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Maximum Wave Heights and Critical Water Depths for Irregular Waves in the Surf Zone

by
William N. Seelig

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The nearshore irregular wave deformation model of Goda (1975) is used to develop prediction curves for the magnitude and location of peak wave heights in the surf zone as a function of profile slope and offshore wave steepness. An example that demonstrates the use of these curves is presented.

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PREFACE

Design curves for the maximum breaker height in the surf zone for monochromatic waves (based on the work of Goda, 1970) are given in Section 7.12 of the Shore Protection Manual (U.S. Army, Corps of Engineers, Coastal Engineering Research Center, 1977). This report presents similar curves for the magnitude and location of peak wave heights for irregular waves, based on the model of Goda (1975). This work was carried out as a part of the offshore breakwaters for shore stabilization program of the U.S. Army Coastal Engineering Research Center (CERC).

This report was prepared by William N. Seelig, Hydraulic Engineer, under the general supervision of Dr. R.M. Sorensen, Chief, Coastal Processes and Structures Branch.

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

d^*	water depth where $H_{s\ max}$ occurs
g	acceleration due to gravity
H_b	maximum breaker height for monochromatic waves
H_1	average height of highest 1 percent of all waves for a given time period
$H_{1\ max}$	peak value of H_1
H_o	deepwater significant wave height
H_s	significant wave height defined as the average of the highest one-third waves
$H_{s\ max}$	peak value of H_s
T_p	wave period defined as the period of peak energy density for irregular waves
m	slope of the bottom

MAXIMUM WAVE HEIGHTS AND CRITICAL WATER DEPTHS FOR IRREGULAR WAVES IN THE SURF ZONE

by
William N. Seelig

I. INTRODUCTION

The Shore Protection Manual (U.S. Army, Corps of Engineers, Coastal Engineering Research Center, 1977)[1] gives methods for estimating wave height nearshore due to monochromatic waves, based on the work of Goda (1970)[2]. However, the action of irregular waves in the surf zone is very complex, involving the interaction of wave shoaling, breaking, and setup; re-formation of broken waves; surf beat; and other mechanisms. Goda (1975)[3] proposed a model for predicting wave height distributions and wave height parameters in the nearshore zone for the case of continuously shallowing profiles. Goda's model assumes that the (a) equivalent deepwater significant wave height and period are known; (b) deepwater wave heights have a Rayleigh distribution; (c) average beach slope one-half to one wavelength seaward of the point of interest is known; (d) surf beat, wave setup, and breaking limits can be described by empirical formulas; (e) wave shoaling is nonlinear; and (f) broken waves re-form at lower heights. Using these assumptions, a numerical procedure was developed to predict nearshore wave heights (see Seelig and Ahrens, 1979)[4]. Limited testing of the model with field and laboratory data suggests that Goda's model gives useful estimates of nearshore wave heights.

II. DESIGN CURVES

Calculations of nearshore wave conditions using Goda's (1975)[5] model show that wave height parameters reach a maximum or peak value at one point along the profile. For example, an irregular wave condition with a deepwater significant wave height, H_o, and a period of peak energy density, T_p, has a peak value of significant wave height, $H_{s\ max}$, at a water depth, d^* (Fig. 1). This would be an especially poor location to build a structure or site any other activity sensitive to wave height, because the significant wave height reaches its largest value at this point. H_1 shown in the figures is defined as the

[1]U.S. ARMY, CORPS OF ENGINEERS, COASTAL ENGINEERING RESEARCH CENTER, *Shore Protection Manual*, 3d ed., Vols. I, II, and III, Stock No. 008-022-00113-1, U.S. Government Printing Office, Washington, D.C., 1977, 1,262 pp.

[2]GODA, Y., "A Synthesis of Breaker Indices," *Transactions of the Japanese Society of Civil Engineers*, Vol. 2, Pt. 2, 1970.

[3]GODA, Y., "Irregular Wave Deformation in the Surf Zone," *Coastal Engineering in Japan*, Vol. 18, 1975, pp. 13-26.

[4]SEELIG, W.N., and AHRENS, J., "Estimating Nearshore Conditions for Irregular Waves," U.S. Army, Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, Va. (in preparation, 1980).

[5]GODA, Y., op. cit.

