CHAPTER 46

LABORATORY EXPERIMENTS ON THE INFLUENCE OF WIND ON NEARSHORE WAVE BREAKING

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ABSTRACT

The influence of wind on nearshore breaking waves was investigated in a laboratory wave tank. Breaker location, geometry, and type depended upon the wind acting on the wave as it broke. Onshore winds tended to cause waves to break earlier, in deeper water, and to spill: offshore winds tended to cause waves to break later, in shallower water, and to plunge. A change in wind direction from offshore to onshore increased the surf zone width by up to 100%. Wind's effect was greatest for waves which were near the transition between breaker types in the absence of wind. For onshore winds, it was observed that micro-scale breaking can initiate spilling breaking by providing a perturbation on the crest of the underlying wave as it shoals.

INTRODUCTION

The most common breaker types on the open ocean coast are spilling and plunging. Spilling breakers are characterized by white-water at the crest which tumbles down the wave face until the entire wave face is a wall of tumbling white water. Plunging breakers are characterized by an unbroken wave face which steepens until it is vertical and then continues to curl over to form a surfer's "tube" before it plunges down on the base of the

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wave face. Collapsing and surging waves, the other two breaker types, are more common on coastal structures and relatively steep beaches. These descriptive breaker types are subjective and the transition from one type to another is not always distinct.

It is well known that wave forces on structures can be extremely sensitive to breaker type. Plunging breakers can cause extremely high, short duration forces when a pocket of air is trapped between the wave face and the structure. It is also known that currents and sediment transport in the surf zone depend on breaker type and surf zone width. Breaker type has an effect on the wave height decay, energy decay, and turbulence across the surf zone, important factors in modeling surf zone dynamics.

Existing models of breaker type (Patrick & Wiegel, 1955; Galvin, 1968; Battjes, 1974) consider two independent dimensionless variables, the wave steepness and the beach slope. Battjes combines these variables in the surf similarity parameter and shows that nearshore breaker type and mechanics can be determined by ranges of the parameter.

There is little mention in the literature of the influence of wind on nearshore breaking waves. Three authors mention the effect in passing without agreement as to its importance. Walker (1974) states that offshore winds tend to cause breakers to plunge and that the optimum wind for surfing (surfers prefer plunging breakers) is a ten knot offshore wind. Walker reached this conclusion on the basis of his observations and a survey of recreational surfers. Kinsman (1965) mentions that an offshore wind is "conducive to the formation of plunging breakers," and that onshore winds contribute to producing spilling breakers. Kinsman goes on in jest that an offshore wind is a reason for graduate students at the University of Hawaii to cut class and go surfing. Peregrine (1983) states that wind effects on wave breaking are probably slight for moderate wind speeds. Neither Kinsman nor Peregrine discuss a basis for their statements.

Although the influence of wind on wave breaking has not been investigated and has rarely even been mentioned in the coastal engineering literature, it is well known by fishermen, surfers, lifeguards and others who spend much time in the surf. The first author has often observed an influence of wind on wave breaking along the southern New Jersey shore. The wind shift from a light land breeze to a sea breeze which occurs many summer days changes the breakers from plungers to spillers. A thunderstorm which quickly changes the wind direction from a sea breeze to a land breeze can dramatically change the breaker type from spilling to plunging within seconds.

This investigation was conducted to fill a gap in the knowledge about the effect of local wind on the nearshore, depth-limited breaking of individual waves. The primary objective was to qualitatively and quantitatively determine what effects winds have on breaking and to investigate the physical explanation of the phenomenon.

EXPERIMENTAL FACILITIES

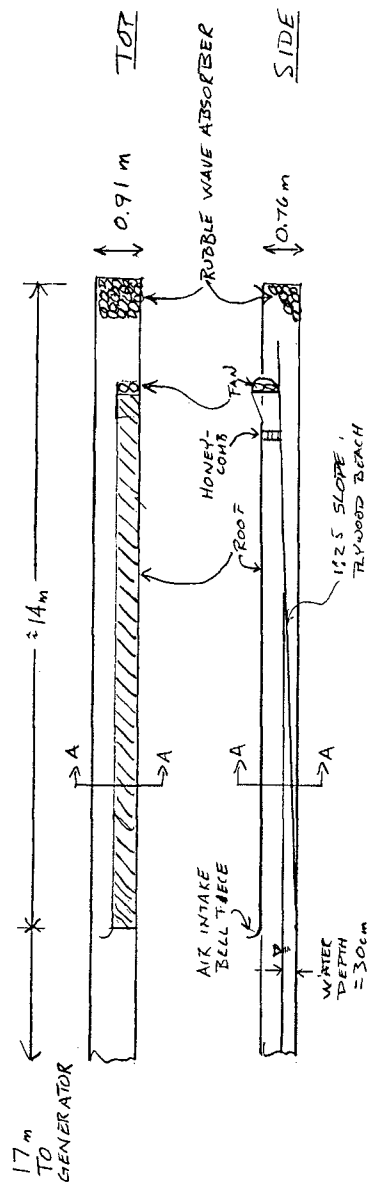
Experiments on the influence of wind on shoaling breakers were conducted in the glass wave tank at Drexel University. The tank is 35 m long, 0.76 m deep and 0.91 m wide. The tank has glass walls and a glass bottom with aluminum supports spaced every 1.52 m along its length. At one end of the tank is a piston-type wave generator capable of generating monochromatic waves.

