EXAMINING THE SLOPE SCALE SPATIAL VARIABILITY OF EXTENDED COLUMN TEST RESULTS

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ABSTRACT: Though a significant amount of research examines the spatial variability of snow stability at the slope scale, most of that work focuses on tests primarily related to fracture initiation. The small number of studies examining the spatial variability of fracture propagation (utilizing tests such as the extended column test (ECT)) are inconsistent. Some work reports homogenous ECT results, while later studies showed more variable and difficult to explain results. Because of these inconsistencies, we measured the spatial variability ECT results on multiple slopes in southwest Montana over the course of two winters. We sampled 23 grids, with each grid containing 28 ECTs for a total of 644 ECTs using a pre-defined semi-random 30m by 30m extent. We tested slopes with a variety of weak layers (surface hoar, depth hoar, new snow, and near surface facets), slab characteristics (slab hardness, slab depth), and snow depths. Further, we sampled during varying levels of forecasted regional avalanche danger. Our data demonstrate that considerable spatial variability in ECT potential exists on many slopes, even without substantial variation in snowpack structure. When the regional avalanche danger is either considerable or low, results are likely to be more consistent, but when the regional danger is moderate, results tend to be more variable. Further, the ratio of ECTPs to ECTNs can be correlated with the forecasted danger level. The practical implications of our results are that ECTs, like all other stability tests, should be interpreted with an appropriate level of caution.

KEYWORDS: Extended Column Test, Spatial variability, Stability evaluation, Propagation.

1. INTRODUCTION/ BACKGROUND

Fracture propagation is required for avalanche release and this makes understanding its spatial variability critically important. There is a substantial body of research over the last 30 years examining spatial variability of snow stability on the slope scale (e.g. Conway and Abrahamson, 1984; Jamieson and Johnston, 1993; Campbell and Jamieson, 2007). However, until recently all of this work focused on measurements related to fracture initiation such as shear frames, compression tests, stuffblock or rutschblock tests (Schweizer et al., 2008). In the last several years, preliminary work has been done examining spatial variability of the Extended Column Test (ECT), a test which gives an indication of propagation propensity (Hendrikx and Birkeland, 2008; Hendrikx et al., 2009; Simenhois and Birkeland, 2009). As initiation and propagation are required to get avalanche release (Heierli et al., 2011), a thorough investigation of propagation's spatial variability is an important missing element in our spatial understanding of snow stability.

Earlier work has shown differing levels of spatial variability in ECT test results. Simenhois and Birkeland (2009) found very little spatial variability in ECT propagation results on the two slopes they investigated. The only variability they found was attributable to hardness changes in a wind slab as they moved away from the ridgeline. On the other hand, Hendrikx and Birkeland (2008) found the potential for much higher levels of spatial variability in ECT results on six slopes in Montana and New Zealand. This research builds upon the smaller datasets of Simenhois and Birkeland (2009) and Hendrikx and Birkeland (2008). We use a consistent sampling scheme to build a much larger and more diverse dataset of ECT results.

2. METHODS

Data was collected at 13 study sites across southwestern Montana. Each site was located below treeline in a relatively topographically uniform, wind sheltered clearing of at least 40m by 40m with snowpacks relatively undisturbed by skiers or snowmobiles. Sites were chosen to be as

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homogenous and planar as possible in an attempt to minimize terrain effects on our results. Twenty eight ECTs were spaced across each slope in a standardized layout with a 30m x 30m extent.

Following Hendrikx et al. (2009), the ECT was modified for use in this study by using loading increments of the stuffblock test (Birkeland and Johnson, 1999) rather than standard hand taps. For each ECT we recorded test score (i.e. drop height), snow depth, and failure height (distance from the ground to the failure), and calculated slab thickness (snow depth minus failure height). At sites where multiple weak layers were failing, each weak layer was tracked independently, and results were analyzed as separate grids. At each site, a full snow pit profile, including a hand hardness profile, temperatures, densities, grain forms and grain size was obtained according to Greene et al. (2010).

3. RESULTS

In total we sampled 23 grids, at 13 sites, with each grid containing 28 ECTs, for a total of 644 tests. Four of these grids had surface hoar as the weak layer, 13 had near surface facets, one was on depth hoar, and five were on interfaces within new snow.

The percentage of ECTs propagating on a slope was calculated as a measure of the variability across a slope (Fig. 1). ECTX test results were treated as a non-response because ECTX results simply indicate a failure to initiate a fracture, rather than giving information related to propagation (Simenhois and Birkeland, 2009). There is a wide range of propagation percentage across the 23 sampled grids. Grids with closer to 100% ECTP or 100% ECTN indicate lower variability. Grids with 50% ECTP/ECTN have the greatest variability, with half of the ECTs giving results that disagree with the other half.

