Dr John Wyatt examines how stand off solutions and blast mitigation can be designed into vulnerable buildings to protect personnel and property from the explosive effects of VBIEDs

INSIDE EXPLO

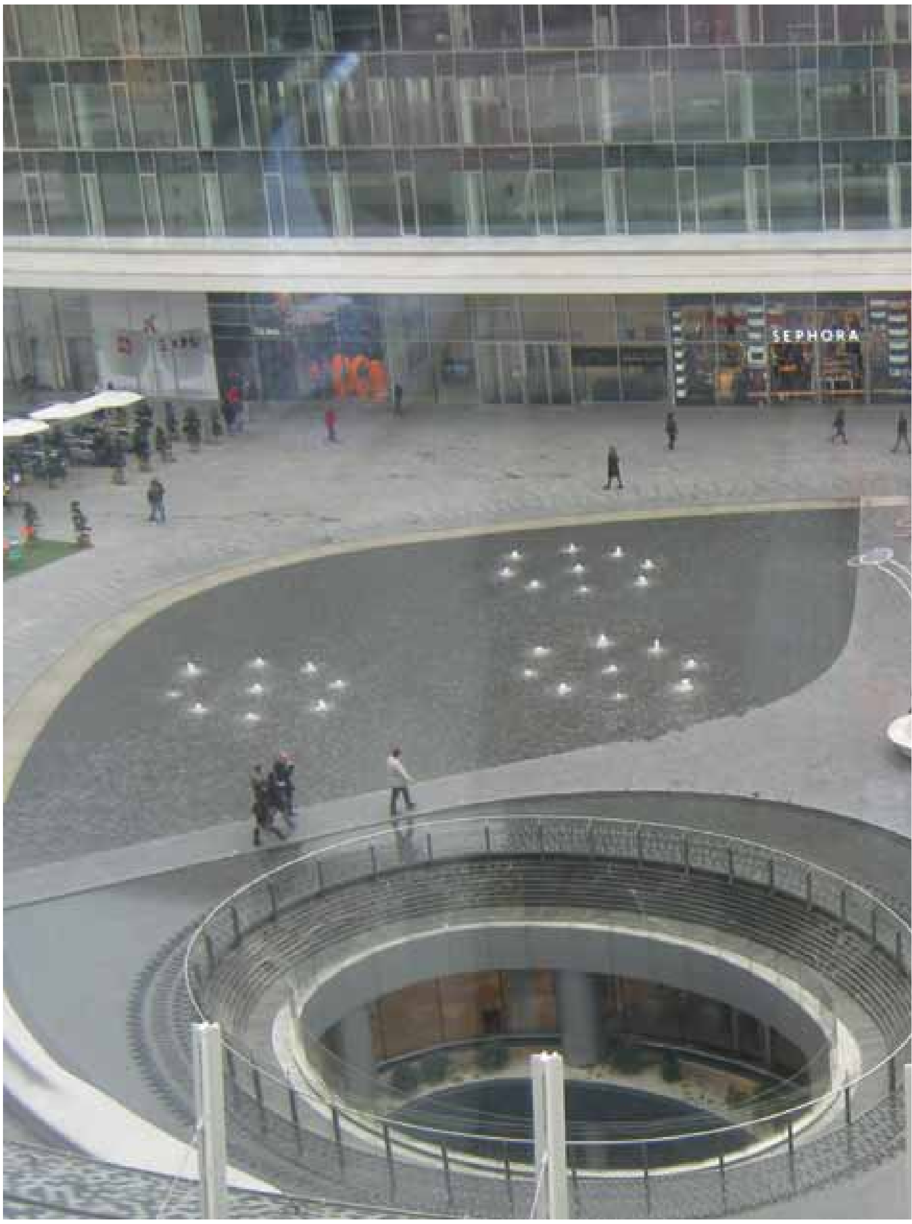
The use of explosives by terrorists, extremists or individuals has not abated despite increased security measures and procedures. The current threat level in the UK is "Substantial" from international terrorism due mainly to the activity of ISIS. The conflicts in Syria and Iraq remain ISIS's overriding priority, but it has previously threatened the West and, recently, it has expanded its regional campaign by calling for attacks against countries such as Saudi Arabia and Yemen. An ISIS threat to Western nations could therefore emerge with little warning and, if Western-led military action or assistance puts the group under pressure in Iraq or Syria, the likelihood of attacks in the West would be increased. If ISIS did strike Western nations, it would put al-Qaeda, its rival, under pressure to do the same. There are a significant number of EU passport holders fighting with ISIS in Syria and Iraq, and many more sympathisers residing in Western nations.

