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Ocean Waves
Flow-Induced Vibrations
Motions of Floating Structures
2nd Order Effects and Slow Drift
Hydrodynamic Forces
Structural Mechanics/Analysis

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NEARSHORE MONSOON WAVES OFF NORTH WEST COAST OF INDIA

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ABSTRACT

Based on the analysis of monsoon wave data collected at four different locations along the North-West coast of India, an attempt is made to evaluate the wave parameters and their distributions for the sake of a comparative study. The wave height distribution relationship given by Longuet-Higgins is found to fit well only in deeper and intermediate waters whereas in shallow waters the deviations are very large. It is observed that the highest waves are not associated with the longest periods. Wave heights are found to decrease as water depth decreases especially in the case of higher waves. The multi-peaked wave spectra are observed all along the West coast. The spectral width parameters are in the range of 0.45 to 0.90.

NOMENCLATURE

H_{\max}	The height of the highest wave in record.
H_{mean}	Mean wave height
H_{rms}	Root-mean-square wave height
H_s	Significant wave height : The average of the one-third highest waves
c	Spectral width parameter
L	Wave length at given water depth
T_s	Significant wave period : The average period of the one-third highest waves
T_z	Zero-upcrossing wave period in seconds

INTRODUCTION

Wave activity has been found to be severe along the West coast of India during the monsoon period (June to September). Studies of monsoonal waves, therefore, are of great importance in the proper planning, designing and constructing of Ocean structures. Wave measurement programs were undertaken by National Institute of Oceanography, Goa for Oil and Natural Gas Commission (ONGC), Bombay at four locations viz. off Daman (1982), off Umbergaon (1982), off Uran (1984) and off Hazira (1985) as shown in Figure 1. The sea bed slope is approximately 1 : 1000 in the above region. Since the tropical monsoon period of the North-West coast of India is from June to September, the monsoon waves measured in different years can be used for evaluation of wave parameters along the coast. This paper presents the results of the analysis and their interpretation for the above four locations.

WAVE DATA COLLECTION AND ANALYSIS

Wave data were collected using the Wave-rider Buoys at four different locations as shown in Figure 1. The wave measurement program was necessitated due to increasing offshore activities related to offshore oil and gas production in the west coast, as well as the location of the proposed submarine gas pipeline leading to Umbrat near Hazira. The geographic features of the four sites and observed highest wave height are given in Table 1.

Time series records of waves, each of 20 minutes duration, were obtained at three hourly intervals. The waves were recorded in

TABLE 1 : Geographic features of the four locations

Location of Waverider Buoy	Water depth (M)	Distance from shore (KM)	Period Jun-Sep. (Year)	No. of records N	Highest Obs.wave Height (M)
Off Daman	27	18	1982	785	5.23
Off Umbergaon	35	25	1982	445	5.85
Off Uran	10	7	1984	674	3.90
Off Hazira	16	10	1985	753	4.40

analog form on chart paper roll and in digitized form for every 0.5 second interval on a 1/4" magnetic tape cassette. Some of the records were found to be not good for the analysis due to occasional interference of the radio and wireless signals coming from other sources.

The wave data were analysed using Tucker's, Zero-upcrossing and Spectral methods, details of which are described in (9). The various wave parameter distributions are presented and discussed.

RESULTS AND DISCUSSIONS

Various wave parameters, namely significant wave height (H_s), mean wave height (H_{mean}), root-mean-square wave height (H_{rms}), zero-upcrossing period (T_z), significant wave period (T_s), spectral width (σ), steepness (H_s/L) and wave spectra are computed using Tucker's, Zero-crossing and Spectral methods for each three hourly wave record of 20 minute length.

Wave heights

Variation in daily maximum wave height (H_{max}) and significant wave height (H_s) for all four locations are shown in Figure 2. This shows that the monsoon waves generally start in first week of June and it could be observed up to September. It slowly decreases by the end of September and then the sea is almost calm. In general, it is found that the higher wave heights decrease as water depth decreases.

