

SURF SIMILARITY

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I. INTRODUCTION

Coastal Engineers and scientists are interested in determining the fluid motions which occur within the surf zone at the beach. The ability to predict these behaviors affects the design of coastal structures as well as our ability to forecast beach profile evolution (e.g., bar/berm formation).

The ability of FLOW-3D to model shorebreak is examined in this investigation.

II. A BRIEF INTRODUCTION TO WAVE BREAKING

The way in which waves break at the beach is affected by incident wave conditions as well as the slope of the beach. The surf similarity parameter described below may be used to predict the nature of breaking waves based on wave height (H), wave length (L), and beach slope ($\tan \beta$).

“In shallow water, waves continue to shoal until they become so large that they become unstable and break. Empirically Battjes (1974) has shown that the breaking wave characteristics can be correlated to the surf similarity parameter, ζ .

$$\zeta = (H/L)^{-1/2} \tan \beta \quad \text{Eq. 1}$$

where: $\tan \beta$ is the beach slope, H is the offshore wave height, and L is the offshore wave length. Battjes (1974) results are shown in Table 1, which show the breaker type, the breaking index, the number of waves in the surf zone and the reflection coefficient from the beach (Dean and Dalrymple, 1993).”

Table 1: Breaking Wave Characteristics and the Surf Similarity Parameter,
Following Battjes (1974)

ζ	0.1	0.5	1.0	2.0	3.0	4.0	5.0
Type	spilling		plunging		collapsing/surging		no breaking
κ	0.8	1.0	1.1	1.2			
N	6-7	2-3	1-2	0-1	0-1		
r	10^{-3}	10^{-2}	0.1	0.4	0.8		

κ = breaking index¹, N = number of waves in surf zone, r = reflection from beach

III. PROBLEM DESCRIPTION

“The means by which waves break depends on the nature of the bottom and the characteristics of the wave (see Figure 1). For very mildly sloping beaches, typically the waves are *spilling* breakers and numerous waves occur within the surf zone (defined as that region where the waves are breaking, extending from the dry beach to the seaward limit of the breaking). *Plunging* breakers occur on steeper beaches and are characterized by the crest of the wave curling forward and impinging onto part of the wave trough. These waves can be spectacular when air, trapped inside the “tube” formed by the wave crest, escapes by bursting through the back of the waves or by blowing out at a nonbreaking section of the wave crest. *Surging* breakers occur on very steep beaches and are characterized by narrow or nonexistent surf zones and high reflection. Galvin (1968) has identified *collapsing* as a fourth classification, which is a combination of plunging and surging (Dean and Dalrymple, 1991).”

