EXPERIENCE WITH RUTSCHBLOCKS

J.B. Jamieson[1] and C.D. Johnston[1]

During the winters of 1990-1992, rutschblock technique and limitations, variability and precision of rutschblock scores, and applications of rutschblocks to slab stability evaluation were studied in the Cariboo and Monashee Mountains of western Canada. The time required for each test was, under many conditions, reduced to 10 minutes or less by using cords, specialized saws or the tails of skis to cut the two sides and the upper wall of the rutschblock. The median rutschblock score was 4 or less on most days when one or more large dry natural slab avalanches were reported by helicopter skiing guides operating within 30 km of the study area. Also, median rutschblock scores were 4 or less near slabs that had been ski-released and individual scores up to 5 were recorded near recently ski-released slabs. On slopes of 20° to over 40°, median rutschblock scores correlate well with a Swiss stability index; however, rutschblock scores on slopes below 20° are inconsistent with the correlation suggesting a minimum angle for rutschblocks of approximately 20°. In spite of natural variability of rutschblock scores on a particular slope, decreasing the slope angle by 10° tended to increase the rutschblock score by 1. A tendency for higher and more variable scores was noticed near the top of several slopes.

INTRODUCTION

During the winters of 1990-1992, over 1000 standard and non-standard rutschblock tests were performed on dry snow in the Cariboo and Monashee Mountains of western Canada. Field studies included the following topics: variations in techniques; variability and precision of scores; rutschblock scores concurrent with dry slab avalanches; the effect of slope angle on rutschblock scores; and spatial variability of rutschblock scores on particular slopes.

FASTER CUTTING TECHNIQUES

The traditional technique for preparing a rutschblock involves exposing the lower wall and both side walls of the block by shovelling (Fig. 1) before cutting the upper wall with a cord or the tail of a ski--a procedure that can require 20-30 minutes (Föhn 1987a). To study potentially faster techniques, we cut the sides and upper wall with a cord, tail of a ski or 1.3 m long saw, and compared the time requirement with that from adjacent tests using the traditional technique. Average time requirements, excluding site selection and equipment preparation, were only

---

[1] Department of Civil Engineering, University of Calgary.

reduced from 10.4 minutes for shovelling the side walls to 9.1 minutes for cutting the side walls with a cord. However, cutting both side walls and the upper wall with a saw or tail of a ski reduced the average time requirement to approximately 5 minutes. These faster techniques have their disadvantages: it is difficult to cut slabs thicker than 0.6 m slabs with the tail of a ski; cords will not cut most slabs containing melt-freeze crusts; and saws are effective under all conditions, but weigh 1.2 to 1.8 kg and are bulky to transport.

