

# Wave Measurement in Severe Ocean Currents

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The measurement of ocean waves has been of particular interest, as wave data and understanding of wave phenomena are essential to ocean engineering, coastal engineering and to many marine operations. The National Institute of Oceanography, Goa, has undertaken a wave measurement programme using Datawell waverider buoys at four locations in the northern part of the west coast of India and at one location in the mouth of the river Godavari in the east coast where high current speeds varying from 2 knots to 5 knots are observed. As a consequence of prevailing high currents, significant drag forces have been experienced by the buoys and their mooring system causing occasional submergence. The paper highlights some of the mooring systems and the components adopted in an attempt to reduce the drag forces. A successful technique adopted for replacing waverider buoys using the original mooring system for attaching buoys in the high flow areas of the Gulf of Cambay has been discussed.

## NOTATION

- $\rho$  = mass density of sea water,  $\text{kg s}^{-2} \text{m}^{-4}$   
 $A$  = projected area,  $\text{m}^2$   
 $C_D$  = coefficient of normal drag  
 $\theta$  = angle between the mooring line and horizontal  
 $DF$  = drag force  
 $V$  = average current speed

## INTRODUCTION

Deployment and operation of Datawell Waverider buoys in high flow areas of coastal waters need special consideration in the selection of various mooring assemblies and their handling. Strong currents increase drag forces acting on various mooring components like rubber cord, mooring rope and the buoys. The standard mooring recommended by the manufacturers wherein a rubber cord attached immediately below 70-cm waverider buoy can be used in waters where current speeds do not exceed 2 knots. For current speeds between 2.5 to 3.5 knots, the manufacturers recommend that the rubber cord should be attached near the bottom anchor so that low bottom currents may considerably reduce the drag force on the rubber cord. The 90-cm waverider buoys giving high buoyancy is recommended for use when surface currents exceed 2 to 3 knots.

The National Institute of Oceanography (NIO), Goa, undertook wave measurement programmes at four locations in the north-west coast of India (Fig 1) where high flow conditions exist and at another location in the Godavari basin where high currents were observed particularly during the high flood discharge from the river. In the gulf areas of the Gujarat coast, drifting fishing nets were abundantly used by local fishermen while in the Godavari basin trawler operations were predominant. The large scale fishing activities in waverider locations posed

several problems concerning safe operation of the buoys. A locally available mechanized boat of length 12 m to 16 m say, a trawler having a derrick boom and a winch of about 2 t capacity was selected for handling waverider buoys.

## WAVERIDER MOORING

In the waverider mooring<sup>1</sup>, introduction of an elastic element like a rubber cord and the use of mooring rope of optimum thickness helps to reduce the effective drag on the mooring line and enhances the free floating ability of the waverider buoy. The U-type waverider mooring (Fig 2) was adopted when the rubber cord was positioned near the anchor end and I-type (Fig 3) was used when the rubber cord was positioned near the waverider end. The drag force  $DF$  acting on the mooring line in a water flow velocity of  $V$  m/s and its vertical and horizontal components are shown in Fig 4.

The Morrison's equation for drag force can be written as

$$DF = 1/2 (\rho AV^2 \sin^2 \theta)$$

and the vertical component as

$$V_{DF} = DF \cos \theta$$

Vertical downward load,  $V_{DF}$ , acting on the mooring line causes submergence of the waverider buoy. Three different mooring configurations as shown in Fig 5 were selected for comparison of  $V_{DF}$  acting on the mooring line. Computed values of  $V_{DF}$  are presented in Table 1. It shows that the drag force reduces by about 4 to 6 kgf when the value of angle  $\theta$  is changed from  $45^\circ$  to  $30^\circ$ .

Assumptions: (i) Average current speed,  $V$ , from the sea surface to a depth of 22 m was observed as 1.25 m/s and that below up to the bottom was observed as 0.85 m/s.

