V-Shaped Conveyor Belt Approach to Snow Transport

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All photos and graphics Genswein/Eide

During an avalanche rescue, excavating the victim takes by far the greatest amount of time. Despite a tremendously well-structured knowledge base for this type of rescue, a significant gap exists in the chain of events between a successful hit with the probe and the care / detection of the air pocket. To address this "missing link," work began in 2004 to develop the most effective approach to extricating an avalanche victim. The V-shaped conveyor belt method is the result. In the spring of 2007, this method was quantitatively assessed during a four-day field test. A quantitative comparison with different coordinated and uncoordinated shovelling techniques was accomplished in the field test.

Field test environment

A site near the field laboratory of the Norwegian Geotechnical Institute in western Norway was chosen. A spring snowpack with high density and hardness proved to be a realistic simulation of dense avalanche debris.

The "victims" were two bags normally used to carry firewood, sewn together and filled with straw. The total size of the target was approximately 80x200cm.The surface texture of the bag is similar to ski clothing and the snow stuck to it quite closely, making it necessary for the rescuers to completely free the target from the snow before being able to transport the victims out of the snow. In order to avoid loose debris around the victims, great care was taken to dig small shafts during burial. In addition, the snow around the victims was left to re-freeze overnight, and the next day the snow around the victims was boot packed layer by layer. Three days after burial, the victims were ready to be rescued.

The victims were buried at three different depths—1 metre, 2 metres and 3 metres—and on two different slope angles, flat and steep. The flat slope was 0˚–5˚ and the steep slope was between 20˚–25˚.

Choice of rescuers

All "rescuers" were chosen carefully. Aged between 19 and 39, they represented the age group that statistically most often becomes avalanche victims. Men and women from three different countries were chosen; the ensuing language challenges simulated to a certain degree the communication problems that often occur between rescuers who, although they may speak the same language, are faced with increased stress levels during a real incident. The call for volunteers read: "Four-day avalanche course free of charge, including food, including active participation in a two-day digging experiment."

In order to eliminate exhaustion as a cause for potential error in the data, the digging experiments were spread out over four days. After digging for a short while, the rescuers were assigned a less physically challenging learning module, after which another section of work with the shovel was completed.

Collection of data

The increase in depth of the hole was measured every 30 seconds. After every excavation, the hole and volume of excavated snow were carefully measured. The time measurements included first visual contact with the victim, head (airway) access time, first visual of the full body, lifting of the victim, and positioning the victim outside the burial site. Documentation included high-definition pictures taken every 60 seconds during all tests as well as real-time video documentation of the entire field test. An instructional video is available.

Shovelling

All rescuers were taught the correct way to use the shovel (i.e. cut blocks). It is difficult for companion rescuers to shovel with the same efficiency on both their right and left sides. Therefore, it is important that the system allows the rescuers to adapt their working position in the V to accommodate personal, body-specific preferences.

Uncoordinated shovelling

Statistics and video analysis of uncoordinated shovelling clearly show how often rescuers stepped on top of the buried subject, possibly compromising the air pocket and causing additional injuries. Rescuers also got in each other's way, resulting in diminished efficiency for excavation. Onset of fatigue was rapid, and work was interrupted for everyone while exchanging exhausted rescuers. With increasing burial depth, not all rescuers could be utilized due to lack of work space.

This series of photos shows poorly coordinated shovelling. A too-deep hole means shovellers have to lift snow above their heads, causing rapid exhaustion and guaranteeing a longer rescue time. All rescuers are unable to work at the same time and, with no exit ramp, gentle transport of the patient is almost impossible.

Challenges for an efficient and careful excavation

Care of the air pocket

During companion rescue a single probe is normally used to locate the victim. This method gives rescuers little knowledge about the exact positioning of the body. On one hand a quick approach to the airway is necessary; on the other hand a certain amount of snow needs to be transported to facilitate efficient removal of the mass of snow. Furthermore, rescuers should be positioned so that the buried subject and possible air pocket are not endangered. The V-shaped conveyor-belt approach to snow transport is the answer to this challenge.

Working efficiently

Maintaining the efficiency of the rescuers is a vital requirement of an effective rescue. We asked ourselves: Why do rescuers get exhausted so quickly when they apply uncoordinated shovelling? It's clear that fatigue results in longer breaks and slows down the rescue. We noted that rescuers rapidly became exhausted when holding an ergonomically challenging position over a long period of time. In response we applied the concept of job rotation, a model used in industrial production. We found rotating the rescuers clockwise every four minutes in the V-shaped conveyor belt method avoided this early exhaustion.

