FACETED SNOW AND DEEP SLAB INSTABILITIES IN THE MARITIME CLIMATE OF THE CASCADES

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ABSTRACT: Forecasting for deep slab instabilities in dense, deep snow can be tricky, especially when the slabs are too dense for most, common stability tests to be effective in using. This paper will show the weather pattern that creates one of the most problematic weak layers in the maritime climate of the Cascades, and how we test for avalanche potential in this type of snow pack.

Keywords: forecasting, faceted snow, maritime climates, deep slab instabilities.

1. INTRODUCTION

In 1987 we had just gone through a large avalanche cycle in and around the Stevens Pass ski area, which lies along the crest of the Cascade Range. I began experimenting with some of the crown faces of these avalanches, doing shear testing. What I found really intrigued me. This avalanche cycle ran on an old rain crust with a weak layer of fine-grained faceted snow.

Using the shovel shear test I found the scores to be very hard and different from what you might expect in this situation. The shears where very hard and the quality of shear was very clean. The temperature gradient around the bed surface, weak layer and slab was quite high even at depths of six to eight feet.

Since that time I have been investigating some of the large avalanche cycles in the Cascade Range and found most of these types of cycles to run on a faceted snow weak layer with a rain crust or wet snow bed surface.

2. THE WEATHER PATTERN

A weather pattern stands out in most large avalanche cycles in the Maritime Climate of the Cascades. This weather pattern can and does produce most of the deep, old slab instabilities involving faceted weak layers in a maritime climate. Most of the common stability tests we use today are not effective in accurately interpreting results because of the depths and supper dense layers of snow.

This weather pattern may produce large destructive avalanche cycles.

After many hours of going through documents and newspaper articles I was able to reconstruct the condition of the snow pack from the February 1910 Wellington avalanche, just west of Stevens Pass that involved two trains and killing over one hundred people during the cycle. This avalanche ran on a faceted weak layer with a rain crust bed surface.

The weather pattern scenario that produces this snowpack condition is: a rain or wet snow event followed by a clear cold spell that can last from an hour to several weeks, then a sometimes slow buildup of snowfall.

This weather pattern tends to give us a false sense of stability. The common idea is that the rain or wet snow stabilizes the snowpack. The mood of skiers is generally down at this time. As it begins to snow again the mood goes up and people tend to forget about the past weather events. This idea is partly true. What we tend to forget is the short to sometimes long cold spell that faceted the new snow above the rain crust.

As it continues to snow it builds over time a snow load to a critical point.

An example of this pattern occurred in January 2002. It was a blue-sky day. No avalanche activity had been observed for some time. Skiers were everywhere. There was a ski frenzy going

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that day. The skiing was excellent and "most avalanches happen during or shortly after a storm" right? There is another phrase that tends to make people stop thinking about conditions. Prior to this day, it had snowed off and on for several weeks with no real avalanche activity. Yet at approximately the same time on this blue-sky day, two ski groups triggered fairly large avalanches about three feet in depth.

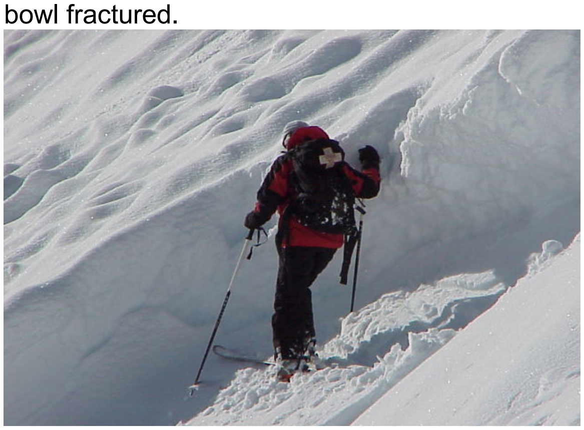
These two groups were about one and a half miles apart on South through Southwest facing aspects. People were hurt in these avalanches but no one was killed.

Avalanche profiles and interviews from the January 2002 accidents revealed that in each case skiers triggered the avalanches from the shallower part of the slab, which is common in human triggered avalanches on faceted snow in the Cascades.

3. THE AVALANCHE CYCLES, HUMAN TRIGGERED AND NATURAL.

Most human triggered avalanches in this type of snowpack-crust-facets-slab-tend to be around three feet in depth or less. In all the documented human triggered avalanches we have observed in this type of snowpack condition, avalanches have been triggered from the shallower part of the slab, at one foot on the average.

January 2000, the East Highland Bowl avalanche was a class 4. The first skier skied the deepest part of the slab, three feet in depth, over to the shoulder with no problems. The second skier jumped of a rock to the slab where it was one foot in depth, made several turns, then the entire bowl fractured.



Natural avalanche on an old faceted layer January 15th 2004.

