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A COMPARISON OF THE CRREL 500 cm³ TUBE AND THE ILTS 200 AND 100 cm³ BOX CUTTERS USED FOR DETERMINING SNOW DENSITIES

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Abstract. The study indicates that no significant difference in snow densities is found when using either the CRREL tube or the ILTS box cutters. However, inexperienced workers tend to overestimate snow densities in light snow and depth hoar by 6 and 4% respectively.

Résumé. *Une comparaison entre le cylindre de 500 cm³ du CRREL et les boites ILTS de 200 et 100 cm³ utilisées pour determiner les densités de neige.* L'étude indique qu'il n'a pas été trouvé de différence significative dans les densités de neige déterminées avec le cylindre CRREL ou les boites ILTS. Cependant, des manipulateurs inexpérimentés tendent à surestimer les densités de neige en neige fraîche ou en givre de profondeur respectivement de 6 et 4%.

Zusammenfassung. *Ein Vergleich zwischen dem CRREL-500 cm³-Rohr und den ILTS-200 und 100 cm³-Blockschneidern zur Schneedichtebestimmung.* Die Studie zeigt, dass sich keine wesentlichen Unterschiede der Schneedichte ergeben, wenn man entweder das CRREL-Rohr oder die ILTS-Blockschneider benutzt. Doch neigen unerfahrene Beobachter dazu, die Schneedichten in lockerem Schnee und bei Tiefenreif um 6 bzw. 4% zu überschätzen.

Introduction

Recently, a box cutter for taking snow density has been introduced into North America from Japan. The 100 and 200 cm³ box cutters are based on a design originated by the Institute of Low Temperature Science (ILTS) in Sapporo, Japan. The ILTS cutters are light, simple to use, and precise. Their rectilinear construction makes it possible to sample within 2 mm of an ice lens. The San Juan Avalanche Project of the Institute of Arctic and Alpine Research, University of Colorado, has been using both the ILTS cutters and the standard 500 cm³ Cold Regions Research and Engineering Laboratory (CRREL) snow sampling tube. The "standard" 500 cm³ tube was originated by the Eidg. Schnee- und Lawinenforschungsinstitut, Weissfluhjoch-Davos, Switzerland and copied by the U.S. Army, CRREL. It is a tube measuring approximately 19 cm by 5.8 cm and is inserted either horizontally or vertically into the snow-pack giving a 500 cm³ sample which is then weighed to determine the snow density. This study compares the three different cutters used by experienced and inexperienced operators.

Other work has been done to estimate the accuracy of various methods used to determine snow density (Work and others, 1965; Peterson and Brown, 1975) but the ILTS system has not been examined.

Experimental procedure

Snow densities were taken along a 1.2 m pit wall which consisted of three well-defined stratigraphic layers produced by three previous storms. The upper layer consisted of fine-grained snow (1.0–3.0 mm) which had undergone moderate equi-temperature metamorphism. The middle layer consisted of fine-grained old snow (1.0–1.5 mm) which had undergone considerable equi-temperature metamorphism and the lower layer was composed of snow crystals (2.0–4.0 mm) which had undergone moderate temperature-gradient metamorphism. The snow-pack temperature decreased uniformly from 0°C at the base of the pack to $-8°C$ at the snow surface. The mean density of the upper, middle, and lower layers were 187, 287, 365 kg m^{-3} respectively. In order to determine the "true" density of each layer, one experienced operator working with one cutter sampled the length of the 8 m section; no systematic variation in snow density along the section was observed.

The three experienced operators had an average of seven years experience taking snow densities; the two inexperienced operators had never taken snow densities before. Each individual took ten densities samples with each of the three cutters at the three different stratigraphic layers in the 1.2 m × 8 m section. All of the operators were instructed in the technique to be used and each took several practice densities. Each operator weighed his samples on the platform scale and reported the weight to the nearest half gram. Densities were not computed in the field.