TABLE 1 COMPUTED VALUES OF  $V_{DF}$

Mooring component for which Drag force is computed (Fig 5)	$V_{DF}$ = Vertical component of drag force, kgf	
	$\theta = 30^\circ$	$\theta = 45^\circ$
Waverider mooring upto the sub-surface buoy	18.51	24.82
Rubber cord at top	22.04	28.81
Rubber cord at bottom	18.17	22.37

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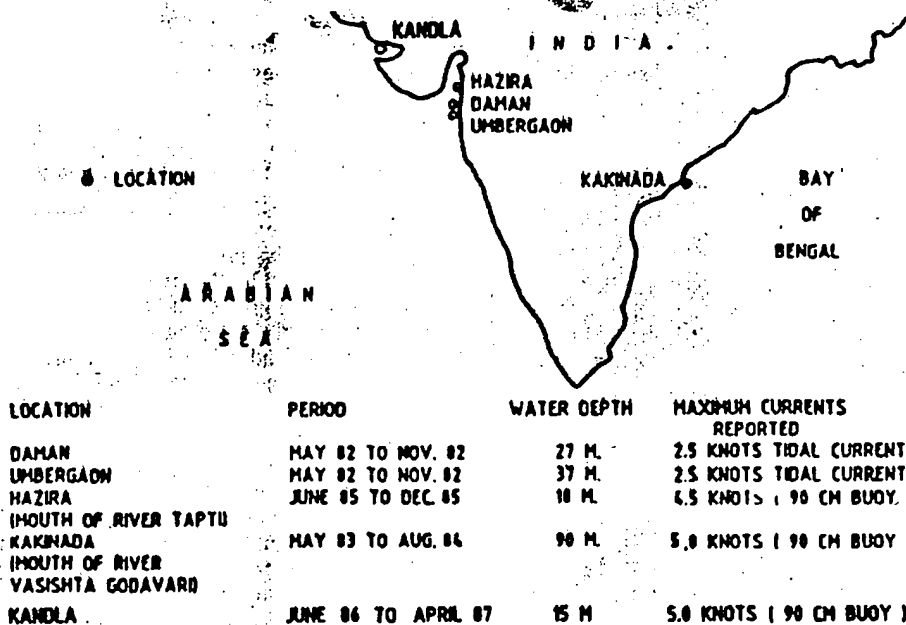


Fig 1 Location map of wave data collection

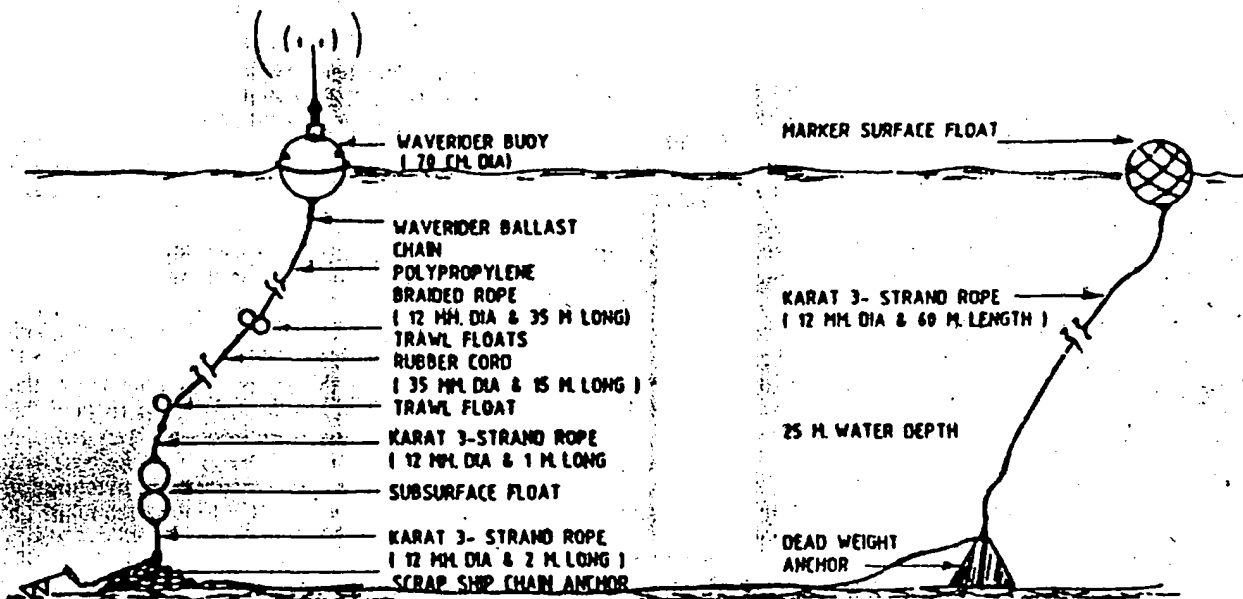


Fig 2 U-mooring-Rubber cord at bottom end

(ii) Coefficient of normal drag,  $C_D$ , for rubber cords and synthetic ropes is 1.2, assuming them to be smooth cylinders<sup>2</sup>.

