CMC News Vol. 6 #3, June / July 1985

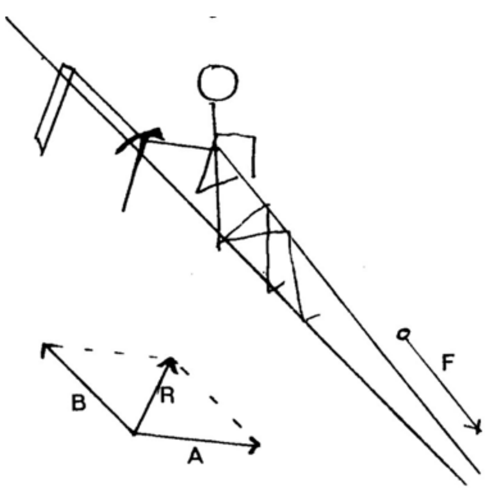
Belays on snow

by **Gottlieb Braun-Elwert**

Who hasn't experienced this situation: Knee deep, soft snow, 'porridge', at the end of a difficult pitch, no decent anchor to secure yourself onto, you are tired, time is pressing. Do you dig a 'deadman' the recommended safe anchoring method under these conditions?

The currently applied method in New Zealand appears to be to compact some snow, to poke your ice axe into the snow, to back it up with the snow stake and to belay off your waist (diagram 1). But how safe is this method really? I claim that some recent accidents in New Zealand happened just like that:

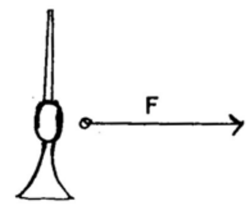
The impact force F experienced by the belayer is transferred straight onto the ice axe, force A, and from there straight onto the back up anchor which in return pulls on the ice axe with force B. Forces A and B result in Force R which pulls the ice axe right out of the snow. Now it is all on the snow stake and that pops, too.



1. Often used method in New Zealand

Let us look a little more closely at the physics of these snow anchors.

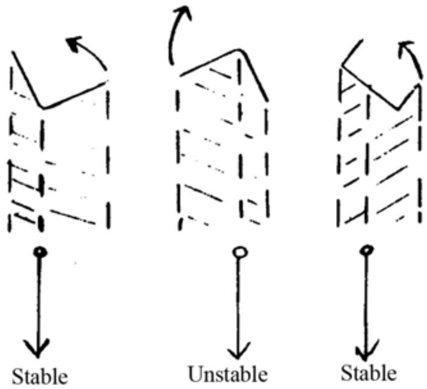
Holding Power and Placement of Anchors. The only research done on the holding power of snow anchors is the one of ice axes (1). An ice axe (long shaft) placed at 105º to the surface, holds approx. 1500 N in soft snow and approx. 3500 N in hard snow (ice axe could just be rammed into the snow with 75 kg body weight). This is a frighteningly small holding power when we consider the forces occurring in an actual fall. Only dynamic belays should be used in order to limit the forces acting on the snow anchor, the belaying set up should guarantee that the direction of pull is parallel to the snow surface.



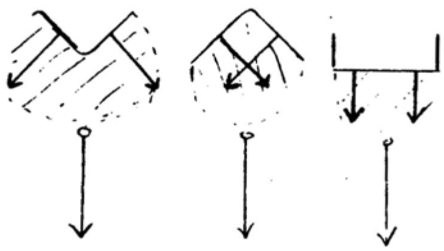
2. Placement of ice axe

As the holding power of snow anchors is directly proportional to the anchor's surface in the direction of the acting force, shape, size and placement of anchors are important. An ice axe should always be placed with the broad side to the direction of the pull (diagram 2). A long shaft is better than a short one, a wooden shaft may easily break long before the above mentioned forces are reached (2), so a longer shaft, metal or fiberglass is recommended.

Snow Stakes. Snow stakes are in use with two different profiles, V shape and U shape. The V down position provides a stable position whereas the inverted V position is unstable (diagram 3). The V down position also exerts its force onto a larger volume of snow whereas the inverted V position and the U shape only affect the snow directly in front of it (diagram 4). The V shape in the V down position is recommended for stability and holding power.

