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## Technical note

# The wave vane — a device to measure the breaker angle

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## ABSTRACT

Estimation of the breaker angle in the littoral environmental observation (LEO) programme is still based on visual methods and therefore is subjective in nature. In the absence of a wave direction recording instrument, a simple device called the wave vane as described here has been developed to measure the breaking wave angle. The changes in the horizontal component of the orbital velocity under a progressive wave govern the operation of the wave vane. The wave vane consists of a pair of fins, one responding to the velocity in the direction of wave propagation below the wave crest, and the other to the velocity in the direction opposite to wave propagation below the wave trough. This results in wave vane orienting itself in the direction of the wave orthogonal. The performance of the wave vane was evaluated using the instrumentally recorded wave directional data as well as the visually observed data. The wave vane was found to give the wave directional information fairly accurate for the open coast where the influence of tidal currents was negligible.

## INTRODUCTION

The usual littoral environmental observation (LEO) programme mainly consists of observations on the breaking wave height, the wave period, the breaker angle, type of breaker, breaking zone width, longshore current velocity and direction, nearshore slope etc. The LEO data are generally used to evaluate the sediment transport rates in the surf zone for given incident wave characteristics. Accuracy in the measurement of breaker angle is equally important like the breaker height and period, as it is one of the primary factors which influence the estimation of longshore sediment transport rate. The breaker angle is the most sensitive variable in determining the longshore cur-

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rent velocity (Galvin, 1991). Basco (1983), Galvin (1987), Komar (1975), and Kraus and Sasaki (1979) have indicated the importance of the breaker angle in the study of the surf zone dynamics. In a sophisticated nearshore measurement programme, the breaker height, period and breaker angle are measured using directional wave gauge at a considerable cost. For economic and practical considerations, visual measurements on the breaker height, the breaker period and the breaker angle are generally made in the LEO programme. The breaker height is recorded as the average height of 10 consecutive breaking wave heights and the wave period as the average period of ten consecutive waves. The breaker angle is visually observed and therefore subjected to significant variation due to human factors involved. It is realised that though the breaker height can be estimated fairly accurate by visual means after some training, it would be difficult to maintain the desirable degree of accuracy. This paper presents the design of a simple device called "wave vane", which can easily be fabricated and used to measure the breaker angle.

## ERROR IN VISUAL ESTIMATION

Three trained persons were asked to stand at the same location on the Karwar beach on the west coast of India, and observe independently the breaker angle every day at a given time for a period of 3 months from July 1989 to September 1989. The deviation in their observations is presented in Fig. 1. Considerable inconsistency was observed among the individual reporters and the difference in their values of breaker angle was found to be very significant. This illustrates how difficult it would be to depend on the visual estimate of the breaker angles.

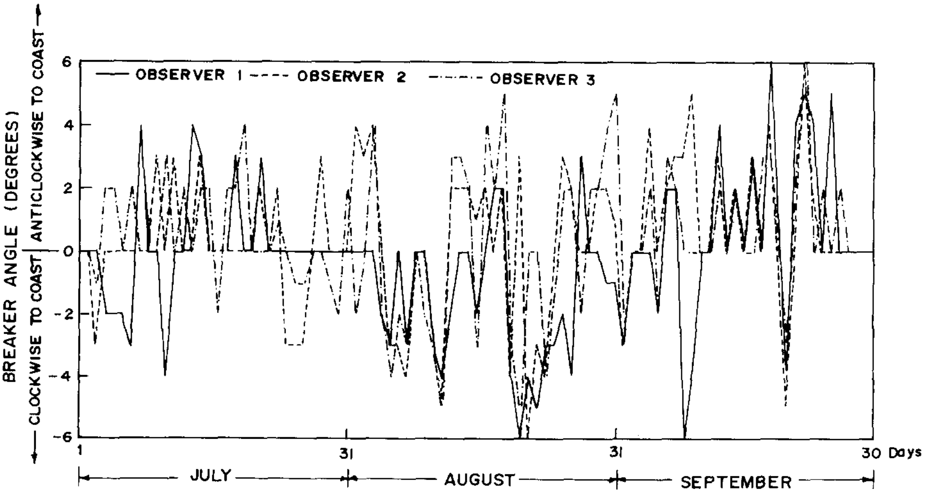

Fig. 1. Variation of breaker angle reported by three observers.

