ARCHITECTURAL MEASURES FOR PUBLIC BUILDINGS TO MITIGATE DAMAGE BY TERRORISM

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree

of

MASTER OF ARCHITECTURE

By

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CANDIDATE'S DECLARATION

I hereby declare that this report entitled **"ARCHITECTURAL MEASURES FOR PUBLIC BUILDINGS TO MITIGATE DAMAGE BY TERRORISM"** which has been submitted in partial fulfillment of the requirement for the award of the degree of **Master of Architecture**, in Department of Architecture and Planning, Indian Institute of Technology- Roorkee, is an authentic record of my own work carried out during the period from July 2011 to June 2012, under supervision and guidance of **Prof. Rita Ahuja**, Assistant Professor, Department of Architecture and Planning, Indian Institute of Technology, Roorkee, India.

The matter embodied in this dissertation has not been submitted by me for the award of any other degree of this or any other institute.

Date: 12|06|12

Place: Roorkee

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This is to certify that the above statement made by the candidate is correct to the best of my knowledge and belief.

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Certified that report entitled **"ARCHITECTURAL MEASURES FOR PUBLIC BUILDINGS TO MITIGATE DAMAGE BY TERRORISM"** which has been submitted by **Ms. RUCHI YADAV**, for partial fulfillment of the requirement for the award of the degree of **Master of Architecture**, in Department of Architecture and Planning, Indian Institute of Technology- Roorkee, is the student's own work under my supervision and guidance. The matter embodied in this dissertation has not been submitted by her for the award of any other degree of this or any other institute.

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Place: Roorkee

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I would also like to thank my friends for their suggestions, cooperation & for making my stay at IIT Roorkee a pleasurable & memorable experience. The acknowledgement will not be complete till I express my regards and thanks to my parents for their blessings, motivation & moral support.

Date: 12/06/12
Place: Roorkee

Ruchi
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EXECUTIVE SUMMARY

Our buildings on certain extent provide security from natural or environmental hazards; structural hazards etc., but generally fail to provide safety security against accidents & crime.

There has been considerable concern about the terrorism due to increase in terrorist attacks. Society must be taught to manage with hazards of terrorism as it does with natural disaster. Currently not much is available to an engineer & architect in terms of guidance on how some features of design, planning and construction can have extreme propositions on the safety of the building and its inhabitants in the event of a future attack by a terrorist.

Building science society has included widespread building science into designing & constructing buildings against natural hazards. But, same echelon of awareness is not available to manmade hazards (intentional acts/ terrorism). Since WTC Attack, terrorism has turn out to be a foremost domestic concern. Safety & Security should not be out looked as a separate capability that can be bought as a late addition & then put in place. Safety & security must turn into a design objective from the start.

Not much is on hand to an architect in terms of assistance on how a few features of planning, design and construction can have far reaching propositions on the safety of the building and its inhabitants in the incident of a future attack by a terrorist.

An attempt has been made in this dissertation to propose some architectural measures, which provide safe & secure environment in a public building against terrorist attack. Terrorist attacks on buildings may not be eradicated entirely, but their effects on buildings and structures can be extenuated to a large extent with precautions and preventative strategies.

PURPOSE

Terrorism is a major trouble all over the world at the moment. The terrorist attack graph is rapidly growing day by day. Safety & security from terrorist attacks has been quite low on priority list of architects, designers, planners & builders. Very less is talked about safety & security from terrorist attack in the process of architectural designing. Building science society has included widespread building science into designing & constructing buildings against natural hazards. But, same echelon of awareness is not available to manmade hazards (intentional acts/ terrorism). Awareness is needed because this attack makes physical as well as psychological impact on a person's daily life. Making him feel safer and comfortable in the neighborhood where he lives and visit daily is also a part of the architect who designs a building, planner who plan the neighborhood. The purpose of this dissertation is to give guidance to evaluate the performance of the buildings against terrorist threats and to rank suggestions. It is up to the architects or decision makers to make a decision which type of terrorist threats they desire to guard against.

OBJECTIVES

The objective of the dissertation is to lessen substantial sabotage to non-structural & structural elements of buildings and associated infrastructure, and also to lessen ensuing fatalities during conventional terrorist attacks. Though the procedure is universal in character & applies to the majority building uses, this dissertation is most appropriate for public buildings.

The Dissertation discusses the following:

- The dissertation analyses the various terrorist hazards and the approaches to reduce the risk from terrorism.
- An analysis is produced of possible damage to buildings due to blast. Particulars are also produced on mechanisms of damage due to blast.
- Architectural measures to be considered while designing new buildings is the central subject matter of the dissertation along with contemplation required in site planning, architectural design & planning, and structural aspects.
- Terror vulnerability assessment of India Habitat Center, New Delhi has been done with respect to formulated architectural measures of mitigation. This building has been taken for assessment because Public buildings have recently become targets for bombs & bomb threats.

METHODOLOGY

The aim of this study is to evolve architectural design measures to reduce the risk from terrorism by reviewing the various terrorist hazards & possible damage to buildings due to blast & its mechanism. Different kind of scenarios showcasing the different encounters with the interface surrounding have been selected to involve each and every kind of impact happened, so that assessment and inferences can be made out. Five cases have been analyzed with respect to parameters like Site Planning, Architectural Configuration (Shape & Size), Building Envelope, functional planning & Structural Elements. Integrative analysis & assessment of data collected from literature & case studies let to formulate the architectural measures of mitigation. Practical stimulation of the understandings and learning from the five studies was to make a statement for architects that it is possible to prevent hazards from terrorism. A conscious approach towards thinking for a venerable building in a public sector and at an important place, I.H.C came out to be a valid example. Formulated architectural measures of mitigations have been used in assessment of India Habitat Centre.

RECOMMENDATIONS

This dissertation addresses security issues in a public building. It also discusses the measures to improve the safety & security of the building by including low cost measures into new buildings at the initial phases of site selection & design. Most important architectural measures formulated in this dissertation are listed below:

- Building should be located as far as practical from the protected perimeter.
- Perimeter should be protected against vehicular invasion by incorporating barrier or landscaping.
- Locate unsecured areas along the exterior of the main structure or outside the footprint of the building.
- Susceptible areas such as the delivery & entry areas should be physically segregated from the rest of the building.
- Lightweight non-structural components or elements must be employed in the building interior and exterior.
- Employ measures to defy progressive collapse.

