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Technical Equipment Branch

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Snow Beams and Abutments using Peter Snow

U. S. ARMY
SNOW ICE AND PERMAFROST
RESEARCH ESTABLISHMENT
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by S. Russell Stearns

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Wilmette, Illinois

PREFACE

This is an interim report prepared as partial fulfillment of USA SIPRE Project 0.22.02.006 (CE Project 13.1). The purpose of this pilot study was to determine the feasibility of using beams cut from snow disaggregated by a Peter snow miller to form a roof over a plowed trench. The testing of snow beams was performed by Dr. Henri Bader, chief scientist, Mr. James Bender, chief, Snow and Ice Basic Research Branch, and Mr. Stearns,* consultant. The testing of snow abutments was performed by Mr. Stearns. The work was under the supervision of Dr. Bader, then acting chief, Snow and Ice Applied Research Branch.

This report has been reviewed and approved for publication by the Office of the Chief of Engineers.

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SUMMARY

The results are reported of a pilot study in August 1957 at Site 2, Greenland, to determine the feasibility of roofing a plowed trench 8 ft wide with beams cut from Peter snow, to study the deflection of the roof beams, and to test Peter snow abutments under direct vertical load. Tapered beams 8 ft long were cantilevered over the trench to a distance of 4 ft singly and in opposed (haunched) pairs, with and without slush cementation at the median joint. The single cantilever beam showed a linear time-deflection relation, with a deflection rate of 3.15 cm/hr under severe loading and flexural stress of 1.5 kg/cm^2 without immediate failure. The haunched beam without slushed center joint behaved similarly, the 2 halves apparently acting as individual beams. The deflection rate was 1 mm/hr for the first 3 days, decreasing to 0.7 mm/hr for the last 8 days. The deflection curve for the double slushed beam was similar to that of a plastic material. A rapid but decreasing deflection rate was recorded the first day, becoming constant at 1.58 mm/hr after 20 hr. The computed allowable abutment loading was 1150 lb/ft using a safety factor of 2 and the smallest failure load measured in 4 tests.

SNOW BEAMS AND ABUTMENTS USING PETER SNOW

by

S. Russell Stearns

INTRODUCTION

This report describes the work and results of a pilot program in Greenland during August, 1957. The object of the work was twofold:

1. To determine the feasibility of cutting beams of Peter snow and of sliding them over a plowed trench to form a roof.

2. To determine the rate and amount of deflection of these snow roof beams.

As a result of an abutment failure during placement of a roof beam, a third phase of work was indicated and carried out:

3. To load test to failure Peter-snow abutments under direct vertical load.

All snow used was "Peter snow", disaggregated by a Peter snow miller at Camp Fistclench (Site 2) and is considered typical of this particular disaggregated and blown snow. Properties of this snow will be reported in other USA SIPRE reports.

PROCEDURE

Snow beams

On July 11, 1957, the Peter miller cut and backfilled two trenches (Fig. 1). The surface was graded level by hand. It was found that the snow did not "set up" enough in three hours to hinder grading.

On August 5, the Peter miller cut an 8-ft wide trench, 8 ft deep, between the two backfilled deposits.

On August 6, the first two snow beams were cut. Use of a chain saw was attempted but a two-man timber saw proved more satisfactory. The first beam cut was 8 ft long, 25 in. wide, and tapered from 24 in. to 12 in. thick in its 8-ft length. This proved too heavy, causing the abutment to shear off when the beam was pulled to an unsupported length of 41 in. over the trench. A weasel and sling were used to slide the beam, and no plastic sheet was used on the sliding surface.

A second beam, 8 ft long, 25 in. wide, tapering from 18 to 6 in., was cut and pulled out as a cantilever over the trench (Fig. 2). This single cantilever beam, with an unsupported length of 48.5 in., was loaded at its free end with 166 lb and end deflection was measured for 4 hr (Fig. 4). Sometime after 4 hr, cracks developed in the tension side, or top surface, above the wall support, thus reducing the beam section, and a fraction failure occurred sometime between 4 and 18 hr after the start. Unfortunately, final failure occurred during the night, so that the actual time is not known.

