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ICEBERG GROUNDING PROBLEMS IN THE NORTH ATLANTIC

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INTRODUCTION

Drifting icebergs have always been a hazard to the North Atlantic shipping lanes. The international ice patrol collects data and issues daily reports during March through July - the iceberg season. Ships in the iceberg infested waters are thus forewarned and furthermore they can take avoidance action. Because of the relative immobility of oil rigs, the problem is more complex for the offshore petroleum industry, which has recently started exploration activity on Canada's Eastern seaboard. While the shipping lanes are across the iceberg alley, the oil exploration is right along the alley, which greatly increases the collision probability. Not only the floating bergs, but the grounding and bottom dragging bergs pose a threat of possible damage to pipelines and other installations contained in the sea bed. The type of information on icebergs, required by the petroleum industry needs more intensive work, covering the entire exploration area along the coast.

This paper outlines some aspects of grounding icebergs. Field data on grounding or grounded bergs is hard to come by and what little published data is available is confined to scour marks with no correlation to the icebergs causing them. Some of these observations and measurements have been made on the Grand Banks[1] and near Belle Isle[6] off Newfoundland. Observation of gouges due to ice islands have also been reported[9] from the Beaufort Sea. Similar field observations all along the Canadian East coast could probably lead to a statistical evaluation of gouge depths and lengths at different locations. Such observations, however, may not be realistic of the present situation, because of uncertainty of the age of the scouring and the difficulty of correlation with the iceberg sizes occurring at the present times. Even if such a correlation were to be possible, collection of data along a 1500 mile stretch of the coast is a formidable task.

To obtain an understanding of the grounding phenomena, a simple analytical model was proposed earlier.[5] From this model, it would be possible to estimate the maximum gouge size in any location from a knowledge of the berg size and the type of ocean sediment at that place. Laboratory tests were conducted to determine the validity of the assumptions made in the analytical model. Some of the results are reported below.

ICEBERG PROBLEMS

The yearly reports of the international ice patrol and their periodic oceanographic reports are at present the source of reliable information on icebergs. In a state-of-the-art paper, Bruneau[4] has presented a review of icebergs and iceberg problems. The 20 major glacier outlets along West Greenland coast, producing about 20,000 icebergs annually[11] are the origin for the bergs drifting into North Atlantic. However, most of these bergs are trapped in the various bays and indentations along the coast of Greenland, Baffin Island, Labrador and Newfoundland. It is estimated that an average of 2500 bergs per year cross the 60th parallel,[7] 1000 at the 55th parallel.[3] and an average of 384 bergs per year[11] reach the Grand Banks area. These bergs are mainly propelled by the ocean currents and the predominant movement is North-South at average speeds of 10 to 12 miles per day. Icebergs appear in random shapes and sizes. Bergs weighing as high as estimated 23 million tons, have been observed off the Grand Banks. On an average, bergs weighing 0.25 million tons would be common in this area. This would be equivalent to a tabular berg, 500 feet long, 200 feet wide and 100 feet total depth. The consequence of a head-on collision with such a berg, carrying an energy of 20 million ft. lbs. can be imagined. Several methods of preventing collision or lessening the collision effect with an offshore oil rig have been proposed by Bruneau and Dempster.[3] Some of these methods are still under active research.

The draft of an iceberg depends on its shape. While the theoretical draft - height ratio of a blocky iceberg is 7:1, actual observations of different shapes indicate that this would vary from 1:1 up to 4:1. The table below gives the values for different berg shapes.[10]

Type	Ratio of Draft to Height
Tabular or Rectangular (blocky)	5:1
Rounded (domed)	4:1
Pyramidal	3:1
Pinacled	2:1
Winged or horned (drydock)	1:1

An iceberg 100 feet high could jut as much as 400 feet into water below. When such bergs come into contact with the sea bed consisting of soft sediments, they continue to move because of their initial momentum and come to rest when the resistance is sufficient to prevent further movement. Side scan sonar observations in the Beaufort sea[9] and near Belle Isle, North of Newfoundland[6] indicate positive gouge marks on the sea bottom due to ice islands and icebergs. The general North-South orientation of the gouge tracks near Belle Isle is in conformity with the iceberg drift path.