- Air intake units of AHU should be kept above the ground level as far as practical.
- Segregated redundant electrical & mechanical control systems should be used.

OUTCOME

The architectural measures of terror mitigation for public building have been proposed with respect to architectural parameters. These parameters include site planning, building configuration, functional planning, and building envelope design and security systems. The expected outcome has been a report telling what all aspects has to be looked upon and how these can become standard guidelines to make public buildings safer.

Due to increase in the terrorist attacks on public buildings, since it is a densely populated building, there is a need of making it a safer place. India Habitat Center, New Delhi has been assessed with respect to formulated architectural measures of mitigation because India Habitat Centre houses not only research organizations & offices but also a convention centre, club as well as performance venues for cultural activities & numerous restaurants.

This study provided a detailed assessment of IHC, New Delhi with respect to planning & design aspects of the mitigation measures in particular. The outcome of the analysis has come in form of a chart where every aspect has been judged and statement has been made. As per assessment, the IHC building will survive in a blast event because of its functional & spatial planning. The complex has a very well planned segregation of spaces. Some operational changes are required in basement parking & access to the courtyards to make it a perfect security based design.

CONCLUSION

Public buildings have been common targets for terrorist attacks. Making buildings secure from negative effects of terrorist attacks needs a systematic treatment. This document provided a detailed treatment of the measures related to planning & design aspects of the mitigation measures in particular. Safety & security measures must not obstruct with daily processes of the building as the possibility of terrorist attack is extremely low. The consequences of a terrorist attack can be disastrous, it is practical to include measures that can reduce business disruption & save lives in a blast event. The measures must offer a competent environment that does not draw unnecessary attention of potential attackers.

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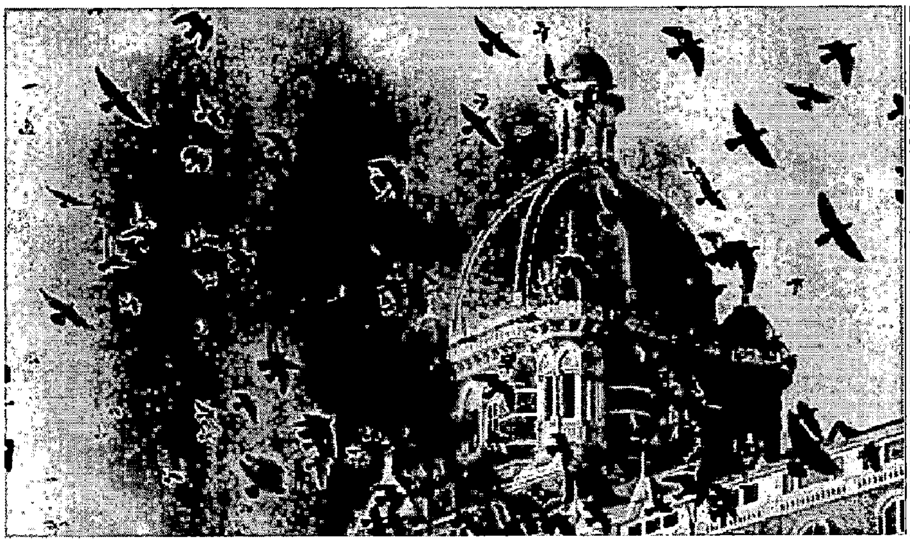
CHAPTER 1. INTRODUCTION

Our buildings on certain extent provide security from natural or environmental hazards; structural hazards etc., but generally fail to provide safety & security against accidents & crime.

Security problems involving public buildings may be divided into two separate categories: criminal & non-criminal. While the criminal security problems far out- weigh the non-criminal problems.

Those criminal acts which might actually affect the building are burglary, theft, vandalism, rioting, arson & terrorism. In the non criminal category are threats which might be termed "acts of god"- fire, flooding, high winds, earthquakes, lightning, etc.

There has been considerable concern about the terrorism due to increase in terrorist attacks. Society must be taught to manage with hazards of terrorism as it does with natural disaster. Currently not much is available to an engineer & architect in terms of guidance on how some features of design, planning and construction can have extreme propositions on the safety of the building and its inhabitants in the event of a future attack by a terrorist.



Building science society has included widespread building science into designing & constructing buildings against natural hazards. But, same echelon of awareness is not available to manmade hazards (intentional acts/ terrorism). Since WTC Attack, terrorism has turn out to be a foremost domestic concern. Safety & Security should not be out looked as a separate capability that can be bought as a late addition & then put in place. Safety & security must turn into a design objective from the start.

Terrorism is the methodical use of terror, particularly as a means of oppression [Terrorism - Wikipedia, the free encyclopedia]. Terrorism is an aggressive act which is intended to generate fear (terror), is committed for a religious, ideological or political purpose, and intentionally aim or disregard the safety & security of non-combatants civilians.

Extenuating the hazard of terrorist attacks against high occupancy public buildings is a difficult job. It is hard to envisage why, when & how terrorists may attack. Terrorist attacks on public buildings may not be eradicated entirely, although their effects on structures & buildings can be extenuated to a large extent with precautions and preventative strategies.

1.1 PROBLEM IDENTIFICATION

1.1.1 INCREASE IN NUMBER OF TERRORIST ATTACK

- Terrorism is something which all over the world is a major trouble at the moment. Everyday there are lots of reports about terrorist attacks.
- The terrorist attack graph is rapidly growing day by day.

1.1.2 DEFICIENCY IN BUILDING CODES RELATED TO TERRORIST ATTACKS

- No document is available in public domain related to terrorism-risk and published by any governmental department or agency in India.
- However, a number of publications are available in the public domain and published by US agencies. (FEMA series)
- Blast loading is one of the dominant loads imposed by effects of terrorist attacks on structures. Criteria for design of structures to resist effects due to blast above ground are given in IS: 4991-1968.
- However, progressive collapse is not dealt within the Indian codes. Since, this forms the core issue in structural hardening.
- Provisions are also required for the design of fenestrations to resist effects of blast (e.g., glass windows) and for the effects of ammunition impact on buildings and structures due to armed attack.
- Further, there are codes dealing with the subjects of HVAC (i.e., heating, ventilation, and air-conditioning). But, details as relevant to chemical, biological, and radiological agents being introduced into the HVAC system by terrorist are not dealt with in these codes.

