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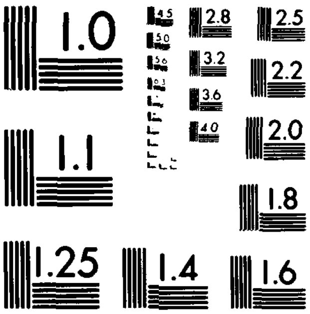

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Two-Dimensional Tests of Wave Transmission and Reflection Characteristics of Laboratory Breakwaters

by

William N. Seelig

TECHNICAL REPORT NO. 80-1

JUNE 1980

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Monochromatic and irregular wave transmission and reflection measurements were made for various subaerial and submerged breakwater cross sections. These two-dimensional laboratory tests included smooth impermeable breakwaters, rubble-mound breakwaters, and breakwaters armored with dolos units. Wave transmission by overtopping was found to be related to breakwater freeboard wave runup, and breakwater crest width; a method of estimating transmission by overtopping coefficients is presented. The Madsen and White (1976) numerical

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) procedure was found to be an important tool for predicting the amount of transmission through permeable breakwaters. Suggested procedures for estimating transmission coefficients have been incorporated into the computer programs OVER and MADSEN (included as appendixes) and these programs may be used to predict wave transmission coefficients for nonbreaking, breaking, monochromatic, and irregular wave conditions.

PREFACE

This report presents the results of research conducted to develop methods for estimating wave transmission past submerged, subaerial, permeable, and impermeable breakwaters. The final prediction techniques are given in the form of computer programs, and the laboratory data used to develop and test the methods are included in appendixes to this report. These methods supplement Section 7.23 of the Shore Protection Manual (SPM). The work was carried out under the offshore breakwaters for shore stabilization program of the U.S. Army Coastal Engineering Research Center (CERC).

The report was prepared by William N. Seelig, Hydraulic Engineer, under the general supervision of Dr. R.M. Sorensen, Chief, Coastal Processes and Structures Branch. J. Ahrens and M. Titus provided a significant contribution to this report by their many useful suggestions and valuable laboratory assistance.

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.

TED E. BISHOP
Colonel, Corps of Engineers
Commander and Director

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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
inches	25.4	millimeters
	2.54	centimeters
square inches	6.452	square centimeters
cubic inches	16.39	cubic centimeters
feet	30.48	centimeters
	0.3048	meters
square feet	0.0929	square meters
cubic feet	0.0283	cubic meters
yards	0.9144	meters
square yards	0.836	square meters
cubic yards	0.7646	cubic meters
miles	1.6093	kilometers
square miles	259.0	hectares
knots	1.852	kilometers per hour
acres	0.4047	hectares
foot-pounds	1.3558	newton meters
millibars	1.0197×10^{-3}	kilograms per square centimeter
ounces	28.35	grams
pounds	453.6	grams
	0.4536	kilograms
ton, long	1.0160	metric tons
ton, short	0.9072	metric tons
degrees (angle)	0.01745	radians
Fahrenheit degrees	5/9	Celsius degrees or Kelvins[1]

---

[1] To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use formula: $C = (5/9)(F - 32)$.

To obtain Kelvin (K) readings, use formula: $K = (5/9)(F - 32) + 273.15$.

SYMBOLS AND DEFINITIONS

A	material identifier
A_1	spectral coefficients
A_2	spectral coefficients
a	empirical rough-slope runup coefficient
a_I	incident wave amplitude at a spectral line
a_R	reflected wave amplitude at a spectral line
B	breakwater top width
B_1	spectral coefficients
B_2	spectral coefficients
b	empirical rough-slope runup coefficient
C	transmission by overtopping coefficient
C_1	empirical wave runup on smooth-slope coefficients
C_2	empirical wave runup on smooth-slope coefficients
C_3	empirical wave runup on smooth-slope coefficients
CF	physical model correction factor = (K_{Tt}) prototype/(K_{Tt}) model
d	water depth
d_s	water depth at toe of a structure
d_{50}	median material diameter
F	breakwater freeboard = $h - d_s$
f	wave frequency = 1/T
g	acceleration due to gravity
H or H_I	incident wave height
H_R	reflected wave height
H_{rms}	root-mean-square (rms) wave height
H_s	significant wave height
H_T	transmitted wave height
$\overline{H}$	mean wave height
ID	a 10-digit identification code (year, month, day, hour, minute) assigned to each data collection run
j	spectral line number

SYMBOLS AND DEFINITIONS--Continued

K_R	reflection coefficient
K_T	transmission coefficient = $\sqrt{K_{To}^2 + K_{Tt}^2}$
K_{To}	wave transmission by overtopping coefficient
K_{Tt}	coefficient of wave transmission through a permeable breakwater
k	wave number = $2\pi/L$
L	wavelength
L_o	deepwater wavelength
P	material porosity
p	probability
Q_p	spectral-peakedness parameter
Q_{pi}	incident spectral-peakedness parameter
Q_{pr}	reflected spectral-peakedness parameter
Q_{pt}	transmitted spectral-peakedness parameter
R	wave runup
$r(H,H + 1)$	autocorrelation of wave heights
$r(H,T)$	correlation of wave heights and periods
T	wave period
T_p	period of peak energy density
W_{50}	median weight of material
γ	specific weight
Δf	band width
$\Delta \ell$	gage spacing
η_{rms}	root-mean-square water level
θ	angle of seaward face of a breakwater
ν	kinematic viscosity of water
ξ	surf parameter = $\left(\tan \theta / \sqrt{H/L_o}\right)$
ρ	autocorrelation of zero up-crossing wave heights ● for incident waves ● for transmitted waves

TWO-DIMENSIONAL TESTS OF WAVE TRANSMISSION AND REFLECTION CHARACTERISTICS OF LABORATORY BREAKWATERS

by
William N. Seelig

I. INTRODUCTION

The primary function of a breakwater is to reduce wave heights in an area being sheltered. Breakwaters are primarily used to protect harbors from excessive wave action, to prevent beach erosion, and to trap sediment for mechanical bypassing at an inlet or harbor entrance. A secondary use of breakwater design is to reduce the wave reflection from the structure. Reflected waves combined with incident waves can produce undesirable water motions that may be a nuisance to navigation or encourage scour at the toe of a structure.

Since the cost of building breakwaters is generally high, methods are needed to estimate transmitted and reflected wave heights to enable comparison of alternative structure designs. This report presents suggested methods for predicting transmission and reflection characteristics of breakwaters based on laboratory experiments, including the work of previous investigators. These methods supplement Section 7.23 of the Shore Protection Manual (SPM) (U.S. Army, Corps of Engineers, Coastal Engineering Research Center, 1977). The basic types of breakwaters considered are permeable and impermeable structures with crest elevations above the stillwater level (subaerial) and below the stillwater level (submerged). The other factors investigated include wave height, period, breakwater cross-section design, and material characteristics. Both monochromatic and irregular waves were tested.

Section II of this report presents a brief review of research conducted by previous investigators. Section III describes the laboratory setup and procedures; Sections IV, V, and VI present data analysis methods and definitions. The conditions tested are summarized in Section VII. Detailed descriptions of the breakwaters tested and materials used are given in Appendixes A and B; summary tables and figures of laboratory results are presented in Appendixes C, D, and E.

Laboratory results are used in this study to develop a method for predicting wave transmission by overtopping coefficients using the ratio of breakwater freeboard to wave runup (suggested by Cross and Sollitt, 1971) and the breakwater crest width (suggested by Saville, 1963). The wave transmission by overtopping prediction method is then combined with the model of wave transmission through permeable structures of Madsen and White (1976) and this combination package is verified with the laboratory results over a wide range of conditions. Prediction methods are summarized in the computer programs OVER and MADSEN (Apps. F and G). An example breakwater design is worked with the aid of the two computer programs to illustrate how the prediction methods can be used to compare alternative breakwater designs, and to illustrate the importance of various design parameters.

II. LITERATURE REVIEW

Some of the important sources of ideas and data used in preparing this report are summarized below in chronological order.

Saville (1963) tested a large number of similar rough structures with a 1 on 2 front-face slope for a proposed breakwater at Point Loma, California. Most of Saville's breakwater models had a crest elevation near the stillwater level, so wave transmission in most of the tests was primarily due to overtopping. Some of the breakwaters tested were first modeled in the large wave tank at the Coastal Engineering Research Center (CERC), then re-tested at a smaller scale to examine scale effects. Some tests were repeated with otherwise identical permeable and impermeable breakwaters to assess the influence of wave transmission through the permeable breakwaters and wave transmission by overtopping. The breakwater crest width was also varied over a wide range of values to determine the influence of width on the wave transmission coefficient. Since wave reflection coefficients were not measured, the burst method was used during testing to avoid laboratory effects caused by re-reflection of waves from the generator blade.

Lamarre (1967) measured wave transmission by overtopping for a structure with a comparatively narrow crest width and 1 on 1.5 structure slopes. Wave conditions and the height of the structure were varied.

Goda (1969) tested vertical, smooth impermeable structures for wave transmission by overtopping. The breakwater crest width was varied and a wide range of submerged and subaerial structure heights and a number of wave conditions were tested. Wave reflection coefficients were measured to determine the incident wave height acting on the structure. A nonlinear empirical equation was developed for predicting wave transmission coefficients. In this formula the transmission coefficient is a function of the ratio of the breakwater freeboard to the incident wave height and two empirical coefficients, where the coefficients are related to structure geometry and the relative water depth.

Davidson (1969) tested a 1 on 40 scale model of a breakwater proposed for Monterey Harbor, California. The breakwater had tribar armor units and experienced a combination of wave transmission over and through the structure.

Cross and Sollitt (1971) developed a semiempirical model for wave transmission by overtopping of subaerial breakwaters. The model was compared to Lamarre's (1967) data for a smooth impermeable structure with a 1 on 1.5 front-face slope. Cross and Sollitt's model suggests that wave transmission by overtopping is a nonlinear function of the ratio of breakwater freeboard to runup. Examination of Saville's (1963) data suggests that a linear model would form an upper envelope for wave transmission over rough structures.

Keulegan (1973) measured wave transmission through a number of vertical-faced permeable breakwaters using a wide variety of materials and wave conditions. Comparison of results led to development of a method for designing scale models that consider scale effects.

Sollitt and Cross (1976) tested wave transmission through a permeable rubble-mound breakwater and used this information to develop an analytical-empirical model.

Bottin, Chatham, and Carver (1976) tested 1 on 22 rubble-mound scale and concrete armor unit breakwaters proposed for Waianae Harbor, Hawaii. Wave transmission consisted of a combination of wave transmission by overtopping and wave transmission through the structures. Wave reflection coefficients were not measured. Wave runup on dolos was observed.

Madsen and White (1976) developed a analytical-empirical model for the prediction of wave transmission and reflection coefficients for wave transmission through subaerial rubble-mound breakwaters. The model employs the long wave assumption, so predictions using their model are expected to be most reliable for shallow-water waves. Comparison of the Madsen and White model with physical model tests by Keulegan (1973) and Cross and Sollitt (1976) shows that the wave transmission coefficient can be predicted more reliably than the reflection coefficient.

The data from independant tests of wave transmission by overtopping conducted in this study, together with the results of Saville (1963), Lamarre (1967), Goda (1969), and Cross and Sollitt (1971), are used to develop a wave transmission by overtopping equation similar to one proposed by Cross and Sollitt (1971). The equation is then combined with the model of wave transmission through permeable breakwaters of Madsen and White (1976) to form a generalized model of wave transmission for breakwaters. This model is verified by comparing numerical and physical model results for a wide range of conditions.

III. LABORATORY TESTING

1. Laboratory Test Setup.

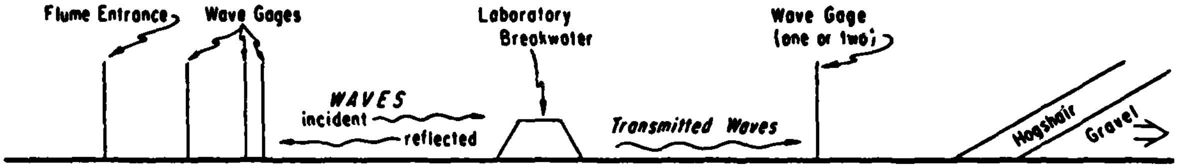
Laboratory tests were performed at CERC in a wave tank 4.57 meters wide, 42.7 meters long, and 1.22 meters deep. A part of the tank was divided by four walls to form two interior test flumes, each 61 centimeters wide; the remaining tank width contained a 1 on 12 absorber beach made of crushed stone with a median diameter of 2.9 centimeters (Fig. 1). This arrangement allowed two experiments to be performed simultaneously, and energy reflecting off of the test structures diffracts out of the test flume to minimize re-reflection of waves off of the generator blade.

The laboratory breakwaters were located between stations 5 and 10 meters along the flume and parallel-wire resistance gages were used to measure wave conditions in the flume. Gages placed at stations 1.40, 2.35, and 2.70 meters along the test flumes were used to document incident and reflected wave conditions. One or two gages placed landward were used to measure transmitted waves (Fig. 1).

A wave absorber consisting of a crushed gravel slope covered with a 0.6-meter-thick layer of hogshair was placed at the end of the test flume to absorb a majority of the transmitted wave energy. The test flume was terminated 3 meters before the end of the wave tank to allow water overtopping the test structure to escape from the flume through the absorber gravel. This arrangement prevented the buildup of water on the landward side of the test structure.

2. Methods of Generating Waves.

Waves in this facility were generated by a programable piston-type generator with a mean blade position 19 meters seaward of the entrance to the test flumes. A minicomputer was used to produce monochromatic waves of a specified wave height and period by moving the blade with a sinusoidal motion. Irregular waves



Profile view of the left test flume.

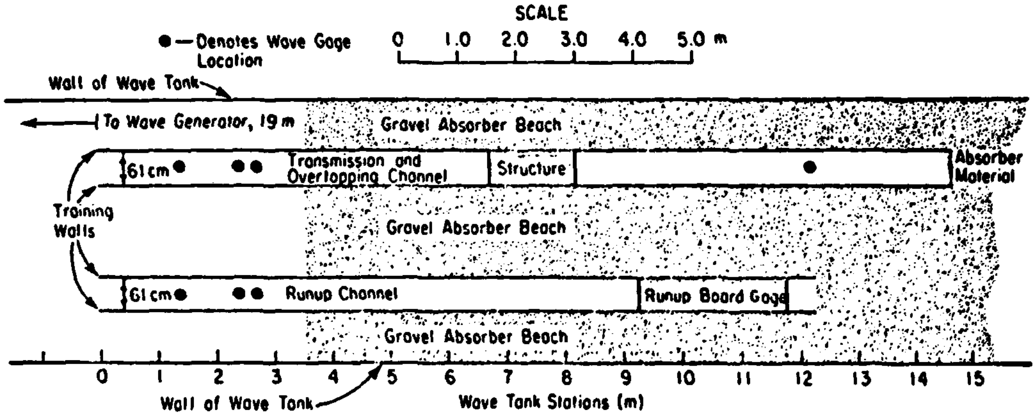


Figure 1. Plan view of wave tank setup.

were produced by using the CERC Data Acquisition System (DAS) to create a signal to move the blade. Irregular waves were made by summing 50 components of varying amplitude, period, and random phase to produce a wide variety of spectral shapes.

3. Data Collection.

The laboratory data collection scheme was designed after the CERC field wave data monitoring program. Data collection was performed automatically by the DAS in the following sequence:

(a) Wave gages were calibrated.

(b) Waves were produced for several minutes to allow tank startup transient conditions to die out.

(c) Wave gages collected data at a sampling rate of 16 times a second over a 256-second sampling interval.

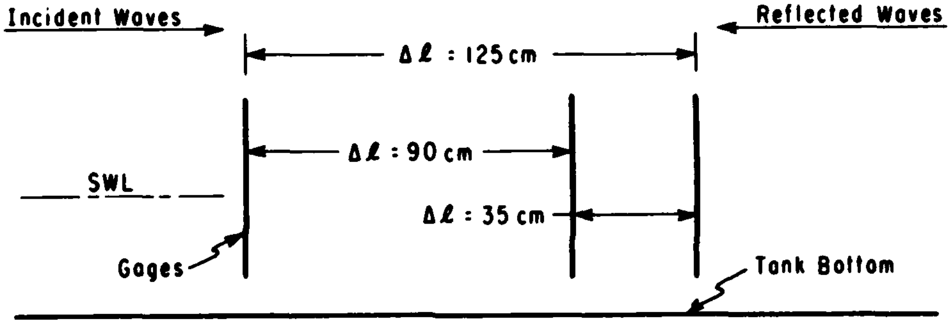
(d) The 4,096 data points from each gage were then stored on magnetic tape for analysis.

(e) A 10-digit identification code consisting of the year, month, day, hour, and minute of the data run was assigned (e.g., ID 7804260916 is a run made 1978, April, 26th day at 09:16).

4. Data Reduction Methods.

Laboratory data sorted on magnetic tape were analyzed on a CDC 6600 computer using a variety of data reduction schemes. The mean water level and the least squares, best-fit linear trend in the data was first removed from each gage record. A Fourier analysis was then performed on each gage record using a fast Fourier transform (FFT) routine and cosine bell function that is part of the CERC wave analysis package.

Incident and reflected waves, which are mixed together in each of the gage records, were separated using the method of Goda and Suzuki (1976) shown in Figure 2. This technique gives an estimate of the incident and reflected wave amplitudes, a_I and a_R, at each spectral line for each gage pair. Using three gages in front of the structure gives three estimates of the incident and reflected wave amplitude spectra. Calculations show that in this study the three estimates of wave amplitudes seldom differed by more than 5 percent, so the average incident and reflected wave amplitudes at each spectral line, j, were taken as representative; i.e., $(a_I)_j$ is the average incident wave amplitude at spectral line, j. The wave amplitude at each of the spectral lines was also determined for transmitted wave conditions; i.e., $(a_T)_j$ is the average transmitted wave amplitude at spectral line, j.



$$a_I = \frac{1}{2|\sin k\Delta\ell|}\sqrt{(A_2 - A_1 \cos k\Delta\ell - B_1 \sin k\Delta\ell)^2 + (B_2 + A_1 \sin k\Delta\ell - B_1 \cos k\Delta\ell)^2}$$

$$a_R = \frac{1}{2|\sin k\Delta\ell|}\sqrt{(A_2 - A_1 \cos k\Delta\ell + B_1 \sin k\Delta\ell)^2 + (B_2 - A_1 \sin k\Delta\ell - B_1 \cos k\Delta\ell)^2}$$

A,B = spectral coefficients

k = wave number = $\frac{2\pi}{L}$

$\Delta\ell$ = gage spacing

where

$$0.05 \le \frac{\Delta\ell}{L} \le 0.45$$

and

$$L = \frac{gT^2}{2\pi} \tanh\left(\frac{2\pi d}{L}\right)$$

where g equals acceleration due to gravity; d equals water depth; and T equals wave period.

Figure 2. Determination of incident and reflected waves using the method of Goda and Suzuki (1976).

Incident, reflected, and transmitted wave heights (H_I, H_R, H_T) are defined as

$$H_I = 2\sqrt{\sum_{j=12}^{411} (a_I)_j^2} \qquad (1)$$

$$H_R = 2\sqrt{\sum_{j=12}^{411} (a_R)_j^2} \qquad (2)$$

$$H_T = 2\sqrt{\sum_{j=12}^{411} (a_T)_j^2} \qquad (3)$$

where H_I is the height of the wave moving landward toward the breakwater, H_R the height of the wave reflecting from the breakwater and moving seaward, and H_T the height of the wave transmitted past and in the lea of the breakwater.

Wave reflection and transmission coefficients, K_R and K_T, are defined as

$$K_R = \frac{H_R}{H_I} \qquad (4)$$

and

$$K_T = \frac{H_T}{H_I} \qquad (5)$$

Wave transmission by overtopping has a transmission coefficient defined as K_{To}; wave transmission through porous structures is given by a transmission coefficient K_{Tt}. The coefficient for total wave transmission over and through a structure, K_T, is

$$K_T = \sqrt{K_{Tt}^2 + K_{To}^2} \qquad (6)$$

In the case of irregular waves the significant wave height, H_s (average of the highest one-third of the waves), is typically used to describe the wave conditions. To include the effects of wave reflection from the structure, significant height is defined as (Goda and Suzuki, 1976)

$$H_s = \frac{4\ \eta_{rms}}{\sqrt{1 + K_R^2}} \qquad (7)$$

where η_{rms} is the average root-mean-square (rms) water level from the three seaward gages. The mean wave height, $\overline{H}$, is defined as

$$\overline{H} = 0.625\,H_s = \frac{2.5\,\eta_{rms}}{\sqrt{1 + K_R^2}} \qquad (8)$$

The wave period used to describe irregular wave conditions is the period of peak energy density, T_p. The spectral-peakedness parameter, Q_p (Goda, 1970), is used to characterize the spectral width for irregular wave conditions,

$$Q_p = \frac{1}{\Delta f}\,\frac{\sum\limits_{j=1}^{36} f_j\, a_j^{4}}{\left(\sum\limits_{j=1}^{36} a_j^{2}\right)^{2}} \qquad (9)$$

where j is the band number (11 spectral lines are used to make each band), f_j the frequency midpoint of the band, and Δf the bandwidth frequency. a_j may be the incident, reflected, or transmitted wave amplitude associated with band, j, so that three values of Q_p (incident, reflected, and transmitted) are determined for each irregular wave run. Q_p was selected as the parameter to describe the spectral peakedness because it is an especially stable parameter not strongly influenced by the spectral techniques used to determine its value (Rye, 1977). The higher the value of Q_p, the more peaked a spectrum. For example, white noise has a Q_p value of 1.0, a Pierson-Moskowitz spectrum a value of 2.0, and JONSWAP values of Q_p vary between 3.0 and 9.0 with a value of 3.15 for the mean JONSWAP spectrum (Fig. 3). Values of Q_p associated with several incident wave spectra used in this study are illustrated in Figure 4.

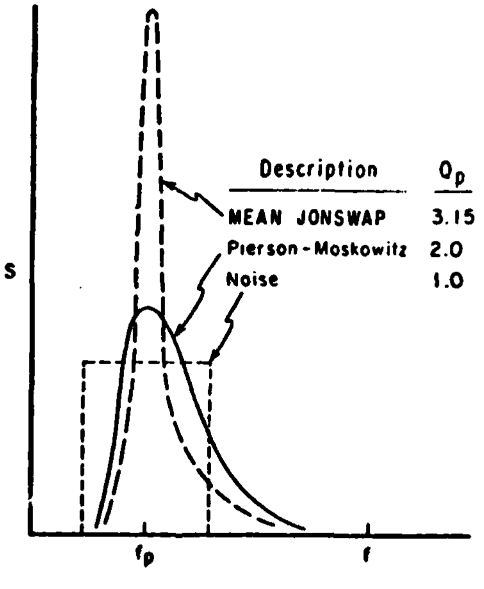


Figure 3. The spectral peakedness, Q_p, for various spectral shapes.

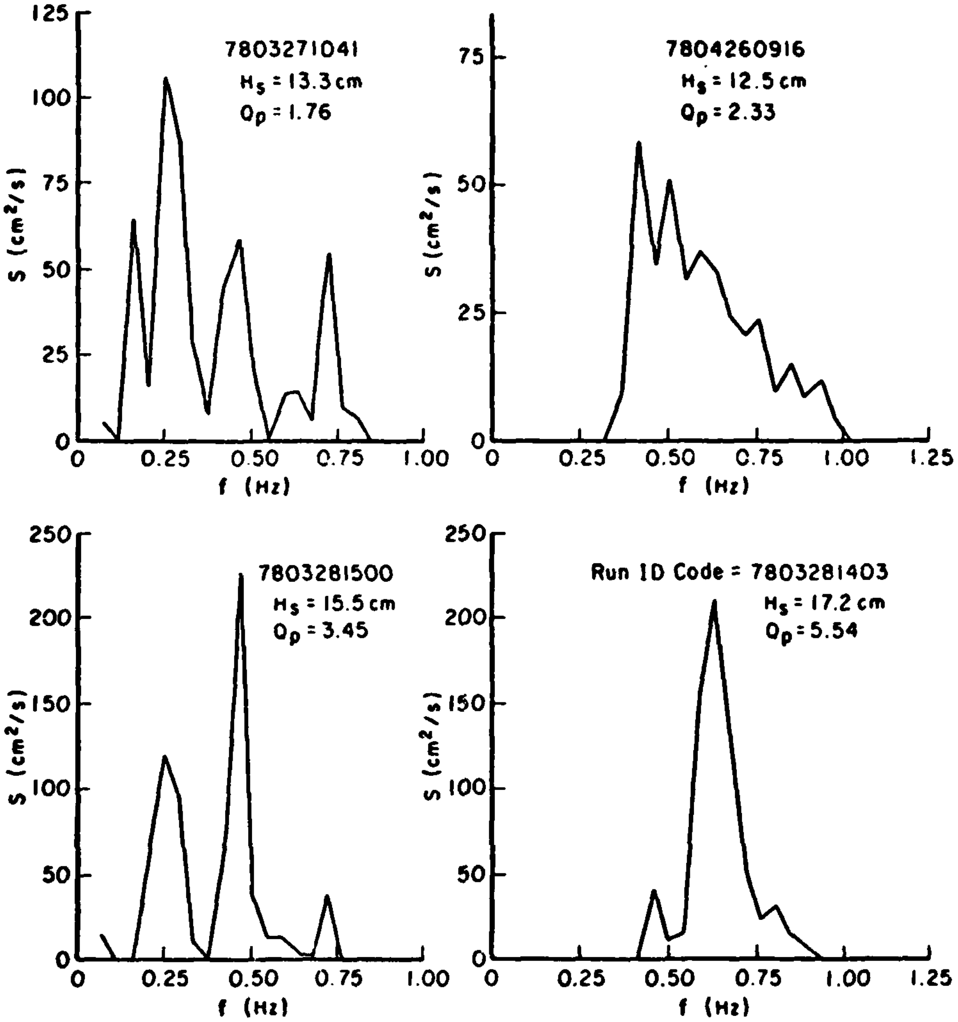


Figure 4. Sample incident laboratory wave spectra.

The zero up-crossing method was also used to analyze wave records. In this method the height of an individual wave is defined as the difference in extreme water elevations (maximum level minus minimum level) between two successive points in time where the water level up-crosses the mean water level. The period associated with that wave is the time between up-crossings. This type of analysis is useful for examining wave characteristics such as wave height, period, or joint wave height-period distributions. Zero up-crossing results may also be used to describe wave grouping (Rye, 1974). A high level of wave grouping means that there is a strong probability that a wave of approximately the same height will follow the previous wave (i.e., large waves are followed by large waves and small waves are followed by small waves). In this study the autocorrelation of zero up-crossing wave heights is used to quantify the amount of wave grouping. The wave gage records seaward of the test structure are somewhat contaminated by reflected waves, depending on the amount of reflection, so the autocorrelation of incident wave heights, ρ_I, is taken as the average wave height autocorrelation of the three gage records seaward of the structure.

Autocorrelation of transmitted waves, ρ_T, is taken as the average autocorrelation of any gage measuring transmitted waves. (Note that ρ may vary between 1.0 and -1.0.) A large positive value of ρ means that waves are strongly grouped. Values of ρ near zero mean that there is little relation between successive wave heights. A negative value of the autocorrelation implies that small waves follow large waves and vice versa. Several wave records measured in this study with various values of ρ are shown in Figure 5. Note that in all cases the water levels have been normalized by the significant wave height.

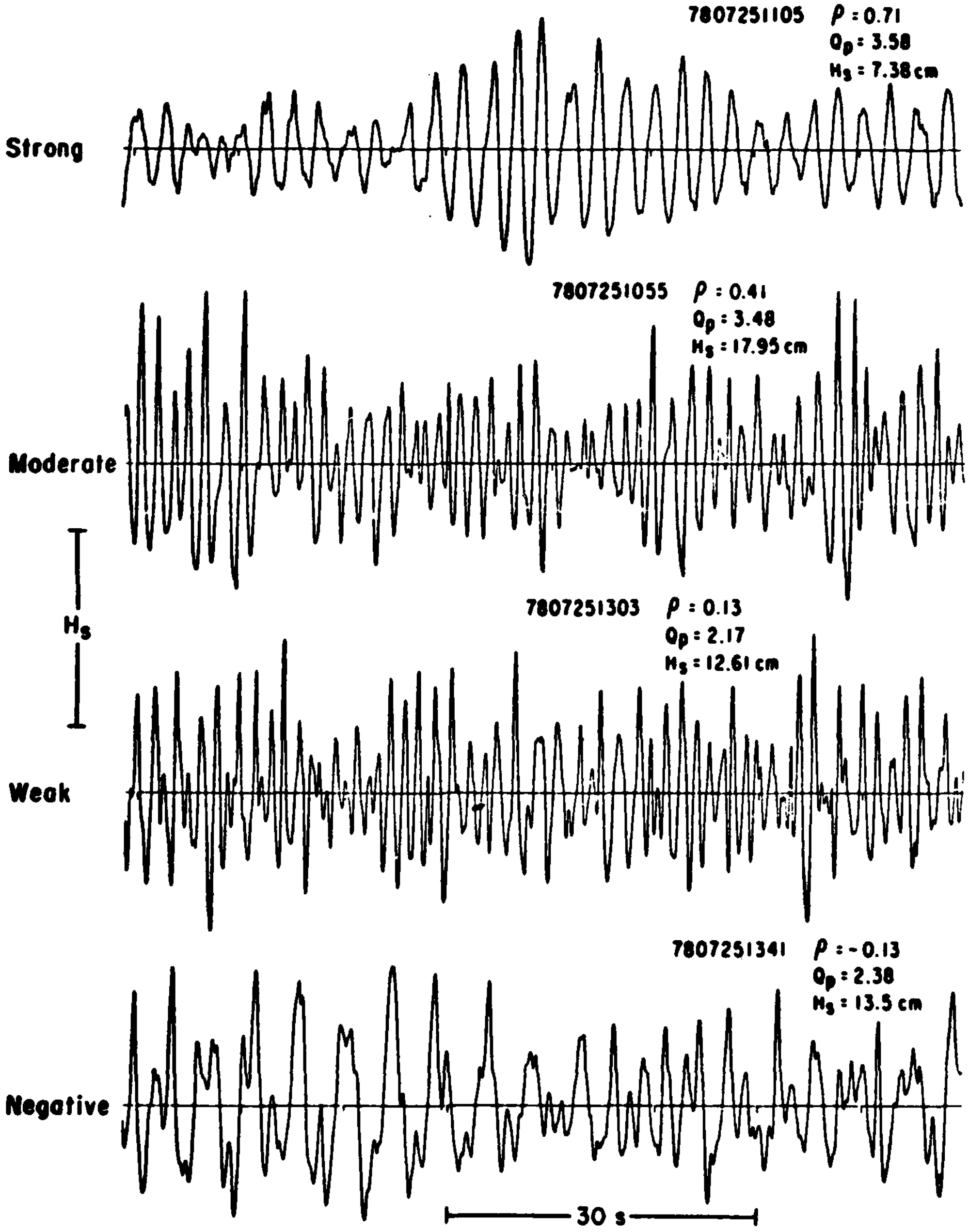


Figure 5. Sample laboratory wave records showing various levels of wave grouping.

For monochromatic wave tests, wave period, T, is defined as the period of wave generator blade motion. For most of the monochromatic wave conditions tested, 90 percent or more of the incident wave energy was found to be in the spectral band containing the blade frequency (Fig. 6). At a given value of wave steepness the amount of wave energy at higher harmonics of the blade frequency increases as the relative depth, d/gT^2, decreases. This energy shift occurs because the waveform becomes more cnoidal and less sinusoidal in shape as d/gT^2 decreases and H/d increases.

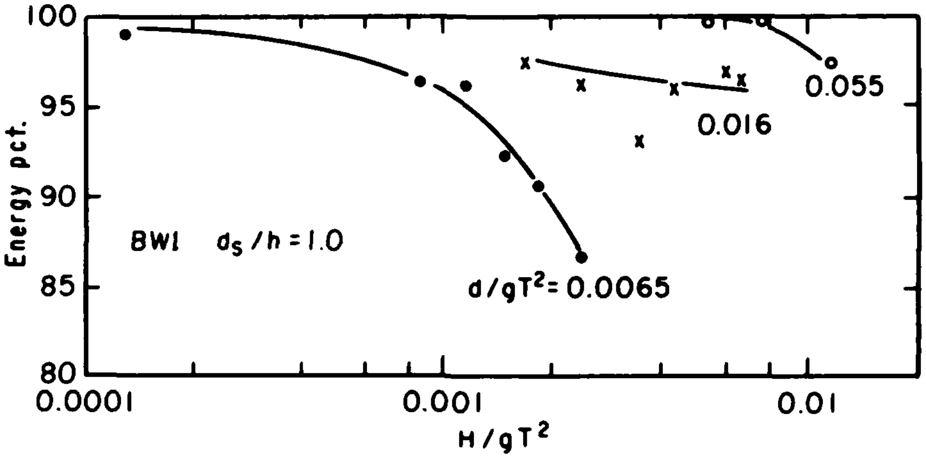


Figure 6. Percent of incident wave energy at the period of wave generator blade motion for sinusoidal wave generator blade motion.

5. Breakwaters Tested.

Cross sections for 17 breakwaters were tested for wave transmission and reflection; the cross-section geometries are illustrated in Appendix A. Each of the structures was assigned the letters BW and a number to identify the structure. Breakwaters BW1 to BW12 were built and tested on the flat bottom of the flume. However, BW13 to BW17 were constructed with a 1 on 15 fronting slope 25 centimeters high and 3.75 meters long. The fronting slope was used to simulate a sloping bottom and allow higher waves to break on the structure being tested.

Most of the breakwaters tested were of rubble-mound construction, because this is the most common type built. However, BW1 and BW14 were smooth and impermeable. BW2 had an impermeable core, and BW8 and BW9 had dolos armor units and an impermeable cap. BW3, BW4, and BW15 were tested with and without a vertical, thin impermeable plate placed in the center of the structure to prevent transmission through the lower section of the breakwater. The symbol W is used to indicate tests where the impermeable plate was used; e.g., BW3 tested with a plate is designated as BW3W. Materials used to construct the breakwaters are described in Appendix B.

6. Test Conditions.

Each breakwater was built with a fixed geometry, then tested at various water depths and wave periods. A number of wave heights were generally examined for each wave period. Most of the experiments were run with monochromatic waves produced by sinusoidal motion of the piston-type generator blade. The ranges of dimensionless water depths (water depth at the toe of the structure divided by structure height, d_s/h) tested with monochromatic waves are given in Table 1. Major emphasis was placed on $d/gT^2 = 0.016$ because laboratory waves at this value of relative depth are comparatively free from secondary and Benjamin-Fier waves.

Table 1. Range of conditions tested with monochromatic and irregular waves.

Breakwater	Monochromatic waves $\frac{d_s}{h}$ (range)	Monochromatic waves $\frac{d}{gT^2}$ (range)	Irregular wave testing[1]
BW1	0.6 to 1.2	0.0065 to 0.055	L
BW2	0.87	0.013 to 0.079	N
BW3	0.69 to 1.4	0.0038 to 0.037	N
BW3W	0.69 to 1.3	0.0065 to 0.08	N
BW4	0.68 to 1.3	0.0065 to 0.055	L
BW4W	0.76 to 1.3	0.0065 to 0.055	L
BW5	0.92 to 2.3	0.0065 to 0.055	L
BW6	0.75 to 1.3	0.0056 to 0.055	L
BW7	0.98 to 1.63	0.0065 to 0.055	N
BW8	0.64 to 0.86	0.016	N
BW9	0.64 to 1.1	0.0065 to 0.055	L
BW10	0.68 to 1.1	0.0065 to 0.055	L
BW11	0.51 to 0.75	0.0065 to 0.055	N
BW12	0.64 to 1.1	0.0065 to 0.055	N
BW13	1.1 to 1.8	0.0038 to 0.055	L
BW14	0.91 to 2.0	0.0038 to 0.055	L
BW15	0.61 to 1.4	0.0039 to 0.055	L
BW15W	0.91 to 1.5	0.0038 to 0.055	L
BW16	0.61 to 1.8	0.002 to 0.055	E
BW17	0.58 to 0.83	0.001 to 0.022	E

[1] Testing: E = extensive; L = limited; N = none.

Breakwaters BW16 and BW17 were tested extensively with a wide variety of irregular wave conditions. A limited number of irregular wave runs were also made for several other breakwaters (Table 1).

7. Test Results.

Test results for monochromatic and irregular wave conditions are presented in tabular form in Appendixes C and D; monochromatic results are presented in graphical form in Appendix E.

IV. ANALYSIS OF TEST RESULTS

This section provides an analysis of the wave transmission and reflection results of the model tests. Impermeable and permeable breakwaters were investigated, and a separate discussion is devoted to each type breakwater. The first part of this section describes observed trends in the values of the transmission and reflection coefficients as a function of the parameters varied in this study. The second part includes development, description, and evaluation of methods for predicting wave transmission coefficients. The third part discusses the effect of a breakwater on other wave characteristics, such as the wave height distribution and shape of the transmitted wave spectra. Since good models are not available for predicting wave reflection coefficients for breakwaters, it is recommended that the model tests be used directly to estimate breakwater wave reflection coefficients.

1. Wave Transmission and Reflection for Impermeable Breakwaters.

a. Observed Trends in Transmission and Reflection Coefficients. As a wave approaches an impermeable breakwater some of the wave energy is supplied to wave runup, some of the energy is dissipated, and the remaining wave energy moves seaward in the form of a reflected wave. If the runup exceeds the crest elevation of the breakwater, waves will be regenerated on the landward side of the structure. Figure 7 shows aspects of this process and defines some of the terms used in wave transmission by overtopping.

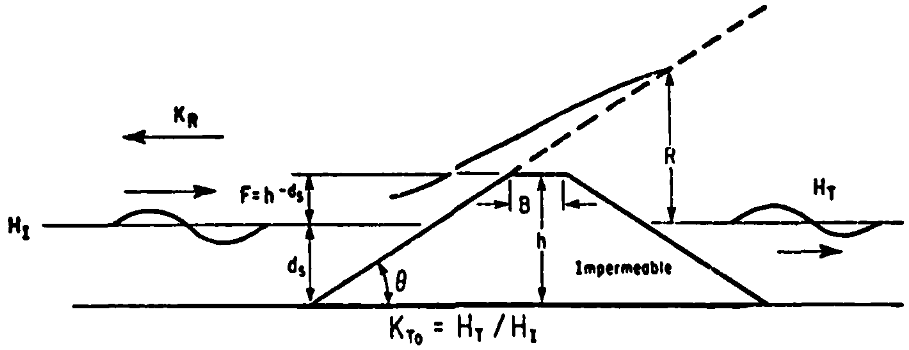


Figure 7. Definition of terms for wave transmission by overtopping.

Madsen and White (1976) found that low reflection coefficients and correspondingly large amounts of wave energy are dissipated on smooth nonovertopping structures. This observation has been verified using the data of Ahrens (1979) for breaking and nonbreaking waves. The data show that for the case of no overtopping the reflection coefficient decreases and a larger fraction of the wave energy is dissipated as the wave steepness increases (Fig. 8). More than 80 percent of the wave energy is dissipated by the smooth slope of 1 on 1.5 for the steepest waves tested. Note that the magnitude of the wave reflection coefficient is approximately the same for monochromatic and irregular waves, for a given value of wave steepness.

As the height of the breakwater is reduced the magnitude of the wave reflection coefficient decreases because much of the wave energy is transmitted by overtopping. For example, with a freeboard of zero (water level at the breakwater crest) BW1 has reflection coefficients that are less than 20 percent of the reflection coefficient for a structure that is not overtopped for the steeper waves tested (Fig. 9). At values of small wave steepness the size of

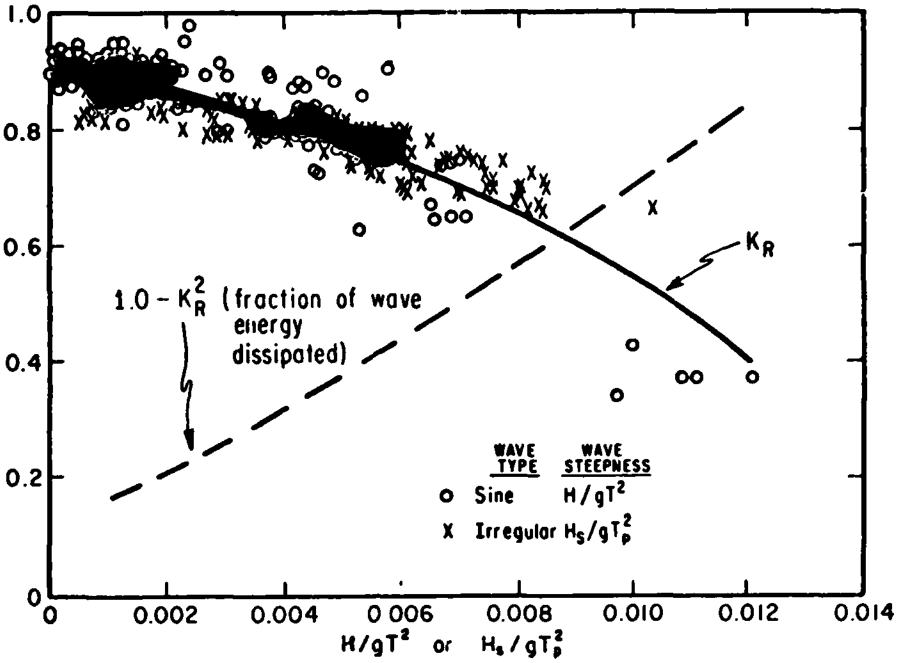


Figure 8. Wave reflection coefficients and fraction of wave energy dissipated for a 1 on 1.5 smooth slope with no wave transmission (data from Ahrens, 1979).

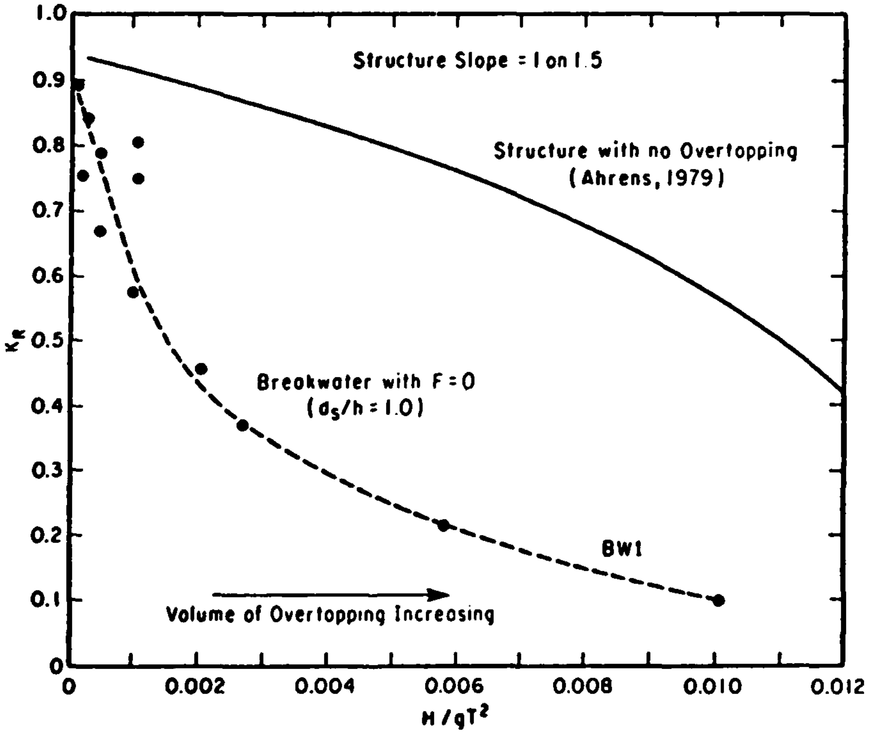


Figure 9. Wave reflection coefficients for a breakwater with zero freeboard compared to a similar structure with no overtopping.

the reflection coefficients for the breakwater and smooth impermeable slope is approximately the same because breakwater overtopping is small.

The wave reflection coefficient decreases as the wave height or steepness increases for a subaerial breakwater, but shows the opposite trend for a submerged breakwater (Fig. 10). There is a slight increase in the reflection coefficient as the wave height increases for the conditions tested.

The variation of the wave transmission coefficient for a smooth impermeable breakwater is the reverse of that found for the reflection coefficient. If the wave runup is less than the breakwater freeboard there is no wave transmission. As soon as the runup exceeds the crest of the breakwater, wave transmission by overtopping occurs. All other factors being fixed, as the wave height increases the size of the runup and the transmission by overtopping coefficient increase (Fig. 10); as the ratio of the water depth to structure height, d_s/h, approaches 1.0 the transmission coefficient increases. Even with zero freeboard ($d_s/h = 1$) there is some increase in the wave transmission coefficient as wave steepness increases (Fig. 10). However, for a submerged breakwater of fixed geometry the wave transmission coefficient declines as wave height or steepness increases (Fig. 10).

b. Estimating Wave Transmission by Overtopping Coefficients. Wave transmission by overtopping is closely related to wave runup and overtopping of a breakwater. Weggel (1976) found that overtopping rates are a function of the ratio of the structure freeboard, F, to the runup, R, on a similar structure high enough to prevent overtopping (Fig. 7). Cross and Sollitt (1971) also recommend the dimensionless parameter, F/R, for predicting wave transmission by overtopping coefficients.

Several methods are available for estimating wave runup on smooth impermeable slopes; some of these methods are summarized in Stoa (1978). The runup prediction equation developed by Franzius (1965) gives the best estimate of wave runup for predicting wave transmission coefficients. The runup is given by

$$R = HC_1 \left(0.123 \frac{L}{H}\right)^{\left(C_2 \sqrt{H/d}+C_3\right)} \tag{10}$$

where L is the local wavelength determined from linear theory using

$$L = \frac{gT^2}{2\pi} \tanh\left(\frac{2\pi d}{L}\right) \tag{11}$$

and C_1, C_2, and C_3 are empirical coefficients. Franzius suggests values for the coefficients, but improved coefficients were obtained in this study using the data of Saville (1955) and Savage (1959) with a nonlinear error minimization computer routine. The recommended values of the empirical coefficients are given in Table 2. These values are linearly interpolated to estimate values of the coefficients for other slopes. An advantage of using equation (10) is that it includes effects of wave height, structure slope, wave steepness, and the ratio of water depth to wave height on wave runup.

The runup on rough slopes is also a complex function of many factors (Stoa, 1978). Madsen and White (1976) give an analytical-empirical model for estimating

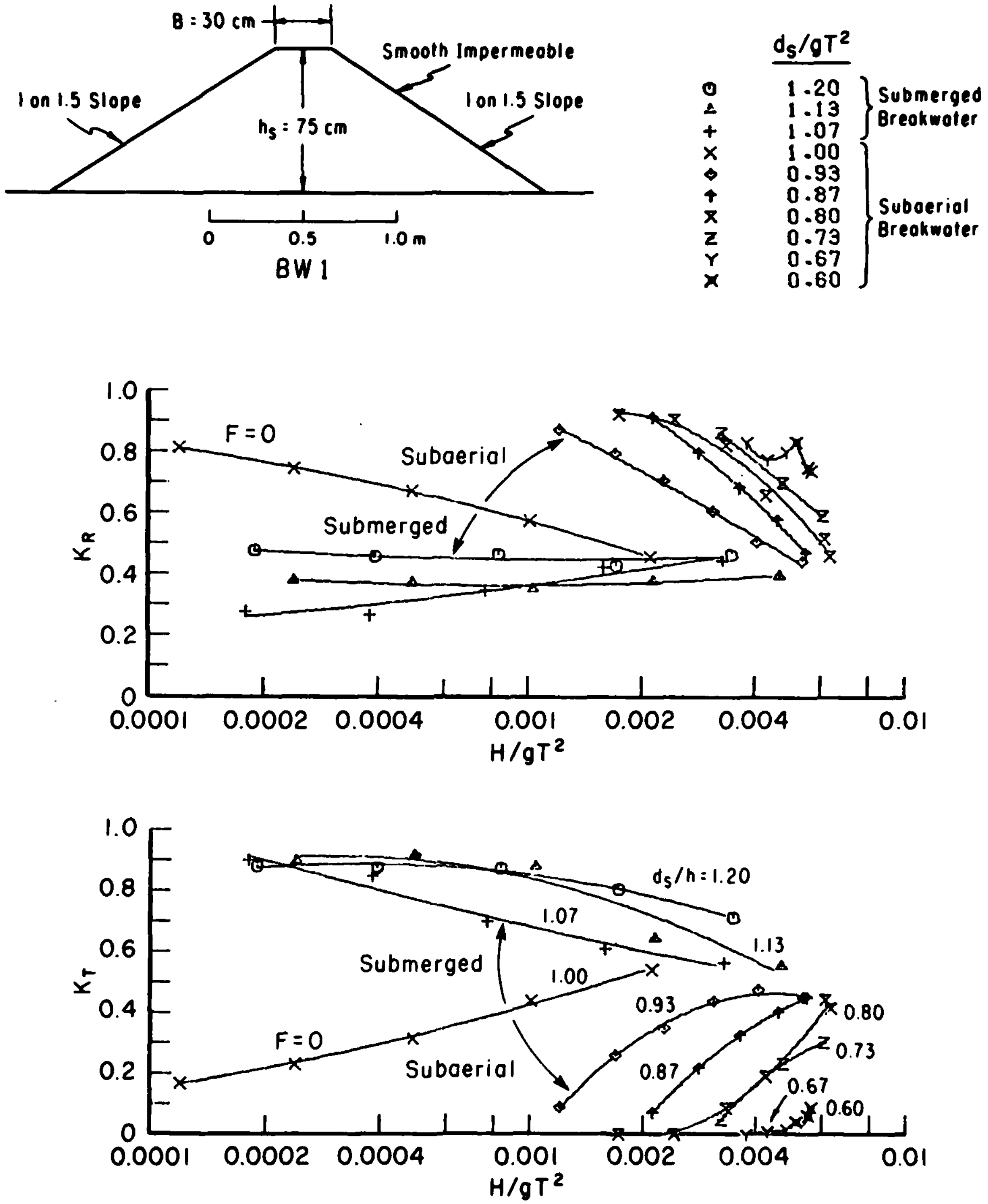


Figure 10. Wave transmission and reflection coefficients for a smooth impermeable breakwater (BW1, d/gT^2 = 0.016, monochromatic waves).

Table 2. Empirical wave runup prediction coefficients for smooth impermeable slopes.

Front-face slope of breakwater	C_1	C_2	C_3
Vertical	0.958	0.228	0.0578
1 on 0.5	1.280	0.390	-0.091
1 on 1.0	1.469	0.346	-0.105
1 on 1.5	1.991	0.498	-0.185
1 on 2.25	1.811	0.469	-0.080
1 on 3.0	1.366	0.512	0.040

runup on an impermeable rough slope armored with one layer of stone. Ahrens and McCartney (1975) present an empirical method for estimating the runup on two layers of riprap overlying a 0.2-meter thick underlayer (Fig. 11). In their method the runup is predicted as a nonlinear function of the surf parameter, ξ,

$$\frac{R}{H} = \frac{a\xi}{1 + b\xi} \quad ; \quad \xi = \frac{\tan \theta}{\sqrt{\frac{H}{L_o}}} \tag{12}$$

where a and b are empirical coefficients with values of a = 0.956 and b = 0.398.

Both the Madsen and White and Ahrens and McCartney prediction methods tend to give high or conservative estimates of wave runup for predicting wave transmission coefficients. However, Hudson (1958) made numerous observations of runup over a wide range of breakwater conditions; the Ahrens and McCartney empirical curve (eq. 1) was fitted to the Hudson data to give the recommended runup coefficients of a = 0.692 and b = 0.504 (Table 3). These coefficients gave a lower prediction of runup than that given for riprap (Fig. 12). The equation

$$\frac{R}{H} = \frac{0.692\ \xi}{1 + 0.504\ \xi} \tag{13}$$

is recommended for predicting runup on stable permeable and impermeable stone breakwaters until a more comprehensive model becomes available. Coefficients for dolos were also estimated using Bottin, Chatham, and Carper's (1976) data for breaking and nonbreaking waves (Table 3). Stoa (1978) provides additional information on runup; runup data for nonbreaking waves on breakwaters are provided in Jackson (1968).

Runup predictions were made for the conditions tested, and observed wave transmission by overtopping coefficients, K_{To}, were plotted as a function of F/R (Fig. 13). This figure shows the case of breakwaters with a slope of 1 on 1.5. The upper part of Figure 13 shows results from BW1 for tests that had a

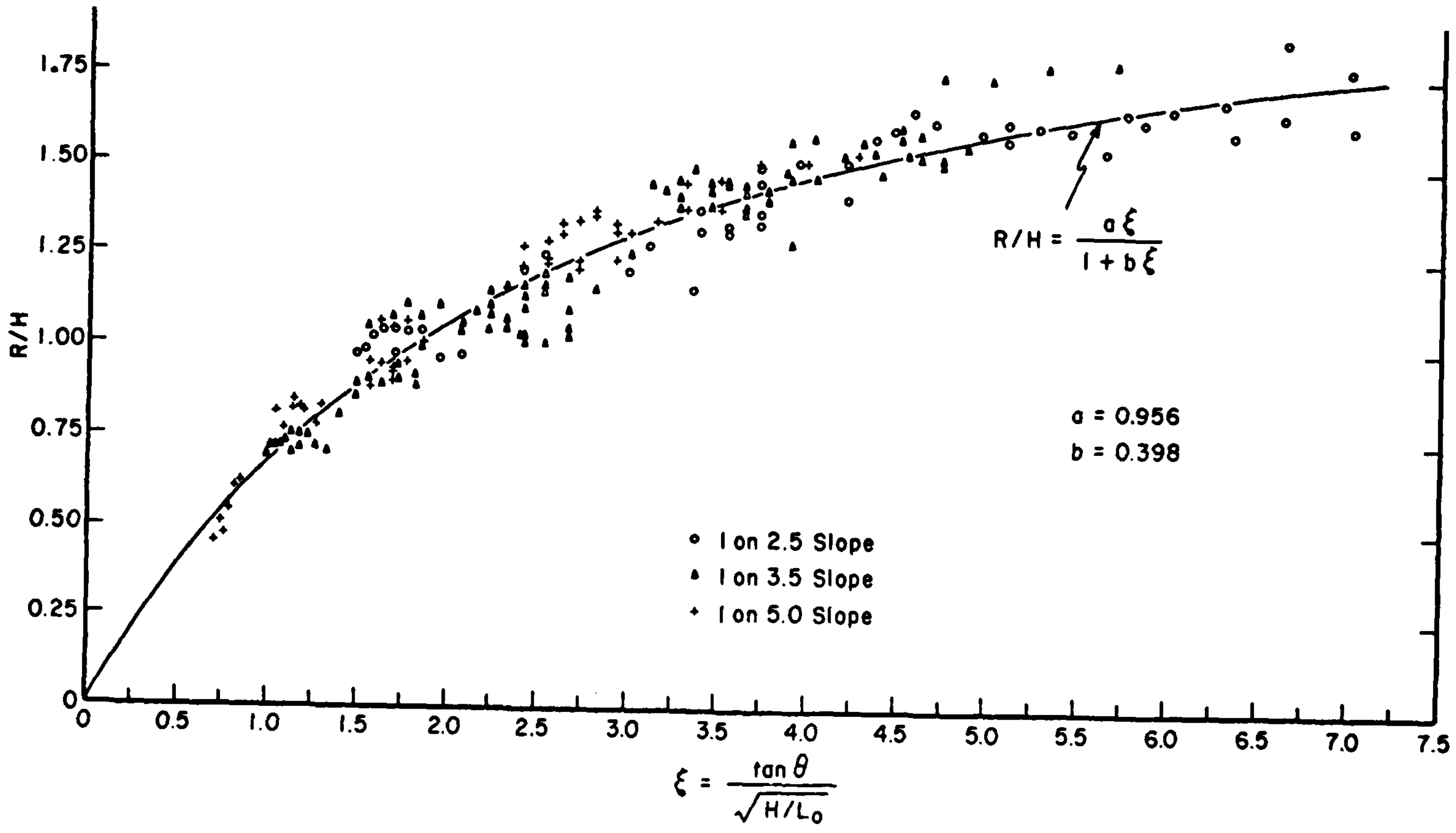


Figure 11. Wave runup on riprap (after Ahrens and McCartney 1975).

Table 3. Wave runup prediction coefficients using the Ahrens and McCartney (1975) method.

Armor unit	No. of layers	Permeability[1]	a[2]	b[2]	$\frac{d}{gT^2}$ (range)	$\frac{H}{gT^2}$ (range)	Cot θ (range)	Source
Rubble	2	I	0.956	0.398	0.0036 to 0.059	0.0004 to 0.013	2.5 to 5.0	Ahrens and McCartney (1975)[3] (large-scale tests)
Rubble	0	P	0.692	0.504	0.0088 to 0.08	0.0004 to 0.02	1.25 to 5.0	Hudson (1958)[4]
Rubble	2	I	0.775	0.361	------------[5]	------------	2.5	Gunbak (1979)[6]
Dolos	2	I	0.988	0.703	0.009 to 0.002	0.0002 to 0.006	2.0	Bottin, Chatham, and Carver (1976)

[1] P = permeable; I = impermeable.

[2] $R/H = a\xi/(1+b\xi)$; $\xi = \tan\theta/\sqrt{H/L_o}$.

[3] Revised a and b.

[4] Means of observations.

[5] Conditions unknown.

[6] $1.2 < \xi < 4.8$.

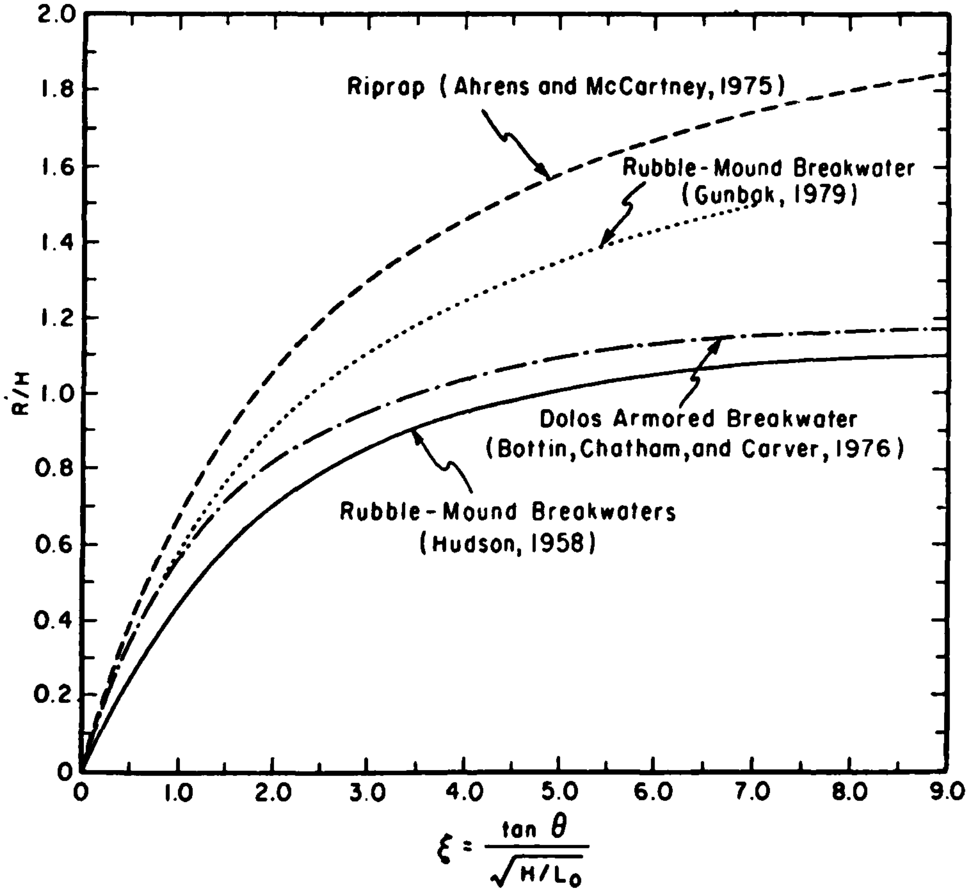


Figure 12. Wave runup prediction for rough structures using the Ahrens and McCartney (1975) method.

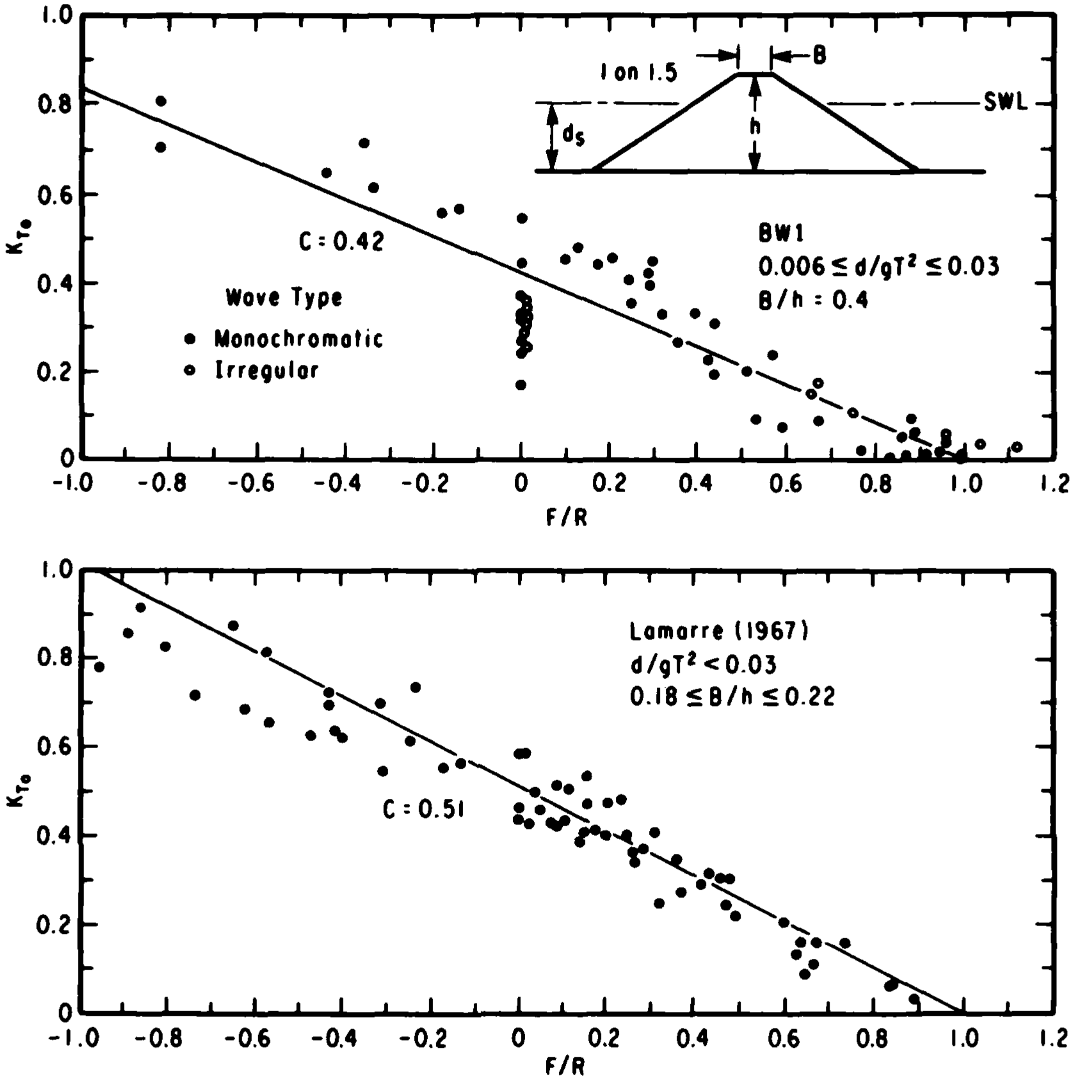


Figure 13. Wave transmission coefficients for smooth impermeable breakwaters with 1 on 1.5 slopes.

breakwater crest width-to-structure height ratio of B/h = 0.4. The lower part of the figure gives test results from Lamarre (1967), who tested structures with smaller values of B/h. Although there is some scatter in these data sets, it appears that the wave transmission coefficient decreases approximately linearly as F/R increases and that this linear trend is found for submerged as well as subaerial breakwaters. Most of the scatter occurs where the crest elevation is at the stillwater level (F/R = 0) for BW1, with small waves having significantly lower wave transmission coefficients than are present in the linear trend. Fortunately, small waves are generally not of interest for design purposes. The few irregular waves tested with BW1 suggest that wave transmission coefficients for irregular waves follow the same trend as for monochromatic waves. The mean wave height, taken as 63 percent of the significant wave height, should be used in equation (12) to determine the effective runup for predicting wave transmission coefficients for irregular wave conditions.

Comparison of the upper and lower parts of Figure 13 suggests that the structure tested by Lamarre (1967) with a smaller relative crest width has slightly higher wave transmission coefficients than found for BW1.

Results from laboratory tests by Goda (1969) for breakwaters with vertical faces (Fig. 14) have the same trends as observed for breakwaters with 1 on 1.5 slopes.

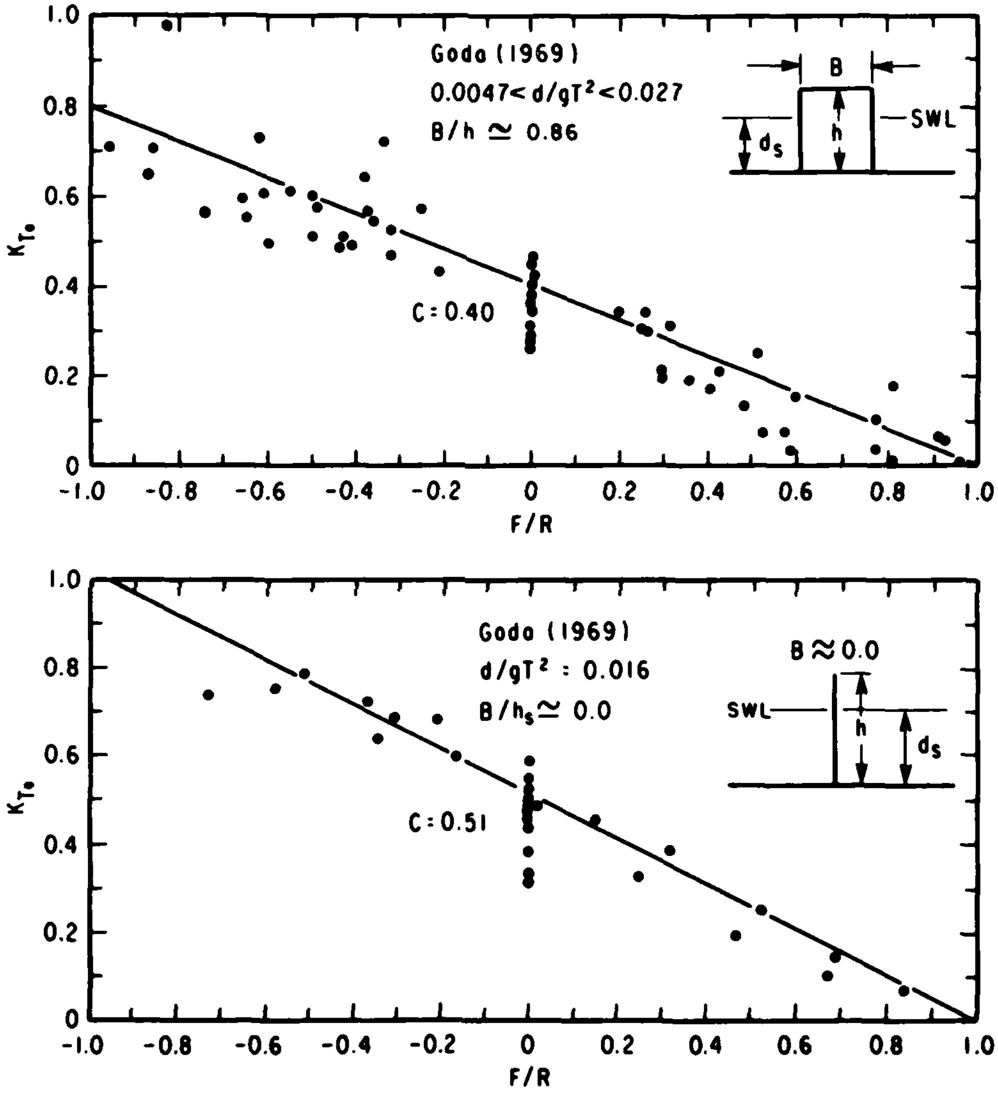


Figure 14. Wave transmission coefficients for vertical, smooth impermeable breakwaters using Goda's (1969) data.

The recommended formula for predicting the wave transmission by overtopping coefficient for the range $0.006 \leq d/gT^2 \leq 0.03$ is

$$K_{To} = C\left(1 - \frac{F}{R}\right) \qquad (14)$$

where C is an empirical coefficient and the minimum and maximum values of K_{To} are 0.0 and 1.0, respectively. The recommended value of C is given by

$$C = 0.51 - \frac{0.11\ B}{h} \quad ; \quad 0 \leq \frac{B}{h} \leq 3.2 \tag{15}$$

for smooth impermeable structures tested over the range $0 \leq B/h \leq 0.86$ and rough impermeable breakwaters tested over the range $0.88 \leq B/h \leq 3.2$ (Fig. 15). However, for submerged breakwaters tested with 1 on 15 fronting slopes, equation (14) underestimates the wave transmission coefficient. For example, equation (14) underestimates the wave transmission coefficient for BW14 when submerged and the error increases as the breakwater becomes relatively more submerged (Fig. 16). The data from BW14 and from Saville (1963) show that for submerged breakwaters with $0.88 \leq B/h \leq 3.2$ and with a 1 on 15 fronting slope equation (14) should be adjusted to

$$K_{To} = C\left(1 - \frac{F}{R}\right) - (1 - 2C)\frac{F}{R} \quad ; \quad \frac{F}{R} < 0 \text{ and 1 on 15 fronting slope} \tag{16}$$

Figures 17 and 18 illustrate the observed and predicted wave transmission coefficients for two of the rough impermeable breakwaters tested by Saville (1963) for two values of crest width. Figure 17 shows the case of a structure with a crest width-to-structure height ratio of 0.88; Figure 18 shows the same information for a much wider structure with a width-to-height ratio of 3.2. A scatter plot of observed and predicted transmission coefficients using Saville's (1963) data indicates the level of ability to predict K_{To} (Fig. 19).

The above discussion shows that the breakwater freeboard and wave runup have a major influence on the magnitude of the wave transmission by overtopping coefficient. Breakwater crest width has a much smaller effect and only large changes in breakwater crest width could be used to reduce the size of the transmission coefficient for a given design situation.

Wave transmission by overtopping coefficients may be predicted for impermeable structures using the computer program OVER (App. F) which applies methods described in this section.

c. Influence of a Breakwater on Other Wave Characteristics. The magnitude of the wave transmission by overtopping coefficient, K_{To}, is generally the most important parameter to determine for the design of an impermeable breakwater used to reduce wave height. However, in addition to reducing the average wave height, the breakwater may also alter other characteristics of the waves, such as spectral shape or wave height distributions. Since these additional wave characteristics may be considered in some design problems, they are briefly discussed below.

The case of monochromatic waves incident on the structure is the condition most often used to test wave transmission of laboratory breakwaters in previous studies. This type of wave is similar to swell wave conditions in the prototype where the incident wave height and period are approximately constant. Spectral analysis of water level records for gages landward of the breakwater indicates that a significant part of the wave energy of transmitted waves may be at harmonic frequencies of the forcing wave (Saville, 1963; Goda, 1969). The fraction of wave energy at the forcing period (Fig. 20) shows the same trend

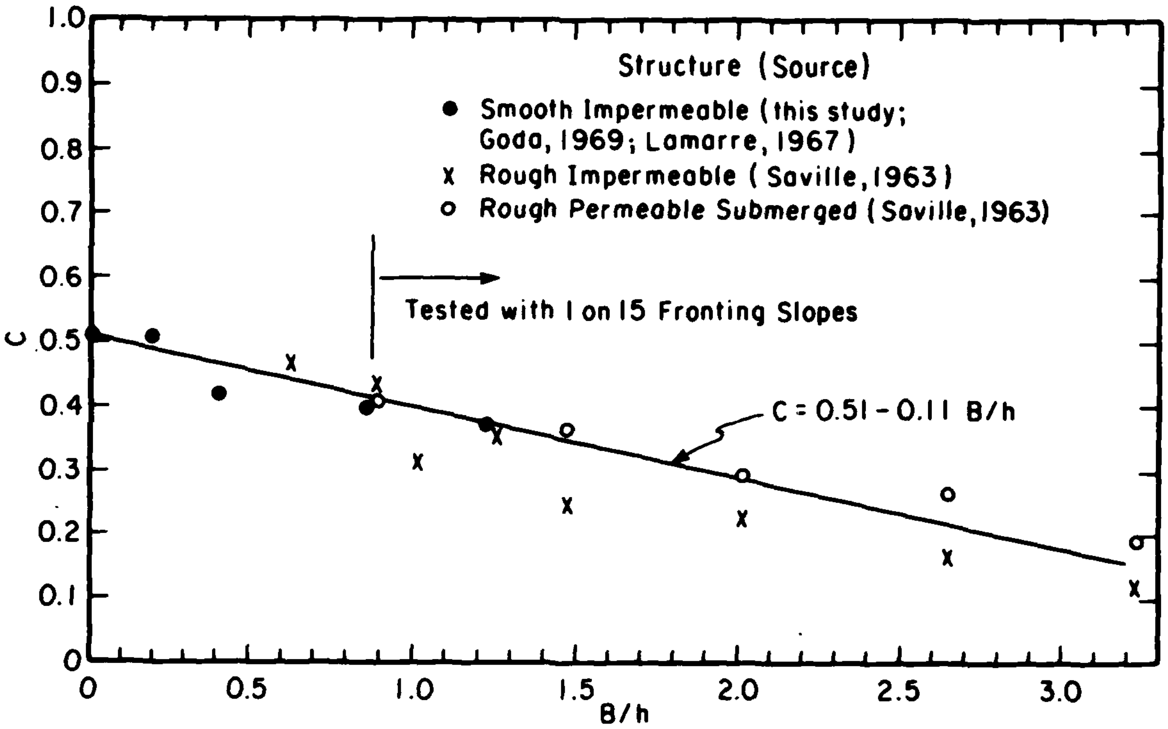


Figure 15. The effect of the relative structure width on wave transmission of impermeable breakwaters.

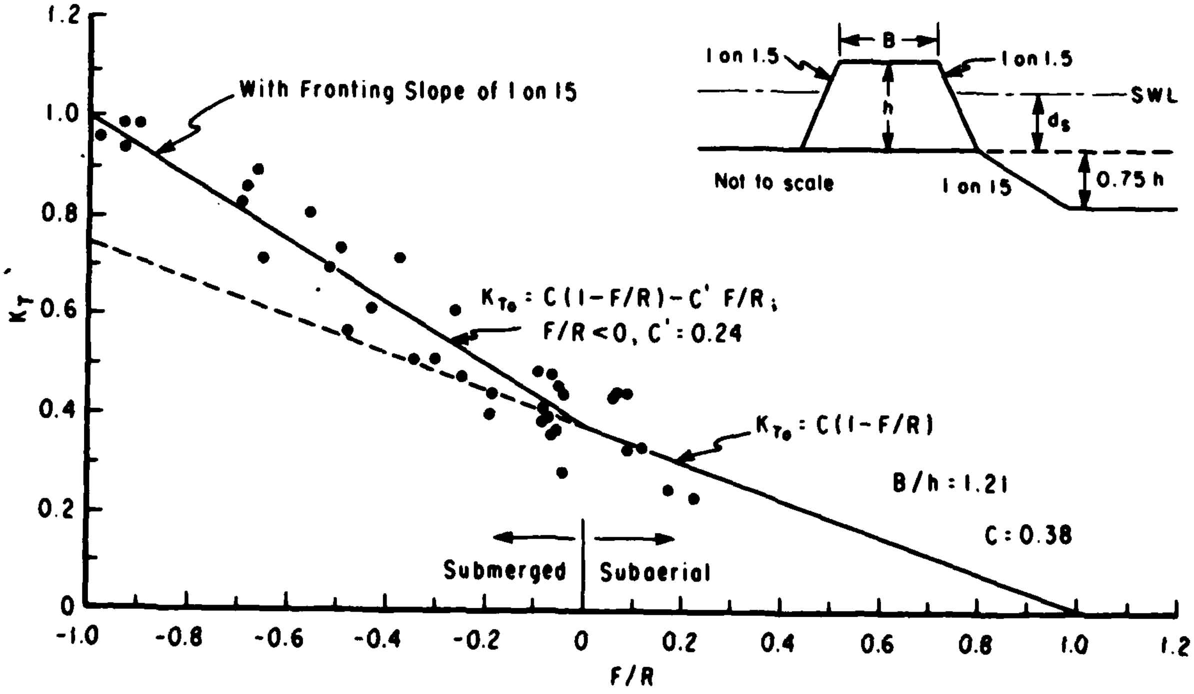


Figure 16. Wave transmission coefficients for BW14.

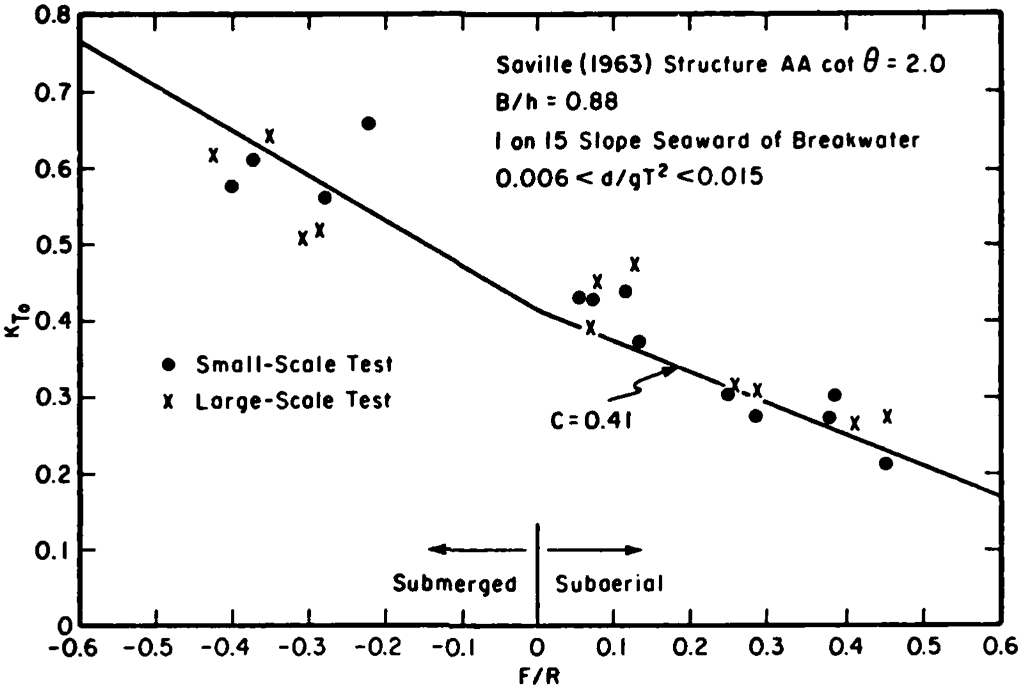


Figure 17. Wave transmission coefficients for a breakwater tested by Saville (1963) with B/h = 0.88.

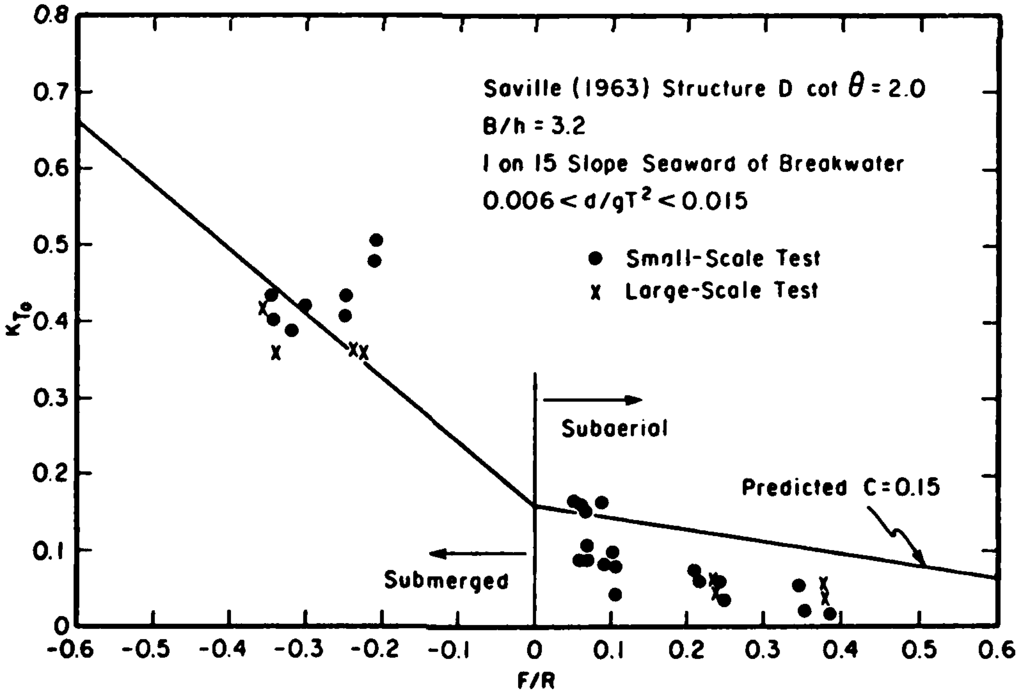


Figure 18. Wave transmission coefficients for a breakwater tested by Saville (1963) with B/h = 3.2.

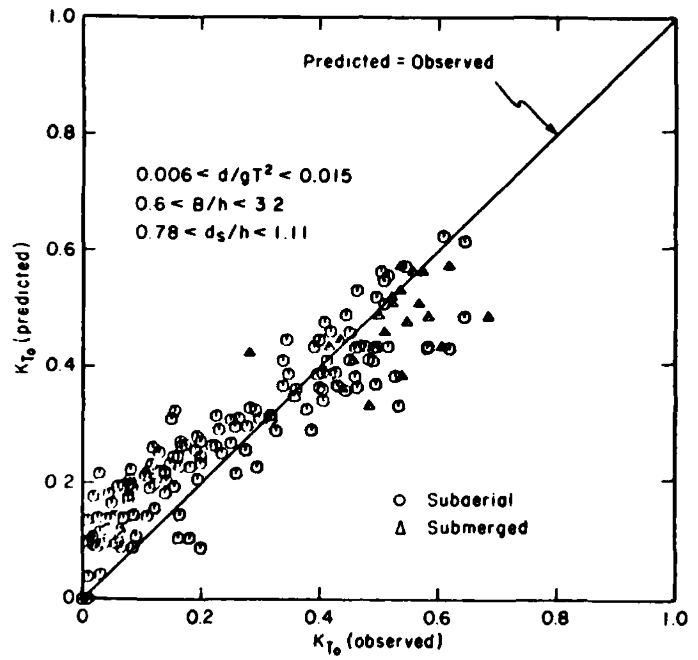


Figure 19. Observed and predicted coefficients of wave transmission by overtopping (Saville, 1963; impermeable breakwaters).

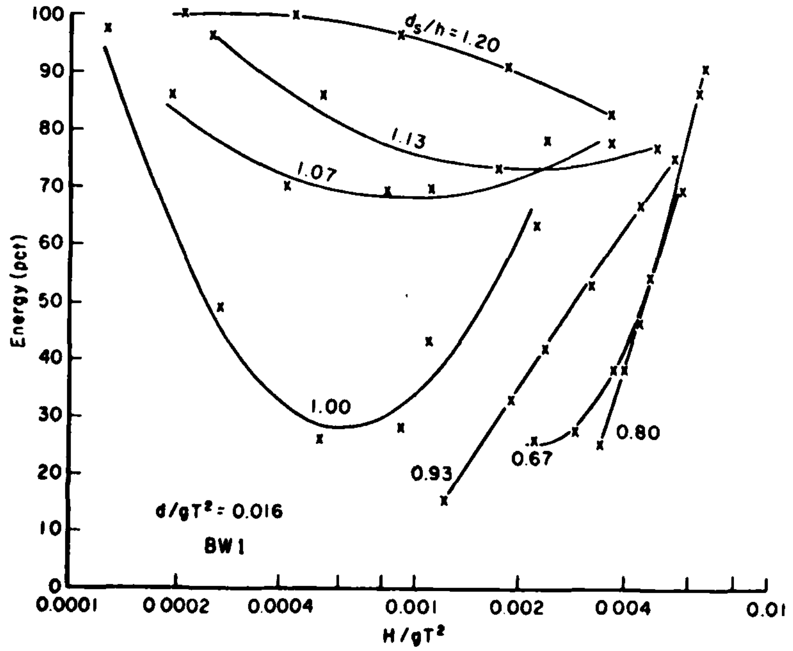


Figure 20. Percent of wave energy at the forcing wave period for wave transmission by overtopping of a smooth impermeable structure (monochromatic waves).

as was found for the transmission coefficient, K_{To} (lower half of Fig. 10). Comparison of Figures 10 and 20 suggests that the amount of wave energy found at the forcing period will increase as the transmission by overtopping coefficient increases.

The case of irregular waves is where the incident wave energy is distributed over a range of wave frequencies (several measured incident laboratory wave records and computed wave spectra are shown in Figs. 4 and 5). Tests with irregular waves indicate that the shapes of the incident and reflected wave spectra are approximately the same (two examples are given in Fig. 21). The approximately constant spectral shape is shown by the spectral-peakedness parameter, Q_p, where the value for the reflected waves, Q_{pr}, is approximately equal to the incident spectral peakedness, Q_{pi} (Fig. 22). The shape of the transmitted spectrum may be approximately equal to or sharper than the incident spectrum (Fig. 22) with the spectral-peakedness parameter of the transmitted waves, Q_{pt}, greater than or equal to Q_{pi} (Fig. 22). Secondary waves may appear in the transmitted wave spectrum at harmonics of the period of peak energy density, T_p, (Fig. 21).

A zero up-crossing analysis (Fig. 23) was performed on the wave records to allow statistical examination of individual wave heights and periods. Since reflected waves contaminate the incident wave conditions, an analysis was performed for the record from each gage, then results averaged to minimize the influence of reflection. Cumulative height distributions were then prepared for incident and transmitted waves. The cumulative curves were put into dimensionless form by dividing by the observed rms wave height, H_{rms}, and the dimensionless heights at various probability levels, p, determined (p = 0.01, 0.02, 0.05, . . . 0.60). A plot of these dimensionless heights for transmitted versus incident waves indicates the shape of the transmitted wave height distribution as a function of the incident wave height distribution. For the case of a breakwater with the water depth at the crest level ($d_s/h = 1.0$ or $F = 0$) the transmitted wave height distribution is approximately the same as the incident height distribution (Fig. 24). If the water level is below the crest elevation ($d_s/h = 0.80$, positive freeboard), the transmitted wave height distribution is skewed toward larger waves (Fig. 25). This means that the larger transmitted waves are bigger than predicted by the transmission coefficient, K_{To}. For example, at the 5-percent level, transmitted waves are 30 percent larger than expected from the overall transmission coefficient and at the 1-percent level 100 percent larger.

