



WAVE MEASUREMENTS OFF THE BOMBAY COAST

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ABSTRACT

A wave rider buoy was installed at about 75 m depth of water at Bombay High. The WAREP Mark II receiver/recorder system was installed on one of the platforms of the Oil and Natural Gas Commission. Twenty minute continuous wave records were obtained on the chart paper at 3-hourly intervals. The wave records were analysed using Tucker's method to determine the significant wave heights, zero crossing periods and various other parameters. In this paper a brief description of the wave measuring system used, its mooring and the problems faced during the measurement programme are presented. The method of analysis of the wave data, variation of the daily highest significant and maximum wave heights, joint distribution of significant wave heights and zero crossing periods, frequency distribution of the wave parameters, cumulative distribution of wave heights and their use in the offshore operations are presented and discussed.

INTRODUCTION

A Datawell wave rider buoy was installed by the National Institute of Oceanography at the Bombay High for collecting continuous data on waves (Fig. 1). Such an installation was necessary as long-term wave data were required for optimum designs and operations in offshore areas. During the last few years, the operational activities at the Bombay High region have become quite intense and the supply vessels keep plying from the shore to the platforms very frequently. In spite of all possible precautions during the installation and operation of the buoy, it was hit by some passing boat with the result that its moorings were broken and the buoy became free and was finally lost. Because of this unfortunate mishap, the wave data could not be collected beyond the limited period during which the buoy was operational.

However, in view of the fact that no long-term instrumental data on waves are available from the offshore deeper waters in

India, it was considered desirable to make the best use of the data at hand. This paper gives some of the information on wave parameters which could be used during the offshore design and operations.

WAVE RIDER BUOY SYSTEM

The Data well wave rider buoy consists of a strong spherical steel buoy 0.7 m in diameter designed to float on the sea surface, a 2 m antenna mounted on the top of the buoy and a mooring arrangement to maintain the buoy at a given station at sea. As the sea surface rises and falls, the wave rider rises and falls along with it. Such motion results in vertical acceleration of the buoy. It is this quantity that is sensed within the buoy housing by a stabilized accelerometer suspended in a plastic sphere placed at the bottom, inside the buoy. The buoy or the water displacement history can then be obtained by twice integrating the acceleration history through an electronic circuitry. The internal workings of the buoy housing are

such that the effects of horizontal acceleration are minimized with the horizontal sensitivity reportedly less than 3 per cent of the vertical. The wave rider has been designed to transmit the information it measures to shore station or to an offshore station upto a distance of 50 km via an FM signal. The receiving unit provides for recording of this FM signal on a strip chart recorder.

The mooring system used for anchoring the buoy at Bombay High consisted of a rubber cord 15 m long, a nylon covered steel wire rope of 50 m length, braided polypropylene rope 100 m in length and an anchor weighing about 500 kg. This is illustrated in Fig. 2.

The receiver part consists of a WAREP Mark II recording system with a programmable strip chart recorder which can switch on the unit at a given interval of time and start recording the data for a desired duration. For the Bombay High wave data collection programme, the recorder was set to operate at 3 hour intervals and a 20 minute continuous wave record was obtained on the chart paper each time.

INSTALLATION AND MEASUREMENT

The wave rider buoy was first installed at a water depth of about 75 m located about 1 km west of platform 'C' on 19th May, 1978 (Figs. 1 and 2). The WAREP Mark II recorder was installed on the oil tanker, Jawaharlal Nehru. The system worked well until 3rd June 1978 on which day the wave rider buoy was found drifting near platform 'E' after it was broken loose from the mooring. The buoy was recovered by the help of a supply boat and brought back to Bombay Harbour. Inspection of the buoy and the remaining connectors indicated that the buoy was broken loose from its mooring due to an accident involving a supply boat. As there was not much of a damage to the buoy, it was re-calibrated and kept ready for re-installation. Due to the onset of the south-west monsoon, the buoy could not be re-installed immediately.

