SNOW CONVEYOR BELT – SUMMARY AND UPDATES ON THE MOST LIFE-SAVING AVALANCHE RESCUE EXCAVATION STRATEGY

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ABSTRACT: The snow conveyor belt excavation strategy was developed in 2006 and has since been updated and fine-tuned in incremental steps. Its development started as an international collaboration, but the team creativity, multiplied intelligence and user group as well as snowpack climate representation provided by the MountainSafety.info Workgroup for Avalanche Rescue covering 27 nations finally landed on a strategy resulting in the fastest possible airway access times, and therefore highest possible survival chances for any imaginable situation in companion and organized avalanche rescue. The unmatched level of versatility of the strategy is founded in the practical robustness of rules of thumb, which allow the rescuers to determine the required lengths of the snow conveyor belt based on burial depth and inclination of the burial site. One rescuer is required to cover each meter of length in the snow conveyor belt. In case the number of rescuers is insufficient, it remains necessary to respect the required length of the snow conveyor belt, thus the rescuers will start one meter below the probe for each missing rescuer in the equation. Without shortage of resources, always start digging at the probe. Starting below the probe systematically leads to a significant increase of airway access time and shall be avoided – unless an insufficient number of rescuers leave no other option. The excavation performance reference database of the snow conveyor belt strategy includes 391 results from 5 countries and allows MountainSafety.info to analyze and optimize the strategy based on user group, activity and gender. The quantitative analysis of the influence of the starting point of the excavation effort has been contributed by the Italian MountainSafety.info workgroup members under the umbrella of the Italian Alpine Club. The most recent updates of the strategy include: (1) the detailed definition of the procedure «Snow Conveyor Belt With Limited Resources»; (2) the extension of the segment length covered by one rescuer to 1m; (3) securing appropriate distances between rescuers as part of each rotation; (4) the reference width of the segment is carved into the snow by each rescuer in the form of a semi-circle, leading to an optimal balance between the size of the workspace required for efficient shoveling and the resulting excavation volume. Reproducible, quantitative field test results in excavation strategies require strict protocols ensuring an adequate user-group specific training level, fatigue bias prevention by minimum rest duration between trials and the number of trials per day per rescuer as well as debris hardness correction factors, leading to standardized debris properties. In hard debris, rescuers remove a median depth of 13.20cm/min; in soft debris, a median depth of 25.32cm/min is removed. These values are achieved when applying the conveyor belt with the appropriate number of rescuers. With limited resources, the excavation performance decreases, but still allows a single rescuer to excavate a buried subject in the mean burial depth in ski touring of 1.5m within the critical first 18min of burial duration based on the "Snow Conveyor Belt With Limited Resources" protocol.

KEYWORDS: Avalanche Rescue, Excavation, Conveyor Belt, Survival Chance Optimization

1. INTRODUCTION

The development of the snow conveyor belt started 2006 in Norway at the field research station of the Norwegian Geotechnical Institute NGI. Prior to 2006, systematic, properly formalized rules on how to excavate a buried subject did not exist and therefore, there was no systematic training for this particularly time-consuming phase of the rescue process.

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The V-Shaped Show Conveyor Belt was published in 2008 and already provided an increase of 31.5% in snow transport volume and did cut the time to completely fee a buried subject at 2m burial depth in half. During the initial development of the snow conveyor belt, the critical ramp angle at which the loose snow blocks start to roll back towards the probe was empirically determined to be 26° and the first quantitative description of the ratio between the length of the conveyor belt in function of burial depth and slow angle was determined. Concerning snow removal technique, we developed and formalized the three modes of snow transport 1. "paddling", 2. "scooping" and 3. "cutting blocks" in order to be able to adapt to different hardness of debris. As the ease and transport volume per minute decreases from paddling over scooping to cutting blocks, one should only step back to the next slower technique when the hardness of the debris requires it. This structured approach ensures that the snow removal efficiency remains high in different debris properties. When a rescue proceeds from one technique to another is depending on physical strength and the characteristic of the used shovel.

