R 617

Technical Report

RING-TENSILE-STRENGTH AND FLEXURE-STRENGTH CORRELATIONS OF SEA ICE

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RING-TENSILE-STRENGTH AND FLEXURE-STRENGTH CORRELATIONS OF SEA ICE

Technical Report R-617

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by

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ABSTRACT

A quick, accurate method of estimating the flexure strength of sea ice is investigated. This report analyzes and discusses two methods of correlation between the ring-tensile strength and flexure strength of antarctic sea ice. The indirect method, using the common parameter brine volume of sea ice, is considered less accurate than the direct method, which associates the data for common calendar periods for both strengths. Neither correlation should be used without taking a larger quantity of ice samples to derive a well-averaged ring-tensile value from the lower one-half thickness of the ice sheet. It is recommended that an effort be made to develop a system for predicting the flexure strength of an ice sheet by correlating the flexure strength with brine volume. This would eliminate the need for any strength testing and would simplify the field work to taking only temperature and salinity measurements.

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INTRODUCTION

Moving aircraft and surface vehicle loadings on sea ice impose tensile stresses through essentially the lower one-half thickness of the ice sheet. Operational usage of sea ice requires an understanding of its load-carrying capacity. Flexure strength is one of the most important factors controlling the load-carrying capacity of sea ice. Flexure strength can be determined by static-load tests to fail the ice sheet or by breaking large in-situ beams. The former method is impractical and the latter one is costly; both methods are time consuming. A quick, accurate method of estimating the flexure strength of sea ice is needed to promote safe and efficient operations.

This report analyzes and discusses correlations between the ring-tensile strength and flexure strength of antarctic sea ice. The analysis uses field data acquired from annual sea ice near McMurdo Station during the austral spring and summer (October-February) of Deep Freeze 65 (DF-65) through DF-68.

BACKGROUND

The ring-tensile test was first developed as a method for determining the strength of rock and concrete. Since it is an easily performed test requiring a minimum of portable equipment, it has been used extensively as a rapid method for determining the index strength of ice and snow in remote areas. Also, it has been used to study the strength properties of saline ice and to correlate them with other parameters, such as temperature and brine volume.

During the austral spring and summer of DF-65 through DF-68, NCEL conducted tests to determine both the flexure (rupture modulus) strength and ring-tensile strength of annual sea ice near McMurdo, Antarctica. Data from the flexure-strength studies (in-situ beam tests) were used to derive load-capacity curves for aircraft operations (Dykins, 1967). Ring-tensile-strength tests were concurrently performed to obtain correlative strength values (Paige and Lee, 1966). Also salinity and ice-temperature measurements were made to relate strength values, as well as additional data gathered on ice and air temperature and ice-crystal structure.

RING-TENSILE THEORY

The ring-tensile-strength theory has been discussed by Ripperger and Davids (1947) and revised by Assur (1960). Butkovich (1958) describes its use for the testing of small samples of seawater and freshwater ice.

The ring-tensile strength, σ_R, is computed from the following equation:

$$\sigma_R = \frac{KP}{\ell_o \pi r_o}$$

where K = the stress-concentration factor

P = the failure load

ℓ_o = the specimen length

r_o = the outer radius of the specimen

The stress-concentration factor, K, in the ring-tensile strength is determined by the diameter of the axial hole drilled in the specimen. The K factor is a function of r_i/r_o where r_i is the radius of the coaxial hole. The K factor varies as the diameter of the coaxial hole varies; however, the function is not linear and is best determined from the graphed equations given by Ripperger and Davids (1947) and revised by Assur (1960). The graph in Figure 1 shows that as the inner-hole diameter increases the K factor also increases. However, as the inner-hole diameter increases, the condition of a loaded curved beam is approached and the ring-tensile-strength theory may no longer be valid (Assur, 1960, p. 127). A K factor of 6 is generally used for a specimen that is assumed to have an infinitesimally small hole at its center (Assur, 1960).

Frankenstein (1964, p. 10) compared solid-cylinder tests with ring-tensile-strength tests using a 1.27-cm-diameter (0.5 inch) hole and indicated that for a solid cylinder, the K factor is actually 5.2 instead of 6.0 as stated by theory. Dykins et al. (1962, p. 72) also tested the effect of different axial-hole diameters and showed that as the diameter increased from 1.27 cm to 2.54 cm (0.5 to 1 inch), the strength decreased. Butkovich (1958, p. 114) compared the effect of 1.27-cm-diameter holes with that of 2.54-cm-diameter holes and found that the strength was the same within the standard error.

