

SNOW ANCHORS

The basic appreciation of some new research into snow anchors, their uses and limitations

George McEwan AMI Technical Officer Photos George McEwan & Shaun Roberts

Using snow anchors on winter climbs has always been a challenge for the climber ever since climbers ventured onto snow and ice. A major part of this challenge has been the variability of the material (ie. the snow), which means that the actual strength of the anchor may be suspect. Creating sound snow anchors has always required a judgment to be made about the quality of the snow we are using, a process which has led to the development of several rules of thumb about how to assess the quality of the anchor and therefore how much it can be relied upon to withstand a load.

Despite the advances made in mountaineering equipment technology over the years the variable mechanical properties of snow have not changed. Technology may make the job of placing anchors in snow faster, or give us more options but the perceived or actual unreliability of the very medium we are burying, placing or hammering in our space technology is also one of the reasons where the old adage 'the leader must not fall' still holds true for the winter mountaineer.

Over the past few years, a great deal of research had been done into looking at the strength of snow anchors. In preparing this article I've referenced several pieces of research all of which are detailed at the end, under sources. After spending not a few hours reading through all this stuff, what are the results of these keenly researched findings that will revolutionise how we use snow anchors?

Well, pretty much the conclusions are that anchors in snow depend on the inherent strength of the material they are placed in! Of course, the results are a great deal more detailed than that, but the bottom line for the poor soul perched at the top of a steep snow slope wondering what to do next is pretty much that.

All the articles I quote are worth reading in their own right and I have no intention of rewriting them here! What this article does do is summarise some of the more technical aspects of snow anchors such as the mechanisms of failure. I would draw your attention to the articles I have used and do

recommend giving them a read. At least then you can always challenge my take on them.

About the Studies

'Predicting Failure Modes of Snow Anchors' by Art Fortini and 'Snow Anchors' by Don Bogie both deal with the issue of the strength of snow anchors. In both cases, by snow anchors they are referring to 'snow pickets' or as we would call them 'snow stakes'. Both studies reference each other, and both come to similar conclusions:-

- In hard snow failure of the anchor is at the upper end of what the anchor would be expected to hold, and is down to mechanical failure of the snow stake, typically failure at the karabiner hole in the snow stake, rather than the snow giving way
- The strength of the anchor is dependent on the integral strength of the snow pack.
- Both put forward strategies for maximising the strength and reliability of the snow anchors, which pretty much echo what we would teach in that you assess the integrity of the snow, and then choose an appropriate anchor technique.

What is interesting is the description of how snow anchors fail. There are three ways in which snow anchors fail.

1: 'In a compression failure the anchor pulls forward through the snow.' *Don Bogie. Snow Anchors.*

Or, in other words, if the surface area of the object we are loading

eg. Deadman or buried horizontal axe, spreads the load evenly across the surface area of the snowpack it is buried in (that is the area it pulls against) and the 'strength' of the snow pack is not equal to this load the snow gradually compresses till failure occurs (the principle behind all snow anchors). You can tell it is compression failure as the object is literally dragged through the snow being moved a significant distance. This type of failure is common in weak snowpacks eg. soft or poorly consolidated snow.

2: 'In a shear failure, a stress cone in the snow is formed around the buried object. It goes out from the sides of the object at approximately 45 (and up from the bottom of it at approximately 30). The stress cone phenomenon was described by Fortini in his presentation. When it fails it does so fast and the snow cone and anchor come out of the snow in an explosive manner.' *Don Bogie. Snow Anchors.*

In this case there is little or no movement of the anchor till failure suddenly occurs. When the anchor fails a large section of snow is ejected from the snowpack. Depending on the homogeneity of the snowpack this either looks like a cone or may break up into several sections. This type of failure is common in denser or stronger snowpacks eg. *nève* or dense wet snow.

3: In very strong snow packs it was noticed that the main mechanism of failure was the object being used as a snow anchor failing ie. the snow stake. This was noted in loads around the 4.4Kn to 11.3Kn range

(that is 444 to 1130Kg approx).

The whole issue about how we make a judgment about determining the strength of the snow pack is dealt with in a great deal of detail by both authors. One field test method described, and used for testing the compressive strength of the snow, is pushing a blunt object into the snow. By using a gradual test ranging from a gloved palm through to a knife you end up with a range of compressive strength values.

For example (taken from Fortini's article) a gloved finger pushed into the snow with 10lb of force exerts a force of 12psi. Of course, such a test is based on several assumptions – that everyone's hand is the same, the snow in which the anchor is placed has the same properties as the snow in which you did the test, and that the snow properties are the same deep in the snow pack as they are at the top.

Using the above example and assuming we are using a snowstake 2.5" wide and 24" long (surface area equals $2.5 \times 24 = 60$ square inches) placed vertically in the snow. The formula used is:-

Anchor strength = hardness of snowpack x surface area of anchor (divided by 2).

So based on our above example we have:-

12×60 divided by 2 = 360lb (163Kg or 1.63Kn)

What was found in the testing that the estimated strengths using the above formula were reasonably close. However, at the level where predicated strengths were greater than 500lb (227Kg or 2.3Kn) they noticed when testing, other failure



USING A BUCKET SEAT AND WAIST BELAY ▲

Photo: George McEwan

modes becoming active ie. the snow pickets themselves began to bend and deform causing them to pull out of the snowpack. The same was found using other variations on snow stake placements e.g. horizontal or vertical. What they were finding was that, at larger loads, the failure was occurring not with the snow pack but with the anchors themselves (this is at loads greater than 1500lbs or 6.8Kn).

