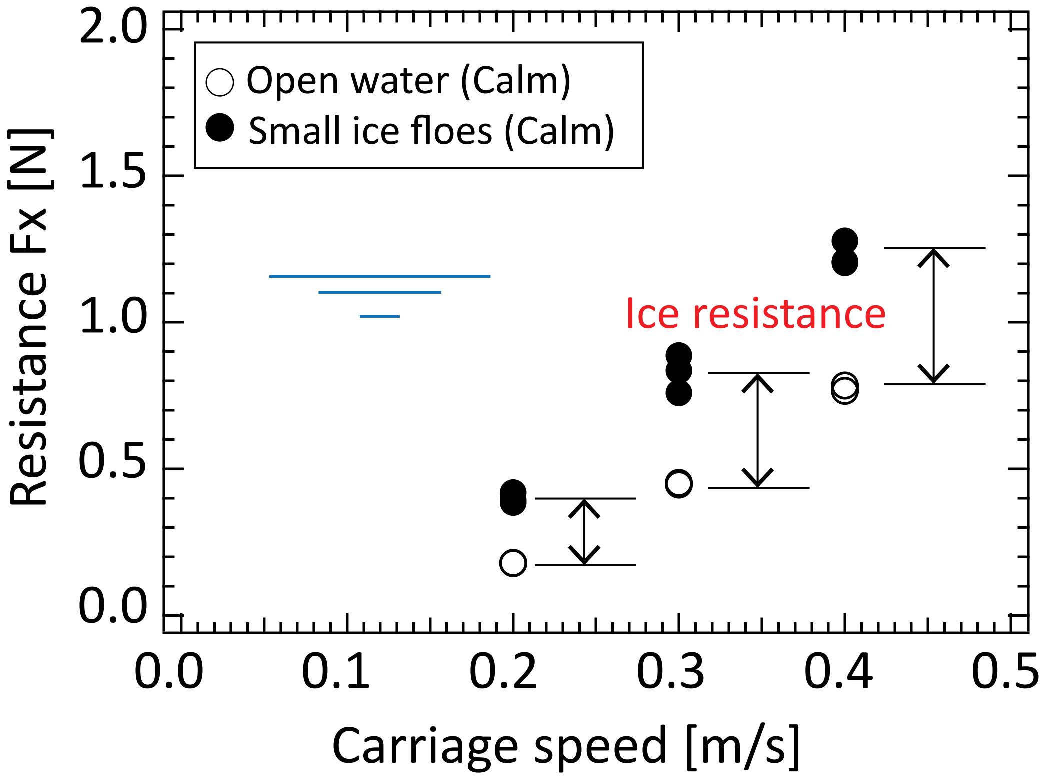
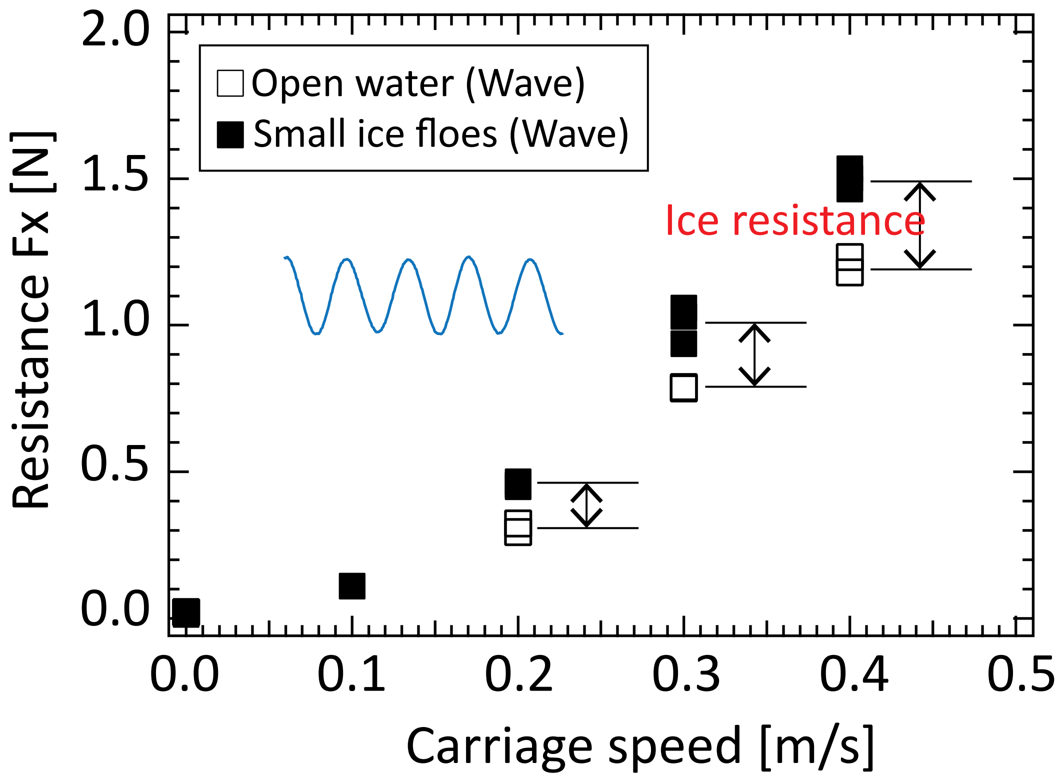
Ship in small ice floes + regular waves