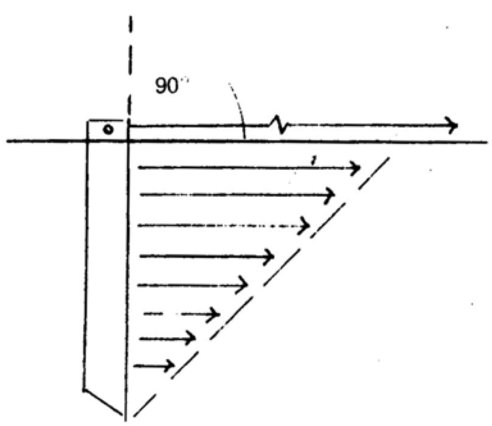


3. Snow stake profiles and placement



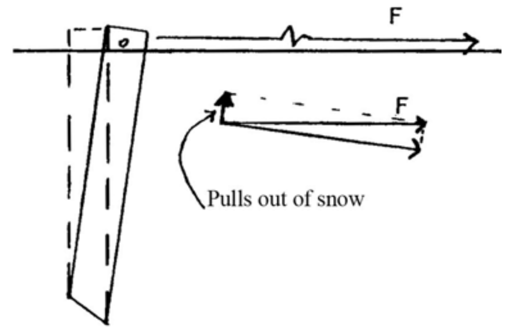
4. Force distribution of snow stakes

The Angle at which an anchor is set is also very important. Placed at 90º (right angle) to the snow surface, the presumed direction of pull, with the force acting on the top end of the anchor, the force distribution looks like a triangle (diagram 5), the pressure (force per unit surface) acting on the snow is greatest close to the surface; so the snow must be compacted there before placing the anchor.



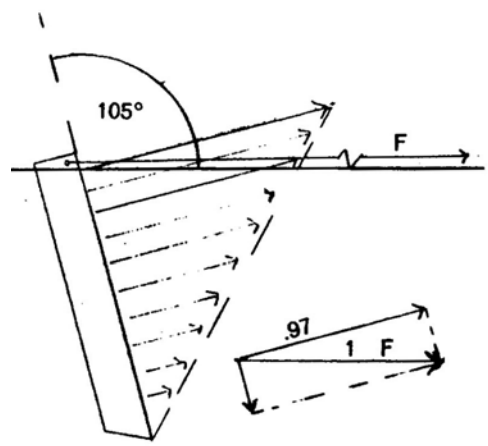
5. Best angle in theory only

The placement at 90º appears to be the best position in theory, however, it does not allow for the slightest error: a direction of pull not parallel to the surface or a movement of the anchor would result in an outward pull of the anchor with obviously disastrous results (diagram 6).



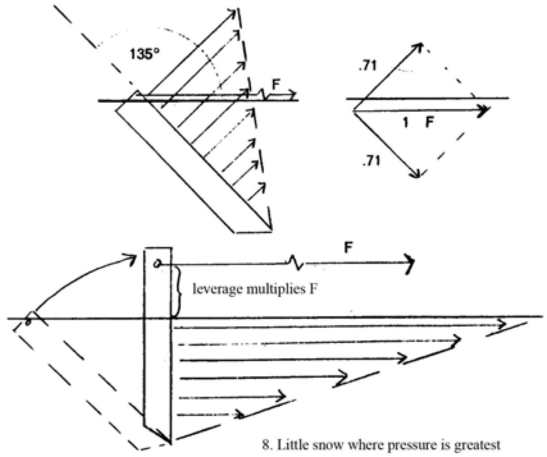
6. Force F is separated into a force parallel to the snow (inwards or outwards pull) and a force perpendicular to the snow stake (exerting pressure onto the snow). The length of arrows indicates the actual forces / pressure on the snow.

A placement angle of 105º to the snow surface provides a reasonable safety margin and leaves enough snow where the pressure is greatest (diagram 7).



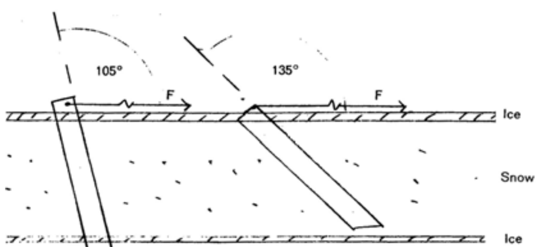
7. Best angle in practice

A steeper angle, e.g. 135º (diagram 8) leaves very little snow where the pressure is greatest. Again the belaying set up should guarantee that the direction of the force is parallel to the snow surface. Any angled pull leads to a weakening of the system (initial example above).



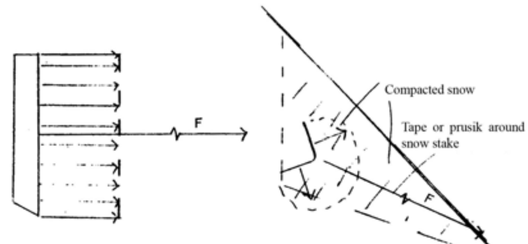
8. Little snow where pressure is greatest

In New Zealand snow conditions often prevail where a hard, icy crust follows a soft patch of snow and so on, hence a deep penetration of the snow stake is desirable in order to secure a stable position held by two hard crusts. A placement angle close to the right angle is thus another advantage (diagram 9).



