CHAPTER 11

CONSECUTIVE HIGH WAVES IN COASTAL WATERS

by Winfried Siefert*)

Abstract

The problem of statistics of numbers of consecutive high waves has not yet been treated in detail. Some numerical results (Goda, 1970) and evaluations of prototype data in water depths of 100 m (Rye, 1975) and 40 m (Wilson and Baird, 1973) respectively were published. Data from measurements in nearshore coastal waters, with unbroken, breaking and broken waves, obtained in the Elbe estuary, are treated in this paper.

Introduction

For the design of coastal structures as well as for the understanding of coastal processes a lot of prototype wave data is necessary. During the last decade research has been intensified all over the world. Usually the wave climate at a certain position is characterized by representative heights and periods ($\bar{H}$, $H_{1/3}$, $\bar{T}$, $T_{H_{1/3}}$) and energy spectra. By correlation with wind data, functions of wave height, period, and spectra occurence and exceedance can be given. In addition to that distribution functions of wave heights and periods for any wave stage can be derived, as has been done by evaluation of about 15.000 wave records in the Elbe estuary at the German North Sea coast (Siefert, 1974) (Fig. 1).

Concerning stability problems of structures extended to wave attack there is another criterion: the number of waves in a run that exceed a predetermined value. There are

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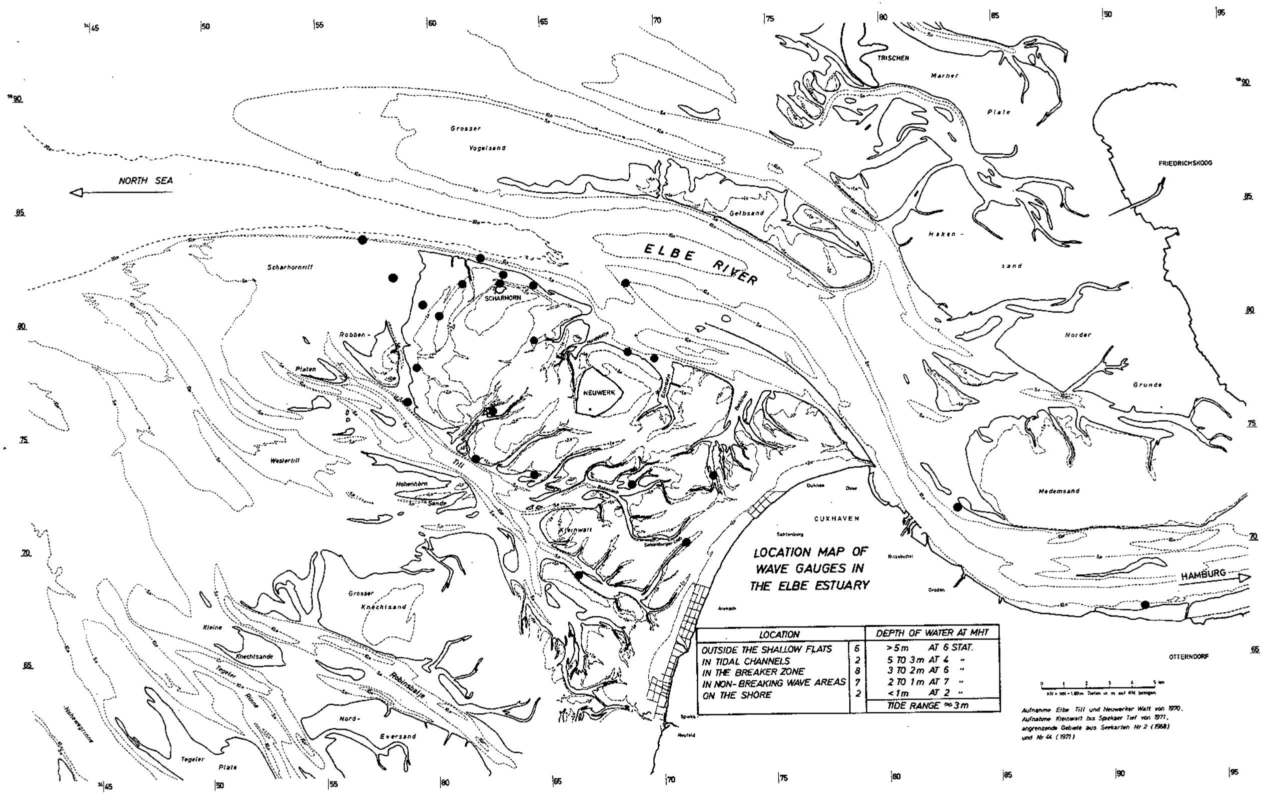

Fig. 1
Wave Investigations in the Elbe Estuary

not yet transfer functions between distributions of heights and periods or energy spectra and the numbers of consecutive high waves. So this problem has to be analyzed separately as an additional information.

