

Special Report 82-2

March 1982



**US Army Corps
of Engineers**

Cold Regions Research &
Engineering Laboratory

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Testing shaped charges in unfrozen and frozen silt in Alaska

North Smith

AD A11 3670

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Special Report 82-2	2. GOVT ACCESSION NO. AD-A113670	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) TESTING SHAPED CHARGES IN UNFROZEN AND FROZEN SILT IN ALASKA		5. TYPE OF REPORT & PERIOD COVERED
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) North Smith		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Cold Regions Research and Engineering Laboratory Hanover, New Hampshire 03755		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS DA Project 4A762730AT42 Task A3, Work Unit 003
11. CONTROLLING OFFICE NAME AND ADDRESS Office of the Chief of Engineers Washington, D.C. 20314		12. REPORT DATE March 1982
		13. NUMBER OF PAGES 16
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Cratering Explosion effects Silt		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Borehole blasting tests using 15- and 40-lb charges were conducted in silt at Fort Wainwright near Eielson Air Force Base. Tests were conducted with the silt unfrozen and with two thicknesses of frozen surface layers (2.0 and 3.7 feet). The standoff distance (the height of the charge above the soil surface) was varied to determine its effect on borehole dimensions. The 15-lb shaped charge was fired over unfrozen silt with a moisture content between 15 and 35% and at stand-off distances of 2.0, 2.5, 3.0 and 3.5 ft produced a borehole of sufficient size to accommodate the 40-lb cratering charge having a 7-in. diameter and 2.0-ft		

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20. Abstract (cont'd)

length. The optimum standoff distance was 2.5 ft to produce a near-optimum depth for placing the cratering charge. The 15-lb shaped charge fired over the same material with the 2- and 3.7-ft-thick frozen surface layer did not produce a borehole of sufficient size to accommodate the 40-lb cratering charge. The 40-lb shaped charge fired at standoff distances of 3.5, 4.0 and 4.5 feet produced boreholes for the unfrozen and the frozen surface layer conditions that are larger than required to accommodate the 40-lb cratering charge; therefore, it is wasteful and more of a problem logistically. Firing a second 15-lb shaped charge in the same locations as the first over the 3.7-ft-thick frozen layer increased the hole cross section by about one-third; however, the hole was still not adequate. The second firing of the 15-lb charge increased the depth by nearly two times; however, with the 40-lb charge, little change in depth was observed.

PREFACE

This report was prepared by North Smith, Civil Engineer (Soils) of the Geotechnical and Materials Branch, Engineering Division, South Pacific Division, U.S. Army Corps of Engineers (formerly Research Civil Engineer, Geotechnical Research Branch, Experimental Engineering Division, U.S. Army Cold Regions Research and Engineering Laboratory). The research was supported by DA Project 4A762730AT42, Design, Construction, and Operations Technology for Cold Regions, Task A3, Cold Regions Military Operations, Work Unit 003, Shock Loading in Frozen Earth Media.

The author appreciates the excellent assistance in field testing provided by Major Adams, Sergeant Gray, and others of the CRREL Alaskan Projects Office. The report was technically reviewed by Dr. M. Mellor and P.V. Sellmann of CRREL.

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CONVERSION FACTORS: U.S. CUSTOMARY TO METRIC (SI)
UNITS OF MEASUREMENT

These conversion factors include all the significant digits given in the conversion tables in the ASTM Metric Practice Guide (E 380), which has been approved for use by the Department of Defense. Converted values should be rounded to have the same precision as the original (see E 380).

<u>Multiply</u>	<u>By</u>	<u>To obtain</u>
foot	0.3048*	metre
inch	25.4*	millimetre
<u>pound (force)</u>	<u>4.448222</u>	<u>newton</u>

*Exact.

