THE SLAB TEST – THE MISSING LINK IN STABILITY TESTING?

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ABSTRACT: An avalanche is released when both the weak layer and the slab fails, still standard stability tests (e.g. CT, ECT) focus on the weak layer only. The SLAB test gives information on both the weak layer and the slab, hence brings additional information when evaluating slope stability. The SLAB test is performed on a 60x30 cm column that is NOT cut at the back. Load is applied by stepping onto the block in load steps similar to a Rutschblock test (but without skis). The SLAB test is easy and quick, especially when performed as the last test in the pit.

Experience and theory show that stability tests (CT, ECT) can overestimate danger when the slab is hard, hence indicate unstable conditions when slope stability is fair. The main reason is that a hard slab adds strength to a slope by edge effects and by spreading out the load (bridging). These stabilizing effects are invisible in tests on isolated columns (e.g. CT, ECT).

Examples are days when CT and ECT indicate instability correlating with danger level 3, while the SLAB test and overall stability evaluation indicate fair stability that correlates with danger level 2. Testing winter 2009/2010 indicated good agreement between SLAB test and evaluated slope stability for conditions with a hard slab (pencil or harder). Then standard stability tests (ECT, CT) indicated unstable conditions, while the SLAB test and our conclusions indicated “fair” stability. The SLAB test brought an extra tool when evaluating slope stability particularly for hard slabs (pencil or harder).

KEYWORDS: slope stability, stability tests, SLAB test.

1. INTRODUCTION

There are days where it is almost impossible to release an avalanche because the slab above the weak layer is too massive and hard. Imagine a small concave test slope with a 0.5 m thick slab with hardness “knife” above a weak layer. Avalanche release would be almost impossible even if stability tests on isolated columns gave easy failures (e.g. CT1, ECT1/1). The slope is stable and avalanche release is almost impossible because the edge effects of the hard slab, and because load is spread out (bridging).

Let’s look at the exact same weak layer but this time the slab is soft. Avalanche release would no longer be unexpected. This simple example illustrates what we all know; slab thickness and hardness plays a role in slope stability. We also know that slab properties are less important (i.e. weak layer more important) when the slab is soft and thin, and when the terrain we are evaluating is large and convex. The bottom line is that an avalanche releases when both the weak layer and the slab fails, still standard stability tests (e.g. CT, ECT) are performed on isolated columns where the slab is cut loose to focus on the weak layer only. The SLAB test gives information on both the weak layer and the slab, hence brings additional information when evaluating slope stability.

The SLAB test is a result of years of discussion and field work trying to solve the avalanche puzzle particularly during the annual 2 week forecasting for the NATO military exercises in northern Norway. These yearly exercises involve some 10.000 soldiers in the field and our job in the Avalanche Team is to provide daily avalanche bulletins to prevent tragedies like the 1986 Vassdalen avalanche that caught 31 soldiers and killed 16. The large forecasting area has mostly a maritime climate where warm periods and rain can create very hard layers in the snowpack. Still there are normally persistent weak layers making avalanche release possible.

There have been particular intense discussions on avalanche danger levels on days when CT and ECT indicate instability correlating with danger level 3, while overall stability evaluation indicate fair stability that correlates with danger level 2. The SLAB test has proved to be a good tool in our evaluation of danger level. It has given us written pit results that correspond well with our danger rating.

Further it has eased the nightmare where we imagined an accident and a lawyer pointing out our irresponsibility giving a moderate danger rating when our pit tests (CT and ECT) gave easy shears.

2. WHY IS AN AVALANCHE RELEASED?

This question is probably not fully understood today, but we know it has to do with the weak layer (fracture initiation and propagation) and the slab above the weak layer.

Nature shows us that the crown face is perpendicular to the slope, and fracture mechanics then tells us that the slab has failed in pure tension. This can only be possible when the weak layer fails first, and then the slab failure results in an avalanche. Most of us have probably been on a slope that has collapsed and fractured, but where there was no avalanche because the fracture did not propagate fare enough or because the slab strength was sufficient to prevent release.

An avalanche releases when the driving force is larger than the stabilizing forces. The stabilizing forces are the strength of the weak layer multiplied by the area of the weak layer, plus the strength of the slab multiplied by the area around the slab (perimeter). Let's play around with the examples from Bruce Trempers excellent book "Staying alive in avalanche terrain" by assuming a 1 m thick slab, and that the slab is 10 times stronger than the weak layer.

Table 1: Areas and forces for a 1 m thick slab that is 10 times stronger than the weak layer.