(iii) Rubber cord diameter, diameter,  $d = 0.035$  m, length,  $L = 15$  m.

(iv) Synthetic rope diameter,  $d = 0.012$  m.

(v) Drag force acting on submerged part of the waverider

is not considered as it is the same for all the cases used for comparison.

Datawell waverider buoys of 70-cm or 90-cm diameter were used depending upon the currents prevailing at the location. The 90-cm diameter buoy was deployed in the Godavari basin where surface currents of the order of even 5 knots were observed during the south-west monsoon. A 90-cm diameter buoy was deployed off Hazira where

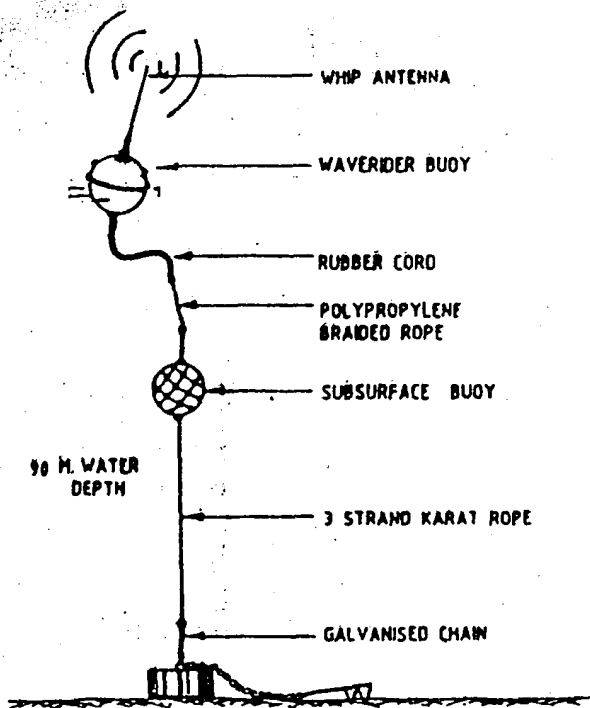


Fig 3 Mooring

dominant tidal currents of the same order were observed throughout the year. The 70-cm wave riders buoys were used off Daman and Umbergaon as 90-cm buoys were not available.

The rubber cord and three-strand karat rope attached to the waverider buoy form the sinking component of the mooring system. The critical drag area  $C_D A$  of the rubber cord is about 2.5 times greater than that of the fully submerged waverider buoy ( $C_D A$  for waverider =  $0.26 \text{ m}^2$  and  $C_D A$  for rubber cord =  $0.63 \text{ m}^2$ ). From Table 4, it can be seen that shifting of the rubber cord nearer to the bottom anchor reduces the vertical component of the drag force by about 6 kgf when the mooring line makes an angle of  $45^\circ$  with the horizontal.

Initially, the 70-cm diameter waverider buoys deployed off Daman, Umbergaon and Kakinada were found to submerge during the spring tide (Fig 6) when current speeds exceeding 2 to 2.5 knots were observed.

Shifting of the rubber cord close to the bottom anchor enhanced the free floating ability of the waverider buoy and satisfactory wave data could be recorded at all the sea conditions. The U-type mooring (Fig 2) was adopted at these locations for ensuring recovery of the rubber cord and the waverider buoy. Besides the buoy, the sub-surface float used below the turbulent wave zone and a piece of braided polypropylene rope used in the slack part of mooring line form the floating components of the mooring (Fig 2 and 3). By connecting a suitable sub-surface buoy in the mooring (Fig 3) below wave noise