A plywood beach and splitter wall were installed beginning 17 m from the wave generator. The splitter wall was located midway across the breadth of the tank and divided the tank into two sections (see Figure 1). On one side of the splitter wall, a rigid 1:25 sloping plywood beach was constructed. On the other side of the splitter wall were the two-by-four bracing for the beach and a wave-absorbing pile of rubble at the far end from the wavemaker. All the seams between the splitter wall and beach and beach and glass walls were sealed.

A plywood cover roof was constructed over the beach section of the flume and a variable-speed, bi-directional fan was installed on the upper end of the beach above the level of wave runup. All the seams in the roof section were sealed with duct tape. This arrangement allowed wind to be blown offshore or drawn onshore over the beach section. A honeycomb was placed in the airflow one meter from the fan. A bell-shaped mouth piece was constructed at the open end of the covered beach section to allow smooth entry of the onshore wind.

EXPERIMENTAL PROCEDURES

Video recording was the primary method of measuring the location of the water surface in the shoaling and breaking waves. A thin, black 2 cm x 2 cm grid on clear plexiglass sheets was attached to the front glass sidewall. During video recording, the room was darkened and the water was lit from below the waterline with lights clipped on the outside of the glass sidewall. This



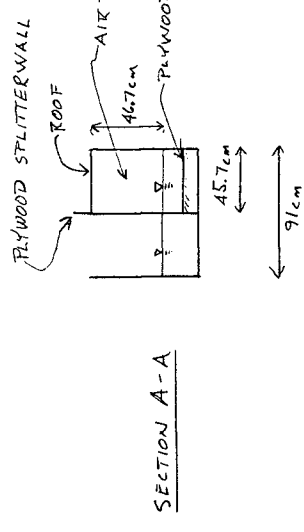


Figure 1. Wave tank schematic

avoided glare and reflection problems from the plexiglass and glass and allowed the water surface to be easily seen through the grid and against the white splitter wall. The recording was done with two goals in mind:

1) to measure the variation in water surface elevation in space at an instant in time (i.e. a snapshot of the water surface elevation),

2) to measure the variation of water surface elevation in time at a specific location along the beach (i.e. a wave gage).

The video tapes were viewed on a professional video editing system with stop-action, frame-by-frame advance, frame counting capability, and a high resolution video screen. Water surface elevation vs. time and elevation vs. distance information were manually viewed during data reduction.

Windspeeds were measured using a pitot tube and micro-manometer. The pitot tube was extended through the plywood cover roof down into the air duct above the beach section.

WAVE AND WIND CONDITIONS TESTED

The range of experimental conditions were selected to produce spilling breaker conditions and plunging breaker conditions when there was no wind. Three different wave conditions; designated S, I, and P; were selected. Wave "S" broke in a spilling manner in the absence of wind. Wave "I" (for Intermediate) was chosen to be as close to the limit between the two breaker types as possible. It was chosen by holding the piston stroke length constant and varying the motor speed until the breaker type switched. The stop action of the video showed that the breaker type varied across the wave tank. The front one-third of the wave (the third adjacent to the glass sidewall) was spilling but along the rest of the wave crest a small jet was visible. A slightly steeper wave spilled evenly across the entire beach and a slightly less steep wave plunged evenly across the entire beach. This cross-tank variation in breaker type was used as an indicator of the midpoint of the demarcation between breaker types. Wave "P" was of very low steepness and clearly plunged.

Wind direction was defined as follows: wind in the direction of wave propagation, i.e. a sea breeze, was called onshore wind; wind in the opposite direction of wave propagation, i.e. a land breeze, was called offshore

wind. The sign convention adopted was onshore winds positive and offshore winds negative.

Thirteen different sets of tests were run using the three wave conditions and the five wind conditions. The test conditions are summarized in Table 1. The low windspeeds were approximately of the same magnitude as the wave celerities. The high windspeeds were approximately twice the wave celerities. Wave steepnesses (H/L) and wave celerities are as calculated in the flat portion of the tank.

