BAM BAM: LARGE SCALE UNITARY DEMOLITION WARHEADS

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Unitary Demolition Warheads (UDW) is an extremely efficient demolition technology that incorporates the defeat mechanisms of a multi-stage munition into a single warhead concept. UDW consists of a unitary shaped charge warhead that delivers energetic material into the target during the jet formation. Reactive material releases its energy inside of the target, producing extremely large amounts of damage to concrete, masonry or geologic material targets. The initial concept was developed using high-rate continuum modeling and demonstrated in an 81mm shaped charge configuration. UDW warheads were computationally scaled-up and evaluated against large roadway and bridge pier representative targets. This new warhead technology is the most effective unitary concrete damaging warhead known to date.

INTRODUCTION

The internal release of explosive energy inside a structure is a much more efficient method for the demolition of concrete and geologic formations than externally placed explosives. A commercial example of this is the manual drilling, and then filling of holes with explosive materials as seen in mining operations. Other examples include the use a dual stage munition with a separate penetration device and follow-through charge [1]. Military applications may also apply this principle using a stand alone shaped charge device along with a separate blast charge, as used for cratoring applications, or may use a dual warhead system with a complex fuzing apparatus. Other schemes have also been used to enhance target damage using a variety of single and multiple shaped charge jets [2-4].

Previously, the Warheads Group at the U.S. Army Armament Research and Development Center, Picatinny, NJ, USA, demonstrated the concept of an extremely efficient demolition technology that incorporates the defeat mechanisms of a multi-stage munition into a unitary warhead concept [5]. These Unitary Demolition Warheads (UDW) produce an energetic shaped charge jet that releases its energy inside of the target, producing extremely large amounts of damage to concrete, masonry or geologic material targets never previously achieved from a shaped charge warhead.

This paper presents the scaled-up of UDW technology from the 81-mm conceptual design to a 220-mm tactical design configuration for use against demolition type targets. The scaling effects of reactive liner shaped charge jet characteristics and target interactions were investigated. The tactical UDW was computationally modeled in CALE and required some geometric design modifications, since many variables such as detonation velocity and reaction kinetics do not scale directly with geometry.

UDW CONCEPT DEVELOPMENT

The UDW concept was previously developed to 'rubblize' concrete and the initial configurations were called 'Barnie' warheads. The concept was investigated through the use of the high-rate dynamic continuum modeling programs CALE and DYNA, which modeled the material response of the energetic materials. These materials were evaluated for energy output and strength characterization. The JAGUAR thermochemical equation of state program was used for energy output calculations. The computational design process concentrated on producing a reasonable jet length, while eliminating reactive material cavitation during jet formation, as well as maintaining relatively low jet formation pressures in the chemical energy material. Developmental testing was conducted in an 81-mm warhead configuration loaded with 70/30 Octal explosive. Test results showed a tremendous increase in concrete target damage over a standard mass matched shaped charge lined device. Figure 1 compares the damage to a 1.5 m (five foot) diameter concrete culvert from a previously developed Barnie reactive lined warhead and a similar warhead with a mass matched aluminum liner.

TACTICAL SMALL-SCALE DESIGN

The first step in the scale-up process was to computationally design and test Barnie warheads in a tactical configuration using pressed explosives. The initial concept designs were previously cast loaded with Octol 70/30 explosive into right-circular cylindrical aluminum warhead bodies with an inside diameter of 81mm, an overall charge length of approximately 180mm and an overall weight of about 1.8 kg. Though

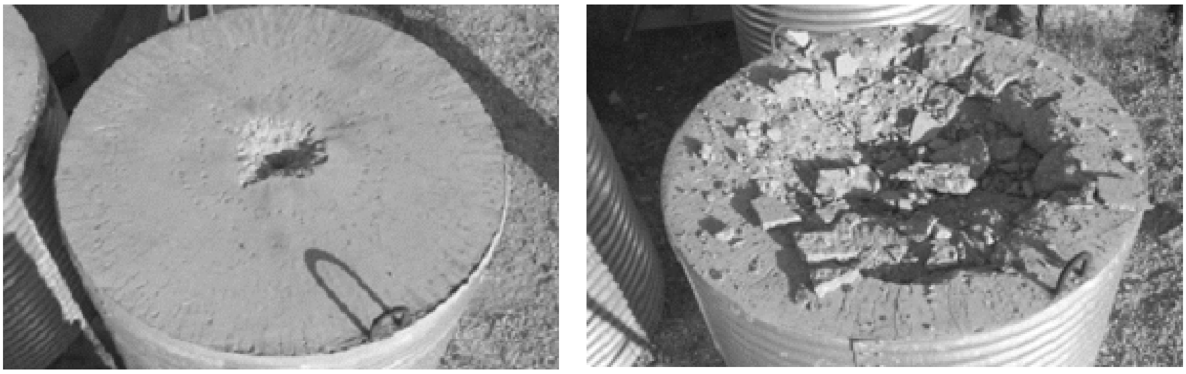

Figure 1. Comparison of concrete damage from the previously developed Barnie warhead with the reactive liner verses a mass matched aluminum liner.