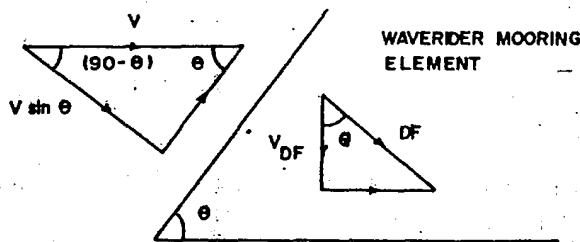


Fig 4 Drag force on mooring line

zone the total effective length of the mooring rope responsible for causing vertical downward load on the waverider buoy was significantly reduced. Thus, it enabled the waverider buoy to be deployed in greater depths and to float freely during high current periods. Table 1 shows that the use of subsurface buoy in the mooring line reduces  $V_{DF}$  by about 4 kgf when the rubber cord is positioned at the top.

While the 70-cm diameter waverider buoy was operational off Kakinada during non-monsoon period, lots of sea weed and plants carried by the river flow got entangled with the mooring line and growth of barnacles (Fig 7) was also observed. As a result, the drag force exerted on the rope was rather heavy leading to frequent submergence of buoy. When the mooring line was cleared of seaweeds and plants, free floating of the waverider buoy was ensured.

MS scrap ship chain links were used as dead weight anchor at the bottom. The sea bed at Daman, Umbergaon Hazira and Kandla is silty and has a smooth slope. hence, use of auxiliary embedment anchor along with ship chains was resorted to prevent drifting of the mooring system due to strong currents prevailing in these locations.

Anchor last method was adopted for the waverider buoy deployment. During deployment or retrieval operation, utmost care was taken to see that no sharp edges of the boat rub against the mooring line including the rubber cord as scratches caused by the sharp edges might prove to be dangerous to the mooring line which is under tension due to the action of strong currents and waves.

#### MEASURES FOR SAFETY OF WAVERIDER BUOY

At waverider buoy locations off Daman and Umbergaon, fishing with large drifting nets and trawlers was intensive. Hence, in order to prevent vandalism or theft of the buoy, a watchboat was anchored in the vicinity (Fig 8).

The 90-cm diameter buoy deployed off Hazira developed pitting on its hull. It was decided to operate the same buoy after applying protective painting. The buoy was operated successfully from June to December 1985 with periodic checking at about two month-intervals and repainting of the hull as and when found necessary. During these operations, it was necessary to retrieve the buoy. A surface marker buoy was used at the location so that the same mooring could be used for the waverider buoy after inspection and repainting.

During retrieval operation, a boat anchor with adequate holding power was dropped little away from the waverider buoy. By positioning the stern facing the buoy, the anchor rope was manually controlled so as to take the boat astern within 5 m to 10 m from the buoy. During changing of buoys, careful manoeuvring of the boat was necessary to prevent excessive tension and stretching of the rubber cord. A slip line was tied to the loop made on the waverider buoy [Fig 9(a)] and it was pulled towards the boat. The rubber fenders mounted on the stern of the boat protected the buoy against possible damage by hitting or rubbing against the boat hull. Care was taken to avoid spinning of the buoy. After removing the whip antenna, the waverider buoy was hauled up on the boat deck using the derrick boom and winch [Fig 9(b)]. Then the rubber cord was unshackled and connected to the large marker buoy kept ready on the deck. As an additional safety measure a fairly long polypropylene rope was tied on the upper detached end of the rubber cord and the other free end of the rope was tied to the tie-down on the boat [Fig 9(c)]. After this surface marker buoy was connected to the rubber cord terminal and dropped carefully in the sea. The detached waverider

