# CHAPTER 17

# OCEAN WAVE RECORD ANALYSIS BY TUCKER'S METHOD - AN EVALUATION

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## INTRODUCTION

The planning and design of any Coastal Engineering structure requires adequate knowledge of the wave characteristics. It is desirable that this knowledge of waves is based on instrumentally recorded data over a number of years, so that reliable values could be used for the computation of the design wave. Analysis of instrumentally recorded data to yield the relevant wave characteristics like the significant wave height, though not complicated is too time consuming. A simple method of analysis has been proposed by Tucker (9, 10), wherein the relevant information is obtained with only a few measurements of the larger waves. This method is also recommended by Draper (6) in his plea for uniformity of the analysis and presentation of wave data. This paper deals with the application of the Tucker's method to analysis of waves recorded off the Mangalore Harbour on the West Coast of India.

## ANALYSIS OF WAVE RECORDS - TUCKER'S METHOD

Tucker (9, 10) has provided a simple method for obtaining the pertinent information of waves in any wave record, by only a few measurements of the larger waves, the theoretical basis of which is given by Cartwright and Longuet-Higgins (1), and by Cartwright (2). The measurements required

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for the Tucker's method of analysis are: A, the height of the highest crest; B, the height of the seoond highest crest measured from the mean water level line; C, the depth of the lowest trough; and D, the depth of the seoond lowest trough from the mean line as shown in Fig. 1. In addition the number of zero-crossings $N_z$, that is, the number of times the record trace crosses the mean line in an upward direction in the duration considered (Fig. 1) is also required. From these measurements, Tucker defines $H_1 = A + C$, and $H_2 = B + D$.

Using these measured values, the other wave height parameters can be estimated from $H_1$ and $H_2$. $D_{RMS}$, defined as the root-mean-square value of the instantaneous distance of the water surface from the mean line, is estimated as follows:

$$D_{RMS} = \tfrac{1}{2} H_1 (2\theta)^{-\frac{1}{2}} [1 + 0.289\ \theta^{-1} - 0.247\ \theta^{-2}]^{-1} \quad \ldots \quad (1)$$

$$D_{RMS} = \tfrac{1}{2} H_2 (2\theta)^{-\frac{1}{2}} [1 - 0.211\ \theta^{-1} - 0.103\ \theta^{-2}]^{-1} \quad \ldots \quad (2)$$

$$\text{in which} \quad \theta = \mathrm{Log}_e\ N_z \quad \ldots \quad (3)$$

It should be noted that in the original papers (9, 10), Tucker had used $H_{RMS}$ instead of $D_{RMS}$, to indicate the root-mean-square value of the displacements of the water surface from the mean line. This results in some confusion as $H_{RMS}$ is also used to indicate the root-mean-square value of the crest to trough heights of waves. To overcome this confusion, Tucker in the closure (5) of one of his paper (10) had suggested the use of $D_{RMS}$ and $H_{RMS}$ to indicate the r.m.s. value of wave displacements and wave heights respectively. For a wave system containing only a narrow band of frequencies, $H_{RMS} = 2\sqrt{2}\ D_{RMS}$ (5). Introducing this, Eqs. 1 and 2 oan now be modified to:

$$H_{RMS} = \sqrt{2}\ H_1 (2\theta)^{-\frac{1}{2}} [1 + 0.289\ \theta^{-1} - 0.247\ \theta^{-2}]^{-1} \quad \ldots \quad (4)$$

$$= K_1 H_1 \quad \ldots \quad (4(a))$$

$$\text{in which } K_1 = \sqrt{2}\ (2\theta)^{-\frac{1}{2}} [1 + 0.289\ \theta^{-1} - 0.247\ \theta^{-2}]^{-1} \ldots (4(b))$$

$$H_{RMS} = \sqrt{2}\ H_2 (2\theta)^{-\frac{1}{2}} [1 - 0.211\ \theta^{-1} - 0.103\ \theta^{-2}]^{-1} \quad \ldots \quad (5)$$

$$= K_2 H_2 \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \quad (5(a))$$

in which $K_2 = \sqrt{2}\,(2\theta)^{-\frac{1}{2}}\,[1 - 0.211\,\theta^{-1} - 0.103\,\theta^{-2}]^{-1}$..(5(b))

It oan be seen from Eqs. 4(b) and 5(b) that $K_1$ and $K_2$ are functions of $\theta$ only, whioh inturn is a function of $N_z$ from Eq. 3. Hence $K_1$ and $K_2$ can be evaluated as functions of $N_z$ and this is shown in Fig. 2.