The above observations are consistent with the wave transmission by overtopping model given by equation (14). At zero freeboard the transmission coefficient is approximately constant, so all waves in a distribution will transmit the same amount and the distribution will remain unchanged. However, for subaerial breakwaters the larger waves will have smaller F/R ratios and transmit more efficiently than small waves, so that the transmitted wave distribution is skewed toward large waves.

The joint distributions of wave heights and periods observed in the laboratory illustrate the same overall trends found in the field. Larger waves have a mean period approximately equal to the period of peak energy density in the spectrum, T_p (Goda, 1978), with the average wave period decreasing for smaller wave heights (Fig. 26). The correlation between

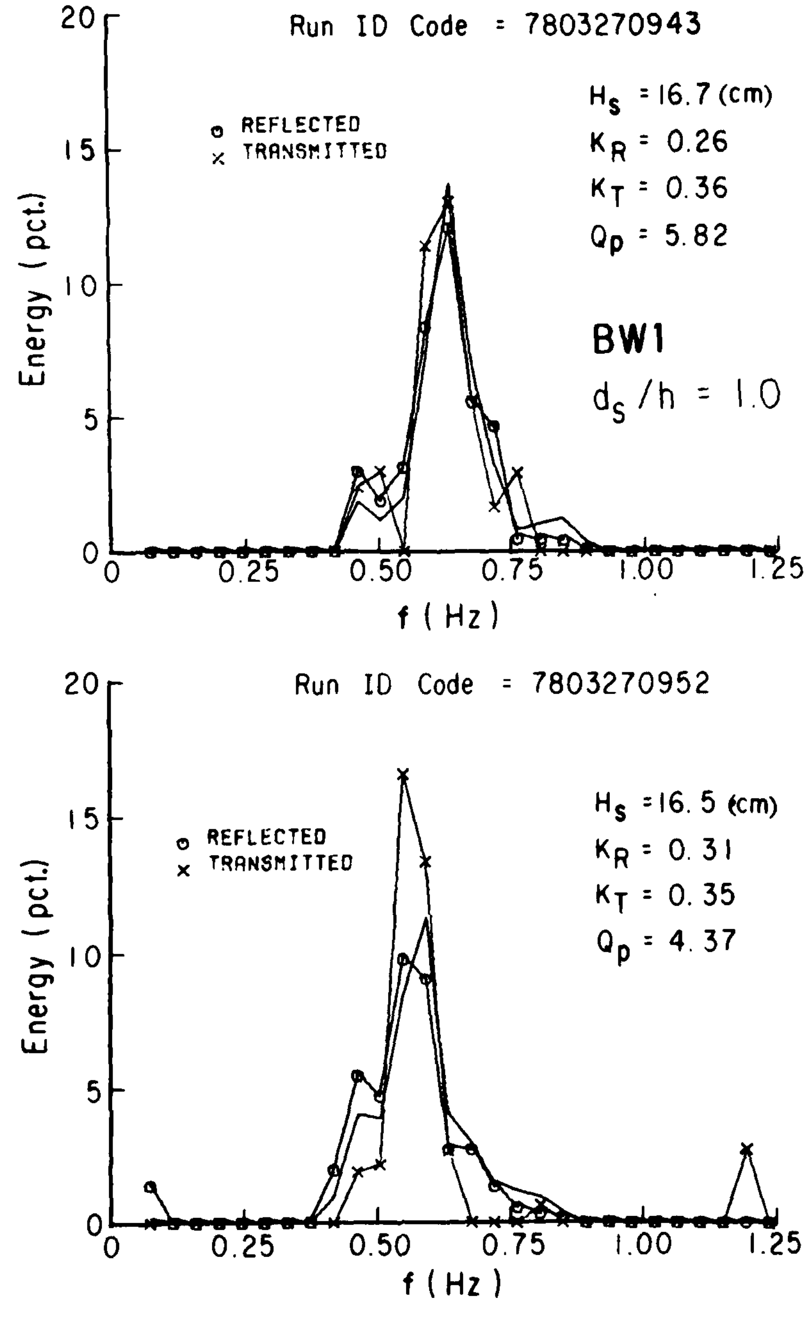


Figure 21. Sample incident, reflected, and transmitted wave spectra.

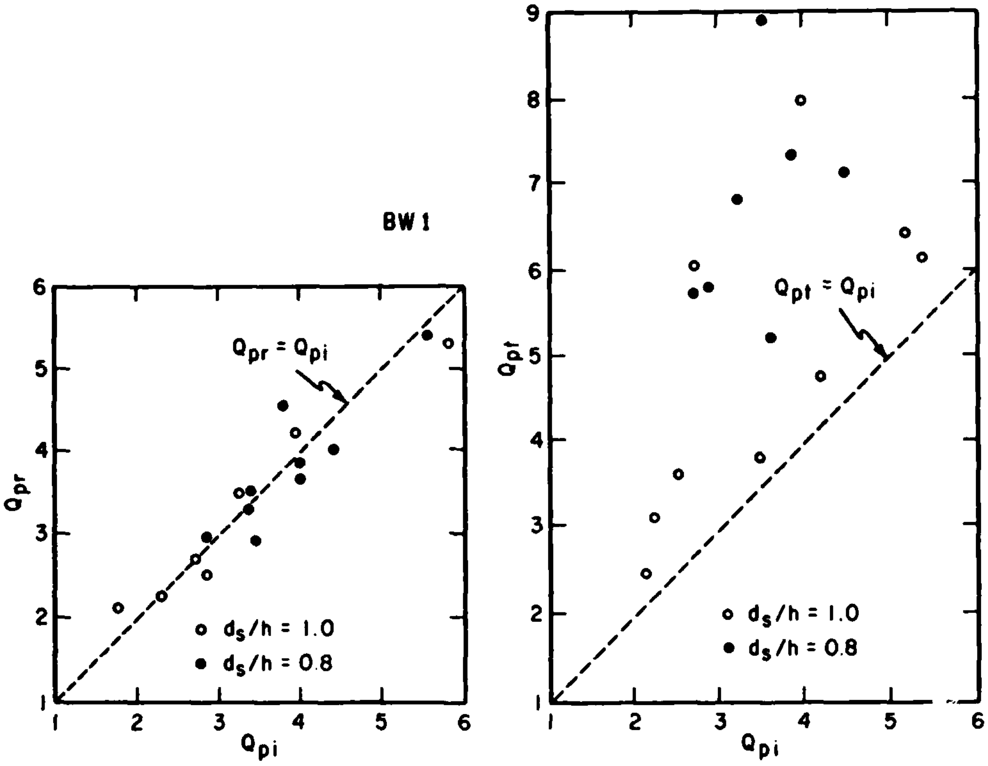


Figure 22. Spectral peakedness of incident, reflected, and transmitted wave spectra.

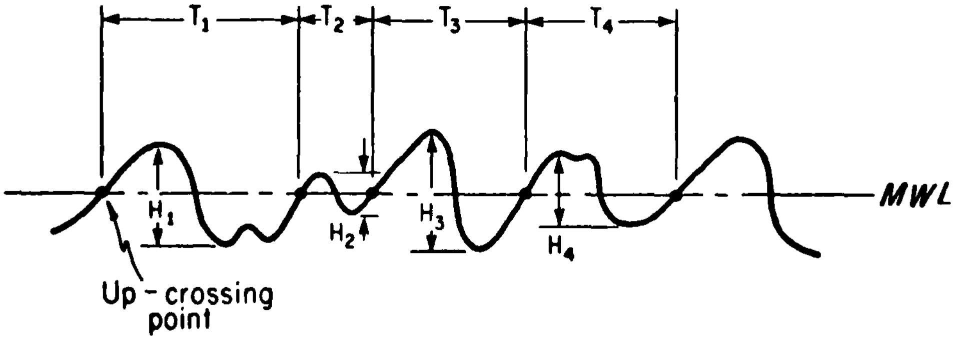
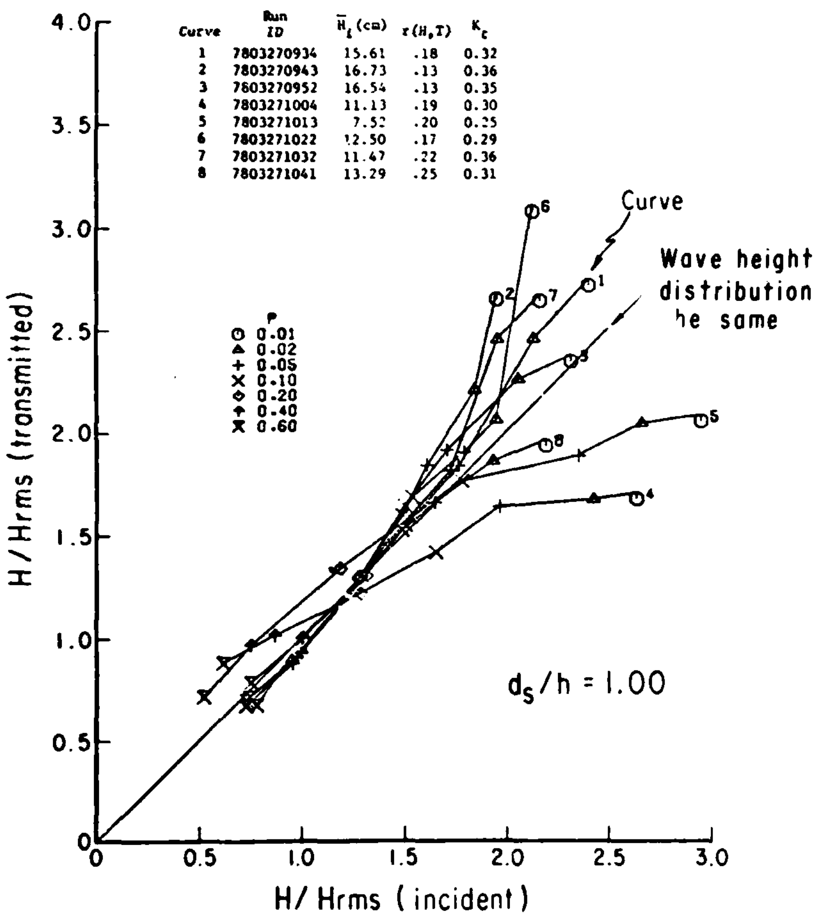
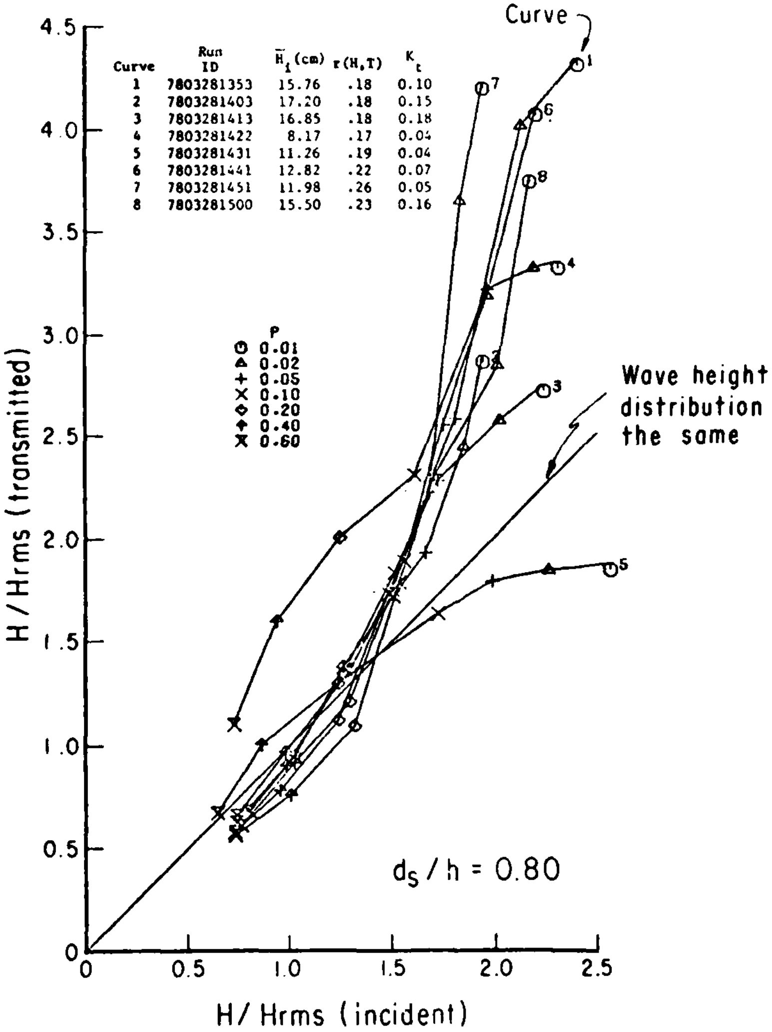


Figure 23. Zero up-crossing analysis.



Curve	Run ID	$\bar{H}_i$ (cm)	r(H,T)	K_t
1	7803270934	15.61	.18	0.32
2	7803270943	16.73	.13	0.36
3	7603270952	16.54	.13	0.35
4	7803271004	11.13	.19	0.30
5	7803271013	7.52	.20	0.25
6	7803271022	12.50	.17	0.29
7	7803271032	11.47	.22	0.36
8	7803271041	13.29	.25	0.31

Figure 24. Transmitted versus incident wave height distributions for a breakwater with $d_s/h = 0.8$.



Curve	Run ID	$\bar{H}_i$ (cm)	r(H,T)	K_t
1	7803281353	15.76	.18	0.10
2	7803281403	17.20	.18	0.15
3	7803281413	16.85	.18	0.18
4	7803281422	8.17	.17	0.04
5	7803281431	11.26	.19	0.04
6	7803281441	12.82	.22	0.07
7	7803281451	11.98	.26	0.05
8	7803281500	15.50	.23	0.16

Figure 25. Transmitted versus incident wave height distributions for a breakwater with $d_s/h = 1.0$.

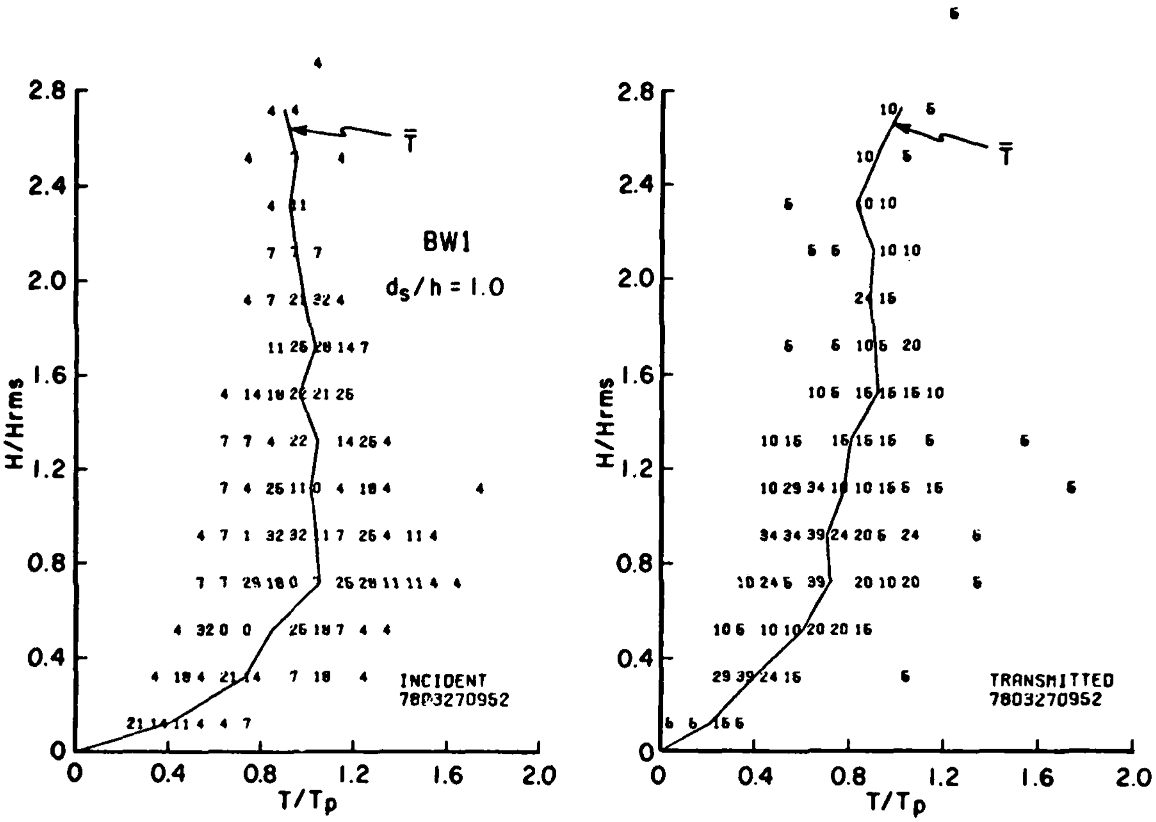
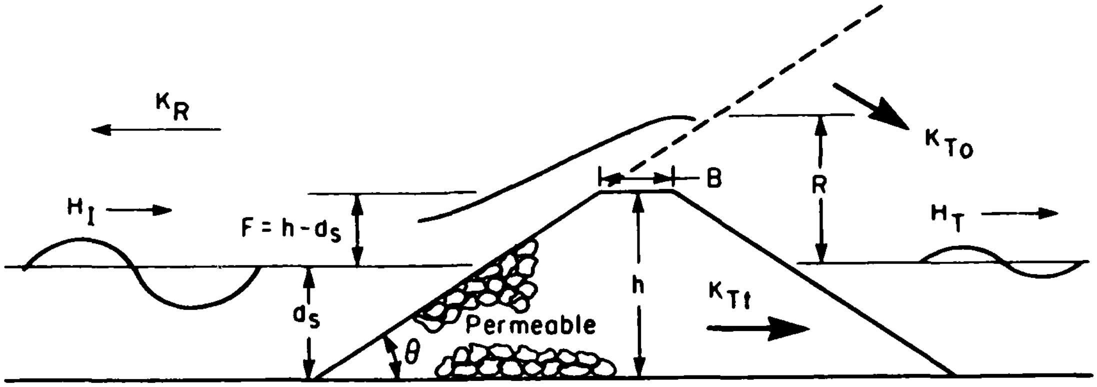


Figure 26. Sample incident and transmitted joint distributions of wave height and period.

heights and periods (Goda, 1978) was observed to be $0.13 \leq r(H,T) \leq 0.26$ for the incident wave conditions tested with approximately the same values for transmitted waves. The major difference between observed and transmitted joint distributions of height and periods is that the mean period of smaller waves is lower for the transmitted waves (Fig. 26) than for the incident waves.

2. Wave Transmission and Reflection for Permeable Breakwaters.

a. Observed Trends in Transmission and Reflection Coefficients. As a wave approaches and interacts with a rough permeable breakwater the sequence of action is similar to that for an impermeable breakwater, but with important differences. First, some of the wave energy moves through the permeable breakwater and this flow through the porous medium may dissipate a significant amount of wave energy. Second, because the breakwater absorbs some of the wave energy and water, the runup and reflection coefficients on a rough permeable breakwater are less than for the same wave condition on a similar smooth impermeable structure. If the runup level exceeds the height of the structure, wave transmission by both overtopping and transmission through the structure will contribute to the overall transmission coefficient, K_T (Fig. 27).



$$K_T = \sqrt{(K_{To})^2 + (K_{Tt})^2} = H_T/H_I$$

Figure 27. Definition of terms for wave transmission for permeable breakwaters.

The relative water depth, d/gT^2, is one of the most important parameters controlling the reflection coefficient, K_R (Fig. 28), with the reflection coefficient increasing as d/gT^2 decreases. The wave steepness, H/gT^2, and the ratio of water depth to structure height, d_s/h, have less influence. In general, the reflection coefficients for rough permeable breakwaters are much less than for similar smooth impermeable breakwaters (Fig. 10). Since no comprehensive model is currently available for predicting reflection coefficients, laboratory model results should be used to estimate K_R. A rough estimate of the reflection coefficient for permeable subaerial breakwaters may be obtained using the method of Madsen and White (1976) (computer program MADSEN in App. G). Typical comparisons between predictions and laboratory measurements are shown in Figure 29.

The wave transmission coefficient, K_T, is primarily a function of wave steepness for a given permeable breakwater design and hydraulic conditions where there is no transmission by overtopping (Fig. 28). Since the wave steepness increases the amount of energy dissipated on the face and inside the breakwater increases (Madsen and White, 1976), the transmission coefficient decreases. However, as soon as the wave runup level exceeds the breakwater crest, wave transmission by overtopping occurs and the transmission coefficient increases with increasing steepness. Figure 30 (lower part) shows the case where no overtopping occurs and K_T decreases (low steepness waves), then K_T increases with increasing steepness where transmission by overtopping and transmission through a breakwater occur simultaneously. In the case of a submerged breakwater the wave transmission coefficient decreases as the wave steepness increases (upper part of Fig. 30).

b. Estimation of the Coefficient of Wave Transmission Through Permeable Breakwaters Using the Madsen and White Model. The advantages of the Madsen and White (1976) model for predicting transmission coefficients are that the model is completely self-contained and it can be used to predict coefficients over a wide range of conditions. Parameters that can be varied include the breakwater height, breakwater width, breakwater slope, the size and relative location of various layers in the breakwater, and the size and porosity of materials used in the breakwater. Another advantage of the model is that it can be used to

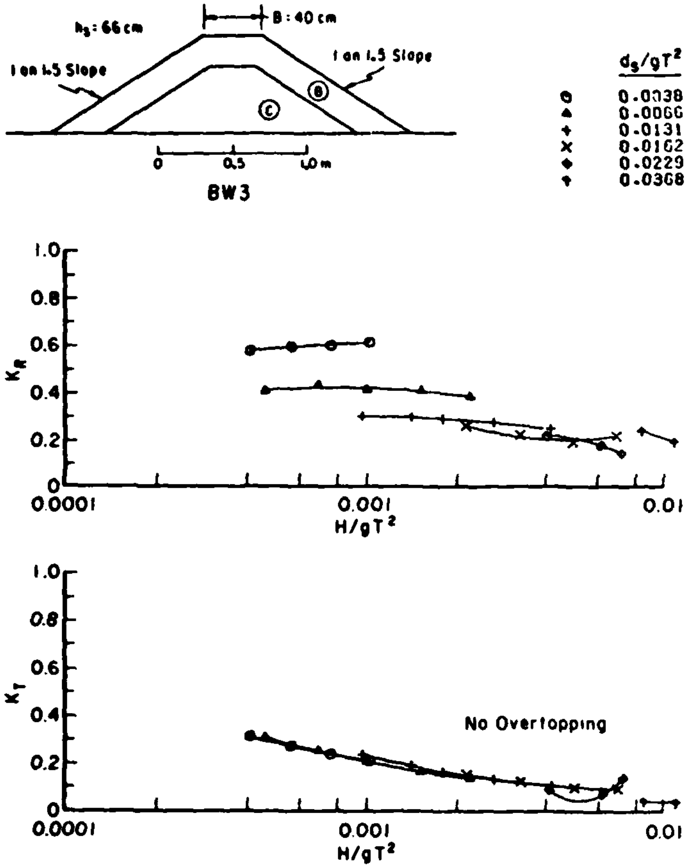


Figure 28. Wave transmission and reflection coefficients for BW3 ($d_s/h = 0.69$).

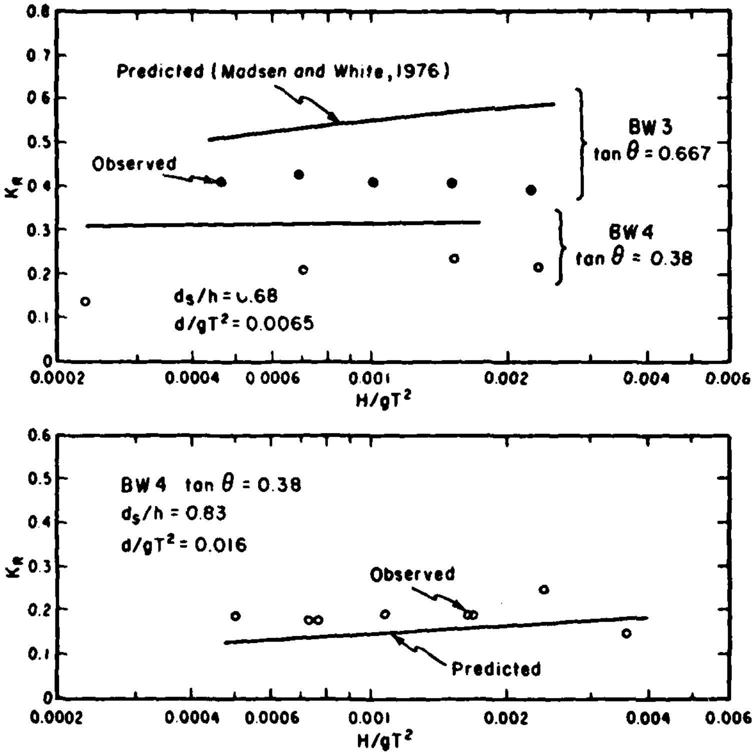


Figure 29. Sample observed and predicted reflection coefficients for permeable subaerial breakwaters.

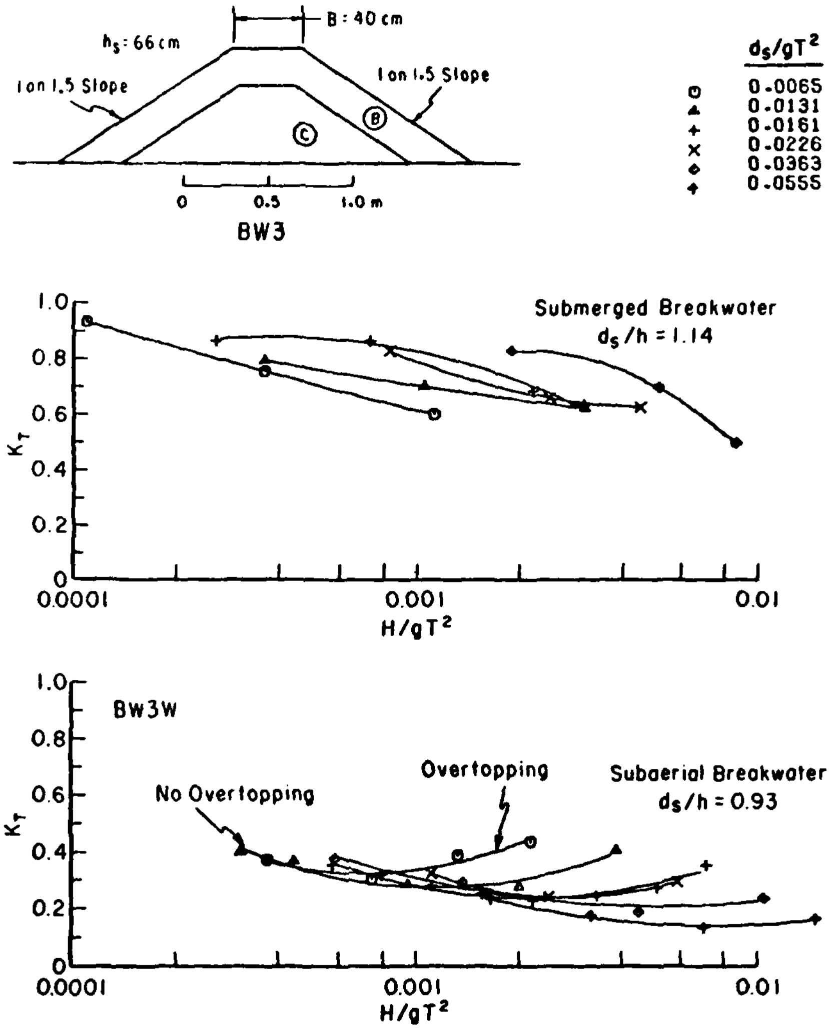


Figure 30. Wave transmission coefficients for a subaerial and a submerged breakwater.

predict coefficients for any size breakwater, useful when designing or assessing scale effects in small-scale physical models (see Sec. V).

The Madsen and White model was designed for manual use, but because of the many calculations and iterations necessary, manual calculation is tedious. The model was automated as a part of this study in a FORTRAN computer program, MADSEN (App. G) to simplify use of the model. Advantages of the computer program are that only a few input cards are required to model even a breakwater with complex geometry and the program computer cost is very low. The program includes all the generality in the original model, and the wave transmission by overtopping model developed in Section IV,1 is also incorporated. Since the Madsen and White (1976) technique is complex, reference is made to their publication for details of the model. A brief summary of the major steps in the model and computer program is given below; additional information on the computer program is given in Appendix G.

(1) Determine the breakwater cross-sectional geometry and material characteristics of diameter and porosity.

(2) Estimate the energy dissipation on the seaward face of the breakwater assuming it is rough and impermeable. This is done by solving Madsen and White's equation (127) implicitly using their Figures 15, 16, and 17 and applying a correction factor from their Table 2.

(3) Assume as a first approximation that the head across the breakwater is equal to runup determined from step 2 above.

(4) Transform the trapezoidal breakwater into a hydraulically equivalent rectangular breakwater (see Sec. 4.2 of Madsen and White).

(5) Estimate the coefficient of transmission through the structure, K_{Tt}, using Madsen and White's Figures 2 and 3 and implicitly solving their equation (57).

(6) Obtain a revised estimate of the head across the breakwater using Madsen and White's equation (161). (Repeat steps 4, 5, and 6 until a converged solution is obtained.)

(7) Estimate wave runup on the breakwater using the method of Ahrens and McCartney (1975) and the coefficients given in Table 3 of this study.

(8) Calculate the transmission by overtopping coefficient, K_{To}, using equations (14) and (15) in this study.

(9) Calculate the transmission coefficient, K_T, using K_{Tt} from step 5 and K_{To} from step 8 and

$$K_T = \sqrt{K_{Tt}^2 + K_{To}^2}$$

Madsen and White compared the model predictions to physical model results from Keulegan (1973) for rectangular breakwaters composed of one rock type, and from Sollitt and Cross (1976) for a multilayered trapezoidal breakwater made of riprap. There was good agreement between analytical and physical model results for predicting the wave transmission coefficient for long nonbreaking waves. However, the following questions need to be answered to determine the range of usefulness of the Madsen and White model:

(1) How useful is the model for predicting transmission coefficients for relatively short waves?

(2) Can the model be used if waves are breaking?

(3) Can the model be used for breakwaters with concrete armor units?

(4) Can the model be used for irregular waves?

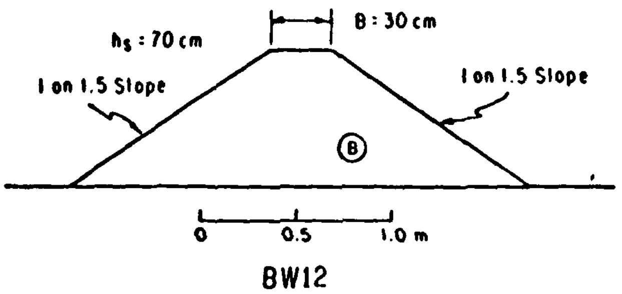
(5) How sensitive is the model to porosity of the materials? (Porosity is an input parameter and although it probably does not vary over a very wide range, its value will probably not be known accurately in a design situation.)

Each of these areas is discussed below.

(1) The case of the relative wavelength. In many of the laboratory tests the wave period was varied to cover the range from shallow-water long waves to deepwater short waves. Comparison of laboratory data and MADSEN computer program predictions shows excellent correspondence for shallow-water waves; e.g., at $d/gT^2 = 0.0065$ (Table 4). As the relative depth becomes larger (the wavelength becomes shorter), the computer program slightly overpredicts the observed transmission coefficient (Fig. 31). This means that the prediction method is conservative. Although the absolute value of the overprediction is small, the percent overprediction may be large (Table 4).

Table 4. Effect of relative depth on prediction of K_{Tt}.

$\frac{d}{gT^2}$	K_{Tt}[1]		Pct. error	Relative depth
	Observed	Predicted		
0.0065	0.34	0.33	-3	Shallow
0.016	0.46	0.44	-4	Transitional
0.055	0.13	0.21	+60	Deep



[1] BW12, $d_s/h = 0.64$, $H/gT^2 \approx 0.0015$.

The ability of the model to predict wave transmission coefficients for a breakwater constructed entirely of armor stone is shown in Figure 32; wave transmission coefficients for a breakwater with a front-face slope of 1 on 2.6 are shown in Figure 33.

(2) The case of waves breaking on the breakwater. It was difficult in the laboratory to generate long waves that would break on a rough permeable structure without any overtopping. However, several tests that met these conditions were run using nonsurging, breaking waves (Galvin, 1968). These laboratory tests show that for breaking and nonbreaking waves the coefficient of transmission decreases gradually as the incident steepness increases (Fig. 34); no difference was evident between K_{Tt} for breaking and nonbreaking waves. The same trend is observed in Bottin, Chatham, and Carver's (1976) data for a breakwater with dolos armor units. Comparison of observed and predicted coefficients of transmission through the structure shows good agreement for the few breaking wave conditions tested (Fig. 34). These few tests suggest that the Madsen and White (1976) model can be used for breaking as well as nonbreaking waves.

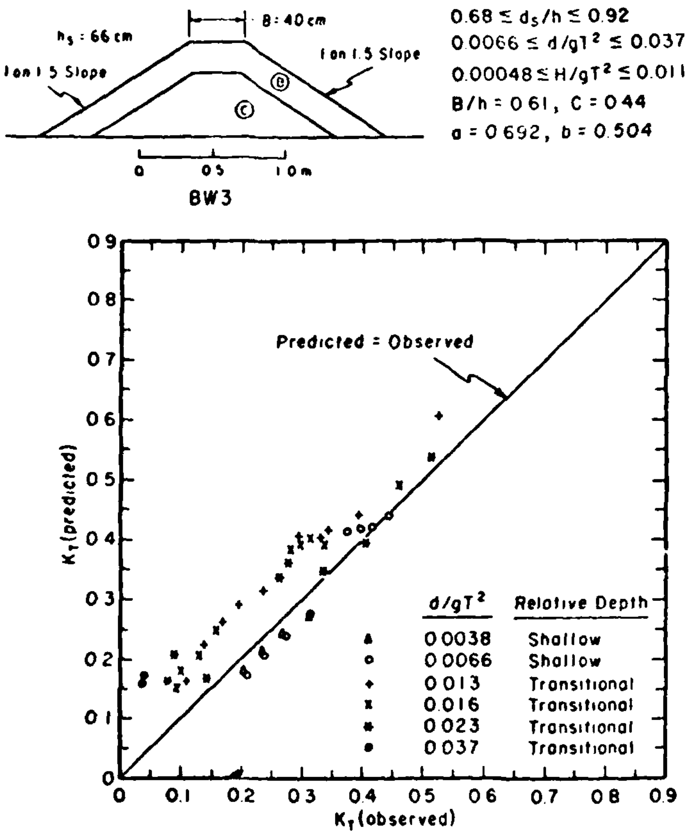


Figure 31. Observed and predicted transmission coefficients for BW3.

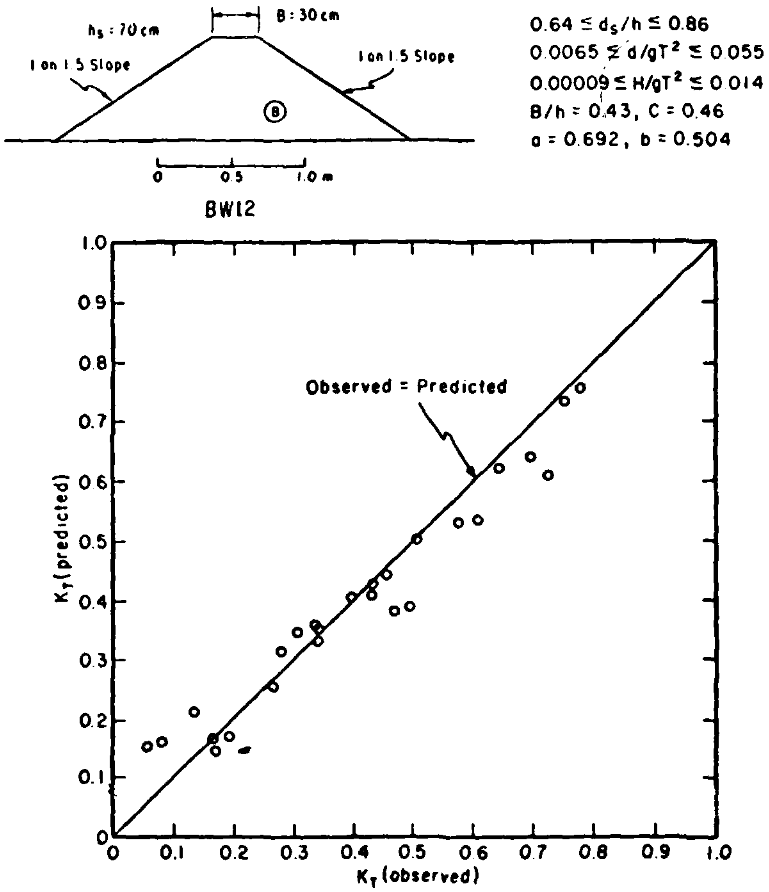


Figure 32. Observed and predicted transmission coefficients for BW12.

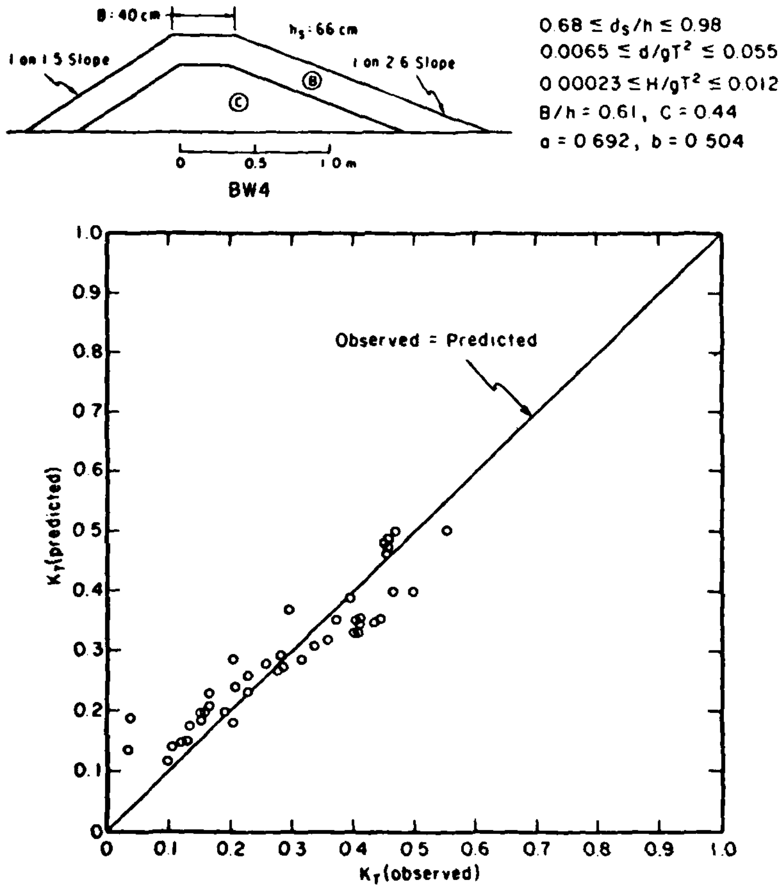


Figure 33. Observed and predicted transmission coefficients for BW4.

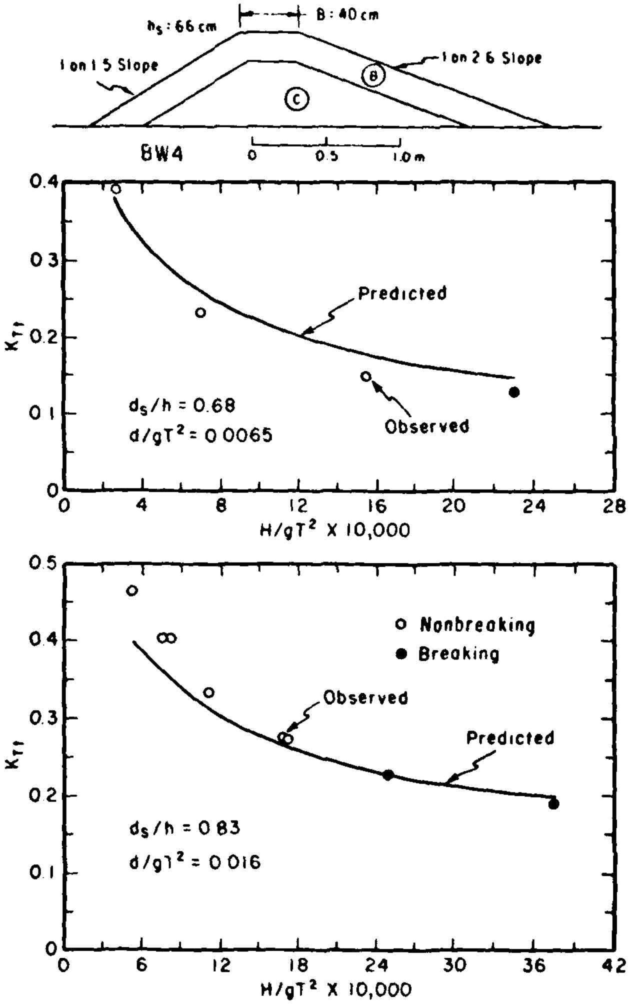


Figure 34. Observed and predicted transmission coefficients for breaking and nonbreaking conditions (BW4).

(3) The case of breakwaters with concrete armor units. The friction factor and porous media flow factors for concrete armor units are unknown, but they are assumed to be similar to the properties of stone with an effective median diameter, d_{50}, of

$$d_{50} = \left(\frac{W_{50}}{\gamma}\right)^{1/3} \tag{17}$$

Figure 35 shows observed and predicted transmission coefficients for a breakwater with two layers of dolos armor units. There is excellent prediction of transmission coefficients for long shallow-water waves with the Madsen and White (1976) model overpredicting transmission coefficients for waves with greater relative depth. This is the same trend found in prediction of transmission coefficients for rubble-mound breakwaters.

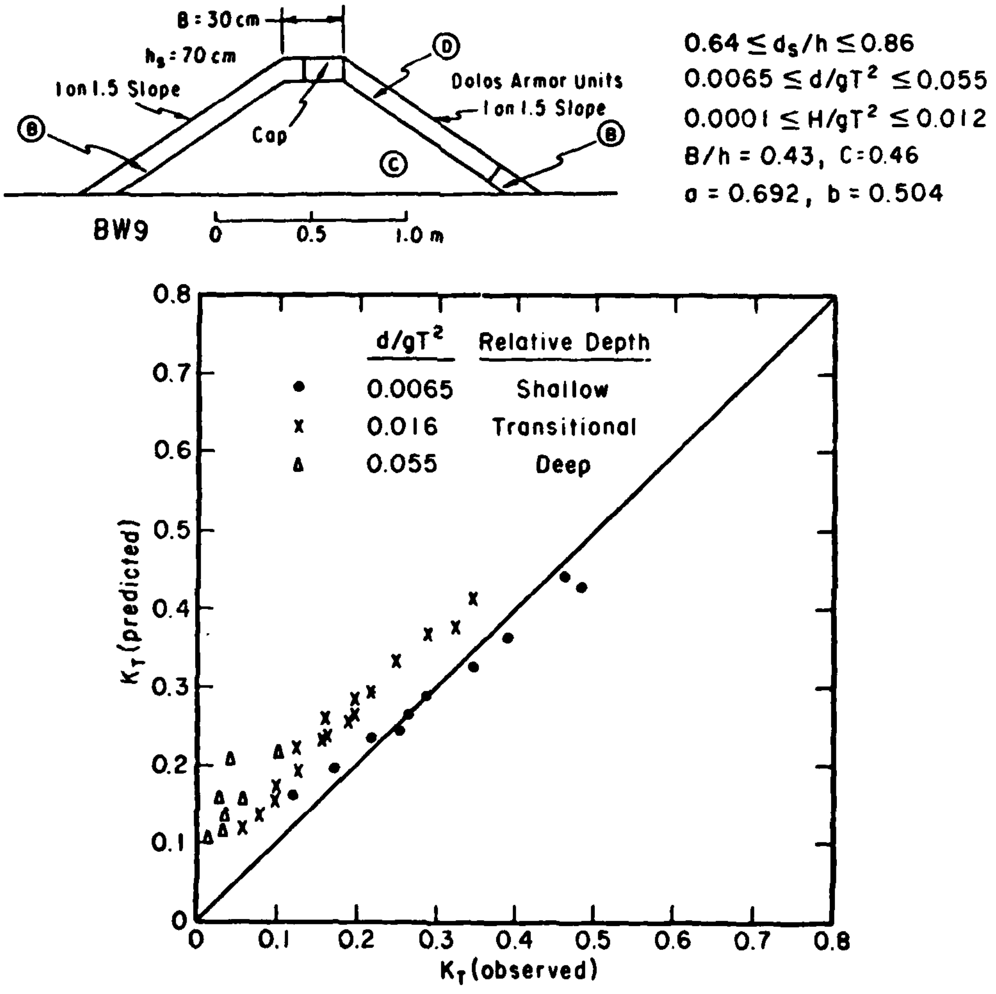


Figure 35. Observed and predicted transmission coefficients for a breakwater with dolos armor units (BW9).

The model also does a good job of predicting the coefficient of transmission through a permeable breakwater armored with tribars tested by Davidson (1969) (Fig. 36). However, the effective transmission by overtopping coefficient, C, is larger than would be expected from Figure 15 for B/h = 0.30. Fortunately, the observed transmission coefficient appears to be approaching a value of approximately 0.48, the limiting value of the overtopping wave transmission coefficient for this breakwater predicted from equations (14) and (15). The relatively high porosity of artificial armor units apparently increases the size of the wave transmission by overtopping coefficient over a limited range of wave heights for this case where the stillwater level is above the core and close to the breakwater crest (D. Davidson, Chief, Wave Research Branch, U.S. Army Waterways Experiment Station, personal communication, 1979).

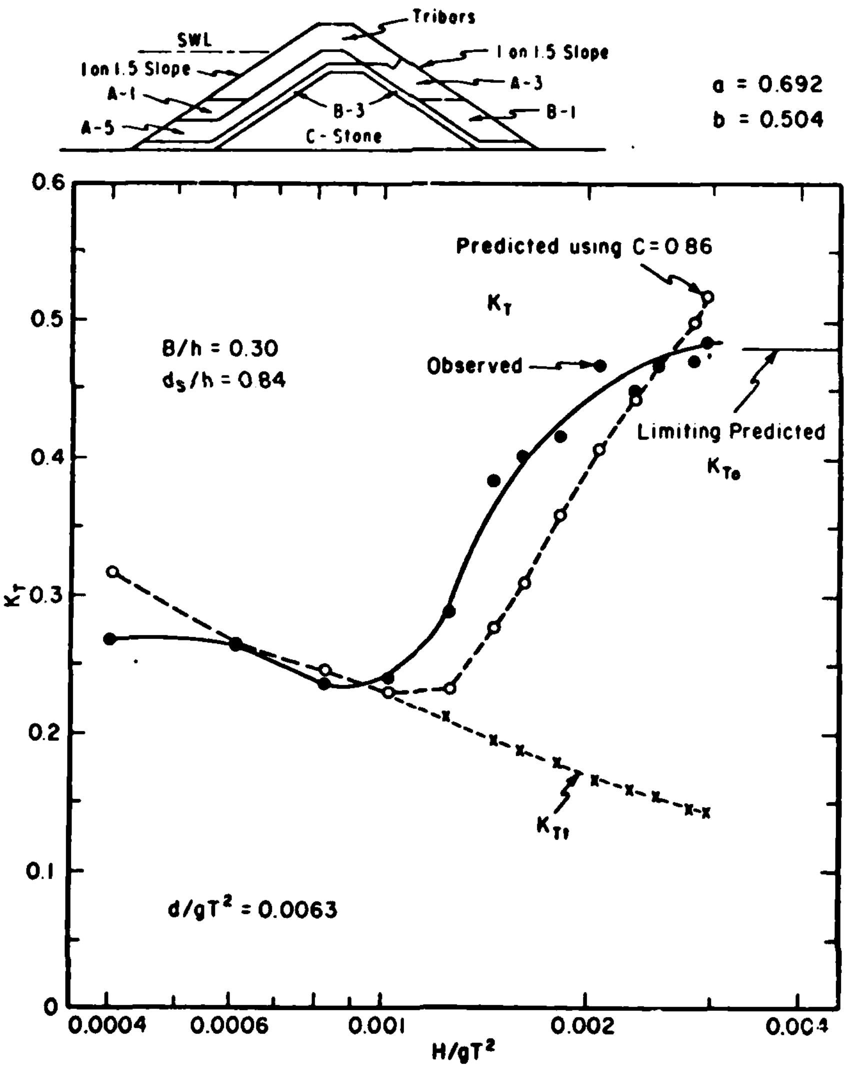


Figure 36. Wave transmission past a heavily overtopped breakwater with tribar armor units (laboratory data from Davidson, 1969).

(4) The case of irregular waves. Laboratory tests with a wide variety of spectral shapes suggest that there is little difference in the transmission coefficient from one spectral type to another. The overall transmission coefficient, K_T, is approximately the same for a monochromatic test as for an equivalent irregular wave test with the period of peak energy density, T_p, and mean incident wave height, $\bar{H}$, used to characterize the irregular wave conditions. Figure 37 shows observed and predicted transmission coefficients for a rubble-mound breakwater tested with monochromatic and irregular waves. The ability of the computer program MADSEN to predict transmission coefficients for irregular waves is at the same level as for monochromatic waves for the conditions tested.

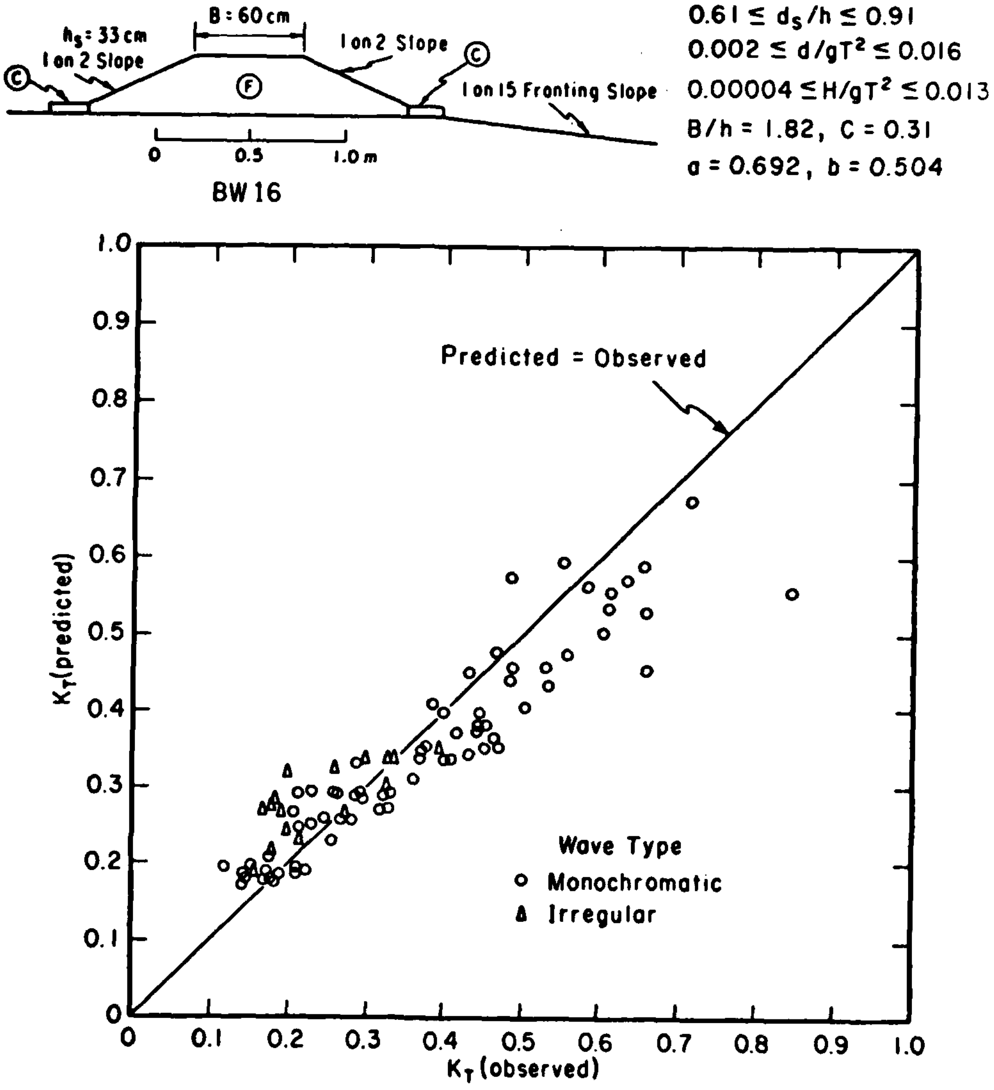


Figure 37. Observed and predicted transmission coefficients for BW16.

(5) The case of porosity of the breakwater. Porosity of each of the materials must be known in order to use the computer program MADSEN. However, in many design situations the value of porosity may be poorly known. Typical values of porosity, P, are given in Table 5. The recommended method of determining the influence of porosity on the predicted transmission coefficient is to run the program MADSEN at various values of porosity keeping all other parameters fixed. Figure 38 shows predicted transmission coefficients over a range of wave steepnesses for three different values of porosity. For this example, the absolute change in K_{Tt} produced by a given change in P is largest for waves of small steepness. The largest percent change in K_{Tt} for a given change in P occurs for the steepest waves tested. In general, the same trend will be observed for any breakwater; the value of K_{Tt} will increase as porosity increases for a given set of conditions. However, the magnitude of change of K_{Tt} is a complex function of all of the parameters in a design (breakwater geometry, water depth, wave height and period, etc.). A sensitivity analysis with the use of the program MADSEN, similar to the analysis shown in Figure 38, is recommended if the porosity of proposed materials is poorly known.

Table 5. Porosity of various armor units (from U.S. Army, Corps of Engineers, Coastal Engineering Research Center, 1977).

Armor unit	No. of layers	Placement	Porosity (P)
Quarrystone (smooth)	2	Random	0.38
Quarrystone (rough)	2	Random	0.37
Quarrystone (rough)	>3	Random	0.40
Cube (modified)	2	Random	0.47
Tetrapod	2	Random	0.50
Quadripod	2	Random	0.49
Hexapod	2	Random	0.47
Tribar	2	Random	0.54
Dolos	2	Random	0.63
Tribar	1	Uniform	0.47
Quarrystone	Graded	Random	0.37

c. Wave Transmission for Submerged Permeable Breakwaters. The coefficient of wave transmission over a submerged permeable breakwater, K_{To}, may be estimated by the methods given in Section IV,2. However, no generalized model is currently available for determining the coefficient of wave transmission through the structure, K_{Tt}. Saville's (1963) data for similar permeable and impermeable structures show that the total coefficient, K_T, approaches the transmission by overtopping coefficient, K_{To}, and transmission through the breakwater becomes less important as the structure becomes more submerged and the incident wave height increases (Fig. 39). At $d_s/h \geq 1.2$, the data from breakwaters BW3, BW3W, BW4, and BW4W show that the coefficients of transmission through the structure are approximately zero, so that $K_{To}/K_T = 1.0$. An upper estimate of the coefficient of transmission through the structure, K_{Tt}, for a submerged breakwater

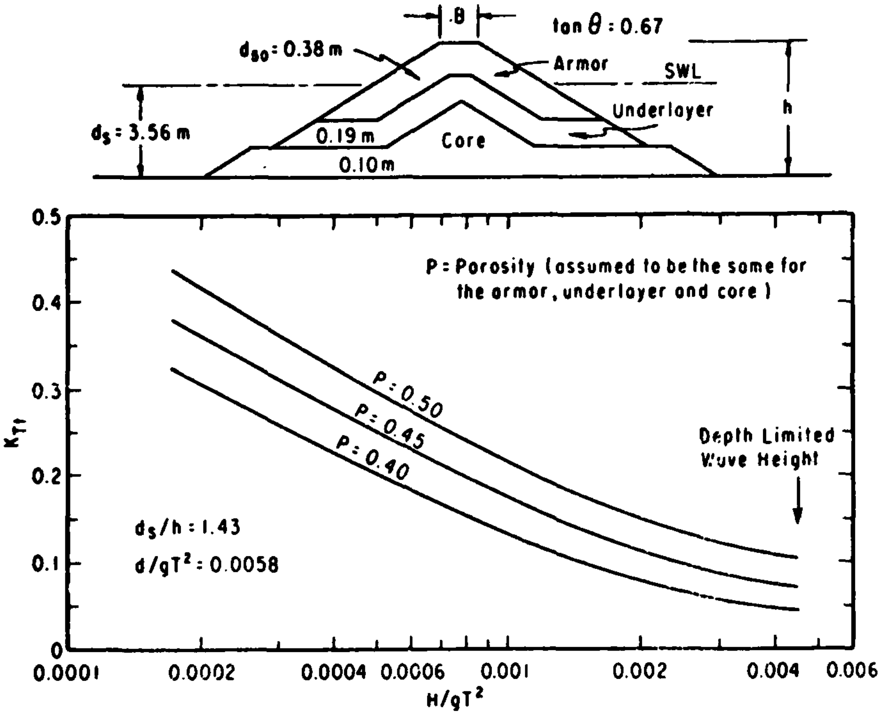


Figure 38. Example of the influence of porosity on the predicted coefficient of transmission for a rubble-mound breakwater.

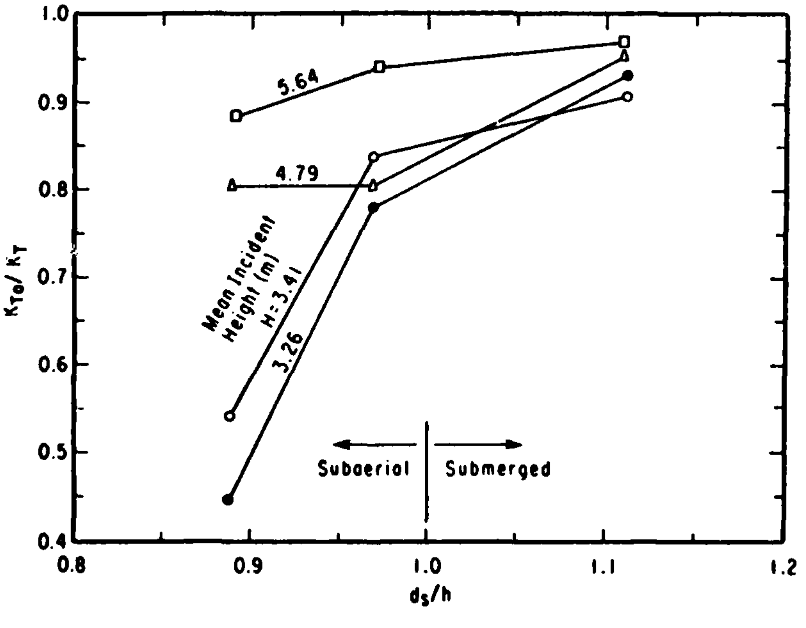


Figure 39. The relative importance of transmission by overtopping as a function of the incident wave height and the water depth-to-structure height ratio (after Saville, 1963).

can be made using the program MADSEN with $d_s/h = 1.0$. As a lower estimate, $K_{Tt} = 0.0$ can be assumed. Laboratory results from BW13, BW15, BW15W, and BW16 show that even using $K_{Tt} = 0$, methods in Section IV,1,b tend to give conservative estimates of the transmission coefficient for submerged permeable breakwaters (Fig. 40).

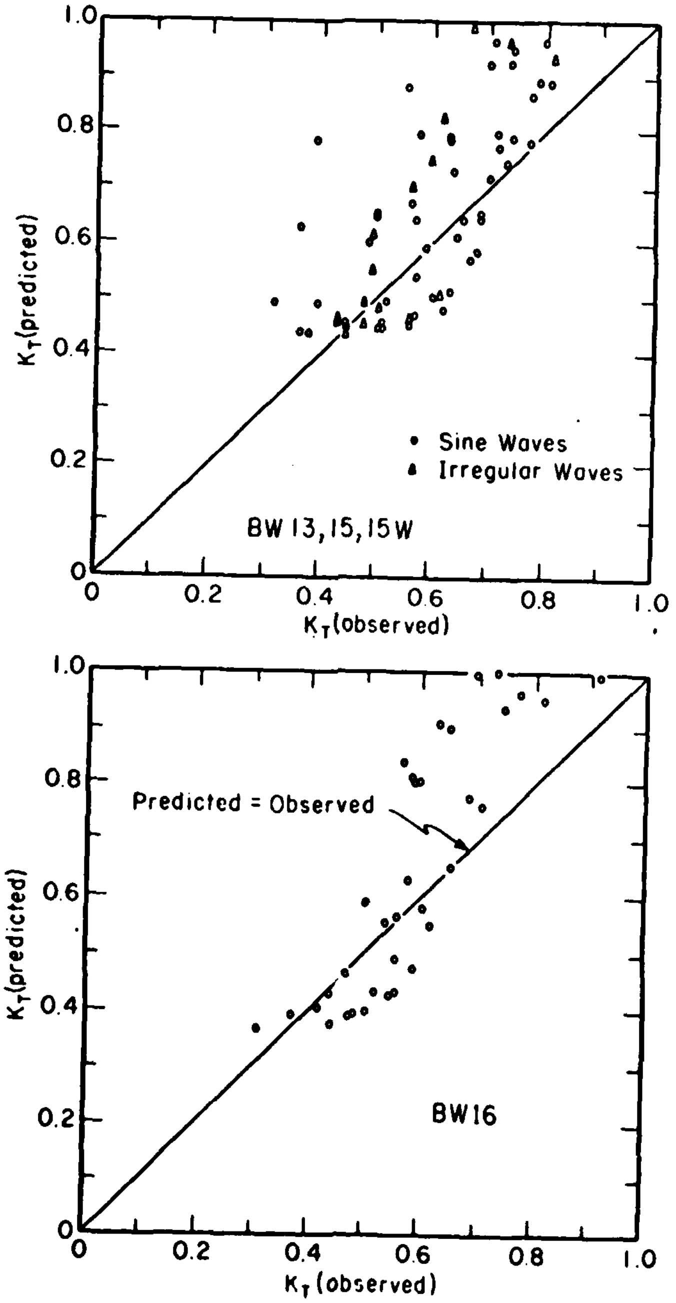


Figure 40. Observed and predicted transmission coefficients for submerged permeable structures assuming $K_{Tt} = 0$.

d. Influence of a Permeable Breakwater on Other Wave Characteristics. Wave energy shifts to higher harmonics are found in the transmitted wave records for monochromatic wave tests, as determined for overtopped impermeable breakwaters (Fig. 41). The energy shift is primarily a function of incident wave steepness and the ratio of the water depth to structure height. The largest shifts of energy to higher harmonics occur for steep waves where the structure crest is near to the stillwater level (Fig. 41).

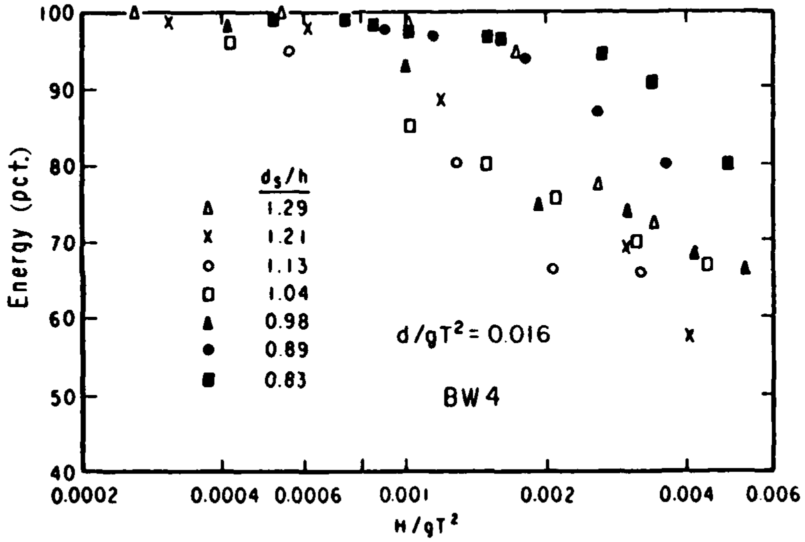


Figure 41. Percent of wave energy at the forcing period for waves transmitted past a permeable breakwater (monochromatic waves).

In the case of irregular waves the higher frequency parts of the reflected and transmitted spectra tend to be dampened out, so relatively more wave energy is found at lower frequencies than in the incident spectrum (Fig. 42). This means that on the average the spectral peakedness, Q_p, of reflected and transmitted spectra is greater than or equal to the spectral peakedness of incident spectra (Fig. 43).

A zero up-crossing analysis of wave records shows that on the average the wave height distribution shape is approximately the same for incident and transmitted waves for the irregular conditions tested for a permeable breakwater (Fig. 44).

The amount of wave grouping or the tendancy of large waves to follow large waves and small waves to follow small waves is characterized by the autocorrelation of zero up-crossing wave heights, ρ (see Sec. III,4). Results from BW16 show that the autocorrelation transmitted waves is less than or equal to that for incident waves in the case of irregular waves incident on a permeable breakwater (Fig. 45).

The joint distribution of transmitted wave heights and periods for an irregular wave condition is similar to that found for smooth impermeable breakwaters. There is a tendancy for lower transmitted waves to have average periods less than found in the incident joint height-period distribution (Fig. 46). Both the incident and transmitted larger wave heights have average periods approximately equal to the period of peak energy density.

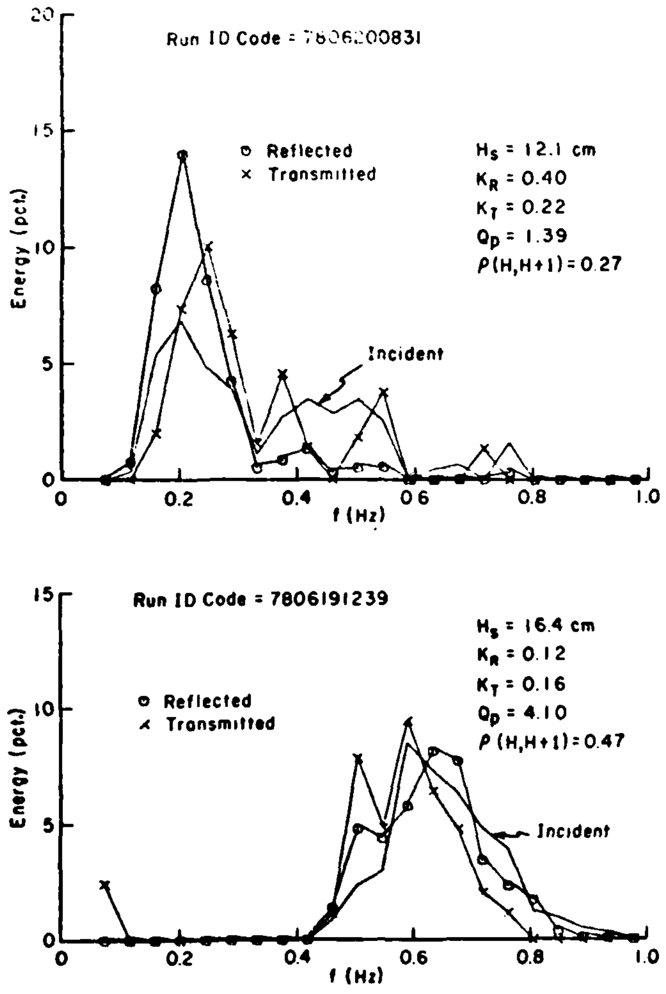


Figure 42. Sample incident, reflected, and transmitted wave spectra for BW16 (d_s/h = 0.76).

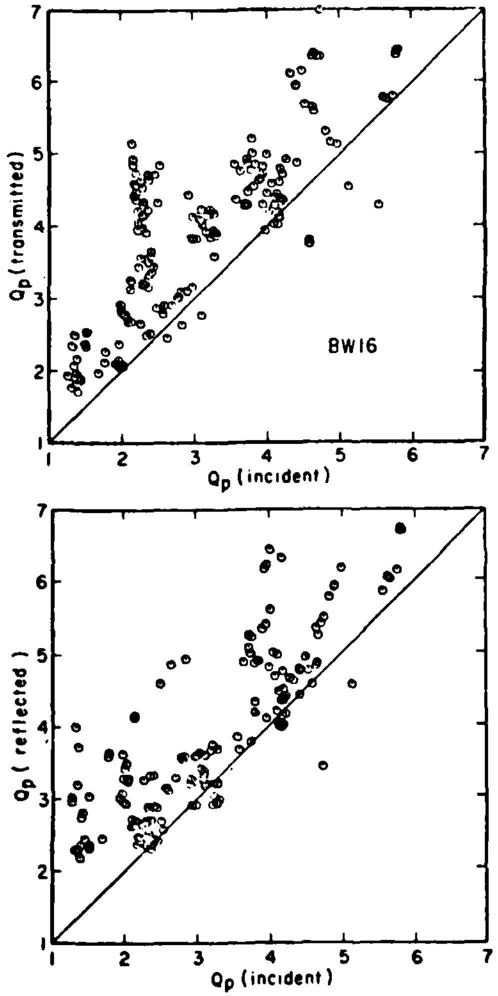


Figure 43. Spectral peakedness of transmitted and reflected wave spectra versus incident spectral peakedness for a permeable breakwater.

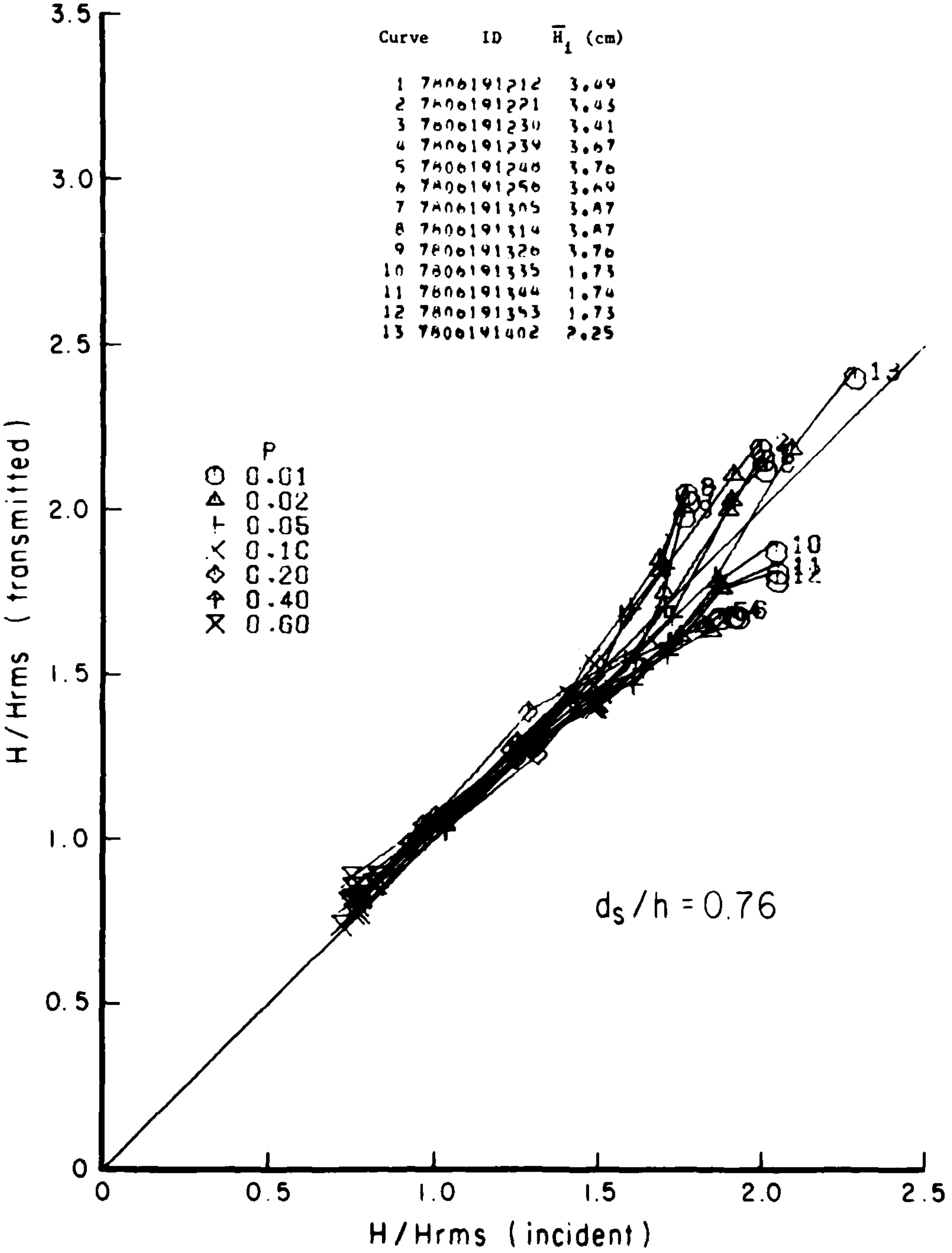


Figure 44. Comparison between incident and transmitted wave height distribution for a permeable breakwater (BW16).

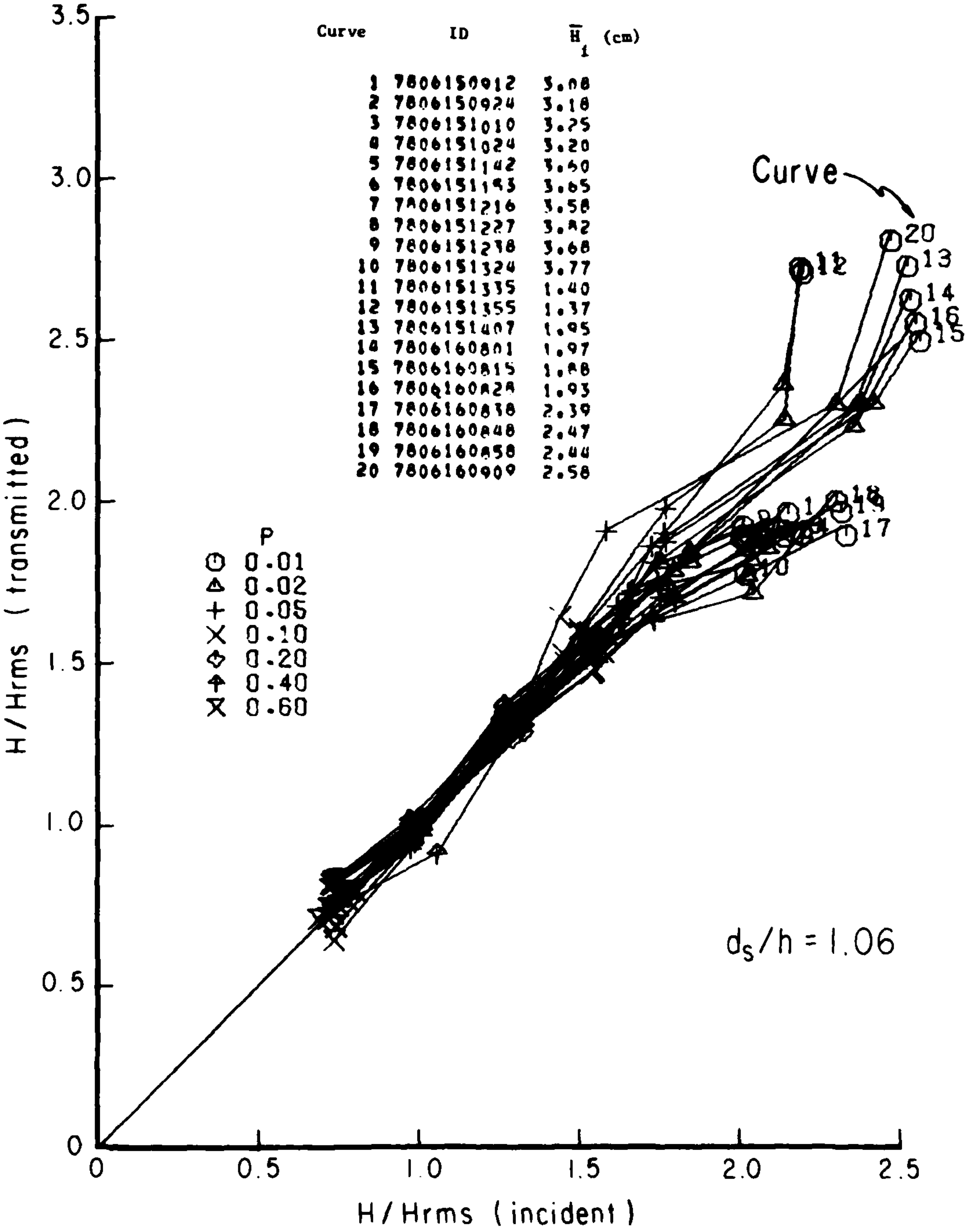


Figure 44. Comparison between incident and transmitted wave height distribution for a permeable breakwater (BW16).--Continued

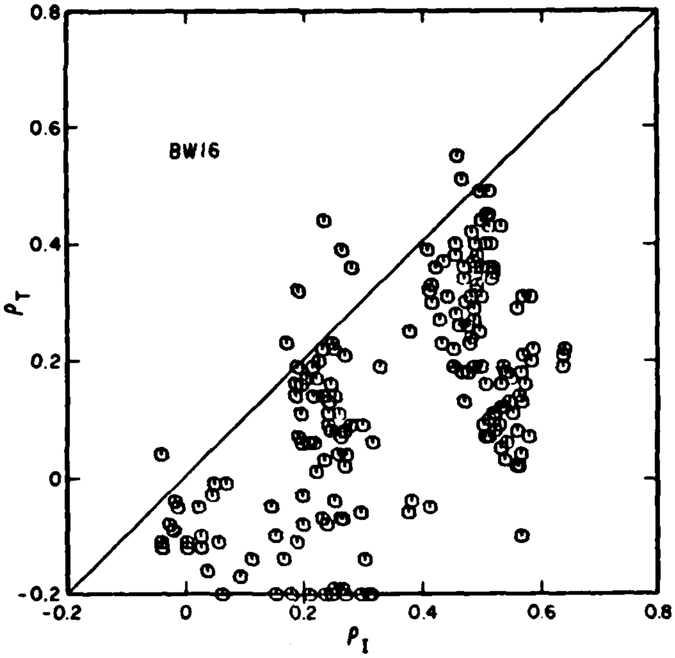


Figure 45. Autocorrelation of zero up-crossing wave heights for transmitted and incident wave records for a permeable breakwater.

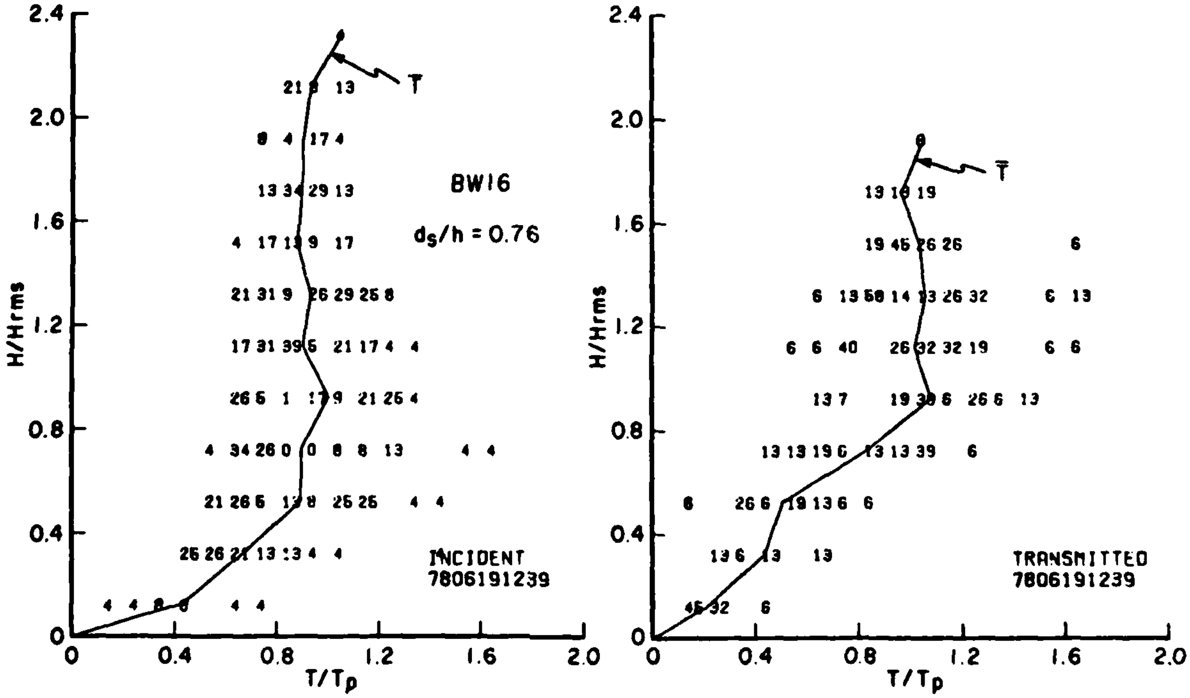


Figure 46. Sample joint distributions of wave height and period for an irregular wave condition and a permeable breakwater.

V. MODEL SCALE EFFECTS

1. Causes of Physical Model Scale Effects.

Wave energy dissipation and resulting reduction of wave height produced by a breakwater are due to a combination of laminar and turbulent energy loss as well as wave modification. Little information is available on scale effects of wave transmission by overtopping, but scale effects are probably small. This is illustrated by Saville (1963) who tested wave transmission by overtopping for similar breakwaters that differed by a scale of 10. There was little systematic difference between the results of tests run at the two scales, with the small-scale tests being slightly conservative.

Wave transmission through permeable breakwaters is controlled primarily by laminar and turbulent energy loss of flow through the structure (Wilson and Cross, 1972; Keulegan, 1973; Madsen and White, 1976). In the protoytpe the wave height reduction is due largely to turbulent effects, but in a model laminar and turbulent losses may be important so that a model underpredicts the coefficient of transmission through a breakwater. The size of the scale effect is a complex function of model design, water depth, and wave height and period.

2. Interpreting and Applying Laboratory Results to Prototype Conditions.

The recommended method of estimating scale effects of transmission through permeable breakwaters is to use the computer program MADSEN to predict transmission coefficients for the model and prototype. The physical model correction factor, CF, is defined as the expected coefficient of wave transmission through the structure in the prototype divided by the coefficient of wave transmission through the structure at the model scale. CF is determined by first running the program MADSEN with prototype conditions to determine K_{Tt} (MADSEN prototype). The program is then run at the model scale to determine K_{Tt} (MADSEN scale model). CF is defined as

$$CF = \frac{K_{Tt} \text{ (MADSEN prototype)}}{K_{Tt} \text{ (MADSEN scale model)}} \tag{18}$$

The coefficient for wave transmission through the structure measured in the physical scale model should then be multiplied by CF to estimate the prototype coefficient.

For example, assume that the laboratory breakwater tested by Sollitt and Cross (1976) is a 1 on 10-scale Froude model of a prototype structure (Fig. 47). There was no transmission by overtopping. The program MADSEN was run at both model and prototype scales and the results together with the physical model measurements are shown in Figure 48. The MADSEN program output shows that the physical model was probably underpredicting the prototype coefficient because the scale model has proportionally more laminar energy loss than the prototype. Even in this large 1 on 10-scale Froude physical model, the prototype K_{Tt} is expected to be as much as 20 percent higher than in the scale model over the range of conditions tested.

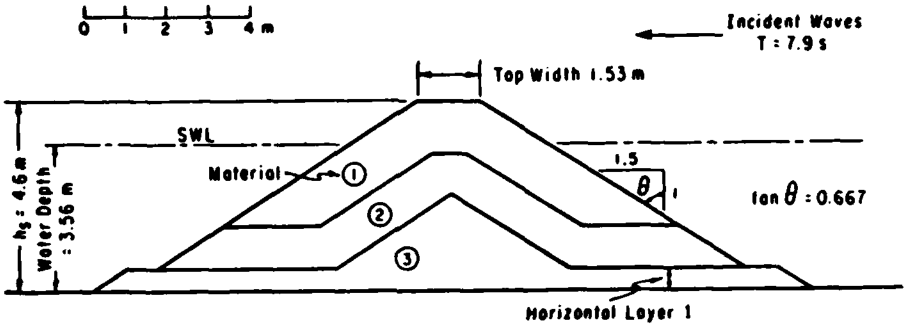


Figure 47. Trapezoidal multilayered breakwater tested by Sollitt and Cross (1976) (prototype).

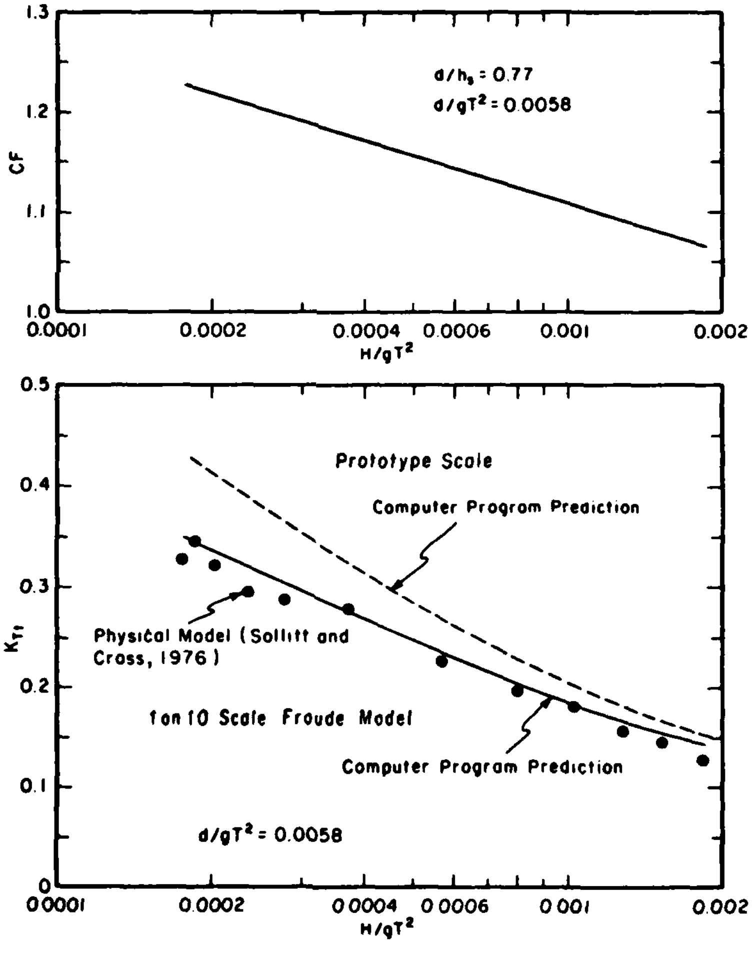


Figure 48. Physical model results and correction factors determined from the analytical model of Madsen and White (1976).