■ Resistance



(A) Without wave

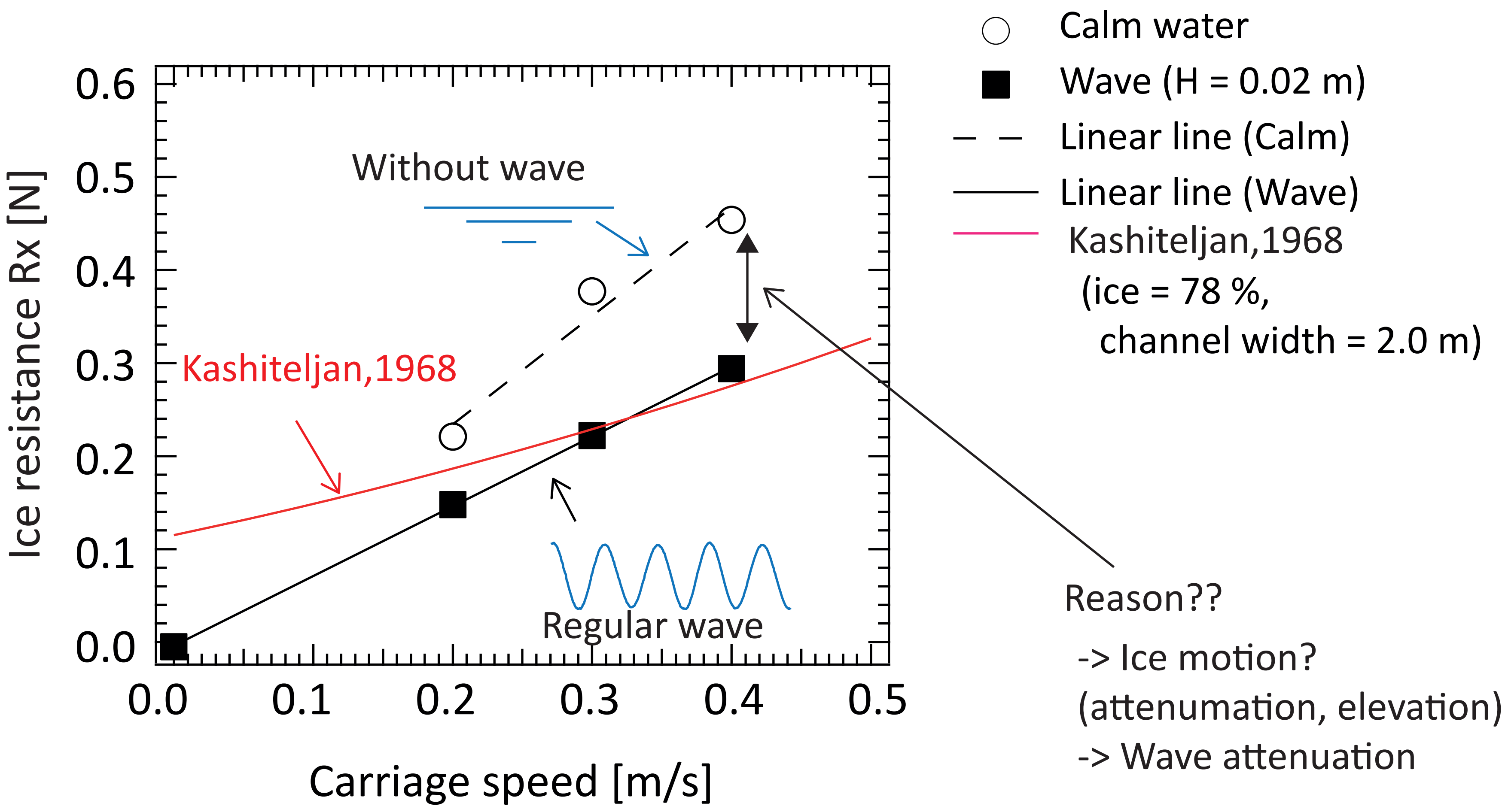


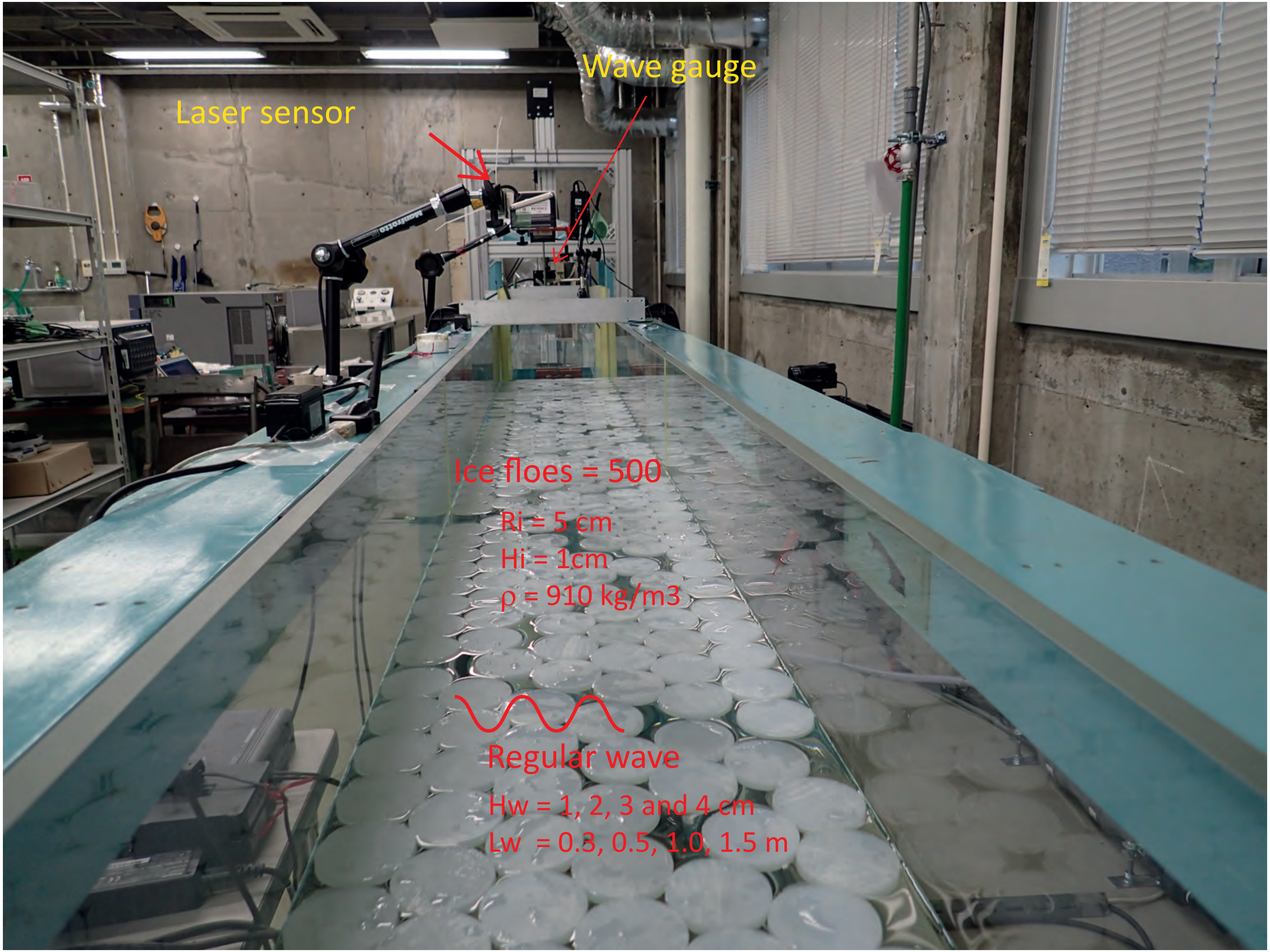
(B) Regular wave

*The test is repeated twice for the open water test and three times for small ice floes in one test condition to verify the accuracy of measurements.

