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SHORT COMMUNICATION

Quantitative Step-loading Block Test: A Substitute for Loaded-column Test

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ABSTRACT

A new snowpack stability test, quantitative step-loading block test (QSLBT) has been developed and used operationally by the Snow and Avalanche Study Establishment during the winter 2004-05 at Patsio Research Station in Great Himalayan range. This test is simple, takes less time in measurement, and effectively communicates the results. In this test, an isolated snow column of area 13 cm x 18 cm (0.234 m^2 or may be up to 0.30 m^2) is cut out of the wall of a snow pit. A wooden block of known weight (0.21 kg) and of the dimension 13 cm x 18 cm is placed over the snow block and loaded in steps with iron weights of known quantity. On loading if the block fails, the height of failure from ground and the load by which the failure of block has taken place, are noted. While most of the stability tests in snow provide just an estimate of snowpack instability, this test provides the quantity of load required to fail the snowpack. More than 40 tests were carried out in Great Himalayan range during the winter 2004-05 and were compared with the shear strength of the failure plane. The results are in good agreement with shear frame test.

Keywords: Stability test, failure load, failure plane, Great Himalayan range, snowpack stability test, quatitative step-loading block test, QSLTB, unstable snow, shear frame test, loaded-column test

1. INTRODUCTION

Stability tests are used to apply stresses to the snowcover to observe the state of instability in a snowpack. When a failure occurs, information may be provided about the depth and areal extent of unstable snow[1]. Many stability tests performed in snow have been developed so far. All tests have merits as well as some shortcomings. The common ones are test skiing, explosive test, rutschblock test[2], collapse test/loaded-column test, tilt-board test, shear frame test, shovel shear test, probing test[1], stuffblock test[3], rammrutsch test[4], quantified loaded-column stability test[5], ski shear test, hand shear test, burp the baby test, etc.

Most of these tests provide qualitatively the failure load information, which is then categorised into different ranges as poor, fair, good, unstable, moderate, stable, etc. These results are not easily communicable and two different observers may analyse the results in two different ways. The most effective tests have been the loaded-column tests, and the rutschblock tests, so far[3], but in these two tests, only loaded- column test provides the failure load quantitatively.

The present quantitative step-loading block test (QSLBT) was developed while testing loaded-column test in a dry snowpack of a mountain slope in Great Himalayan range. Snowpack thickness was

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46 cm and low-density depth hoar grains were dominating the snowpack up to 36 cm from the ground. A block of 30 cm x 30 cm was cut and isolated from the rest of the snowpack. Snow grains from the block of snow were disintegrating in large amounts during cutting and weighing the block for loading the column (Fig. 1 shows a snow block over the weighing machine, prepared for loading the column).

Because of the very low-density snow available at site, large number of snow blocks were required to attempt stability test by loading the column. It was difficult to manage the snow blocks one over another. As the snow for loading could not be made in block shape perfectly and snow was disintegrating during this exercise (disintegration of snow grains from block is shown in Fig. 1), though it was tried hard to get some result of loaded-column test in this snowpack but failed to get it even after attempting the test on six columns (Fig. 2 shows one of those 6 snow columns which were prepared for loaded-column test). A new stability test known as QSLBT was then introduced to overcome difficulties encountered in loaded-column test.

Figure 1. A snow block over the weighing machine for loading the snow columns but snow grains disintegrated in large amount during the preparation and weighing of snow block.

2. METHODOLOGY

The present QSLBT were performed on different slopes of Patsio bowl in Great Himalayan range between altitudes 3800 m to 4200 m from mean sea level on different aspects. In this test, a wooden block of dimension 18 cm x 13 cm and known weight was placed gently above the snow column of same horizontal dimensions and dug deep up to ground (Figs 3 and 4).

Then the column was loaded by the iron weight in steps (Fig. 5) until failure of the column occured (Fig. 6). In the present case, 1 kg iron weight were used for step-loading of the column. The step-loading weight can be varied from 0.25 kg to 5 kg, depending on the snowpack condition and observers

Figure 2. Prepared snow column for loaded-column test on a mountain slope.

Figure 3. Wooden block placed over the snow column.

Figure 4. Snow column of upper dimension 18 cm x 13 cm.

Figure 5. Loaded-column after some steps.

Figure 6. A column failed after few steps of loading.