1.1.3 NEGLIGENCE

- Safety & security from terrorist attacks has been quite low on priority list of architects, designers, planners & builders. Very less is talked about safety & security from terrorist attack in the process of architectural designing.
- Building science society has included widespread building science into designing & constructing buildings against natural hazards. But, same echelon of awareness is not available to manmade hazards (intentional acts/ terrorism).

1.1.4 INDIAN CONTEXT

- No concrete work has been done in this field in India.
- No document is available in public domain related to terrorism-risk and published by any governmental department or agency in India.

1.1.5 AREA OF CONCERN: PUBLIC BUILDINGS

Public buildings have recently become targets for bombs & bomb threats. Due to increase in the terrorist attacks on these buildings, since it is a densely populated building, there is a need of making them a safer place.

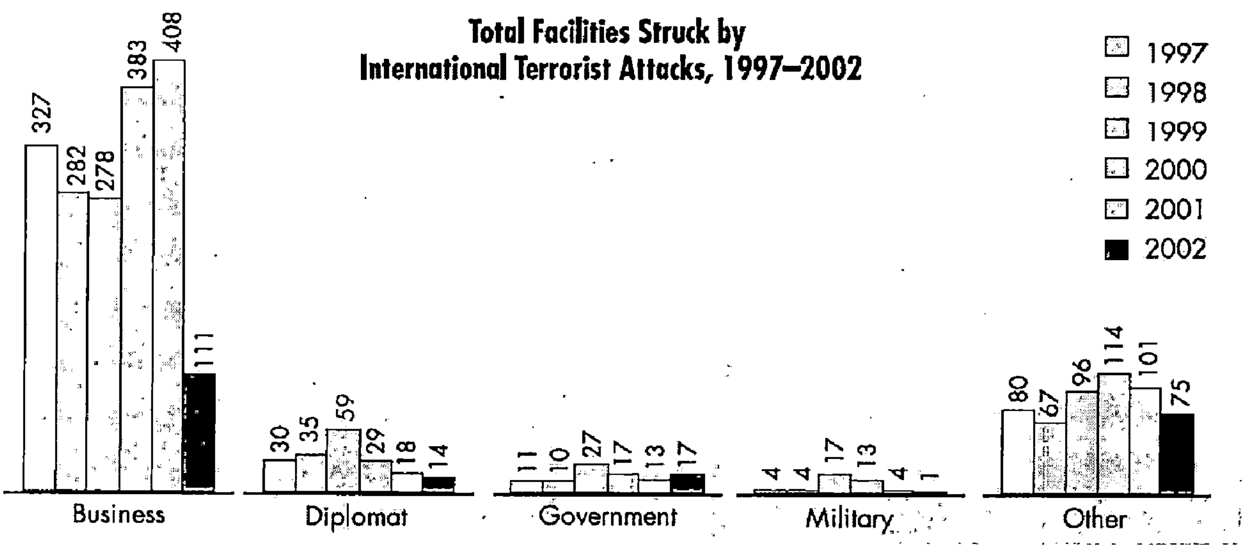


Figure 1: Total facilities hit by international terrorist attack in 1997-2002, Source: department of state patterns of global terrorism 2002

1.2 AIM

The aim of this study is to propose architectural measures, which provide safe & secure environment in a public building against terrorist attack.

1.3 OBJECTIVES

- To review the various terrorist hazards & possible damage to buildings due to blast & its mechanism.
- To evolve design strategies to reduce the risk from terrorism.
- To evolve solutions through parameters like Site Planning, Architectural Configuration (Shape & Size), Building Envelope, functional planning & Structural Elements to reduce the risk from terrorism.

1.4 SCOPE & LIMITATIONS

The scope of dissertation focuses on the:

- Study of Public buildings to achieve safe & secure environment against terrorist attacks.
- Explosive or bomb attacks only. Design approach to mitigate the effects of chemical, biological, and radiological attacks will not be addressed.
- Terror mitigation of New Buildings only. Retrofitting to mitigate terrorist attack will not be addressed.

1.5 RESEARCH METHODOLOGY

Identification of Research Topic
Need and background for the study

⇩

Framing Aim , Objectives, Scopes & Limitations

⇩

Data collection

⇩

Literature Review

- **Terrorist threats**
- **Blast Loading on Structures**
- **Blast Effects on Buildings**
- **Mechanisms of Damage in Buildings**
- **Current Building bye laws for terrorism risk reduction**

Case Studies (live/literature)

- **Study of terrorist attacks on Public buildings.**
- **Finding out areas susceptible to attack.**
- **Evaluation of the case study w.r.t. parameters:**
  - Site Planning
  - Architectural Configuration (Shape & Size)
  - Building Envelop
  - Functional planning
  - Structural aspects
- **Inferences**

⇩

Integrative Analysis and assessment of the data
Collected From Literature And Case Studies

⇩

Formulation of Architectural Measures of mitigation

⇩

IHC Building – Terror Vulnerability Assessment

The aim of this study is to evolve architectural design measures to reduce the threat from terrorism by reviewing the diverse terrorist hazards & potential damage to buildings due to blast & its mechanism. Six cases have been analyzed with respect to parameters like Site Planning, Architectural Configuration (Shape & Size), Building Envelope, functional planning & Structural Elements. Integrative analysis & assessment of data collected from literature & case studies let to formulate the architectural measures of mitigation. Formulated architectural measures of mitigations have been used in assessment of India Habitat Centre.

