Sandwell

SPRAY ICE RESEARCH

Sandwell

FENCO CONSULTANTS LTD.
CLIENT: APOA (Elf Oil Exploration and Production Canada Ltd.)
REPORT DATE: November 27, 1973

Beaufort Sea Summer Ice Testing Project

Overview:

During the early summer of 1973, Foundation of Canada Engineering Corporation Limited (FENCO) was retained by the Arctic Petroleum Operators Association (APOA) to conduct a survey and strength tests, under the direction of Gulf Oil of Canada, on ice found in the Beaufort Sea within approximately 50 miles of shore. The east-west boundaries were to be approximately Herschel Island on the west and Kugmallit Bay on the east.

Two expeditions, one after breakup and one in mid or late summer were to be conducted. The parameters to be determined were:

- Floe positions
- Floe sizes
- Floe thicknesses
- Ice strengths (insitu)
- Ice temperatures, density and salinity

PHASE I

From July 15 to July 22 a helicopter was used to fly daily, using Swimming Point as a base, to the ice which was about 20 miles offshore in a NNW direction from the camp. The approximate extent of the ice field encountered is shown in Figure 1 (as can be seen from the map in Figure 1 the ice field was extensive). Many of the individual floes landed upon were quite large, greater than 1/4 mile in diameter, and some were of indefinite extent.

Average floe thicknesses were estimated at 20 to 25 feet from observations on the freeboard and bore holes and electronic profiling indicated thicknesses in excess of 10 to 12 feet. The electronic profiling also indicated layers of melted or nearly melted ice within the mass.

Surface and in depth strength tests indicated the following average values:

Unconfined compression	307 psi
Maximum contact pressure	887 psi
Elastic modulus	51,000 psi

Borehole tests indicated that these properties were fairly uniform throughout the depth of the floes.

FENCO CONSULTANTS LTD.
CLIENT: APOA (Elf Oil Exploration and Production Canada Ltd.)
REPORT DATE: November 27, 1973

Beaufort Sea Summer Ice Testing Project

The ice can be described as being quite different in its mechanical behaviour from winter ice. The temperature was at or very near the melting point and the electronic profiling system indicated that much of the latent heat had been lost in some places. It was not brittle as is observed in winter but was very ductile with a well defined yield point. The elastic modulus was about 1/20 of that of winter ice. Large deformations were noted in the strength tests and failure was not sudden but was indicated by the reaching of a plateau.

The ice was porous and blue in color until drained of the brine inside at which point the samples were colorless.

PHASE II

From September 18 to September 21 a small tugboat was chartered and seven floes were boarded and tested during a four day period.

The same types of measurements were taken as for the July tests. The approximate extent of the ice as determined from a reconnaissance flight in a small aircraft and from the boat is shown on the map in Figure 31. The floes were in general smaller than the ones seen in July, averaging about 500 feet in diameter. Larger floes were found to be conglomerates of smaller pieces.

The surface of most floes was smoother than in July and average floe thicknesses were 15 to 20 feet.

The results of the strength tests can be summarized with the following average values:

Unconfined compression	580 psi
Maximum contact pressure	1,110 psi
Elastic modulus	54,000 psi

Again no great variation in mechanical properties with depth was noted. The ice temperature was at or near the melting point and the ice was very ductile in its behaviour. Except for one floe, the elastic moduli were low and no sudden failure was noted in the strength tests.

The ice was very porous and drained easily of the trapped brine.

Sandwell

FENCO CONSULTANTS LTD.
CLIENT: TOTAL EASTCAN EXPLORATION LTD.
(Operator for Labrador Group)
REPORT DATE: August 30, 1977

1977 Winter Field Ice Survey Offshore Labrador

Overview:

This report contains results of the Ice Survey conducted offshore Labrador in February, March , April and May, 1977. What follows are tests and observations:

1. Ice thickness obtained from drilling holes and results of aerial photography.
2. In situ ice strength tests to determine unconfined and confined compressive strengths and the elastic modulus.
3. Ice salinity profiles.
4. Ice temperature profiles.
5. Surface topography measurements by means of aerial photographs.
6. Aerial observations of ice conditions, both visually and by means of photography.