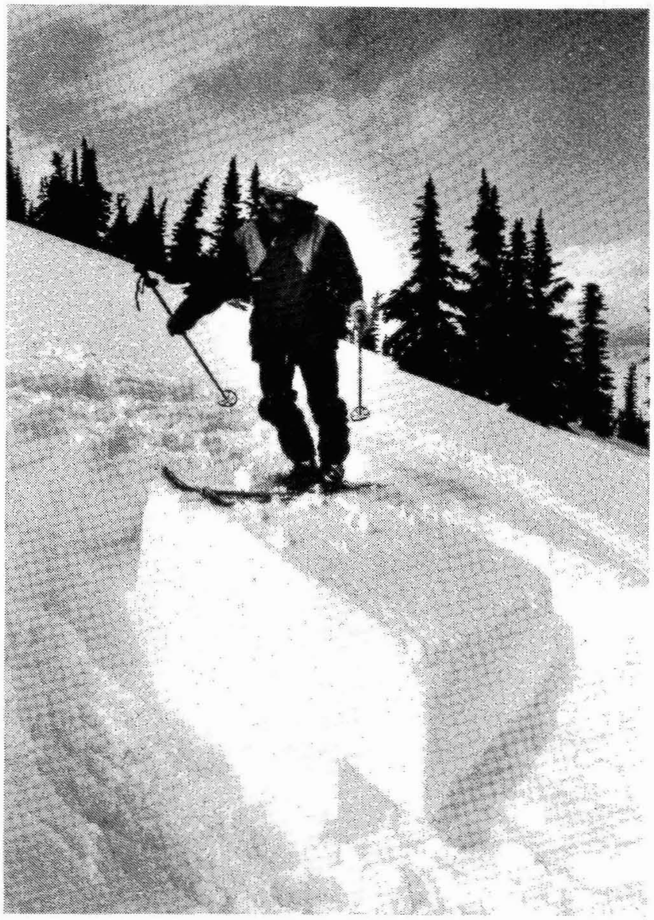

Figure 1. *Rutschblock test showing displaced block.*

To minimize any effect of friction or bonding in the narrow side cuts made by cords or saws, we angled the side walls so that the block was 1.9 m wide at the upper wall and 2.1 m wide at the lower wall (Jamieson and Johnston 1992). In a concurrent paper recently submitted to the Journal of Glaciology and cited here as JJ, scores from saw- or cord-cut rutschblocks averaged 0.3 more than the scores from shovelled rutschblocks. However, the difference was not significant at the 90% level or higher based on a two-tailed t-test or Wilcoxon test for matched pairs.

A VARIATION ON THE RUTSCHBLOCK TEST

Some guides prefer ski cutting to rutschblock testing. Ski cutting tests the slab with the perimeter support from the surrounding snow slope, whereas only an isolated block of the slab is loaded in the rutschblock test. While ski cutting is faster than the rutschblock test, its disadvantages include the requirement that the slope be steep enough to produce an avalanche and the fact that the result is dichotomous--the slope either releases or it does not. Except for the occasional cracking of the slab, ski cutting provides no distinction between slopes that did not release and slopes that almost released.

To consider the effect of perimeter support, we investigated a variation of the rutschblock called the ski-block in which the upper wall was not cut. This allowed testing of a block that was partly anchored to the surrounding snow slope.

On over 40 days, two or more ski-block tests were done on the same slope as two or more rutschblock tests. When the median rutschblock scores were 2 or 3, median ski-block scores were typically one-half score higher (Fig. 2). However, the significance of the differences between median rutschblock score and median ski-block scores is marginal: 89% and 84% for median rutschblock scores of 2 and 3 respectively and less for higher scores (Table 1). The tendency for higher ski-block scores is likely caused by the additional energy necessary to propagate the fracture through the slab under the operator's skis.

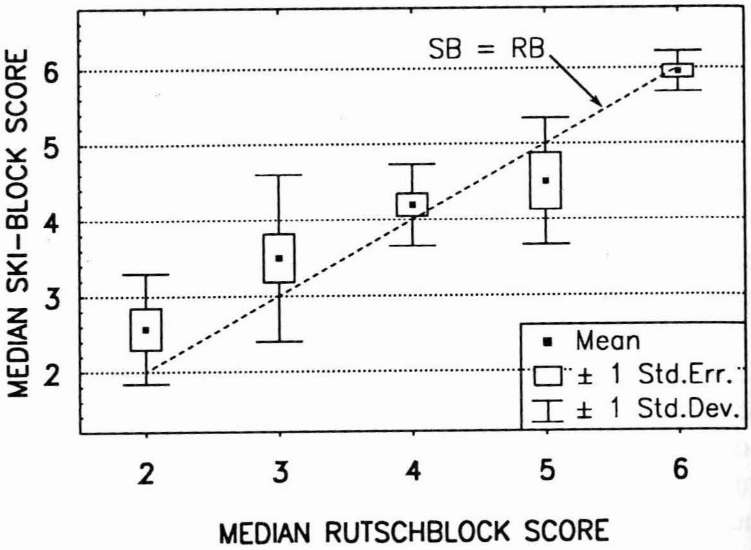

Figure 2. *Results of ski-blocks compared with adjacent rutschblocks.*

Table 1. Comparison of scores from ski-block and adjacent rutschblocks tests.

