A parametric study for storm waves is conducted by varying wave conditions and deck geometry. For engineering purposes, a simplified design equation to estimate the wave-induced loads, which would assist design engineers, is missing. Two empirical equations for the vertical force and horizontal force on a submerged deck due to storm waves are developed. The equations are optimized (using MATLAB) to give the smallest mean absolute error for the load. Results of the parametric study will be presented, along with comparison between the GN empirical equations, and existing laboratory experiments.

The Empirical Equations

Typically, a computational fluid dynamics (CFD) program is used to determine the loads on a submerged deck. Empirical equations that estimate the loads on the deck based on deck geometry and wave conditions would help engineers in the design process by saving time that it would have taken for the CFD program to run. Hence, a design-type equation to estimate the loads on a submerged deck is of interest. Using the results of the parametric study, the general forms of the empirical equations are determined. Empirical equations are developed to describe the uplift force and horizontal positive force given by the Level I GN equations. MATLAB is then used to optimize coefficients in the general form to minimize the mean absolute error of the load. The optimization process is performed by using nested loops that calculate and compare the load for different combinations of coefficients to the results of the parametric study. The final form of the dimensionless empirical equations are given in Eqs. (1) and (2).

\[ F_2 = 0.34(1.68 - B_0) \left( \frac{H}{L} \right) \left( 1 - e^{-B_2 \frac{h}{L}} \right) \]  

\[ F_1 = 2.75B_0 \frac{H}{L} \left( 1 - e^{-B_1 \frac{h}{L}} \right) \]

The dimensional form of the empirical equations for the uplift force and horizontal positive force are given in Eqs. (3) and (4), respectively.

\[ F_2 = F_2 \rho g L^2 \]  

\[ F_1 = F_1 \rho g L^2 \frac{B_1}{\rho g L^2} \]

Comparisons

The empirical equations are compared against laboratory experiment data and wave loads on prototype bridge cases. The laboratory experiment data also includes a comparison against the Level I GN equations and long-wave approximation 3-WAV (see Fig. 10). The comparison of time series of storm load calculated by OpenFOAM (a computation fluid dynamics program), Level I GN equations and the empirical equations for the Majapahit bridge on Oahu is shown in Fig. 10. The results show good agreement between the empirical equations and laboratory data while Equation (1) slightly overestimates the horizontal force on the Majapahit bridge.

Conclusion

- A parametric study for storm waves is conducted by varying wave conditions and deck geometry.
- A design-type equation to estimate the loads on a submerged deck is determined. The results of the empirical equations are in good agreement with the Level I GN equations, laboratory experiment data and bridge prototype cases.
- The design-type equations can be used by engineers when designing new bridges or piers.

References
