
	<b>ITTC – Recommended Procedures</b>	7.5-02 -04-02 Page 1 of 4	
	<b>Testing and Extrapolation Methods Ice Testing Test Methods for Model Ice Properties</b>	Effective Date 2002	Revision 01

## CONTENTS

- 1 INTRODUCTION
- 2 FLEXURAL STRENGTH OF ICE
  - 2.1 Quantities to be reported
- 3 MODULUS OF ELASTICITY OF ICE
  - 3.1 Quantities to be reported
- 4 SPECIFIC WEIGHT AND DENSITY OF ICE
  - 4.1 Quantities to be reported
- 5 COMPRESSIVE STRENGTH OF ICE
  - 5.1 Quantities to be reported
- 6 VALIDATION
  - 6.1 Uncertainty Analysis

<b>Updated by</b>	<b>Approved</b>
Specialist Committee: Ice of 23 <sup>rd</sup> ITTC 2002	23 <sup>rd</sup> ITTC 2002
<b>Date</b>	<b>Date 2002</b>

	<b>ITTC – Recommended Procedures</b>	7.5-02 -04-02 Page 2 of 4	
	<b>Testing and Extrapolation Methods Ice Testing Test Methods for Model Ice Properties</b>	Effective Date 2002	Revision 01

## Test Methods for Model Ice Properties

### 1 INTRODUCTION

In ice testing Froudes scaling laws are followed. Model testing facilities are using different types of model ice materials. None of the existing model ice materials is perfect. Ice properties measured with one type of material cannot be directly compared with the others. The ice committee recognizes that, in most cases, the values measured are only “indices”. However, whether it is an index value or a fundamental mechanical property, the measurement procedure is to be standardized.

Model ice materials are quite weak and environment dependent. To maintain good reliable results, it is recommended to perform the property measurements in-situ in the tank water, without lifting the samples out of the natural environment, whenever possible. The timing and location of the measurements are important. The measurements are to be done as close as possible to the actual test area and test time.

All measurement procedures are to be very simple, the procedures are to be documented, and the personnel performing the measurements have to be qualified. In all measurements, equipments are to be calibrated in ambient temperatures.

### 2 FLEXURAL STRENGTH OF ICE

The in-situ cantilever beam method is recommended to measure the flexural strength of an ice sheet. A floating cantilever beam having

length,  $L$ , and width  $B$ , is cut in-situ. The tip of the beam is loaded at a constant speed until the beam fails. The loading direction can be either downward or upward, and will correspond to the same bending direction as is anticipated in the scheduled model test.

The recommended dimensions of a beam are:  $L = (5-7) \times h$ ,  $B = (2-3) \times h$ , where  $h$  is the thickness of ice. To cut the beams in the same manner each time, it is recommended to use standard pattern/jigs for a selection of ice thickness values. The loading speed (i.e. the displacement rate at the tip) is recommended to be about 1 mm/s.


The flexural strength  $\sigma_f$  is calculated from the following equation:

$$\sigma_f = \frac{F}{W} = \frac{6FL}{bh^2} \quad (1)$$

where  $F =$  loading force (measured)  
 $L =$  distance from loading point  
 $b =$  width of beam  
 $h =$  ice thickness

#### 2.1 Quantities to be reported

- Dimensions of the beam;  $L$ ,  $B$ , and  $h$ .
- Failure load;  $F$ .
- Flexural strength
- Time-load/deflection curves
- Time of the day and location in the basin

 <b>ITTC</b> INTERNATIONAL TOWING TANK CONFERENCE	<b>ITTC – Recommended          Procedures</b>	7.5-02 -04-02 Page 3 of 4	
	<b>Testing and Extrapolation Methods          Ice Testing          Test Methods for Model Ice Properties</b>	Effective Date 2002	Revision 01

### 3 MODULUS OF ELASTICITY OF ICE

The infinite plate test is recommended for defining the elastic modulus of model ice. A model ice sheet is loaded uniformly over a circular area by placing dead weights in discrete increments. The deflection at the centre of the load is measured by a displacement measuring device. The loads should be as small as possible to avoid any plastic deformation of the ice sheet. Also the loads should not remain on the ice sheet long enough to cause large creep deformation in the ice sheet. The load should be applied at a distance of at least four characteristic lengths of the ice sheet from the tank walls. The tank water must be still and sources of vibration (slamming doors etc.) are to be eliminated.