	Median Rutschblock Score				
	2	3	4	5	6
Number of pairs, n	7	3	4	5	10
Mean of median ski-block scores	2.57	3.50	4.19	4.50	5.95
Mean difference between medians, d	0.57	0.50	0.19	-0.50	-0.05
Std. dev. of difference, s	0.79	1.15	0.56	0.95	0.28
$t = \lvert d \rvert / (s/\sqrt{n})$	1.91	1.51	1.22	1.19	0.57
Confidence in difference (%)	89	84	75	68	41

However, for rutschblock scores of 4 or higher, failure in the standard rutschblock test usually involves a fracture extending from the shear failure in the weak layer through the slab to the operator's skis so that the part of the block up-slope from the operator's skis does not displace. Since a fracture through the slab must occur for a ski-block to fail, it is not surprising that median ski-block scores are not substantially higher than median rutschblock scores of 4 or more, as shown in Fig. 2. For the soft slabs common in our study area, the differences between the median rutschblock and median ski-block scores are not significant for median rutschblock scores of 4 or more ($p \leq 0.75$ as shown in Table 1).

On a few occasions when testing hard slabs, we have observed rutschblock scores of 6 and 7 in which the entire block displaces from the upper wall. We do not have experience with ski-block tests in such hard slab conditions, but expect them to score higher than adjacent rutschblocks for rutschblock scores of 1-6.

MINIMUM SLAB THICKNESS FOR RUTSCHBLOCKS

A rutschblock test is effective only for weak layers deeper than ski penetration, and several jumps on a soft slab can result in considerable ski penetration. Since this ski penetration problem can result in erroneously high rutschblock scores and a serious over-estimation of snow stability, we are sceptical of rutschblock results involving weak layers that are within 50 mm of ski penetration. For the soft slabs in our study area, almost all ski penetration problems occurred when the load over the weak layer was less than 400 Pa (4.0 g/cm^2). For densities ranging from 100 to 300 kg/m^3, this critical load corresponds to slab thicknesses ranging from 0.40 to 0.13 m respectively.

VARIABILITY AND APPROXIMATE PRECISION OF RUTSCHBLOCK SCORES ON UNIFORM SLOPES

Sets of 36 to 73 rutschblock tests were done on each of 6 slopes that had mean slope angles of 28-33° and varied in slope angle by less than ±4°. Median rutschblock scores for the six slopes ranged from 3 to 5. The median score was obtained on 67% of the tests (JJ). Scores 1 and 2 steps above the median were obtained on 12% and 2% of the tests respectively. Scores 1 and 2 steps below the median were obtained on 18% and 1% of the tests respectively. No scores 3 steps above or below the median were obtained.

By assuming the above distributions of deviations from medians are representative of uniform slopes, the probability of a single rutschblock score on a uniform slope being the median is 67%. Similarly, the probability of one score being within one step of the median is approximately 18% + 67% + 12% = 97%. The probability of the median of two independent tests being within ½ step of the slope median is approximately 91% and or being within 1 step of the slope median is approximately 99% (JJ). We suggest independent tests be 10 m apart.

These estimates of the precision of 1 or 2 tests are appropriate only when the tests are done at sites with 4° of the mean slope angle and on slopes free of trees, rock outcrops or terrain features that might prevent relatively uniform layering of the snowpack. Also, these estimates do not apply to slopes with medians of 1, 2, 6 or 7 for which truncated distributions of rutschblock scores are expected. However, the precision of 1 or 2 rutschblock tests is certainly of practical interest when median scores are in the range of 3-5.

RUTSCHBLOCK SCORES AND CONCURRENT NATURAL AVALANCHING

Since rutschblock tests and natural slab avalanches both involve shear failure within a weak snowpack layer, we attempted to correlate natural slab avalanche activity with rutschblock scores. On a total of 80 days during the winters of 1990-92, the rutschblock tests were performed in two study areas that we felt were often representative of widespread snow conditions. These areas are located at 1900 m and 2050 m in the Cariboo Mountains, and consist of slopes that are in lee of most storm winds. The avalanche activity was reported by the helicopter skiing guides operating in the nearby areas of the Cariboo and Monashee Mountains. Most of the reported avalanches were within 10-15 km of the study area although some were up to 30 km away.