CHAPTER 2. LITERATURE REVIEW

2.1 TERRORIST THREATS

Several types of terrorist threats are listed below:

- Explosion
- Arson
- Armed Attack
- Biological, Chemical, Nuclear and Radiological Attack
- Others

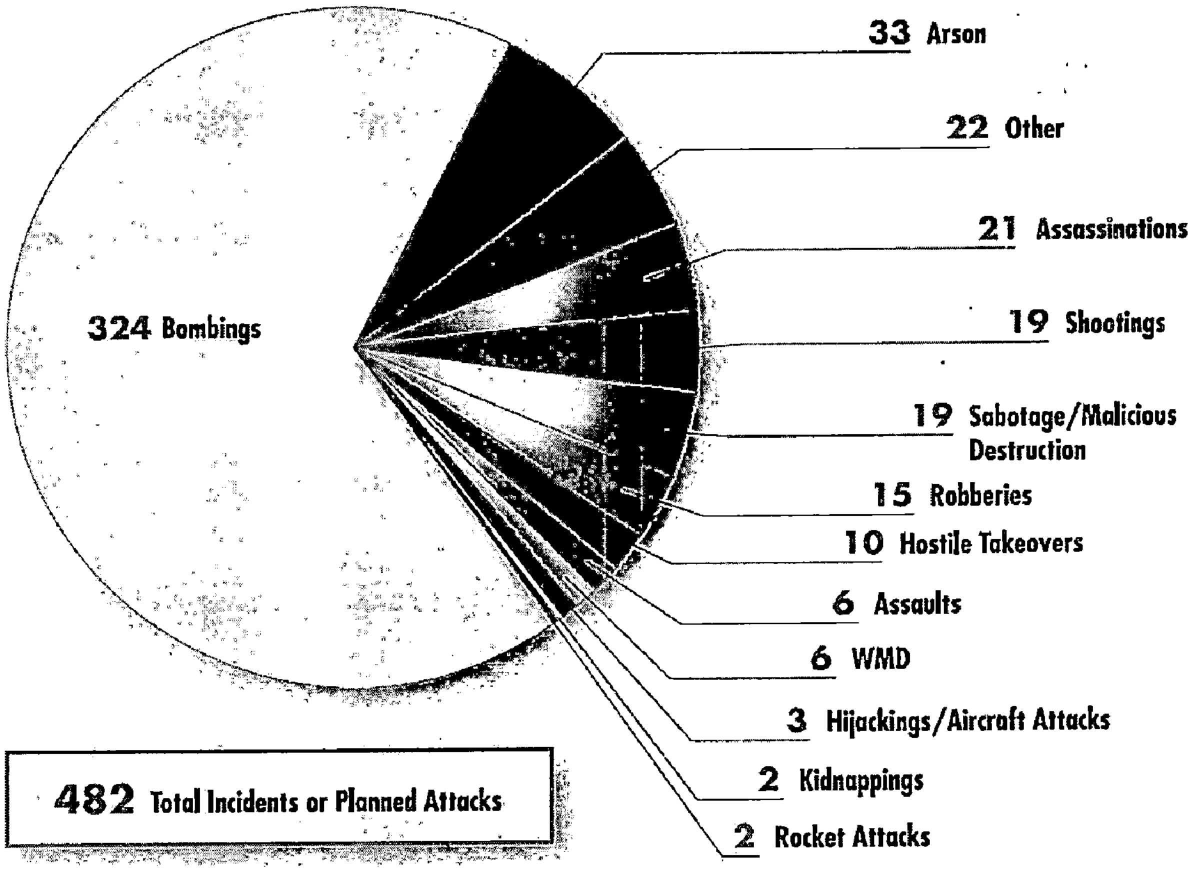


Figure 2: Events of terrorism, from 1980 to 2001, Source: FBI, Terrorism, 2000/2001 publication #308

Even if it is likely that the primary threat method may change in the future, bombings have previously been a preferred method of terrorists. Bombing is effortless & fast to implement. Lastly, the remarkable components of blast in terms of the utter destruction they cause generate a media consciousness which is extremely successful in conveying the terrorist's message to the general public.