Ship in small ice floes + regular waves

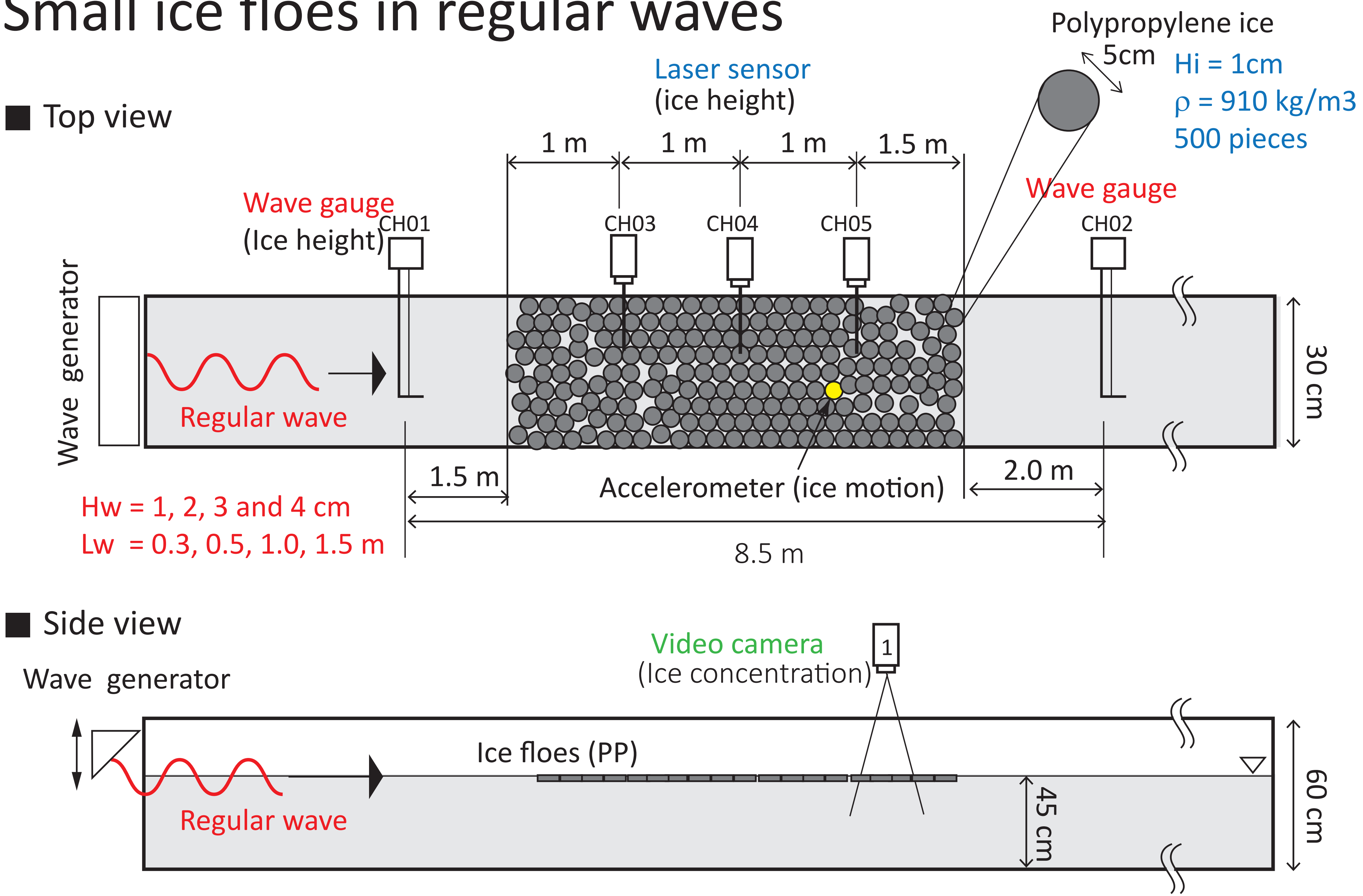
■ Comparison of ice resistance



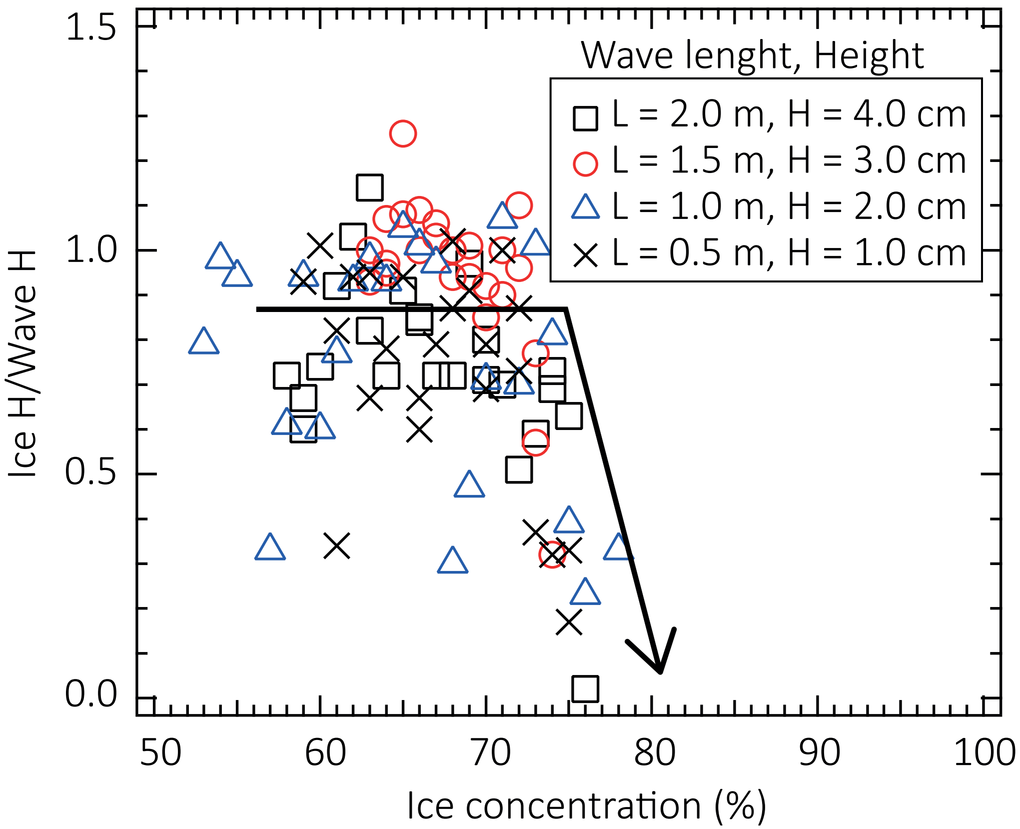


2D tank: Osaka University