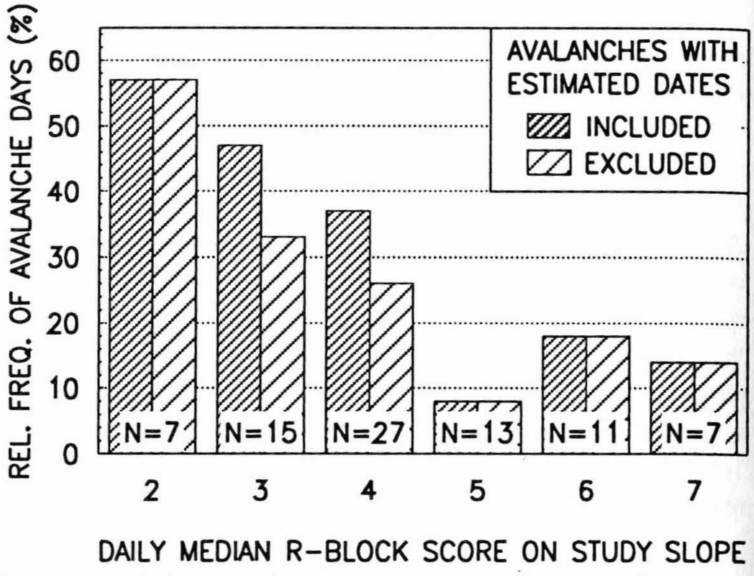

Figure 3. *Relative frequency of avalanche days for concurrent rutschblock scores. N is the total number of days on which the median rutschblock score was observed.*

An avalanche day is a day in which one or more dry natural slab avalanches large enough to injure or kill a person (class 1.5 or larger according to NRCC/CAA 1989) were reported. For days in which the median rutschblock scores were 2 to 7, the percentage of avalanche days is plotted in Fig. 3. Because some storms restricted helicopter skiing, some avalanches were not observed for several days after they occurred, resulting in estimated dates. The percentage of avalanche days excluding avalanches with estimated dates is plotted separately.

In Fig. 3, the percentage of avalanche days reduces as the median rutschblock score increases. However, even when the median rutschblock score was 5, 6 or 7, there was one or more large dry natural slab avalanches on 8 to 18% of the days. Clearly, rutschblock tests on carefully selected slopes provide only an approximate indication of natural slab stability on surrounding slopes.

RUTSCHBLOCK SCORES ON SLOPES TRIGGERED BY PEOPLE

For those rutschblocks performed on avalanche slopes, the percentage of those slopes triggered by skiers or people on foot is plotted against median rutschblock score in Fig. 4. Except for two cases when the rutschblock tests were performed one day after the avalanche, the slopes were loaded by people on foot or skiers within 3 hours of the avalanche activity.

The percentage of slopes triggered by people decreases with increasing median rutschblock score as shown in Fig. 4. However, this is a small data set involving only 5 slopes that produced avalanches and 39 that did not. In particular, only twice have we obtained a median rutschblock score of 2 on an avalanche slope. Nevertheless, Fig. 4 like Fig. 3 shows a decrease in avalanche activity with increasing rutschblock score.

Although we have not observed slab avalanches triggered by people on slopes with median rutschblock scores of 5, 6, or 7, this does not mean that all such slopes are safe. Based on a larger data set, Föhn (1987a) reports avalanche activity on slopes with rutschblock scores as high as 7 and attributes this result to difficulty with selecting representative sites for rutschblocks (discussed subsequently). Also, even for rutschblock tests at sites within ±4° of the mean slope angle, there is an approximately 14% probability of getting a score one or two steps higher than the median (JJ). Once, when testing a slope that had produced a large slab avalanche, our first rutschblock score was 4 and our second score was a 5, although repeated testing resulted in a median score of 3. Clearly, some slopes that exhibit a single score of 4 or 5 are unstable.

