OE4080

Wave loads Estimations Using Morison Equation

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Summary

This report describes the application of Morisons Equation to calculate the wave loads on a cylindrical pile submerged in water. We have implemented the same in MATLAB, using several input parameters like the dimension of structures, the wave characteristics, and the theory to calculate the kinematics. We have implemented two theories: **The Extrapolate Airt Wave Theory** and **The Wheelers Stretching Theory**, then the wave loads obtained were compared.

Morison Equation

When designing offshore structures, the Morison Equation is a semi-empirical equation used to calculate the wave loads. The Inertia force and the Drag force are the two forces that make it up. The drag term is proportional to the signed square of the local instantaneous velocity, whereas the inertia force is related to the local particle acceleration. Two empirical hydrodynamic coefficients, an inertia coefficient C_D, and a drag coefficient C_M, which are derived from experimental data, are included in the Morison equation.

Morisons Equation can be written as:

$$F(t) = \frac{1}{2}\rho C_D D U(t)\left|U(t)\right| + \rho C_M V \dot{U}(t)$$

where,

ρ is the density of the fluid

C_D, C_M are the empirical coefficients

D is the diameter of the cylinder

V is the cylinder volume per unit length

$\left(U(t), \dot{U}(t)\right)$ describes the local instantaneous kinematics of the water particle.

Extrapolated Airy Wave Theory

The kinematics described by the Airy Wave Theory is applicable at a distance z below the mean water level. Mathematically,

$$U(t) = \frac{\pi H}{T}\frac{\cosh\left[k(d+z)\right]}{\sinh(kd)}\cos(kx - wt)$$

$$\dot{U}(t) = agk\frac{\cosh\left[k(d+z)\right]}{\cosh(kd)}\sin(kx - wt)$$

where,

$U(t)$ and $\dot{U}(t)$.represent the particle horizontal velocity and acceleration

H, T, k, w are wave height, time period, wave number, and angular frequency respectively.

Wheeler's Stretching

In Wheeler's Stretching, the distribution down to the seabed is stretched by the kinematics produced by the Airy Wave Theory at the mean water level and applied to the true water level. Substitute the vertical coordinate z with z', where z' is determined by:

$$z' = (z - \eta)\frac{d}{d + \eta}$$

where η is the free surface elevation.

Force Estimation

The algorithm used to estimate the force experienced by the cylindrical structure placed in water with regular waves and known parameters is explained below.

1. Divide the waves into n time steps.
2. Divide the submerged structure into sub-segments.
3. Apply the Morison Equation with appropriate kinematics to estimate the force per unit length at each of the sub-segment.
4. To determine the force at this specific time step, perform numerical integration of the determining force on all the sub-segments according to certain accepted rules.
5. Repeat the above steps for each time step to get the force-time data.

The algorithm was implemented in MATLAB and the code can be accessed here.

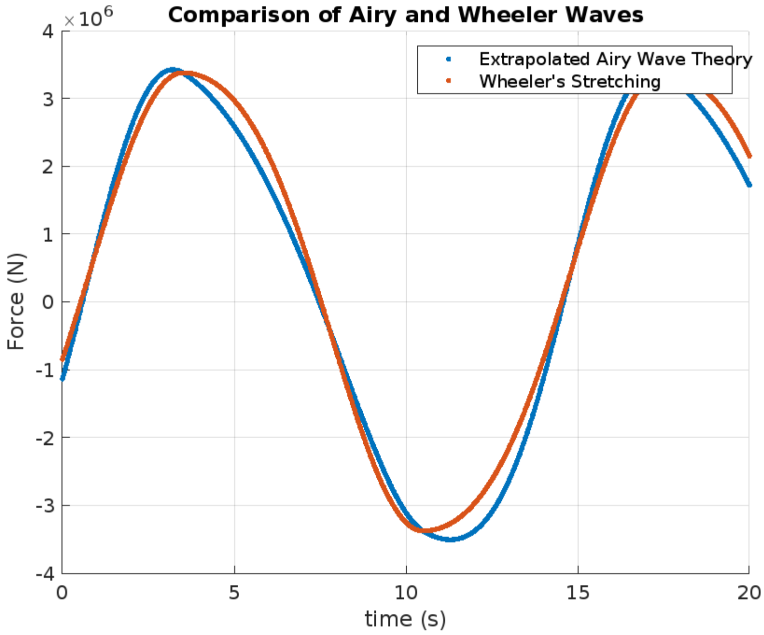
Results

Using the algorithm described above, the forces on two different cylindrical constructions for a given input regular wave were calculated. The following were used as the wave parameters and sea depth inputs:

- $H = 18$ m
- $T = 14$ s
- $d = 85$ m
- $L = 85$ m

1. Mass dominated structure

   $D = 5$ m



2. Drag dominated structure

   $D = 0.5$ m