AVALANCHE EXPOSIVE MITIGATION ANALYSIS & IMPLICATIONS ON THE ANTI-CRACK MODEL INTERNATIONAL SNOW SCIENCE WORKSHOP 2014 IN BANFF, AB

Ella Darham[1*]

[1]Bridger Bowl Ski Area, Bozeman, MT, USA

ABSTRACT: In its early stages, this project aims to explore the practical implications of the Anti-Crack Model utilizing various delivery methods of avalanche explosives. This study is comprised of two main questions; the first, examines whether aerial or surface detonations of explosives are more effective in producing larger avalanches, while the second questions whether aspects of the Anti-Crack Model hold true for the application of repetitive avalanche explosive detonations in the same location.

KEYWORDS: Avalanche control, anti-crack model, avalanche explosives.

1. INTRODUCTION

The first published scientific study to question the effectiveness of explosives used as a method for avalanche control was conducted in the Swiss Alps in 1977. (Gubler, 1977) Gubler discovered that the optimal aerial explosive placement is one-two meters above the snow surface. Later, Joel Juergens explored the practical implications of aerial explosives delivered by a high-tech tram system compared to surface blasts in an adjacent slide path. (Juergens, 1984) This research documented the percent of slide path affected by the explosive results, which supported Gubler's original claim that air blasts were more effective than surface blasts; however the study lacked much of the quantitative data and analysis required for a concrete conclusion. Since then there has not been another complete analytical study comparing air and surface blasts in an operational setting. There have been many studies discussing various aerial deployment methods and analyzing how the physical properties of the snowpack responds to different methods of avalanche explosives delivery and on the mass of the explosive. (Binger et al., 2006) (Dombroski, 1990) (Frigo et al., 2012) (Miller, Tichota, & Adams, 2010) (Wooldridge et al., 2012) Contrastingly to Juergens' research, these studies had very high-end quantitative analysis, but lacked the practical implementation of testing slopes that were actually avalanche prone.

The goal of the proposed research is to provide quantitative evidence of various avalanche explosive delivery methods comparing their effectiveness for triggering larger avalanches in an operational setting. Additionally, the research will test practical implications of the Anti-crack model with respect to slab 'communication' in explosive induced avalanches. The following research will be conducted within the operational boundary of the Bridger Bowl Ski Area located in southwest Montana.

* *Corresponding author address:*
Ella Darham, Bridger Bowl Ski Area,
Bozeman, MT 59715;
email: ekdarham@gmail.com

2. THE PROJECT

2.1 Question 1

Is there a correlation between various avalanche mitigation methods and their effectiveness for triggering a larger percentage of a slide path's area and volume?

2.2 Purpose 1

Compare effectiveness of different avalanche mitigation methods (air blasts, surface blasts, cornice drops…) on two major slide paths within the Bridger Bowl Ski Area boundary.

2.3 Methods 1

A stationary time-lapse camera will be placed on tower 17 at the top of the Alpine lift facing Hidden Gulley and Northwest Passage. The camera will be programed to capture a photograph every one-minute during avalanche control (7:30am-9:30am) to ensure photographic documentation before and after each of the shot is detonated. From the photographs that capture the avalanche activity, the percent of slide path area involved in the resulting avalanche will be calculated; thus, determining the relative size of the avalanches (R Scale). From the triggering locations the approximate depth of the avalanches will be recorded to assist with calculating the approximate volume, destructive size (D Scale), of the avalanches. Upon the conclusion of the winter season the data (area and volume) from the triggered avalanches in the profiled slide paths will be analyzed and compared to determine whether there is a correlation between various control methods and their effectiveness for triggering a larger percentage of a slide path's area and volume.

2.4 Part 2

Since the research is conducted in an operating ski area, measures need to be taken outside of the research parameters to ensure avalanche safety for the skiing public. Subsequently, if the surface blast is ineffective to the degree to which we determine risk to be satisfactory, a second charge (air blast) will be detonated in the respected slide path.

2.5 Question 2

If a surface blast triggers a small avalanche, or even none at all, will an air blast initiated directly following trigger a larger avalanche? In other words, if the collapse of the slab layer does not initiate the fracture of the weak layer exceeding the critical crack length thus triggering an avalanche, will (A) the force from the air blast be able to re-communicate the same fracture mechanics though the vertical cracks created by the surface blast? (Heierli et al., 2008) Or (B) will the vertical cracks disrupt and limit the triggering affectability of the subsequent air blast? (Heierli et al., 2008) (Gauthier and Jamieson, 2010) Alternatively, is it (C) that the air blast simply affects more of the snow since the fracture from the surface blast may not communicate throughout the whole path, while the air blast manages to "hit" everything?

2.6 Hypothesis 2

The subsequent air blast will (A) trigger an avalanche if the surface blast did not, or (B) larger avalanche if the surface blast triggered a small avalanche.

2.7 Purpose 2

To determine (A) if air blasts can trigger additional avalanches after a surface blast detonation in the same location and (B) if the 'communication' of force from an air blast is disrupted due to vertical cracks inflicted in the slab layer from the previous surface blast; thus, affecting the subsequent avalanche size.

2.8 Methods 2

After the detonation of the surface blast in the given slide path, the route team will determine whether additional control measures need to be taken to ensure avalanche safety within the ski area affected by these two paths. For this segment of the research the focus will be on the potential second charge required for the slide path that used a surface blast. If the surface blast results did not meet our safety standards the route team will use the explosive tram in the respected slide path to deploy and detonate a corresponding sized air blast approximately one-two meters above the snow surface (Gubler, 1977). Following the subsequent air blast another photograph will be taken to determine the percentage of slide path involved in this subsequent slide. From this step forward, the data recording and analysis will be exactly the same as the first question's methodology.

3. SUMMARY AND CONCLUSIONS

During the winter of 2013-14 minimal tests occurred due to administrative and technical logistics. From these few results it was found that the aerial shots were more effective than the surface blasts. So far, there is no conclusive evidence as to whether the shots are continually producing larger avalanches on the same slab/weak layer interface. Testing will carry on during the 2014-15 winter, and potentially 2015-16 depending on results. The hope is that the future findings will be useful for all avalanche control operations utilizing explosives (heli-skiing, ski areas, departments of transportation, mines etc.), as they will now have in-depth, practical, and comprehensive evidence to support their avalanche mitigation programs.

This research is in its early stages and is a work in progress. Comments, suggestions, and critiques are gladly welcomed and encouraged. Please feel free to contact me at any time.

4. ACKNOWLEDGMENTS

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