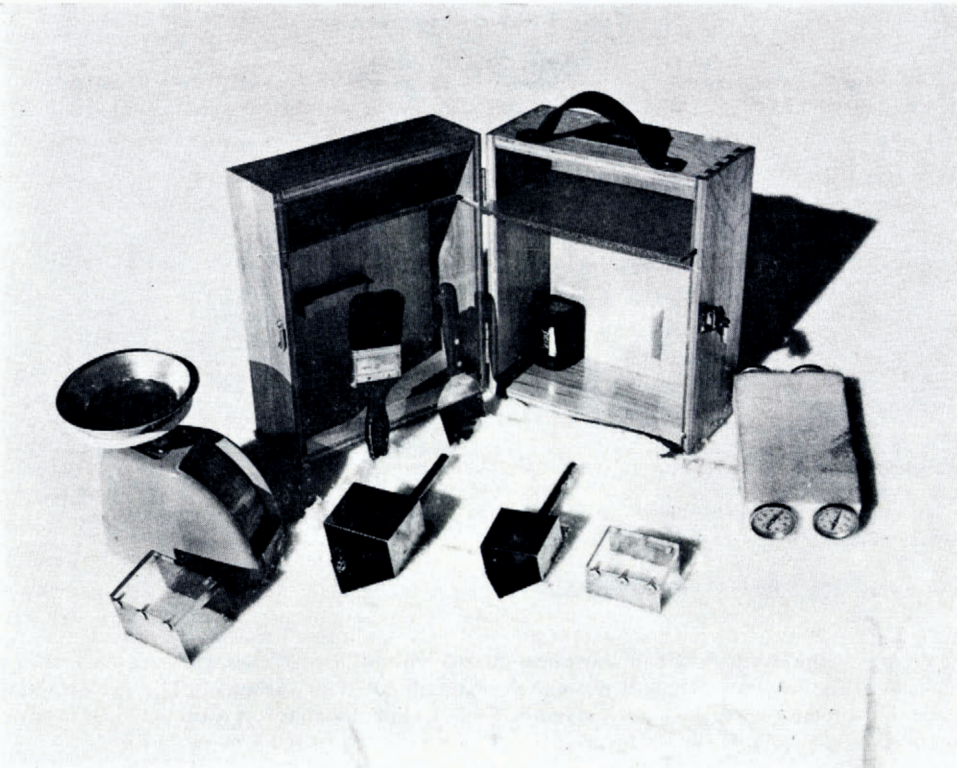

Fig. 1. The snow-density kit includes a 100 g scale, a small spatula, a brush, a 200 and 100 cm³ box cutter, each with a cutter which slips over the box while it is still in the snow-pack: in this way, depth hoar can be sampled with little risk of losing part of the sample. Also included is the wooden carrying case. (Space for four stem thermometers is also provided.)

Analysis

A mixed model (i.e. with both fixed and random effects) two-way analysis of variance with replications was used for each of the three stratigraphic sections. The standard statistical terminology is used here and described by Hays (1973) and Scheffé (1959). The fixed effects of the analysis are the cutter types while the random effects are the experienced–inexperienced operators. A three-way analysis was not used because an estimate of the error variance for each level was desired and also difficulties arise when interpreting the two-way and three-way interaction of the three-way design. The results are given in Table I. In all three stratigraphic units, there is insufficient evidence to suggest that the main cutter effects are present. In the top and bottom section there is evidence which indicates that main operator effects do exist. In all cases, a significant interaction is present.

Data from the middle section indicate that no significant main effects are present; however, there are significant differences among the cell means. The conclusion should be that there are differences, but that when the effects of the levels of one factor (cutter type) are averaged over the levels of the other factor (experienced–inexperienced worker), no differences of these averaged effects can be demonstrated. In the upper and lower sections, a significant main effect is present as well as an interaction. Again, when cutter effects are averaged over the levels of the other factor, no significant cutter effect can be shown.

