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Anchoring Tests on the Filchner/Ronne Ice Shelf 1979/80

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Summary: As part of the site-survey investigations for the German Antarctic winter-over station, a few improvised tests could be conducted with various dug-in anchoring objects. Besides this, the forming of ice plugs for anchoring purposes was examined.

Zusammenfassung: Während der Standorterkundung für die deutsche Antarktis-Station konnten einige improvisierte Tests mit verschiedenen eingegrabenen Ankern durchgeführt werden. Außerdem wurde die Ausbildung von Eisplomben als Verankerungskörper untersucht.

In the course of a research programme, entitled ,,Development of an Anchoring System suitable for Use in Ice and Snow'' and conducted by Dr. Maidl of the Ruhr University of Bochum, preliminary tests were performed by Dorsch Consult during exploration work of local conditions in 1979/80. As the most important aparatus and materials necessary for such preliminary tests had been lost during transport, only a few improvised tests could be conducted at that time, however.

1. FROZEN-IN ANCHORINGS

In conformity with the above mentioned test programme, specifying a traction member to be inserted into a borehole, and to then form the anchoring component into an ice plug, the design and actual configuration of this anchoring component was examined. In addition, steel-wire ropes, provided with an increased roughness by means of rope clamps, so-called ,,frogs'', were then frozen in the various boreholes to be pulled out again with the aid of an electric winch mounted on the locally available snowmobile.

1.1 *Description of Test*

With core drilling bits borrowed from the glaciological exploration programme, vertical holes of 11.5 cm diameter were drilled (refer to Tab. 1 for data).

After the first borehole (V1) was filled with 32 litres of seawater dyed with potassium permanganate, it became evident that due to the permeability of the snow, no anchoring by means of an ice plug could be accomplished in any of the boreholes (for detailed data, please refer to the Glaciological Report), as all the water had seeped away within a very short time. Subsequently, several means were tried to stop the seepage of the water and/or to retard and delay it (Tab. 1).

It was found, however, that none of the chosen measures was suitable to delay the water seepage long enough so that an ice plug could be formed.

In order to obtain more information on the distribution of the water seepage, a vertical section was cut down in-situ through the ice along all of the borehole axes to a depth of approximately 3 m below top edge of borehole. The actual path of the seepage can be recognized in Fig. 1.

1.2. *Results and Findings*

The establishment of any firm tie and traction anchors by the method as recommended by Dr. Maidl does

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Borehole no.	Level of edge of borehole below top of normal (m)	Depth of borehole (m)	Preparation of borehole	Quantity of water (litres)	Filling time (sec)	Annotations
V 1	1.50	1.00	none	32	4 x 40 Intervals 3 x 70	Bottom of borehole 17 cm lower after filling
V1/A	1.50	0.5	Cardboard on bottom of borehole	8	40	Water rose to 15 cm above bottom of borehole for a short time
V1/B	1.50	0,5	filled up with loose snow before filling hole with water	8	40	Water filled in with watering can
V1/C	1.50	0.5	Borehole was heated for about 8 minutes with the exhaust fumes of a Bosch 2-stroke generator. Water was filled in the following day.	8	40	—

General Values: Air temperature at the time of making the borehole: —5.7° C
Water temperature: plus 0.1° C . . . minus 0.2° C
Snow temperature at borehole: approx. minus 8° C
Filling-in through steel pipe 8 cm ∅, 2 m long, projecting 10 cm above bottom of borehole.

Tab. 1: Characteristic values of borehole investigation.

Tab. 1: Charakteristische Werte der Bohrloch-Untersuchungen.

thus not seem feasible, i. e. not under those conditions and circumstances found at the site, except, perhaps, when applied in a different way and manner. It should be taken into account, however, that the tests conducted by us, were improvised tests, and that the effects of salinity, for instance, and that of the potassium permanganate upon the formation of solid ice, would require closer examination.

2. ANCHORAGE BY MEANS OF DUG-IN OBJECTS

The more customary way of absorption of horizontal forces that has been practised hitherto in polar snow regions, e. g. for the anchorage of ships, is the digging-in (burying) of suitable objects in the snow, whereby the anchoring rope is run at as low an angle in relation to the surface of the snow as possible. Quite frequently used are gasoline drums or barrels filled with water, horizontally placed square timbers and planks, or similar objects.

