



Protective Design

Half a century of hardening structures.

The U.S. Federal Building in Oklahoma City features an elliptical courtyard with a sweeping blast-resistant curtain wall.

September 11th may have marked a turning point in public awareness that buildings are vulnerable to terrorism, but the attack on the U.S. Embassy in Beirut in 1983 was arguably more significant as a protective design milestone. With each major attack on an American target since then, new engineering strategies have been employed to improve the safety of public and private buildings. Weidlinger Associates has played a major role in this quiet revolution and continues to lead the effort. The firm's recommendations have the force of twenty years of experience in anti-terrorist engineering, based on a prior thirty years of research in nuclear and conventional weapons effects and design of military structures.

The new U.S. Federal Building in Oklahoma City is inviting to the public and also satisfies stringent blast design criteria.

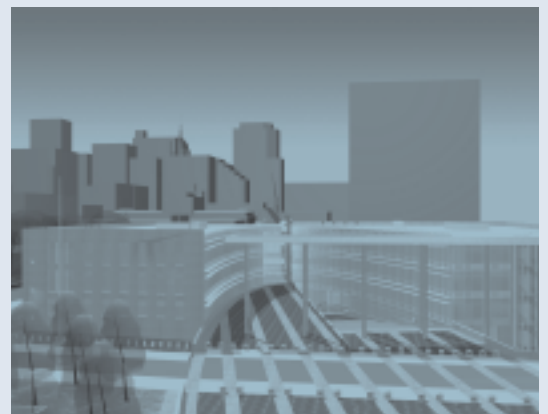
As the field of protective design has matured, Weidlinger experts have learned to safeguard structures at nominal cost. September 11th did not alter that trend. No one advocates an aesthetically extreme and cost-prohibitive city of fortresses and underground bunkers as a defense against more attacks from fully-fueled jets. Nevertheless, Tod Rittenhouse, a Weidlinger principal who has supervised more than 200 blast projects, believes that "it is professionally responsible to encourage a general return to more robust structures," a position that is finding favor with the broader engineering community.

Weidlinger engineers have already encountered the demand for protective design of a greater range of building types, from civic and educational facilities to commercial buildings and laboratories. Fortunately, a baseline of experience exists as a result of

designing embassies, courthouses, airports, corporate headquarters, military facilities and infrastructure to resist blast that has broad application to any structure at risk of direct attack or collateral damage. At the Pentagon, occupants were protected by Weidlinger designed blast-resistant glass adjacent to the area of impact, even though blast assumptions fell short of reality. At the World Trade Center, Weidlinger's analysis that led to the reinforcement of the lower floors after the attack in 1993 aided evacuation in 2001.

From Beirut to Lower Manhattan

The 1983 attack on the U.S. Embassy in Beirut had a profound effect on Weidlinger Associates. The firm immediately expanded its research in nuclear weapons effects and design of NATO military installations to include research in conventional weapons effects and the protection of embassies. Within a year, Weidlinger engineers were visiting the sites of U.S. embassies worldwide, defining the terrorist threat in technical terms and developing precedent-setting Structural Engineering Guidelines for the Protection of U.S. Embassy Buildings against Terrorist Attack for the Department of State. To date,





U.S. Courthouse in Las Vegas.



Brooklyn GPO Courthouse.

Weidlinger has completed more than 100 new embassy designs, protection evaluations and upgrades. The challenge has been to provide safety for the occupants of these architectural-ly significant public buildings without sacrificing aesthetics.

The first World Trade Center attack in 1993 was another turning point. It shifted the focus from international posts to the homeland and put national and local public agencies as well as private corporations on alert. The Oklahoma City event added courthouses and federal buildings to the growing list of potential targets and restructured the debate around the dangers of progressive collapse, flying glass and damage to neighboring structures. Federal office buildings are now being designed according to criteria developed by the Interagency Security Committee (ISC), which superseded the General Services

The Brooklyn GPO Courthouse was the first renovation design to use GSA blast criteria. The new U.S. Courthouse in Las Vegas has a ‘nearly conventional’ blast-protected curtain wall.

Administration’s Security Criteria. They were applied in full for the first time to the new U.S. Federal Courthouse in downtown Brooklyn. Though not required, many non-federal public buildings are following the mitigation techniques outlined in the ISC Criteria. Private owners have also benefited from the knowledge gained on public projects, but they are still burdened with assessing risk to their individual properties and balancing added cost against the potential loss of lives and assets.

Advantages of Robustness

A building does not have to be the intended target to sustain significant damage. In Lower Manhattan, at least 22 of 45 severely damaged buildings remained closed five months after September 11th. Fortunately, conservative design may offer some implicit protection for buildings that are inadvertently in harm’s way.

According to Weidlinger blast expert, Dr. Robert Smilowitz, “Certain types of construction perform better against abnormal loadings, and they may be a better investment in the long run than extremely lightweight structures that cost less.” There are many secondary gains to designing against blast. For instance, encasing vulnerable steel in concrete to harden the structure makes it more resistant to fire damage. Constructing safe areas and protecting emergency mechanical and electrical equipment improves life safety and facilitates evacuation. However, the protection of structures against one hazard doesn’t necessarily protect against all hazards. For instance, earthquake and blast design loads and failure mechanisms are very different from each other and yield different results; and one is never a substitute for the other.

A total security plan can be summed up in three words: *detecting*, *deterring* and *defending*. The goals are to save lives, reduce injury, provide efficient evacuation, and protect mission-critical utilities and communications systems.



U.S. Embassy in Moscow.