The buoy was re-installed on 6th November, 1978 at a water depth of about 75 m located about 1 km west of platform F. The receiver

was installed on the platform F. Till early January, 1979, the system was functioning well and later again it was broken loose and the buoy was finally lost probably due to another accident involving a supply boat.

ANALYSIS

Data Preparation:

The wave records were analysed using Ticker's method to arrive at significant wave height H_s and zero crossing period T_z . This method, in brief, consists of measuring highest crest 'A', second highest crest 'B' lowest trough 'C' and the second lowest trough 'D'. From these quantities the wave heights $H_1 = A + C$ and $H_2 = B + D$ are determined. Number of zero up-crossings N_z are read whenever the wave train crosses the mean water line in the upward direction (Fig. 3).

The quantities H_1 , H_2 and N_z are then substituted in the following statistically derived equations to obtain the root mean square wave height:

$$H_{rms_1} = H_1/2(2 \ln N_z)^{-1/2} [1 + 0.289(\ln N_z)^{-1} - 0.247(\ln N_z)^{-2}]^{-1} \dots \dots \dots 1$$

$$H_{rms_2} = H_2/2(2 \ln N_z)^{-1/2} [1 - 0.211(\ln N_z)^{-1} - 0.103(\ln N_z)^{-2}]^{-1} \dots \dots \dots 2$$

$$H_{s_1} = 4 H_{rms_1} \dots \dots \dots 3$$

$$\text{and } H_{s_2} = 4 H_{rms_2} \dots \dots \dots 4$$

The highest of the values from Eqns. (3) and (4) was taken for the significant wave height. Maximum wave height H_{max} and the period associated with it T_{max} are directly read from each 20 minute record. The spectral width parameter is computed using the number of zero up-crossings N_z and the number of crests N_c in the wave record as:

$$\epsilon = \sqrt{1 - (N_z/N_c)^2} \dots \dots \dots 5$$

Data Analysis:

Daily variation of wave heights:

Figs 4 and 5 show the variation of daily highest significant wave height H_s for the study periods, 19th May to 3rd June 1978 and

6th November to 29th December 1978. It can be seen that during May 78, the significant wave height H_s ranged from 1.25 m to 1.75 m. In the beginning of June 1978, it increased to 2 m. During November, H_s value was found to be as high as 2.8 m, but for a short duration of one day only. Figs. 6 and 7 show the variation of daily highest maximum wave height H_{max} for the periods, 19th May to 3rd June 1978 and 6th November to 29th December 1978 respectively. During May and the beginning of June, H_{max} was found to fluctuate between 2 m and 3 m.

Joint distribution of H_s and T_z :

Joint distribution of H_s and T_z is presented in Figs. 8a and 8b. The waves in the study period, 19th May to 3rd June 1978 appear to be less steeper compared to those recorded during the period, 6th November to 29th December, 1978. One important observation that could be made from Fig. 8b is that there is a good correlation between wave heights and periods.

Frequency distributions:

In Figs. 9a to 9d and 10a to 10d, frequency distribution diagrams of daily highest significant wave height, H_s , daily highest maximum wave height H_{max} , zero-crossing period, T_z and spectral width parameter, ϵ are presented. They show the percentage occurrence of each of these wave parameters in different class intervals.

Cumulative distribution of wave heights:

Fig. 11 shows cumulative distribution of significant wave heights H_s and the maximum wave height H_{max} for the study period. From this, the percentage of time for which H_s or H_{max} exceeded a given wave height can be determined. For example, the maximum wave height H_{max} exceeded 2 m for 80% of the time and 3 m for only 4% of the time in the period, 19th May to 3rd June, 1978. Whereas, in the recording period of 6th November to 29th December, 1978, maximum wave height H_{max} exceeded 2 m for 32% of the time, 3 m for 14% of the time and 4 m for 4% of the

time. This type of information is very useful for planning various types of offshore operations such as drilling or transfer of men and material from platform to supply vessel and vice-versa.

