CHAPTER 2

WAVES OFF BENGHAZI HARBOUR - LIBYA

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ABSTRACT

This paper gives details of the wave studies associated with the reconstruction of Benghazi Harbour, from the early forecasts, the installation of a recording instrument, its failures and repairs, to forecasts based on more recent techniques and subsequent analysis and presentation of results of records taken from 1961 to 1965. Conclusions have been drawn and some suggestions for future consideration have been given.

INTRODUCTION

At the time of preparing the designs for the Reconstruction of Benghazi Harbour, there was hardly any information available on the observed or measured waves. Recourse had therefore to be made to wave forecasting techniques using whatever wind records that were available. It was decided to include this information in this paper as a record of historical development of forecasting techniques.

In order to obtain more reliable information it was decided to install a wave recorder. Wave records have been analysed in accordance with Draper's[1] and Tucker's[2] methods except that H_{max} instead of $H_{1/3}$ was abstracted from every 10min. record because it was found that for all practical purposes $H_{max.}$ was equal to $H_{1/3}$ The results of the analysis have been presented in accordance with the proposals made by Draper[3] at the 10th Coastal Engineering Conference.

It was considered important to give in some detail the damages and breakdown sustained by the wave recorder installation in order to emphasize the hazards which are liable to affect almost any wave recording enterprise.

It was also felt important to compare the maximum waves predicted by using the actual wave records with those obtained by the latest forecasting techniques in order to ascertain how much reliance could be placed on these techniques which have to be used on many occasions to predict "design waves" in the absence of information on actual wave records.

WAVE FORECASTS (OR HINDCASTS)

In 1955, Sir William Halcrow & Partners asked Neyrpic, Laboratoire Dauphinios d'Hydraulique, Grenoble, to undertake hydraulic model tests for breakwater designs and for various layouts of the harbour. As the information on waves at that time was very scarce and unreliable, Neyrpic decided to resort to forecasting methods based on the knowledge of winds in order to augment the available data on waves. Various National meteorological records were consulted for information on winds. Two values of wind velocities; 40 knots which was the maximum observed value, and 28 knots corresponding to Beaufort 7, were used in making the forecasts. It was assumed, although no positive evidence was available, that these wind velocities were constant for the directions and fetches under consideration for relatively long periods. Methods of Suthons and Sverdrup as well as empirical formulae of Stevenson and Iribarren were used. Four directions were considered but Neyrpic's results for N.W. and N. only, which have the maximum fetch of 350 nautical miles, are given below.

	Wind velocity - 40 knots		Wind velocity - 28 knots	
	Suthons	Sverdrup	Suthons	Sverdrup
Wave Height	25'	30'	15'	16'
Period	12 sec.	10.2 sec.	9.7 sec.	8.7 sec.
Min. Duration	24 hrs.	31 hrs.	28 hrs.	36 hrs.

Stevenson's formula: $H(ft) = 1.5\sqrt{\text{fetch (nautical miles)}} = 28'$

Iribarren's formula: $H(m.) = 1.2\sqrt[4]{\text{fetch (km.)}} = 20'$

It was assumed that Suthon's method gave maximum wave height and Sverdrup's method gave significant height. It was also assumed that maximum wave heights were obtained from the formulae of Stevenson and Iribarren. Neyrpic recommended that for directions N.W. and N. a wave height of 23' of 10 sec. period should be used for wave agitation tests in the harbour but that to allow for exceptional storms higher waves of 25' to 30' height and 12 sec. period should be used for breakwater stability tests. Further meteorological data based on actual storms upto January, 1968 has been examined and it is now concluded that a wind speed of 40 knots for a duration of 24 hours is possible for the most severe storms. Using the latest methods the following forecasts are now made for deeper water off the harbour.

Darbyshire - Draper graphical method (oceanic)[4]:

$H_s = 20'$, $H_{max.\ (storm)} = 44'$ and $Ts = 11.5$ secs.

Bretschneider's method[5]:

$H_s = 26'$, $H_{max.\ (storm)} = 52'$ and $Ts = 13.5$ secs.

Fig. 1. Underwater Unit, Wave Recorder.