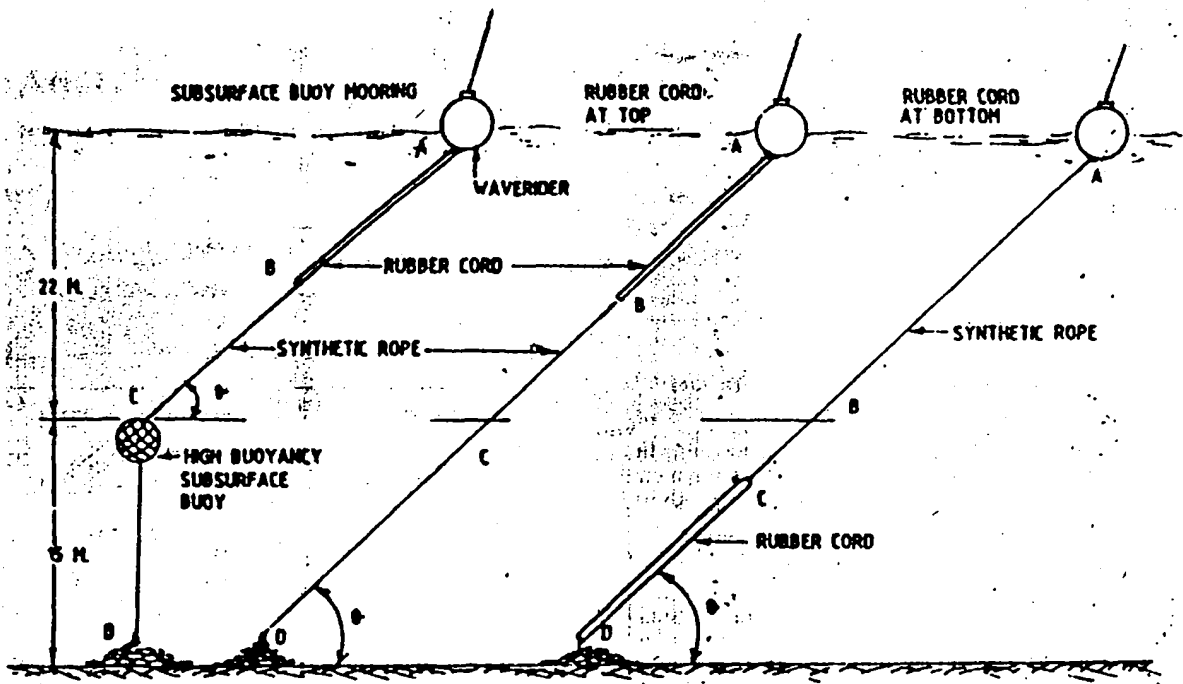


Fig 5 Typical waverider moorings considered for computations of drag force

buoy could thus be taken to the shore for inspection, repairs and repainting of the hull. Later the same waverider buoy was redeployed by replacing the surface marker buoy.

### DISCUSSIONS AND CONCLUSIONS

The success of wave data measurement using waverider buoys in high flow coastal waters depends upon the free floating ability of waverider buoys under all weather conditions. Based on the experiences gained during wave measurement programmes at NIO, the following conclusions are made.

By the introduction of the rubber cord at the anchor end, the 70cm waverider buoy could be operated even in rough sea conditions with current speeds up to 2 knots. When the buoy has to be operated over extended period of time, monitoring of the mooring line, sub-surface buoy and waverider buoy against marine growth, etc is essential, as it tends to increase the drag force on the waverider buoy. Use of a sub-surface buoy, particularly in deeper waters, would be essential to reduce the drag

and downward pull on the waverider buoy.

When the waverider buoy is to be operated over an extended period of time, it can be detached from the mooring line after attaching a surface marker buoy to it. The detached waverider buoy can be inspected for batter-