In the interaction of an iceberg with sea bottom, it is obvious that the relative strength of the two materials would decide the type of the resulting bottom feature. The crushing strength of fresh water ice varies over a wide range. A value of 400 psi can be considered as an average. When bergs ground on hard rocky sea floor, they are likely to disintegrate first. Recent studies off the Labrador coast[2] tend to confirm this. Growlers were found strewn in areas where bergs grounded on rocky ledges and no gouge tracks were observed. If an oil installation is located within such hard features, it is likely to be safe from a grounding berg. But where the sea bed is a soft unconsolidated sediment, there would be positive damage.

MODEL STUDIES - ANALYTICAL

An analytical model of a simple, blocky idealized berg was examined and it was suggested that the gouge depth could be theoretically expressed as[5]

$$E = \frac{LB}{4}(\gamma H^2 + 4CH + 4CL) + \frac{\mu L^2 H}{6}(\gamma H + 6C) \quad \ldots\ldots \quad (1)$$

where E = initial kinetic energy of the berg

L = Length of gouge

H = Maximum depth of gouge

γ = Unit submerged weight of sediment

C = Cohesive strength of sediment and

μ = Coefficient of friction between soil and iceberg.

Using the above expression, curves relating the berg weight to gouge size could be drawn, for a known set of soil properties. Figure 1, is one such plot.