2.1. *Description of Test*

As no data at all were available on the forces which such anchors are able to absorb, we built timber an-

Description	Material	Dimensions (m)	Perimeter (m)	Surface m^2
a1	Square Timber	1.1 x 0.1 x 0.1	2.40	0.11
a2	Board	0.44 x 0.22	1.32	0.096
a3	Boards	0.67 x 0.33	2.00	0.2211
a4	Boards	1.02 x 0.66	3.36	0.67

Tab. 2: Characteristic values of the dug-in (buried) anchors.

Tab. 2: Charakteristische Werte der eingegrabenen Anker.

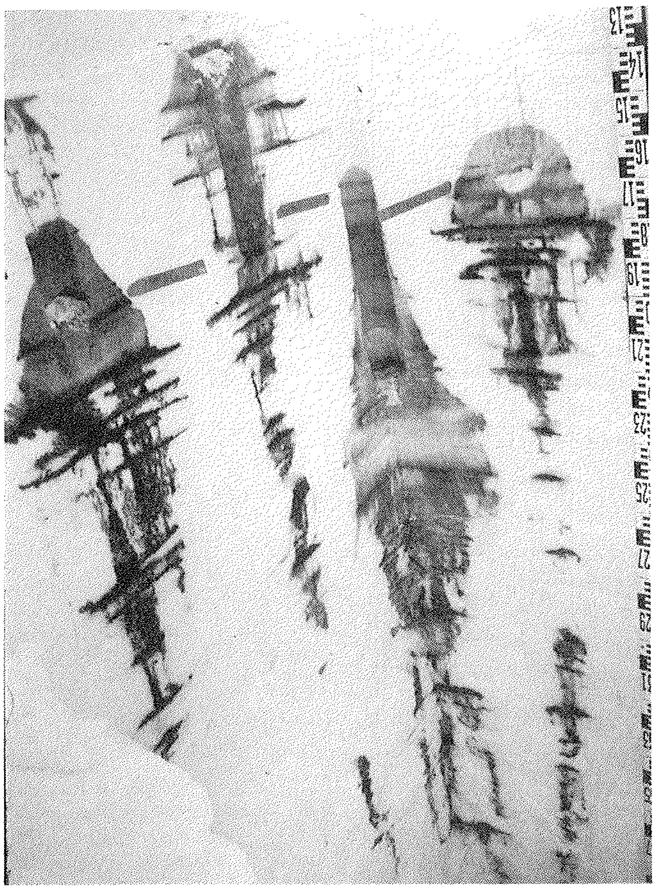

Fig. 1: Seepage path of dyed seawater filling in a dug-out borehole.

Abb. 1: Versickerungsverlauf der gefärbten Meerwasserfüllung in einem aufgegrabenen Bohrloch.

chors of various sizes (see Tab. 2). The anchors, mostly built of composite boards were sufficiently braced with square timbers on the rear, so as to correspond with their overall sizes and contours. The traction force was introduced centrally with the aid of a steel rope. The point of gravity was found to be situated 1.50 m below the natural horizon of the snow plane, the angle of traction was 30° in relation to the horizontal plane, and the anchoring surface was — by visual estimate — arranged perpendicularly to the direction of traction. The holes for the accommodation of the tension rope were punched by means of surveyor rods (Balisen type) having a diameter of 4 cm and the ropes were then fed in so that the structure of the snow was only moderately disturbed.

The electric winch mounted on the snowmobile, capable of reaching a traction of about 3 tons and a steel rope of 50 m length were made available as traction equipment. Measurements were taken by means of a spring balance with a weighing capacity of only 500 kg. A traction pulley block, permitting the measurement of up to 3 tons maximum anchor traction force with said spring balance, was built from pulleys taken from the ship's tackle.

The transfer of forces at 30 degrees in relation to the winch of the snowmobile was effected via a steel pipe being moved along on two pieces of squared timber.