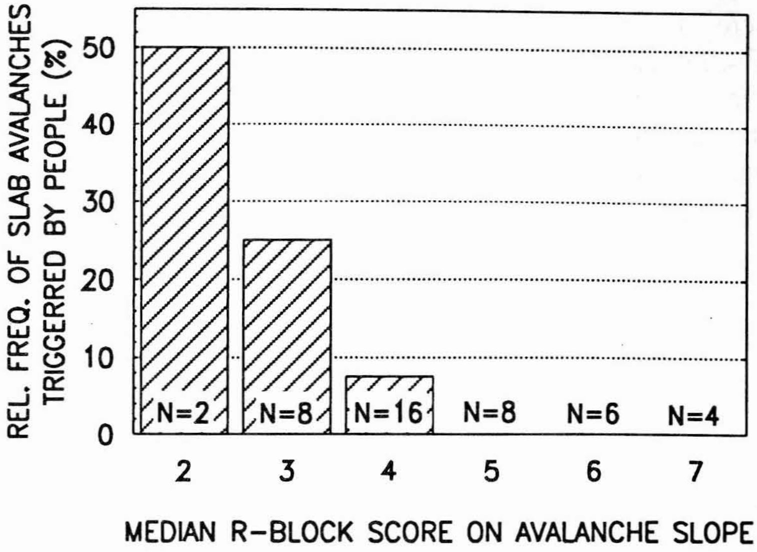

Figure 4. *Percentage of slab avalanches triggered by people on slopes tested with rutschblocks. N is the total number of avalanche slopes on which the median rutschblock score was observed.*

Based on Fig. 4 and on our experience with rutschblocks, we concur with Föhn's (1987a) interpretation of rutschblocks performed in starting zones: rutschblocks that fail before the first jump (scores of 1, 2 or 3) indicate that avalanche slopes with similar snow conditions are likely to be triggered by skier; rutschblocks that fail on the first or second jump (scores of 4 or 5) indicate marginal stability--other meteorological and snowpack observations and tests should be used to assess similar slopes; and rutschblocks that have not failed after two jumps (scores of 6 or 7) indicate a low--but not negligible--risk of skiers triggering avalanches on similar slopes. However, when rutschblock tests are made at locations not steep enough to produce avalanches, the effect of slope angle on rutschblock score should be considered.

EFFECT OF SLOPE ANGLE ON RUTSCHBLOCK SCORE

What does a rutschblock on a 25° slope tell us about a nearby 40° slope? First, unless there is a reason why the layering might be different (e.g. the 40° slope is wind-loaded and the 25° slope is not), we expect the rutschblock to fail on the same layer as a skier might trigger on the steeper slope. Second, the rutschblock score might be higher on the 25° slope than on the 40° slope because the shear stress caused by the weight of the slab and skier is reduced on the less steep slope.

To study the effect of slope angle on rutschblock scores, we selected 24 sets of 4 or more rutschblocks from data collected during the winters of 1991 and 1992 based on the following criteria: each rutschblock in a set slid on the same surface; each set of tests was completed in 2 to 6 hours; and slope angles within each set varied by at least 8°.

An example of such a set consisting of 42 tests is shown in Figure 5. The slope angle varied from 23° to 36° and the rutschblock scores varied from 4 to 6. In spite of the variability, there is a general trend for rutschblock scores to increase as slope angle decreases. Based on a straight line fitted to the data in Fig. 5 by least squares, decreasing the slope angle by 12° tended to increase the rutschblock score by 1 step.

The effect of slope angle on rutschblock score was only significant for 10 of the 24 sets of rutschblocks we assessed based on the gamma correlation from nonparametric statistics (JJ). Hence, slope effects are often obscured by natural variability of rutschblock scores. However, for these 10 sets, the decrease in slope angle required to increase rutschblock scores by 1 averaged 10°.