## WAVE VANE DESIGN

The kinematics of the fluid particles just before wave breaking is governed by wave characteristics. Wind and tide induced currents may also influence the fluid particle motion to some extent. A device intended to measure the wave direction should not be influenced by the wind or the tide induced currents. The wave vane presented herein, is so designed that it responds to the orbital particle motions caused by the propagating oscillatory waves of the ocean. The diagram showing the wave vane is presented in Fig. 2. It consists of three parts viz. (i) the base, (ii) the vertical spindle, and (iii) the revolving arm. The wave vane with recommended dimensions of various components are shown in Figs. 2 and 3. These dimensions can be modified depending upon the local conditions.

The base, consisting of the four-legged frame fabricated in G.I. pipe and

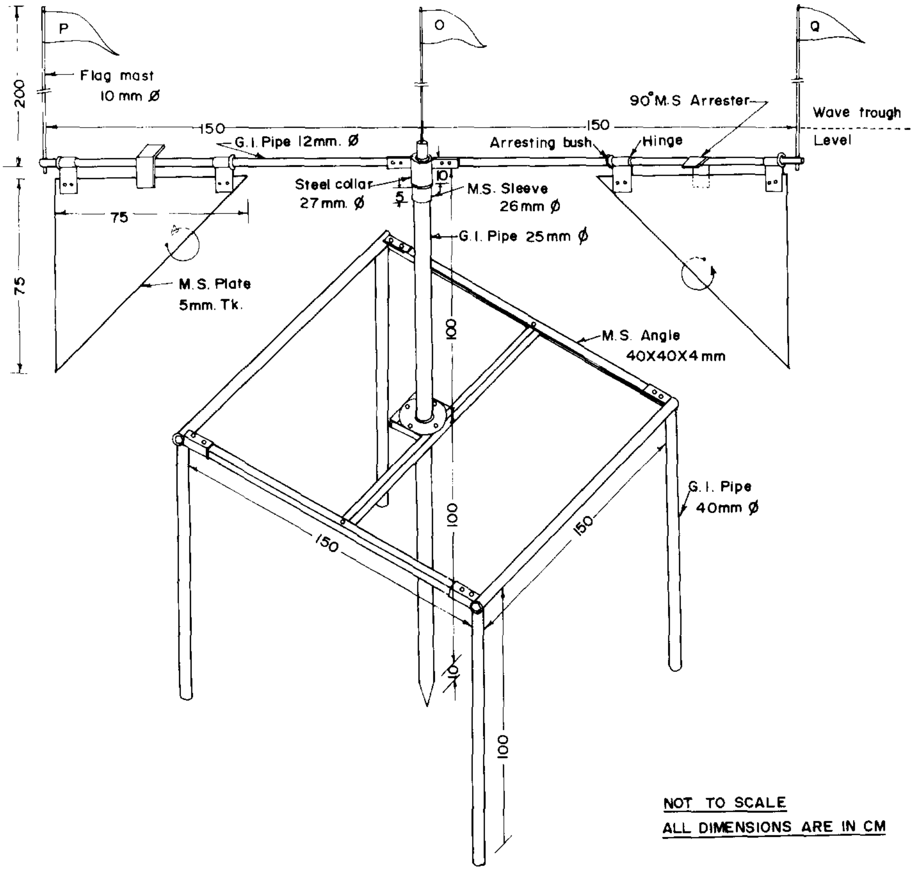

Fig. 2. Schematic diagram of wave vane.

