



# ***Blast-Resistant Building Design Technology Analysis of its Application to Modern Hotel Design***

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## Introduction

Protecting civilian buildings from increasing crime and terrorist activity is one of the most critical architectural design challenges today. The September 11 terrorist attack on World Trade Centre has forever changed our perspective on homeland safety. The tragedy and the continuous terrorist alerts thereafter heightened the awareness of the vulnerability of our built environment and the need for passive deterrents.

No civilian buildings can be designed to withstand the kind of extreme attack that happened to the World Trade Centre. Building owners and design professionals alike, however, can take steps to better understand the potential threats and protect the occupants and assets in an uncertain environment.

There is the clear conflict between the need to construct secure facilities on the one hand and the importance of designing warm, open and welcoming buildings such as hotels on the other. Consequently, the tension exists between architects who desire openness and natural light, and security professionals who want to build fortresses.

Preventive measures in civilian building design to deter terrorist attacks can go overboard. Accepting that a building cannot be defended against every potential threat, the approach must be balanced against the probability of threats. The architectural and engineering community has a critical role to play in finding and promoting rational, balanced solutions to terrorist violence.

### 1. **TERRORIST TACTICS**

Moving-vehicle bombs	Suicide attack. Car, van or truck laden with explosives ram into the facility at high speed
Stationary-vehicle bombs	Vehicles parked outside or underneath the building, detonated by time delay or remote control
Exterior attack	Grenades, hand-placed bombs, home-made bombs
Stand-off weapon attack	Rockets, mortars
Ballistic attack	Small arms
Covert entry	Enter using false credentials, carry weapons or explosives into the building
Arson	Flammable material smuggled into the building and ignited or detonated
Mail bombs	Envelopes or small packages mailed to mail room
Supplies bombs	Larger bombs in various containers delivered to loading dock
Airborne contamination	Chemical or biological agents
Waterborne contamination	Chemical, biological or radiological agents

## 2. SELECTED RECENT RECORD OF TERRORIST ATTACKS TO HOTELS

<i>Hotel</i>	<i>date</i>	<i>Where occurre d/# of storeys</i>	<i># of deaths/i njured</i>	<i>Cause</i>
Luxury hotel, Jerusalem	12/5/01	Ext./	1/6	bomb outside entrance
International chain hotel in Uganda	4/98		5/0	
Two 5-star hotels in Colombo, Sri Lanka	10/97		11/105	truck bomb
Diplomat Hotel, Bahrain	2/11/96			home-made bomb
Le Royal Meridien Hotel, Bahrain	1/17/96	Upper floor/	0/0	time-bomb
Glenavna Hotel, Newtownabbey, north of Belfast	10/13/93	Ext./	0/0	car bomb outside the hotel
Hotel Crillon, Lima	10/21/93	Ext./	2/30	car bomb parked behind the hotel
Gosford House Hotel, Markethill, North Ireland	9/30/93	Ext./	0/0	car bomb
Hotel Cabana, coastal resort in SE Spain	7/24/93	Ext./	0/0	bomb planted in garden
Hyatt Regency Manila	6/4/91		1/2	arson
Nikko Manila Gardens Hotel, Manila	9/24/90	9/	8?	bomb
Mandarin Oriental Hotel, Manila	9/24/90	4/	8?	bomb
Manila Garden Hotel	10/13/87	Ext.	0/4	bomb at entrance
Makati Hotel, Manila	10/13/87	Ext./	0/7	bomb in flower box at entrance
Manila Peninsula Hotel	7/17/87	Ext./11	0/0	bomb
Tropical Palace Hotel, Paranaque, Philippines	6/28/86		0/0	arson
Pines Hotel, Baguio, Philippines	10/23/85	/4	4/40	arson
a bayside hotel, Manila	2/14/85		24/0	arson
Regent of Manila	2/12/85	2&9/9	17/0	arson
Regent of Manila	2/14/85		23/0	arson
Iseya Hotel, Manila	2/25/85	4/6	0/5	arson
Las Palmas Hotel	11/8/84	3 or 4/8	0/0	arson
Ambassador Hotel, Manila	11/1/84	7/16	12/0	arson
Grand Hotel, Brighton	10/12/84		5/0	2 bombs