Wave height distribution

The best representation of wave height distribution can be considered as the theoretical Rayleigh distribution relationship given by Longuet-Higgins (7). This has been discussed by Colonell & Perry (2). Dattatri (3) and Harish & Baba (5) have shown that the theoretical relationships are generally valid for the wide banded observed spectra off West coast of India. Figure 3 shows the comparison of the computed wave height parameters with the Longuet-Higgins theoretical Rayleigh distribution relationships which are

$$\begin{aligned} H_s &= 1.416 H_{rms} \\ H_{rms} &= 1.130 H_{mean} \\ \text{and } H_{max} &= 2.172 H_{rms} \end{aligned}$$

For the first two locations, the observed data are found to follow the theoretical relationship quite well. But when waves approach the coast, their characteristics change. For the location off Hazira, the waves of more than 4.5 m height are found to deviate marginally from the theoretical relationship whereas the waves measured off Uran do not follow the theoretical relationship. This may be attributed to very shallow water conditions prevailing at the location of measurement.

The cumulative distributions of significant wave height (H_s) and maximum wave height (H_{max}) are shown in Figure 4. Although Figure 2 shows the comparison of wave height variation over the monsoon period, it does not reveal any clear conclusion. But it is clearly seen from Figure 4 that the higher waves generally occur in deeper region. In other words, higher waves while approaching the shore with shoaling coefficient less than one, decrease their heights as observed for above four locations. This phenomenon is also described by Svendsen and Jonson (11). As an example, H_{max} was found to exceed 2.0 m for 70%, 60%, 20% and 28% of the time for Daman, Umbergaon, Hazira and Uran respectively.

Significant period and zero-crossing period

The significant period can be defined as the average period of the highest one third of the waves in the record. The zero-upcrossing period is defined as the total period of the record divided by the number of zero-upcrossing waves. In order to establish a relationship, significant period (T_s) and zero-upcrossing period (T_z) were compared. The least square fit gives

$$\begin{aligned} T_s &= 0.224 + 1.169 T_z \text{ for off Daman} \\ T_s &= 0.374 + 1.111 T_z \text{ for off Umbergaon} \\ T_s &= 0.588 + 1.063 T_z \text{ for off Uran} \\ T_s &= -0.754 + 1.360 T_z \text{ for off Hazira} \end{aligned}$$

This shows that significant wave periods are, in general, higher than the zero-upcrossing wave periods as can be expected.

Scatter diagram of H_s vs T_z

The scatter diagram representing the joint distribution of H_s and T_z is shown in Figure 5. During the monsoon period, the waves are relatively steeper for deeper region and wave steepness (H_s/L) is mostly distributed in the range of 0.02-0.05. The steepest wave observed has a steepness of 0.09. The period of concentration of predominant waves are in the range of 5.0-7.0 seconds. The intensity of higher waves decreases nearer to the coast. Concentration of waves can also be represented by the contours. The inner-most contour gives the highest occurrence of waves.

From the scatter diagram, it can be observed that the highest waves are not associated with the longest periods. This was also concluded by Harris (6) and Dattatri (3). Based on the theoretical investigation (8) on wave generation, the wave height increases with period in the initial stage and after a certain stage, the wave height decreases even though period increases. As long as wave height increases with period, it is a growing wind-sea state. When the wave height starts decreasing, it is fully developed sea and then a part of the wind wave energy is being converted into swell energy. This phenomena can also be seen from the wave energy spectra (9).

Wave spectra

For the response analysis of offshore structures, the study on the shape of the wave spectra is essential. In general, higher energy spectra were observed off Daman and Umbergaon as compared to other two locations. Some examples of observed wave spectra are shown in Figure 6. At all locations, mostly multi-peaked spectra are observed. This was confirmed by Harish and Baba (5) for the South-West coast of India. The peak frequency varies from 0.06-0.15 H_z .

The major peaks are caused due to independent wave trains (1) representing the sea and swell waves or waves derived from different sources. Thompson (12) also confirmed that the multi-peaked spectrum is a typical characteristic for shallow water region.