The static wave force on a structure is usually characterized by the design water level plus highest wave height. The dynamic force - evaluated by one or the other good or bad formula - is usually derived from the significant wave height or $H_{1/10}$ or something similar. The realistic force, caused by a run of waves of a certain height and generating vibrations and perhaps resonance, is not yet subject to wave design.

Analysis

Numerical treatments of the problem of statistics of consecutive high waves were done by Goda (1970), for wide spectra, with additional derivations for narrow band spectra by Ewing (1973); evaluations of prototype data in water depths of 100 m by Rye (1975) and 40 m by Wilson and Baird (1973). These results are shown together with some results from the Elbe estuary in linear scale on Fig. 2.

The presented values for waves in a run higher than $H_{1/3}$ show large agreement, though there seem to be some specific differences.

Most of the "runs" with waves $>H_{1/3}$ occur in runs of only one wave, i.e. preceded and followed by smaller waves (70 to 85%). About 10 to 20% of the runs consist of 2 waves, up to 7% of 3 waves, up to 2.5% of 4 waves. More than 5 waves $> H_{1/3}$ in a run are not yet identified.

For further analysis this graph will be presented in semilogarithmic scale. Before that it seems to be useful to do some remarks on the evaluation and the definition of a group or "run". Table 1 gives the height numbers of consecutive waves in a record with the notification of waves $>H_{1/3}$ and numbers of wave groups. In general, one "event" is