### 3. **BOMBING AND ARSON**

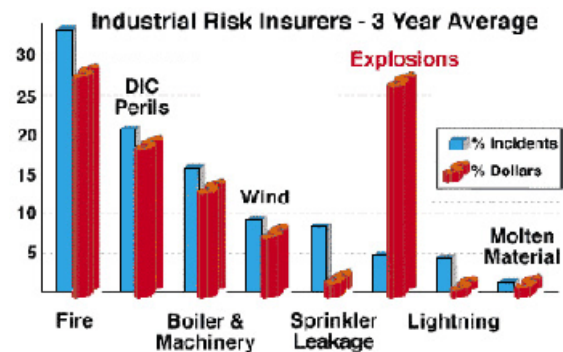
In a hotel environment, bombing and arson are the greatest perceived terrorist threat. Despite the new threats of chemical, nuclear, airborne and cyber attack, recent experience and the opinion of antiterrorism experts suggest that attacks against buildings using conventional explosives will, in all likelihood, continue to be the primary tactic of terrorists for the foreseeable future.

#### **Arson**

- Current building codes in North America are adequate.
- 85% of US hotels lack fire sprinkler systems – *US Subcommittee on Science, Research and Technology*.
- US and Canada has the highest rates of death by fire in the world.
- Sprinkler testing, fire alarm audibility, smoke alarm light on.

#### **Bombing**

- Of all kinds of property damages explosions cause the highest financial loss.
- In a bomb attack more than 80% of injuries and fatalities are attributable to flying glass and falling debris.
- Civilian buildings cannot be designed to be bomb-proof. Blast-resistant design can be expensive. Budgets are seldom enough for incorporating even limited protective provisions. The insurance industry does not provide incentives.
- Terrorist bombing is a very low probability event. It is difficult to justify the costly provision of protective design measures.
- Existing buildings can be upgraded. Retrofitting is costly and may generate unanticipated design problems.
- Military buildings: save the structure to maintain the operation  
Civilian buildings, including hotels: save the occupants, not the structure



### 4. **RISK ASSESSMENT**

- Terrorist attacks include bombing and attempted bombing, arson, kidnapping, suicide attacks, hostage taking, strikes, sabotage, murders and assault.
- Analyze regional crime statistics and terrorist activities
- Analyze the probability of threats, potential for disasters to the hotel
- Building's symbolic importance – American chain hotel in the middle of hostile territory

- Highly visible landmark
- Proximity to landmarks or buildings of national prominence, e.g., American Embassy.
- Temporary threat or significance – high profile VIP stay/visit, political conference.

## **5. PRINCIPLES OF BLAST-RESISTANT DESIGN**

- Maintain safe separation of attackers and targets
- Design to sustain and contain a certain amount of bomb damage. Allow for limited localized damage and prevent progressive collapse and catastrophic total structural failure.
- Minimize the quantity and hazard of broken glass and blast-induced debris.
- Facilitate rescue and recovery operations. Permit safe rescue and adequate time for evacuation of the occupants.

### **5.1 Stand-off Zone**

- Bollards, planters, fountains, fences as obstacles to ramming vehicles/truck bombs. Provide operational bollards or fences to allow emergency vehicle access.
- Raise the building 4' above grade (provide ramps for barrier-free access).
- Use earth berms as blast barriers.
- Keep parking away from the building. Restricted parking or no parking underneath the building.
- Secured access to loading dock. All deliveries should be registered, screened and logged prior to acceptance.
- Remove hiding spots for bombs -- trash receptacles, mailboxes, courier boxes, newspaper boxes, plant materials, garbage containers, etc.
- Bags-free zone – no backpacks, shopping bags, carts.

