Preliminary results of snow surface friction coefficient measurements

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ABSTRACT: A measure of the strength of bonding of new snow to surface layers would be useful for avalanche workers. A new instrument to measure snow surface friction was created using a weighted piece of rough plastic mounted on a 10 cm by 10 cm piece of plywood. The device was dragged over the snow surface with a force gauge to measure the force it took to overcome bonding between the device and the snow surface. Different snow types at various temperatures were investigated in the San Juan Mountains of Colorado, USA. A coefficient of dry static friction was calculated for each snow type. Coefficients ranged from 0.53 – 1.76. Some of these coefficients were compared to shear strength numbers derived from shear frame measurements on the previous surface layer 24 hours after new snow fell on the surface.

INTRODUCTION:

Many avalanches release on buried surface layers (Birkeland et al., 1996). It would be useful for avalanche workers to be able to predict how new snow would bond to a given surface layer. Shear strength, a relative measure of bond formation between layers, can be measured with a shear frame (Jamieson and Johnston, 1995). A device which predicts the strength of a surface layer before it is buried by subsequent snowfall would be useful for avalanche forecasting. Others have measured the friction coefficients between two blocks of snow or between skis and snow, but have not attempted to utilize this information as a predictor for bond strength between layers of snow (Casassa et al., 1989; Lang and Dent, 1982).

METHODS:

A new instrument to measure snow surface friction was created using a weighted piece of rough plastic mounted on a 10 cm by 10 cm piece of plywood. The rough plastic is a piece of indoor-outdoor carpet. Different size naps were tested for maximum resistance and a nap of approximately 1.5 cm was chosen for the study (Figure 1). The friction device was dragged over a horizontal snow surface with a force gauge to measure the force it took to overcome bonding between the device and the snow surface. The pulling technique is the same as that used for a shear frame, with a quick pull of less than one second (Jamieson and Johnston, 1995). The device was tested in different types of snow surface conditions at various temperatures (Table 1). For each snow surface type, at least 7 pull tests were conducted. The initial pull tests indicated that the device was not heavy enough to register on the force gauge that was available for the study (< 130 g). A weight was attached to the friction device, which increased bonding and enabled the use of a 100-1000 gram force gauge.

A coefficient of dry static friction was calculated for each snow type using the equation;
$\mu_s = F/N$
μ_s is the coefficient of static friction, F is the force used to pull the device and N is the normal component of the device (mass x gravity).
During each test the type of snow, grain size, snow temperature at the surface and air temperature were recorded.

Figure 1. Friction Device; (i.e. the carpet puller).

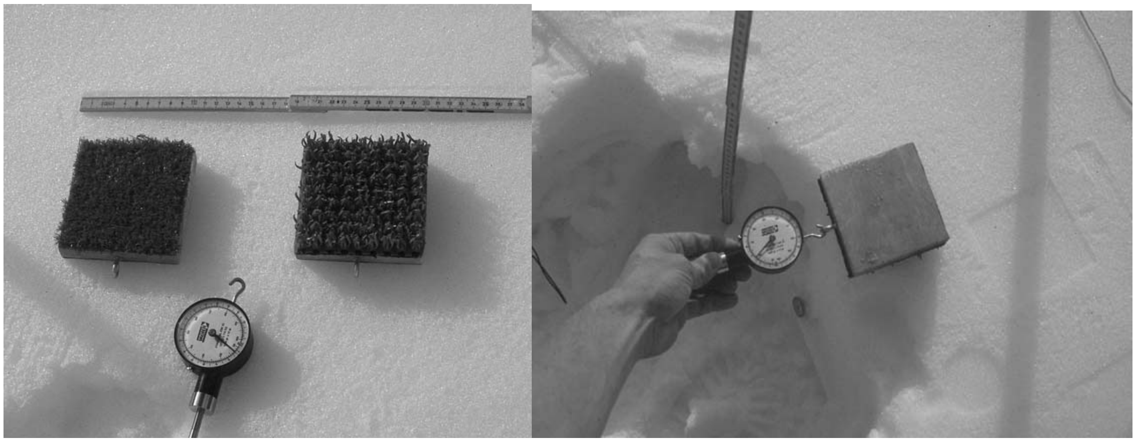

Table 1. Results of friction device tests, calculated coefficients of friction and snow types.

Friction Device	u	Snow Surface Temp	Air Temp	Crystal Type at Surface
205*	1.763668	-8	-4	Near surface facets and some rounding 0.5 -1 mm
287.5	0.930376	-0.5	5.5	RR grains 1-1.5, and surface hoar 1-1.5mm
211	0.682815	-11	-6.5	Surface hoar and near surface facets 0.5-1mm
267.5	0.865654	0	6	R Rounds, refrozen slush
285.5	0.923903	-1.5	0	Melt-freeze clusters 2-3mm
310.5	1.004806	-1	0	Rimed stellars 0.5mm
200	0.647218	-7	-4	Melt freeze crust 4cm thick, temp -7c
247	0.799314	-2	-1	Melt freeze crust, knife-hard 2-5mm clusters
164.5	0.532337	-1	0	Suncrust, knife-hard flat
227	0.734592	-1	0	Near surface facets, 5mm on crust, Fist hard