The first-year ice thicknesses ranged from 0.60 m to 5.80 m. The monthly mean thicknesses were 1.00 m for February, 1.77 m for March, 2.08 m for April and 4.62 m for May. First-year ice floe surface areas measured ranged between 145 m^2 and 46,000 m^2

with a mean of 1028 m^2 for February, 754 m^2 for March, 360 m^2 for April and 14504 m^2 for May. The calculated first-year ice floe mass ranged from 300 tonnes to 146,300 tonnes. The monthly mean masses were 3920 tonnes for February, 2158 tonnes for March, 826 tonnes for April and 54,962 tonnes for May.

The mean unconfined compressive strengths of first-year ice were 62.7 Kg/cm^2 for February and 40.0 Kg/cm^2 for May. The mean confined compressive strengths of first-year ice were, 88.8 Kg/cm^2 for February, 102.3 Kg/cm^2 for March, 125.4 Kg/cm^2 for April, and 78.4 Kg/cm^2 for May.

The mean elastic modulus values for first-year ice were, 1521 Kg/cm^2 for February and 2220 Kg/cm^2 for May.

From the salinity profiles the mean salinities for first-year ice were 6.9 o/oo for February, 4.7 o/oo for April and 3.9 o/oo for May.

The mean first-year ice floe temperatures were -5.8°C for February, -1.0°C for April and -0.1°C for May.

The multi-year ice floe thicknesses ranged from 3.0 m to 30.0 m. The monthly mean thicknesses were 6.94 m for March, and 10.18 m for April.

The multi-year ice floe surface areas, from aerial photos, ranged from 100 m^2 to 10,000 m^2. The mean surface areas were 758 m^2 for March and 1345 m^2 for April. The calculated multi-year ice floe mass ranged from 583 tonnes to 174,000 tonnes with a mean of 7,058 tonnes for March and 17,983 tonnes for April.

The mean unconfined compressive strengths of multi-year ice were 62.1 Kg/cm^2 for March, 48.9 Kg/cm^2 for April and 40.7 Kg/cm^2 for May. The mean confined compressive strengths for multi-year ice were 211.0 Kg/cm^2 for March, 198.5 Kg/cm^2 for April and 202.3 Kg/cm^2 for May.

The mean elastic modulus values for multi-year ice were 17,460 Kg/cm^2 for March, 11,680 Kg/cm^2 for April and 17,192 Kg/cm^2 for May.

The mean salinities of multi-year ice were 0.8 o/oo for March, 1.5 o/oo for April and 1.5 o/oo for May.

The mean multi-year floe temperatures were -6.9°C for March, -3.6°C for April and -1.2°C for May.

Sandwell

FENCO CONSULTANTS LTD.
CLIENT: TOTAL EASTCAN EXPLORATION LTD.
(Operator for Labrador Group)
REPORT DATE: August 30, 1977

1977 Winter Field Ice Survey Offshore Labrador

Regression analyses were done on data collected this year as well as that from the two previous surveys. These show a definite relationship between ice strength, ice temperature and ice brine volume.

Through the use of aerial photography, floe size, thickness, surface area and mass were calculated. This is a very quick and efficient way to study the physical properties of ice floes.

Through the use of our new equipment, ice cores greater in length than any previously taken were obtained and auger holes of depths greater than 15 m were made.

The measurements taken this year contribute to the understanding of the composition and characteristics, both physical and mechanical, of the Labrador ice pack. Due to time and operating limitations, sampling was sporadic and limited in quantity.

FENCO CONSULTANTS LTD.
CLIENT: TOTAL EASTCAN EXPLORATION LTD.
(Operator for Labrador Group)
REPORT DATE: June 8, 1978

1978 Winter Field Ice Survey Offshore Labrador

Overview:

This report contains results of the Ice Survey conducted offshore Labrador in January and February, 1978. Flight lines were flow perpendicular to the coastline at the following outboard headings:

107° magnetic from Nain
076° magnetic from Hopedale and
084° magnetic from Cartwright.

The distances measured offshore were in nautical miles from the point of departure, i.e. Nain, Hopedale or Cartwright.