Already in the early years of the development, severe weaknesses of the work tools, the avalanche rescue shovels became apparent, which led to a first large scale test and qualitative needs assessment of generic characterization of an efficient, ergonomic, and durable shovel.

The publication of the V-shaped snow conveyor belt and alternative excavation techniques have not only dramatically increased the level of awareness for the importance of training of the excavation process in avalanche rescue training, but foremost have for the first time provided the base for a systematic, rule-based approach which could be taught in courses.

The more frequent training of the excavation process has positively contributed to raising the level of awareness that every winter backcountry user should carry not only a transceiver, but as well a probe and a shovel. In 2013, the extent of use of avalanche rescue shovels and the dissatisfactory situation that there were no formal product standards motivated UIAA to task its SafeCom to develop the first standard for avalanche rescue probes.

2. METHODS

Field tests were carried out in 5 countries over 17 years including 391 rescuers applying the snow conveyor belt strategy. The field tests included participants of different user groups and different levels of experience. However, all participants were trained in proper snow removal techniques and a snow conveyor belt excavation strategy prior to recording of quantitative field test data. Furthermore, all field tests were supervised to ensure the proper application of the individual techniques and overall excavation strategy. These measures and the application of a system to compensate the effect of different snow layer hardness are mandatory requirements for a low standard deviation and high consistency of results between different datasets recorded in different nation, with different user groups and with different snowpack/debris properties. The snow conveyor belt dataset currently is the only reliable statistical base on avalanche burial excavation. It allows to develop and optimize excavation strategies with quantitative evidence of performance, quantitative proof of shortening burial duration and thus ultimately, quantitative proof of increasing probability of survival.

We analyzed the generic requirements an excavation strategy shall fulfil:

Requirements for an excavation strategy

- Provide efficiency independent of:
  - Burial depth
  - Number of rescuers
  - Inclination at the surface of the debris at the burial site
  - Downslope or upslope direction of snow transport
  - Hardness of debris
  - Basic, intermediate or expert training level

Furthermore, an excavation strategy shall avoid unnecessary injury of the buried subject:

Factors to protect the buried subject from undesired mechanical impact

- Access to the probe/buried subject extending in a line from the probe, not shoveling all around the probe
- Width of the excavation only as large as required for efficient snow removal, shape narrowing at the probe
- Knowledge concerning the position of the buried subject at the start of the excavation (position probing)
- Progression and technique applied shortly before reaching the end of the avalanche rescue probe and when the first parts of the patient, clothing, or equipment of the buried subject become visible

We then analyzed the contributing factors to individual and group snow removal performance:

Individual snow removal performance factors:

- Short term:
  - Age
  - Gender
  - Physical strength (maximum force)
  - Snow removal technique
  - Suitability of the avalanche rescue shovel to the profile of the rescuer
  - Hardness of the debris
  - Density of the debris
- Long term:
  - Endurance of the rescuer
  - Ergonomics of the excavation strategy

Group excavation performance factors:

- Efficiency of the excavation strategy in taking advantage of the individual performance of each rescuer at its full extent
- Efficiency of the excavation strategy in compensating differences in individual rescuer performance

In the vast majority of the cases, the position of the buried subject in the debris remains unknown as the search effort is concluded with a single probe hit. Therefore, it does not make sense that the excavation width exceeds the effective snow removal radius of one rescuer, until the first signs of the buried subject allow to anticipate the exact position of the patient relative to the probe hit. Furthermore, a large excavation width in close proximity of the probe hit increased the likelihood of unnecessarily injuring the buried subject. These facts have strongly influenced the characteristic of the shape of the snow conveyor belt excavation strategy from the very start with a V-shaped conveyor belt.