VI. EXAMPLE OF ESTIMATING WAVE TRANSMISSION COEFFICIENTS

* * * * * * * * * * * * * * * * * * EXAMPLE PROBLEM * * * * * * * * * * * * * * * * * *

GIVEN: $T = 7.9$ seconds

$d_s = 3.56$ meters

Breakwater top width, $B = 1.53$ meters

Breakwater seaward slope, $\tan \theta = 0.667$ (1 on 1.5)

FIND: The influence of incident wave height and structure height on the transmission coefficient for the permeable breakwater shown in the upper part of Figure 49 (change the structure height by varying the thickness of horizontal layer 1). Also, compare the predicted transmitted wave heights to heights for a similar smooth impermeable structure (lower part of Fig. 49).

SOLUTION: The computer program MADSEN (App. G) is used to predict wave transmission coefficients for the permeable structure and the program OVER (App. F) is used to predict coefficients for the smooth impermeable breakwater. The transmission coefficient for the permeable structure decreases as wave steepness increases, until overtopping occurs when the transmission coefficient increases with steepness (Fig. 50). The transmission coefficient decreases as structure height increases and the initiation of overtopping occurs at a larger value of the incident wave height as the structure height increases. The similar shaped smooth impermeable breakwater has larger values of the transmission coefficient for the steeper waves examined (Fig. 50) because the runup is higher on the smooth structure. However, there is no transmission for the impermeable structure for the small waves where the runup does not reach the breakwater crest. The predicted transmitted wave height as a function of breakwater crest height is given in Figure 51 for two values of the incident wave height.

Material	d_{50} (m)	Porosity
1	0.381	0.435
2	0.190	0.435
3	0.095	0.435

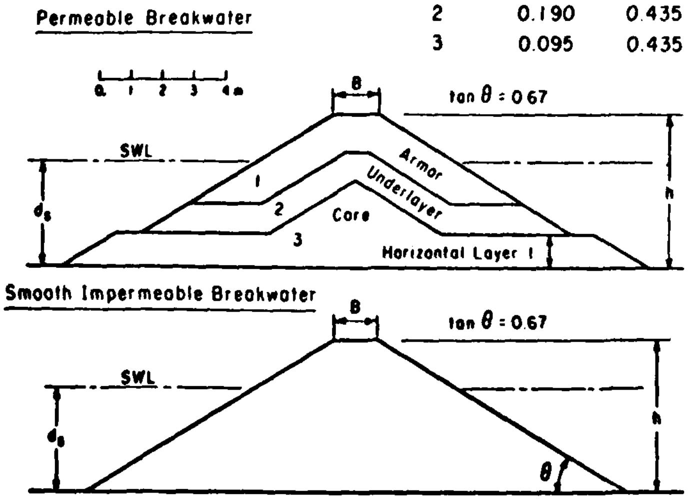


Figure 49. Breakwater cross sections used in the example for estimating wave transmission coefficients.

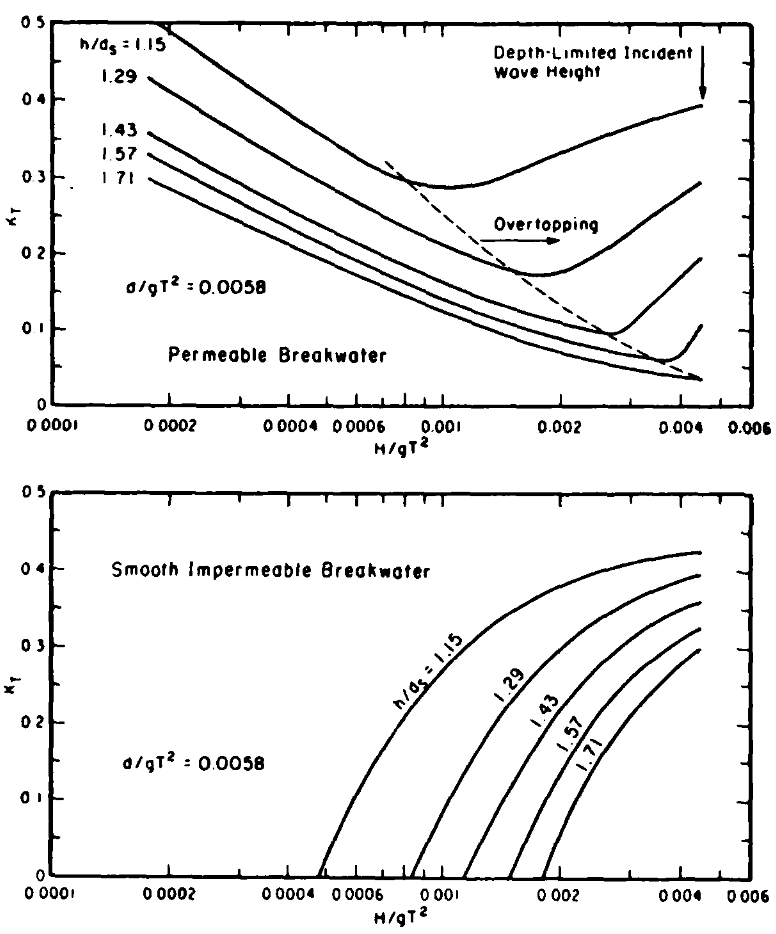


Figure 50. Predicted wave transmission coefficients.

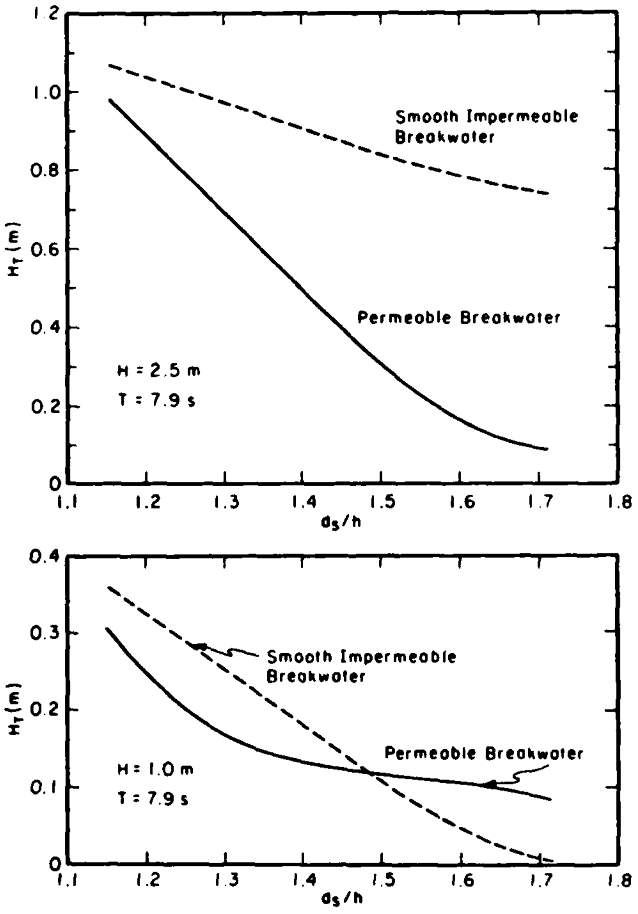


Figure 51. Predicted transmitted wave height as a function of breakwater crest height.

VII. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The primary conclusions from the tests of wave transmission and reflection of laboratory breakwaters conducted for this study are:

1. A simple formula for predicting wave transmission by overtopping coefficients together with the model of Madsen and White (1976) for transmission through permeable structures can be used to obtain estimates of wave transmission coefficients.

2. Limited tests with breaking waves suggest that the methods can be used for breaking or nonbreaking conditions.

3. Tests with irregular waves show that the transmission coefficient for irregular waves is approximately the same as for a similar monochromatic wave test. The mean wave height and period of peak energy density are the parameters recommended to describe irregular waves.

4. Irregular wave tests indicate that for permeable or submerged breakwaters the incident and transmitted wave height distributions have similar shape. However, smooth impermeable subaerial breakwaters have height distributions biased toward the larger heights for irregular waves because large waves transmit more efficiently than small waves.

5. Transmitted and reflected spectra for irregular waves generally have equal or higher spectral peakedness than incident spectra.

6. Joint wave height-period distributions have similar dimensionless shapes for incident and transmitted wave records.

7. There is a tendancy for wave heights to be less grouped after they have transmitted past a breakwater.

8. Transmitted wave energy may appear at higher order harmonics of the incident waves for monochromatic wave tests. However, the tendancy for energy shifts decreases as the wave transmission coefficient increases.

9. Additional work is necessary to develop generalized models for predicting wave reflection coefficients and wave transmission through the crests of breakwaters armored with relatively porous materials, such as concrete armor units.

The recommended steps for design of a breakwater for wave transmission are:

1. Use the computer programs MADSEN and OVER to estimate transmission coefficients for preliminary breakwater design. Alternative designs can be tested by varying parameters such as:

(a) structure height
(b) crest width
(c) seaward and landward breakwater slopes
(d) water depth
(e) number, thickness, location, and diameter of materials
(f) porosity
(g) permeability
(h) wave height
(i) wave period

2. A sensitivity analysis is recommended on those input parameters that are poorly known. For example, if there is some uncertainty in the value of the design water level, predictions should be made over the range of expected water levels keeping all other factors fixed. Comparison between the predictions at different levels will indicate the importance of water level.

3. Estimate reflection coefficients from model results.

4. If possible, final breakwater design should be made with the use of physical models. The program MADSEN can be used to assist in designing and interpreting physical laboratory models and results for permeable breakwaters.

Copies of the program decks for the program MADSEN and OVER described in Appendixes F and G may be obtained from the Automatic Data Processing Coordinator, Coastal Engineering Research Center, Fort Belvoir, Virginia 22060.

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APPENDIX A

BREAKWATER GEOMETRIES

Each of the breakwaters tested is assigned an identifying code (e.g., BW1). This appendix includes a cross-section drawing and a brief description of each of the breakwaters. Note that breakwaters 1 to 12 (Figs. A-1 to A-14) were tested on a flat tank bottom; breakwaters 13 to 17 (Figs. A-15 to A-19) had a 1 on 15 fronting slope 3.75 meters long. Materials used in construction of the structures are identified by a circled letter; material characteristics are discussed in Appendix B.

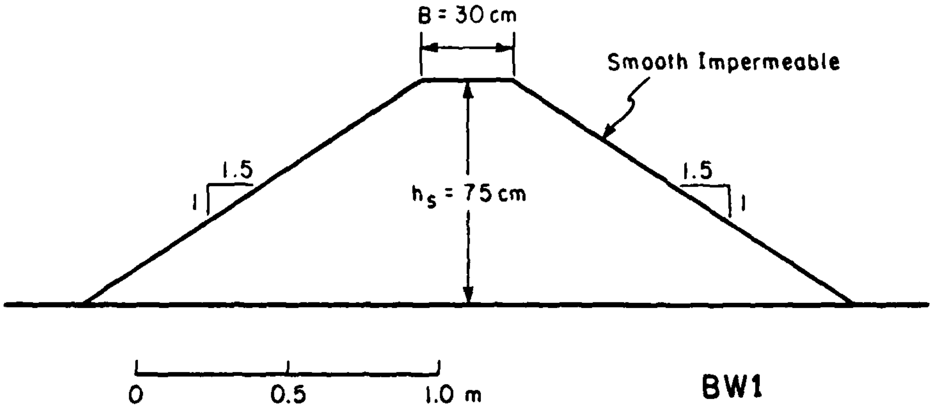

Figure A-1. Breakwater 1 cross section.

BW1 is a smooth impermeable structure tested for wave transmission by overtopping and reflection. Note that simultaneous measurements of wave runup were being made on a smooth 1 on 1.5 slope in an adjacent flume by Ahrens (1978) while the breakwater tests were underway (see Fig. 1).

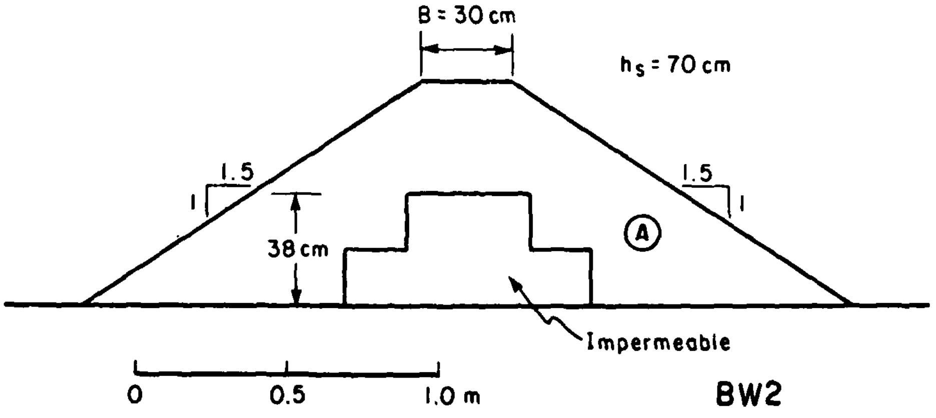

Figure A-2. Breakwater 2 cross section.

BW2 is similar to a casson breakwater that has been rehabilitated by adding rock armor units. The major emphasis of these tests was to examine the effects of wave period and height on transmission and reflection. Armor material was randomly placed.

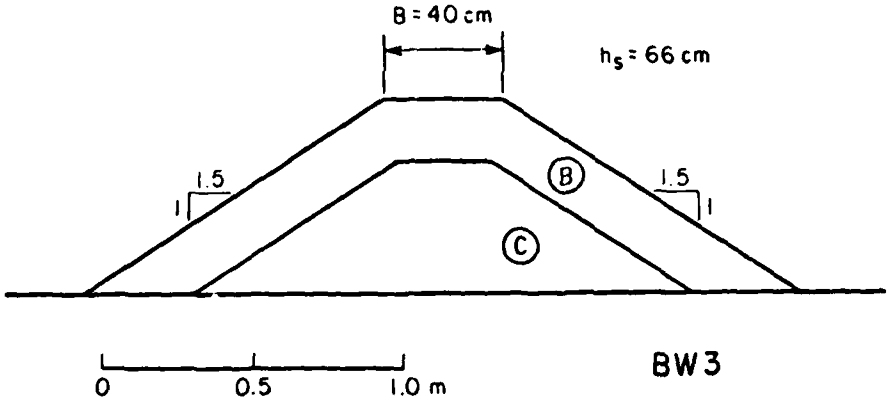

Figure A-3. Breakwater 3 cross section.

BW3 has an armor two units thick of angular stone. A moderate amount of fitting was used in placing the armor, especially near the crest. Core material was placed by dumping.

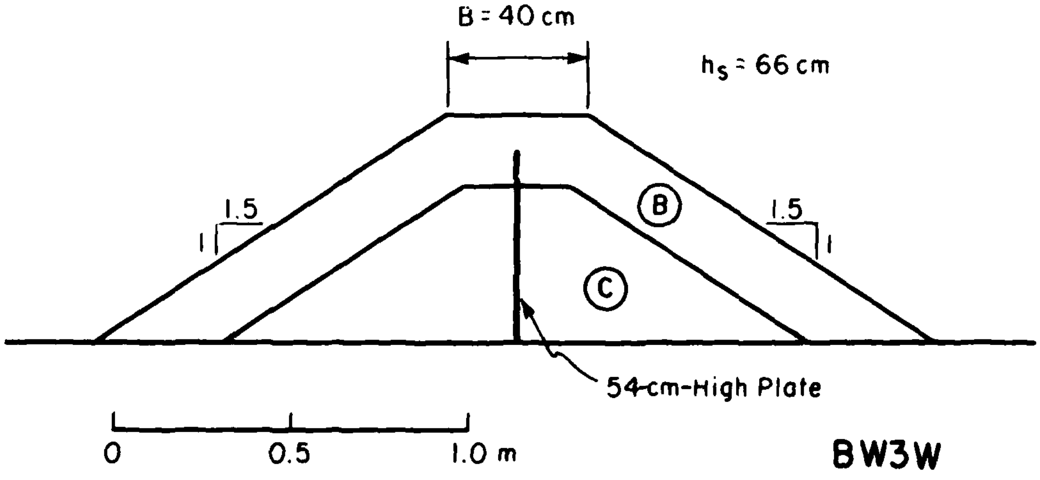

Figure A-4. Breakwater 3W cross section.

BW3W is similar to BW3, except that a 5-millimeter-thick metal plate was installed in the center of the structure. The caulked plate extended from the bottom to within one armor unit of the crest (54 centimeters high).

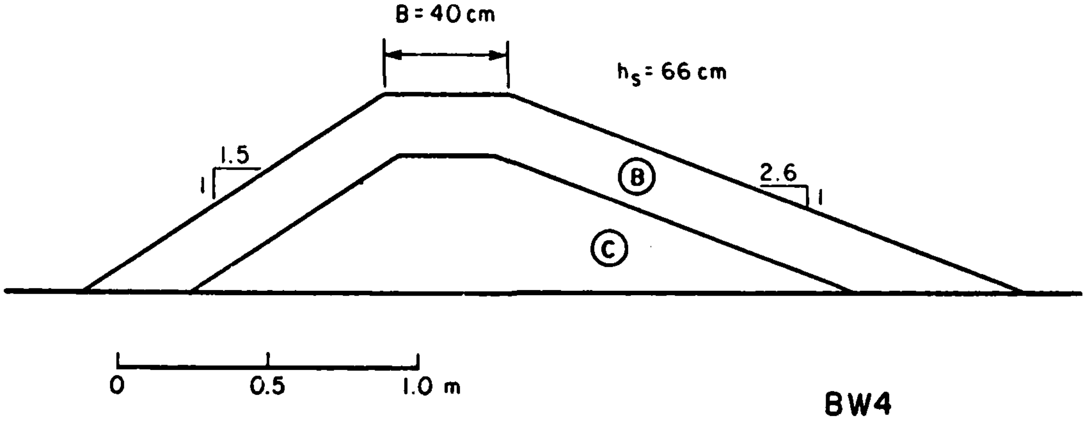

Figure A-5. Breakwater 4 cross section.

BW4 is similar to BW3, except with a 1 on 2.6 front-face slope.

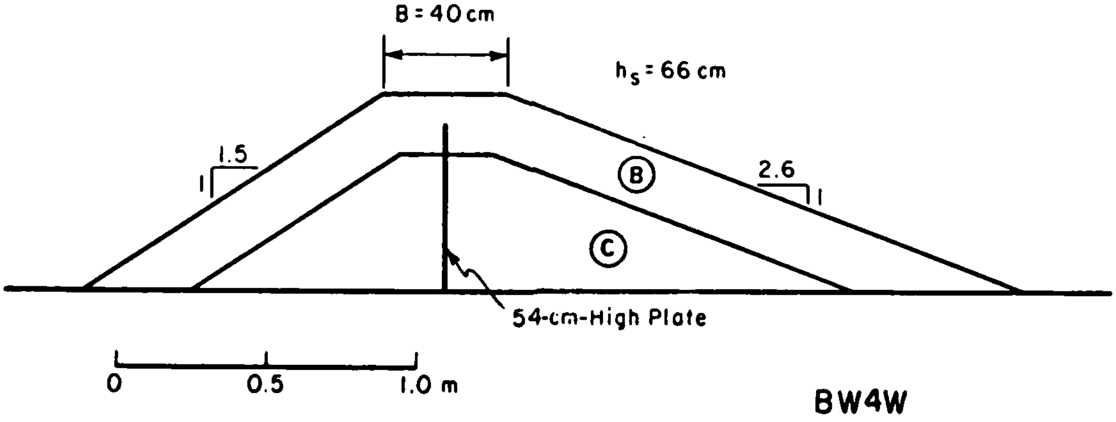

Figure A-6. Breakwater 4W cross section.

BW4W is similar to BW4, but includes a 54-centimeter-high impermeable pla in the center of the structure.

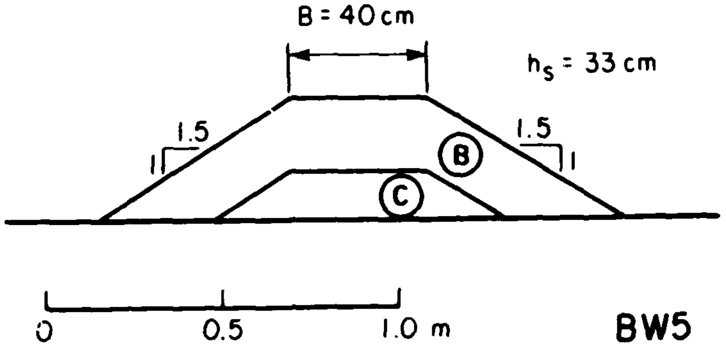

Figure A-7. Breakwater 5 cross section.

BW5, geometrically similar to the upper part of BW3, is typical of a breakwater built in relatively shallow water. The armor unit size is large compared to the structure height and the core size relatively small.

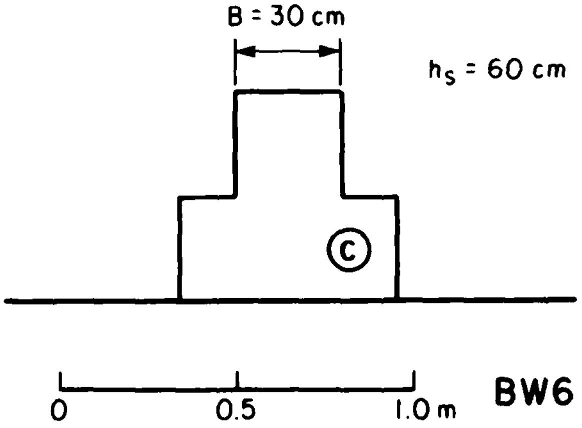

Figure A-8. Breakwater 6 cross section.

BW6 was made of three triangular, fine wire containers filled with core material.

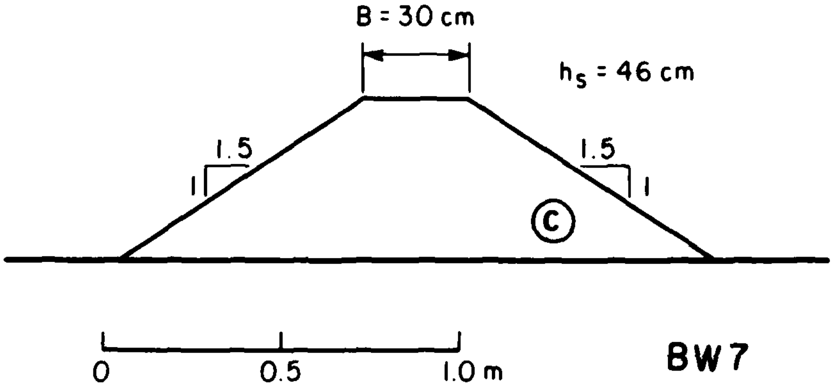

Figure A-9. Breakwater 7 cross section.

BW7 is geometrically similar to the core of BW3. The material was held in a fine wire structure to prevent motion of the stone.

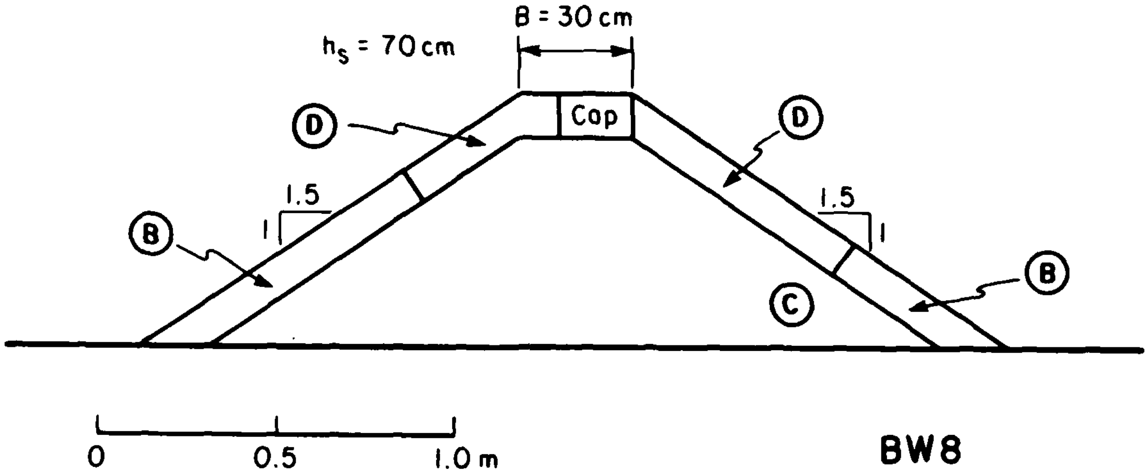

Figure A-10. Breakwater 8 cross section.

BW8 uses dolos artificial units as part of the armor material on both the front and back of the structure near the crest. Stone was used in the lower parts of the armor. A moderate amount of fitting was used in placing the armor units. An impermeable cap was installed toward the seaward side of the crest.

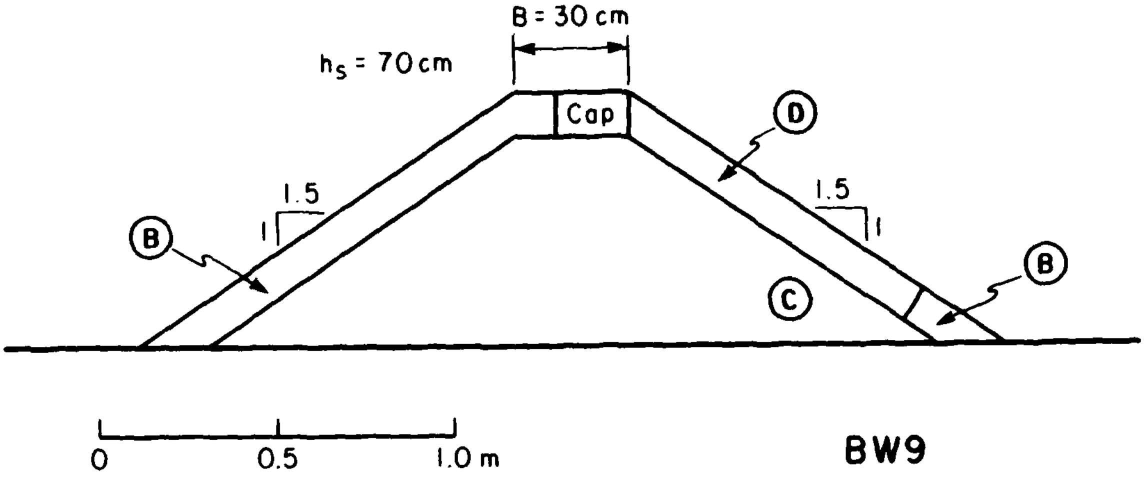

Figure A-11. Breakwater 9 cross section.

BW9 is similar to BW8, except that armor units have been arranged so that all of the dolos units are on the seaward side of the structure.

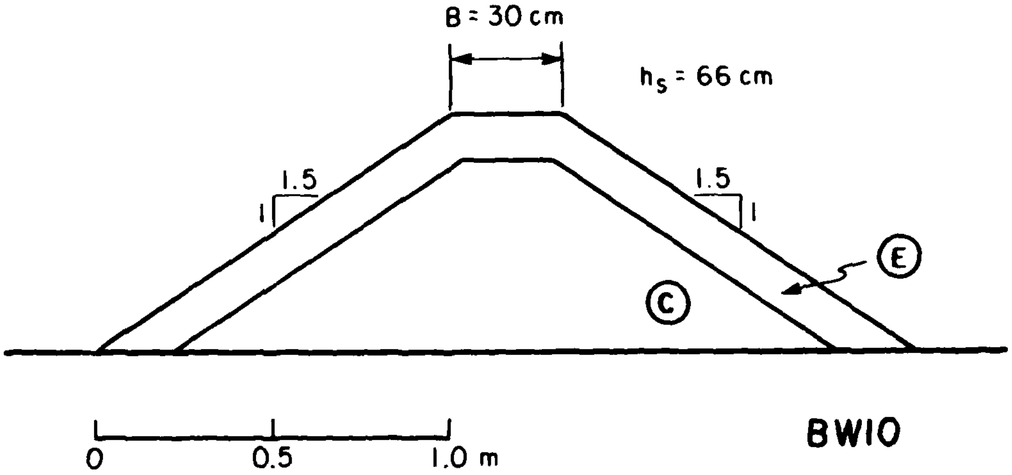

Figure A-12. Breakwater 10 cross section.

BW10 was made with an armor one unit thick of well-fitted rectangular rock. The material was placed with one surface parallel to the structure face.

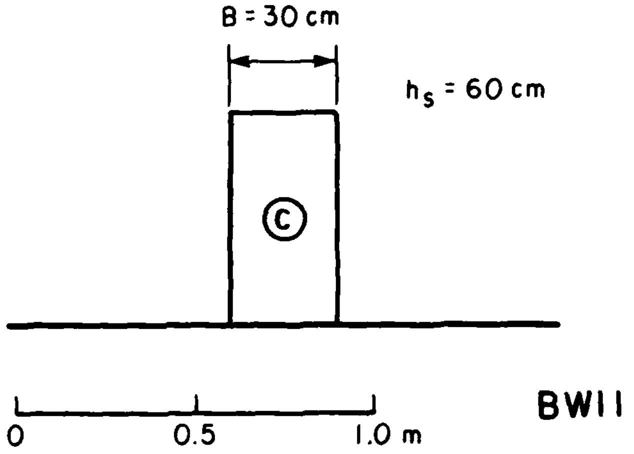

Figure A-13. Breakwater 11 cross section.

BW11 was made of two fine-wire rectangular baskets that enclosed core-type stone. The primary purpose of this structure was to examine the wave transmission and reflection characteristics of permeable material.

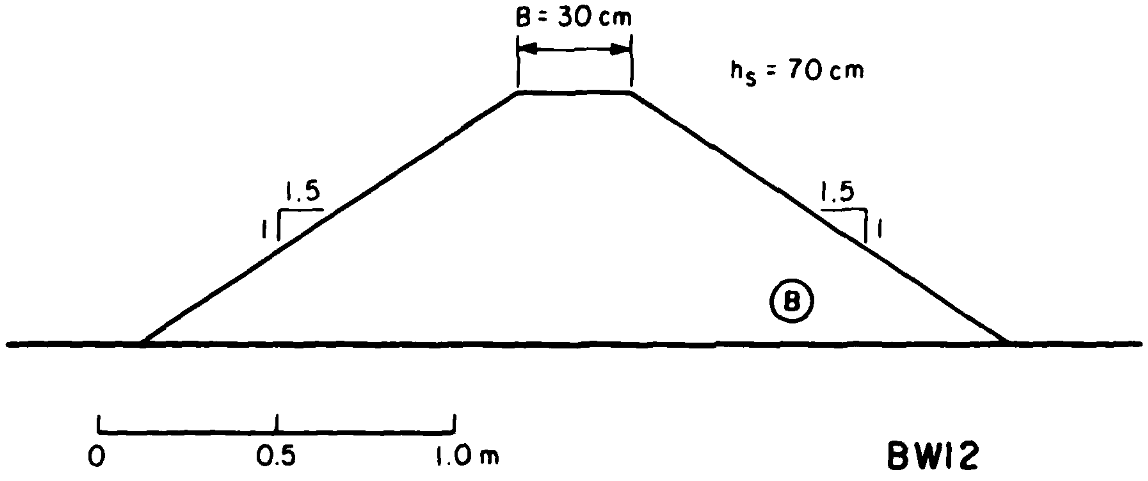

Figure A-14. Breakwater 12 cross section.

BW12 is a structure with no core similar in geometry to breakwaters 8 and 9.

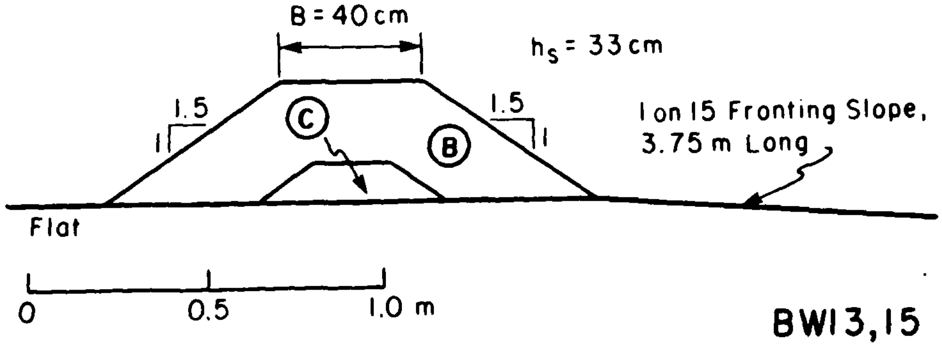

Figure A-15. Breakwaters 13 and 15 cross section.

BW13 and BW15 were tested with a 1 on 15 fronting slope 3.75 meters. Note that these structures are the same geometry as BW5 (built on a flat tank bottom).

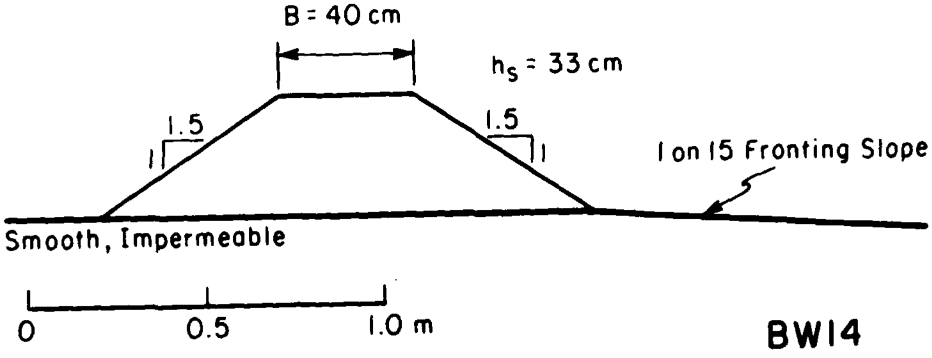

Figure A-16. Breakwater 14 cross section.

BW14, a smooth impermeable structure, has the same outside dimensions as permeable breakwaters BW5, BW13, and BW15.

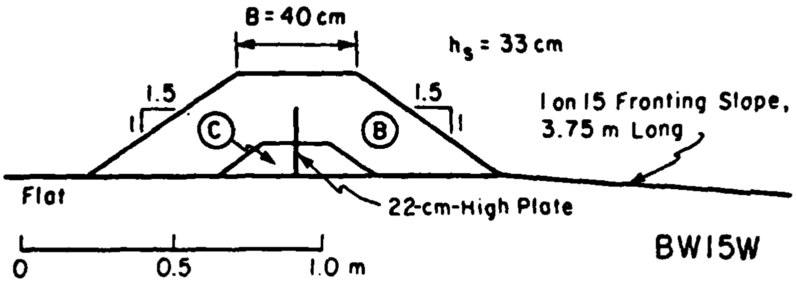

Figure A-17. Breakwater 15W cross section.

BW15W has the same dimensions and materials as BW13 and BW15, except that a 22-centimeter-high metal plate 5 millimeters thick has been installed in the center of the structure. This plate prevents transmission through the lower part of the structure.

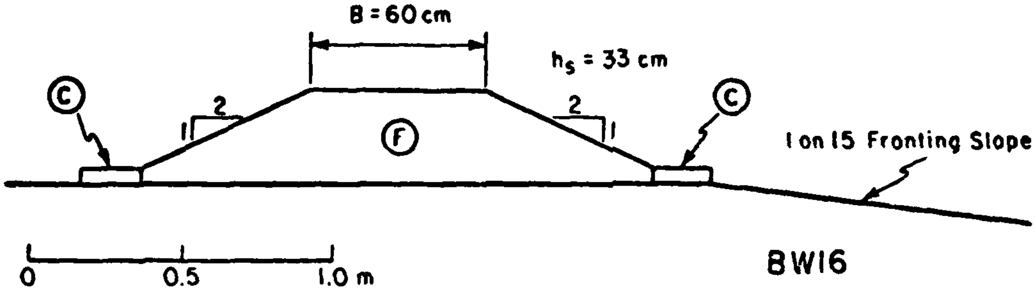

Figure A-18. Breakwater 16 cross section.

BW16 is a one-ninth scale Froude model of a proposed submerged breakwater for Imperial Beach, California.

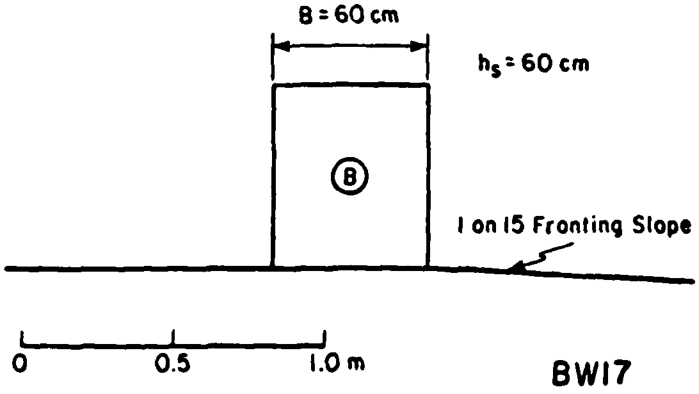

Figure A-19. Breakwater 17 cross section.

BW17 is a vertical permeable structure, similar to BW11, with the rock retained by a thin wire mesh.

APPENDIX B

MATERIAL CHARACTERISTICS

Materials used to construct permeable breakwaters are discussed in this appendix. Each material is identified by a circled letter and shown on the breakwaters where it was used in Appendix A. Figure B-1 includes photos of samples of the various materials (material F, not shown, is similar to A and B). Some basic parameters, such as weights, diameters, and porosities, are shown in Table B-1. The weight distribution of each of the materials is given in Figure B-2.

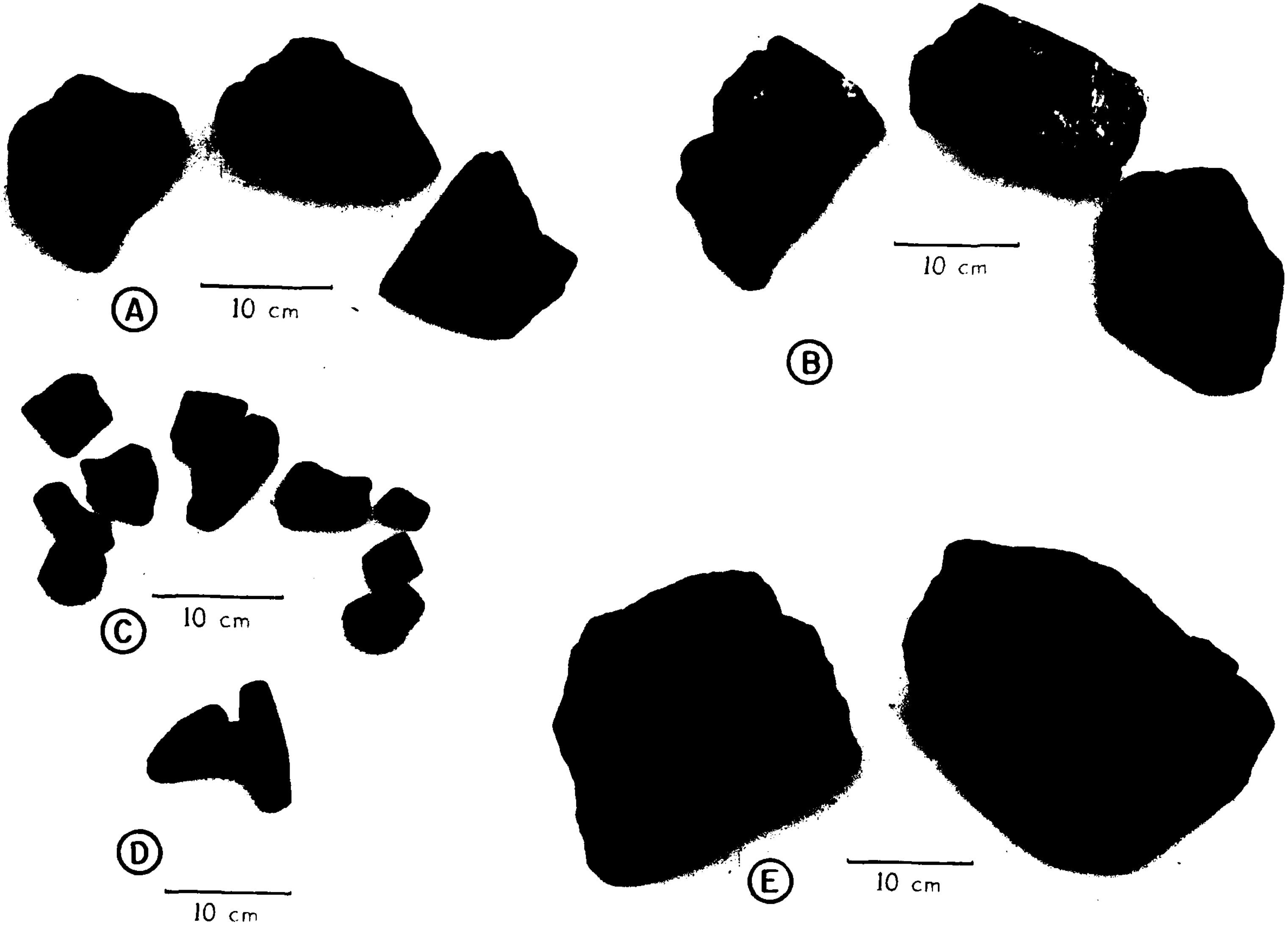

Figure B-1. Photos of construction materials.

Table B-1. Material characteristics.

Material	Description	W_{85}[1] (g)	W_{50}[2] (g)	W_{15}[3] (g)	d_{50}[4] (cm)
A	Angular stone	2,520	1,530	990	8.3
B	Angular stone	4,680	3,690	2,900	11.1
C	Angular stone	180	68	31	2.9
D	Dolos	405	390	390	----
E	Flat stone	13,200	11,200	8,100	16.1
F	Angular stone	7,600	4,900	2,500	12.2

[1] Weight at which 85 percent by weight of the material is heavier than.

[2] Weight at which 50 percent by weight of the material is heavier than.

[3] Weight at which 15 percent by weight of the material is heavier than.

[4] Representative diameter corresponding to W_{50}.

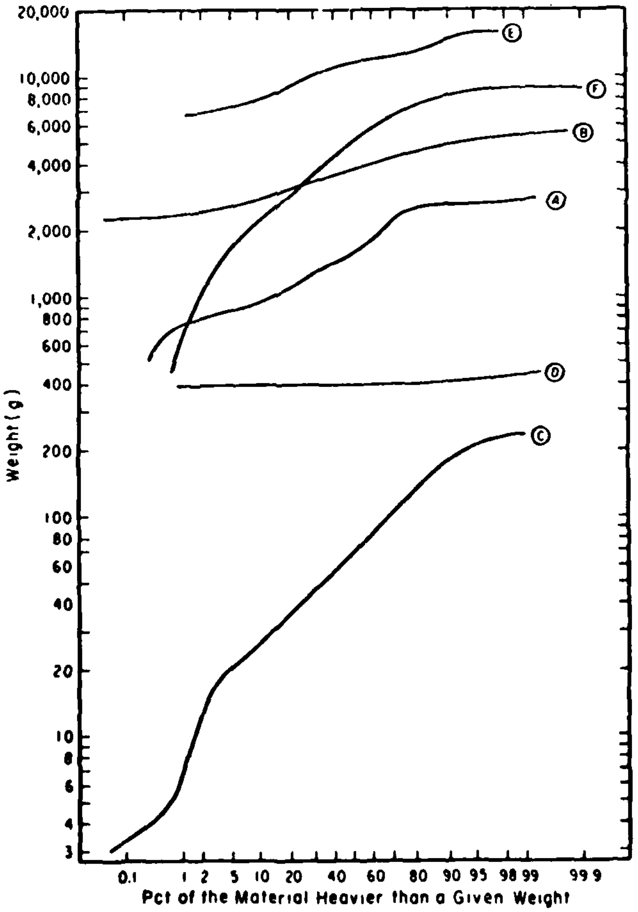

Figure B-2. Weight distribution of the construction materials.

APPENDIX C

TEST RESULTS (SINUSOIDAL BLADE MOTION)

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                                          SINE BLADE MOTION
     ID       D(CM) T(S) H(CM) KT       KR D/GT2 H/GT2          ID       D(CM) T(S) H(CM) KT       KR D/GT2 H/GT2

                                            BREAKWATER  1

7803240831. 90. 2.39  1.1 .880 .880 .016 .0002      7803240880. 90. 2.39  2.2 .876 .876 .016 .0004
7803240849. 90. 2.39  4.7 .876 .876 .016 .0008      7803240858. 90. 2.39  9.6 .806 .806 .016 .0017
7803240914. 90. 2.39 19.3 .714 .714 .016 .0034      7803240942. 85. 2.32  1.3 .898 .898 .016 .0002
7803240950. 85. 2.32  2.6 .918 .918 .016 .0005      7803241003. 85. 2.32  5.4 .881 .881 .016 .0010
7803241012. 85. 2.32 11.3 .646 .646 .016 .0021      7803241020. 85. 2.32 24.5 .555 .555 .016 .0046
7803241055. 80. 2.25   .9 .899 .899 .016 .0002      7803241105. 80. 2.25  1.9 .848 .848 .016 .0004
7803241113. 80. 2.25  3.8 .700 .700 .016 .0008      7803241122. 80. 2.25  7.8 .611 .611 .016 .0016
7803241130. 80. 2.25 16.2 .564 .564 .016 .0033      7803271119. 75. 3.42  1.4 .240 .240 .007 .0001
7803271112. 75. 3.42  2.9 .264 .264 .007 .0003      7803271104. 75. 3.42  6.1 .332 .332 .007 .0005
7803271055. 75. 3.42 13.0 .367 .367 .007 .0011      7803241152. 75. 2.18   .6 .168 .168 .016 .0001
7803241202. 75. 2.18  1.1 .231 .231 .016 .0002      7803241212. 75. 2.18  2.3 .315 .315 .016 .0005
7803241222. 75. 2.18  4.7 .441 .441 .016 .0010      7803241239. 75. 2.18  9.8 .543 .543 .016 .0021
7803271143. 75. 1.18  3.6 .275 .275 .055 .0026      7803271136. 75. 1.18  8.0 .369 .369 .055 .0059
7803271129. 75. 1.18 13.8 .373 .373 .055 .0101      7803271335. 70. 2.11  5.3 .089 .089 .016 .0012
7803271325. 70. 2.11  7.4 .259 .259 .016 .0017      7803271318. 70. 2.11  9.9 .349 .349 .016 .0023
7803271311. 70. 2.11 13.4 .441 .441 .016 .0031      7803271303. 70. 2.11 17.6 .478 .478 .016 .0040
7803271256. 70. 2.11 23.2 .452 .452 .016 .0053      7803271436. 65. 2.03  8.6 .073 .073 .016 .0021
7803271429. 65. 2.03 11.4 .220 .220 .016 .0028      7803271421. 65. 2.03 14.6 .328 .328 .016 .0036
7803271413. 65. 2.03 18.5 .405 .405 .016 .0046      7803271405. 65. 2.03 22.0 .452 .452 .016 .0054
7803281132. 60. 3.06  8.1 .016 .016 .007 .0009      7803281142. 60. 3.06 10.7 .087 .087 .007 .0012
7803281150. 60. 3.06 13.4 .202 .202 .007 .0015      7803281238. 60. 3.06 16.8 .331 .331 .007 .0018
7803281244. 60. 3.06 22.0 .394 .394 .007 .0024      7803281122. 60. 1.95  6.5 .001 .001 .016 .0017
7803281114. 60. 1.95  9.0 .001 .001 .016 .0024      7803281107. 60. 1.95 12.4 .088 .088 .016 .0033
7803281059. 60. 1.95 15.8 .193 .193 .016 .0042      7803281514. 60. 1.95 22.7 .444 .444 .016 .0061
7803281522. 60. 1.95 23.5 .417 .417 .016 .0063      7803281314. 60. 1.05  5.9 .003 .003 .056 .0055
7803281307. 60. 1.05  8.2 .084 .084 .056 .0076      7803281330. 60. 1.05 12.4 .145 .145 .056 .0115
7803281253. 60. 1.05 14.0 .122 .122 .056 .0130      7803281608. 55. 1.87 11.1 .051 .051 .016 .0032
7803281600. 55. 1.87 16.2 .234 .234 .016 .0047      7803281552. 55. 1.87 20.7 .304 .304 .016 .0060
7803290958. 50. 1.78 11.8 .001 .001 .016 .0038      7803290940. 50. 1.78 13.3 .011 .011 .016 .0043
7803290930. 50. 1.78 15.0 .018 .018 .016 .0048      7803291331. 45. 2.65 13.3 .009 .009 .007 .0019
7803291259. 45. 2.65 14.4 .012 .012 .007 .0021      7803291245. 45. 1.69 14.4 .043 .043 .016 .0051
7803291142. 45. 1.69 15.5 .062 .062 .016 .0055      7803291134. 45. 1.69 15.7 .089 .089 .016 .0056

                                            BREAKWATER  2

7711021130. 61. 2.18  4.4 .397 .397 .013 .0009      7711021155. 61. 2.18  9.1 .276 .276 .013 .0020
7711021147. 61. 2.18  9.2 .278 .278 .013 .0020      7711021200. 61. 2.18 16.9 .239 .239 .013 .0036
7711021211. 61. 2.18 17.1 .240 .240 .013 .0037      7711081000. 61. 1.97   .9 .689 .689 .016 .0002
7711081009. 61. 1.97  1.3 .622 .622 .016 .0003      7711081021. 61. 1.97  1.8 .567 .567 .016 .0005
7711021018. 61. 1.97  2.5 .480 .480 .016 .0007      7711080852. 61. 1.97  2.6 .489 .489 .016 .0007
7711080902. 61. 1.97  3.7 .420 .420 .016 .0010      7711021026. 61. 1.97  5.2 .350 .350 .016 .0014
7711080911. 61. 1.97  5.2 .353 .353 .016 .0014      7711080920. 61. 1.97  7.5 .300 .300 .016 .0020
7711021044. 61. 1.97 10.3 .253 .253 .016 .0027      7711021034. 61. 1.97 10.4 .255 .255 .016 .0027
7711080929. 61. 1.97 10.5 .256 .256 .016 .0028      7711080939. 61. 1.97 13.9 .236 .236 .016 .0037
7711080948. 61. 1.97 18.4 .260 .260 .016 .0048      7711021103. 61. 1.97 18.6 .253 .253 .016 .0049
7711021056. 61. 1.97 18.8 .246 .246 .016 .0049      7711021223. 61. 1.66  2.3 .469 .469 .023 .0009
7711021230. 61. 1.66  2.3 .476 .476 .023 .0009      7711021242. 61. 1.66  4.6 .349 .349 .023 .0017
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7711021252. 61. 1.66  9.8 .244 .244 .023 .0036      7711081029. 61. 1.31  2.2 .336 .336 .036 .0013
7711081037. 61. 1.31  3.1 .293 .293 .036 .0018      7711081046. 61. 1.31  4.2 .256 .256 .036 .0025
7711081054. 61. 1.31  5.3 .228 .228 .036 .0032      7711081103. 61. 1.31  5.7 .220 .220 .036 .0034
7711081111. 61. 1.31  6.0 .227 .227 .036 .0036      7711081119. 61. 1.31  8.3 .191 .191 .036 .0049
7711081127. 61. 1.31 14.8 .145 .145 .036 .0068      7711081139. 61. 1.31 18.2 .164 .164 .036 .0108
7711021318. 61. 1.06  7.6 .196 .196 .056 .0069      7711021310. 61. 1.06  9.0 .194 .194 .056 .0082
7711021332. 61. 1.06 16.6 .081 .081 .056 .0151      7711021326. 61. 1.06 17.3 .104 .104 .056 .0157
7711081145. 61.  .89  2.3 .216 .216 .079 .0030      7711081153. 61.  .89  4.1 .166 .166 .079 .0053
7711081201. 61.  .89  5.1 .156 .156 .079 .0066      7711081209. 61.  .89  6.1 .148 .148 .079 .0079
7711081217. 61.  .89  8.4 .134 .134 .079 .0108

                                            BREAKWATER  3

7712231340. 95. 2.46  8.4 .826 .826 .016 .0014      7712231307. 95. 2.46 12.0 .809 .809 .016 .0020
7712231359. 95. 2.46 16.9 .841 .841 .016 .0028      7712231405. 95. 2.46 23.7 .854 .854 .016 .0040
7712231129. 91. 3.77  2.0 .817 .817 .007 .0001      7712231122. 91. 3.77  4.2 .804 .804 .007 .0003
7712231115. 91. 3.77  8.5 .785 .785 .007 .0006      7712231138. 91. 2.67  4.0 .830 .830 .013 .0006
7712231147. 91. 2.87 12.4 .827 .827 .013 .0018      7712231208. 91. 2.40  3.0 .851 .851 .016 .0005
7712231201. 91. 2.40  6.3 .845 .845 .016 .0011      7712231153. 91. 2.40 13.7 .838 .838 .016 .0024
7712231239. 91. 2.40 19.7 .805 .805 .016 .0035      7712231215. 91. 2.02  6.1 .838 .838 .023 .0015
7712231226. 91. 2.02 11.6 .830 .830 .023 .0029      7712231233. 91. 2.02 16.4 .846 .846 .023 .0041
7712231253. 91. 2.02 22.0 .787 .787 .023 .0055      7712231300. 91. 1.60 24.0 .715 .715 .036 .0096
7712230720. 85. 3.05  1.5 .832 .832 .007 .0001      7712230733. 85. 3.65  3.2 .793 .793 .007 .0002
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                                          SINE BLADE MOTION
      ID     D(CM) T(S) H(CM) KT   KR D/GT2 H/GT2        ID     D(CM) T(S) H(CM) KT   KR D/GT2 H/GT2

                                          BREAKWATER  3

7712230750. 85. 3.65 14.5 .723 .723 .007 .0011    7712230816. 85. 2.58  1.6 .804 .804 .013 .0002
7712230808. 85. 2.58  4.5 .802 .802 .013 .0007    7712230759. 85. 2.58 12.9 .791 .791 .013 .0020
7712230825. 85. 2.32  1.0 .904 .904 .016 .0002    7712230832. 85. 2.32  3.1 .840 .840 .016 .0006
7712230839. 85. 2.32  9.4 .781 .781 .016 .0018    7712230846. 85. 2.32 13.5 .766 .766 .016 .0026
7712230855. 85. 2.32 19.2 .733 .733 .016 .0036    7712230915. 85. 1.96  2.9 .864 .864 .023 .0008
7712230908. 85. 1.96  8.7 .818 .818 .023 .0023    7712230901. 85. 1.96 17.8 .798 .798 .023 .0047
7712230922. 85. 1.54  2.0 .912 .912 .037 .0009    7712230929. 85. 1.54  5.8 .859 .859 .037 .0025
7712230941. 85. 1.54 17.2 .735 .735 .037 .0074    7712221830. 75. 3.42  1.3 .939 .939 .007 .0001
7712221836. 75. 3.42  4.1 .758 .758 .007 .0004    7712221843. 75. 3.42 12.7 .600 .600 .007 .0011
7712221903. 75. 2.42  8.1 .796 .796 .013 .0004    7712221857. 75. 2.42  6.0 .702 .702 .013 .0010
7712221850. 75. 2.42 17.5 .622 .622 .013 .0030    7712221916. 75. 2.18  1.2 .871 .871 .016 .0003
7712221909. 75. 2.18  3.4 .867 .867 .016 .0007    7712221922. 75. 2.18 10.0 .685 .685 .016 .0021
7712221929. 75. 2.18 14.1 .635 .635 .016 .0030    7712221948. 75. 1.84  2.8 .829 .829 .023 .0008
7712221942. 75. 1.84  8.0 .661 .661 .023 .0024    7712221936. 75. 1.84 14.7 .627 .627 .023 .0044
7712221954. 75. 1.45  3.8 .829 .829 .036 .0018    7712222001. 75. 1.45 10.3 .697 .697 .036 .0050
7712222007. 75. 1.45 17.3 .496 .496 .036 .0084    7712221012. 61. 3.06  5.4 .446 .446 .007 .0006
7712221006. 61. 3.06  7.7 .398 .398 .007 .0008    7712220959. 61. 3.06 10.5 .369 .369 .007 .0011
7712220952. 61. 3.06 13.7 .414 .414 .007 .0015    7712221044. 61. 2.17  1.4 .529 .529 .013 .0003
7712221038. 61. 2.17  4.6 .392 .392 .013 .0010    7712221031. 61. 2.17  7.1 .341 .341 .013 .0015
7712221025. 61. 2.17 10.7 .297 .297 .013 .0023    7712221019. 61. 2.17 15.5 .337 .337 .013 .0034
7712221051. 61. 1.95  2.6 .460 .460 .016 .0007    7712221057. 61. 1.95  7.4 .339 .339 .016 .0020
7712221104. 61. 1.95 11.3 .281 .281 .016 .0030    7712221110. 61. 1.95 15.9 .297 .297 .016 .0043
7712221117. 61. 1.95 21.3 .312 .312 .016 .0057    7712221152. 61. 1.64  1.3 .518 .518 .023 .0005
7712221144. 61. 1.64  3.5 .401 .401 .023 .0013    7712221135. 61. 1.64  5.4 .336 .336 .023 .0020
7712221129. 61. 1.64 10.5 .259 .259 .023 .0040    7712221123. 61. 1.64 15.8 .276 .276 .023 .0060
7712221158. 61. 1.30  2.7 .413 .413 .037 .0016    7712221204. 61. 1.30  5.7 .295 .295 .037 .0034
7712221210. 61. 1.30  8.1 .250 .250 .037 .0049    7712221216. 61. 1.30 12.0 .224 .224 .037 .0072
7712221222. 61. 1.30 17.3 .238 .238 .037 .0104    7712191336. 45. 3.51  5.0 .314 .314 .004 .0004
7712191328. 45. 3.51  6.7 .274 .274 .004 .0006    7712191319. 45. 3.51  9.2 .240 .240 .004 .0008
7712191310. 45. 3.51 12.3 .211 .211 .004 .0010    7712191425. 45. 2.65  3.2 .309 .309 .007 .0005
7712191407. 45. 2.65  4.7 .256 .256 .007 .0007    7712191414. 45. 2.65  6.9 .209 .209 .007 .0010
7712191354. 45. 2.65 10.4 .165 .165 .007 .0015    7712191344. 45. 2.65 15.3 .139 .139 .007 .0022
7712211020. 45. 1.88  3.4 .238 .238 .013 .0010    7712211008. 45. 1.88  4.9 .193 .193 .013 .0014
7712191043. 45. 1.88  9.3 .134 .134 .013 .0027    7712191033. 45. 1.88 14.3 .107 .107 .013 .0041
7712211052. 45. 1.69  6.1 .156 .156 .016 .0022    7712211049. 45. 1.69  9.2 .124 .124 .016 .0033
7712211038. 45. 1.69 13.7 .100 .100 .016 .0049    7712211029. 45. 1.69 19.2 .096 .096 .016 .0069
7712211112. 45. 1.42  8.0 .089 .089 .023 .0040    7712211106. 45. 1.42 12.1 .072 .072 .023 .0061
7712211059. 45. 1.42 14.1 .141 .141 .023 .0071    7712211126. 45. 1.12 10.3 .040 .040 .037 .0084
7712211119. 45. 1.12 13.1 .038 .038 .037 .0107

                                          BREAKWATER  3W

7711290906. 85. 4.83  1.4 .843 .843 .004 .0001    7711290927. 85. 4.83  4.8 .779 .779 .004 .0002
7711290937. 85. 4.83 14.7 .813 .813 .004 .0006    7711290949. 85. 3.65   .8 .864 .864 .007 .0001
7711290959. 85. 3.65  2.6 .826 .826 .007 .0002    7711291009. 85. 3.65  8.4 .776 .776 .007 .0006
7711291021. 85. 2.58  1.8 .817 .817 .013 .0003    7711291029. 85. 2.58  5.1 .828 .828 .013 .0008
7711291037. 85. 2.58 14.3 .872 .872 .013 .0022    7711291048. 85. 2.32   .9 .890 .890 .016 .0002
7711291057. 85. 2.32  2.7 .848 .848 .016 .0005    7711291106. 85. 2.32  8.2 .784 .784 .016 .0016
7711291120. 85. 1.96  1.0 .918 .918 .023 .0003    7711291133. 85. 1.96  2.9 .881 .881 .023 .0008
7711291148. 85. 1.96  8.6 .838 .838 .023 .0023    7711291158. 85. 1.96 16.6 .845 .845 .023 .0044
7711291208. 85. 1.54  2.1 .891 .891 .037 .0009    7711291216. 85. 1.54  6.5 .842 .842 .037 .0028
7711280936. 76. 3.42  2.1 .778 .778 .007 .0002    7711280943. 76. 3.42  6.0 .642 .642 .007 .0005
7711280951. 76. 3.42 15.8 .529 .529 .007 .0014    7711281027. 76. 2.42  1.8 .739 .739 .013 .0003
7711281016. 76. 2.42  5.4 .673 .673 .013 .0009    7711281001. 76. 2.42 16.8 .603 .603 .013 .0029
7711281037. 76. 2.18  1.4 .772 .772 .016 .0003    7711281048. 76. 2.18  4.0 .706 .706 .016 .0009
7711281059. 76. 2.18 12.6 .574 .574 .016 .0027    7711281112. 76. 2.18 18.5 .492 .492 .016 .0040
7711281156. 76. 1.84  3.0 .754 .754 .023 .0009    7711281146. 76. 1.84  8.5 .629 .629 .023 .0026
7711281122. 76. 1.84 15.7 .562 .562 .023 .0047    7711281203. 76. 1.45  2.8 .825 .825 .037 .0014
7711281210. 76. 1.45  8.1 .719 .719 .037 .0039    7711281216. 76. 1.45 15.2 .545 .545 .037 .0074
7711281224. 76. 1.18  2.3 .811 .811 .056 .0017    7711281359. 76. 1.18  7.6 .656 .656 .056 .0056
7711281406. 76. 1.18 15.9 .462 .462 .056 .0117    7711281414. 76.  .98  2.5 .932 .932 .081 .0027
7711281421. 76.  .98  5.7 .762 .762 .081 .0061    7711281427. 76.  .98  8.8 .686 .686 .081 .0093
7711230830. 61. 3.09  3.4 .378 .378 .007 .0004    7711221440. 61. 3.09  6.9 .304 .304 .006 .0007
7711221429. 61. 3.09 12.4 .392 .392 .006 .0013    7711221408. 61. 3.09 20.0 .443 .443 .006 .0021
7711230839. 61. 2.18  1.4 .405 .405 .013 .0003    7711230846. 61. 2.18  2.1 .371 .371 .013 .0005
7711230854. 61. 2.18  4.4 .286 .286 .013 .0009    7711230902. 61. 2.18  9.2 .277 .277 .013 .0020
7711230910. 61. 2.18 17.7 .411 .411 .013 .0038    7711230920. 61. 1.97  2.2 .357 .357 .016 .0036
7711230927. 61. 1.97  3.0 .320 .320 .016 .0008    7711230935. 61. 1.97  4.2 .280 .280 .016 .0011
7711230942. 61. 1.97  5.9 .250 .250 .016 .0016    7711230949. 61. 1.97  8.3 .228 .228 .016 .0022
7711231003. 61. 1.97 19.0 .272 .272 .016 .0050    7711231010. 61. 1.97 26.4 .356 .356 .016 .0069
7711231028. 61. 1.66  3.0 .324 .324 .023 .0011    7711231036. 61. 1.66  6.6 .239 .239 .023 .0024
7711231045. 61. 1.66 15.5 .294 .294 .023 .0057    7711231055. 61. 1.31  1.0 .383 .383 .036 .0006
7711231102. 61. 1.31  2.3 .296 .296 .036 .0014    7711231120. 61. 1.31  7.4 .184 .184 .036 .0044
7711231128. 61. 1.31 17.1 .234 .234 .036 .0102    7711231139. 61. 1.06  1.8 .233 .233 .055 .0016
7711231146. 61. 1.06  3.5 .173 .173 .055 .0032    7711231153. 61. 1.06  7.5 .127 .127 .055 .0068
7711231200. 61. 1.06 15.7 .157 .157 .055 .0143    7712191119. 45. 3.51  7.0 .084 .084 .004 .0006
7712191109. 45. 3.51 12.2 .077 .077 .004 .0010    7712191134. 45. 2.65  7.1 .058 .058 .007 .0010
7712191127. 45. 2.65 15.5 .052 .052 .007 .0023    7712191141. 45. 1.88  9.5 .034 .034 .013 .0027
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                                   SINE BLADE MOTION
   ID      D(CM) T(S) H(CM) KT    KR D/GT2 H/GT2          ID      D(CM) T(S) H(CM) KT    KR D/GT2 H/GT2

                                      BREAKWATER  4

7801181430. 85. 3.05   .6 .913 .913 .007 .0000    7801181420. 85. 3.65  1.4 .876 .876 .007 .0001
7801181414. 85. 3.05  3.0 .842 .842 .007 .0002    7801181406. 85. 3.65  6.4 .801 .801 .007 .0005
7801181359. 85. 3.65  9.4 .783 .783 .007 .0007    7801181350. 85. 3.65 13.6 .782 .782 .007 .0010
7801181503. 85. 2.32  1.4 .904 .904 .016 .0003    7801181456. 85. 2.32  2.9 .861 .861 .016 .0005
7801181450. 85. 2.32  6.1 .804 .804 .016 .0012    7801181444. 85. 2.32 12.8 .762 .762 .016 .0024
7801181437. 85. 2.32 19.1 .699 .699 .016 .0036    7801181510. 85. 1.26  1.8 **** **** .055 .0012
7801181515. 85. 1.26  5.3 .920 .920 .055 .0034    7801191040. 85. 1.26 13.6 .812 .812 .055 .0087
7801191106. 80. 2.25  1.5 .890 .890 .016 .0003    7801191113. 80. 2.25  5.0 .855 .855 .016 [illegible]
7801191128. 80. 2.25  6.3 .776 .776 .016 .0013    7801191136. 80. 2.25 13.5 .685 .685 .016 .0027
7801191145. 80. 2.25 19.9 .610 .610 .016 .0040    7801201156. 75. 2.18  1.3 .853 .853 .016 .0003
7801201149. 75. 2.18  2.7 .792 .792 .016 .0006    7801201140. 75. 2.18  5.4 .758 .758 .016 .0012
7801201133. 75. 2.18 11.3 .683 .683 .016 .0024    7801201107. 75. 2.18 15.6 .608 .608 .016 .0034
7801191241. 74. 3.42   .9 **** **** .006 .0001    7801191248. 74. 3.42  4.5 .752 .752 .006 .0004
7801191255. 74. 3.42 14.3 .588 .588 .006 .0012    7801191331. 74. 2.18  1.3 .787 .787 .016 .0003
7801191324. 74. 2.18  2.6 .736 .736 .016 .0006    7801191317. 74. 2.18  5.4 .707 .707 .016 .0012
7801191310. 74. 2.18 11.1 .642 .642 .016 .0024    7801191303. 74. 2.18 15.5 .559 .559 .016 .0033
7801191439. 72. 1.18  2.3 .762 .762 .053 .0017    7801191433. 72. 1.18  5.0 .631 .631 .053 .0037
7801191427. 72. 1.18  9.1 .562 .562 .053 .0067    7801191414. 72. 1.18 13.2 .462 .462 .053 .0097
7801200959. 70. 2.11  1.7 .728 .728 .016 .0004    7801201006. 70. 2.11  4.9 .607 .607 .016 .0011
7801201013. 70. 2.11  6.8 .589 .589 .016 .0016    7801201023. 70. 2.11  9.4 .560 .560 .016 .0022
7801201030. 70. 2.11 13.4 .524 .524 .016 .0051    7801201036. 70. 2.11 19.4 .487 .487 .016 .0044
7801201215. 65. 2.03  1.9 .553 .553 .016 .0005    7801201221. 65. 2.03  3.9 .468 .468 .016 .0010
7801201227. 65. 2.03  7.9 .457 .457 .016 .0020    7801201233. 65. 2.03 11.3 .448 .448 .016 .0028
7801201239. 65. 2.03 15.9 .455 .455 .016 .0039    7801201245. 65. 2.03 22.1 .452 .452 .016 .0055
7801201311. 60. 3.06  6.1 .444 .444 .007 .0007    7801201317. 60. 3.06  8.5 .404 .404 .007 .0009
7801201323. 60. 3.06 11.7 .402 .402 .007 .0013    7801201330. 60. 3.06 16.1 .433 .433 .007 .0018
7801201344. 60. 1.95  3.3 .407 .407 .016 .0009    7801201350. 60. 1.95  4.6 .356 .356 .016 .0012
7801201357. 60. 1.95  6.5 .315 .315 .016 .0017    7801201404. 60. 1.95  9.6 .284 .284 .016 .0026
7801201411. 60. 1.95 14.0 .281 .281 .016 .0038    7801201450. 60. 1.05  2.0 .293 .293 .055 .0019
7801201444. 60. 1.05  4.2 .204 .204 .055 .0039    7801201438. 60. 1.05  7.3 .164 .164 .055 .0068
7801201431. 60. 1.05 11.5 .153 .153 .055 .0106    7801201425. 60. 1.05 13.5 .153 .153 .055 .0125
7801211357. 55. 1.88  1.7 .465 .465 .016 .0005    7801211403. 55. 1.87  2.5 .402 .402 .016 .0007
7801211514. 55. 1.87  2.6 .405 .405 .016 .0008    7801211409. 55. 1.87  3.7 .335 .335 .016 .0011
7801211415. 55. 1.87  5.6 .275 .275 .016 .0016    7801211521. 55. 1.87  5.7 .276 .276 .016 .0017
7801211421. 55. 1.87  9.3 .228 .228 .016 .0024    7801211428. 55. 1.87 12.5 .190 .190 .016 .0036
7801211528. 55. 1.87 12.5 .190 .190 .016 .0036    7801211435. 55. 1.87 18.4 .204 .204 .016 .0054
7801211542. 49. 1.85  1.9 .371 .371 .015 .0006    7801211548. 49. 1.85  3.8 .257 .257 .015 .0011
7801211554. 49. 1.85  5.6 .207 .207 .015 .0017    7801211600. 49. 1.65  8.2 .165 .165 .015 .0024
7801211606. 49. 1.85 12.3 .136 .136 .015 .0037    7801211612. 49. 1.65 17.5 .120 .120 .015 .0052
7801211631. 45. 2.65  1.6 .393 .393 .007 .0002    7801211638. 45. 2.65  4.8 .227 .227 .007 .0007
7801211644. 45. 2.65 10.7 .151 .151 .007 .0016    7801211651. 45. 2.65 15.9 .130 .130 .007 .0023
7801211659. 45. 1.69  2.0 .279 .279 .016 .0007    7801211705. 45. 1.69  6.3 .149 .149 .016 .0023
7801211711. 45. 1.69 13.5 .105 .105 .016 .0048    7801211717. 45. 1.69 19.1 .096 .096 .016 .0068
7801211723. 45.  .91  4.6 .037 .037 .055 .0057    7801211729. 45.  .91  9.7 .033 .033 .055 .0120

                                      BREAKWATER  4W

7801181155. 85. 3.65   .6 .886 .886 .007 .0000    7801181148. 85. 3.65  1.3 .857 .857 .007 .0001
7801181140. 85. 3.65  2.9 .834 .834 .007 .0002    7801181132. 85. 3.65  6.1 .804 .804 .007 .0005
7801181124. 85. 3.65  9.1 .788 .788 .007 .0007    7801181118. 85. 3.65 13.3 .776 .776 .007 .0010
7801181227. 85. 2.32  1.3 .896 .896 .016 .0002    7801181220. 85. 2.32  2.8 .860 .860 .016 .0005
7801181214. 85. 2.32  5.9 .827 .827 .016 .0011    7801181208. 85. 2.32 12.6 .790 .790 .016 .0024
7801181201. 85. 2.32 18.2 .744 .744 .016 .0035    7801181233. 85. 1.26  1.9 **** **** .055 .0012
7801181239. 85. 1.26  3.9 .948 .948 .055 .0025    7801181245. 85. 1.26  6.0 .925 .925 .055 .0039
7801181258. 85. 1.26 11.9 .832 .832 .055 .0076    7801181041. 80. 2.25  1.3 .909 .909 .016 .0003
7801181034. 80. 2.25  2.8 .836 .836 .016 .0006    7801181027. 80. 2.25  6.0 .783 .783 .016 .0012
7801181020. 80. 2.25 13.0 .661 .661 .016 .0026    7801181013. 80. 2.25 18.5 .591 .591 .016 .0037
7801180803. 76. 3.42   .9 .974 .974 .007 .0001    7801180809. 76. 3.42  4.0 .727 .727 .007 .0003
7801180815.   .  3.42 13.4 .556 .556 .007 .0012    7801180859. 76. 2.18  1.3 .846 .846 .016 .0003
7801180842.      2.18  2.6 .779 .779 .016 .0006    7801180836. 76. 2.18  5.4 .736 .736 .016 .0012
7801180823. 76. 2.18 10.0 .977 .977 .016 .0034    7801180856. 76. 1.18  2.2 .848 .846 .055 .0016
7801180902. 76. 1.18  4.4 .766 .766 .055 .0032    7801180918. 76. 1.18 10.2 .614 .614 .055 .0075
7801180914. 76. 1.18 15.0 .492 .492 .055 .0110    7801171318. 70. 2.11  1.9 .658 .658 .016 .0004
7801171324. 70. 2.11  5.1 .571 .571 .016 .0012    7801171330. 70. 2.11  7.3 .526 .526 .016 .0017
7801171336. 70. 2.11  9.7 .490 .490 .016 .0022    7801171342. 70. 2.11 13.3 .477 .477 .016 .0030
7801171349. 70. 2.11 19.2 .453 .453 .016 .0044    7801171235. 65. 2.03  2.3 .387 .387 .016 .0006
7801171242. 65. 2.03  4.6 .333 .333 .016 .0011    7801171249. 65. 2.03  8.3 .369 .369 .016 .0021
7801171255. 65. 2.03 11.8 .363 .363 .016 .0029    7801171301. 65. 2.03 15.8 .385 .385 .016 .0039
7801171307. 65. 2.03 19.6 .403 .403 .016 .0049    7801171018. 60. 3.06  2.1 .385 .385 .007 .0002
[illegible] 60. 3.06  4.2 .296 .296 .007 .0005    7801171031. 60. 3.06  6.1 .260 .260 .007 .0007
[illegible] 60. 3.06  8.5 .252 .252 .007 .0009    7801171044. 60. 3.06 11.8 .278 .278 .007 .0013
[illegible] 60. 3.06 16.3 .320 .320 .007 .0018    7801171059. 60. 1.95  1.6 .348 .348 .016 .0004
[illegible] 60. 1.95  3.2 .270 .270 .016 .0009    7801171111. 60. 1.95  4.5 .233 .233 .016 .0012
[illegible] 60. 1.95  6.5 .203 .203 .016 .0017    7801171124. 60. 1.95  9.6 .193 .193 .016 .0026
[illegible] 60. 1.95 13.8 .206 .206 .016 .0037    7801171136. 60. 1.95 19.1 .246 .246 .016 .0051
[illegible] 60. 1.05  2.0 .241 .241 .056 .0019    7801171215. 60. 1.05  4.1 .162 .162 .056 .0038
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                                          SINE BLADE MOTION
    ID      D(CM) T(S) H(CM) KT    KR D/GT2 H/GT2          ID      D(CM) T(S) H(CM) KT    KR D/GT2 H/GT2

                                          BREAKWATER  4W

7801171209. 60. 1.05  5.4 .147 .147 .056 .0050       7801171203. 60. 1.05  6.9 .125 .125 .056 .0064
7801171157. 60. 1.05 11.7 .119 .119 .056 .0108       7801171151. 60. 1.05 12.9 .124 .124 .056 .0119
7801170922. 56. 1.88  1.8 .327 .327 .016 .0005       7801170929. 56. 1.88  2.6 .267 .267 .016 .0008
7801170935. 56. 1.88  3.6 .221 .221 .016 .0010       7801170941. 56. 1.88  5.4 .177 .177 .016 .0016
7801170947. 56. 1.88  8.0 .141 .141 .016 .0023       7801170955. 56. 1.88 12.4 .119 .119 .016 .0036
7801171000. 56. 1.88 17.6 .149 .149 .016 .0051       7801170841. 50. 1.78  5.6 .022 .022 .016 .0018
7801170848. 50. 1.78  8.5 .051 .051 .016 .0027       7801170855. 50. 1.78 12.8 .058 .058 .016 .0041
7801170901. 50. 1.78 10.1 .065 .065 .016 .0058

                                          BREAKWATER  5

7802011154. 75. 3.42  3.1 .879 .879 .007 .0003       7802011205. 75. 3.42  6.5 .846 .846 .007 .0006
7802011222. 75. 3.42 13.4 .818 .818 .007 .0012       7802011120. 75. 2.18  2.7 .979 .979 .016 .0006
7802011128. 75. 2.18  5.3 .974 .974 .016 .0011       7802011138. 75. 2.18 10.6 **** **** .016 .0023
7802011250. 75. 2.18 19.5 **** **** .016 .0042       7802011236. 75. 1.18  3.9 .972 .972 .055 .0029
7802011243. 75. 1.18  9.3 .970 .970 .055 .0068       7801311328. 60. 3.09  2.5 .879 .879 .006 .0003
7801311336. 60. 3.09  5.6 .855 .855 .006 .0006       7801311344. 60. 3.09 11.5 .873 .873 .006 .0012
7801311220. 60. 1.97   .8 **** **** .016 .0002       7801311242. 60. 1.97  1.7 **** **** .016 .0004
7801311252. 60. 1.97  3.6 **** **** .016 .0009       7801311302. 60. 1.97  7.4 .991 .991 .016 .0019
7802021213. 45. 2.01  3.8 .960 .960 .011 .0010       7802021219. 45. 2.01  5.5 .949 .949 .011 .0014
7802021231. 45. 2.01 14.8 .811 .811 .011 .0037       7802021106. 45. 1.69  1.0 **** **** .016 .0004
7802021117. 45. 1.69  3.0 **** **** .016 .0011       7802021124. 45. 1.69  4.3 .989 .989 .016 .0015
7802021137. 45. 1.69  6.4 .965 .965 .016 .0023       7802021145. 45. 1.69  9.6 .928 .928 .016 .0034
7802021158. 45. 1.69 13.9 .790 .790 .016 .0050       7802021025. 45. 1.18  2.8 .911 .911 .033 .0021
7802021033. 45. 1.18  4.1 .901 .901 .033 .0030       7802021044. 45. 1.18  6.5 .867 .867 .033 .0048
7802021050. 45. 1.18  8.4 .839 .839 .033 .0062       7802020914. 45.  .91  2.1 .966 .966 .055 .0026
7802021006. 45.  .91  5.5 .920 .920 .055 .0068       7802021018. 45.  .91  9.3 .744 .744 .055 .0115
7802021337. 31. 1.39  1.4 .530 .530 .016 .0007       7802021346. 31. 1.39  2.8 .438 .438 .016 .0015
7802021355. 31. 1.39  3.8 .409 .409 .016 .0020       7802021404. 31. 1.39  5.9 .372 .372 .016 .0031
7802021414. 31. 1.39  8.5 .375 .375 .016 .0045       7802021425. 31. 1.39  9.8 .359 .359 .016 .0052

                                          BREAKWATER  6

7802071045. 75. 3.42   .9 .792 .792 .007 .0001       7802071054. 75. 3.42  2.9 .732 .732 .007 .0003
7802071102. 75. 3.42  6.2 .689 .689 .007 .0005       7802071109. 75. 3.42 13.2 .687 .687 .007 .0012
7802071220. 75. 2.60  2.2 .805 .805 .011 .0003       7802071227. 75. 2.60  4.5 .760 .760 .011 .0007
7802071235. 75. 2.60  9.2 .716 .716 .011 .0014       7802071309. 75. 2.60 17.8 .798 .798 .011 .0027
7802070946. 75. 2.18  1.3 .851 .851 .016 .0003       7802070952. 75. 2.18  2.5 .835 .835 .016 .0005
7802071000. 75. 2.18  3.5 .794 .794 .016 .0008       7802071010. 75. 2.18  5.1 .748 .748 .016 .0011
7802071019. 75. 2.18  7.1 .737 .737 .016 .0015       7802071027. 75. 2.18 10.0 .717 .717 .016 .0021
7802071035. 75. 2.18 14.2 .683 .683 .016 .0030       7802071145. 75. 1.40  5.7 .788 .788 .039 .0030
7802071156. 75. 1.40 10.9 .755 .755 .039 .0057       7802071205. 75. 1.40 14.8 .747 .747 .039 .0077
7802071117. 75. 1.18  2.2 .821 .821 .055 .0016       7802071123. 75. 1.18  6.4 .712 .712 .055 .0047
7802071129. 75. 1.18 14.2 .711 .711 .055 .0104       7802061132. 60. 3.06   .9 .735 .735 .007 .0001
7802061147. 60. 3.06  3.3 .525 .525 .007 .0004       7802061158. 60. 3.06 10.3 .487 .487 .007 .0011
7802060155. 60. 2.32  5.3 .463 .463 .011 .0010       7802060204. 60. 2.32 11.4 .400 .400 .011 .0022
7802061014. 60. 1.95  3.8 .498 .498 .016 .0010       7802061021. 60. 1.95  7.5 .474 .474 .016 .0020
7802061032. 60. 1.95 14.9 .467 .467 .016 .0040       7802061040. 60. 1.95 10.8 .439 .439 .016 .0055
7802061218. 60. 1.25  2.5 .365 .365 .039 .0016       7802061229. 60. 1.25  5.2 .389 .389 .039 .0034
7802061250. 60. 1.25  6.6 .391 .391 .039 .0043       7802061323. 60. 1.25 11.3 .361 .361 .039 .0074
7802061051. 60. 1.05  2.1 .280 .280 .056 .0019       7802061059. 60. 1.05  3.8 .266 .266 .056 .0035
7802061110. 60. 1.05  7.4 .297 .297 .055 .0068       7802061119. 60. 1.05 14.3 .386 .386 .056 .0132
7802081204. 45. 2.86  1.6 .550 .550 .006 .0002       7802081213. 45. 2.86  3.1 .469 .469 .006 .0004
7802081217. 45. 2.86  5.3 .378 .378 .006 .0008       7802081226. 45. 2.86  8.9 .328 .328 .006 .0011
7802081032. 45. 2.65  1.0 .604 .604 .007 .0001       7802081039. 45. 2.65  2.0 .534 .534 .007 .0003
7802081045. 45. 2.65  4.4 .430 .430 .007 .0006       7802071435. 45. 2.65 10.0 .271 .271 .007 .0015
7802071451. 45. 2.65 13.9 .234 .234 .007 .0020       7802081024. 45. 1.64  1.8 .499 .499 .017 .0007
7802080852. 45. 1.64  3.5 .426 .426 .017 .0013       7802071501. 45. 1.69  7.3 .334 .334 .016 .0026
7802071422. 45. 1.69 14.7 .237 .237 .016 .0053       7802081052. 45.  .91  1.6 .259 .259 .055 .0020
7802081059. 45.  .91  5.8 .167 .167 .055 .0071       7802081107. 45.  .91  8.3 .137 .137 .055 .0102

                                          BREAKWATER  7

7802121022. 45. 2.65   .7 .559 .559 .007 .0001       7802121428. 45. 2.65  1.4 .499 .499 .007 .0002
7802121434. 45. 2.65  2.9 .408 .408 .007 .0004       7802121440. 45. 2.65  6.4 .334 .334 .007 .0009
7802121447. 45. 2.65 13.8 .378 .378 .007 .0020       7802121349. 45. 1.69  1.1 .457 .457 .016 .0004
7802121355. 45. 1.69  2.3 .367 .367 .016 .0008       7802121401. 45. 1.69  4.0 .277 .277 .016 .0016
7802121408. 45. 1.69  9.9 .293 .293 .016 .0035       7802121414. 45. 1.69 14.1 .326 .326 .016 .0050
7802121455. 45.  .91  1.7 .132 .132 .055 .0021       7802121501. 45.  .91  4.4 .085 .085 .055 .0054
7802121506. 45.  .91  9.4 .091 .091 .055 .0116       7802121612. 60. 3.06  1.6 .864 .864 .007 .0002
7802121618. 60. 3.06  8.0 .767 .767 .007 .0009       7802121625. 60. 3.06 15.8 .780 .780 .007 .0017
7802121545. 60. 1.95  1.2 .865 .865 .016 .0003       7802121551. 60. 1.95  4.3 .791 .791 .016 .0012
7802121557. 60. 1.95  9.5 .811 .811 .016 .0025       7802121603. 60. 1.95 19.6 .641 .641 .016 .0053
7802121632. 60. 1.05  1.9 .911 .911 .056 .0018       7802121639. 60. 1.05  5.7 .755 .755 .056 .0053
7802121645. 60. 1.05 10.9 .708 .708 .056 .0101       7802131003. 75. 3.42  1.3 .800 .800 .007 .0001
7802131012. 75. 3.42  2.8 .807 .807 .007 .0002       7802131021. 75. 3.42  5.9 .799 .799 .007 .0005
7802131030. 75. 3.42 12.7 .743 .743 .007 .0011       7802130914. 75. 2.18  1.3 .927 .927 .016 .0003
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SINE BLADE MOTION

BREAKWATER 7

ID	D(CM)	T(S)	H(CM)	KT	KR	D/GT2	H/GT2	ID	D(CM)	T(S)	H(CM)	KT	KR	D/GT2	H/GT2
7802130922.	75.	2.18	2.6	.914	.914	.016	.0006	7802130932.	75.	2.18	5.2	.867	.867	.016	.0011
7802130943.	75.	2.18	10.5	.845	.845	.016	.0023	7802130954.	75.	2.18	14.3	.870	.870	.016	.0031
7802131041.	75.	1.18	2.2	.855	.855	.055	.0016	7802131048.	75.	1.18	5.7	.861	.861	.055	.0042
7802131056.	75.	1.18	14.9	.894	.894	.055	.0109								

BREAKWATER 8

ID	D(CM)	T(S)	H(CM)	KT	KR	D/GT2	H/GT2	ID	D(CM)	T(S)	H(CM)	KT	KR	D/GT2	H/GT2
7802141016.	45.	1.69	1.5	.270	.270	.016	.0005	7802141029.	45.	1.69	3.1	.193	.193	.016	.0011
7802141035.	45.	1.69	6.7	.121	.121	.016	.0024	7802141047.	45.	1.69	9.7	.094	.094	.016	.0035
7802141055.	45.	1.69	13.8	.071	.071	.016	.0049	7802151020.	60.	1.95	1.9	.334	.334	.016	.0005
7802151043.	60.	1.95	3.8	.251	.251	.016	.0010	7802151033.	60.	1.95	8.0	.188	.188	.016	.0021
7802151051.	60.	1.95	15.8	.159	.159	.016	.0042	7802151058.	60.	1.95	20.9	.205	.205	.016	.0056