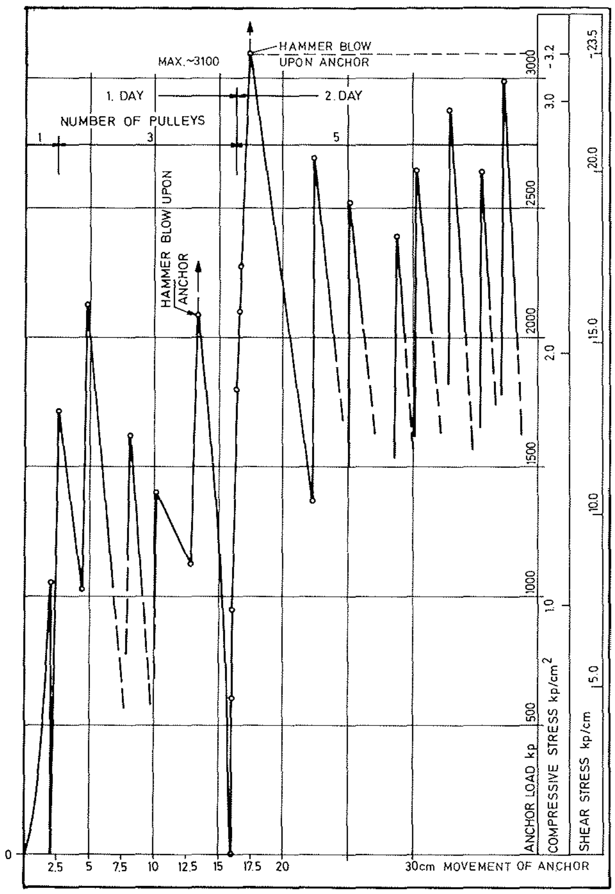

Fig. 2: Load-yield diagram, anchor a2 (0.44 x 0.22 m).

Abb. 2: Last-Weg-Diagramm, Anker a2 (0.44 x 0.22 m).

2.2. *Results and Findings*

a) Anchor a 2

Fig. 2 illustrates the ways which anchor a2 traveled in the snow during its exposure to the applied load. The assumption that the entire snow wedge would be squeezed and/or pressed out under a definite angle of shear, was not confirmed. Rather one was able to observe the phenomenon of a punch-through, simi lar to that well-known from reinforced concrete construction. The hole that was formed when the anchor was pulled through the snow showed uniform wall-surfaces in an exact circumscription of the perimeter of the anchor.

Every time when the „limit load" was reached, the anchor jerked for a short distance with an audible sharp report in the direction of the anchor traction, approaching, at a temporary drop of pressure, but under a steady pull-up of the winch, the next limit load.

The maximum load achieved at the beginning of the second day, when it reached 3.1 tons, permits the assumption that a certain degree of hardening and stabilization (sintering) had taken place during the 12 hour period of interruption. As the measuring apparatus had reached its maximum capacity at 2120 kp (using 3 pulleys) and/or 3100 kp (using 5 pulleys), and additional movement of the anchor was provoked by heavy blows applied with an 800 g carpenters hammer. The load shown in the diagram for a2 amounted to an additional 2—3 tons. After a total travel of about 60 cm the anchor plate started to tilt, rendering all other values and data irrelevant.

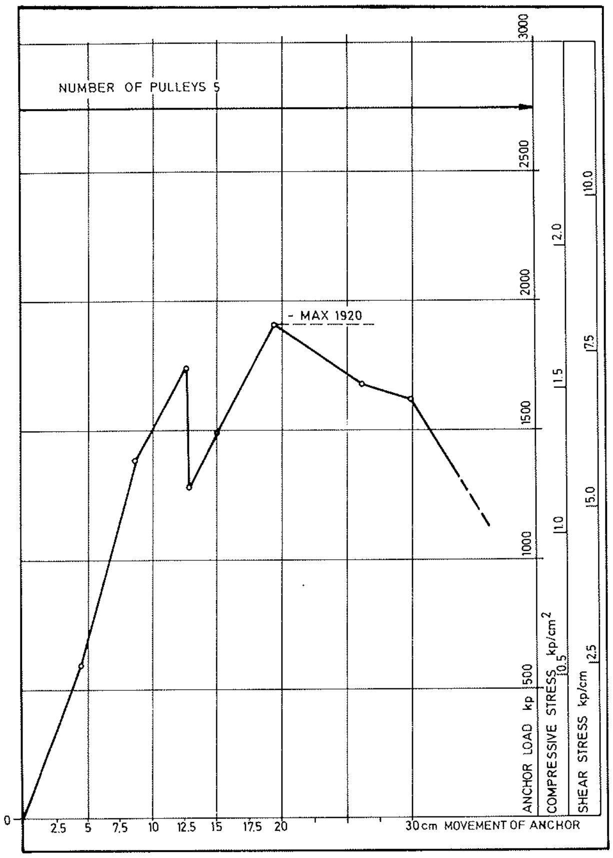

Fig. 3: Load-yield diagram, anchor a1 (1.10 x 0.10 m).

Abb. 3: Last-Weg-Diagramm, Anker a1 (1.10 x 0.10 m).