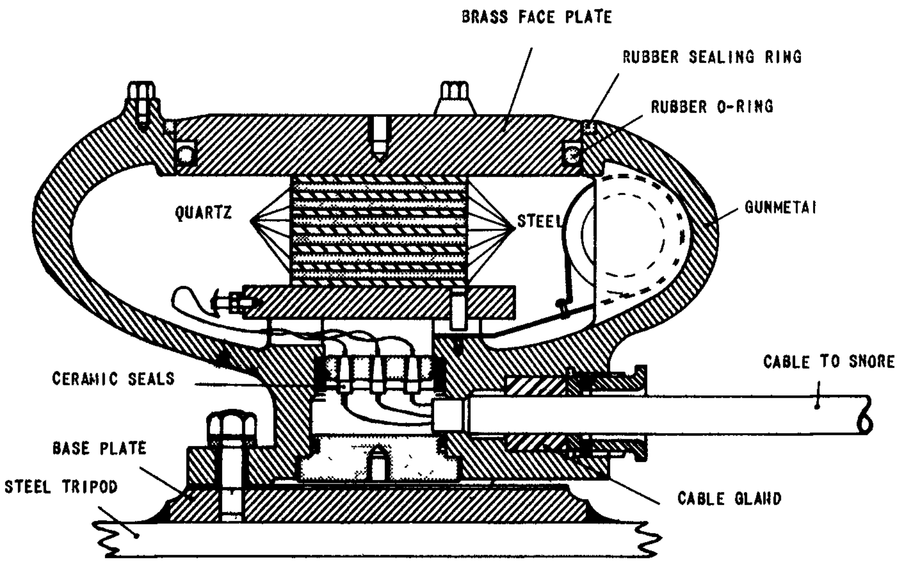

Fig. 2. Section through the Underwater Unit.

Wave Spectrum (P-N-J) method[5]:

$H_s = 25'$, $H_{max.(storm)} = 50'$ and $T_s = 12$ secs.

It should be noted that $H_{max.(storm)}$ given above is the maximum wave height which is likely to occur in a storm of 24 hours duration. In the case of Darbyshire - Draper method the appropriate height factors given in their paper[4] were used. For Bretschneider and Wave Spectrum methods the height factor was obtained from the formula: $H_{max.} = 0.707\ H_s\sqrt{\log_e N}$ where N = number of waves in the duration under consideration.

WAVE RECORDER INSTALLATION

The instrument is an N.I.O. piezo-electric wave recorder which measures fluctuations in pressure. These are transmitted as voltages through a seven core cable to the amplifier and recording instrument located on shore. An outside view of the sea unit is given in Fig. 1 and a cross-section through it is given in Fig. 2. The underwater unit is mounted on top of a steel tripod 6' high. The wave traces are recorded on two separate charts, a continuous record being taken at a chart speed of 6"/hour and an intermittent record of 12 min. duration taken every four hours at a speed of 2"/min.

The instrument was first installed in 1956 and functioned until early 1958 when the submarine cable was damaged by tanker moorings. The meter head was lifted up, re-assembled and re-placed in August 1960. During a severe storm on 5th/6th February 1961, the power supply to the recorder failed and records at the peak of the storm were not obtained. In 1962 a standby generating set was provided which automatically came into operation in the event of mains failure. Wave records obtained during the storm of 15th/16th March 1962, showed unusual features suggesting that the cable was damaged. Subsequent inspection showed that the cable was stretched to breaking point by tanker moorings. It was then decided to re-locate the sea unit where the cable would be clear of moorings. This opportunity was taken to obtain a more streamlined meter head as the old one was suspected of suffering from eddies and turbulence. The recording instrument was also moved close to the Chief Resident Engineer's Office where it could be kept under close supervision. The new unit and the cable were installed in December 1962. The instrument functioned reasonably satisfactorily until July 1965, when the cable was broken in a storm. A completely new cable had to be provided and was connected up in November 1967.

WAVE RECORDS AND ANALYSIS

The first and second sitings of the sea unit were in depths of water of 42' and 48' respectively. Some of the deep sea waves were, therefore, not measured as they had already broken before reaching the recorder. Intermittent wave records covering the period from 1961 to 1965 have been analysed in accordance with the methods described by Draper and Tucker. The results are presented in Figs. 3, 4 and 5.