BREAKWATER 9

ID	D(CM)	T(S)	H(CM)	KT	KR	D/GT2	H/GT2	ID	D(CM)	T(S)	H(CM)	KT	KR	D/GT2	H/GT2
7802161313.	45.	2.65	.7	.460	.460	.007	.0001	7802161321.	45.	2.65	1.5	.391	.391	.007	.0002
7802161329.	45.	2.65	3.1	.285	.285	.007	.0005	7802161337.	45.	2.65	7.2	.169	.169	.007	.0010
7802161346.	45.	2.65	11.8	.117	.117	.007	.0017	7802281407.	45.	1.69	1.3	.322	.322	.016	.0005
7802160906.	45.	1.69	1.4	.284	.284	.016	.0005	7802160914.	45.	1.69	3.1	.197	.197	.016	.0011
7802281017.	45.	1.69	4.0	.196	.196	.016	.0014	7802281427.	45.	1.69	5.7	.159	.159	.016	.0020
7802160922.	45.	1.69	6.6	.122	.122	.016	.0024	7802281438.	45.	1.69	8.4	.125	.125	.016	.0030
7802281448.	45.	1.69	12.6	.096	.096	.016	.0045	7802281458.	45.	1.69	17.8	.075	.075	.016	.0064
7802281513.	45.	1.69	24.6	.057	.057	.016	.0088	7802161353.	45.	.91	.7	.040	.040	.055	.0009
7802161150.	45.	.91	2.0	.028	.028	.055	.0025	7802161138.	45.	.91	9.5	.007	.007	.055	.0117
7802211014.	60.	3.06	1.5	.480	.480	.007	.0002	7802211021.	60.	3.06	3.5	.345	.345	.007	.0004
7802211029.	60.	3.06	7.9	.250	.250	.007	.0009	7802211036.	60.	3.06	11.2	.216	.216	.007	.0012
7802211044.	60.	3.06	15.2	.261	.261	.007	.0017	7802210916.	60.	1.95	1.8	.349	.349	.016	.0005
7802210924.	60.	1.95	3.7	.247	.247	.016	.0010	7802210931.	60.	1.95	5.3	.214	.214	.016	.0014
7802210939.	60.	1.95	7.7	.182	.182	.016	.0021	7802210946.	60.	1.95	11.1	.157	.157	.016	.0030
7802211006.	60.	1.95	15.8	.154	.154	.016	.0042	7802211051.	60.	1.05	1.5	.113	.113	.056	.0014
7802211059.	60.	1.05	4.6	.054	.054	.056	.0043	7802211107.	60.	1.05	7.6	.032	.032	.056	.0070
7802211114.	60.	1.05	12.1	.030	.030	.056	.0112	7802220946.	75.	3.42	1.4	.624	.624	.007	.0001
7802220954.	75.	3.42	2.9	.630	.630	.007	.0003	7802221001.	75.	3.42	6.3	.528	.528	.007	.0005
7802221009.	75.	3.42	13.7	.487	.487	.007	.0012	7802220909.	75.	2.18	1.3	.775	.775	.016	.0003
7802220916.	75.	2.18	2.6	.741	.741	.016	.0006	7802220924.	75.	2.18	5.3	.660	.660	.016	.0011
7802220931.	75.	2.18	10.7	.583	.583	.016	.0023	7802220938.	75.	2.18	15.7	.555	.555	.016	.0034
7802221017.	75.	1.18	3.1	.633	.633	.055	.0023	7802221024.	75.	1.18	7.3	.526	.526	.055	.0053
7802221034.	75.	1.18	14.0	.413	.413	.055	.0103								

BREAKWATER 10

ID	D(CM)	T(S)	H(CM)	KT	KR	D/GT2	H/GT2	ID	D(CM)	T(S)	H(CM)	KT	KR	D/GT2	H/GT2
7803061141.	75.	3.42	1.3	.643	.643	.007	.0001	7803061149.	75.	3.42	2.9	.630	.630	.007	.0003
7803061157.	75.	3.42	6.2	.584	.584	.007	.0005	7803061205.	75.	3.42	13.6	.498	.498	.007	.0012
7803061213.	75.	3.42	20.4	.475	.475	.007	.0018	7803061047.	75.	2.18	1.3	.830	.830	.016	.0003
7803061056.	75.	2.18	2.7	.785	.785	.016	.0006	7803061103.	75.	2.18	5.5	.733	.733	.016	.0012
7803061110.	75.	2.18	11.5	.675	.675	.016	.0025	7803061118.	75.	2.18	17.1	.632	.632	.016	.0037
7803061126.	75.	2.18	22.8	.535	.535	.016	.0049	7803061222.	75.	1.18	3.1	.726	.726	.055	.0023
7803061231.	75.	1.18	7.9	.642	.642	.055	.0058	7803031308.	60.	3.06	1.1	.498	.498	.007	.0001
7803031322.	60.	3.06	3.8	.361	.361	.007	.0004	7803031330.	60.	3.06	11.1	.340	.340	.007	.0012
7803031340.	60.	3.06	19.5	.435	.435	.007	.0021	7803031348.	60.	3.06	24.9	.451	.451	.007	.0027
7803031016.	60.	1.95	4.2	.302	.302	.016	.0011	7803031025.	60.	1.95	8.3	.249	.249	.016	.0022
7803031032.	60.	1.95	16.0	.304	.304	.016	.0043	7803031208.	60.	1.95	21.8	.406	.406	.016	.0059
7803031225.	60.	1.05	2.1	.184	.184	.056	.0019	7803031241.	60.	1.05	3.6	.145	.145	.056	.0033
7803031248.	60.	1.05	8.1	.115	.115	.056	.0075	7803031255.	60.	1.05	14.1	.181	.181	.056	.0131
7803021156.	45.	2.65	.7	.393	.393	.007	.0001	7803021203.	45.	2.65	1.5	.343	.343	.007	.0002
7803021210.	45.	2.65	3.2	.253	.253	.007	.0005	7803021217.	45.	2.65	7.2	.157	.157	.007	.0010
7803021224.	45.	2.65	14.6	.106	.106	.007	.0021	7803021059.	45.	1.69	1.0	.337	.337	.016	.0004
7803021124.	45.	1.69	4.3	.165	.165	.016	.0015	7803021133.	45.	1.69	9.6	.100	.100	.016	.0034
7803021140.	45.	1.69	13.8	.074	.074	.016	.0049	7803021147.	45.	1.69	17.0	.060	.060	.016	.0061

BREAKWATER 11

ID	D(CM)	T(S)	H(CM)	KT	KR	D/GT2	H/GT2	ID	D(CM)	T(S)	H(CM)	KT	KR	D/GT2	H/GT2
7803131303.	45.	2.65	.8	.676	.676	.007	.0001	7803131311.	45.	2.65	1.5	.607	.607	.007	.0002
7803131319.	45.	2.65	3.2	.506	.506	.007	.0005	7803131327.	45.	2.65	6.8	.398	.398	.007	.0010
7803131334.	45.	2.65	13.3	.297	.297	.007	.0019	7803131146.	45.	1.69	2.4	.499	.499	.016	.0009
7803131153.	45.	1.69	5.1	.429	.429	.016	.0018	7803131239.	45.	1.69	10.9	.336	.336	.016	.0039
7803131207.	45.	1.69	14.1	.324	.324	.016	.0050	7803131254.	45.	1.69	15.7	.309	.309	.016	.0056
7803131342.	45.	.91	1.7	.286	.286	.055	.0021	7803131349.	45.	.91	5.0	.182	.182	.055	.0062
7803131356.	45.	.91	7.8	.153	.153	.055	.0096	7803131408.	45.	.91	8.6	.145	.145	.055	.0106
7803131440.	31.	1.94	.8	.707	.707	.008	.0002	7803131448.	31.	1.94	1.7	.605	.605	.008	.0005
7803131455.	31.	1.94	3.8	.493	.493	.008	.0010	7803131503.	31.	1.94	10.5	.315	.315	.008	.0028
7803131510.	31.	1.53	1.1	.472	.472	.013	.0005	7803131517.	31.	1.53	2.4	.400	.400	.013	.0010
7803131524.	31.	1.53	5.2	.345	.345	.013	.0023	7803141021.	31.	1.53	13.1	.228	.228	.013	.0057
7803141028.	31.	1.41	.8	.387	.387	.016	.0004	7803141038.	31.	1.41	1.6	.367	.367	.016	.0008
7803141045.	31.	1.41	3.1	.338	.338	.016	.0016	7803141052.	31.	1.41	7.0	.273	.273	.016	.0036
7803141100.	31.	1.16	.6	.375	.375	.023	.0005	7803141107.	31.	1.16	1.4	.317	.317	.023	.0011

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                                      SINE BLADE MOTION
    ID      D(CM) T(S) H(CM) KT     KR D/GT2 H/GT2          ID      D(CM) T(S) H(CM) KT     KR D/GT2 H/GT2

                                       BREAKWATER 11

7803141114. 31. 1.16  3.0 .278 .278 .023 .0023      7803141121. 31. 1.16  7.8 .225 .225 .023 .0059
7803141130. 31. 1.00   .6 .284 .284 .031 .0006      7803141137. 31. 1.00  1.8 .213 .213 .031 .0018
7803141144. 31. 1.00  3.6 .205 .205 .031 .0037      7803141152. 31. 1.00  5.4 .195 .195 .031 .0055

                                       BREAKWATER 12

7803171001. 75. 3.42  1.3 .751 .751 .007 .0001      7803170902. 75. 3.42  1.3 .762 .762 .007 .0001
7803170910. 75. 3.42  2.8 .738 .738 .007 .0002      7803170919. 75. 3.42  6.2 .659 .659 .007 .0005
7803170927. 75. 3.42 13.5 .569 .569 .007 .0012      7803170824. 75. 2.18  1.4 .890 .890 .016 .0003
7803170832. 75. 2.18  2.7 .864 .864 .016 .0006      7803170839. 75. 2.18  5.6 .793 .793 .016 .0012
7803170847. 75. 2.18 11.4 .712 .712 .016 .0024      7803170854. 75. 2.18 16.3 .684 .684 .016 .0035
7803170937. 75. 1.18  3.5 .732 .732 .055 .0026      7803170944. 75. 1.18  7.5 .656 .656 .055 .0055
7803170951. 75. 1.18 14.4 .509 .509 .055 .0106      7803171240. 60. 3.06   .8 .779 .779 .007 .0001
7803171255. 60. 3.06  9.7 .430 .430 .007 .0011      7803171303. 60. 3.06 19.2 .468 .468 .007 .0021
7803171311. 60. 3.06 25.2 .493 .493 .007 .0027      7803171028. 60. 1.95  1.3 .643 .643 .016 .0003
7803171035. 60. 1.95  3.9 .507 .507 .016 .0010      7803171042. 60. 1.95  8.2 .396 .396 .016 .0022
7803171049. 60. 1.95 16.6 .341 .341 .016 .0045      7803171057. 60. 1.95 22.4 .335 .335 .016 .0060
7803171106. 60. 1.05   .9 .266 .266 .056 .0008      7803170005. 60. 1.05  4.1 .192 .192 .056 .0038
7803170013. 60. 1.05  7.4 .170 .170 .056 .0068      7803171153. 60. 1.05 14.8 .164 .164 .056 .0137
7803160923. 45. 2.65   .6 .753 .753 .007 .0001      7803160930. 45. 2.65  1.3 .697 .697 .007 .0002
7803160945. 45. 2.65  6.0 .433 .433 .007 .0009      7803160954. 45. 2.65 11.7 .340 .340 .007 .0017
7803160842. 45. 1.69   .9 .727 .727 .016 .0003      7803160849. 45. 1.69  1.8 .608 .608 .016 .0006
7803160858. 45. 1.69  3.7 .455 .455 .016 .0013      7803160906. 45. 1.69  8.2 .306 .306 .016 .0029
7803160913. 45. 1.69 10.6 .280 .280 .016 .0038      7803161003. 45.  .91  1.1 .134 .134 .055 .0014
7803161010. 45.  .91  3.1 .079 .079 .055 .0038      7803161017. 45.  .91  8.0 .057 .057 .055 .0099

                                       BREAKWATER 13

7804211154. 60. 3.06   .9 .932 .932 .007 .0001      7804211146. 60. 3.06  2.0 .893 .893 .007 .0002
7804211138. 60. 3.06  4.2 .870 .870 .007 .0005      7804211129. 60. 3.06  9.1 .860 .860 .007 .0010
7804211120. 60. 3.06 13.6 .885 .885 .007 .0015      7804211024. 60. 1.95  1.5 .951 .951 .016 .0004
7804211032. 60. 1.95  3.2 .947 .947 .016 .0009      7804211047. 60. 1.95  6.4 .912 .912 .016 .0017
7804211100. 60. 1.95 13.6 .859 .859 .016 .0036      7804211109. 60. 1.95 26.5 .712 .712 .016 .0071
7804211203. 60. 1.05  1.6 .884 .884 .056 .0015      7804211211. 60. 1.05  3.0 .895 .895 .056 .0028
7804211219. 60. 1.05  6.4 .898 .898 .056 .0059      7804211227. 60. 1.05 11.9 .903 .903 .056 .0110
7804201436. 45. 3.31  2.5 .806 .806 .004 .0002      7804201407. 45. 3.31  5.3 .756 .756 .004 .0005
7804201357. 45. 3.31 11.1 .704 .704 .004 .0010      7804210830. 45. 2.65  2.0 .979 .979 .007 .0003
7804210843. 45. 2.65  4.5 .915 .915 .007 .0007      7804210851. 45. 2.65  9.6 .903 .903 .007 .0014
7804210900. 45. 2.65 18.8 .769 .769 .007 .0027      7804201311. 45. 2.11  2.2 .881 .881 .010 .0005
7804201320. 45. 2.11  4.5 .849 .849 .010 .0010      7804201329. 45. 2.11  8.3 .856 .856 .010 .0019
7804201341. 45. 2.11 11.8 .836 .836 .010 .0027      7804201454. 45. 1.69  1.4 .850 .850 .016 .0005
7804201504. 45. 1.69  2.9 .844 .844 .016 .0010      7804201512. 45. 1.69  6.0 .793 .793 .016 .0021
7804201520. 45. 1.69 12.8 .705 .705 .016 .0046      7804201528. 45. 1.69 18.1 .572 .572 .016 .0065
7804201536. 45. 1.14  1.5 .805 .805 .035 .0012      7804201544. 45. 1.14  4.3 .773 .773 .035 .0034
7804210927. 45.  .91  2.1 .881 .881 .055 .0026      7804210917. 45.  .91  3.5 .844 .844 .055 .0043
7804210909. 45.  .91  7.8 .607 .607 .055 .0096      7804201047. 35. 3.06   .7 .828 .828 .004 .0001
7804201057. 35. 3.06  1.5 .737 .737 .004 .0002      7804201119. 35. 3.06  3.6 .635 .635 .004 .0004
7804201130. 35. 3.06  8.0 .569 .569 .004 .0009      7804201140. 35. 3.06 17.1 .507 .507 .004 .0019
7804200959. 35. 1.95  1.1 .791 .791 .009 .0003      7804201008. 35. 1.95  2.3 .734 .734 .009 .0006
7804201015. 35. 1.95  4.8 .655 .655 .009 .0013      7804201025. 35. 1.95 10.3 .600 .600 .009 .0028
7804201034. 35. 1.95 19.8 .444 .444 .009 .0053      7804201210. 35. 1.25  2.5 .549 .549 .023 .0016
7804201157. 35. 1.25  4.6 .497 .497 .023 .0030      7804201203. 35. 1.25  4.7 .497 .497 .023 .0031
7804201149. 35. 1.25 11.5 .390 .390 .023 .0075      7804201217. 35. 1.05  3.1 .384 .384 .032 .0029
7804201224. 35. 1.05  5.1 .358 .358 .032 .0047      7804201231. 35. 1.05 11.1 .311 .311 .032 .0103

                                       BREAKWATER 14

7804240907. 65. 2.03  2.7 .960 .960 .016 .0007      7804240816. 65. 2.03  5.8 .979 .979 .016 .0014
7804240825. 65. 2.03  8.3 .987 .987 .016 .0021      7804240833. 65. 2.03 11.8 .997 .997 .016 .0029
7804241007. 60. 3.06   .9 .940 .940 .007 .0001      7804241015. 60. 3.06  2.8 .900 .900 .007 .0003
7804241024. 60. 3.06  8.9 .900 .900 .007 .0010      7804241034. 60. 3.06 13.4 .939 .939 .007 .0015
7804240909. 60. 1.95  1.1 .961 .961 .016 .0003      7804240918. 60. 1.95  2.3 .964 .964 .016 .0006
7804240926. 60. 1.95  4.6 .974 .974 .016 .0012      7804240934. 60. 1.95  6.5 .984 .984 .016 .0017
7804240942. 60. 1.95  9.4 .991 .991 .016 .0025      7804240951. 60. 1.95 13.7 .988 .988 .016 .0037
7804240959. 60. 1.95 18.9 .892 .892 .016 .0051      7804241044. 60. 1.05  1.5 .921 .921 .056 .0014
7804241051. 60. 1.05  4.0 .939 .939 .056 .0037      7804241059. 60. 1.05  9.7 **** **** .056 .0090
7804241145. 55. 1.87  1.3 .889 .889 .016 .0004      7804241243. 55. 1.87  2.7 .927 .927 .016 .0008
7804241252. 55. 1.87  5.4 .934 .934 .016 .0016      7804241304. 55. 1.87 10.8 .961 .961 .016 .0032
7804250802. 55. 1.87 15.0 .860 .860 .016 .0044      7804250812. 55. 1.87 20.5 .732 .732 .016 .0060
7804250846. 50. 1.78   .7 .861 .861 .016 .0002      7804250855. 50. 1.78  1.6 .913 .913 .016 .0005
7804250904. 50. 1.78  3.5 .950 .950 .016 .0011      7804250917. 50. 1.78  7.4 .889 .889 .016 .0024
7804250926. 50. 1.78 11.6 .826 .826 .016 .0037      7804250935. 50. 1.78 15.2 .693 .693 .016 .0049
7804251122. 45. 2.65  4.9 .922 .922 .007 .0007      7804251132. 45. 2.65 10.0 .806 .806 .007 .0015
7804251141. 45. 2.65 14.1 .713 .713 .007 .0020      7804251150. 45. 2.65 19.7 .605 .605 .007 .0029
7804251011. 45. 1.69  1.0 .934 .934 .016 .0004      7804251022. 45. 1.69  2.1 .952 .952 .016 .0008
7804251030. 45. 1.69  4.4 .981 .981 .016 .0016      7804251039. 45. 1.69  8.9 .713 .713 .016 .0032
7804251048. 45. 1.69 12.9 .609 .609 .016 .0046      7804251058. 45. 1.69 18.3 .510 .510 .016 .0065
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                                   SINE BLADE MOTION
   ID     D(CM) T(S) H(CM) KT    KR D/GT2 H/GT2          ID     D(CM) T(S) H(CM) KT    KR D/GT2 H/GT2

                                    BREAKWATER 14

7804251236. 45.  .91  1.9 .879 .879 .055 .0023     7804251246. 45.  .91  4.3 .820 .820 .055 .0053
7804251254. 45.  .91  5.6 .729 .729 .055 .0069     7804251305. 45.  .91  7.8 .484 .484 .055 .0096
7804251316. 45.  .91  8.9 .530 .530 .055 .0110     7804251342. 40. 1.59  2.1 .852 .852 .016 .0008
7804251350. 40. 1.59  4.0 .670 .670 .016 .0016     7804251359. 40. 1.59  7.1 .564 .564 .016 .0029
7804251407. 40. 1.59  9.6 .509 .509 .016 .0039     7804251415. 40. 1.59 13.1 .473 .473 .016 .0053
7804251505. 35. 1.49 11.7 .410 .410 .016 .0054     7804251426. 40. 1.59 17.6 .438 .438 .016 .0071
7804251457. 35. 1.49 17.2 .363 .363 .016 .0079     7804251448. 35. 1.49 23.9 .280 .280 .016 .0110
7804261031. 35. 3.06 12.2 .390 .390 .004 .0013     7804261040. 35. 3.06 17.0 .452 .452 .004 .0019
7804261049. 35. 3.06 21.2 .437 .437 .004 .0023     7804260956. 35. 1.95  9.9 .483 .483 .009 .0027
7804261005. 35. 1.95 14.1 .477 .477 .009 .0038     7804261103. 35. 1.49  1.8 .417 .417 .016 .0008
7804261111. 35. 1.49  5.3 .397 .397 .016 .0024     7804261013. 35. 1.30 11.5 .382 .382 .021 .0069
7804261022. 35. 1.30 14.8 .354 .354 .021 .0069     7804261236. 30. 2.17  7.7 .246 .246 .007 .0017
7804261229. 30. 2.17 13.7 .439 .439 .007 .0030     7804261221. 30. 2.17 17.5 .440 .440 .007 .0038
7804261213. 30. 2.17 20.1 .429 .429 .007 .0044     7804261150. 30. 1.38  6.3 .229 .229 .016 .0034
7804261158. 30. 1.38 11.2 .330 .330 .016 .0060     7804261205. 30. 1.38 14.8 .326 .326 .016 .0079

                                    BREAKWATER 15

7805021015. 45. 2.80  4.7 .903 .903 .006 .0006     7805021026. 45. 2.80  7.1 .863 .863 .006 .0009
7805021036. 45. 2.80 10.3 .833 .833 .006 .0013     7805021045. 45. 2.80 14.8 .805 .805 .006 .0019
7805021058. 45. 2.80 18.4 .739 .739 .006 .0024     7805021108. 45. 1.69  1.0 .908 .908 .016 .0004
7805021116. 45. 1.69  2.1 .908 .908 .016 .0008     7805021128. 45. 1.69  4.2 .890 .890 .016 .0015
7805021136. 45. 1.69  6.0 .858 .858 .016 .0021     7805021145. 45. 1.69  8.7 .821 .821 .016 .0031
7805021155. 45. 1.69 12.9 .795 .795 .016 .0046     7805021204. 45. 1.69 18.3 .627 .627 .016 .0065
7805021311. 45.  .91  1.8 .865 .865 .055 .0022     7805021321. 45.  .91  2.4 .850 .850 .055 .0030
7805021330. 45.  .91  3.1 .851 .851 .055 .0038     7805021239. 45.  .91  3.9 .866 .866 .055 .0048
7805021247. 45.  .91  8.2 .594 .594 .055 .0101     7805021329. 40. 2.80  5.9 .788 .788 .005 .0008
7805021337. 40. 2.80  8.6 .785 .785 .005 .0011     7805021348. 40. 2.80 12.1 .729 .729 .005 .0016
7805021358. 40. 2.80 16.6 .685 .685 .005 .0022     7805030732. 40. 2.80 20.8 .588 .588 .005 .0027
7805030854. 40. 2.50   .7 .931 .931 .007 .0001     7805030905. 40. 2.50  1.5 .864 .864 .007 .0002
7805030930. 40. 2.50  3.1 .826 .826 .007 .0005     7805030939. 40. 2.50  6.3 .810 .810 .007 .0010
7805030947. 40. 2.50  9.0 .772 .772 .007 .0015     7805030956. 40. 2.50 13.0 .700 .700 .007 .0021
7805031007. 40. 2.50 19.1 .641 .641 .007 .0031     7805030845. 40. 1.59  1.3 .861 .861 .016 .0005
7805030827. 40. 1.59  2.8 .813 .813 .016 .0011     7805030816. 40. 1.59  5.6 .718 .718 .016 .0023
7805030756. 40. 1.59 10.8 .627 .627 .016 .0044     7805030748. 40. 1.59 15.0 .561 .561 .016 .0061
7805030740. 40. 1.59 20.0 .484 .484 .016 .0081     7805031143. 40.  .86  2.2 .772 .772 .055 .0030
7805031052. 40.  .86  3.2 .755 .755 .055 .0044     7805031044. 40.  .86  4.2 .726 .726 .055 .0058
7805031037. 40. [illegible]  5.6 .730 .730 .055 .0077     7805031026. 40.  .86  6.0 .521 .521 .055 .0083
7805031018. 40.  .86  7.4 .516 .516 .055 .0102     7805040935. 35. 2.80  1.5 .789 .789 .005 .0002
7805040945. 35. 2.80  3.0 .713 .713 .005 .0004     7805040953. 35. 2.80  6.1 .679 .679 .005 .0008
7805041002. 35. 2.80 12.6 .619 .619 .005 .0016     7805041012. 35. 2.80 17.7 .557 .557 .005 .0023
7805041027. 35. 2.80 20.6 .501 .501 .005 .0027     7805041157. 35. 2.34   .5 .889 .889 .007 .0001
7805041206. 35. 2.34  1.1 .819 .819 .007 .0002     7805041215. 35. 2.34  2.2 .739 .739 .007 .0004
7805041226. 35. 2.34  3.2 .714 .714 .007 .0006     7805040135. 35. 2.34  4.6 .685 .685 .007 .0009
7805040109. 35. 2.34  6.6 .665 .665 .007 .0012     7805040120. 35. 2.34  9.6 .630 .630 .007 .0018
7805040129. 35. 2.34 14.3 .567 .567 .007 .0027     7805040137. 35. 2.34 20.3 .506 .506 .007 .0038
7805041149. 35. 1.49  1.1 .796 .796 .016 .0005     7805041138. 35. 1.49  2.3 .696 .696 .016 .0011
7805041114. 35. 1.49  4.8 .569 .569 .016 .0022     7805041102. 35. 1.49 11.1 .516 .516 .016 .0051
7805041053. 35. 1.49 16.7 .440 .440 .016 .0077     7805040146. 35. 1.49 22.3 .359 .359 .016 .0102
7805041042. 35. 1.49 23.0 .374 .374 .016 .0106     7805040203. 30. 2.80  2.6 .538 .538 .004 .0003
7805040211. 30. 2.80  5.1 .480 .480 .004 .0007     7805040219. 30. 2.80 10.6 .537 .537 .004 .0014
7805051228. 30. 2.17  1.6 .673 .673 .007 .0003     7805051222. 30. 2.17  1.7 .674 .674 .007 .0004
7805051215. 30. 2.17  3.3 .602 .602 .007 .0007     7805051155. 30. 2.17  6.3 .543 .543 .007 .0014
7805051003. 30. 2.17 12.1 .551 .551 .007 .0026     7805050944. 30. 2.17 15.9 .510 .510 .007 .0034
7805050933. 30. 2.17 21.0 .436 .436 .007 .0046     7805050840. 30. 1.38  1.1 .566 .566 .016 .0006
7805050848. 30. 1.38  2.2 .501 .501 .016 .0012     7805050857. 30. 1.38  4.9 .425 .425 .016 .0026
7805050906. 30. 1.38  9.6 .408 .408 .016 .0051     7805050916. 30. 1.38 12.0 .362 .362 .016 .0064
7805050924. 30. 1.38 16.9 .303 .303 .016 .0091     7805081048. 25. 1.98   .7 .767 .767 .007 .0002
7805081040. 25. 1.98  1.4 .692 .692 .007 .0004     7805081032. 25. 1.98  3.1 .573 .573 .007 .0008
7805081024. 25. 1.98  6.5 .437 .437 .007 .0017     7805081012. 25. 1.98  9.5 .417 .417 .007 .0025
7805081004. 25. 1.98 13.6 .366 .366 .007 .0035     7805080858. 25. 1.26  1.4 .609 .609 .016 .0009
7805080907. 25. 1.26  3.0 .460 .460 .016 .0019     7805080919. 25. 1.26  6.3 .346 .346 .016 .0040
7805080928. 25. 1.26  9.3 .311 .311 .016 .0060     7805080941. 25. 1.26 13.7 .297 .297 .016 .0088
7805080956. 25. 1.26 14.9 .256 .256 .016 .0096     7805091028. 20. 1.77  5.5 .405 .405 .007 .0018
7805091036. 20. 1.77  8.0 .341 .341 .007 .0026     7805091044. 20. 1.77 11.9 .309 .309 .007 .0039
7805090845. 20. 1.13   .7 .371 .371 .016 .0006     7805090837. 20. 1.13  1.2 .335 .335 .016 .0010
7805090855. 20. 1.13  2.7 .271 .271 .016 .0022     7805090903. 20. 1.13  3.8 .233 .233 .016 .0030
7805090913. 20. 1.13  5.6 .198 .198 .016 .0045     7805090923. 20. 1.13  7.8 .176 .176 .016 .0062

                                    BREAKWATER 15a

7804270021. 50. 2.18   .9 **** **** .011 .0002     7804270032. 50. 2.18  1.8 .955 .955 .011 .0004
7804270942. 50. 2.18  3.6 .918 .918 .011 .0008     7804270953. 50. 2.18  7.5 .897 .897 .011 .0016
7804271003. 50. 2.18 10.7 .877 .877 .011 .0023     7804271015. 50. 2.18 15.7 .856 .856 .011 .0034
7804271055. 50. 1.78  1.1 .868 .868 .016 .0004     7804271048. 50. 1.78  2.3 .868 .868 .016 .0007
7804271040. 50. 1.78  5.6 .824 .824 .016 .0018     7804271032. 50. 1.78 11.8 .851 .851 .016 .0038
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                                         SINE BLADE MOTION
   ID       D(CM) T(S) H(CM) KT          KR D/GT2 H/GT2          ID       D(CM) T(S) H(CM) KT    KR D/GT2 H/GT2

                                         BREAKWATER 15W

7804271023. 50. 1.78 14.7 .783 .783 .016 .0047        7804271202. 45. 2.65   .9 .975 .975 .007 .0001
7804271210. 45. 2.65  4.5 .860 .860 .007 .0007        7804271219. 45. 2.65  9.7 .871 .871 .007 .0014
7804271227. 45. 2.65 13.6 .811 .811 .007 .0020        7804271111. 45. 1.69  1.4 .880 .880 .016 .0005
7804271119. 45. 1.69  3.0 .859 .859 .016 .0011        7804271127. 45. 1.69  6.2 .810 .810 .016 .0022
7804271135. 45. 1.69  8.9 .802 .802 .016 .0032        7804271143. 45. 1.69 12.9 .732 .732 .016 .0046
7804271151. 45. 1.69 16.9 .615 .615 .016 .0060        7804271259. 45.  .91  1.9 .637 .637 .055 .0023
7804271252. 45.  .91  3.5 .859 .859 .055 .0043        7804271244. 45.  .91  8.1 .600 .600 .055 .0100
7804281251. 40. 1.59  1.9 .835 .835 .016 .0008        7804281259. 40. 1.59  3.8 .754 .754 .016 .0015
7804281307. 40. 1.59  7.2 .664 .664 .016 .0029        7804281316. 40. 1.59 13.7 .561 .561 .016 .0055
7804281324. 40. 1.59 18.7 .491 .491 .016 .0075        7804281151. 35. 3.06 12.5 .502 .502 .004 .0014
7804281256. 35. 3.06 17.6 .476 .476 .004 .0019        7804281305. 35. 3.06 22.5 .444 .444 .004 .0025
7804281142. 35. 1.95 14.9 .558 .558 .009 .0040        7804281222. 35. 1.49  1.6 .675 .675 .016 .0007
7804281230. 35. 1.49  3.4 .594 .594 .016 .0016        7804281239. 35. 1.49  7.4 .489 .489 .016 .0034
7804281247. 35. 1.49 16.7 .430 .430 .016 .0077        7804281116. 35. 1.30 11.3 .476 .476 .021 .0068
7804281125. 35. 1.30 15.0 .428 .428 .021 .0091        7804271409. 30. 2.17  2.2 .555 .555 .007 .0005
7804271417. 30. 2.17  4.4 .464 .464 .007 .0010        7804271425. 30. 2.17  8.6 .463 .463 .007 .0019
7804271432. 30. 2.17 16.2 .478 .478 .007 .0035        7804271442. 30. 2.17 20.7 .438 .438 .007 .0045
7804271324. 30. 1.38  1.4 .453 .453 .016 .0008        7804271332. 30. 1.38  3.1 .355 .355 .016 .0017
7804271341. 30. 1.38  7.1 .332 .332 .016 .0038        7804271349. 30. 1.38  9.6 .342 .342 .016 .0051
7804271357. 30. 1.38 13.0 .318 .318 .016 .0070

                                         BREAKWATER 16

7805110706. 60. 4.83   .8 .826 .826 .003 .0000        7805110715. 60. 4.83  2.8 .794 .794 .003 .0001
7805110723. 60. 4.83  6.0 .766 .766 .003 .0003        7805110735. 60. 4.83 12.6 .758 .758 .003 .0006
7805110746. 60. 4.83 17.8 .793 .793 .003 .0008        7805110840. 60. 3.06   .9 .956 .956 .007 .0001
7805110831. 60. 3.06  2.8 .917 .917 .007 .0003        7805110820. 60. 3.06  6.1 .902 .902 .007 .0007
7805110811. 60. 3.06  8.9 .908 .908 .007 .0010        7805110802. 60. 3.06 13.5 .939 .939 .007 .0015
7805110856. 60. 1.95  1.7 .959 .959 .016 .0005        7805110913. 60. 1.95  3.4 .947 .947 .016 .0009
7805110924. 60. 1.95  6.7 .915 .915 .016 .0018        7805110937. 60. 1.95 13.7 .871 .871 .016 .0037
7805111010. 60. 1.95 26.4 .706 .706 .016 .0071        7805111208. 60. 1.05  2.8 .947 .947 .056 .0026
7805111201. 60. 1.05  4.1 .953 .953 .056 .0038        7805111046. 60. 1.05  6.5 .952 .952 .056 .0060
7805111038. 60. 1.05  9.3 .969 .969 .056 .0086        7805111022. 60. 1.05 11.8 .780 .780 .056 .0109
7805111232. 55. 4.69  1.2 .786 .786 .003 .0001        7805111242. 55. 4.69  4.0 .760 .760 .003 .0002
7805111252. 55. 4.69  8.3 .764 .764 .003 .0004        7805111304. 55. 4.69 16.1 .822 .822 .003 .0007
7805111313. 55. 4.69 21.5 .624 .624 .003 .0010        7805120832. 55. 2.93  1.1 .979 .979 .007 .0001
7805120822. 55. 2.93  3.5 .972 .972 .007 .0004        7805120810. 55. 2.93  7.7 .949 .949 .007 .0009
7805111348. 55. 2.93 11.1 .949 .949 .007 .0013        7805111339. 55. 2.93 15.9 .981 .981 .007 .0019
7805111326. 55. 2.93 22.2 .909 .909 .007 .0026        7805120843. 55. 1.87  1.6 .860 .860 .016 .0005
7805120857. 55. 1.87  3.3 .860 .860 .016 .0010        7805120913. 55. 1.87  6.5 .852 .852 .016 .0019
7805120935. 55. 1.87 13.6 .823 .823 .016 .0040        7805120946. 55. 1.87 19.2 .754 .754 .016 .0056
7805120955. 55. 1.87 25.7 .643 .643 .016 .0075        7805121031. 55. 1.01  1.3 .927 .927 .055 .0013
7805121023. 55. 1.01  3.8 .900 .900 .055 .0038        7805121005. 55. 1.01  4.3 .893 .893 .055 .0043
7805121014. 55. 1.01  4.8 .897 .897 .055 .0048        7805121152. 50. 4.54  2.0 .714 .714 .002 .0001
7805121205. 50. 4.54  4.0 .715 .715 .002 .0002        7805121215. 50. 4.54  7.9 .734 .734 .002 .0004
7805121225. 50. 4.54 11.2 .762 .762 .002 .0006        7805121235. 50. 4.54 16.4 .731 .731 .002 .0008
7805121247. 50. 4.54 23.7 .591 .591 .002 .0012        7805140836. 50. 2.80  4.2 .954 .954 .007 .0005
7805121319. 50. 2.80  9.5 .908 .908 .007 .0012        7805121310. 50. 2.80 13.6 .916 .916 .007 .0018
7805121259. 50. 2.80 16.1 .923 .923 .007 .0021        7805140921. 50. 1.78  1.1 .820 .820 .016 .0004
7805140942. 50. 1.78  2.4 .840 .840 .016 .0008        7805140959. 50. 1.78  5.0 .852 .852 .016 .0016
7805141015. 50. 1.78  8.5 .849 .849 .016 .0027        7805141029. 50. 1.78 12.4 .828 .828 .016 .0040
7805141042. 50. 1.78 17.1 .688 .688 .016 .0055        7805141144. 50. 1.78 23.3 .578 .578 .016 .0075
7805141241. 45. 4.38  1.3 .694 .694 .002 .0001        7805141253. 45. 4.38  2.8 .688 .688 .002 .0001
7805141306. 45. 4.38  6.1 .671 .671 .002 .0003        7805141318. 45. 4.38  8.9 .695 .695 .002 .0005
7805141329. 45. 4.38 12.7 .768 .768 .002 .0007        7805141340. 45. 4.38 17.7 .678 .678 .002 .0009
7805141411. 45. 2.65 12.9 .810 .810 .007 .0019        7805141400. 45. 2.65 18.3 .702 .702 .007 .0027
7805141350. 45. 2.65 25.7 .574 .574 .007 .0037        7805170815. 35. 4.06  2.6 .562 .562 .002 .0002
7805170838. 35. 4.06  5.4 .555 .555 .002 .0003        7805170847. 35. 4.06 11.1 .552 .552 .002 .0007
7805170857. 35. 4.06 15.4 .499 .499 .002 .0010        7805170911. 35. 4.06 20.9 .437 .437 .002 .0013
7805220937. 35. 3.10   .9 .871 .871 .004 .0001        7805220955. 35. 3.10  2.2 .739 .739 .004 .0002
7805221003. 35. 3.10  5.1 .601 .601 .004 .0005        7805221013. 35. 3.10  7.6 .554 .554 .004 .0008
7805221022. 35. 3.10 11.1 .516 .516 .004 .0012        7805221032. 35. 3.10 16.1 .478 .478 .004 .0017
7805170921. 35. 2.34  1.0 .799 .799 .007 .0002        7805170930. 35. 2.34  2.0 .725 .725 .007 .0004
7805170939. 35. 2.34  4.0 .650 .650 .007 .0007        7805170948. 35. 2.34  5.7 .615 .615 .007 .0011
7805170957. 35. 2.34  8.3 .587 .587 .007 .0015        7805171005. 35. 2.34 11.6 .542 .542 .007 .0022
7805171022. 35. 2.34 16.9 .468 .468 .007 .0031        7805221041. 35. 1.65   .7 .750 .750 .013 .0003
7805221049. 35. 1.65  1.4 .673 .673 .013 .0005        7805221137. 35. 1.65  2.8 .583 .583 .013 .0010
7805221145. 35. 1.65  5.6 .534 .534 .013 .0021        7805221154. 35. 1.65  8.8 .464 .464 .013 .0033
7805221203. 35. 1.65 14.4 .414 .414 .013 .0054        7805171034. 35. 1.49  1.1 .703 .703 .016 .0005
7805171043. 35. 1.49  2.3 .624 .624 .016 .0011        7805171052. 35. 1.49  4.9 .498 .498 .016 .0023
7805171150. 35. 1.49 11.5 .435 .435 .016 .0053        7805171203. 35. 1.49 16.5 .366 .366 .016 .0076
7805171214. 35. 1.49 23.2 .305 .305 .016 .0107        7805171233. 30. 3.89  1.4 .553 .553 .002 .0001
7805171243. 30. 3.89  3.0 .468 .468 .002 .0002        7805171253. 30. 3.89  6.5 .401 .401 .002 .0004
7805171303. 30. 3.89 10.3 .417 .417 .002 .0007        7805171313. 30. 3.89 14.8 .373 .373 .002 .0010
7805180937. 30. 2.87  1.8 .616 .616 .004 .0002        7805180946. 30. 2.87  3.5 .531 .531 .004 .0004
7805180959. 30. 2.87  7.2 .454 .454 .004 .0009        7805181004. 30. 2.87 10.2 .465 .465 .004 .0013
7805181241. 30. 2.87 14.7 .453 .453 .004 .0018        7805181252. 30. 2.87 21.3 .403 .403 .004 .0026
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                              SINE BLADE MOTION
   ID     D(CM) T(S) H(CM) KT    KR D/GT2 H/GT2        ID     D(CM) T(S) H(CM) KT    KR D/GT2 H/GT2

                                BREAKWATER 16

7805171321. 30. 2.17  2.0 .660 .660 .007 .0004    7805171330. 30. 2.17  4.1 .536 .536 .007 .0009
7805171339. 30. 2.17  8.1 .444 .444 .007 .0018    7805171347. 30. 2.17 14.9 .434 .434 .007 .0032
7805171355. 30. 2.17 18.1 .411 .411 .007 .0041    7805180832. 30. 1.53   .7 .636 .636 .013 .0003
7805180902. 30. 1.53  4.5 .362 .362 .013 .0020    7805180910. 30. 1.53 12.4 .330 .330 .013 .0054
7805180920. 30. 1.53 18.2 .264 .264 .013 .0079    7805180928. 30. 1.53 24.1 .213 .213 .013 .0105
7805180733. 30. 1.38  1.3 .490 .490 .016 .0007    7805180741. 30. 1.38  2.7 .377 .377 .016 .0014
7805180750. 30. 1.38  5.9 .292 .292 .016 .0032    7805180759. 30. 1.38  8.3 .298 .298 .016 .0044
7805180807. 30. 1.38 10.7 .288 .288 .016 .0057    7805180815. 30. 1.38 15.0 .261 .261 .016 .0080
7805180823. 30. 1.38 18.6 .228 .228 .016 .0100    7805190910. 25. 3.70  1.1 .487 .487 .002 .0001
7805190936. 25. 3.70  2.4 .434 .434 .002 .0002    7805190945. 25. 3.70  3.1 .387 .387 .002 .0002
7805191011. 25. 3.70 12.7 .245 .245 .002 .0009    7805191021. 25. 3.70 18.6 .267 .267 .002 .0014
7805181315. 25. 2.62  1.2 .585 .585 .004 .0002    7805181323. 25. 2.62  2.7 .487 .487 .004 .0004
7805181331. 25. 2.62  5.6 .371 .371 .004 .0008    7805181340. 25. 2.62  8.0 .324 .324 .004 .0012
7805181348. 25. 2.62 11.6 .282 .282 .004 .0017    7805181357. 25. 2.62 16.7 .283 .283 .004 .0025
7805190747. 25. 1.40  2.6 .288 .288 .013 .0014    7805190801. 25. 1.40  5.3 .211 .211 .013 .0028
7805190809. 25. 1.40  9.8 .171 .171 .013 .0051    7805190818. 25. 1.40 18.1 .144 .144 .013 .0094
7805190826. 25. 1.26  4.8 .206 .206 .016 .0028    7805190834. 25. 1.26  9.9 .150 .150 .016 .0064
7805190843. 25. 1.26 13.9 .167 .167 .016 .0089    7805190851. 25. 1.26 17.5 .140 .140 .016 .0112
7805190930. 25. 1.26 20.4 .118 .118 .016 .0131    7805191225. 20. 3.51   .4 .717 .717 .002 .0000
7805191234. 20. 3.51   .7 .658 .658 .002 .0001    7805191251. 20. 3.51  1.0 .612 .612 .002 .0001
7805191301. 20. 3.51  1.5 .559 .559 .002 .0001    7805191311. 20. 3.51  3.0 .444 .444 .002 .0002
7805191322. 20. 3.51  6.3 .328 .328 .002 .0005    7805191331. 20. 3.51 13.5 .225 .225 .002 .0011
7805191340. 20. 3.51 20.0 .187 .187 .002 .0017    7805220820. 20. 2.34   .9 .845 .845 .004 .0002
7805220812. 20. 2.34  1.8 .662 .662 .004 .0003    7805220803. 20. 2.34  3.6 .472 .472 .004 .0007
7805191405. 20. 2.34  7.0 .317 .317 .004 .0013    7805220754. 20. 2.34  7.1 .316 .316 .004 .0013
7805220746. 20. 2.34  9.9 .257 .257 .004 .0018    7805191356. 20. 2.34 13.5 .209 .209 .004 .0025
7805220736. 20. 2.34 14.3 .210 .210 .004 .0027    7805191349. 20. 2.34 20.7 .169 .169 .004 .0039
7805220727. 20. 2.34 19.9 .180 .180 .004 .0037    7805220829. 20. 1.77  1.2 .605 .605 .007 .0004
7805220838. 20. 1.77  2.5 .447 .447 .007 .0008    7805220846. 20. 1.77  5.4 .293 .293 .007 .0018
7805220855. 20. 1.77  8.1 .229 .229 .007 .0026    7805220904. 20. 1.77 12.4 .175 .175 .007 .0040
7805220912. 20. 1.77 18.1 .138 .138 .007 .0059

                                BREAKWATER 17

7807070834. 50. 6.99  2.1 .780 .780 .001 .0000    7807070844. 50. 6.99  4.3 .692 .692 .001 .0001
7807070854. 50. 6.99  8.5 .586 .586 .001 .0002    7807070904. 50. 6.99  8.5 .559 .559 .001 .0002
7807070937. 50. 6.99 16.4 .457 .457 .001 .0003    7808010135. 50. 6.34   .4 .934 .934 .001 .0000
7808151017. 50. 6.34  1.5 .742 .742 .001 .0000    7808151025. 50. 6.34  2.8 .671 .671 .001 .0001
7808151033. 50. 6.34  3.9 .649 .649 .001 .0001    7808010206. 50. 6.34  4.1 .682 .682 .001 .0001
7808151049. 50. 6.34  8.9 .529 .529 .001 .0002    7808010155. 50. 6.34  9.1 .561 .561 .001 .0002
7808151057. 50. 6.34 14.8 .435 .435 .001 .0004    7808010145. 50. 6.34 14.9 .458 .458 .001 .0004
7807070923. 50. 5.17  1.0 .709 .709 .002 .0000    7807070814. 50. 5.17  2.0 .670 .670 .002 .0001
7807070804. 50. 5.17  4.0 .596 .596 .002 .0002    7807070755. 50. 5.17  5.9 .543 .543 .002 .0002
7807070746. 50. 5.17  8.8 .491 .491 .002 .0003    7808151133. 50. 4.54  2.3 .546 .546 .002 .0001
7808151127. 50. 4.54  7.1 .427 .427 .002 .0004    7808151119. 50. 4.54 10.5 .377 .377 .002 .0005
7808151112. 50. 4.54 15.7 .330 .330 .002 .0008    7808151105. 50. 4.54 23.3 .296 .296 .002 .0012
7807070914. 50. 3.70  2.8 .565 .565 .004 .0002    7807071005. 50. 3.70  5.7 .501 .501 .004 .0004
7807070956. 50. 3.70 11.0 .419 .419 .004 .0008    7807070947. 50. 3.70 14.8 .387 .387 .004 .0011
7807071040. 50. 2.80  1.6 .765 .765 .007 .0002    7807071031. 50. 2.80  3.4 .689 .689 .007 .0004
7808020709. 50. 1.87  2.3 .508 .508 .015 .0007    7808020719. 50. 1.87  4.7 .467 .467 .015 .0014
7808020727. 50. 1.87  6.7 .433 .433 .015 .0020    7808020735. 50. 1.87  9.7 .409 .409 .015 .0028
7808151151. 50. 1.87 14.0 .339 .339 .015 .0041    7808151145. 50. 1.87 18.8 .311 .311 .015 .0055
7808151139. 50. 1.87 26.4 .269 .269 .015 .0077    7807071129. 50. 1.78  6.0 .472 .472 .016 .0019
7807071122. 50. 1.78 12.7 .370 .370 .016 .0041    7807071047. 50. 1.78 23.2 .294 .294 .016 .0075
7807071144. 50. 1.50  6.8 .437 .437 .023 .0031    7807071136. 50. 1.50 11.7 .352 .352 .023 .0053
7807051508. 45. 6.90  2.8 .760 .760 .001 .0001    7807051458. 45. 6.90  5.8 .660 .660 .001 .0001
7807051449. 45. 6.90  8.6 .586 .586 .001 .0002    7807051441. 45. 6.90 13.7 .475 .475 .001 .0003
7807051308. 45. 4.91  2.1 .579 .579 .002 .0001    7807051316. 45. 4.91  3.1 .553 .553 .002 .0001
7807051326. 45. 4.91  4.7 .519 .519 .002 .0002    7807051334. 45. 4.91  6.9 .471 .471 .002 .0003
7807051342. 45. 4.91 10.3 .426 .426 .002 .0004    7807051350. 45. 4.91 15.1 .384 .384 .002 .0006
7807051358. 45. 3.51  1.4 .689 .689 .004 .0001    7807051405. 45. 3.51  2.9 .624 .624 .004 .0002
7807051416. 45. 3.51  6.0 .534 .534 .004 .0005    7807051424. 45. 3.51 12.4 .443 .443 .004 .0010
7807051432. 45. 3.51 18.2 .386 .386 .004 .0015    7807051515. 45. 2.65  1.2 .734 .734 .007 .0002
7807051521. 45. 2.65  2.7 .664 .664 .007 .0004    7807051528. 45. 2.65  6.2 .553 .553 .007 .0009
7807051536. 45. 2.65 13.6 .424 .424 .007 .0020    7807051543. 45. 2.65 18.5 .381 .381 .007 .0027
7807051608. 45. 1.88  2.8 .544 .544 .013 .0008    7807051601. 45. 1.88  5.4 .492 .492 .013 .0016
7807051555. 45. 1.88 10.6 .407 .407 .013 .0031    7807051549. 45. 1.88 21.0 .317 .317 .013 .0061
7807051614. 45. 1.69   .6 .552 .552 .016 .0002    7807051620. 45. 1.69  1.3 .551 .551 .016 .0005
7807051626. 45. 1.69  2.8 .523 .523 .016 .0010    7807051632. 45. 1.69  6.2 .453 .453 .016 .0022
7807071430. 35. 6.09  1.6 .836 .836 .001 .0000    7807071437. 35. 6.09  3.3 .728 .728 .001 .0001
7807071444. 35. 6.09  6.9 .589 .589 .001 .0002    7807071453. 35. 6.09 10.1 .523 .523 .001 .0003
7807071218. 35. 4.33  3.0 .471 .471 .002 .0002    7807071226. 35. 4.33  8.7 .370 .370 .002 .0005
7807071244. 35. 4.33 14.8 .345 .345 .002 .0008    7807071315. 35. 3.10  1.2 .707 .707 .004 .0001
7807071308. 35. 3.10  3.9 .706 .706 .004 .0004    7807071300. 35. 3.10  5.6 .596 .596 .004 .0006
7807071252. 35. 3.10  8.5 .501 .501 .004 .0009    7807071322. 35. 2.34  1.5 .637 .637 .007 .0003
7807071330. 35. 2.34  4.4 .557 .557 .007 .0008    7807071338. 35. 2.34  9.5 .460 .460 .007 .0018
7807071347. 35. 2.34 14.7 .390 .390 .007 .0027    7807071419. 35. 1.49  1.4 .603 .603 .016 .0006
7807071411. 35. 1.49  2.8 .523 .523 .016 .0013    7807071404. 35. 1.49  6.3 .425 .425 .016 .0029
7807071355. 35. 1.49 18.6 .304 .304 .016 .0067
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APPENDIX D

TEST RESULTS (IRREGULAR WAVES)

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                                  IRREGULAR WAVES
     ID      D(CM) T(S) H(CM) KT   KR D/GT2 H/GT2 QP           ID      D(CM) T(S) H(CM) KT   KR D/GT2 H/GT2 QP

                                   BREAKWATER  1

7803281353. 60. 1.00 15.8 .103 .103 .024 .0063 3.38    7803281403. 60. 1.46 17.2 .151 .151 .029 .0082 5.54
7803281413. 60. 1.02 16.9 .176 .176 .025 .0066 4.01    7803281422. 60. 3.08  8.2 .035 .035 .006 .0009 3.97
7803281431. 60. 3.32 11.3 .039 .039 .006 .0010 3.38    7803281441. 60. 2.05 12.8 .068 .068 .015 .0031 3.77
7803281451. 60. 3.32 12.0 .045 .045 .006 .0011 2.84    7803281500. 60. 2.02 15.5 .160 .160 .015 .0039 3.45
7803270934. 75. 1.34 15.6 .319 .319 .043 .0089 2.78    7803270943. 75. 1.45 16.7 .355 .355 .036 .0081 5.82
7803270952. 75. 1.56 16.5 .347 .347 .031 .0069 4.37    7803271004. 75. 3.32 11.1 .303 .303 .007 .0010 3.94
7803271013. 75. 3.28  7.5 .253 .253 .007 .0007 3.24    7803271022. 75. 1.33 12.5 .291 .291 .043 .0072 2.69
7803271032. 75. 2.00 11.5 .356 .356 .019 .0029 2.85    7803271041. 75. 1.38 13.3 .305 .305 .043 .0076 1.76

                                   BREAKWATER  4

7801191338. 74. 2.12 13.3 .543 .543 .017 .0030 5.11    7801191346. 74.  .97 15.6 .488 .488 .080 .0169 5.39
7801191354. 74. 2.03 16.1 .495 .495 .018 .0040 4.56    7801191404. 74. 1.53 15.6 .484 .484 .032 .0068 6.05
7801191410. 74. 1.44 14.6 .501 .501 .036 .0072 7.54    7801240808. 60. 2.12 14.7 .226 .226 .014 .0033 5.14
7801240817. 60. 2.23 15.0 .231 .231 .012 .0031 4.98    7801240825. 60. 1.38 17.4 .237 .237 .032 .0093 4.59
7801240834. 60. 1.53 15.0 .193 .193 .026 .0065 5.62    7801240843. 60. 1.44 14.6 .187 .187 .030 .0072 7.26
7801211312. 60. 2.12 14.6 .229 .229 .014 .0033 5.15    7801211320. 60. 2.23 14.8 .228 .228 .012 .0030 4.82
7801211327. 60. 2.03 17.0 .233 .233 .015 .0042 4.37    7801211122. 60. 1.38 15.4 .209 .209 .032 .0083 6.22
7801211339. 60. 1.44 14.6 .188 .188 .029 .0072 7.42    7801211735. 45. 2.12 12.1 .113 .113 .010 .0027 4.46
7801211749. 45. 2.35 14.4 .113 .113 .008 .0030 3.62    7801211755. 45. 1.53 14.9 .084 .084 .020 .0065 8.30
7801211820. 45. 1.30 12.4 .071 .071 .027 .0075 6.53    7801211830. 45. 1.70 12.4 .109 .109 .016 .0044 9.99

                                   BREAKWATER 4W

7801181004. 80. 1.38 17.4 .658 .658 .043 .0093 4.49    7801191004. 85. 1.53 16.7 .755 .755 .037 .0073 6.30
7801191019. 85. 1.82 17.0 .766 .766 .026 .0052 8.64    7801191026. 85. 1.94 15.3 .768 .768 .023 .0041 4.82
7801191041. 85. 1.44 15.2 .786 .786 .042 .0075 9.85    7801180938. 76. 1.30 15.7 .518 .518 .046 .0095 5.24
7801180945. 76. 1.02 16.4 .551 .551 .074 .0161 5.35

                                   BREAKWATER  5

7802010849. 75. 1.88 15.1 .769 .769 .022 .0044 2.13    7802010901. 75. 1.19 16.8 .844 .844 .054 .0121 2.18
7802010912. 75. 1.19 16.7 .846 .846 .054 .0120 2.12    7802010924. 75. 2.46  9.9 .843 .843 .013 .0017 2.50
7802010935. 75. 2.44  9.8 .803 .803 .013 .0017 2.54    7802010947. 75. 1.45  9.6 .825 .825 .036 .0047 2.03
7802010957. 75. 1.45  9.5 .807 .807 .036 .0046 2.03    7802011010. 75. 1.34 17.7 .885 .885 .043 .0101 6.31
7802011021. 75. 1.34 17.8 .898 .898 .043 .0101 6.70    7802011034. 75. 1.26 17.3 .922 .922 .048 .0111 8.90
7802011057. 75. 1.88 15.3 .823 .823 .022 .0044 2.23    7802011107. 75. 1.88 15.3 .826 .826 .022 .0044 2.24
7801310957. 60. 2.04 12.5 .777 .777 .009 .0018 2.15    7801311011. 60. 1.26 15.8 .792 .792 .039 .0102 2.70
7801311023. 60. 1.55 15.2 .815 .815 .025 .0065 3.87    7801311034. 60. 1.97 17.0 .814 .814 .016 .0045 2.76
7801311046. 60. 1.16 13.4 .663 .663 .045 .0102 1.59    7801311058. 60. 2.84 13.1 .713 .713 .008 .0017 1.91
7801311109. 60. 2.04 12.6 .804 .804 .009 .0018 2.19    7801311119. 60. 1.26 16.0 .791 .791 .039 .0103 2.65
7801311131. 60. 1.55 15.3 .815 .815 .025 .0065 3.75    7801311142. 60. 1.97 17.1 .810 .810 .016 .0045 2.74
7801311154. 60. 1.16 13.4 .652 .652 .045 .0102 1.63    7802020832. 45. 2.12 12.3 .842 .842 .010 .0028 4.90
7802020832. 45. 2.12 12.2 .798 .798 .010 .0028 4.77    7802020840. 45. 2.23 14.4 .735 .735 .009 .0030 4.59
7802020847. 45. 2.35 15.8 .685 .685 .008 .0029 3.53    7802020857. 45. 1.53 14.8 .662 .662 .020 .0065 5.71
7802020904. 45. 1.30 12.2 .710 .710 .027 .0074 6.51    7802020952. 45.  .91  8.0 .708 .708 .055 .0099 2.58

                                   BREAKWATER  6

7802071316. 75.  .91 13.3 .677 .677 .092 .0164 5.86    7802071324. 75. 1.30 16.1 .648 .648 .045 .0097 5.23
7802071332. 75. 1.82 10.2 .643 .643 .023 .0050 4.69    7802071339. 75. 1.53 17.5 .934 .934 .033 .0076 5.29
7802071308. 75. 1.44 14.6 .840 .840 .037 .0072 6.31    7802060216. 60. 1.62 14.0 .380 .380 .023 .0054 5.42
7802060225. 60. 1.30 15.1 .403 .403 .036 .0091 5.38    7802060232. 60. 2.03 18.3 .405 .405 .015 .0045 4.87
7802060239. 60. 1.53 15.3 .364 .364 .026 .0067 6.02    7802060246. 60. 1.30 15.0 .342 .342 .036 .0091 8.01
7802081115. 45. 2.12 12.3 .288 .288 .010 .0028 4.54    7802081125. 45. 2.23 16.2 .276 .276 .009 .0033 5.60
7802081134. 45. 1.37 15.6 .268 .268 .024 .0085 4.85    7802081144. 45. 1.53 14.4 .223 .223 .020 .0063 5.05
7802081154. 45. 1.30 12.6 .230 .230 .027 .0076 6.61

                                   BREAKWATER  9

7802221044. 75. 1.23 13.4 .428 .428 .051 .0090 5.46    7802221333. 75. 1.30 15.9 .404 .404 .045 .0096 4.91
7802221341. 75. 2.03 16.3 .431 .431 .019 .0040 4.46    7802221349. 75. 1.53 16.6 .401 .401 .033 .0072 5.96
7802221357. 75. 1.44 14.3 .394 .394 .037 .0070 6.74    7802231016. 75. 1.38 15.8 .364 .364 .043 .0090 2.11
7802231026. 75. 1.45 16.0 .393 .393 .036 .0078 6.02    7802231035. 75. 1.63 17.3 .372 .372 .029 .0066 3.52
7802231055. 75. 3.24  7.1 .555 .555 .007 .0007 4.53    7802240951. 75. 1.33 12.3 .361 .361 .043 .0071 2.40
7802241003. 75. 2.00 11.0 .421 .421 .019 .0028 1.56    7802241013. 75. 1.34 13.3 .417 .417 .043 .0076 1.45
7802271156. 60. 2.75 15.9 .151 .151 .008 .0021 2.09    7802271205. 60. 1.46 16.6 .120 .120 .029 .0079 6.11
7802271214. 60. 1.63 17.2 .136 .136 .023 .0066 3.37    7802281243. 45. 1.60 19.0 .104 .104 .018 .0076 2.10
7802281301. 45. 1.06 21.7 .081 .081 .017 .0080 4.46    7802281310. 45. 3.12  9.0 .217 .217 .005 .0009 2.96
7802281322. 45. 3.32 14.3 .167 .167 .004 .0013 2.98    7802281332. 45. 2.05 16.2 .098 .098 .011 .0039 2.41
7802281342. 45. 3.56 16.3 .147 .147 .004 .0013 3.03

                                   BREAKWATER 10

7803060930. 75. 1.38 16.0 .408 .408 .043 .0091 2.15    7803060939. 75. 1.45 16.2 .447 .447 .036 .0079 6.25
7803060948. 75. 1.72 17.0 .418 .418 .026 .0059 4.15    7803060957. 75. 2.64 10.3 .552 .552 .011 .0015 4.59
7803061006. 75. 2.81  6.7 .625 .625 .011 .0010 3.67    7803061016. 75. 1.33 12.5 .405 .405 .043 .0072 2.37
7803061025. 75. 2.00 11.0 .475 .475 .019 .0028 1.79    7803061035. 75. 1.34 13.0 .458 .458 .043 .0074 1.46
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                                   IRREGULAR WAVES
    ID      D(CM) T(S) H(CM) KT    KR D/GT2 H/GT2 OP          ID      D(CM) T(S) H(CM) KT    KR L.GT2 H/GT2 OP

                                   BREAKWATER 10

7803031003. 60. 1.95  2.1 .381 .381 .016 .0006 9.99   7803031051. 60. 1.54 14.6 .229 .229 .026 .0063 2.56
7803031101. 60. 1.51 16.2 .191 .191 .027 .0072 4.44   7803031110. 60. 1.64 16.9 .215 .215 .023 .0064 3.64
7803031120. 60. 3.12  7.4 .305 .305 .006 .0008 3.24   7803031129. 60. 3.32 11.2 .268 .268 .006 .0010 3.50
7803031139. 60. 1.14 12.2 .190 .190 .047 .0096 2.35   7803031148. 60. 3.66 11.3 .232 .232 .005 .0009 2.12
7803031158. 60. 3.24 14.4 .286 .286 .006 .0014 2.69   7803020021. 45. 2.21 15.4 .090 .090 .009 .0032 2.38
7803021413. 45. 1.36 15.8 .062 .062 .025 .0087 4.61   7803021422. 45. 1.67 16.1 .082 .082 .016 .0059 4.17
7803021431. 45. 3.12  6.7 .213 .213 .005 .0007 2.41   7803021440. 45. 3.28 10.9 .155 .155 .004 .0010 4.03
7803021450. 45. 2.21 12.5 .098 .098 .009 .0026 2.50   7803021459. 45. 3.46 12.3 .126 .126 .004 .0010 2.64

                                   BREAKWATER 13

7804211247. 60. 1.95 17.8 .724 .724 .016 .0048 2.50   7804211256. 60. 1.52 19.2 .773 .773 .026 .0085 3.98
7804211305. 60. 1.83 20.0 .755 .755 .018 .0061 3.46   7804211315. 60. 2.84  7.8 .767 .767 .008 .0010 3.23
7804211334. 60. 1.82 14.0 .713 .713 .018 .0043 2.70   7804211343. 60. 4.20 16.2 .608 .608 .003 .0009 1.76
7804211353. 60. 4.34 20.0 .606 .606 .003 .0011 1.83

                                   BREAKWATER 14

7804260816. 35. 2.10 15.6 .301 .301 .008 .0036 2.49   7804260829. 35. 1.55 16.6 .261 .261 .015 .0071 3.73
7804260852. 35. 2.84  6.8 .357 .357 .004 .0009 5.67   7804260904. 35. 2.78  9.9 .352 .352 .005 .0013 4.66
7804260916. 35. 2.10 12.5 .266 .266 .008 .0029 2.33   7804260928. 35. 4.20 14.0 .330 .330 .002 .0008 1.81
7804260940. 35. 4.00 18.4 .297 .297 .002 .0012 2.03

                                   BREAKWATER 15

7805010809. 50. 1.23 16.3 .590 .590 .034 .0110 2.00   7805010830. 50. 1.45 17.2 .652 .652 .024 .0083 3.93
7805010844. 50. 1.57 17.8 .653 .653 .021 .0074 3.24   7805031228. 35. 1.55 17.1 .370 .370 .015 .0073 3.72
7805031237. 35. 1.63 18.2 .340 .340 .013 .0070 3.25   7805031247. 35. 2.81  6.4 .510 .510 .005 .0008 3.06
7805031256. 35. 2.61  9.7 .476 .476 .005 .0015 4.19   7805031306. 35. 2.08 12.3 .383 .383 .008 .0029 2.10
7805031315. 35. 4.49 12.5 .362 .362 .002 .0006 1.37   7805031326. 35. 4.74 17.3 .361 .361 .002 .0008 1.99
7805031334. 35. 2.10 16.3 .355 .355 .008 .0038 2.29   7805081115. 20. 2.29 14.8 .169 .169 .004 .0028 2.26
7805081126. 20. 1.40 16.3 .154 .154 .010 .0085 4.17   7805081134. 20. 1.65 16.3 .157 .157 .007 .0061 3.89
7805081143. 20. 3.12  6.7 .280 .280 .002 .0007 2.86   7805081153. 20. 3.24 10.4 .240 .240 .002 .0010 2.94
7805081204. 20. 2.29 12.3 .182 .182 .004 .0024 2.32   7805081215. 20. 3.56 11.7 .196 .196 .002 .0009 1.69

                                   BREAKWATER 15W

7804280947. 35. 2.10 15.2 .374 .374 .008 .0035 2.42   7804281003. 35. 1.45 16.1 .347 .347 .017 .0078 3.74
7804281014. 35. 1.58 17.2 .325 .325 .014 .0070 3.13   7804281024. 35. 2.84  6.3 .488 .488 .004 .0008 5.21
7804281033. 35. 2.78  9.5 .444 .444 .005 .0013 4.29   7804281043. 35. 2.10 11.7 .356 .356 .008 .0027 2.21
7804281053. 35. 4.20 13.1 .383 .383 .002 .0008 1.92   7804281104. 35. 4.00 16.9 .323 .323 .002 .0011 2.05

                                   BREAKWATER 16

7806300828. 45. 2.03 16.2 .501 .501 .011 .0040 2.44   7806300838. 45. 2.03 16.5 .500 .500 .011 .0041 2.40
7806300847. 45. 1.55 17.3 .517 .517 .019 .0073 4.16   7806300857. 45. 1.55 17.7 .515 .515 .019 .0075 3.93
7806300906. 45. 1.55 17.3 .511 .511 .019 .0073 4.05   7806300917. 45. 1.58 18.4 .496 .496 .018 .0075 3.26
7806300927. 45. 1.58 18.4 .496 .496 .018 .0075 3.26   7806300936. 45. 1.64 18.6 .505 .505 .017 .0071 3.29
7806300948. 45. 3.05  6.3 .655 .655 .005 .0007 3.62   7806301001. 45. 3.05  6.3 .651 .651 .005 .0007 3.71
7806301010. 45. 3.05  6.3 .654 .654 .005 .0007 3.72   7806301020. 45. 2.72  9.8 .589 .589 .006 .0014 3.54
7806301029. 45. 2.75  9.8 .599 .599 .006 .0013 3.56   7806301038. 45. 2.75  9.8 .614 .614 .006 .0013 3.73
7806301048. 45. 1.43 12.9 .504 .504 .022 .0064 2.34   7806301057. 45. 1.43 13.2 .486 .486 .022 .0066 2.29
7806301120. 45. 4.27 12.8 .497 .497 .005 .0007 1.36   7806301130. 45. 1.72 17.9 .466 .466 .016 .0062 4.71
7806301140. 45. 4.27 13.0 .524 .524 .003 .0007 1.32   7806301152. 45. 4.20 13.2 .476 .476 .003 .0008 1.35
7806301202. 45. 3.88 18.1 .500 .500 .003 .0012 2.63   7806301211. 45. 3.88 18.0 .491 .491 .003 .0012 2.83
7806301221. 45. 4.00 18.7 .498 .498 .003 .0012 2.49   7806261248. 40. 2.75 15.4 .419 .419 .005 .0021 2.40
7806261300. 40. 2.75 15.3 .406 .406 .005 .0021 2.35   7806261310. 40. 2.75 15.6 .414 .414 .005 .0021 2.26
7806261321. 40. 1.48 16.3 .399 .399 .019 .0076 4.12   7806261330. 40. 1.40 16.5 .393 .393 .021 .0086 3.93
7806261339. 40. 1.40 16.4 .393 .393 .021 .0085 3.99   7806261349. 40. 1.58 17.6 .416 .416 .016 .0072 3.15
7806270809. 40. 1.58 17.9 .407 .407 .016 .0073 3.20   7806270827. 40. 2.88  6.2 .578 .578 .005 .0008 3.98
7806270845. 40. 2.88  6.2 .583 .583 .005 .0008 3.92   7806270854. 40. 2.88  6.3 .587 .587 .005 .0008 3.90
7806270904. 40. 3.16  9.4 .519 .519 .004 .0010 5.53   7806270913. 40. 2.75  9.5 .512 .512 .005 .0013 4.10
7806270922. 40. 2.75  9.5 .510 .510 .005 .0013 4.10   7806270931. 40. 1.14 12.9 .388 .388 .031 .0101 2.38
7806270940. 40. 1.14 12.8 .391 .391 .031 .0101 2.36   7806270949. 40. 1.14 12.8 .388 .388 .031 .0101 2.37
7806270959. 40. 4.20 14.1 .439 .439 .002 .0008 1.78   7806271007. 40. 4.20 14.3 .428 .428 .002 .0008 1.79
7806271016. 40. 4.13 14.2 .443 .443 .002 .0008 1.97   7806271026. 40. 4.00 17.9 .400 .400 .003 .0011 2.13
7806271035. 40. 4.00 17.9 .388 .388 .003 .0011 2.12   7806271043. 40. 4.00 17.9 .390 .390 .003 .0011 2.14
7806271141. 40. 2.75 14.3 .420 .420 .005 .0019 2.13   7806271150. 40. 2.75 14.5 .412 .412 .005 .0020 2.09
7806271158. 40. 2.75 14.5 .412 .412 .005 .0020 2.09   7806271208. 40. 1.40 15.6 .405 .405 .021 .0081 3.69
7806271216. 40. 1.40 15.6 .406 .406 .021 .0081 3.69   7806271225. 40. 1.40 15.5 .401 .401 .021 .0081 3.73
7806271235. 40. 1.58 16.4 .412 .412 .016 .0067 2.97   7806271245. 40. 1.58 16.5 .401 .401 .016 .0067 2.91
7806271254. 40. 1.58 16.8 .411 .411 .016 .0069 3.21   7806271304. 40. 2.69 14.3 .500 .500 .006 .0020 4.39
7806271313. 40. 2.84  8.7 .547 .547 .005 .0011 5.11   7806271322. 40. 2.75  8.3 .547 .547 .005 .0011 4.14
7806271332. 40. 2.72  5.6 .607 .607 .006 .0008 4.39   7806271341. 40. 2.72  5.6 .608 .608 .006 .0008 4.39
7806271349. 40. 2.72  5.6 .603 .603 .006 .0008 4.31   7806271359. 40. 1.43 11.4 .410 .410 .020 .0057 2.23
7806280037. 40. 1.20 11.6 .357 .357 .028 .0082 2.31   7806280048. 40. 1.14 11.7 .387 .387 .031 .0092 2.22
7806280115. 40. 3.51 12.0 .431 .431 .003 .0010 1.27   7806280123. 40. 3.51 11.9 .431 .431 .003 .0010 1.27
7806280132. 40. 3.51 12.0 .430 .430 .003 .0010 1.27   7806280142. 40. 4.27 15.7 .474 .474 .002 .0009 1.40
7806280205. 40. 4.20 16.0 .430 .430 .002 .0009 1.50   7806280213. 40. 4.27 15.9 .430 .430 .002 .0009 1.42
7806260805. 35. 4.20 12.5 .372 .372 .002 .0007 1.92   7806260815. 35. 4.20 12.4 .371 .371 .002 .0007 1.96
7806260824. 35. 4.20 12.3 .369 .369 .002 .0007 1.97   7806260833. 35. 4.00 16.1 .308 .308 .002 .0010 2.01
7806260842. 35. 4.00 16.0 .306 .306 .002 .0010 2.00   7806260851. 35. 4.00 16.2 .318 .318 .002 .0010 2.00
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IRREGULAR WAVES

BREAKWATER 16

ID	D(CM)	T(S)	H(CM)	KT	KR	D/GT2	H/GT2	QP	ID	D(CM)	T(S)	H(CM)	KT	KR	D/GT2	H/GT2	QP
7806260900.	35.	2.08	17.1	.313	.313	.008	.0040	2.31	7806260910.	35.	1.54	17.3	.302	.302	.015	.0074	2.20
7806260918.	35.	2.10	17.3	.312	.312	.008	.0040	2.32	7806260928.	35.	1.55	17.9	.295	.295	.015	.0076	4.08
7806260937.	35.	1.55	17.9	.294	.294	.015	.0076	4.02	7806260946.	35.	1.55	17.9	.297	.297	.015	.0076	3.96
7806261004.	35.	1.58	19.2	.292	.292	.014	.0078	3.26	7806261013.	35.	1.58	19.2	.288	.288	.014	.0078	3.18
7806261023.	35.	2.88	7.1	.474	.474	.004	.0009	4.95	7806261032.	35.	2.84	7.1	.478	.478	.004	.0009	4.86
7806261040.	35.	2.84	7.2	.470	.470	.004	.0009	4.79	7806261050.	35.	2.84	10.2	.407	.407	.004	.0013	2.97
7806261059.	35.	2.84	10.2	.407	.407	.004	.0013	2.98	7806261108.	35.	2.84	10.2	.409	.409	.004	.0013	3.03
7806261118.	35.	1.25	13.6	.319	.319	.023	.0089	2.30	7806261126.	35.	1.25	13.5	.333	.333	.023	.0088	2.29
7806261135.	35.	1.73	13.5	.326	.326	.012	.0046	2.50	7806261147.	35.	4.20	13.9	.384	.384	.002	.0008	1.45
7806261156.	35.	4.20	14.0	.368	.368	.002	.0008	1.69	7806261206.	35.	4.20	13.8	.384	.384	.002	.0008	1.45
7806150912.	35.	2.10	15.1	.261	.261	.008	.0035	2.41	7806150924.	35.	2.10	15.1	.270	.270	.008	.0035	2.42
7806151010.	35.	2.10	15.3	.263	.263	.008	.0035	2.37	7806151024.	35.	2.10	15.2	.261	.261	.008	.0035	2.40
7806151142.	35.	1.55	16.5	.235	.235	.015	.0070	3.78	7806151153.	35.	1.55	16.6	.235	.235	.015	.0071	3.78
7806151216.	35.	1.55	16.5	.229	.229	.015	.0070	3.83	7806151227.	35.	1.58	17.4	.242	.242	.014	.0071	3.10
7806151239.	35.	1.59	17.3	.244	.244	.014	.0071	3.12	7806151324.	35.	1.58	17.4	.242	.242	.014	.0071	3.10
7806151335.	35.	2.84	6.2	.385	.385	.004	.0008	4.47	7806151355.	35.	2.84	6.2	.380	.380	.004	.0008	4.63
7806151407.	35.	2.78	9.4	.367	.367	.005	.0012	4.08	7806230718.	35.	2.78	8.1	.474	.474	.005	.0011	4.17
7806230728.	35.	2.78	8.1	.474	.474	.005	.0011	4.18	7806230737.	35.	2.78	8.1	.474	.474	.005	.0011	4.21
7806230747.	35.	2.78	5.4	.511	.511	.005	.0007	4.63	7806230755.	35.	2.78	5.5	.510	.510	.005	.0007	4.51
7806230804.	35.	2.78	5.4	.514	.514	.005	.0007	4.61	7806230814.	35.	1.33	10.6	.336	.336	.020	.0061	2.15
7806230822.	35.	1.33	10.6	.326	.326	.020	.0061	2.15	7806230831.	35.	1.25	10.6	.331	.331	.023	.0069	2.15
7806230903.	35.	4.57	10.8	.386	.386	.002	.0005	1.32	7806230932.	35.	4.27	14.6	.358	.358	.002	.0008	1.51
7806230941.	35.	4.27	14.6	.356	.356	.002	.0008	1.52	7806230949.	35.	4.27	14.6	.360	.360	.002	.0008	1.51
7806230959.	35.	2.10	15.1	.324	.324	.008	.0035	2.26	7806231008.	35.	2.10	15.1	.335	.335	.008	.0035	2.38
7806231017.	35.	2.10	15.1	.330	.330	.008	.0035	2.38	7806231026.	35.	1.55	16.1	.292	.292	.015	.0068	3.87
7806231035.	35.	1.55	16.5	.291	.291	.015	.0070	3.77	7806231043.	35.	1.55	16.4	.289	.289	.015	.0070	3.80
7806231054.	35.	1.58	17.1	.291	.291	.014	.0070	3.07	7806231110.	35.	1.58	17.2	.293	.293	.014	.0070	3.09
7806231119.	35.	1.58	17.2	.295	.295	.014	.0070	3.08	7806231132.	35.	2.84	6.1	.470	.470	.004	.0008	4.68
7806231141.	35.	2.84	6.1	.468	.468	.004	.0008	4.61	7806231150.	35.	2.84	6.1	.469	.469	.004	.0008	4.72
7806231159.	35.	2.78	9.3	.455	.455	.005	.0012	4.15	7806231208.	35.	2.78	9.3	.459	.459	.005	.0012	4.57
7806231217.	35.	2.78	9.3	.456	.456	.005	.0012	4.56	7806231226.	35.	2.78	9.3	.453	.453	.005	.0012	4.14
7806231245.	35.	2.78	9.3	.454	.454	.005	.0012	4.17	7806231255.	35.	1.58	17.2	.298	.298	.014	.0070	3.05
7806231303.	35.	1.58	17.0	.327	.327	.014	.0069	3.10	7806231314.	35.	1.58	17.3	.296	.296	.014	.0071	3.09
7806231337.	35.	1.25	11.9	.303	.303	.023	.0078	2.19	7806231347.	35.	2.10	11.8	.319	.319	.008	.0027	2.20
7806231356.	35.	2.10	11.9	.311	.311	.008	.0028	2.17	7806231408.	35.	4.20	12.8	.370	.370	.002	.0007	1.98
7806160801.	35.	2.78	9.5	.367	.367	.005	.0013	4.16	7806160815.	35.	2.81	9.5	.355	.355	.005	.0012	4.17
7806160838.	35.	2.10	12.0	.259	.259	.008	.0028	2.20	7806160848.	35.	2.10	12.1	.252	.252	.008	.0028	2.18
7806160858.	35.	2.10	12.1	.249	.249	.008	.0028	2.20	7806160909.	35.	4.20	13.0	.297	.297	.002	.0008	2.03
7806160919.	35.	4.20	12.9	.298	.298	.002	.0007	2.00	7806160928.	35.	4.20	13.0	.290	.290	.002	.0008	2.02
7806160939.	35.	4.00	16.9	.247	.247	.002	.0011	2.04	7806160949.	35.	4.00	16.9	.247	.247	.002	.0011	2.06
7806161000.	35.	4.00	16.9	.244	.244	.002	.0011	2.04	7806161332.	30.	2.15	16.1	.199	.199	.007	.0036	2.52
7806161342.	30.	1.54	17.1	.190	.190	.013	.0074	2.46	7806161352.	30.	1.54	17.2	.190	.190	.013	.0074	2.37
7806161402.	30.	1.55	18.0	.166	.166	.013	.0076	4.25	7806161412.	30.	1.55	18.6	.166	.166	.013	.0079	4.11
7806161421.	30.	1.55	18.5	.166	.166	.013	.0079	4.17	7806161430.	30.	1.58	18.8	.178	.178	.012	.0077	3.28
7806161439.	30.	1.64	18.6	.183	.183	.011	.0071	3.27	7806161448.	30.	1.58	18.7	.180	.180	.012	.0076	3.22
7806190957.	30.	3.05	7.1	.392	.392	.003	.0008	5.60	7806191008.	30.	3.05	7.1	.393	.393	.003	.0008	5.63
7806191017.	30.	3.05	7.1	.394	.394	.003	.0008	5.72	7806191028.	30.	2.84	9.9	.337	.337	.004	.0013	2.58
7806191037.	30.	2.84	9.9	.336	.336	.004	.0013	2.57	7806191046.	30.	2.84	10.0	.329	.329	.004	.0013	2.60
7806191056.	30.	2.13	12.7	.262	.262	.007	.0029	2.26	7806191104.	30.	2.13	13.0	.258	.258	.007	.0029	2.30
7806191113.	30.	2.13	12.9	.260	.260	.007	.0029	2.29	7806191123.	30.	4.20	12.8	.300	.300	.002	.0007	1.37
7806191132.	30.	4.20	12.8	.297	.297	.002	.0007	1.34	7806191141.	30.	4.20	12.9	.297	.297	.002	.0007	1.40
7806191212.	25.	1.49	15.4	.175	.175	.011	.0071	2.32	7806191221.	25.	1.49	15.3	.176	.176	.011	.0070	2.36
7806191230.	25.	1.49	15.3	.175	.175	.011	.0070	2.36	7806191239.	25.	1.55	16.4	.162	.162	.011	.0070	4.10
7806191248.	25.	1.55	16.5	.159	.159	.011	.0070	4.15	7806191256.	25.	1.55	16.4	.156	.156	.011	.0070	4.20
7806191305.	25.	2.23	17.1	.178	.178	.005	.0035	2.98	7806191314.	25.	2.23	17.1	.179	.179	.005	.0035	2.91
7806191326.	25.	2.23	17.0	.179	.179	.005	.0035	2.90	7806191335.	25.	3.05	6.7	.326	.326	.003	.0007	5.77
7806191340.	25.	3.05	6.7	.326	.326	.003	.0007	5.77	7806191353.	25.	3.05	6.7	.328	.328	.003	.0007	5.79
7806191402.	25.	3.20	9.5	.280	.280	.002	.0009	2.71	7806200731.	25.	3.20	9.3	.274	.274	.002	.0009	2.78
7806200742.	25.	3.20	9.4	.273	.273	.002	.0009	2.83	7806200752.	25.	3.20	9.3	.273	.273	.002	.0009	2.80
7806200802.	25.	2.21	11.8	.205	.205	.005	.0025	2.23	7806200811.	25.	2.21	11.9	.196	.196	.005	.0025	2.24
7806200821.	25.	2.21	12.0	.196	.196	.005	.0025	2.27	7806200831.	25.	3.76	12.1	.219	.219	.002	.0009	1.39
7806200839.	25.	3.76	12.1	.214	.214	.002	.0009	1.39									

BREAKWATER 17

ID	D(CM)	T(S)	H(CM)	KT	KR	D/GT2	H/GT2	QP	ID	D(CM)	T(S)	H(CM)	KT	KR	D/GT2	H/GT2	QP
7808010845.	50.	1.55	18.4	.278	.278	.021	.0078	4.63	7808010855.	50.	1.55	18.5	.282	.282	.021	.0079	4.63
7808010913.	50.	1.87	19.5	.303	.303	.015	.0057	3.72	7808010922.	50.	1.87	19.6	.296	.296	.015	.0057	3.59
7808010930.	50.	1.87	19.7	.299	.299	.015	.0057	3.66	7808010940.	50.	3.32	7.0	.496	.496	.005	.0006	2.89
7808010948.	50.	3.32	7.0	.502	.502	.005	.0006	2.90	7808010958.	50.	3.32	7.0	.502	.502	.005	.0006	2.89
7808011016.	50.	3.28	10.9	.444	.444	.005	.0010	2.60	7808011224.	50.	3.28	10.9	.445	.445	.005	.0010	2.59
7808011236.	50.	2.46	14.0	.330	.330	.008	.0024	3.00	7808011300.	50.	1.50	14.0	.329	.329	.022	.0060	3.03
7807060919.	50.	2.39	16.3	.338	.338	.009	.0029	2.21	7807060928.	50.	1.55	16.7	.308	.308	.021	.0071	4.20
7807060937.	50.	1.55	16.8	.309	.309	.021	.0071	4.31	7807060947.	50.	1.55	16.8	.306	.306	.021	.0071	4.19
7807061321.	50.	1.35	12.7	.350	.350	.029	.0073	2.76	7807061331.	50.	1.34	15.6	.393	.393	.028	.0089	1.87
7807061340.	50.	1.34	15.4	.395	.395	.028	.0088	1.95	7807061349.	50.	1.34	15.7	.394	.394	.028	.0089	1.91
7807061359.	50.	3.76	21.0	.362	.362	.004	.0015	2.21	7807061407.	50.	3.76	20.9	.368	.368	.004	.0015	2.18
7808210957.	40.	2.56	17.2	.329	.329	.006	.0027	2.88	7808211006.	40.	2.56	17.1	.329	.329	.006	.0027	3.02
7808211149.	40.	2.56	16.5	.337	.337	.006	.0026	2.85	7808211201.	40.	1.36	17.9	.315	.315	.022	.0099	4.44
7808211212.	40.	1.60	15.9	.316	.316	.016	.0063	4.75	7808211230.	40.	1.60	17.7	.317	.317	.016	.0071	4.35
7808211239.	40.	1.57	18.4	.327	.327	.017	.0076	3.37	7808211249.	40.	1.57	19.5	.312	.312	.017	.0081	3.41
7808211258.	40.	1.57	18.3	.327	.327	.017	.0076	3.31	7808211307.	40.	2.84	6.4	.501	.501	.005	.0008	3.04
7808211316.	40.	2.53	6.5	.488	.488	.006	.0010	3.11	7808211325.	40.	2.53	6.6	.483	.483	.006	.0011	3.14
7808211334.	40.	2.56	9.6	.461	.461	.006	.0015	3.13	7808211343.	40.	2.81	9.3	.455	.455	.005	.0012	3.19
7808211352.	40.	2.81	9.3	.455	.455	.005	.0012	3.24	7808221202.	40.	1.97	15.2	.324	.324	.011	.0040	2.88