TESTING SHAPED CHARGES IN
UNFROZEN AND FROZEN SILT IN ALASKA

North Smith

INTRODUCTION

The Department of the Army field manual titled Explosives and Demolitions* provides guidance for "the use of explosives in the destruction of military obstacles, and in certain construction projects." In Table 3-5 of the manual, performance data on the blasting of boreholes with shaped charges are presented. Of particular interest in that table are the data on borehole sizes in frozen and unfrozen soil. The purpose of this project was to test some apparent inaccuracies in Table 3-5.

The Company Commander of the 47th Engineers at Fort Wainwright asked if I could verify his findings that the M2A4 (15-lb) shaped charge cannot produce a borehole in frozen soil large enough to accommodate a standard 40-lb ammonium nitrate block demolition charge, or cratering charge. The cratering charge is intended to be used to produce obstacle craters in open terrain and in roads or airfields for denial purposes. It is 7 in. in diameter and 24 in. long. To produce optimum crater depths, the cratering charges should be placed in boreholes that are about 3.4 and 4.4 ft deep in frozen silt and frozen gravel, respectively, and 4.8 and 6.2 ft deep in thawed gravel and thawed silt, respectively.†

I decided to document the borehole-producing capabilities of both the M2A4 (15-lb) shaped charge and the M3A1 (40-lb) shaped charge in unfrozen and frozen silt fired at various standoff distances (charge distances above the soil surface) and compare the results with those in Table 3-5 of FM 5-25. I also wanted to determine at what frost depths the shaped charges became ineffective in producing a suitable borehole for the cratering charge.

* Department of the Army (1971) Explosives and Demolitions. Field Manual 5-25.

† Smith, N. (1980) High-explosive cratering in frozen and unfrozen soils in Alaska. CRREL Report 80-9.



Figure 1. Location of test site near Eielson Air Force Base.

TEST SITE

The test site was on the Fort Wainwright range near Eielson Air Force Base in central Alaska (Fig. 1). The trail had been cleared of trees some years previously and was traversed by military vehicles and snowmobiles, mostly during the winter for access to a winter training camp and for small game hunting. The soil is commonly known as Fairbanks silt and has a moisture content ranging from about 15 to 35% in the top 10 ft.

TEST PROCEDURES

In October 1979, before the ground froze, a frost tube was installed to a depth of 10 ft at the test site (Fig. 2) to provide readings on the depth of frost throughout the winter. The first series of explosive tests was also conducted at that time. The second and third test series were conducted in December 1979 and February 1980, when the frost depths were 25 and 44 in., respectively. Standoff tripods (Fig. 3 and 4), made of 1- x 2-in. scrap lumber, were varied in height to determine the effect of standoff distance on borehole cross section size and depth. The maximum standoff distance was limited to what could reasonably be used by combat troops. Typical surface views of the boreholes made in the thawed silt by the 15- and 40-lb shaped charges are shown in Figures 5 and 6. The



Figure 2. Frost tube installation.

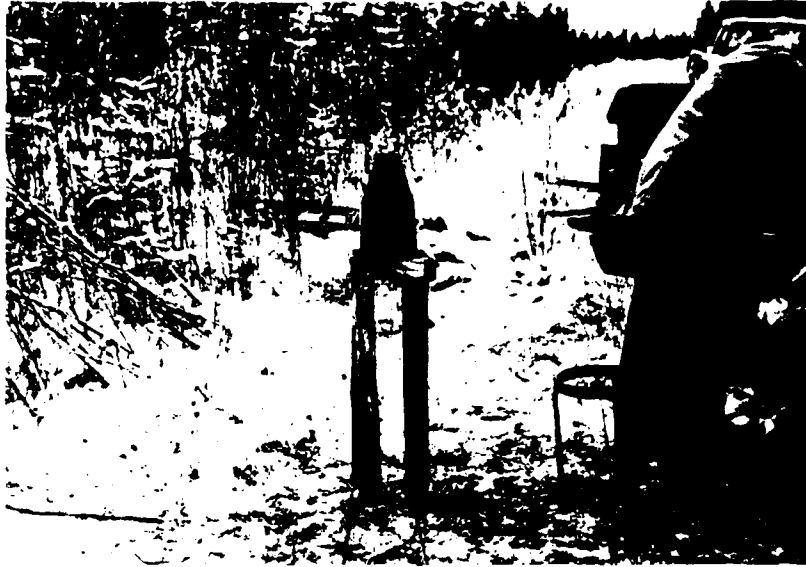


Figure 3. Fifteen-pound shaped charge on standoff tripod.