Transporting snow

An additional challenge to efficiency is how the rescuers transport the excavated snow. Lifting the snow vertically constitutes one of the least efficient methods. Despite maximum use of strength, snow still does not get transferred away from the victim. Another significant drawback to this method is that bigger lifts often leads to more snow falling off the shovel. The V-shaped conveyor belt method allows a paddling motion, where the range of motion of the whole body can be utilized as opposed to just using the arms. This is much more efficient and results in the transportation of a bigger mass of snow (measured in litres/rescuers/minute). Shovelling methods that suggest steps be dug for snow transport or recommending kneeling or sitting positions which do not allow the use of the body's full range of motion are also inefficient.

V-shaped Conveyor Belt Method

Position of rescuers

Rescuers form a V, with the first two rescuers positioned one shovel length apart; the rest are two shovel lengths from each other. This positioning—which can be assumed quickly—enables everyone to work without disturbing each other in individual segments of the V, while offering the optimal length of motion in the snow conveyor for each person. The principle of the individual segments allows the rescuer to find the optimal work position considering his or her personal preferences (i.e. left handed or right handed)

The size of the V depends on the depth of the victim, which is determined by probing. In a flat debris field (0˚–5˚), the required length of the V is double the burial depth. On a steep slope (20˚–25˚), the length of the V equals the burial depth. Values in between can be interpolated. The width of the V at its open end always equals burial depth.

As a general rule, one rescuer can cover 80 cm of the V's height. So, if a victim is buried 2 metres deep on a flat area, five is the perfect number of rescuers (2x2 metres deep = 4m/80 cm = 5). It's up to the rescuers where to position themselves within their sector of V height.

Excavating the victim

The person closest to the probe cuts blocks only. The second person starts the transport of the blocks, and might still have enough time to cut a few blocks as well. The primary job of each person in the conveyor is to move the snow from their section backwards to the next section behind them. Once there is no snow to transport, blocks should be cut to increase depth.

The further back in the V, the more work is applied to transporting the snow and less to gaining depth. This results in a sloping plane that slants towards the buried victim. If the angle of this slope becomes greater than approximately 25˚, snow falls back into the hole. This is avoided by ensuring the V is the correct length for the depth of the hole.

Rotation of rescuers is initiated by the front person. A four-minute cycle has been found to be the optimal balance between getting used to the new position and onset of fatigue. A greater gain in depth was measured during the first two minutes of the rotation, as opposed to the last two minutes. The psychological effect of expecting the rotation was rated as very important, and resulted in increased motivation. Of course, those four minutes don't have to be measured exactly. At maximum, the rotation should be made at the first sign of fatigue by any of the rescuers.

When the buried victim is first seen, the last rotation is made in which a second rescuer moves to the tip of the V. Stopping the rotation at this point avoids the challenge of rescuers having to communicate information about the victim's 3D position in the snow. Furthermore it would be psychologically challenging for a conscious victim to have to adapt to a different rescuer every few minutes.

The rescuers in position at the tip of the V work directly and carefully near the victim. This means the amount of snow available to feed the capacity of the snow conveyor decreases. To compensate, the person behind the first two rescuers should aggressively cut out the sidewalls in order to make more space for the two front rescuers, and to adapt the tip of the V to the real orientation of the victim. During this phase the first sign of a cave can be observed, as there is no purpose to removing the entire height of the front and sidewalls.

During this phase, more rescuers are used at the tip of the V. The V does not need to be fully maintained anymore. Often it is sufficient to keep only one side of the V open and to use the free space as an additional depository for snow.

Organized rescue

Once organized rescuers appear on the scene, they often require additional space for first aid and the transport / loading zone of victim. While this request is well founded, it should not result in wasting time to gain access to the victim's airway. The V-shaped conveyor belt approach to snow transport should be used for all user groups until commencement of first aid. At that time the diggers can step back a couple of metres and, while maintaining the V formation, start transporting the snow further away to create more space, unless they are needed for more pressing tasks.

Above pictures L to R: In this example of coordinated shovelling, the rescuers decided to transport the snow sideways (micro management). The front team at work after first visual contact with buried person. After the shovelling is completed, there is enough space for four rescuers to lift the buried person to the top of the V.

The avalanche shovel

This test was not conducted to systematically test avalanche shovels. However, valuable observations were made regarding different models of shovels. All rescuers received detailed instructions in the correct use of each shovel. Not one single shovel failed due to incorrect use. Plastic shovels serve the purpose of merely "having a shovel" but usually fail before reaching the first metre of depth.