A clear relationship was found between the forecasted regional danger rating and the percentage of ECTs propagating in a grid (Fig. 2). The daily danger rating for each sampling day was obtained from the local regional Avalanche Center, the Gallatin National Forest Avalanche Center (2014). When there were multiple danger ratings given for a region (e.g. wind loaded and non-wind loaded), the danger rating applicable to the snowpack and terrain at the sampling site was used. Grids with a low danger rating never had more than two ECTPs out of 28 ECTs. Four out of five grids (80%) with a considerable danger rating had greater than 79% ECTPs. The greatest variability in propagation comes with a moderate danger. With a danger rating of moderate, grids showed between 0% and 65% propagation.

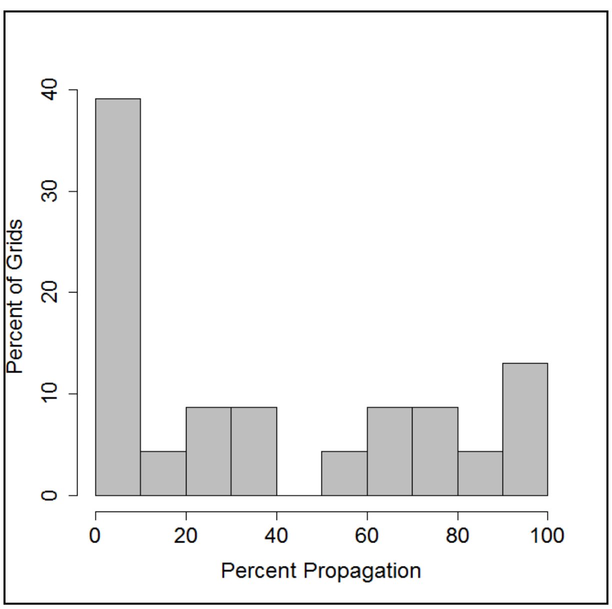

Fig. 1: Distribution of percent of ECTPs across the 23 sampled grids. Note the distribution of grids across the entire range of percent propagation.

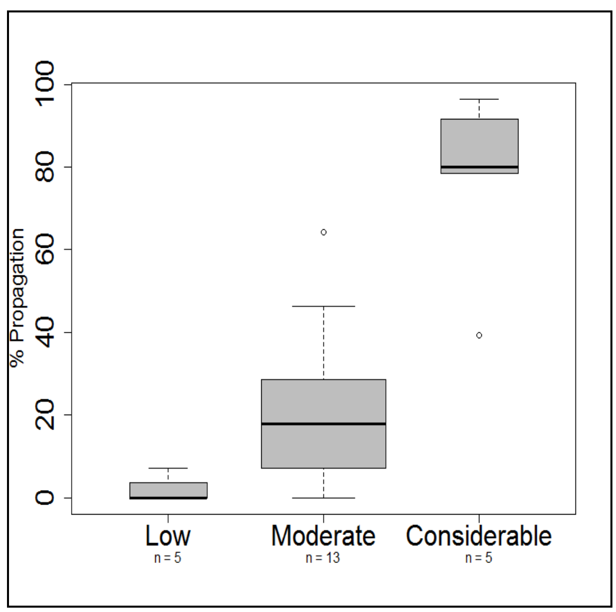

Fig. 2: Boxplot of the propagation percentage by regional forecasted hazard rating. Note the high degree of variability under moderate hazard.

4. DISCUSSION & CONCLUSIONS

Our unexpectedly high slope scale variability in ECT results reinforces the advice given by Birkeland and Chabot (2006) to perform multiple stability tests to reduce the probability of false-stable results. Because of this potential, observers must always be looking for instability and must place a much higher weight on an unstable test result.

A number of factors including weak layer type, slab thickness, snow depth, and failure height were analyzed as possible explanations for this variability. However, we found no trend in ECT result variability by weak layer type, average slab thickness, average snow depth, average failure height, or coefficient of variability of snow depth/failure height/ slab thickness. There is also no consistent association between snow depth, slab thickness, failure height, or drop height across a slope and where propagation is most likely on that slope. Unfortunately, this suggests that we there is not a simple indicator like slab depth, snow depth, or weak layer type we can use as a proxy for the spatial variability of a given slope.

The correlation we found between a moderate danger rating and the greatest variability in propagation results presents challenges for hazard assessment. These results indicate that the ECT is least reliable for assessing stability under moderate danger conditions, which is exactly the situation where a reliable stability test would be the most useful.

We found no physical variables that work as a proxy for variability in ECT results. However, when the regional avalanche danger is either considerable or low, results are likely to be more consistent. When the regional danger is moderate our results were more variable. In addition, the ratio of ECTPs to ECTNs on a slope can be correlated with the forecasted danger level, with increasing propagation as the regional danger increases.

The key practical implication of our results is that ECTs, like all other stability tests, should be interpreted with an appropriate level of caution and in a holistic fashion considerable all other relevant variables. The spatial variability of this test has the potential to be high on some slopes under some conditions, while on other slopes test results will be entirely in agreement.

ACKNOWLEDGEMENTS

We would like to grateful acknowledge the funding that made this research possible, including support from the American Avalanche Association, the American Alpine Club, the Barry C. Bishop Scholarship for Mountain Research, and the Montana State University Earth Sciences Department. We also thank the Yellowstone Club and Big Sky Ski patrols for allowing access to field sites, and all of our field assistants for their tireless digging.

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