RAPID RUNWAY CUTTING WITH SHAPED CHARGES

Charles E. Joachim

U. S. Army Engineer Waterways Experiment Station

ABSTRACT

Research has shown that removal of large, partially damaged, concrete runway slabs is a major element in the time required to perform a runway repair operation. A rapid method for cleanly cutting away damaged sections would significantly reduce overall repair time. Shaped charges are potentially just such a rapid runway cutting technique. This paper presents the results of field tests designed to evaluate the runway cutting abilities of standard and linear shaped charges. A series of 25 runway cutting tests was conducted on the 1-ft-thick (4 in of asphalt + 8 in of concrete) undamaged taxiway segments constructed for a recent Air Force test program at the White Sands Missile Range. Although TOW warhead charges successfully penetrated well into the subgrade, no cracks were observed between holes, even at the closest charge spacing. Arrays of linear shaped charges were successfully fired to produce a relatively smooth, uniform cut through the concrete. It was found that inexpensive, "homemade" linear charges gave results comparable to commercially manufactured charges.

BACKGROUND

The U. S. Army Corps of Engineers is charged with responsibility for runway repairs at U. S. Air Force (USAF) airfields damaged by conventional attack when such repairs exceed USAF on-site capabilities. The importance of this wartime mission is obvious in light of our commitments in both Europe and the Middle East, where rapid aerial reinforcement and resupply will be essential. Research on Repair and Restoration of Paved Surfaces (REREPS) has been performed at the Waterways Experiment Station (WES) to develop an improved Army capability for rapid runway repair under combat conditions.

REREPS research has shown that removal of large, partially damaged, concrete runway slabs is a major element in the time required to perform a runway repair operation. A rapid method for cleanly cutting away the damaged portions of these slabs is needed to significantly reduce overall repair time. Some cutting techniques currently under investigation include concrete saws, water jets and shaped charges. This paper presents the results of shaped charge runway cutting tests conducted by the WES Structures Laboratory (with the assistance of personnel from Company D, 52nd Engineer Battalion (Ft. Bliss, TX)) at the White Sands Missile Range, NM.

OBJECTIVE

The study objective was to evaluate shaped charges as a means for rapidly cutting damaged runways. Specific test objectives were to evaluate the runway cutting abilities of conical shaped charges, and commercially manufactured and "homemade" linear shaped charges.

APPROACH

Shaped charge runway cutting tests were conducted on undamaged taxiway segments constructed for recent Air Force quantity-distance experiments at the Queen 15 site on the White Sands Missile Range, NM. The taxiways were built to design standards currently in use at USAF Europe bases in Germany. Pavements consisted of 8 in thick unreinforced concrete slabs overlain by 4 in of asphalt, and underlain by a 6 in stabilized aggregate base course over a compacted subgrade (Figure 1).

WES obtained a number of surplus TOW (Tube-launched, optically-tracked, wire-guided, antitank weapon) warheads. The TOW warhead consists of a conical shaped charge approximately 5 in diameter containing 5.4 lb Composition B explosive (Figure 2). The warheads were fired individually to determine optimum standoff and in linear arrays to determine if the slab would fracture between penetrations. The charges were statically fired with the windbreak left inplace giving a minimum shaped charge standoff of 4.2 in. Standoffs for individual firings ranged from this minimum to a maximum of 2.85 ft. The linear arrays were fired with spacings of 9, 12, and 18 in, all using the minimum standoff.

Commercial linear shaped charges were purchased "off the shelf" from Jet Research, Inc (JR), Arlington, Texas, in 2.5 and 4.5 lb/ft designs. The charges contained Composition B as the primary explosive. The manufacturer's quoted price was $125 and $145 per ft length, respectively. The 2.5 lb/ft charge came with an underwater housing

(Figure 3), giving a minimum standoff of 1.75 in. The 4.5 lb/ft charge (Figure 4) could be placed directly on the target surface (0 in minimum standoff, i.e., with no standoff).

