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MET O 3 TECHNICAL NOTE 19

FACTORS FOR CONVERTING THE MEASURED SIGNIFICANT WAVE AND RESULTANT ESTIMATED WAVE TO THE MAXIMUM THREE HOURLY WAVE HEIGHT

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1. Introduction

For the design and planning of offshore structures the wave height expected to be exceeded, on average, once in 50 years is required. This height is often referred to as the 50 year return value. Where measured data are available the 50 year return value is quoted in terms of either the significant wave height, or the most likely maximum wave height in a specified period, which is usually 3 hours. Often there are no measured data available in the area required and visual estimates of wave heights must be used.

The most likely maximum wave height depends on the number of significant waves and their distribution and is calculated using the relevant significant wave height as explained below.

2. Definitions

Zero-up-crossing wave

Wave recorders produce a wave trace of about 15 minutes duration every 3 hours. The trace is assigned (by eye) a mean line ie the line that would be produced if the sea were calm. A zero-up-crossing occurs when the surface passes through the mean line in an upwards direction. A zero-up-crossing wave is the portion of the record between adjacent zero-up-crossings (see figure 1).

Significant wave height: Hs

The significant wave height is derived from the 15 minute sample of a recorded wave trace extracted every 3 hours. The method used to derive the significant wave height and the associated zero-up-crossing period, Tz, is described in Carter and Challenor 1981. Hs is defined by:

$$Hs = 4\sqrt{m_0}$$

where m_0 is the variance of the sea surface elevation, or the area under the energy/frequency spectrum.

Maximum three hourly wave height: Hm

This is the most likely highest wave to occur in three hours, and depends upon the number and distribution of waves in that period. The heights of successive waves are assumed to be independent and to follow a Rayleigh distribution.

Hm is defined by:

$$Hm = Hs\sqrt{\ln(Nz)/2}$$

where Nz is the number of zero-up-crossing waves during the 3 hour period, ie:

$$Nz = \frac{3 \times 60 \times 60}{Tz}$$

Resultant wave: R

Deck officers of the voluntary observing fleet make visual estimates to the nearest half metre of the heights of the separate wave trains which combine to form the sea conditions encountered by the ship. The wave trains fall into two categories; the first consists of waves directly attirbutable to winds experienced at the time of observation and is known as the wind wave. The second category consists of waves generated by former wind conditions, or those which have propagated from other sea areas, and is known as the swell wave. The individual component heights are combined to give a resultant wave height. The combination of the two estimates is required to produce a distribution which is reasonably comparable with that of the measured significant waves. The wind and swell waves are initially combined using the relationship:

$$c = \sqrt{(\text{wind wave})^2 + (\text{swell wave})^2}$$

An 'equivalent' significant wave height, here called the resultant wave height, R, is calculated using the formula developed by Nordenstrøm (1971):

$$R = 1.68c^{0.75}$$

3. Method of Analysis

To calculate the once in 50 year return value of Hm two methods are available. Either the distribution of Hm could be used or the once in 50 year extreme value of Hs could be converted to the extreme Hm by assuming an average value of Tz.

The advantage of the second method is that it can also be used for converting an extreme value derived from resultant estimated wave heights to an equivalent Hm extreme.

To determine, in both cases, a suitable average value of Tz ratios of Hm/Hs and Hm/R were calculated. The data used is described below and the mean and standard deviations of the resulting distributions are shown in Table 1.

Data

The data used for comparison were measured values of Hs, and corresponding Hm, and the resultant, R, of the visual estimates of wave height from the $2^{\circ} \times 2^{\circ}$ area around the measuring stations. Only simultaneously observed wave heights were used, ie waves measured or estimated at the same time.

