THE CANTILEVER BEAM OR "BRIDGEBLOCK" SNOW STRENGTH TEST

Craig Sterbenz*
Snow Safety Director, Telluride Ski & Golf Co., Telluride, CO.

ABSTRACT: Weak layers buried within the snowpack are chiefly responsible for slab avalanche formation. These weak layers tend to fail in shear when subjected to internal snowpack stresses. There are myriads of snow stability tests used to locate and quantify the weakness of these shear layers. Knowledge gained from these shear tests forms the basis for most avalanche forecasting programs. However, the relationship between stress and strength within the snowpack remains complex and important. Stress must equal or exceed strength for failure and avalanche release. The shear fracture within the weak layer must also precipitate tensile failure of the overlying slab for avalanche release to occur. Because the weak layers are so important for avalanche formation, little has been done to evaluate the strength of the slab layer. The "Bridgeblock" or cantilever beam test is a simple field test designed to evaluate the tensile strength of the slab material overlying the bed surface weakness.

KEYWORDS: Avalanche forecasting, avalanche formation, snow mechanics, snow hardness, snow strength.

1. INTRODUCTION

It is now widely accepted throughout the avalanche community that dry slab avalanche release begins first, or initiates, with shear failure in a weak layer of the snowpack. Internal snowpack deformation leads to shear stress, shear failure and subsequent shear fracture across the bed surface. The shear fracture at the bed surface rapidly precipitates additional fractures at the crown, flanks and stauchwall. The bed surface is, by far, the largest and most important slab boundary layer to consider in a study of avalanche release mechanics. Virtually all snow stability tests are designed to find and quantify the relative weakness of suspected bed surface shear planes. Most avalanche forecasting programs rely heavily on the knowledge of these buried weak layers.

The continental-radiational snow climate of the San Juan Mountains in Southwestern Colorado frequently produces a snowpack that is predominantly well developed depth hoar. A meter or more of cohesionless 4 to 6 mm depth hoar is not uncommon. This weak layer is so obvious that traditional snow stability tests are hardly needed to locate or evaluate it. Attempts to fully isolate columns of snow frequently fail with collapse of the entire column. Such a pervasive and overwhelming weakness makes avalanche forecasting in the San Juans exciting to say the least. Forecasters visiting from other snow climates often ask why it isn't constantly avalanching. The thickness of the weak layer in the San Juans occasionally produces interesting avalanche release characteristics. Frequently, early-season "off-piste" skiing there is not even possible until a slab or "bridging layer" develops. (Before that it's just "bottom feeding.") Shear fracture of these thick weak layers often results in audible "woompfing" and visible collapse of the substratum. This collapsing substratum is observed most frequently on flat to gentle terrain, where tension stresses are minimal, and seldom results in visible fractures of the slab. Occasionally, even on steep terrain, where tension stresses are higher, this collapse may fail to produce an avalanche fracture or release.

Avalanche release requires the tensile failure and fracture of the overlying slab material as well as the shear fracture along the bed surface. The fracture at the crown is a result of tension failure. (The collapse of a thick weak layer adds a bending moment to the tensile stress on the slab above and may help explain observed crown fractures that are not perpendicular to the bed surface.) Fractures at the flanks result from both tensile and shear forces while the stauchwall fails primarily in shear with the bed surface. If any one of these slab boundaries fails to fracture, avalanche release may be partial or not occur at all. Presumably, there is sufficient cohesion or

*Craig Sterbenz, Snow Safety Supervisor,
Telluride Ski & Golf Co.
P. O. Box 11155, Telluride, CO. 81435
tel: 970 728 7587; e-mail: sterbie @ rmi .net

strength in the slab to"bridge" out to anchors or pinning areas and resist tensile failure. Experience also indicates that thick strong slabs may spread out the weight of a skier or new snow load and help decrease the stress being added to the weak layer. It is true that "slabs do not cause avalanches, weak layers do." But, maybe strong slabs can help prevent avalanches.

2. TESTING SNOW STRENGTH

Snow data pits can provide good information on snow density, temperature, snow grain size, type and relative hardness. Some of this information is used to infer snow strength. Tensile snow strength within a single layer is simply a measure of cohesion or bonding between the grains. Shear strength within the snowpack is a measure of grain cohesion and friction between layers. It can be measured with a shear frame. Low density, large grain snow usually has low strength. Fine grain high density snow is usually stronger. High density large grain snow, like depth hoar, has little strength. Density frequently increases with depth in the snowpack while strength does not. Density and grain size do not seem to be reliable measures of snow strength. Hardness, as measured by ramsonde or relative resistance to penetration, is a better measure of snow strength than density. A ram profile may tell us a lot about the strength of the individual layers of the snowpack. However, it can tell us little about the effects of strain softening or how several layers of slab may respond to the stress from shear failure below it. It is also an expensive and cumbersome tool for use as a quick and simple field test. The "Bridgeblock" or cantilever beam test is a quick simple field test designed to quantify the tensile strength and resistance to failure of the slab material overlying or "bridging" the bed surface weakness.