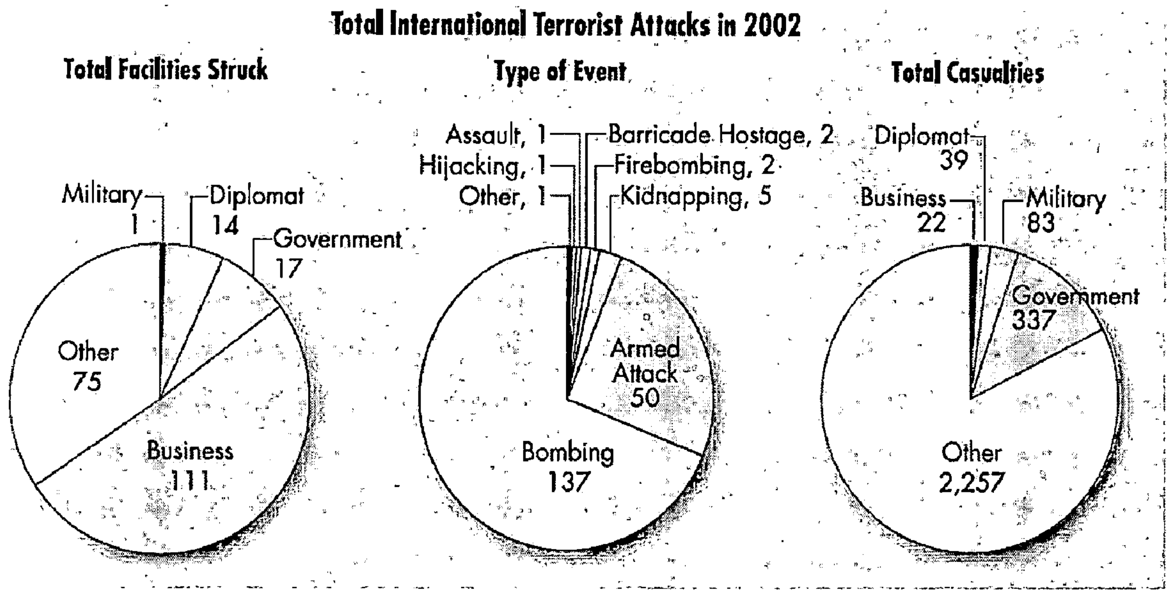


Figure 3: Total international terrorist attack in 2002, Source: FEMA 426, 2003

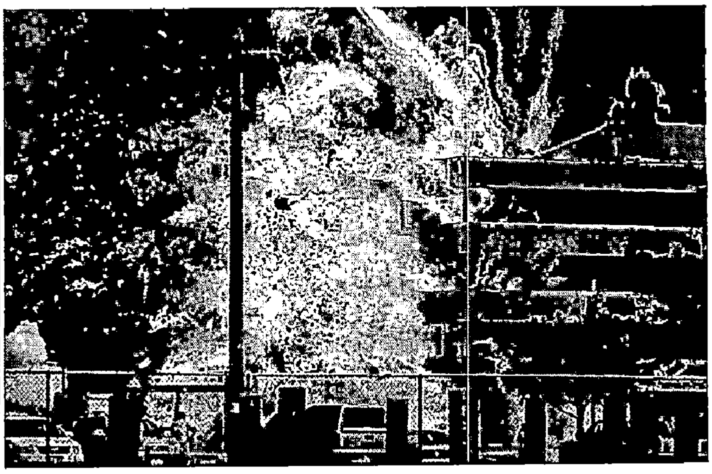
2.1.1 EXPLOSIVE ATTACKS

The definition of an explosion in non-scientific terms is the very rapid release of energy with an audible sound of a blast. The energy from the explosion is released in parts by thermal radiation, air blast & ground shock waves. The air blast accounts for most of the injury caused by an explosion. The high velocity wind produced by air blast will spread debris over a huge area causing harm to other buildings & people.

Explosive Threats are of two types:

- Vehicle weapon
- Hand-delivered weapon

From the point of view of structural design, the vehicle bomb is the essential concern. Vehicle bombs are capable to transport a large amount of explosives to cause destructive structural sabotage. Safety & Security design proposed to restrict or alleviate damage from a vehicle bomb presumes that the vehicle bomb is exploded at a critical location which is a function of the site planning, the building arrangement, and the security measures in place [www.fema.gov]. For a vehicle bomb, the critical location can be a parking area directly underneath the building, the loading dock & the entry control points where checking takes place.

One more explosive attack hazard is the hand delivered small bomb. Small weapons can cause the extreme injury if carried into unsecured & susceptible areas of the building such as the mail room, retail spaces & building lobby.

Places where bombs are usually planted include elevator shafts, access points, stairwells, rest rooms, mail rooms, unsecured points of access to plumbing or electrical fixtures, ceiling areas, access doors, crawl spaces, record storage areas, boiler & air conditioning rooms, utility closets, flammable storage areas, indoor trash receptacles, main switches & valves, fire hose racks. Careful planning of building design can minimize the danger by preventing unauthorized access to these areas.

Two factors describe the design risk:

- Standoff distance
- weapon size (equivalent pounds of TNT)

The standoff distance is the distance taken from the center of gravity of the threat, weapon or vehicle to the concerned component. **The intensity of energy expected at a point due to the explosion is inversely proportional to the cube of the stand-off distance from the point of blast** [www.fema.gov]. Therefore, enlarged stand-off distance is a straight measure of security to the facility.

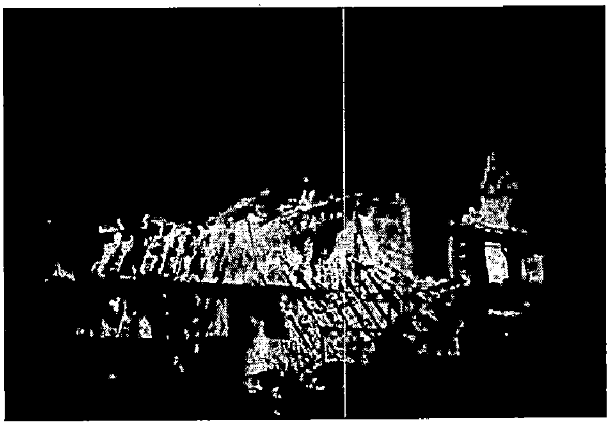
Effective approach for mitigating harmful effects of explosions involves awareness to a number of factors:

- Ease of access by the aggressor to the facility,
- Opportunities for aggressors to effortlessly conceal the devices in the proximity of the facility.
- Lack of barriers to the facility.
- No structural hardening.

2.1.2 ARSON

The fundamental measures to reduce effects of arson on buildings include:

- Built-in systems for fire protection,
- Fire detection, and fire-resistant construction techniques.
- Preventing ease of access to concerned facility, ease of concealment of the combustible gadget & undetected commencement of a fire.
- Conformity with fire-related building codes and regular maintenance of the existing fire protection systems significantly help in diminishing the harmful effects of fire weapons used by the aggressors.



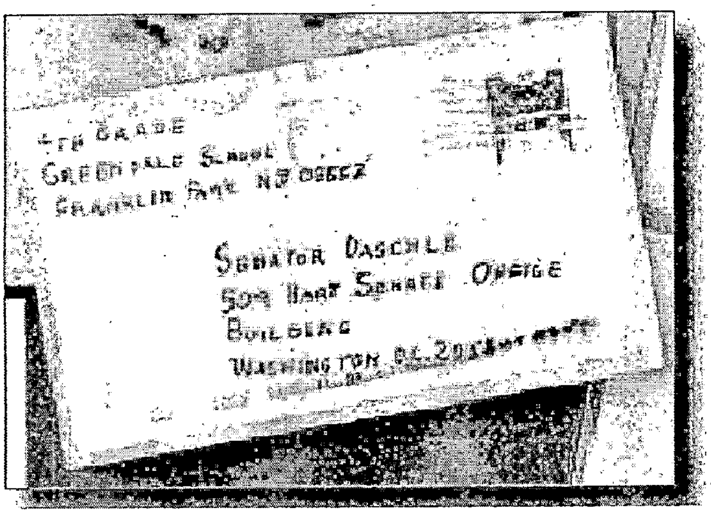
2.1.3 ARMED ATTACK

The success of preventing armed attackers is contingent on the security posted at the building. An intelligent and strong security system can prevent access to aggressors, identify concealed weapons, and detect initiation of an attack.

2.1.4 CHEMICAL, BIOLOGICAL, NUCLEAR AND RADIOLOGICAL ATTACK

While drawing up clear strategies for mitigating detrimental effects of biological, chemical and radiological attacks, the following information is helpful.

- Altitude of release of the biological agent affects its dispersion; higher the release, greater is the dispersion. High winds can destroy the aerosol clouds and hence their dispersion.
- Higher temperatures cause evaporation of chemical aerosols in air and of chemical contamination on ground.
- High humidity enlarges the chemical aerosol particles and reduces the likelihood of inhalation.
- Precipitation dilutes the chemical agent, but leads to its dispersion.
- Wind disperses the chemical vapors, but makes the area on which the chemical can attack uncertain.
- Presence of buildings and certain types of terrains can change the dispersion patterns. Shielding by buildings is seen as an important way of protecting life and property from the ill effects of chemical contamination.
- Similarly, the severity of the radiation attacks depends on duration of radiation release, distance of radiation release from the target, and amount of shielding between Source and target. Understandably, since usually the first two parameters are not design quantities, amount of shielding is the focus of most mitigation efforts.