9. Penetration

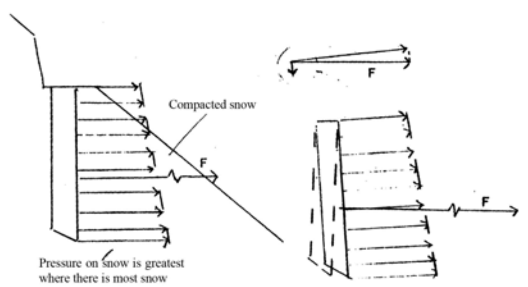
Obviously a more balanced force distribution is obtained by placing the snow stake or ice axe as a 'deadman' (diagram 10), however, this requires a little digging, but can save your life. The holding power of a deadman is much higher and when placed properly in compacted snow, the strength of the attached prusik loop is undoubtedly the limit. Digging the buried snow stake / ice axe in and out takes a few minutes and it is these few minutes and the additional energy needed that prevent many from applying this excellent method. Bending over with a heavy pack while digging is also tiring.



10. Horizontal deadman

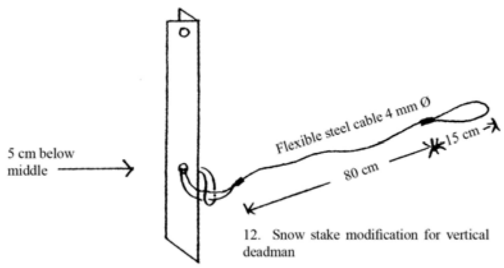
I suggest the following methods as alternatives. These methods are not completely new, they have been used in one form or the other in various other countries, they are the result of many discussions with colleague guides and personal testing during the 1984/85 guiding season.

Vertical Deadman. (diagram 11) This method already exists with commercially available 'deadman plates', a plough-like alloy plate connected to a cable; these plates are not very popular in New Zealand for their limited use to soft snow only.



11. Vertical deadman

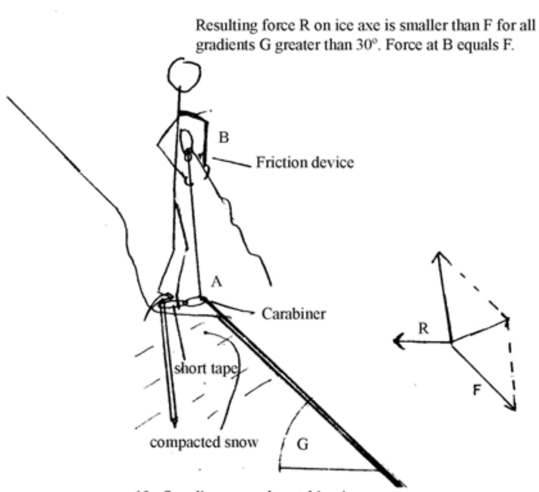
Russian speed climbers developed a fast belaying method by attaching a cable a little below the middle of the ice axe. Personally I don't fancy any cables or prusiks attached to the ice axe as they can impede working with this tool. Snow stakes are already commonly used in New Zealand, so it appears logical to combine the cable with the snow stake: An 80cm, 4mm Ø flexible steel cable with a 15 cm loop on either end (breaking strain 10400 N) attached to the snow stake 5cm below the middle by the way shown in the diagram 12.



12. Snow stake modification for vertical deadman

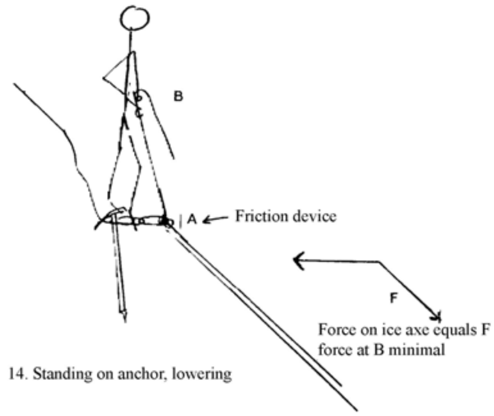
The snow stake is pushed into the compacted snow, the cable cuts through the snow when it is pulled tight. This arrangement is self-stabilising and if placed at the correct angle provides an inward pull. The placement of the vertical deadman is quick, effortless, its holding power is absolutely amazing. The anchor can be removed just as effortlessly. This, however, demonstrates that the vertical deadman is NOT suitable for holding a pull in an upwards direction. If needed the cable can easily be moved to the top of the snow stake for its conventional use.

Standing on Anchor. The belaying person is standing on the ice axe / snow stake with one foot and with the other foot on the snow in front of the anchor. For taking in the rope, bringing up the second climber, the rope runs through the carabiner (diagram 13) at point A and is secured to the climber with a friction device (Italian Hitch, Figure 8, etc) at point B.