3.CONDUCTING A BRIDGEBLOCK TEST

First step: Dig a standard snowpit and collect the usual data.

Second step: Perform standard snow stability tests to locate and evaluate suspect weak layers.

Third step: Measure and mark 1 meter in width across the top of the snowpit wall. (See Figure 1.) From each end of this mark; again measure and mark 1 meter back on the snow surface behind the pit wall. (Similar to preparation for a rutschblock test.) From each end of the first mark; mark plumb lines on the pit wall to just below the weakest layer (or other weak layer of interest).

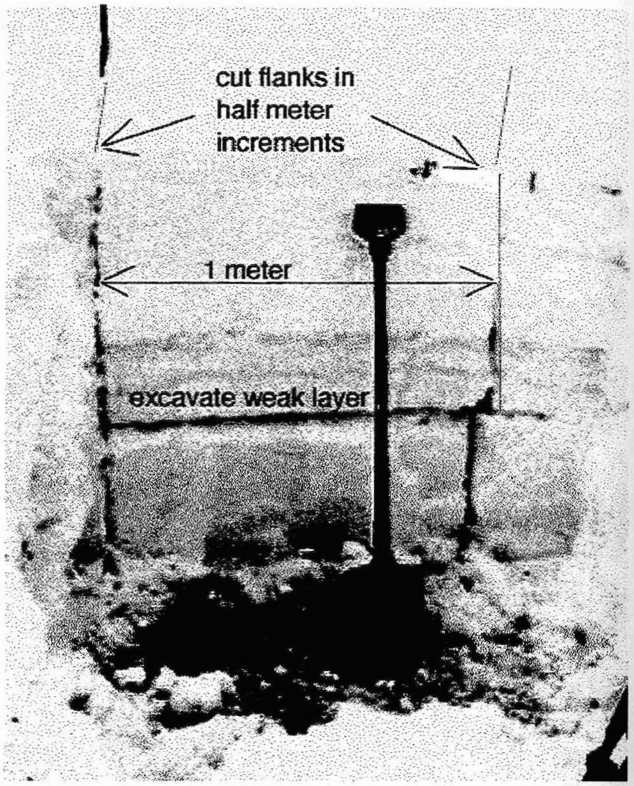


Figure 1. Pit wall with layout and partially isolated slab.

Fourth Step: Create an artificial bed surface fracture by excavating one square meter of weak layer from between the plumb lines using a ski pole or pole & snowsaw. Cut horizontally across the face of the snowpit wall and cut parallel to the slope a meter back from the pit wall surface. If the slab above the cut fractures during the excavation it gets a score of zero. If it survives excavation it gets a score of 1.

Fifth step: Cantilever the suspended slab along the flank by first cutting 1/2 meter deep into the slab along the plumb line on either side and following the 1 meter marks laid out on the snow surface earlier. If it doesn't fail, it gets a score of 2. Next make another 1/2 meter deep cut along the other plumb line. If it doesn't fail, it gets a score of 3. Half of the beam is now cut on both flanks and cantilevered out 1/2 meter. Next; extend the plumb side cuts, one at a time, the second half meter back until the slab is now cantilevered a full meter, like a diving board. (See Figure 2.)Each cut getting scores of 4 and 5 respectively.

Sixth step: If the "bridge" layer survives the excavation and successive flank cuts (score of 5) the next step is to load the cantilever using some of the stuff block, shovel tap or loaded column techniques of standard stability tests until the cantilevered slab fails in tension at the crown...providing scores of 6 or more.