Along these flight lines the following tests and observations were conducted:

1. Ice type and coverage obtained from results of aerial photography

2. First-year ice thickness obtained from drilling holes

3. First-year ice floe surface area and geometry from results of aerial photography

4. Visual observations of ice conditions.

In addition to the above, when flights were made offshore Hopedale, the following tests were performed:

1) In situ ice strength tests to determine confined and unconfined compressive strengths and the elastic modulus of first-year ice

2) First-year ice temperature profiles

3) First-year ice salinity profiles.

In each of the aerial photographs an ice floe, which was representative of all the ice floes contained in the photograph was selected and analyzed. This representative ice floe was labelled average size floe. In addition to the average size floe, the largest size floe contained in each photograph was selected and analyzed this was labelled largest size floe.

From the analysis of the aerial photographs the sea surface was covered by approximately 50% grey ice, 5% brash, 34% first-year ice and 11% open water during the January portion of the survey. During the February portion of the survey the sea surface was covered by approximately 31% grey ice, 13% brash, 50% first-year ice and 6% open water.

The thickness of the first-year ice was quite variable. During the January portion of the survey the first-year ice thickness measured:

FENCO CONSULTANTS LTD.
CLIENT: TOTAL EASTCAN EXPLORATION LTD.
(Operator for Labrador Group)
REPORT DATE: June 8, 1978

1978 Winter Field Ice Survey Offshore Labrador

- from 0.13 m to 2.87 m with an average thickness of 1.09 m and a standard deviation of 0.84 m offshore Nain;
- from 0.21 m to 1.73 m+, with an average thickness of 0.76 m+ and a standard deviation of 0.52 m+ offshore Hopedale;
- from 0.51 m to 1.37 m, with an average thickness of 0.92 m and a standard deviation of 0.25 m offshore Cartwright.

During the February portion of the survey the first-year ice thickness measured:

- from 0.94 m to 4.48 m+ with an average thickness of 1.95 m+ and a standard deviation of 0.92 m+ offshore Nain;
- from 0.79 m to 4.63 m+ with an average thickness of 2.71 m+ and a standard deviation of 1.19 m+ offshore Hopedale;
- from 0.70 m to 4.57 m+ with an average thickness of 1.76 m+ with a standard deviation of 1.10 m+ offshore Cartwright.

The geometry of the observed first-year ice floes varied widely. From the analyses of the aerial photographs the surface areas of the average size first-year ice floes:

- ranged from 10 m^2 to 2590 m^2 with an average surface area of 280 m^2, for the January portion of the survey;
- ranged from 10 m^2 to 13070 m^2 with an average surface area of 320 m^2, for the February portion of the survey.

From the analyses of the aerial photographs the surface areas of the largest size first-year ice floes:

- ranged from 20 m^2 to 28490 m^2+ with an average surface area of 1510 m^2, for the January portion of the survey;
- ranged from 10 m^2 to 28490 m^2+ with an average surface area of 3690 m^2+, for the February portion of the survey.

Approximately 60% of all the observed first-year ice floes were polygonal in shape, and 25% were classified as being rectangular in shape. The remainder of the first-year ice floes were either triangular, circular or elliptical in shape.

From the temperature profiles the average temperature of the first-year ice was -6.9°C during the January portion of the survey and -3.6°C during the February portion of the survey.

FENCO CONSULTANTS LTD.
CLIENT: TOTAL EASTCAN EXPLORATION LTD.
(Operator for Labrador Group)
REPORT DATE: June 8, 1978

1978 Winter Field Ice Survey Offshore Labrador

From the salinity profiles the average salinity of the first-year ice was 7.7 o/oo during the January portion of the survey and 6.8 o/oo during the February portion of the survey.

The first-year ice confined compressive strengths ranged from 59.6 kg/cm^2 to 208.5 kg/cm^2 with a mean confined compressive strength of 143.2 kg/cm^2 during the January portion of the survey and, ranged from 34.7 kg/cm^2 to 178.7 kg/cm^2 with a mean confined compressive strength of 95.3 kg/cm^2 during the February portion of the survey.

Tests for unconfined compressive strength in first-year ice were limited in number, however, during the February portion of the survey unconfined compressive strengths ranged from 62.1 kg/cm^2 to 85.8 kg/cm^2 with a mean value of 70.8 kg/cm^2.

