

# CREST-BREAKING TIME-LAPSE APPROACH FOR MEASURING BREAKER ANGLE

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**ABSTRACT:** Estimation of breaker angle in a littoral environmental observation (LEO) program is still based on a visual method and therefore is subjective. Breaker angles thus measured generally vary from person to person. In the absence of a sophisticated wave-direction recording instrument, a simple and practical method has been evolved based on the time lapse between the wave breaking progressively at two points along the crest parallel to the shoreline. This method removes to a greater extent the subjectivity in observation, thereby making it a more reliable practical procedure. The method can be readily adopted for field observation by coastal engineers.

## INTRODUCTION

The littoral environmental observation (LEO) program includes observations on breaking wave height, wave period, breaker angle, type of breaker, surf-zone width, longshore current velocity and direction, beach slope, and so on. Most of these data are meant to evaluate the sediment transport rates in the surf zone for any incident wave characteristics. Accuracy in the measurement of breaker angle is very important (as is the case for breaker height and period), and it is a primary factor influencing the estimation of longshore sediment-transport rate. The breaker angle is the most sensitive variable in determining the longshore current velocity (Galvin 1991). Basco (1983), Galvin (1987), Komar (1975), and Kraus and Sasaki (1979) identified the importance of the breaker angle in the study of the dynamics of the surf zone. In a sophisticated nearshore measurement program, the breaker height, period and breaker angle are measured using a directional wave gage, which involves high initial financial investment. Nevertheless, it is common in most of the regular LEO programs to visually observe the breaker height, period, and breaker angle. Visually observed breaker angle is subject to significant variation due to the human factor involved. Three persons were asked to stand at the same location on Karwar beach on the west coast of India and observe independently the breaker angle every day at a given time for a period of three months, from July 1989 through September 1989. The deviation in their observations is presented in Fig. 1. The standard deviation of the visually reported breaker angles between the observers 1 and 2 is 2.6°, between the observers 2 and 3 is 2.2°, and between the observers 3 and 1 is 2.5°. The inconsistency among the individual reporters indicates the nondependability of such visual estimates of the breaker angle. This paper describes a procedure to estimate the breaker angle using the time lapse between wave crest breaking progressively from one point to another along the coastline parallel to the shore.

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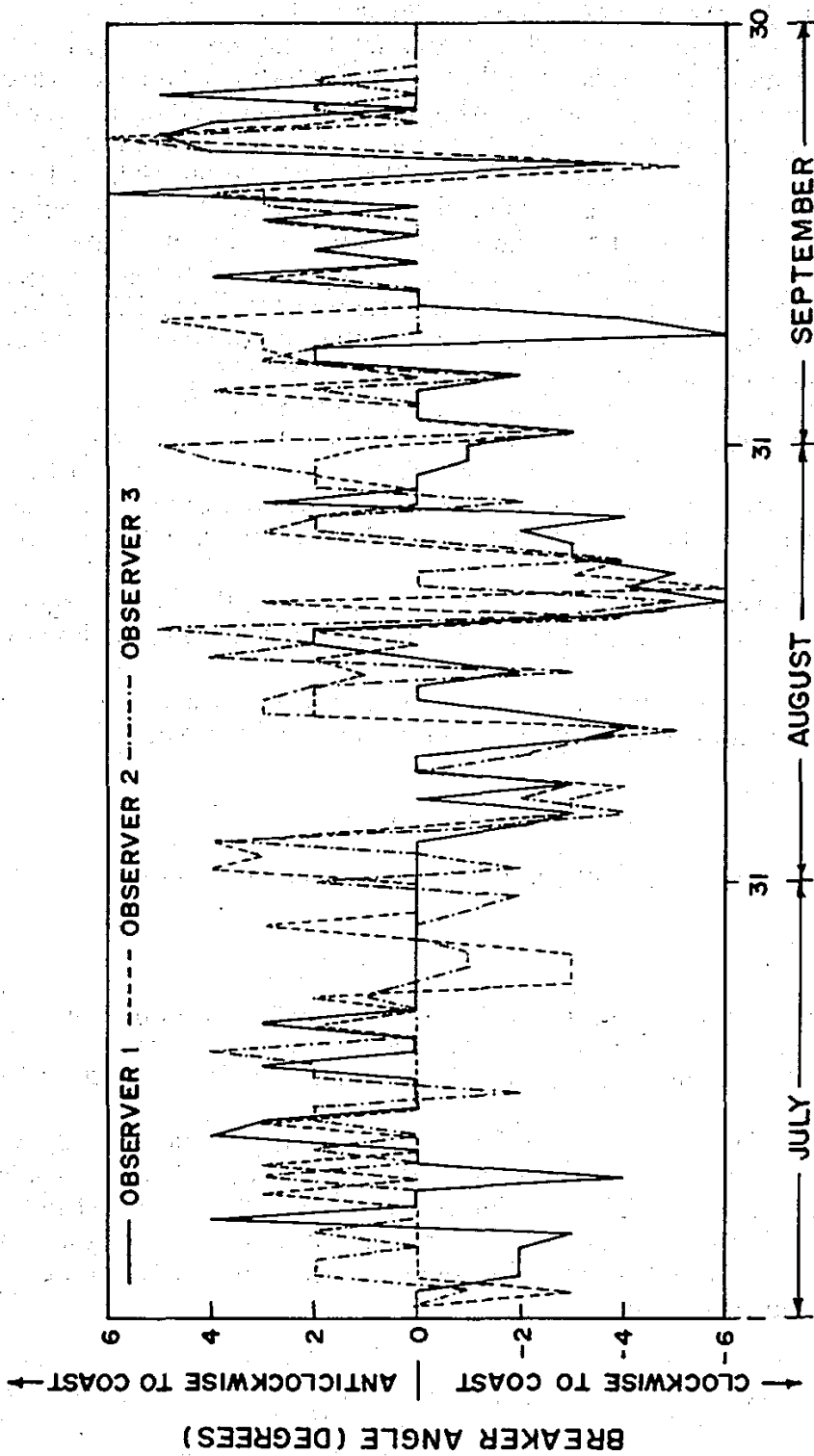