In this analysis, it is useful not only to know whether effects exist, but also the strength of association. This can be done by estimating the variance component associated with the fixed, random, and interaction effects. The proportion of variance accounted for by a factor (A) is given by:

$$\frac{\text{est. } \sigma_A^2}{\text{est. } (\sigma_A^2 + \sigma_B^2 + \sigma_{AB}^2 + \sigma_E^2)}$$

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TABLE I. ANALYSIS OF VARIANCE

Source	*Sum of squares*	*Degrees of freedom*	*Mean square*	*F*	*% of total variance*
	Upper layer		Mean density = 187 kg m^{-3}		
Row	0.003 287	1	0.003 287	34.145 9*	30.6
Column	0.000 724	2	0.000 362	0.608 9	0.0
Interaction	0.001 189	2	0.000 595	6.175 8*	14.3
Error	0.010 974	114	0.000 096		
Total	0.016 174	119			
	Middle layer		Mean density = 287 kg m^{-3}		
Row	0.000 402	1	0.000 402	1.642	0.6
Column	0.010 515	2	0.005 258	2.349 6	17.8
Interaction	0.004 475	2	0.002 238	9.140 3*	23.6
Error	0.027 907	114	0.000 245		
Total	0.043 299	119			
	Lower layer		Mean density = 365 kg m^{-3}		
Row	0.005 803	1	0.005 803	16.216*	13.4
Column	0.002 132	2	0.001 066	0.219	0.0
Interaction	0.009 735	2	0.004 868	13.602*	33.4
Error	0.040 795	114	0.000 358		
Total	0.058 465	119			

* Null hypothesis rejected at 0.01 level.

where est. σ_A^2 is the estimate of row variance, est. σ_B^2 the estimate of column variance, est. σ_{AB}^2 the estimate of interaction variance, and est. σ_E^2 the estimate of error variance. The percentage of the variance accounted for by each factor is given in Table I. For example, it is estimated that in the upper section of the pack, 30% of the total variance can be attributed to operator variance.

An examination of the homogeneity of the experienced versus inexperienced variance can be useful. The suggestion is that experienced workers would show a smaller within-sample pooled estimate of variance than would be found with inexperienced workers. Letting population 1 stand for the experienced workers, and 2 for the inexperienced workers, the hypotheses are:

$$H_0: \quad \sigma_1^2 \geqslant \sigma_2^2,$$
$$H_1: \quad \sigma_1^2 < \sigma_2^2.$$

The F-ratio is defined here as the variance of sample 2 divided by that of sample 1 rather than the traditional form of the greater variance divided by the lesser variance. If the exact null hypothesis (H_0) is true, so that both of these values are estimates of the same population value σ^2, the ratio

$$F = \frac{s_2^2}{s_1^2}$$

should be distributed as the F distribution with $N_1 - 1 = 59$ and $N_2 - 1 = 59$ degrees of freedom. The value required for significance at the 0.05 level, one-tailed, is 1.53. For the upper, middle, and lower section the resulting F-values are 2.17, 1.87, and 1.78 respectively. Consequently, it is fairly safe to say that experienced workers demonstrate a smaller within-sample variance. No significant difference between the pooled estimate of the variances of the cutter types used by the experienced operators was observed.

Since the analysis of variance is based on the assumption of equal variances, it may seem quite sensible to carry out a test for homogeneous variance on the sample data and then use the result of that test to decide if the analysis of variance is legitimate. However, the standard tests for equality of several variances are extremely sensitive to any departure from normality in the populations. Consequently, a test for homogeneity of variances before the analysis of variance has a rather limited practical utility, and modern opinion holds that the analysis of variance can and should be carried on without a preliminary test of variances, especially in situations where the number of cases in the various samples are equal, as in the above case (Box, 1953, 1954[a], [b]).

Conclusion

There is strong evidence to suggest that there is no significant difference between cutter types when used in snow with a density of up to 365 kg m^{-3}. However, in light snow (187 kg m^{-3}) and in dense snow (depth hoar with 365 kg m^{-3}) there is a significant difference between experienced and inexperienced operators. In the middle section of the pack (287 kg m^{-3}) there appears to be no significant difference between cutter type or experienced versus inexperienced operator. This can be partially explained when looking at the physical properties of the sampled snow. Light snow and depth hoar are somewhat difficult to work with, and the inexperienced workers may have unwittingly weighed snow which adhered to the outside of the cutter. Consequently, the inexperienced operators tended to overestimate the densities found by the experienced workers in light snow and in depth hoar by 6 and 4% respectively.

An experienced observer can obtain quick and accurate density measurements in light snow and mature depth hoar with the ILTS cutters.

A complete snow-density kit based on the ILTS system is available for $80.00 from Hydro-Tech, 4658 N.E. 178th Street, Seattle, Washington 98155, U.S.A.

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