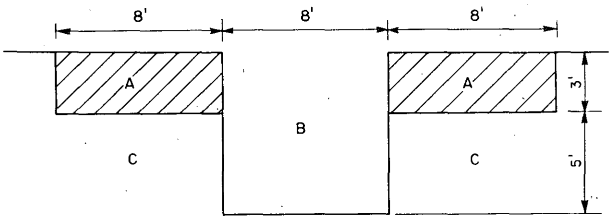


Figure 1. Trench and abutment preparation.

A. Plowed and backfilled by Peter snowplow
B. Plowed trench - 25 days later
C. Natural undisturbed snow.

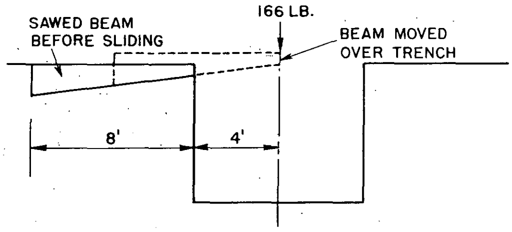


Figure 2. Single cantilever beam.
Taper: 18 in. to 6 in. Width: 25 in.

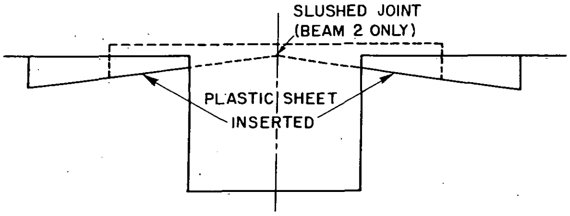


Figure 3. Double cantilever or haunched beam. Taper 18 in. to 6 in.; Width: 18 in. Peter snow 12 in. deep was placed on beam 2 for the full 16 ft.

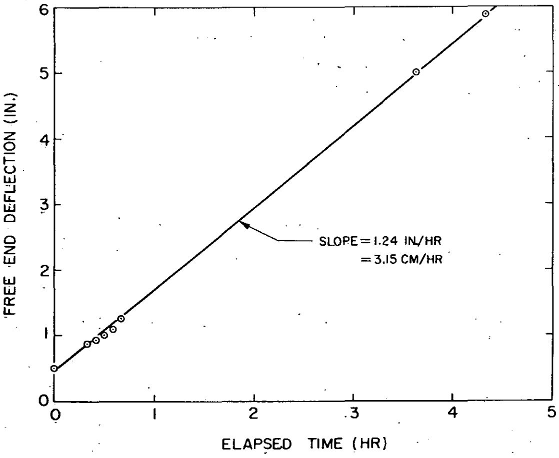


Figure 4. Deflection of single cantilever beam, under concentrated end load. Total deflection at failure $18\frac{7}{8}$ in. Failure occurred between 5 and $18\frac{1}{2}$ hr.

On August 13 two snow beams were cut on opposite sides of the trench, each 8 ft long, 18 in. wide, and tapering from 18 to 6 in. A polyethylene plastic sheet was placed on the sliding plane, and these beams were moved by hand over the trench until they abutted in the center (Fig. 3). No slush joint material was used in the center joint.

The center deflection of this combined, haunched beam acting under its own weight only was recorded for 11 days (Fig. 5). It was still in place after these 11 days when the USA SIPRE party left Site 2. A crack on the underside of the centerline joint appeared on the second day, and had progressed halfway through the beam by the fourth day. No additional penetration of the crack developed in the remaining 7 days. On August 20, a second set of beams was cut and moved by sliding over the trench (Fig. 3). These had the same dimensions as the set described above and the plastic sheet was used. The center joint of this haunched beam was slushed tight. In addition to its own weight, this beam was loaded with Peter snow 12 in. thick and full beam width.