FIG. 1. Variation of Breaker Angle Reported by Three Observers

## PRINCIPLE

Waves approaching parallel to the coast break along the crest simultaneously; waves approaching obliquely break progressively along the crest parallel to the shoreline. Accordingly, there is a time lapse for an oblique wave to break between two points on the shoreline.

Consider a segment of beach approximately 250 m long. Within such a short reach in the field, it is possible to assume that: (1) The waves are two-dimensional, i.e., there is no variation of wave height along the crest; and (2) the depth contours in the breaker zone are parallel to the coast.

Fix an observation point O on the backshore, about 200 m from the waterline (Fig. 2). Keeping a magnetic compass at O, fix two ranging rods K and E such that the line of sight OKE is perpendicular to the waterline AB. Let E be close to the waterline and K approximately halfway between points O and E. Fix another set of two ranging rods L and F, such that the line of sight OLF makes an angle of  $45^\circ$  to the line of sight OKE. Let F be close to the waterline and L almost in the middle of OF.

Assume that the waves are approaching the shore from the left of an observer standing on the beach facing the sea. The observer has to stand at O and view along the line of sight OKE. Note time  $t$ , when the wave breaks along the line of sight OKE at C at depth  $d_b$ . Simultaneously note by visual observation, the breaker height ( $H_b$ ) and the breaker distance ( $w$ ) from the waterline.

Now the observer has to immediately view along the line of sight OLF, and note the time  $t + \Delta t$ , for the same wave to break along the line of sight OLF at D.

Using the shallow-water approximation for the wave celerity ( $c_b = \sqrt{gd_b}$ ) and the approximate expression for depth of breaking ( $d_b = 1.28H_b$ ) (Shore 1984), then

$$c_b = 3.544\sqrt{H_b} \quad (1)$$

where  $H_b$  = breaker height (in m); and  $g$  = acceleration due to gravity (in  $m/s^2$ ). In Fig. 2

$$OC = b = s + w \quad (2)$$

where  $b$  = distance between the observer and first breaking point (OC);  $s$  = distance between the observer and waterline; and  $w$  = perpendicular distance between the waterline and first breaking point (i.e., the width of surf zone).

Since the triangle OCD form an isosceles right triangle (Fig. 2),  $CD = OC = b$ . CG was the orientation of the wave crest when the wave was initially breaking at C. The crest at G traveled a distance of GD in time  $\Delta t$  before breaking at D. Assuming the refraction of wave orthogonal within the short reach of GD is negligibly small, the triangle GCD can be treated as right triangle. Hence

$$GD = C_b \Delta t \quad (3)$$

Using (1) in (3),  $GD = 3.544\sqrt{H_b}\Delta t$ , and, hence

$$\angle GCD = \alpha_b = \sin^{-1}\left(\frac{3.544\sqrt{H_b}\Delta t}{b}\right) \quad (4)$$

Hence, knowing the breaker height, the sum of width of surf zone and the distance of observation point from waterline, and time lapse between