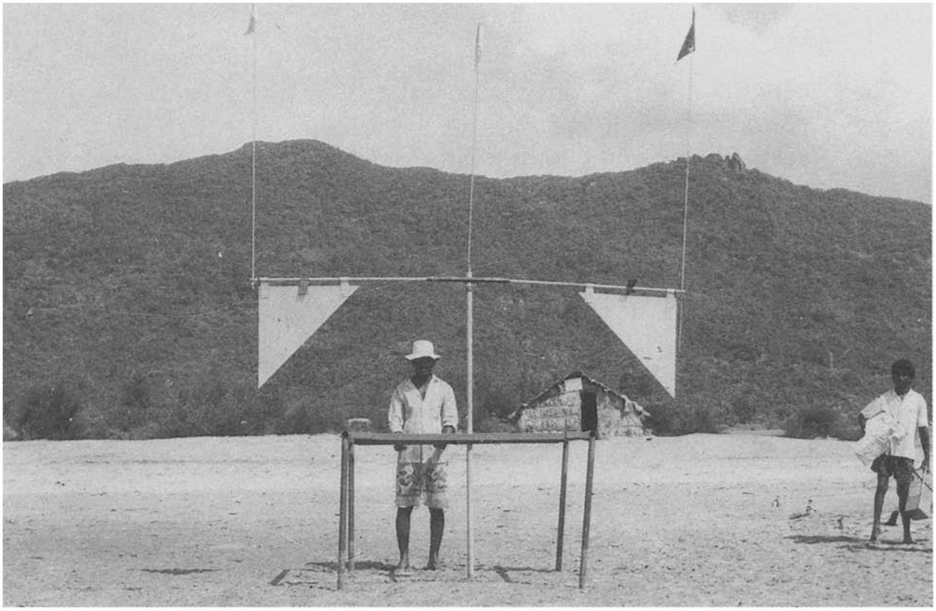

Fig. 3. Wave vane.

M.S. angles as shown in Fig. 2, acts as the support for the wave vane assembly to stand erect on the sea bed. The vertical spindle, made of G.I. pipe, is mounted on the base frame with a 10 cm projection under the base. A circular M.S. sleeve is welded at the top of the spindle and a flag mast is inserted. A rotating steel collar is inserted in the vertical spindle and made to rest on the M.S. sleeve. Two arms of G.I. pipes are fixed on either side of the steel collar. Triangular M.S. plates are hinged to the arms. Two L-shaped M.S. arresters are attached to the revolving arms, one on the front side of the first fin and the other on the rear side of the second fin. This arrester configuration would allow one fin to rotate 90° clockwise while the other fin can rotate 90° anticlockwise. There are two arresting bushes in each arm to avoid the horizontal movement of the fins. Flag masts are fixed on either end of the arms. The whole assembly thus revolves around the spindle resting on the sleeve.

## WORKING PRINCIPLE

The flag masts, two on the revolving arms and one on the top of the spindle lie always in a straight line. The wave vane assembly is installed on the sea bed just beyond the breaker zone, ensuring that the fins always remain submerged below the water surface.

When the wave crest passes over the wave vane, it exerts a force on the two fins and pushes them in the direction of wave propagation. Due to the arresters fixed on alternate side, while one fin swings upwards, the other fin obstructed by the arrester would rotate the arm. During the passage of the trough, the force is exerted in the opposite direction, pushing the first fin to rotate the arm and the second fin to swing up. Thus, when the wave propagates, the leading fin facing the approaching wave always responds to the wave trough and the rear fin always responds to the wave crest, thereby the revolving arm aligning itself in the direction of the wave propagation. Once the arm orients itself to this position, the wave forces acting on each of the fins becomes negligible, and the alignment of the three flag masts coincides with the direction of the wave orthogonal. The swinging of the fins in opposite direction due to waves, reduces the influence of wind and tide induced currents which may exist in the breaker zone.

## PROCEDURE

Establish a base line AB on the beach, parallel to the waterline as shown in Fig. 4 with marking at 1 m intervals. Install the wave vane at location O, just beyond the breaker zone, along the line of sight from A set at right angle to AB. Compute the distance OA by taking a transect using a theodolite centered at D on AB. Once the wave vane is installed, the arm POQ would orient to the incoming wave orthogonal. Mark the point C, where the line of sight of three flag masts, POQ, intersects the base line AB.

