CHAPTER ONE

THE THREAT TO BUILDINGS FROM EXPLOSIVE DEVICES

Although terrorists employ a wide variety of tactics and strategies, their attacks have often targeted buildings in urban environments. Buildings in densely populated areas are attractive targets for several reasons: they tend to be tall structures with high concentrations of occupants, allowing for mass casualties and injuries from a single targeted strike; and they tend to be valuable assets, allowing for extensive property losses in the event of an attack.

Explosive devices can cause casualties and property damage in a variety of ways. Beyond a building's collapse, an explosion can initiate uncontrollable fires that spread rapidly throughout the building; produce structural damage that traps people within the building; and cause debris, broken glass, and fragmented furniture to become harmful projectiles. This chapter provides an overview of the threat to buildings from explosive devices.

Explosive Devices

Conventional explosive devices used in terrorist attacks on buildings are called improvised explosive devices (IEDs). IEDs vary in size, design, and material. The means by which an IED reaches its target has broad implications for the type and extent of damage it can cause; for this reason, IEDs are often characterized by delivery mechanism: vehicle-borne or man-portable devices.

Vehicle-Borne Improvised Explosive Devices

A vehicle-borne improvised explosive device (VBIED) has the capacity to hold enough explosive material to significantly damage or even destroy a building. Because the extent of damage a VBIED can cause depends largely on its proximity to a target, terrorists have chosen to detonate VBIEDs in vehicles parked outside of buildings or within garages, or in vehicles that strike buildings. The mass-casualty potential of a VBIED became clear in 1983, after two deadly terrorist attacks on U.S. government buildings in Beirut, Lebanon: on April 18, a VBIED delivered by a pickup truck destroyed the U.S. Embassy in Beirut, killing 63 people;[1] and, on October 23, a truck believed to have been carrying a 12,000-pound TNT-equivalent VBIED crashed into the U.S. Marine Corps Barracks at the Beirut International Airport, killing 241 American service personnel.[2]

VBIED attacks have also been carried out in the United States. On February 26, 1993, Ramzi Yousef led a terrorist cell that detonated a 900-pound TNT-equivalent urea-nitrate VBIED delivered in a rented Ryder van in the underground garage of the World Trade Center.[3] The attack killed six, injured more than 1,000, and caused significant structural damage that resulted in over $858 million in insured property losses.[4] On April 19, 1995, Timothy McVeigh detonated a 4,000-pound TNT-equivalent VBIED delivered in a rented truck outside the Alfred P. Murrah Federal Building in Oklahoma City, causing progressive collapse of part of the building and killing 168 people.[5]

U.S. Marine Corps Barracks, Beirut, Lebanon 1983

VBIED attacks in urban environments have the potential to cause considerable financial loss. In 2006, for instance, the American Academy of Actuaries estimated that a truck bomb attack in New York City could produce $11.8 billion in insured losses.[6] Successful attacks can also have unintended

Box 2: Port Authority Liability in 1993 World Trade Center Bombing

In the aftermath of the 1993 World Trade Center bombing, the victims and their families sued the Port Authority of New York and New Jersey for failing to implement security enhancements in response to known vulnerabilities. From 1984 to 1986, five separate reviews of the World Trade Center site, including reviews conducted by the Port Authority and Scotland Yard, found that the underground public parking garage presented a potential risk. At the Port Authority's request, three reports on the site's security were written, each providing risk mitigation recommendations. On April 29, 2008, the New York State Appellate Division upheld a 2005 New York County Supreme Court ruling, finding the Port Authority liable for failing to meet "its basic proprietary obligation to its commercial tenants and invitees" by not securing its facilities in the face of "ample notice" that a VBIED attack was possible in the public parking garage. The 2005 and 2008 decisions held the Port Authority liable for damages potentially upwards of $100 million.

References: *Nash v. Port Authority of New York and New Jersey,* 51 A.D. 3d 337 (First Dept, NY 2008); Anemona Hartocollis, "Port Authority Liable in 1993 Trade Center Attack," *The New York Times*, April 30, 2008, http://www.nytimes.com/2008/04/30/nyregion/30bombing.html.

financial implications, such as exposing building owners to liability for failure to enact sufficient protective security design measures.