Anthrax spores formulated as a white powder were mailed to individuals in the Federal Government and media in the fall of 2001. Postal sorting machines and the opening of letters dispersed the spores as aerosols. Several deaths resulted. The effect was to disrupt mail service and to cause a widespread fear of handling delivered mail among the public.

Figure 4: Sample anthrax letter. Source: FEMA 426, 2003

Likewise, even for nuclear attacks shielding is the main strategy for minimizing the harmful effects of radiation. Since, light, heat and blast energy reduce logarithmically with increase in distance from the Source. Terrain forestation, obstruction structures, and large wall thickness are seen as some of the measures of shielding so that the effects of nuclear attack (i.e., blast overpressure, radiation, and radioactive contamination) are absorbed or deflected.

2.1.5 OTHERS

Countering cyber-terrorism requires counter-intelligence and pre-empting moves by aggressors. In the absence of such innovations, critical computer networks/systems need to be isolated or allowed restricted entry. As in cyber-terrorism, inadequate security is also the reason of agro-terrorism. And, as in case of agro-terrorism, the trial tested strategy for avoiding or mitigating agro-terrorism is physical security of the agricultural land. Protecting against unauthorized entry into a building is achieved by undertaking a building design that includes at least the standard measures of physical security. For more critical assets, a wider spectrum of security measures need to be incorporated, e.g., closed circuit television, access control points for visitors, and non-contact sensors for assisting in detection of aggressors.

Similarly, unauthorized surveillance can be minimized by conducting the architectural design of the building in a way that the lines of sight are broken and acoustic collection is not possible by outsiders.

2.2 BLAST LOADING ON STRUCTURES

When a detonation occurs, an exothermic chemical reaction takes place in a period of few milliseconds. The volatile material is transformed to very high-pressure gas. This highly compressed air travels radially outward from the Source at supersonic velocities which is called as the shock wave front. It spreads out at very high speeds. As the shock wave expands, pressure reduces rapidly with distance D (as $1/D^3$). A blast causes an almost immediate increase in air pressure from atmospheric pressure to a large overpressure.

Air explosions caused by bomb blasts lead to widespread damage to the built environment and thereby a major disaster. Blasts can be both above ground and below ground. Understandably, the impact of above ground blasts is more widespread on the built environment. Knowledge on blasts at ground level or in air – their magnitude, mechanisms and effects on environment around, are essential to be able to reduce these losses.

During the detonation, there is an unexpected expansion of the small amount of air surrounding the explosive or bomb. The pressure created within the explosive is much higher than that around it. The generated surrounding air pressure is adequate to cause far-reaching damage in the built environment.

2.2.1 WEAPONS OF BLAST

Explosives are categorized as low and high depending on the quantity of energy released by them and the resultant harm caused by them. The low explosives only blaze, but do not explode. An example of the low explosive is the black powder. On the other hand, the high explosive is designed to explode. Examples of the high explosives are dynamite and TNT.

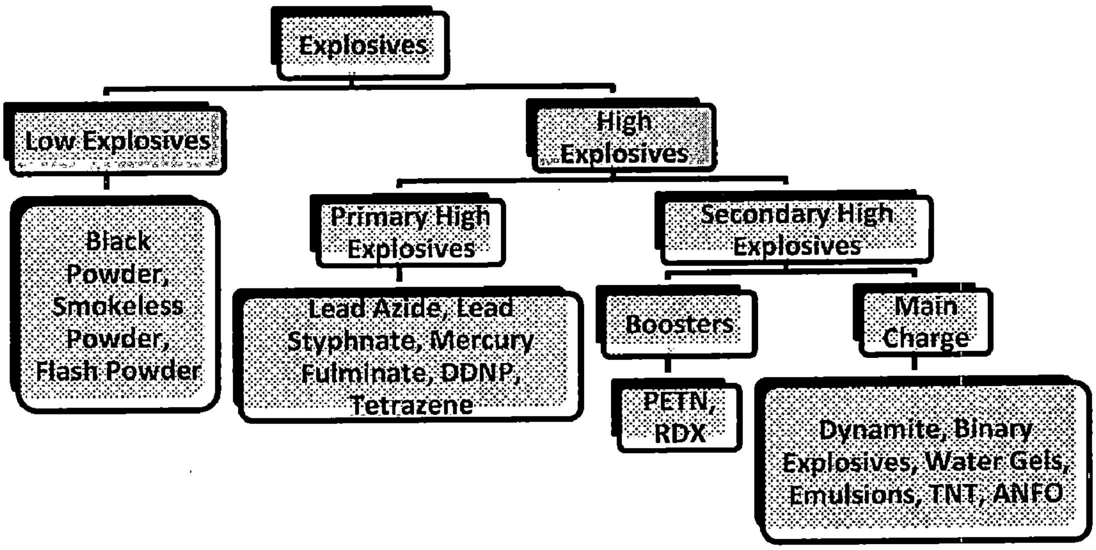


Figure 5: Classification of explosives and their examples, Source: www.fireandsafety.eku.edu

Two considerable by-products of a blast are huge amount of heat and enormously high overpressure in the air adjoining the explosive or bomb. Evidently, very high temperatures are viable in the locality of the detonation. Hence, combustible material must be kept away from potentially harmful areas where blast can be anticipated.