The spectral width parameter, ϵ is found to be in the range of 0.45 to 0.90 for all the four locations. This shows that the wave spectra no longer conform to the narrow frequency band. In the case of Uran and Hazira, higher concentration of ϵ is in the range of 0.70 to 0.90, whereas for other two locations ϵ is in the range of 0.50 to 0.75. This may cause poor correlation as observed in Figure 3 for Uran and Hazira.

CONCLUSIONS

Based on the observations and analysis, the following points may be concluded.

1. Longuet-Higgins Rayleigh distribution relationship is not applicable to the distribution of observed wave heights in very shallow waters.
2. Occurrence of higher waves is more pronounced in deeper region. The higher waves approaching the coast generally decrease their height.
3. Concentration of observed wave periods is almost same for all the four locations.
4. The highest waves are not associated with the longest periods.
5. The wave spectra are broad frequency banded.
6. Wave steepness is in the range of 0.02-0.05 during monsoon period. Steeper waves are observed in deeper region. The steepest waves recorded has a steepness (H_s/L) of 0.09.
7. Multi-peaked wave spectra are observed all along the West coast.

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REFERENCES

1. Bretschneider, C. L. "Discussion on investigations of statistics of wave Height", Journal of Waterways and Harbors Division, ASCE, Vol. 90(1), 1964, pp 153-166.
2. Colonell, J. N. and Perry, B. "Laboratory simulation of sea-waves", Journal of Waterways and Harbors Division, ASCE, Vol. 94(2), 1968, pp. 159-174.
3. Dattatri, J. "Waves off Mangalore-West Coast of India" Journal of Waterways Harbors and Coastal Engineering Division, ASCE, Vol. 99(1), 1973, pp 39-58.
4. Draper, L. "The analysis and presentation of wave data - a plea for uniformity", Proc. 10th Conf. Coastal Engg., ASCE, Vol. 1, 1966, pp 1-11.
5. Harish, C. M. and Baba, M. "On spectral and statistical characteristics of shallow water waves", Journal of Ocean Engg., Vol. 13(3), 1986, pp 239-248.

6. Harris, D. L. "Characteristics of wave records in the coastal zone", Advanced seminar on waves and beaches, Academic Press, N.Y., 1972.
7. Longuet-Higgins, M. S. "On the statistical distribution of the heights of sea waves", Journal of Marine Research, Vol. 11(3), 1952, pp 245-266.
8. Mandal, S. "A numerical wave prediction model DOLPHIN: Theory and test results", Report No. 3/85, 1985, Delft Univ. of Technology, The Netherlands.
9. Nayak, B. U., Chandramohan, P. C. and Mandal, S. "Wave measurement and evaluation techniques adopted at Daman on the West coast of India", Paper presented in International Conference on Coastal and Port Engg. in Developing Countries, 7-12 Sept. 1987, Beijing, China.
10. Nayak, B. U. and Mandal, S. "Analysis of waves off Umbergaon - West Coast of India", Proc. 3rd Indian Conf. on Ocean Engg., Vol. 1, 1986, pp G101-110.
11. Svendsen, I. A. and Jonsson, I. G., Hydrodynamics of Coastal Regions, Den Private Ingeniorfond, Technical University of Denmark, 1976.
12. Thompson, E. F. "Shallow water surface wave elevation distributions", Journal of Waterways, Port, Coastal and Ocean Division, ASCE, Vol. 106(2), 1980, pp 285-289.