The first-year ice elastic modulus values ranged from 350 kg/cm^2 to 10550 kg/cm^2 with a mean value of 4497 kg/cm^2 during the January portion of the survey, and ranged from 350 kg/cm^2 to 14060 kg/cm^2 with a mean value of 4913 kg/cm^2 during the February portion of the survey.

Regression analyses were done on data collected this year. These show a definite relationship between ice strength, ice temperature and ice brine volume.

Aerial photography was a quick and efficient means of gathering data on ice type, spatial coverage, surface topography , size and shape of floes in the ice pack.

Although a portion of the freeze-up data was missed, due to the lateness of the first offshore flight, the measurements taken this year contribute to the understanding of the composition and characteristics, both physical and mechanical, of the Labrador ice pack. Due to time and operating limitations, sampling was sporadic and limited in quantity.

FENCO CONSULTANTS LTD.
CLIENT: TOTAL EASTCAN EXPLORATION LTD.
(OPERATOR FOR THE LABRADOR GROUP)
REPORT DATE: September 29, 1978

Multi-Year Ice Floe Population Offshore Labrador 1978

Overview:

The purpose of this survey was to study and gather information on the population of multi-year ice floes found offshore Labrador during the season of ice cover in this area. This study was undertaken by means of airborne stereophotography. The operation was staged from Goose Bay, Labrador and primary offshore flights were made from three locations; Fish Cove Point, Cape Kiglapait and Saglek. Personnel flew offshore these locations on an outbound heading perpendicular to the coastline passing over existing well sites, and aerial photographs of the pack ice were taken.

From the analysis of the airborne stereophotographs the population of the multi-year ice floes was studied as well as ice types and spatial distribution of the ice pack as a whole. This airborne stereophotography worked extremely well and will be of considerable use in future ice surveys.

Introduction:

From the analysis of 2900 nautical miles, or 9200 aerial photographs, the population of multi-year ice floes found in the pack ice offshore Labrador vary considerably.

The results indicate that the amount and size of the multi-year ice vary with respect to time and location. Normally the average number of multi-year ice floes observed per flight was larger in the northern portions of the study area. It was also seen that the average number of multi-year ice floes observed per flight was larger in the latter portions of the study. In confirmation of previous observations the multi-year ice floes are generally found in fields of multi-year ice.

The average surface areas of the multi-year ice floe population were generally larger in the northern portion of the study area and were larger in the latter portions of the survey.

The total area of the ice pack photographed during the survey on the three main flight lines, Fish Cove Point, Cape Kiglapait and Saglek, was 4453 km^2. In this area 1277 multi-year ice floes were observed. The combined surface area of these floes was 5.5 km^2 or 0.12% of the total area photographed. As mentioned above, the multi-year floes are normally found in fields of multi-year ice and the coverage of multi-year ice can be somewhat higher than this figure. The distribution of surface areas of the observed multi-year ice floes were generally log normal.

FENCO CONSULTANTS LTD.
CLIENT: TOTAL EASTCAN EXPLORATION LTD.
(OPERATOR FOR THE LABRADOR GROUP)
REPORT DATE: September 29, 1978

Multi-Year Ice Floe Population Offshore Labrador 1978

The number of multi-year ice floes seen from a strip of photography, 10 nautical miles long and .75 nautical miles wide, centered over the existing wellsites, varied from 0 to 15 with a mean of 6 on any given flight at each of the locations.

The number of multi-year ice floes in the area of existing wellsites can vary even more as strong onshore or offshore winds can compact or broaden the width of the ice pack thereby shifting the locations of the floes either towards onshore or towards offshore with respect to the wellsite location. Chances of collision between multi-year floes and structures may be higher than indicated by the aforementioned figures.

The composition of the ice pack is continuously changing with time and with distance offshore. Normally the sea surface in the area of the existing wellsites was ice covered, however, on some occasions the sea surface at these locations was ice free.

Throughout the survey the location and numbers of icebergs was observed. The overall average ratio of multi-year ice floes to icebergs, taken from aerial photographs, was 51:1. These ratios ranged from 12:1 to 209:1. The total amount of icebergs observed visually for the duration of the study was 2214. This is not to be confused with the number of icebergs contained in the aerial photographs. The number of visually observed icebergs per nautical mile of flight ranged from 0.12 in March to 0.55 in June.

