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Exploration of Technologies of Use to Civil Security Forces

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Abstract

This is the final report of a two-year, Laboratory Directed Research and Development (LDRD) project at the Los Alamos National Laboratory (LANL). The objective was to determine whether armor tile technology could be used to solve problems of civil law enforcement as identified by the New Mexico State Police. Most of the effort focused on the design and construction of a lightweight, portable box that could contain the shrapnel and redirect the blast from a steel-pipe/black-powder bomb. The bomb box task was carried out in collaboration with two companies, Foster Miller, Inc. and Ordnance Body Armor Co., who constructed most of the boxes tested. The results of the tests indicated that soft, flexible fabrics are superior to hard tiles in containing the bomb fragments. Subsequent to our experiments, Foster Miller has developed a bomb container that is commercialized and is currently being sold to law enforcement agencies.

Background and Research Objectives

This project evaluated the use of flexible armor tiles in conjunction with the most advanced equipment available to civilian security forces. A technology developed in a previous Laboratory/industry collaboration, these tiles contain ceramic or kevlar plates and high-strength polymers to minimize weight and for ballistic applications. In addition, we have developed new, functional graded ceramic/metal and ceramic/polymer systems that could offer even better protection. Three applications were evaluated --bomb disposal containers, portable armor, and protective vests.

Present bomb-containment systems consist of large, heavy containers made of concrete or steel. Such a container is mounted on a trailer, which is towed to the site of a suspected explosive device. The explosive device is removed from a building, at high risk

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to bomb-disposal personnel, and then is placed into this container. This method is time-consuming, inflexible, and does not protect the public, the building or bomb-disposal personnel during the bomb removal phase. Our objective was to determine whether lightweight, portable bomb containers using flexible armor tiles could be used to contain the explosive device during all phases of transportation away from its discovered location.

Conventional ballistic vests are designed to protect the torso of the wearer against pistol-fired bullets of various degrees of velocity and weight. Typical vests used by civil security forces will withstand most common pistol rounds, but they are vulnerable to penetration by sharp objects such as a "shiv" or ice pick because the object will penetrate woven fabrics. Such objects are common in prison riot situations and are becoming increasingly common in "street" police encounters. We found a commercially available, very light weight aluminum/fiberglass laminate material that in preliminary tests demonstrated a very high penetration resistance to ice picks. We have developed a flexible tile concept to apply these to a normal ballistic vest.

Police vehicles typically have no armor protection. When police encounter a situation in which the criminal has a high-powered rifle, they have to call for special armored vehicles, often available only from the National Guard, to approach the criminal or to rescue police officers who already may be shot and in need of medical help. Our discussions with the New Mexico State Police have uncovered a need for a portable armor blanket that can be temporarily attached to a police vehicle and would provide protection during an assault or rescue operation. Our flexible armor tile technology is ideal for this situation, offering lightweight portability, flexibility, and easy attachment to a police vehicle.

In this project we evaluated the potential for use of tile technology and developed concepts for how tiles would be used for each application. Because of time and resources constraints, we have not pursued portable armor and protective vests applications any further.

Importance to LANL's Science and Technology Base and National R&D Needs

Advanced materials is a Laboratory core competency. Pursuit of the applications in this project will open up a possibility for applying our knowledge of advanced materials to develop new functional graded ceramic-polymer systems. These functional graded systems then may be applied to the needs of the weapons program. Nationally, functional graded ceramics offer a solution to the classic problem of ceramic applications: brittle failure.

Scientific Approach and Accomplishments

In the first year substantial progress was made in defining the needs of security forces for the new tile technology. Discussions with the New Mexico State Police, the Laboratory Emergency Management Office Bomb Team and the Office of Law Enforcement Technology Commercialization provided feedback on initial concepts and led to designs that were constructed by the Foster Miller Company and were tested in September, 1996.

In the second year we tested four box designs, two that were designed at LANL and two that were designed by the Last Armor Division of the Foster Miller Company. The Last Armor boxes were designed to meet a severe cost limitation and the LANL boxes were designed to maximize the capture of fragments. The Los Alamos concept was based on laminated Kevlar panels wrapped with Kevlar restraining bands and was based on our experience with designing ballistic armor for the C-141 aircraft. In the Los Alamos design, the computer code BLASTX, provided by the Army Research Laboratory, was used to calculate the peak pressure. All of the boxes were designed to beat a 2-inch-diameter by 8-inch-long steel pipe containing about 14 ounces of black powder. These designs were tested in two separate tests, one in June and one in September, 1997.

As a result of these tests, the Foster Miller Company has begun commercial production of a low-cost, highly effective bomb container called the "Frag Bag" that contains more than 90% of the fragments and reduces blast pressure to less than 1.5 pounds per square foot at 5 feet from the blast. This is a highly successful accomplishment.

