Insulating Concrete Form Association

Insulating Concrete Forms as a Blast Resistant Building Material

Force Protection Equipment Demonstration
May 6, 7 & 8, 2003
Quantico Marine Corps Base

Genesis

On May 6, 7 and 8, 2003, the Insulating Concrete Form Association and its members participated in the Force Protection Equipment Demonstration IV (FPED) held at Quantico Marine Corps Base. FPED is sponsored by the United States Military's Joint Staff, as well as the Department of Defense, the Department of Energy, the National Institute of Justice, and the Transportation Security Administration, and features commercial off-the-shelf (COTS) solutions to force protection needs such as blast and ballistics mitgation.

Encouraged by Stephen Baldridge, P.E.,S.E. and President of Baldridge and Associates, the Insulating Concrete Form Association participated in FPED to demonstrate the blast resistant properties and value-added benefits of ICFs. Over a three-day period, the ICF building system was subjected to blasts from a 50-pound charge of military grade TNT at distances of 40 feet to 6 feet.

FPED's Importance

With recent events in the world, bombings and terrorist threats have become very real concerns. Thus, life protection during a man-made disaster has become an important consideration of the design process of new and existing structures. Such concerns have lead to the development and passage of the Anti-Terrorism/ Force Protection Standard, which has challenged designers of government buildings to not only create long-term value for the client, but also consider blast resistance as a design feature.

Although ICF buildings are renowned for their energy-conservation properties and their quiet interiors, another important benefit of ICF structures is their security and integrity during natural disasters such as hurricanes and tornados. However, there has been little evaluation of ICF under man-made disasters such as terrorist acts. FPED was ICFA's opportunity to demonstrate the blast-mitigation potential of ICF systems.

Fabricating the ICF Reaction Boxes

45 days before FPED, representatives from seven ICFA member companies, as well as ready mix concrete producers from the Northern Virginia Concrete Promotion Council met in Northern Virginia to construct six ICF reaction boxes. Each box consisted of three 8' by 8' walls arranged in a U-shape with a 6"-thick concrete slab and a 6"-thick concrete roof. The fourth side, or back, was left open to allow for inspection of the interior after the trial. The 3/8" aggregate 4000 PSI concrete mix was reinforced with #4 steel bars at 16" on center and three reaction boxes (C, D, and F) were further reinforced with a structural fiber

mix. Although ICF walls are typically finished with stucco, brick, or wood siding, the decision was made not to put an exterior cladding on the specimens so that the walls were exposed to the full brunt of the explosive charge. This also simplified the assessment of damage after the blast. The standard design used in the ICF reaction boxes was important for the purpose of proving that ICFs can reduce the damage and risk associated with explosive events using materials commonly used in residential construction. The structures were lightly reinforced and did not require the special reinforcing detail typically recommended for use in blast resistant walls.

However, there was another consideration that needed to be addressed during the design phase. With the bomb generating forces in excess of 10 times the weight of the boxes, they needed to be constructed heavy enough to withstand the pressure of the blast without tipping over or being picked up and thrown downrange. In the end, a design was chosen to satisfy both concerns. The boxes weighed over 26,000 pounds each.

The Blast Demonstration

Two ICF reaction boxes were blasted each day of the three-day show. A range of standoff distances were used to evaluate the damage at various levels of airblast. The farthest standoff distance was a relatively close 40’ and the closest specimen was a danger-close 6’ from the charge. Since the force of the airblast is proportional to the cubed root of the distance, the closest specimen faced an air blast pressure approximately 275 times the pressure encountered by the farthest specimen.

Image 1 - Blast on third day

Each day, the ICF reaction boxes were placed on the range, and faced a 50-pound charge of TNT located on a concrete bolster directly against a steel blast wall. In addition to the initial blast, the boxes experienced an additional force created from the initial blast rebounding off of the steel wall. During the blasts, the TNT created a huge fireball as the explosion sucked the oxygen out of the surrounding area to fuel its destruction. (*See image 1.*) Therefore, the closest specimens faced an incredible quantity of destructive force. Since the explosion decimated the concrete bolster, the location of the charge had to be moved every day. (*See image 2.*)