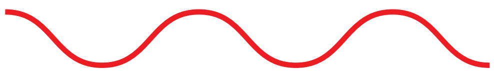
Small ice floes in regular waves

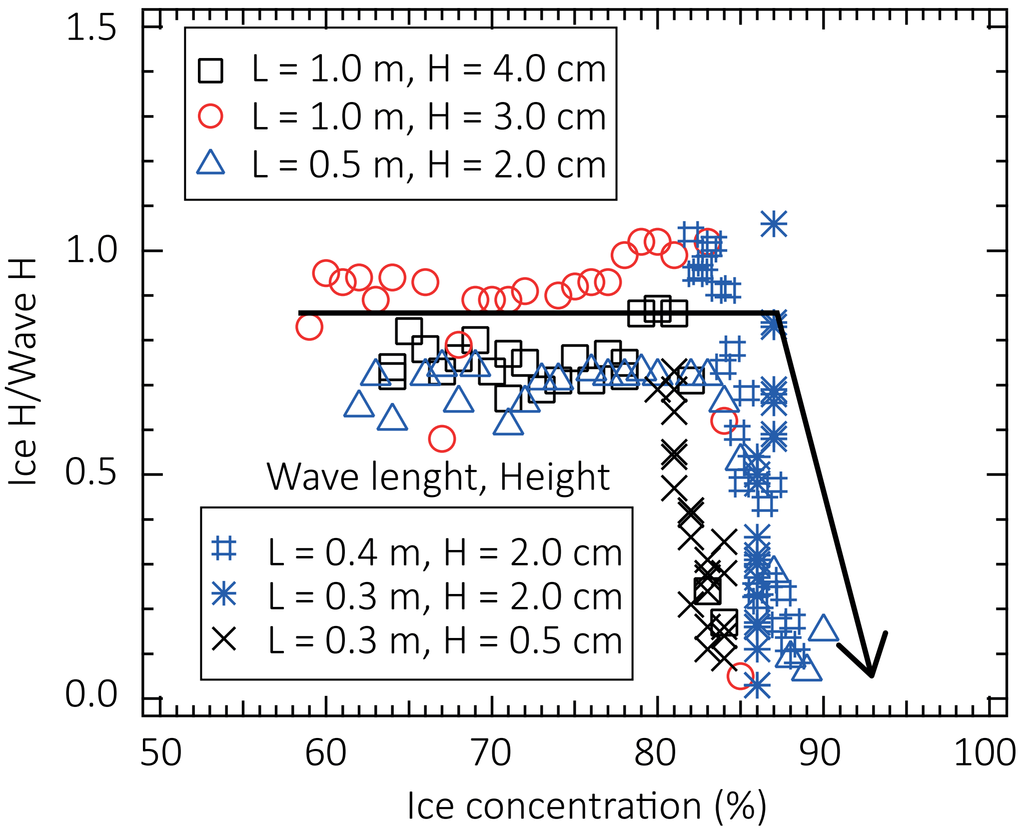


Relationship between Wave H/ice H and Ice C
(Wave attenuation)