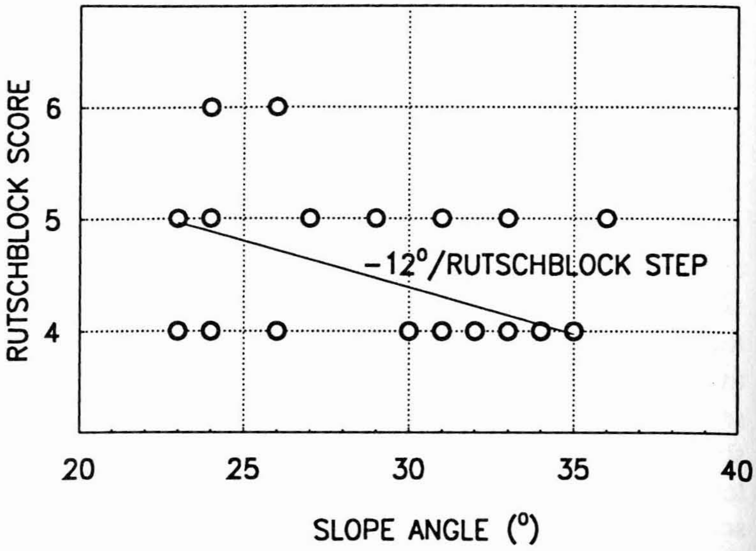

Figure 5. *Scores for 42 rutschblock tests on a slope that varied in angle from 23-36°. Some symbols represent several points.*

A MINIMUM SLOPE ANGLE FOR RUTSCHBLOCKS ?

Föhn (1987b) showed that rutschblock scores correlate with a stability index that is calculated from shear frame measurements of the strength of active weak layers. This stability index, which we denote by S_S, includes the additional stress due to a hypothetical skier. In Figure 6, S_S is plotted against the median score from adjacent rutschblock tests that failed on the same weak layer. There is a good correlation (r=0.72) except for those tests on slopes below 20° that produced rutschblock

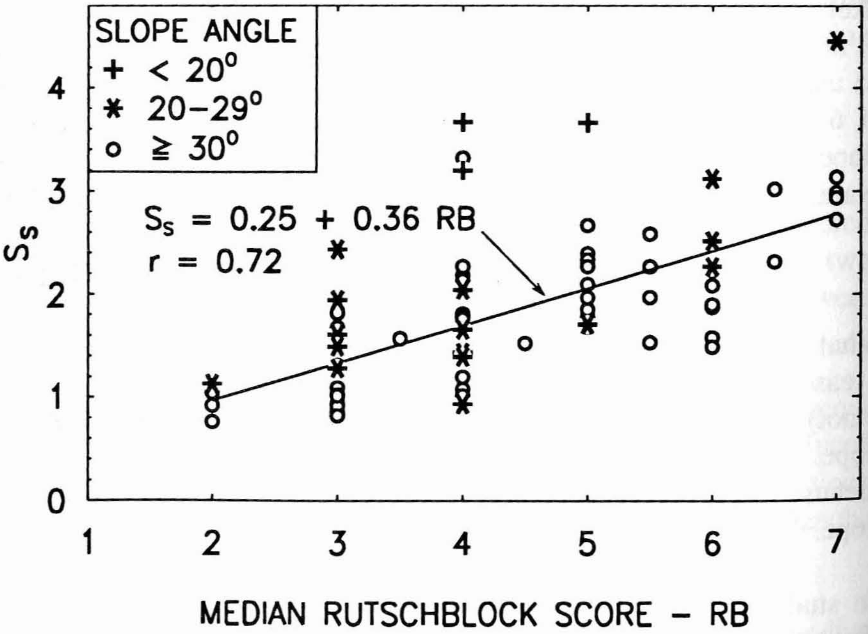

Figure 6. *Relation between S_S and rutschblock score for various slope angles.*

scores which, given their values of S_S, were surprisingly low. Since the calculation for S_S adjusts the shear strength and the shear stress for slope angle, the discrepancy must lie with the rutschblock test. We suspect that on slopes below 20°, rutschblocks fail by compressing rather than by shearing the weak layer. Therefore, on slopes of less than 20°, the rutschblock score and possibly the weak layer identified by rutschblock tests may be misleading.

Detecting failure is often more difficult for rutschblock on shallow slopes. On slopes of less than 30°, rutschblocks often displaced only 2-20 mm. Such small displacements can always be detected by a person watching the lower wall of the block but not consistently by the person stepping or jumping on the block. Therefore, two people are recommended for tests on shallow slopes.