a charge length to diameter ratio greater than two is not generally required for this type of warhead, the extra length provides for ease in explosive casting and the straight wall configuration somewhat reduces precision requirements compared to tactical boat tail billet configurations, by providing higher charge to mass ratios. The reduction in precision requirements helps to ease the process of comparing developmental liner materials and geometries. Cast loading is also a convenient method for evaluating multiple developmental warhead designs because it eliminates the need for fabricating a press punch for each shaped charge liner configurations. However, the extra explosive length and weight of these cast warheads is not desirable for a tactical warhead design.

As such, warhead designs were modeled using the high-rate dynamic continuum modeling program CALE in order to reduce the overall warhead length, while maintaining similar jet characteristics. In addition, a rear boattail was incorporated into the explosive billet to further reduce overall weight. The press-loadable explosive LX-14 was as a replacement for the Octol explosive fill. For comparison purposes, baseline warhead designs were modeled with both explosives using the long body configuration (cast body) and in a foreshortened configuration (boat tail). A mass match aluminum liner was used for the initial boat tail calculation studies. In addition, LX-14 loaded boat tailed designs were modeled with a head height (distance between the liner apex and rear of the charge) of 60, 70 and 80 percent of the warhead diameter.

For the mass matched aluminum liner designs, the resulting computational outputs showed a drop in tip velocity of about 0.7 km/sec from the long to short body configuration for both explosives. There was a calculated increase of 0.4 km/sec when the Octol was replaced with the LX-14 explosive for both the long and short body configurations. When tip velocities for the aluminum lined devices were compared to the reactive lined designs, there was a calculated drop of only 0.1 km/sec for the longer body configurations and a drop of 0.2 km/sec for the short body configurations, indicating the designs are fairly robust and independent of liner material. A drop of 0.1 km/sec was calculated for each ten percent reduction in head height for the LX-14 loaded boattailed designs. In addition, there were no observed cavitations of the reactive material during jet formation. Figure 2 presents the CALE output for several of these design configurations.

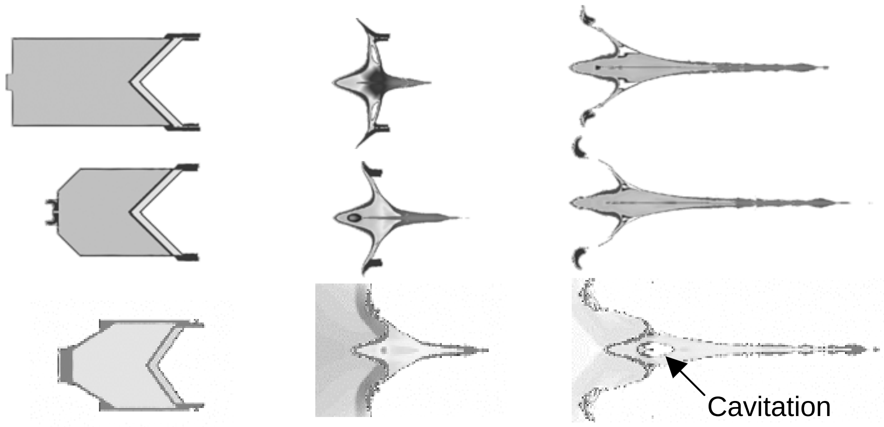

Figure 2. CALE density output for cast Octol Barnie warhead (top), LX-14 press load tactical Barnie warheads (middle) and an example of energetic material cavitation (bottom).

Based on these results, warheads were fabricated using a near net shaped pressed LX-14 explosive billet that was machined to final configuration. The finished warheads weighed a total of 1.2 kg, representing a 30% reduction in overall weight. The warheads were tested against a 1.5 m (five foot) diameter concrete filled culvert to compare performance results. Test results of a tactical Barnie warhead against geologic and concrete structures are presented in figure 3.

LARGE SCALE WARHEAD DESIGN

UDW technology was scaled-up and tested against large size targets. The large tactical design configuration, named Bam Bam, was designed as a unitary system that uses a standard field detonator for initiation. It is less complex and easier to use than other multi-stage demolition systems that require multiple warheads, multiple fuze systems and delay timers.