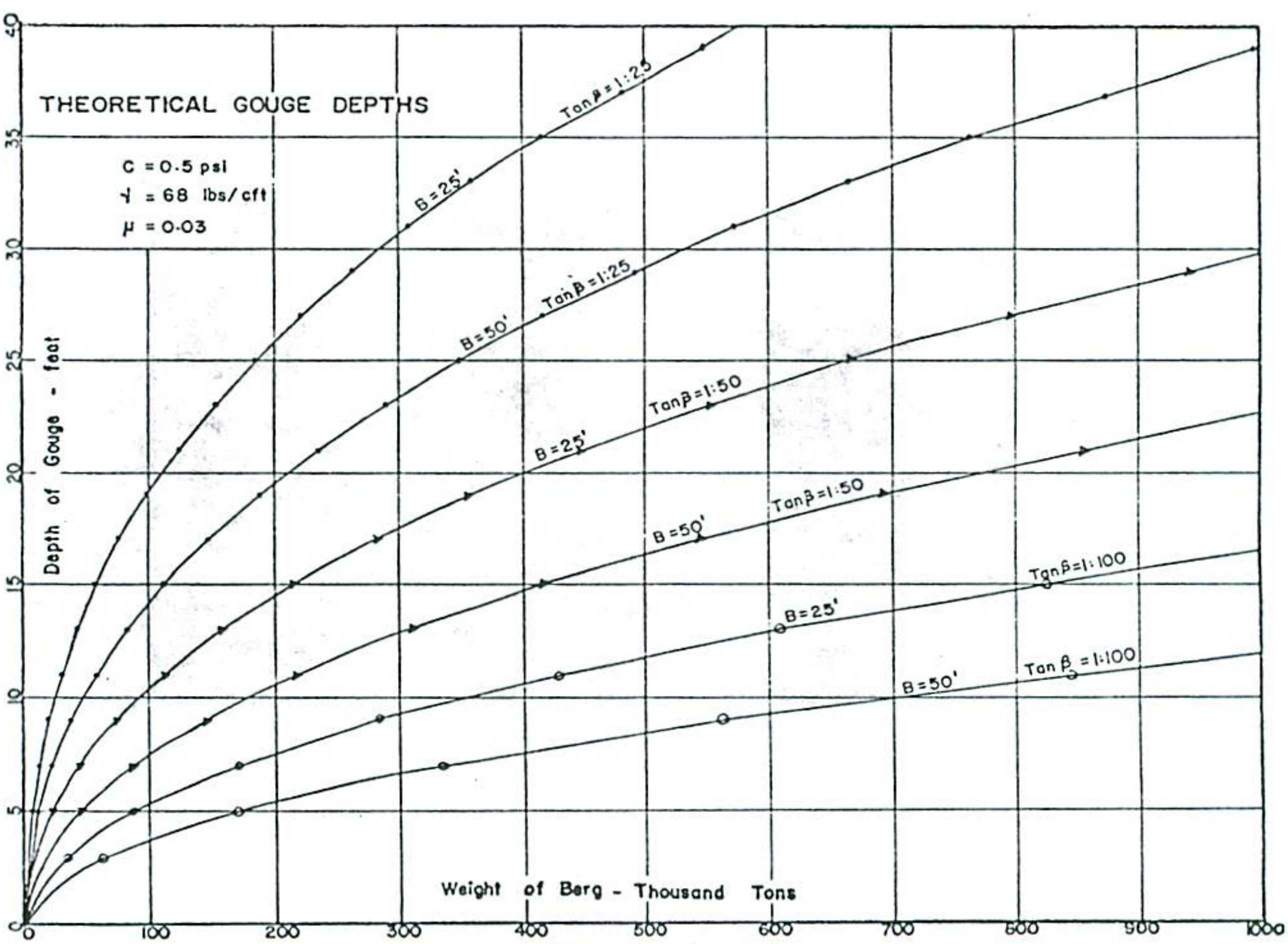

Figure 1.

In deriving the equation I above, a number of simplifying and idealized assumptions were made, both of the iceberg and the soil. One of these was that the soil exerts passive pressure on the front and sides of the berg and that the iceberg continues to be buoyant as it ploughs through the soil. An experimental model was set up to verify these assumptions and to extend the theory to icebergs of random shapes.

PHYSICAL MODEL

The requirements of the experimental facility are a sloping sediment deposit, a mode of towing models of different shape and the measurement of pressures. Figure 2 shows a view of the test assembly. This consists of a steel tank, 12' -0 X 2' -6 X 3' -3 (internal) with glass on one side. One end of the tank is supported on hinges. A hydraulic jack at the other end facilitates tilting of the tank to any desired slope. A variable speed motor at the top of the tank drives a carriage through a chain drive. The carriage moves on tracks along the top edges of the tank. An instrumented plexiglas model of the iceberg is supported from the moving carriage.

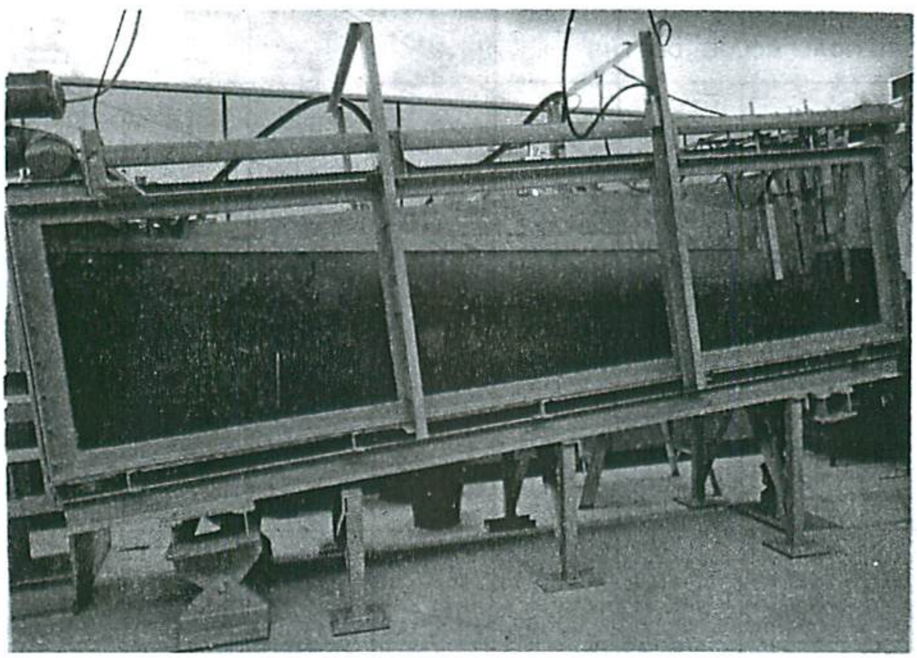

Figure 2.
General View of Test Assembly
(Tank in tilted position)

