# INVESTIGATION INTO SNAP LOADING OF CABLES USED IN MOORED BREAKWATERS

by

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(ABSTRACT)

A two-dimensional, nonlinear dynamic analysis is conducted on a moored breakwater configuration to investigate snap loads in mooring lines. Breakwaters are structures used to attenuate or eliminate waves and protect shorelines, harbors, and other natural and man-made marine structures from wave damage. The breakwater in this investigation is modeled both as a point mass and as a rigid body. Both models are subjected to free undamped motions and forced undamped wave motion. Energy is dissipated through the use of a coefficient of restitution applied when a mooring line becomes taut (i.e., reaches its natural length). The mooring line is modeled as an inextensible cable with no axial or bending resistance when slack. Snap loading arises when a mooring line transitions suddenly from a slack condition to a taut condition. The analysis was conducted on a breakwater configured upside down and hanging by two mooring lines. The length of the mooring lines, coefficient of restitution, size and shape of the breakwater, initial position of the breakwater, amplitude of wave forcing, ratio of vertical to horizontal forcing, and frequency of forcing were all varied in the analysis. The results show that the rotations of the rigid body and the wave forcing have a significant role in the analysis, indicating that a rigid-body model for a moored breakwater under wave forcing is the more accurate model.

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# Nomenclature

**(Definitions of Symbols and Terms)**

| | |
|---|---|
| A,a: | horizontal dimension of breakwater, from center to edge |
| $a_{mn}$: | entry in velocity matrix |
| B,b: | vertical dimension of breakwater, from center to edge |
| $b_{mn}$: | entry in impact condition matrix |
| C: | center of mass of breakwater |
| $c_n$: | various constants of integration |
| $CV_x$: | distance from C to V in x direction |
| $CV_y$: | distance from C to V in y direction |
| $CW_x$: | distance from C to W in x direction |
| $CW_y$: | distance from C to W in y direction |
| e: | coefficient of restitution |
| $f_{cr}$: | critical force |
| $f_o$: | amplitude of harmonic forcing function |
| $F_x$,$f_x$: | harmonic force applied in x direction |
| $F_y$,$f_y$: | harmonic force applied in y direction |
| g: | gravitational acceleration |
| $g_1$: | circular arc defined by right cable being taut |
| $g_2$: | circular arc defined by left cable being taut |
| H,h: | height of region U |
| $I_c$: | mass moment of inertia about its center |
| J: | left connection of cable to breakwater |
| $JV_x$: | distance from J to V in x direction |
| $JV_y$: | distance from J to V in y direction |
| K: | right connection of cable to breakwater |

KE: kinetic energy

$KW_x$: distance from K to W in x direction

$KW_y$: distance from K to W in y direction

L: Lagrangian

m: mass of breakwater

PE: potential energy

$Q_q$: generalized force for coordinate q

q: coordinate (x, y, $\theta$, $\alpha$, or $\beta$)

R/r: length of cable (radius of $g_1$ or $g_2$ circular arc)

S,s: spacing between centerline of the symmetric configuration and a support

T,t: time

$T_x$,$t_x$: phase for harmonic horizontal force component $F_x$

$T_y$,$t_y$: phase for harmonic vertical force component $F_y$

U: valley-shaped region defined by circular arcs $g_1$ and $g_2$

V: left support of cable to breakwater

$v_n$: normal velocity

$v_t$: tangential velocity

$v_x$: velocity in x direction

$v_y$: velocity in y direction

W: right support of cable to breakwater

X,x: horizontal direction

$\dot{x}$ : velocity in x direction

$\ddot{x}$ : acceleration in x direction

Y,y: vertical direction

$\dot{y}$ : velocity in y direction

$\ddot{y}$ : acceleration in y direction

$\alpha$: angle from vertical to taut mooring line

$\beta$: angle from vertical to line between connection points

$\gamma$: incoming and rebound angle

$\delta$: virtual displacement

$\delta W$: virtual work

$\theta$: angle of rotation of breakwater measured about its centroid

$\dot{\theta}$: angular velocity of breakwater measured about its centroid

$\ddot{\theta}$: angular acceleration of breakwater measured about its centroid

$\lambda$, $\lambda_1$, $\lambda_2$: Lagrange multipliers

$\nu$: ratio of amplitude of $f_y$ to amplitude of $f_x$

$\phi$: angle measured from horizontal to tangent line at point on $g_1$ circular arc

$\psi$: angle measured from horizontal to tangent line at point on $g_2$ circular arc

$\Omega$: frequency of harmonic forces

Note:

- upper case letters represent dimensional parameters
- lower case letters represent nondimensional parameters
- subscript (i) indicates a variable at time of impact or new initial condition after impact
- subscript (m) integer indicates column position in matrix
- subscript (n) integer indicates row position in matrix
- subscript (x) indicates a variable in the horizontal direction
- subscript (y) indicates a variable in the vertical direction
- subscript ($\theta$) indicates a rotational variable
- superscript (-) indicates a variable just before impact
- superscript (+) indicates a variable just after impact
- dot ($\bullet$) indicates a derivative
- subscript (o) indicates an initial condition
- hat ($\wedge$) indicates impulsive action