International Journal of Offshore and Polar Engineering
Vol. 2, No. 3, September 1992 (ISSN 1053-5381)

Ice Action onto Multilegged Structures Due to Change of Water Level

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ABSTRACT

In this paper the interaction of multilegged structures with the ice sheet rigidly frozen around them is considered. The ice sheet is moved vertically due to the change of the water level. The problem is treated as a static plate-bending one. The ice cover is treated as a brittle-elastic plate on the hydraulic foundation. It has been shown that the existence of the neighboring piles leads to a decreasing of the vertical ice load. The bending moment acting on the in-cluster piles is the new factor; it is studied in this paper. Some considerations about the existing relations for the determination of the ice force acting on the isolated pile are presented also.

NOMENCLATURE

a	: temperature conductivity factor
d	: pile diameter
D	: bending stiffness of ice sheet ($\mathbf{D} = \mathbf{E}h^3/12\ (1 - \nu^2)$)
$\mathbf{e}_r\mathbf{e}_\theta\mathbf{e}_z$	: unit vectors in cylindrical coordinates
$\mathbf{e}_x\mathbf{e}_y\mathbf{e}_z$	: Cartesian unit vectors
E	: Young's modulus for ice
h	: ice thickness
J_1	: Bessel's functions
ker, kei	: Kelvin's functions
K	: piles' mutual influence factor
L	: distance between pile centers,
$\underline{\mathbf{M}}$	: bending moment vector acting onto the pile
$\mathbf{n}_i$	: output unit normal vector to i-th pile cross section contours
$\mathbf{N}_i$	: shear force acting onto i-th pile
$\underline{\mathbf{N}}_i$	: vector of shear force ($\underline{\mathbf{N}}_i = \mathbf{N}_i e_z$)
P	: vertical force acting onto pile
r_i, θ_i	: polar coordinates associated with i-th pile
$\underline{\mathbf{r}}$	: radius vector
R	: pile radius
$\mathbf{R}_{eff}$	: equivalent pile radius
t	: time
W	: displacement of ice sheet in vertical direction
Γ_i	: cross-section contours of i-th pile
δ	: change of water level
$\Delta\mathbf{W}$	: Laplacian of **W**
γ	: specific weight of water
λ	: characteristic length ($\lambda^4 = \gamma / \mathbf{D}$)
μ	: thermal conductivity
ν	: Poisson's ratio for ice

INTRODUCTION

Existing ice codes and recommendations suggest the following equation to determine the maximal vertical ice force acting onto the isolated pile due to change of water level:

$$\mathbf{P}_{max} = \mathbf{k}_f \sigma_f \mathbf{h}^2 \qquad (1)$$

where $\mathbf{k}_f$ depends on the aspect ratio **d/h** (Table 1).

The relations presented in Table 1 are based mostly on a few results of the laboratory experiments (Frederking and Karri, 1983; Christensen, 1988; Nevel, 1972; Vershinin, 1985), in vivo observations (Hodek and Doud, 1975) and also on the solution of the thin plate-bending problem (Kerr, 1975; Kerr, 1978; Kerr, 1984).

At first, the problem of concentrated force action on the thin plate has been considered (Mishel, 1978). Gamayunov (1960) has considered the bending of the thin ring rigidly attached inside to the pile and loaded by the uniform pressure. Kerr (1975) obtained the expression for vertical force estimation using the exact solution obtained by Timoshenko and Woinowsky-Kriger (1959).

ICE CONE INFLUENCE

The experiments carried out by Christensen (1988) have shown that the actual values of the ice forces corresponding to the circu-

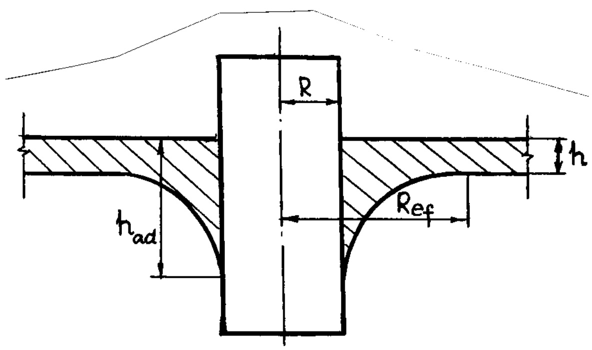

Fig. 1 Ice cones around the piles: a) MISI, 1985, in vivo test, natural ice: **R** = 51 cm, **h** = 6 cm; b) LSTU, March 1987, laboratory test, natural fresh ice: **R** = 11 cm, $\mathbf{R}_{eff}$ = 18 cm, $\mathbf{h}_{ad}$ = 9.5cm, **h** = 3 cm; c) Nippon Steel, 1988, laboratory test, ethylene glycol ice: **R** = 2.5 cm, $\mathbf{R}_{eff}$ = 4.5 - 5.5 cm, **h** = 3 cm, $\mathbf{h}_{ad}$ = 9 - 11 cm.

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Received July 20, 1991: revised manuscript received by the editors March 10, 1992. The original version (prior to the final revised manuscript) was presented at The Second International Offshore and Polar Engineering Conference (ISOPE-92), San Francisco, USA, June 14-19, 1992.
KEY WORDS: Multilegged structure, ice forces, change of water level,