In an earlier study at WES, the effectiveness of nitromethane (NM) as an explosive source in "homemade," conical shaped sharges was investigated. Although it was found that twice as much NM was needed to obtain the same shaped charge penetration depth as standard shaped charges using solid explosive, it was felt that NM has several overriding advantages. The advantages of using for example; 1) it is classified as a flammable liquid and is shipped and stored as such, and 2) as a liquid it has uniform properties and assumes the shape of the container used. Conventional shaped charges, on the other hand, use high explosives and are subject to the shipping and storage restrictions of those materials, with controls much more stringent than those for flammable materials. Because of these reduced restrictions, the use of NM for runway cutting charges could be a distinct advantage at USAF Europe bases, with their congestion and limited munition storage capacities.

The NM linear shaped charge container used in these tests was designed and fabricated at WES. This container is shown in Figure 5 (plan and cross-sectional view). A 3/16 in thick brass liner with 60° included angle and 4 in throat width was selected for this charge. Thus, the liner thickness is 4.7 percent of the throat width, which is larger than the normal range of 0.5 to 3 percent for conical shaped charges. Limited comparative testing with 1/8 and 3/16 in thick liners at WES indicates that the thicker liner performed better for soil penetration. A 4 ft charge length was selected to insure that the detonation would propagate in a linear fashion.

RESULTS

Shot geometry and penetration data are presented in Table 1. The holes produced by all TOW warhead firings are sketched in Figure 6. The TOW penetrated the pavement without difficulty, reaching a maximum hole depth of 7.2 ft at the minimum standoff of 0.35 ft. Typically, the warhead cratered the 4 in thick bituminous surface layer of the pavement, and punched a hole on the order of 2 in in diameter through the underlying concrete and well into the subgrade. However, no interhole concrete cracking was noted in any of the linear arrays (even with a charge spacing as close as 9 in), although the asphalt layer was usually excavated between shot holes by the blast.

The NM linear shaped charge craters are sketched in Figure 7. These charges showed a capacity to satisfactorily penetrate the taxiway. The maximum penetration of 1.0 ft was obtained from charges at 4 in standoff, or one throat width above the surface. Typically, the crater width in the asphalt was 2 ft, or 3 to 4 times the crater width in the underlying concrete. When individually-boosted NM linear shaped charges were placed end-to-end and detonated through a primacord ring main, they successfully sustained a relatively uniform cutting action over the length of the array.

Craters produced by the JR commercial linear shaped charges are sketched in Figures 8 and 9 (2.5 and 4.5 lb/ft charges, respectively). The charges performed best at the manufacturer's built-in standoffs of 1.75 and 2.25 in for the 2.5 and 4.5 lb/ft charges, respectively. The smaller charge did not completely penetrate the concrete. The larger JR charge, like the NM charge, was just adequate for this purpose. It also demonstrated the capability to excavate a relatively smooth cut over whatever distance might be desired, including a cut around a 90° corner (Shot 25).

DISCUSSION AND CONCLUSIONS

An early Picatinny Arsenal report (Reference 1) indicates that the conical shaped charge penetration roughly scales in proportion to the cube root of the explosive charge weight in permafrost. Using the analogy of spherical cratering charges to linear cratering (ditching) charges, square root scaling of linear shaped charge penetration is suggested as a logical extension. The maximum penetration of the 2.5 and 4.5 ft/lb JR charges and the WES 12 lb/ft NM charge are plotted in Figure 10 in an attempt to provide information for prediction of the linear shaped charge necessary to cut various runway thicknesses.

Square root scaling curves are presented in Figure 10 for the 4.5 lb/ft JR charge and the WES 12 lb/ft NM charge. The 2.5 lb/ft JR charge penetration data point falls 38% below the prediction curve. This is probably due to the fact that the smaller JR charge was not an exact physical model of the larger charge, and partly due to normal data scatter. A larger sample of penetration versus optimum standoff data is necessary before a statistical scaling relation can be determined.