Avalanche Size (slab size)	Area ratio (Slab area / weak layer area)	Force ratio (Slab force/ weak layer force)
Small: 10 x 10 m	40/100 =0.4=40 %	400/100 = 4 = 400 %
Average: 100 x 100 m	400/10000 =0.04 =4 %	4000/10000 =0.4 = 40 %
Large: 1000 x 1000 m	4000/1000000 =0.004 = 0.4 %	40000/1000000 = 0.04= 4 %

These simple calculations show that the slab boundary forces (edge effects) are dominant for the stability of a small avalanche (400 % of the weak layer resistance). Further the slab strength is neglect able (4 %) for a large avalanche.

Slab properties play a role in avalanche release and should be adequately addressed in slope stability evaluations. This requires systematic testing of slab properties. The SLAB test can be used for this.

3. PERFORMING THE SLAB TEST

The SLAB test is easy and quick to perform as the last test in the pit. Make 2 vertical cuts with the saw 60 cm apart to get a 60x30 cm column that is NOT cut at the back side. Apply load by steeping by foot (no skis) onto the block at the inner part of the block.

Figure 1: Performing the SLAB-test.

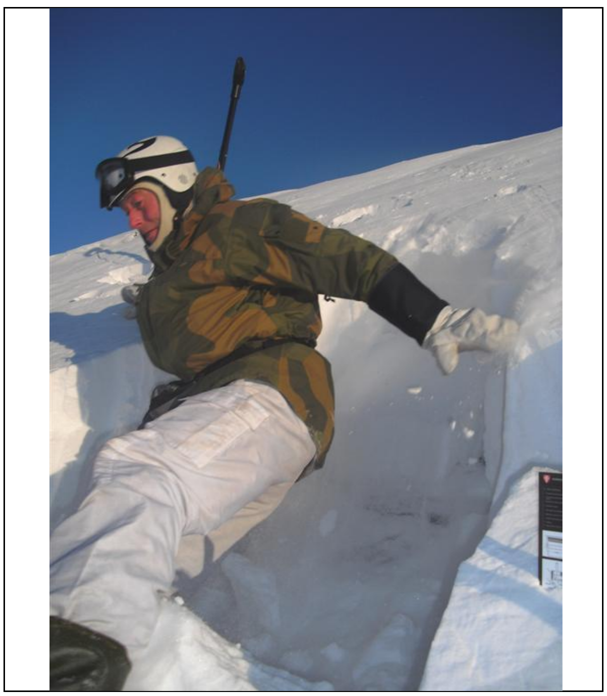
Figure 2: Block fails at SLAB 4

Load steps, fails when:
SLAB 1: Cutting
SLAB 2: One foot on block with ½ body weight.
SLAB 3: One foot on block with full body weight.
SLAB 4: One easy weighing (knee bend).
SLAB 5: One easy jump (10 cm).
SLAB 6: One high jump.
SLAB 7: Three high jumps.
SLAB 8: No failure.

SLAB_PEN: Penetration failure of outer edge of block (invalid test)

4. TEST RESULTS

Most of the tests were done by the Avalanche Team during the NATO Cold Response exercise in northern Norway winter 2009/2010 between 15th February and 4th March. The Avalanche Team has 2 avalanche experts from the Norwegian Geotechnical Institute and 6 officers from the Norwegian School of Winter Warfare. All personnel are trained avalanche forecasters and instructors.

Extensive field work is done daily with 4 teams of 2 persons using skidoos, or helicopter and skis. Each team did daily 2 to 4 snow pits with: snow profile; shovel test (ST), compression test (CT), Extended Colum Test (ECT) and SLAB tests. The avalanche hazard in every test area was set according to an overall evaluation of pit results, weather, obvious clues and often verified in test slopes with skis or skidoos. In addition all tests and observations were evaluated in the evening by all members of the Avalanche Team.

The objective of the Avalanche Team is to issue correct daily avalanche bulletins to the some 10.000 soldiers in the field. Despite recording almost 200 snow pits, there were only about 20 pits that had clear test results with failure in the same layer with CT, ECT and SLAB test. These tests have been analyzed further.

The number of tests is insufficient to make statistical analyses, but it shows some trends and results that indicate the valuable information that can be obtained from the SLAB test.

Practically it is very difficult to classify a slope as “stable” or “unstable”, since reality is not “black or white”. Even if you add “uncertain” as a middle class, you are often unsure in the classification.

The ECT test is believed to distinguish excellent between stable and unstable slopes (Simenhois, 2009). Therefore we decided to compare the tests by defining ECTP slopes as unstable, and ECTN slopes as stable. (ECTP is 1 or less difference in initiation and propagation of fracture). The definitions and test results are given in Table 2-5.