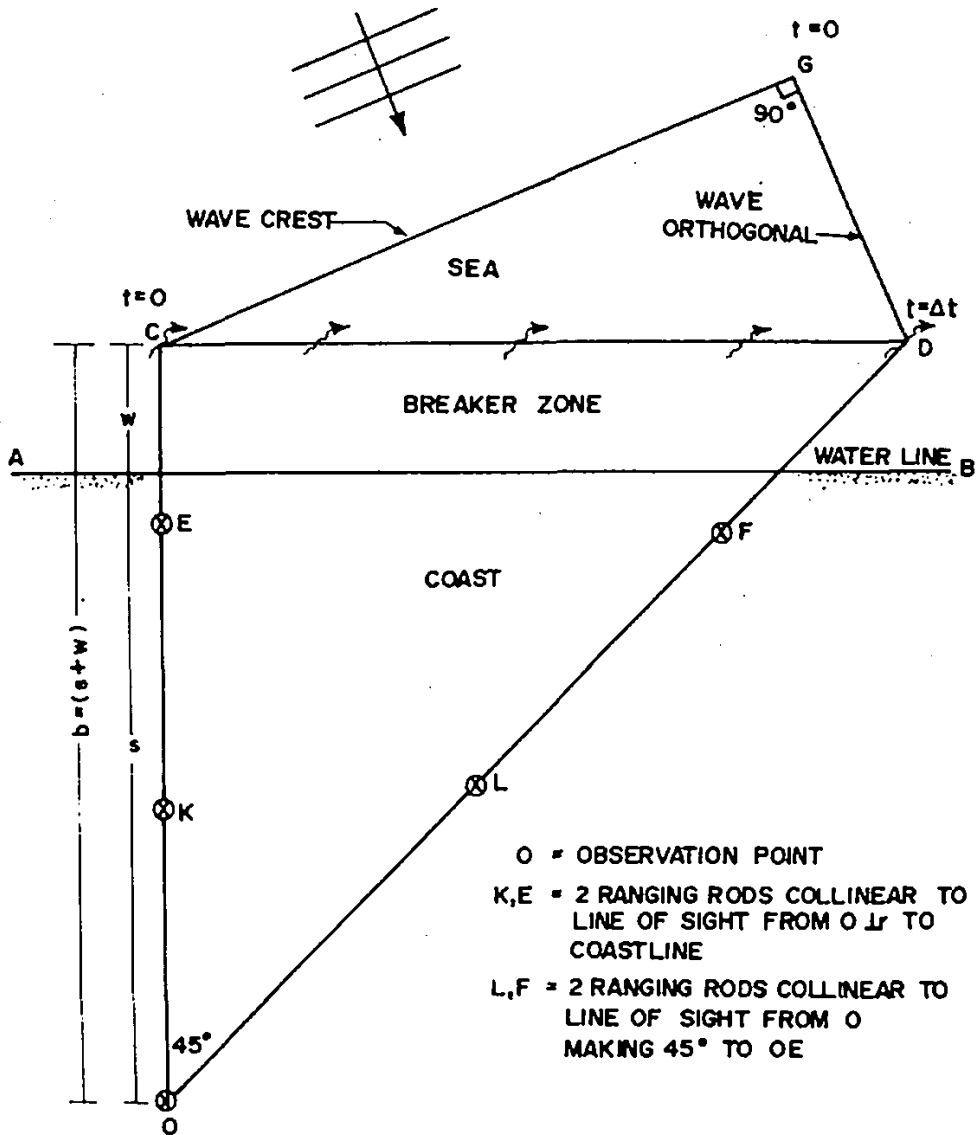


FIG. 2. Definition Sketch

the wave breaking at two locations along the shore, the breaker angle can be estimated using (4).

For the waves approaching from the right-hand side for an observer standing on the beach and facing the sea, the same procedure can be adopted, but taking the  $45^\circ$  line of sight OLF counter clockwise to the line of sight OKE.

## FIELD TEST

A 4-km-long segment of beach at Karwar, on the west coast of India, was selected for the field test. The beach was straight and open, and the offshore contours were almost parallel. A directional wave rider buoy was deployed at a water depth of 16 m, and the significant wave height, zero crossing wave period, and wave direction corresponding to peak energy were measured for a 20-min duration daily from Nov. 1 to Nov. 30, 1991. The spectral information of the measured waves represented that the waves were narrowband on some days and broadband over the rest of the days.