The analysis of wave records is now reduced to a simple process of determining $H_1$, $H_2$ and $N_z$ from the wave record and then determining $K_1$ and $K_2$ from Fig. 2 using the measured value of $N_z$. From these values, $H_{RMS}$ can be evaluated using Eq. 4(a) or Eq. 5(a). Once $H_{RMS}$ has been evaluated, the other wave height parameters like the significant wave height can be determined using the relations given by Longuet-Higgins (8). Analysis of ocean wave records in India (3) and abroad (7) have shown that the relations between the various wave height parameters as given by Longuet-Higgins, to be substantially the same for the records analysed.

Tucker (10) recommends that the zero-crossing period $T_z$, (= duration of record, in seoonds/$N_z$) could be the relevant period to be used with the above wave heights.

## APPLICATION OF TUCKER'S METHOD

The primary objeotive of the present investigations was to study the applicability of the Tucker's method to waves recorded along the Indian Coasts. For this purpose, the wave records obtained by the Mangalore Harbour Project authorities on the West Coast of India were utilized. About 12 months' records were available for analysis and the results of the analysis regarding the wave height and wave period distributions etc., has been reported in an earlier paper (3). For the present investigations about 50 samples of the wave records of 15 minutes duration, picked at random were utilized for analysis by the Tucker's method.

For each sample, the heights A, B, C and D were direotly read from the records. From these values $H_1$ = A+C and $H_2$ = B+D were evaluated. For each sample the number of zero-crossings, $N_z$ was also noted. From the known value of $N_z$, the values of the constants $K_1$ and $K_2$, $H_{RMS}$ was evaluated from Eqs. 4(a) and 5(a), and this $H_{RMS}$ will hereafter be referred to as the $H_{RMS}$ estimated from $H_1$ or $H_2$.

For each wave record sample, the crest to trough heights of the individual waves were also read and the root-mean-square wave height, $H_{RMS}$, was also directly computed from these individual heights.

As the wave recorder used, was of the sub-surface pressure type, all the wave heights read from the wave records were corrected to account for the attenuation of wave pressure with depth and the frequency response of the instrument as per standard procedures (3).

## PRESENTATION AND INTERPRETATION OF DATA

Eqs. 4 and 5 can only give the estimate of the value of $H_{RMS}$, since a statistical average value like $H_{RMS}$ is being evaluated based on a single reading of $H_1$ or $H_2$. As stated by Tucker (9), the statistical errors in these estimates are less than what might be expected and are not much worse than that of the mean of the highest one third waves in the records. Tucker (9) mentions that the proportional standard error in the estimate of $H_{RMS}$ from $H_1$ could be approximately 13 percent and from $H_2$ about 10 percent, under certain conditions. The direct computation of any statistical average like $H_{RMS}$, from the individual wave heights itself is subject to error depending on the length of the record (4). In view of these considerations, perfect agreement cannot be expected between the $H_{RMS}$, estimated from $H_1$ or $H_2$, and the $H_{RMS}$ directly computed from all the individual wave heights in the record.

In Fig. 3 the $H_{RMS}$ estimated from $H_1$ and $H_2$ is compared with the $H_{RMS}$ directly computed. As discussed earlier, perfect agreement is absent. But, it can be seen that the $H_{RMS}$ estimated from $H_1$ or $H_2$ is within $\pm 15$ percent of the directly computed value. There is a strong tendency for the $H_{RMS}$ estimated from $H_2$, to be more than the directly computed value. The spectral width parameter $\varepsilon$, for the samples analysed ranged from 0.2 to 0.8. The possibility of the variation in the spectral width parameter being a reason for the deviations of the data was also considered, but no systematic variation was noticed. A possible reason for the scatter could be that crest to trough heights are used in the computation instead of water surface heights from the mean line, and the theoretical relationships are derived using the latter.