In the right angled triangle OAC, knowing the distances AC and AO, the

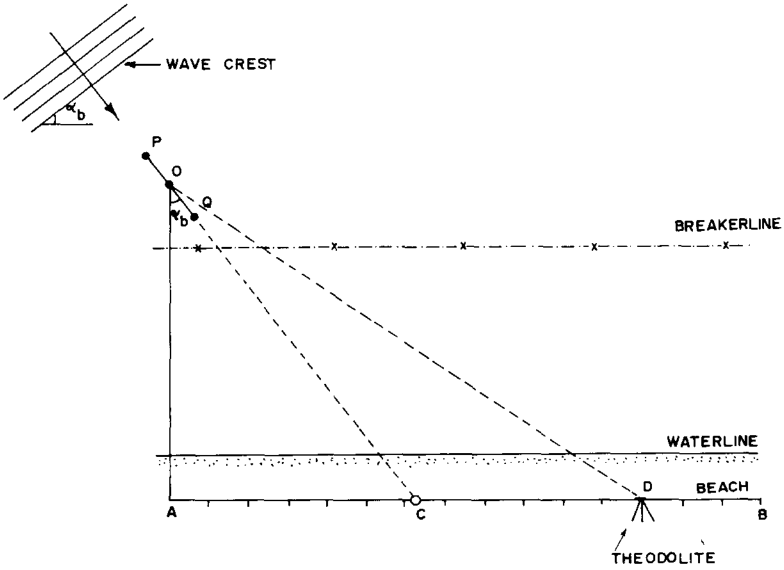

Fig. 4. Definition sketch.

angle AOC can be calculated, which would be the wave breaker angle with respect to the coastline. It is assumed that the angle made by the crestline with the shoreline at the wave vane is equal to the breaker angle as the wave vane is installed very close to breaker zone. Repeating the procedure, the breaker angles for a required duration can be estimated.

## FIELD TEST

A 4 km long beach near Karwar on the west coast of India was selected for the field experiments. The beach was straight and open, and the offshore contours were almost parallel. The wave vane was installed just beyond the breaker zone for 15 days in November–December, 1991 as indicated in Table 1. Observations on breaker angles were made for 20 minutes duration every day. The average breaker angle computed based on the 20 minute observation is presented in Table 1.

A directional wave rider buoy was deployed at 16 m water depth, and the measurement on significant wave height, zero crossing wave period and wave direction corresponding to peak energy were measured for 20 minutes duration for the above period of 15 days in November–December 1991. Assuming the contours to be straight and parallel, the wave directions measured at 16 m water depth were corrected for refraction effects using Snell's law (Shore

TABLE 1

Measurement of breaker angles by various methods

| Date | Buoy | | | Visual | Wave vane |
|---|---|---|---|---|---|
| | $H_s$ (m) | $T_z$ (s) | $\alpha_b$ (°) | $\alpha_b$ (°) | $\alpha_b$ (°) |
| 20.11.91 | 0.5 | 5 | 7.5 | 13 | 11.3 |
| 24.11.91 | 0.4 | 4.3 | 7.5 | 6 | 8.3 |
| 11.12.91 | 0.4 | 4.9 | 7.7 | 5 | 8.7 |
| 13.12.91 | 0.6 | 5.2 | 6.5 | 4 | 3.1 |
| 16.12.91 | 0.5 | 4.8 | 3 | 6 | 4 |
| 17.12.91 | 0.5 | 4 | 4.4 | 5 | 5.2 |
| 19.12.91 | 0.5 | 4.7 | 6.1 | 7 | 8.5 |
| 20.12.91 | 0.6 | 6.1 | 4.4 | 6 | 7.1 |
| 21.12.91 | 0.8 | 4.7 | 7.7 | 8 | 8.5 |
| 22.12.91 | 0.9 | 4.4 | 9.6 | 6 | 9 |
| 23.12.91 | 0.6 | 5.2 | 7.1 | 7 | 9.2 |
| 24.12.91 | 0.6 | 5 | 3.6 | 5 | 5.7 |
| 26.12.91 | 0.8 | 5.5 | 8.5 | 4 | 10.2 |
| 27.12.91 | 1.0 | 5.4 | 16.6 | 4 | 12.1 |
| 28.12.91 | 0.8 | 4.9 | 6.4 | 3 | 7.8 |

$H_s$ = significant wave height; $T_z$ = zero crossing wave period; $\alpha_b$ = breaker angle.