Man-Portable Improvised Explosive Devices

Man-portable improvised explosive devices (MPIEDs) are generally used to target people rather than structures. They tend to be significantly smaller than VBIEDs, and may be concealable in backpacks and suitcases, allowing for ease of entry into a building. Victims of such attacks are often injured by shrapnel and projectiles, including furniture fragments and shattered glass, rather than building collapse. MPIEDs range in size from under five pounds to as much as 100 pounds and are generally used against soft targets, such as shopping malls, nightclubs, and trains. They can cause extensive property damage and produce significant casualties. For example, on November 9, 2005, a team of suicide bombers carried out near simultaneous attacks on three hotels in Amman, Jordan, killing 58 people and injuring over 100 others.[7] One device alone killed 38 people at the Radisson SAS Hotel. The blasts also caused considerable damage to the hotels' interiors. MPIEDs used in the attacks were responsible for collapsed pillars, buckled ceiling panels, and shattered glass doors and windows.[8]

Although MPIEDs are unlikely to cause building collapse, when multiple MPIEDs are simultaneously employed against primary structural elements, such a result is theoretically possible.[9]

Blast Effects

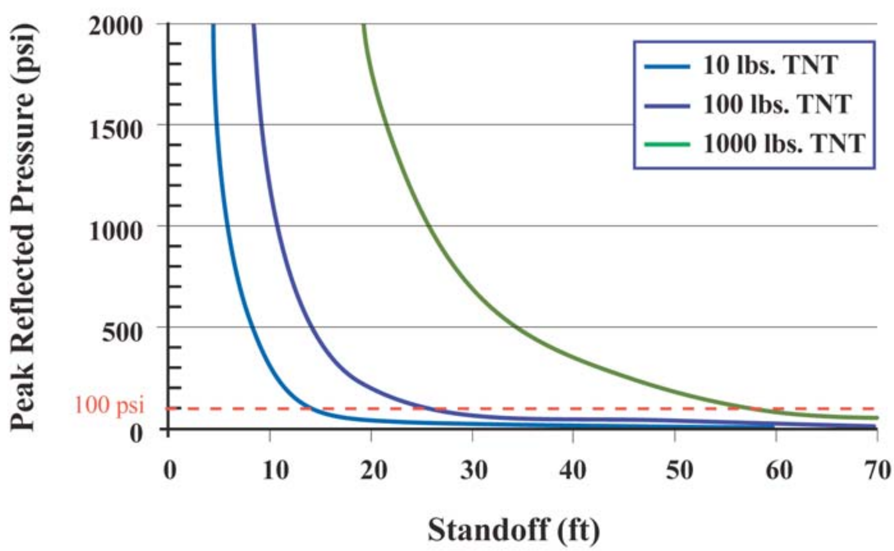
The physics of explosive blasts may be used to determine the types of protective security design measures that buildings should employ. An explosives attack creates significant pressures and impulses that vastly exceed normal loads. Unlike environmental conditions such as high winds, which can exert sustained pressure on buildings, explosions damage buildings by exerting tremendous air-blast pressure over a relatively short time span – on the order of milliseconds. This tremendous pressure and its associated impulse can affect primary structural elements, such as columns and beams, which contribute to overall structural stability, potentially leading to structural failure.[10] One type of structural failure is progressive collapse, which occurs when abnormal loading causes individual structural elements to fail locally, shifting the loads to remaining structural elements unequipped to provide the requisite structural support; the result is catastrophic failure of the entire building or significant portions of the structure.[11] The same pressures can also impact non-structural elements, leading to facade fragmentation, shattered windows, and flying glass.[12]

A building subjected to an explosion is affected by several types of pressures that occur in two phases. The positive pressure phase refers to the rapid outward expansion of energy as the shock waves radiate in all directions from the source of the explosion; these waves are amplified by waves that reflect off the ground or surrounding buildings. The pressure envelopes the structure, loading the sides and the roof; it may be further amplified if the waves are stagnated by the structure. The pressures in the positive phase push on the building's exterior and may induce the localized failure of exterior walls, windows, floor systems, columns, and girders. Narrow freestanding columns may benefit from pressures wrapping around their surface and minimizing the net loading. Downward pressure directly beneath the explosion leaves a crater below the source, potentially damaging underground structural elements and creating intense vibrations through the ground similar to the effects of an earthquake. The negative pressure phase refers to the low intensity, longer duration inward movement of air that fills the void created by the positive phase. The pressures in the negative phase reverse the positive phase loading, pulling structural elements towards the source of the blast, which may dislodge windows and sloped roofs. Once the applied pressures deform building components, the elements attempt to rebound back to their original shapes, which may result in additional structural damage.[13]

