

DEVELOPMENT OF A FIRST-YEAR RIDGE
KEEL LOAD MODEL

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ABSTRACT

This short document documents the development of a new modelling approach for first-year ridge keel loads. The development involves a detailed review of previous and new ice rubble indentation and shear strength experiments. A systematic regression analysis of compiled laboratory data sets is used to establish a basic approach to keel load modelling.

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analogous to that for soil retaining structures. Experiments pioneered by the modelling of first-year ridge keels with sand are also described. The dry sand tests afforded a high degree of control which led to the development of a new sand force prediction model that was adapted to ice rubble.

MODEL

The advantage of the new first-year ridge keel load model is that new effective structure width and keel shape methods are utilized, ridge width is factored in and surcharge effects are included. The model is based on fundamental earth pressure equilibrium principles as are other approaches already in the literature.

By

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A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES IN
PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

FACULTY OF ENGINEERING AND APPLIED SCIENCE

MEMORIAL UNIVERSITY OF NEWFOUNDLAND

DECEMBER, 1996

ST. JOHN'S

NEWFOUNDLAND

CANADA

ABSTRACT

This thesis documents the development of a new modelling approach for first-year ridge keel loads. The development involves a detailed review of previous and new ice rubble indentation and shear strength experiments. A systematic regression analysis of compiled laboratory data sets is used to establish a basic approach to keel load modelling, analogous to that for soil retaining problems. Experiments pioneering the modelling of first-year ridge keels with sand are also described. The dry sand tests afforded a high degree of control which led to the development of a new sand force prediction model that was adapted and calibrated for ice keel modelling.

The advantage of the new first-year ridge keel load model is that new effective structure width and keel shape models are utilized, ridge width is factored in and surcharge effects are considered. The model shows excellent agreement with a large body of new experimental data and the best field data available. Also, it is closed-form, has been successfully applied to both vertical and conical structures, and is based on fundamental earth pressure equilibrium mechanics as are other approaches already in the literature. A further advantage is that ice rubble shear strength yield criteria used in the model have been thoroughly examined so that associated parametric uncertainties are quantified and reduced. An *in situ* technique for testing the shear strength of ridge keels is developed and direction for future field work and modelling efforts is given.

ACKNOWLEDGEMENTS

The author wishes to express sincere gratitude for the contributions and guidance of the supervisory committee comprised of Gus Cammaert, Ken Croasdale and John Molgaard. Their insight, and friendly support has made the PhD academic process a rewarding one.

Support from colleagues Greg Crocker and Richard McKenna is also deeply appreciated. Dr Jack Clark and the helpful and professional staff at C-CORE are gratefully acknowledged for their support and friendship. Thanks also to Memorial University, Faculty of Engineering and Applied Science (esp. Dr J.J. Sharp) for providing the opportunity to undertake this work.

Special thanks to and recognition of the author's supportive family: wife Mary, children David and Laura, parents Jean and Angus, and brothers Peter and Ian.

This work has been financially supported by the following:

- The National Sciences and Engineering Research Council Canada,
- Government of Newfoundland and Labrador, Department of Education - Atlantic, Accord Career Development Awards,
- Centre for Cold Ocean Resources Engineering (C-CORE),
- Memorial University of Newfoundland, Faculty of Engineering and Applied, Sciences,
- K.R.Croasdale and Associates Ltd,
- Cold Ocean Design Associates Ltd (CODA),
- The National Energy Board,
- Public Works Canada, and
- Strait Crossing Incorporated.

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H_p	depth at point of peak load	W	total width
H_s	soil height	w	specified weight
H_{sur}	surcharge height	x	specified quantity
H_t	total height of sand at structure	x_1, x_2	mean standard dev. of quantity
h	level ice thickness	Σ	summation force
I	indentation coefficient	z	specified vertical position
K_a	active earth pressure coefficient		

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A	specified cross-sectional area	K_p	passive earth pressure coefficient
A_c	acceleration	K_o	at rest earth pressure coefficient
A_p	projected area	k	thermal conductivity
A_r	aspect ratio	L	latent heat of fusion
a	keel angle	L_i	ice blocks: thickness (minimum dimension)
B	specified length dimension	L_x	ice blocks: median of maximum dimension
b	limit sail height exponent	M	mass
C	limit sail height constant	Ma	added mass
C_d	drag coefficient	m	rupture distance for cone
C_m	inertia coefficient	m_c	shape factor
c	cohesion	n	void ratio
c_i	specific heat of ice	P	specified pressure
D	diameter/width of a structure	P_{en}	penetration distance
D_b	cone base diameter	q	Dolgoplov <i>et al.</i> (1975) shape factor
D_{eff}	effective structure width	R	radial distance
D_f	furrow width	R_f	ridge factor
D_s	neck diameter	r	forward rupture distance
d	vessel depth	r^2	regression correlation coefficient
E	modulus of elasticity	r_a	radius
e	porosity	S	salinity
F	specified force	s	side rupture distance
F_c	crushing force	T	temperature
F_{keel}	keel failure force	T_f	freezing point temperature
F_l	level ice failure force	T_i	ice surface temperature
F_n	normal force	t	duration
F_r	ridge failure force	U_o	far field velocity
F_s	shear force	u	longitudinal velocity component
F_{sail}	sail failure force	V	specified speed or velocity quantity
f	specified function	v	lateral velocity component
f_c	contact factor	W	ridge or keel width
g	gravitational constant	W_s	sail width
H	keel depth	w	specified weight
H_f	furrow depth	x	specified quantity
H_{ks}	total ridge thickness ($H+H_s$)	x_m, x_{sd}	mean, standard dev. of quantity
H_p	depth at point of peak load	Z_h	Weaver inertia force
H_s	sail height	z	specified vertical position
H_{sur}	surcharge height		
H_t	total height of sand at structure		
h	level ice thickness		
I	indentation coefficient		
K_a	active earth pressure coefficient		

Nomenclature continued

α	structure angle from vertical
β	flare angle
β'	apex angle
β''	half-apex angle
γ	specified unit weight
δ	surcharge angle from horizontal
θ	specified angle
λ	Weaver added mass factor
ν	dynamic viscosity
ν_p	Poisson's ratio
ξ	$= 90 - \alpha + \phi_1$
π	3.1415926
ρ	specified density
ρ_i	density of ice
ρ_w	density of water
σ	specified stress
$\sigma_1\sigma_2\sigma_3$	principal stresses: major, intermediate, minor
σ_{fl}	flexural strength
σ_h	horizontal stress
σ_{max}	maximum confinement stress
σ_n	normal stress
σ_v	vertical stress
τ	shear stress or strength as specified
ϕ	internal friction angle
ϕ_1	soil or ice against structure friction
ψ	Keinonen bow flare angle
ψ_2	Keinonen stem angle
ψ_3	Keinonen entrance angle
ω	rupture angle