Applied in a group effort, the shape of the excavation site is a result of how the effective snow removal radiuses of multiple rescuers are aligned or orientated to each other. In the definition of the snow conveyor belt, the effective snow removal radius of a rescuer is called a segment.

As the width of the excavation site in close proximity of the buried subject is limited to one effective snow removal radius, the volume of snow passed from the first to the second segment can be efficiently process by one rescuer.

The same is true for the third segment, the volume of snow which is passed from the second to the third segment can be efficiently process by the third rescuer. Unless the number of rescuers is very high (16+), the snow removal performance in each segment allows not only to forward the volume of snow arriving from the previous segments, but to add some volume, which is gained by lowering the segment.

Therefore, the further a segment is away from the probe, the larger is the volume of snow which is passed in a conveyor belt approach from one segment to the next. However, with the increasing volume which needs to be processed, the percentage of work time available to lower the segment is decreasing.

This leads to a shallow ramp angle between all segments, and practical experience has shown that the progression of this ramp angle over multiple segments does not impose a problem.

As the subsequent segments are capable to process the volume of snow, the snow is forwarded in a strictly serial process from one segment to the next. Consequently, to align the segments in a straight line, forming a conveyor belt is the most logical approach.

3. RESULTS

The Basic Snow Conveyor Belt is the preferred excavation strategy for beginners and an initial practical lesson requires only 5 to 7min.

The spacing between the first rescuer and the probe as well as all the additional rescuers is therefore determined by holding the handle to your body while the blade of the extended shovel touches either the probe or the rescuer in front of you.

The snow conveyor belt starts directly at the probe and is pointing in the direction snow transport is easiest. Whenever there is a slope angle, this is always parallel to the fall line.

Not directly following the probe when excavating a buried subject leads to a systematic and considerable increase of the head access time (Rogora et al. 2023) and therefore is only applied in the following two exceptions: 1. Burial depth is very marginal AND foot penetration almost equal to burial depth; 2. The number of available rescuers is insufficient for the required length of the conveyor belt and the “snow conveyor belt with limited resources protocol” needs to be applies.

The radius of the effective snow removal is given by the area you can reach with the extended shovel while holding it with both hands in the regular work position. As soon as in the initial alinement procedure is done, the rescuers stand in the right distance from each other, they all carve with their shovel a semi-circle into the snow, which visualizes the size of the segment they are currently responsible for. While digging down in the snow conveyor belt, rescuers may verify if the width of the snow conveyor belt is optimal by repeating this semi-circle motion with the shovel around them.

Efficiency in snow removal means transporting as much volume per minute as possible. Thus, to step back from paddling to scooping to cutting blocks should be postponed as long as possible. This is done by starting the movement with the shovel towards the snow surface as far out as possible, allowing to gain build up kinetic energy and hitting the snow surface with high speed. Instead of applying maximum force to penetrate the debris, the built-up kinetic energy leads to the same result with much less fatigue.

The clockwise rotations shall be applied every two to four minutes. During each rotation, hold the shovel forward as in the initial alinement procedure. Like this, the spacing between rescuers is again optimal after search rotation. Furthermore, frequent rotations equal out differences between snow removal performance between individual rescuers.

Every rescuer covers 1m in length of the snow conveyor belt.