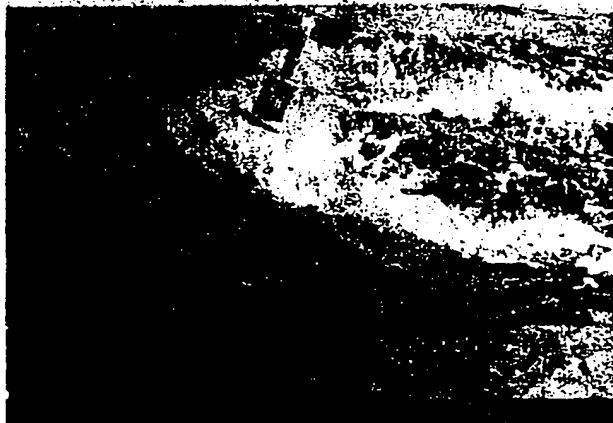


Fig 6 Submergence of waverider buoy off Kakinada

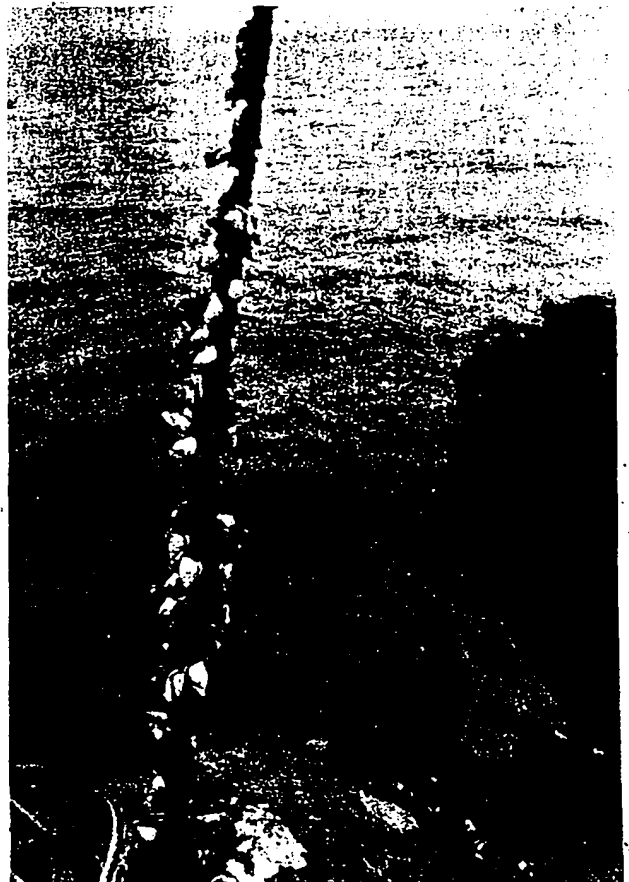


Fig 7 Growth of barnacles on mooring rope

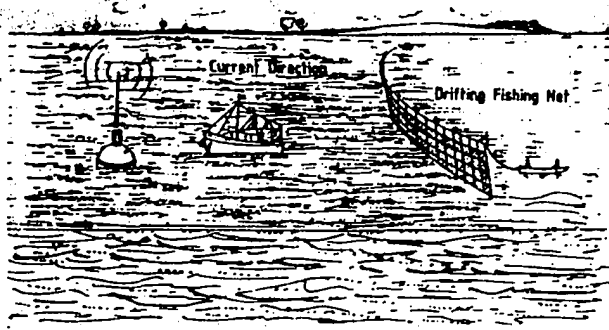


Fig 8 Safeguarding waverider buoy against fishing activities

ies or faulty electronics, etc before attaching it to the same mooring line. If proper care in choosing the mooring hardware is taken during initial deployment, the same mooring line can be used for repeated short-term deployment of the waverider buoy.

#### ACKNOWLEDGMENTS

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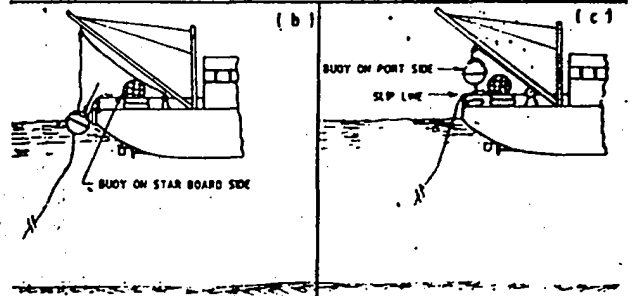
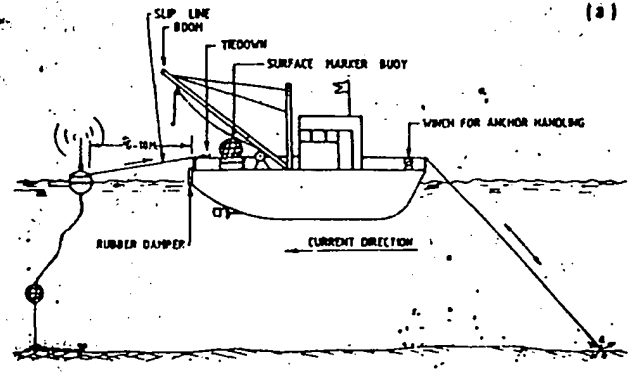


Fig 9 Retrieval of waverider buoy for checking

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