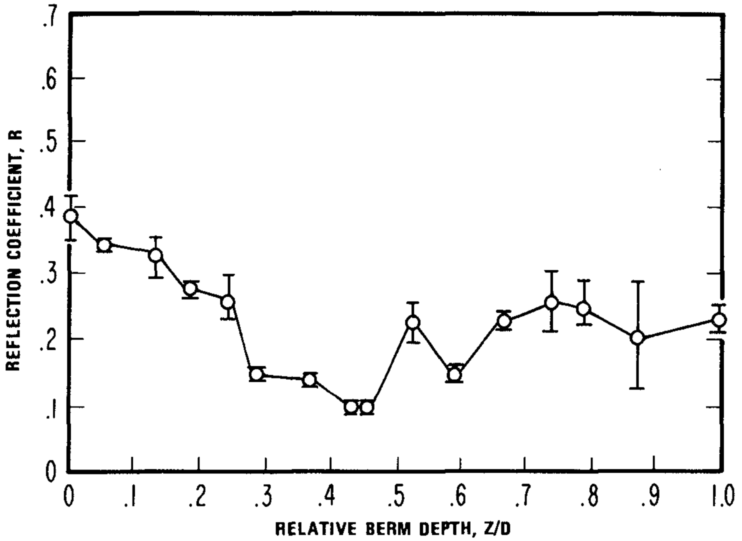
FIGURE 4
TEST RESULTS FOR TYPICAL CONDITIONS.



WAVELENGTH TO DEPTH RATIO L/D = 9
WAVE STEEPNESS H/L = .008

WATER DEPTH D = 4.0 INCHES
LOWER SLOPE A = 34°
UPPER SLOPE B = 18°

FIGURE 5
TEST RESULTS FOR NO STONES.