13. Standing on anchor, taking in

For lowering purposes the friction device is better placed at point A (diagram 14).

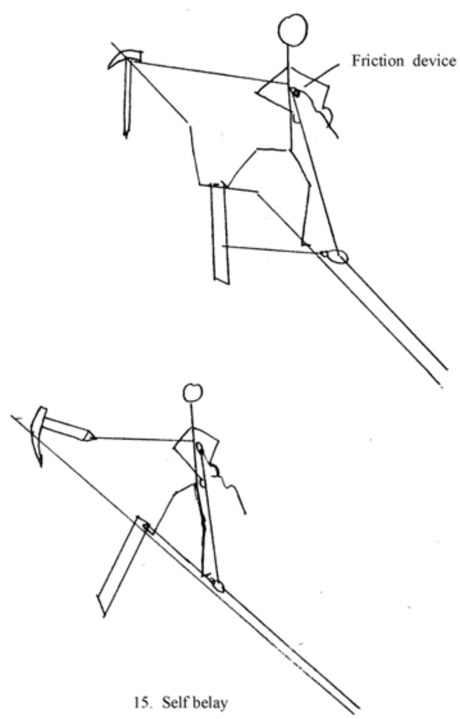


14. Standing on anchor, lowering

This method has the following advantages:

- quick and efficient
- direction of pull on the ice axe / snow stake is parallel to the snow surface
- weight of the climber prevents anchor from being pulled out
- upright and thus relaxing working position for the belayer

If needed the belayer can secure himself with his spare ice tool (diagram 15).

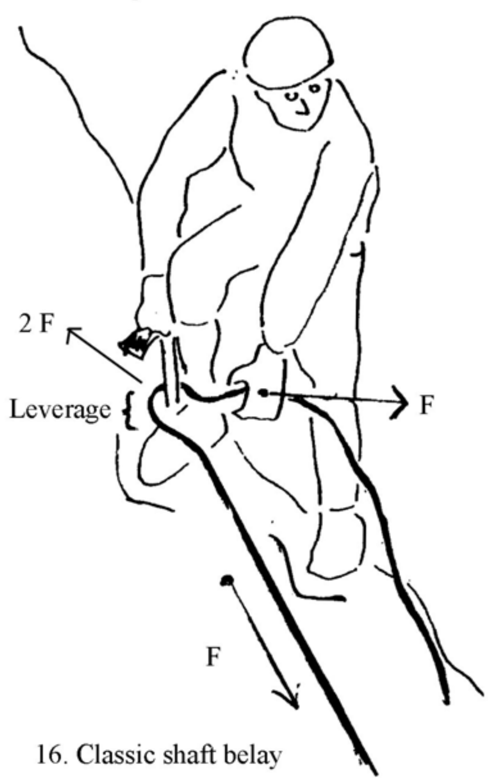


15. Self belay

Personally I found this method very useful for guiding purposes on **not too technical** ground (steeper snow slopes etc). When using the ice axe for this method the shaft should be of a reasonable length (70cm plus).

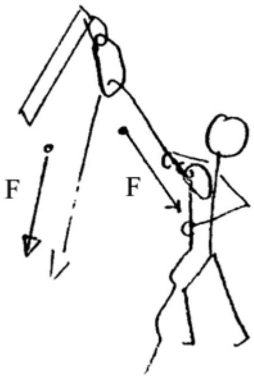
The **classic shaft belay** (diagram 16) **should be abolished** for the following reasons:

- a double (!) force acts on the ice axe due to a pulley effect (diagram 16a)
- the height at which the force acts on the ice axe at boot level, constitutes a leverage
- the belayer has to bend down, very awkward with a pack on.
- the belayer never has full control over the system: if he handles the rope with two hands for taking in, the ice axe can pop easily, if he holds onto the ice axe only one hand is left for rope handling.



16. Classic shaft belay

Any other method where the direction of the pull is reversed by a runner should be abolished for the same reason as above (pulley effect doubles the impact force acting on the runner, diagram 17).



17. Belay through runner, double force on anchor

On more technical ground the friction device should be attached straight to the anchor, thus ensuring that only the single force is exerted onto the anchor, i.e. the frictional force of the Italian Hitch or figure 8, and also to ensure that the acting force comes parallel to the surface, diagram 18.

All methods outlined above require a certain degree of practice, but once familiar with these techniques, I trust that many climbers will find them a worthwhile contribution towards safety in the mountains.

Acknowledgements.

1.German Alpine Club Sicherheitskreis Test Report 1971- 1973. pp. 107-112.

2. ibid, pp. 95-106.

3. Thomas Wüschner, Switzerland