### **5.2 Access Control**

#### *Special Events Planning. Terrorist Alert.*

- Implement checkpoint at entrance and exits as temporary security procedure, e.g., high profile VIP stay/visit, political conference, terrorist alert, sudden wave of terrorist attacks. Build-in spatial and utility provision for hook-up.
- Provide security checkpoint airport-style
- Walk-through metal detector
- Scanning machine for guest luggage, bags
- Security screening and clearance for employees

### **5.3 Structural Reinforcement**

### *Facade Structure*

- Avoid re-entrant corners on the exterior where blast pressures may build up.
- Eaves and overhangs to be designed to withstand high local pressure and suction during blast.
- Curtain walls and masonry walls break up readily and become secondary fragments during blast. Consider using reinforced cast-in-place concrete walls, at least for the lower floors. It minimizes flying debris and assists in carrying additional load.

### *Structural Framing*

- Avoid exposed structural elements such as columns on the exterior.
- Provide structural redundancy to carry severe dynamic loading and reduce the chance of progressive collapse.
- Provide alternate load paths. Build-in back-up support system to carry damaged slabs or columns.
- Contain concrete floor slab failure locally. Transfer load to adjacent horizontal support. Ditto for columns.
- Properly detail beam-column connections to resist upward or downward blast loads.
- Provide ductile details for structural connections to absorb the blast energy.
- Provide spandrel beams to tie the structure together.
- Provide drop panels at perimeter column capitals to reduce the supporting span of slab above.
- Provide additional beams at critical areas for additional vertical and lateral support.
- Limit the use of transfer girders which work against this principle.
- Additional structural reinforcement – composite fibre wrap, polymer lining, steel plates, geotextile fabric

## **5.4 Glazing**

- Guests do not want to stay in bunker-like buildings. Hotels want to be open and welcoming, with abundant natural light, operable windows – expression of cordial hospitality.
- Blast pressure from a car bomb can be hundred times higher than the allowable pressures of any glazing system, e.g., the blast pressure in Oklahoma City bombing was about 4000 psi.
- Install high performance window glass which will fail properly if overloaded. They require engineered support and attachment system. High cost and high maintenance.
- US embassies limit glazing to 15%.
- Orient glazing perpendicular to the street to reduce exposure to blast and projectiles.

- Standard window glass (2 psi)
- TTG Thermally Tempered Glass (30-40 psi). Breaks into rock salt pieces, as on side and rear windows of cars.
- ESP (Engineered Stress Profile) glass (15 psi)
- Laminated glass or polycarbonate, bullet-resistant glass. Remains one cracked piece, as on windshields of cars.
- Consider window safety laminate (mylar film) or other fragment-retention film over glazing to reduce fragmentation. Fails in one sheet. Laminates deteriorate and easily vandalized.
- Others: Fibre composite material
- Blast curtains with Kevlar or just heavy drapes in high-threat areas

### **5.5 Space Planning**

- Analyze horizontal and vertical adjacencies
- Isolate high security spaces
- Locate assets as far into the interior of the building as possible.
- Place area of high visitor traffic away from assets.
- Locate critical assets in 24/7 zone and surveillance by multiple personnel.
- Place mail room on the building perimeter to minimize damage caused by mail bomb. Consider hardening the walls and ceiling similar a transformer vault.
- Provide foyer with reinforced concrete walls and offset doors to block blast pressure.
- Stagger doors in corridor to limit effects of blast through the structure.

#### *Temporary Security Implementation*

- Secured floor with controlled access.
- Provide secured, alternate entrance/exit routes.
- Internal logistics – designated elevators and timing, keep out other guests

### **5.6 Utility**

- Primary goal for the mechanical and electrical systems is to continue operation of the key life safety systems after the blast.
- Build-in surplus operational capacity to survive the attack.
- Mount exterior louvers at high level to minimize their vulnerability.
- Avoid mounting utility lines on vulnerable components -- inside of exterior walls, ceiling, roof slab.
- Locate utilities away from likely area of attack – parking area, loading dock, lobby.
- Harden the operational control areas and utility feeds from direct attack.
- Separate the prime power line and backup power line and keep apart as far as possible so that one bomb cannot disable the primary utility feed and the backup system.



- Fortify the computer server room.
- Provide manually activated or continuously active air filtration system to reduce risk of airborne contaminants.
- Battery check of emergency lights.
- Illuminate building access points to facilitate surveillance.