The modulus of elasticity is calculated using the following equation:

$$E = \frac{3}{16} \frac{1-\nu^2}{kh^3} \left( \frac{F}{\delta} \right)^2 \quad (2)$$

where  $F$  = loading force,  
 $k$  = foundation factor,  
 $h$  = ice thickness,  
 $\delta$  = displacement measured and  
 $\nu$  = Poisson ratio

#### 3.1 Quantities to be reported

- Thickness of model ice sheet
- Weights used
- Location in the tank
- Time-deflection curves
- Calculated modulus of elasticity
- Time of the day when measured


### 4 SPECIFIC WEIGHT AND DENSITY OF ICE

The specific weight of model ice is measured simply by submerging a piece of model ice of known mass or volume. The test can be done using the same equipment as in the cantilever beam tests. A round cut is sawn into the ice sheet according to a jig. The measurement device is placed to position. The plastic plate is to be positioned in the centre of the sawn circle. The device is turned on and the force gauge/plastic plate combination is moving down sinking the round ice plate. The ice plate is to be sunk properly. The force gauge is stopped and lifted back to start position. Subsequently the thickness and diameter of the ice plate is measured. This test is to be performed at two locations and after one of the tests (the water in the hole, with ice plate removed) is pressed in a similar way as the ice plate.

The density of ice is calculated using the following equation:

$$\rho_{ice} = \rho_{water} - \frac{F}{g\pi \left( \frac{d}{2} \right)^2 h} \quad (3)$$

where  $\rho_{ice}$  = density of ice  
 $\rho_{water}$  = density of water  
 $F$  = measured force  
 $G$  = acceleration of gravity  
 $d$  = diameter of ice plate  
 $h$  = ice thickness

	<b>ITTC – Recommended Procedures</b>	7.5-02 -04-02 Page 4 of 4	
	<b>Testing and Extrapolation Methods Ice Testing Test Methods for Model Ice Properties</b>	Effective Date 2002	Revision 01

#### 4.1 Quantities to be reported

- Dimensions of ice piece tested, i.e. thickness, width, length, radius
- Measured submergence load
- Specific weight of the tank water
- Calculated specific weight of the model ice

where  $F$  = force (measured)  
 $m$  = shape factor  
(round structure 0.9)  
 $k$  = contact factor (0.4 - 0.7)  
 $h$  = ice thickness  
 $b$  = diameter of indenter  
 $ci$  = constant, function of  $b/h$

## 5 COMPRESSIVE STRENGTH OF ICE

The compressive strength of model ice can be defined using mainly three methods: Cut an ice cube and lift it from the water and perform an uni-axial test, or perform the uni-axial test in water, or use an indenter to press the ice sheet horizontally. The compressive strength is most difficult to measure reliably. Also the structure of model ice does not always allow each method. Thus the measurement method of compressive strength is still under development. One practical method is the indenter test.

The indentation test is done in a place where the indenter can be put into the ice sheet through an existing hole (holes for beam or density tests). The device is placed vertically. The tests are typically performed at several speeds, such as 30, 10, 3, and 1 mm/s.

The compressive strength is calculated using the following equation:

$$\sigma_c = \frac{F}{ci * mkbh} \quad (4)$$

#### 5.1 Quantities to be reported

- Dimensions of the indenter
- Ice thickness tested
- Location of the tests in the tank
- Time of measurements
- Speeds
- Measured loads
- Calculated compressive strength

## 6 VALIDATION

#### 6.1 Uncertainty Analysis

Not treated yet.