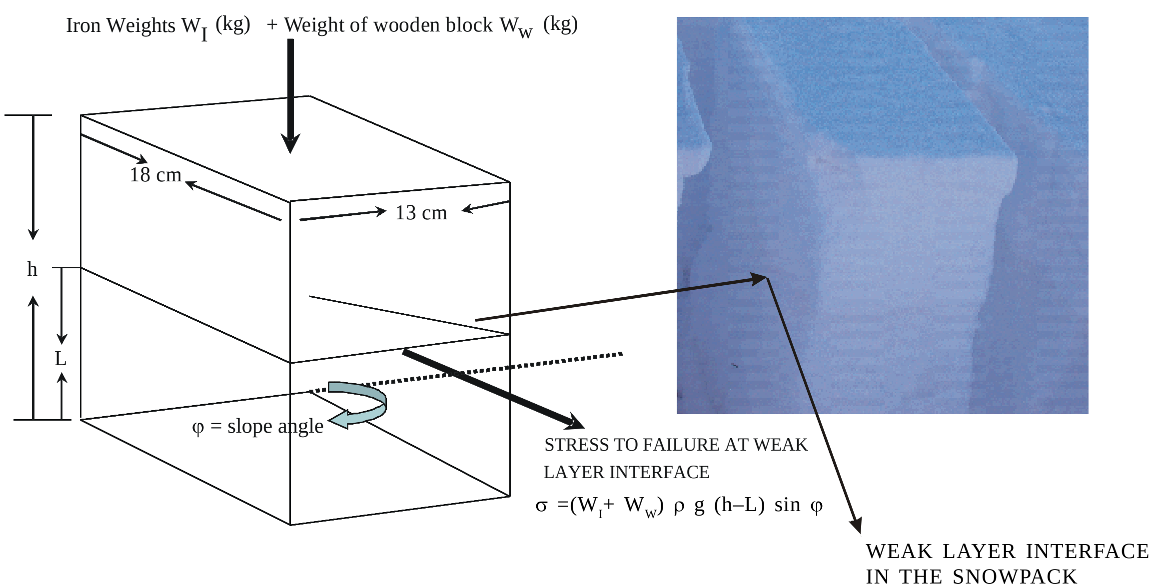

Figure 7. Schematic diagram of the test (showing stress to failure at weak layer interface, at a depth of (h-L) from snow surface).

assessment. The schematic diagram and the complete procedure of the test are shown in Fig. 7.

3. RESULTS AND DISCUSSION

More than 40 column tests were performed between 5th and 17th December 2004 on different slopes with different aspects, elevation, and snow slope angles. Load by which the snow column failed after few steps of loading, is called the failure load and the plane from where the column failed is the failure plane. Shear strength of the failure plane was then calculated by shear frame test. Failure load and shear strength of failure plane was calculated in Newton/m^2. Detailed information about test sites, failure load, and shear strength of failure plane is given in Table 1.

Table 1. Failure load and shear strength of failure plane at different sites

S No.	Date	Elevation from mean sea level (m)	Aspect (from magnetic north)	Slope (in degrees)	Failure load (Newton/m^2)	Shear strength of failure layer (Newton/m^2)
1.	05-12-04	3875	40	15	1708	3200
2.	-do-	3870	72	29	746	1700
3.	-do-	3870	58	26	1035	100
4.	-do-	3880	101	28	1035	700
5.	07-12-04	3830	148	9	458	800
6.	-do-	3835	136	15	842	600
7.	-do-	3850	123	25	458	500
8.	-do-	3865	130	26	650	800
9.	-do-	3880	115	28	265	750
10.	-do-	3890	113	27	458	250
11.	-do-	3910	131	28	458	600
12.	-do-	3940	132	32	2765	5000
13.	-do-	3940	122	31	458	100
14.	-do-	3960	140	43	265	450
15.	-do-	3970	125	31	842	1200
16.	09-12-04	3820	115	16	532	250
17.	-do-	3840	135	23	532	300
18.	-do-	3850	121	20	3244	7000
19.	-do-	3865	108	22	2729	700
20.	10-12-04	3825	128	17	532	300
21.	-do-	3825	118	16	532	200
22.	-do-	3825	92	17	532	100
23.	-do-	3835	131	28	532	330
24.	-do-	3835	117	26	532	400
25.	-do-	3835	126	28	532	800
26.	-do-	3845	110	30	6905	10000
27.	-do-	3845	116	31	971	850
28.	-do-	3845	126	27	532	100
29.	16-12-04	3905	95	27	532	50
30.	-do-	3905	83	23	971	70
31.	-do-	3905	61	25	4927	5000
32.	-do-	3910	62	25	971	200
33.	-do-	3910	69	23	971	600
34.	-do-	3910	73	26	3609	5500
35.	-do-	3920	81	26	532	200
36.	-do-	3920	72	25	532	100
37.	-do-	3920	73	25	532	100
38.	17-12-04	4010	65	16	532	300
39.	-do-	4010	55	15	971	200
40.	-do-	4010	53	21	532	200
41.	-do-	4020	74	25	532	150
42.	-do-	4020	75	23	532	200
44.	-do-	4020	74	27	532	100
45.	-do-	4030	59	24	532	200
46.	-do-	4030	65	24	532	100
45.	-do-	4030	80	28	532	100

Spearman rank-order correlation was used to statistically compare the failure load and shear strength of failure plane. For 45 observations, a highly significant correlation coefficient of the order of 0.92 was observed between the failure load and shear strength (Fig. 8). This indicates that the present test is providing a good agreement with the shear strength test for failure of the snow column.