ISIS, al-Qaeda and its affiliates have regularly used explosive devices in a wide variety of scenarios and forms. Although recent shootings in France, Belgium, Denmark and Canada have killed and injured dozens of people, in terms of media exposure they compare poorly against the use of the bomb. The media does not show graphic pictures of those shot; they are soon covered and taken away, but the devastation caused by an explosion is there for all to see, often for weeks or months. It is therefore extremely important that we try to mitigate this damage and injuries to people as much as is reasonably possible in a democratic society.

This mitigation is initiated by an explosive effects analysis carried out on the site or individual building we feel is vulnerable to this type of attack. This may be a part of a comprehensive threat vulnerability risk assessment (TVRA) which takes into account all aspects of security; physical, procedural and training. We should use the terminology "explosive effects analysis" with care. This author started using explosives nearly 50 years ago as part of his military engineering training in demolitions. All we had to guide us was experience (actually carrying out explosions) and some military pamphlets which, of course, were based on the experience of others. It was not much better when he went into bomb disposal more than 40 years ago. There were some calculations of what to do to shore up a house or build sandbag walls to mitigate against a 250kg, 500kg or 1,000kg bomb, but very little technology. We could have used Hopkinson's cube root scaling (Hopkinson, B. British Ordnance Board Minutes 13565, 1915) to calculate peak overpressures at certain distances, but we did not and incidentally they still do not! Then came computers.

The most widely used and popular computer model for calculating peak pressures, impulses, duration and decay coefficients is the Conventional Weapon Effects Program (CONWEP), prepared by DW Hyde, US Waterways Experiment Station, Vicksburg, Mississippi 1991, mainly using the equations and curves from TM5-855-1 (Design and Analysis of Hardened Structures to Conventional Weapons Effects, Joint Departments of the Army, Air Force and Navy and the Defence Special Weapons Agency). This uses a variety of conventional weapons effects calculations including an assortment of airblast routines, fragment and projectile penetrations, breach, cratering and ground shock. Subsequently in the 1990s there was a proliferation of other, more specific computer models such as BLASTIN (Applied Research Associates Inc – used for internal explosions) BLASTX (Science Applications Int Corp – blast in multi-form structures) and AUTODYN 2D and 3D (Century Dynamics – blast simulation, impact and penetration).

As with any tool, the user needs experience, knowledge



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Secure design: blast mitigation and standoff protection are now essential design elements for vulnerable sites

OSIVE EFFECTS

analysis really needs to be conducted in conjunction with several other aspects. Inevitably this includes security elements such as access control, CCTV, alarms, manpower (selection, training and procedures) and equipment, but it should also include environmental issues and management of the real estate. Mitigation of explosive effects includes stand-off, (overpressures considerably reduce over distance) management of the overpressures such as making them use up energy or venting them in a direction controlled by you, or literally stopping the blast wave.

Not all locations can increase stand-off, particularly those in an urban environment, but stopping a threat such as a vehicle-borne improvised explosive device (VBIED) at street level instead of allowing it to crash into the side of the building may mean the difference between building partial collapse and only outer bay damage. A wide variety of blockers, barriers and bollards are available in the market. Only BSI PAS (Publicly Assessable Standard) 68 hostile vehicle mitigation (HVM) rated equipment should be installed, and it should be fitted to PAS 69 standard. Such equipment does not need to be architecturally intrusive; it can be designed to blend in with the surroundings, sometimes even enhancing the environment.

These measures are obviously much easier implemented at the design stage of a project rather than as a retrofit. This is a key message within the Home Office Guidance Document "Crowded Places: The Planning System and Counter-Terrorism". But, of the 400-plus projects on which this author has used this analysis, only about 20 have been at the design stage – and these have been for high-profile projects such as the Jewel House in the Tower of London, the Shard, and the Sheikh Zayed Museum in Abu Dhabi. Oddly enough, although it is easier to implement at this stage, it is more difficult for the consultant because at the design stage both the client and contracted engineers (not least being the architects themselves) can argue over details; you end up doing twice the number of calculations as ideas and suppositions are bounced around. At least once it's built you have a finite parameter.

