USA SIPRE

Special Report 39

EFFECTS OF A SHOCK WAVE ON A PETER SNOW ARCH

(PRELIMINARY REPORT)

U. S. ARMY

SNOW ICE AND PERMAFROST RESEARCH ESTABLISHMENT

CORPS OF ENGINEERS

Special Report 39

EFFECTS OF A SHOCK WAVE ON A PETER SNOW ARCH

Preliminary Report

by

John E. McCoy and Robert W. Waterhouse

July 1960

U. S. ARMY SNOW ICE AND PERMAFROST RESEARCH ESTABLISHMENT
CORPS OF ENGINEERS
WILMETTE, ILLINOIS

CONTENTS

ILLUSTRATIONS

EFFECTS OF A SHOCK WAVE ON A PETER SNOW ARCH

Preliminary Report
by
John E. McCoy and Robert W. Waterhouse

Introduction

During July 1959, the U. S. Army Snow Ice and Permafrost Research Establishment (USA SIPRE) was requested by the Office, Chief of Engineers to conduct a small-scale test to evaluate the resistance of a rigid snow trench cover to the blast effects of a military explosive. The USA SIPRE field crew conducting research on snow structures at Camp Century, 138 miles inland from Camp Tuto, Greenland, was requested to prepare the test setup. U. S. Army Engineer Waterways Experiment Station (USA WES) was requested to measure the magnitude of the pressure wave during the test. The objective of the test was to obtain preliminary information which would be used to estimate the probable effect of large-scale explosions on a snow arch roof.

Test preparations and conditions

A trench 9 ft wide, 8 ft deep, and 77 ft long was cut into the natural snow at a location approximately 1/2 mile west of the Camp Century site. The arch roof was to be placed on a Peter snow pad to provide a stable foundation for the cover, but the pad was not made because of other commitments for the equipment. Therefore, the arch form supports were placed on natural snow.

Granular snow was deposited on these forms by the Peter Miller and leveled by hand to a thickness of 6 to 24 in. (Fig. 1) before it could take an initial set (Fig. 4, 5). At the thick end of the roof section, soft snow was hand-placed against the steel end panel to close the opening at the juncture of roof and end panel. The arch forms were removed 24 hr after the snow was deposited.

Composition of the milled snow was typical "Peter" snow, which ranges in significant grain size from 0.25 mm to 2.0 mm. At the time of the blast test, this material had aged 15 days at air temperatures varying from -4 to -14C. The strength of Peter snow is strongly time-dependent, increasing rapidly for 20 to 30 days after deposition (Fig. 3). Unconfined compressive strength tests of similar snow samples tested during the three previous summer seasons at Site 2 (Camp Fistclench) indicate that the 15-day strength should be 50% to 75% of the ultimate strength, which could be as high as 200 psi. Snow cylinders tested in this way respond elastically to rapid loading and show distinctive shear planes, indicating intergranular as well as cohesive resistance. Density of 15-day old Peter snow varies with composition but can be considered as approximately 0.5 g/cm^3.

Shot 1 consisted of 67.5 lb of Demolition Blocks M5A1 (Composition C-4) tightly bound together to ensure complete demolition and primed with three U. S. Army Special blasting caps. This charge was placed on a wooden pedestal at a height of 6.5 ft above the natural snow surface (Fig. 1). Shot 2 was 62.5 lb of Composition C-4, placed on a pedestal at a height of 7.3 ft above the natural snow surface.

The apparatus provided by WES to measure and record the blast pressure magnitude and duration consisted essentially of two mechanically operated pressure-time gages. More accurate electronic equipment was also provided but there was no generator available to power it. Both charges were fired on the afternoon of 18 August. The location of the explosive and the positioning of the gages are shown in Figure 1.

Test results and discussion

As reported by WES (Preliminary Report - Effects of air blast on a snow arch), the overpressures developed were approximately 9 psi for shot 1 and 13 psi, diminishing to 8 psi on the far side of the trench, for shot 2.