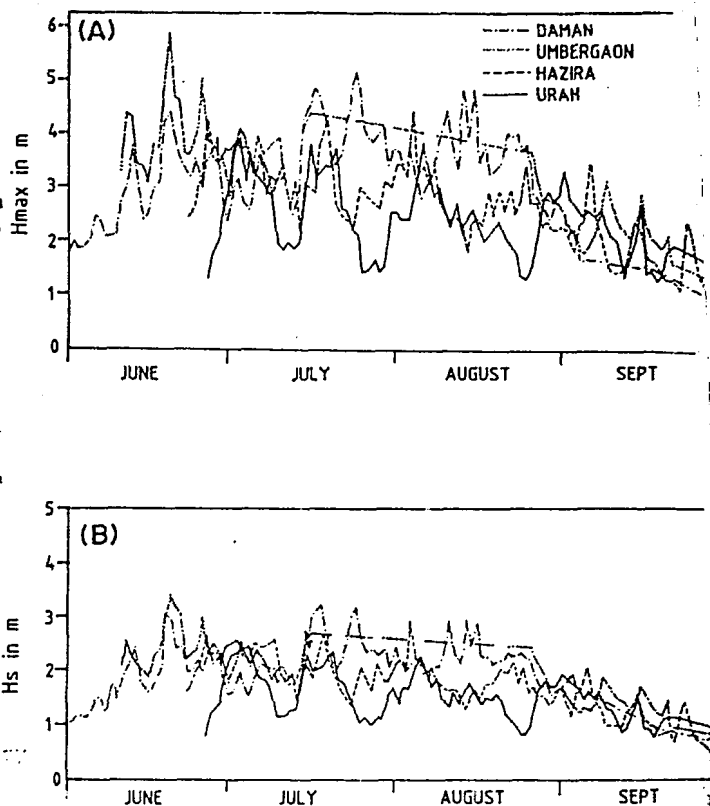


Fig. 2 DAILY VARIATION OF (A) MAXIMUM WAVE HEIGHT (H_{max}) AND (B) SIGNIFICANT WAVE HEIGHT (H_s)

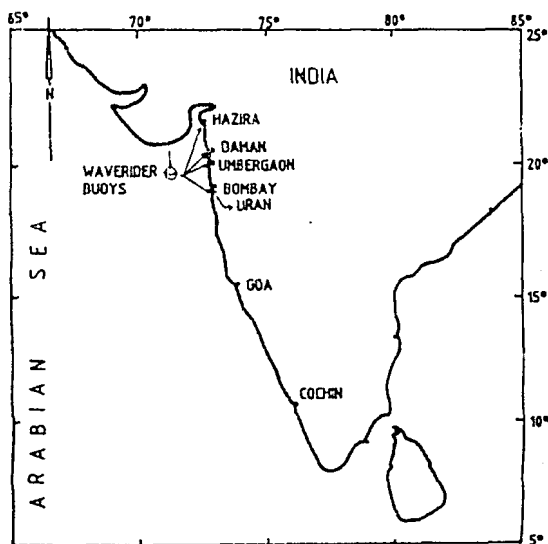


FIG. 1 LOCATIONS OF THE WAVERIDER BUOYS.