Where the measured wave heights were from ship-borne wave recorders (SBWR), it was necessary to convert to the equivalent wave rider buoy (WRB) wave heights because the SBWR is know to produce higher wave heights than the more acceptable WRB. The SBWR heights were reduced by 7 per cent using the relationship:

equivalent WRB = 0.94 SBWR (Graham et al, 1979)

The stations used and their positions are shown in Figure 1, ocean weather station 'L' is the only oceanic site but Famita, Brent, Stevenson, Boyle and FitzRoy are in well exposed positions as is the Seven Stones light vessel (LV). The other LV; Shambles and Varne, are close inshore and the corresponding resultant wave heights have been taken from the more exposed sea areas surrounding these sites.

4. Results

The mean value of the ratios of Hm/Hs is fairly consistent with small standard deviations, except for the two LV; Shambles and Varne. The different results here are probably due to the higher proportion of low significant wave heights at these stations due to their inshore positions. The mean value of all the ratios is 1.92, weighted according to the number of observations at each site. This gives Tz = 6.8 seconds.

The ratios Hm/R are more varied with larger standard deviations. The mean value of the ratios is 2.17 (also weighted) with mean standard deviation 1.39.

5. Conclusion

The factors given by analysis of wave data from 12 offshore recording sites for converting significant wave to the most likely 3 hourly maximum wave height, is 1.92, and for resultant wave to the most likely 3 hour maximum wave height is 2.17.

References

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Nordenstrøm, N. 1971 Methods for predicting long term distributions of wave loads and probability of failure for ships. Part 1, DnV-Report, No 71-2-5, Oslo.

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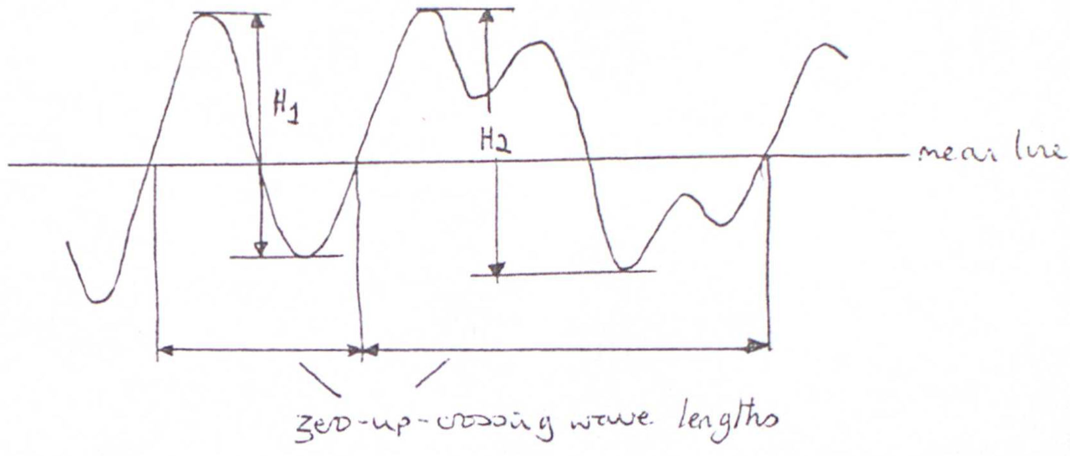
Table 1. Conversion factors

Station	R to Hm		Hs to Hm	
	mean	standard deviation	mean	standard deviation
Seven Stones LV	2.39	1.55	1.92	0.07
Shambles LV	1.25	1.01	1.79	0.56
Varne LV	1.80	1.24	1.88	0.40
Famita	2.24	1.01	1.92	0.01
OWS 'L'	2.13	0.89	1.91	0.02
Brent	2.22	1.23	1.97	0.10
Boyle (WRB)	2.20	1.25	1.92	0.06
Boyle (SBWR)	2.30	1.42	1.91	0.05
Fitzroy (WRB)	1.78	1.76	1.91	0.05
Fitzroy (SBWR)	1.88	1.74	1.91	0.05
Stevenson (WRB)	2.42	1.78	1.91	0.04
Stevenson (SBWR)	2.85	1.82	1.91	0.03

Figure 1 From Tann 1976, to illustrate zero-up-crossing waves.



H_1 and H_2 are zero-up-crossing wave heights.