Figure 4. Forty-pound shaped charge on standoff tripod.

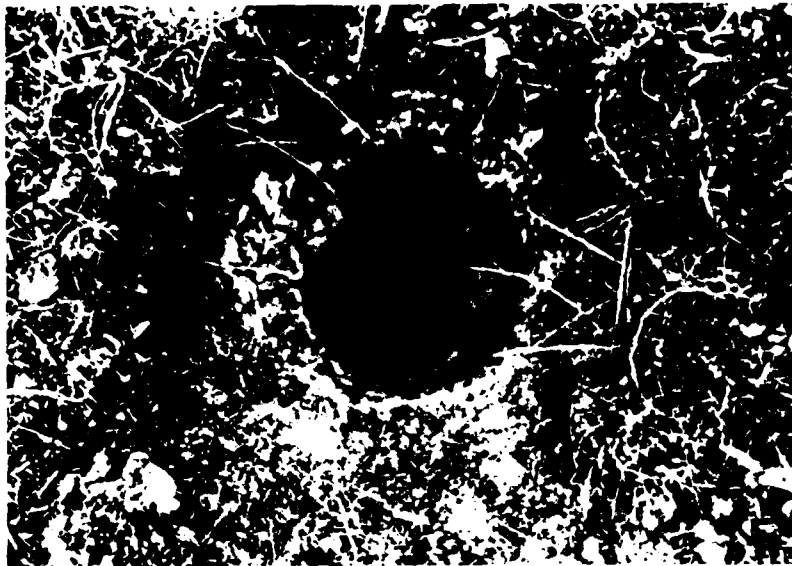


Figure 5. Borehole in unfrozen silt from 15-lb shaped charge.

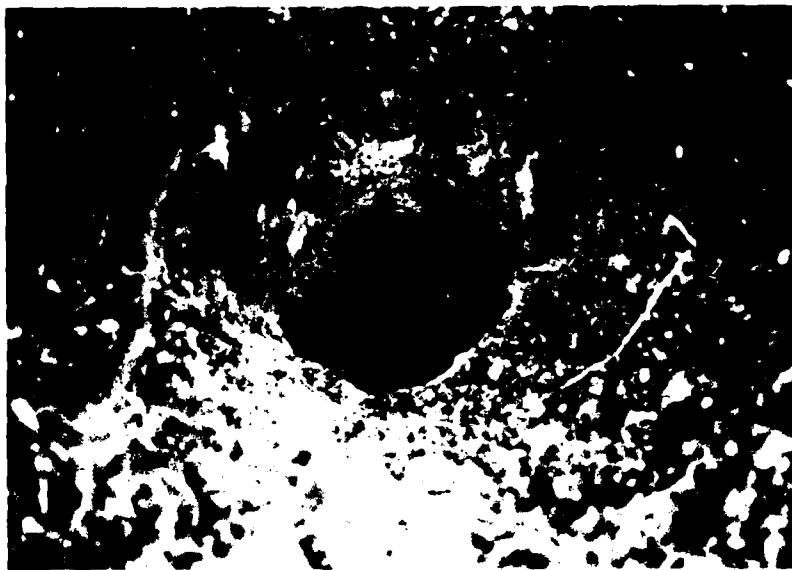


Figure 6. Borehole in unfrozen silt from 40-lb shaped charge.

fireball at the firing of a 15-lb charge is shown in Figure 7. The experimental measurements made on the test holes are shown in Figure 8.