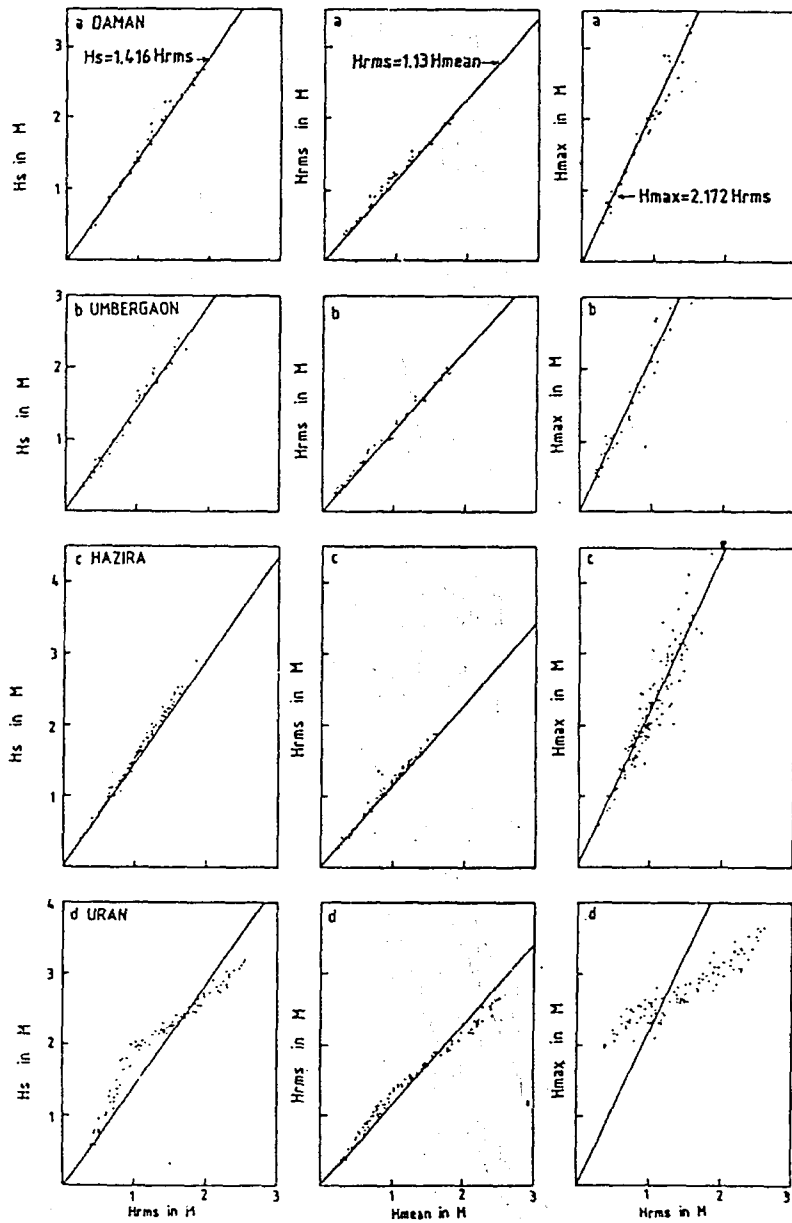


FIG. 3 WAVE HEIGHT RELATIONSHIPS

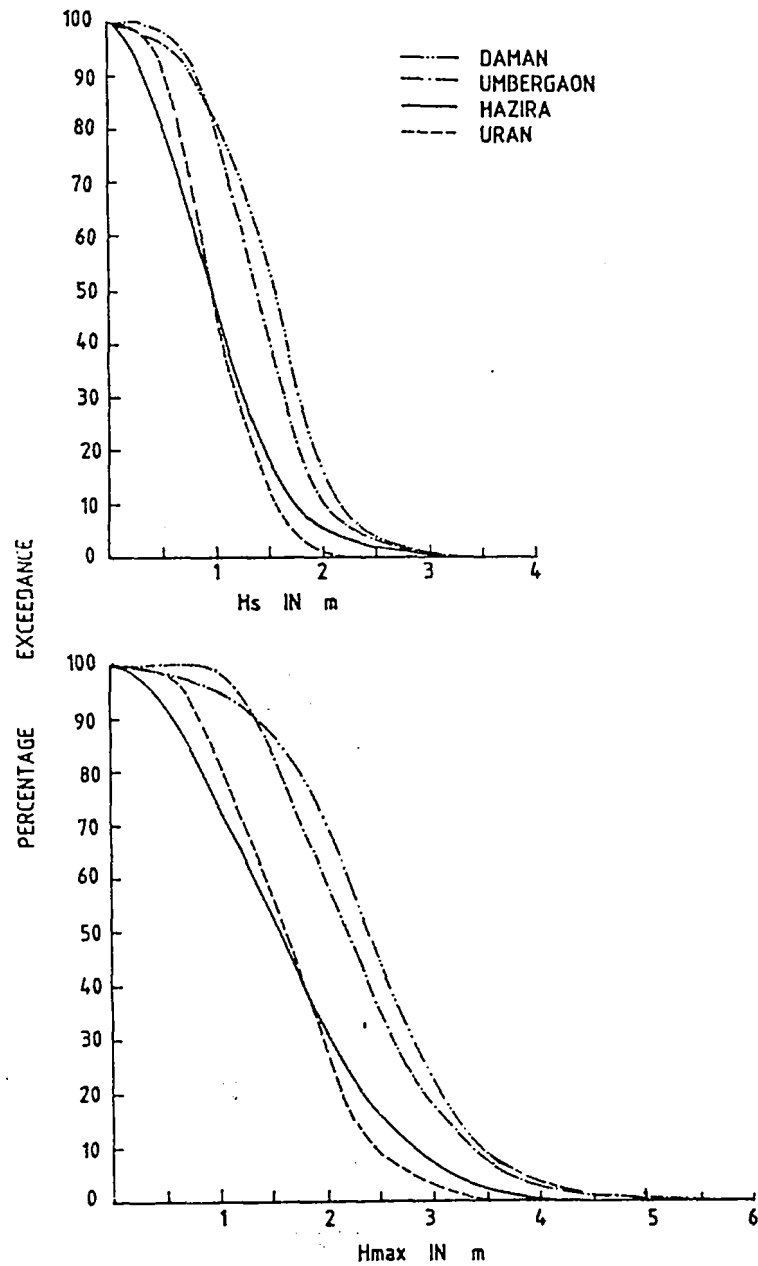


FIG. 4 CUMULATIVE DISTRIBUTION OF SIGNIFICANT WAVE HEIGHT (H_s) AND MAXIMUM WAVE HEIGHT (H_{max})