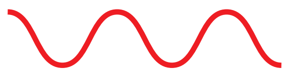


(A) Wave Height / Wave Length = 1/50





(B) Wave Height / Wave Length = 1/20-1/33.3

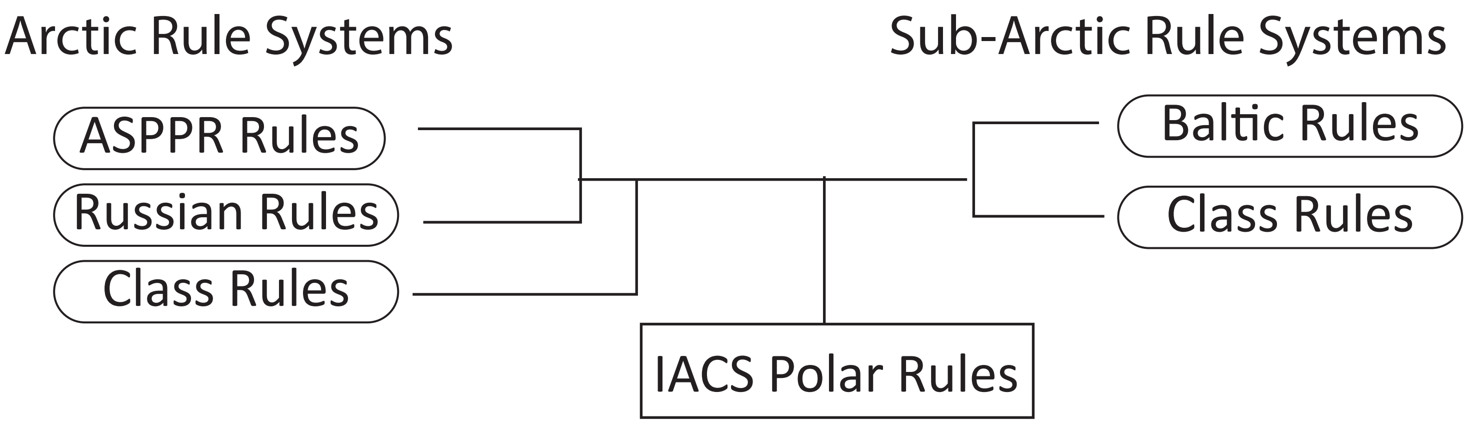


Ice Rules

Ice class refers to a notation assigned by a classification society or a national authority to denote the additional level of strengthening as well as other arrangements that enable a ship to navigate through sea ice. Some ice classes also have requirements for the ice-going performance of the vessel (from Wikipedia).

1. Power requirement 2. Hull strength 3. Propulsion machinery

IACS Polar Class Rules (URI)



Comparing Ice Class Rules

1. Design scenarios
2. Ice mechanics concepts (Ice load model)
3. Strength formulations (Elastic, Plastic, Ice Strengthened Hull Areas)
4. Operational
5. Parameters considered

Ref: Daley Claude, 2014 ,Ice Class Rules (From Wikipedia)