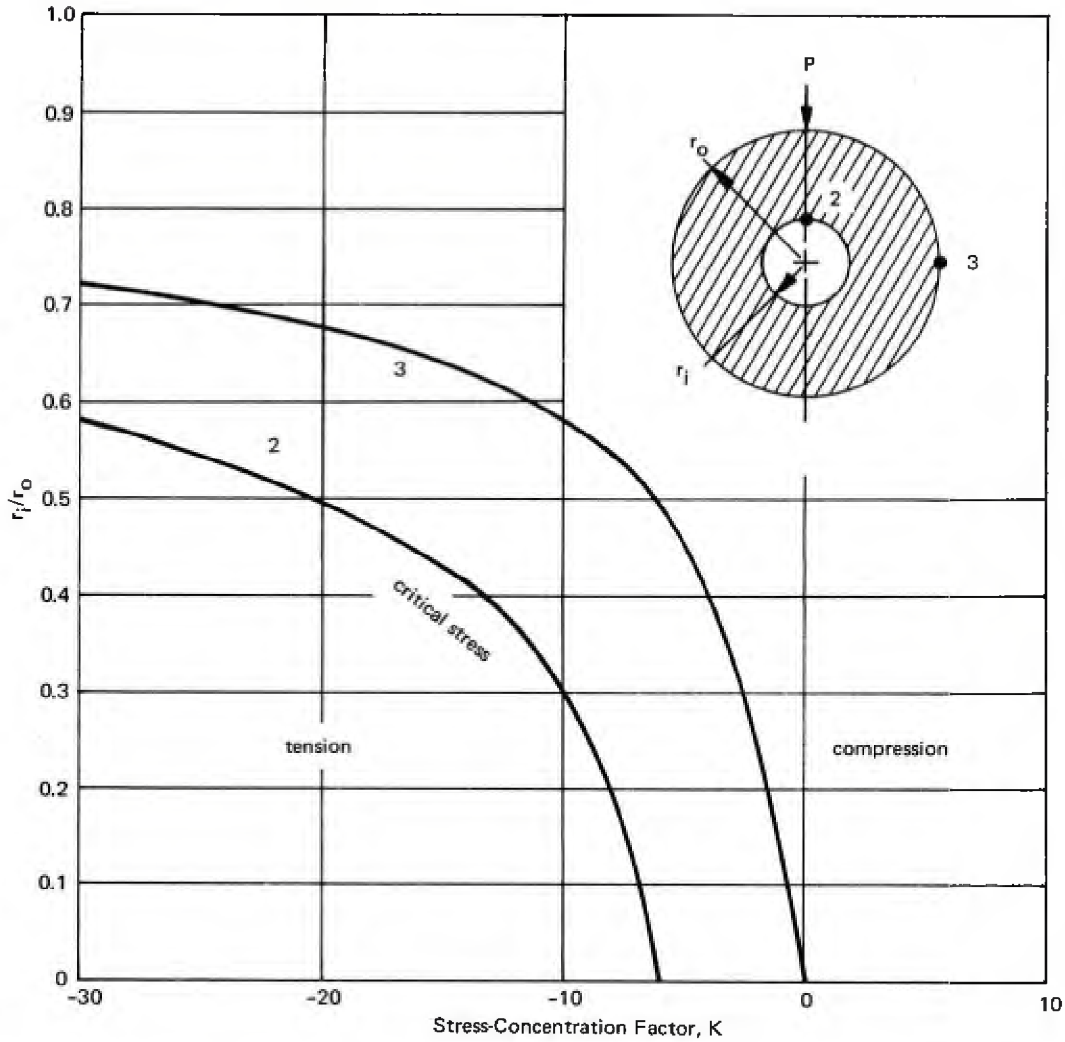

Figure 1. Stress at characteristic points in a ring under compression (from Assur, 1960).

DATA ANALYSIS

Depth profiles of temperature, salinity, ring-tensile strength, and brine volume were compiled from data gathered from the annual sea ice during the austral spring and summer of DF-65 through DF-68 near McMurdo, Antarctica. Large in-situ beams were also tested during this period to determine the flexure-strength property. The snow cover on the test site was maintained at a minimum so that the data obtained would reflect the conditions of an operable vehicle surface.

Temperature Data

Copper-constantan thermocouples and thermistors were used to obtain the temperature-profile data. The probes were inserted through the ice, and the bore hole was allowed to refreeze. Thermal stabilization after refreezing was assured before temperatures were recorded.

Three characteristics of the temperature gradients during the warming season (spring to summer) were observed to be very consistent: (1) the gradient shifted chronologically with the season warm-up, (2) as the warming season progressed, the temperature gradient through a sea-ice sheet became essentially vertical and isothermal as indicated by the data in Figure 2, and (3) due to the pivotal action of the temperature gradient about the approximate, nearly constant -2°C temperature of the lower interface region, the mean temperature of the lower half of the ice sheet had a maximum variation on the order of 5°C.

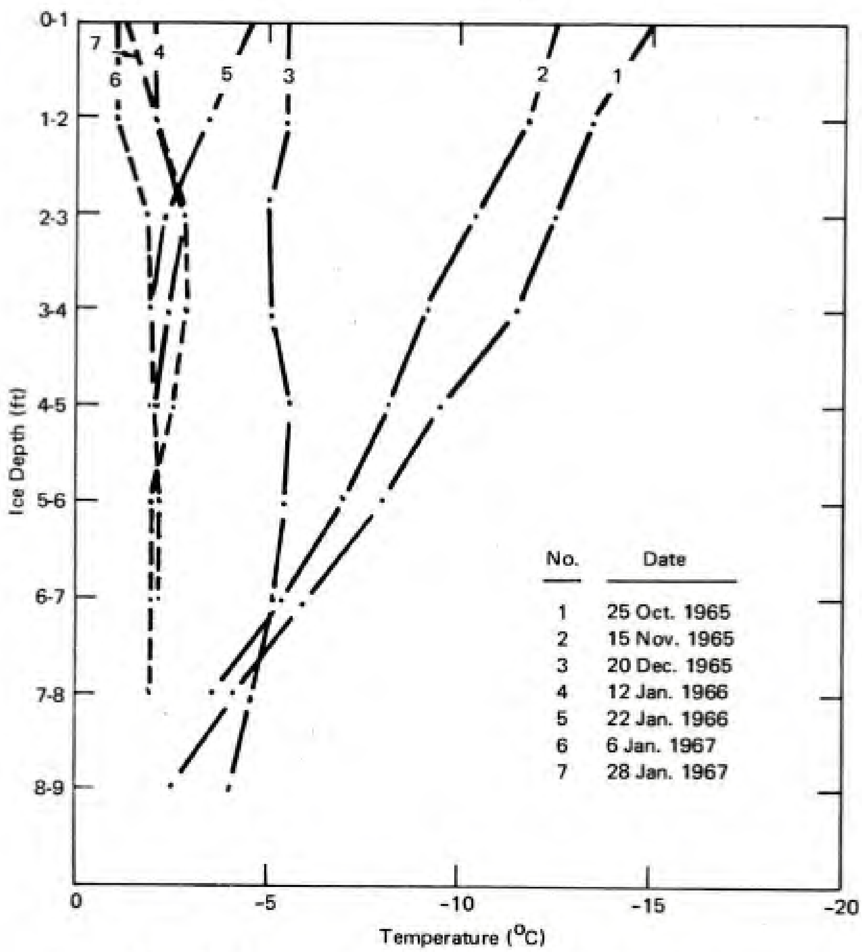

Figure 2. Chronological trend in temperature profile.