The TOW warheads are not by themselves usefull in cutting runway slabs. Linear shaped charges are a feasible method for rapidly cutting runways so as to permit removal of damaged slabs. Final proof of this awaits a full scale demonstration to include removal of a slab.

REFERENCES

1. Klamer, Oscar A., "Shaped Charge Scaling," Technical Memorandum 1383, March 1964, Ammunition Engineering Directorate, Picatinny Arsenal, Dover, NJ.

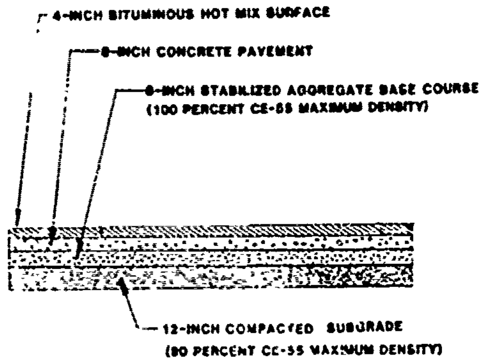

Figure 1. Typical DISTANT RUNNER taxiway cross-section. "CE-55" refers to a standardized compactive effort developed by the American Association of Highway Officials.

Figure 2. TOW warhead being placed nose down on pavement for firing.

Figure 3. Two 2.5-lb/ft JR charges with underwater housing.

Figure 4. Two 4.5-lb/ft JR charges mounted end-to-end on manufacturer-furnished standoff.

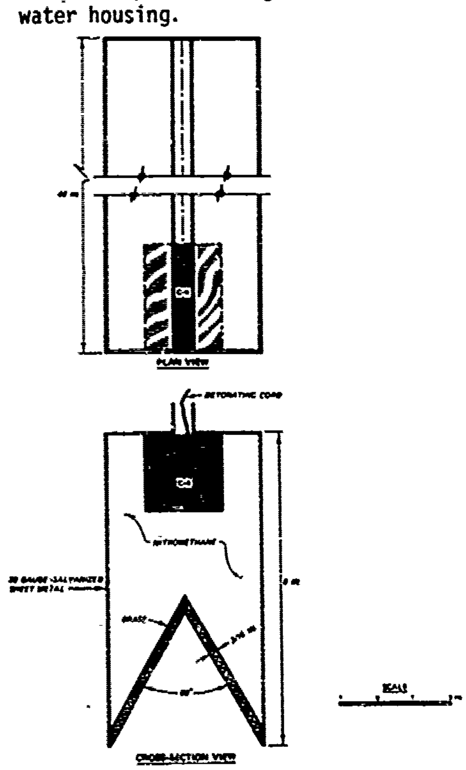

Figure 5. Design of 12.0-lb/ft nm linear shaped charge.

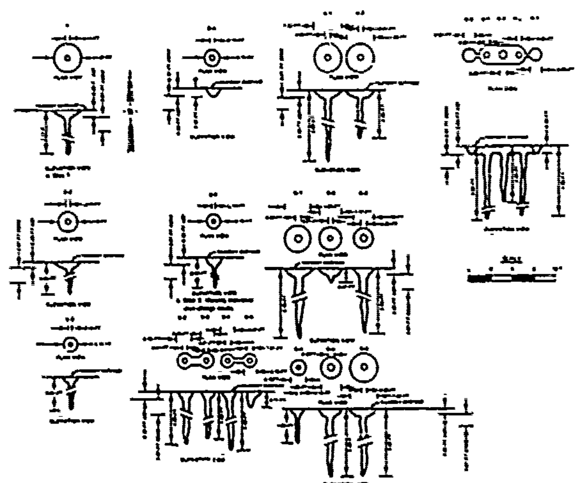

Figure 6. Results of TOW warhead shots. "CONC" and "ASP" identify concrete and asphalt.