SITE SELECTION FOR RUTSCHBLOCK TESTS

Föhn (1987a) notes that rutschblock sites near ridge crests are seldom suitable. Our studies of rutschblocks indicate that, compared to the lower part of a slope, scores may increase and become more variable near the top of a slope even if that upper part is steeper.

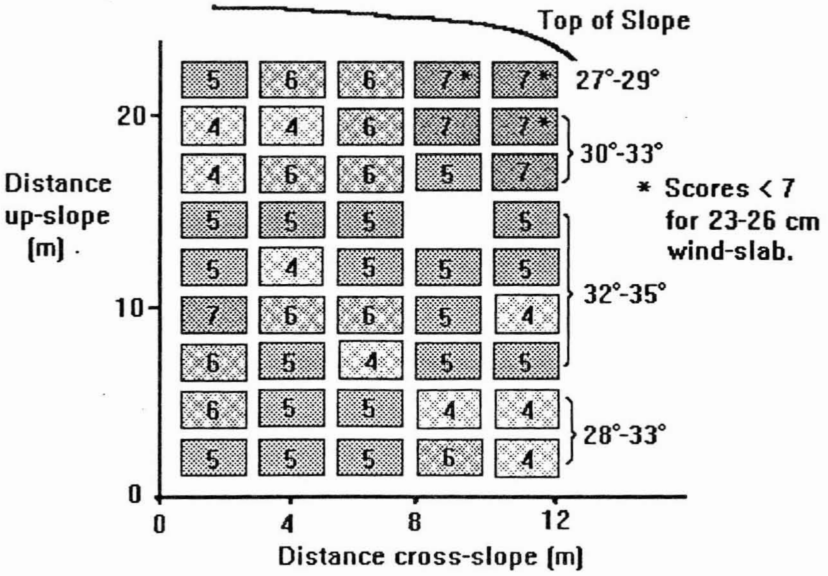

Figure 7. *Rutschblock results for 47-63 cm slab over graupel layer. 1992-02-03, Cariboos, north aspect, 2100 m.*

A set of 44 rutschblocks from a 27° to 35° slope is shown in Figure 7. In the lower six rows, most scores range from 4 to 6, the median score is a 5, and there is only one score of 7. In the top three rows which are almost as steep, scores range from 4 to 7, the median is a 6, and there is at least one score of 7 in each row. The weak layer of graupel was less evident in these upper rows, possibly because the wind had removed much of the graupel from the upper part of the slope.

A set of 20 rutschblocks on a 19° to 36° slope are shown in Figure 8. In the bottom six rows, scores range from 3 to 5 and the median is 4. In the top two rows which are steeper and near the top of the slope, the median is a 4 but scores range from 3 to 7.

Figures 7 and 8 show examples of higher and more variable rutschblock scores on the upper part of a slope even though the active weak layer varies from graupel to surface hoar. This suggests that single rutschblock tests, and probably other slope tests such as ski cuts, done near the top of slopes may be less indicative of slope stability than tests done farther down the slope.

CONCLUSIONS

1. Cutting the side walls of rutschblocks with a specialized saw or the tail of a ski can reduce the time requirement by approximately half. Cutting the sides and upper wall with a cord extended around poles at the top corners of a rutschblock can reduce the time requirement slightly. These faster techniques do not appear to affect the score significantly.

2. The rutschblock technique is only suitable for weak layers deeper than ski penetration. For soft slabs, problems with skis penetrating too close to weak layers are rare when the weak layer is buried by a slab weighing more than 400 Pa.