Standoff

Standoff is defined as the distance between the explosive threat location and the nearest building element that requires protection.[14] Increasing this distance improves a building's ability to withstand an explosives attack because the peak pressure per square inch (psi) associated with such an attack decreases significantly as standoff increases.[15] Specifically, the peak pressure falls roughly by the cube of the ratio of increased distance. For example, if standoff is doubled, the peak pressure reduces by a factor of 2^3, or 8; this means that the peak pressure from an 800-pound blast 10 feet

Figure 1: Peak Reflected Pressure and Standoff



Note: Fatalities and structural failure may occur between 50 and 100 psi.

away from a structure is approximately equivalent to the peak pressure from a 100-pound blast five feet away. The effects of standoff are further illustrated in Figure 1.

Design Basis Threat

Design basis threat (DBT) is the magnitude of the blast from an explosive device that a building or particular building element should be designed to withstand at a specified distance. The magnitude of this threat is expressed in TNT-equivalent charge weight, and the distance in feet. For example, a building's DBT may be stated as a 500-pound TNT-equivalent explosive charge at 20 feet of standoff, meaning the building, or the particular building element to which the DBT is assigned, must be able to withstand the loading associated with a 500-pound TNT-equivalent explosive charge, from 20 feet away. Increasing standoff and using building design techniques to harden structures may allow buildings and particular building elements to resist explosive threats that present abnormal loading.

The load a specific building element must withstand varies with both the distance and magnitude of the threat from an explosive device. The distance component of DBT takes into account the most probable scenario: that attackers will get as close to their targets as possible. For this reason, the distance component of DBT tends to be no more than the standoff afforded the building or the particular building element under consideration. The magnitude component of DBT takes into account the different types of threats in urban environments, ranging from small pipe bombs to explosives in quantities large enough to fill a cargo van.

Figure 2 presents a summary of the NYPD's DBT coding system, referenced in subsequent chapters as M-values. Each M-value represents a distinct order of magnitude, corresponding to the range of explosive threats buildings or particular building elements should be designed to withstand. The NYPD provides a range rather than specific values for DBT charge weights to avoid disclosure of sensitive security information to potential terrorists and to account for variations among buildings in factors such as: amount of available standoff, type of access control, threshold for screening procedures, and site orientation.

Threats from the true perimeter generally come from VBIEDs, containing potentially large amounts of explosives. For a building that has protection from a hard perimeter,

Figure 2: NYPD Design Basis Threat Coding System			
DBT Code	**Order of Magnitude**	**Charge Weight***	**Potential Threat**
M1	10^1	10 - 99 lbs.	Pipe Bomb Suicide Belt/Vest Satchel/Suitcase
M2	10^2	100 - 999 lbs.	Duffel Bag Luggage Compact Sedan
M3	10^3	1000 - 9,999 lbs.	Standard Sedan Cargo Van Delivery Van

*** Expressed in TNT-equivalent weight**

the true perimeter is defined as the anti-ram barrier line. For a building that lacks protection from a hard perimeter, the true perimeter is generally defined as the building's envelope. For threats from the true perimeter, the NYPD recommends that primary structural elements in High Tier buildings "satisfy" M3 standards – a threat in the thousands-of-pounds range ("satisfy" means the element in question is adequately robust that the building: does not engage in progressive collapse; meets an industry standard definition of non-disproportionate damage; and performs to a level that allows for evacuation, rescue, and recovery operations). By contrast, threats at zero feet of standoff, representing contact with the column, generally come from MPIEDs, containing an amount of explosives limited to what an individual can carry. Therefore, for threats from a contact charge, the NYPD recommends that columns in High Tier buildings satisfy M1 standards – a threat in the tens-of-pounds range.

The design loads necessary to meet the NYPD's recommended DBT standards will almost certainly be greater than the load requirements set out in applicable local building codes. Building owners should consult with blast engineers and the NYPD Counterterrorism Bureau to determine building-specific DBT standards. Once DBT levels are established for a site, building owners, in consultation with appropriate experts, must decide on specific methods to achieve sufficient design performance. The specific DBT levels determined for each building are sensitive security information and should be strictly controlled and protected.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