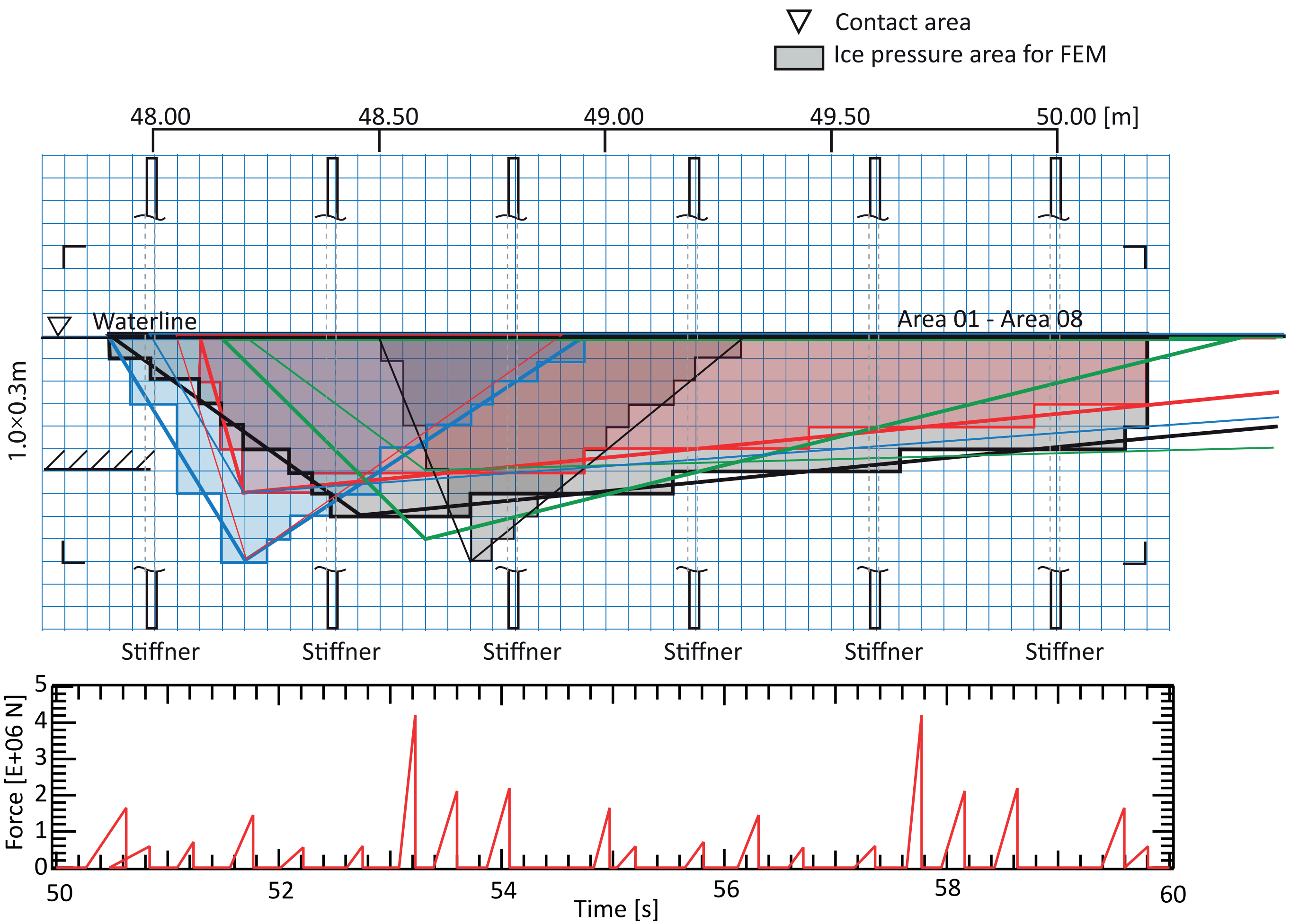
Comparison of Ice class rules

Ice Class							
RS (Rules 2008)		Arc9	Arc8	Arc7	Arc6	Arc5	Arc4
RS (Rules 1995)			-	ULA	-	UL	L1
IACS POLAR	PC1	PC2	PC3	PC4	PC5	PC6	PC7
CASPPR, 1995			CAC2	CAC3	CAC4	A	B
ABS			A4	A3	A2	A1	A0
DNV			POLAR-20	POLAR-15	POLAR-10	ICE-10	ICE-05
					ICE-15	ICE-1A	ICE-1A
LR			AC2	AC1.5	AC1	1AS	1A
GL (Old Rules)			Arc3	Arc 2	Arc1	E4	E3
FSICR			-	-	-	1A Super	1A
BV			-	-	-	1A Super	1A
NKK			-	-	-	1A Super	1A
KR			-	-	-	ISS	IS1
CCS			-	-	-	B1	B1
RINA			-	-	-	1AS	1A

Data from

1) Daley Claude, 2014 ,Ice Class Rules (From Wikipedia)
2) Northern Sea Route Handbook B_E, 2006, The Japan Association of Marine Safety
3) lecture note of DESIGN OF ICE-GOING SHIPS, 2007, Prof. Kaj Riska, NTNU

