Strength of V-Thread versus A-Thread Ice Anchors In Melting Glacier Ice[1]

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International Technical Rescue Symposium
Pueblo, Colorado, USA
November 6-8, 2009

Abstract

Testing by others has shown a new configuration of the traditional V-thread ice anchor (the V-thread is also known as the Abalakov anchor) to be stronger than the traditional configuration. In the new configuration the legs of the V in the ice are aligned with the direction of pull, instead of perpendicular to direction of pull as with the traditional V-thread. This new alignment has been called the A-thread anchor. Seattle Mountain Rescue (SMR) tested the strength of both anchor configurations in melting glacier ice because these ice conditions frequently occur in the area served by SMR. Both V-thread and A-thread anchors were pulled to failure. When properly constructed and using 1" tubular webbing, the minimum breaking strength of A-thread anchors was 12% greater than comparable V-thread anchors. When anchors were located in apparently solid ice and holes were drilled with a 17 cm (6 ¾ inch) ice screw, A-thread anchors had a minimum breaking strength of 16.9 kN (3800 pounds), and V-thread anchors had a minimum breaking strength of 15.1 kN (3400 pounds). When a longer ice screw was used to make the holes the strength of the webbing was the limiting factor, and the webbing broke before the ice broke. This research included tests of questionable anchors, including one test each of an anchor (a) placed on an ice bulge, on (b) white colored ice that was possibly rotten ice, and (c) using 8 mm perlon instead of 1" tubular webbing. Even these sub-optimal quality anchors had at least 10 kN (2250 pound) breaking strength. In this testing, no single anchor had the 20 kN (4500 pound) minimum breaking strength desired for SMR to classify an anchor as a full strength rescue anchor. All anchors tested had at least 10 kN breaking strength, so two anchors ganged together in parallel should give at least 20 kN strength.

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[1] Please cite as: Smith, Gordon R. 2009. "Strength of V-thread versus A-thread ice anchors in melting glacier ice." Presented at International Technical Rescue Symposium. 6-8 November, 2009. Pueblo, CO.

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Introduction

Marc Beverly and Vince Anderson came up with the idea of changing the alignment of the traditional V-thread ice anchor (Figure 1, also known as the Abalakov anchor) so that the legs of the V in the ice are aligned with the direction of pull instead of perpendicular to direction of pull as with the traditional V-thread (Figure 2). Marc calls this new alignment the A-thread anchor. Marc Beverly and Stephen Attaway tested the strength of V-thread versus A-thread ice anchors in well-frozen pond and waterfall ice, and found the A-thread to have a mean breaking strength 27% greater than the mean breaking strength of V-thread anchors.[3]

Ice conditions are highly variable and this variability can affect the strength of the ice. Ice is weaker if the grains are larger, the temperature is higher, or it is loaded fast.[4] In theory, glacier ice is similar to most other water ice. However, the development of glacier ice from snow, metamorphosis of glacier ice over time, trapped air, and warm temperatures could make glacier ice weaker than sub-freezing water ice. Considering the adoption of the A-thread anchor as its default ice anchor for holding rescue loads, Seattle Mountain Rescue (SMR) tested both V-thread and A-thread anchors in melting glacier ice that is often found in the SMR service area.

Figure 1. A-thread anchor.

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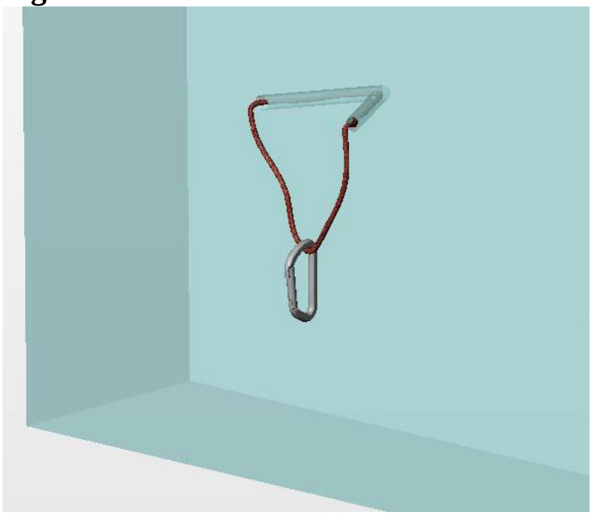
[3] Beverly, J Marc, and Stephen W. Attaway. 2009. “Ice climbing anchor strength: and in-depth analysis.” Paper presented at Mountain Rescue Association spring meeting, June 26-28, 2009. Timberline Lodge, OR.