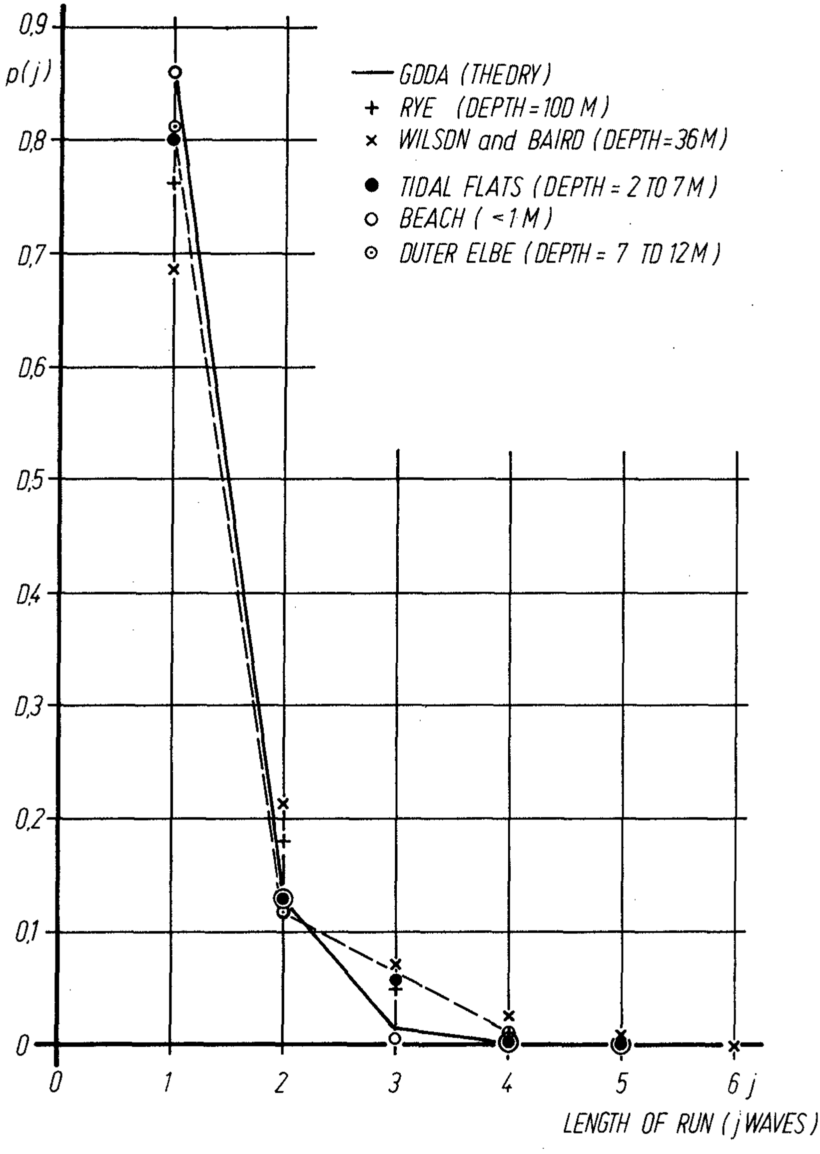

Fig. 2
Probability of Wave Group Formation,
Waves Greater than $H_{1/3}$

Table 1

Example for Evaluation of Wave Groups

Wave Heights in cm	Waves greater than $H_{1/3}$	Wave Group No.
23		
73	x	1
12		
40		
66	x	
66	x	2
84	x	
30		
30		
47		
50		
50		
18		
19		
14		
68	x	3
65	x	
45		
50		
36		

Mean values of the complete record: $\bar{H} = 40$ cm
$H_{1/3} = 61$ cm
$\bar{T} = 3.3$ sec

understood as a "group" of consecutive waves above a chosen limit, a "group" consisting of one or more waves in a row.

On the left side of Fig. 3 we see the before mentioned results. Theory seems to give too small probabilities for the occurance of 3 and more waves $> H_{1/3}$ in a run. The results from the outer Elbe and in greater depths are more or less identical.