Salinity Data

Salinity data from the ice sheet were obtained using 3-inch-diameter cores cut into 3-inch-long specimens. The salinity of the specimens was determined by measuring the specific conductance of the melted sample. The profiles were prepared for average salinity over 1-foot intervals. The sample profiles in Figure 3 do not show the same well-defined chronological trend for change in salinity as do the profiles for ice-sheet temperature.

Brine-Volume Conversion

The smooth temperature profiles and rough salinity profiles, when incorporated with Assur's (1960) salinity-multiplier table, result in well-defined, chronologically ordered, brine-volume profiles (Figure 4). The smooth profiles are obtained because brine volume is more sensitive to temperature change than to salinity change. The brine-volume profiles are shown only through the lower half of the ice sheet, as only this portion of ice which is under tension from surface loading will be used to analyze the ring-tensile data.

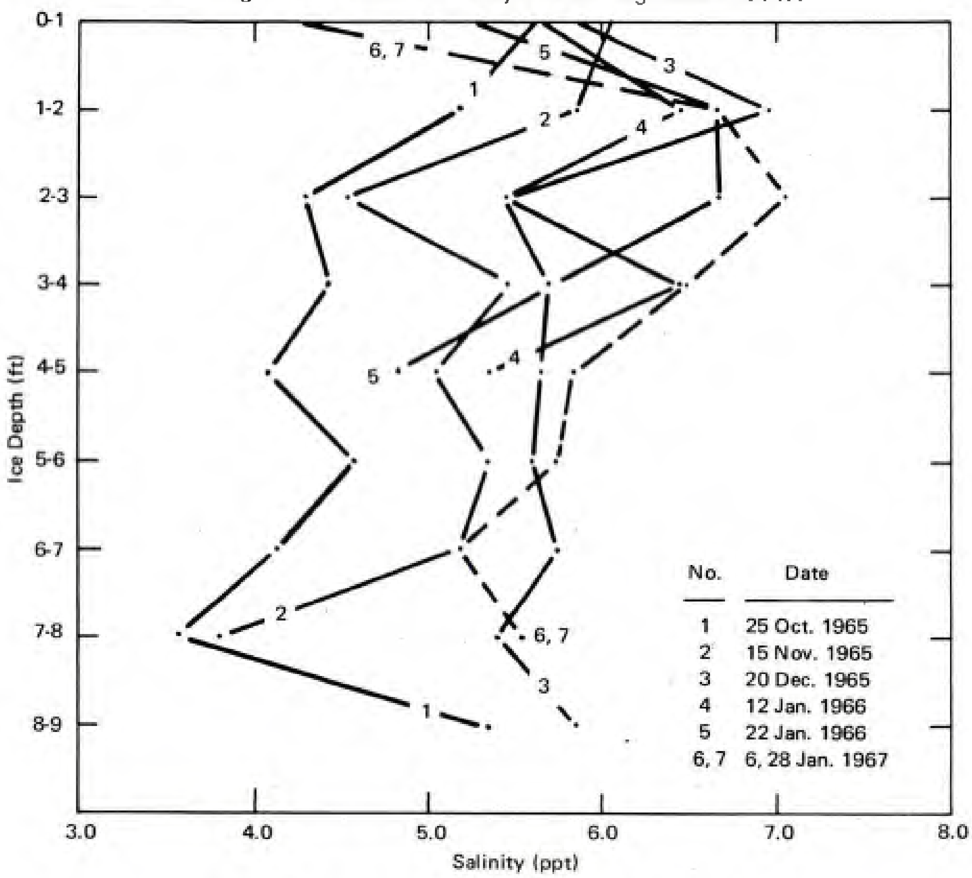

Figure 3. Chronological trend in salinity profile.

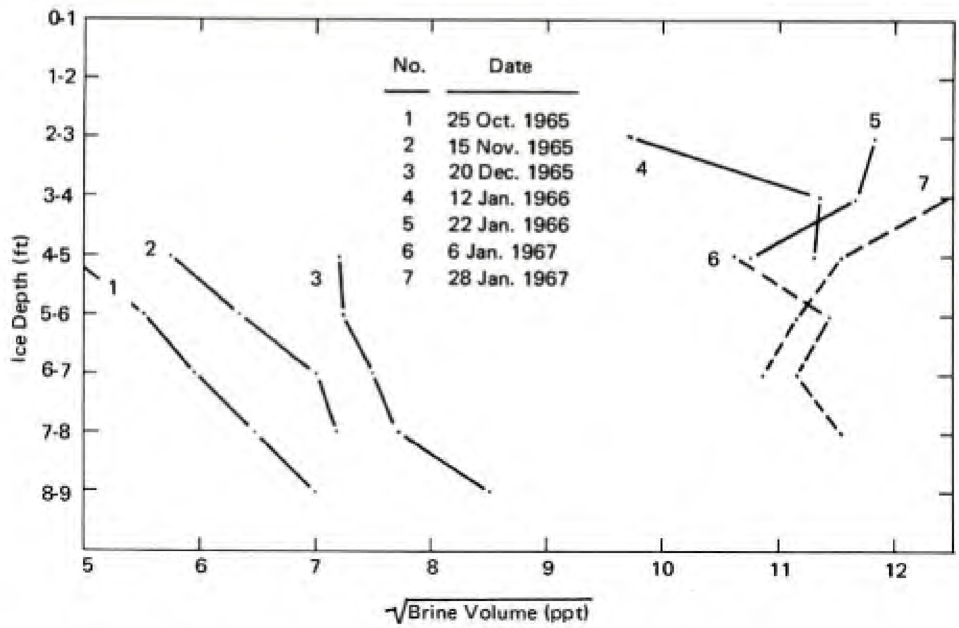

Figure 4. Chronological trend in brine volume profile over the lower one-half thickness of the sea ice.