The snow was removed from the test site after each snowfall to allow the frost to penetrate to a greater depth than would be the case with an insulating surface layer of snow. The shaped charges were primed with one electrical detonating cap and were fired from a distance of about 1000 ft.

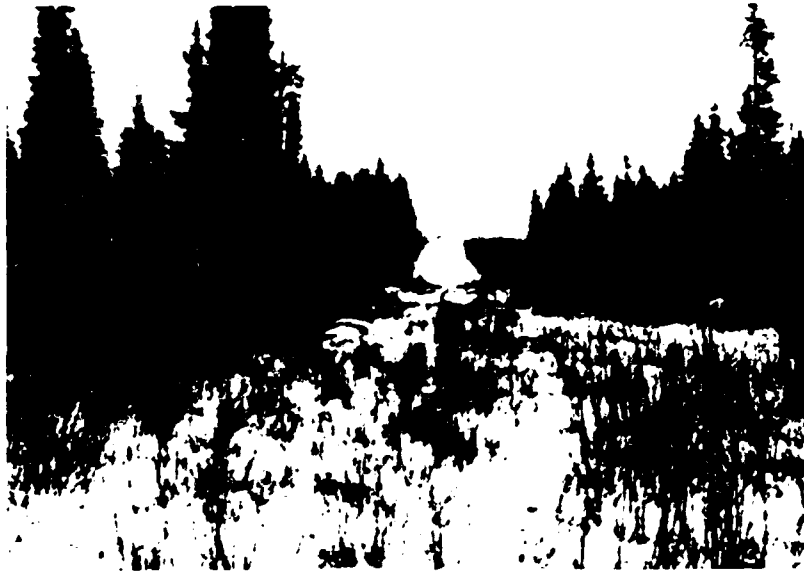


Figure 7. Fireball at firing of a 15-lb shaped charge.

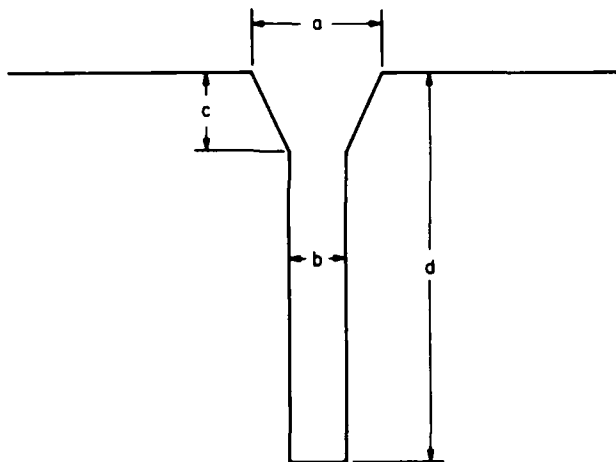


Figure 8. Experimental measurements.
a) surface crater dimensions; b) shot-hole dimensions, c) surface crater depth, d) total hole depth.

The electrical continuity of the firing line and detonating cap was checked with a blaster's volt-ohm meter prior to each firing. Each test setup was situated a minimum of 4 ft from any previously blasted boreholes to avoid any test interaction, such as a possible increase in soil density due to compaction or melting of the frozen soil by the fireball. (The borehole is produced by a jet of high-velocity detonation gases.)

DATA ANALYSIS AND DISCUSSION

The test data are presented in Table 1. Data for the first test series (when the soil was unfrozen) show that the borehole cross section dimensions and total depths were sufficient at all standoff distances tested for both charge weights except for one 15-lb charge at a 30-in. standoff distance. In that case, the minimum borehole dimension was 6 in. instead of the required 7 in. However, the average of two shots was 7 in. Also, it was obvious that the hole could easily have been reamed to the required size with a hand-operated post-hole digger or auger.