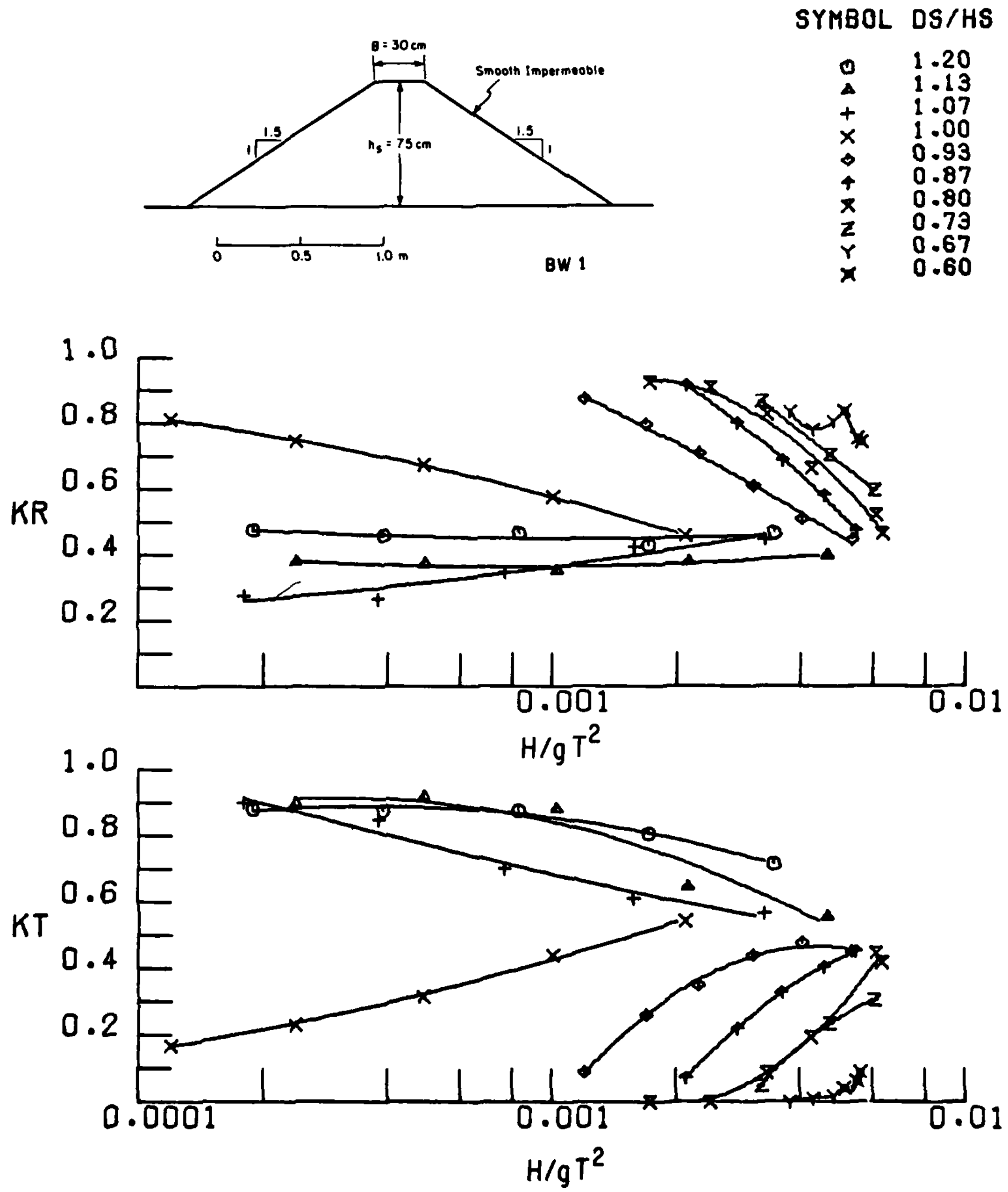
IRREGULAR WAVES

BREAKWATER 17

ID	D(CM)	T(S)	H(CM)	KT	KR	D/GT2	H/GT2	QP	ID	D(CM)	T(S)	H(CM)	KT	KR	D/GT2	H/GT2	QP
7808221211.	40.	1.97	15.6	.317	.317	.011	.0041	2.85	7808221220.	40.	1.97	15.4	.322	.322	.011	.0040	2.88
7808221229.	40.	4.20	17.7	.336	.336	.002	.0010	2.73	7808221238.	40.	4.20	17.6	.340	.340	.002	.0010	2.78
7808221246.	40.	4.20	17.7	.343	.343	.002	.0010	2.80	7808180758.	35.	2.56	14.3	.356	.356	.005	.0022	2.86
7808180820.	35.	2.00	14.1	.353	.353	.009	.0036	2.89	7808180828.	35.	2.00	14.1	.352	.352	.009	.0036	2.86
7808180837.	35.	1.60	15.1	.322	.322	.018	.0079	3.95	7808180847.	35.	1.62	14.9	.319	.319	.014	.0058	3.89
7808180856.	35.	1.62	15.1	.317	.317	.014	.0059	3.85	7808180906.	35.	1.63	15.9	.305	.305	.013	.0061	3.44
7808180915.	35.	1.63	15.6	.307	.307	.013	.0060	3.53	7808180924.	35.	1.63	15.6	.312	.312	.013	.0060	3.46
7808180933.	35.	2.78	7.6	.431	.431	.005	.0010	4.18	7808180942.	35.	2.78	7.6	.432	.432	.005	.0010	4.08
7808180951.	35.	2.78	7.6	.433	.433	.005	.0010	4.12	7808181003.	35.	2.78	5.0	.467	.467	.005	.0007	5.09
7808181011.	35.	2.61	4.9	.458	.458	.005	.0007	6.19	7808181022.	35.	2.61	4.9	.458	.458	.005	.0007	6.28
7808181032.	35.	1.97	10.6	.341	.341	.009	.0028	2.39	7808181040.	35.	1.97	10.6	.345	.345	.009	.0028	2.40
7808181049.	35.	1.97	10.6	.348	.348	.009	.0028	2.43	7808210847.	35.	2.00	12.7	.367	.367	.009	.0032	2.02
7808210850.	35.	2.00	12.5	.368	.368	.009	.0032	2.00	7808210905.	35.	2.00	12.5	.368	.368	.009	.0032	2.03
7808210915.	35.	4.27	16.8	.319	.319	.002	.0009	2.19	7808210924.	35.	4.27	16.7	.320	.320	.002	.0009	2.09
7808210932.	35.	4.27	16.6	.322	.322	.002	.0009	2.07	7807130022.	35.	2.56	15.8	.320	.320	.005	.0025	3.01
7807131245.	35.	2.56	15.7	.319	.319	.005	.0024	2.91	7807131254.	35.	2.56	15.6	.321	.321	.005	.0024	2.92
7807131317.	35.	1.63	17.5	.302	.302	.013	.0067	3.59	7807131328.	35.	1.63	17.4	.296	.296	.013	.0067	3.57
7807131338.	35.	1.63	17.6	.300	.300	.013	.0068	3.59	7807131415.	35.	2.84	5.8	.446	.446	.004	.0007	3.73
7807131433.	35.	2.78	8.9	.380	.380	.005	.0012	4.26	7807131443.	35.	2.78	8.9	.382	.382	.005	.0012	4.17
7807260759.	30.	2.06	17.8	.280	.280	.007	.0043	2.96	7807260912.	30.	2.06	17.9	.279	.279	.007	.0043	2.94
7807260820.	30.	2.06	17.7	.278	.278	.007	.0043	2.97	7807260830.	30.	1.47	18.9	.274	.274	.014	.0089	4.44
7807260839.	30.	1.47	18.0	.275	.275	.014	.0089	4.37	7807260847.	30.	1.47	18.6	.268	.268	.014	.0088	4.45
7807260857.	30.	1.66	19.7	.280	.280	.011	.0073	3.82	7807260905.	30.	1.66	19.6	.281	.281	.011	.0073	3.81
7807260914.	30.	1.66	19.8	.282	.282	.011	.0073	3.91	7807260924.	30.	2.69	7.1	.378	.378	.004	.0010	4.14
7807260932.	30.	2.84	7.0	.379	.379	.004	.0009	4.16	7807260941.	30.	2.69	7.0	.378	.378	.004	.0010	4.23
7807260951.	30.	2.84	9.8	.347	.347	.004	.0012	3.46	7807261001.	30.	2.84	9.8	.349	.349	.004	.0012	3.48
7807261010.	30.	2.84	9.8	.350	.350	.004	.0012	3.46	7807261020.	30.	2.05	14.1	.314	.314	.007	.0034	2.56
7807261028.	30.	2.05	14.6	.292	.292	.007	.0035	2.51	7807261037.	30.	2.05	14.5	.293	.293	.007	.0035	2.48
7807261047.	30.	4.20	15.5	.291	.291	.002	.0009	1.91	7807261056.	30.	4.20	15.6	.281	.281	.002	.0009	2.06
7807261105.	30.	4.20	15.4	.288	.288	.002	.0009	1.89	7807261118.	30.	2.06	14.0	.300	.300	.007	.0034	2.77
7807261127.	30.	2.06	14.1	.300	.300	.007	.0034	2.80	7807261136.	30.	2.06	14.2	.296	.296	.007	.0034	2.71
7807261145.	30.	1.47	15.0	.283	.283	.014	.0071	3.73	7807261154.	30.	1.47	15.0	.287	.287	.014	.0071	3.74
7807261304.	30.	1.47	14.8	.285	.285	.014	.0070	3.34	7807261314.	30.	2.06	16.1	.297	.297	.007	.0039	3.35
7807261323.	30.	2.06	16.1	.295	.295	.007	.0039	3.39	7807261331.	30.	2.06	16.2	.296	.296	.007	.0039	3.38
7807261342.	30.	2.91	7.8	.344	.344	.004	.0009	5.82	7807261351.	30.	2.72	7.8	.351	.351	.004	.0011	4.60
7807261359.	30.	2.69	7.8	.352	.352	.004	.0011	4.64	7807261409.	30.	2.69	5.2	.397	.397	.004	.0007	6.42
7807251020.	30.	1.47	15.7	.295	.295	.014	.0074	4.26	7807251029.	30.	1.47	15.9	.293	.293	.014	.0075	4.20
7807251038.	30.	1.66	17.0	.304	.304	.011	.0063	3.66	7807251046.	30.	1.66	17.1	.302	.302	[illegible]	.0063	3.61
7807251055.	30.	1.66	17.4	.300	.300	.011	.0064	4.19	7807251105.	30.	2.67	5.6	.427	.427	.004	.0005	4.05
7807251214.	30.	2.84	5.7	.422	.422	.004	.0007	4.19	7807251223.	30.	2.84	5.6	.424	.424	.004	.0007	4.12
7807251232.	30.	2.72	8.6	.359	.359	.004	.0012	4.62	7807251242.	30.	2.72	8.6	.358	.358	.004	.0012	4.66
7807251253.	30.	2.72	8.6	.357	.357	.004	.0012	4.65	7807251303.	30.	2.05	12.2	.315	.315	.007	.0030	2.22
7807251312.	30.	2.05	12.5	.309	.309	.007	.0030	2.24	7807251320.	30.	2.05	12.4	.313	.313	.007	.0030	2.19
7807251331.	30.	1.97	14.1	.305	.305	.008	.0037	2.94	7807251341.	30.	1.97	14.1	.299	.299	.008	.0037	2.96
7807251350.	30.	4.20	14.0	.302	.302	.002	.0008	2.71	7807251400.	30.	4.34	17.5	.296	.296	.002	.0009	2.94
7807251409.	30.	4.34	17.5	.300	.300	.002	.0009	2.95	7807251417.	30.	4.34	17.6	.298	.298	.002	.0010	2.93
7807251427.	30.	1.47	16.1	.292	.292	.014	.0076	3.94	7807251435.	30.	1.46	16.1	.293	.293	.014	.0077	4.13
7807251444.	30.	1.46	16.1	.293	.293	.014	.0077	4.12	7807270700.	30.	2.69	4.9	.408	.408	.004	.0007	6.71
7807270710.	30.	2.69	5.0	.410	.410	.004	.0007	6.72	7807270719.	30.	2.05	10.3	.348	.348	.007	.0025	2.39
7807270728.	30.	2.05	10.2	.352	.352	.007	.0025	2.40	7807270737.	30.	2.05	10.4	.350	.350	.007	.0025	2.37
7807270746.	30.	4.57	11.6	.328	.328	.001	.0006	1.48	7807270755.	30.	4.34	10.8	.321	.321	.002	.0006	1.50
7807270814.	30.	4.27	15.3	.301	.301	.002	.0009	2.05	7807270823.	30.	4.27	14.9	.304	.304	.002	.0008	2.12
7807270832.	30.	4.27	15.2	.300	.300	.002	.0009	1.98	7807281253.	25.	1.55	16.8	.266	.266	.011	.0071	4.16
7807281302.	25.	2.23	17.6	.269	.269	.005	.0036	2.94	7807281311.	25.	2.23	17.5	.275	.275	.005	.0036	3.02
7807281403.	25.	4.49	13.2	.293	.293	.001	.0007	1.47	7807281412.	25.	4.41	13.3	.291	.291	.001	.0007	1.64
7807270910.	25.	2.75	13.0	.294	.294	.003	.0018	2.35	7807270924.	25.	2.75	13.1	.293	.293	.003	.0018	2.28
7807270933.	25.	2.75	13.1	.293	.293	.003	.0018	2.33	7807270942.	25.	1.45	13.5	.279	.279	.012	.0066	3.90
7807270951.	25.	1.45	13.8	.284	.284	.012	.0067	3.73	7807271000.	25.	1.45	13.7	.280	.280	.012	.0066	3.85
7807271009.	25.	1.45	14.2	.300	.300	.012	.0069	2.89	7807271018.	25.	1.45	14.4	.298	.298	.012	.0070	2.88
7807271026.	25.	2.23	14.3	.299	.299	.005	.0029	2.92	7807271036.	25.	2.75	7.6	.333	.333	.003	.0010	4.78
7807271045.	25.	2.75	7.5	.333	.333	.003	.0010	4.86	7807271150.	25.	2.75	4.9	.380	.380	.003	.0007	5.12
7807271159.	25.	2.75	5.0	.374	.374	.003	.0007	5.18	7807271207.	25.	2.75	5.0	.380	.380	.003	.0007	5.10
7807271218.	25.	2.75	7.5	.335	.335	.003	.0010	4.76	7807271238.	25.	1.50	9.9	.308	.308	.011	.0045	2.51
7807271247.	25.	1.50	10.1	.318	.318	.011	.0046	2.50	7807271256.	25.	1.50	10.1	.311	.311	.011	.0046	2.50
7807271305.	25.	4.57	10.3	.304	.304	.001	.0005	1.43	7807271315.	25.	4.57	10.3	.305	.305	.001	.0005	1.43
7807271324.	25.	4.57	10.1	.312	.312	.001	.0005	1.44	7807271334.	25.	4.41	14.1	.293	.293	.001	.0007	1.72
7807271343.	25.	4.41	14.1	.295	.295	.001	.0007	1.74	7807271351.	25.	4.27	14.1	.297	.297	.001	.0008	1.72
7808221305.	20.	1.54	13.5	.279	.279	.009	.0058	3.97	7808221314.	20.	1.54	13.8	.275	.275	.009	.0059	4.01
7808221323.	20.	1.55	14.0	.275	.275	.008	.0059	4.06	7808221333.	20.	1.52	14.4	.284	.284	.009	.0064	3.04
7808221342.	20.	1.53	14.4	.287	.287	.009	.0063	2.95	7808221350.	20.	1.53	14.5	.290	.290	.009	.0063	2.97
7808221359.	20.	3.05	5.6	.414	.414	.002	.0006	5.67	7808230743.	20.	3.05	5.6	.494	.494	.002	.0006	5.26
7808230751.	20.	3.05	5.5	.501	.501	.002	.0006	5.61	7808230811.	20.	3.20	8.1	.408	.408	.002	.0008	3.46
7808230820.	20.	3.16	8.1	.381	.381	.002	.0008	5.73	7808230828.	20.	3.24	8.0	.421	.421	.002	.0008	3.19
7808290906.	20.	1.91	10.4	.316	.316	.006	.0029	1.52	7808290755.	20.	1.91	10.4	.266	.266	.006	.0029	1.55
7808290804.	20.	1.97	10.5	.286	.286	.005	.0028	1.54	7808290814.	20.	2.21	14.1	.274	.274	.004	.0029	1.99
7808290823.	20.	2.21	14.1	.277	.277	.004	.0029	2.01	7808290831.	20.	2.21	14.6	.274	.274	.004	.0031	2.00
7808291155.	20.	2.29	11.1	.351	.351	.004	.0022	2.24	7808291204.	20.	2.29	11.0	.352	.352	.004	.0021	2.27
7808291213.	20.	2.29	11.0	.347	.347	.004	.0021	2.29	7808291222.	20.	1.54	12.4	.312	.312	.009	.0055	3.94
7808291231.	20.	1.54	12.3	.310	.310	.009	.0053	3.70	7808291239.	20.	1.54	12.4	.308	.308	.009	.0053	3.74
7808291245.	20.	2.23	12.9	.326	.326	.004	.0026	2.90	7808291257.	20.	2.23	13.0	.325	.325	.004	.0027	2.90
7808291305.	20.	2.23	12.8	.327	.327	.004	.0026	2.95	7808291315.	20.	3.20	7.2	.383	.383	.002	.0007	3.56
7808291323.	20.	3.20	7.2	.383	.383	.002	.0007	3.54	7808291332.	20.	3.20	7.2	.377	.377	.002	.0007	3.75
7808291344.	20.	3.16	4.8	.441	.441	.002	.0005	4.64	7808291352.	20.	3.16	4.8	.437	.437	.002	.0005	4.86
7808291401.	20.	3.16	4.8	.443	.443	.002	.0005	4.56	7808291411.	20.	2.29	9.2	.352	.352	.004	.0018	2.18
7808291429.	20.	4.57	8.7	.330	.330	.001	.0004	1.40	7808291437.	20.	4.57	8.7	.326	.326	.001	.0004	1.39
7808291447.	20.	2.27	12.1	.292	.292	.004	.0024	1.72	7808291456.	20.	2.27	12.1	.296	.296	.004	.0024	1.70

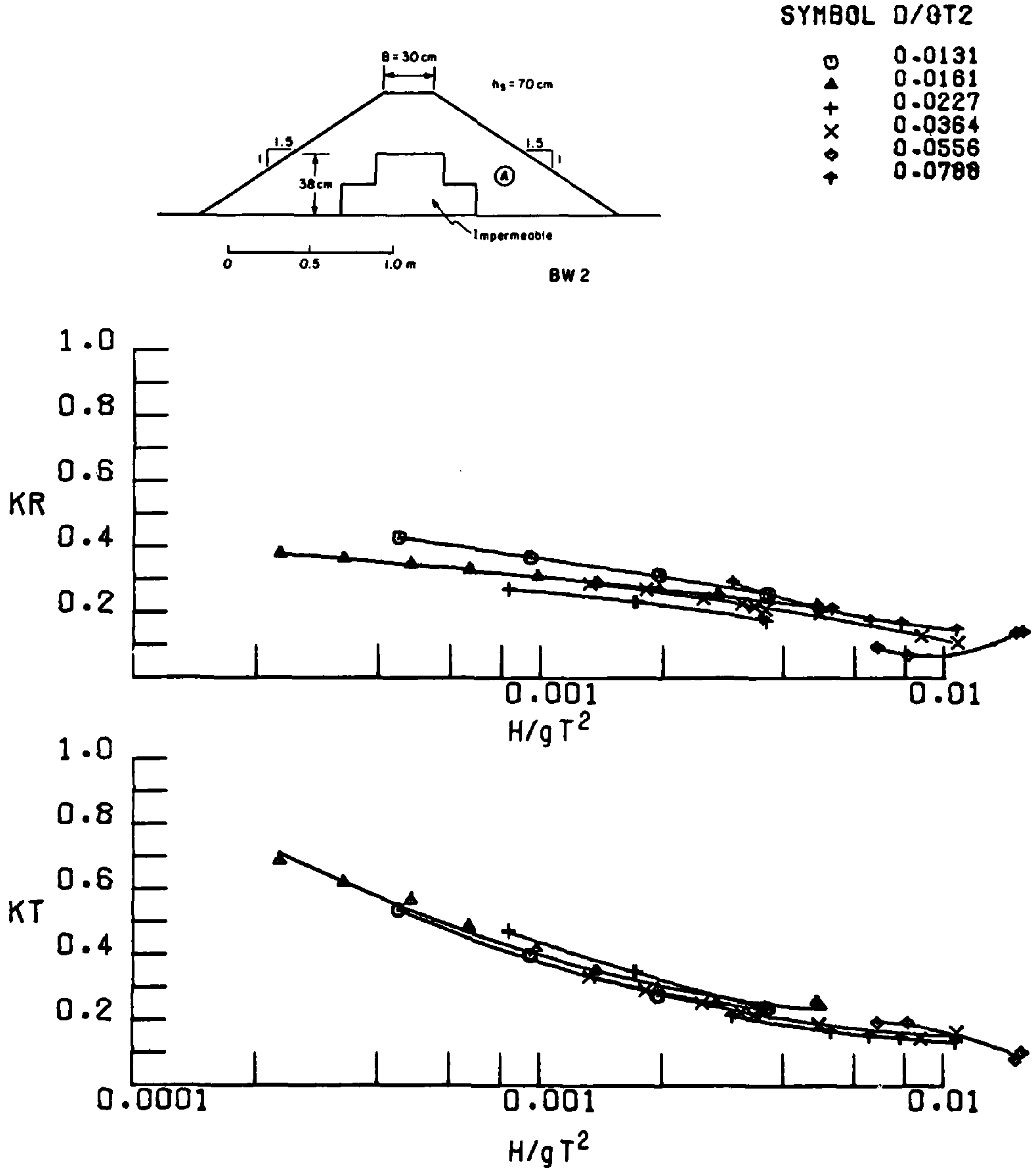
APPENDIX E

TEST RESULTS (GRAPHICAL FORM)



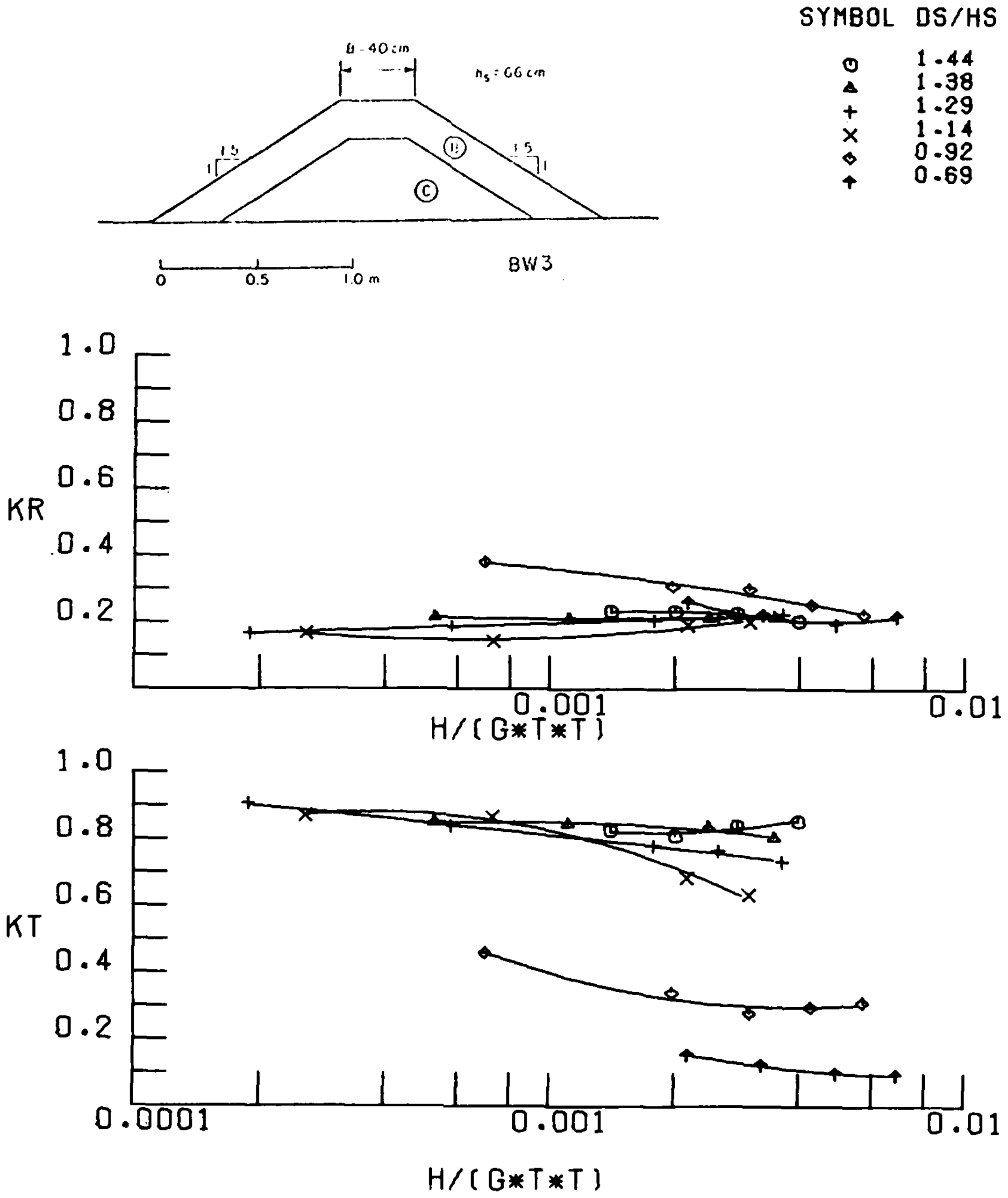
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 1 D/(GT2)=0.016



WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 2 DS/HS= 0.87



WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 3 D/(GT2)=0.016

AD-A089 603 COASTAL ENGINEERING RESEARCH CENTER FORT BELVOIR VA F/G 8/3
TWO-DIMENSIONAL TESTS OF WAVE TRANSMISSION AND REFLECTION CHARA--ETC(U)
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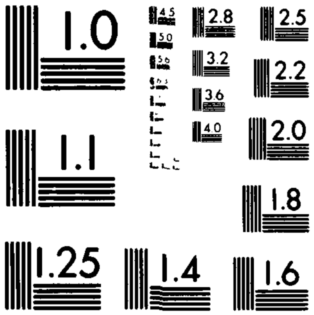
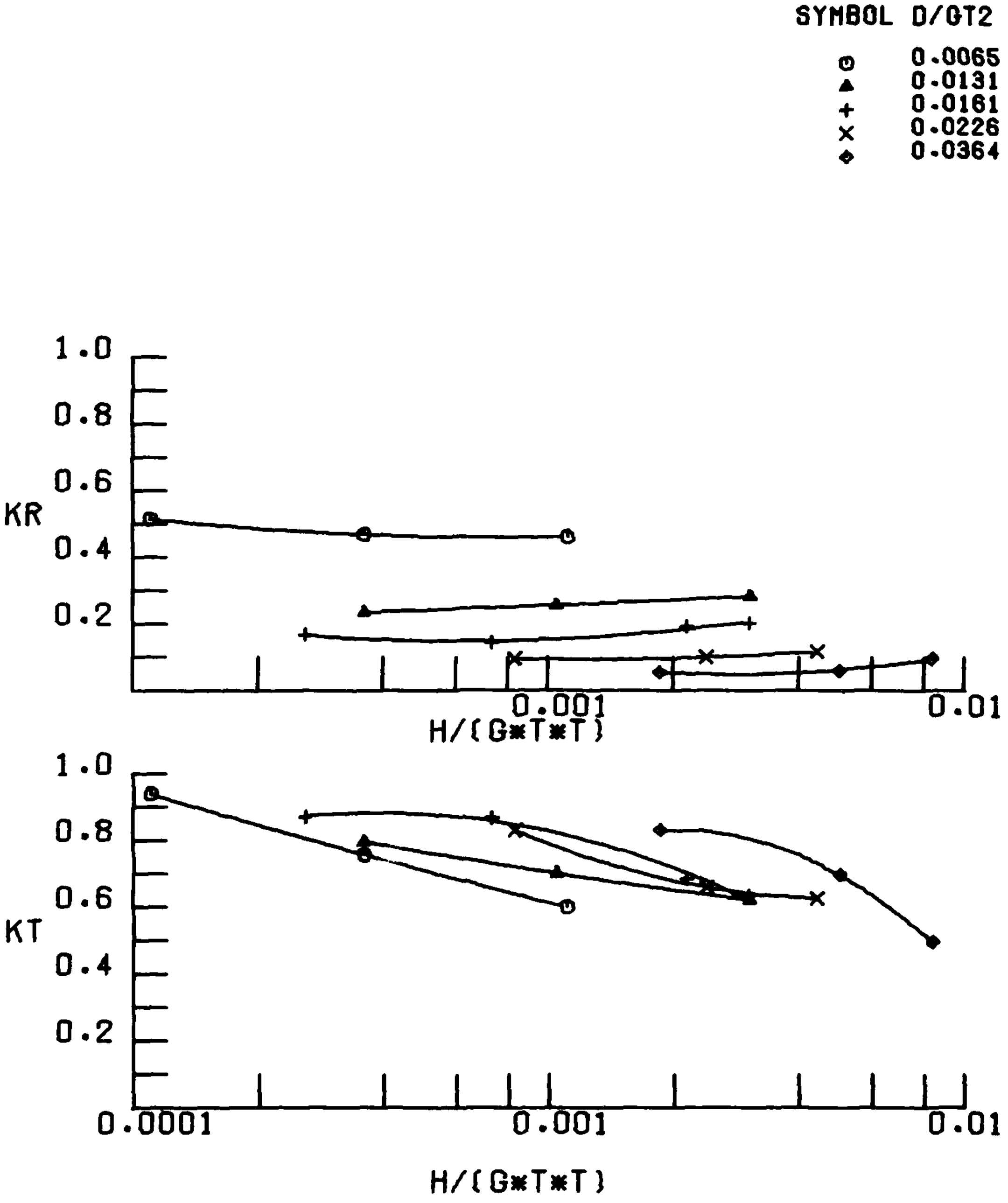


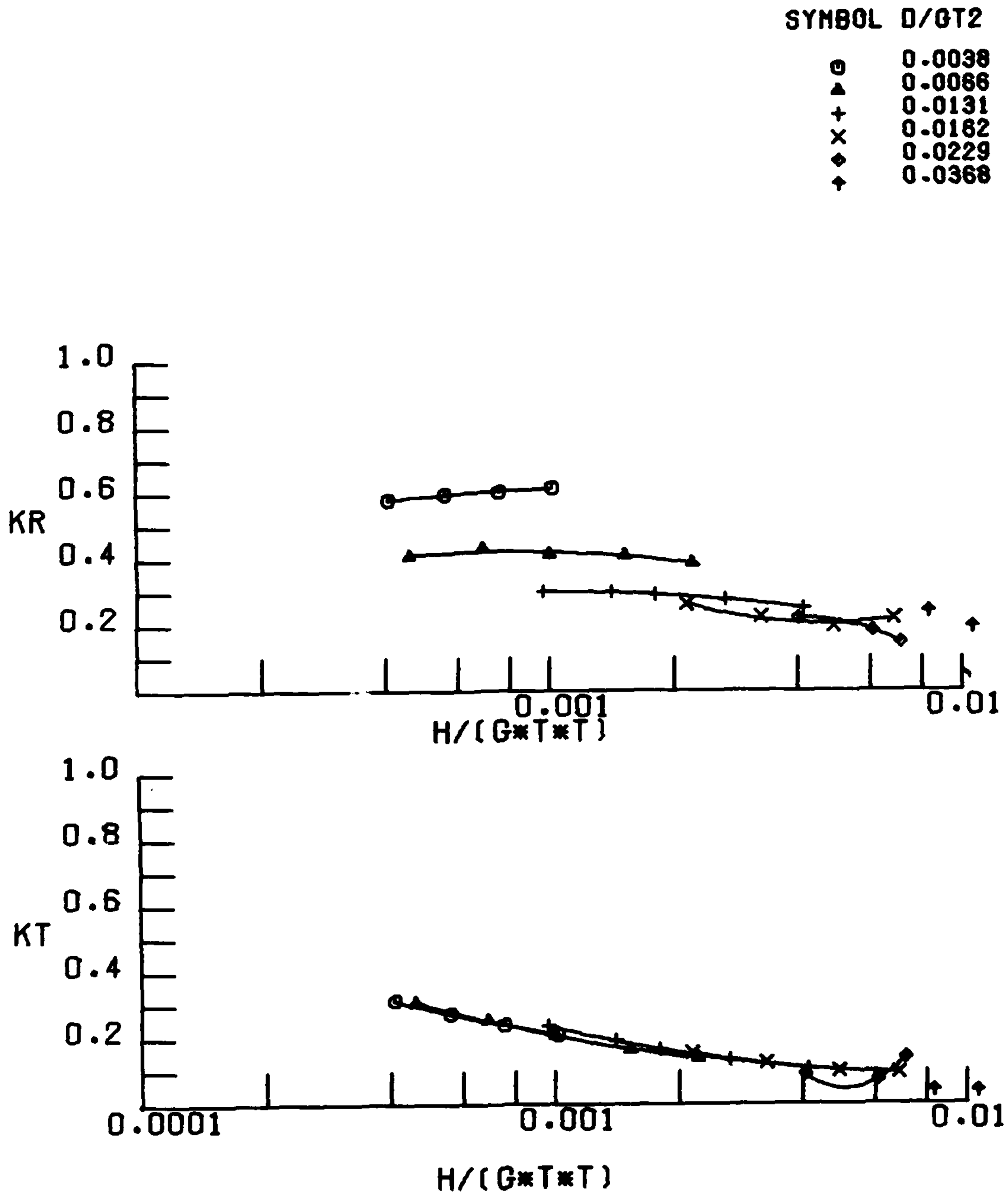
MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU



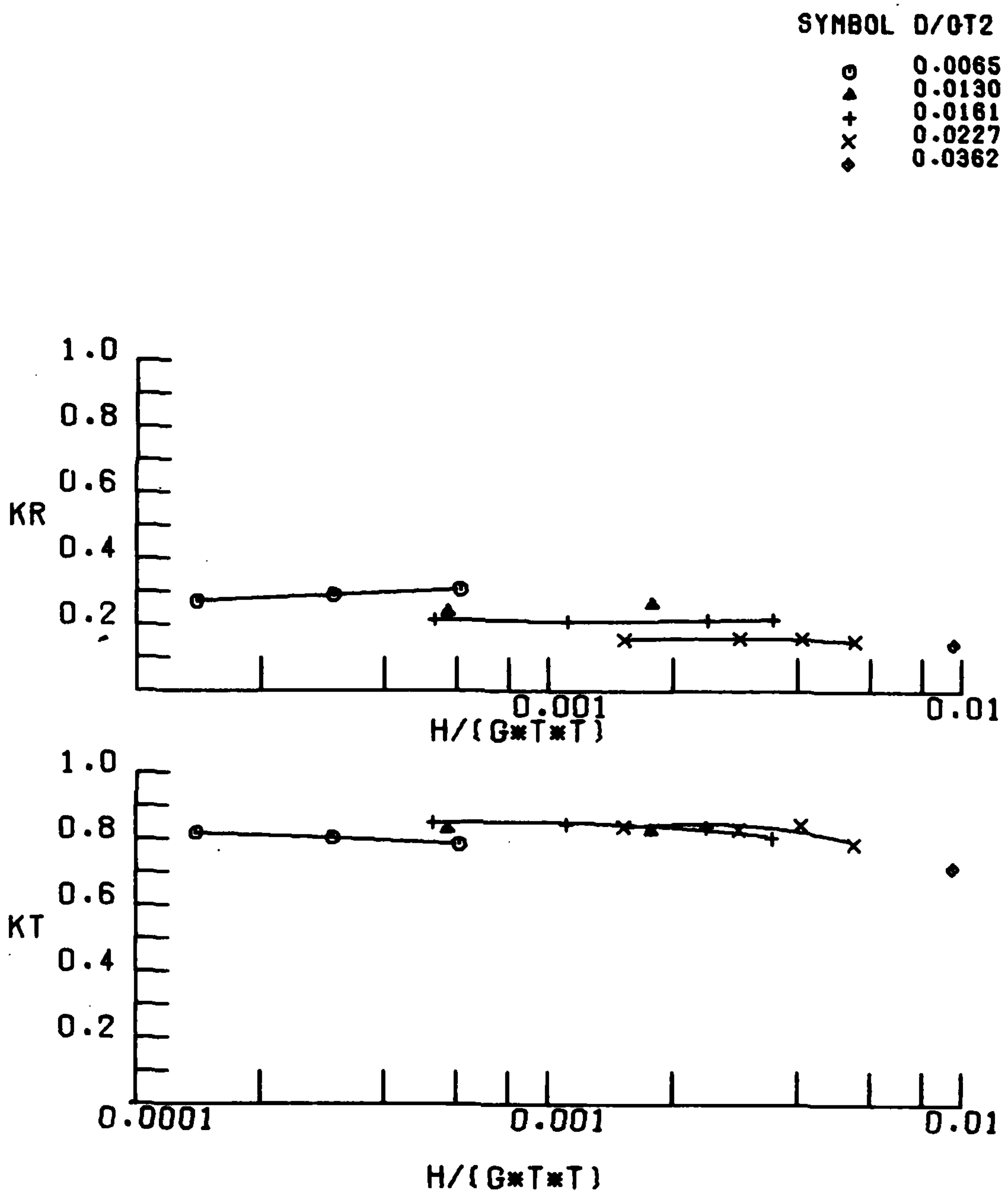
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 3 DS/HS= 1.14



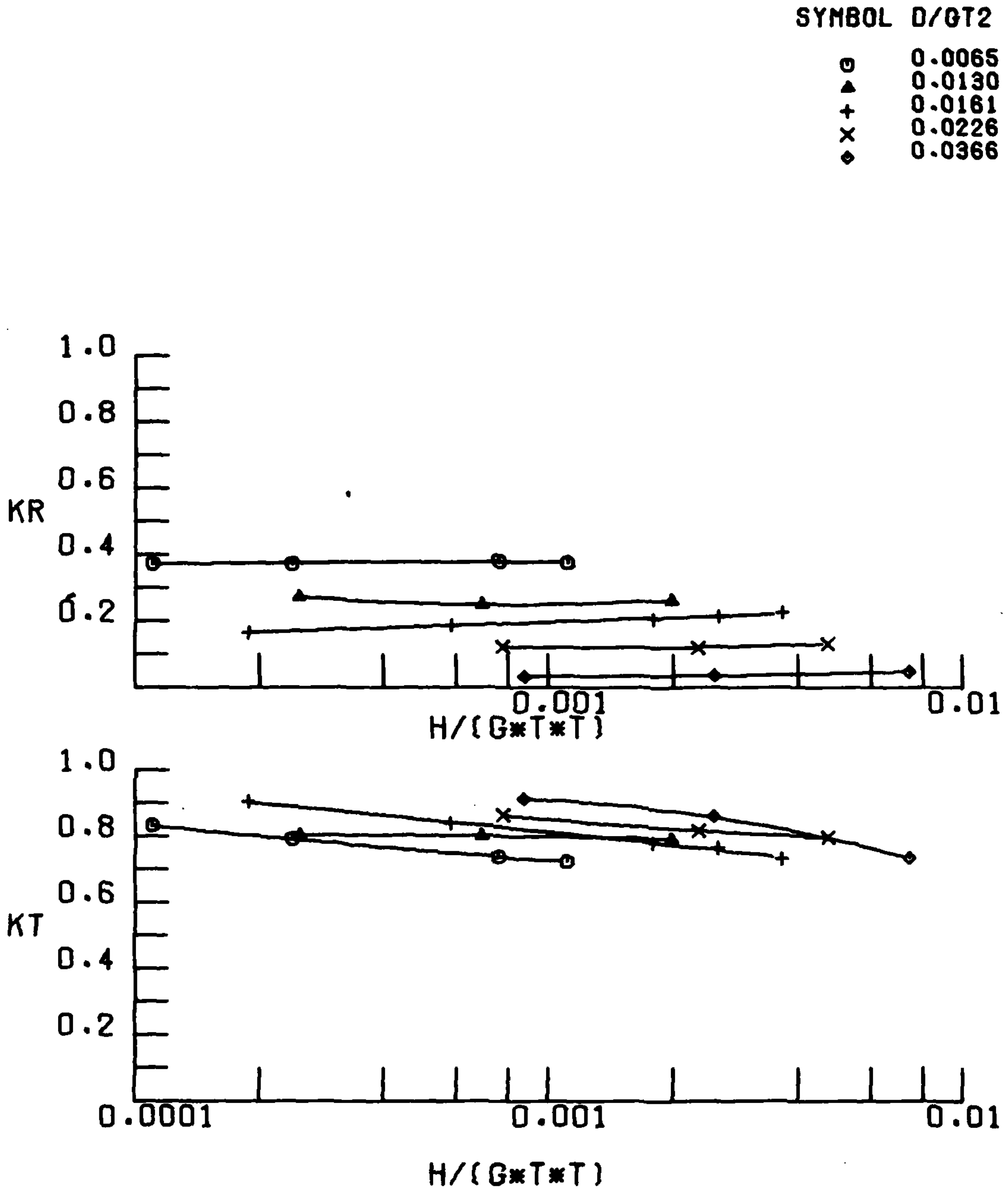
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 3 DS/HS= 0.69



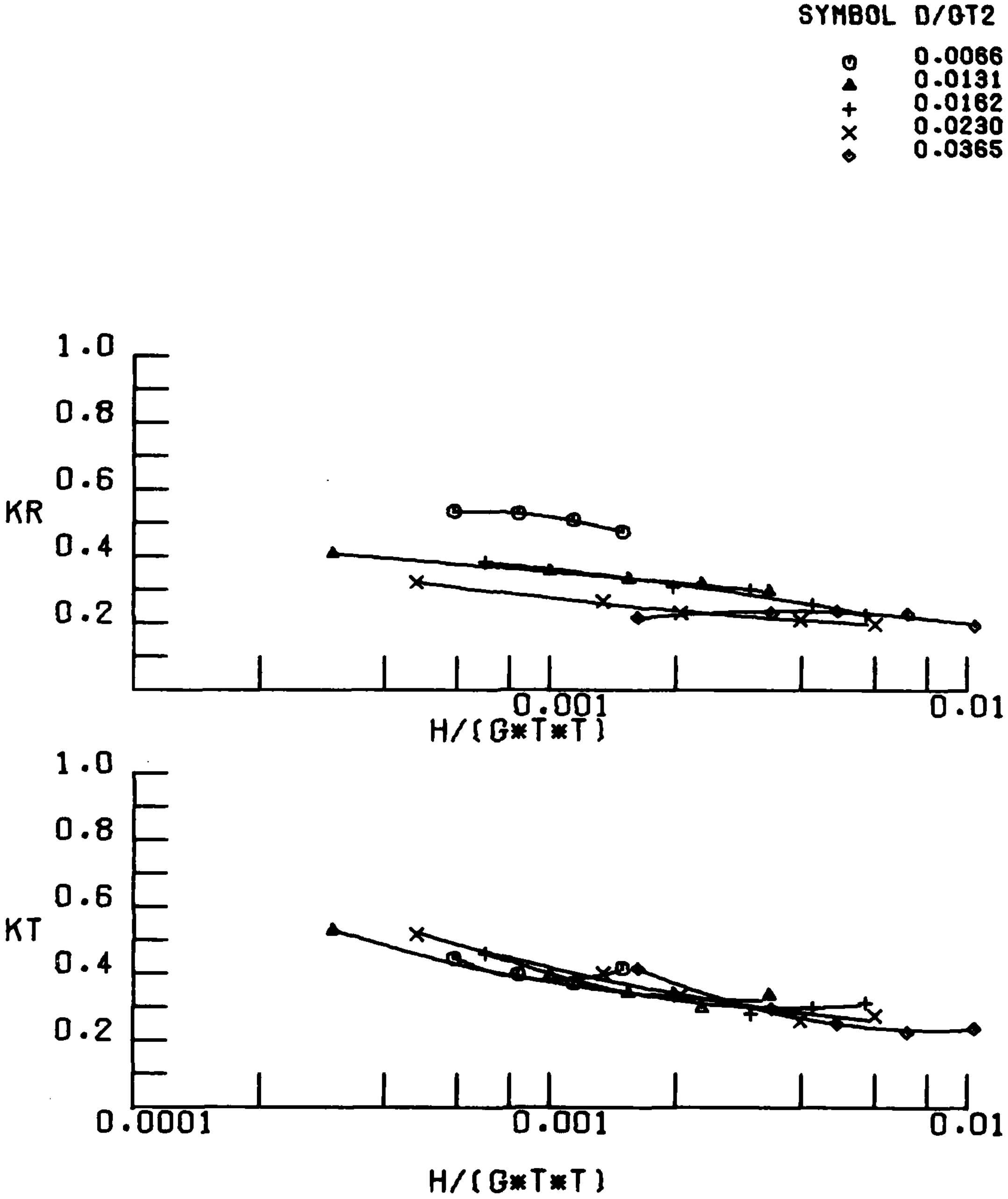
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 3 DS/HS= 1.38



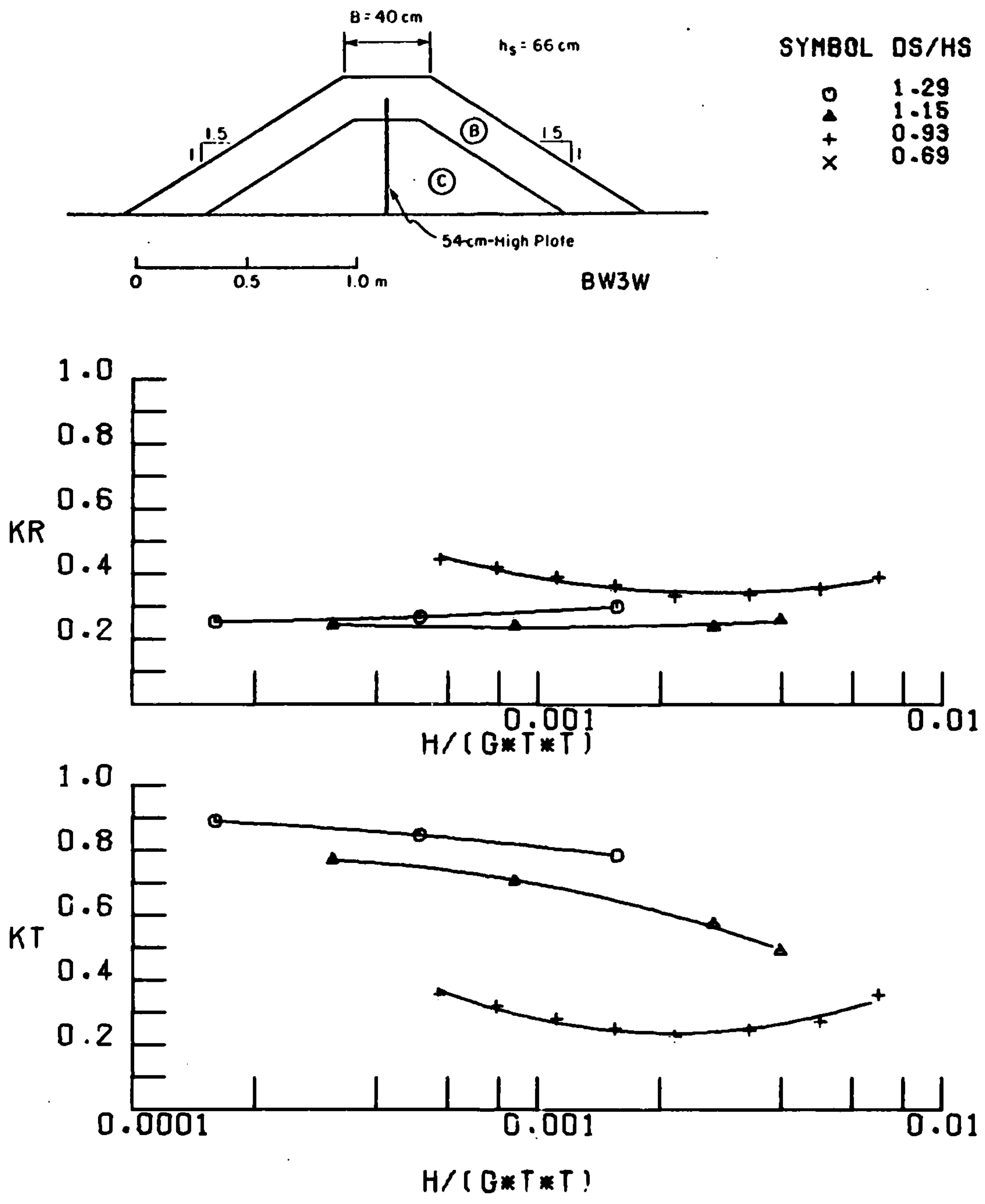
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 3 DS/HS= 1.29



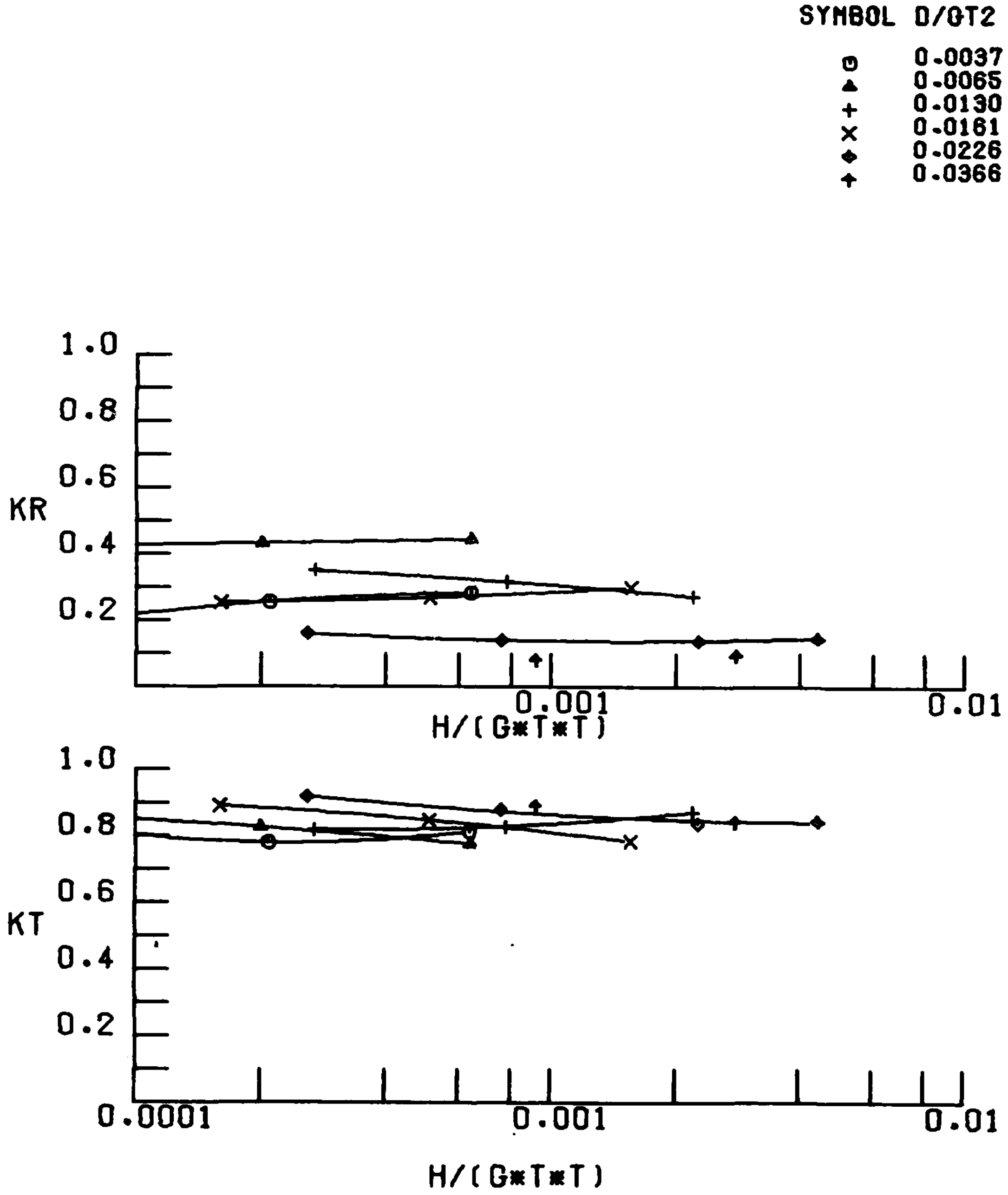
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 3 DS/HS= 0.92



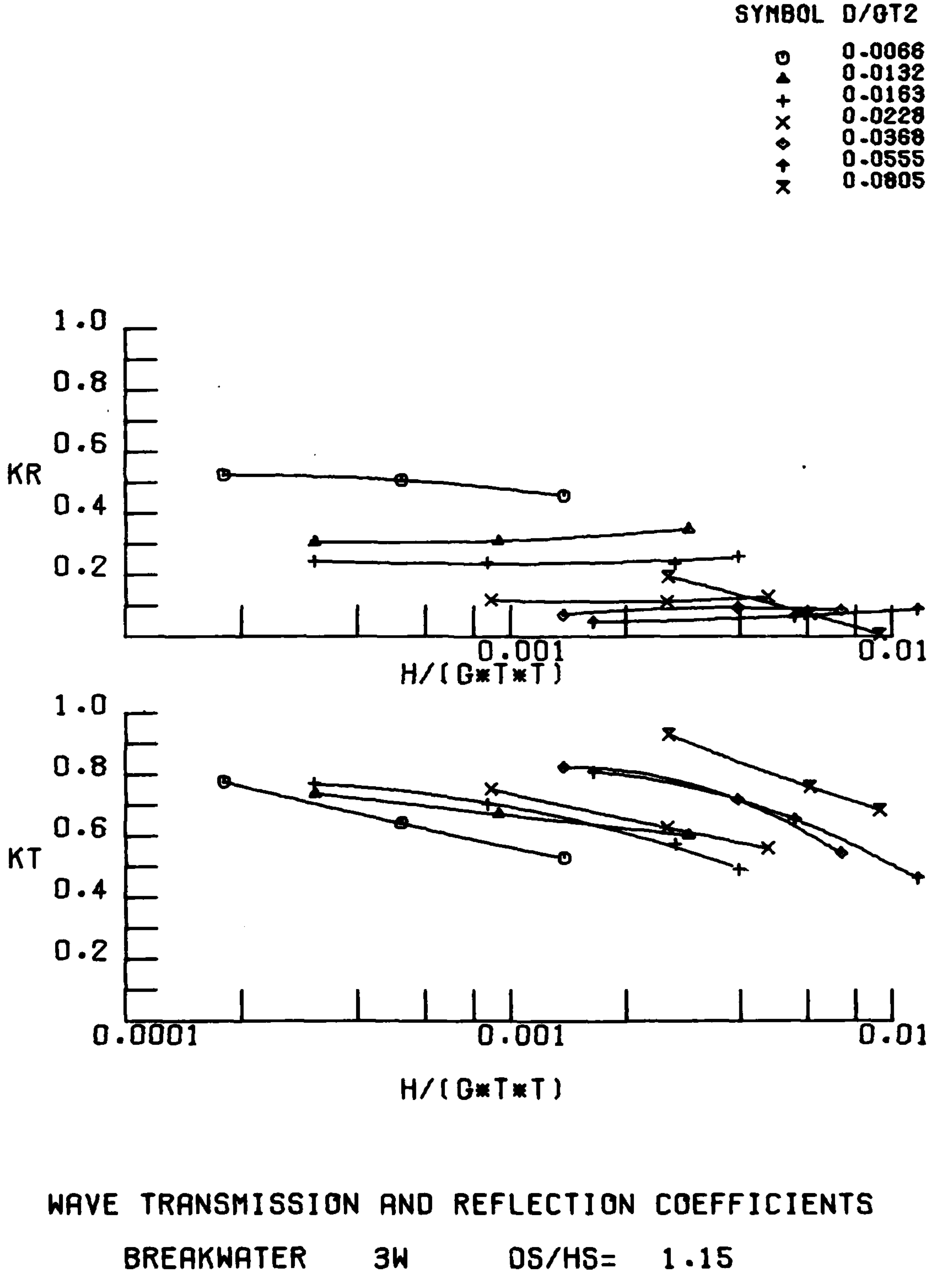
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 3W D/(GT2)=0.016



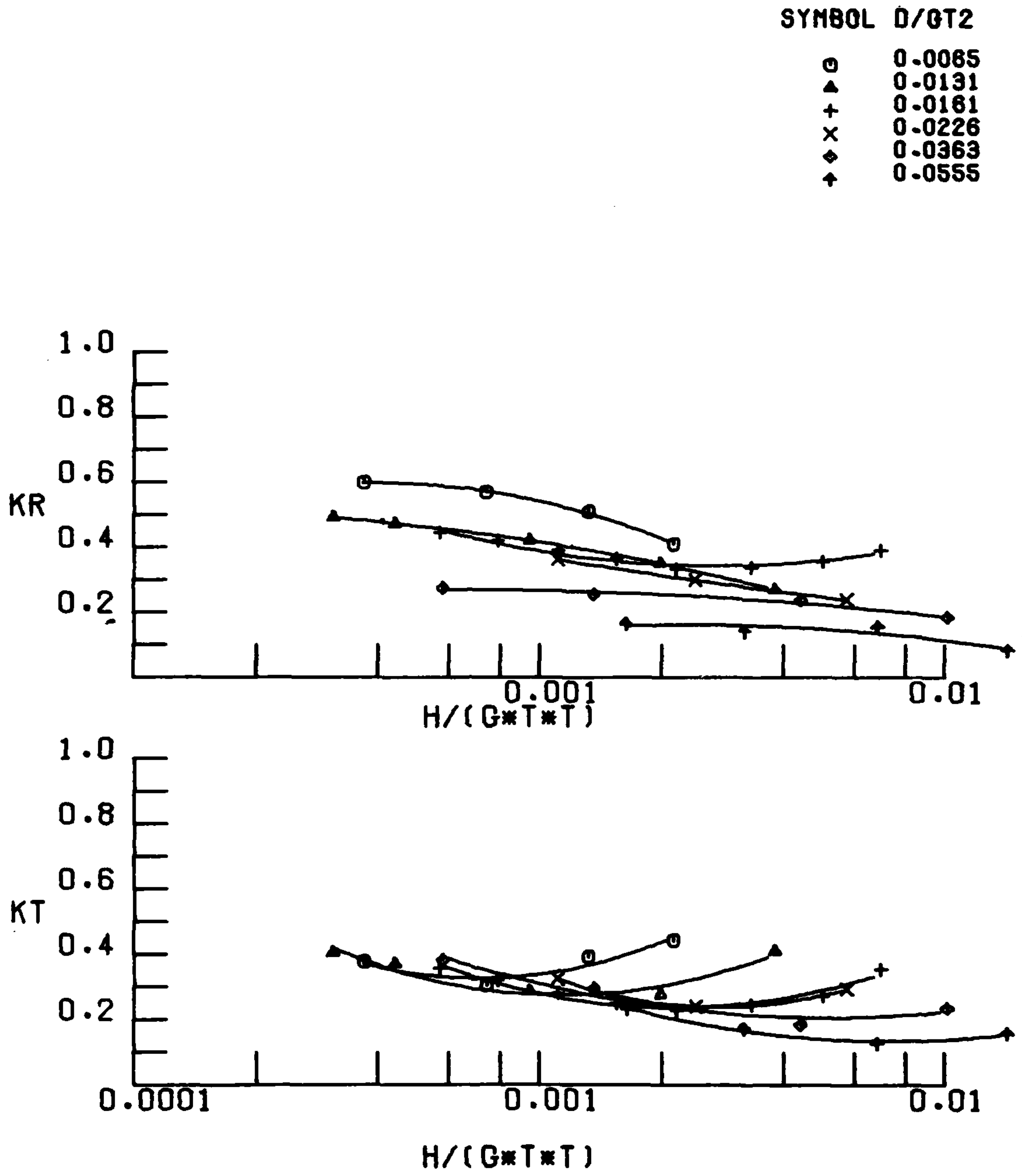
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 3W DS/HS= 1.29



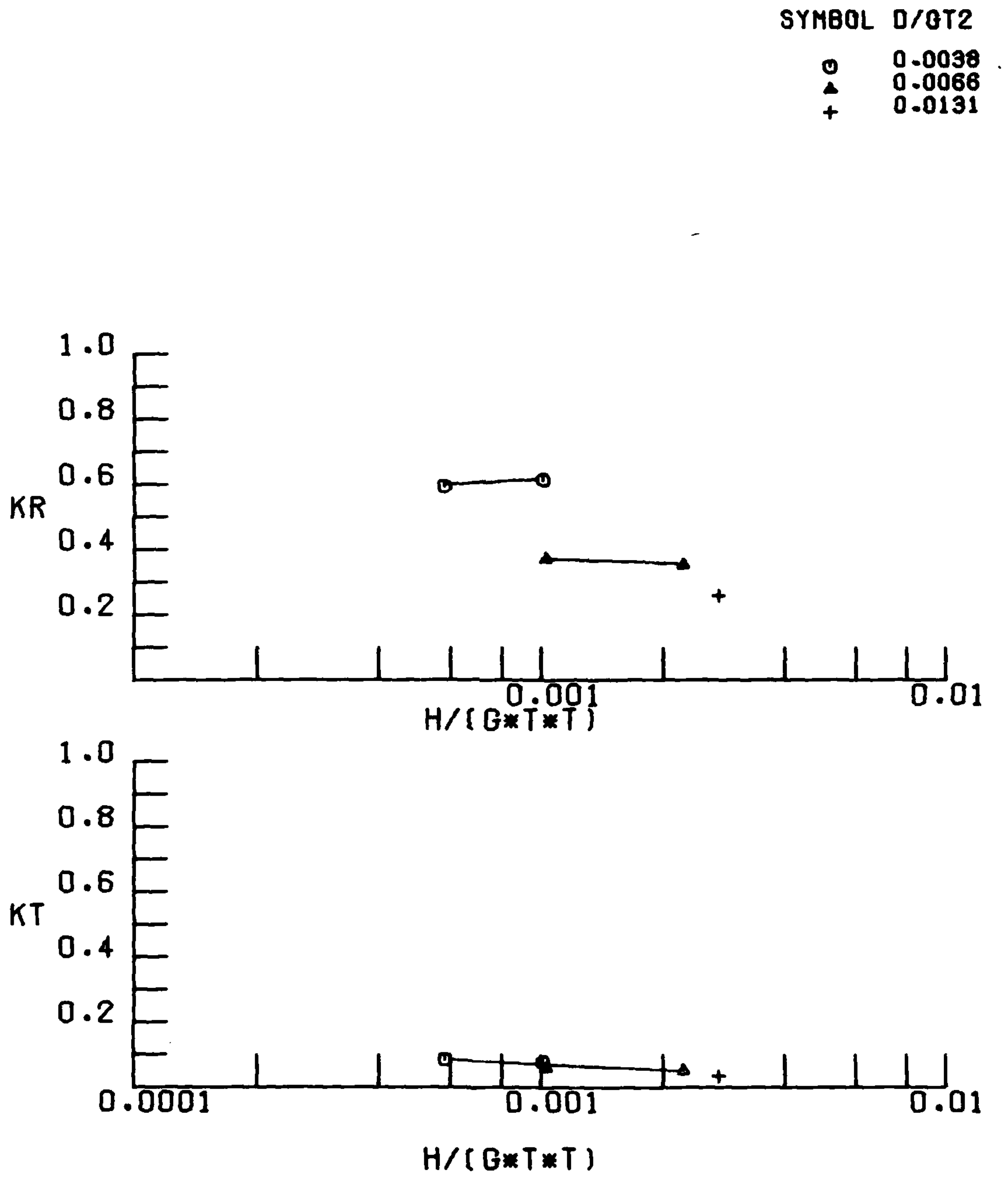
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 3W DS/HS= 1.15



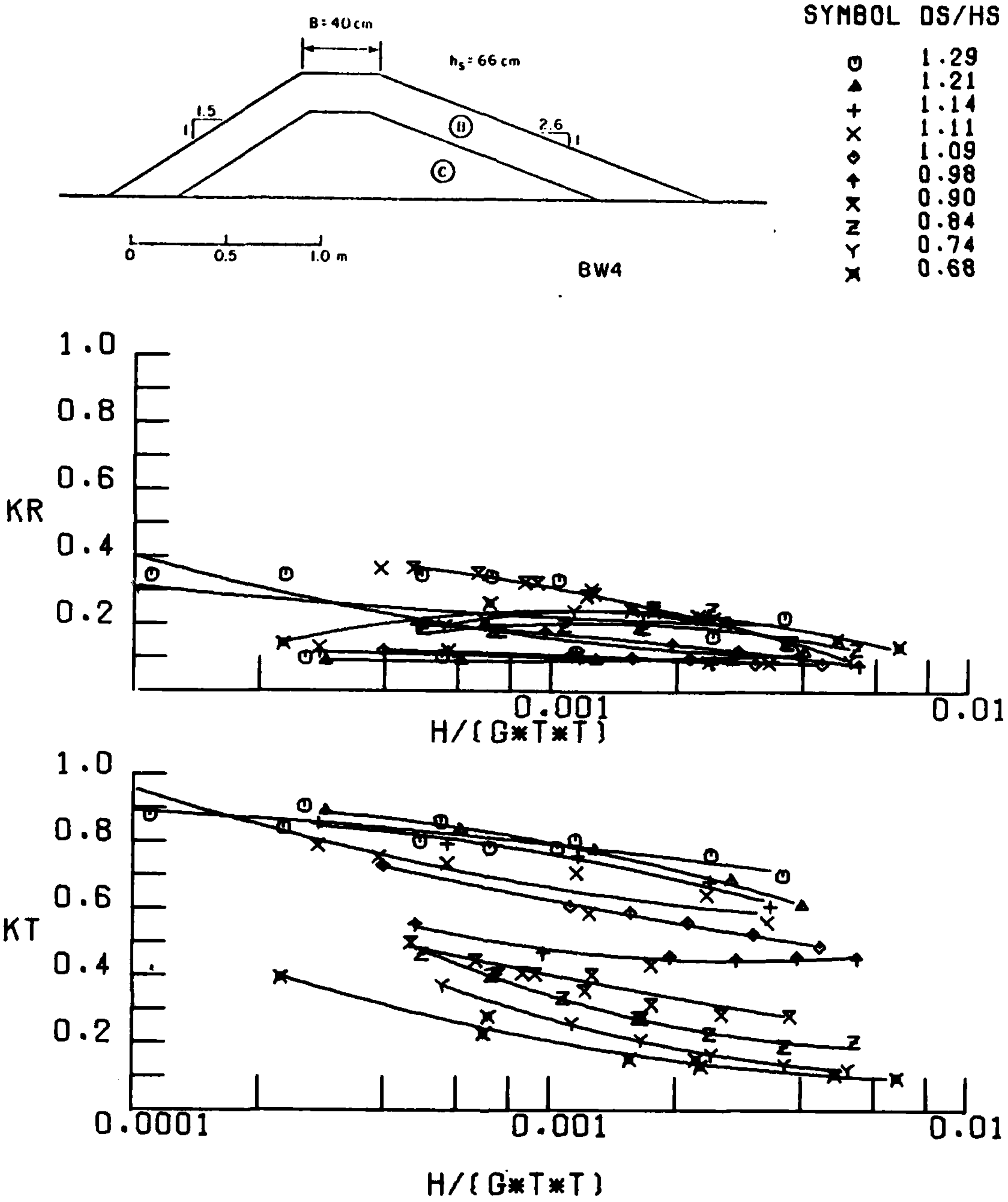
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 3W DS/HS= 0.93



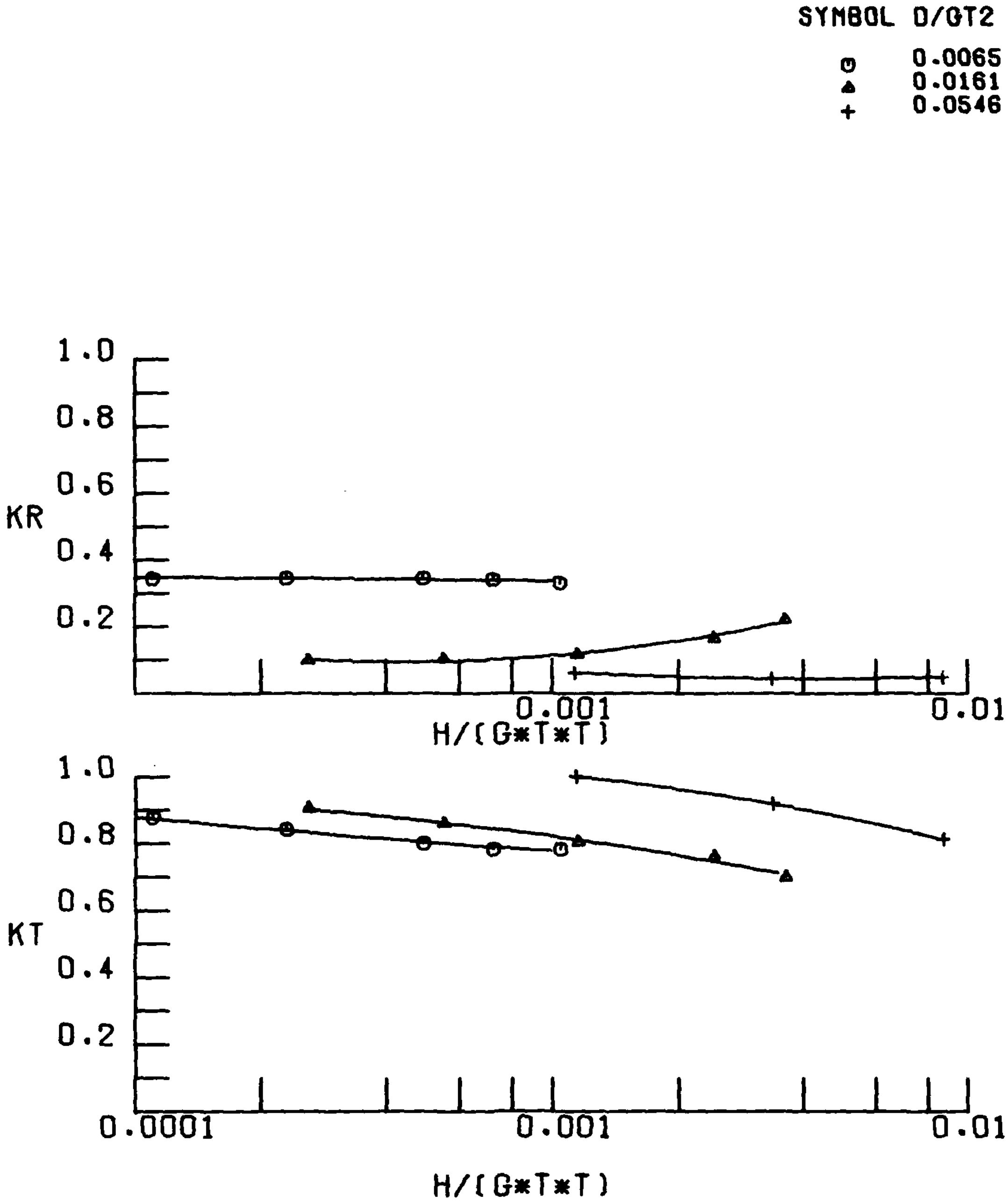
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 3W DS/HS= 0.69



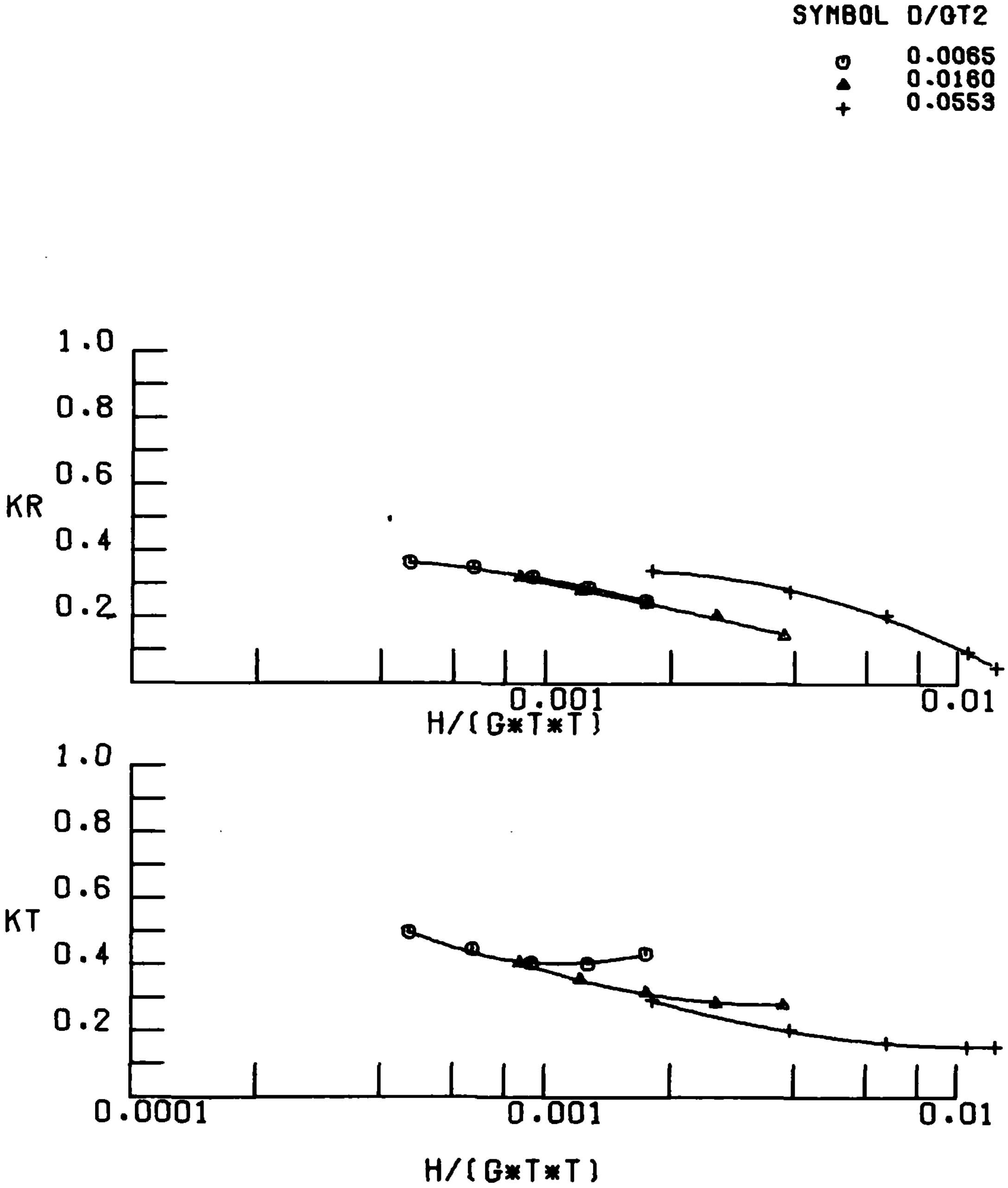
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 4 D/(GT2)=0.016



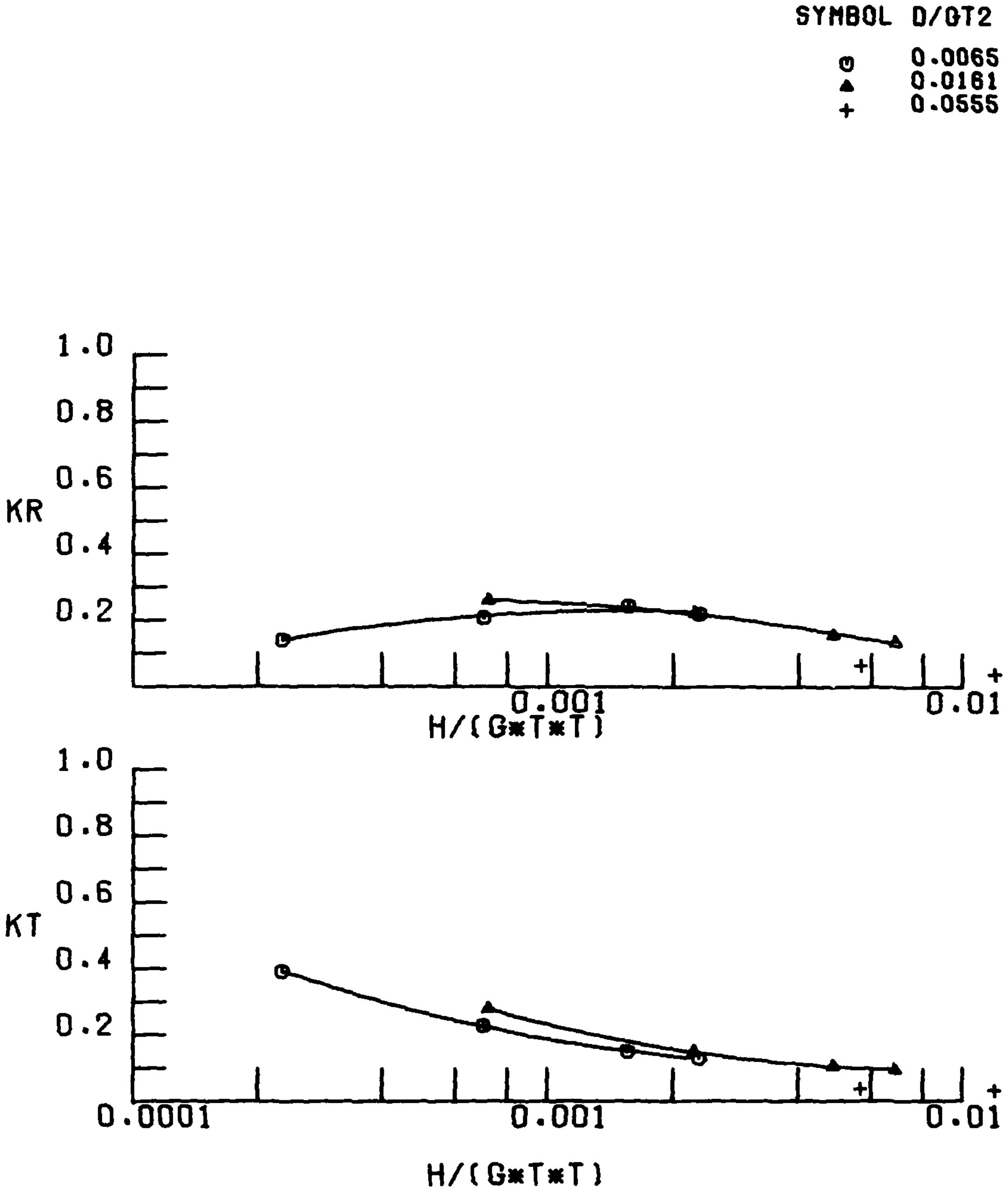
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 4 DS/HS= 1.29



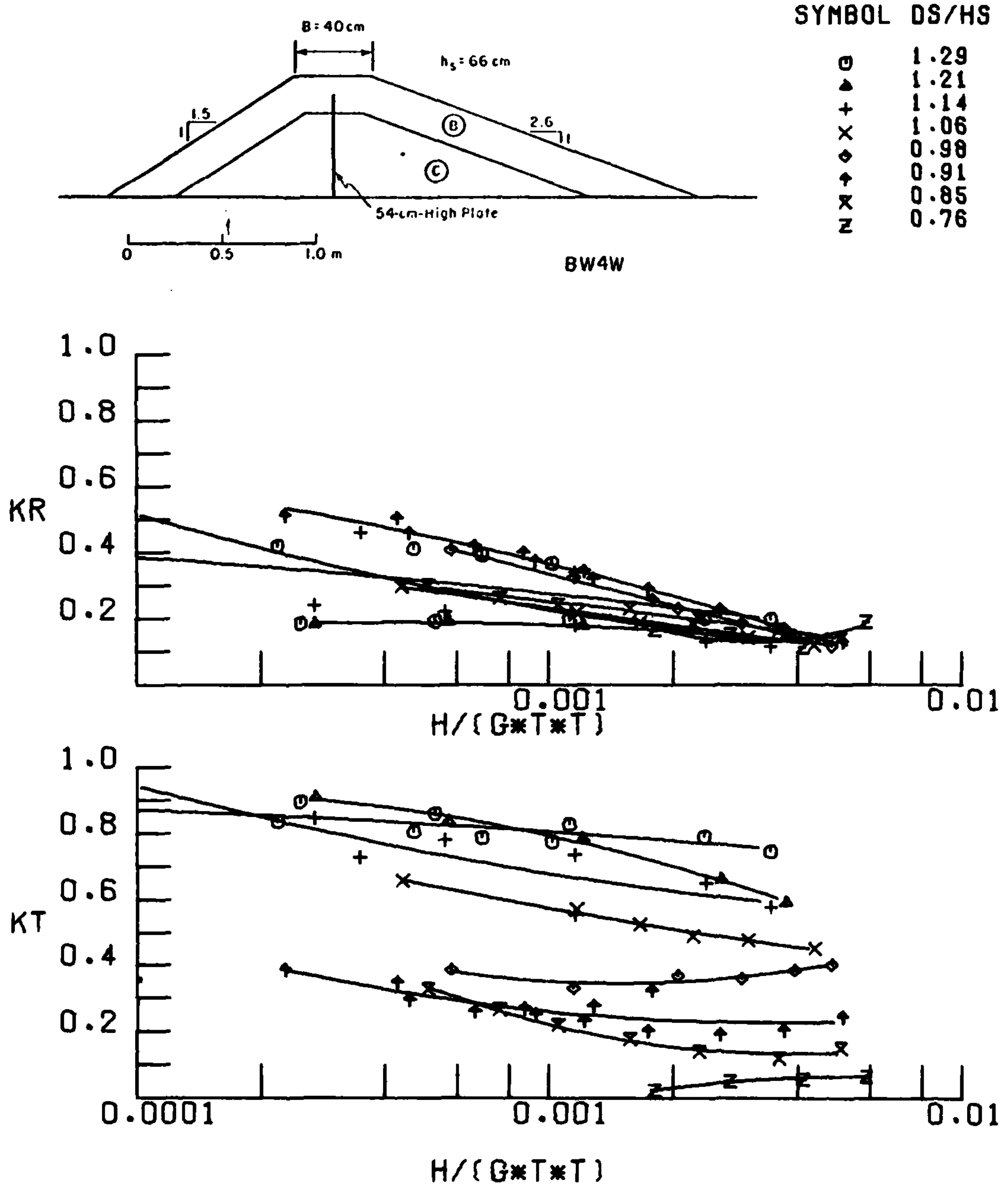
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 4 DS/HS= 0.90



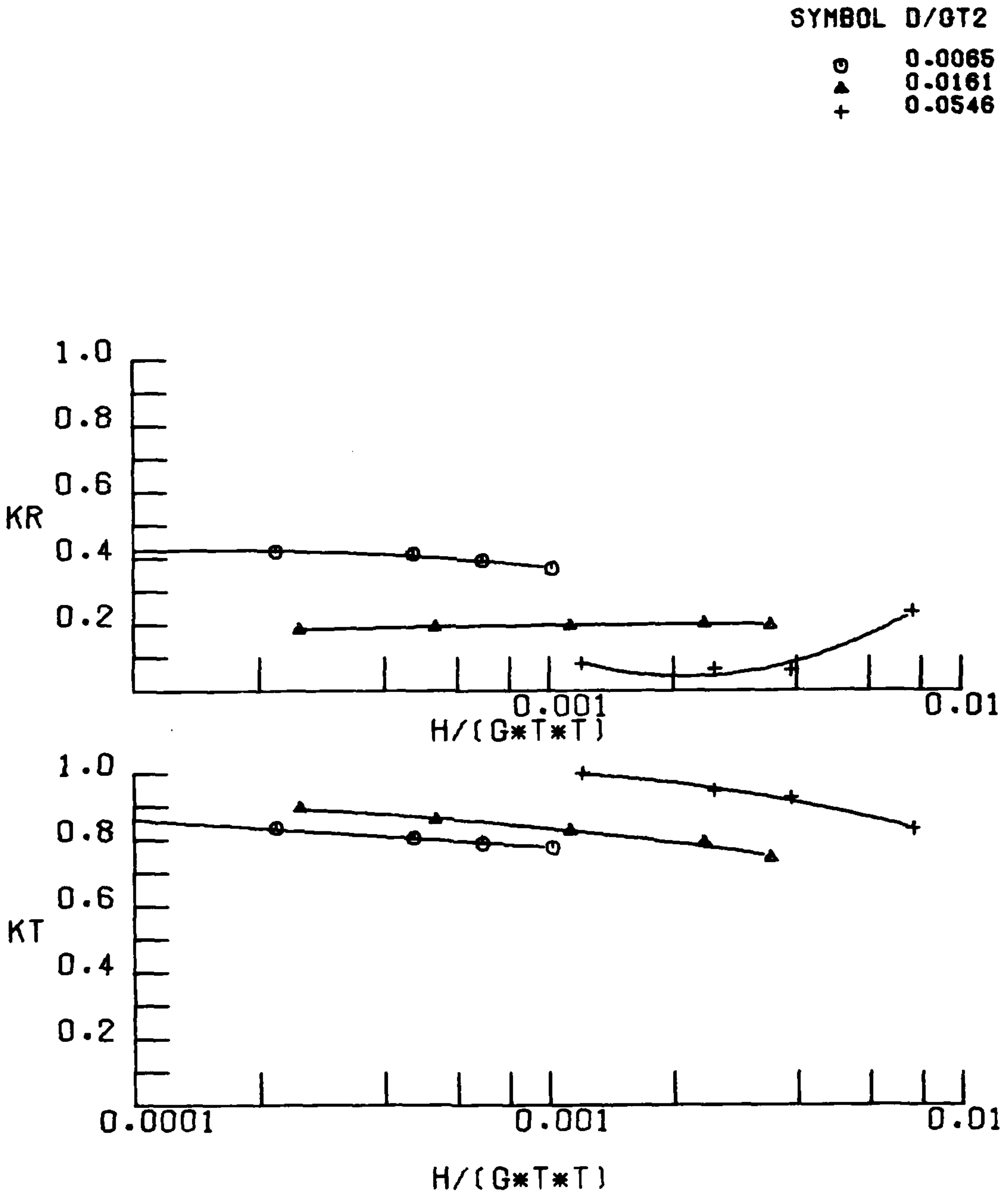
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 4 DS/HS= 0.68