Structural response of stiffened panel under ice force



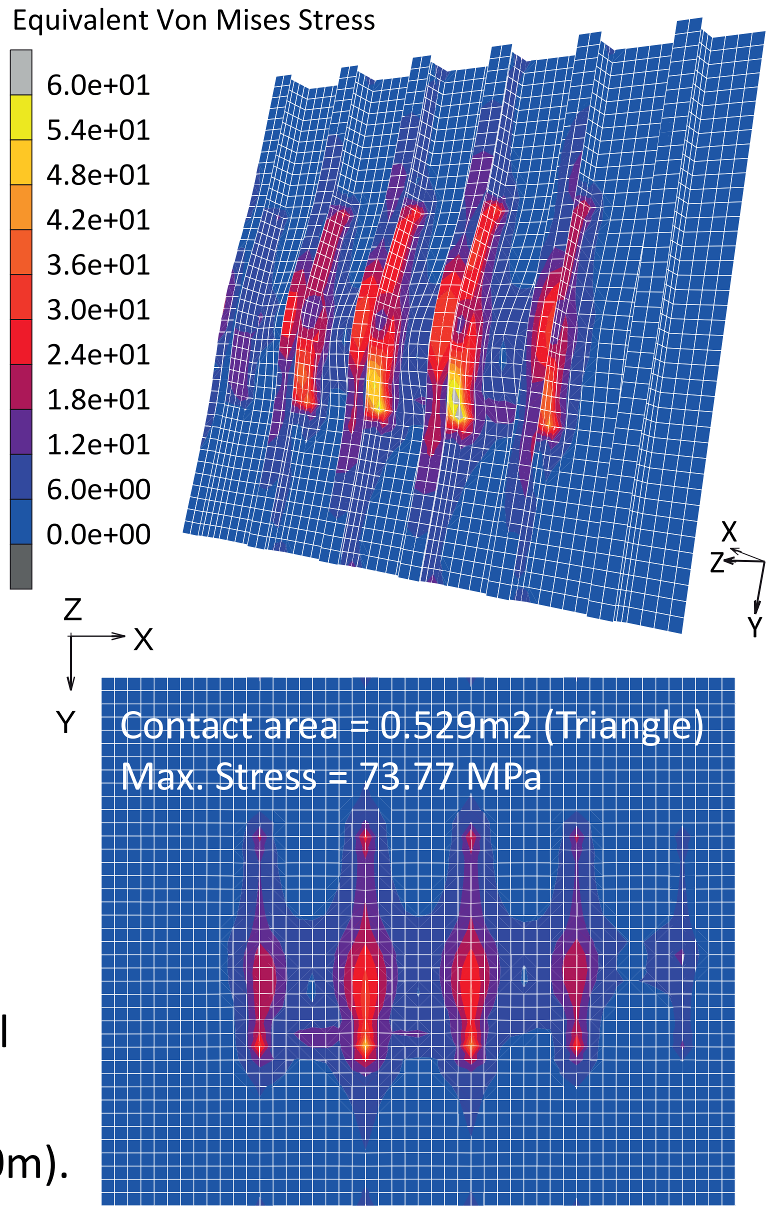


Fig.1 Ice pressured area and time history acting on the stiffened panel (Ice thickness = 0.5m, ship speed = 5.0 m/s).

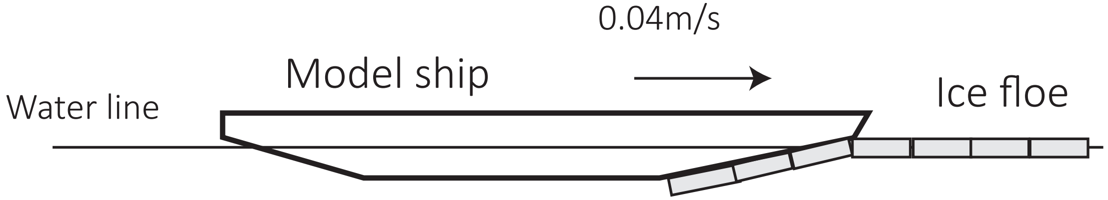
Fig.2 Equivalence Von Mises of stiffened panel (ice thickness = 1.0m).

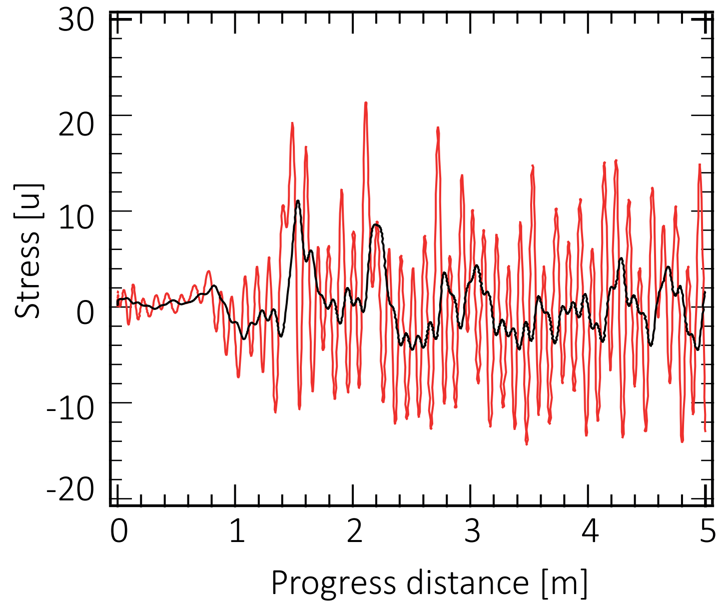
Junji Sawamura, Numerical study on the local ice force distribution in the ice breaking and ice submerging for the ship maneuvering in level ice, The proceeding of the 27th Asian-Pacific Technical Exchange and Advisory Meeting on Marine Structures, 2013, pp.280-287