Light metal-alloy shovels need to be hardened by a metallurgical or temperature process (i.e. alloy 6061 T6), as the majority of those metal-alloy shovels from prominent manufacturers were seriously bent after little use. The front edge cannot end in a triangle with one exposed tip, since that will bend and deform the entire blade after continued stress. Collapsible handles have a clear advantage because of the increased length of the shaft, but the two parts must sufficiently overlap in the extended state. By creating a second hole this doubling can be increased. A D-shaped grip proved to be superior to a T-shaped grip. The Voilé Telepro T6 proved to be a very sturdy and ergonomic working tool.

THANKS

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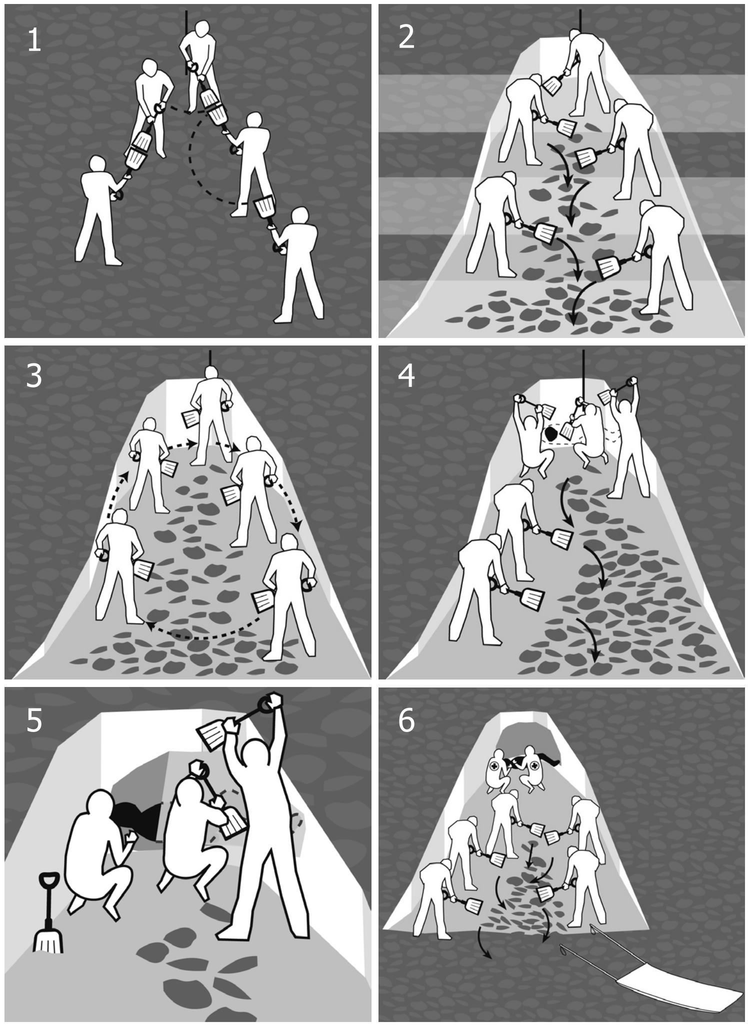
The results of this study will be presented at the ISSW2008 in Whistler, BC, September 21 – 27, 2008.



V-shaped Conveyor Belt Method

1. Positioning of rescuers: Quick measurement of distance between shovelers
2. Working in sectors on the 'snow conveyor belt': Snow is transported with paddling motions.
3. Clock-wise rotation is initiated by the front person: "Job Rotation" maintains a high level of motivation and minimizes early fatigue.
4. Buried victim is first seen: More rescuers are needed at the front, the snow conveyor belt only need to be partly kept running.
5. Careful work near the buried victim while some shovelers aggressively cut the side walls to adapt the tip of the V to the real position of the victim.
6. Interface to organized rescue: More space is shovelled only after medical treatment of victim has started.

Manuel Genswein has been working for 15 years in more than 20 different countries as an independent instructor for avalanche rescue and prevention. He developed many of today's most advanced avalanche rescue search technologies as well as search and excavation strategies. As a consultant and trainer for many of the largest players in the industry, he has gathered a broad-scale knowledge within the field of avalanches, avalanche rescue, development projects and teaching participants with very different backgrounds.

Ragnhild Eide has been working as a nationally certified mountain guide in Norway since 1997. She has, together with Manuel Genswein, been part of the development of the V-shaped snow conveyor technique for excavating avalanche victims.