CONCLUSIONS

Based on the analysis of the limited wave data acquired during the above measurement programme, the following conclusions are drawn:

1. For the study period, 19th May to 3rd June 1978, the highest significant wave height was 2 m with the corresponding zero crossing period of 8 secs, and the maximum wave height recorded was 3.2 m with the associated wave period of 7 secs.
2. For the study period, 6th November to 29th December 1978, the highest significant wave height was 2.9 m with the corresponding zero crossing period of 7.5 secs, and the maximum wave height recorded was 4.45 m with the associated wave period of 8.5 secs.
3. The waves during the period from 6th November to 29th December 1978 were generally steeper than those recorded from 19th May to 3rd June 1978. The wave steepnesses ranged from 1/15 to 1/100 in the study period, 6th November to 29th December 1978. The wave steepnesses varied from 1/33 to less than 1/100 during 19th May to 3rd June 1978.
4. In the study period, 19th May to 3rd June 1978, the significant wave height exceeded 1.5 m for 40% of the time and 2 m for only 1% of the time, whereas, the maximum wave height exceeded 2 m for 80% of the time and 3 m for 4% of the time.
5. In the study period, 6th November to 29th December 1978, the significant wave height exceeded 1 m for 49% of the time, 2 m for 14% of the time and 2.5 m for only 4% of the time. During the same period, the maximum wave height exceeded 2 m for 32% of the time, 3 m for 14% of the time and 4 m for only 4% of the time.
6. It is very essential to undertake a well coordinated long-term wave data collection programme for more meaningful analysis.

Only based on such large data base, long-term analysis or the extreme value analysis can be carried out to derive most useful design parameters for application to various offshore activities related to design, construction, operation and maintenance of offshore facilities.

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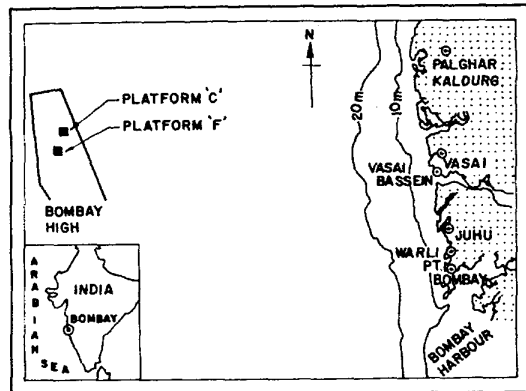