Data shown in Figure 4, and contained in Table 1 of the Appendix, are used in the brine-volume versus ring-tensile-strength correlation. For the brine-volume versus flexure-strength correlation, a separate, but similar, set of brine-volume data taken during flexure-strength testing (presented in Table 2 of the Appendix) is used.

Ring-Tensile-Strength Data

Sampling and Testing. NCEL performed field sampling and testing of ice-core specimens from the annual sea ice near McMurdo Station, Antarctica (Paige and Lee, 1966). In sampling for a profile, two or three 3-inch-diameter ice cores, extending through the thickness of the ice sheet, were obtained with a SIPRE auger. Starting from the upper surface end of each core, the cores were divided into 3-inch-long specimens. The specimen was further prepared for the ring-tensile-strength test by drilling through each a 0.5-inch-diameter coaxial hole. This allowed an approximate ~7.1 theoretical stress-concentration factor.

The specimens were failed by a hydraulic ram mounted in a frame so that the specimen was loaded vertically downward against a load cell. A ram speed of 20 in./min was used to obtain an elastic failure (Paige and Kennedy, 1967). A strip chart recorded the loading history of each specimen.

For the analysis of a ring-tensile-strength depth profile, the strengths from the 3-inch-long specimens were averaged over 1-foot stratas. A few specimens were unsuitable for testing due to cracking from augering or drilling the coaxial hole. Therefore, only five to ten strength values per 1-foot strata were available for averaging.

Data Evaluation. The temperature, salinity, and brine-volume gradients through the ice sheet become essentially vertical near the end of the spring-to-summer warming period. These conditions cause the sheet to gradually thin and weaken. The ring-tensile data taken during DF-65 through DF-68 were not always consistent in showing the weakening effect.

For the analysis, it was necessary to formulate a set of strength profiles obtained during the entire DF-65 to DF-68 test period since no single test effort was extensive enough to provide the full season strength change in the ice sheet. This set of combined data resulted in some disorder of the profiles, particularly where the data of different test seasons overlapped, which was contrary to the normally expected chronological strength trend. To establish a consistent set of data for the analysis, disordered profiles in the regions of overlapping data were eliminated. Though it is recognized that this biased the data and the solution to some extent, it was preferred over the results which would have been obtained if the disordered profiles had been included. The refined profiles are shown in Figure 5; the profiles were prepared from data included in Table 1 of the Appendix. The date of each profile corresponds to the dates of the temperature, salinity, and brine-volume profiles in Figures 2 through 4.

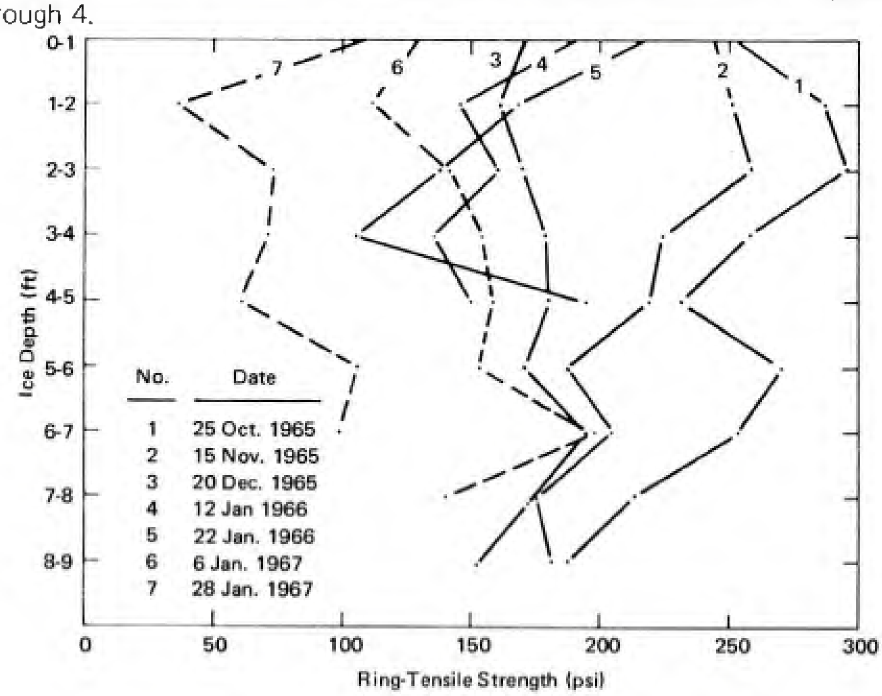

Figure 5. Chronological trend in ring-tensile strength profile.

Scatter between successive depths along a given profile is quite predominant in Figure 5, despite the fact that each ring-tensile point is the average of five to ten specimens. Scatter is caused primarily by the difference in crystal orientation and structure and the random locations of defects, which results in a stress-concentration factor. Scatter can be reduced somewhat by orienting the crystal structure for either the weakest or strongest break (Paige and Kennedy, 1967). Since the technique of selective orientation is both difficult and time consuming, the average value for the ring-tensile strength was obtained by testing a relatively large number of randomly oriented specimens.

Full-depth profiles of ring-tensile data were examined to arrive at the final data set. Since only the bottom half of the ice sheet is in tension under surface loading, the data was further refined to include only this portion of the thickness. The 28 data points used for the analysis represent approximately 175 individual test specimens.

Flexure-Strength Data

The apparatus for cutting and testing ice beams includes a special chain saw, a hydraulic loading ram, and a strain-gage load cell. All beams were failed by a center-point load producing tension on the bottom face; the rate of loading for most tests resulted in a stress rate in excess of 14 psi/sec. Both fixed-end and simple-supported beams were tested. Only data accumulated from large in-situ beams (summarized in Table 2 of the Appendix) was used to correlate the flexure- and ring-tensile-strength test data.