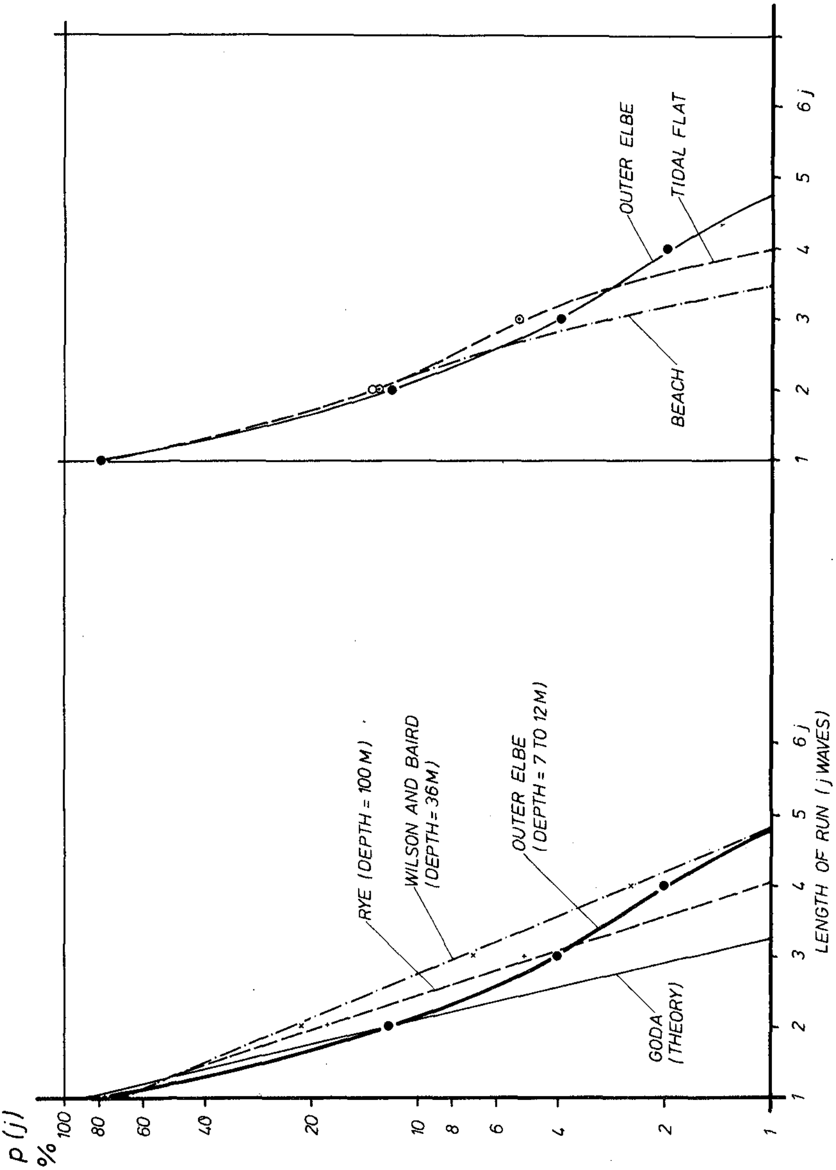

Fig. 3
Probability of Wave Group Formation with Waves Greater than $H_{1/3}$

The comparison on the right side of Fig. 3 shows that in very shallow water the probability of long runs is diminished and nearly the same as Goda's theory.

Some hints of changes of wave group behaviour with mean wave height can be given on Fig. 4. In three different topographic areas with different water depths it turns out that the probability of longer runs with $H > H_{1/3}$ raises with mean wave height. As possible mean wave height raises with water depth, the tendency is the same as on Fig. 3: increase of probability of long runs with high waves with increasing water depth.

The analysis of wave groups $> 1.8\,\bar{H}$ shows on the left side of Fig. 5 the same tendency as was seen with groups$>H_{1/3}$: In shallow water the probability of long runs of high waves becomes smaller.

On the right side we see that the probability of long runs diminishes with increasing predetermined height. But this result has to be considered in detail, as is shown on Fig. 6.

These graphs show the probability of wave group formation versus the relation of predetermined and mean wave height.

A certain number of records was evaluated as follows: All waves higher than H^* are 100%. Now each run contains a certain amount of these 100%.

The dots indicate the percentage of waves with $H > H^*$ that occured in the longest run of a record.

In connection with this the increase of wave periods with wave heights has to be taken into account, i.e. on Table 2 from the right to the left:

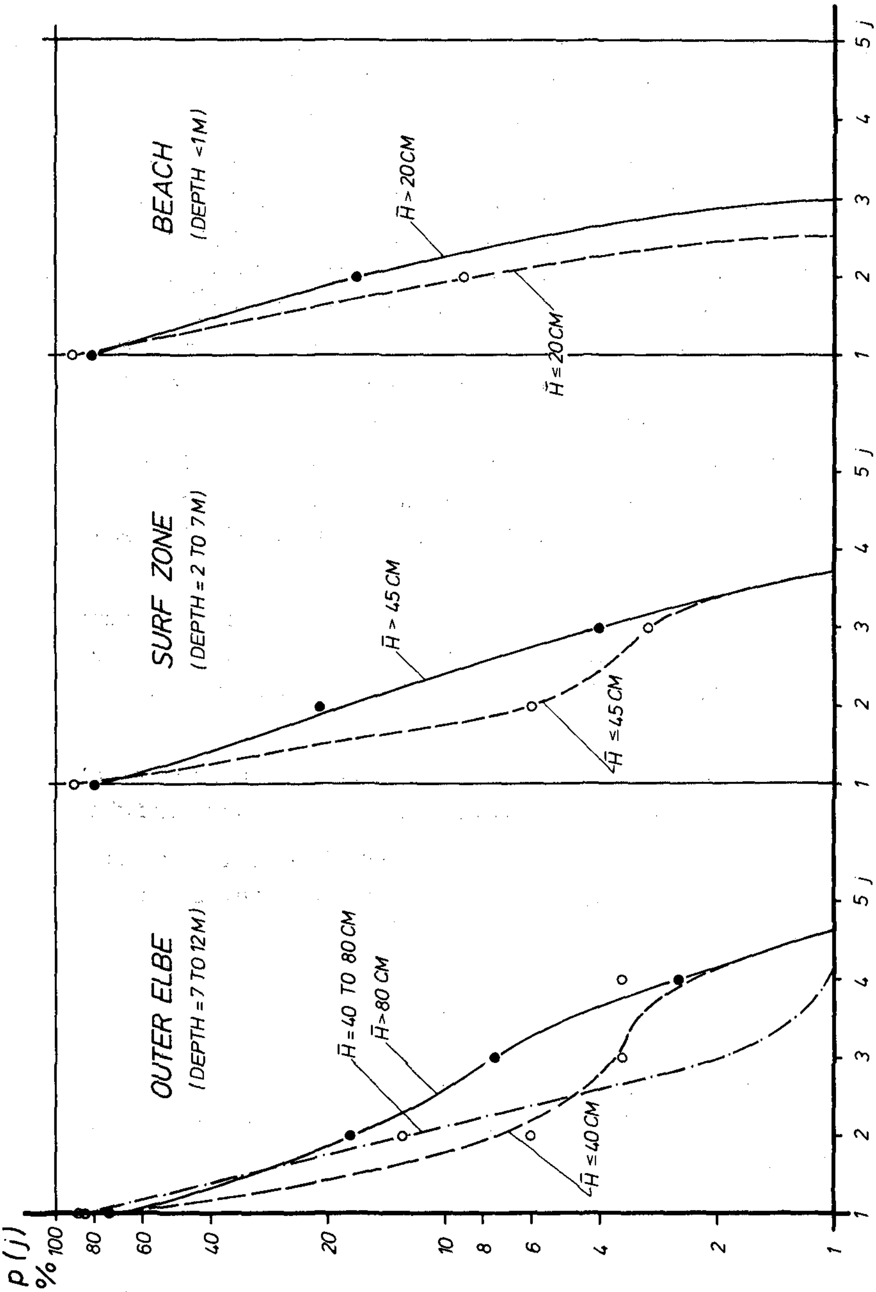

Fig. 4

Probability of Wave Group Formation with Waves Greater than $H_{1/3}$ for Different Topographic Areas and Mean Wave Heights