Fig. 1 Location Map of Bombay High

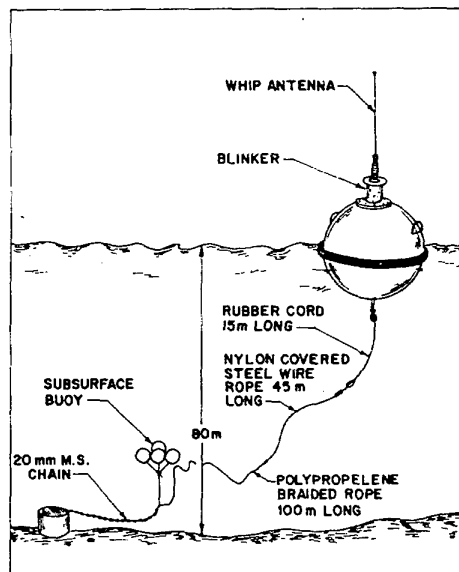


Fig. 2 Wave Rider Buoy Mooring System

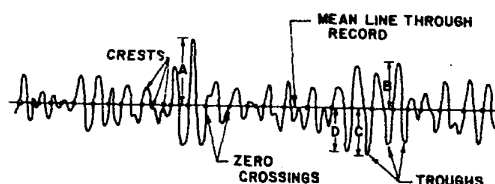


Fig. 3 Definition Sketch of a Wave Record

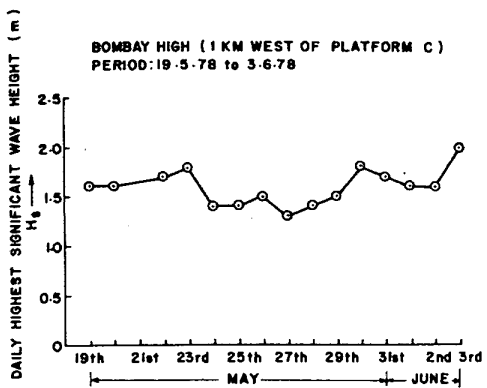


Fig. 4 Plot of H_s Versus Time in Days

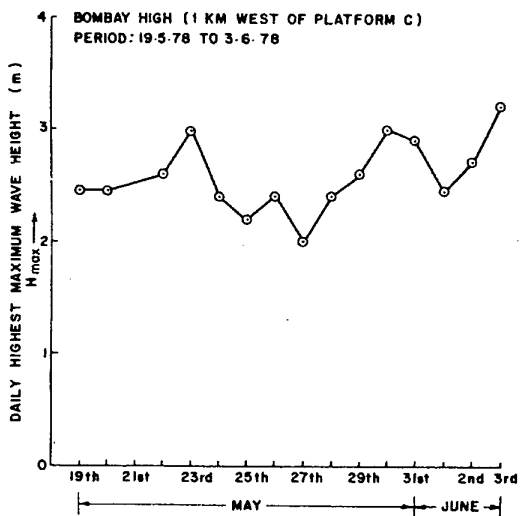


Fig. 6 Plot of H_{max} Versus Time in Days

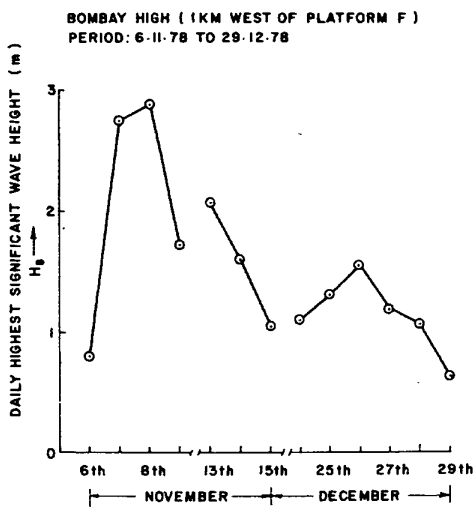


Fig. 5 Plot of H_s Versus Time in Days