Beams at temperatures up to $-2.5^{\circ}C$ represent essentially an isothermal condition of the ice, while beams tested at lower temperatures have a thermal gradient. Flexure strength for the latter group thus represents an effective strength and not an exact strength-temperature relationship since the temperature is treated as the mean of the gradient across the lower half beam thickness.

ANALYSIS

To establish whether brine volume can be used as the correlating parameter between flexure and ring-tensile strengths, it was first necessary to develop individual correlations for each of the strengths with brine volume. The method of polynomial-least-squares curve fitting was utilized with pertinent data contained in Tables 1 and 2 of the Appendix. All fitted curves are straight lines since no data sets were considered sufficiently accurate to justify a higher than first order or linear fit.

The decision to perform linear curve fitting was further reinforced by computing the correlation coefficient "r" from the observed data. The value of "r" for the 28 points of ring-tensile and brine-volume data was -0.81 and for the 19 points of flexure and brine-volume data it was -0.75. The correlation coefficient has values equal to ±1 for observed points falling exactly on a straight line. In these two cases, it was judged that the "r" values are sufficiently close to an absolute value of 1 to permit linear curve fitting.

The standard deviations computed in the curve fittings are defined as the square root of the sum of the squares of the differences between observed and fitted strengths divided by the number of points minus one. From this definition, it is seen that each point is weighted equally and, thus, the standard deviation is an average error for the entire fitted line. By assuming a normal distribution of points, each of the two fitted curves has an approximate confidence limit of 68%.

Ring-Tensile-Strength and Brine-Volume Correlation

Data for the ring-tensile-strength correlation with brine volume were curve-fitted to obtain the straight line shown in Figure 6. The equation of this line is:

$$\sigma_R = (316.29 - 16.568\,x) \pm 29.714 \qquad (1)$$

where σ_R = ring-tensile strength, psi

$x = \sqrt{\text{brine volume (ppt)}}$

29.714 = standard deviation, psi

For this solution, the square root of brine-volume range was 4.9 to 12.5. This range reflects the ring-tensile data obtained from late October, when **x** was 4.9 to late January when **x** was 12.5. The correlation produced a definite chronological trend in ring-tensile strength (Figure 6).

Flexure-Strength and Brine-Volume Correlation

Data for the flexure-strength correlation with brine volume were curve-fitted to obtain the straight line shown in Figure 7. The equation of this line is:

$$\sigma_f = (175.58 - 12.470\,x) \pm 13.809 \qquad (2)$$

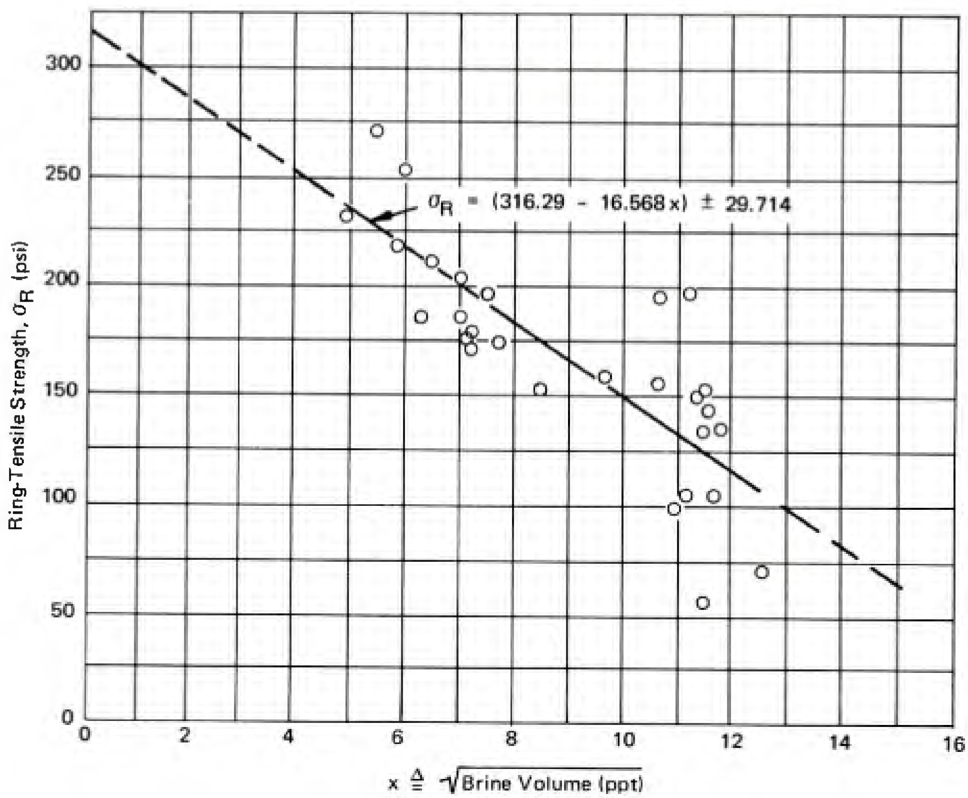

Figure 6. Ring-tensile strength and brine-volume correlation.