WAVELENGTH TO DEPTH RATIO L/D = 9
WAVE STEEPNESS H/L = .008

WATER DEPTH D = 4.0 INCHES
LOWER SLOPE A = 18°
UPPER SLOPE B = 18°
BERM WIDTH W = 6.0 INCHES

STONE DIAMETER d = 0.64 INCHES

FIGURE 6
TEST RESULTS FOR NO SLOPE DISCONTINUITY

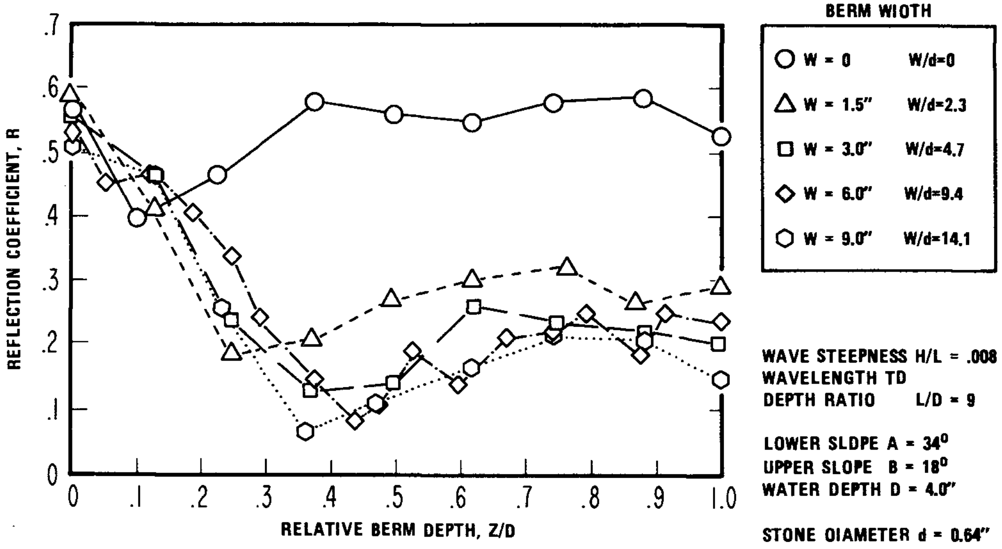


FIGURE 7

EFFECT ON REFLECTION COEFFICIENT OF BERM WIDTH

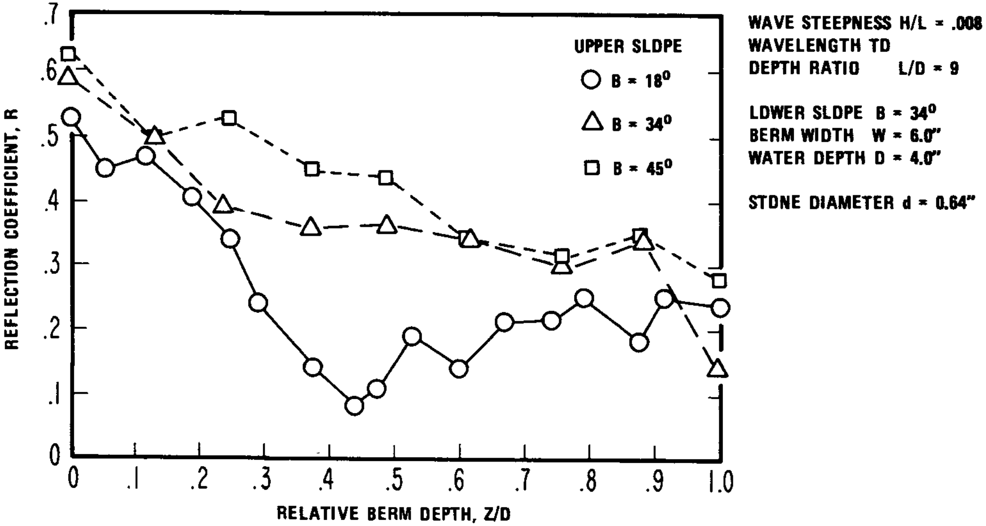


FIGURE 8

EFFECT ON REFLECTION COEFFICIENT OF UPPER SLOPE

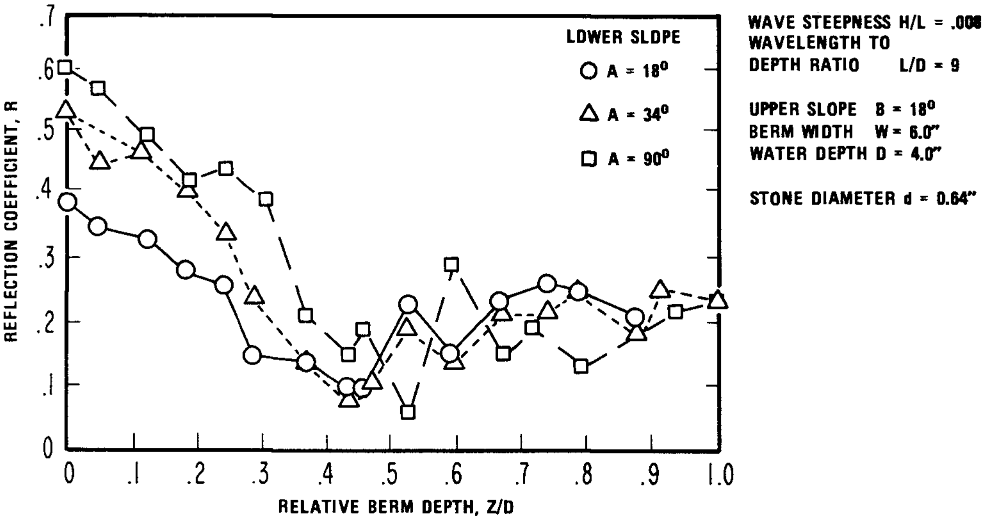


FIGURE 9

EFFECT ON REFLECTION COEFFICIENT OF LOWER SLOPE

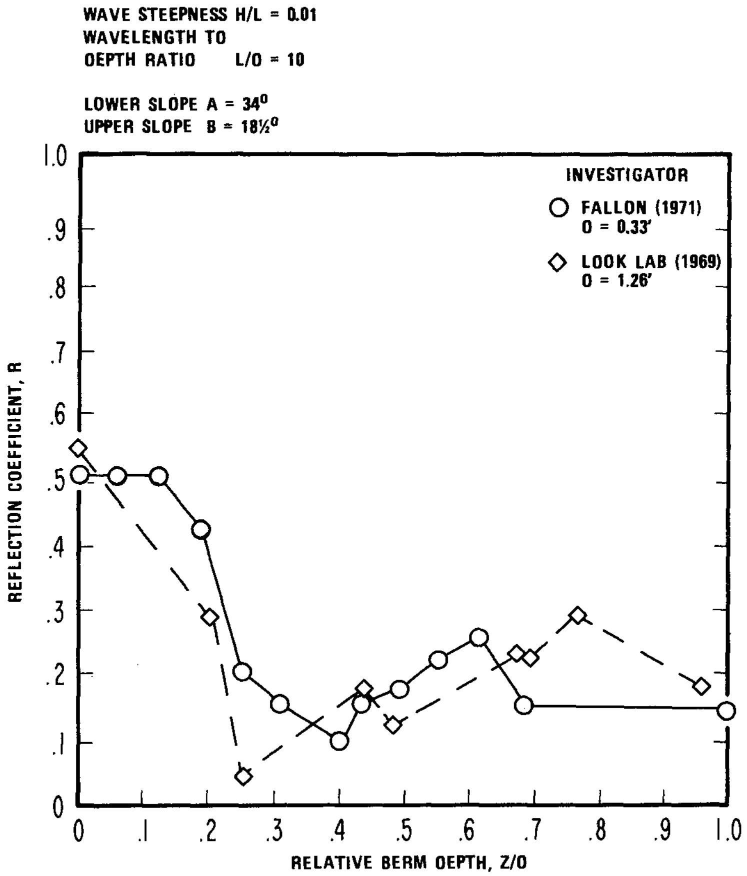


FIGURE 10

COMPARISON OF REFLECTION COEFFICIENTS
FROM A DISCONTINUOUS, ROCK-FILLED
WAVE ABSORBER FOR L/D = 10