Rate of deflection of the center point was recorded for 4 days, until USA SIPRE left the camp (Fig. 3). During this period no cracking appeared in the beam, either at the bottom of the center joint, or over the supports.

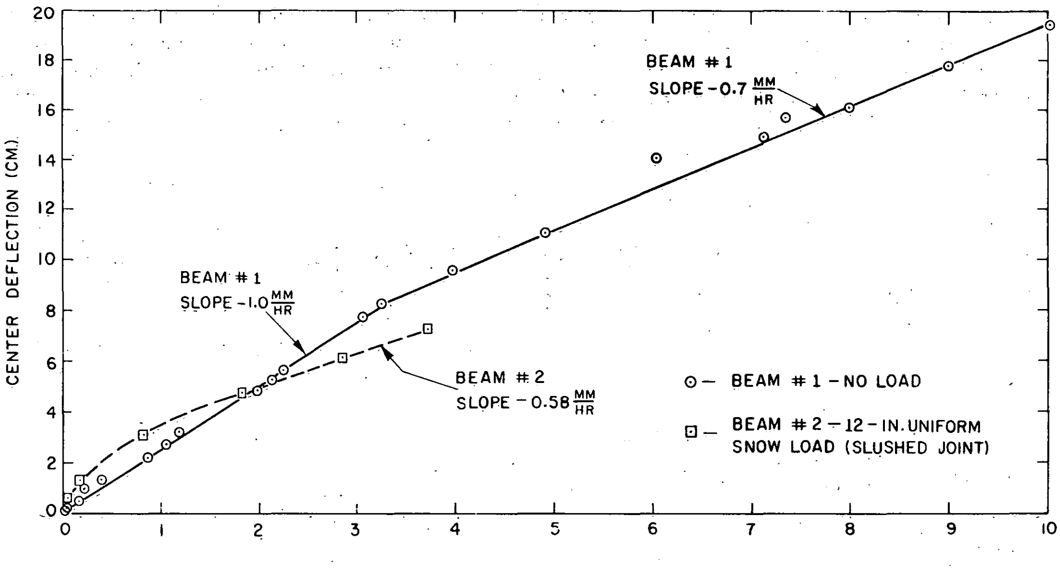


Figure 5. Center deflection of double cantilever beams.

Flexural stresses were computed using standard beam theory (Table I).

Snow abutments

Several blocks, or keys, were cut into the side wall of the Peter snow backfill along the trench (Fig. 6). A vertical load was applied to each snow key or abutment using a weasel as reaction and a timber beam as lever (Fig. 7). The load causing failure was obtained, the failure surface (Fig. 8) was measured, and the indicated stress at failure was computed (Table II).

Table I. Flexural stresses in the snow beams.

Beam	Type	Tensile stress (kg/cm^2)
1	Simple cantilever beam, concentrated load on the end.	1.49 *
2	Continuous haunched beam, no slush in center joint.	0.50 *
3	Continuous, haunched beam. Center joint slushed. 12-in. snow dead load added.	1.23 *
4	Simple cantilever beam loaded to failure with a concentrated load.	2.33 **

* No flexural failure.
** Failure stress.

Table II. Shear strength of the snow abutments.

Abutment	Shear stress Col. 1 (kg/cm^2)	Shear stress Col. 2 (kg/cm^2)	Crushing Col. 3 (kg/cm^2)
1	0.35 *	Straight diagonal	
2	Vertical (0.35)	Vertical	1.18
3	0.89	0.24	2.28
4	0.82	0.06	1.32

Col. 1 - Based on back face only; neglecting bottom crushing.
Col. 2 - Based on shear stress applied to a circular arc approximating both back and bottom.
Col. 3 - Based on bottom crushing only followed by rotation of block and back tension.
* This stress was carried successfully until it became dynamic when the reaction load (weasel) moved.