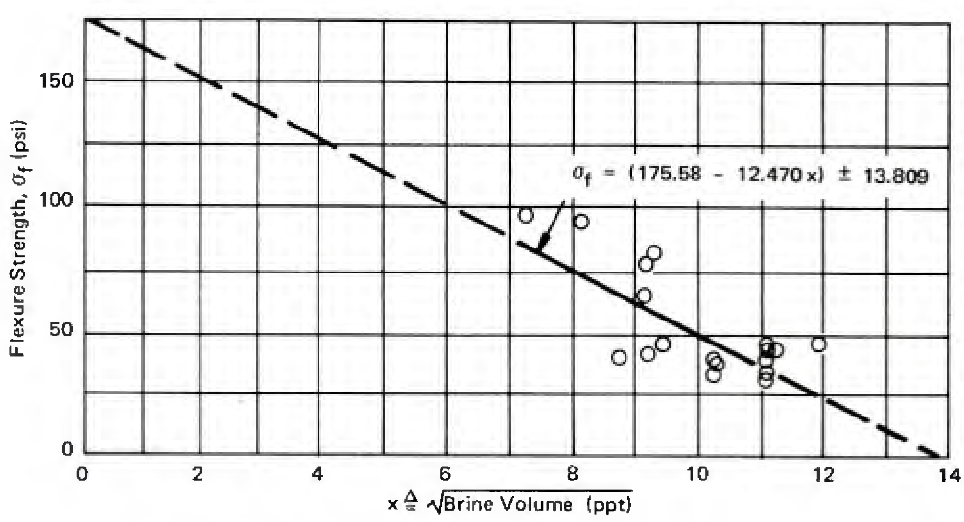

Figure 7. Flexure strength and brine-volume correlation.

where σ_f = flexure strength, psi

$x = \sqrt{\text{brine volume (ppt)}}$

13.809 = standard deviation, psi

For this solution, the square root of brine-volume range was 7.1 to 11.9. This range reflects data obtained from mid-November when x was 7.1 to early February when x was 11.9. The flexure data, like the ring-tensile strength when correlated with brine volume, produces the proper chronological trend.

Flexure- Versus Ring-Tensile-Strength Correlation

Correlation between flexure and ring-tensile strengths was investigated by the following two methods of analysis: (1) an indirect method which used brine volume as the common parameter between the two strengths, and (2) a direct method which used strength values selected for common calendar periods during austral spring and summer months.

Indirect Correlation. Using brine volume as the common parameter, the correlation results in an equation of the form:

$$\sigma_f = -62.49 + 0.753\,\sigma_R \qquad (3)$$

Equation 3 is shown graphically in Figure 8 and is obtained by eliminating the independent variable x from Equations 1 and 2. Derivation of Equation 3 was based on the fitted-line values of these equations and, therefore, does not reflect the standard deviation associated with each. The solution complexity resulting from applying the plus and minus configurations of these two was not considered justifiable. The validity of the correlation found by Equation 3 is also clearly questionable—a negative flexure-strength intercept value of –62.49 psi at zero ring-tensile strength was obtained contrary to the expected behavior of a zero convergence of both strength values.

Direct Correlation. This solution for correlating the flexure strength with the ring-tensile strength is based on selecting data values obtained at common time periods during the seasonal strength change. The result was an equation of the form:

$$\sigma_f = -1.94 + 0.428\,\sigma_R \pm 5.982 \qquad (4)$$

where 5.982 is the standard deviation, psi.

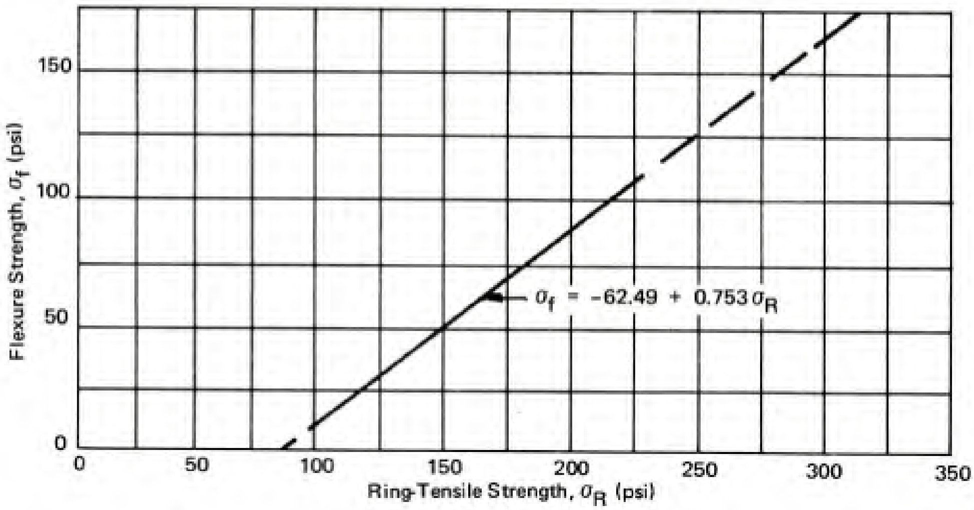

Figure 8. Flexure strength versus ring-tensile strength (indirect correlation).

The straight line shown in Figure 9 has been curve-fitted through points 1 through 4. Point 1 was used to force the straight line near the origin. Without point 1, the resulting straight line would have intercepted the ring-tensile axis at a higher value. The other three points are averages of data from Tables 1 and 2 of the Appendix. Point 2 represents average ring-tensile and flexure strengths during the midsummer period 22 January to 28 January. The 39-psi flexure strength used is the average of 11 beams failed over 2 consecutive years when the essentially isothermal temperature gradient through the ice was -2.5°C. Point 3 represents December strength data for which only a single data point, 80 psi, for the flexure strength was available. Point 4 represents strength data for late October to late November. The flexure strength of 95 psi was the failure strength obtained when the ice sheet had a temperature gradient similar to that for October shown in Figure 2.