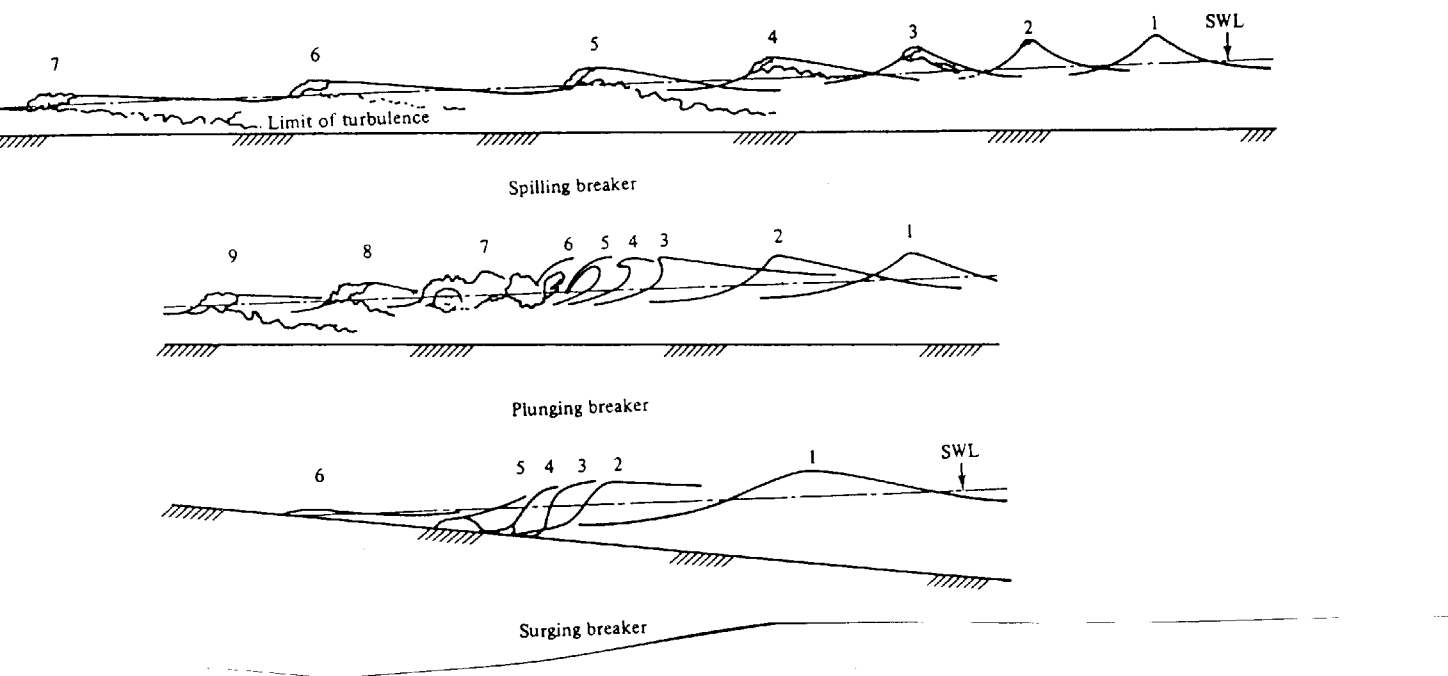


Figure 1: Three types of waves breaking on beaches. Small figures denote different stages of the breaking process. (Adapted from I. A. Svendsen)

Each of the three wave breaking types appearing in Figure 1 are characterized by a different value of the surf similarity parameter. Spilling waves correspond to $\zeta = 0.1$, plunging waves correspond to $\zeta = 1.0$, and collapsing/surging waves correspond to $\zeta = 3.0$. In this exercise we attempt to model these three different motions using FLOW-3D.

IV. NUMERICAL MODEL

Physical units for the model were taken to be length in meters, time in second, and mass in kilograms. The origin of the computational coordinate system (x,z) was located on the ocean floor at a location furthest from shore. The computational grid used to cover the model area consists of 193 cells in the x direction (offshore/onshore direction) and 42 cells vertically. The physical size of the domain ranged from 60 to 390 meters.ⁱⁱ

A specified velocity boundary condition was used at the offshore (left) limit of the mesh. The boundary condition was implemented by (Hirt, 1995) and is based on linear wave theory (see Kinsman [1965] for details). The boundary condition requires the user to specify the amplitude, wave number, and frequency of the incoming wave. The wave is furthermore assumed to be in deep water $h/L > 1/2$. Here, h is the water depth and L is the length of the wave. The same incident wave conditions was used for all of the simulations performed: wave amplitude, 0.5; wave number, 0.524; frequency, 2.27. Note that the wave amplitude was kept purposely small to satisfy the linearized (i.e., small amplitude) theory used to develop the boundary condition. Symmetry boundary conditions were used at the lateral boundaries and a no flow boundary condition was used at the onshore (right) limit of the mesh.

The beach used in these simulations was linear. The toe of the beach was located at $x=24$. This allowed the incident wave to propagate through “deep water” (i.e., $h=6m$) for two waves lengths prior shoaling. The expression for surf similarity (eq. 1) was used to determine the appropriate slope of the beach for each of the three simulations performed.

$$\text{slope} = \zeta (H/L)^{1/2} \qquad \text{Eq. 2}$$

The simulations were performed for ζ equal to 0.1, 1.0, and 3.0, and for H/L equal to 1/12.

The working fluid was water. For initial conditions, the water was level and quiescent. A complete input file used by FLOW-3D for this computation is given in Figure 2. The file contains all physical property data, mesh and obstacle descriptions, boundary and initial conditions, as well as all computational parameters controlling the operation and output of the code.

The computations were performed on a 75 Mhz Pentium PC. Approximately one hour was required to perform each of the simulations.

V. COMPUTATIONAL RESULTS

$\zeta = 0.1$

An initial simulation was performed for $\zeta = 0.1$. Figure 3 shows a portion of the numerical solution. The reader will note that no wave “breaking” is shown. For this case

Surf Similarity Equal to 0.1

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  twfin=80.0,          ipdis=1,          gz=-9.81,
  itb=1,              pltdt=80.0,        prtdt=1000.0,
  epsadj=1.0,        avrck=-2.1,          nmat=1,
  ifvis=0,
  remark='dum1 is wave frequency',
  dum1=2.27,
  remark='dum2 is wave number',
  dum2=0.524,
  remark='dum3 is wave amplitude',
  dum3=0.5,
/
&limits
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/
&props
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  wr=2,
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/
&bf
/
&temp
/
&grafic
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  zv2(1)=8.0,
/
&parts
/
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Figure 2: Input File

the beach slope was very mild and the energy of the incoming waves was dissipated over a great distance (approximately 17 wavelengths). The resulting wave train appears very similar to the one shown in Figure 1, upper image.

