DEFORMATION ANALYSIS OF THE PROPAGATION SAW TEST

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ABSTRACT: We present results of high speed photography films which show that the scale of slope normal deformation prior to unstable fracture in the propagation saw test (PST) is on the order of 1 mm. Tests were filmed at up to 1200 frames per second and the slab was seeded with tracing particles immediately above the weak layer. Particle tracking software measured the displacement, velocity and acceleration of each particle frame by frame during the test. The pixel resolution in close-up films was as high as 0.1 mm per pixel. The films consistently show that the majority of the slope normal deformation (collapse) of the weak layer occurs after the fracture has propagated within the weak layer. The films also show that the weak layer provides some residual support to the slab following the saw cut. We discuss several implications of these findings.

1. INTRODUCTION

The deformation of snow slabs during the propagation saw test (PST) were filmed using a high speed camera. The tests discussed here were conducted on both flat and angled terrain at Kootenay Pass in the Columbia Mountains of British Columbia in March 2009. The purpose of the tests was to learn more about the deformation of the slab and weak layer prior to the propagation condition being met and then during the propagation of fracture in the weak layer.

The slab was seeded with tracer particles, typically peppercorns, for tracking using a commercial particle tracking software. In some tests, the free end of the slab where the saw cut began was filmed in order to quantify the scale of slope normal deformation prior to propagation. In other cases the dynamic propagation beyond the end of the saw cut was filmed to capture the dynamic deformation pattern. In both cases the scale of deformation associated with the fracture of the weak layer was relatively small. The much larger scale collapse of the weak layer occurred after the propagation passed.

2. METHODS

2.1 *High speed photography*

The camera used to film the saw tests was a Casio Exilim EX-F1. The pixel resolution recorded by the camera was 512 by 384 pixels at 300 frames per second (fps), 432 by 192 pixels at 600 fps and 336 by 96 pixels at 1200 fps. The smallest field of view that the camera could focus on was about 6 cm across. For a 300 fps sequence this leads to a nominal spatial resolution of around 0.1 mm per pixel.

2.2. *Particle tracking*

The particle tracking software TEMA Motion (version 3.0-34) from Image Systems AB was used to calculate the displacement, velocity and acceleration of the particles (peppercorns) embedded in the slab.

3. RESULTS

3.1 *Deformation prior to propagation*

Prior to propagation, the scale of slope normal deformation in the PST was on the order of 1 mm. This scale of deformation was observed for weak layers as thick as 25 mm. The slope normal deformation appeared to be independent of the thickness of the weak layer. However, the scale of deformation did appear to scale with the thickness of the saw used to make the cut. Thicker saws led to greater slope normal deformation and often to a tensile fracture through the slab a short distance (on the order of the slab depth) ahead of the saw. This observation led us to adopt a thin saw as a testing standard.

Following the passage of the saw through the

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weak layer, there appeared to be residual support of the slab provided by the broken and redistributed weak layer crystals. None of our observations or movies indicated that an open gap between the slab and the remaining weak layer or substratum occurred as a consequence of making the saw cut.

3.2 *Deformation during dynamic propagation*

During dynamic propagation, the deformation of the slab immediately above the weak layer was mixed mode. The slope normal component was several millimeters and the slope parallel component was an order of magnitude smaller. It was not possible to resolve which component of deformation was the first to occur as the propagation passed. The slope normal component agrees with the scale reported by Johnson et al. (2004) for whumpfing on flat terrain.

The majority of slope normal deformation occurred after the passage of the dynamic propagation in the weak layer and was coincident with the initiation of sliding of the slab after the propagation reached the end of the column.

3.3. *Elastic modulus calculations*

The slope normal deformation measurements from the videos allow estimates of the elastic modulus of the slab to be calculated. Under the assumption that the slab is a freely cantilevered elastic beam, the elastic modulus can be found from the mean slab density, the critical cut length, the dimensions of the cantilevered slab and the slope normal deformation at the onset of fracture propagation.

In many of the experiments, some of the low density and low hardness snow at the top of the slab contributed only as dead weight rather contributing any flexural rigidity to the slab. Depending on where the line was drawn between which part of the slab was dead weight and which (lower) part was the beam, the elastic (Young's) modulus calculations for the slab varied between the approximate limits 0.1-1 MPa. The lower limit applied when the entire depth of the slab was considered the beam.

However, the typical saw cut in a PST lasts on the order of one to several seconds. Therefore the time scale for viscoelastic response of the slab is on the order of seconds. Over this time scale, the response of snow is not fully elastic but will display some stress relaxation.
Furthermore, the observation that the weak layer provides some residual support to the slab indicates that the cantilevered beam calculations will predict modulus values that are too large. Therefore the modulus calculations from simple beam theory can be considered upper bounds. The true value of the modulus appropriate for modeling the slab behavior may be considerably smaller.

4. CONCLUSIONS

The scale of slope normal deformation associated with fracture initiation and propagation in the PST is only a few millimeters, even for weak layers as thick as 25 mm. The majority of the collapse of the weak layer is an effect of fracture propagation knocking out the strength of the weak layer rather than a cause of the propagation. Additionally, the appropriate elastic or viscoelastic modulus of the slab for the analysis of PST results is considerably lower than previously thought.

5. REFERENCES

Johnson, B.C., Jamieson, J.B. and Stewart, R.R. 2004. Seismic measurement of fracture speed in a weak snowpack layer. *Cold Reg. Sci. Technol.*, 40:41–45.