The snow block in front of the anchor had broken off at a load of approximately 1700 kp. The unexpectedly far-reaching parabolic shear surfaces have, in their final course, been slightly affected by the superimposed structures. Notwithstanding that influence, the general course can be well recognized, however. The shear diagram leads to the assumption that the snow is able to take up relatively large traction forces. This assumption is additionally supported by the breakage or failure diagram which was plotted during the excavation of the snowblocks that were sawn free (Fig. 5).

b) Anchor a1 (squared timber)
This test was conducted similarly to that for anchor a2. The reaction of the anchor with that of anchor a2 can be considered comparable. As can be readily seen on Fig. 3, the achieved load values were substantially lower though. It is quite possible that the factor of forms, width over length ratio (at a2 = 1:2, and at a1 = 1:11) or any slight tilting or edging of a1 (wedge effect) have affected the test somewhat.

c) Anchors a3 and a4
From the results of the traction tests on hand, and particularly in the case of anchor a2, one had to anticipate that, due to the lack of suitable equipment, these two anchors could not be measured in the previously intended manner.

For that reason, anchor a3 was not placed. As can be derived from Fig. 4 a shear angle had been determinded by means of anchor a4.

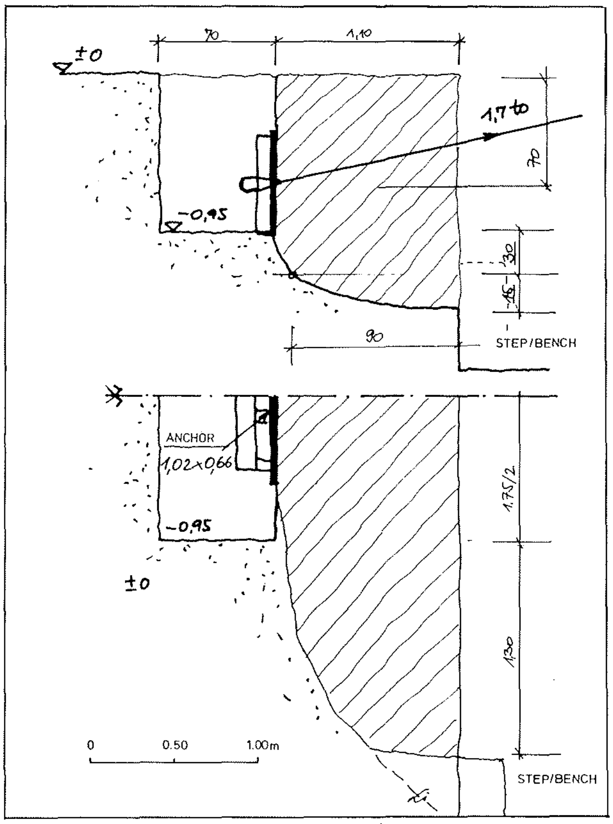

Fig. 4: Drawing of shearing-rupture, anchor a4.

Abb. 4: Scherbruch-Bild, Anker a4.

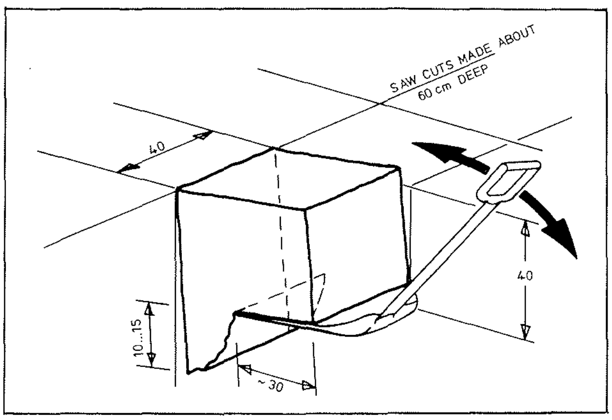

Fig. 5: Drawing of breakage, showing ruptures on snow blocks when dug out a 3 m below snow grade at approx. -25 °C.

Abb. 5: Bruchbild: Bruchverlauf auf Schneeblöcken aus 3 m Tiefe bei ca. -25 °C.

CONCLUSION

By means of these improvised tests the anchoring problems that are posed by ice and snow could merely be touched and not thoroughly explored. Based on the results obtained, the shaping and installation of anchoring objects, devised as ice plugs, should therefore be restudied carefully. All tests conducted until now with dug-in or buried objects can, for that reason, be only regarded as the beginning of a comprehensive series of tests to be conducted in the future.