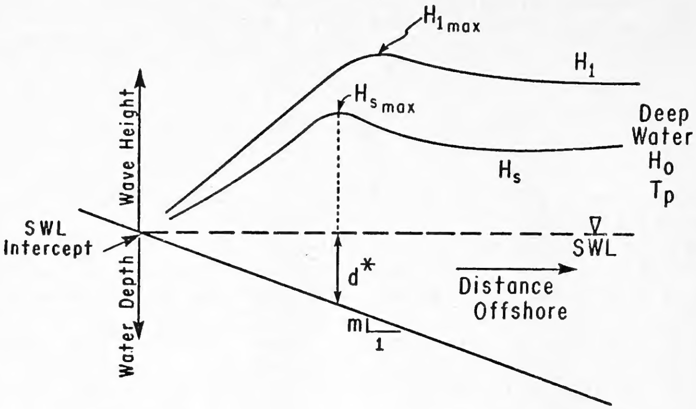

Figure 1. Predicted nearshore wave heights using Goda's model.

average of the highest 1 percent of the waves and is the wave height with an exceedance probability of approximately 1/260. Goda's model predicts that the peak value of H_1 occurs just seaward of $d*$ (Fig. 1).

Figure 2 gives the design curves for $H_{s\ max}$ and $H_{1\ max}$ as a function of deepwater wave steepness and beach slope. These curves show that the peak wave heights decrease as the wave steepness increases and the beach slope becomes flatter. The dimensionless water depth where the peak significant wave height occurs becomes smaller as the beach slope or wave steepness increases, except for the steepest waves (Fig. 3).

III. EXAMPLE PROBLEM

GIVEN: Wave conditions of H_o = 6.56 feet (2.0 meters) and T_p = 10 seconds with a beach slope, m, = 1/100.

FIND: The peak significant and maximum wave heights in the surf zone and their locations.

SOLUTION: For this example:

$$H_o/gT_p^2 = 2.0/(9.8 * 10^2) = 0.002.$$

From Figure 2,

$$\frac{H_{s\ max}}{H_o} = 1.18 \text{ or } H_{s\ max} = 7.7 \text{ feet (2.3 meters)},$$

and

$$\frac{H_{1\ max}}{H_o} = 1.81 \text{ or } H_{1\ max} = 11.8 \text{ feet (3.62 meters)}.$$

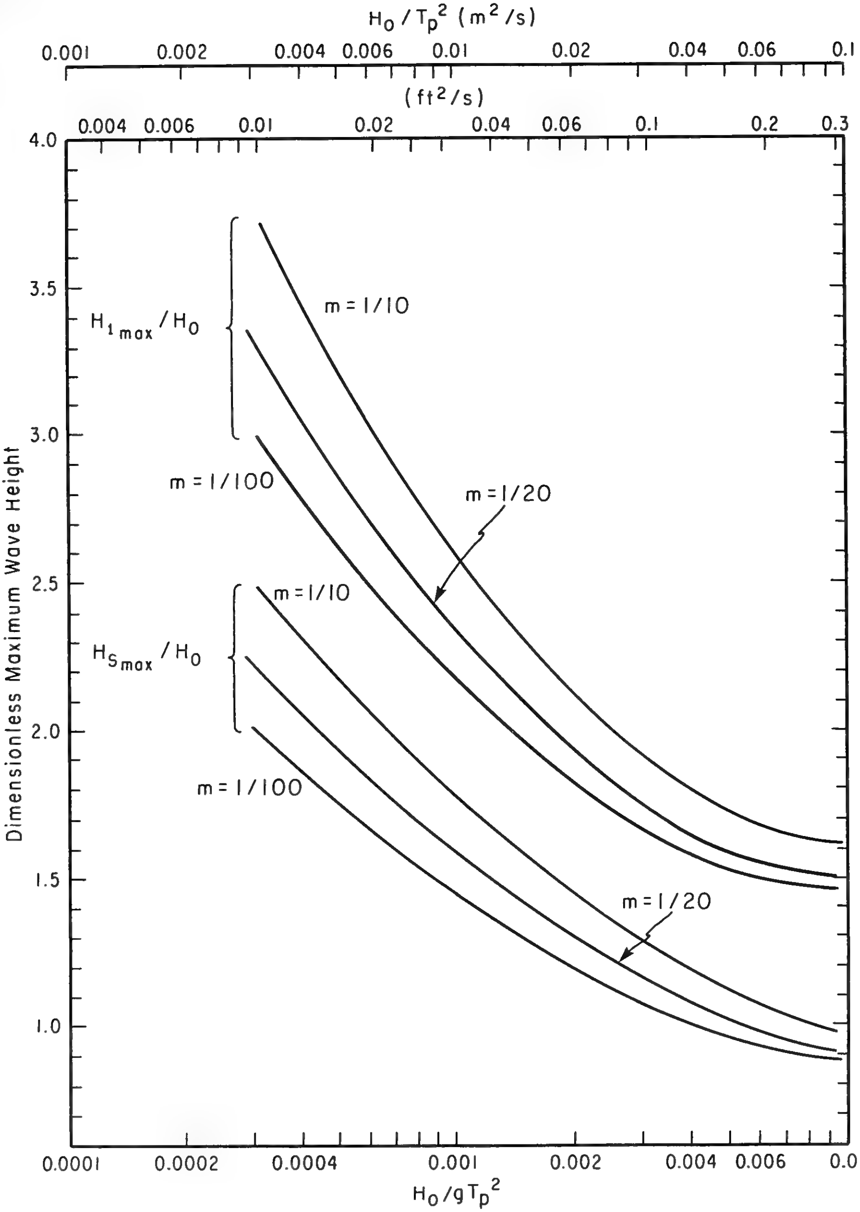

Figure 2. Peak values of wave height in the nearshore zone.