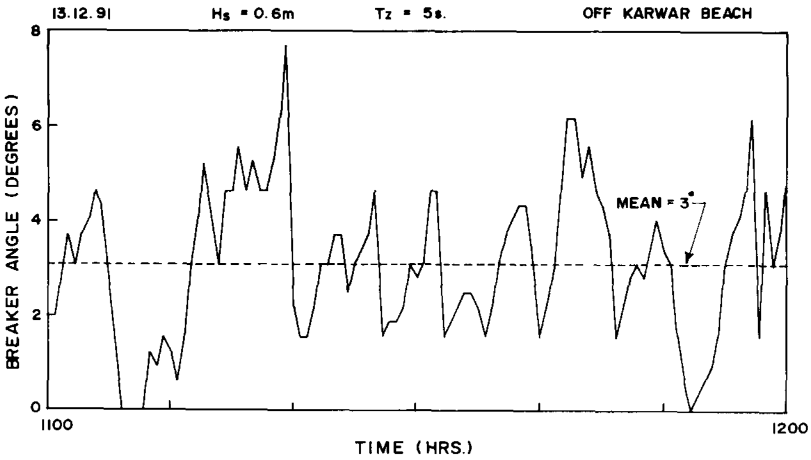

Fig. 5. Variation of breaker angles measured using wave vane.

Protection Manual, 1984), and the breaker angles were estimated. The results are presented in Table 1. Visual observations on the breaker angle were also carried out for the above period; the values are also presented in Table 1.

Breaker angles measured using the wave vane indicated the same trend as those measured by the wave rider buoy and the visual method. The values estimated by the wave vane were found to be slightly higher than the values obtained by the directional wave rider buoy. The standard deviation of the 15 days results between the wave vane and wave rider buoy was 2.1°. The breaker angles measured using the wave vane were also higher than the visually measured values. The standard deviation of the 15 days results between the wave vane and the visual estimate was 2.8°.

The reliability of each method for giving the true value is again a subject of discussion. Of course, the instrumentally measured direction should be the correct one. However, in the present case the values were measured at 16 m depth and the correction for the refraction effect was applied theoretically to estimate the breaker angle. This may introduce some error due to the assumption of parallel contours and the estimation of celerity based on the linear wave theory in very shallow water. The standard deviation of the 15 days results between the wave rider buoy and the visual estimate was 4.1°. In visual observations, measurement of the breaker angle when the variation is small, would be an extremely difficult task even to an experienced oceanographer. Visual data would therefore be more subjective in nature and might differ from observation to observation.

The estimated breaker angles using the wave vane, however, do not seem to deviate very much when compared to the data obtained from the directional wave rider buoy.

When the waves approach in a group with different wave periods, they break with different angles to the coastline. It would be convenient to estimate such variation in the breaker angles using a wave vane. The variation of breaker angles measured by means of the wave vane for 60 minutes duration on 13.12.91 is presented in Fig. 5. The breaker angles varied between 0° and 7.5°. The average of the breaker angles observed over 60 minutes is estimated as 3°. This infers that the wave vane can conveniently be used to measure the variation in the angle of the approaching waves during the period of observation.

## DISCUSSION AND CONCLUSION

The wave vane is a simple and convenient device to measure wave breaker angles in the field for practical applications. The variation in breaker angles during a given length of time can also be measured using the wave vane. The method involved is very simple and can easily be adopted by coastal engineers in the field. The dimensions of the wave vane presented here were determined based on field trials and is useful for the typical wave climate on the west coast of India. They can conveniently be altered to suit local requirements. For example, for higher waves, the height of the vertical spindle and the size of the base may have to be increased. The wave vane was tested at Karwar, where the maximum tidal currents as recorded were within 10 cm/s close to the breaker zone. The performance evaluation of the wave vane should be carried out on a coast having strong tidal currents in the vicinity of the breaker zone. The possible sources of error that may arise in the use of wave vane can be summarised as: (i) time-lag in the response of the revolving arm of the wave vane when there is a large variation between consecutive breaker angles, (ii) likelihood of overtopping due to very high waves, and (iii) the human error in fixing the land mark while aligning the three flags of the arms. The first two factors would cause a gap in the data during the observation period and the third factor would affect the accuracy of the measured angle.

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