Although pack ice is much thinner than multi-year ice, there is extreme danger regarding collisions with structures where pack ice pushes on a multi-year floe which in turn collides with a structure. The pack has ample strength to push these multi-year floes and create high forces.

It is concluded that the forces acting on the pack exceed the actual strength of the pack and a violent process takes place which results in considerable deformations of the pack. Evidence of this was seen in the form of large chunks of ice piled on multi-year ice floes where the multi-year floe's freeboard was 2 or 3 metres.

While the data on the multi-year ice population obtained this year gave an initial data base it is still insufficient to allow for accurate predictions. Data must be obtained for several more years before an understanding of the multi-year ice floe population can be reached.

Sandwell

FENCO CONSULTANTS LTD.
CLIENT: WORLD OCEAN SYSTEM
REPORT DATE: June 16, 1980

Basic Study of Offshore Structures in Ice Affected Waters

Overview:

This study outlines in general terms the present state-of-the-art of offshore structures in ice-affected waters. "General" because environmental information which represents a paramount prerequisite for the design of offshore structures is still scarce for most ice covered waters. This applies in particular to ice, its distribution with time and its mechanical and structural properties. Some of the conceptual designs represented in this report are based on assumed environmental data and hence they should be treated as such.

It would be beyond the scope of this report to deal in detail with the design of each possible structure or even with one particular structure. Instead, a broad spectrum of offshore structures has been presented - supported by some sketches - along with typical ice conditions in which they (the structures) could most likely withstand the expected ice forces.

A novel analytical model was developed representing the sequencial breakdown of an ice edge in a crushing mode. This model can be applied to determine static and dynamic forces on slender structures as well as wide rigid structures by employing probability methods.

The two main objectives of this study are:

(a) A general review of offshore structures applicable for drilling and/or production purposes in ice-affected waters. Advantages and disadvantages have been listed for each structure depending on the severety of the ice conditions, water depth and other parameters.

(b) An evaluation of ice forces in general terms as well as for several offshore structures. The inter-relation between the magnitude of ice forces and the size and the shape of the structures has been demonstrated.

FENCO CONSULTANTS LTD.
CLIENT: INTERNAL USE ONLY
REPORT DATE: October 1980

Monitoring On Ice Platform Construction Manual

Overview:

A manual giving important information concerning travelling, preparing the ice pad for flooding, installation of the Moonpool, Flooding, Thermistor Banks, Borehole Jack Tests, Flaking Tests, Strain Gauges, Installation of tide recorder, Installation of Float recorder, Measurements of Deflection and Floating Ice sheets.

Sandwell

FENCO CONSULTANTS LTD.
CLIENT: DOME PETROLEUM LTD.
REPORT DATE: January 5, 1982

Ice Data Beaufort Sea, August and October 1981

Overview:

This report covers ice data collected from the Beaufort Sea during sea ice trials in August and October, 1981. The study included temperature and salinity profiles, borehole jack confined compressive tests, uniaxial compressive tests, and crystallographic analysis. The uniaxial compression tests and crystallographic analysis were performed in the FENCO Calgary Ice Lab on ice cores brought back from the field.

All of the ice floes tested were multi-year ice with warm temperatures. In the case of the August tests, the second-year ice exhibited extensive ridging.

This report includes a description of the test procedures as well as a presentation and discussion of the results. Ice strengths are described in terms of temperature, grain structure (size, shape and orientation) salinity, and stress rates; a standard format used for similar studies of this type.

Introduction:

The multi-year ice, during both the August and October tests, had very little saline content. The floes tested during the August trials were very ridged, while those tested in October had a lower relief but were more rafted. The grain structure was generally granular snow ice with some horizontally columnar sections. Ice temperatures ranged between 0 to -1°C during the August trials and -1 to -3°C during the October trials.

Borehole jack ultimate compressive strengths, which averaged 7.4 MPa, and elastic modulus values averaging 385 MPa from the August trials, were lower than the borehole jack ultimate compressive strengths (averaging 18.2 MPa) and elastic modulus values (averaging 2183 MPa) found during the October trials. These differences are a result of colder ice temperatures and older ice during the October trials. Ice strengths and elastic modulus values increase as ice temperatures drop.