**TABLE 1. Measurement of Breaker Angles by Various Methods**

Date (November 1991) (1)	Buoy			Visual $\alpha_b$ (degrees) (5)	Time lapse $\alpha_b$ (degrees) (6)
	$H_r^a$ (m) (2)	$T_r^b$ (s) (3)	$\alpha_b^c$ (degrees) (4)		
1	0.7	6.3	4.5	4	4.1
2	0.7	7.2	4.2	3	3.9
3	0.6	6.2	7.5	6	4.5
4	0.5	6.9	4.5	4	4
5	0.5	6.5	5.1	3	4.2
6	0.6	5.9	6.2	3	5.1
7	0.6	6.2	5.7	2	5
8	0.7	6.1	3.5	2	4.1
9	0.6	5.4	4.2	5	3.7
10	0.6	5.9	4.7	3	5.2
11	0.5	5.7	5.4	3	4.4
12	0.5	4.5	6.2	5	4.7
13	0.4	4.6	7.4	4	8
14	0.4	4.2	7.6	5	6.1
15	0.6	4	6.2	4	4.7
16	0.4	5.6	5.3	6	4.3
17	0.4	5.4	5.8	5	5
18	0.6	3.6	8.2	6	7.4
19	0.5	4	9	6	7.1
20	0.5	5	4	13	6.7
21	0.4	5	7.3	6	6
22	0.4	3.7	10.1	8	12.2
23	0.4	3.4	5.8	4	4.6
24	0.4	3.3	4.5	5	4
25	0.5	3.8	6.7	5	5.1
26	0.4	3.4	8.2	6	6.9
27	0.4	3.4	8.8	8	7.1
28	0.4	4.7	8.9	6	6.5
29	0.4	5.5	6.9	10	6.1
30	0.5	6.7	2.7	8	5.3

<sup>a</sup>Significant wave height.

<sup>b</sup>Zero crossing wave period.

<sup>c</sup>Breaker angle.

Assuming the contours to be straight and parallel, the wave directions measured at the 16-m water depth were corrected for refraction effects using Snell's law (*Shore* 1984), and the breaker angles were calculated. The results are presented in Table 1. Visual observations on the breaker angles were simultaneously made every day at the same time and the values are presented in Table 1. Observations of breaker height, surf-zone width, and time lapse of wave breaking between two points along the crest were noted for 20 min daily at the same time during the same 30-day period. The average breaker angle for the 20-min duration, estimated using (4), is presented in Table 1.

Breaker angles obtained by the time-lapse method indicated the same trend as those measured by the wave-rider buoy and the visual method. The values estimated by the time-lapse method were slightly lower than the