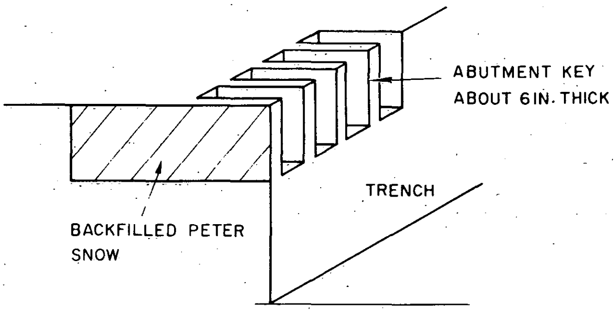


Figure 6. Sawed abutment keys.

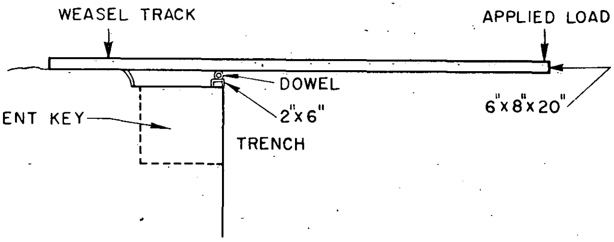
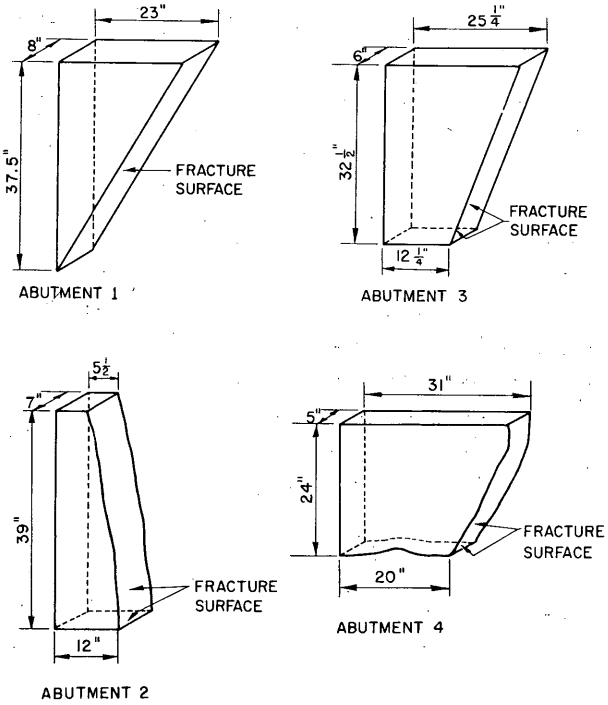


Figure 7. Abutment loading system.



ABUTMENT 1

ABUTMENT 3

ABUTMENT 2

ABUTMENT 4

Figure 8. Abutment failure surfaces.

EXPERIMENTAL RESULTS

Snow beams

For the simple cantilever beam with concentrated end load, the time-deflection relation was linear (Fig. 4). The deflection rate was excessive (3.15 cm/hr), but this was a most severe loading with computed flexural stress of 1.5 kg/cm^2 without immediate failure (Table I). The progressive deformation, or creep, is a plastic action and is the critical limitation of the beam. In fact, the final failure was accompanied by a progressive tensile crack development over the support. These cracks would reduce the effective beam section and might increase the bending stresses by as much as four times that computed for the full beam section.

The double cantilever or haunched beam without slushed center joint (Fig. 5) also showed a linear time-deflection relation, indicating that the two halves were acting as two individual cantilever beams. It is interesting to note that the slope of the curve changed at 3+ days. The rate is 1 mm/hr for the first 3 days and 0.7 mm/hr for the last 8 days. This indicates that the upper portions of the two beams become better bonded at the joint, probably due to top fiber compression in the early part of the test.

The curve for the second double cantilever beam is somewhat different, particularly in the first portion (Fig. 5). The center joint at the contact of the two cantilevers was completely bonded by slush thus guaranteeing a continuous beam section. No cracking was observed although this beam was loaded with 12 in. of Peter snow in addition to its own weight.