2.2.2 PROPAGATION OF OVERPRESSURE

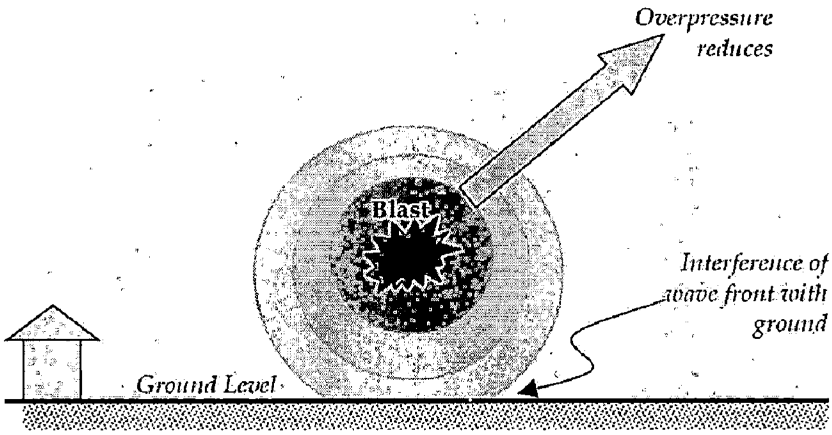


Figure 6: Propagation of Blast: Radial outward motion of pressure wave front and reducing pressure with increase in distance, Source: ASCE, 1985

A perfect blast in air generates a shock wave front which moves radially outward at supersonic velocities and concurrently expands, thus causing a drop in the overpressure. A surface or near-surface blast generates a hemispherical wave front. The velocities of these pressure wave fronts differ depending on distance from Source.

2.2.3 BLAST EFFECTS ON BUILDINGS

Blast effects are clearly different from other hazards like earthquakes. The following are some of the unique features:

1. The blast pressures created on a targeted facility may be of huge magnitude larger than those generated by wind or wave.
2. Blast pressures perish extremely fast with distance from the threat. Thus, damages on the facade of the building in front of the blast may be extensively harsher than those on the other sides of the building. Hence, air blasts tend to cause localized damage. When the

building is surrounded by other buildings as in an urban area, reflections from nearby buildings can lead to amplified sabotage even on the back side of the building.

3. The period of the blast shock wave front is of the order of milliseconds. This is in disparity to the period of loading of seconds during earthquakes. In earthquakes, larger mass can induce amplified inertia forces, which can worsen the damage.

2.2.3.1 CRATER EFFECTS

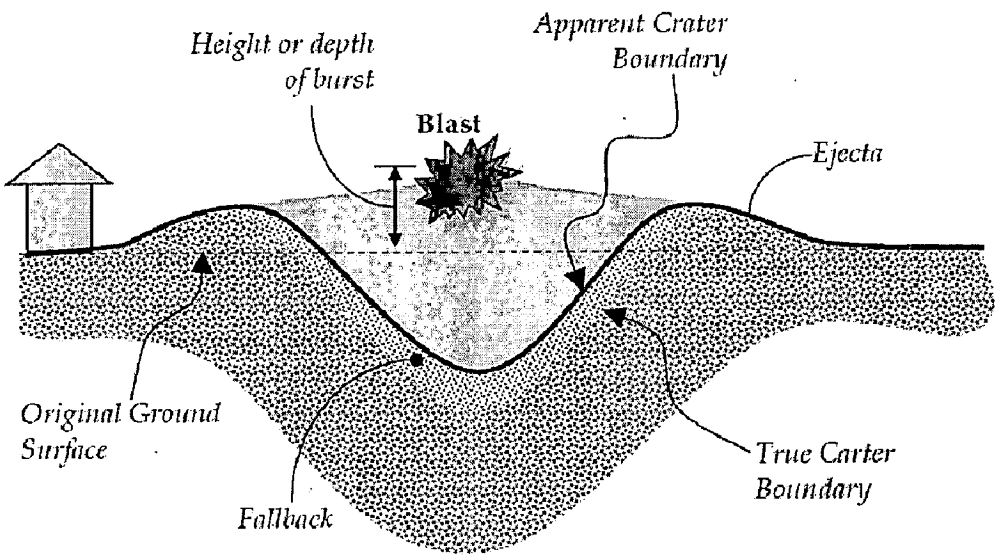


Figure 7: Geometry of a crater formed by near-surface explosion. Source: ASCE, 1985

Blast that occur close to, at or under the Earth's surface result in craters, large depression in the ground surface. The size of the crater depends on the size of the blast. Research showed that the most considerable cratering occurs when the explosion is close to the surface. The main feature of this crater is the depth up to which the blast penetrates into the ground.

2.2.3.2 GROUND SHAKING

A blast on underground causes direct shaking of the ground due to the overpressure of the explosion slapping on the earth surface. On the other hand, a blast slightly above ground causes both direct shaking of the ground and shaking of the ground due to interference of the reflected wave and the incident wave.

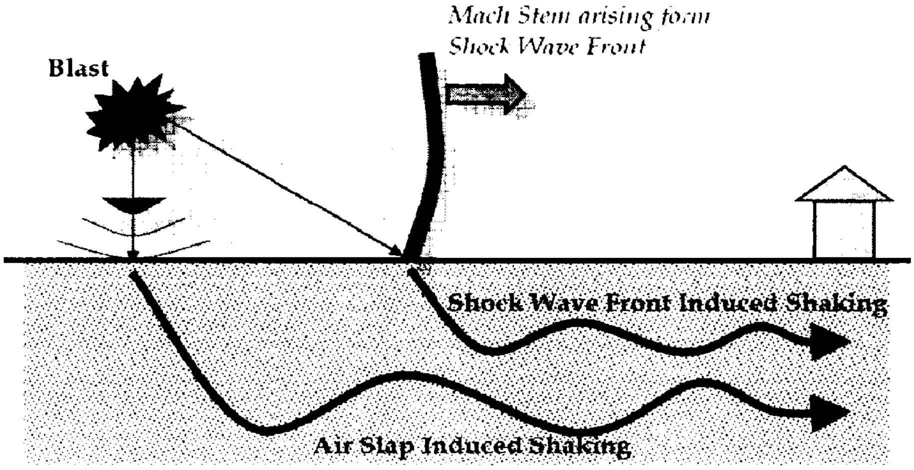


Figure 8: Shaking of earth due to above ground explosion results in two distinct components of shaking, Source: ASCE, 1985

The ground shaking generates inertial effects on the buildings and structures with overpressures generated by the blast. Thus, the design of structures should be competent of resisting both these effects.

2.2.4 STAND-OFF DISTANCE

The stand-off distance is the distance between the center of gravity of the bomb placed in a vehicle or a container and the concerned building. The intensity of blast rapidly reduces with distance. Consequently, the damage is also likewise lesser. Hence, the cost of providing mitigating measures decreases with distance. In contrast, higher stand-off distance implies the need for larger area of land around the building. This means a longer perimeter to be secured with barriers, thus, increasing the cost of mitigation measures.