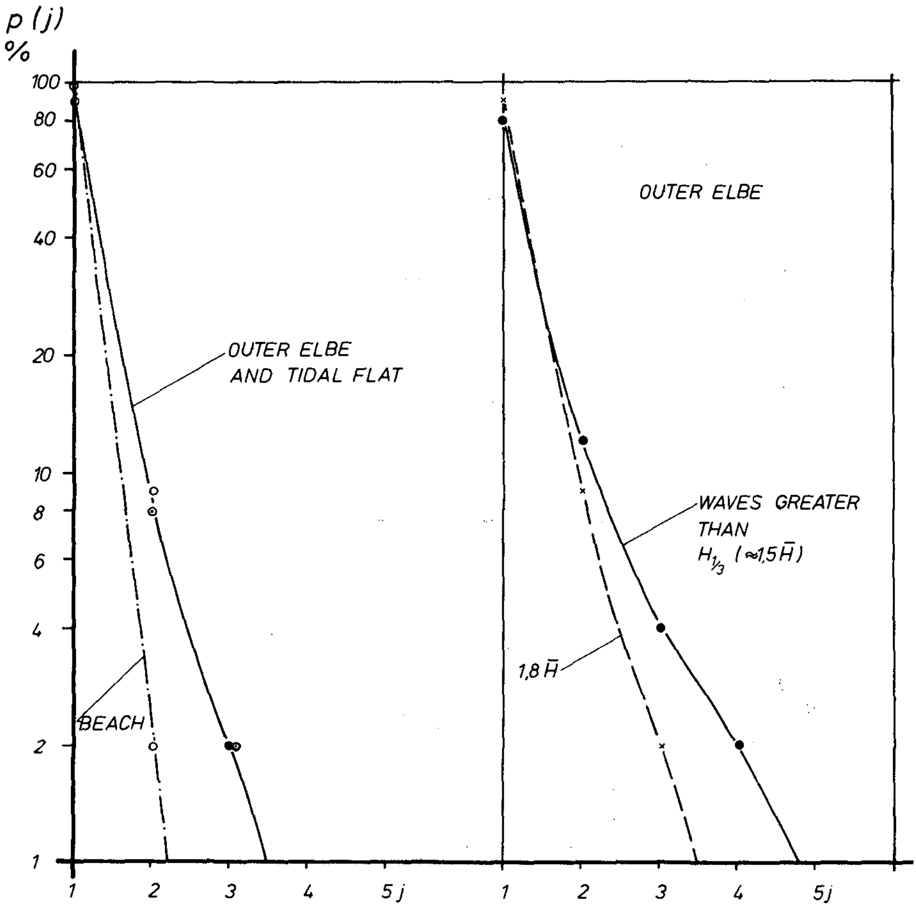

Fig. 5
Probability of Wave Group Formation
Waves Greater than 1.8 $\bar{H}$

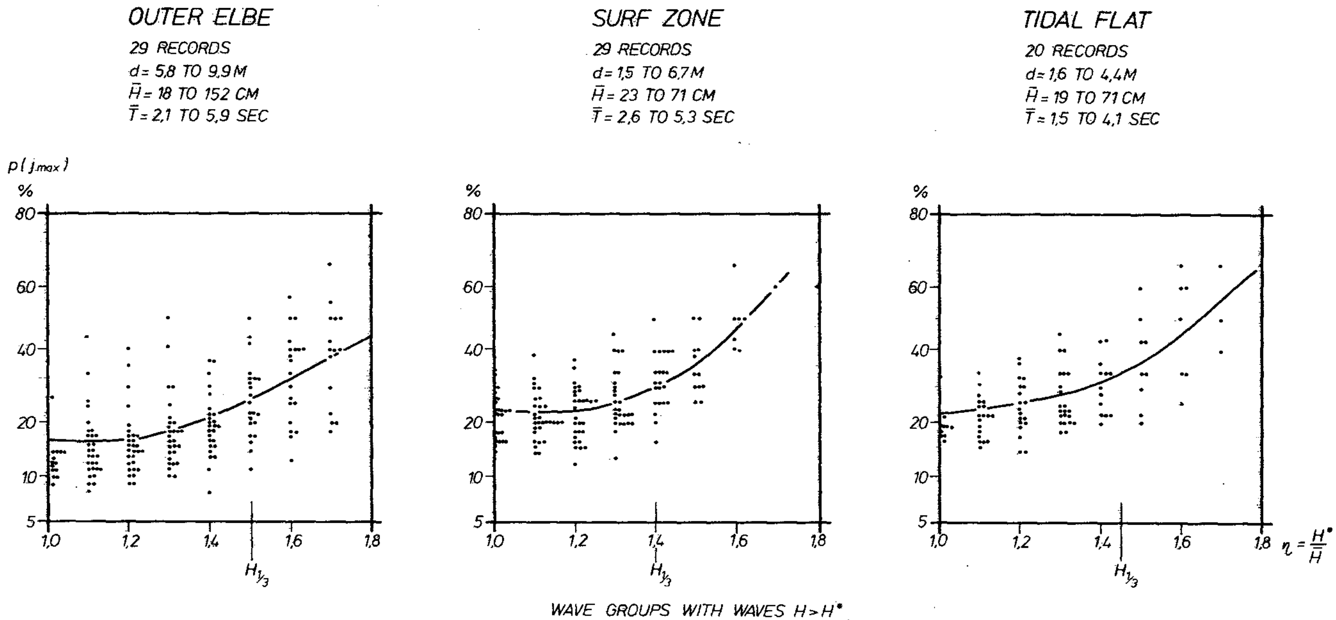

Fig. 6

Probability of Wave Group Formation
(Longest Run of Each Record with j_{max} Consecutive Waves $H > H^*$)

Table 2
Connections Between Wave Periods Of Different Wave Height Groups

SOUTHERN NORTH SEA	SURF ZONE	TIDAL FLATS
$T_{H_{1/3}} = 1.25\ \bar{T}$	$T_{H_{1/3}} = 1.19\ \bar{T}$	$T_{H_{1/3}} = 1.15\ \bar{T}$
$T_{H_{1/10}} = 1.33\ \bar{T}$	$T_{H_{1/10}} = 1.30\ \bar{T}$	$T_{H_{1/10}} = 1.22\ \bar{T}$
$T_{H_{max}} = 1.46\ \bar{T}$	$T_{H_{max}} = 1.30\ \bar{T}$	$T_{H_{max}} = 1.28\ \bar{T}$

Moreover, the formation of wave groups influences oscillations of wave set-up, and this way of wave analysis will also give some hints about the reliability of laboratory test results with monochromatic waves.

Not treated in this paper is the mean number of small waves between runs of high waves. Some informations on this problem are given by Ewing (1973).

Summary

The result of Figs. 3 to 6 is:

1. The greater H^* - the lower limit of the heights in the run - is, the lower is the number of waves above H^*;

2. The greater H^* is, the greater is the probability that a lot of the waves $>H^*$ occur in one run: Waves greater than 1.6 $\bar{H}$ appear in a run of 2 or 3 as often as in a "run" of 1 wave. Groups of 2 and 3 waves of a height greater than 1.7 or 1.8 $\bar{H}$ have been recorded.

3. The greater the relation of design wave height and mean wave height is, the more important becomes the dynamic force by consecutive design wave heights.

References

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