[4] Schulson, EM. 2001. “Brittle failure of ice.” *Eng Fracture Mechanics.* 68: 1839-87. Cited in Beverly, J Marc, and Stephen W. Attaway. 2009. “Ice climbing anchor strength: and in-depth analysis.” Paper presented at Mountain Rescue Association spring meeting, June 26-28, 2009. Timberline Lodge, OR.

Figure 2. V-thread anchor.



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The Tests

To simulate a rescue load that could be applied during a raise or a lower, anchors were weighted with a manual winch. Anchors were slow-pulled to failure, and the maximum force held was measured with a load cell, using the peak force recording function of the load cell. The maximum force held was recorded. The pulling system was composed of winch anchors built of two A-thread anchors loaded in parallel, a winch, steel cable forming a 2:1 mechanical advantage system on a 2:1, the load cell, and chain connecting the load cell to the anchor being tested (Figure 3). A separate ice screw was connected to the chain via a runner and used to limit the high-velocity travel of metal parts that typically occurred when anchors failed. The duration of loading was as long as it took to stretch the anchor webbing, generally a couple minutes.

Testing was performed on July 18, 2009, a warm and sunny day. The test site was on the Nisqually Glacier on Mount Rainier, at approximately 6,000' of elevation. The site was gently sloping (approximately 15 degrees) and faced south-southeast (aspect 160 degrees). The surface was exposed glacier ice, without snow. The air temperature was warm, with a high temperature of about 60 degrees Fahrenheit (15 C). Testing was started in late morning and continued through mid afternoon. Through the entire testing period melt water was flowing over the glacier ice surface, and the ice surface was decomposing into uncohesive grains as the ice melted.

Prior to installing an anchor to be tested, loose granular ice on the surface was removed by scraping and chipping with an ice axe adze, to clear an area of intact, unmelted ice for building the anchor. Except for the tests of "bad" anchor construction, the ice in and around all anchors was judged by the testers to be solid, which means it had no significant defects, was clear or moderately translucent, and was flat or located in a slight depression. Also, the construction of anchors was proper and each "good" anchor would have been accepted as an adequate anchor if used in a real rescue. As preliminary testing of the bounds of adequacy of anchors, some anchors were tested that would not have been used on a real mission, if any better alternative existed. These tests were: locating an anchor on a modest ice bulge instead of on a flat surface, locating an anchor in opaque white ice that was possibly rotten, and building an anchor with 8 mm perlon cord instead of 1” tubular webbing.

Figure 1. The testing system, preparing to pull a V-thread anchor.

Photo © Doug Seitz.

Anchor holes were drilled using ice screws typical of the screws commonly used for recreational ice climbing. To make the tests as representative as possible of SMR’s actual rescue situations, testing was done with used webbing, not new webbing. Tested anchors were built of webbing and cord that had been retired from SMR rigging kits because it was five years old, but had no signs of wear or known experience that would have otherwise caused it to be retired.

When building anchors, we tried to drill holes at an angle of 60 degrees to the surface of the ice, in an attempt to create an equilateral triangle of ice encompassed by the anchor, to maximize the cross sectional area of ice being pulled during the test. The angle of each hole, relative to the ice surface, was measured with a protractor. Angles varied between 50 and 65 degrees. The distance between the two holes of each anchor was measured.

Anchors were built through the day and each anchor was pulled to failure less than an hour after it was built. V-thread anchors were tested before and after A-thread anchors to minimize any potential influence of time of day on anchor strength. All anchors holes filled with melt water in seconds to minutes after they were drilled. Anchor material immediately became saturated with water, and was saturated for at least a few minutes before the anchor was tested. The strengths reported here should be considered to be the strengths of wet material, not dry. This point is important because prior testing has shown wet nylon cordage and webbing to be weaker than dry material.

Results

Data on pull tests is presented in Table 1. Pull number is the sequential order of tests. Configuration is either A-thread or V-thread. Material is 1” tubular webbing or 8 mm perlon utility cord. Breaking strength of each anchor is reported in pounds and kilonewtons. Unless otherwise stated in the “notes” section of Table 1, all anchors failed by the ice failing. Ice failed by pulling up and out, or by shear failure of the ice surrounded by the anchor webbing.

Table 1. Pull test data.