SUMMARY

In order to obtain the proper perspective for comparing the validity and accuracy of the two methods used to investigate possible correlations between flexure and ring-tensile strength, it is necessary to review how inconsistencies and scatter found in the ring-tensile data were treated. An inconsistency found in the data was the frequent appearance of a ring-tensile-strength profile of the ice sheet which was considerably displaced from the normal chronological strength trend that is established as the warming season progresses. Such deviations were found not only within the same spring-to-summer seasonal test period, but also between yearly test seasons even though

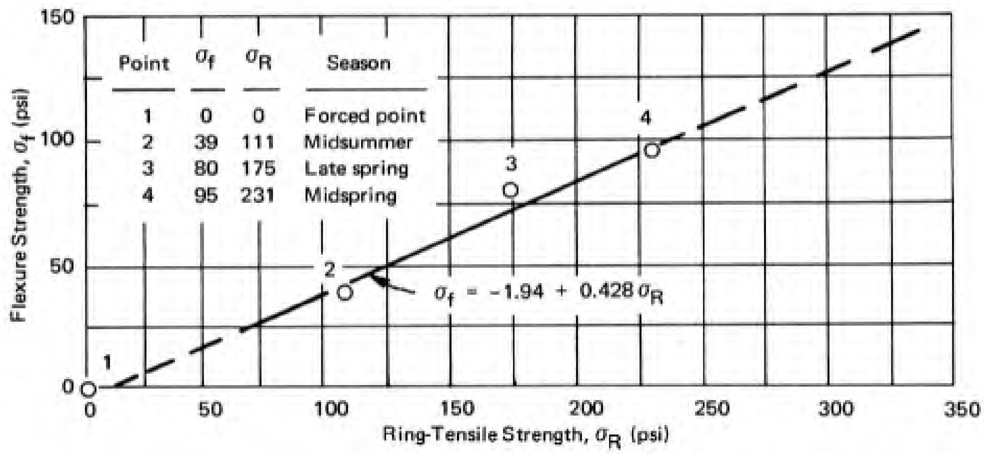

Figure 9. Flexure strength versus ring-tensile strength (direct correlation).

the calendar period was nearly the same. Since no single season had sufficient test data to be used solely for the analysis, it was necessary to overlay the strength profiles of several seasons and systematically eliminate the displaced profiles in order to develop a pattern of chronological strength change.

Once a basic set of ring-tensile vertical profiles was established, it was necessary to consider only the ring-tensile data over the lower half of the ice sheet, as only this portion is under tension when the ice sheet is loaded on its surface. This technique removed disorder in the data, but the divergency or scatter along the vertical profile still remained. This scatter, however, should reflect the true ring-tensile condition, because of the relatively large weighting given to each point (5 to 10 specimens). Thus, no smoothing along the lower half length of the ring-tensile profiles was considered.

An investigation by Paige and Kennedy (1967) showed that scatter can be primarily attributed to crystal orientation of test specimen and random location of stress-concentration features. These effects, however, should be completely randomized since orientation was not given any special treatment in this series of tests. Human error and variation in the operating of test equipment under adverse test conditions may be of consequence in the profile inconsistency and profile point scatter. These factors were reviewed but in no real sense could they be evaluated as to the true magnitude of their effect. Crystal size as related to specimen size may also contribute to data scatter.

In contrast to the shifting profile effect and profile scatter of the ring-tensile tests, the flexure-strength data, though of somewhat limited quantity, were consistent with comparable results obtained for tests that were repeated during a 2-year period at the same seasonal period. Flexure data also showed the proper weakening trend as the warming cycle progressed from spring to summer; this resulted in good correlation with brine volume.

For the indirect method of correlating ring-tensile strength with flexure strength and for the purpose of estimating flexure strength from ring-tensile data, both strengths were first individually correlated with brine volume. The standard deviation (see page 9) found for the flexure-strength correlation with brine volume was ±13.809 psi, and that for the ring-tensile strength correlation with brine volume ±29.714 psi. At first it would appear that the flexure-strength correlation with brine volume, because of its lower numerical value, is the better of two correlations. However, when associating the standard deviation on a percentage basis with the strength for specific brine volumes, each of the standard deviations, ±13.809 and ±29.714, is approximately of the same magnitude. This, together with almost identical correlation coefficients, −0.75 and −0.81, makes it irrelevant to evaluate which of the correlations is the better.

These correlations were performed by using the method of polynomial-least-squares curve fitting. In each case, only a straight-line fit was tried. This was justified as the small range of values for brine volume was insufficient to indicate more than first-order curve-fitting, and second, the correlation coefficients of observed data were sufficiently close to an absolute value of 1. The indirect correlation between the strengths, obtained by eliminating brine volume from the two linear equations, resulted in a linear equation for the two strengths. An immediate disadvantage of this equation was that neither the origin nor its neighborhood was intercepted within reason. Instead, the equation gave a −62.49-psi flexure strength for a zero ring-tensile strength. The slope of the line obtained from the equation also appears to be too steep; the ring-tensile values for early spring and late summer predict flexure-strength values either too high or too low. It is obvious that the utility and reliability of the indirect correlation is questionable.

The direct method of correlation between ring-tensile and flexure strength provides a reasonably good method of estimating the flexure strength if one assumes that as the flexure strength approaches zero value, so will the ring-tensile strength approach this value. However, observed ring-tensile data at the low-strength end of the correlation are too high in relation to observed flexure data; the implication is that the two strengths approach zero at different rates, and as a result, there is some uncertainty in the original assumption of a linear proportionate between the strengths, particularly in the zero-strength region. The other three points used to develop the correlation equation contain paired coordinates which are observed strengths for common calendar times spread along the strength trend of the spring-to-summer warming season. Equation 4 is derived from the linear curve fitted to these four points. The straight line obtained from Equation 4 produces reasonable estimates of the safe flexure strength. No significance can be attached to the low standard deviation ±5.982 psi due to the bias in the solution resulting from data selection. However, it is cautioned that for actual application it would be necessary to take a large number of ring-tensile samples because of the apparent scatter and divergence of this type of data.

CONCLUSIONS

1. The best method of estimating flexure strength (modulus of rupture) using ring-tensile-strength data is provided by the equation developed by the direct correlative method.

2. Scatter in the ring-tensile data contributes to inaccuracies in both the direct and indirect methods of correlating flexure strength with ring-tensile strength.

3. The flexure strength determined from in-situ beam tests is considered more reliable than the data obtained from the small sample size of the ring-tensile test. The flexure-strength data was found to be consistent in following the chronological weakening trend of the ice sheet.