FENCO CONSULTANTS LTD.
CLIENT: DOME PETROLEUM LTD.
REPORT DATE: January 5, 1982

Ice Data Beaufort Sea, August and October 1981

Uniaxial compressive strengths averaged 2.9 MPa for the August samples and 4.3 MPa for the October cores. The results again indicate the weakness of the test samples due to the warm testing temperatures in the field which were duplicated in the laboratory tests.

Elastic modulus values, calculated from the stress-strain curves of the uniaxial tests, for the two trial periods, averaged 4300 MPa indicating the brittleness of the ice due to its' low salinity content and age.

No definite relationships between ice strengths and crystallographic orientation were reached due to the small number of samples tested.

Uniaxial compressive strength studies of Arctic ice should be tested in the field, especially if they are to be compared to in situ compressive strengths. An alternative to the uniaxial tests is the flaking pit test, which is considerably easier to perform in the field.

Sandwell

FENCO CONSULTANTS LTD.
CLIENT: Department of Supply and Services
REPORT DATE: August 30, 1984

Evaluation of Medof Ice Load Sensor in the Arctic Environment

Overview:

During the winter season of 1983/84, FMS Engineers were contracted by the Department of Public Works, Government of Canada to install, monitor and analyze data from the performance of two MEDOF brand ice load panels. The MEDOF brand name ice stress panel is a hydraulic load versus fluid output device developed in partnership by Dr. M. Metge, Fenco Consultants Ltd. and Dome Petroleum Ltd. This panel has been used extensively by firms operating in Arctic offshore locations, as to date, over 200 of these typical 1 m x 2 m panels have been sold for offshore use.

The MEDOF panel installation at the Nanasivik DPW, Baffin Island, N.W.T. wharf was a remote location and as such a complete -50°C rated data logging system was setup to record the data. Located immediately adjacent to the MEDOF panel installation were similar systems of ice stress panels of three other firms. This entire project was carried out to study the performance of these four different ice stress sensors, relative to each other and also to investigate the ice stress regime around the DPW Nanasivik dock.

MEDOF SENSOR THEORY AND OPERATION

In recent years, offshore development in the Beaufort Sea and other offshore ice infested areas has resulted in the need for a sensing device for ice load measurement in the order of the structural component size of the involved structure. For this purpose, the MEDOF sensor typically of 1.0 m x 2.0 m size was developed.

The basic concept of the MEDOF sensor can be stated as follows: two large (usually 1 m x 2 m x 3.1 mm) steel plates are separated by a porous rubber material (2.5 mm thick) (Figure 2.1). The edges of the steel plates are welded together to form a large contained structure which through a vacuuming process is filled with a non-freezing fluid. This panel structure, when subjected to a load, expels the contained fluid proportional to the total load on the panel. This performance property is due to the fact that the inner rubber material exhibits linear elastic performance up to 20 MPa. Therefore, although the ice pressure over the panel will be non-uniform, the panel integrates the load response over the whole panel area with a resulting proportional total load versus expelled fluid relationship.

The MEDOF sensor has a linear calibration curve up to approximately 10 MPa since the effective inner rubber material area is approximately 50% of the panel area. The effect of temperature is small, less than 7 kPa/°C. The effect of creep in the buttons cannot be neglected, but it is relatively small: 10% in 24 hours at 1 MPa and a further 5% if a load is sustained over a 1 to 2 month period.

To measure ice forces, the MEDOF panel is either inserted in a slot in the ice and frozen in place or bolted or welded to the walls of the structure being monitored. As ice forces are exerted on the panel, fluid is expelled into a standpipe at atmospheric pressure. The amount of fluid or therefore the corresponding load is measured through the use of a 0 to 35 kPa pressure transducer located at the bottom of the standpipe. It is also typical that on a daily basis, a visual reading is taken on the fluid level in the standpipe as a check of the accuracy of the pressure transducer. However, at Nanasivik, this was not done since the site was remote and in the interest of a durable design, a steel standpipe was used instead of the usual plexiglass standpipe required for visual readings.

MEDOF panels constructed to date have varied considerably in size and weight to fit the requirements of various projects. For manual installation, where the use of equipment is restricted, a 100 kg, 1 m x 2 m panel has typically been employed (Figure 2.1). Where MEDOF panels have been welded to structures which are to be used in the Beaufort Sea, panels of up to 650 kg and 1.2 m x 2.8 m have been constructed.