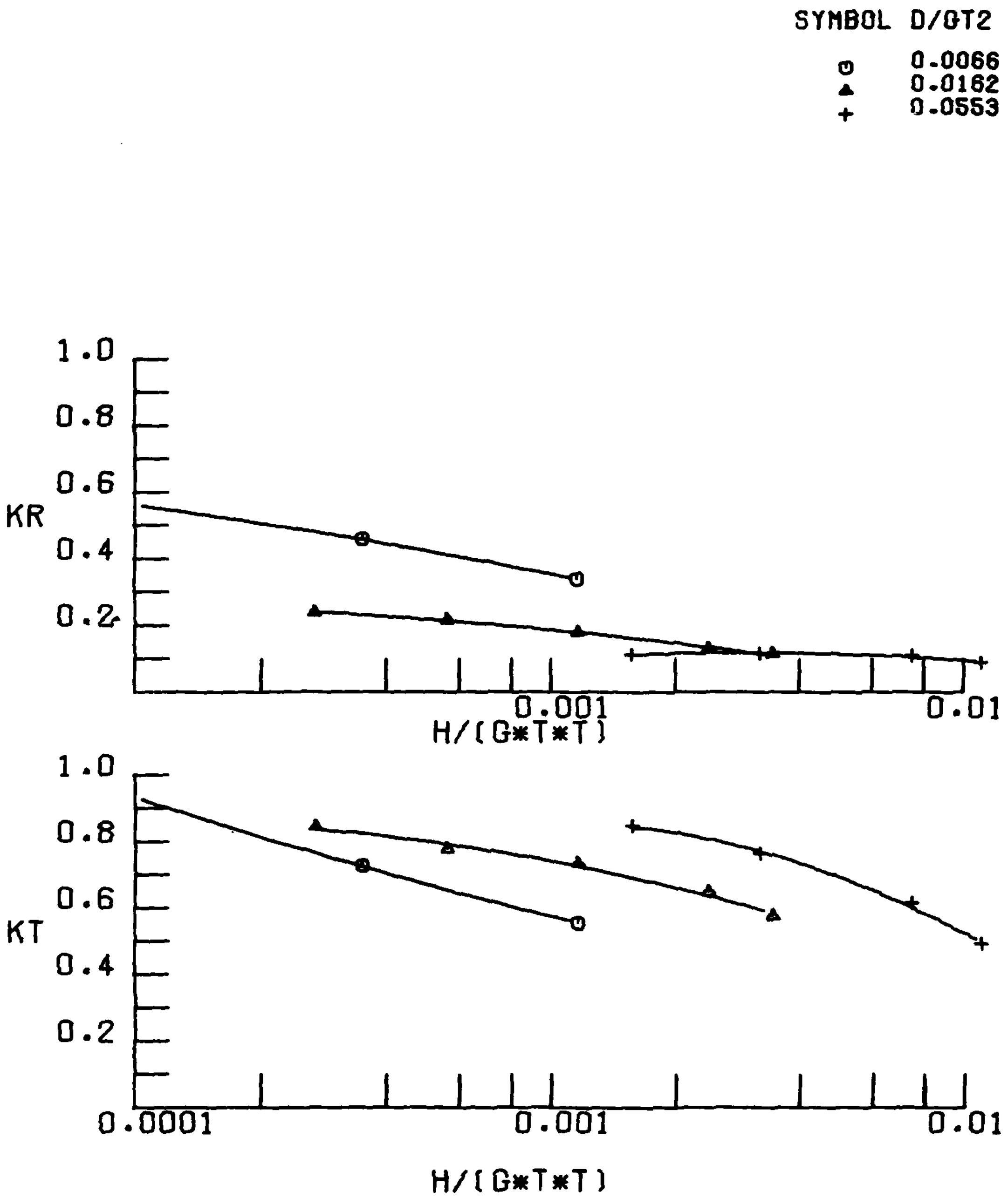
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 4W D/(GT2)=0.016



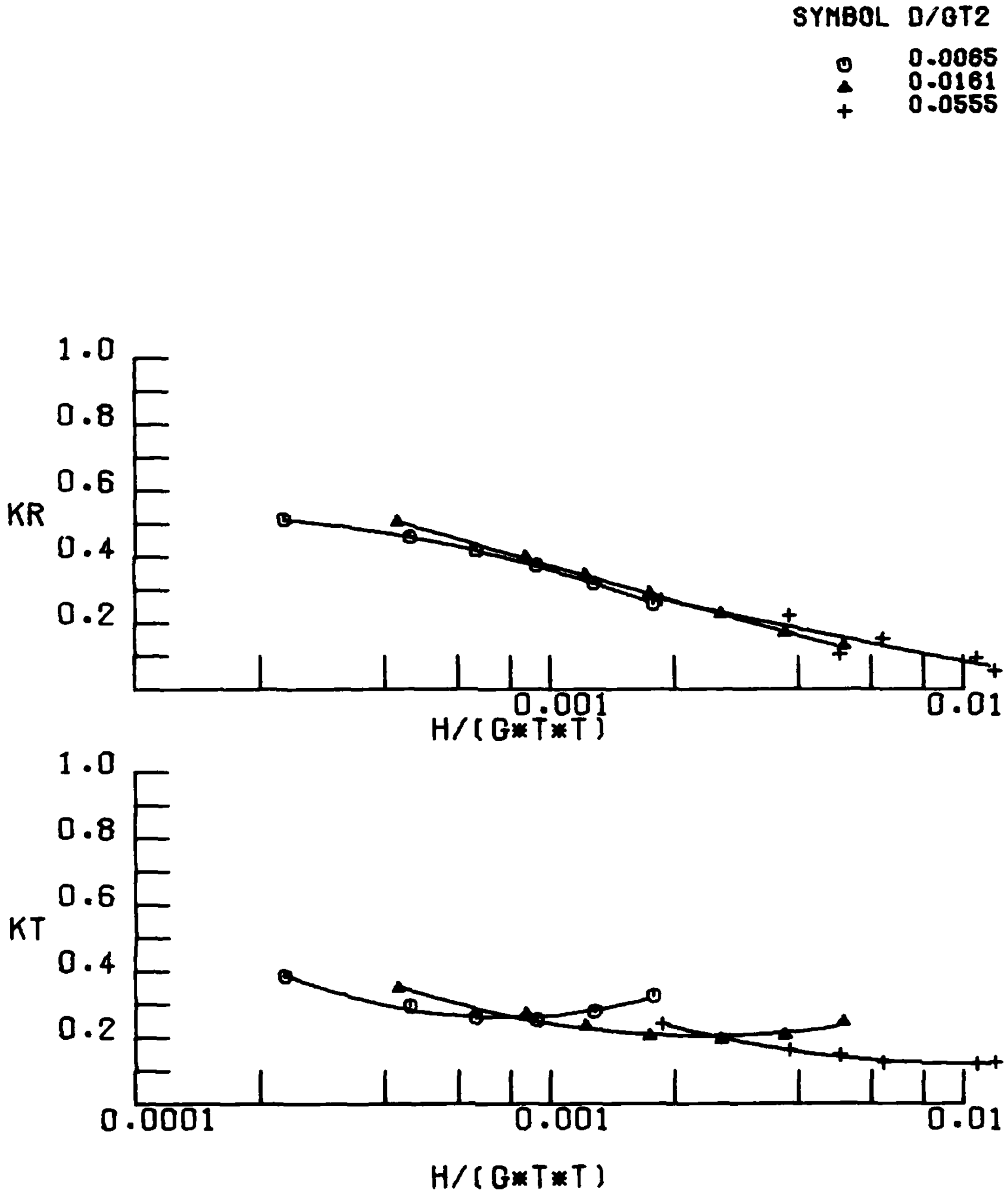
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 4W DS/HS= 1.29



WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 4W DS/HS= 1.14



WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

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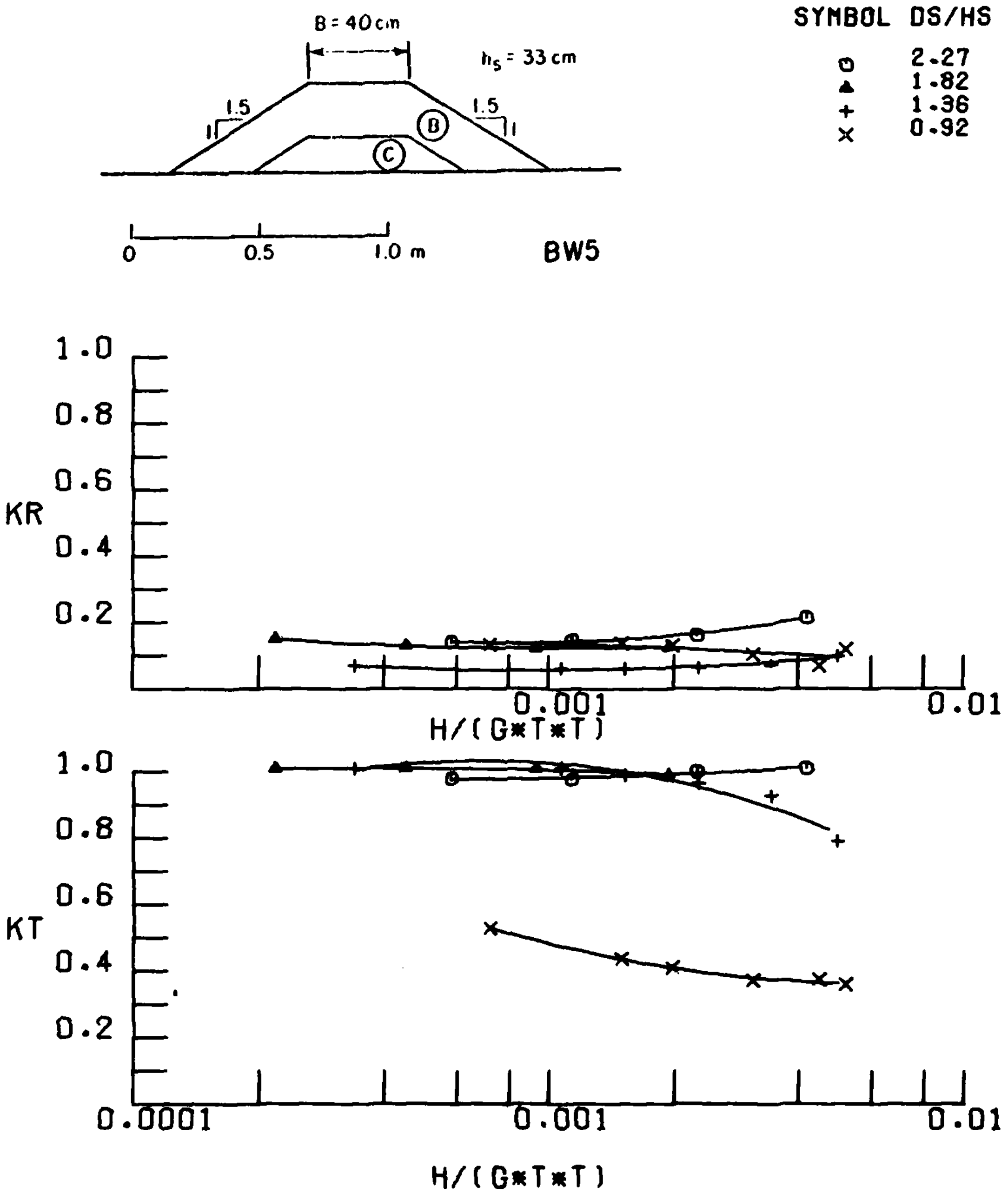
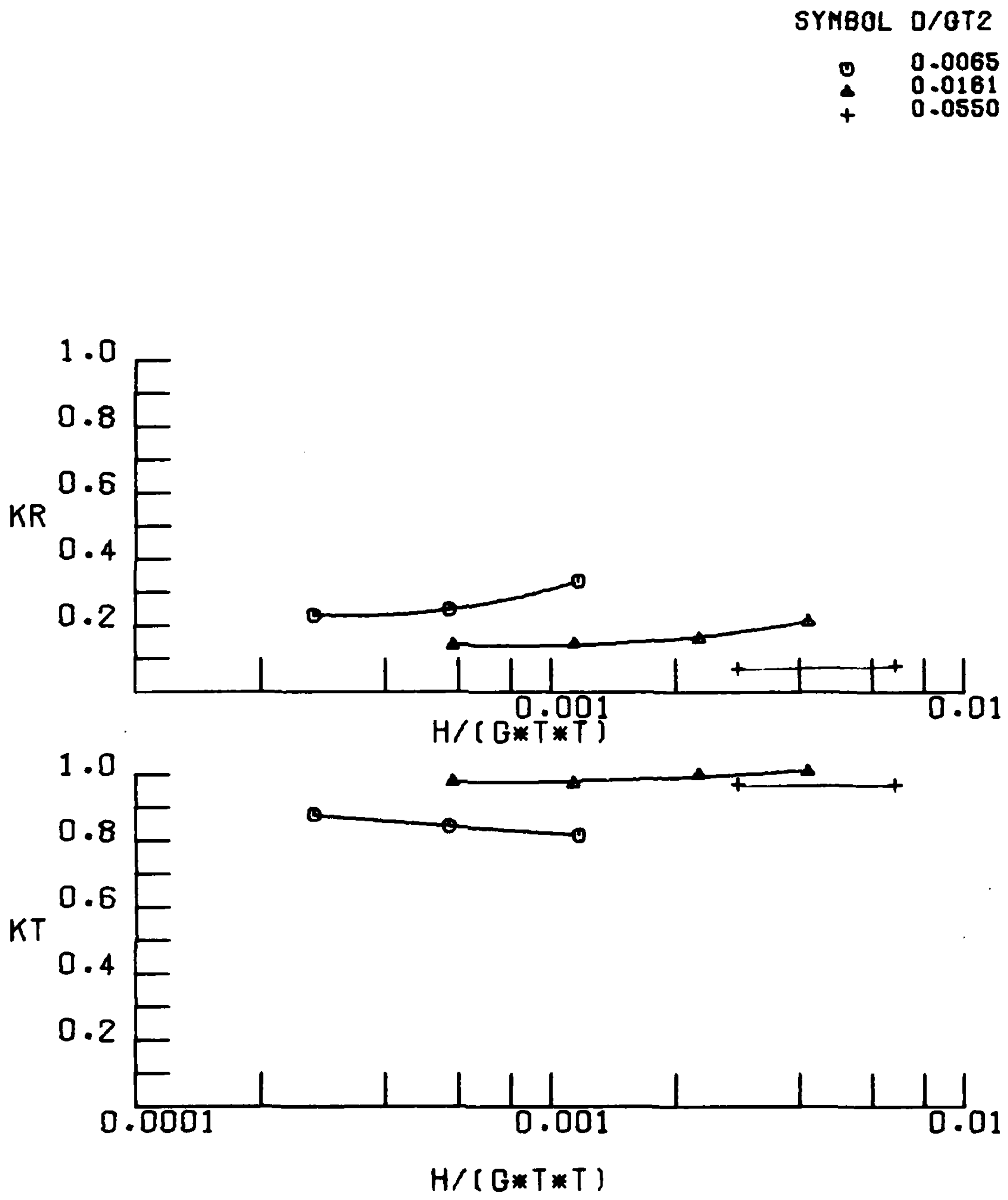


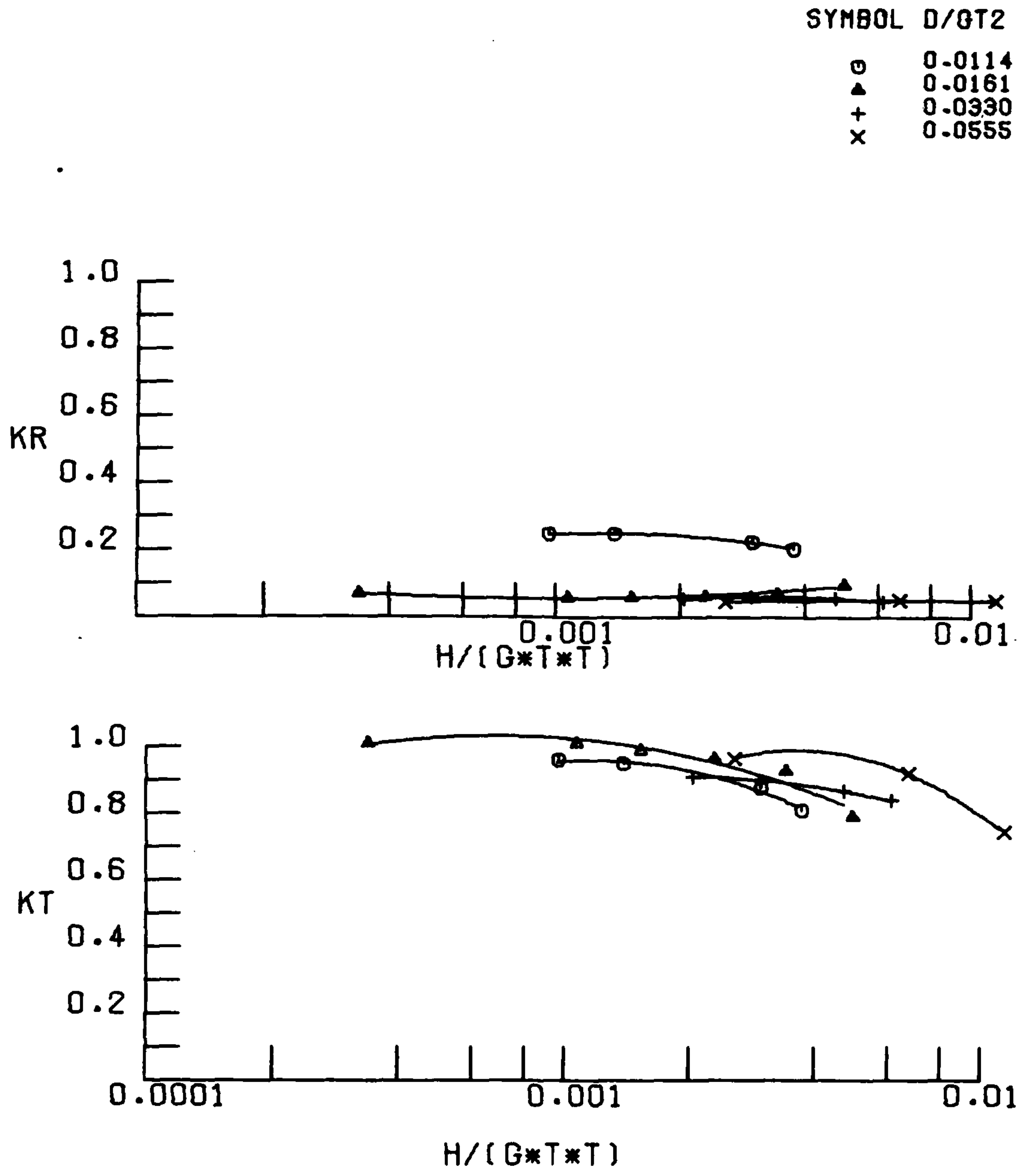
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 5 D/(GT2)=0.016



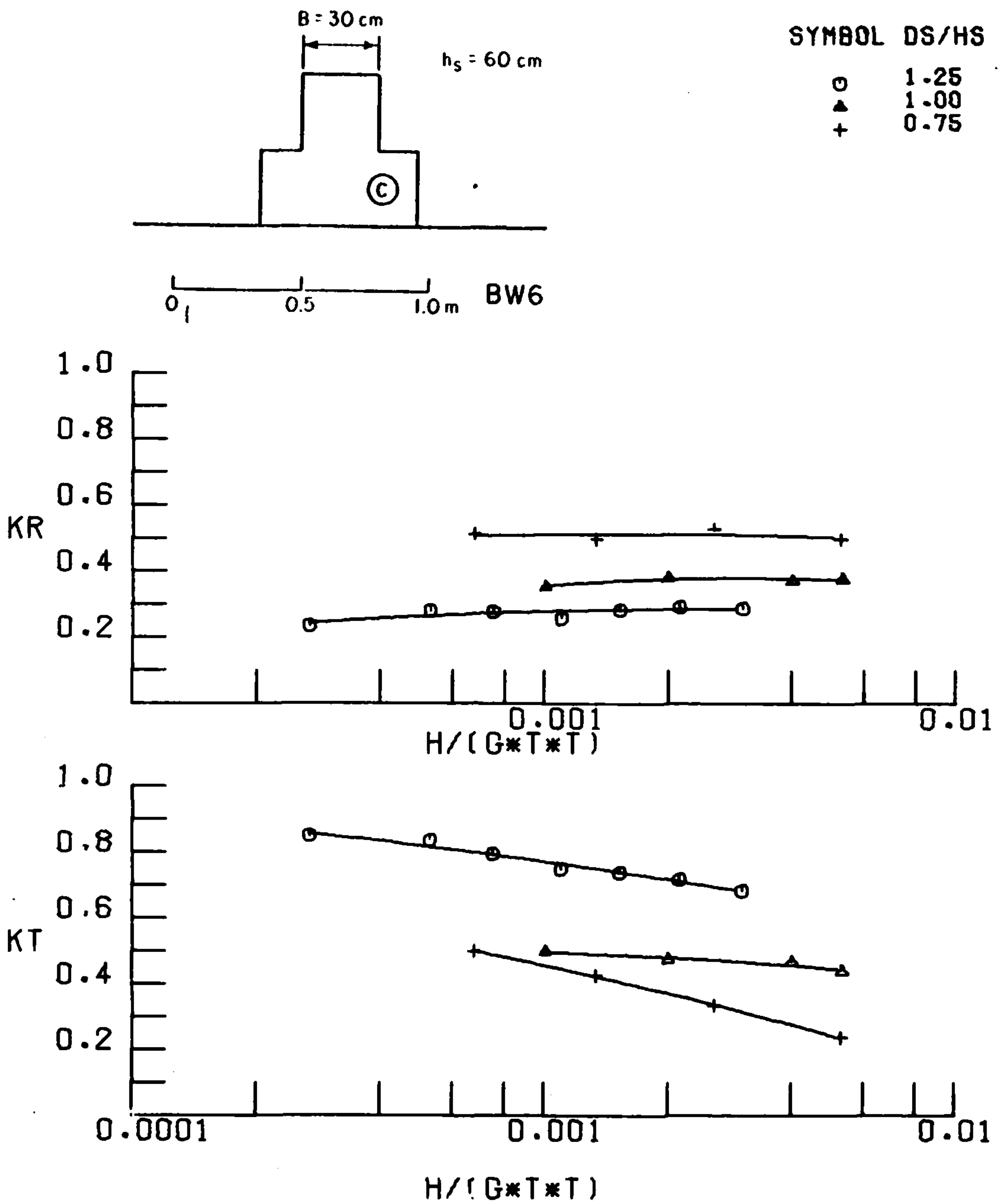
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 5 DS/HS= 2.27



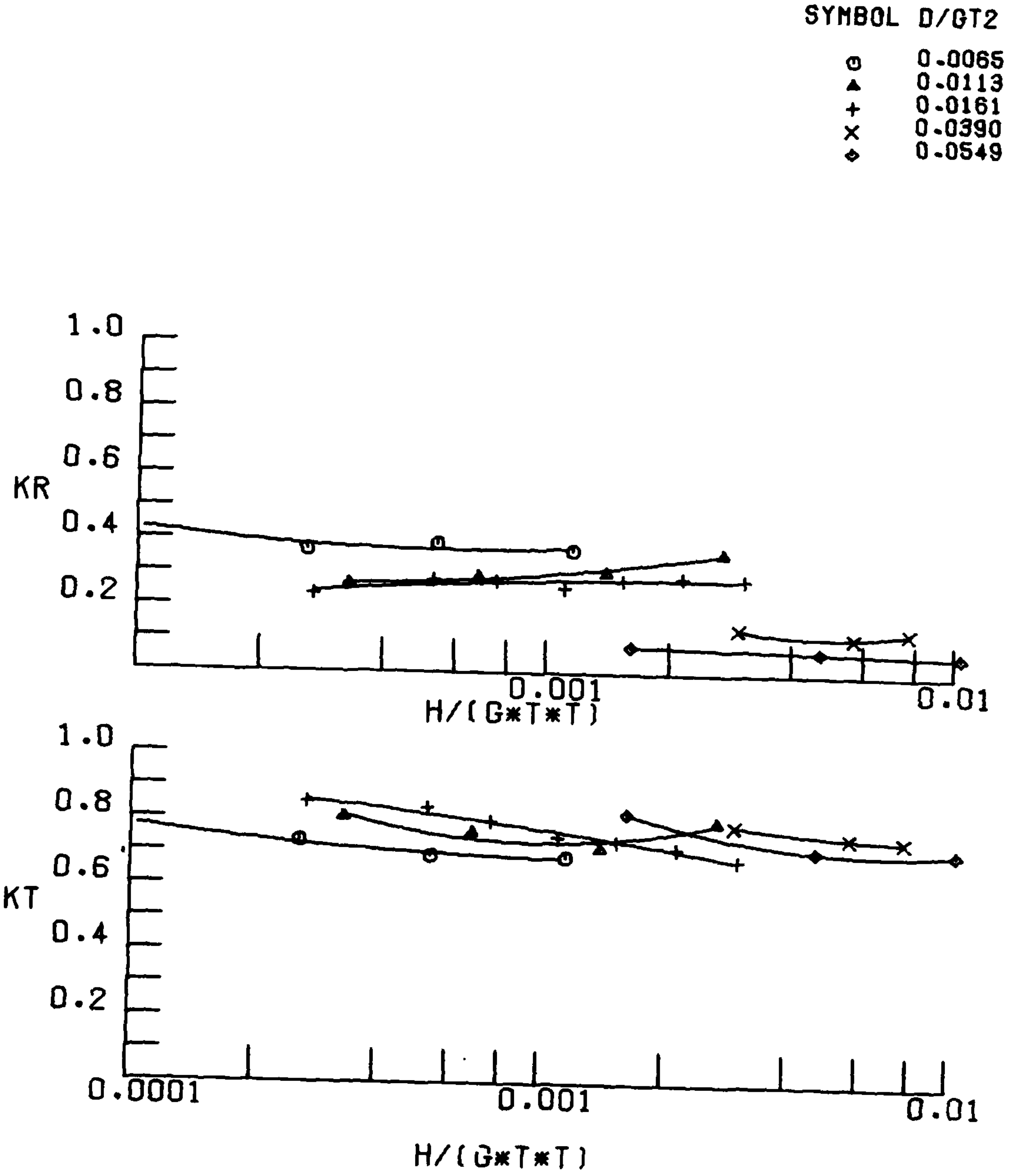
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 5 DS/HS= 1.36



WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 6 D/(GT2)=0.016



WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

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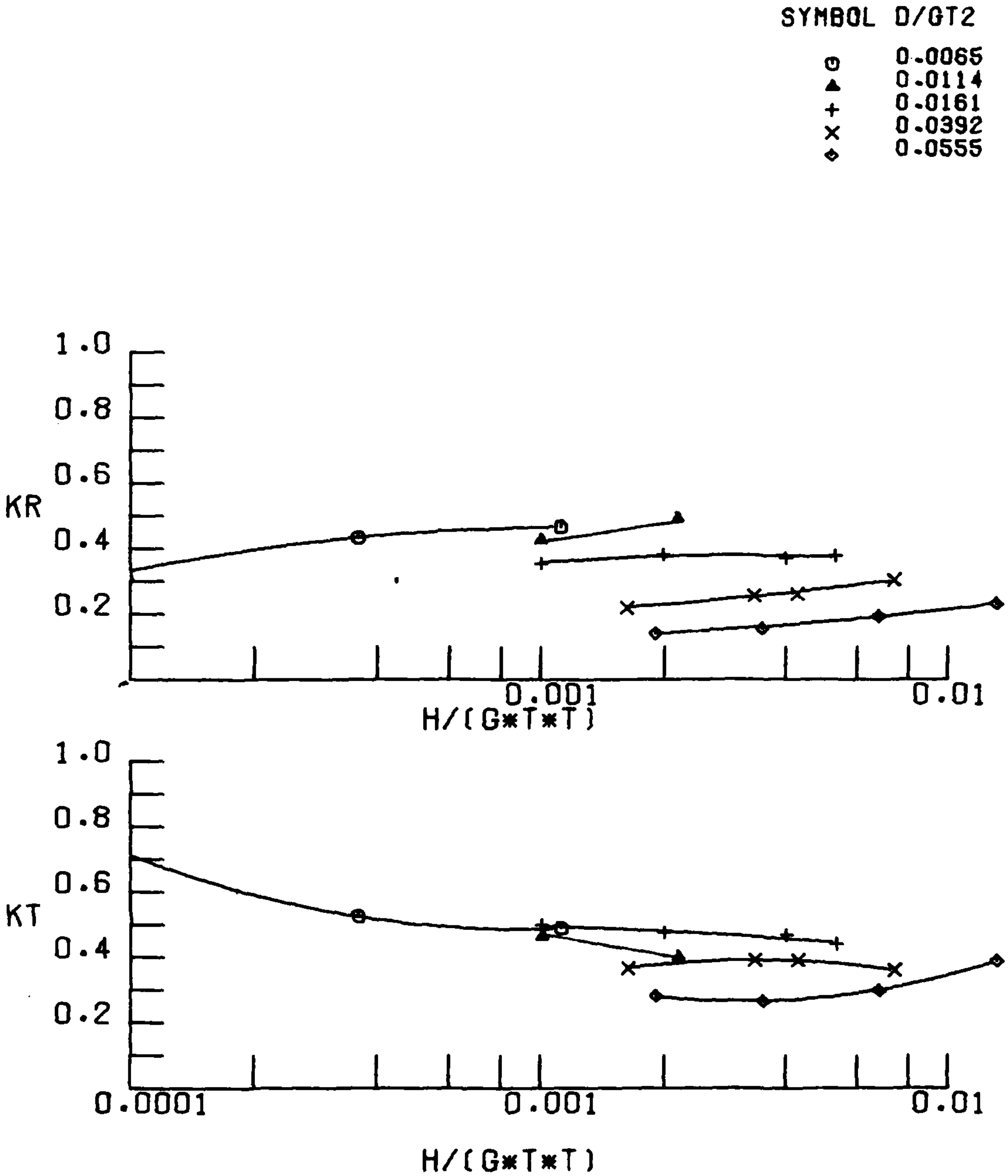
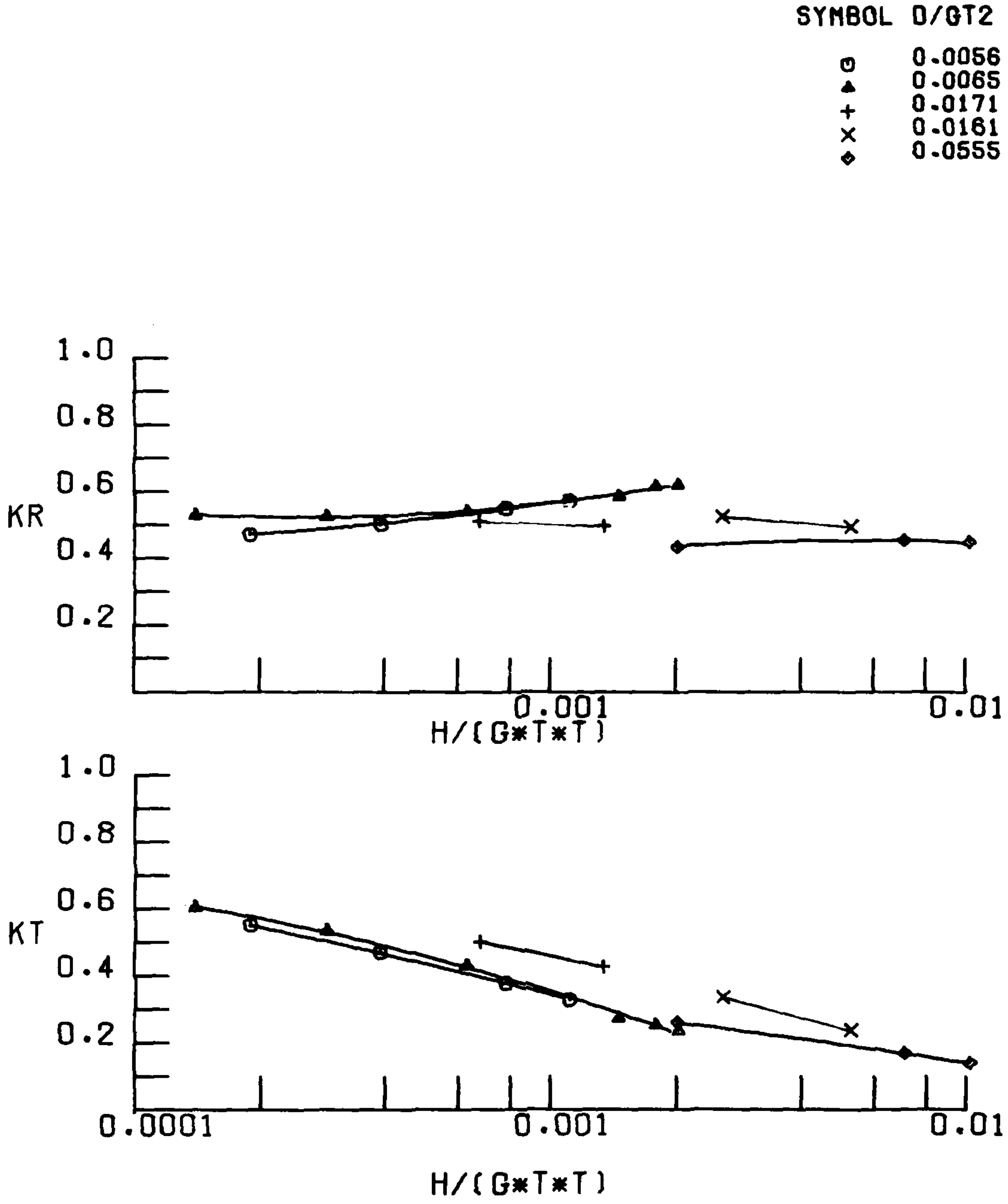


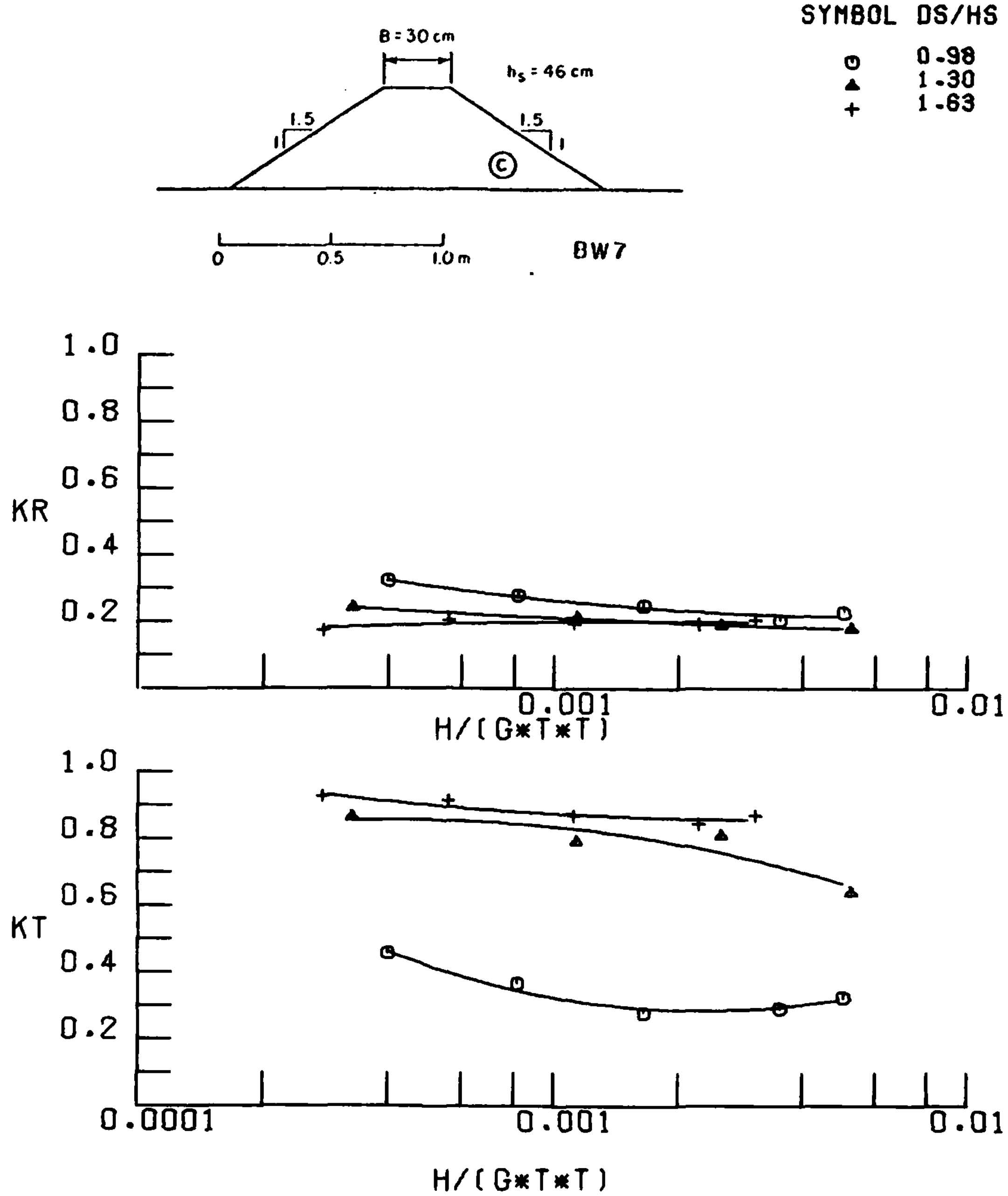
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 6 DS/HS= 1.00



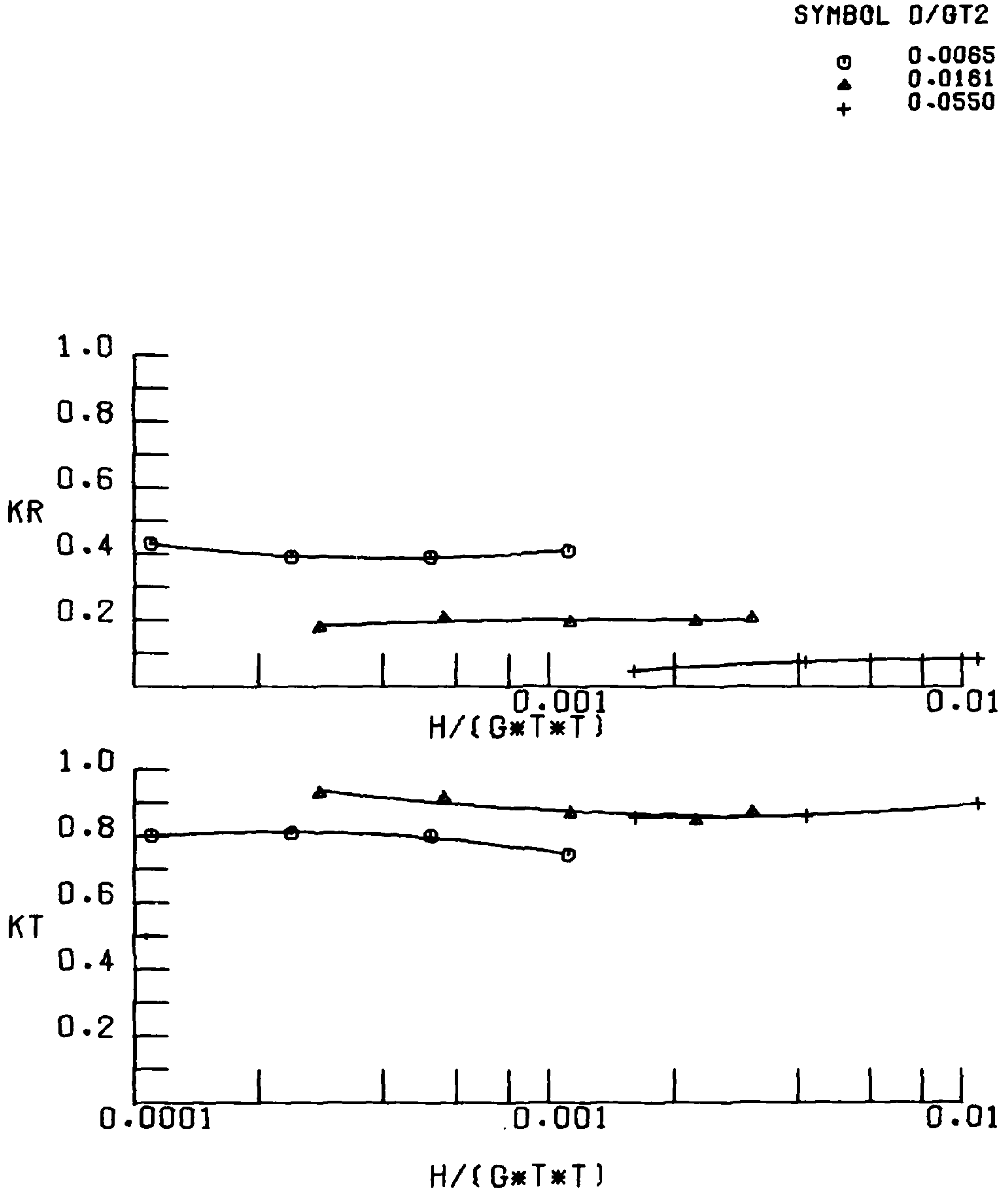
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 6 DS/HS= 0.75



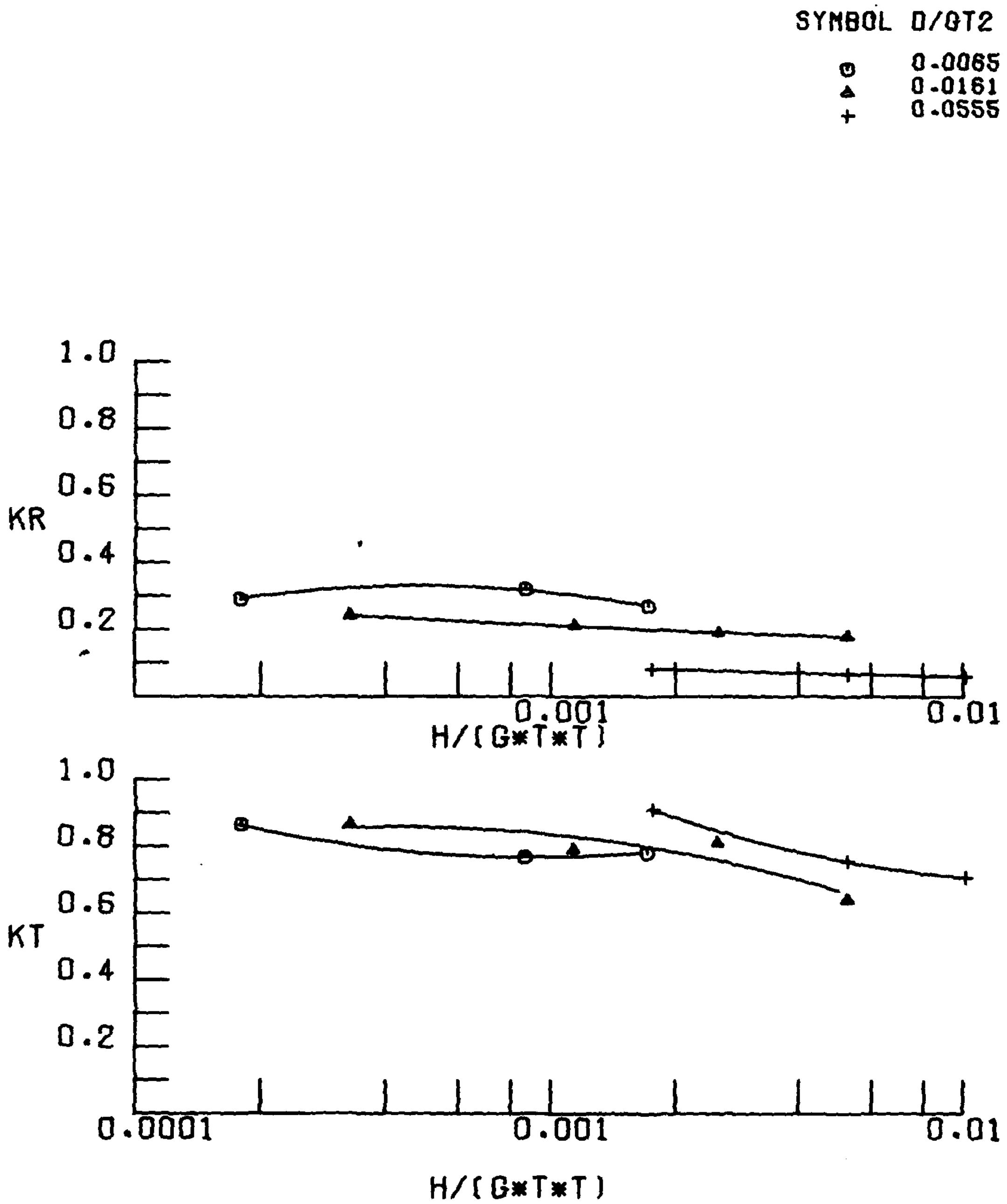
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 7 D/(GT2)=0.016



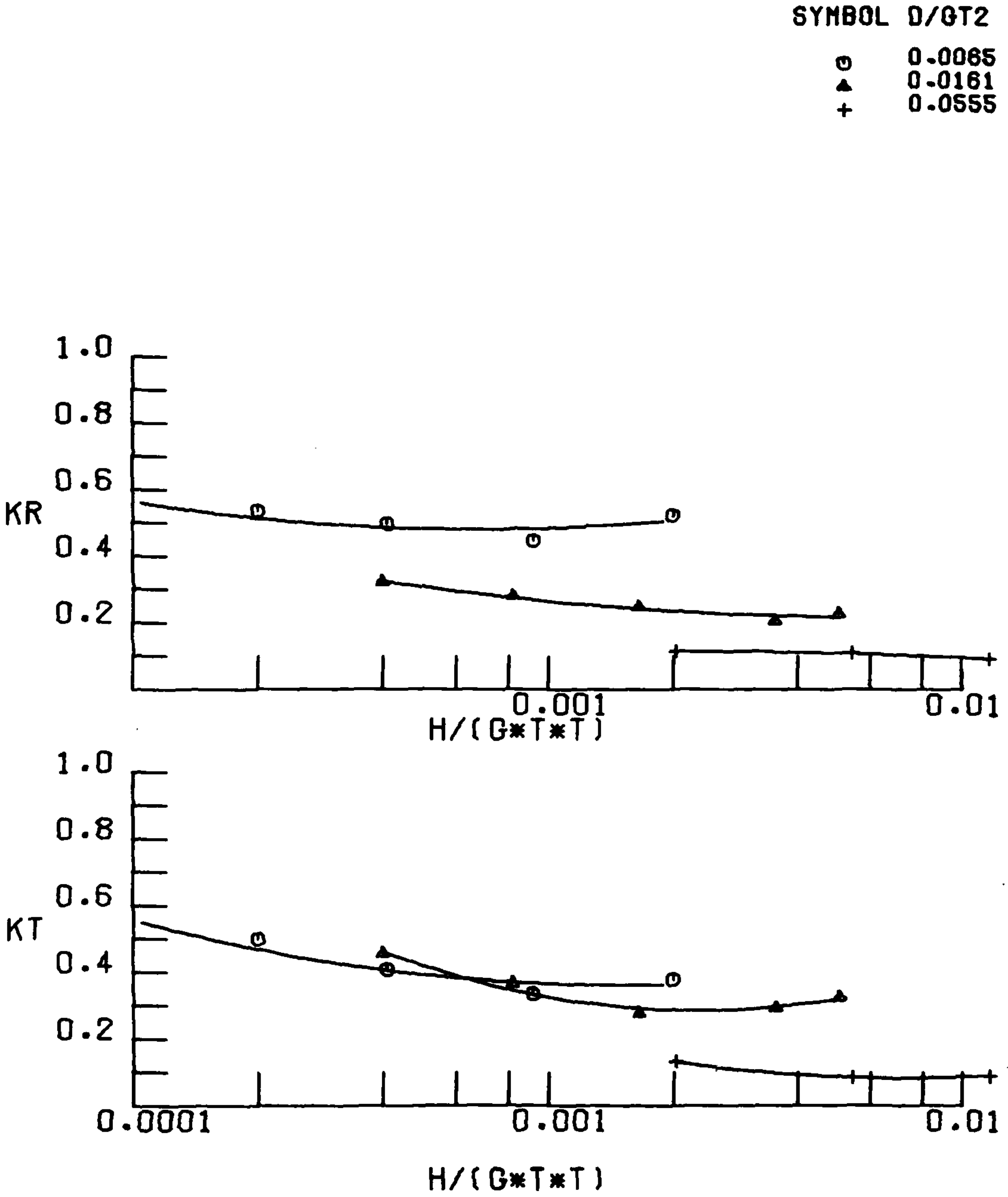
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 7 DS/HS= 1.63



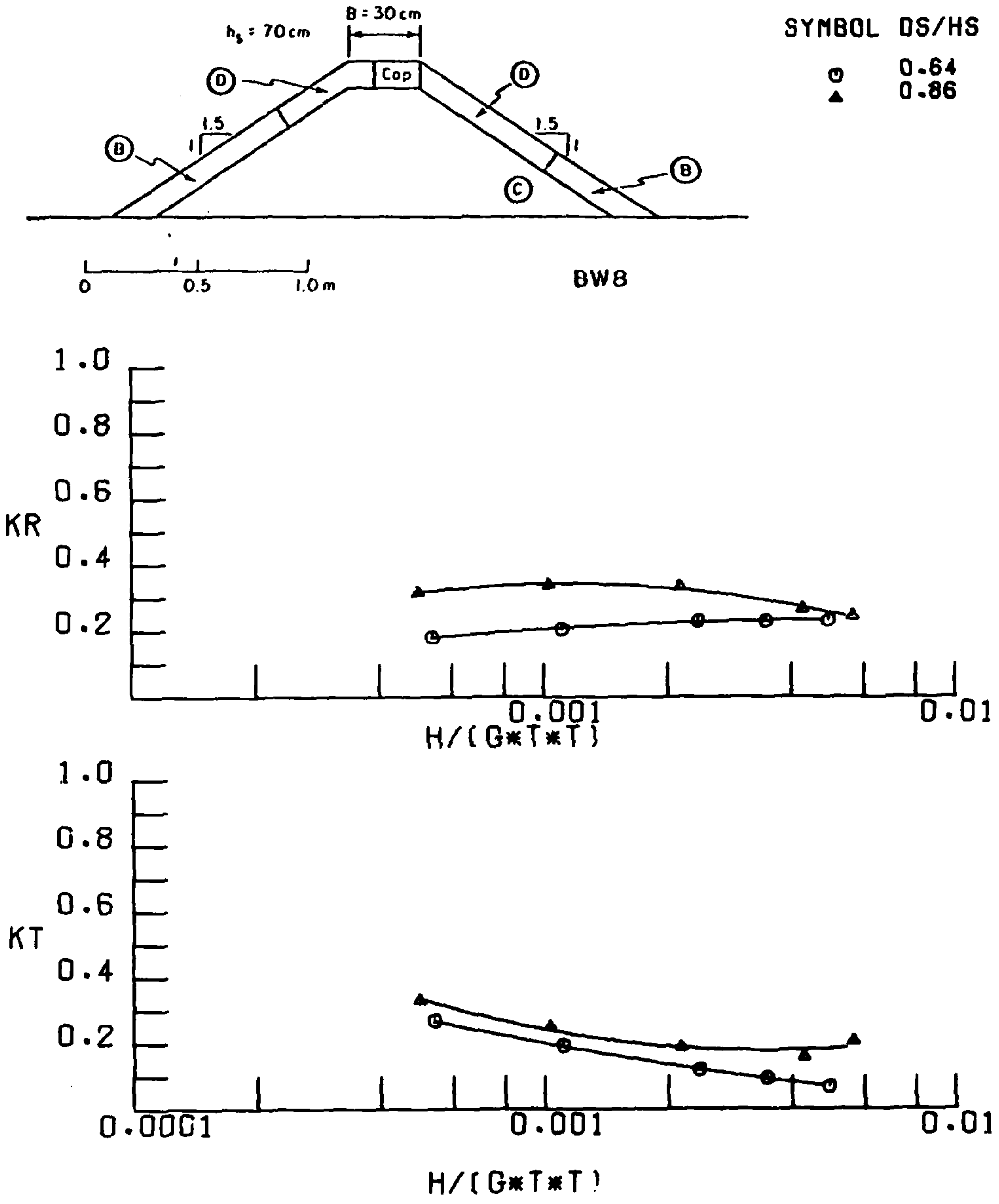
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 7 DS/HS= 1.30



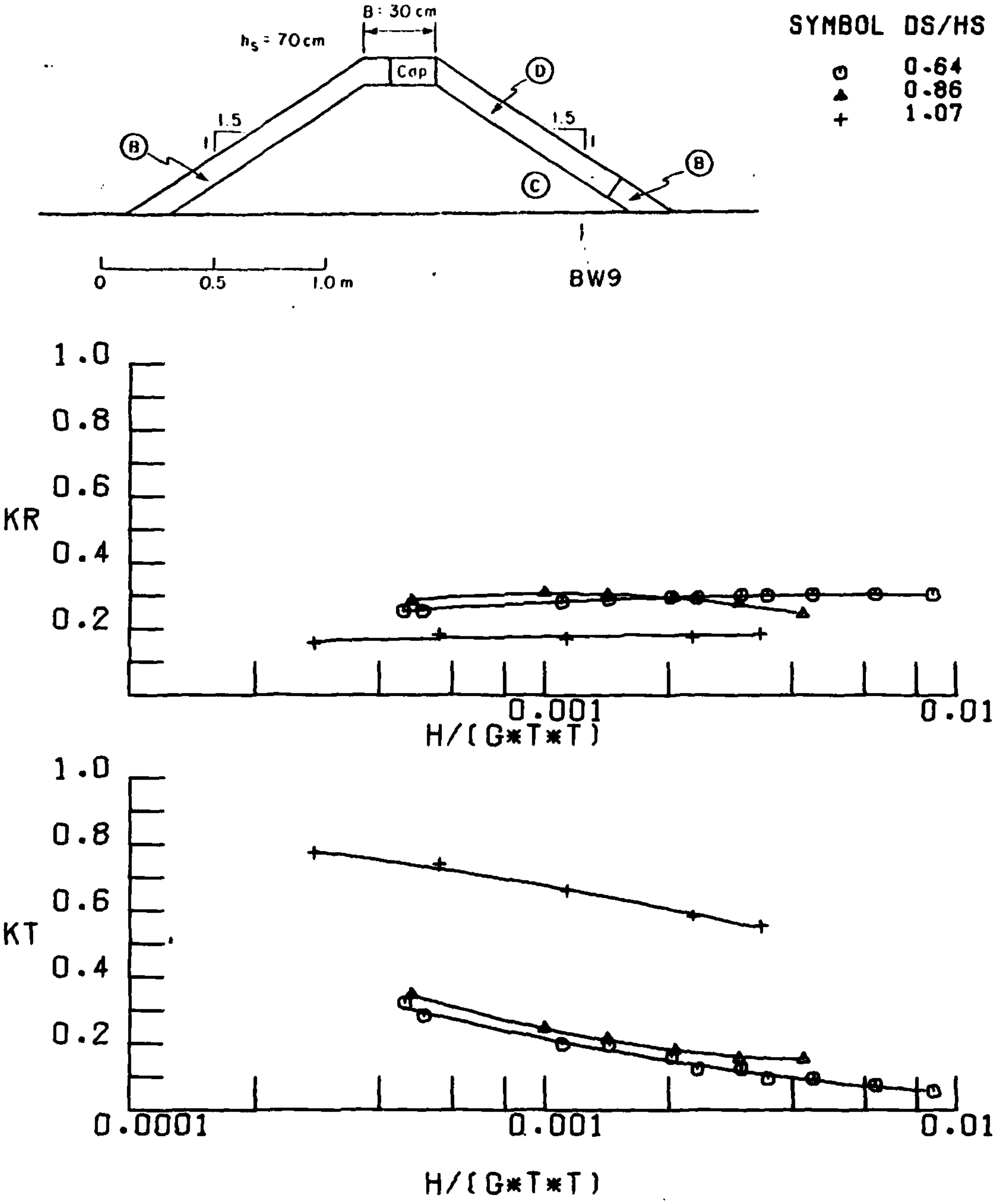
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 7 DS/HS= 0.98



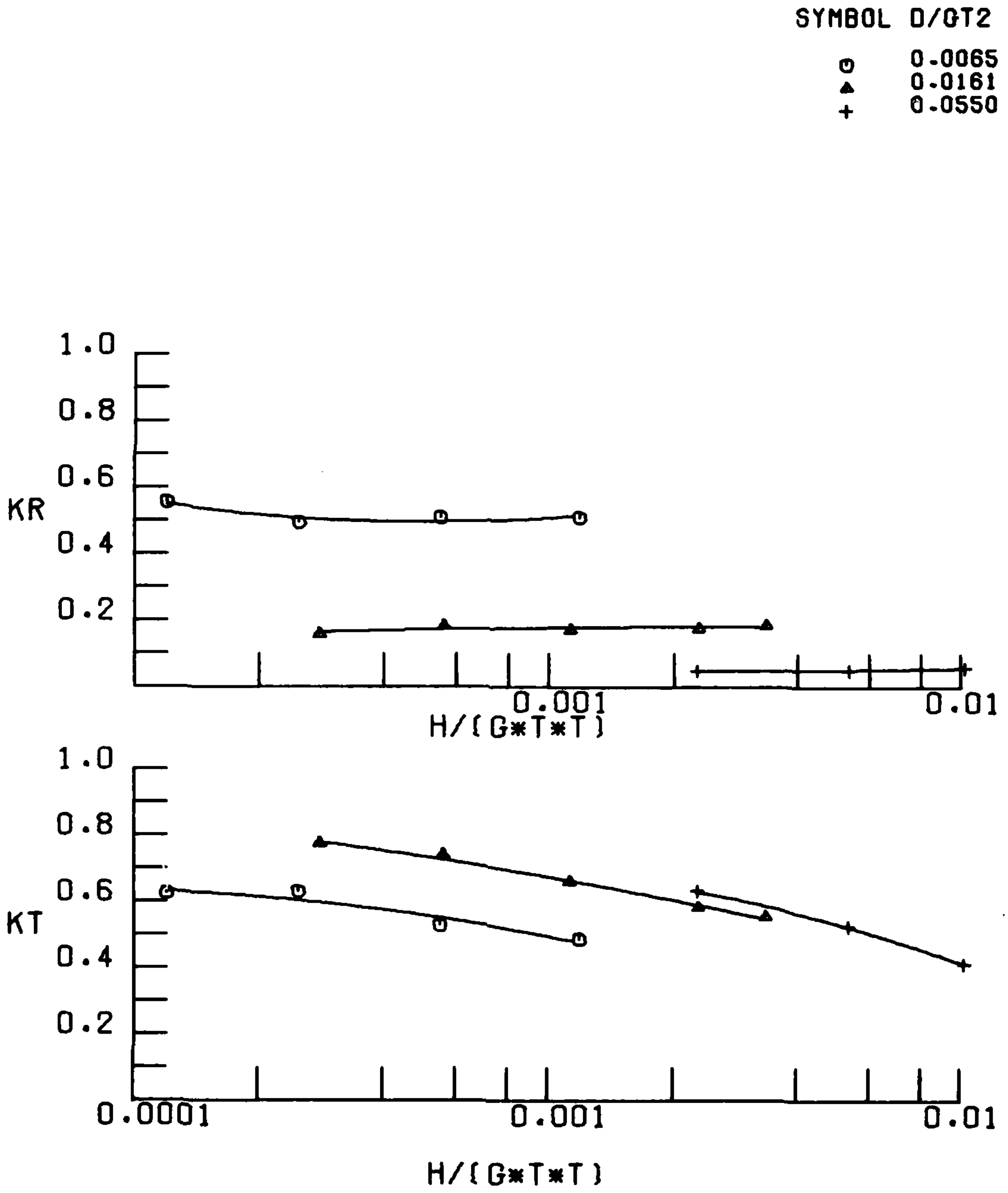
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 8 D/(GT2)=0.016



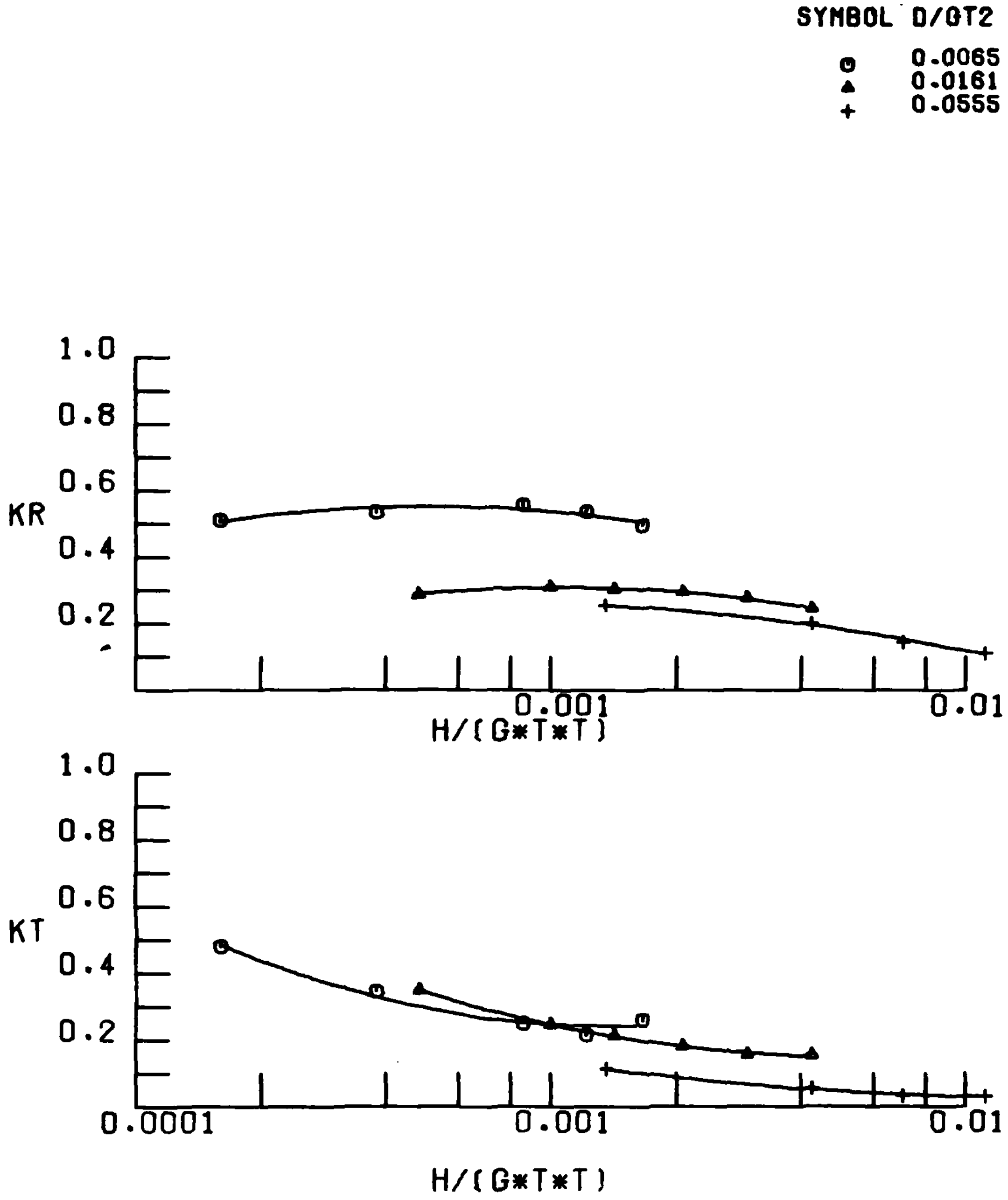
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 9 D/(GT2)=0.016



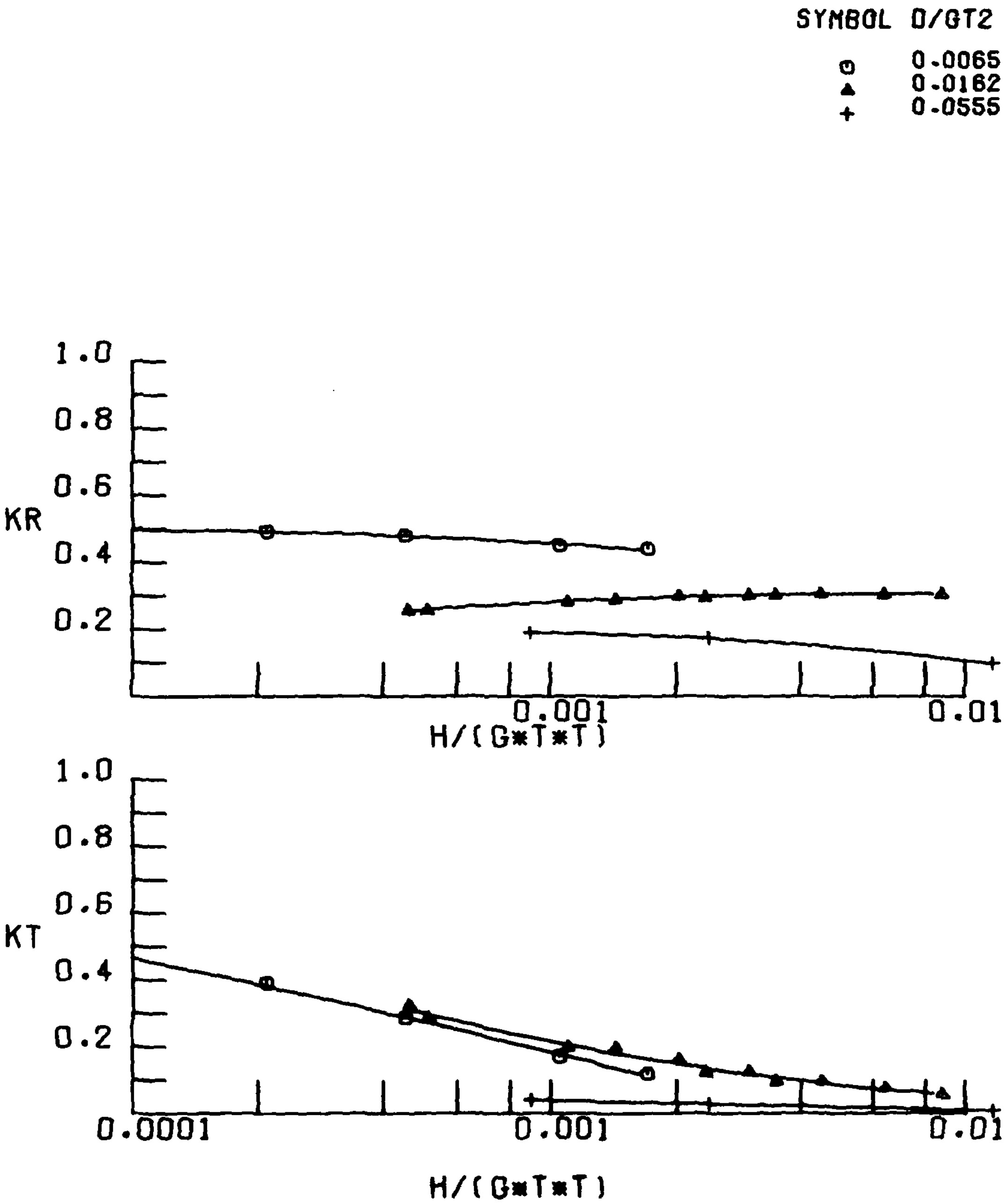
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 9 DS/HS= 1.07



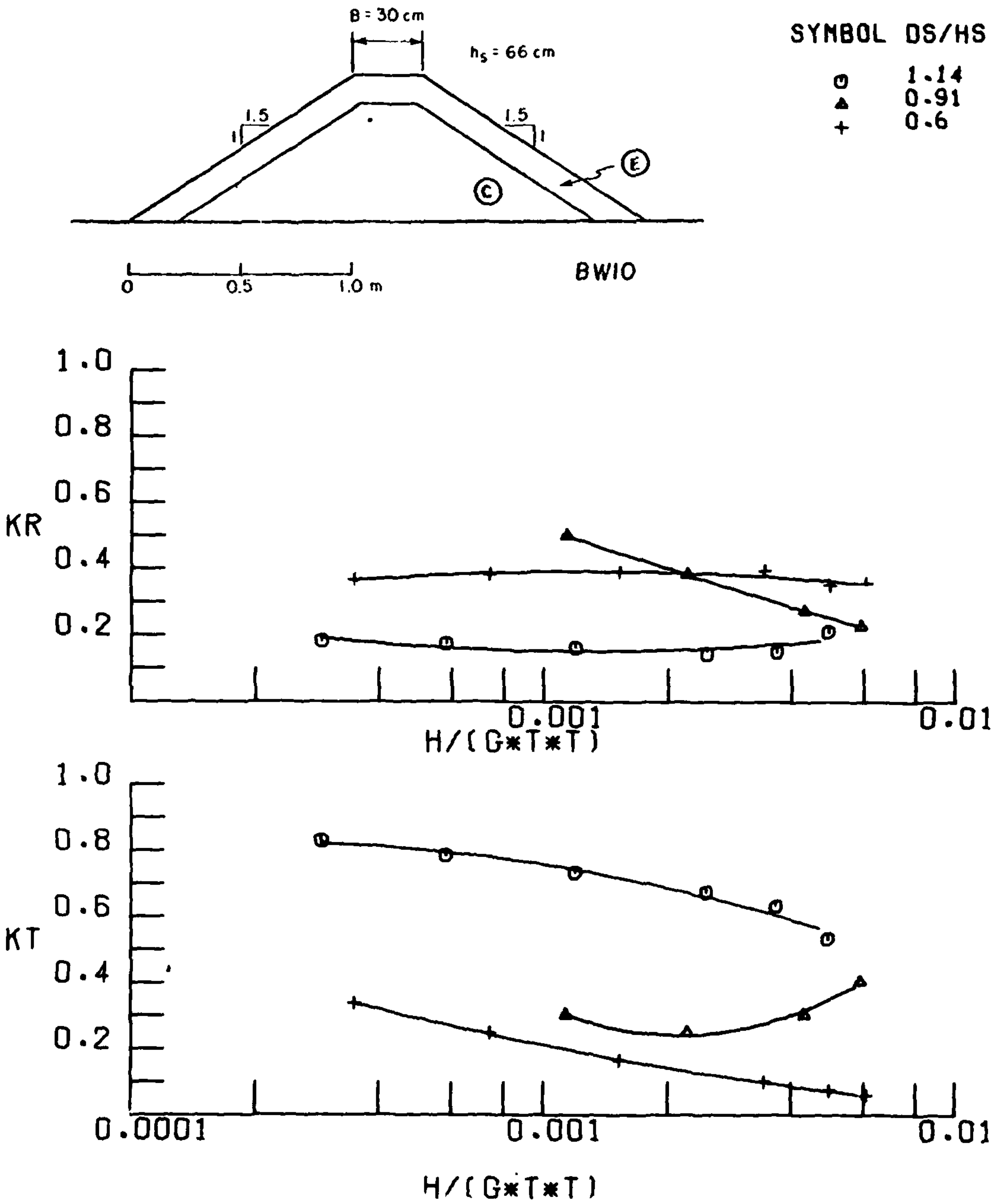
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 9 DS/HS= 0.86



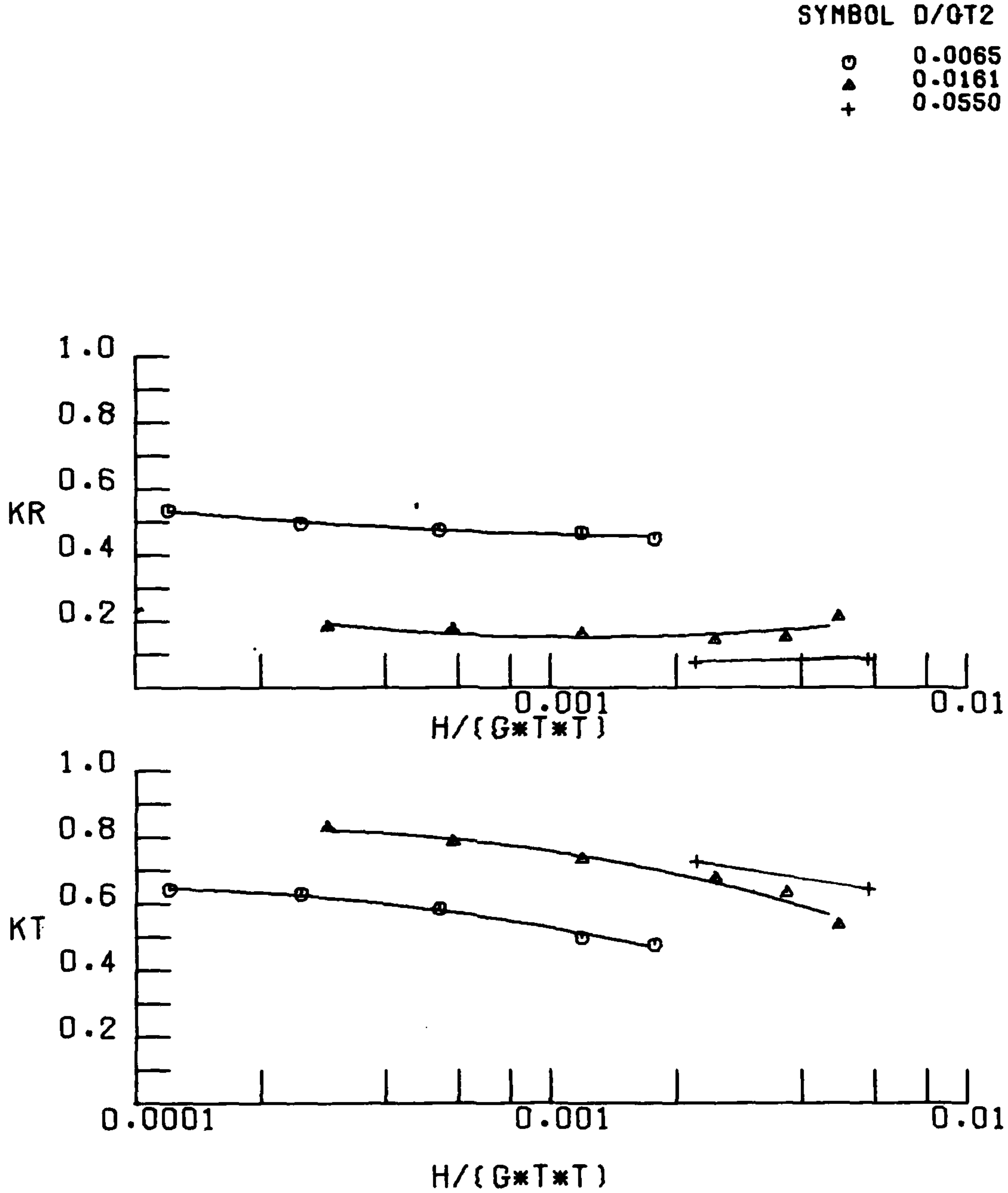
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 9 DS/HS= 0.64



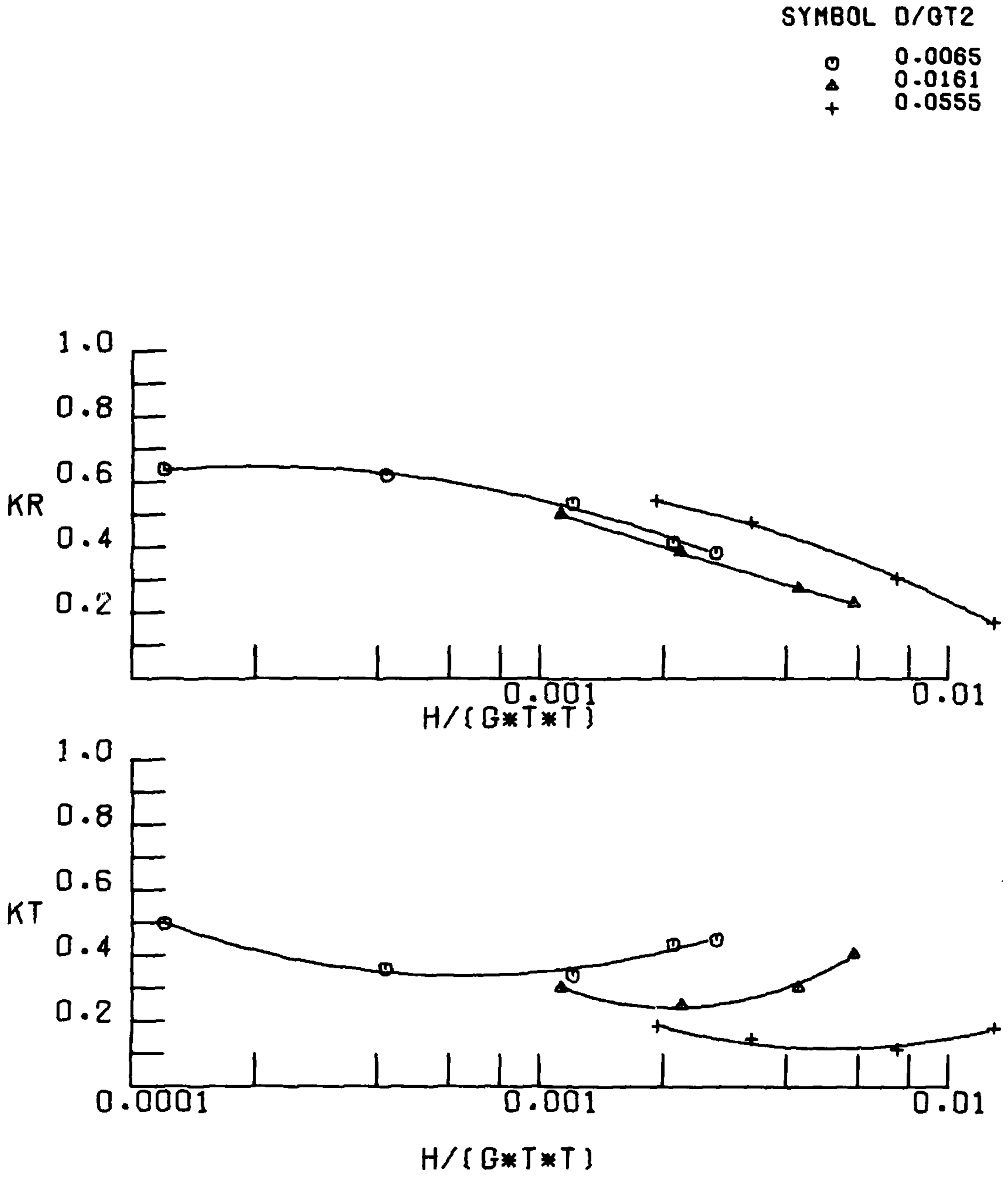
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 10 D/(GT2)=0.016



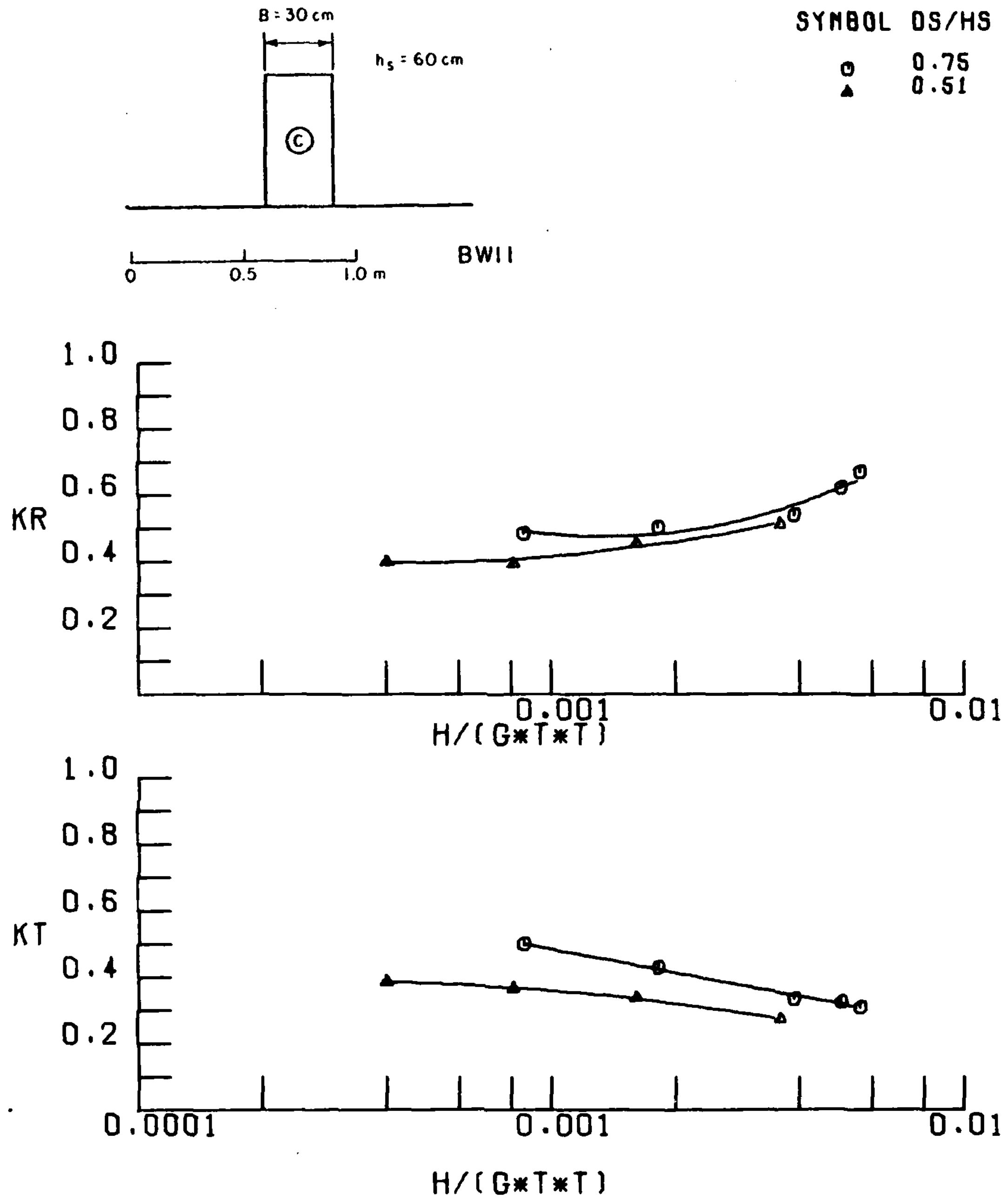
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 10 DS/HS= 1.14



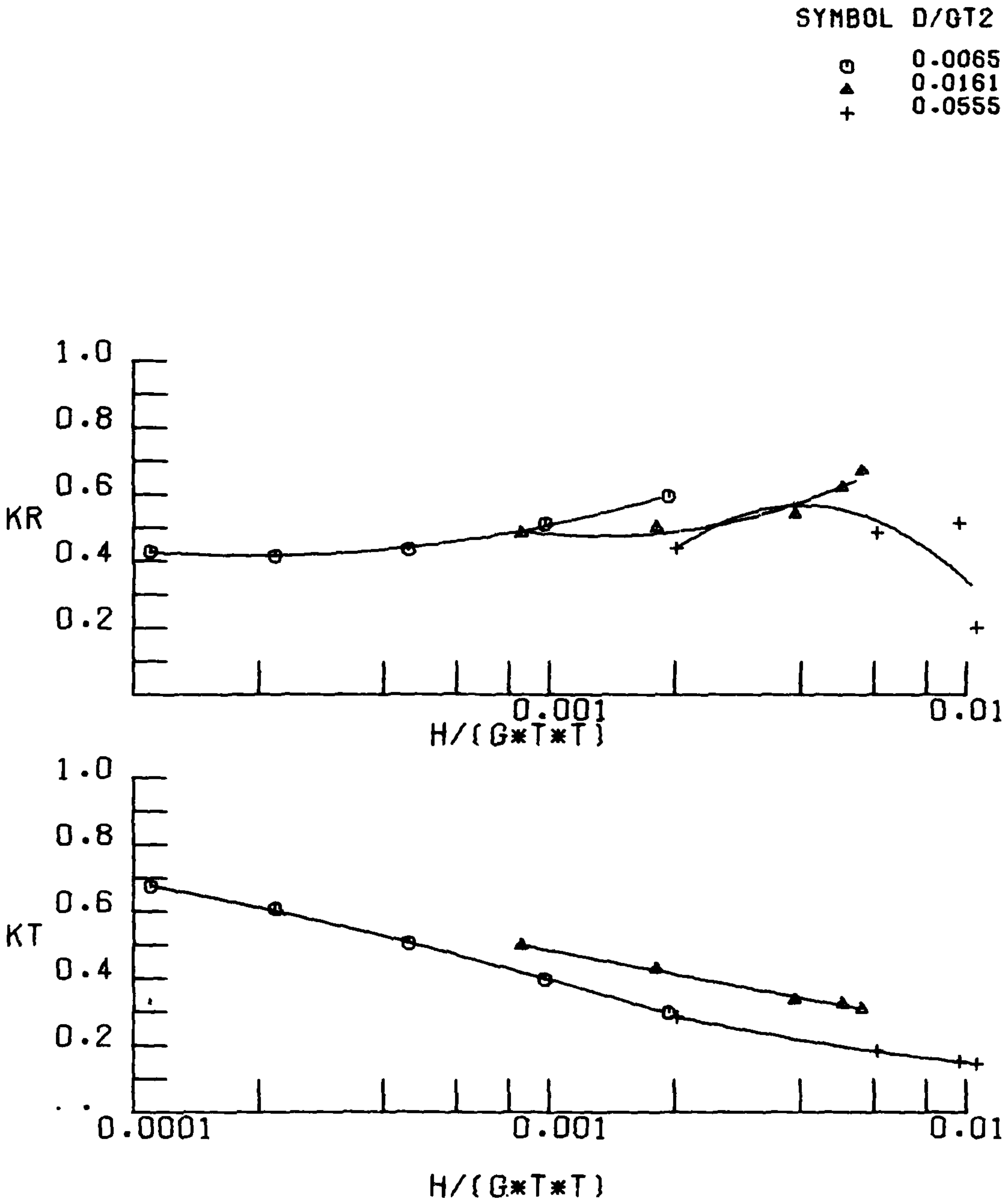
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 10 DS/HS= 0.91



WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 11 D/(GT2)=0.016



WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

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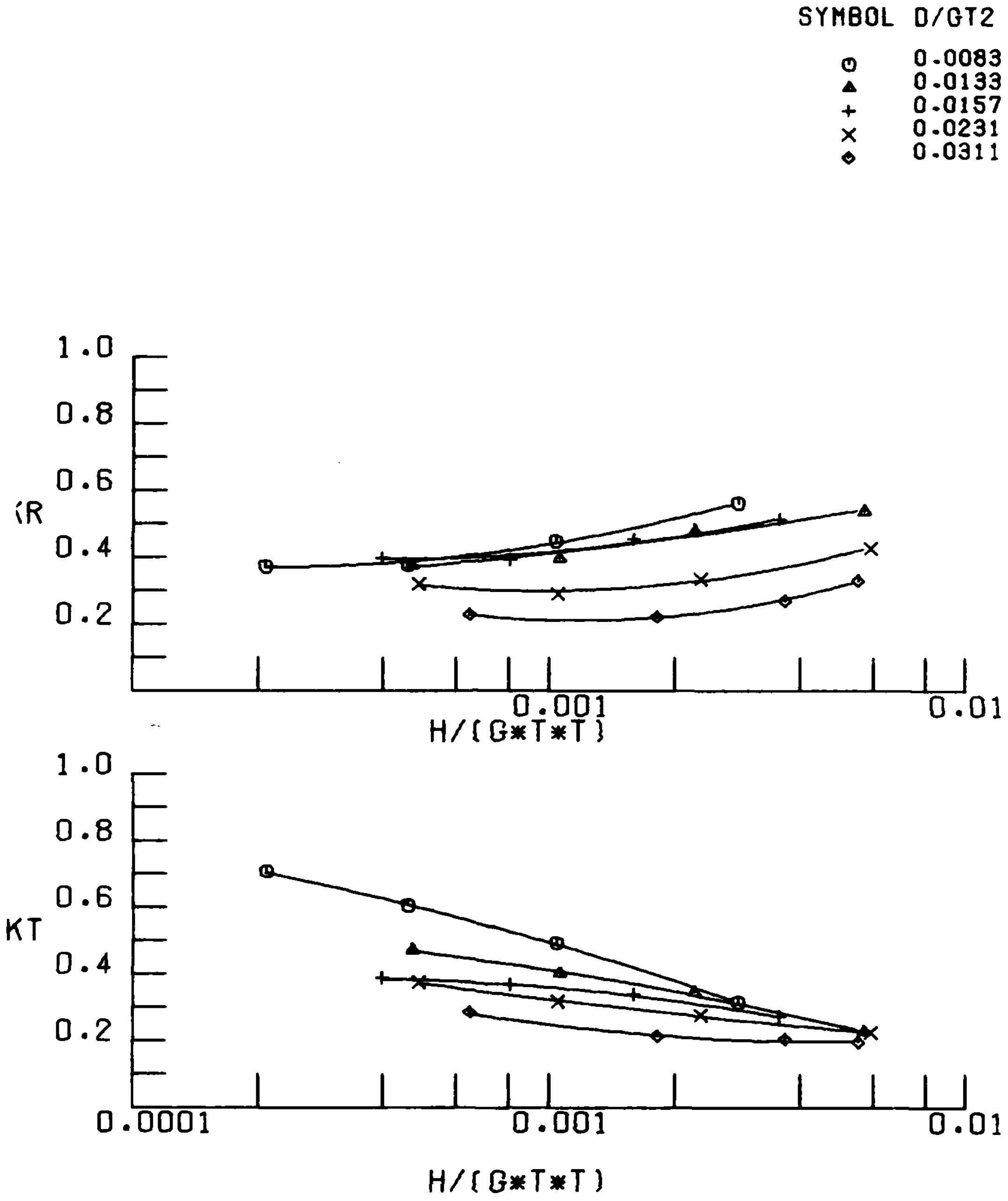
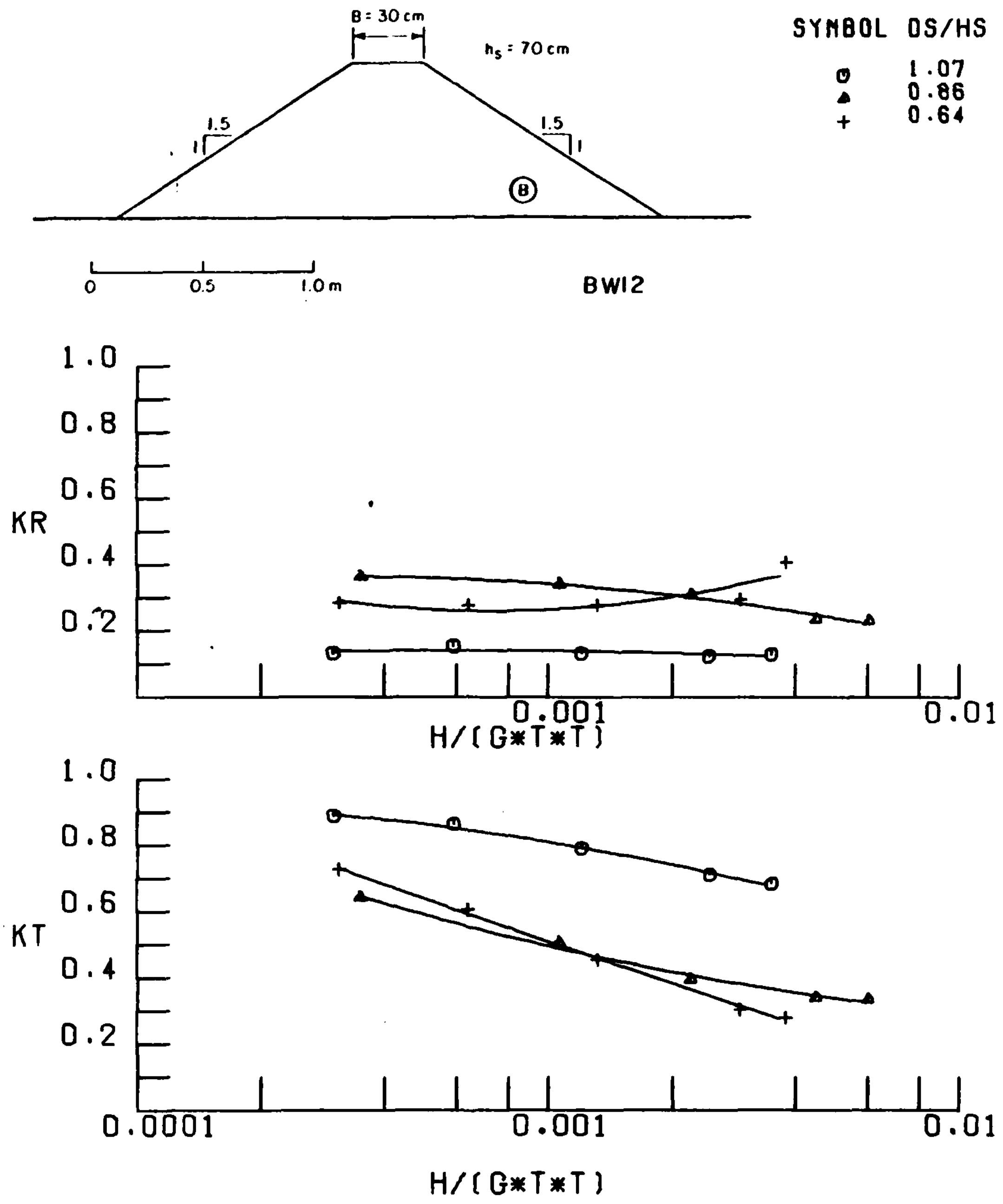


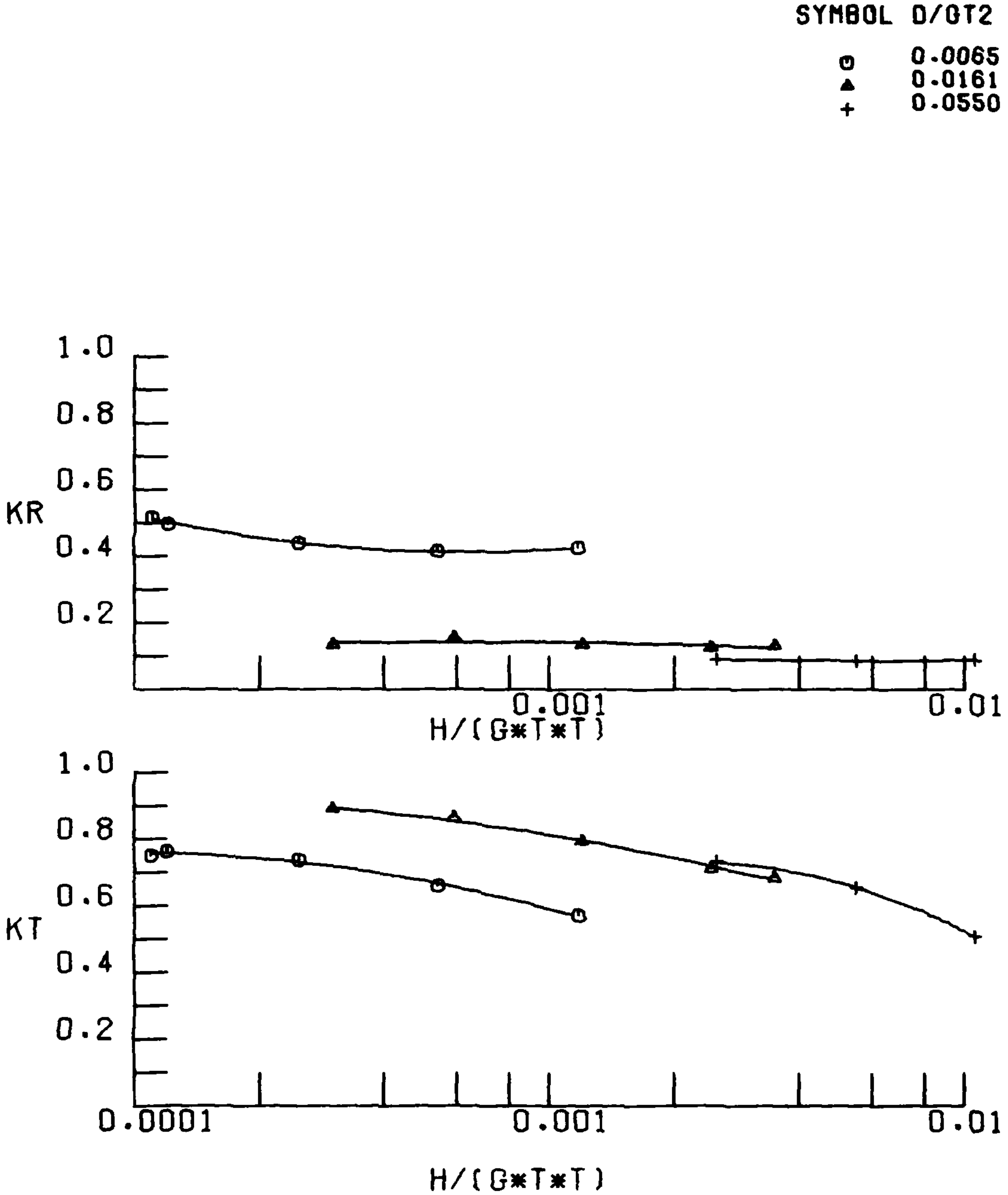
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 11 DS/HS= 0.51



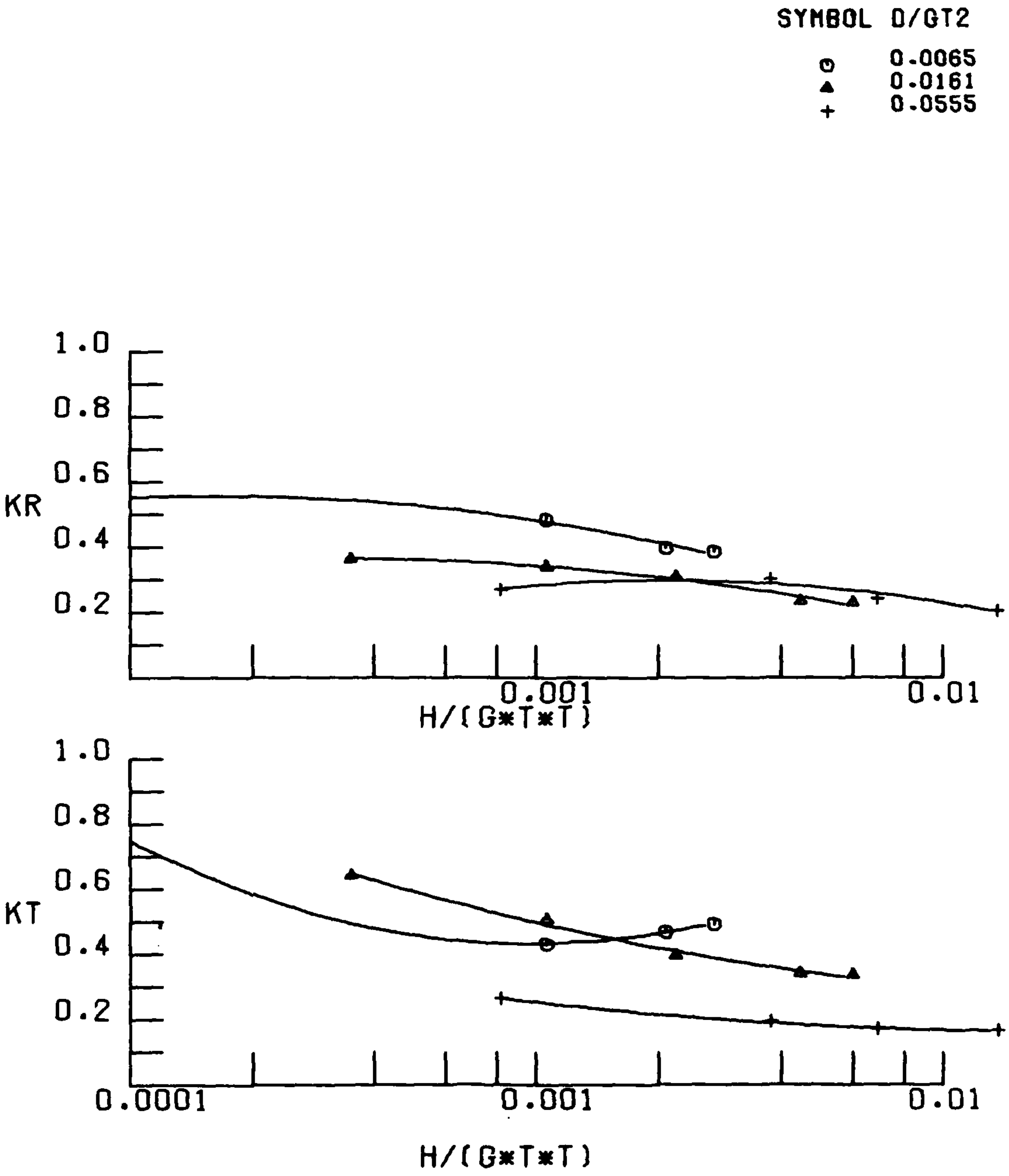
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 12 D/(GT2)=0.016



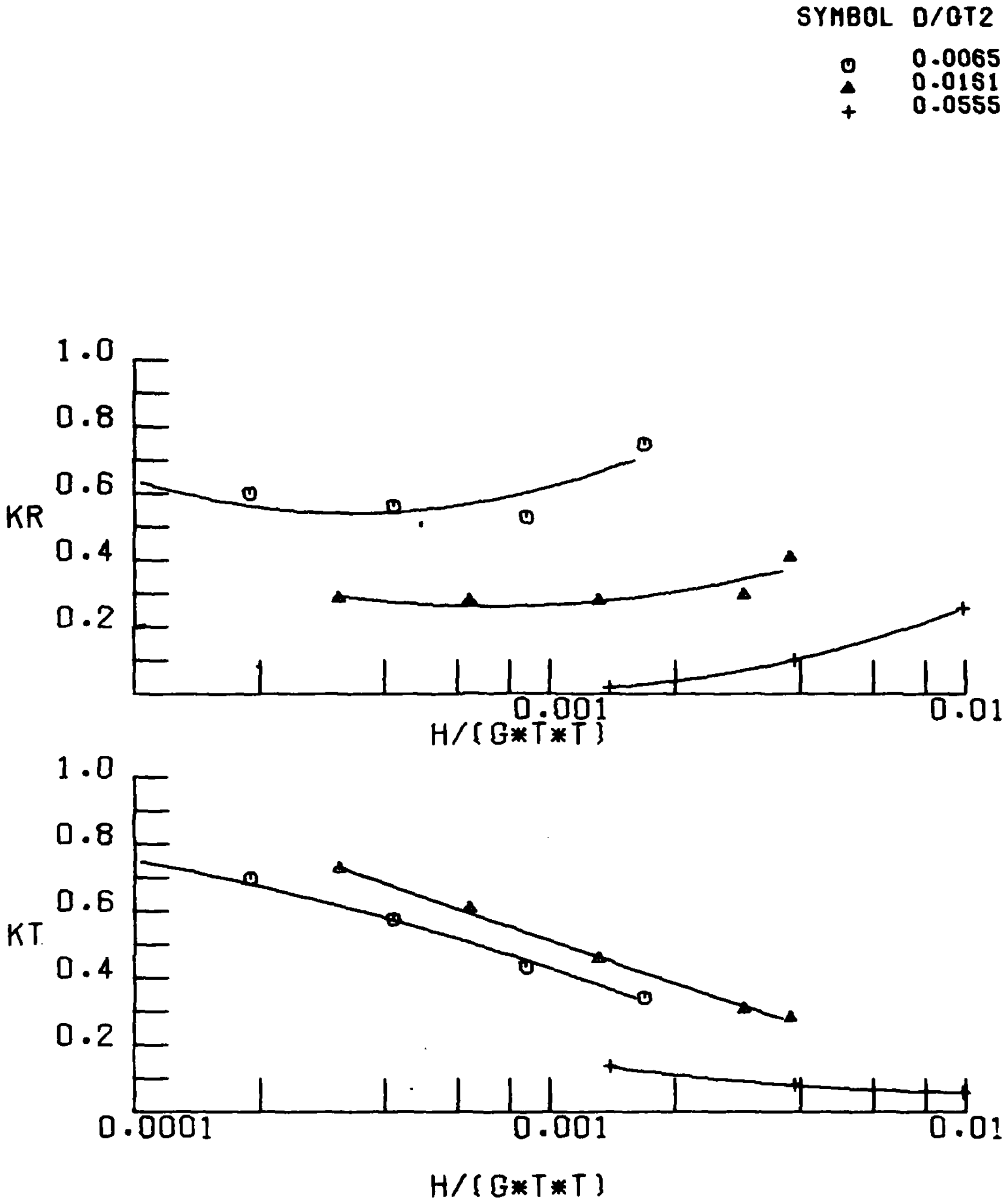
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 12 DS/HS= 1.07



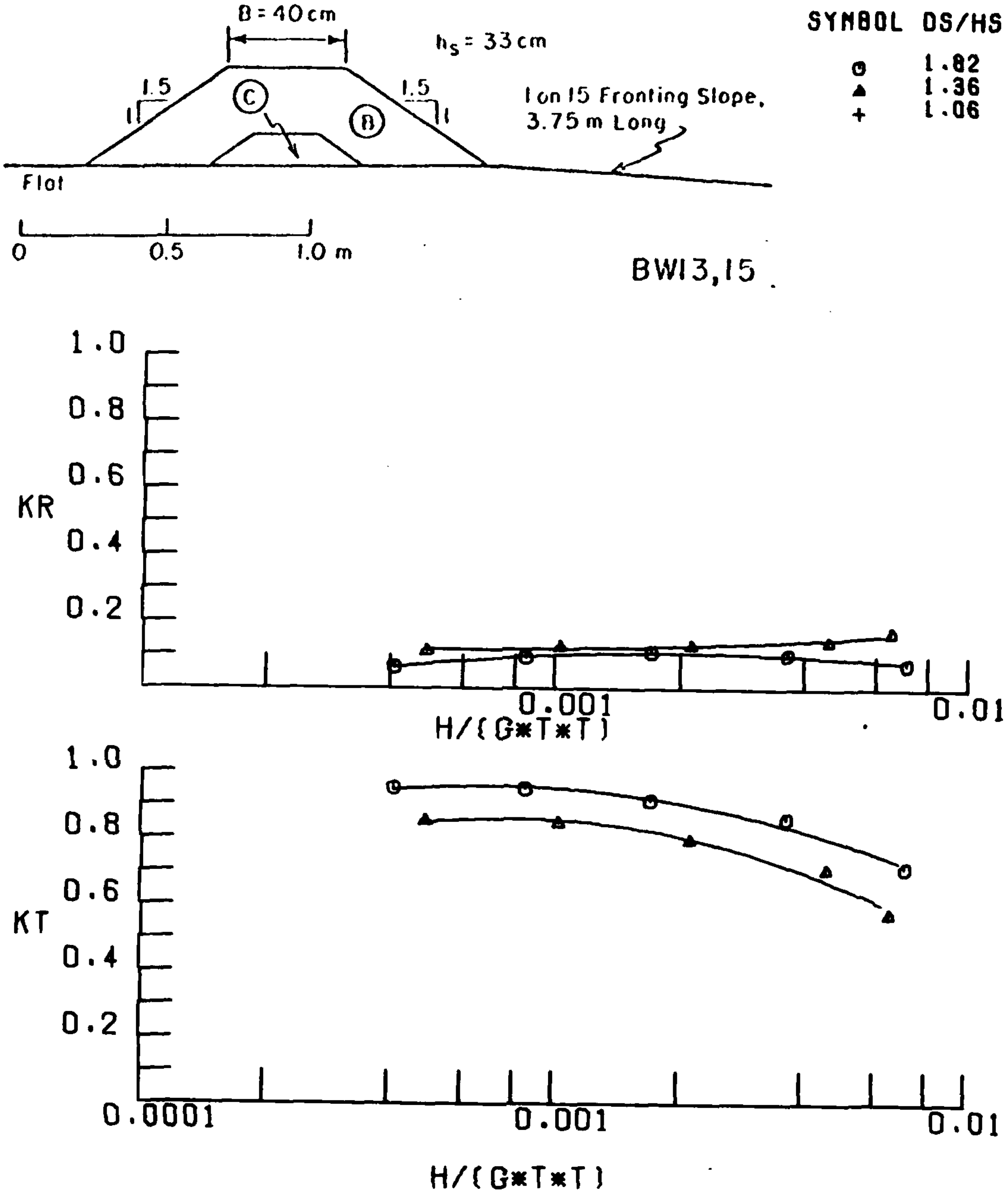
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 12 DS/HS= 0.86



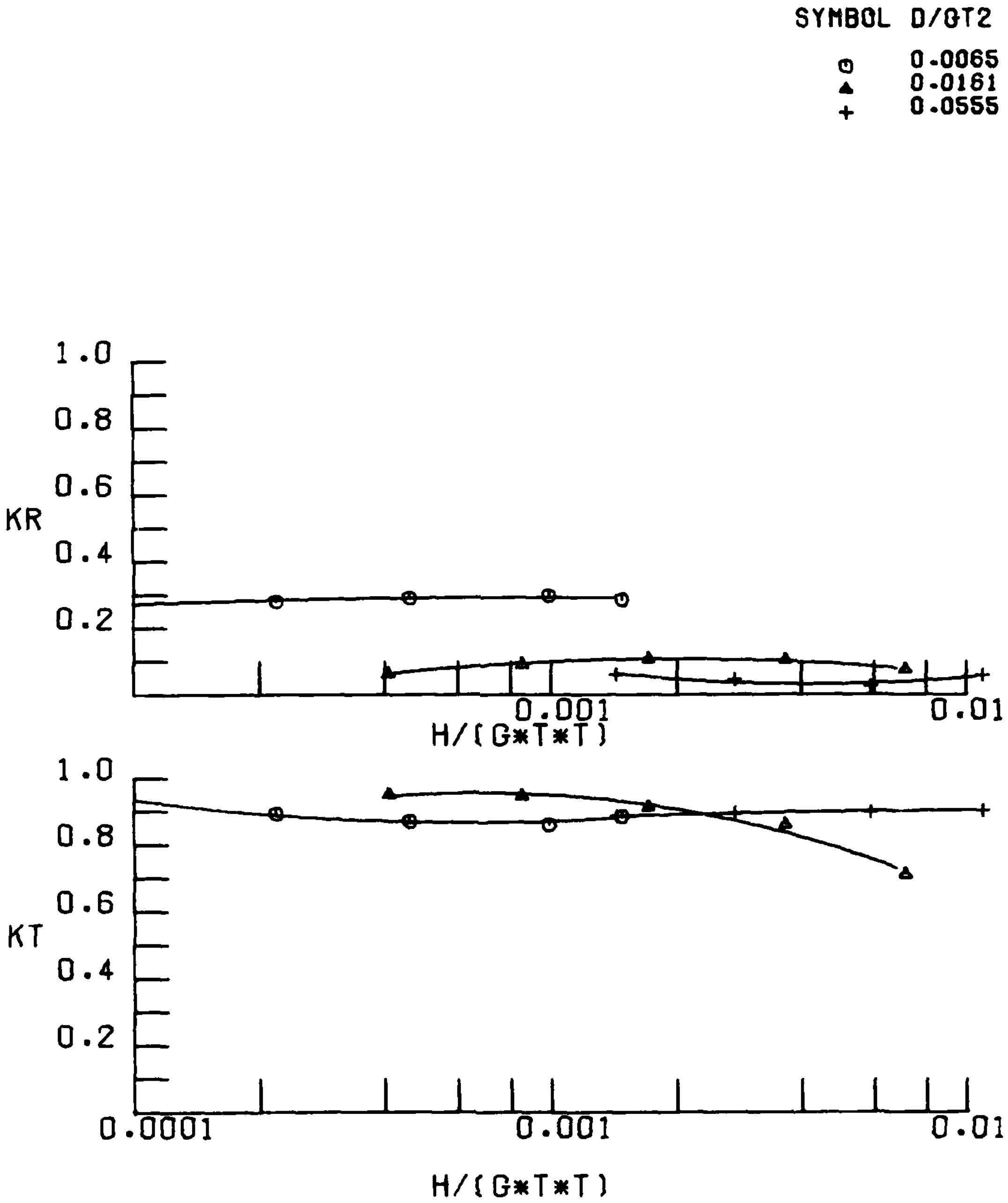
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 12 DS/HS= 0.64



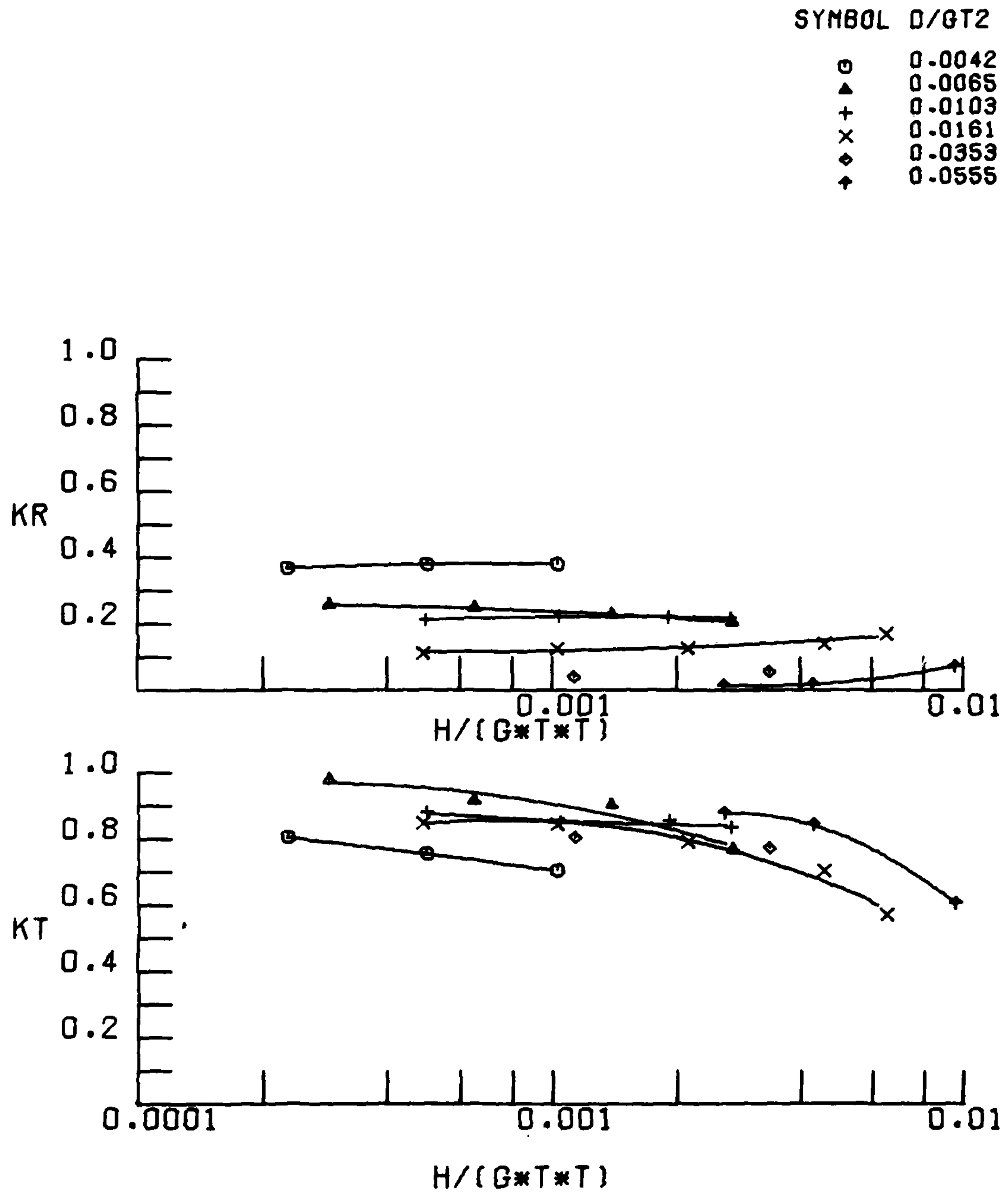
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 13 D/(GT2)=0.016



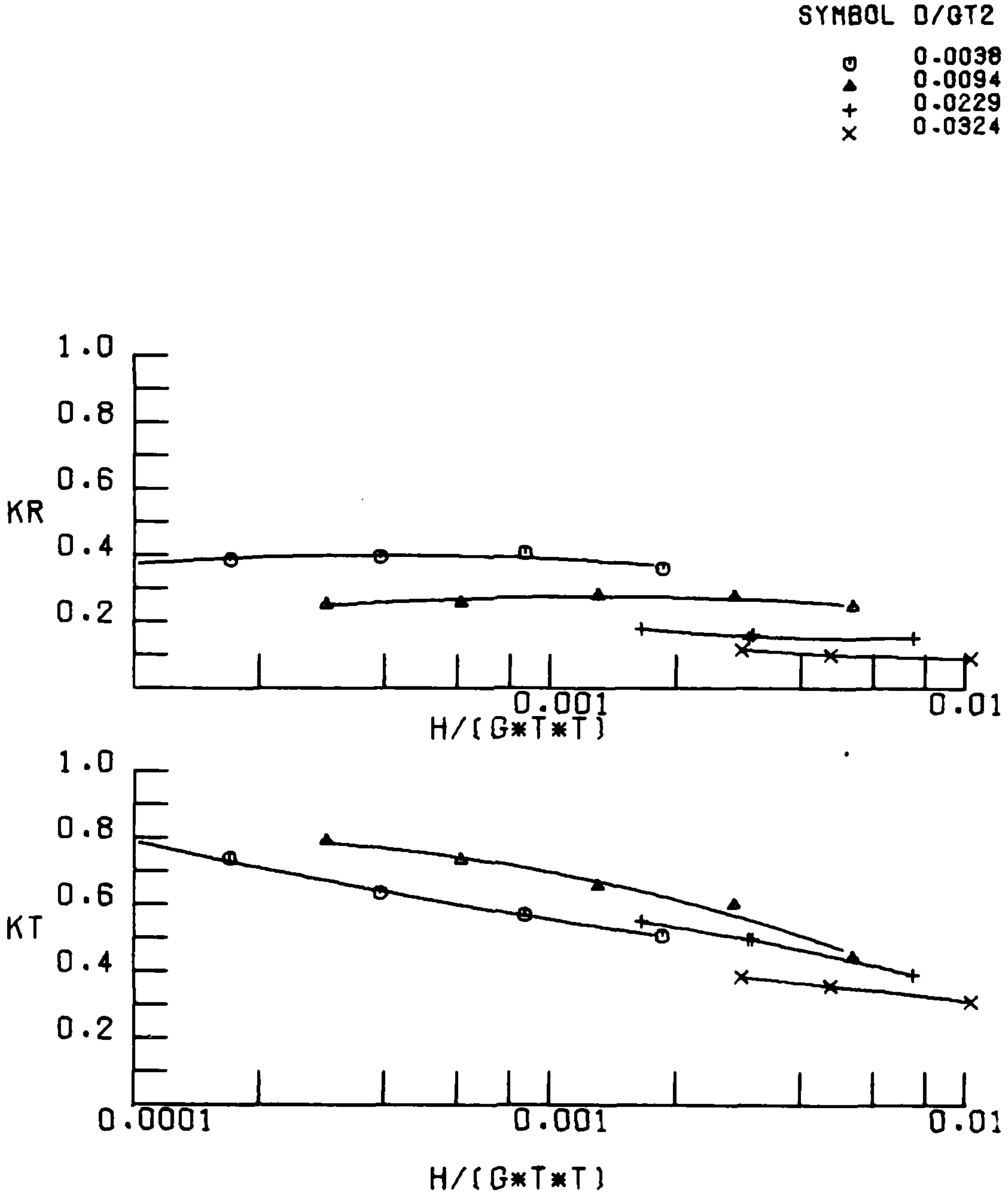
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 13 DS/HS= 1.82



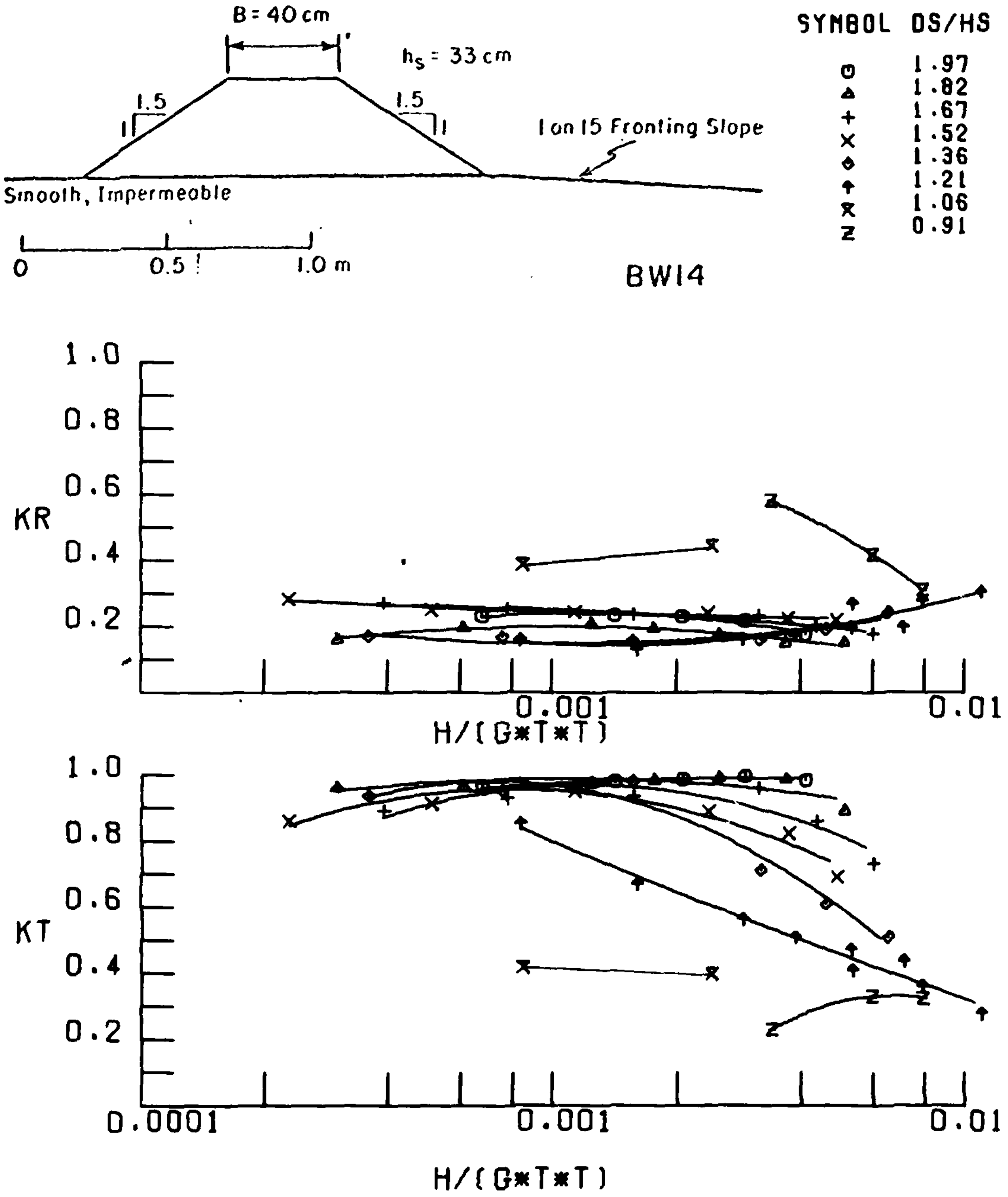
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 13 DS/HS= 1.36



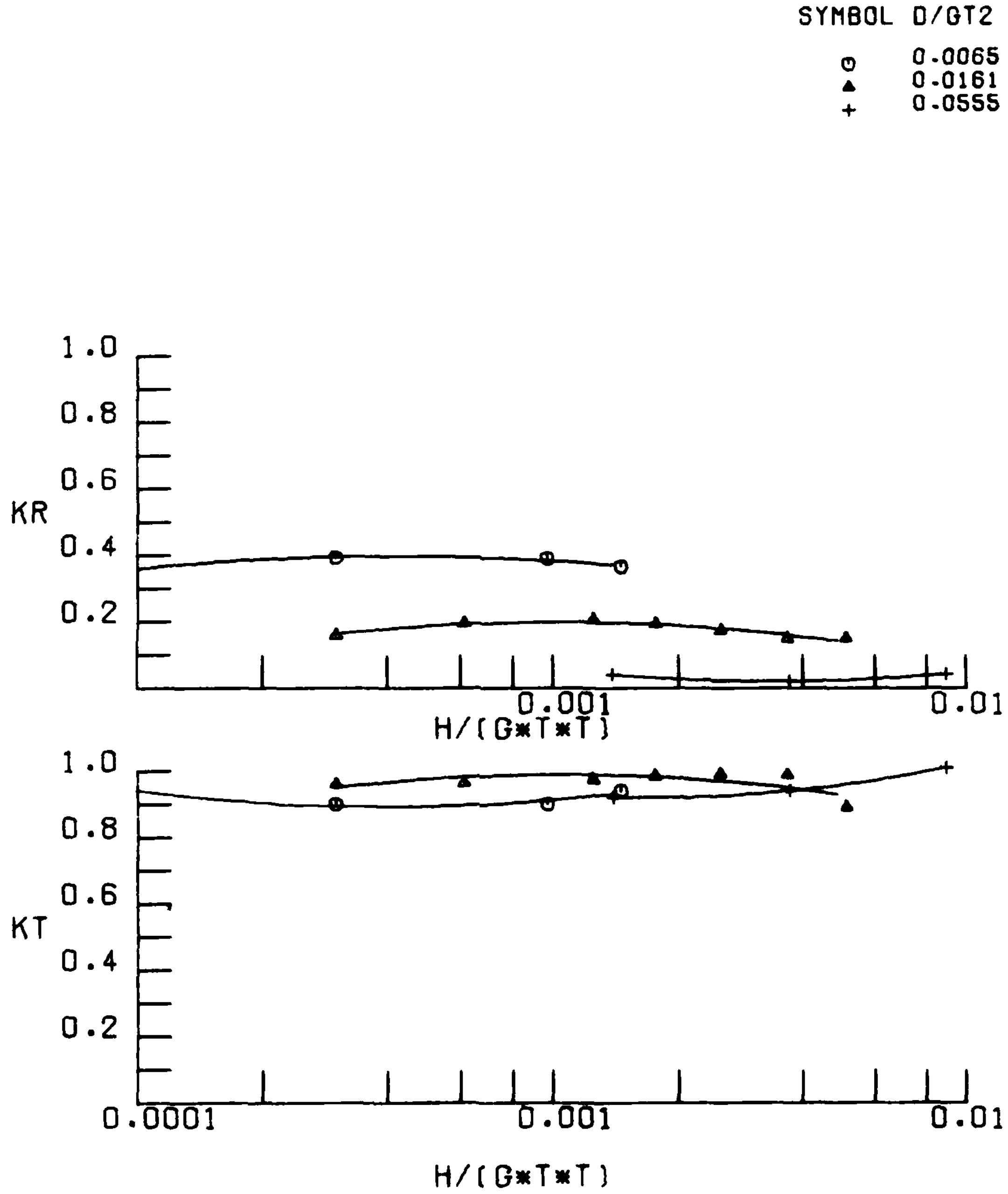
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 13 DS/HS= 1.06



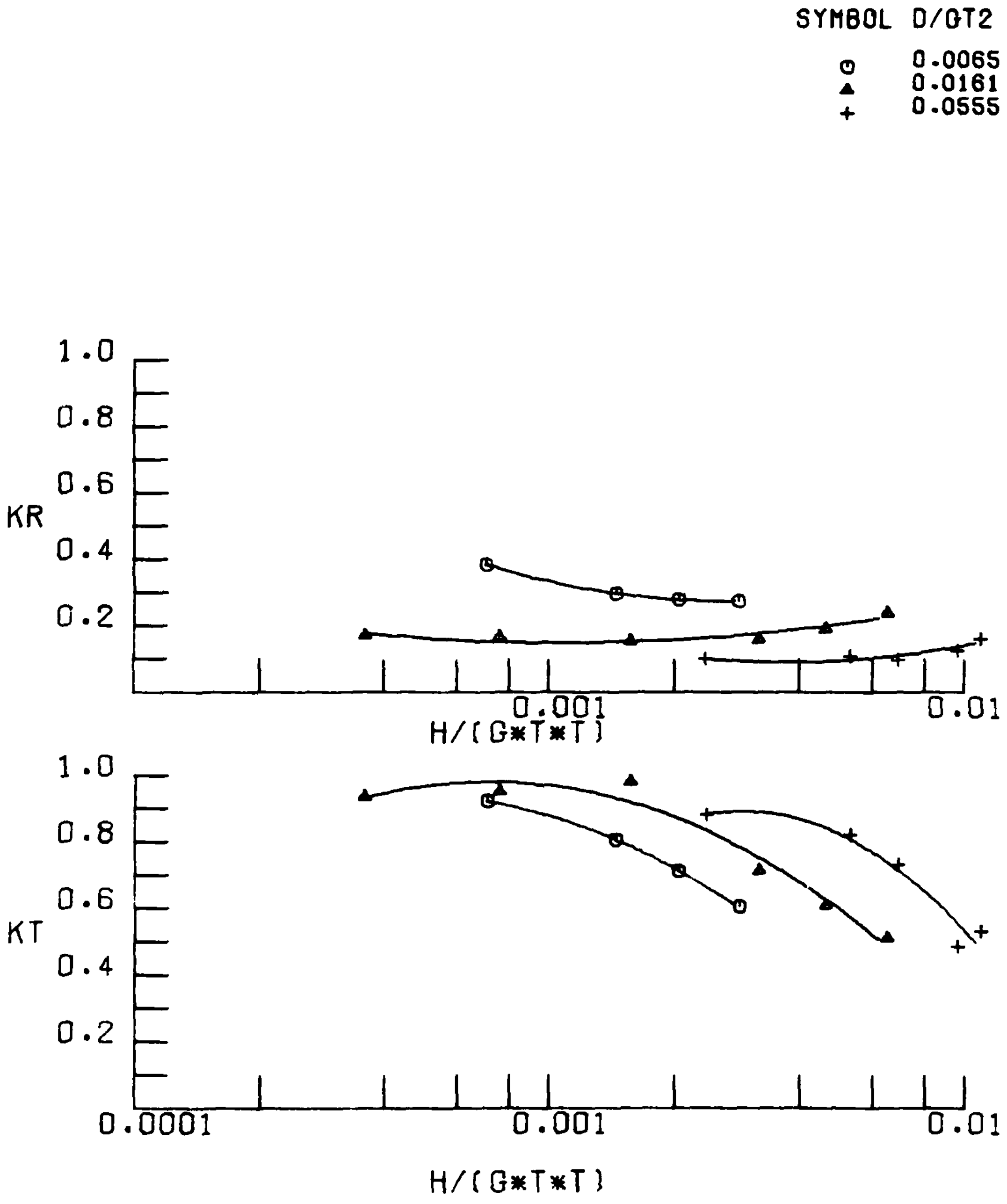
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 14 D/(GT2)=0.016



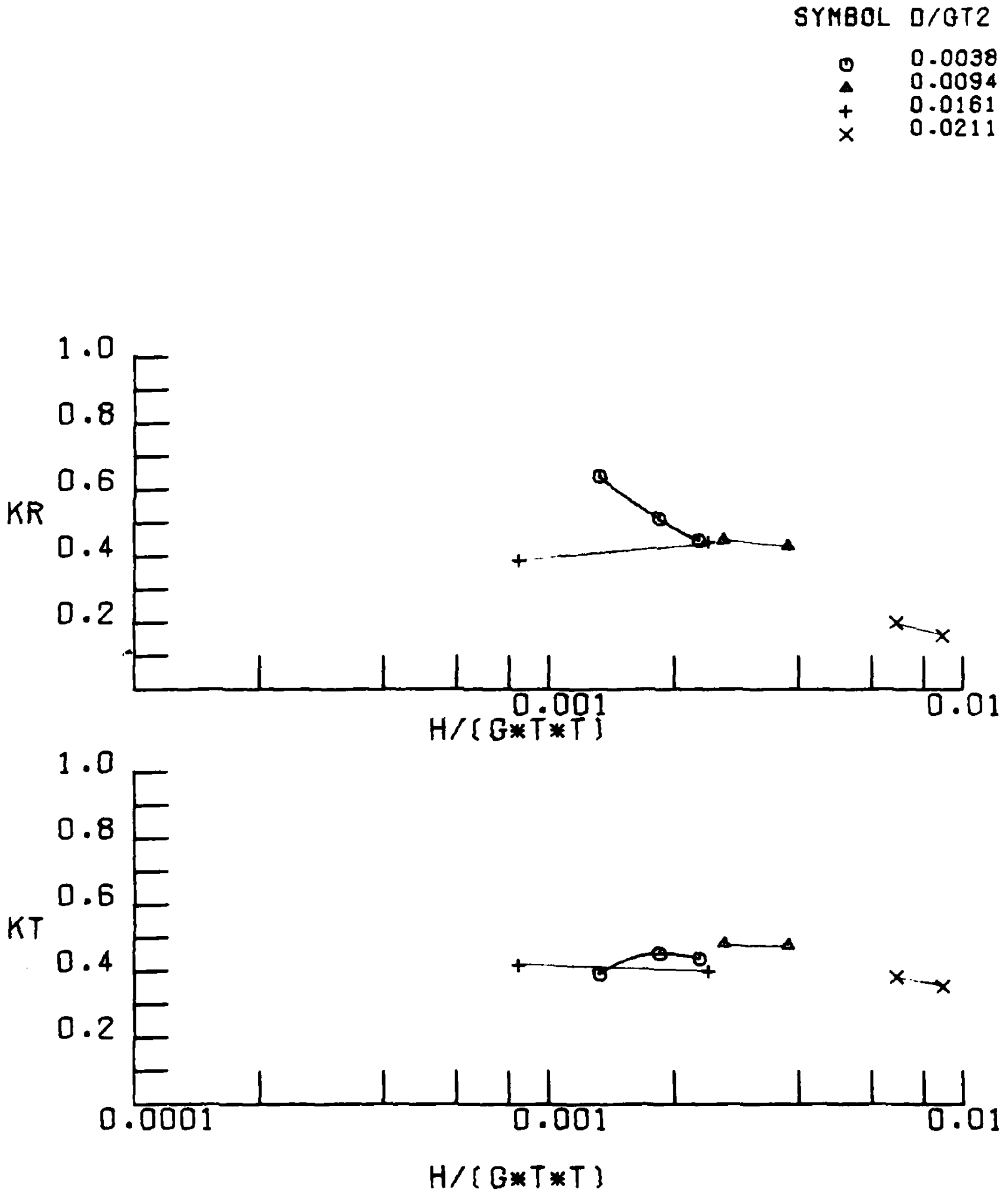
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 14 DS/HS= 1.82



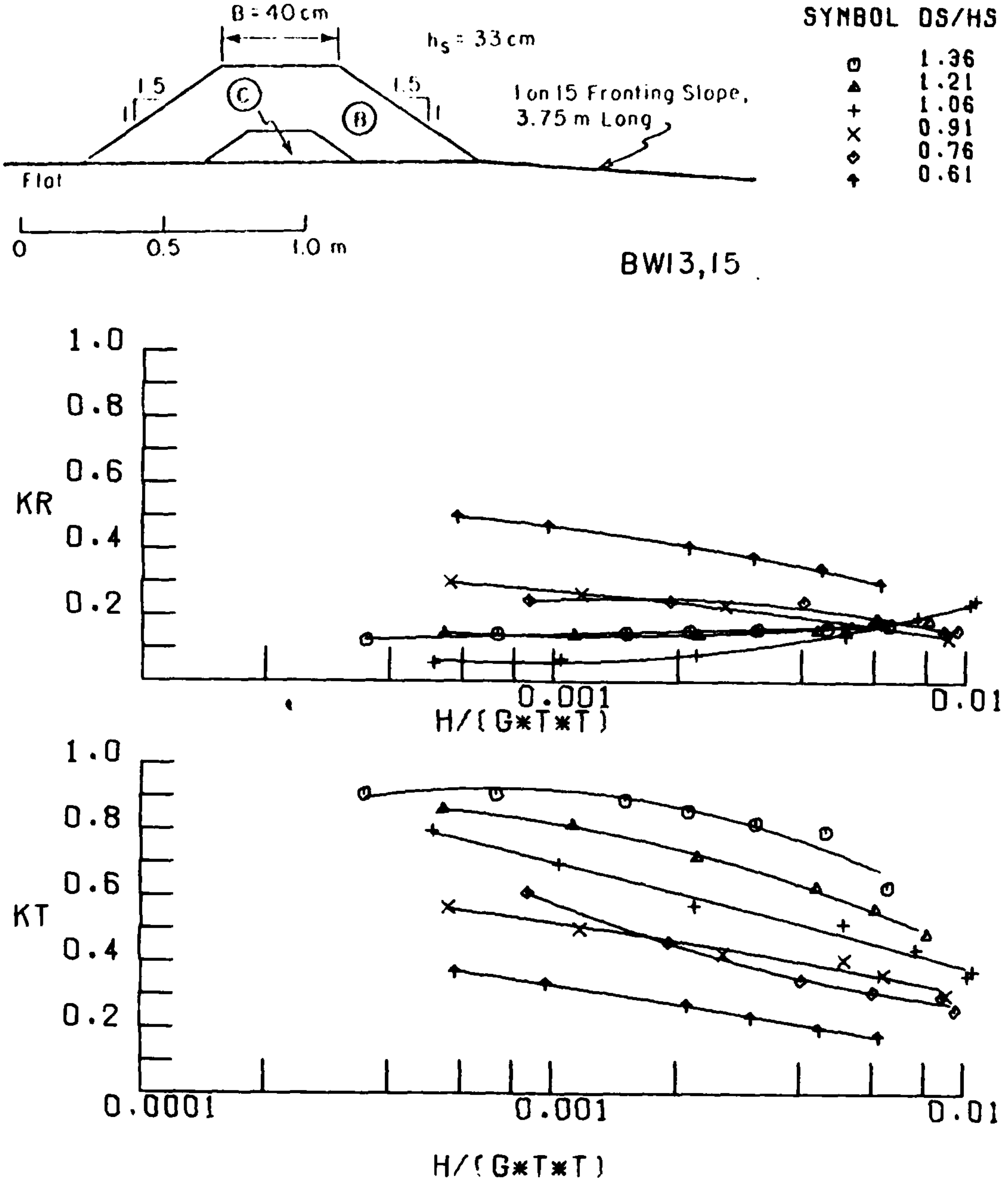
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 14 DS/HS= 1.36



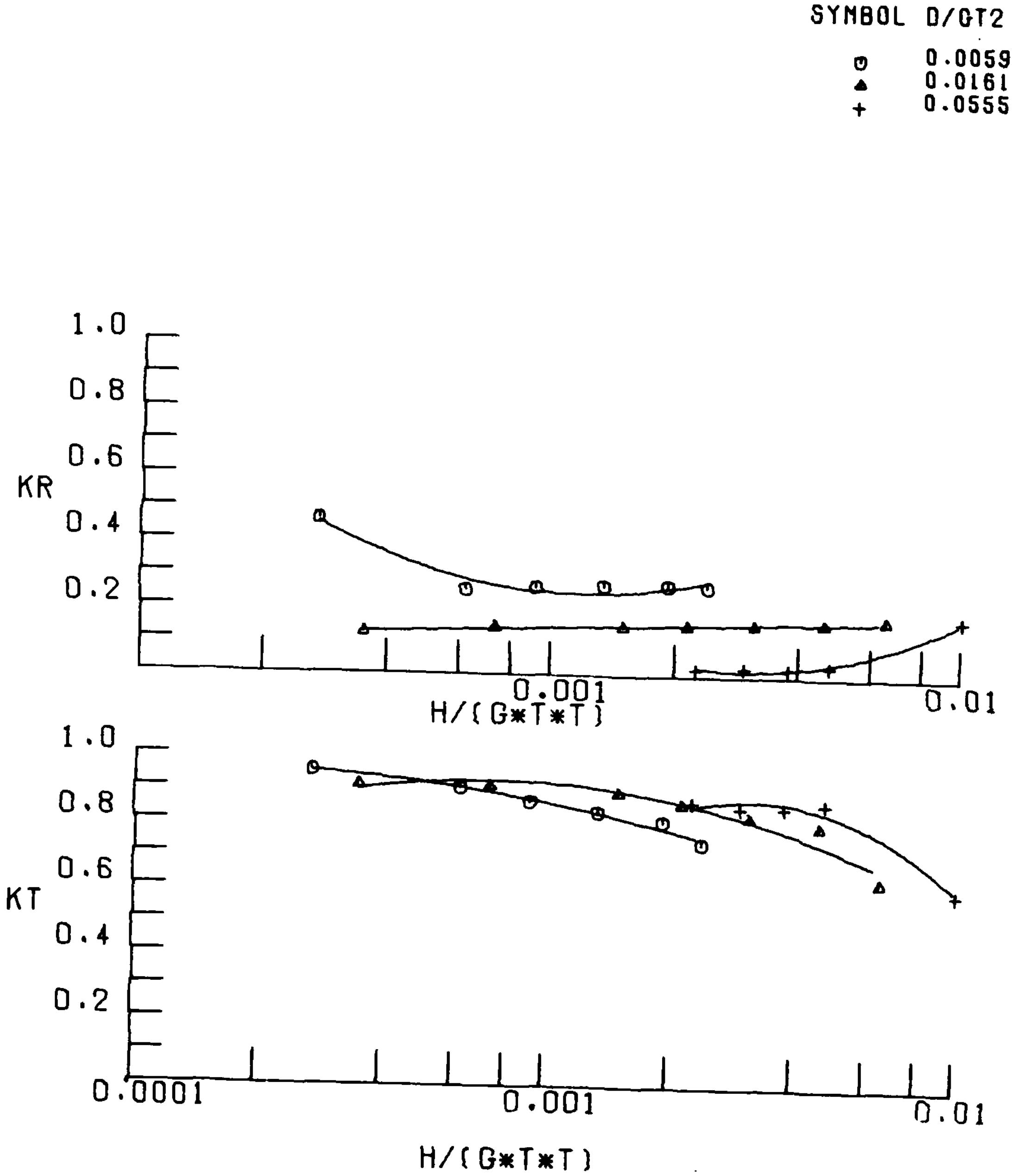
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 14 DS/HS= 1.06

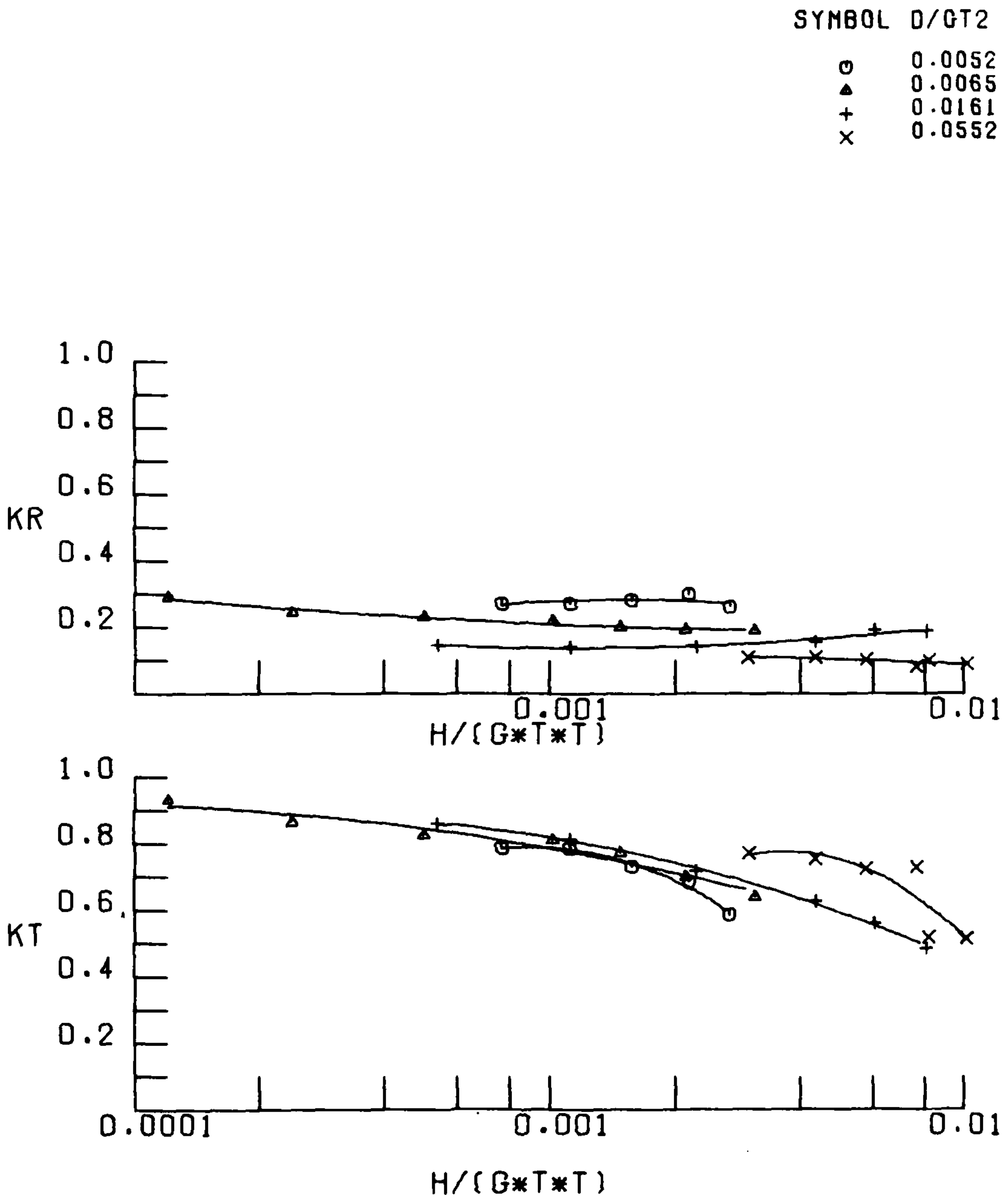


WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 15 D/(GT2)=0.016

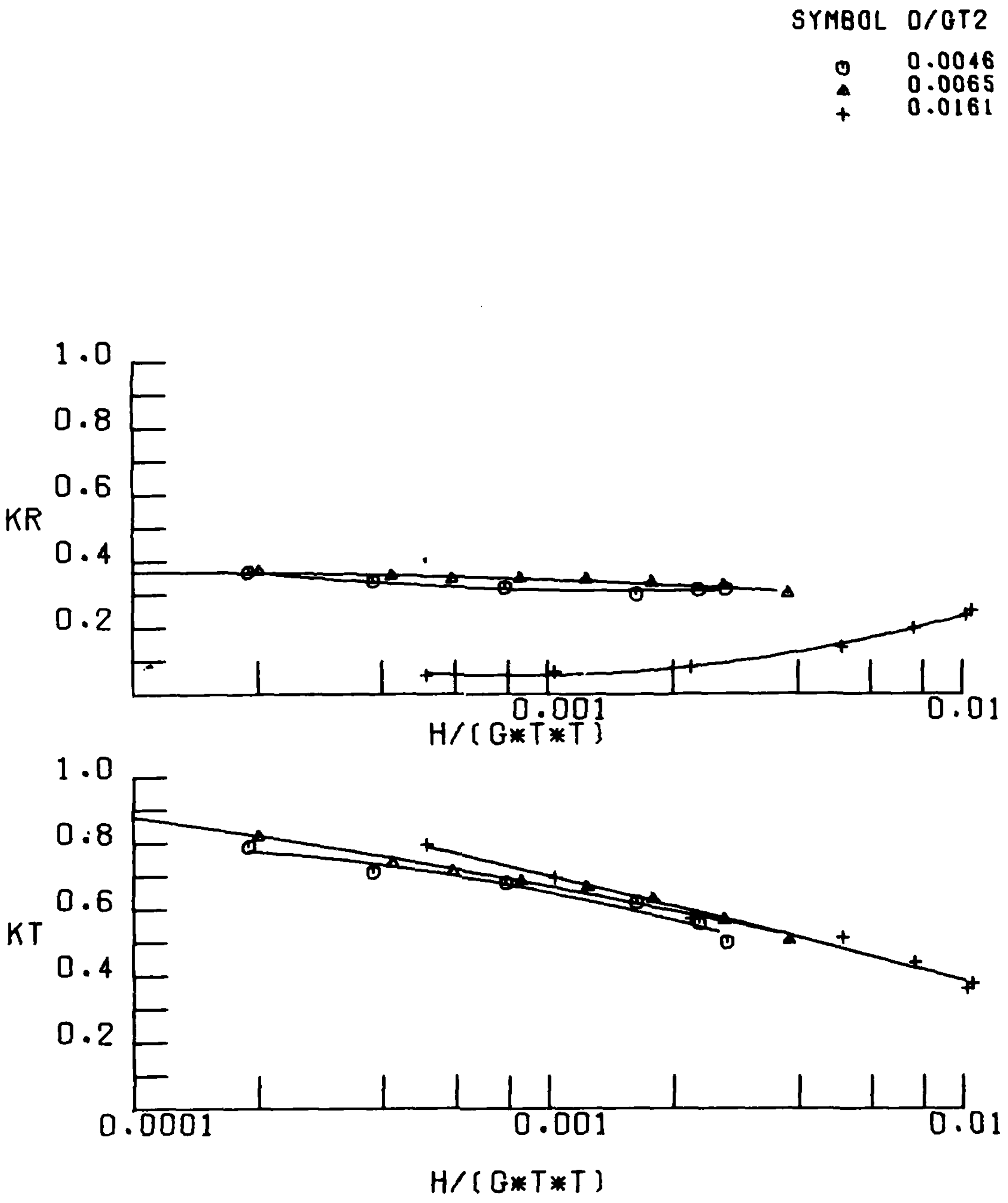


WAVE TRANSMISSION AND REFLECTION COEFFICIENTS
BREAKWATER 15 DS/HS= 1.36



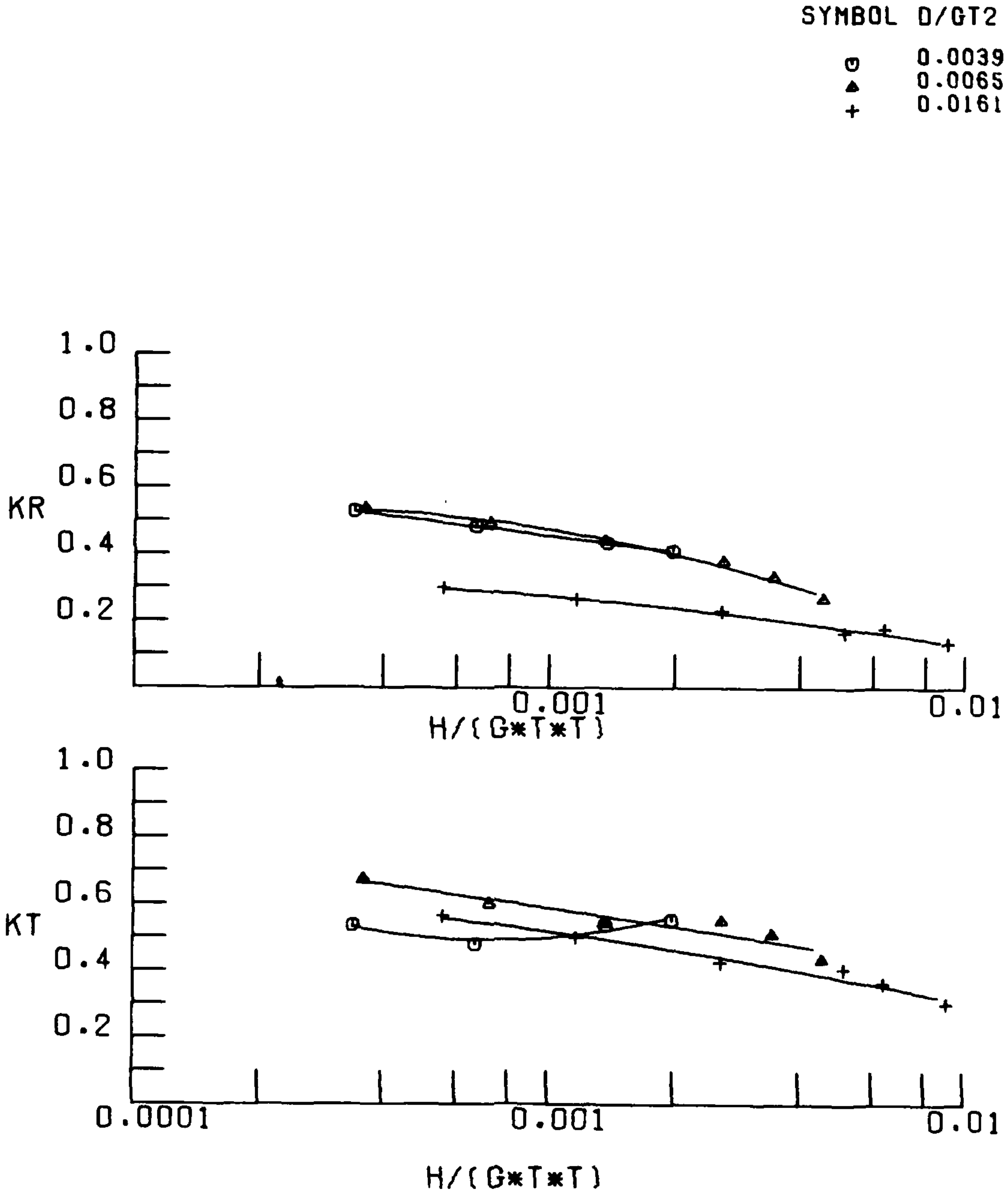
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 15 DS/HS= 1.21



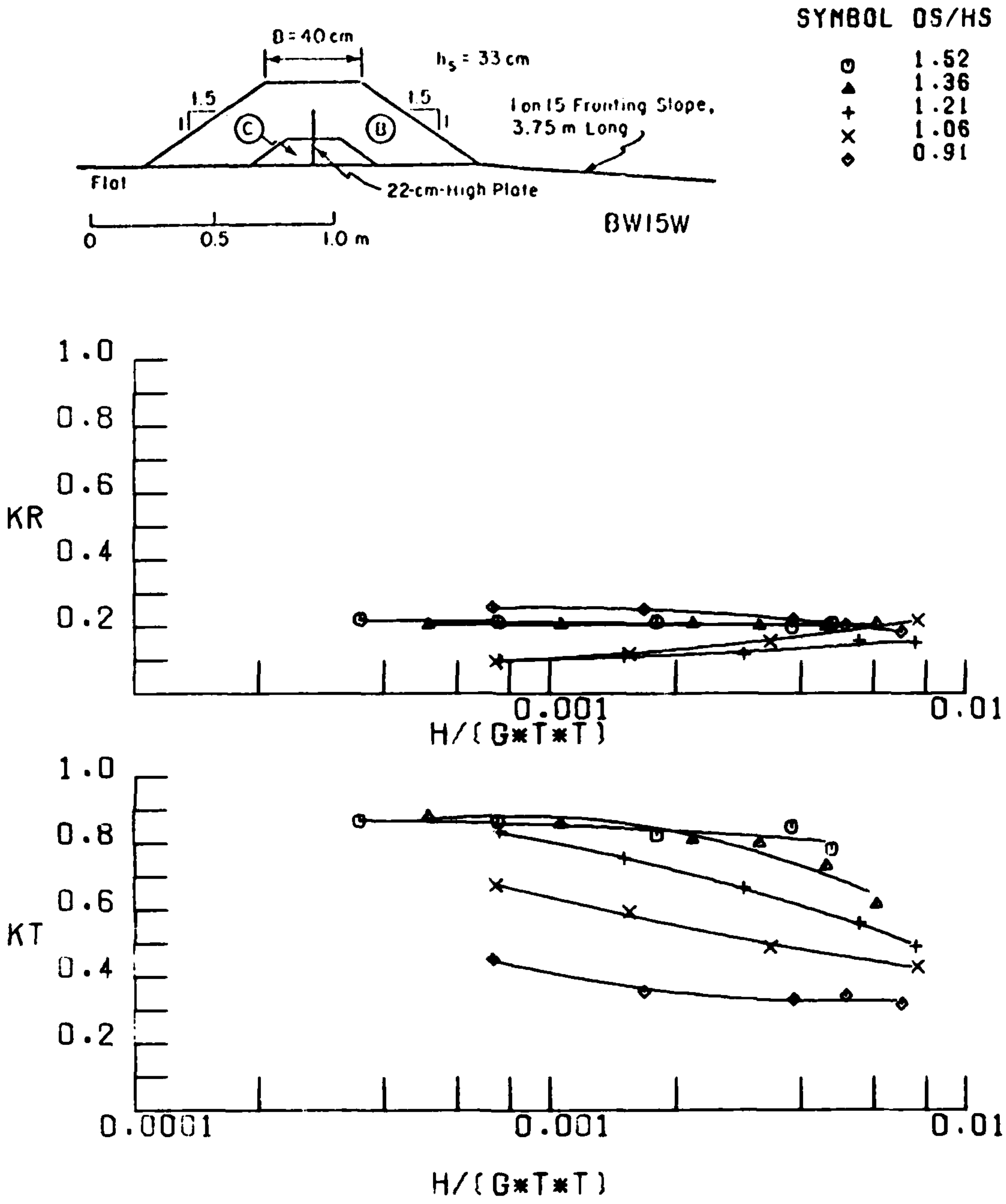
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 15 DS/HS= 1.06



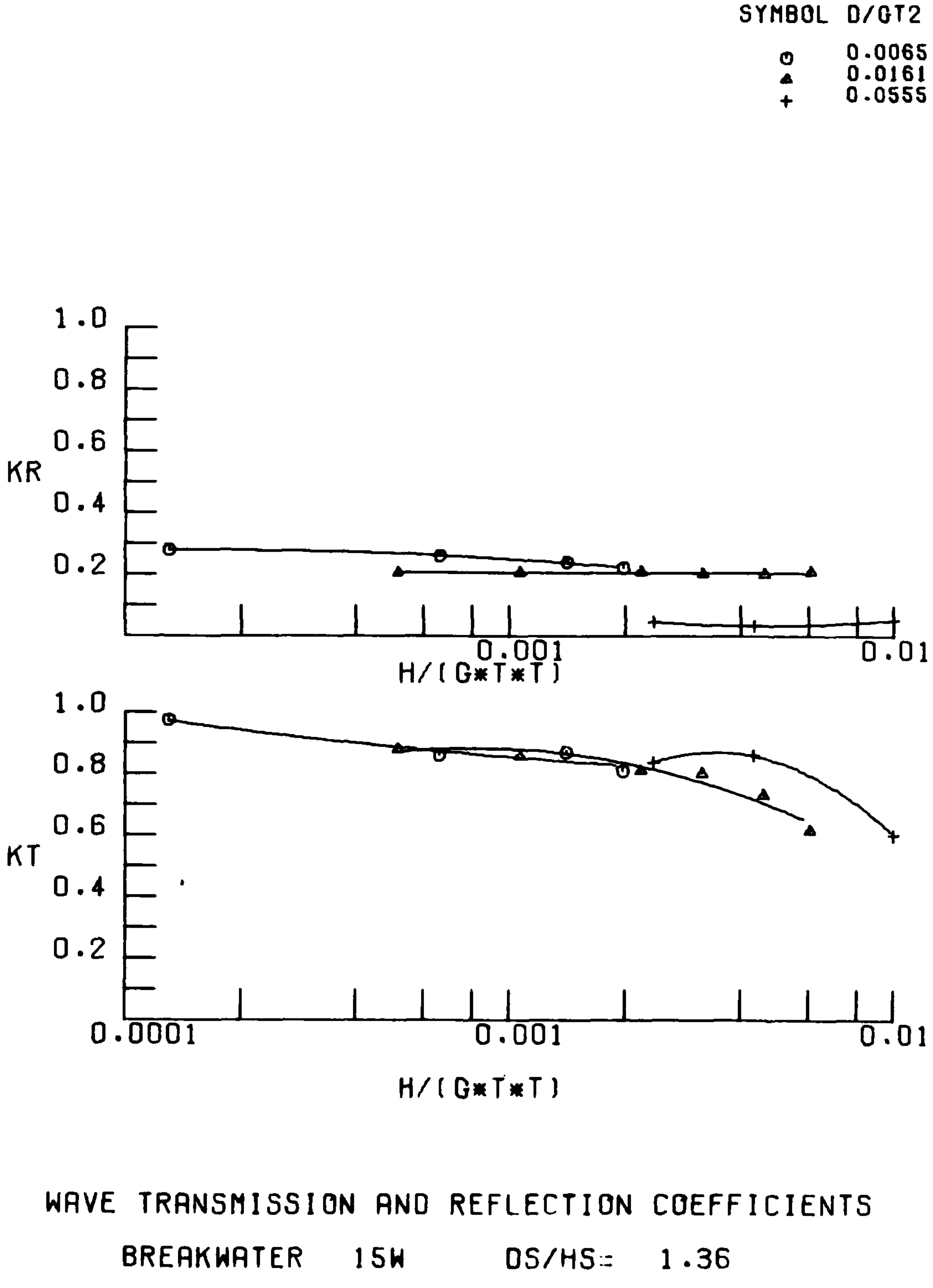
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 15 DS/HS= 0.91



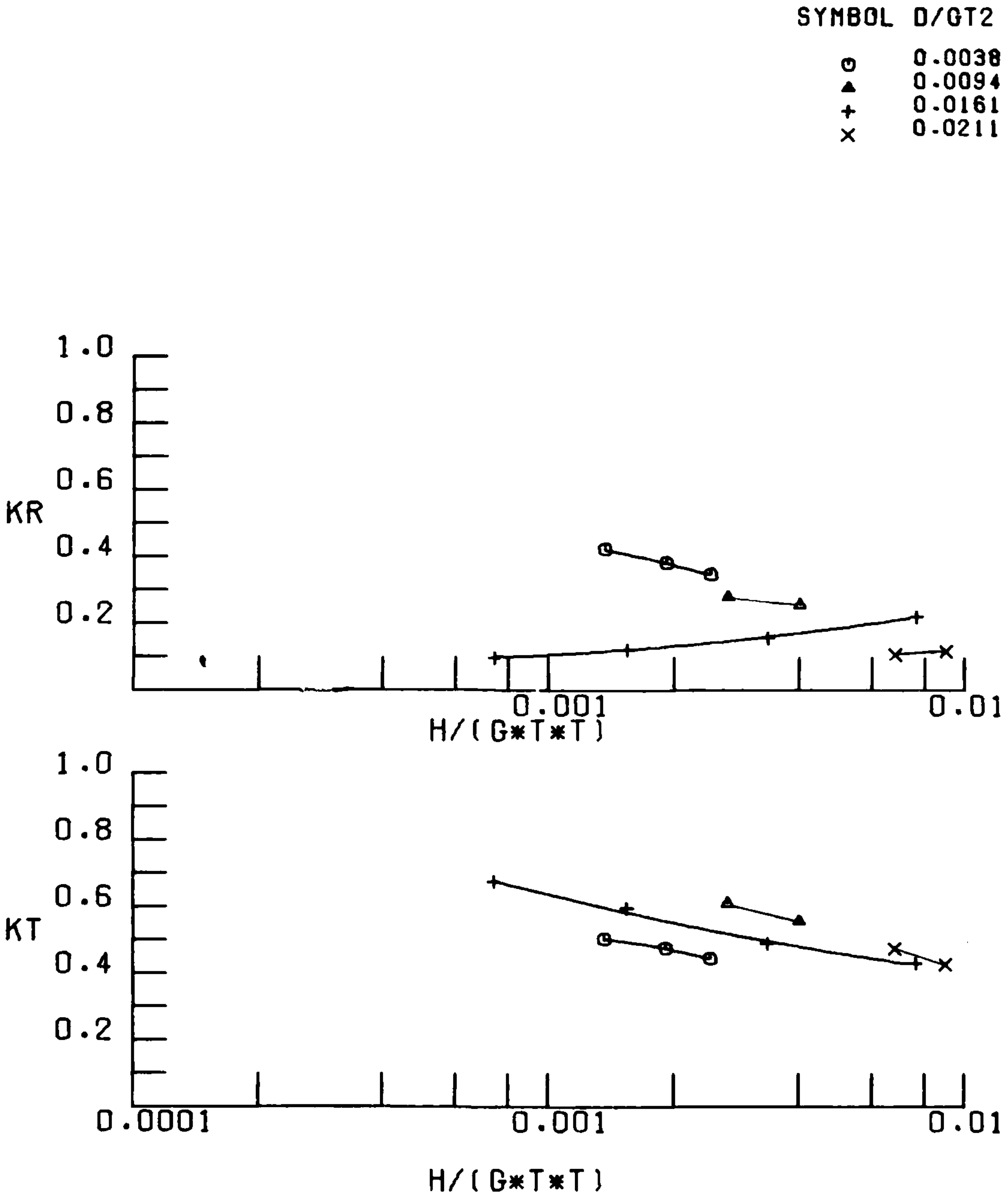
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 15W D/(GT2)=0.016



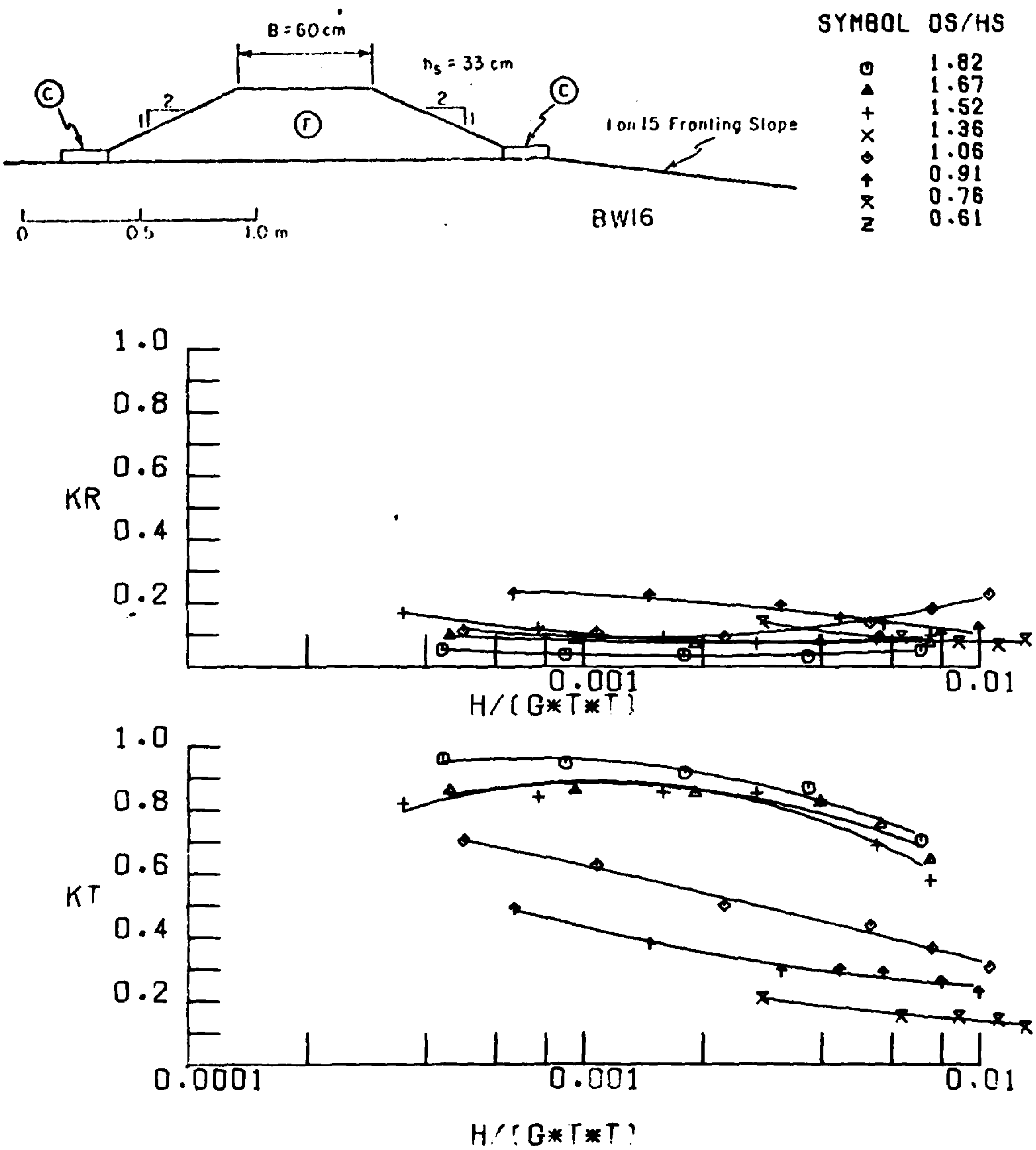
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 15W DS/HS= 1.36



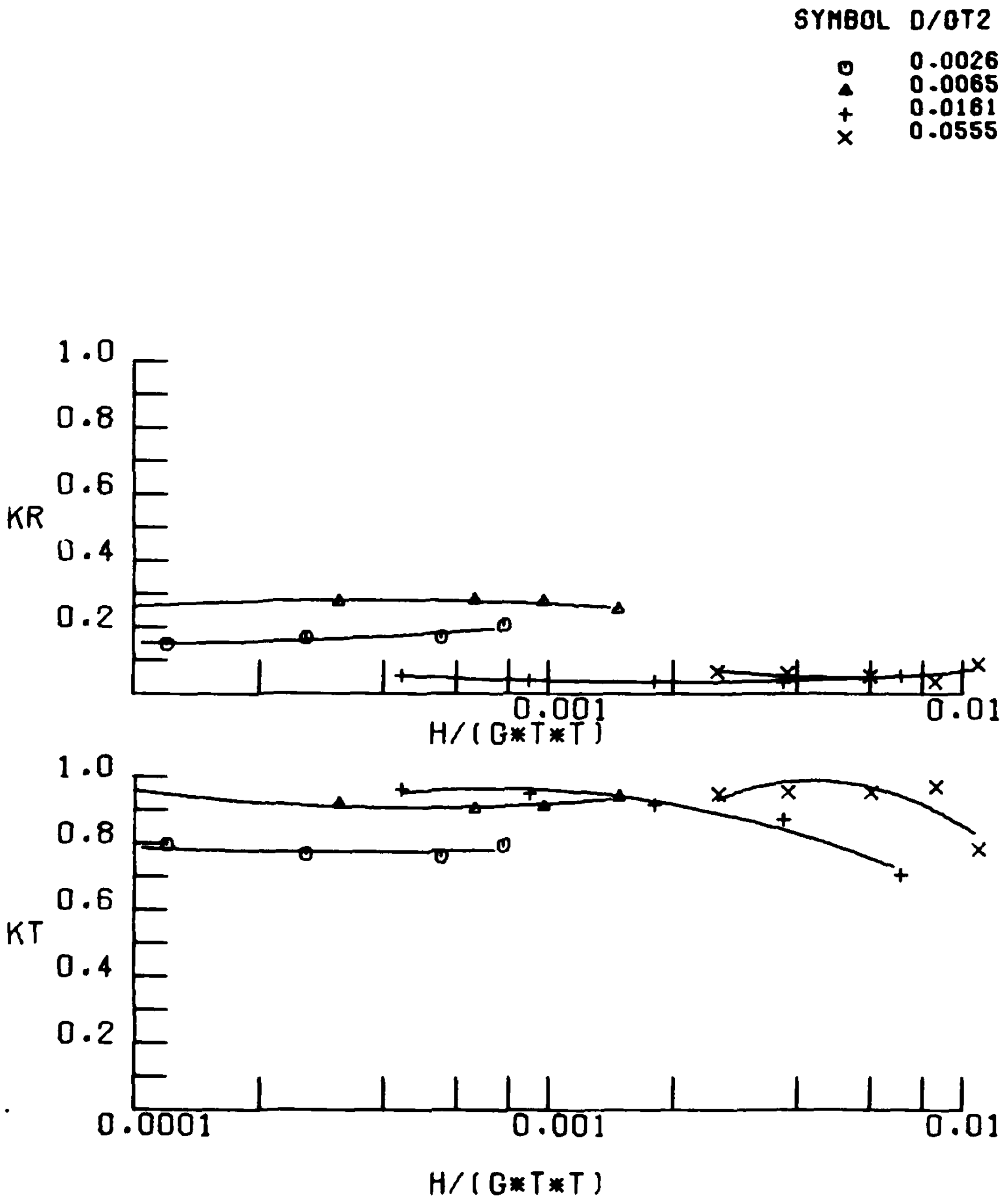
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 15W DS/HS= 1.06



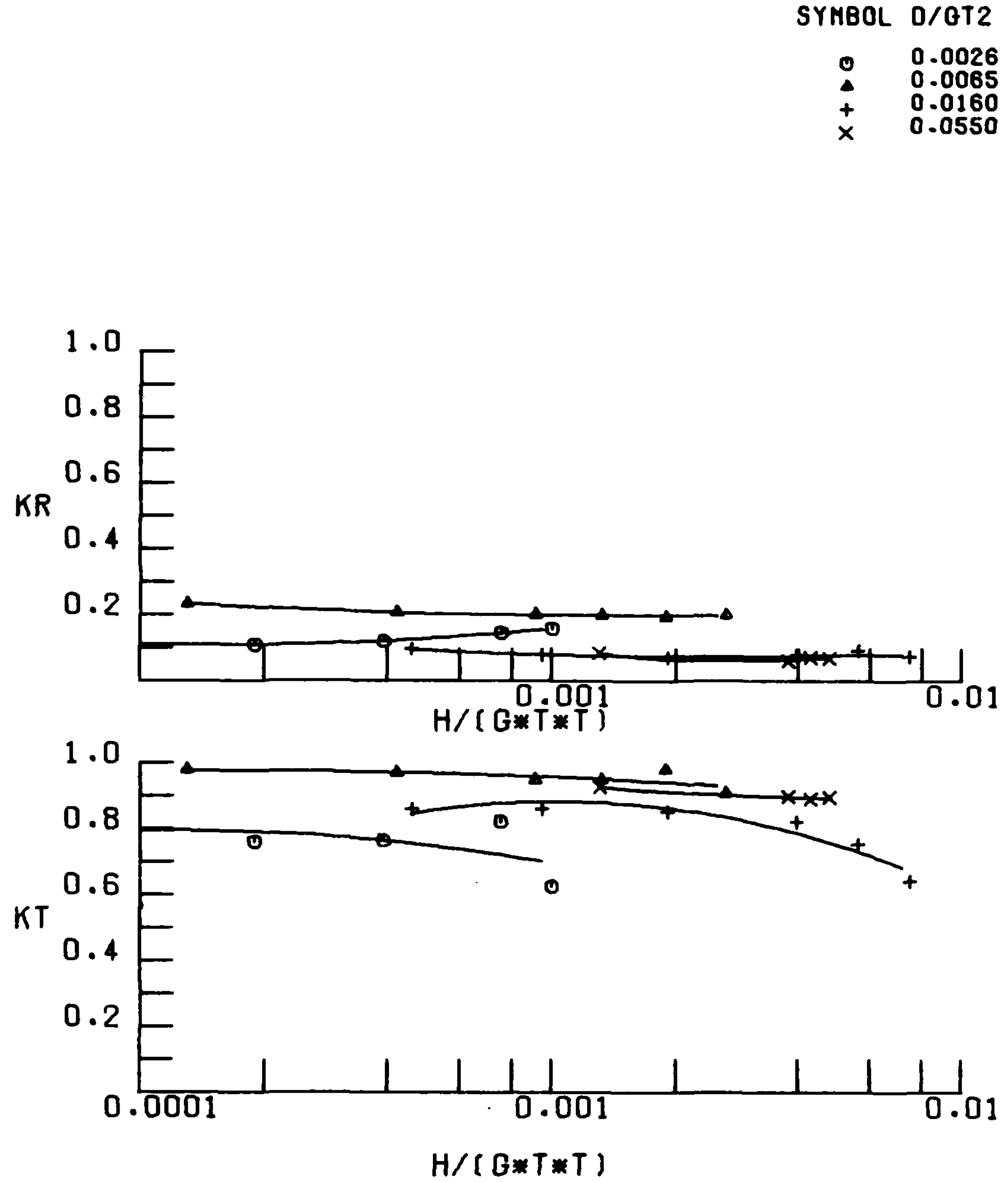
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 16 D/(GT2)=0.016