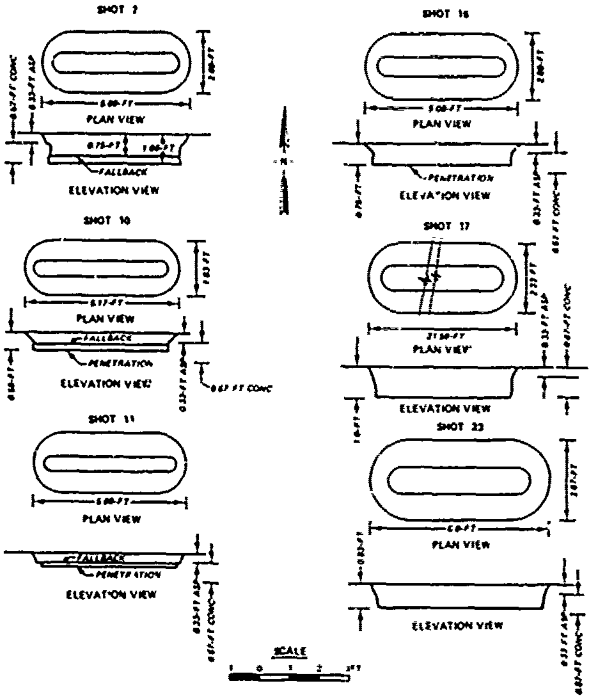

Figure 7. Results of NM charges.

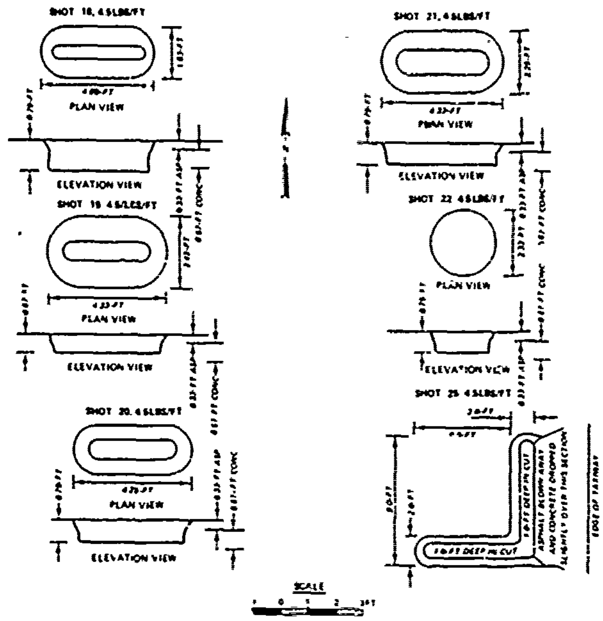

Figure 9. Results of JR 4.5-lb/ft charges.

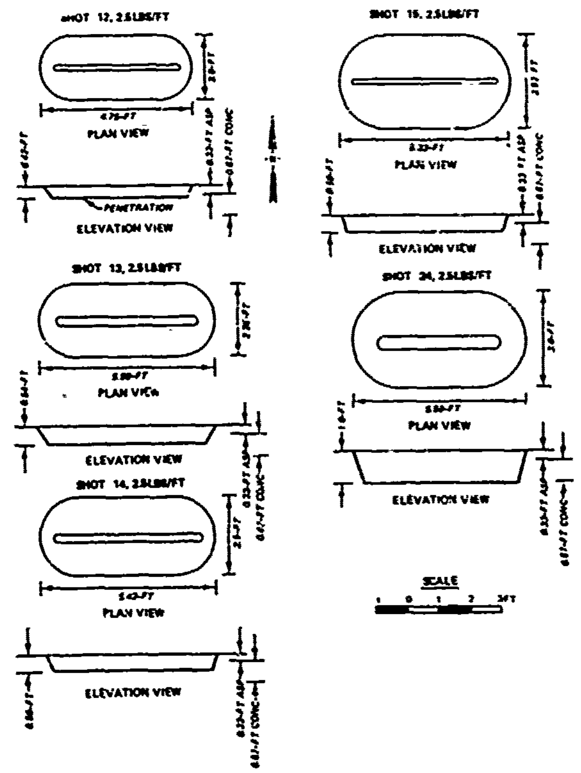

Figure 8. Results of JR 2.5-lb/ft charges.

