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Relationship between high-order non-linearity of random waves and wave pressures acting on offshore breakwaters

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In the design of breakwaters, the wave pressures out of the surf zone are estimated by the maximum wave height which corresponds to the 1.8 times of significant wave height according to Rayleigh theory. On the other hand, the nonlinear four-wave interactions can lead to a significant enhancement of occurrence frequency of extreme waves which have more than twice the significant wave height. It is necessary to appropriately evaluate the effects of the deviation from Rayleigh theory on the wave pressures acting on offshore breakwaters under extreme wave conditions. In this study, the physical experiments in a wave tank were conducted to understand the effect of the occurrence frequency of the maximum wave height on the wave pressures acting on offshore breakwaters. In our analysis, the wave pressures acting on breakwaters were estimated by using three kinds of the maximum wave heights. The first and second are the maximum wave height and the 1.8 times of significant wave height obtained from the physical experiments. The last is the maximum wave height given by the Japanese design method for breakwaters taking into account the nonlinear wave shoaling effects. As a result, the occurrence frequency of the maximum wave height given by the physical experiments is in a good agreement with the high-order nonlinear theory by Mori and Janssen (2006) and there is the deviation from the Rayleigh theory not only offshore but also in the intermediate depth. Moreover, the wave pressures using the maximum wave height are widely distributed to the designed value of the wave pressure while the dispersion of the wave pressures using the 1.8 times of the significant wave height is small. As the non-linearity of the waves becomes stronger, the wave pressures tend to exceed the designed value of the wave pressure on the average through the behavior of the maximum wave height depending on the kurtosis which is the indicator of the high-order nonlinear interactions. Finally, it is possible to evaluate the uncertainty of the wave pressures including the deviation from the Rayleigh theory by using the occurrence frequency of the maximum wave height which depends on the kurtosis changing.