Most of the time these faceted weak layers become so dense that it takes localized energy to make them propagate. Sometimes the densities between the weak layer and slab are very comparable. The only way I know to tell if we have a bed surface, weak layer and slab, is by looking at and comparing the weak layer and the slab structure. Usually you can see with a glass that there is no bond in the weak layer, but generally good bond in the slab.

The natural avalanche cycles in this type of snowpack have been observed with crowns up to twelve feet in depth.

One of the largest and lengthiest natural avalanche cycles I observed begin in late February 2002, and lasted into May.

Most of the snow for this season stayed along the crest of the Cascades. Many large avalanches were observed out side the ski area with crown depths of five to eight feet. One class 4 avalanche ran the night of April 13th in the ski area boundary with a crown depth of eight feet. This avalanche ran on a faceted layer of snow sitting on a rain crust that developed in late November.

Spending a lot of time in the summer of 2002 in the mountains along the crest of the Cascades, from Snoqualmie Pass to the Glacier Peak Wilderness, we were astounded how extensive this natural cycle had gone. Several paths we observed ran over five miles in length through and across valley floors. Many paths had been redefined, the snow taking out millions of board feet of old growth timber.

By the first of October of the summer of 2002 some of the run out zones had a fair amount of snow buried under old growth timber.

The 2002 avalanche cycle is an example of another observation regarding faceted snow in the Cascades.

In leaner snow years such as the season of 2002 the Stevens Pass ski area recorded only three hundred inches of snowfall. Yet we saw one of the largest avalanche cycles.

During lower snowfall seasons we tend to see more of a variety in weather patterns with prolonged clearing trends creating crusts and surface weak layers that get buried over time. By contrast, the winter of 1996, we recorded above average snowfall for the season with six hundred and sixty inches. The temperature was fairly consistent, and the snowfall was consistent averaging eight inches every twenty-four hours from December through February. By March there were no crusts or weak layers in the snowpack and no large slab avalanche cycles.

Talking with some of the old timers from the area and going through documents and newspaper articles, it was evident that most of the large avalanche cycles occurred with the weather scenario of crusts-facets and snow.

4. TESTING FOR DEEP SLAB INSTABILITY IN FACETED SNOW OF A MARITIME CLIMATE.

Most of the natural avalanche cycles in this snowpack structure tend to be rain induced. However several large avalanche cycles have been observed during rapid cooling trends.

In 1994 the weather went from 36 degrees and rain to –20 degrees and clear in twelve hours. This rapid cooling trend produced several large avalanches when the temperature got below freezing.

Testing for slab instability in the sometimes very dense snow we see in maritime climate of the Cascades can be very tricky. A lot of the time we ski on large, deep, dense slabs that our normal evaluating techniques do not tell us there could be a problem. Sometimes the slabs become deep, eight maybe ten feet or so, past where most people give up, figuring its out of their hands and more than likely skiers won't trigger something that deep or that dense. Distribution of the slab in this situation is important to look at. Usually finding the weakness over a large area can be done with a probe.

One season we had a very dense layer of snow, pencil hardness, over laying a layer of small dense facets. Large charges where not removing this instability and it was a pain to dig through snow you had a hard time sawing through. I took a snow cat to a low angle slope, cut the face with the cat, sawed the other three sides with a large timber saw and drove the snow cat on top to see if we could displace the block. It worked. The block displaced, but I normally do not carry a snow cat in my pack.

I got to thinking, maybe we really need to be looking at the interface between the bed surface-weak layer and slab more closely.

Using a variety of tests such as the Rutschblock, Compression test, large charges and lots of digging, I found the Shovel Shear test brought out the most meaningful information for me.

The three factors I look at when testing for avalanche potential are;

1) **Shear Strength**
2) **Shear Quality**
3) **Measure the temperature gradient across the weak layer.**

Some folks do not think the shovel shear test can effectively be used for a stability test, but I feel just about any of the test methods work as stability tests if they are use consistently and over long periods of time.

The shovel shear test is one that I have used for many years and consistently.

Tracking these weak layers of dense faceted snow over time is very important. As soon as a crust forms I follow the condition and test once a week.

This last snow season we had a late November rain crust develop low in the snowpack near the ground. After the rain we ended up with about four inches of snow on the crust. Then it cleared off and cooled down for a short time.

These four inches of snow faceted out immediately.

I started testing this weak layer around the first of December every seven days.

By the middle part of January we had received 136" of snowfall. We saw over fifty percent settlement by the end of this storm cycle.

The slab over this time period was really starting to gain energy by the end of December.

12-11-03	**- 1oC**	
12-16-03	**- . 5oC**	
12-23-03	**- . 5oC**	
12-29-03	**- 1oC**	
1-05-04	**- 1. 5oC**	**Time of highest**
1-11-04	**- . 5oC**	**temperature**
change		
1-15-04	**No gradient**	
1-19-04	**- . 5oC**	
1-26-04	**- . 5oC**	
2-02-04	**No gradient**	

Temperature profile over a nine-week period, 10cms across the weak layer.