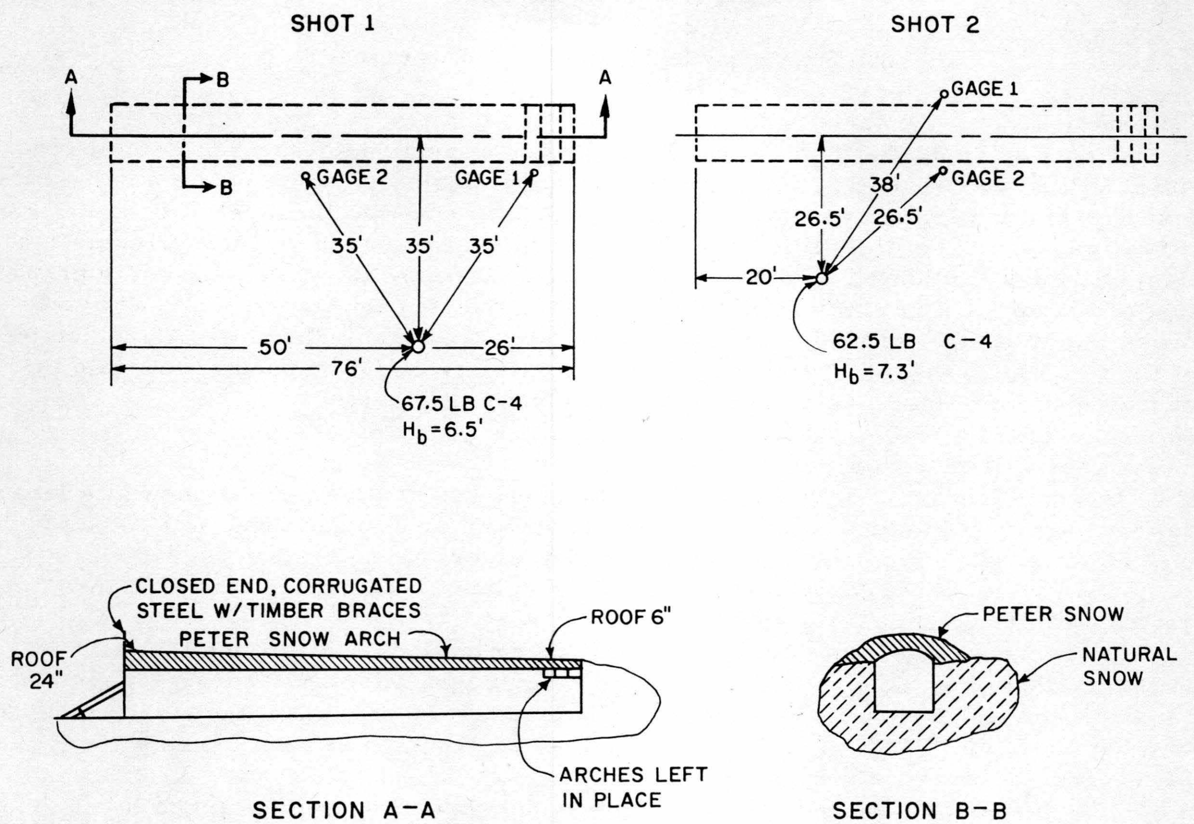

Figure 1. Test conditions, snow-arch blast test.

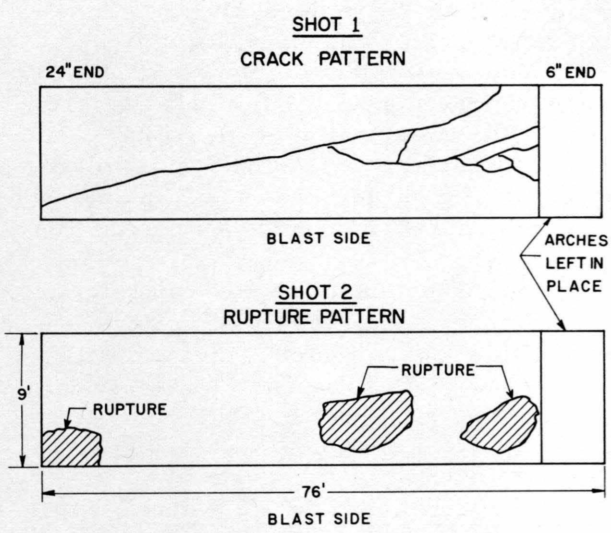

Figure 2. Effects of blast on Peter-snow arch.

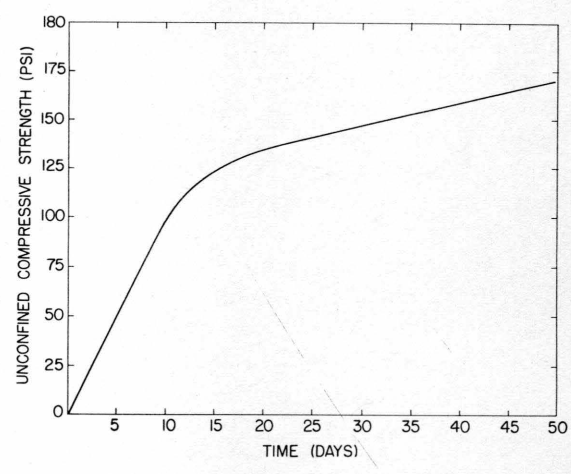

Figure 3. Typical time-strength curve for Peter snow.