To simulate soft sea floor sediments, dry powdered modelling clay was suspended in water in the tank and allowed to settle. Required slopes can be formed by tilting the tank, agitating the soil in water and allowing the sediments to settle when the tank remains in the tilted position. After the soil settles, (usually overnight) the tank is righted back resulting in a bed of sloping soil.

Pressure cells are mounted on the front, side and bottom of the iceberg model and the instrumented model is dragged into the sediment at a predetermined velocity.

PRELIMINARY TEST RESULTS

For a proper evaluation of the pressure variation on the faces of the model, it is felt that measurement in two directions with at least three inter-related readings would be necessary. The model is 9 inches wide in front, 18 inches long and 15 inches high. With a free-board clearance of 3 inches, an area 9" X 12" on the front face is available for mounting pressure gauges. To facilitate observation at a number of points, the gauges have to be as small as possible. A miniature silicon NPN transistor about 0.25" diameter was mounted on a plexiglas flanged mount, which in turn was fixed to the model. The maximum pressure expected was of the order of 150 lbs. per sq. ft.. To get good resolution, gauges of 2 psi maximum capacity were selected. Output from the gauges was connected to a 10 channel scanner and a digital volt meter-printer. Ten gauges could thus be monitored continuously as the model moves into soil. A 2 channel storage oscilloscope was also connected to record the output from any two typical gauges.

Qualitative results of the initial tests were encouraging, but it was found that the pressure transistors were getting damaged and drifted after a couple of runs of the test. This was probably due to abrasion or physical damage, as the gauges were primarily meant for fluid measurements. However, some of the readings obtained are shown in figures 3 and 4. The pressure on the front of the model increases gradually in accordance with the assumption in the analytical model. There is also no pressure increase on the bottom of the model, as it gouges into the sediment bed. But the pressure increase on the side is far less than that on the front of the model. It may be possible that the shearing of the soil by the front of the model causes active and not passive pressure, on the sides.

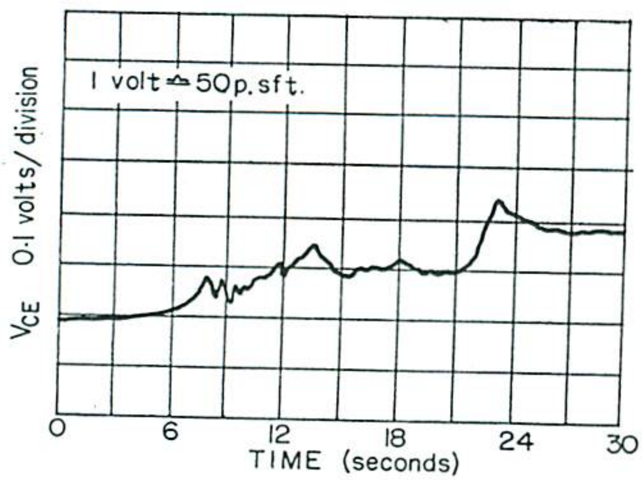

Figure 3.
Variation of Pressure on the Front Face (Oscilloscope trace).

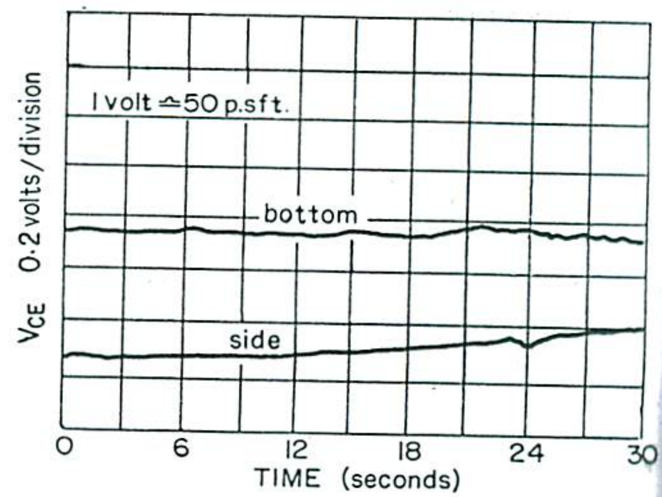

Figure 4.
Variation of Pressure at the Bottom and Sides (Oscilloscope trace).

