Wave energy attenuation by a thin rigid floating plate

Background

The interaction between water waves and long thin floating objects has a wider range of applications in different research fields linked to ocean, sea and coastal areas (e.g. wave-ice interaction and hydrodynamic of VLFS). A proportion of water waves is transmitted by the floating object, a proportion is reflected and the rest is dissipated. Wave-induced motions and flexural motions (for the case of an elastic body) occur. In the case the freeboard (the height of the upper surface of the body with respect to the calm water line) of the floating object is very low, water can wash the upper surface, causing an extra energy dissipation (which is a strong non-linear phenomenon). It is fundamental to understand the energy transmission by the floating plate and the role of different dissipative mechanisms, especially overwash.

Objective

It is aimed to explore the role of overwash and downwash (water traveling underneath the plate) on the energy dissipation caused by a thin rigid floating plate using numerical simulations.

Method: CFD model

Computational Fluid Dynamics (CFD) is used to numerically solve the problem. An open source fluid dynamic library, OpenFOAM, is used to do so. A numerical (virtual) wave tank is designed. The plate is located in an overwash region, which moves with the body itself. Finite Volume Method (FVM) is used to discretize the governing equations. The discretization of all convective terms of NS are performed using Gauss integration. Diffusion terms of the NS equations are interpreted using a second-order central scheme. The convective terms of governing equation are discretised using Van Leer limiter. The temporal discretization is performed using Euler scheme. The time step size is adopted in the numerical simulation (each time step) such that the maximum local Courant Number within the domain is less than 0.3. NS are solved using the PISO algorithm. Dynamic equations are coupled with the fluid equations. Equations of motion are solved using a fifth-order cash-karp embedded Runge-Kutta method.

Forcing condition

Random waves are numerically generated at the left end of the domain, and absorbed at the right end. JONSWAP spectrum is used to generate the waves. A wide range of waves with peak wavelengths varying between 0.2L to 10L and steepness (the product of the wave number and half of the significant wave height) ranging between 0.04 to 0.15 are produced.

Results

Energy dissipation caused by the overwash and downwash are found. Overwash waves are seen to highly depend on the steepness of the incoming wave. But, energy dissipation caused by overwash converges to zero by the increase in the peak wavelength. Downwash is observed to cause significant dissipation at small wavelengths. It has been seen that downwash energy dissipation vs. steepness follows a linear function.

Overwash energy is formulated as $\frac{E_{OW}}{E_{in}} = 6g^2\gamma V_s^2 L\frac{1}{10^\gamma}$. The mean height of overwash, and is found using curve fitting. The downwash energy dissipation is formulated as $\frac{E_{DW}}{E_{in}} = C_D g^{-\gamma}d_{FW}$. $C_D$ is the drag coefficient of the thin plate (found by curve fitting), which depends on the draft (the depth of the lower surface of the plate with respect to calm water line) over length ratio of the plate.

Conclusion

Overwash and downwash are two important dissipative mechanisms that can cause significant energy dissipation. CFD models can properly compute the energy dissipation caused by these two mechanisms. Two equations are used to estimate the overwash and downwash energy dissipations, the results of which fit with the CFD data.

More Information

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