JOINT PROBABILITY ANALYSIS OF EXTREME WAVES AND WATER LEVELS AT A TYPHOON INVADED COASTAL REGION

LI, C.W.*, and SONG, Y

Department of Civil & Structural Engineering, the Hong Kong Polytechnic University
*Correspondence address: Department of Civil & Structural Engineering, the Hong Kong Polytechnic University, Hong Kong
(Tel: +852-27666043, Fax: +852-23346389, e-mail: cecwli@polyu.edu.hk)

The coastal areas of Hong Kong are always subjected to the invasion of typhoons in summer. The typhoon-generated waves and surges are the extreme events that should be considered in setting the design criteria of coastal structures. As there is usually a time lag between the occurrence of the maximum waves and the occurrence of maximum water level (mainly due to surges), joint probability analysis of the joint events of wind waves and water levels is important. This work reports the joint probability analysis of wind waves and surges in the coastal waters of Hong Kong.

Criteria of selection of extreme joint events are first obtained by the analysis of available field data at Waglan Island. Joint event data of wave and surge are constructed firstly by combining the simultaneous data of significant wave height and surge level at tri-hourly intervals. To extract the joint event data for extreme values analysis, the joint event data should be statistically independent. A time interval τ of 24 hours is used to ensure that no more than one joint event datum is chosen from one storm. The local maximum within the time interval τ can be selected by several different methods. For the analysis of the field data all the following three methods were tried. The first is to use the maximum wave height in the interval τ with concomitant surge level. The second is to use the maximum surge level in the interval τ with concomitant wave height. And the last one is to use the joint events of wave height and surge which give the maximum structural response in the interval τ. In this study the algebraic sum of wave and surge is taken as the response function. The analyzed results show that the sampling methods using maximum wave or maximum structural response give the severer sea state comparing with the method using maximum surge or water level. The response function is structure dependent and is not general. So wave height is the key variable in selecting extreme joint events.

Fifty years of synthetic data of annual extreme wind waves and surges are then generated by means of a 3rd generation wind wave model and a flow model, with the tide level data produced by harmonic analysis. Using the models, the time history of the significant wave height and peak spectral frequency at 16 specified points around Hong Kong are simulated from 1950-1999. During the same period, the time history of the water level at the 16 points is computed. From the analysis of the field measured data of wave and surge (water level) at Waglan Island, it is apparent that the wave height is predominant in the joint probability analysis. So the selection criterion of annual extreme typhoon event is that the typhoon should produce the annual maximum wave height. From the modelled data the annual extreme joint events of wave height and water level with wave height being the maximum can be extracted for further analysis.

The bivariate logistic model is used in the joint probability analysis. For typical results,

Fig. 1 displays the isolines of the joint exceedance probability at Point 6.

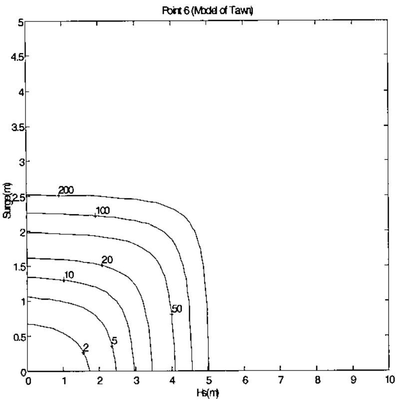

Fig. 1 Isolines of joint-events with different return periods (joint exceedance probability) at point 6

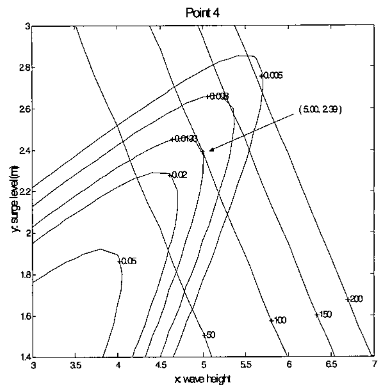

Fig.2 Illustration of the failure domain and the joint exceedance probability plotted on the graph of probability density function

To demonstrate the application of the results to coastal engineering design, various environmental loading functions due to waves and water level are selected. And the failure probabilities are calculated directly using the joint density function of waves and water level. Compared with the criterion of using joint exceedance probability, the present approach offers some advantages. It can take full account of all possible failure conditions under a specified response function and can give the uni-solution with maximum possibility which can be directly applied in coastal structure design.

Fig. 2 gives the isolines of the load effect on sea defense at Point 4 with different return periods. On each isoline of load-effect, the point corresponding to the highest probability density is the most probable extreme sea state of environment factors. It is just the tangential point between the isoline of load effect and a particular isoline of the probability density as indicated by an arrow in Fig. 2.

The results show that the failure probabilities are not sensitive to the commonly employed design function for coastal structures, and the simplest case of failure probabilities for total water level can be used as a close approximation.