A rapid but decreasing deflection rate was recorded during the first day, but after 20 hr the rate became constant for the remaining 3 days of observation. This constant rate, 0.58 mm/hr, is less than the 0.7 mm/hr rate for the first beam, despite the additional load. This shows quite well the advantage gained by slushing the center joint.

The curve for this beam is similar to the deformation rate curves obtained for plastic materials. Therefore the stresses computed by elastic theory and shown in Table I apply only at the start of the test.

Snow abutments

The four abutment tests did not give conclusive results. Nevertheless, some information can be reported along with some recommendations.

The average bearing load for the four tests is 3850 pounds per foot of wall; the smallest value obtained was 2320 lb/ft. These values give a measure of the safe roof load on a trench wall considering only immediate shear, crushing, or fracture failure. Using a safety factor of two and the smallest failure load obtained gives an allowable abutment loading of 1150 lb/ft. This is conservative since the tests were on narrow isolated wall sections and a continuous wall would be stronger. For example, a load which was estimated as larger than 1150 lb/ft was applied successfully to a snow corner abutment in the 1957 undersnow camp at Site 2.

The failure surfaces resulting from a vertical load on the abutments were not identical. One surface was diagonal and the other three had vertical or diagonal back faces and a horizontal bottom (Fig. 8). This indicates that, if a back shear plane develops at all, it is accompanied or preceded by bottom crushing. The location of the load relative to the wall edge may influence the type and shape of failure surface. In the first test, the only one giving a true diagonal shear failure, the load was applied twice the distance from the edge — 6 in. instead of 3 in. The shear strength was computed in two ways:

1. Assuming shear on back face only and neglecting crushing at bottom (Table II, col. 1).
2. Assuming shear on a circular arc approximating both back and bottom (Table II, col. 2).

In addition, the crushing strength of the snow was computed assuming failure by bottom crushing only, followed by an outward rotation placing the back in tension (Table II, col. 3).

The conclusions are as follows:

1. The shape of the failure surfaces shows a critical bottom crushing condition. This average failure stress is 1.6 kg/cm^2.
2. A diagonal or circular arc surface representing shear failure is not expected if the point of load application is close to the wall edge.
3. The location of the load from the edge may affect the type of failure.
4. A safe bearing value for Peter-snow wall abutments is 1150 lb/ft of wall. The value is considered conservative because of the small abutment tested (3- to 6-in. seat).

The low crushing stress for abutment 2 at failure, indicates that tension on the fracture surface may have become critical and initiated failure.

In any case, failure by shear or tension in the Peter snow or by crushing of the underlying natural deposit depends significantly on the depth or thickness of the backfill material (Peter snow), which for these tests was 3 ft. The interpretation of the safe bearing value should be governed accordingly.

Additional testing of wall abutments is recommended since loaded abutments are used for almost all types of undersnow camp roofs. The effect of load position and the actual motion of the failure block should be investigated. To determine failure stresses the actual method of failure must be determined: shear, crushing, or tension.

CONCLUSIONS

The tests showed that:

1. Two cantilever Peter snow beams can be cut and moved together by sliding out over an 8-ft trench, until contact is made at the center (Fig. 1). This combined roof beam will remain in place for at least 10 days.

2. It is considerably easier to slide the beams if a plastic sheet is placed in the saw cut on the sliding surface.

3. The beams will deflect less if they are bonded together with slush at their point of contact.

4. The vertical deflection of the combined beam, after 4 days under a load of 12 in. of Peter snow, is small enough that the method could be used for a trench roof.

5. The vertical load required to cause the snow abutment to fail is much larger than the load resulting from the beams and a superimposed cover load of several feet thickness.

6. Additional loading of snow abutments to failure is necessary to determine reasonable values for the shear and crushing strengths of the snow.

7. A safe value for the bearing strength of wall abutments is 1150 pounds per foot of wall.

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