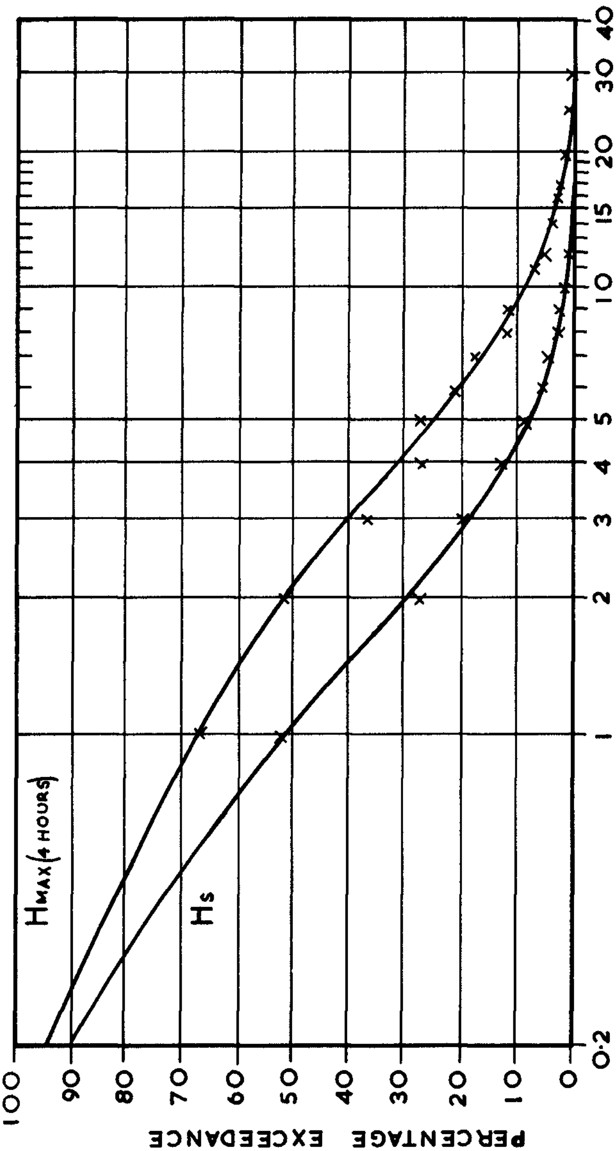

Fig. 3. The cumulative distribution of significant wave height and the most probable highest wave in the recording interval.