Assuming the $H_{RMS}$ directly computed to be the correct value, analysis was made of the percentage error in the estimation of the wave height from the single measurement of $H_1$ or $H_2$, and these results are presented in Fig. 4. It can be seen in Fig. 4, that in nearly 90 percent of the cases, the estimated $H_{RMS}$ differed from the directly computed value by less than 15 percent. These studies show that the $H_{RMS}$ estimated from $H_1$ or $H_2$ is close enough to the $H_{RMS}$ directly evaluated, for practical purposes. This supports the usefulness of the Tucker's method as a rapid means of obtaining the pertinent wave characteristics without a detailed and time consuming analysis of the wave records.

Another aspect studied was the relation between $H_{Max}$ (the maximum crest to trough wave height in the sample under investigation) and, $H_1$ and $H_2$. Actually Tucker recommends that for many civil engineering purposes, the relevant wave height could be $H_1$ and the period $T_z$.

In Fig. 5 is plotted $H_{Max}$ versus $H_1$ and $H_{Max}$ versus $H_2$. For the data analysed, it can be seen that $H_1$ is generally greater than $H_{max}$ and $H_2 = H_{Max}$. In general, for records containing only a narrow band of frequencies, $H_{Max}$ should be nearly equal to $H_1$. This is because the narrow band assumption implies that the highest crest is associated with the deepest trough and in that case, it follows that $H_{Max}$ should be equal to $H_1$. But the present set of wave records, with the spectral width parameter ranging from 0.2 to 0.8, cannot be regarded as belonging to the narrow band process. For the wide band process, the highest crest is not associated with the deepest trough and it is to be expected that $H_1$ will be greater than $H_{Max}$ and the results in the present analysis confirm it.

## CONCLUSIONS

Tucker's simple method of obtaining the pertinent information of waves in any wave record by only a few measurements of the larger waves is found to be applicable to waves recorded on the West Coast of India. The error involved in such computations in comparison with more refined calculations is found to be generally below 15 percent.

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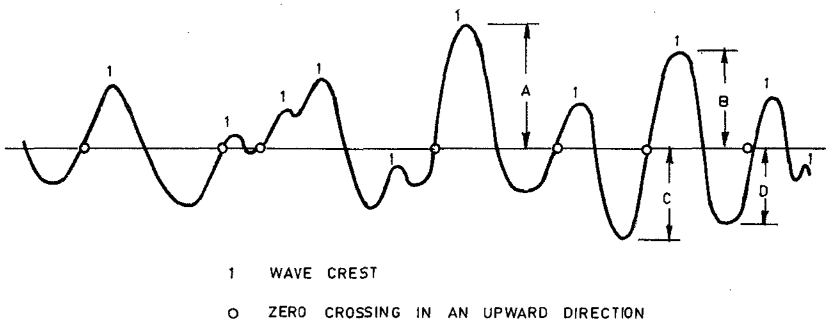


FIG.1 AN ILLUSTRATION OF THE SIMPLE MEASUREMENT OF A WAVE RECORD (ONLY SHORT LENGTH OF RECORD SHOWN)