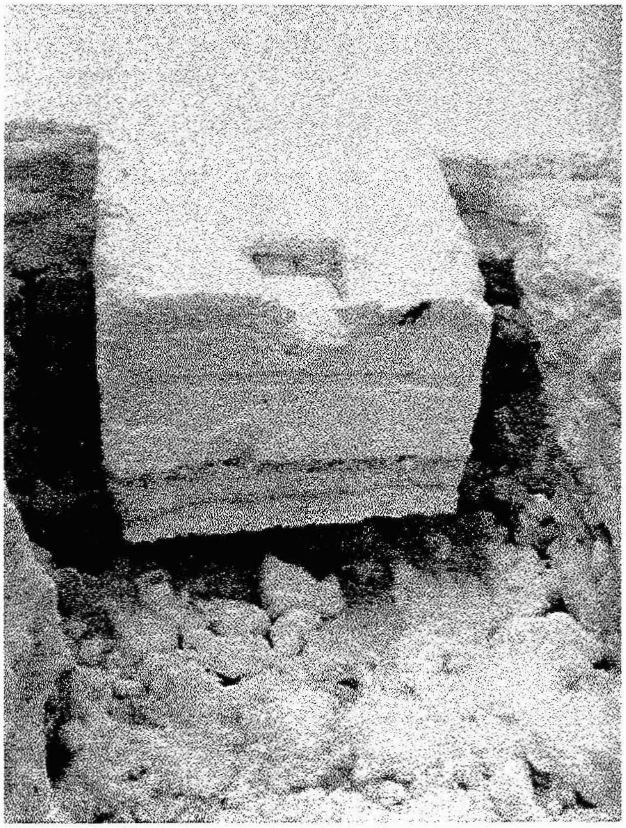


Figure 2. Fully isolated and cantilevered beam.

4. METHODOLOGY AND OBSERVATIONS

Several seasons were spent conducting these tests in the San Juans. Initially, the test was conducted by cutting the flanks back 1 meter on each side and then measuring how far the weak layer needed to be excavated before the slab would fail. This provided good information but led to operational difficulties when tools and workers were invariably buried by the falling beams. The tests were conducted primarily, but not exclusively, on relatively flat study plot areas in order to isolate possible slope angle factors. The test seems easiest to conduct (and possibly more germane?) in a faceted layer at least several cm thick. Most, if not all, of the crowns resulting from the test were not perpendicular to the snowpack layers. This seemed to suggest that both tensile and bending stress were being applied to the slab.

Over the course of the 1997-1998 season, a low density snowfall from early December developed into a very weak layer of faceted grains at about 50 cm from the ground. (See Snow Cover Profile 2). This weak layer persisted throughout the winter. It was the failure plane for most of the deep slab avalanches during the remainder of the season. This was the layer of interest excavated during the bridgeblock tests conducted at the Gunroom Study Plot. The test was very useful for tracking increases and decreases in slab strength above this layer. Cantilever beam scores were low, but increasing through late February. (See Snow Cover Profiles 3 and 4). Heavy snowfall in late February and early March produced an avalanche cycle releasing in the December layer. Deep new snow and warmer temperatures quickly improved snow strength and by mid-March cantilever beam scores were high. New snow added 30 cm to the snowpack between March 15 and March 19. (See Snow Cover Profiles 5 and 6) This new snow load decreased cantilever beam scores and resulted in another deep slab cycle with numerous releases in the same December weak layer. Warm temperatures and strengthening outpaced heavy new snowfall from mid-March through early April. Beam test scores again increased and deep slab activity ended.

6. TEST RESULT INTERPRETATION

Scores of 0 to 1 were very common, especially early season, in the San Juans. These scores suggested very little slab strength but seldom produced much in the way of slab avalanche activity, even with new snow events. Loose cohesionless sugar sluffs or isolated deep pockets of soft slab with little horizontal fracture propagation characterized the avalanche activity.

Scores of 2 to 3 seemed to indicate moderate slab strength. However, new snow loading resulted in an observed increase in the frequency and magnitude of deep slab avalanche activity. Most of these were medium size soft slabs with moderate horizontal fracture propagation.

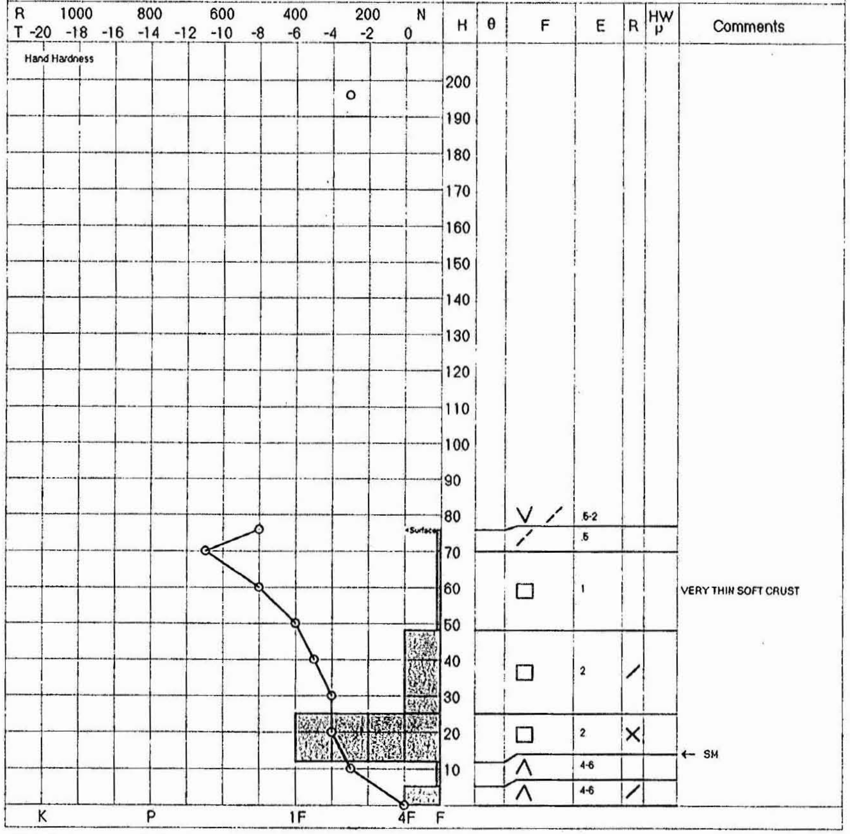
Scores of 4 to 5 were seldom recorded until late season in the San Juans. These scores appeared to suggest strong slab material. A decrease in the frequency of slab avalanches was observed. However, large storm events continued to produce deep slab avalanches. These were frequently observed as class 4 or 5 hard slabs with crowns that would propagate long distances.