Snow Conveyor Belt with Limited Resources

In case the number of available rescuers is insufficient to cover the entire length of the snow conveyor belt, apply the protocol “snow conveyor belt with limited resources”: align the available rescuers with the usual spacing of one extended shovel between them starting at the end of the conveyor belt towards the probe. In the first phase, excavate a trench towards the probe by throwing the snow to the side. The depth of the trench is half of the total burial depth, but never exceeds 1m, as lifting the snow more than waist-height is extremely strenuous. The depth of the trench is split equally in the number of available rescuers. Each rescuer removes his/her layer of the trench and works his/her way forward towards the probe. While excavating the initial trench, all rescuers are constantly changing their work position and thus, no rotations are applied. The more superficial the layer of the trench you are responsible for, the further out over the side the snow need to be thrown. This leaves the required space for the snow of the lowest layer and avoids that the side walls increase in height. By the time the probe is reached, each rescuer will have transported an equal volume of snow, and thus the rescuers finish their task synchronized in time. The deposit space created behind the rescuer by creating the trench will compensate for the fact that the number of rescuers is insufficient and will ensure that the steepness of the ramp angle will stay below the critical 26°. From now on, apply the regular snow conveyor belt approach, thus the snow is transported in the long axis of the snow conveyor belt and the regular rotations are applied. In this phase it is important to make sure that the back end of the trench gets filled in to its full capacity. Only like this, the volume of the trench is able to play its important role in ensuring that the ramp angle remains below 26° and thus allows an efficient excavation with the limited number of available rescuers.

Patient Becomes Visible

When the buried subject become visible, it becomes a patient in terms of terminology. From this moment on, it is possible to see how the patient is orientated in the debris relative to the probe hit. Now the tip of the conveyor belt needs to be enlarged in the direction of the head. In case one or two rescuers are available, one rescuer works in front in immediate proximity of the patient, if there are three or more rescuers available two rescuers work directly in front. In order to avoid unnecessary injuries to the patient, the rescuer(s) working in immediate proximity of the patient work in a kneeling position and with the shortened shovel shaft. As soon as the first parts of the patient is visible, verbal contact should be established with the patient and the patient should be informed that you are working swiftly, but at the same time with care towards the head. The last part of the excavation in immediate proximity of the head is done with the gloves only. If there is a medically trained rescuer, he or she should be in the front. In case there is the slightest doubt that the patient does not breath normally, first priority is to try to give five rescue breath. This requires that chest raise is possible. If the patient does not show vital signs, continue applying the AvaLife Avalanche Patient Treatment Protocol (see MountainSafety.info).

In order to keep the critical ramp angle below 26°, the length of the snow conveyor belt in flat terrain is twice the burial depth, in terrain steeper than 20°, the length of the snow conveyor belt is equal to burial depth. If the buried subject has ended up in a terrain trap and the snow needs to be transported uphill, the length of the snow conveyor belt is four times burial depth.

Position Probing

Position probing brings additional information on the position of the buried subject and therefore allows to position the snow conveyor belt in an optimal manner. Depending on the number of available rescuers and the anticipated position of the buried subject, it might even be an advantage to dig two conveyor belts simultaneously. Consider “Position Probing” (see MountainSafety.info) below 35min burial time when additional intelligence is likely to reduce excavation time (harder debris, increased burial depth) and above 35min burial time to avoid unnecessary mechanical injuries and abrupt handling.

Deep Burials

There are no adaptations to the snow conveyor belt strategy concerning deep burials. However, as the fine search precision decreases with increasing burial depth, in particular when searching with a triple antenna avalanche rescue transceiver, there is an interaction between specialized deep burial search protocols and the snow conveyor belt excavation strategy. When the probe is too short to make a probe hit from the surface of the debris, apply the «Where to dig when a probe hit is impossible» protocol (see MountainSafety.info). While this protocol is applicable with all transceivers, it adds 1.5m of lengths to the snow conveyor belt for subsequent fine searching until the snow conveyor belt has been sufficiently lowered to allow a probe hit. The deeper the buried subject, the more additional volume will add up. For extremely deep burials, and in particular when there is a risk that the buried subject has been swept into a crevasse or serac zone, consider applying “Fine Search in a Circle” (see MountainSafety.info). In despite of the fact that this fine search technique is initially more time-consuming and requires a transceiver which supports analog sound, the fact that it only adds 0.5m to the length of the snow conveyor belt will finally result in a shorter burial duration thanks to its superior fine search precision.