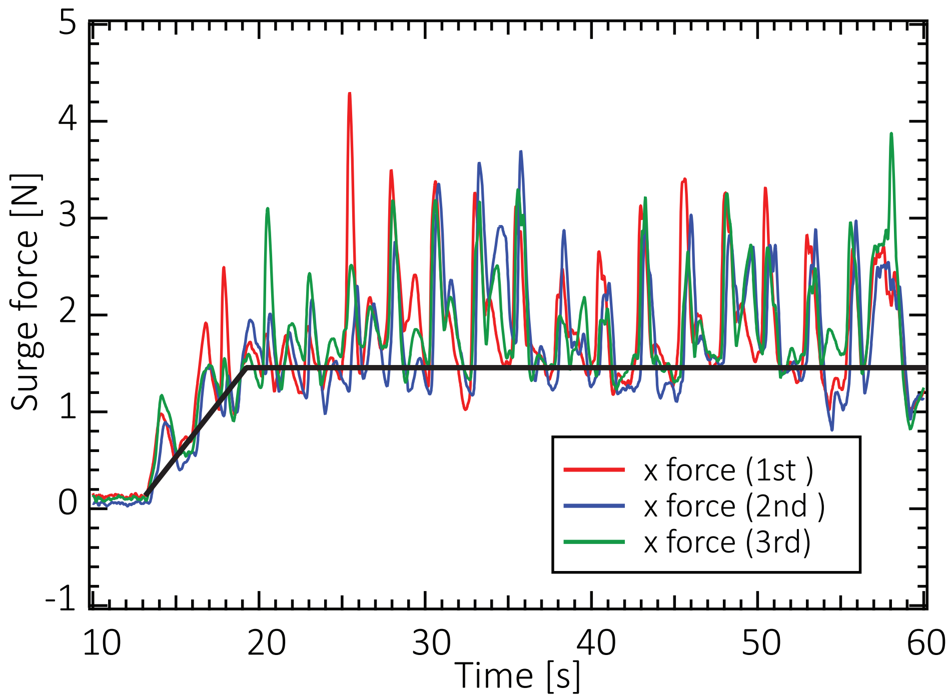
Ship local/global response

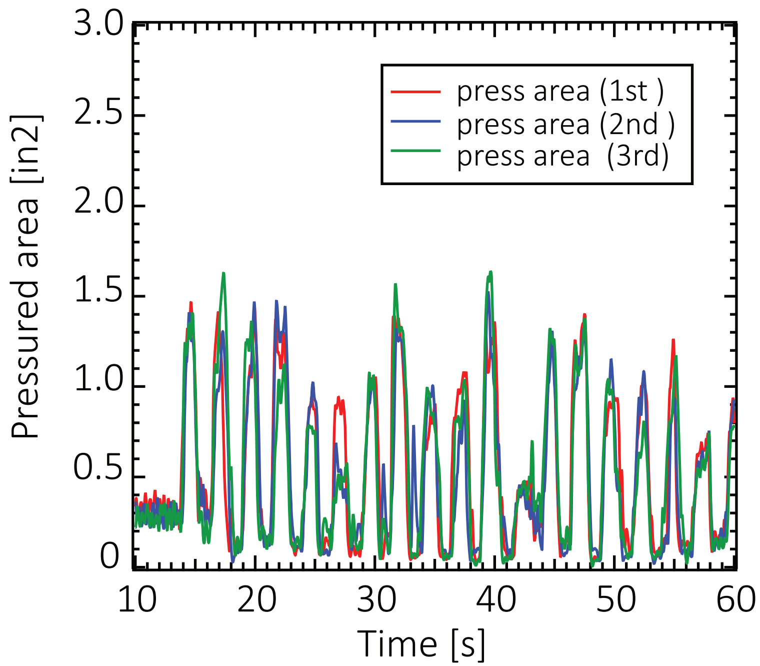
■ Ice force and ice puressure of 2D ship model

- Ship speed = 0.04 m/s
- Ice thickness = 0.02 m
- Ice length = 0.10 m









Junji Sawamura, Shinji Kioka and Akihisa Konno, Experimental and numerical investigation on ice submerging for icebreaker with 2D model test using synthetic ice, Proceedings of the 23nd International Conference on Port and Ocean Engineering under Arctic Conditions, 2015, No.34.

Ship local hull response

■ Comparison of Fatigue Damage in Sea ice (Ship side hull)

$$Z = \frac{p \cdot s \cdot h \cdot l}{m_t \cdot \sigma_y} 10^6$$

p: ice pressure as given in 4.2.2 [Mpa]
s: fram spacing [m]
h: height of load area as given in 4.2.1 [m]
l : span of the frames [m]
mt: 7m0/(7-5h/l)
σy: yield stress as in 4.3.2 [N/mm2]

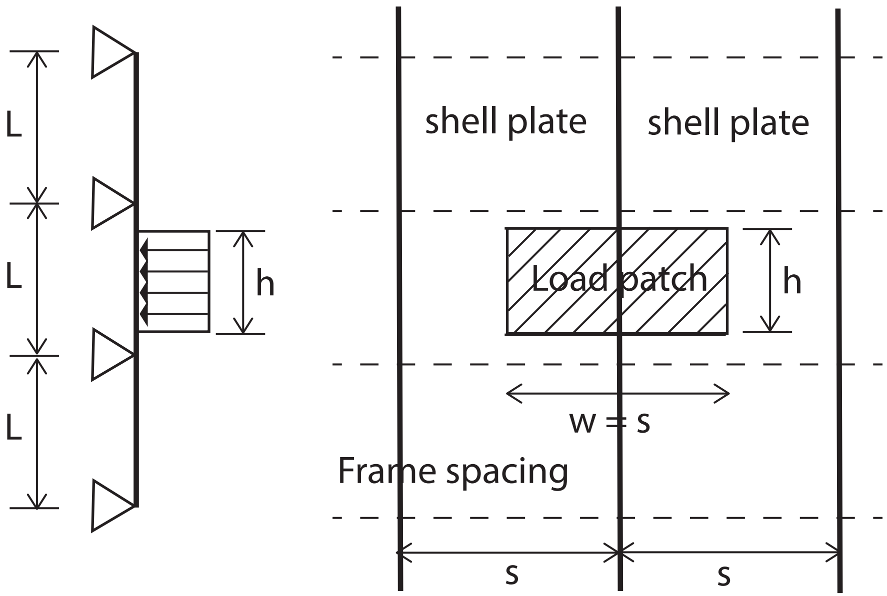


Fig. Model of ice load acting on the transverse frames and structures.
(Ref: THE STRUCTURAL DESIGN AND ENGINE OUTPUT REQUIRED OF HIPS FOR NAVIGATION IN ICE "FINNISH-SWEDISH ICE CLASS RULES (FSICR)")

Published by	Sea area	Ice condition	Fatigue damege
Suyuthi. A, et al. (2013)	Baltic Sea	Pack ice + Level ice + Ridge ice	5.836 × 10-4
Han and Sawamura (2016)	Baltic Sea	Level ice	5.617 × 10-3
Han and Sawamura (2017)	Antarctic Sea (Worby et al.,2008)	Pack ice	1.788 × 10-4
Han and Sawamura (2018)	Baltic Sea	Level ice + Ridge ice	4.270× 10-2

Yue Han and Junji Sawamura, Calculation of Ship Hull Fatigue Damage caused by Local Ice Loads in Ridged Ice Fields, The proceeding of 28th International Offshore and Polar Engineering Conference, 2018, pp. 1755-1762