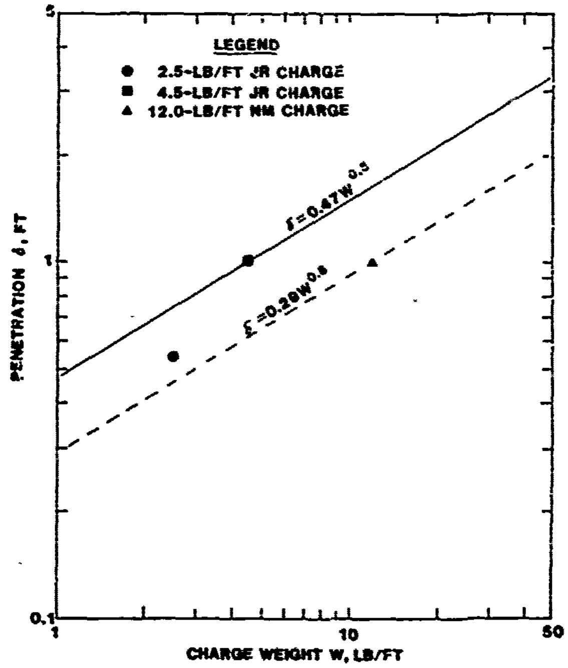

FIGURE 10. LINEAR SHAPED CHARGE TAXIWAY PENETRATION VERSUS CHARGE WEIGHT.

Table 1. Shot Schedule and Results

Shot Day/Time August 1982	Shot No.	Charge No.	Charge Type	Location*	Shot Geometry Standoff ft	Shot Geometry Spacing ft	Shot Geometry Description	Results Penetration ft	Results Description	Figure No.
16/0958	1	--	TOW	E-12	0.35**	--	Nose cone on pavement	7.17	0.17 ft diameter	8
16/1104	2	-1	TOW	E-12	0.83	--	--	--	Fell over during detonation, shallow crater	8
		-2	TOW	E-13	1.35	--	--	5.25	0.17 ft diameter	8
		-3	TOW	E-13	1.85	--	--	5.67	0.12 ft diameter	8
		-4	TOW	E-14	2.35	--	--	0.42	hole plugged	8
		-5	TOW	E-14	2.85	--	--	5.33	0.12 ft diameter	8
16/1208	3	-1	TOW	C-13	0.35	1.00	Nose cone on pavement	--	Malfunctioned†	
		-2	TOW	C-13	0.35	1.00	Nose cone on pavement	4.83	0.21 ft diameter; shallow connection to 3-3	8
		-3	TOW	C-13	0.35	1.00	Nose cone on pavement	4.42	0.17 ft diameter; shallow connection to 3-2	8
		-4	TOW	C-13	0.35	1.00	Nose cone on pavement	5.42	0.21 ft diameter; shallow connection to 3-5	8
		-5	TOW	C-13	0.35	1.00	Nose cone on pavement	0.71	0.21 ft diameter; shallow connection to 3-4	8
16/1330	4	-1	TOW	C-12	0.35	1.5	Nose cone on pavement	5.83	0.25 ft diameter	8
		-2	TOW	C-12	0.35	1.5	Nose cone on pavement	3.25	0.21 ft diameter	8
		-3	TOW	C-12	0.35	1.5	Nose cone on pavement	--	Malfunctioned†	
		-4	TOW	C-12	0.35	1.5	Nose cone on pavement	--	Malfunctioned†	
		-5	TOW	C-12	0.35	1.5	Nose cone on pavement	--	Malfunctioned†	
16/1447	5	-1	TOW	C-12	0.35	1.5	Nose cone on pavement	5.75	0.33-ft diameter	8
		-2	TOW	C-12	0.35	1.5	Nose cone on pavement	0.67	0.21-ft diameter	8
		-3	TOW	C-12	0.35	1.5	Nose cone on pavement	5.50	0.33-ft diameter	8
		-4	TOW	C-12	0.35	1.5	Nose cone on pavement	1.58	0.22-ft diameter	8
		-5	TOW	C-12	0.35	1.5	Nose cone on pavement	5.42	0.33-ft diameter	8
		-6	TOW	C-12	0.35	1.5	Nose cone on pavement	5.42	0.25-ft diameter	8
17/0934	6	-1	TOW	W-13	0.35	0.75	Nose cone on pavement	--	Shallow crater through asphalt only	8
		-2	TOW	W-13	0.35	0.75	Nose cone on pavement	4.83	0.29-ft diameter; connected to 6-3 by trench through asphalt	8
		-3	TOW	W-13	0.35	0.75	Nose cone on pavement	2.25	0.38-ft diameter; connected to 6-2 and 6-4	8
		-4	TOW	W-13	0.35	0.75	Nose cone on pavement	[illegible]	0.25-ft diameter, connected to 6-3 by trench through asphalt	8
		-5	TOW	W-13	0.35	0.75	Nose cone on pavement	--	Shallow crater through asphalt only	8
17/1103	7	--	SM	E-11	0.33	--	--	[illegible]	0.25 ft fallback	9
17/1239	8	--	SM	E-11	0.67	--	--	--	Misfire	
17/1323	9	--	SM	E-11	0.67	--	--	--	Misfire	
17/1405	10	--	SM	E-11	0.67	--	--	0.58	Some fallback	9
17/1453	11	--	SM	C-11	1.50	--	--	0.46	Some fallback	9