RESULTS

Breaker Type

Table 2 shows the changes in breaker type due to wind (S-spilling, P-plunging). Wind changed the breaker type for both waves "I" and "S". In the absence of wind, wave "I" was intermediate between spilling and plunging. With an onshore wind the breaker distinctly spilled. With an offshore wind the breaker distinctly plunged. Wave "S", which spilled in the absence of wind, plunged with an offshore wind. Wind did not effect the breaker type for wave "P" which was always plunging. Wind had little effect whatsoever on wave "P".

Breaker Location and Width of Surf Zone

The change in breaker location was one of the most visually obvious effects of wind on wave breaking. Breaking was defined as the moment the front face became vertical or started to entrain air. The change in surf zone width (defined as the horizontal distance from the breaker location to the intersection of the still water level and the beach) as a function of the ratio of wind velocity, U, to wave celerity, C, is shown in Figure 2. Acceleration due to gravity, g, and wave period, T, are used to non-dimensionalize the breaker depth, d. For wave "I", the surf zone width was 43% narrower with the high offshore wind than with no wind. The change in wind direction from high offshore to high onshore about doubled the surf zone width. For wave "S", the changes were not as large but were still significant. For wave "P", the change in breaker location was much smaller.

Breaker Height to Depth Ratio

The influence of wind on the breaker height to depth ratio is shown in Figure 3. Most of the influence of wind on breaker height to depth ratio is due to wind's effect on breaker depth (Figure 4). The effect of wind on

Table 1. Test Conditions

TEST CONDITIONS

WIND CONDITION	WAVE CONDITION "S" H/L = 0.025 SPILLING	"I" 0.019 SPILLING/ PLUNGING	"P" 0.004 PLUNGING
HIGH ONSHORE	▬	▬	▬
LOW ONSHORE	▬	▬	
NO WIND	▬	▬	▬
LOW OFFSHORE	▬	▬	
HIGH OFFSHORE	▬	▬	▬

Table 2. Change in breaker type due to wind.

INFLUENCE OF WIND ON BREAKER TYPE

WIND CONDITION	WAVE CONDITION "S"	"I"	"P"
HIGH ONSHORE	S	S	P
LOW ONSHORE	S	S	-
NO WIND	S	S/P	P
LOW OFFSHORE	P	P	-
HIGH OFFSHORE	P	P	P

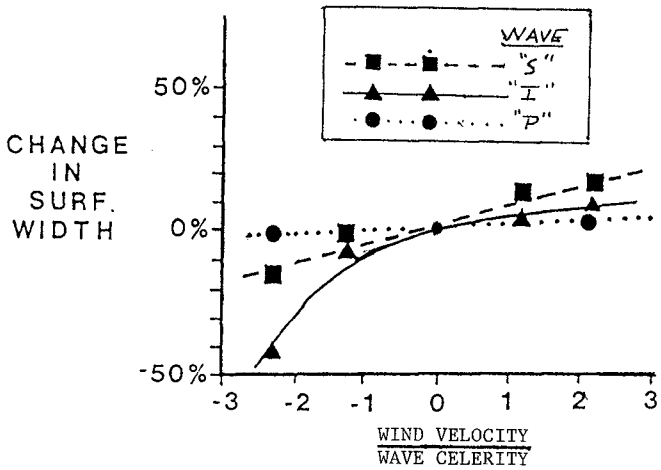


Figure 2. Effect of wind on surf zone width.

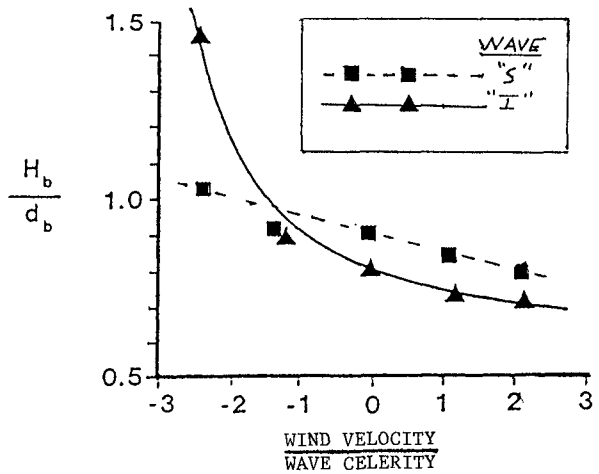


Figure 3. Effect of wind on breaker height to depth ratio.