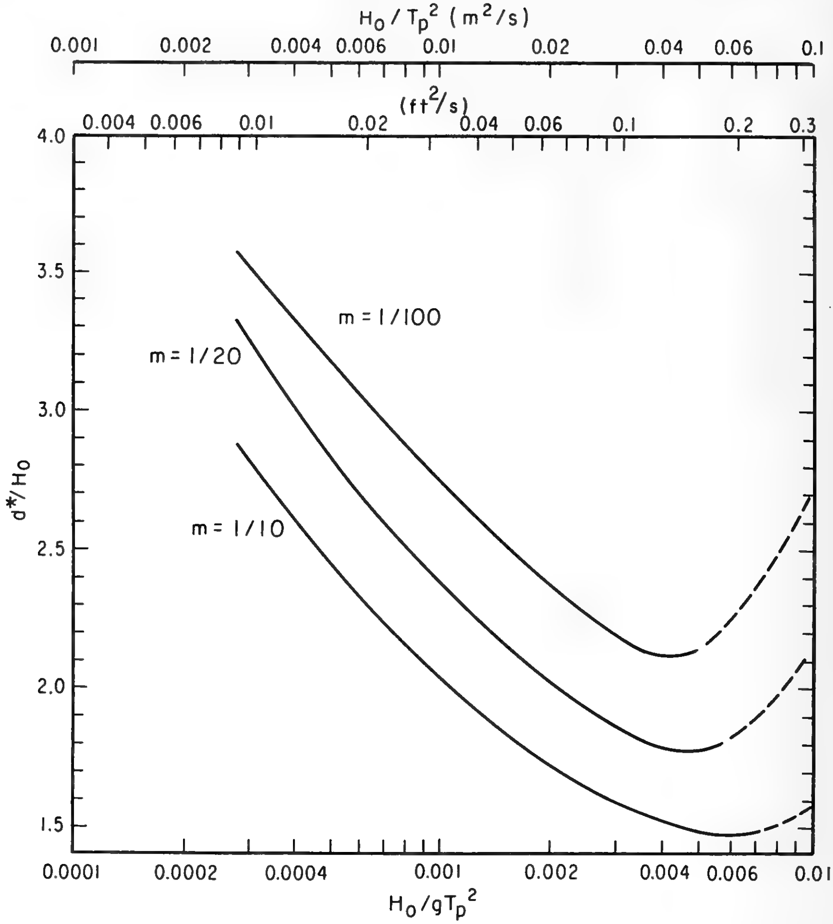

Figure 3. Water depth for the peak significant wave height.

From Figure 3,

$$\frac{d^*}{H_o} = 2.36 \text{ or } d^* = 15.5 \text{ feet (4.72 meters)}$$

which occurs 1,550 feet (472 meters) offshore of the beach stillwater level (SWL) intercept for a 1/100 slope beach.

Note that monochromatic theory predicts a breaker height, H_b, (Fig. 7-3 in U.S. Army, Corps of Engineers, Coastal Engineering Research Center, 1977)[6] that occurs between the peak significant and maximum one percent heights (see Table).

Table. Predicted peak wave heights using irregular and monochromatic theories (T = 10 seconds; m = 1/20).

H_o		$H_{s\ max}$		H_b		$H_{1\ max}$	
(ft)	(m)	(ft)	(m)	(ft)	(m)	(ft)	(m)
3.28	(1.0)	5.25	(1.6)	5.9	(1.8)	7.54	(2.3)
6.56	(2.0)	8.53	(2.6)	10.2	(3.1)	12.5	(3.8)
13.1	(4.0)	13.8	(4.2)	16.7	(5.1)	21.3	(6.5)
19.7	(6.0)	19.0	(5.8)	23.0	(7.0)	30.2	(9.2)

IV. SUMMARY

The model of Goda (1975)[7] for predicting heights of irregular waves in the surf zone is used to determine the peak significant and maximum wave heights and location where peak wave heights will occur.

[6]U.S. ARMY, op. cit., p. 7.

[7]GODA, Y., op. cit., p. 7.

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The nearshore irregular wave deformation model of Goda (1975) is used to develop prediction curves for the magnitude and location of peak wave heights in the surf zone as a function of profile slope and offshore wave steepness. An example that demonstrates the use of these curves is presented.

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