Table 1. Concluded

Shot Day/Time August 1982	Shot No.	Charge No.	Charge Type		Location*	Shot Geometry Standoff ft	Shot Geometry Spacing ft	Shot Geometry Description	Results Penetration ft	Results Description	Figure No.
18/1036	12	--	JR	2.5 lb/ft	W-11	0.15	End to end	4 charges	0.42	Some cracking below penetration	10
18/1127	13	--	JR	2.5 lb/ft	W-12	0.48	End to end	2 charges	0.54	--	10
18/1250	14	--	JR	2.5 lb/ft	CW-11	0.31	--	--	0.50	--	10
18/1337	15	--	JR	2.5 lb/ft	E-11	0.15	--	--	0.50	Concrete cracked below penetration	10
18/1430	16	--	SM		CW-12	1.00	--	--	0.75	--	9
18/1522	17	--	SM		C-10	0.33	End to end	5 charges	1.00	--	9
19/1015	18	--	JR	4.5 lb/ft	C-11	0.19	End to end	2 charges	0.79	--	11
19/1050	19	--	JR	4.5 lb/ft	C-10	0.00	End to end	2 charges	0.67	--	11
19/1127	20	--	JR	4.5 lb/ft	C-11	0.38	End to end	2 charges	0.79	--	11
19/1248	21	--	JR	4.5 lb/ft	C-10	0.56	End to end	2 charges	0.79	--	11
19/1327	22	--	JR	4.5 lb/ft	E-10	0.28	End to end	2 charges	0.75	--	11
19/1413	23	--	SM		C-10	0.00	--	Single charge	0.83	--	9
19/1451	24	--	JR	2.5 lb/ft	E-11	-0.19	End to end	2 charges placed over crack in concrete from shot 15 (below original surface).	1.00	Total penetration shots 15 and 24	10
20/0944	25	--	JR	4.5 lb/ft	E-9	0.19	End to end	Charges in "L" formation. 5 charges in each leg.	1.00	--	11

* Expansion-joint "coordinates": east, center, west (E, C, W)--joint no.
** Includes built-in standoff in nose (0.35 ft).
† Apparently detonated, but produced no penetration or crater.