Scores of 6 and higher were rare in mid winter in the San Juans. These high scores were only found during mid to late spring following melt freeze cycles and the development of multiple dense layers. Scores of 6 and greater indicated considerable snow strength. No deep slab avalanches were observed during periods with these high scores. However, scores were observed to lower again with new snow load.

6. CONCLUSIONS

After several seasons of conducting the bridgeblock test and observing related avalanche activity several conclusions may be drawn. The test is repeatable and quantifiable on a relative scale. Tensile snow strength of the slab can be measured with such a test. Snow strength of the slab does have some relationship with observed avalanche activity. Difficulty in precise interpretation of test results continues to obscure the nature of this relationship. High test scores did not appear to preclude future avalanche activity. Interestingly, bridgeblock test scores did seem to correlate well with avalanche size. Perhaps this test is better suited as an indicator of the type and size of avalanche activity that might be expected than it is as a forecasting tool for avalanche occurrence.

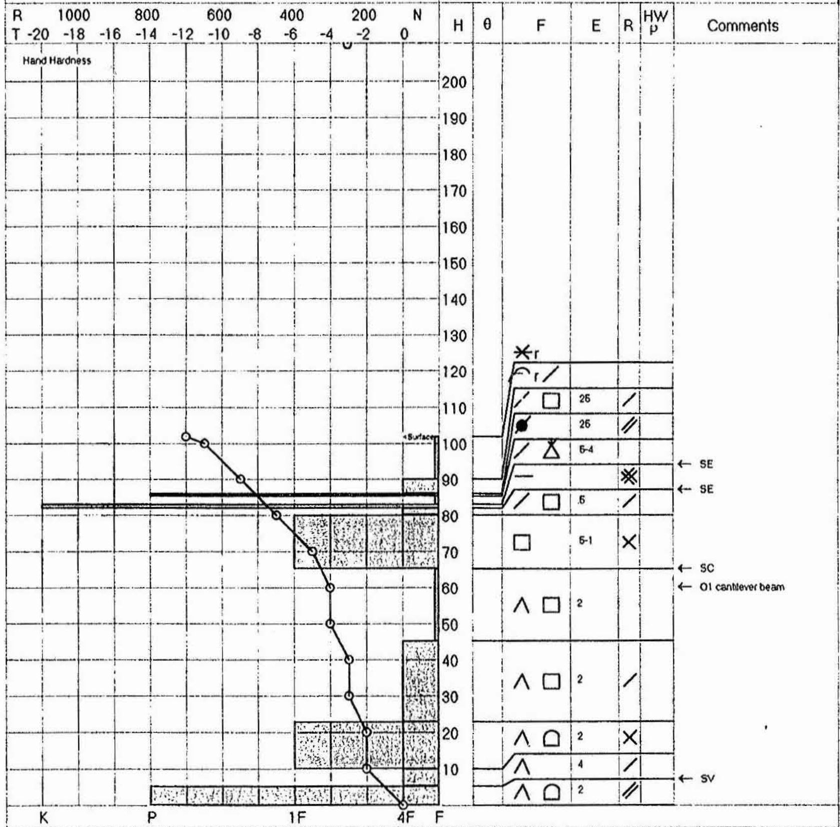
SNOW COVER PROFILE TELLURIDE SKI PATROL 1997-98	Obs. STERB & JEFF Date 97-12-30 Time 11:00	Profile Type Full No. 2 Surface Roughness ——— Smooth Penetration Foot 60 Ski 15
Location GUNROOM STUDY PLOT		Air Temperature -3
H.A.S.L. 11200 ft Co-ords		Sky Condition ○ Clear
Aspect N Slope 1		Precipitation Nil
HS 76 HSW ρ R N		Wind Calm