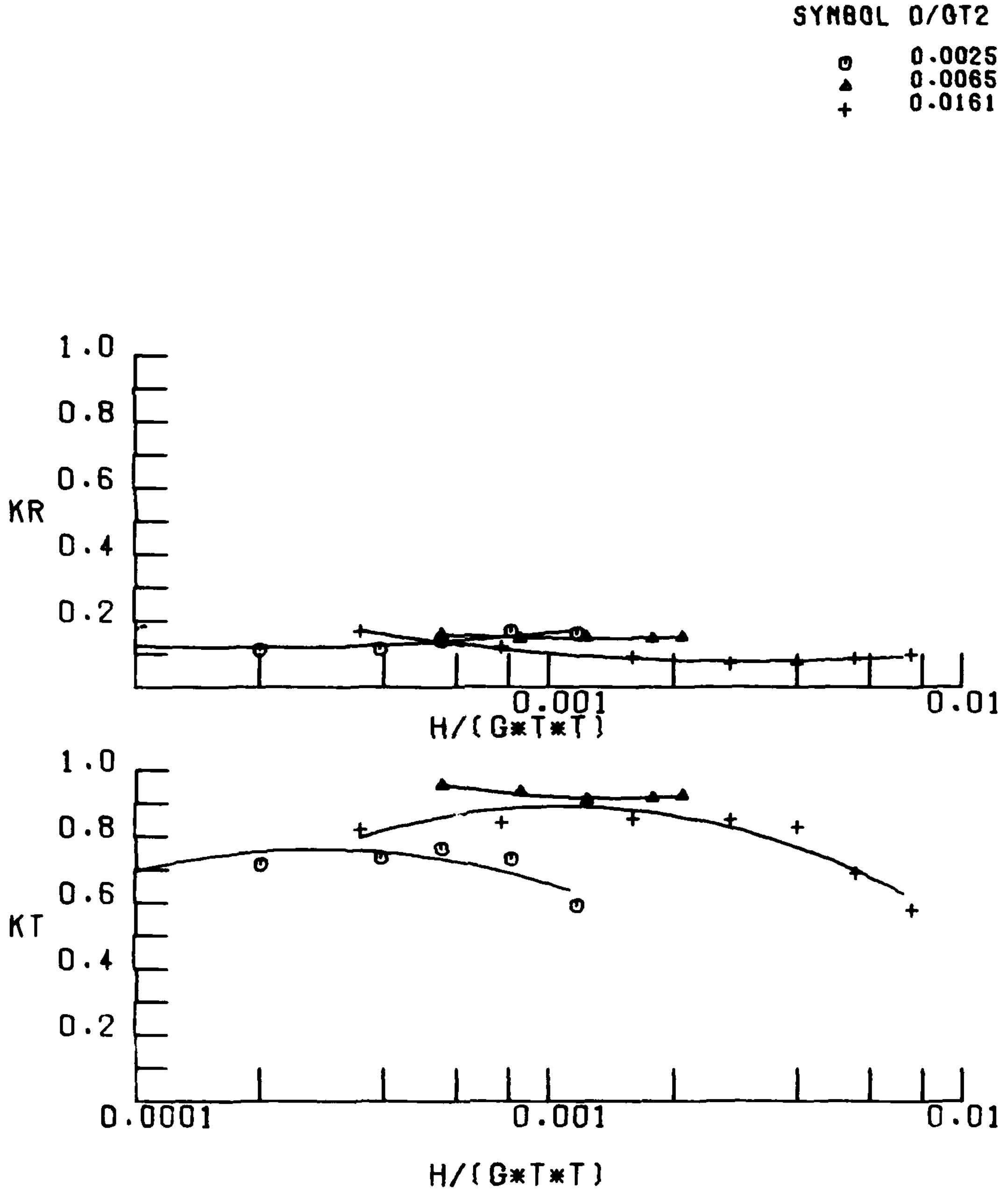
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 16 DS/HS= 1.82



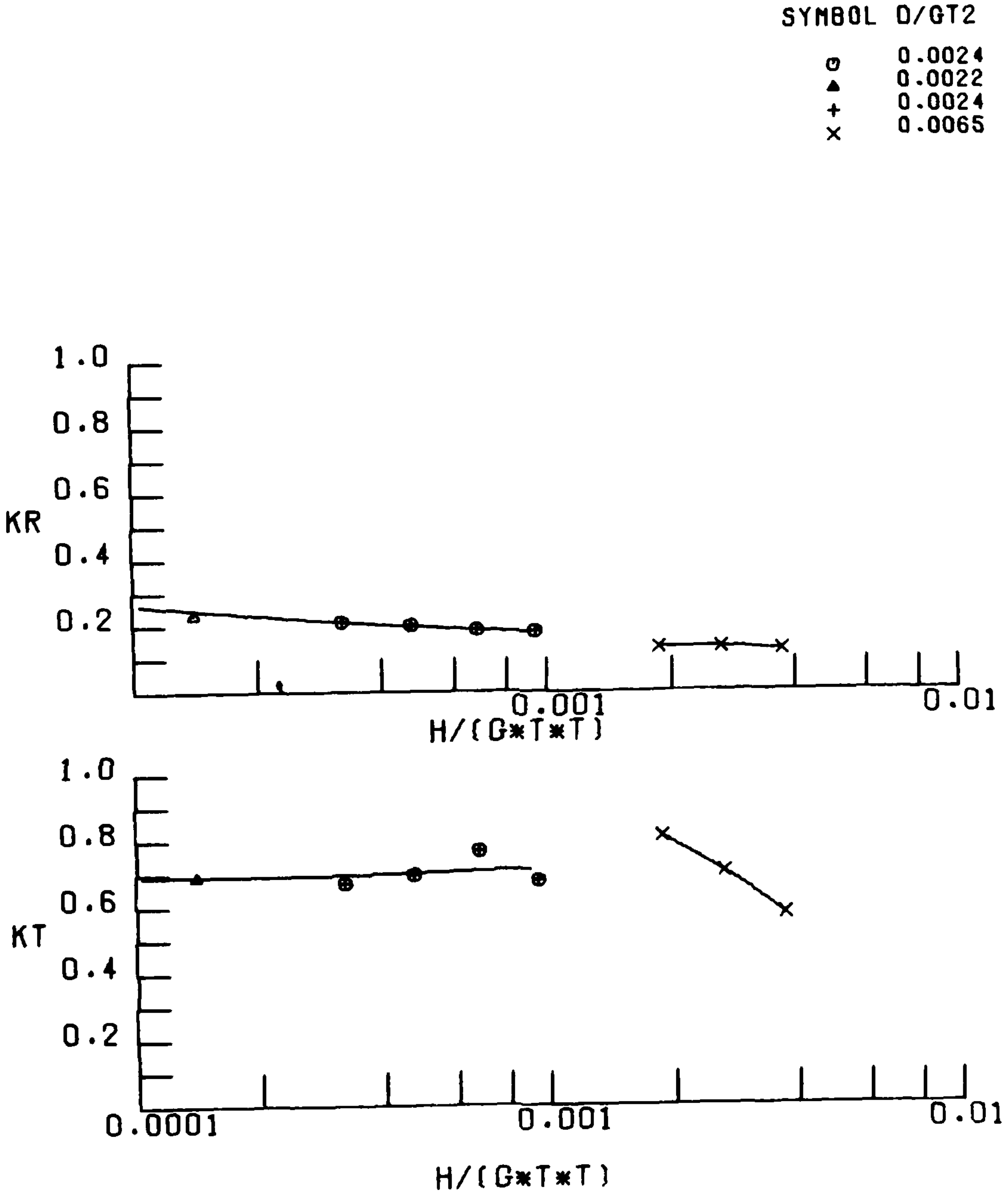
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 16 DS/HS= 1.67



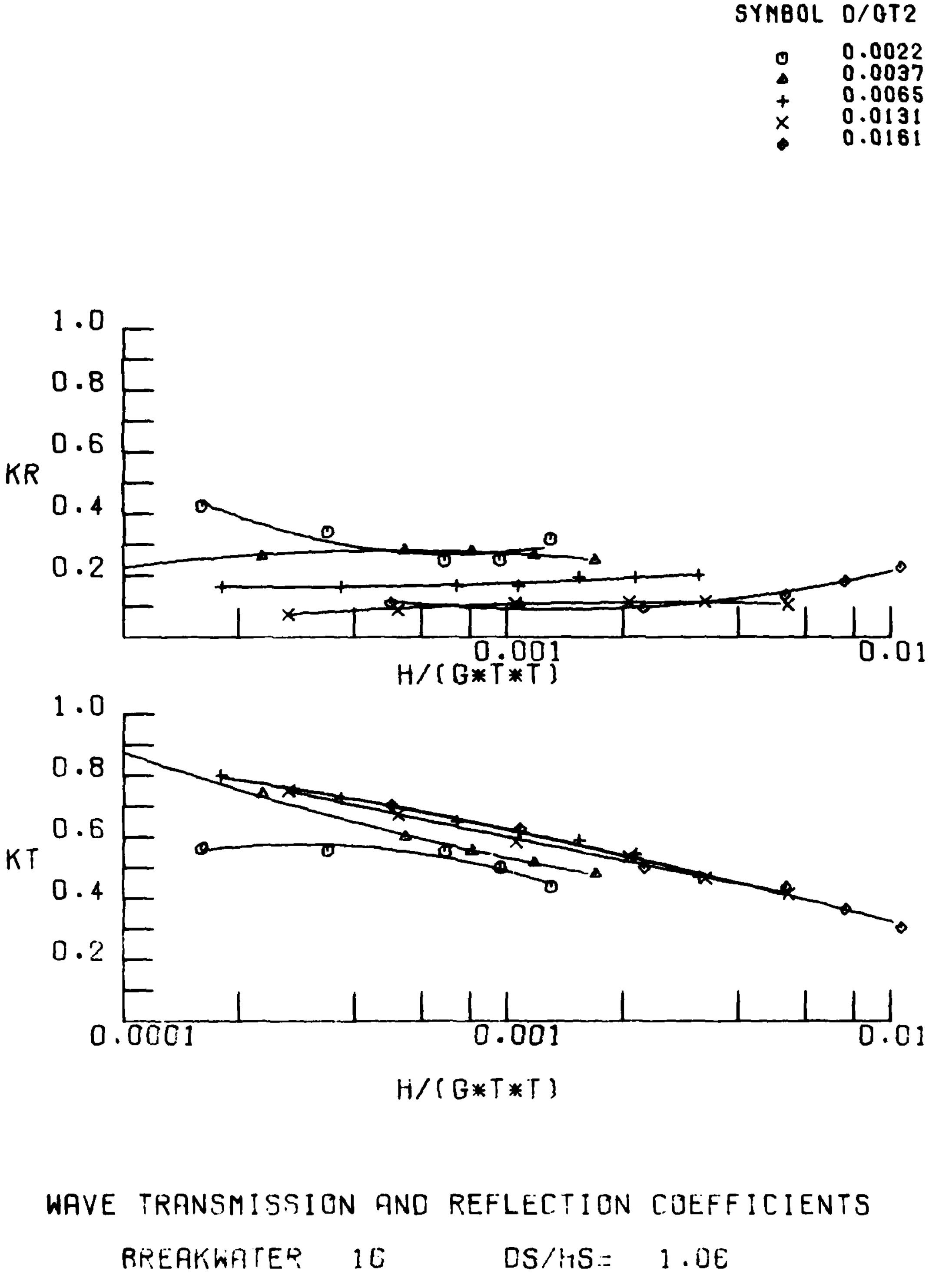
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 16 DS/HS= 1.52



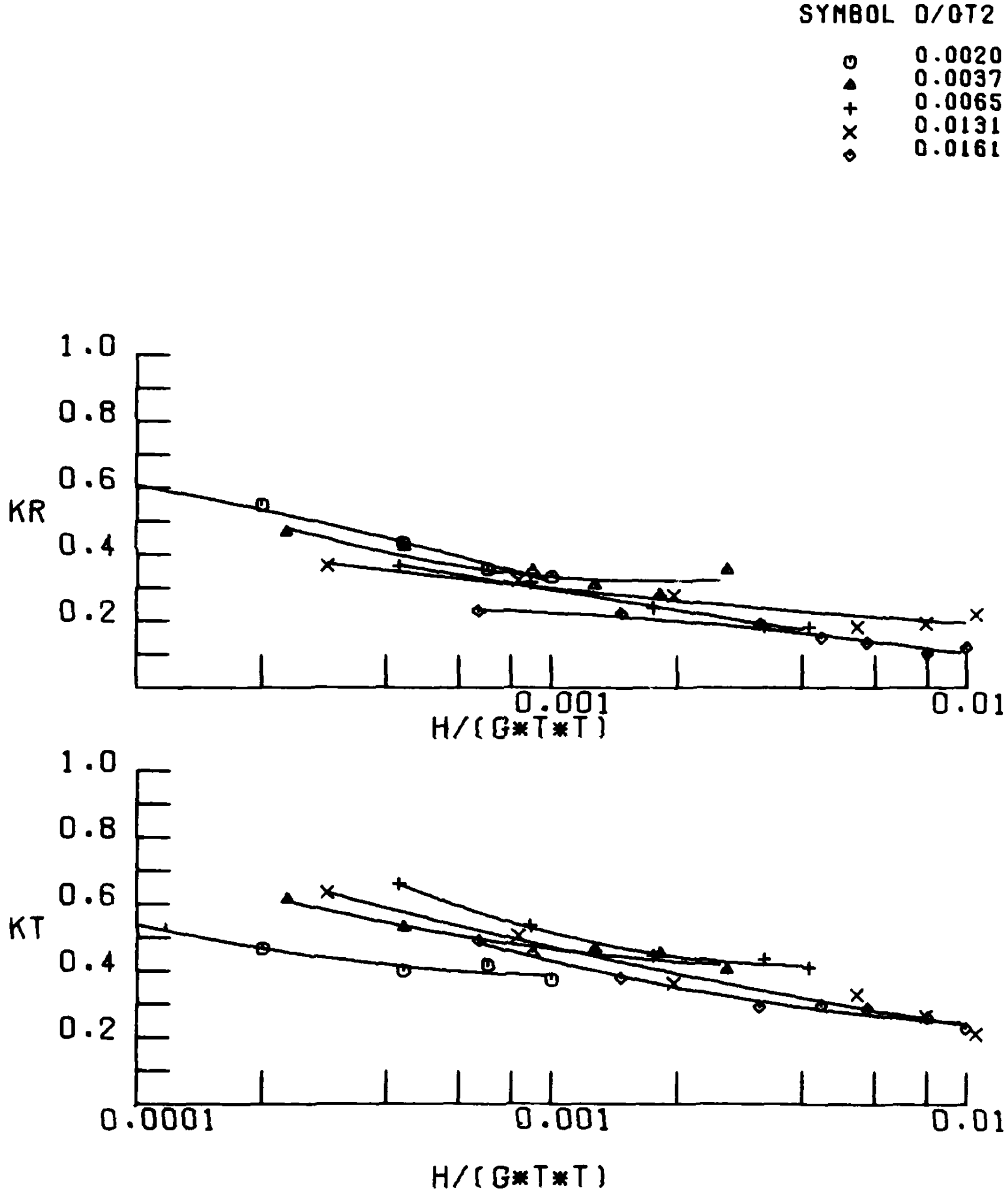
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 16 DS/HS= 1.36



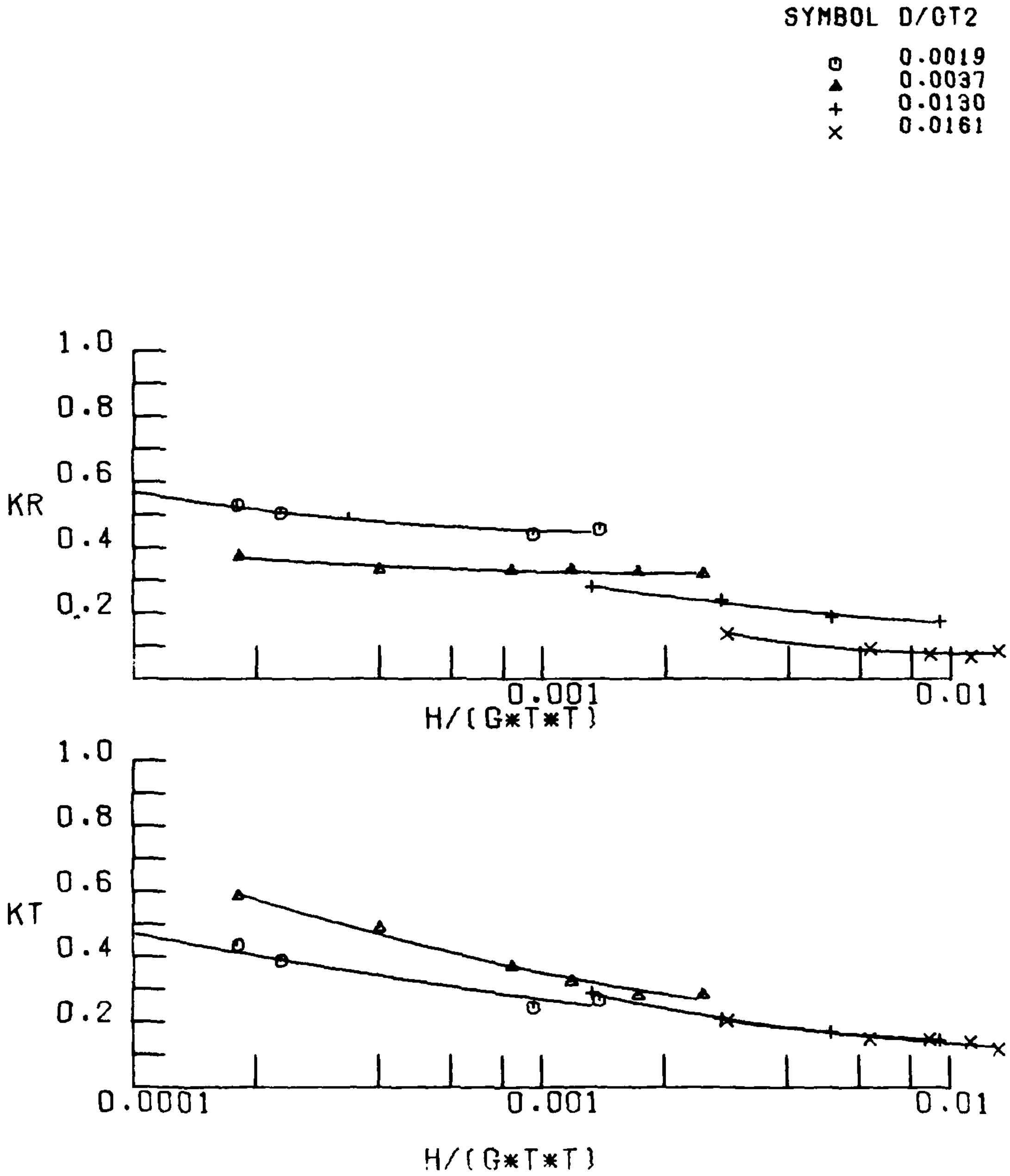
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 1G DS/HS= 1.06



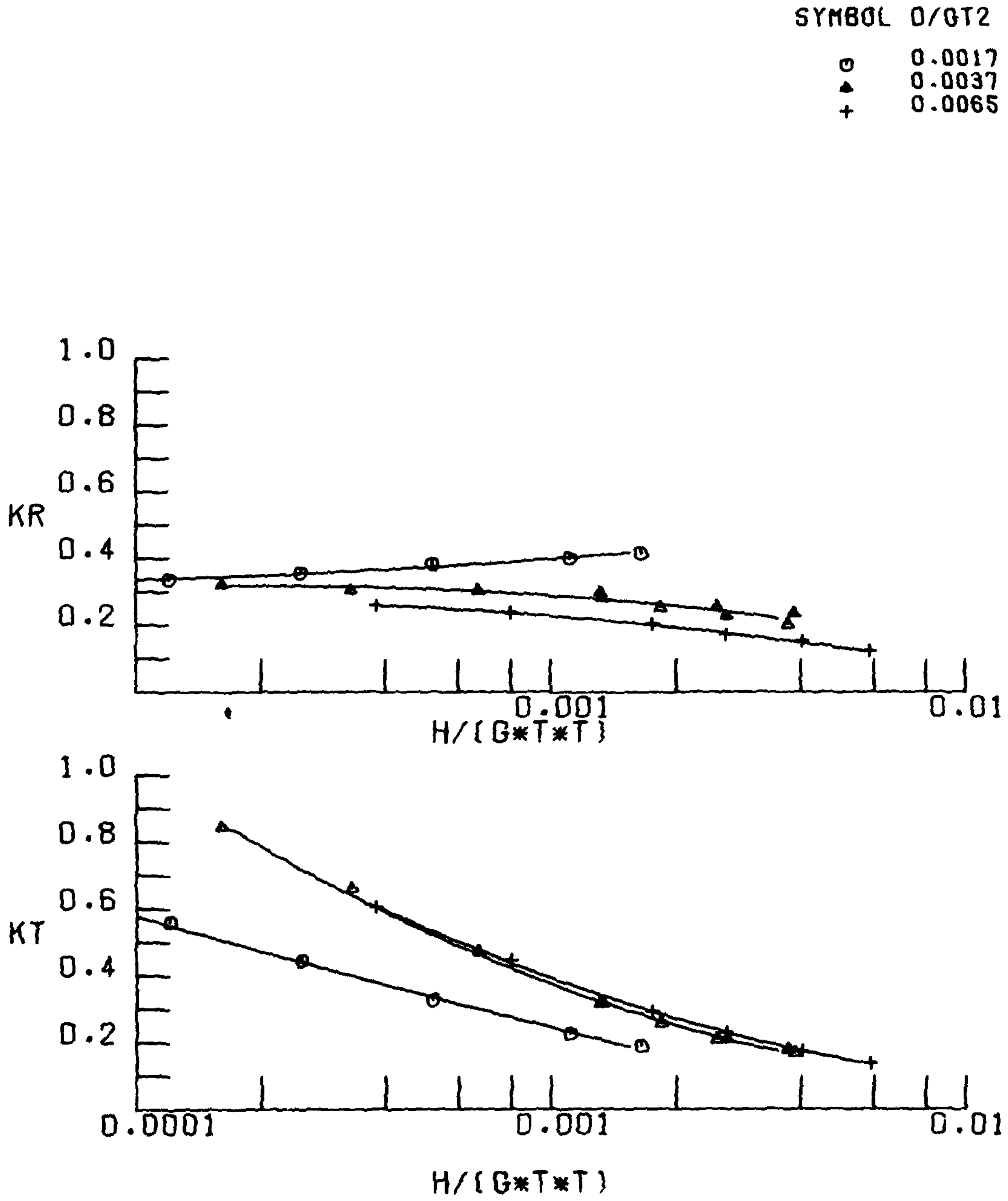
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 16 DS/HS= 0.91



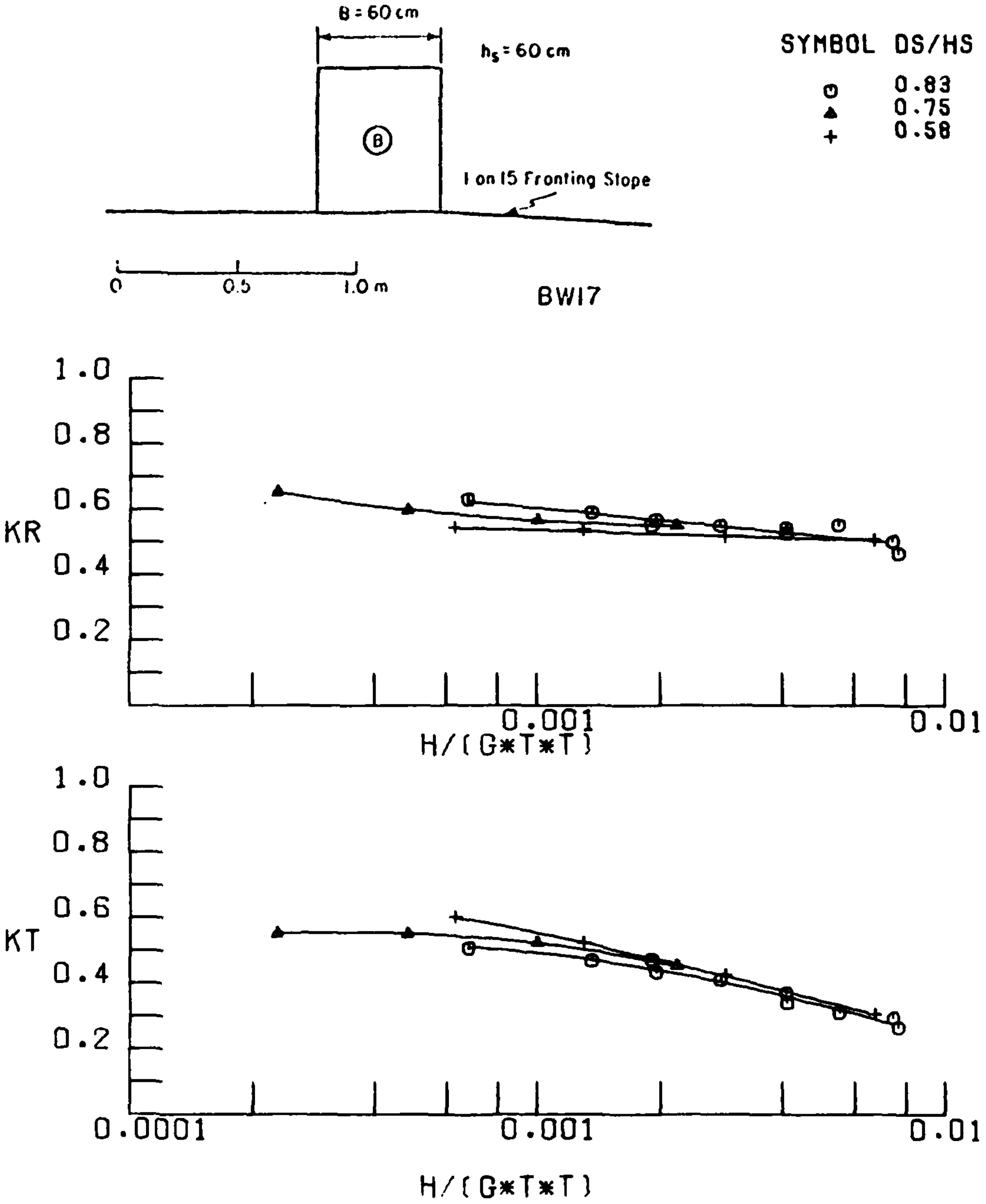
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 16 DS/HS = 0.76



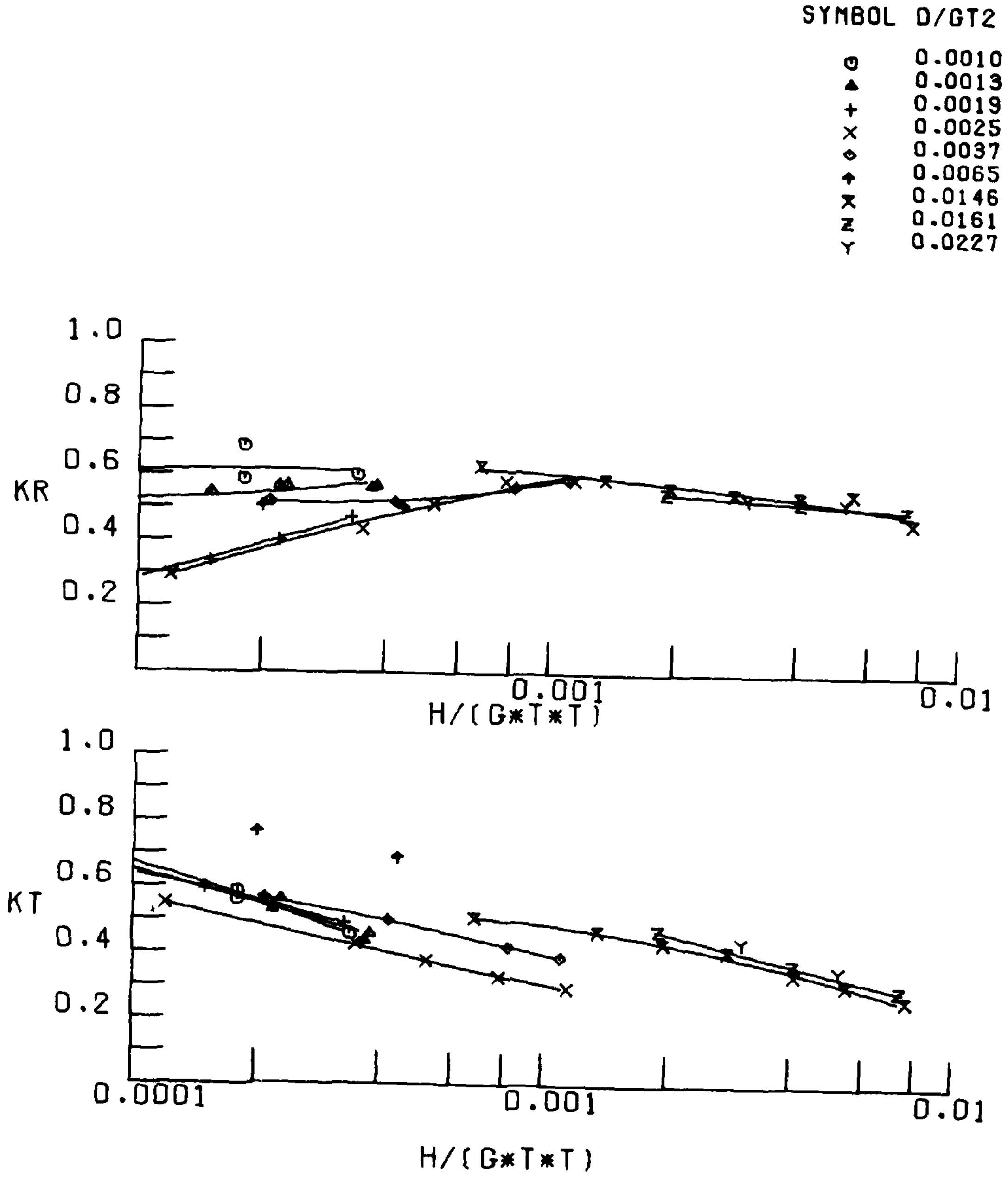
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 16 DS/HS= 0.61



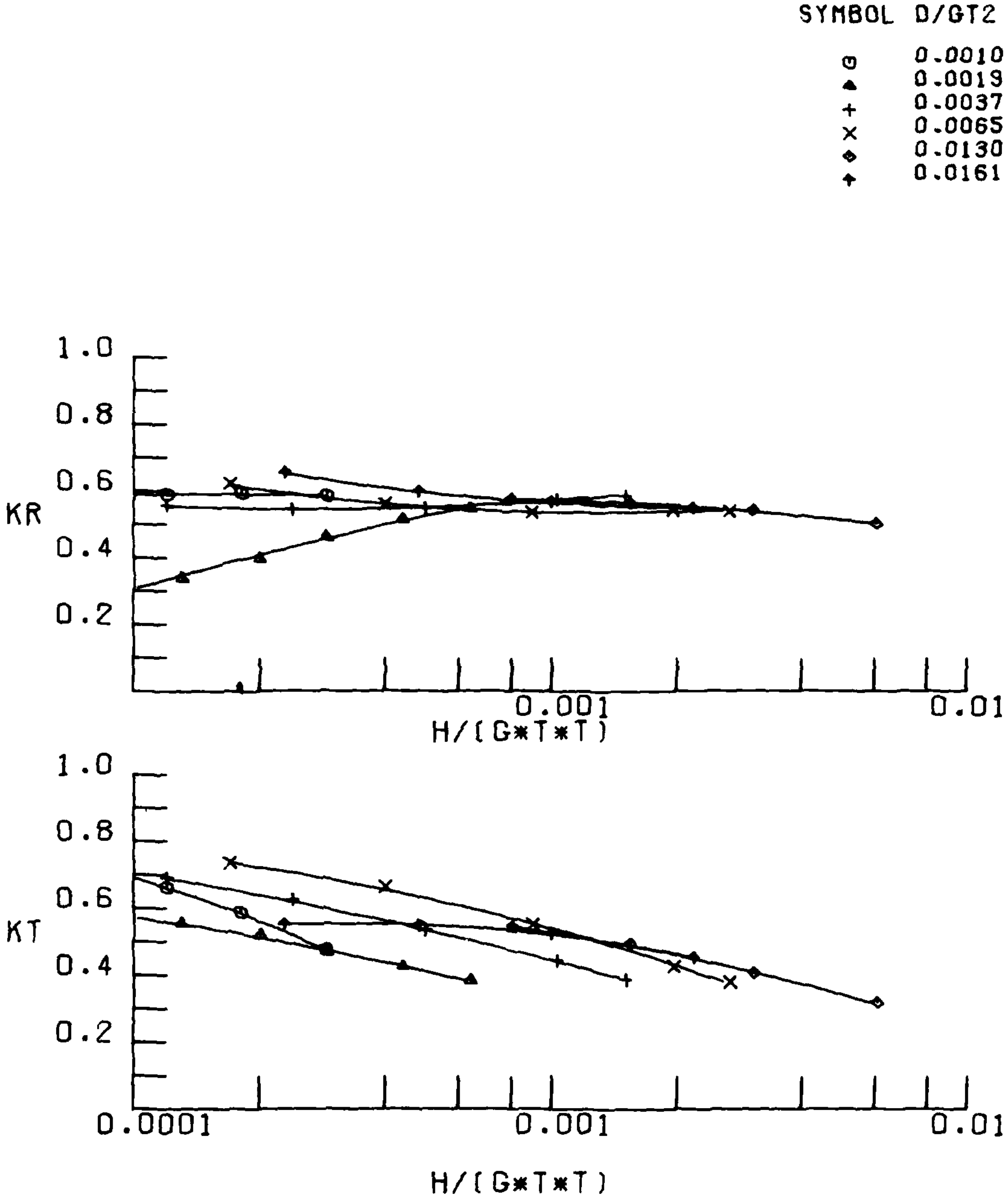
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 17 D/(GT2)=0.016



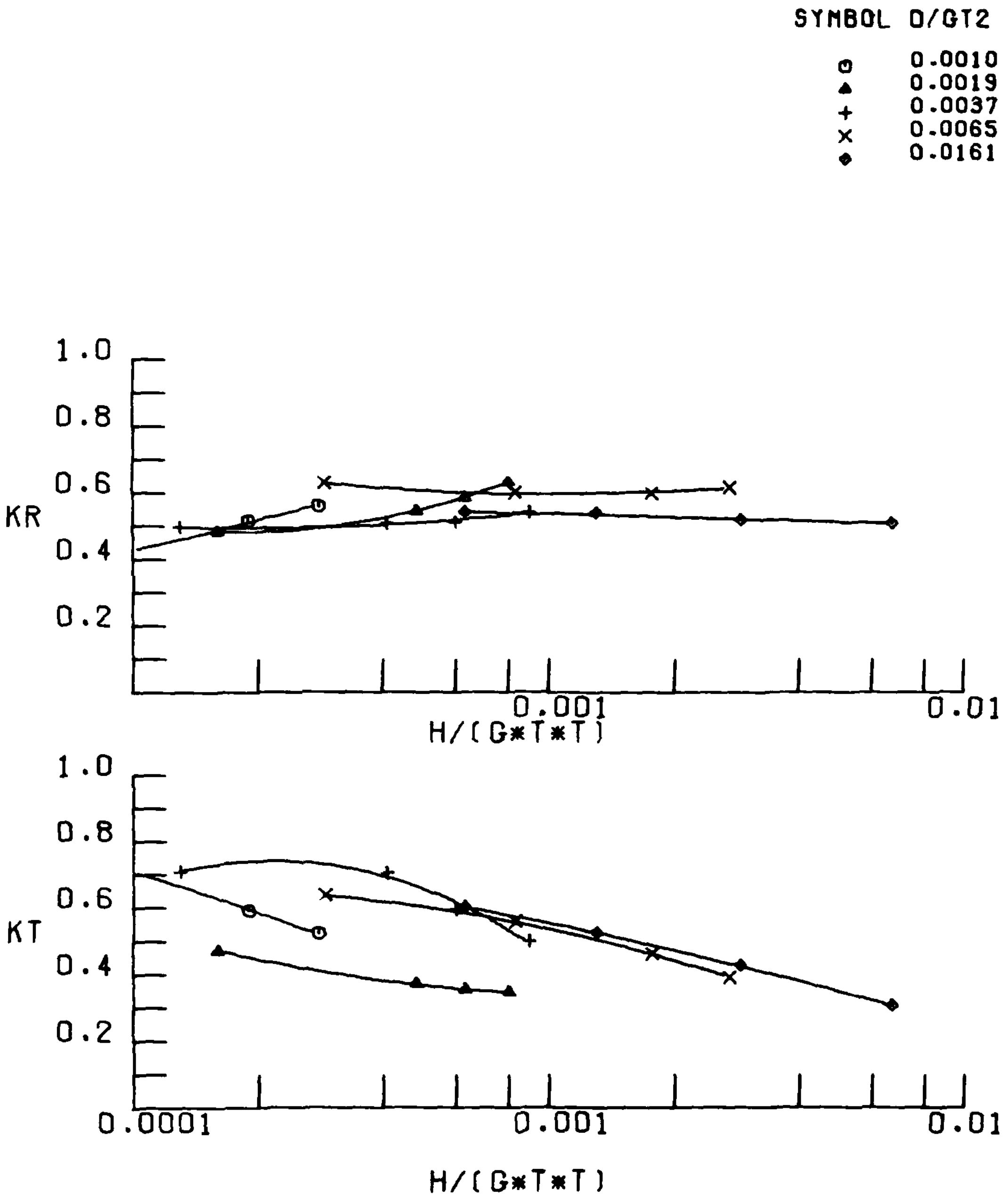
WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 17 DS/HS= 0.83



WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 17 DS/HS= 0.75



WAVE TRANSMISSION AND REFLECTION COEFFICIENTS

BREAKWATER 17 DS/HS= 0.58

APPENDIX F

DOCUMENTATION OF THE PROGRAM OVER (752X6R1CY0)

1. Purpose. This FORTRAN program estimates wave transmission by overtopping coefficients and transmitted wave heights for smooth impermeable breakwaters. The method can be used for subaerial and submerged breakwaters with structure seaward-face slopes from vertical to 1 on 3. It is recommended for values of $d_s/(gT^2) \leq 0.03$.

2. Mathematical Method and Procedure. The program uses the methods developed in this report. The procedure is to estimate wave runup on smooth impermeable slopes, R, using the equation

$$R = HC_1 \left(\frac{0.123\ L}{H} \right)^{\left(C_2 \sqrt{H/d} + C_3 \right)}$$

where C_1, C_2, and C_3 are empirical coefficients related to the structure slope, H is incident wave height, d is water depth, and L is the local wavelength. Runup on rough slopes is estimated using

$$R = \frac{Ha\xi}{(1 + b\xi)}$$

where a and b are empirical coefficients and ξ is the surf parameter given by

$$\xi = \frac{\tan \Theta}{\sqrt{\frac{H}{L_o}}}$$

where Θ is the angle of the front face of the breakwater and L_o is the deepwater wavelength.

A wave transmission by overtopping coefficient, C, is estimated from

$$C = 0.51 - \frac{0.11\ B}{h}$$

where B is the breakwater crest width and h the structure height. The transmission by overtopping coefficient, K_{To}, is determined from

$$K_{To} = C \left(1 - \frac{F}{R} \right)$$

where F is the breakwater freeboard. For submerged breakwaters with a 1 on 15 fronting slope the equation

$$K_{To} = C\left(1 - \frac{F}{R}\right) - (1 - 2C) \left(\frac{F}{R}\right)$$

is used.

The transmitted wave height, H_T, is given by

$$H_T = K_{To}\ H$$

3. Program Variables. A description of all program variables is presented in Table F-1.

4. Input. A description and an example of the imput parameters are given in Table F-2. Note that all measurements are in metric units.

5. Output. Program output includes a summary table of input information together with the predicted ratio of the breakwater freeboard to wave runup, the wave transmission by overtopping coefficient, and the predicted transmitted wave height. An example output corresponding to the input is shown in Table F-3.

6. Program Listing. A listing of the program is shown in Table F-4. The subroutine LENGTH finds the value of d/L given d/L_o by using linear wave theory.

Table F-1. Variables used in the program OVER.

Variable	Description
AC	a; rough-slope runup coefficient
BC	b; rough-slope runup coefficient
B	breakwater crest width (meter)
BH	B/h
C	transmission by overtopping coefficient = 0.51 - 0.11 B/h
CA, CB, CC	runup coefficient lookup tables
C1, C2, C3	smooth-slope runup coefficients (a function of slope) $R/H = C_1(0.123\ L/H)^{(C_2\sqrt{H/d}+C_2}$
DGT2	$d_s/(gT^2)$
DL	d_s/L
DLO	d_s/L_o
DS	structure water depth, d_s
F	breakwater freeboard = $h - d_s$
FR	F/R
H	incident wave height, H
HGT2	$H/(gT^2)$
HMAX	depth-limited maximum wave height = 0.78 d_s
HS	structure height, h_s
HT	transmitted wave height
I	counter index
IFRONT	flag to indicate the presence of a fronting slope (IFRONT = 1 for fronting slope of 1 on 15)
KTO	wave transmission by overtopping coefficient
L	wavelength
N	number of wave conditions of interest
P	linear interpolation factor to find C1, C2, C3
R	predicted smooth-slope runup
RH	R/H
SURF	the surf parameter = $\tan\theta/\sqrt{H/L_o}$
T	wave period (second)
TANA	lookup table of structure slopes corresponding to CA, CB, CC
TANT	tangent of the seaward face of the breakwater = $\tan\theta$

Table F-2. Input to the program OVER.

Card	Format	Description
1	I2	number of breakwaters
2	I2	number of wave conditions of interest ● equals 1 if breakwater has a 1 on 15 fronting slope seaward of the structure
	4X	
	F10.5	tangent of breakwater seaward slope ● breakwater crest width (m) ● breakwater structure height (m) ● water depth at toe of the structure (m) ● rough-slope runup parameter, a (a = 0 for smooth slopes) ● rough-slope runup parameter, b
3 (one card per wave condition)	F10.5	wave period (s) ● incident wave height (in)
(repeat card types 2 and 3 for each breakwater)		

Sample input

14.0	0.667	1.53	4.6	3.56	0.	0.
7.9	0.2					
7.9	0.4					
7.9	0.6					
7.9	0.8					
7.9	1.0					
7.9	1.2					
7.9	1.4					
7.9	1.6					
7.9	1.8					
7.9	2.0					
7.9	2.2					
7.9	2.4					
7.9	2.6					
7.9	2.8					

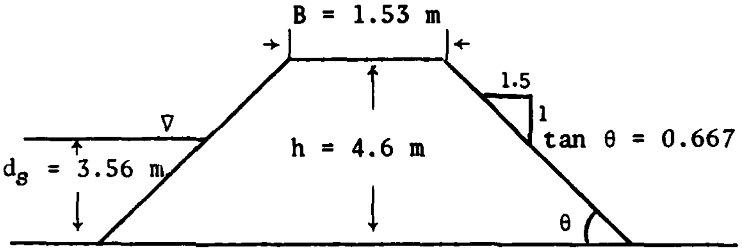


Table F-3. Sample output from the program OVER.

```
 PREDICTION OF WAVE TRANSMISSION COEFFICIENTS FOR
AN IMPERMEABLE BREAKWATER

NUMBER OF WAVE CONDITIONS = 14
IFRONT = 0
TAN(SLOPE)=   .667
BREAKWATER TOP WIDTH(M)= 1.530
STRUCTURE HEIGHT(M)= 4.600
WATER DEPTH(M)= 3.560
FREEBOARD(M)= 1.040
COEFFICIENT OF OVERTOPPING C=   .473


C1=1.9910
C2= .4980
C3=-.1850



 T(SEC)  D/GT2   H(M)   H/GT2   R/H    F/H    KTO   HT(M)

 7.900   .0058   .200 .00033 1.594 3.261 0.000 0.000
 7.900   .0058   .400 .00065 1.899 1.369 0.000 0.000
 7.900   .0058   .600 .00098 2.079  .834  .079  .047
 7.900   .0058   .800 .00131 2.197  .592  .193  .155
 7.900   .0058 1.000 .00164 2.278  .456  .257  .257
 7.900   .0058 1.200 .00196 2.334  .371  .298  .357
 7.900   .0058 1.400 .00229 2.371  .313  .325  .455
 7.900   .0058 1.600 .00262 2.394  .272  .345  .552
 7.900   .0058 1.800 .00294 2.406  .240  .360  .648
 7.900   .0058 2.000 .00327 2.410  .216  .371  .743
 7.900   .0058 2.200 .00360 2.407  .196  .380  .837
 7.900   .0058 2.400 .00392 2.399  .181  .388  .931
 7.900   .0058 2.600 .00425 2.386  .168  .394 1.025
 7.900   .0058 2.800 .00458 2.370  .157  .399 1.116
```

Table F-4. Listing of the program OVER.

```
      PROGRAM OVER(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
      REAL L,KTO
      DIMENSION TANA(6),CA(6),CB(6),CC(6)
      DATA TANA/10.,2.,1.,.667,.444,0.333/
      DATA CA/0.958,1.280,1.469,1.991,1.811,1.366/
      DATA CB/.228,.390,.346,.498,.469,.512/
      DATA CC/.0578,-.091,-.105,-.185,-.080,.040/
      READ(5,1) NBW
      DO 100 IBW=1,NBW
      READ(5,1) N,IFRONT,TANT,B,HS,DS,AC,BC
 1    FORMAT(2I2,6X,7F10.5)
C N = NUMBER OF WAVE CONDITIONS
C IFRONT = 1 FOR 1/15 FRONTING SLOPE
C TANT = TANGENT OF FRONT BREAKWATER SLOPE ANGLE
C B = STRUCTURE WIDTH AT THE CREST (M)
C HS = STRUCTURE HEIGHT (M)
C DS = WATER DEPTH AT TOE OF STRUCTURE (M)
C AC = AHRENS ROUGH SLOPE RUNUP COEFFICIENT (=0 FOR SMOOTH SLOPES)
C BC = AHRENS ROUGH SLOPE RUNUP COEFFICIENT
      F=HS-DS
      BH=B/HS
      C=0.51-0.11*BH
      WRITE(6,2) N,IFRONT,TANT,B,HS,DS,F,C
 2    FORMAT(1H1,2X,(PREDICTION OF WAVE TRANSMISSION COEFFICIENTS FOR(,/
     *,2X,       (AN IMPERMEABLE BREAKWATER(,//,1X,(NUMBER OF WAVE CONDIT
     *IONS =(,I3,  /,1X,(IFRONT =(,I2,/,1X,(TAN(SLOPE)=(,F6.3,/,1X,(BREAK
     *WATER TOP WIDTH(M)=(,F6.3,/,1X,  (STRUCTURE HEIGHT(M)=(,F6.3,/,1X
     *  ,(WATER DEPTH(M)=(,F6.3,/,1X,(FREEBOARD(M)=(,F6.3,/,1X,
     * (COEFFICIENT OF OVERTOPPING C=(F6.3,//)
      IF(AC.LT.0.001) GO TO 21
      WRITE(6,22) AC,BC
 22   FORMAT(1X,(RUNUP COEFFICIENTS FOR ROUGH SLOPE RUNUP  AC=(,F6.2,
     * ( BC=(,F6.2)
      GO TO 23
 21   DO 3 I=1,5
      IF(TANT.GT.TANA(I).OR.TANT.LT.TANA(I+1)) GO TO 3
      P=(TANA(I)-TANT)/(TANA(I)-TANA(I+1))
      C1=CA(I)-(CA(I)-CA(I+1))*P
      C2=CB(I)-(CB(I)-CB(I+1))*P
      C3=CC(I)-(CC(I)-CC(I+1))*P
 3    CONTINUE
      IF(TANT.GT.10.) C1=CA(1)
      IF(TANT.GT.10.) C2=CB(1)
      IF(TANT.GT.10.) C3=CC(1)
      IF(TANT.LT.0.333) C1=CA(6)
      IF(TANT.LT.0.333) C2=CB(6)
      IF(TANT.LT.0.333) C3=CC(6)
      WRITE(6,7) C1,C2,C3
 7    FORMAT(1X,(C1=(,F6.4,/,1X,(C2=(,F6.4,/,1X,(C3=(,F6.4,//)
 23   WRITE(6,14)
 14   FORMAT(/,1X,( T(SEC) D/GT2  H(M)  H/GT2  R/H   F/R   KTO   HT(M)(,
     */)
      DO 4 I=1,N
      READ(5,5) T,H
 5    FORMAT(2F10.5)
      DLO=DS/(1.56*T*T)
      CALL LENGTH(DLO,DL)
```

Table F-4. Listing of the program OVER.--Continued

```
      L=DS/DL
      HGT2=H/(9.8*T*T)
      DGT2=DS/(9.8*T*T)
      RH=C1*(0.123*L/H)**(C2*SQRT(H/DS)+C3)
      SURF=TANT/SQRT(H/(1.56*T*T))
      IF(AC.GT.0.001) RH=AC*SURF/(1.+BC*SURF)
      R=RH*H
      FR=F/R
      KTO=C*(1.-FR)
      IF(IFRONT.EQ.1.AND.F.LT.0.) KTO=C*(1.-FR)-(1.-2.*C)*FR
      IF(FR.GT.1.) KTO=0.
      HT=H*KTO
      WRITE(6,12) T,DGT2,H,HGT2,RH,FR,KTO,HT
12    FORMAT(1X,F6.3,F7.4,F6.3,F7.5,4F6.3)
4     CONTINUE
100   CONTINUE
      STOP
      END


      SUBROUTINE LENGTH(DLO,DL)
      REAL LO,LONEW,LOO
      LO=1.0/DLO
      LOO=1.0/DLO
      N=1
      PI=3.14159
1     ARG=2.0*PI/LO
      LONEW=LOO*TANH(ARG)
      N=N+1
      DIFF=ABS(LONEW-LO)
      IF(N-200) 3,4,4
3     IF(DIFF-0.0005) 2,2,5
5     LO=(LONEW+LO)/2.0
      GO TO 1
4     DL=1.0/LONEW
      WRITE(6,100) DLO,DL
100   FORMAT(44H SUBROUTINE LENGTH DID NOT CONVERGE, D/LO =    ,F10.5,
     1  8HD/L =    ,F10.5)
2     DL=1.0/LONEW
      RETURN
      END
```

APPENDIX G

DOCUMENTATION OF THE COMPUTER PROGRAM MADSEN

The computer program MADSEN (CERC program number 752X1R1CPO) is used to predict wave transmission through rubble-mound breakwaters using methods developed by Madsen and White (1976). (Note: Equations and figures referenced from that publication are identified by the symbol MW.) A wave transmission by overtopping model is also included as discussed in the text of this report. The program is organized as shown in Figure G-1. Whenever possible the variable names used are a close approximation to the symbols used by Madsen and White (1976). Table G-1 lists important variable names, corresponding symbols used in Madsen and White, and gives a description including references to defining equations in Madsen and White (1976). A description of each of the program subroutines is given below:

SUBROUTINE READI - This routine reads standard lookup tables corresponding to MW Figures 2, 3, 15, 16, and 17 from Madsen and White (1976). Lookup tables with a combination linear and logarithmic interpolation were selected to avoid having to use Bessel functions with complex arguments. The 53 standard lookup table cards are given in Table G-2.

SUBROUTINE REFL - This routine determines reflection coefficients from rough impermeable slopes to account for energy dissipation on the breakwater face (see Ch. III of Madsen and White, 1976). MW equation (127) is solved iteratively and the final result corrected by the corresponding correction factor from MW Table 2 (a linear fit to these points is used). Lookup tables from MW Figures 15, 16, and 17 are employed in this routine.

```
Read standard lookup tables (53 cards), CALL READI
Read number of breakwaters to analyze, NCOMP
                                                            Loops
For each NCOMP read breakwater geometry
    For each period, NT, read wave heights, HHI
        For each wave height loop to 100
            Determine dissipation on BW face, CALL REFL
            Iterate of $\Delta H_e$ and $\Delta H_T$ to find $\ell_e$ using MW equations (172) and (161)
                Find equivalent breakwater (Sec. IV,2, eq. 158), CALL EQBW
                Find internal transmission and reflection coefficients, (Sec. II), CALL INTER
                Reestimate $\Delta H_e$ from MW equation (161)
            Determine transmission and reflection coefficients, $K_{Tt}$ and $K_R$, from MW
             equations (175) and (176)
            Find wave transmission by overtopping coefficient, $K_{To}$
            Print results
        100 CONTINUE
    199 CONTINUE
200 CONTINUE
STOP
END
SUBROUTINES
53 standard lookup cards
Input cards (see Table G-4)
```

Figure G-1. General program organization.

Table G-1. Program variables.

Symbol (Madsen and White, 1976)	Variables	Description
a_i	A	incident wave amplitude
RII	RII	reflection coefficient (Sec. III)
ΔH_T	DHT	head (MW eq. 160)
ΔH_e	DHE	equivalent head (MW eq. 159)
d_r	DR	reference diameter
β_r	BETAR	reference beta
ν	NU	kinematic viscosity
d	D	diameter (cm)
a_I	AI	equals RII a_i (MW eq. 146)
RI	RI	internal reflection coefficient (Sec. II)
TI	TI	internal transmission coefficient (Sec. II)
T	KTT	coefficient of wave transmission for transmission through the structure (MW eq. 175)
	KTO	transmission by overtopping coefficient
	KT	total wave transmission coefficient equals $\sqrt{KTT^2 + KTO^2}$
R	KR	reflection coefficient (eq. 176)
n	N	porosity
S_*	SS	$(n/0.45)^2$
$n k_o \ell$	NKL	equivalent
ℓ_e	LE	equivalent BW width (eq. 158)
h_o	HO	water depth
T	T	wave period
f/S_*	FS	
λ	LAMBDA	
k_o	KO	$2\pi/L$
	TS	lookup tables

Table G-1. Program variables.--Continued

Symbol (Madsen and White, 1976)	Variables	Description
	RS	lookup tables
	FST	lookup tables
	RUT	lookup tables
	RT	lookup tables
	GSS	lookup tables
	FUS	lookup tables
	TX	lookup tables
	RX	lookup tables
F_s	FS	(Fig. 17)
ℓ_s	LS	slope length
L	L	wavelength
	NM	number of materials (maximum of 10)
	NL	number of layers (maximum of 10)
Δh_j	TH	level thickness
$\frac{\Delta h_j}{h_o}$	DH	relative thickness
	NR	reference porosity = 0.45
$\frac{\Delta h_j}{h_o} \frac{1}{\left(\sum \frac{\beta_i}{p_r} \ell_i\right)^{1/2}}$	SUM2	
$\sum \frac{\beta_i}{\beta_r} \ell_i$	SUM1	
	TOPW	width of top of structure
ℓ_n	LL	length of materials in horizontal layers
	F	breakwater freeboard
	R	wave runup

Table G-2. Standard lookup tables to be read by READI.

```
 1   .85 .83 .901.502.192.333.233.463.96
 2   .85 .83 .901.492.192.303.193.423.90
 3   .85 .83 .901.492.162.293.103.283.70
 4   .85 .83 .901.472.102.222.943.073.40
 5   .85 .83 .901.462.052.142.742.803.00
 6   .85 .83 .901.451.982.032.502.502.60
 7   .85 .83 .901.441.891.922.282.222.20
 8   .85 .83 .901.421.801.792.021.911.83
 9   .85 .83 .901.401.701.681.791.631.60
10   .85 .83 .901.361.611.521.571.381.24
11   .85 .83 .901.301.501.401.371.171.00
12  1.001.242.032.492.693.283.353.744.00
13  1.001.231.942.322.502.682.973.203.34
14  1.001.221.852.162.312.562.632.732.80
15  1.001.201.762.032.142.282.322.342.36
16  1.001.191.701.901.982.042.042.021.97
17  1.001.191.611.781.821.821.791.731.65
18  1.001.181.541.681.671.651.581.491.38
19  1.001.181.481.571.541.471.371.271.18
20  1.001.171.431.481.421.321.211.08 .97
21  1.001.161.371.381.311.181.05 .93 .80
22  1.001.161.321.291.191.06 .93 .80 .67
23  1.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.00
24  1.001.00 .98 .96 .92 .87 .87 .88 .87 .81 .76 .78 .79 .77 .72 .69 .70
25  1.001.00 .98 .93 .83 .75 .76 .78 .75 .66 .60 .61 .66 .60 .54 .48 .48
26  1.001.00 .97 .90 .75 .65 .66 .69 .65 .53 .46 .48 .50 .47 .38 .32 .34
27  1.001.00 .97 .87 .68 .55 .58 .62 .56 .42 .34 .38 .40 .37 .27 .21 .24
28  1.001.00 .95 .83 .62 .46 .52 .55 .48 .33 .25 .30 .33 .29 .18 .12 .18
29  1.00 .99 .94 .79 .57 .40 .45 .50 .43 .26 .18 .24 .28 .24 .13 .06 .14
30  1.00 .99 .93 .75 .51 .34 .40 .45 .38 .21 .12 .20 .24 .20 .08 .02 .13
31  1.00 .99 .92 .72 .44 .28 .36 .42 .33 .16 .07 .17 .22 .18 .07 .02 .13
32  1.00 .99 .91 .70 .40 .23 .33 .38 .30 .12 .05 .17 .20 .18 .07 .02 .13
33  1.00 .98 .90 .67 .35 .18 .31 .35 .27 .10 .05 .17 .20 .18 .07 .02 .13
34   .80 .66 .57 .50 .46 .42 .38 .36 .34
35   .67 .50 .41 .34 .30 .26 .22 .18 .16
36   .58 .41 .32 .26 .21 .17 .13 .11 .08
37   .50 .33 .26 .19 .16 .12 .99 .07 .05
38   .45 .30 .22 .16 .12 .08 .07 .04 .03
39   .41 .26 .18 .13 .09 .07 .05 .03 .02
40   .37 .23 .16 .11 .08 .05 .03 .02 .02
41   .33 .21 .13 .09 .06 .04 .03 .02 .01
42   .31 .18 .12 .08 .05 .03 .03 .02 .01
43   .29 .17 .11 .07 .04 .03 .02 .01 .01
44   .25 .40 .49 .56 .58 .59 .58 .56 .53
45   .35 .52 .60 .65 .66 .65 .63 .62 .60
46   .44 .60 .68 .71 .71 .69 .67 .67 .66
47   .50 .67 .73 .74 .73 .72 .71 .70 .70
48   .57 .71 .75 .77 .76 .74 .73 .73 .73
49   .60 .73 .78 .78 .77 .76  76 .76 .76
50   .63 .76 .80 .79 .78 .78  77 .77 .77
51   .66 .78 .81 .80 .79 .79 .79 .79 .79
52   .68 .80 .82 .81 .80 .80 .80 .80 .80
53   .71 .81 .83 .82 .81 .81 .81 .81 .81
```

SUBROUTINE INTER - Internal wave transmission and reflection coefficients for the equivalent breakwater found in EQBW are solved in this routine. MW equations (57) and (37) are solved implicitly using R_c = 170 and interpolation of MW Figures 2 and 3, when nkl is greater than 0.1. If nkl is greater than 0.9 the coefficients cannot be solved, so another equivalent breakwater with smaller reference diameter stone is determined.

SUBROUTINE EQBW - This routine determines the rectangular breakwater corresponding to the multilayered trapezoidal breakwater using the methods described in MW Section IV,2. The initial reference diameter is taken as one-half the armor diameter and reference porosity is defined as 0.435.

SUBROUTINE LENGTH - Finds the relative depth given the ratio of water depth to deepwater wavelength.

1. Program Use. The following steps are required to use the program MADSEN:

(a) Assign each of the materials used in the various layers of the breakwater a consecutive number making the armor "material number 1." Determine the diameter of each material from

$$d_{50} = \left(\frac{W_{50}}{\gamma}\right)^{1/3}$$

where W_{50} is the median weight and γ the specific weight. Also estimate the material porosity.

(b) Divide the breakwater into horizontal layers. A new layer occurs any time there is a change vertically in any material type of slope (see Fig. G-2 for an example problem). Make the layer next to the seabed "layer number 1." Find the thickness of each layer and determine the average horizontal length of each material in each layer. Remove the outer layer of armor from the seaward face of the breakwater before making length calculations, because energy dissipation on the front face is determined separately in the program.

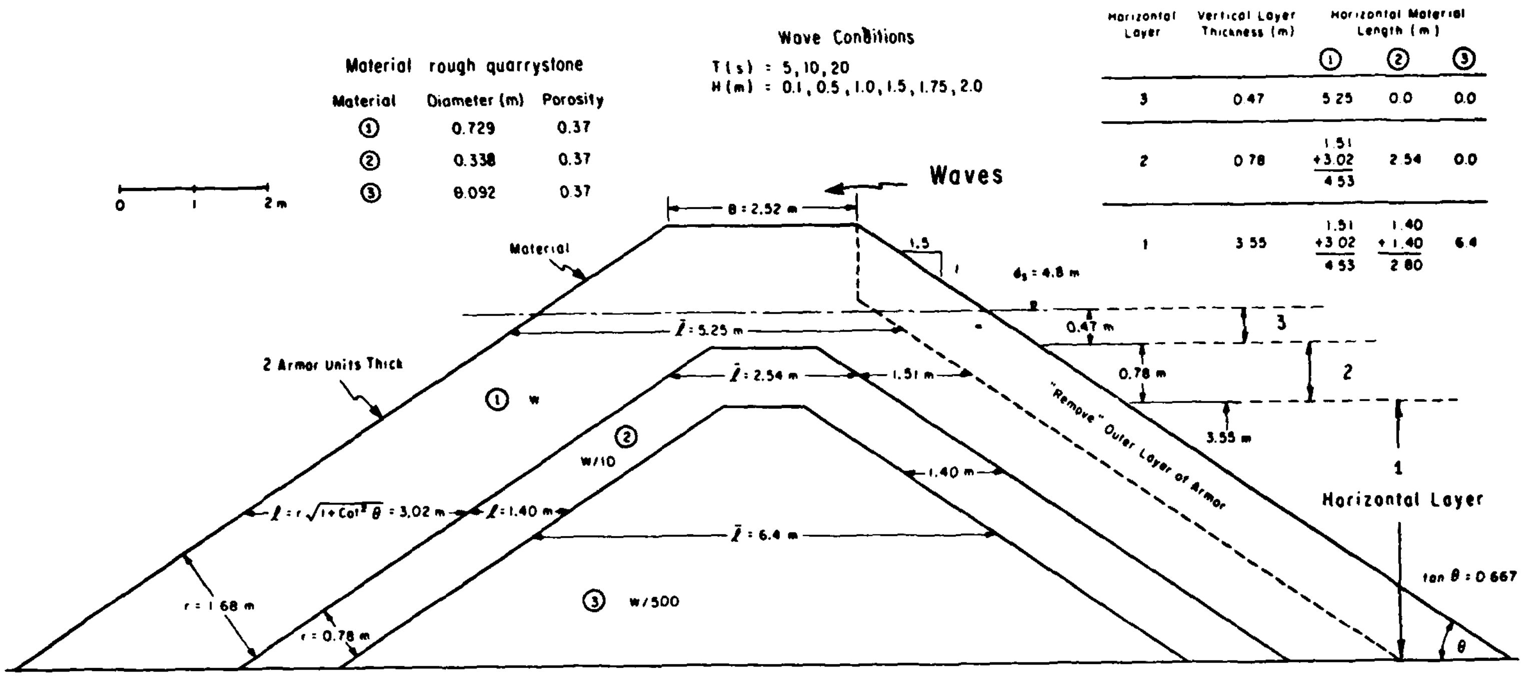
(c) Estimate the kinematic viscosity of water as a function of water temperature (Table G-3).

(d) Estimate breakwater water runup parameters, a and b. At the present time the values of a = 0.692 and b = 0.504 are recommended based on the laboratory data of Hudson (1958).

(e) Put the information into the required input format (Table G-4). Input cards for the example breakwater (Fig. G-2) are shown in Table G-5.

(f) Sample output for the example problem is shown in Table G-6.

2. Computer Program. A listing of the computer program MADSEN is given in Table G-7.



Material rough quarrystone

Material	Diameter (m)	Porosity
①	0.729	0.37
②	0.338	0.37
③	0.092	0.37

Wave Conditions

T(s) : 5, 10, 20

H(m) : 0.1, 0.5, 1.0, 1.5, 1.75, 2.0

Horizontal Layer	Vertical Layer Thickness (m)	Horizontal Material Length (m)		
		①	②	③
3	0.47	5.25	0.0	0.0
2	0.78	1.51 +3.02 4.53	2.54	0.0
1	3.55	1.51 +3.02 4.53	1.40 +1.40 2.80	6.4

Figure G-2. Sample breakwater input information required.

Table G-3. Kinematic viscosity of water.

Water temperature (C°)	Kinematic viscosity of water (m^2/s)
0	0.0000018
10	0.0000013
20	0.0000010
30	0.0000008

Table G-4. Format of input information.

Card type	Format	Description
standard		53 standard input cards (see Table G-3)
1	I2	number of breakwater configurations or water depths to test
2	20A4	title card
3	3I2, 4X, 7F10.5	number of wave conditions to test
		number of materials
		number of horizontal layers
		structure height (m)
		water depth (m)
		kinematic viscosity (m^2/s)
		width of top of breakwater (m)
		front slope of breakwater = tan (θ)
		wave runup parameter a = 0.692
		wave runup parameter b = 0.504
4	10X, 2F10.5 (one card per material)	material diameter (m) (armor 1st)
		material porosity
5	10X, 7F10.5 (one card per horizontal layer)	layer thickness (m)
		mean length of each material type in the layer (put in consecutive order, material 1 (armor 1st), etc.)
6	2F10.5 (wave condition card; one card per wave condition)	wave period (s)
		wave heights (m)

NOTE.--Repeat card types 2 to 6 for each water depth or breakwater configuration to be tested.

Table G-5. Sample input to program MADSEN.

```
 1
EXAMPLE PROBLEM
18 3 3      6.0      4.0     .00000043  2.52     0.667     0.692     0.504
MAT 1       0.729    0.57
MAT 2       0.538    0.57
MAT 3       0.092    0.57
LAV 1       3.55     4.53     2.60      6.40
LAV 2       0.78     4.53     2.50      1.0
LAV 3       0.47     5.25     0.0       0.0
 5.0        0.1
 5.0        0.5
 5.0        1.0
 5.0        1.5
 5.0        1.75
 5.0        2.0
 10.0       0.1
 10.0       0.5
10.0        1.0
 10.0       1.5
 10.0       1.75
 10.0       2.0
 20.0       0.1
 20.0       0.5
 20.0       1.0
 20.0       1.5
 20.0       1.75
 20.0       2.0
```

Table G-6. Sample output.

```
     EXAMPLE PROBLEM

    COMPUTATIONS OF WAVE TRANSMISSION THROUGH A POROUS BREAKWATER


NUM OF WAVE CONDITIONS                  18
NUM OF MATERIALS=                        3
NUM OF HORIZONTIAL LAYERS=               3
STRUCTURE HEIGHT (M)=                6.000
WATER DEPTH (M)=                     4.800
KINEMATIC VISCOSITY (M2/SEC)= .000000930
BW TOP WIDTH (M)=                    2.520
TANH OF FRONT SLOPE=                 .6670
RUNUP COEFFICIENTS  A=  .692 B=   .504
MATERIAL CHARACTERISTICS (MAKE ARMOR MATERIAL NUMBER 1)

MATERIAL=  1 DIAMETER (M)=  .729 POROSITY=  .370
MATERIAL=  2 DIAMETER (M)=  .338 POROSITY=  .370
MATERIAL=  3 DIAMETER (M)=  .092 POROSITY=  .370


HORIZONTIAL LAYER CHARACTERISTICS
(MAKE LAYER NEXT TO SEABED LAYER NUMBER 1)
                                                      MATERIAL=   1     2     3
HORIZONTIAL LAYER=  1 THICHNESS (M)= 3.550 LENGTHS (M)=   4.5   2.8   6.0
HORIZONTIAL LAYER=  2 THICHNESS (M)=  .780 LENGTHS (M)=   4.5   2.5   0.0
HORIZONTIAL LAYER=  3 THICHNESS (M)=  .470 LENGTHS (M)=   5.3   0.0   0.0


 H(M)    T(SEC)    H/(G*T*T)     H/L      D/(G*T*T/) KTT   KTO     KT      KR    HT(M)
  .100      5.00    .000408     .00335        .0196  .392 0.000  .392    .26    .039
 .500       5.00    .002041     .01674        .0196  .213 0.000  .213    .28    .106
 1.000      5.00    .004082     .03349        .0196  .151 0.000  .151    .27    .151
 1.500      5.00    .006122     .05023        .0196  .131  .036  .136    .27    .203
 1.750      5.00    .007143     .05860        .0196  .122  .082  .149    .26    .262
 2.000      5.00    .008163     .06697        .0196  .115  .125  .169    .26    .337
  .100     10.00    .000102     .00151        .0049  .401 0.000  .401    .50    .040
  .500     10.00    .000510     .00753        .0049  .202 0.000  .202    .59    .101
 1.000     10.00    .001020     .01507        .0049  .135 0.000  .135    .62    .135
 1.500     10.00    .001531     .02260        .0049  .100  .115  .152    .63    .229
 1.750     10.00    .001786     .02637        .0049  .088  .159  .182    .64    .318
 2.000     10.00    .002041     .03013        .0049  .080  .193  .209    .64    .413
  .100     20.00    .000026     .00073        .0012  .381 0.000  .381    .55    .038
  .500     20.00    .000128     .00367        .0012  .186 0.000  .186    .66    .093
 1.000     20.00    .000255     .00735        .0012  .127  .010  .127    .70    .127
 1.500     20.00    .000383     .01102        .0012  .098  .154  .182    .71    .274
 1.750     20.00    .000446     .01286        .0012  .087  .196  .214    .72    .375
 2.000     20.00    .000510     .01470        .0012  .081  .227  .241    .72    .482

KTT = WAVE TRANSMISSION THROUGH THE STRUCTURE
KTO = WAVE TRANSMISSION BY OVERTOPPING COEFFICIENT
KT  = TOTAL WAVE TRANSMISSION COEFFICIENT
KR  = WAVE REFLECTION COEFFICIENT
HT  = TRANSMITTED WAVE HEIGHT
```

Table G-7. Listing of the computer program MADSEN.

```
      PROGRAM MADSEN(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE3)
      COMMON/MADS1/NM,NL,D(11),N(11),LL(11,11),TH(11)
      COMMON/SEEL/NKL,FS
      REAL NKL
      DIMENSION IBUF(1),TITLE(20),NUM(10)
      REAL L,NU,KT,KR,N,LE,NR,LL,KTO,KTT
      DATA NUM/1,2,3,4,5,6,7,8,9,10/
      PI=3.14159
      CALL READI
      READ(5,590) NCOMP
  590 FORMAT(3I2,4X,7F10.5)
      DO 200 IJ=1,NCOMP
C READ INPUT INFORMATION
      READ(5,171) (TITLE(JJM),JJM=1,20)
  171 FORMAT(20A4)
      WRITE(6,172) (TITLE(JJM),JJM=1,20)
  172 FORMAT(1H1,10X,20A4)
      READ(5,590) NT,NM,NL,HS,HO,NU,TOPW,TANB,RA,RB
      FS=HS-HO
      IF(RA.LE.0.) RA=0.692
      IF(RB.LE.0.) RB=.504
      WRITE(6,971) NT,NM,NL,HS,HO,NU,TOPW,TANB,RA,RB
  971 FORMAT(/  ,10X,[COMPUTATIONS OF WAVE TRANSMISSION THROUGH A POROUS
     * BREAKWATER[,///,5X, [NUM OF WAVE CONDITIONS[,12X,I3,/,5X,
     * [NUM OF MATERIALS=[,17X,I3,/,5X,
     *      [NUM OF HORIZONTIAL LAYERS=[,6X,I5,/,5X,[STRUCTURE HEIGHT (M)
     *=[,4X,F10.3,/,5X,[WATER DEPTH (M)=[,11X,F10.3,/,5X,
     *[KINEMATIC VISCOSITY (M2/SEC)=[,F11.9,   /,5X,[BW TOP WIDTH (M)=[,
     *10X,F10.3,/,5X,[TANB OF FRONT SLOPE=[,9X,F3.4,/,5X,[RUNUP COEFFICI
     *ENTS  A=[,F6.3,[ B=[,F6.3)
      DO 99 I=1,11
      DO 98 J=1,11
   98 LL(I,J)=0.
   99 CONTINUE
      WRITE(6,283)
  283 FORMAT(5X,[MATERIAL CHARACTERISTICS (MAKE ARMOR MATERIAL NUMBER 1)
     *[,/)
      DO 6 I=1,NM
      READ(5,7) D(I),N(I)
    7 FORMAT(10X,7F10.5)
      WRITE(6,177) I,D(I),N(I)
  177 FORMAT(5X,[MATERIAL=[,I3,[ DIAMETER (M)=[,F 6.3,[ POROSITY=[,F6.3)
    6 CONTINUE
      WRITE(6,284) (NUM(JM),JM=1,NM)
  284 FORMAT(//,5X,[HORIZONTIAL LAYER CHARACTERISTICS[,/,5X,
     *[(MAKE LAYER NEXT TO SEABED LAYER NUMBER 1)[,/,
     * 52X,[MATERIAL=    [,7(I1,5X),/,63X,6(I2,4X),/)
      DO 33 J=1,NL
      READ(5,7) TH(J),(LL(I,J),I=1,NM)
      WRITE(6,178) J,TH(J),(LL(I,J),I=1,NM)
  178 FORMAT(5X,[HORIZONTIAL LAYER=[,I3,[ THICKNESS (M)=[, F6.3,[ LENGTH
     *S (M)=[,7F6.1,/,60X,7F6.1)
   33 CONTINUE
      NM=NM+1
      D(NM)=D(1)
      N(NM)=0.01
      NL=NL+1
      TH(NL)=10000000.
      LL(NM,NL)=3.*D(1)
      WRITE(6,942)
  942 FORMAT(//, 6X,[H(M)    T(SEC)    H/(G*T*T)    H/L      D/(G*T*T/) KTT
     *  KTO    KT     KR    HT(M)[)
      DO 199 IK=1,NT
      READ(5,8) T,H
    8 FORMAT(2F10.5)
      A=H*0.5
      DR=D(1)*0.5
```

Table G-7. Listing of the computer program MADSEN.--Continued

```
      IF(A.LT.0.00001) GO TO 100
      IF(TANB.LE.0.) GO TO 37
      CALL REFL(A,HS,D(1),HO,TANB,T,RII,RU,L)
      AI=RII*A
   22 DHT=2.*RU*A
      IFLAG=0
C ASSUME DHE=DHT AND ITERATE ON THE EQUILIVANT BW
      ICOUNT=0
      DHE=DHT
   10 ICOUNT=ICOUNT+1
      CALL EQBW(DHE,DHT,LE,HO,HS,TANB,NR,DR,TOPW)
      CALL INTER(NR,T,LE,HO,AI,NU,DR,TI,RI,L,IFLAG)
      IF(IFLAG.EQ.1) DR=DR*0.95
      IF(IFLAG.EQ.1) GO TO 22
      DHE=(1.+RI)*RII*A
      IF(ICOUNT.LT.4) GO TO 10
      KR=RI*RII
      KTT=TI*RII
   37 IF(TANB.LE.0.) CALL INTER(N(1),T,TOPW,HO,A,NU,D(1),KTT,KR,L,IFLAG)
      IF(IFLAG.EQ.1) DR=DR*0.5
      IF(IFLAG.EQ.1) GO TO 37
      SURF=TANB/SQRT(H/(1.56*T*T))
      RH=RA*SURF/(1.+RB*SURF)
      R=H*RH
      FR=F/R
      C=0.51 -0.11*TOPW/HS
      KTO=C*(1.-FR)
      IF((TOPW/HS).GT.0.8A.AND.F.LT.0.) KTO=C*(1.-FR)-(1.-2.*C)*FR
      IF(KTO.GT.1.) KTO=1.
      IF(FR.GT.1.0) KTO=0.
      HGT2=A*2./(9.80*T*T)
      HL=2.*A/L
      DGT2=HO/(9.80*T*T)
      FLAG=3H
      KT=SQRT(KTT**2+KTO**2)
      IF(KT.GT.1.0) KT=1.0
      HT=H*KT
      WRITE(6,981) H,T,HGT2,HL,DGT2,KTT,KTO,KT,KR,HT
  981 FORMAT( 5X,F6.3,F10.2,F10.6,F10.5,F10.4,3F6.3,F6.2,F7.3)
  100 CONTINUE
  199 CONTINUE
      WRITE(6,201)
  201 FORMAT(//,2X,'KTT = WAVE TRANSMISSION THROUGH THE STRUCTURE',/,
     *2X,'KTO = WAVE TRANSMISSION BY OVERTOPPING COEFFICIENT',/,
     * 2X,'KT  = TOTAL WAVE TRANSMISSION COEFFICIENT',/,2X,
     * 'KR  = WAVE REFLECTION COEFFICIENT',
     */,2X,'HT  = TRANSMITTED WAVE HEIGHT')
  200 CONTINUE
      STOP
      END
      SUBROUTINE REFL(A,HS,D,HO,TANB,T,RII,RU,L)
      COMMON/MADS/FST(9,11),RUT(9,11),RT(17,11),TX(9,10),RX(9,10)
      DIMENSION FSS(11),RUS(11),HS(11)
      REAL L,LSL,LS
C   CF = MODEL CORRECTION FACTOR TO ACCOUNT FOR MODEL SLOPE EFFECTS
      CF=1.28-0.578*TANB
      IF(TANB.LT.0.4) CF=1.02
      IF(TANB.GT.0.68) CF=0.89
C FIND WAVE LENGTH L
      HOLO=HO/(1.56*T*T)
      CALL LENGT(HOLO,HOL)
      L=HO/HOL
      LS=HO/TANB
      IF(HS.LT.HO) LS=HS/TANB
      LSL=LS/L
      IF(LSL.LT.0.8) GO TO 105
      TMIN=SQRT(6.283*(LS/0.8)/(9.8*TANH(6.283*HO/(LS/0.8))))
      WRITE(6,101) TMIN
  101 FORMAT(///,1X,'WARNING-THE MINIMUM WAVE PERIOD TO BE ANALYZED BY T
```

Table G-7. Listing of the computer program MADSEN.--Continued

```
      *HIS PROGRAM IS(,F6.2,( SEC FOR THIS CONDITION()
       LSL=0.799
  105  I=(LSL*10.+1.)
C INTERPOLATE INPUT TABLE FOR THIS LSL VALUE
       II=LSL*20.+1.
        DO 3 J=1,11
       FSS(J)=FST(I,J)+(FST(I+1,J)-FST(I,J))*(LSL-(I-1)*0.1)/0.1
       RUS(J)=RUT(I,J)+(RUT(I+1,J)-RUT(I,J))*(LSL-(I-1)*0.1)/0.1
    3  RS(J)=RT(II,J)+(RT(II+1,J)-RT(II,J))*(LSL-(II-1)*0.05)/0.05
C GUESS PHI AND ITERATE
       PHI=5.0
       M=0
    6  J=PHI
       FAC=(ALOG(PHI+1.)-ALUG(J+1.))/(ALOG(J+2.)-ALOG(J+1.))
       FS=FSS(J+1)+             FAC*(FSS(J+2)-FSS(J+1))
       RU=RUS(J+1)+             FAC*(RUS(J+2)-RUS(J+1))
       RII=RS(J+1)+(RS(J+2)-RS(J+1))*FAC
       ARG=0.29*(D/HO)**0.2*(RU*2.*A/(HO*TANB))**0.3*FS
       PHIN=0.5*ATAN(ARG)*57.29578
       M=M+1
       DEL=ABS(PHIN-PHI)
       IF(M.GT.20) GO TO 9
       PHI=PHIN
       IF(PHI.LT.0.01) PHI=0.01
       IF(PHI.GT.9.99) PHI=9.99
       IF(DEL.GT.0.05) GO TO 6
    9  RII=RII*CF
       RETURN
       END
       SUBROUTINF READT
       COMMON/MADS/FST(9,11),RUT(9,11),RT(17,11),TX(9,10),RX(9,10)
  177  FORMAT(3X,17F4.2)
       DO 1 M=1,11
    1  READ(5,177) (FST(N,M),N=1,9)
       DO 2 M=1,11
    2  READ(5,177) (RUT(N,M),N=1,9)
       DO 3 M=1,11
    3  READ(5,177) (RT(N,M),N=1,17)
       DO 4 M=1,10
    4  READ(5,177) (TX(N,M),N=1,9)
       DO 5 M=1,10
    5  READ(5,177) (RX(N,M),N=1,9)
       RETURN
       END
       SUBROUTINE EURW(DHE,DHT,LE,HO,HS,TANB,NR,DR,TOPW)
       COMMON/MADS1/NM,NL,D(11),N(11), L(11,11),TH(11)
       DIMENSION BETA(11),DH(11)
       REAL N,L,LE,NR
       NR=0.435
       BETAR=2.7*(1.-NR)/(NR**3*DR)
       DO 21 I=1,NM
   21  BETA(I)=2.7*(1.-N(I))/(N(I)**3*D(I))
       TH1=0.
       TH2=0.
       DO 4 J=1,NL
       TH1=TH1+TH(J)
       NYL=J
       DH(J)=TH(J)/HO
       IF(TH1.GT.HO) DH(J)=(HO-TH2)/HO
       IF(TH1.GT.HO) GO TO 5
    4  TH2=TH2+TH(J)
    5   SUM2=0.
       DO 16 J=1,NYL
       SUM1=0.
       DO 17 I=1,NM
   17  SUM1=SUM1+BETA(I)/BETAR*L(I,J)
   16  SUM2=SUM2+DH(J)/(SQRT(SUM1))
       LE=1./(SUM2**2)*DHE/DHT
```

Table G-7. Listing of the computer program MADSEN.--Continued

```
      RETURN
      END
      SUBROUTINE INTER(N,T,L,HO,A,NU,D,TI,RI,WL,IFLAG)
      COMMON/SEEL/NKL,FS
      COMMON/MADS/FST(9,11),RUT(9,11),RT(17,11),TX(9,10),RX(9,10)
      DIMENSION TS(10),RS(10)
      REAL NKL,L,NU,KO,LAMBDA,N
      SS=(N/0.45)**2
      KO=2.*3.14159/WL
      NKL=N*KO*L
      BETA=2.7*(1.-N)/(N**3*D)
      LAMBDA=1.
      F=0.
      RC=170.
      IC=0
    2 FN=F
      IC=IC+1
      U=A*SQRT(9.80/HO)/(1.+LAMBDA)
      RD=U*D/NU
      F=N/(KO*L)*(SQRT(1.+(1.+RC/RD)*(16.*BETA*A*L/(3.*3.14159*HO)))-1.)
      LAMBDA=KO*L*F/(2.*N)
      IF(IC.GT.10) GO TO 5
      IF((ABS(FN-F)/F).GT.0.02) GO TO 2
    5 TI=1./(1.+LAMBDA)
      RI=LAMBDA/(1.+LAMBDA)
      FS=F/SS
C     WRITE(6,397) F,FS,U,RD
  397 FORMAT(20X,(F,FS,U,RD=(,4E13.5)
      IF(NKL.GT.0.9) IFLAG=1
      IF(NKL.GT.0.9) RETURN
      IF(NKL.LT.0.1) RETURN
      IF(FS.GT.35.) FS=35.
      J=NKL*10.
      I=FS
C INTERPOLATE MADSEN CURVES 2 AND 3
      DO 1 M=1,10
      RS(M)=RX(J,M)+(RX(J+1,M)-RX(J,M))*(NKL-0.1*J)/0.1
    1 TS(M)=TX(J,M)+(TX(J+1,M)-TX(J,M))*(NKL-0.1*J)/0.1
      IF(FS.LE.1.0) TI=TS(1)+ALOG10(FS)*(TS(10)-TS(1))
      IF(FS.LE.1.0) RI=RS(1)+ALOG10(FS)*(RS(10)-RS(1))
      IF(FS.GE.10.) TI=TS(10)*(35.-FS)/25.
      IF(FS.GE.10.) RI=RS(10)+(1.-RS(10))*(FS-10.)/25.
      IF(FS.LE.1.0.OR.FS.GE.10.0) RETURN
      RI=RS(I)+(RS(I+1)-RS(I))*(ALOG(FS)-ALOG(I*1.))/(ALOG(I+1.)-ALOG(I*
     *1.))
      TI=TS(I)+(TS(I+1)-TS(I))*(ALOG(FS)-ALOG(I*1.))/(ALOG(I+1.)-ALOG(I*
     *1.))
      RETURN
      END
      SUBROUTINE LENGT( DLO,DL)
      REAL LO,LONEW,LOD
      LO=1.0/DLO
      LOD=1.0/DLO
      N=1
      PI=3.14159
    1 ARG=2.0*PI/LO
      LONEW=LOD*TANH(ARG)
      N=N+1
      DIFF=ABS(LONEW-LO)
      IF(N-200) 3,4,4
    3 IF(DIFF-0.0005) 2,2,5
    5 LO=(LONEW+LO)/2.0
      GO TO 1
    4 DL=1.0/LONEW
      WRITE(6,100) DLO,DL
  100 FORMAT(44H SUBROUTINE LENGTH DID NOT CONVERGE, D/LO =     ,F10.5,
     1  8HD/L =    ,F10.5)
    2 DL=1.0/LONEW
      RETURN
      END
```

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