Image 2 - Damage to concrete bolsters

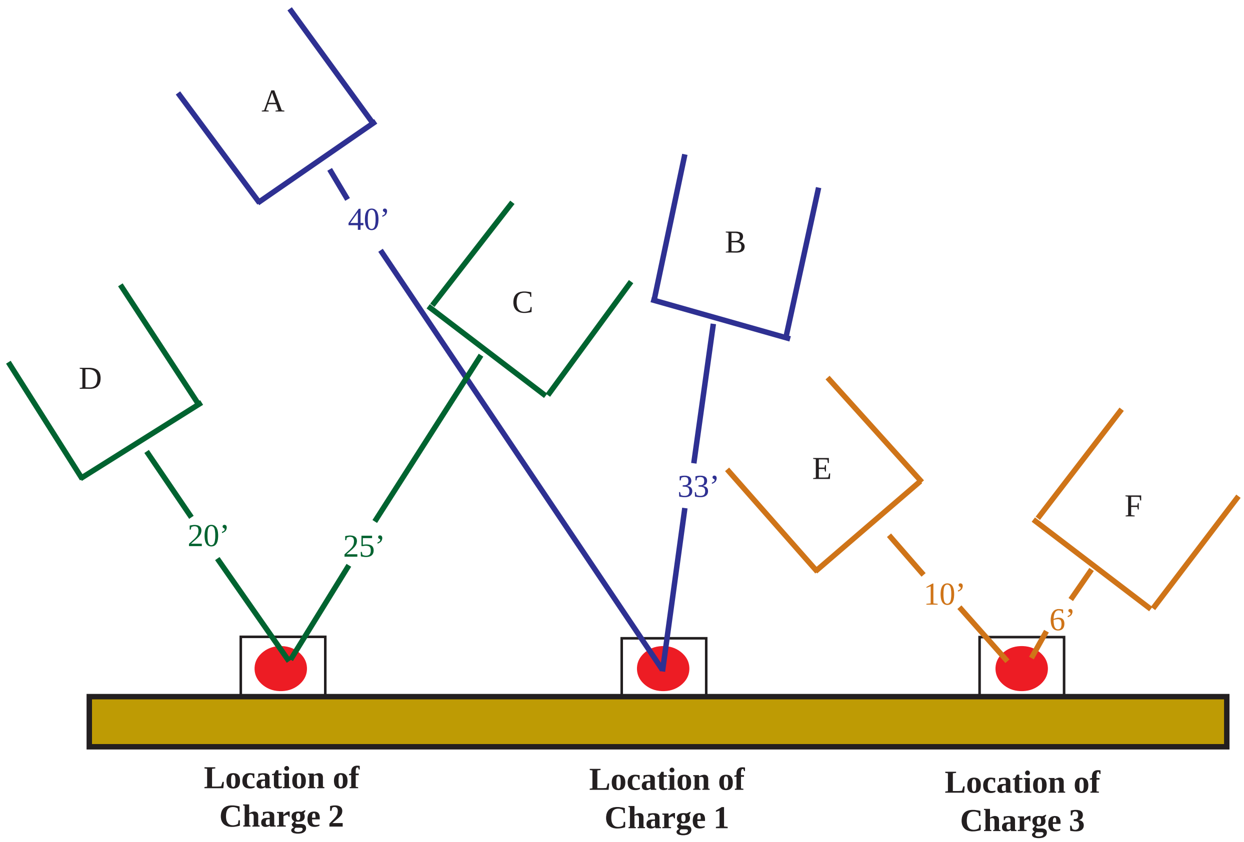

Figure 1 – Plan of the test. The standoff distance between the charge and the specimens ranged from 6’ to 40’. Each day, two specimens were tested after which they were analyzed and then removed.

Image 3 – Since the TNT charge decimated the concrete bolster on which it was sitting, the TNT charge was placed on a different bolster each day. This photograph was taken after the second day. The bolster to be used on the third day can be seen in the foreground. (The charge will be placed where the blue folder in the photograph is located.) The remnants of the bolsters used on the first and second day can be seen along the center and right side of the wall. The rebar in the bolsters is #7. Damage to the blast wall itself can also be observed behind the sites of the first and second charges.

Image 3 - Location of explosive charges

Evaluating the ICF Reaction Boxes

After each blast, the specimens were thoroughly evaluated. After the EPS (Expanded Polystyrene or foam) was assessed, portions of the EPS were manually removed so that the underlying concrete could be evaluated. None of the specimens experienced catastrophic failure; in fact all the assemblies were readily lifted by the crane after the demonstration.