Mechanized/Motorized Snow Removal or Snow Transport for Very Deep Burials

In case of very deep burial, mechanized / motorized snow removal options should be considered. Passive snow slides are often mentioned as an option, but as there is a very clear correlation between deep burials and flat run out zones and terrain depression zones / terrain traps, the option of letting the snow passively glide down slope seldom exists. A relatively simple option is the use of a small snow blower, preferably with tracks towards the end of the snow conveyor belt. As the ramp angle of the snow conveyor belt is in such cases always negative, thus the rescuers working in the snow conveyor belt are standing in a lower position than the snow blower, the exhaust of the snowblower needs to be diverted (hose, tube) so that it is NOT intoxicating the rescuers. Depending on the accident location and situation, heavy, motorized snow removal equipment such as snow groomers of diggers might be considered. For all these cases, it is mandatory to fine probe ahead of the mechanized snow removal and to leave at least a one meter thick snow layer as a safety margin (see Mountain-Safety.info protocol “Probing Strategy: Sequence Of Actions”).

Excavation in Special Circumstances

In case of very hard debris, and debris contaminated with ice or trees use a chain saw with a long blade. Cut the snow preferably in a fine checkerboard pattern. The harder the debris, the finer the pattern. Instead of holding the blade vertically, hold the blade in an inclined plane and switch the incline angle in every other row to facilitate the removal of the small blocks with (steel) shovels. Use the necessary protection equipment when using chain saw, leave sufficient space to the other rescuers. Aways fine probe ahead to using a chain saw and leave a sufficient safety margin around the buried subject.

4. CONCLUSION

The snow conveyor belt excavation strategy is the most versatile excavation strategy available. It is a modular, scalable system and offers a systematic, consistent progression to be able to cover everything from the beginners level to the most complex situations.

In hard debris, rescuers remove a median depth of 13.20cm/min; in soft debris, a median depth of 25.32cm/min is removed. These values are achieved when applying the conveyor belt with the appropriate number of rescuers. With limited resources, the excavation performance decreases, but still allows a single rescuer to excavate a buried subject in the mean burial depth in ski touring of 1.5m within the critical first 18min of burial duration based on the “Snow Conveyor Belt with Limited Resources” protocol.

ADDITIONAL TEACHING RESOURCES AND ILLUSTRATIONS

Additional teaching resources and all illustrations showing the different stages of the application of the snow conveyor belt are available at www.Mountain-Safety.info

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After 30 years of research and development work in 32 nations in the domain of snow and avalanche safety and rescue, I developed and published many much more complex systems, methods and strategies than the snow conveyor belt. However, there is no doubt that when looking at the criterion “number of lives saved”, this development project and fine-tuning over 17 years has been the by far most successful one. Not only digging out a buried subject is physically demanding, as well the entire development and fine-tuning over such a long time with hundreds of snow conveyor belts dug in a quantitative field test setting is very demanding. Ragnhild Eide and myself started in 2006 at zero, nothing existed before. I am very thankful to all those who have contributed in an often strenuous effort in a cold, wet environment, sometimes for days in a row. The members of the MountainSafety.info workgroup for avalanche rescue as co-authors have not only made numerous valuable contributions, but made it as well possible that the snow conveyor belt materials are available in over 20 languages. Lori Zacaruk and Daisuke Sasaki did contribute some specific ideas, which lead to a distinct step in an otherwise incremental finetuning progress. Volunteers of the Sawtooth Avalanche Center, and some individual mountain guides and ski patrol from the Wood River Valley as well as François Mathey and Torbjorn Ohlen have particularly contributed this year to finalizing the “snow conveyor belt with limited resources” protocol. THANK YOU to all of you – your efforts helped to save many lives, worldwide!

REFERENCES

Genswein M, Ragnhild E (2008) The V-shaped snow conveyor belt, International Snow Science Workshop Proceedings, Whistler. https://arc.lib.montana.edu/snow-science/objects/P__8248.pdf