This is not solely a UK problem, and many other countries are going through a similar process, This author recently worked on a project in Milan around a landmark site consisting of three tower blocks – respectively 31, 21 and ten floors high, which surround a very picturesque piazza. There are shops and coffee houses at ground level, two basement level car parks which go under the towers and the piazza and a supermarket. The car parks are split between public and private use. The piazza is often used as a marketplace at weekends and can include promotions for cars, bicycles etc. The aim of the explosive effects analysis was to calculate what would happen to the towers and the people in them if a LVBIED, VBIED or PBIED exploded in certain areas, and what mitigation could be cost-effectively and aesthetically put in place.

and practice to gain full benefit from these. In the wrong or inexperienced hands they can of course be dangerous. I liken it a bit to repairing a vehicle engine. There are plenty of people who can get away with a bit of "tinkering", but for any significant work you really must know what you are doing. A properly qualified mechanic will not only understand the theory (even following a handbook), but also have the awareness of how other components fit into the overall solution – sounds, look and other symptoms will all contribute towards the final answer.

Regrettably, the current threat now extends to many vulnerable installations and buildings, including shopping centres, tourist attractions and transport hubs – anywhere where there are a lot of people and preferably somewhere recognisable to the wider public. The explosive effects

INSIDE EXPLOSIVE EFFECTS

To the layman, a car bomb exploding in an underground car park would seem catastrophic, but as was seen when a large (606kg urea nitrate) vehicle bomb exploded in the underground car park of the North Tower of the World Trade Centre in New York in February 1993, it is not. The damage will depend on a number of factors, including the design of the building and the position of the vehicle. Even at the lower levels, the supporting columns are probably lightly loaded with little precompression. They would most likely fail completely, due to the action on the columns of the energy contained within the peak incident pressure from the blast. In addition, the relatively low storey height of 3.5m suggests that the lower ground floor slab will experience, locally, a high-reflected pressure from the blast. This could cause the slab to deflect upwards and unload the nearby supporting columns. This action, combined with the incident pressure on the column, provides a further cause of column failure. As a consequence, the area of the slab above the seat of the explosion is likely to also collapse. The slab is, however, formed from in-situ concrete and contains a continuous reinforcing cage. The damage is therefore unlikely to extend over more than one structural bay.

The superstructure of the towers had been built remarkably robustly using a reinforced concrete frame with a central core and a small core at each end. Buildings in the City of London presently seem to prefer a steel frame, but also using reinforced concrete cores. Framed buildings perform much better against short-duration large overpressures than traditional masonry or stone buildings due to their form, ductility and harmonic frequency. The most vulnerable part of modern buildings is generally the glazing, either in curtain walling or windows. Again, I was pleasantly surprised to find a robust enclosure in the form of a factory-sealed double glazed unit of 10mm toughened glass outer pane, 16mm air gap, and 11mm laminated glass inner pane. This is a higher specification than many of the UK buildings. The toughened outer pane is best against the peak overpressure (the "punch") while the laminated pane can sustain the impulse (the "push") better; even if it fails, it will not fragment is therefore less likely to cause injury.

To a certain extent, no matter how robust the glazing, it is going to fail if a LVBIED is detonated close by. What we don't want is catastrophic failure, so stand-off is important. In this case we had to design a system of planters and rising bollards to enable normal working to be maintained, but at the same time reduce the potential damage. The difference between being 15m away from a Tower and 30m is the difference between little or no damage and widespread damage to the glazing. For example, a van (250kg) at 15m produces a peak incident pressure of 115kPa, but at 30m it drops to 30.38kPa. The rising bollards achieved the necessary stand-off, while the planters delineated the safer zone. For the weekend market, however, we needed closer access and could not install more bollards due to the car park slab underneath, so we recommended a road blocker using surface-mounted technology (SMT).

Finally – common to most buildings this author surveys – the glazed entrance was vulnerable. A lot of buildings, including those in the UK, use revolving doors surrounded by glazed panels. Due to the weight for the mechanical movement these will be made with toughened glass (single pane) and have similar panels either side. These need to have anti-shatter film (ASF) applied to reduce fragmentation. Generally 200-micron thickness is sufficient, but thicker films can be applied if the threat is high and the frame's robustness can match it. Alternatively the ASF can be anchored into the frame to provide extra robustness and increased protection.

Explosive devices have been detonated by terrorists/extremists every year for more than 50 years and that is unlikely to change any day soon. There is no doubt that modern framed buildings are more robust than their masonry predecessors, and there has been a big improvement in the specification of glazing against blast, but if we let vehicles – particularly large vehicles – near our buildings, there will still be significant, although perhaps not catastrophic, damage. Measures derived from properly calculated analysis need to be put in place to reduce the likelihood of injuries and to assist in business continuity.

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Blocking VBIEDs: standoff measures can be overt and utilitarian (above), but they can also be subtle and aesthetically pleasing (below).

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Dr John Wyatt is an independent blast consultant and regularly supports SDS Group/Pentagon Protection Global.