Stability Assessment: Good

CANTILEVER BEAM TEST. SLAB FAILED UPON COMPLETION OF EXCAVATION OF 1 SQ METER OF THE 6-12 CM DEPTH HOAR LAYER. SAME LAYER FAILED ON SECOND TAP FROM ELBOW
BUT WOULD NOT COLLAPSE W/ RUTSCHBLOCK TEST

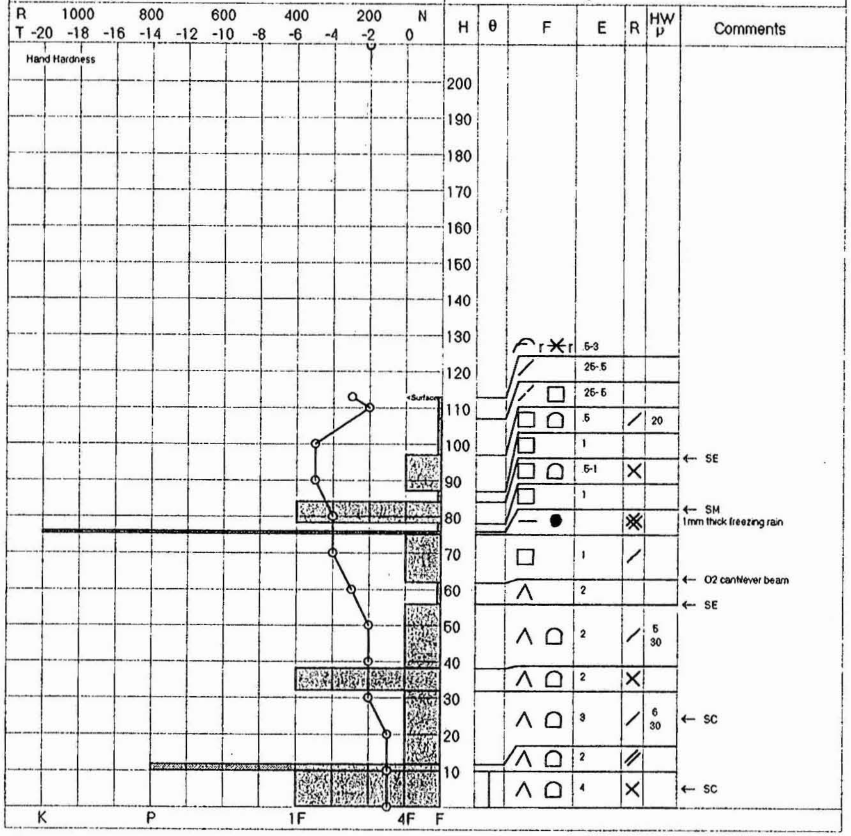
SNOW COVER PROFILE TELLURIDE SKI PATROL 1997-98	Obs. STERB Date 98-01-26 Time 11:00	Profile Type Full No. 3 Surface Roughness ——— Smooth Penetration Foot 100 Ski 20
Location Gunroom Study Plot		Air Temperature -3
H.A.S.L. 11200 ft Co-ords		Sky Condition ○ Clear
Aspect W Slope 1		Precipitation Nil
HS 102 HSW ρ R N		Wind Light - West



Stability Assessment: Very Poor

bndge block failed on completion of excavation of 60-65layer
weak needs laoding

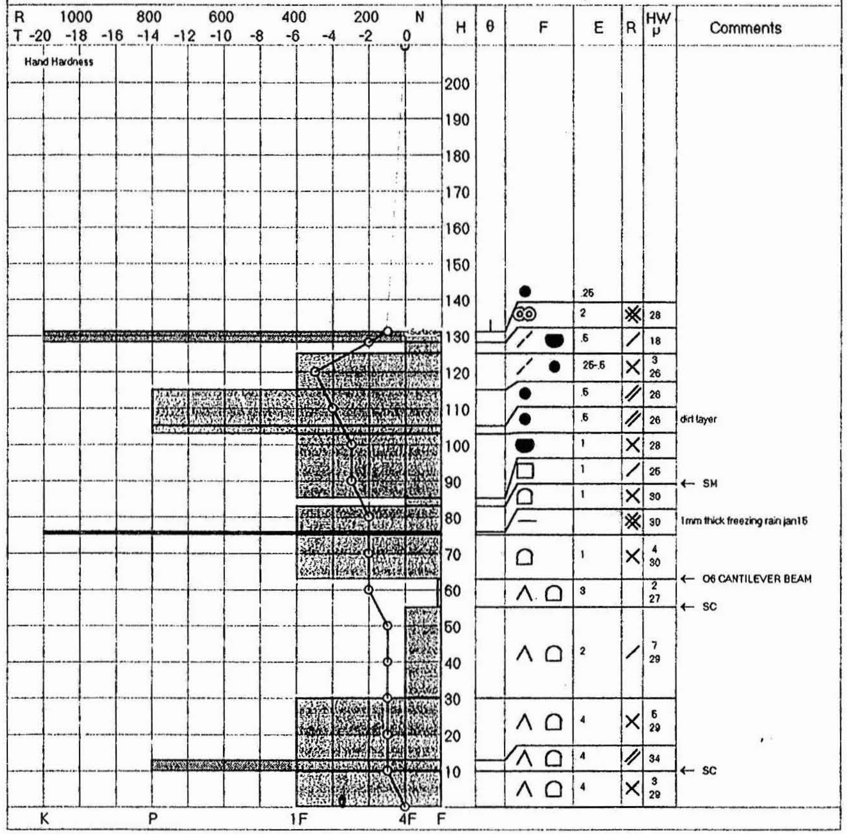
SNOW COVER PROFILE TELLURIDE SKI PATROL 1997-98	Obs. STERB Date 98-02-22 Time 13:00	Profile Type Full No. 4 Surface Roughness ——— Smooth Penetration Foot 100 Ski 15
Location Gunroom Study Plot		Air Temperature -2
H.A.S.L. 11200 ft Co-ords		Sky Condition ⦶ Broken Clouds
Aspect NA Slope 0		Precipitation Snow - Very Light
HS 113 HSW 13 ρ 14 R N		Wind Light - South West