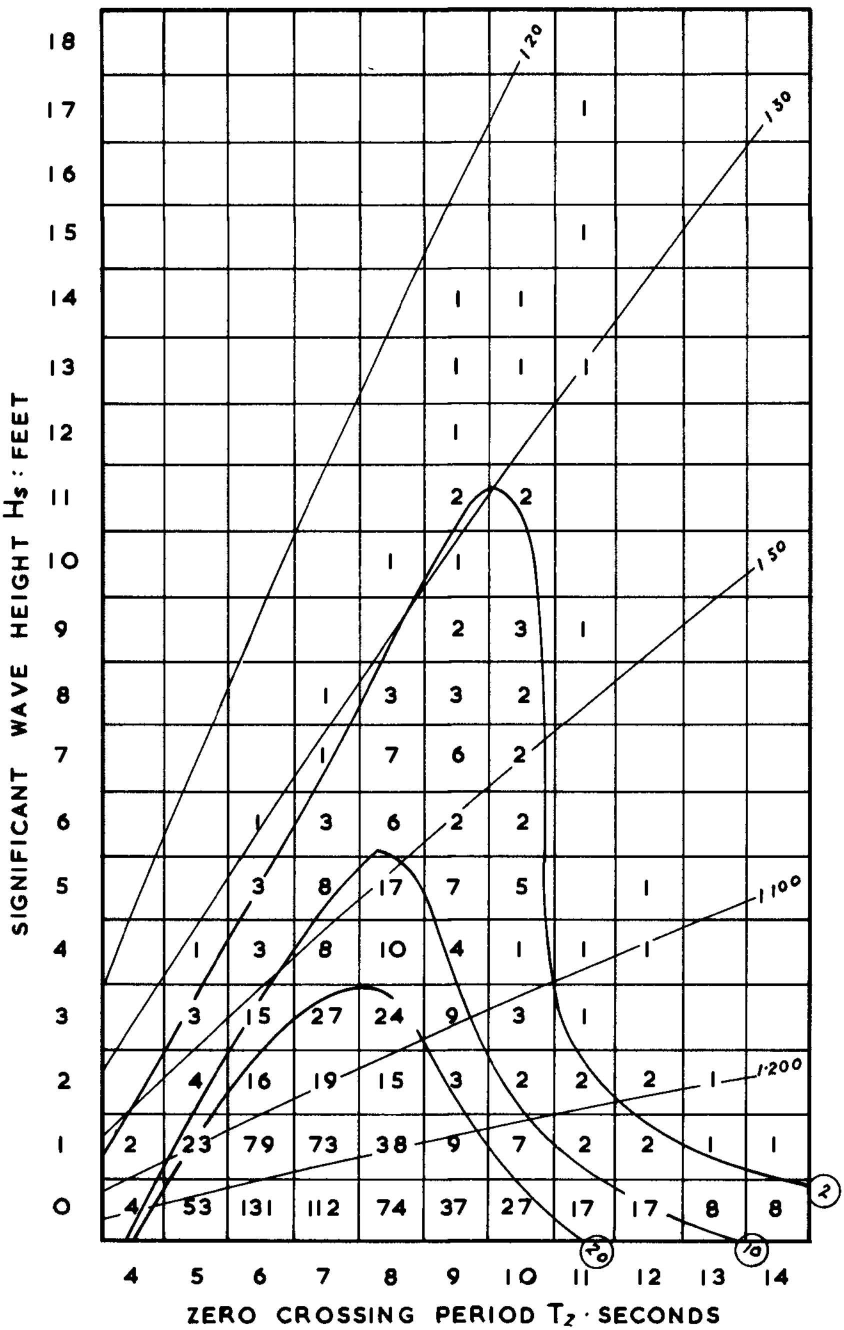

Fig. 4. A scatter diagram.