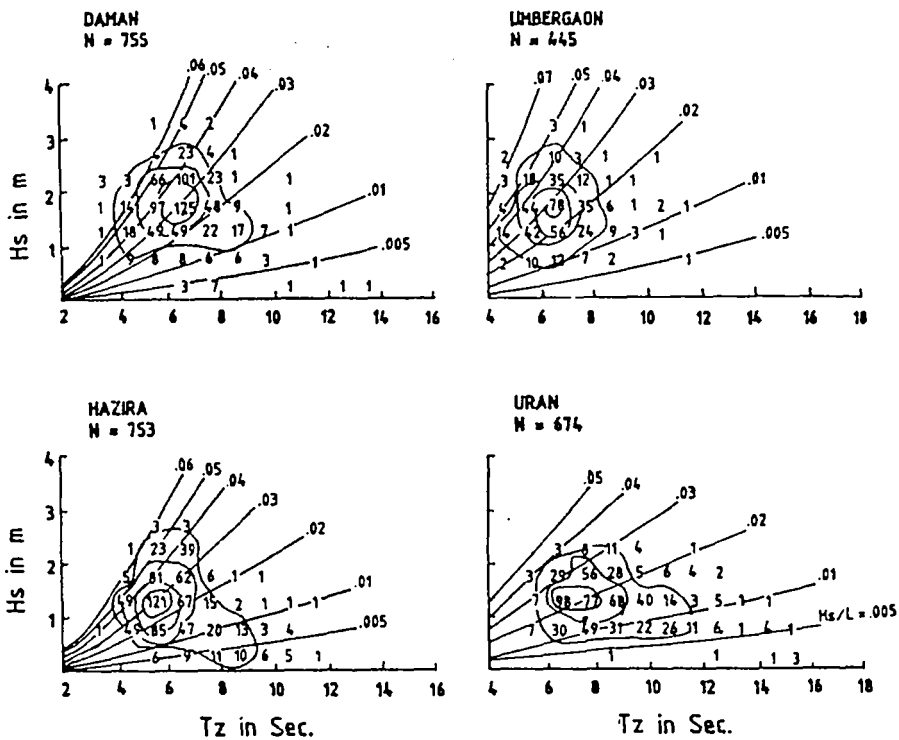


Fig. 5 SCATTER DIAGRAM OF SIGNIFICANT WAVE HEIGHT VS ZERO CROSSING PERIOD.

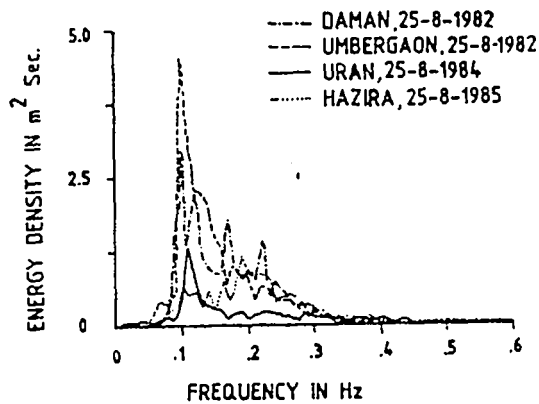


Fig. 6 TYPICAL SPECTRA FROM THE FOUR LOCATIONS.