Stability Assessment: Fair

Ground frozen

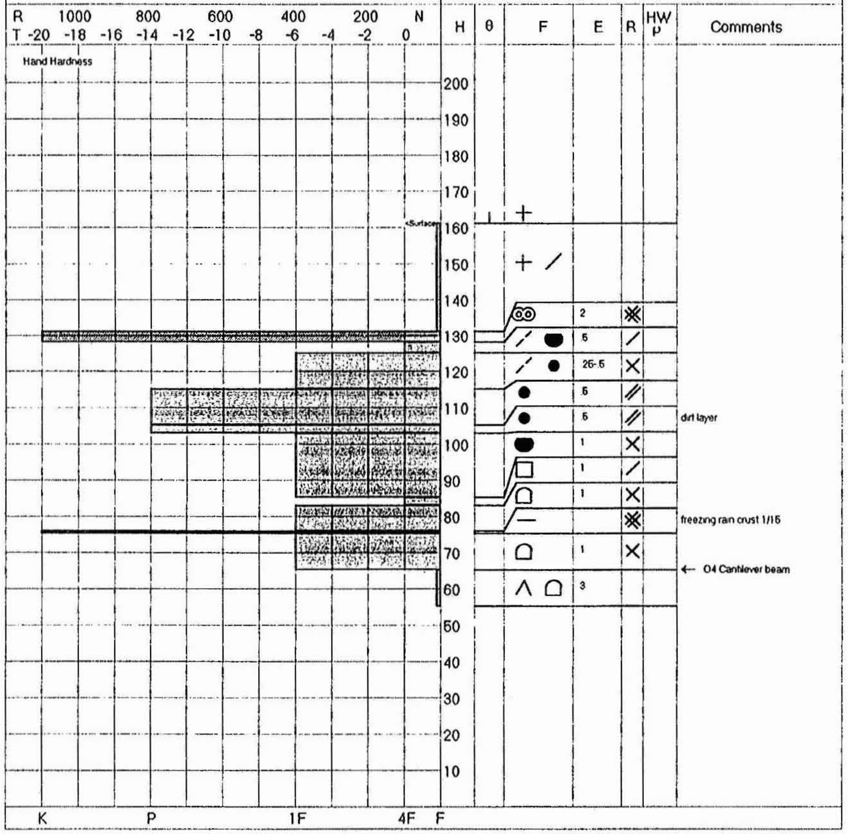
SNOW COVER PROFILE TELLURIDE SKI PATROL 1997-98	Obs. STERB Date 98-03-15 Time 11:00	Profile Type Full No. 5 Surface Roughness ——— Smooth Penetration Foot 25 Ski 2
Location Gun Room Study Plot		Air Temperature 0
H.A.S.L. 11200 ft Co-ords		Sky Condition ○ Clear
Aspect W Slope 10		Precipitation Nil
HS 131 HSW 39 ρ 28 R N		Wind Light - North East