* Unweighted friction device

During five of the surface snow types studied, the surface layer which was tested was marked in the snowpack by a light-weight string. The string was positioned on the surface of the snow, tied to a nearby stake, and subsequently buried by new snowfall. Twenty-four hours after the snowfall began, a shear frame test was conducted on the marked layer. New snow and old snow temperatures were recorded as well as crystal type and grain size of the new snow. The overlying new snow was removed, leaving a few cm of snow above the buried surface layer. A 100 cm^2 shear frame was used with the same force gauge to determine the force necessary to cause failure between the buried surface layer and the new snow (Perla and Beck, 1983). For each snow type, at least 7 shear tests were conducted. The data from the shear frame tests were correlated with the friction device tests using standard regression analysis (Tables 2 and 3).

RESULTS and DISCUSSION:

The data for the coefficients of dry friction are shown in Table 1. There are not enough data to conclude that certain types of near surface snow will have precise friction coefficients. With more data collection in the future, it is hoped that some measure of bonding will become evident based on surface snow parameters including the friction coefficient.

The preliminary data show an R-square of .58 between the friction device test and the subsequent shear frame tests (Figure 2, Table 2). When the data are averaged for the five snow types that were tested for both surface friction and shear strength, the R-square drops to .38 (Table 3). Obviously there is not enough data for a good correlation, but with future tests, a pattern may emerge that will help avalanche workers determine how well new snow will bond to surface layers. Other problems with this preliminary study include the type and temperature of the new snow. There was not enough data to correlate these other parameters to the results of the friction test. Future research will include a multiple regression analysis which takes new snow type and temperature into consideration.

Figure 2. Shear Frame force versus Friction Device force.

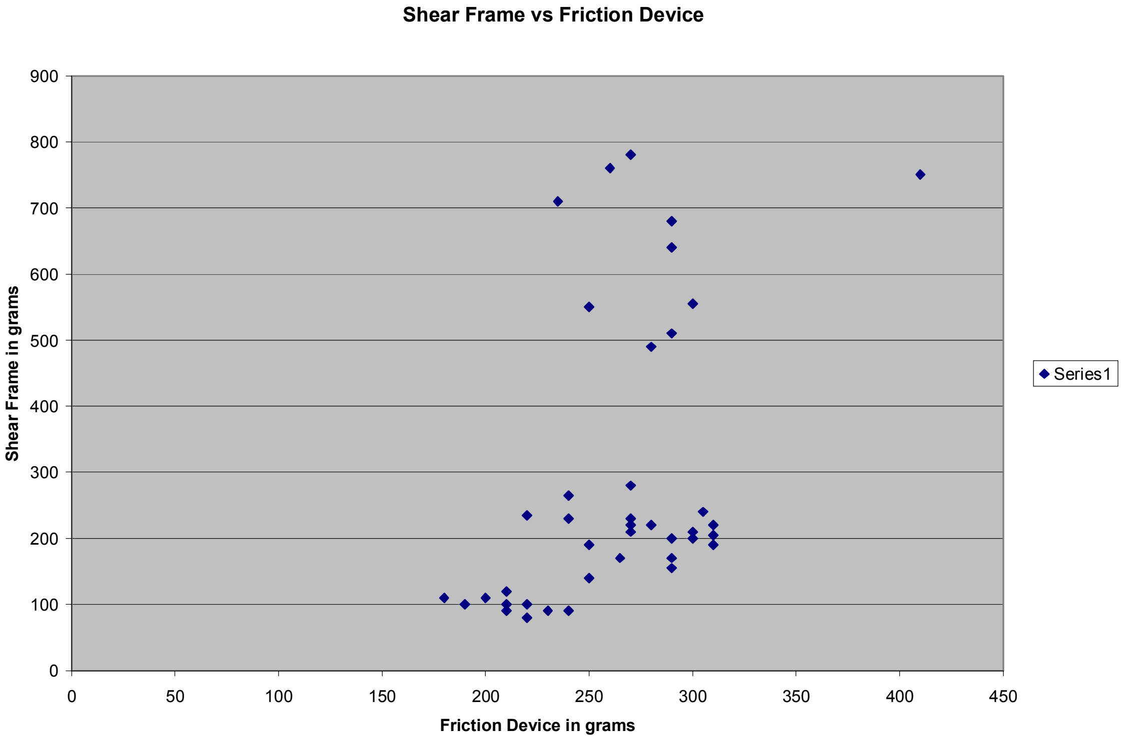

Table 2. Regression analysis between shear frame and friction device.

Regression Statistics	
Multiple R	0.762358633
R Square	0.581190685
Adjusted R Square	0.511389133
Standard Error	31.13469222
Observations	8

Table 3. Regression analysis between shear frame and friction coefficients (averaged data).

Regression Statistics	
Multiple R	0.6218679
R Square	0.3867197
Adjusted R Square	0.0800795
Standard Error	231.27785
Observations	4

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