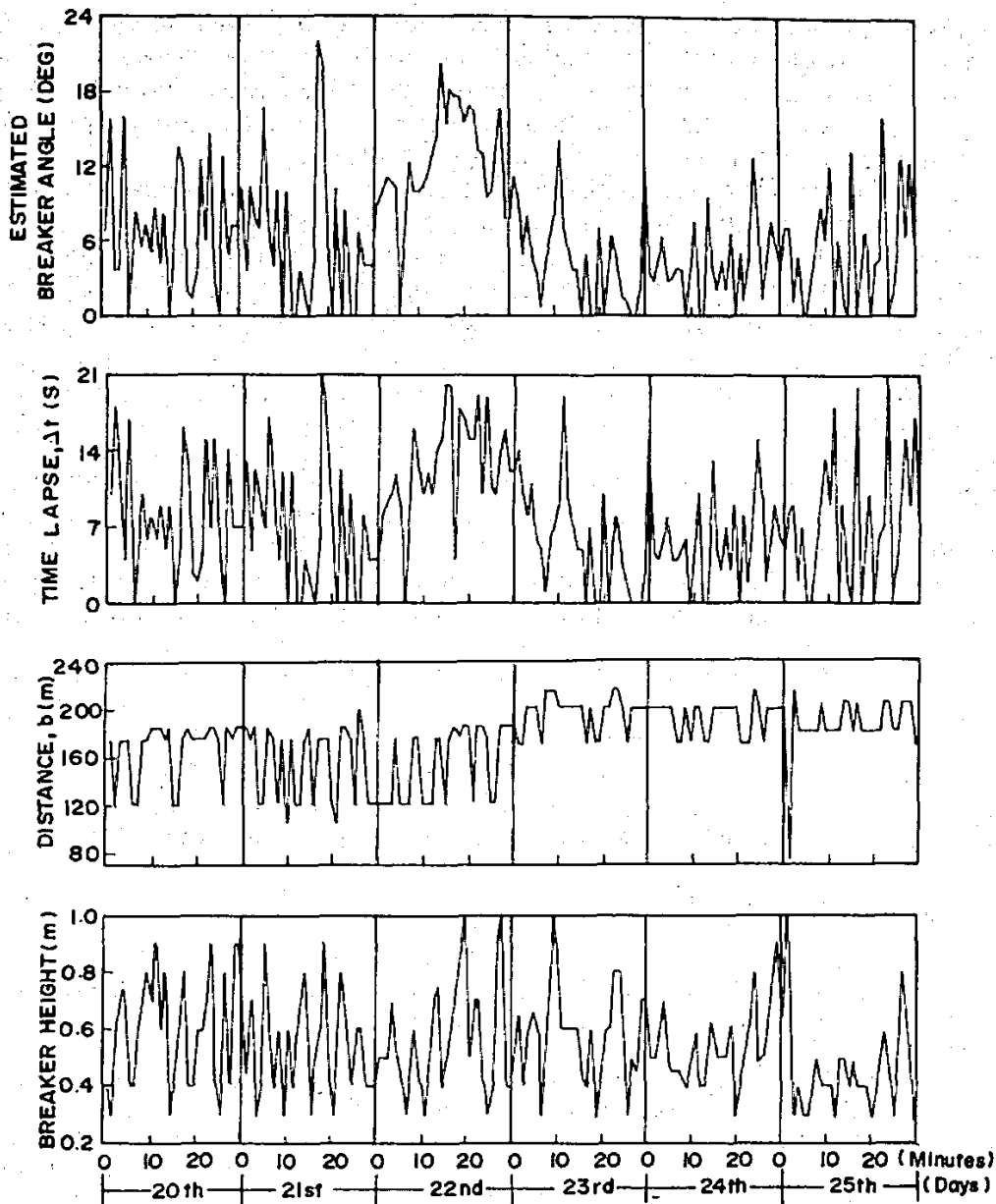


FIG. 3. Estimated Breaker Angle Using Time-Lapse Method

values obtained by the wave-rider buoy. The standard deviation of the 30 days results between the time-lapse method and wave rider buoy was  $1.3^\circ$ . The breaker angle obtained by the time lapse method was slightly higher than the visually measured values. The standard deviation of the 30 days' results between the time lapse method and the visual estimate was  $2.2^\circ$ . The standard deviation of the 30 days' results between the wave rider buoy and the visual estimate was  $2.7^\circ$ .

The reliability of each method with the true value is again a question of discussion. It is most likely that the instrumentally measured direction is the correct one, but in the present case it was measured at 16 m depth, and the correction for the refraction effect was applied theoretically to estimate breaker angle. This may introduce some error due to the assumption of parallel contours and the estimation of celerity based on linear wave theory in very shallow water. In the visual observations, measurement of breaker

angles with a variation of a couple of degrees is a difficult task even to an experienced oceanographer. Visual data would therefore be more subjective in nature and might differ observation to observation. The estimated breaker angles based on time-lapse method, however, do not deviate very much from the results obtained from the wave-rider buoy.

The variation of breaker angles obtained based on the time-lapse method, carried out for 30 min duration each day covering about 30–40 breakers, from Nov. 20 to Nov. 25, 1991, is presented in Fig. 3. It indicates that this method can satisfactorily be used to measure the variation in the angle of the approaching waves rather than the single observation noted in the visual method.

## CONCLUSIONS

The crest-breaking time-lapse method gives a simple reliable average value of breaker angle in the absence of instrumental methods. As the waves are not really unidirectional, the variation in the breaker angle for a required duration can satisfactorily be estimated using the crest-breaking time-lapse method. The principle yields good results for single train of long crested waves.

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## APPENDIX. REFERENCES

- Basco, D. R. (1983). "Surfzone currents." *Coastal Engrg.*, 7(4), 331–335.
- Galvin, C. (1987). "The continuity equation for longshore current velocity with breaker angle adjusted for a wave-current interaction." *Coastal Engrg.*, 11(2), 115–129.
- Galvin, C. (1991). "Longshore currents in two laboratory studies: relevance to theory." *J. Wtrwy., Port, Coast., and Oc. Engrg.*, ASCE, 117(1), 44–59.
- Komar, P. D. (1975). "Nearshore currents: Generation by obliquely incident waves and longshore variations in breaker height." *Nearshore sediment dynamics and sedimentations*, J. R. Hails and A. P. Carr, eds., John Wiley and Sons, London, England, 17–45.
- Kraus, N. C., and Sasaki, T. O. (1979). "Effects of wave angle and lateral mixing on the longshore current." *Coastal Engrg. Japan*, 22, 59–74.
- Shore protection manual*. (1984). U.S. Army Coastal Engineering Research Center, Department of the Army, Corps of Engineers, Washington, D.C.