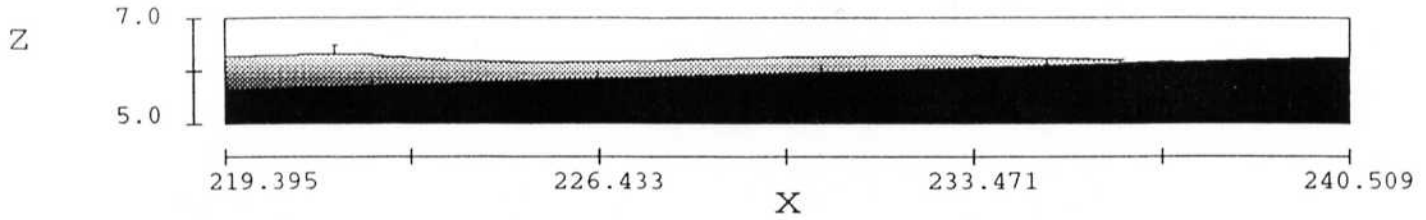


Figure 3: Waves Breaking on a Mild Slope

For $\zeta = 0.1$, very little energy is reflected from the beach and as a result the incident wave boundary condition performs quite well.

$\zeta = 3.0$

Figure 4 shows results for the case $\zeta = 3.0$ (note the similarity to the waves shown in Figure 1, lower image). The beach slope in this case is very steep. For this case the wave transformation occurs over a distance of less than 1 wavelength. As a result, the surf zone is almost nonexistent. For this simulation the specified velocity boundary condition did not perform adequately because of the great amount of wave energy which was reflected by the beach. The simulations were stopped after a short time to prevent unphysical interactions between the left and right boundaries from adversely affecting the solutions at the beach.

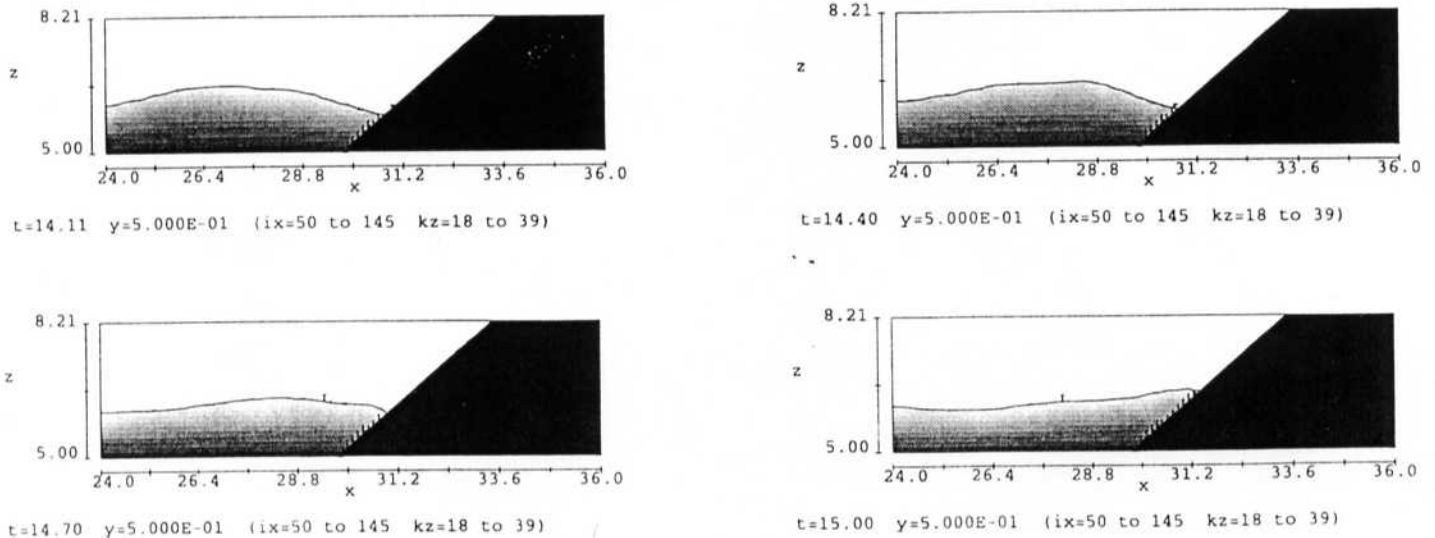


Figure 4: Waves Breaking on a Steep Beach