After an examination of the other types of commercially available pressure gauges, it was decided to use piezoelectric transducers, 30 psi range with a resolution of 0.005 psi. These are more rugged and abrasion resistant. Modification of the model using these gauges is now in progress.

SHAPE OF MODEL

In large scale deformation problems in cohesive soils, research in soil-vehicle mechanics shows that a compacted core of the soil moves[8] in front. Further, in iceberg grounding problems, cohesive soils with a strength of 0.1 psi and less are being considered. It is thus reasonable to anticipate that the berg would build up a core of the soil in front and also continue to be buoyant as it grounds. In theory, it thus appears easily possible to extend the analytical model already discussed to bergs of any shape, with minor modifications. Experiments are being designed to test physical models of different shapes and also to study the soil failure pattern by forming soil grids in a small bin.

CONCLUSIONS

Preliminary results of laboratory tests show that the assumptions in the analytical model, about the pressure variation on the front face and bottom are correct. However, pressure on the sides seems to be active and not passive. Further tests are in progress.

REFERENCES

[1] Allen, J. H. et al. "Cruise Report C.S.S. Dawson, June 2-June 12, 1971" Internal Report, Faculty of Engineering, Memorial University of Newfoundland, 1971.

[2] Allen, J. H. et al. "Iceberg Study, Saglek, Labrador and Cruise Report C.S.S. Dawson, Aug. 7-Aug. 26, 1972", Faculty of Engineering Report, Memorial University of Newfoundland, 1972.

[3] Bruneau, A. A. and Dempster, R. T. "Engineering and Economic Implications of Icebergs in the North Atlantic"; Proceedings, Oceanology International Conference, Brighton, March 1972 pp: 176-180.

[4] Bruneau, A. A. "Icebergs Over the Canadian Continental Shelf"; Paper Presented at C.S.E.G. National Convention; Canada's North - An Information Update, Calgary, April 1973.

[5] Chari, T. R. and Allen, J. H. "Iceberg Grounding - A Preliminary Theory"; Applications of Solid Mechanics, Proceedings of the Symposium held at the University of Waterloo, June 1972 (S.M. Study No. 7, University of Waterloo) pp: 81-95.

[6] Harris, I. M. and Jollymore, P. G. "Iceberg Furrow Marks on the Continental Shalf, North East of Belle Isle, Newfoundland" (to be published) Atlantic Oceanographic Laboratory, Bedford Institute, Halifax, Nova Scotia 1973.

[7] McMillan, N. J. "Surficial Geology of Labrador and Baffin Island Shelves" Earth Science Symposium on Offshore Eastern Canada; Geological Survey of Canada Paper 71-23; pp: 451-469.

[8] Selig, W. R. & R. D. Nelson "Observation of Soil Cutting With Blades" Journal of Terramechanics, Vol. I, No. 3, 1964 pp:32-53.

[9] Shearer, J. M. "Preliminary Interpretation of Shallow Seismic Reflection Profiles from the West Side of Mackenzie Bay - Beaufort Sea" Geological Survey of Canada, Report of activities, Nov. 1970 to March 1971.

[10] Smith, E. H. "The Marion Expedition to Davis Strait and Baffin Bay", U. S. Coast Guard Bulletin, No. 19, Part 3, Scientific results, 1931, pp:60-205.

[11] U. S. Naval Oceanographic Office "Ice and Its Drift into the North Atlantic Ocean" Pilot Chart of the North Atlantic Ocean, April 1973.

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