Technical Results and Conclusions

The investigations and tests conducted in the second year lead to a number of conclusions. The first is that light-weight, portable bomb boxes can be effective in capturing fragments (shrapnel) and redirecting the blast from common explosive devices. The bombs were constructed by New Mexico State Police personnel and consisted of 14 ounces of Pyrodex FFF powder in a 2-inch-diameter, 8-inch-long, schedule 40, steel pipe that was threaded for steel end caps. The firing mechanism was an electrical squib detonator wired through one end cap. The position of the detonator was estimated to be ~1 inch from the center of the pipe along the long axis. The 1-inch pipe bomb was of similar construction but used a 1-inch-diameter steel pipe with about 5 ounces of Pyrodex. The test setup is shown in Figure 1. Five blast gages at various distances from the bomb, plywood witness plates on three sides, normal speed video and high speed photography were used to diagnose the boxes' effectiveness.

In the first test in June, 1997, we tested two soft boxes made of ballistic nylon that were provided by the Last Armor Division of the Foster Miller Company: one test against the standard 2-inch pipe bomb, and one test against a smaller 1-inch diameter pipe bomb. In addition we tested a small box of LANL design made from retired body armor vests provided by the New Mexico State Police.

At a weight of less than 25 pounds, the Last Armor box contained the majority of the shrapnel from both pipe bombs and yielded significant blast overpressure mitigation. The peak overpressure recorded from the 2-inch bomb was between 1.3 and 2.4 psi at a 5-foot standoff. At distances of 6 feet or more the pressure was less than 1.3 psi. The peak overpressure from the 1-inch bomb was below the pressure gage threshold of 1.3 psi. A few pieces of shrapnel from the 2-inch pipe bomb escaped the containment system but impacts on the witness plates were small and did not penetrate the 1/2" plywood panel. Slightly more than 90% by weight of the fragments were found inside the bag lying near the site of the explosion. The high-speed video showed that the box initially deflected the blast downward and then redirected it upward as was planned in the design. Pieces of the lid of the box were scattered over a radius of about 30 feet. The very low blast pressures reflect the gradual release of explosive gases that finally destroyed the box with minimal release of shrapnel. This box was considered to be successful.

At a weight of less than 12 pounds, the LANL box made of body armor panels was much less successful. A 2-inch pipe bomb would barely fit in this box and the restraining mechanisms did not allow for gradual release of the gases. The box disassembled early in the explosion, failing to contain either the shrapnel or the blast. Peak pressures in excess of 6.5 psi were recorded in gages out to 6 feet. This test was not considered successful, but the importance of gas venting was realized.

A second test was conducted in September, 1997, of a kevlar-panel box designed at LANL and constructed by Ordnance Body Armor Co. and by Last Armor Division. We believed that the special kevlar/rubber construction of the Ordnance Body Armor Co. panels would provide superior penetration resistance for fragments. This 18-pound box was wrapped with wide bands of sewn Kevlar cloth that were held in place with Velcro® closures. The box was made of an inner and outer folded H-shaped assembly in which each assembly was 10 layers of 1500 denier Twaron® cloth bonded with rubber in the process developed by the Ord Arm Company. The wrappings were each 4 layers of 1500 denier Kevlar® cloth that had approximately 72 square inches of hook and loop fastening (from Last Armor Division) sewed onto the wrappings. When assembled, all four sides of the box had three layers of the Ord Arm material and two to three layers of the cloth wrap.

An opening in one side of the top lid provided a gas release path. The box was tested against a 2-inch pipe bomb.

The box disassembled in the test, failing at the Velcro® closures. None of the Ord Arm panels in the outer box were penetrated by shrapnel and the impact of the end caps was visible on the inner surfaces of the inner box. Nevertheless, the fragments of the bomb were not recovered, and one end cap penetrated the witness plate, even though it did not penetrate the Ord Arm panel. Both H-shaped pieces of the box were intact and the restraining cloth wrap was also intact. Our conclusion is that the Ord Arm panels were so successful in containing the bomb fragments that the box was blown apart by the gasses.

The final conclusion from these tests is that the softer panels of the nylon-wrapped box made by Last Armor were the most successful in stopping the fragments. While the harder panels of the Ord Arm material were not penetrated, the shrapnel ricocheted from these panels and was not captured.

Our collaborations and evaluation of armor tile technology are complete with the last series of tests. Last Armor is now manufacturing and offering for sale their box called "Frag Bag". While the armor tiles were not successful in this application, a technology was developed that will provide an important new capability for law enforcement agencies. The New Mexico State Police and the LANL Hazardous Devices Team are currently field testing and evaluating several of these "Frag Bags" for use in their normal activities.

Figure 1. Experimental arrangement for bomb disposal tests.