All of the holes were deeper than the optimum cratering charge depth. The center of the 2-ft-long cratering charge canister for a fully stemmed (backfilled) hole should be about 6 ft deep to produce the largest crater cross section and about 5 ft deep to produce the maximum crater depth. However, since there is no soil debris as a result of the firing of the shaped charge, the cratering charge will probably be fired without any stemming. Without stemming, the borehole should be about 2 ft deeper than for the stemmed condition; therefore, the best standoff distance for the unfrozen soil condition was 2.5 ft, which produced a hole only about 1-2 ft deeper than the optimum.

The data indicate that there is no benefit to be gained by increasing the standoff distance above 2.5 ft for the 15-lb charge when firing into unfrozen silt. The cross sections and depths of the hole produced in the unfrozen silt by the 40-lb shaped charges were greater than required at all standoff distances. At a standoff distance of 3.5 ft, the cross section of the hole was only about one-half of that obtained at standoff distances of 4.0 and 4.5 ft. However, the results of the second test series, with a 2-ft-thick frozen surface layer, indicate that this could have been due to some abnormality in the first test.

The second test was conducted in December 1979, when the silt was frozen to a depth of about 2 ft. The 15-lb charges did not produce any boreholes of sufficient cross section at any of the standoff distances tested. All total hole depths, however, were greater than the optimum of about 3.4 ft (the 3.0-ft standoff being the best). The 40-lb charges fired at all standoff distances in this series produced boreholes with both cross sections and depths that were greater than necessary. However, some soil clods had to be cleared with a post-hole digger to allow measurements to be made or a cratering charge to be placed.

Table 1. Shaped charge test data.

Shaped charge weight (lbs)	Standoff height (ft)	Surface crater dimensions (ft)	Shothole dimensions (ft)	Surface crater depth (ft)	Total hole depth (ft)
<u>Series 1: No frost (24-25 October 1979)</u>					
15	2.0	1.0 x 1.0	0.7 x 0.7	1.3	8.8
15	2.5	1.3 x 1.7	0.5 x 0.5	1.8	8.2
15	2.5	0.7 x 0.7	0.7 x 0.7	0	7.9
15	3.0	0.9 x 1.0	0.5 x 0.6	1.2	8.8
15	3.0	1.0 x 1.1	0.6 x 0.6	1.2	8.7
15	3.5	1.0 x 1.0	0.7 x 0.8	1.3	7.6
40	3.5	3.2 x 3.6	0.6 x 0.8	1.8	8.5
40	4.0	2.3 x 2.5	1.2 x 1.2	1.2	10.8
40	4.5	2.8 x 3.4	1.2 x 1.2	1.5	10.0
<u>Series 2: 2.0-ft frozen surface layer (5 December 1979)</u>					
15	2.0	1.2 x 1.5	0.4 x 0.4	0.7	8.0*
15	2.5	1.4 x 1.8	0.4 x 0.5	0.8	8.5*
15	3.0	0.9 x 1.0	0.4 x 0.4	0.5	5.8
15	3.5	1.1 x 1.2	0.4 x 0.4	0.5	9.4
40	3.5	2.4 x 2.7	1.2 x 1.2	1.3	9.2
40	4.0	2.3 x 2.5	1.2 x 1.2	1.0	9.0
40	4.5	2.6 x 3.3	1.0 x 1.0	1.4	4.0+
<u>Series 3: 3.7-ft frozen surface layer (5 February 1980)</u>					
15	2.0	0.7 x 0.8	0.3 x 0.3	0.6	7.3
15	2.0	0.8 x 1.5	0.3 x 0.4	0.4	12.2**
15	2.5	0.9 x 1.0	0.3 x 0.3	0.5	6.1
15	2.5	1.7 x 1.8	0.4 x 0.6	0.7	8.2**
15	3.0	1.1 x 1.2	0.4 x 0.4	0.5	6.1
15	3.0	0.7 x 0.7	0.3 x 0.4	0.1	9.4++
15	3.5	1.2 x 1.4	0.3 x 0.3	0.4	10.0
15	3.5	1.4 x 1.6	0.4 x 0.5	0.5	11.0**
40	3.5	3.5 x 3.9	1.0 x 1.0	1.2	***
40	3.5	3.3 x 4.0	0.9 x 1.2	1.5	7.5**
40	4.0	2.2 x 2.6	0.8 x 0.9	0.7	7.0
40	4.0	2.3 x 2.3	0.8 x 1.2	0.9	6.8**
40	4.5	2.2 x 2.5	0.7 x 0.9	0.8	3.1+
40	4.5	2.6 x 2.8	0.7 x 1.2	0.9	9.9**

*Mud clods had to be removed from the surface crater to make the measurements.