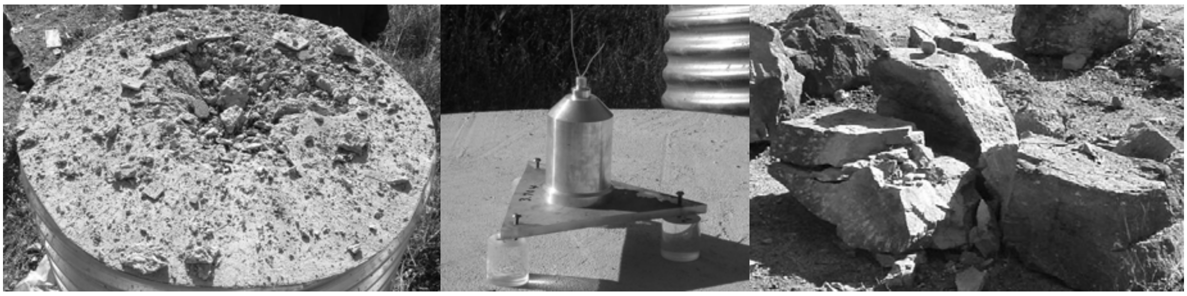

Figure 3. Test results of a tactical Barnie warhead against concrete and geologic structures.

An overall weight constraint for the Bam Bam warhead was set at 18.1 kg (forty pounds) to provide the highest performance possible, while staying within soldier carry-weight guidelines. Of major concern was whether the jet properties of the reactive liner material and the reaction kinetics would scale-up proportionally with warhead dimensions. Warheads were first scaled to an intermediate weight of 13.6 kg (thirty pounds) and approximately 200mm (eight inches) in diameter. Designs were dimensionally scaled directly from the small-scale tactical warhead and computationally modeled using the high-rate dynamic continuum modeling program CALE.

The CALE output showed a decrease in jet tip velocity of 0.7 km/sec due to scale-up issues. Computational studies showed that increasing the liner angle by fourteen degrees further reduced the tip velocity by 0.7 km/sec. Decreasing the liner angle by ten degrees increased the tip velocity by 0.4 km/sec, bringing the velocity back up to within 0.2 km/sec of the tactical Barnie warhead. Based on these results, a reduced liner angle design (reduced by ten degrees from Barnie) was scale to the forty pound version and modeled in CALE. The resulting output showed the tip velocity was increased by 0.4 km/sec. In all cases, there was no reactive material cavitation of the jet due to the scaling process.

It is interesting that the velocity dropped when scaling from the 1.2 kg (2.7 pound) tactical Barnie warhead to the thirty pound size, but then increased when scaled to forty pounds. However, there are competing phenomenon that can influence the tip velocity, including the charge to mass liner ratio, inverse jet tip velocity gradients [6] for liners with pointed apexes and perturbations of the tip velocity due to perturbations in the very rapid early liner accelerations associated with initial shock loading [7]. Typical CALE outputs are presented in figure 4.

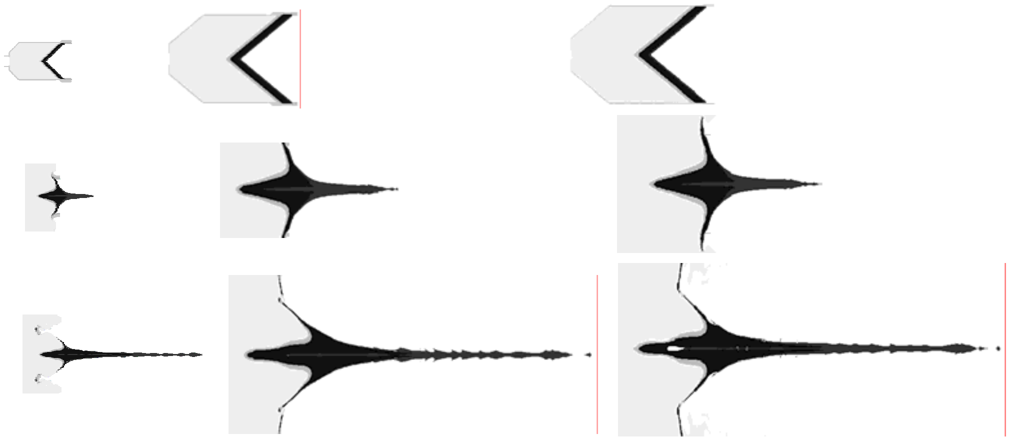

Figure 4. CALE outputs comparing boundary conditions for the 2.7 lbs (left), 30 lbs (center) and 40 lbs warheads (right).