Stability Assessment: Good

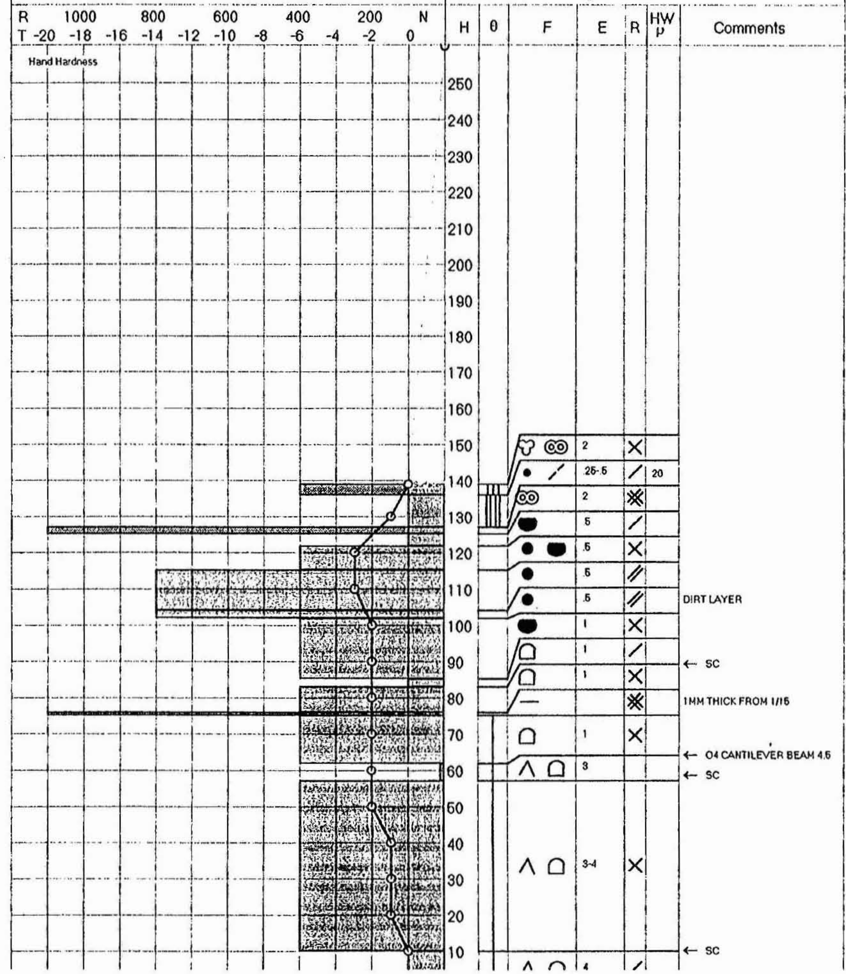
CANTILEVER BEAM: 65-63CM LAYER EXCAVATED. DID NOT FAIL UNTIL FULLY CANTILEVERED ,WEIGHTED W/ LARGE BLOCK OF SNOW

SNOW COVER PROFILE	Obs.	STERB & AHERN	Profile Type	Test	No. 6
TELLURIDE SKI PATROL	Date	98-03-19	Surface Roughness	——— Smooth	
1997-98	Time	14:00	Penetration Foot	30	Ski 20
Location	Gun Room Study Plot		Air Temperature		
H.A.S.L. 11200 ft	Co-ords		Sky Condition	Scattered Clouds	
Aspect W	Slope 8		Precipitation	Nil	
HS 161	HSW	ρ R N	Wind	Light - North West	

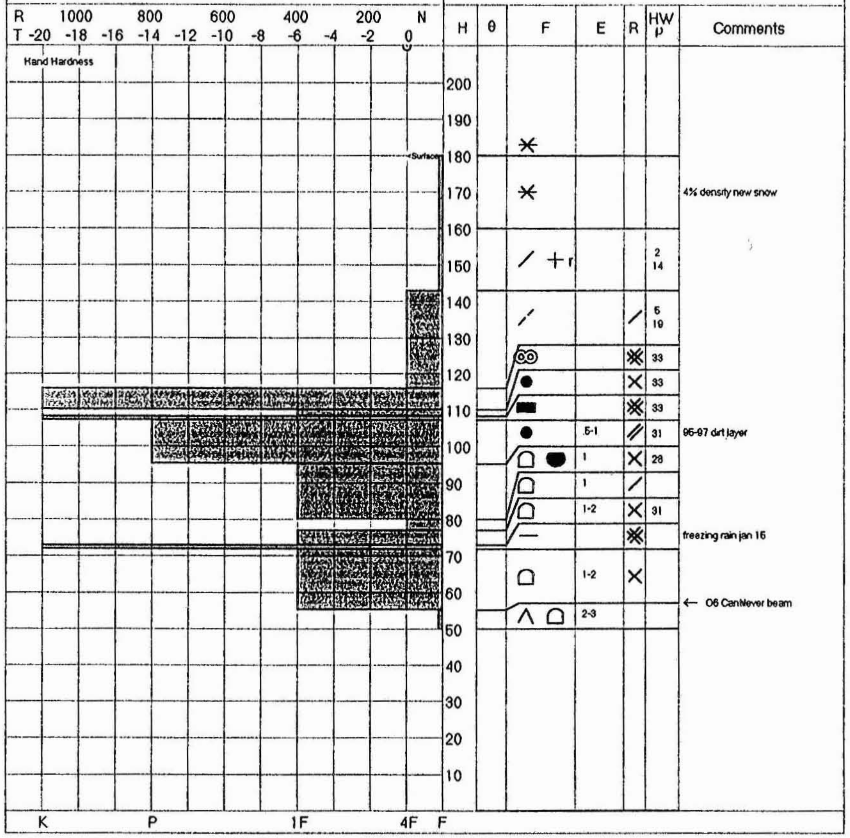


Cantilever beam test adjacent to test site from 3/15 new snow loading decreased the score of 6 to a score of 4 failing just at completion of first full 1 meter side cut.