Pull No.	Anchor Type	Material	Cross Sectional Area (in^2)	Strength (kN)	Strength (lbs)	Notes
2	A	web 1"	8.8	16.9	3800	
3	A	web 1"	11.1	16.9	3800	Come-along anchor failed
4	A	web 1"	15.6	18.7	3910	Web failed
4.1	A	web 1"	15.6	18.7	4200	Web failed; same holes as 4
1	V	web 1"	9.1	15.6	3500	
6	V	web 1"	16.9	16.9	3790	Web failed; blue water-ice
7	V	web 1"	9.2	15.1	3400	“Questionable,” white ice
5	V	web 1"	7.8	10.0	2250	“Bad,” on ice bulge
8	V	cord 8mm	16.9	12.9	2900	

Conclusions

In this testing, both the mean breaking strength and minimum breaking strength were greater for A-thread anchors than for V-thread anchors. These strengths are given in Table 2. Pull 7 was performed in white, opaque glacier ice. Testers were concerned that this was a “bad” anchor because the ice might be rotten and decomposing, but this anchor was almost as strong as the “good” anchors so this pull was included in the calculations of strengths of good anchors, to increase the number of sample size.

We are most concerned about avoiding anchor failure, so we are more concerned about minimum breaking strength than average breaking strength. However, many people are concerned about average breaking strength, so it is also reported here. The number of pulls was too small to give useful statistics of standard deviation and confidence intervals so these statistics are not reported; readers can look at the data in Table 1.

Table 2. Mean and minimum breaking strengths, by anchor type.

Anchor Type	Minimum Breaking Strength, lbs	Minimum Breaking Strength, kN	Avgerage Breaking Strength, lbs	Avgerage Breaking Strength, kN
A-Thread	3800	16.9	3928	17.5
V-Thread	3400	15.1	3563	15.9

Our initial theory was that anchor strength would be mainly a function of the cross-sectional are of ice encompassed by the anchor. However, for all the anchors built of webbing and built in “good” ice, and where the cross-sectional area of ice encompassed by the anchor was greater than 15 square inches (97 cm^2), the webbing failed before the ice failed. Also, questionable anchors failed at lower forces than would be suggested by cross-sectional area of ice encompassed.

This testing had one curious result that merits further investigation. After being loaded to close to breaking strength and then being unloaded, we observed two instances of anchors failing at a force less than the initial force that the anchor had held. One of these failures occurred in one of the anchors used to hold the winch. The winch anchor failed on the third pull test. We do not know if this anchor failed because of repeated loading or because of some other cause. Other possible causes include poor equalization of the anchors, or improper construction. The winch anchor was a set of two A-thread anchors ganged together so than they were being pulled in parallel. Each of these two winch anchors was intended to be loaded with approximately half the force necessary to fail the anchors being tested. However, it is possible that the winch anchors were not well equalized, which could have resulted in one of the winch anchors holding most of the test load. Also, the ice screw hole angles and distance between the screw holes were not measured on the winch anchors. It is possible that the anchor that failed was weak because it encompassed a small cross-sectional area of ice. Even more curious, when testing resumed after replacement of the failed winch anchor, the anchor that was being tested when the winch anchor failed then failed at a lower force than it had held a few minutes before. Prior to the winch anchor failing, the test anchor held 16.9 kN (3800 lbs), and upon re-loading it failed at 15.3 kN (3430 lbs). It is possible that the re-loading occurred faster than the initial loading but this loading still took more than 15 seconds and was almost certainly slow enough that the ice did not exhibit the decrease of strength that occurs with shock loading.

In light of these instances of curious weakening of anchors after loading, we recommend further research into the mechanism or mechanisms of weakening of ice on repeated loading to near failure.

Conclusions useful to rescuers are:

- A-thread anchors had a minimum breaking strength 12% stronger than V-thread anchors.
- Melting glacier ice is adequately strong for making rescue anchors.
- Of the ice anchors tested, no single anchor provided the 20 kN (4500 lb) strength desired for a rescue anchor.
- All anchors tested here, including the questionably constructed anchors, held at least 10 kN. Presumably any two anchors rigged in parallel would provide 20 kN strength. However, we do not recommend using bad anchors.
- The ice will probably be stronger than wet 1” tubular webbing if the ice anchor encompasses an equilateral triangle of ice that is more than about 6” (15 cm) on a side.
- 1” tubular webbing makes a much stronger anchor than 8 mm perlon cord.
- Until further research shows otherwise, ice anchors that have been loaded to close to their breaking strengths should not be re-used because they may be weakened.