Figure 7 shows the effects of the blasts. The longitudinal crack which runs the length of the arch is visible just beneath the glove in Figure 8. The crack is open on the surface (Fig. 7) and closed on the inside of the arch (Fig. 6). Also the snow on each side of the crack is offset, which indicates that the foundation of the arch on the blast side may have been lowered. It is suspected that the shock wave through the snow coupled with the higher pressures on the blast side collapsed the soft snow on which the arch was placed. This collapse could have caused the arch foundation to lower and move in toward the trench, which would account for the observed crack phenomena.

The presence of soft snow placed by hand at the juncture of the end form and the vertical cutoff panel may have contributed to the failure of the thick end of the trench after shot 2.

The cutoff panel was left in place and reinforced to produce a closed condition. The protruding metal may have caused a damaging pressure reflection (Fig. 7, 9). Holes produced by the second shot are not a true indication of its specific effect, because of the damage produced around the hole locations by shot 1. The inclined external face of the arch towards the blast may have amplified the overpressure measured on a horizontal plane. Though shot 1, which was the only true test, created overpressures around 9 psi and did cause cracking and a little spalling, it is suspected that Peter snow arches 6 in. to 24 in. thick placed on dense snow abutments would have remained intact. It should be noted that the snow had not reached its maximum stability so that an analysis based on these results is conservative.

Conclusions

This test indicates that a fully age-strengthened Peter-snow arched trench cover of 9 ft span and 24 in. thickness at the crown could resist a 15 psi blast overpressure. A roof arch of 6-in. crown thickness can resist overpressures of 10 psi, sustaining only crack damage if the structure contains no marked discontinuities such as are produced by chunks of natural snow, poor form setting, or rough surface treatment in final processing of the deposited disaggregated snow.

Recommendations

In view of the current interest in arctic structures made of natural materials, we recommend

1. A program to determine the static strength properties of Peter snow arches and hemispherical domes by load testing of representative structures to destruction.
2. Dynamic load tests by use of explosives on snow structures which have been more precisely constructed than that used in this test.
3. Tests of various types of closure control to find the most effective configuration to minimize blast damage.
4. Pressure measurements and deflection-time measurements with larger charges than those used in this test, to permit better extrapolation of scaling predictions into the nuclear explosive range.
5. Tests on the deeply buried tunnels at Site 2 to determine the increase in target resistance due to age and various depth of cover.

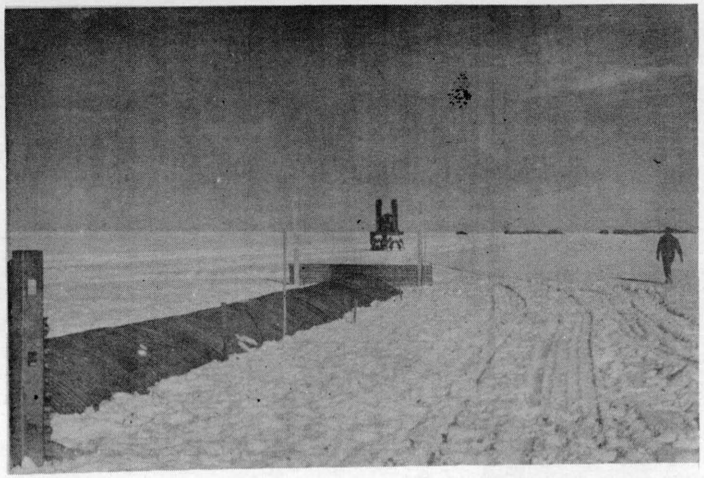

Figure 4. Arch forms for test arch before covering.

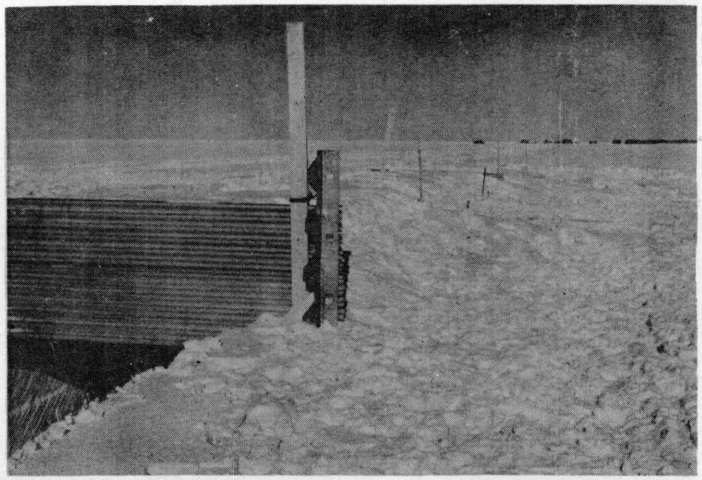

Figure 5. Arch forms for test arch after covering.

