Photography: Cranfield University

Master Blasters

By Tony Newton

A bomb attack on a major city centre: It's a scenario nobody wants to imagine but that still has to be planned for. Now new research into blast waves is revealing how we can limit the damage.

Terrorist attacks on civilian targets seem to involve the use of larger and larger weights of explosive material. The larger the charge size, the greater the number of buildings affected by the blast but the more difficult it becomes to predict the damage pattern of the blast. A building close to the blast in which all windows might be expected to have been destroyed somehow retains a substantial number of panels, while a building at a much greater distance suffers more extensive damage.

One aspect of such apparent unpredictability lies in the design and build quality of the buildings themselves but the second is the subject of work being undertaken through an EPSRC grant by Cranfield University at the Royal Military College of Science (RMCS), Shrivenham by Dr Tim Rose and Dr Peter Smith.

"The magnitude of the blast and the damage done depend on both the charge size and the geometry of the street" – Dr Tim Rose

"When an explosion occurs in a city street, the magnitude of the blast and the damage done depend on both the charge size and the geometry of the street. While urban environments can be extremely complex, there are a number of key geometrical properties which define the overall effect of the blast. These include the charge weight, the street width and the height of buildings in the street but also the existence of intersections, side streets or dead ends," explains Dr Rose. "The work we are undertaking at RMCS is really the first attempt to quantify some of the fundamental geometric parameters in an orderly manner." The RCMS team is investigating five typical, but generic, street configurations in order to understand better the 'street channelling' of blast waves. Reinforced concrete blocks are used to create 1:40 scale models of a crossroads, T-junction, right angle bend, straight thoroughfare and a dead end. Transducers are mounted flush with the surface of the blocks to measure the time-varying pressure of the blast that arises from a scaled down amount of plastic explosive. At this scale, 12g of plastic simulates a 1000 kg vehicle bomb. Dr Smith explains: "Scale models work because there is a cube root relationship between the size of the charge and the distance from the blast – whether you're 1m away from a 1 kg charge or 10m from a 1000 kg charge, the 'overpressure' of the blast will be the same. This gives us confidence in the data from our scale models and makes it straightforward to model variables such as street width and building height, which we know to be important in determining the way that a blast wave propagates."

The scale 'buildings' used by the RMCS team comprise smooth-faced concrete bricks, separated by sheets of steel or plywood to simulate floors. By adjusting the spaces between bricks, the team can model the different building facade 'porosities' exhibited by real buildings associated with their design, window area and cladding. While blast waves from an explosion in an open field would spread out as a spherical wave front, waves from a blast within a constrained environment – like a city street – interfere with each other, reflecting from the sides, diffracting and coalescing with each other. The narrower the street, the more likely it is that reflections from the opposite side of the street will coalesce to form a single, enhanced pulse.

Building height is also an important element and helps explain why so much glass ends up in the street after an explosion rather than inside the building.

Left: Dr Rose and Dr Smith detonate small charges near scale model buildings built out of concrete bricks and then measure the resulting pressure wave with an array of transducers.

"There is clearly a limit of one atmosphere underpressure, that is, total vacuum, that can occur during a blast. Conventional wisdom says that the positive overpressure will usually exceed this greatly and so dominate the effects of underpressure. The problem is that as distance from the blast increases, so does the relative importance of the negative phase pulse in a confined setting like a city street," explains Dr Rose. When a blast wave reaches the top of a building, it diffracts and spreads, resulting in a reduction in pressure and velocity of the blast wave front. This in turn causes the remainder of the wave to accelerate into the larger volume and lower pressure region behind the newly expanded wave. The lower the height of the building, the sooner the blast wave can reach the top and the secondary expansion travel back to ground level.

The net effect is that the positive phase impulse is greater than the negative impulse up to a distance defined by the height of the buildings. At greater distances the negative impulse may be greater, explaining why glass and cladding materials can be pulled into the street by the blast.

Modelling glass houses

The RMCS team has also used Computational Fluid Dynamics (CFD) to model numerically the complex behaviour of a blast wave as it encounters varying street geometry and building porosity. "As part of the EPSRC funded project, we've developed a program called Air3d, which we are using to model numerically an actual incident which occurred a few years ago. We have a lot of data on the nature and extent of the actual damage caused by the blast, and we can compare that with the predictions made by our software. We can't yet do these analyses in real time: It takes a week or so to set up the numerical model and a day and a half to process it on a 600 MHz computer. That's for 3.25 million calculation cells within the model. Eventually we want to be working with eight times as many," says Dr Rose. Having run the model, it is possible to view the blast events on screen from any perspective and through any axis, with a clear view as to how the blast wave diffracts round corners and enters buildings.

"In the UK, we have developed building codes as a result of incidents such as Ronan Point which, if correctly applied, lead to 'robust' buildings.

As we've seen, the situation may be different elsewhere. The result is that in this country, much of the damage caused by an explosive incident is through breakage of glazing elements. If glass breaks, there is potential for tremendous internal damage, not only the obvious one of high speed glass shard 'bullets' flying around at head height but because the blast itself can then enter the building and destroy internal structures. Our numerical and experimental work has shown that the single most useful things that UK designers and planners can do to protect structures and their occupants is to install laminated glass in a suitable deep rebate framing system that will allow glazing to withstand significant inward and outward deflection."

A long-term goal of the RMCS team is to offer modelling of threat situations, to help emergency forces decide who should be evacuated. In the shorter term, Dr Rose is confident that they will be able to provide better information than ever before as to the potential for damage from any given threat. ■

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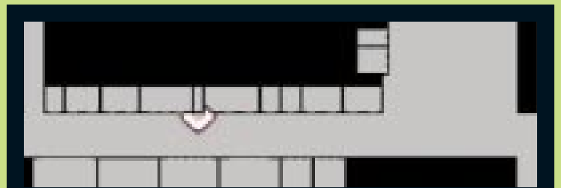
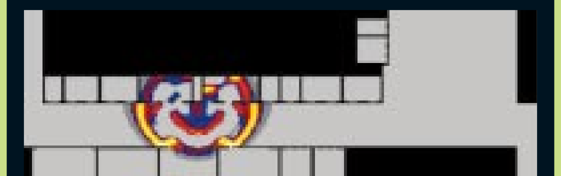
Wave Behaviour

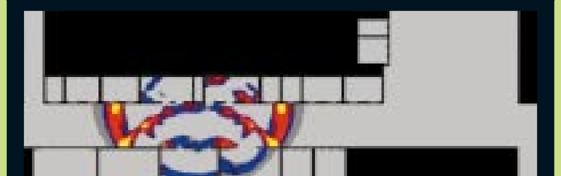
Understanding how a blast wave propagates in an urban setting is essential for working out evacuation strategies and ways to build more robust structures. Below is modelling of a real incident using the team's Air3d program.



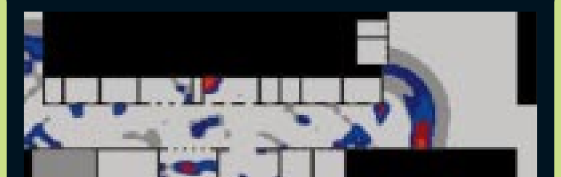
A blast from a parcel bomb left in the doorway of a UK street.



A smaller secondary blast wave is now evident.



The wave propagates and enters the buildings opposite.



It continues down this street and invades the open area (right).