Table 2: Definitions used to classify tests.

	ECT	CT	SLAB	Q
Unstable	ECTP	13	1-2	Q1
Uncertain		14-20	3-5	Q2
Stable	ECTN	21-30	6-8	Q3

Table 3-5 show 9 “unstable slopes” and “9 “stable slopes” (defined from ECT). For unstable slopes there is a full agreement between ECT and CT (Table 3). For all other tests there is a lot more diversity mostly because a majority of tests classifies as “uncertain”.

Table 3: CT compared to ECT results.

ECT	CT		
	Unstable	Uncertain	Stable
Unstable	100 %	0	0
Stable	12 %	50 %	38 %

Table 4: Shear Quality (Q-score) compared to ECT results.

ECT	Q		
	Unstable	Uncertain	Stable
Unstable	43 %	57 %	0
Stable	0	50 %	50 %

Table 5: SLAB tests compared to ECT results.

ECT	SLAB test		
	Unstable	Uncertain	Stable
Unstable	33 %	66 %	0
Stable	11 %	67 %	22 %

The SLAB test was invented because CT and ECT can overestimate unstability for conditions with a hard and thick slab.

Looking at the “unstable slopes” (defined from ECT) it can be seen in Table 5 that only 3 of 9 SLAB tests gave “unstable” results, and 6 of 9 gave “uncertain” results. All the “unstable” SLAB tests had a soft slab (typically hardness 4-fingers). All the “uncertain” SLAB tests had a hard slab (typically hardness pencil), except for one test that had hardness 4-fingers. In our opinion the stability indicated by the SLAB test was more correct than other tests for hard slabs.

5. DISCUSSION

The SLAB test has one major negative concern since it will most likely give more stable result than other tests when the slab is hard and thick. Then you might have CT and ECT results indicating instability, while the SLAB test indicates more stable conditions. People can then be tempted to use the indication of stability to ski a slope, and trigger an avalanche where the slab is thinner or where the slab is softer. This is a concern, but can also be considered as a reminder that test must be performed at sites and situations that are representative for typical trigger points, and that a stable test does not imply that the slope is stable. We must not be afraid of seeking information on stability even though some people can abuse this information to excluded clues of instability.

One the other hand, the SLAB test will give more unstable results during daytime heating of the slab and at locations where the slab is thin. These results can be used to prevent accidents. In our knowledge there are no studies of CT and ECT tests that show reduced stability during daytime heating or at location with a thin slab, hence these tests do not clarify these important facts.

The SLAB test is designed to be a practical and quick test. There are two concerns about the setup:

Slab ratio: The 60x30 column has a weak layer area of about 0.18 m^2, which is equal to the area of the slab boundary when the slab is 30 cm thick. This gives an area ratio (weak layer/slab) of 1 which is even higher than a small avalanche (ref. Chapter 2). The setup exaggerates the stabilizing effect of the slab compared to a “real slope”. However, this can be balanced by test interpretation and by always base decisions on several types of tests and observations. The SLAB test must never be used as the only stability test.

The slab area ratio would be more like a real avalanche by increasing the length (uphill) to increase the weak layer area. However, this will make the test more time consuming since cutting of the sides would no longer be done by a standard snow saw. The present miss-proportioned test setup must be considered in the interpretation of the results.

Penetration failure: For soft slabs (4 fingers or softer) you will often push your foot into the snow and penetrate the outer edge of the block without getting a failure in the weak layer. Such results are invalid and should not be used in slope stability assessment. Such results are labeled SLAB_PEN.

6. CONCLUSIONS

The property of the slab above the weak layer is not properly addressed among avalanche professionals when evaluating slope stability and avalanche danger. Slab property is part of the stabilizing forces and cannot be neglected. We recommend doing the SLAB test to collect relevant slab information. It is a quick test and is effectively performed as the last test in the pit.

Testing winter 2009/2010 indicated good agreement between SLAB test and evaluated slope stability for conditions with a hard slab (pencil or harder). Then standard stability tests (ECT, CT) indicated unstable conditions, while the SLAB test and our conclusions indicated “fair” stability.

The SLAB test gave good agreement with standard stability tests for soft slabs (4 fingers or softer).

The SLAB test brought an extra tool when evaluating slope stability particularly for hard slabs (pencil or harder).

Slope stability cannot be concluded on the results from the SLAB test only. Slope stability must be elaborated based on all available information, knowledge and good judgment.

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