The only damage to reaction boxes A and B (the farthest two specimens) was the EPS peeling away at the corners. Reaction Boxes C and D displayed minor distress to the foam, but no damage to the concrete was observed. It was only after the standoff distance was reduced to a mere 10' were cracks observed in the concrete. None of the cracks exceeded 2 mm across. Chunks of concrete were dislodged from Specimen E, the specimen at the 10' standoff distance, but none of the reaction boxes experienced deflection, spalling of concrete or any structural damage. (*See Table 1*.)

Table 1 - Damage Evaluation

Sample	Standoff Distance	Structural Fibers	Evaluation
A	40'	No	EPS removed from the corners. Concrete was not exposed. No signs of cracking in the concrete.
B	33'	No	EPS removed from the corners. Concrete was not exposed. No signs of cracking in the concrete.
C	25'	Yes	EPS removed from the corners and compressed. Concrete was exposed only at corners. No signs of cracking in the concrete.
D	20'	Yes	EPS removed from the corners and compressed. Concrete was exposed only at corners. No signs of cracking in the concrete.
E	10'	No	EPS significantly compressed. Concrete exposed in several sections and several large chunks (up to ~20 pounds) of concrete were dislodged. Cracking in the concrete of the walls, slab on ground and elevated slab. All cracks were less than 2 mm in width.
F	6'	Yes	EPS severely damaged and singed. Concrete exposed in several sections. Cracking in the concrete of the wall, but not in either the elevated slab or the slab on ground. All cracks were less than 2 mm in width.

The EPS on the interior of the specimens was never damaged and no deflections were observed in any reaction box. Pieces of shrapnel were imbedded into the exterior EPS but there were no indications that the shrapnel penetrated to the underlying concrete.

Assessment

The EPS cover is a major reason for the superior blast mitigation of the ICF system. Evidence of the EPS compressing could be seen in all specimens. As the specimens came closer to the charge and the blast force increased, the compression of the EPS became more pronounced. This compression dampened the force of the airblast and absorbed a considerable portion of the blast energy.

The blast demonstration at FPED IV confirms the effectiveness of ICFs as a blast mitigation material. The reaction boxes at the larger standoff distance only suffered superficial damage while the ICF boxes closest to the charge maintained their structural integrity. Evidence of the compression could be seen in all reaction boxes, with the EPS dampening the force of the airblast and absorbing a considerable portion of the blast energy. Since all explosions are complex phenomenon with many factors influencing the damage to a structure, a competent design professional must consider all factors when designing a structure to withstand threats and assaults.

Image 4 - Blast area on May 8, 2003

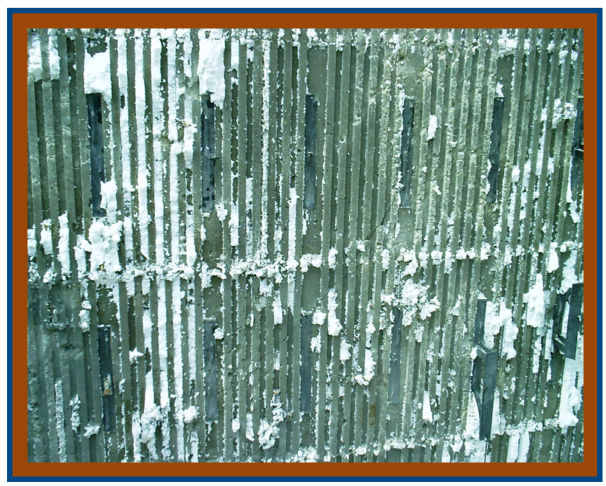

Image 5 - ICF wall at six feet

Image 4 – Specimens E (left) and F (right). Signs of compression of the EPS can be seen in the wall facing the blast of Specimen E. (Note how the ribs are only seen on the side facing the blast.) Embedded shrapnel can be seen on the bottom of Specimen E. Also, although exposed, no damage was seen to the edge of the upper slab. Reaction Box F had the closest standoff distance to the charge. The EPS was severely damaged, but the concrete maintained its structural integrity.
Image 5 - A close-up of the ICF wall at six feet stand-off distance.