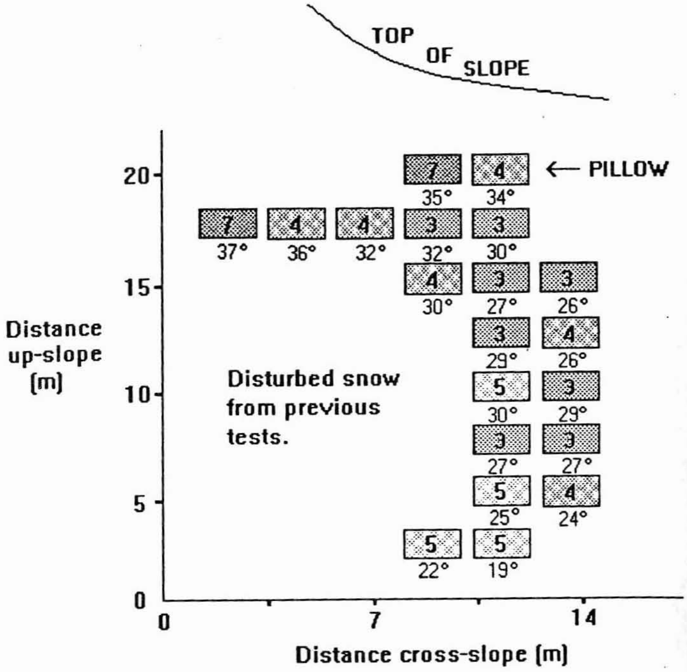

Figure 8. *Rutschblock results for a 45 cm slab over a surface hoar layer. 1992-02-29, Cariboos, northeast aspect, 1900 m.*

3. For soft slabs, not cutting the upper wall tended to increase rutschblock scores of 2 and 3 by ½ step. This difference was of marginal significance and no significant difference was noticed for higher rutschblock scores.

4. On a uniform slope that varies in slope angle by ±4° or less, one test has an approximately 67% probability of being the slope median and an approximately 97% probability of being within 1 step of the slope median. The median of two tests has an approximately 91% probability of being within ½ step of the slope median and an approximately 99% probability of being with 1 step of the slope median.

5. As the median rutschblock score obtained at a representative location increased from 2 to 7, the percentage of days on which large dry natural slab avalanches were reported (most within 10-15 km) was reduced from 57% to 14%. However, large dry natural avalanches were reported on 8-18% of the days when median rutschblock scores were 5, 6 or 7. Hence, rutschblock tests provide only an approximate indication of natural slab stability for slopes several km away.

6. As the median rutschblock score obtained in avalanche starting zones increased from 2 to 5, the percentage of those slopes that were released by a person on skis or foot decreased from 50% to 0%. No slab avalanches occurred when the median rutschblock score was 5, 6 or 7. However, individual rutschblock scores ranged as high as 5 on avalanche slopes that were

triggered by people. More tests are needed to clarify the relationship between rutschblock scores and slab stability for human triggers.

7. Decreasing the slope angle by 10° tended to increase rutschblock scores by 1 although the effect of slope angle on rutschblock score was obscured by the natural variability of rutschblock scores on 14 of 24 slopes.

8. Rutschblock scores and possibly the weak layer identified by rutschblock tests may be misleading on slopes of less than 20°.

9. A single rutschblock test, and probably other slope tests, done near the top of a slope may be less indicative of slope stability than tests done farther down the slope.

REFERENCES

Föhn, P.M.B. 1987a. "The rutschblock as a practical tool for slope stability evaluation." In: Avalanche Formation, Movement and Effects, IAHS Publ. 162, 223-228.

Föhn, P.M.B. 1987b. "The stability index and various triggering mechanisms." In: Avalanche Formation, Movement and Effects, IAHS Publ. 162, 195-211.

J.B. Jamieson and C.D. Johnston. 1992. "Rutschblock technique and interpretation." Avalanche News 37(1), 3-6.

J.B. Jamieson and C.D. Johnston. "Rutschblock precision, variations on technique and limitations", submitted to the Journal of Glaciology.

NRCC/CAA. 1989. "Guidelines for Weather, Snowpack and Avalanche Observations", National Research Council of Canada and Canadian Avalanche Association, Technical Memorandum 132.

ACKNOWLEDGEMENTS

We are grateful to Mike Wiegele Helicopter Skiing and the Natural Sciences and Engineering Research Council of Canada for financial support of this collaborative research and development project funded through the Council's University/Industry program. Mike Wiegele Helicopter Skiing also provided logistical support and a productive working environment. Many thanks to Mark Shubin and Jill Hughes for their dedication and careful field measurements.