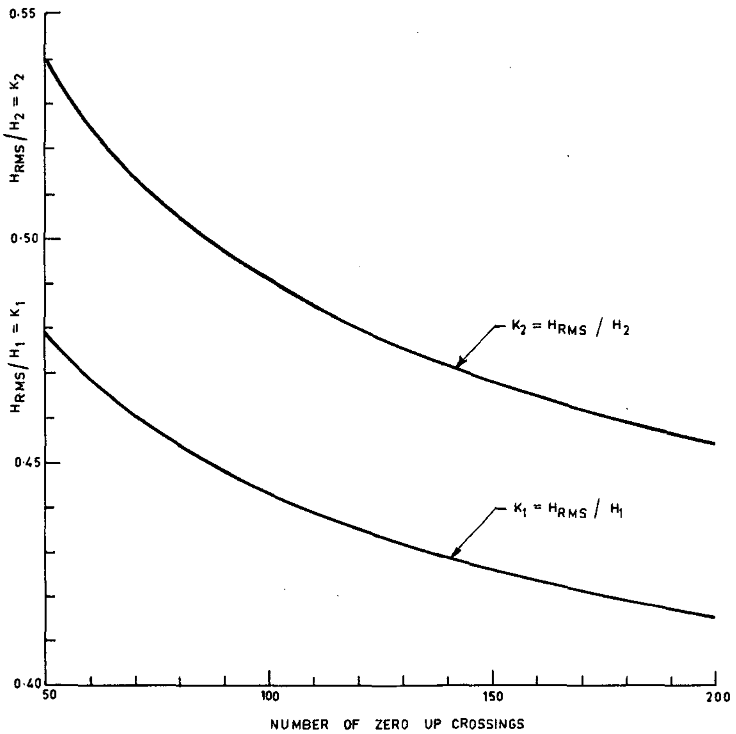


FIG. 2 : $K_1$ AND $K_2$ PLOTTED AGAINST THE NUMBER OF ZERO UP CROSSINGS.

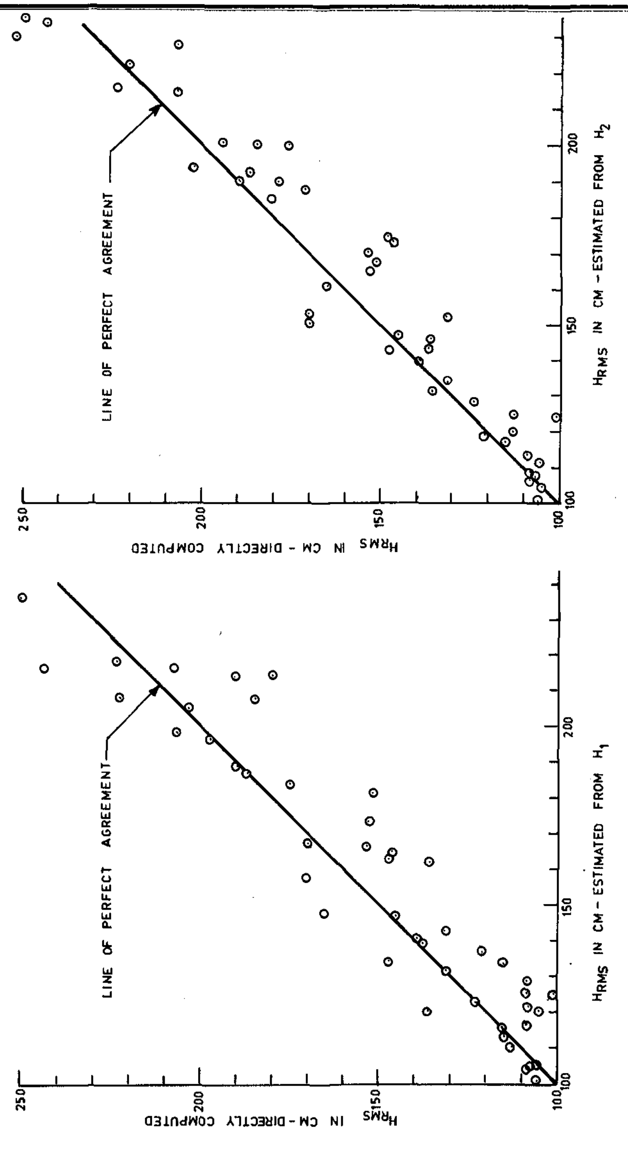


FIG.3: COMPARISON OF ESTIMATED AND COMPUTED $H_{RMS}$.