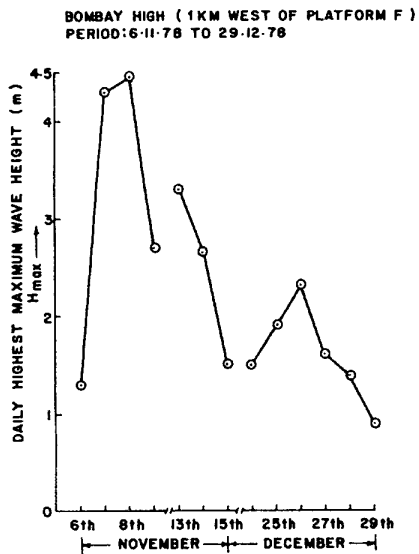


Fig. 7 Plot of H_{max} Versus Time in Days

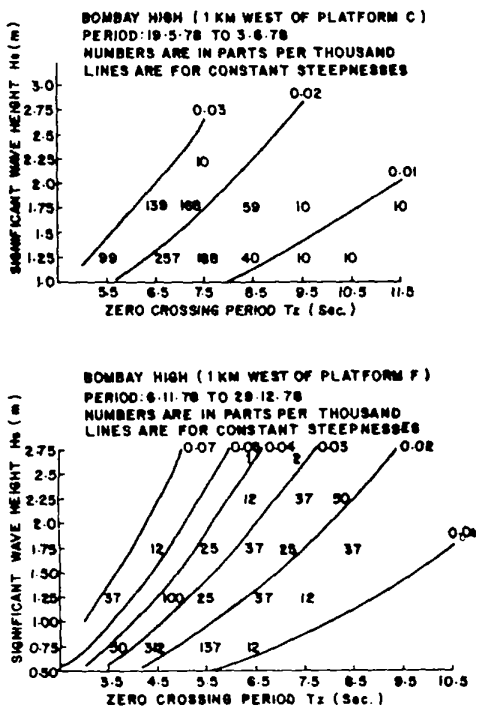


Fig. 8 Plot of H_s Versus T_z

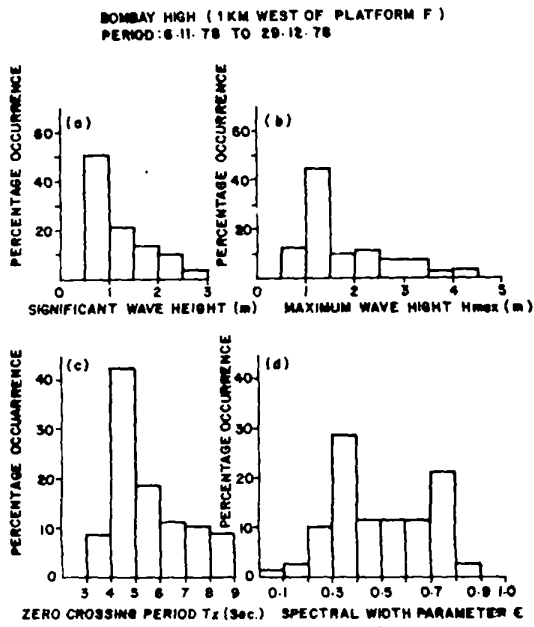


Fig.10 Distribution of H_s , H_{max} , T_z and ϵ

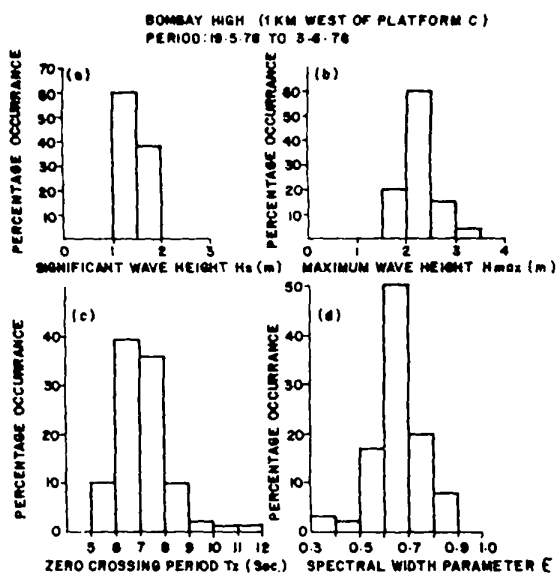


Fig. 9 Distribution of H_s , H_{max} , T_z and ϵ

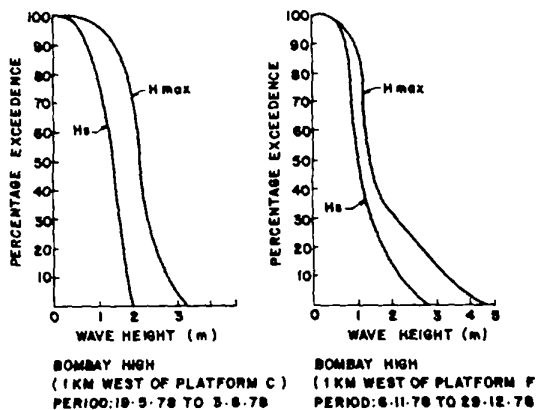


Fig.11 Cumulative Distribution of H_s and H_{max}