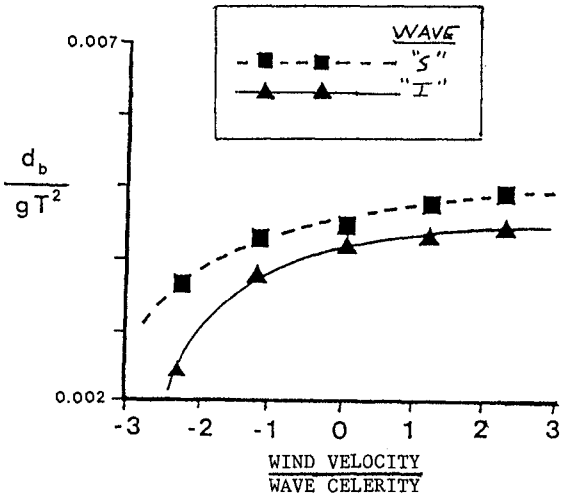


Figure 4. Effect of wind on breaker depth.

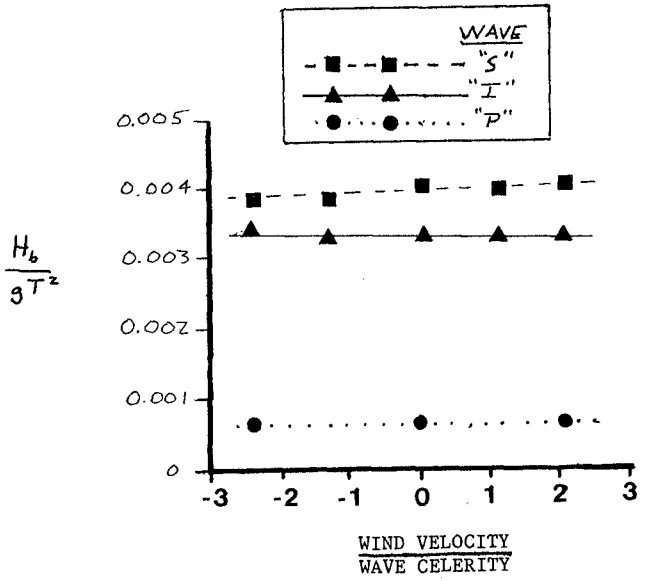


Figure 5. Effect of wind on breaker height.

breaker height (Figure 5) is only 5 to 10%. Height was defined as crest to trough height at the point of breaking. Depth was defined as the vertical distance from the still water level to the bottom. Set-down and wind's effect on set-down were found to be smaller than the experimental error introduced by the resolution of the video procedure.

The above results show that wind's influence on breaking was greatest for waves which were near the transition between breaker types in the absence of wind, waves "1" and "S". Wave "P" had such a low steepness it was closer to the transition to collapsing/surging than to the transition to spilling. It was barely effected by the wind.

DISCUSSION

The recent numerical studies of breaking waves using potential flow theories (see New, et al., 1985) supplemented by observations (Basco, 1985) have led to the concept that both plunging and spilling breaking are due to the same hydrodynamic instability. The difference between spilling and plunging waves is the size of the jet. This study does not contradict this concept but shows that the approach to such breaking may be physically unstable to perturbations such as wind shear.

The video recordings of the onshore wind tests for waves "S" and "1" showed that the spilling breakers were initiated by a micro-scale breaking wave. Micro-scale breaking waves occur on the crests of the underlying longer waves due to the shearing effect of the wind (Phillips, 1977). Most of these micro-scale breakers are short-lived but as the primary underlying wave shoals, eventually one of the micro-scale breakers is the instability which triggers spilling of the primary wave. Thus, it appears that the wind effect is enough to trigger the initiation of breaking for waves which are approaching but not yet at the point of breaking in the absence of wind. Spilling breaking occured farther offshore as the onshore wind speed was increased.

The mechanisms responsible for the influence of an offshore wind on breaking waves appear to be a reduction in shoaling combined with surface wind drag and perhaps wind pressure differences. Wind drag prevents small instabilities from tumbling forward down the wave face. Once a jet begins to form, the shear layer is probably of little importance since it is thin compared with the thickness of the jet. By that point, the water surface is vertical on the front face and the distribution of

pressure due to the wind can play a more significant role. It was found that the offshore wind effectively retarded the last stages of wave shoaling. This explains the waves propagating farther inshore before breaking. The reduced wave height at a specific location on the beach may be due to interactions between the offshore-propagating, wind-driven ripples and the primary wave. The reduced wave height implies a lower steepness which would tend toward a plunging breaker for a fixed beach slope.

SUMMARY

Laboratory studies show that breaker location, type, and geometry depend critically upon the wind acting on the wave as it breaks. Onshore winds tend to cause waves to break earlier, in deeper water, and to spill. Offshore winds tend to cause waves to break later, in shallower water and to plunge.

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