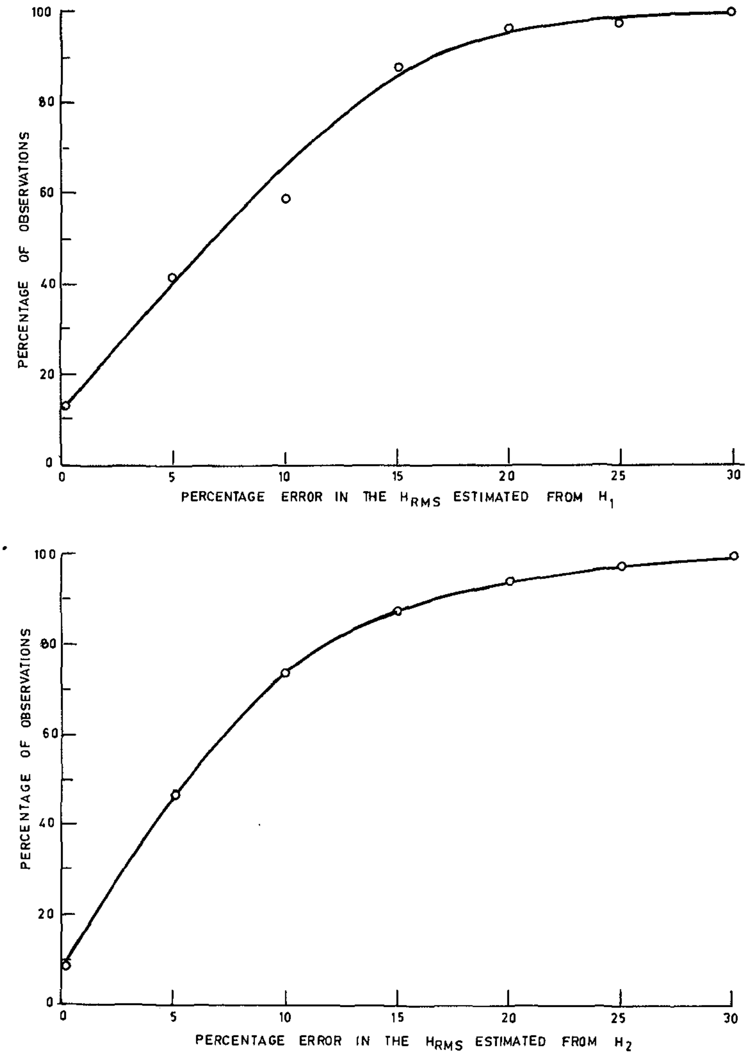


FIG. 4: PLOT DEPICTING ACCURACY OF THE TUCKER'S METHOD

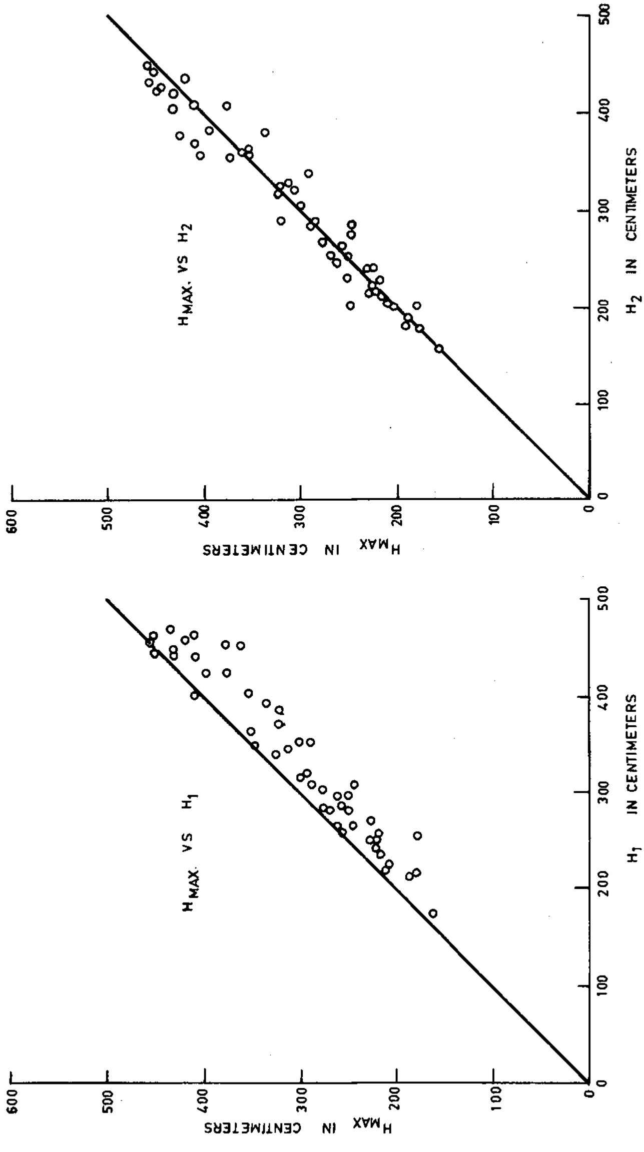


FIG. 5: COMPARISON OF $H_{MAX}$ WITH $H_1$ AND $H_2$