+The hole would have to be cleaned with a post-hole digger; it was apparent that it was blasted deeper.

**The shot was fired in the same location as the previous shot.

++Before this shot, a 15-lb shaped charge was detonated in the vicinity of the previous hole. This extra shot created a crater around the previous hole. The measurements on this line were taken from the bottom of the crater of the extra shot.

***The hole was filled with disturbed mud clods and by-products of the detonation. It was apparent that the hole had been blasted deeper and would have been easy to clean out with a post-hole digger.

The frozen surface layer was about 3 ft 8 in. thick in February 1980, when the third test series was conducted. During this series I decided to try to increase the cross section size of the borehole by firing a second shaped charge in the same location as the first. The data indicate that the maximum cross section measurement of the hole was increased by about one-third by double firing with either charge weight. However, the minimum cross section measurements for the 15-lb charges were still not large enough to allow placement of the 7-in.-diameter crater charge. The cross section dimensions of the holes from the 40-lb charges were more than adequate, even before the double firing. There were some rather large increases in total hole depths (e.g. at standoff distances of 2.0, 2.5, and 3.0 ft with the 15-lb charge) with the double firing. However, there was little need to increase the depth of the holes as produced by a single firing, except where the holes were clogged with frozen soil clods.

CONCLUSIONS

The 15-lb shaped charge fired at standpoint distances of 2.0, 2.5, 3.0 and 3.5 ft over unfrozen silt with a moisture content between 15 and 35% produces a borehole of sufficient size to accommodate the 40-lb cratering charge. The cross section size for a standoff of 2.5 ft agrees with Table 3-5 of FM 5-25, but the depth is 1 ft greater. The optimum standoff distance is 2.5 ft. There is no need to use the 40-lb shaped charge to blast a borehole for the 40-lb cratering charge in the unfrozen silt; in fact, it would be a waste of munitions and an extra burden for the combat troops.

The cross section size for the 40-lb charge at a standoff distance of 4.0 ft agrees with that in FM 5-25, but the depth is 2 ft greater. When the seasonal frost layer in silt is only 2 ft thick, the 15-lb shaped charge does not produce a borehole with a large enough cross section to accommodate the 40-lb cratering charge, but the 40-lb shaped charge is more than adequate. Firing two 15-lb shaped charges at the same location with a frozen surface layer of silt about 3 ft 8 in. thick increases the cross section dimensions of the borehole by about one-third. However, the holes are still not adequate. Double firing has a greater effect on the total depth than on the cross section (nearly doubling the depth); however, the depths with single firings are nearly always adequate. Table 3-5 of FM 5-25 lacks data for partially frozen soil.

The 40-lb shaped charge fired with a 3.5-ft standoff distance on unfrozen silt or on silt frozen to a depth of about 3 ft 8 in. produce a borehole larger than is required to accommodate the 40-lb cratering charge.

RECOMMENDATIONS

Tests similar to these should be conducted in granular soils. Tests should also be conducted on unfrozen and frozen gravel-surfaced and paved roads and airfields with various depths of seasonal frost. Bulk explosives should be tested in the boreholes produced with the 15-lb and 40-lb shaped charges in both unfrozen and frozen soils to compare the cratering results with those of the standard 40-lb cratering charge. The advantages and disadvantages of using bulk explosives for these applications should be determined. FM 5-25 should be updated with these data and any new data as they become available.