4. A large quantity of ring-tensile specimens from the lower half thickness of the ice sheet (to establish a well-averaged strength value) is required in order to estimate the flexure strength using either the direct or indirect correlation equations.

5. In order to use ring-tensile data as an estimator of flexure strength (rupture modulus), adherence to well-founded test procedures and precision in the test method are required.

RECOMMENDATIONS

1. Further effort to correlate ring-tensile strength with the flexure-strength property is not recommended; instead, a correlation between flexure strength and brine volume is recommended. This would eliminate the need for ring-tensile tests and would reduce the field effort for ice-strength determinations to measurements of temperature and salinity only.

2. An effort should be made to develop a system for predicting the flexure strength of a sea-ice sheet by referring directly to the temperature gradient and the general salinity range.

Appendix

SUMMARY OF RING-TENSILE AND FLEXURE-STRENGTH FIELD DATA

Table 1. Summary of Ring-Tensile-Strength Data

Location	Date	Average Ice Core Length	Air Temperature (^{o}C)	Ice Core Sections (ft)	Ring-Tensile Strength (psi)	Salinity (ppt)	Temperature (^{o}C)	$\sqrt{\text{Brine Vol (ppt)}}$ *
Station 1	10/25/65	8 ft 10 in.	-9	0-1	253	5.61	-15.0	—
				1-2	287	5.19	-13.5	—
				2-3	296	4.28	-12.5	—
				3-4	258	4.42	-11.5	—
				4-5	232	4.09	-9.8	4.86
				5-6	270	4.58	-8.0	5.52
				6-7	253	4.13	-6.0	5.96
				7-8	213	3.57	-4.2	6.49
				8-9	187	5.33	-2.5	7.00
Station 1	11/15/65	8 ft 10 in.	-10	0-1	244	6.05	-12.6	—
				1-2	252	5.85	-11.8	—
				2-3	259	4.53	-10.4	—
				3-4	224	5.45	-9.2	—
				4-5	219	5.05	-8.2	5.75
				5-6	187	5.35	-7.0	6.34
				6-7	204	5.18	-5.4	7.01
				7-8	175	3.80	-3.6	7.19
				8-9	**	**	**	**

Continued

Table 1. Continued.

Location	Date	Average Ice Core Length	Air Temperature (^oC)	Ice Core Sections (ft)	Ring-Tensile Strength (psi)	Salinity (ppt)	Temperature (^oC)	$\sqrt{\text{Brine Vol (ppt)}}$ *
Station 1	12/20/65	9 ft 0 in.	-2	0-1	170	5.83	-5.5	—
				1-2	161	6.95	-5.5	—
				2-3	170	5.45	-5.0	—
				3-4	178	5.70	-5.0	—
				4-5	180	5.65	-5.6	7.20
				5-6	172	5.60	-5.5	7.23
				6-7	195	5.73	-5.2	7.50
				7-8	174	5.40	-4.6	7.71
				8-9	153	5.83	-4.0	8.50
Station 1	1/12/66	5 ft 0 in.	-6	0-1	191	5.63	-2.0	—
				1-2	146	6.45	-2.2	—
				2-3	161	5.45	-2.8	9.71
				3-4	136	6.45	-2.4	11.37
				4-5	150	5.34	-2.0	11.32
Station 1	1/22/66	4 ft 3 in.	-4.5	0-1	218	5.30	-4.5	—
				1-2	168	6.65	-3.5	—
				2-3	138	6.68	-2.3	11.82
				3-4	105	5.69	-2.0	11.69
				4-5	195	4.80	-2.0	10.73

Continued

Table 1. Continued.

Location	Date	Average Ice Core Length	Air Temperature (°C)	Ice Core Sections (ft)	Ring-Tensile Strength (psi)	Salinity (ppt)	Temperature (°C)	$\sqrt{\text{Brine Vol (ppt)}}$ *
Beam Test Area	1/6/67	7 ft 9 in.	0	0-1	130	4.25	-1.3	—
				1-2	112	6.63	-2.1	—
				2-3	142	7.05	-2.8	—
				3-4	154	6.48	-2.9	—
				4-5	158	5.83	-2.5	10.61
				5-6	154	5.73	-2.1	11.43
				6-7	198	5.19	-2.0	11.16
				7-8	140	5.53	-2.0	11.52
Beam Test Area	1/28/67	6 ft 9 in.	-0.6	0-1	110	4.25	-1.1	—
				1-2	37	6.63	-1.1	—
				2-3	73	7.05	-1.8	—
				3-4	72	6.48	-2.0	12.47
				4-5	61	5.83	-2.1	11.53
				5-6	106	5.73	-2.2	11.18
				6-7	99	5.19	-2.1	10.88

* Only lower one-half thickness of sea ice data included.
** Data missing.

Table 2. Summary of Flexure-Strength Data

Beams Tested	Mean Temperature* (^{o}C)	Mean Salinity* (ppt)	$\sqrt{\text{Brine Vol (ppt)}}$ *	Flexure Strength (Rupture Modulus) (psi)
Fixed end	-2.5	5.47	10.30	36.5
	-3.0	5.47	9.42	38.5
	-2.0	5.11	11.09	38.0
	-2.0	5.11	11.09	33.0
	-3.0	5.30	9.26	82.0
	-4.2	5.68	8.19	90.0
	-4.9	5.10	7.28	95.0
Simple supported	-2.5	5.47	10.30	39.2
	-2.5	5.47	10.30	34.4
	-3.0	5.47	9.41	44.4
	-2.0	5.11	11.09	33.8
	-2.0	5.11	11.09	30.5
	-2.0	5.11	11.09	46.0
	-2.0	5.11	11.09	40.5
	-2.0	5.20	11.18	42.0
	-2.0	5.90	11.92	46.0
	-3.0	5.20	9.18	41.0

* Mean value of lower one-half thickness of ice sheet.

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TR-617 21 p. illus Mar 1969 Unclassified

1. Sea ice strength correlations I. YF 38.536.002.01.001

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