18.1 kg (forty pound) Bam Bam warheads were subsequently press loaded with LX-14 explosive and experimentally evaluated against concrete-filled culverts, standard 8-inch asphalt roadways and against a 1.5 m by 1.8 m by 5.5m (5-foot by 6-foot by 18-foot) reinforced concrete bridge target. Bam Bam produced significant cratering in the asphalt roadway and produced severe damage to the bridge pier targets. Test results are presented in figures 5-7. The test results clearly show that the scale-up effect was extremely successful, producing extremely high target damage and cratering.

Figure 5. Bam Bam warhead tested against a 1.5m (five foot) diameter concrete culvert.

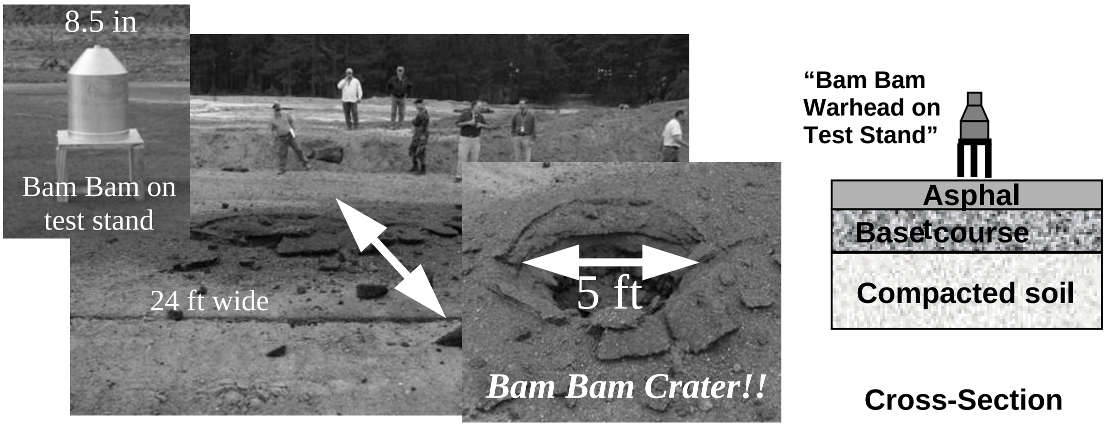

Figure 6. Bam Bam test results against a standard eight inch thick asphalt roadway.

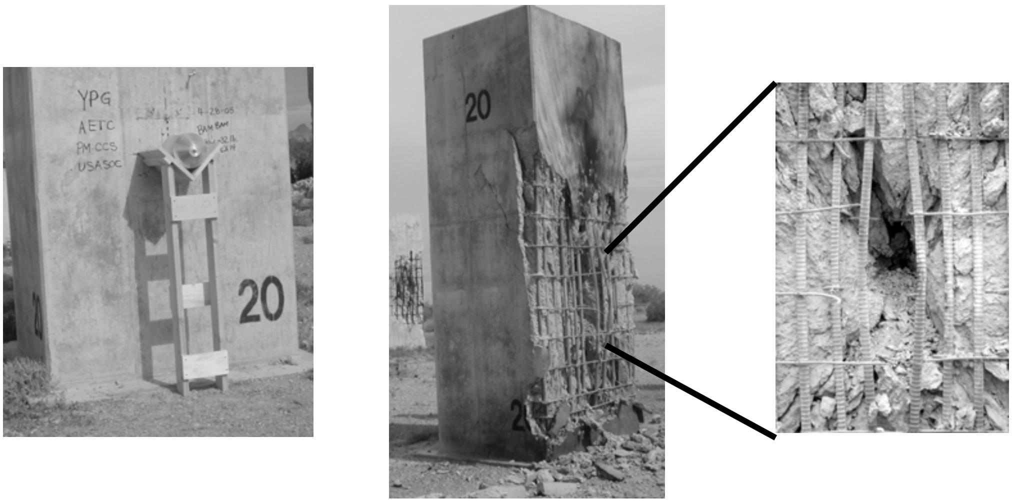

Figure 7. Test result of Bam Bam against a 1.5-m by 1.8-m by 5.5-m (5-ft by 6-ft by 18-ft) steel reinforced concrete target.

CONCLUSIONS

The initial Unitary Demolition Warhead concept was scaled-up and successfully tested against full size roadway and reinforced concrete targets. High-rate continuum modeling was used to evaluate and select potential warhead designs for experimental demonstration and verification. Shaped charge jet tip velocities and other jet characteristics were affected by explosive type and warhead configuration, but were successfully modified using modeling and simulation tools. Unitary Demolition Warheads are less complex than other multi-stage demolition systems that require multiple warheads, multiple fuze systems and delay timers. This new warhead technology is the most effective unitary concrete damaging warhead known to date.

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