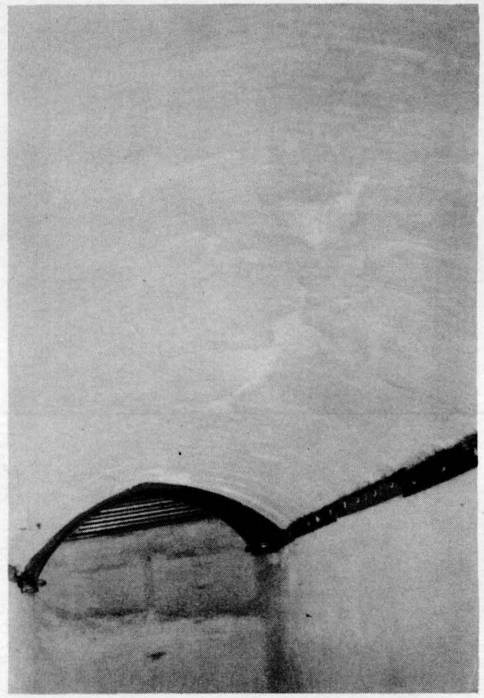

Figure 6. Interior of arch after shot 1, looking toward thin end of arch section. Note longitudinal crack which runs the length of the arch. (Blast side - right)

GPO 802561-1

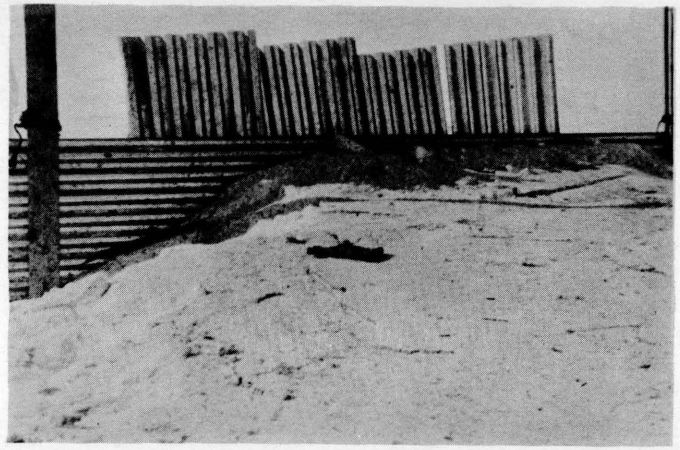

Figure 7. Longitudinal crack and settlement of the near-blast side of the arch after shot 1. Also shows the exposed overhang of the closure structures. (Looking toward thick end; Blast side - left)

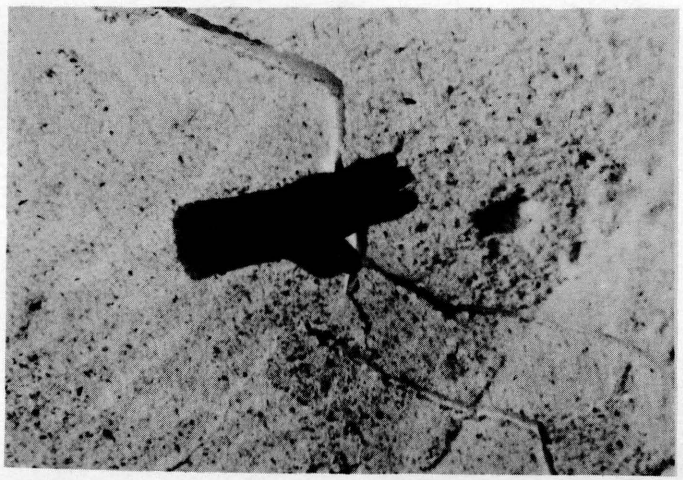

Figure 8. Close-up of crack in Fig. 3.

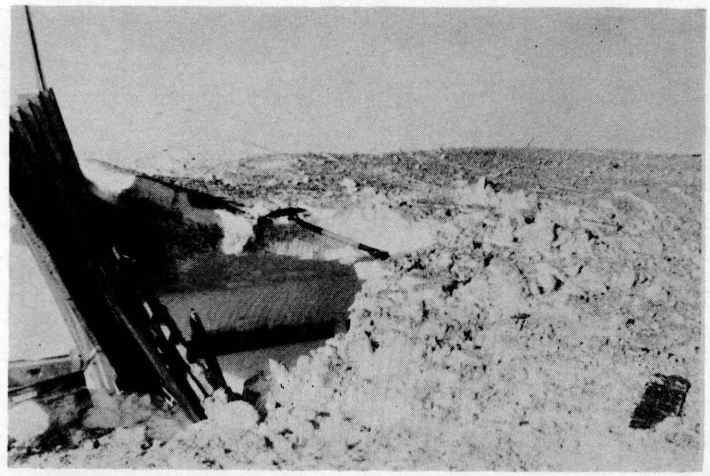

Figure 9. Movement and bending of the end structure caused by the second shot.