EVALUATION OF THE SHOVEL SHEAR TEST

Extended Summary

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INTRODUCTION

The shovel shear test - an index observation of the stability of snow packs - consists of cutting a vertical column of snow, applying a force by pressing with a shovel parallel to the snow surface, observing the location of a failure, and rating the force that was required to produce the failure. The test, simulating in situ a failure of snow in shear, has the objectives of: a) locating a weak snow layer or a weak interface between layers; b) estimating the strength in shear of the weak layer or interface.

Field observers use the test frequently because it is simple and quick, and the only equipment required is a shovel, but the test must be carried out with care and the results must be interpreted with caution.The objective of this paper is to draw attention to the limitations of the shovel shear test and make recommendation on how to apply it.

TEST CONDITIONS

The breaking force that can be applied by hand limits the cross section area of the column. A person holding a shovel in both hands can reliably apply and rate a shear force of maximum 400 N. Measurements by several observers in Canada have shown that 4000 $N\ m^{-2}$ is about an upper limit of the shear strength of snow in layers that failed and produced slab avalanches. These values suggest that the area under shear should not exceed 0.1 m^2 In practice snow observers confirmed this by finding a square column with an area between 0.09 m^2 (sides 0.3 m) and 0.12 m^2(sides 0.35 m) optimal.

A snow column pushed with a shovel acts as a cantilever and is stressed in a combination of shear, bending, and axial load (the latter due to its weight). The column fails in bending rather than in shear when the normal stress at the back side exceeds the tensile strength of the snow and the shear stress is lower than the shear strength in column centre. A failure in bending must be avoided because the objective is to test the snowpack in shear. A shear failure occurs when (Figure 1):

a) the distance "z" between the centre of application of the shovel force and the shear layer is small;

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b) the width "a" of the column in direction of the shovel force is great;

c) the ratio "k" between tensile strength and shear strength of the snow is high.

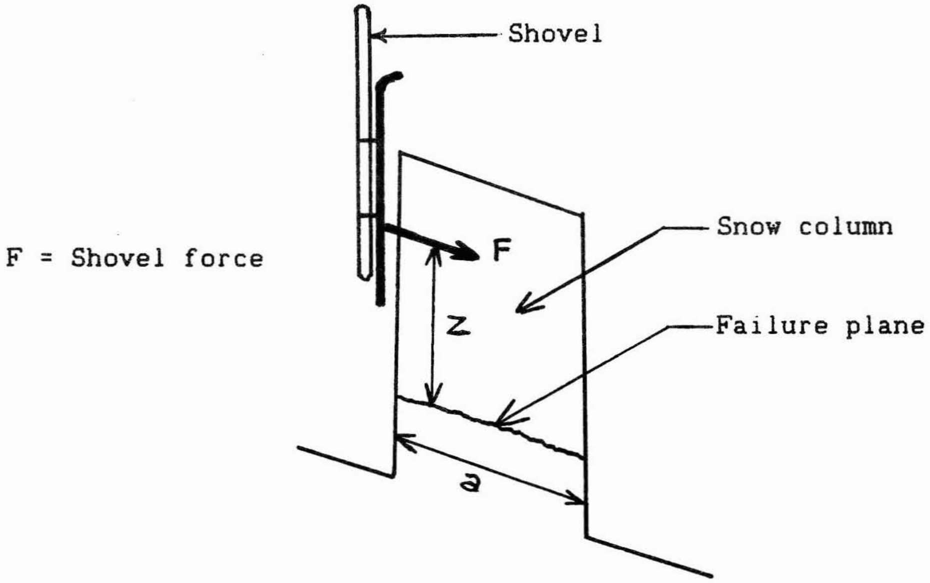

Figure 1

The width "a" is limited by the maximum column cross section area 0.1 m^2 and a minimum width in direction perpendicular to the shovel force. The latter should not be less than 0.25 m to allow accurate preparation of the column. These conditions yield optimum column sides o.4 m x 0.25 m.

No studies are known concerning the ratio "k" in thin weak snow layers and interfaces between layers. Tests in homogeneous snow suggest an approximate value $k = 3$. Application of maximum shear stress theory, asuming brittle failure, with $a = 0.4$ m and $k = 3$ leads to the condition $z < 0.32$ m for shear failure rather than failure in bending.

The column height is less critical for finding the location of weaknesses in the snowpack than it is for observation of the shear strength, because snow that is weak in shear tends to be weak also in tension. Owing to a linear increase of the tensile stress with column height (due to bending) deep layers are more likely to fail than layers close to the surface, therefore potential failure planes in the upper part of the snow pack may go undetected.

These conditions lead to the conclusion that the shovel shear test must be carried out in two separate steps:

1st step: Identification of weak layers with a column about 0.7 m high;

2nd step: Test for strength of the layers and interfaces found in the first step with a column of max. 0.35 m height above the weak layer under test.

A further limitation is that the shovel must not be pressed against very soft snow (hardness "Fist") and must be applied in soft snow (hardness "Four Fingers") with caution, because snow with a low hardness fails in compression and transfers the force to the shear failure plane in an inhomogeneous manner.

VARIABILITY OF THE OBSERVATIONS

Expected variations of the shovel shear test - both with respect to the location of the shear plane and the observed force - are the result of observational errors (inaccurate cutting of the column, and application of the shovel, subjective judgement of the force) and variations of the snow properties. Studies were carried out about the variabilty on slope areas 10 to 100 m^2, by cutting columns of size 0.25 m x 0.4 m and height 0.7 m for locating weak layers and height 0.3 m for testing for strength.

The experiments were inconclusive with respect to the location of potential shear planes. One well-defined weak layer or layer boundary could be identified in numerous tests, but large variations were found in others.

Large variations were found with respect to the rating of shear strength within the same weak layer. Means and standard deviations could be obtained by assigning numerical values to the subjective force ratings: very easy = 1; easy = 2; moderate = 3; hard = 4; no break = 5 .The standard deviation of observed breaking forces increased with the strength of the snow. The observed variations suggest that at least 3 tests should be made in snow with "very easy" rating and 10 tests are required in snow with a rating "moderate"in order to make confident conclusions.

The correlation between the shovel shear rating and the shear frame index (frame size 100 mm x 100 mm) proved to be poor. This could be attributed to both a strong variation of the shovel shear test and the difficulty of making shear frame observations in deep. old snow layers. A fair correlation was found between the mean shovel shear rating (mean of 3 to 12 tests) and the snow stability determined by test skiing and the Rutschblock test.

CONCLUSION

The shovel shear test is appropriate for identifying weak snow layers and weak interfaces, but requires a great number of tests for rating reliably their shear strengths. It must be interpreted with caution and in association with other snow pack observations. Examinations of the snow crystal type and size in the failure plane are important supplementary observations.