It was found that there was a great deal of variation in the actual integral strength of snow stakes themselves. Checking this out, it does appear that there is no agreed standard for snow stakes. The only standard I could find for snow anchors was a UIAA standard for a Deadman snow anchor, which is tested to a peak force of 6Kn.

These are pretty large loads and, in a climbing context, it would be a very unusual situation indeed where we are expecting our anchor system to hold such extreme loads. What you also have to factor in is that, when using snow anchors, we use other techniques such as a bucket seat and dynamic belay

(waist or body belay), which are all designed to reduce the actual impact on our snow anchor.

Although I found the information about the snow stakes interesting (albeit challenging to make sense of the vast amount of information) it did get me thinking what the implications were for us in a climbing context.

To simplify the findings from the studies it basically came down to the fact that in a good stable snow pack your snow anchors were good (although in very dense snow – what we would call *nève* – the mechanism of failure for the stakes at high loads was material ie. the stake itself failing). In a poor snowpack then anchors were not so good. It's a bit of a no-brainer I guess, and I must stress this a simplification of what is a set of very complicated set of findings.

However, in the context of what we do on the hill there is nothing we are currently doing that necessarily needs changing. Remember we tend to use our snow anchors in conjunction with a bucket seat and dynamic waist belay. For sure, in a

rescue situation with large loads eg. doing stretcher lowers etc, then there are implications, but in the few technical rescue lowers I have been involved in which have used snow anchors there has been so much anchor redundancy created it has never been a problem practically.

Other Types of Snow Anchors

As stated above the tests conducted in the above quoted reports were focused on snow stakes. In the UK the use of stakes is very limited although I am sure people do use them. What are more commonly used, and taught, the use of ice tools for snow anchors, and Deadmen.

On the subject of ice tools, it is worth mentioning that there are two standards for ice tools. Again these are stated in the UIAA standard – B (or Basic) rated and T (or Technical) rated tools. What this means is that B-rated tools are not as strong as technical tools (eg. for a B-rated tool a 50cm shaft must be able to withstand a load of 2.5Kn loaded

cross ways) whilst a T-rated tool must be able to withstand a load of 3.5Kn.

With regard to the actual strength of Deadmen, whilst researching this article, I was told that the late Eric Langmuir tested the Deadman snow anchors when he was principle at the lodge. The tests were carried out on the Cairngorm ski road, loading supplied by Land Rover, and a gauge applied between the Deadman and Land Rover. It appears that in the tests the snowpack always failed, and never the Deadman (ie. the material plate, cable etc). It would appear that the system normally failed due to the plate rotating as the snow deformed, resulting in the plate, shooting out of the snow. Of course, this is only anecdotal. As of yet I have not managed to track down any actual figures but I have been told that they exist. If true, then a properly placed Deadman is a pretty sound anchor (I must admit to liking Deadmen – the anchors that is...).





HOLDING A SLIDING FALL ▲
Photo: Shaun Roberts

Practical Applications

I guess all the above brings us back full circle. Snow anchors as we all know are by the very nature of the material we are building them in variable in their strength. By virtue of this fact we have evolved techniques to account for this variability and, it is hoped, reduce the actual shock load on our anchor set-up. So a common set-up for winter climbing would be using a snow anchor, belayer attached to it then settled down in a bucket seat,

whilst using a waist belay to hold any fall.

As I'm sure you all know this is an indirect belay set-up – the idea being that the body/waist belay allows the fall to be dynamically arrested, whilst the belayer's body, sitting in the bucket seat absorbs some/most of the load generated in the fall. As an aside, it is worth noting that using a belay plate to dynamically arrest a fall in this context does not work. I've done a few informal tests on the likes of

MIC courses and when attempting to arrest a leader fall using a belay plate you cannot allow the same level of dynamicism that a body belay allows. The result? A shock load on both the belayer and the anchor which, in one case, caused the belay to fail.

We don't just use snow anchors though in a lead climber context.

When descending steep snow terrain, anchors can be used to lower people. Again common sense should prevail – the easier the digging the

poorer the anchor; harder the digging the better the anchor. So if you are looking to do the likes of a direct belay of say a deadman or a buried axe then best to make sure the snow is like concrete. Any less than that and you are pushing your luck I reckon. If the snow is easy to dig, then you are better using an indirect belay option to lower/protect your people as they climb down.

When using snow anchors, watch out for situations where unusually high loads could be encountered eg. counterbalance abseils, climber being avalanched, cornice collapse etc. All these situations can create larger than normal loads, so make sure your snow anchor set-up is strong enough to cope with that. In the case of a counterbalance not only does your anchor hold your students' weight but also yours, so this easily doubles the load on the actual anchor, more than enough to cause it to fail. Better to lower your team down, have them dig-in then abseil down yourself (they can still be attached to the rope, just don't have them loading the rope).

Summary

The studies I looked at are worth taking a look through. They are not light reading by any stretch of the imagination but they do contain some technical and in-depth information about how the snow pack works when an anchor is loaded. That alone makes them worth the read. If you would rather read something else then don't worry, there is nothing in there that will require you to do anything less than what you currently do on the winter hills when making up snow anchors. In a nutshell, good snow pack = good anchor. Poor snow = not so good anchor. If in doubt back it up!

Sources

'Predicting Failure Modes of Snow Anchors' by Art Fortini, Sierra Nevada SAR. November 2005

'Snow Anchors' by Don Bogie, DOC Canterbury, NZMSC Snow and Avalanche Committee, NZ LandSAR Technical Rescue Sub Committee

Various documents relating to UIAA test standards for snow and ice anchors on-line at www.uiaa.ch

Petzl Fall Simulator on-line at <http://en.petzl.com/petzl/SportConseils?Conseil=56&Activite=3>



BURIED AXE AND BUCKET SEAT ▲
Photo: George McEwan