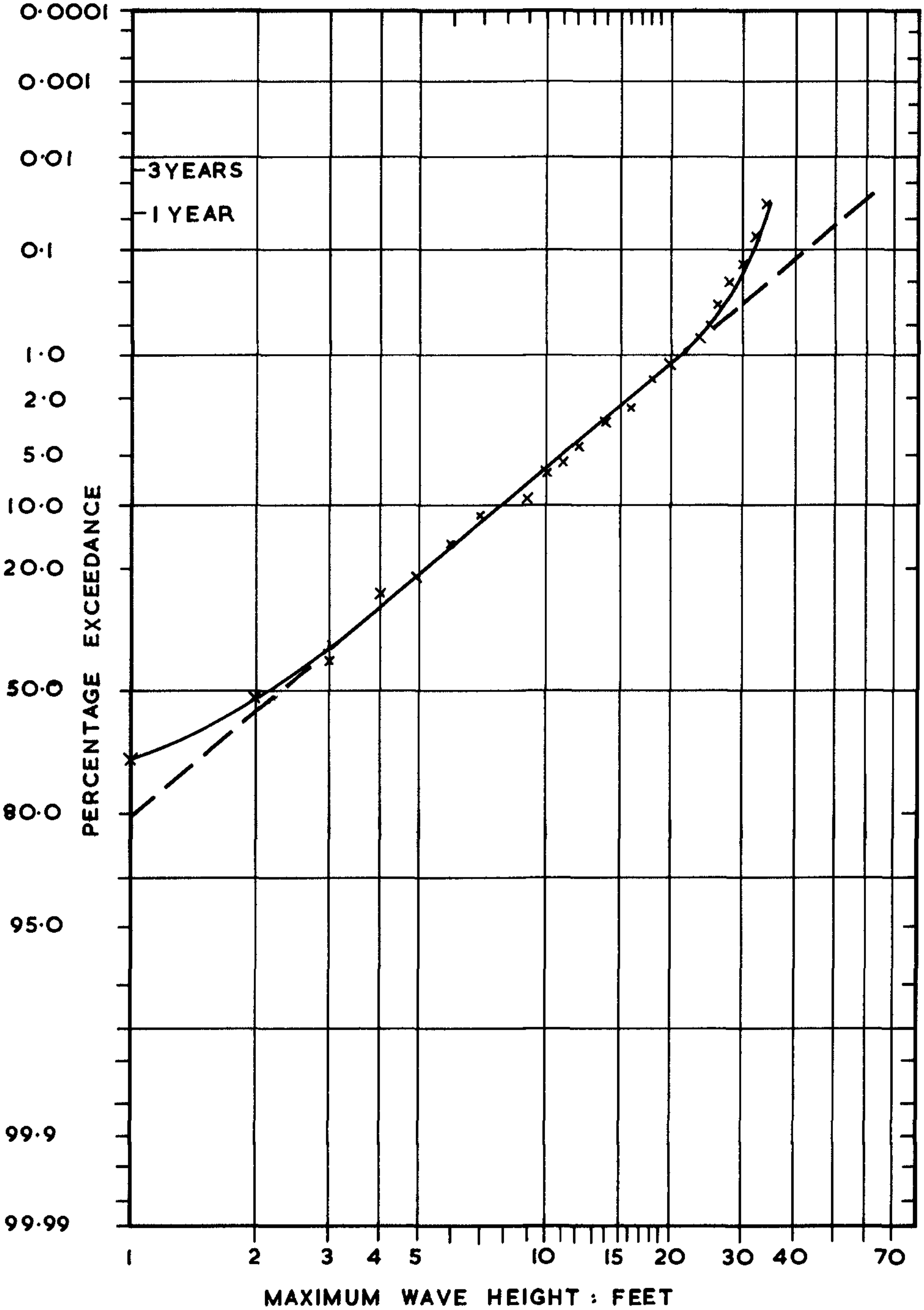

Fig. 5. Prediction curve.

Fig.3. This diagram shows the proportion of time for which H_s and H_{max}. (4 hours) exceeded any given height. For example, H_s exceeded 3 feet for 20% of the time.

Fig.4. This is the scatter diagram relating the significant wave height to the zero crossing period. The wave records are presented as parts per thousand. The wave steepness lines are drawn using the wave length at the recorder location and from these it can be seen that most of the waves lie between steepnesses of 1:200 to 1:20. Contours have been drawn from which the frequency of occurrence of certain combinations of wave height and period can be obtained. The most common zero crossing period appears to be 7 seconds.

Fig.5. The calculated values of H_{max} (4 hours) have been plotted against percentage exceedance. The graph is a straight line between wave heights of 3' and 25' and breakaways below and above these heights. The non-linearity above about 25' is due in part to the shallow water, as depths of 42' and 48' cannot sustain waves of a height greater than about 32' to 37' respectively. Low wave heights are often associated with short periods resulting in large depth attenuation which prevents such waves appearing on the record. This results in a lower apparent percentage of waves of one and two feet in height and may explain some of the non-linearity at low heights. Using the straight dotted extension of the graph it can be predicted that a wave height of 52' (maximum) can be expected to occur once every year in deeper water. This compares well with the waves forecast by the Bretschneider and P-N-J methods. Non-linearities are almost certain to occur at these wave heights, yielding extremes somewhat less than those predicted by the straight line, but until the behaviour of waves at these heights is better understood the linear extrapolation must be used. This should give a slight error on the "safe" side.

CONCLUSIONS AND SUGGESTIONS

Although reasonable agreement has been obtained between the waves forecast using the latest techniques and the actual measured records, it is obvious that there is still considerable room for improvement in both the forecasting and recording techniques. Forecasting would be more accurate if wind speed and its duration over the fetch could be determined with greater accuracy. It is suggested that if wind data is available in a form suitable for extrapolation to long intervals of time it might included in the paper to enable the user to make his own forecasts at a later date if more accurate wave forecasting techniques become available.

There is still a great need for a simple but reliable wave recording instrument which would be less subject to breakdowns. There are instruments available now which reduce the manual task of analysis but their use in remote locations devoid of servicing facilities probably causes more problems than it solves. It is also suggested that every encouragement be given to the development of instruments which would record wave heights and directions simultaneously.

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REFERENCES

1. L. Draper. Derivation of a "design wave" from instrumental records of sea waves. Proc.Instn.Civ.Engrs., 1963, 26, pp. 291 - 304.

2. M. J. Tucker. Analysis of records of sea waves. Proc.Instn. Civ.Engrs., 1963, 26, pp. 305 - 316.

3. L. Draper. The analysis and presentation of wave data - a plea for uniformity. 1966. Proc.Xth Conf. Coastal Eng. pp. 1 - 11.

4. M. Darbyshire and L. Draper. Wind-Generated Sea Waves. Engineering. 1963, April, pp. 482 - 484.

5. Shore Protection Planning & Design. Technical Report No.4. U.S. Beach Erosion Board.