CONCLUSIONS AND RECOMMENDATIONS

The MEDOF panel is not overly sensitive to temperature change where stress levels are in the order of 500-1000 kPa. However, for the Nanasivik project where the maximum stress levels were in the order of 80 kPa maximum, the thermal correction factors became quite significant. Since panels P18 and P10 had thermal correction factors of 7.3 and 4.0 kPa/°C for the 10°C ice temperature change present at the dock site, which represented 73 and 40 kPa. Two thermistors we installed in the ice profile; however, for accurate ice temperature data about 5 beads through the ice profile would have been desirable.

The above fact was noted to have caused a 0 pressure baseline drift in the panel data. In order to compensate for thermal drift a baseline was drawn through the lower peak values of the pressure data. Therefore it was assumed that on a regular daily basis the pressure on the MEDOF panel would drop to near 0 level. With this method the highest stress level observed was 80 kPa by panel P10 on March 22, 1984. The panel P10 pressure data was concluded overall to be quite accurate while the data of panel P18 was concluded to be useful for only qualitative analysis.

FENCO CONSULTANTS LTD./LAVALIN
CLIENT: TRANSPORT CANADA , TRANSPORT DEVELOPMENT CENTRE
REPORT DATE: September, 1984

Arctic Marine Design and Construction Handbook – Volumes I and II

Overview:

This handbook presents in two volumes a compendium of information and current practice in the design and construction of marine structures in the Canadian Arctic. The term "Arctic Marine Structures" is defined for the purpose of this handbook, as marine civil structures essential for secure berthing of vessels and transfer of cargo between vessels and a terminal.

The objectives of this handbook are:

1. To consolidate in one document existing knowledge related to the design and construction of Arctic marine structures.

2. To provide a useful reference document for planners, engineers and contractors.

3. To provide a basis for establishing design standards, guidelines and regulations for Canadian Arctic marine construction.

4. To identify gaps in current knowledge of ice engineering and/or Arctic marine design and construction practice.

5. To establish priorities for future research and development in the field of Arctic marine structures.

Volume 1 provides an overview of current Arctic technology as it applies to Arctic marine structures. Chapter contents are summarized as follows:

Chapter 1 presents background information on the Canadian Arctic as related to economic resources and environmental conditions. Basic functional requirements and types of port related civil engineering structures for the Arctic are identified.

Chapter 2 describes the Canadian Arctic marine environment and presents information on wind, waves, currents, snow, and other climatic and oceanographic phenomena.

Chapter 3 presents major aspects of ice technology and provides technical information upon which ice design criteria in the Canadian Arctic are based.

Chapter 4 defines Arctic geotechnical conditions and presents information on permafrost. The geotechnical design aspects of structures in permafrost are discussed. Information on instrumentation and monitoring of structures affected by geotechnical considerations are presented.

FENCO CONSULTANTS LTD./LAVALIN
CLIENT: TRANSPORT CANADA , TRANSPORT DEVELOPMENT CENTRE
REPORT DATE: September, 1984

Arctic Marine Design and Construction Handbook – Volumes I and II

Chapter 5 discusses responses to the Arctic ice environment. Ice control techniques are identified and various options for ice resistant structures are presented.

Chapter 6 presents existing regulations and standards for Arctic marine structures.

Chapter 7 presents design guidelines for Arctic marine structures based upon existing state of the art design practice.

Chapter 8 presents an outline of construction procedures and techniques currently utilized in the Arctic.

Chapter 9 presents an inventory of existing Arctic marine facilities.

Chapter 10 identifies information deficiencies and indicates those areas where research and development are required to upgrade existing knowledge in the design and construction of Arctic marine facilities.

Volume 2 provides a selected inventory of technical data which is most likely to be of value to engineers and contractors working on Arctic marine projects. The volume contains lists of technical publications, according to subject, followed by the abstracts of the listed publications. The appendix portion, in four parts, provides sources of information on the Arctic, as follows:

- List of regulatory agencies and organization, with latest addresses
- List of additional useful references
- List of technical conferences, of interest to the Arctic engineering
- List of Companies providing sealift transportation in the Canadian Arctic