SNOW COVER PROFILE	Obs.	STERB	Profile Type	Full	No. 7
TELLURIDE SKI PATROL	Date	98-03-23	Surface Roughness	——— Smooth	
1997-98	Time	12:00	Penetration Foot	15	Ski 2
Location	Gun Room Study Plot		Air Temperature	2	
H.A.S.L. 11200 ft	Co-ords		Sky Condition	Clear	
Aspect W	Slope 8		Precipitation	Nil	
HS 139	HSW 2	ρ 1 R N	Wind	Light - West	



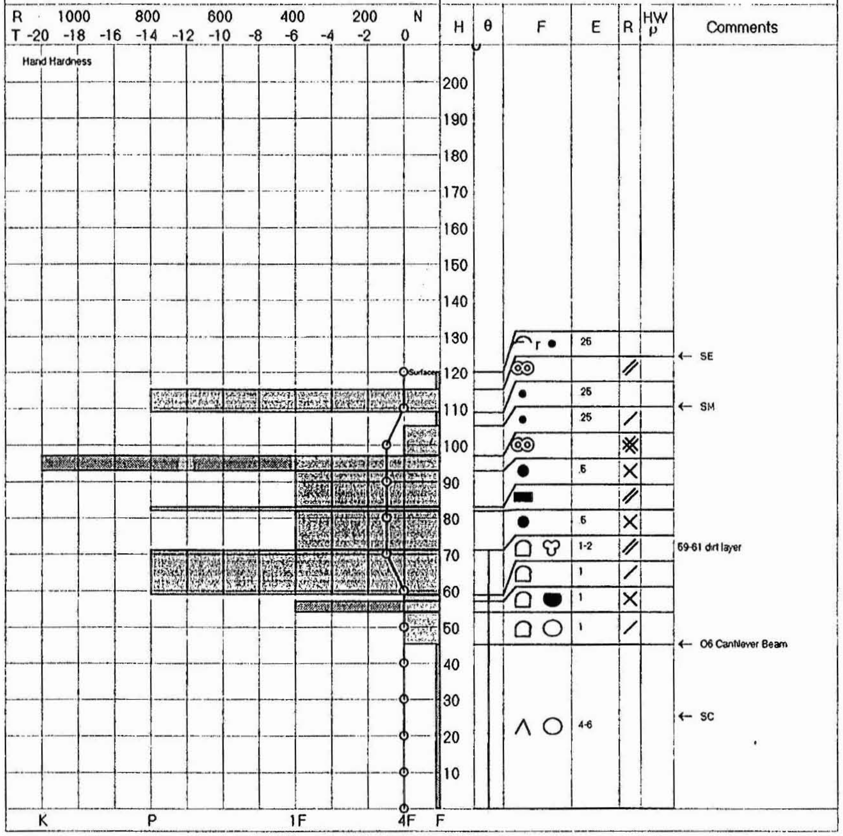
SNOW COVER PROFILE TELLURIDE SKI PATROL 1997-98	Obs. STERB & ART MEAR Date 98-03-26 Time 12:00	Profile Type Test No. 8 Surface Roughness ——— Smooth Penetration Foot 50 Ski 40
Location Gun Room Study Plot		Air Temperature 0
H.A.S.L. 11200 ft	Co-ords	Sky Condition ⦶ Scattered Clouds
Aspect W	Slope 5	Precipitation Nil
HS 180 HSW 19 ρ 12	R N	Wind Calm



Stability Assessment: Good

Cantilever beam failed after complete excavtion, isolation and 1 hard shovel tap from the wrist

SNOW COVER PROFILE TELLURIDE SKI PATROL 1997-98	Obs. STERB & AHERN Date 98-04-09 Time 13:30	Profile Type Full No. Surface Roughness ——— Smooth Penetration Foot 15 Ski 5
Location North of Angle Station		Air Temperature 4
H.A.S.L. 10400 ft	Co-ords	Sky Condition ⦶ Broken Clouds
Aspect E	Slope 13	Precipitation Nil
HS 120 HSW ρ	R N	Wind Calm



Stability Assessment: Good

Entire layer from 0-45cm excavated and both sides of beam fully excavated. then repeated shovel thump tests required to get beam to break