A steep temperature gradient developed in the snowpack due to a cold spell around the mid part of December into January.

However the temperature gradient around the faceted layer on the November rain crust remained high enough to continue to facet the weak layer from the time it formed in November through mid-January.

Using the shovel shear test I constantly isolated a block, each week, at 30 cm above the weak layer, testing the shear strength, shear quality and measuring the temperature gradient across the weak layer.

Here are the test results starting December 11th and running through February 2nd of this last season, 2004.

12-11-03 E-SS-QS 2
12-16-03 M-SS-QS 2
12-23-03 M-SS-QS 1
12-29-03 M-SS-QS 1
1-05-04 H-SS-QS 1 Tests showing
1-11-04 H-SS-QS 1 time period of
1-15-04 H+-SS-QS 1+ highest energy
1-19-04 M-SS-QS 2
1-26-04 M-SS-QS 2
2-02-04 E-SS-QS 3

Avalanche cycle began on the morning of January 15th.

What I have found over the seasons of testing this snowpack condition in this manor, is that as the slab gains energy over time the shear strength goes up and the shear quality goes up.

In most cases the temperature gradient around the weak layer stays high enough to promote faceting even if the weak layer is buried over three feet.

By the 15th of January the shear strength and quality had gone way up. The shears where very hard, making a lot of noise when they would release.

During the two previous weeks of January 5th and the 11th we felt we where close to avalanche potential on this faceted weak layer that had developed in late November.

During the night of the 14th of January we received about a half –inch of rain up to 5000' in elevation.

On the morning of January 15th it began to cool down and snow heavily at 5000'. After I dug my weekly snow test pit the slope below me released down to the November rain crust. The visibility was very poor due to the heavy snowfall but I could hear avalanches starting to run across the valley.

This avalanche cycle was short lived due to the rapid cooling trend.

Because of the instability at the time we were not able to do a fracture profile until the next day.

During the first through the middle part of December tests were showing the slab in a more relaxed state but starting to build energy. By the first of January there were definite changes in the energy of the slab. By the 5th of January we felt we were close to avalanche potential, just waiting for the right trigger. By January 11th shear tests were actually making noise on release.

The morning of January 15th I was two handed on the shovel to make the weak layer release with very loud noise from the slab release.

This indicated to me super energy stored in the slab or weak layer or both.

After the avalanche cycle on the 15th the weekly tests started to show a more relaxed state of energy in the slab.

The temperature gradient evened out and the slab appeared to start a good bond between the bed surface, weak layer and slab.

By the 2nd of February the weekly tests were showing a real relaxed state of energy,

E-SS-QS 3

It seems it is important to monitor all three parameters, shear strength, shear quality and monitor the temperature gradient.

In many cases we have tested these types of snow pack conditions with little to no temperature gradient around the weak layer. In these cases there appeared to be little energy in the slab/weak layer area. However we have observed large avalanche cycles in warmer type conditions with what we might consider small triggers such as a fifteenth inch of rain or a one degree drop in temperature below freezing or and rapid cooling spell.

This energy building and relax of the slab/weak layer has mainly to do with the weather conditions. Certain types of weather patterns are conducive to building energy in the snow pack and certain weather patterns are conducive to a more relaxed state of energy.

5. CONCLUSIONS

If I went to an area I was not familiar with, not knowing the weather and snow pack history, and found this type of snow pack condition of bed surface, facets and slab, I would have to look at the test results in a different way.

I think it is important in a forecasting operation to watch trends in the weather and snow pack over time.

I think a variety of the common tests we use today work in forecasting avalanche potential, but they need to be used consistently and over long periods of time to come up with consistent results.

Using more than one or two tests in a snow pit can get confusing. Keep things simple.

In using the shovel shear test in faceted snow in a maritime climate I have found the tests results in most of these cases to be different from what you would normally find in testing the snow pack. These results I have shown you are specific to faceted snow in a maritime climate.

In all other types of snow pack conditions I test, the test results remain the same as we all interpret them.

I think finding the results this way, almost opposite of what we normally find, has a lot to do with the high densities we find in the faceted layers in a maritime climate.

It is important to use only a few stability tests. Be consistent in using your tests. Watch for trends in the weather and snowpack conditions.

6. CONTINUED RESEARCH ON FACETED SNOW IN A MARITIME CLIMATE.

1) How does energy build in a slab or snowpack?
2) What types of weather patterns are conducive to energy building in the snowpack?
3) Testing this type of snowpack condition with a verity of stability tests.
4) If I went to an unfamiliar snowpack and was not able to read the trends, how would I interpret test results-differently?