The QSLBT was also performed on the thick snowpack (thickness > 1 m) of the Great Himalayan range on various slopes during January 2005. The test performed well by communicating the exact information of required failure load and the depth of failure plane inside the snowpack (Fig. 9). This suggests that the test is fairly good for stability evaluation of the various snow slopes used by pedestrian, skiers, avalanche workers and snow mobiles during winter.

4. CONCLUSION

For dry and low-density snowpack with main constituent of depth hoar grains, QSLBT was found a good substitute of loaded-column test with simple

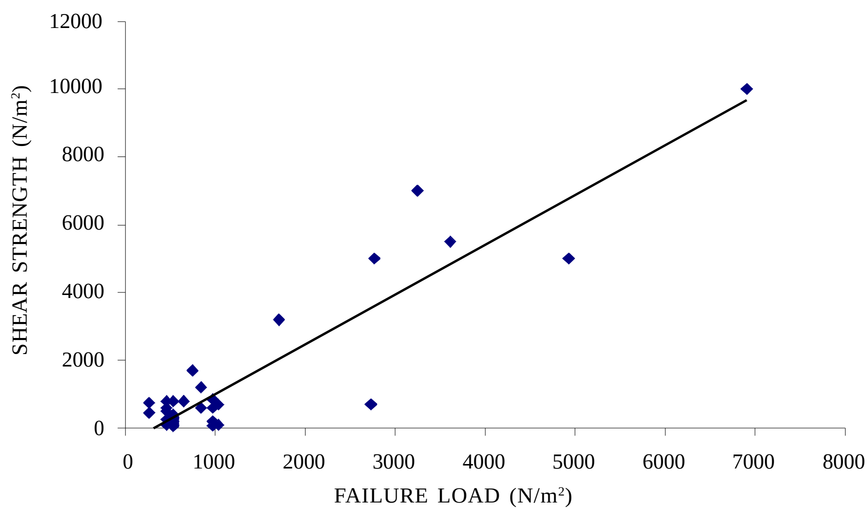

Figure 8. Correlation between failure load and failure layer shear strength

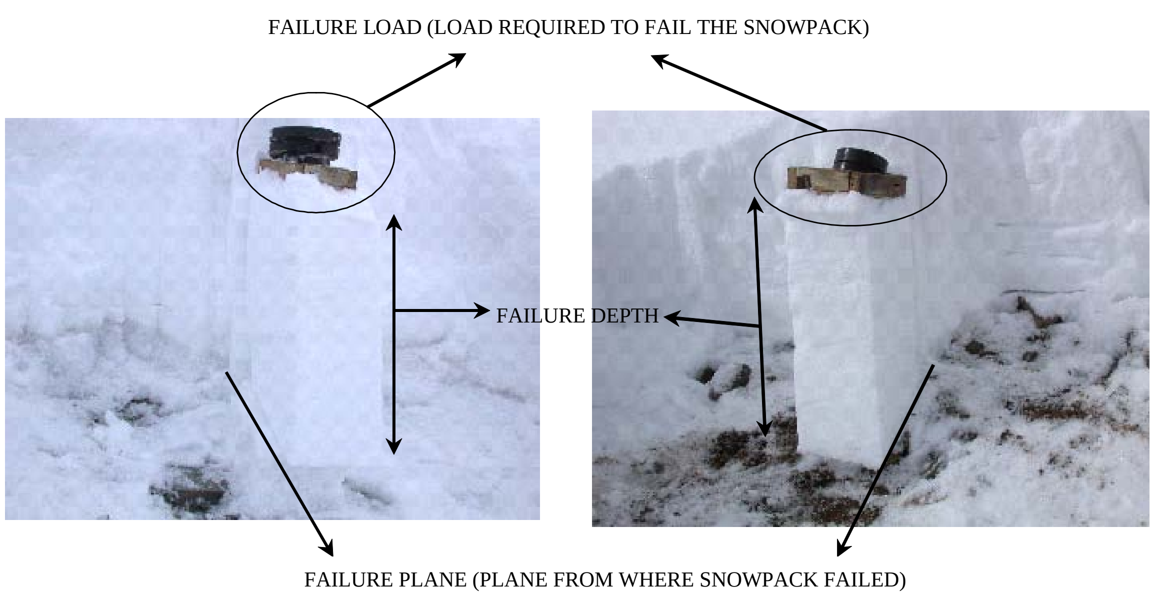

Figure 9. Information of failure load, failure plane, and failure depth provided by the test

experimental procedure. This test effectively communicates about the failure load, failure plane, and failure depth. Observational results in various snowpacks with different snowcover properties are required in future for wide acceptance of the test.

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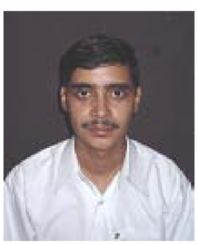

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