STRATEGY 1

Preventing Access

A comprehensive protection plan employs a combination of technical, operational and physical security measures. Unfortunately, the best technical and operational security systems can be breached, and perimeter security, the first physical defense against terrorism, is difficult to achieve in urban centers. Land is scarce or too costly for proper setbacks or extensive landscaping and street architecture. Even if underground parking and loading docks are eliminated, there is usually uncontrolled vehicular and pedestrian traffic on the streets close to the site.

Despite these difficulties, since increased distance from an explosion reduces its effect, the first goal is still to prevent delivery of explosives to or within the structure. A small bomb detonated internally can do as much damage as a larger one that explodes outside the perimeter of the building. Exterior screening stations are therefore important, and while the 100-foot standoff specified for embassies is usually impractical for urban settings, landscape features such as anti-ram bollards and large planters can be used to enforce the maximum available distance from the protected building to the public right-of-way.

STRATEGY 2

Avoiding Progressive Collapse

After barriers, the second line of physical defense is in the choice of building materials. Concrete heads the list of preferred materials; timber and post-tensioned precast construction are at the bottom. Steel construction is inherently ductile, but paradoxically its efficiency as a building material may create vulnerability to blast if engineers

go too far in minimizing weight and construction details to reduce cost.

A proper defense against the progressive collapse that occurred in Oklahoma City depends on the design of redundant load paths and robust details to develop continuity and harden critical load-bearing elements. In lieu of increasing member size, blast engineers commonly recommend jacketing concrete columns with steel plate or wrapping them with composite materials. Similarly, steel columns may be encased in concrete to add mass and protect cross-sections. Important candidates for protection are exterior columns and columns in unsecured interior spaces,

The new Brooklyn Federal Courthouse was the first domestic building designed according to Interagency Security Committee Criteria and the first to use Weidlinger's 'balanced window system.'

as well as the beams and girders that span lobbies and loading docks.

STRATEGY 3

Isolating Interiors

Not all areas within a building are equally at risk from an explosion. Lobbies, loading docks and unsecured public spaces are especially vulnerable as are the spaces near them. The idea is to contain the most severe effects, accept localized damage without compromising overall stability and redistribute loads to undamaged elements. Walls and slabs are designed or retrofitted to isolate the threat, limit hazardous debris, assure safe evacuation and protect emergency power and distribution systems.

STRATEGY 4

Protecting Glazing and Facades

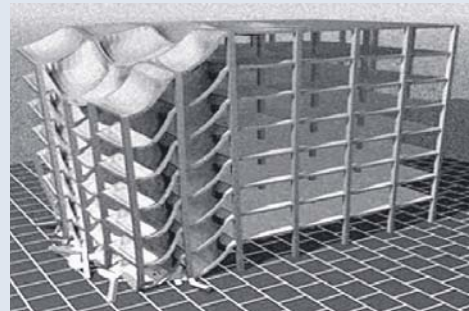
Historically, glass is the greatest hazard to people in or near buildings under attack. While upgrading the facade of a building is the single most costly improvement, it offers the greatest level of protection to occupants. In general, the alternative to reducing the size of windows is to improve their post-damage behavior. Glass hazard mitigation solutions include strengthened glazing, laminated glazing, film applications, blast curtains, and energy-absorbing systems. It is important to understand that glass fragmentation is not the only concern. Frames, mullions and connections are required to withstand the large forces collected by the glazing, while the walls to which the windows are attached have to be strong enough to accept the reaction forces.

Significant improvements in the ability to analyze glass allowed Weidlinger to create the 'balanced system.' Frame and anchorage capacity were matched to glass capacity to provide the most comprehensive protection. Replacing the GSA standard of thick windows with rigid frames, the Weidlinger system, now the industry standard, proved flexible enough to be developed into a blast-resistant curtain wall system. The latter was used to design the Las Vegas Federal Courthouse and the new Oklahoma City Federal Building.

STRATEGY 5

Advanced Analysis

Protection against blast loads requires advanced analysis. Seductive visualization software is useful for risk management decision-making, but it is no substitute for physics-based engineering analysis programs. Weidlinger has developed sophisticated analysis tools based on Department of Defense and Department of State research. They make the difference between a protective design that has minimal impact on architecture and one that doesn't. Weidlinger's detailed blast programs use transient dynamic analyses of structures and facades to demonstrate hazard potentials and structural response. Separate software is used to analyze glass structures. Since there is no single solution to all blast protection problems, no single set of criteria or software program will ever make blast protection automatic. Using advanced tools reduces cost to practical levels because it helps to balance the combination of risk, aesthetics and budget that is unique to each project. In every instance, however, experienced professionals and owners have to weigh the alternatives to find the most appropriate level of protection given the particular circumstances.



WEIDLINGER ASSOCIATES INC

CONSULTING ENGINEERS

375 HUDSON STREET NEW YORK NY 10014-3656 PHONE 212 367.3000 FAX 212 367.3030

ONE BROADWAY 11TH FLOOR CAMBRIDGE MA 02142-1100 PHONE 617 374.0000 FAX 617 374.0010

1030 15TH STREET NW SUITE 950 WASHINGTON DC 20005-1503 PHONE 202 326.9070 FAX 202 326.9071

4410 EL CAMINO REAL SUITE 110 LOS ALTOS CA 94022-1049 PHONE 650 949.3010 FAX 650 949.5735

2525 MICHIGAN AVENUE D2-3 SANTA MONICA CA 90404-4042 PHONE 310 998.9154 FAX 310 998.9254

WEIDLINGER ASSOCIATES LTD PO BOX 14488 GLENROTHES FIFE KY7 6WP UNITED KINGDOM THOMPSON@WAI.COM

<http://www.wai.com>