The significant locations for external weapons (bombs in vehicle) are the closest points on each side of the perimeter that a vehicle can approach. These locations are normally where a vehicle can be parked by the side of the curb directly outside the concerned building, or at the access control points where security checking is done. The significant location for internal weapons (bombs placed in containers) is the location of publicly accessible areas in the building, e.g., lobbies, corridors, cafeterias, auditoriums or gymnasiums.

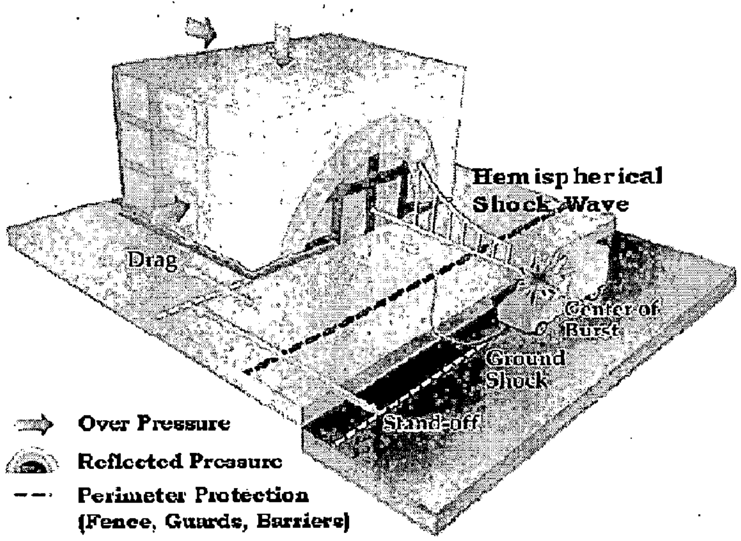


Figure 9: Schematic of vehicle-based weapon blast indicating threat parameters and definitions, Source: FEMA 426, 2003

The amount of building sabotage is determined by the stand-off distance. This parameter is widely used in the design of structures against blast. The overpressure due to a blast is vitally dependant on the distance from the blast; the larger is the distance from the blast, the better it is from the point of vulnerability of the structure. Therefore, stand-off distance between the location of a possible blast and the structure in focus is very important. The hand-carried bombs raise a severe requirement for security screening of persons entering the building, while vehicle-mounted bombs are essential in planning the proximity of parking areas to the building.

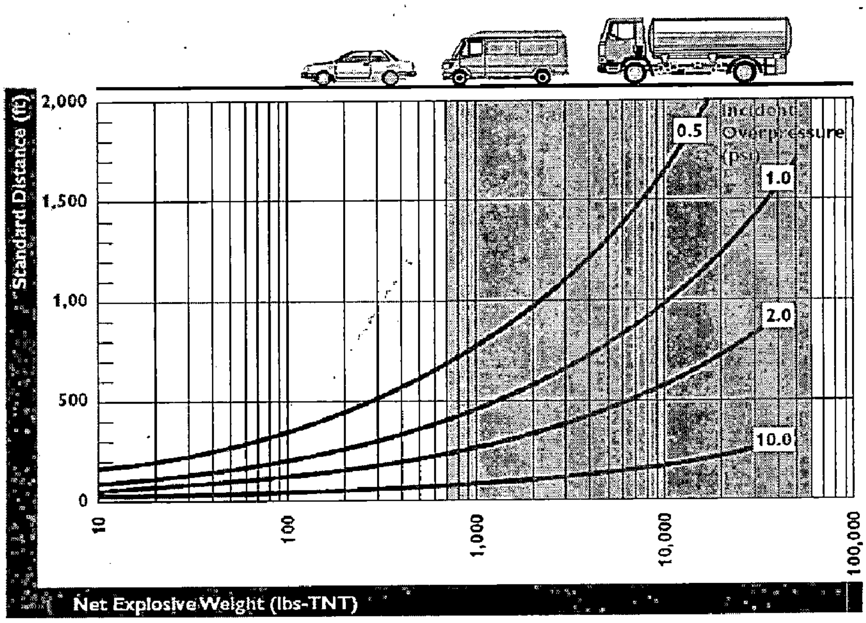
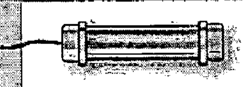
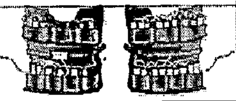
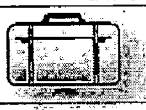
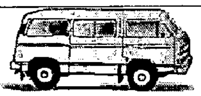
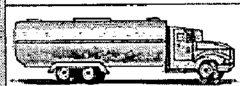
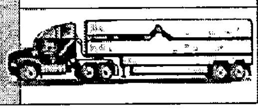


Figure 10: Incident overpressure (psi) as a function stand-off distance and net explosive weight, Source: U.S. Air Force, Installation Force Protection Guide.

Figure above gives a quick method for predicting the estimated overpressure on a building for a particular stand-off distance and explosive weight. The anticipated explosive weight a terrorist might employ is demonstrated by X-axis and known stand-off distance from a building is demonstrated by y-axis. The degree of sabotage of different components of a building can be predicted by comparing the resultant effects of overpressure with other data. The comparative size of the vehicles that can be utilized to carry diverse quantities of explosives is shown by the vehicle icons in the above figure.

Table 1: Safe Evacuation Distances from Explosive Threats. Source: The Department of Defense (DoD)

Threat Description			Explosives Mass* (TNT equivalent)	Building Evacuation Distance**	Outdoor Evacuation Distance***
High Explosives (TNT Equivalent)		Pipe Bomb	5 lbs 2.3 kg	70 ft 21 m	850 ft 259 m
		Suicide Belt	10 lbs 4.5 kg	90 ft 27 m	1,080 ft 330 m
		Suicide Vest	20 lbs 9 kg	110 ft 34 m	1,360 ft 415 m
		Briefcase/ Suitcase Bomb	50 lbs 23 kg	150 ft 46 m	1,850 ft 564 m
		Compact Sedan	500 lbs 227 kg	320 ft 98 m	1,500 ft 457 m
		Sedan	1,000 lbs 454 kg	400 ft 122 m	1,750 ft 534 m
		Passenger/ Cargo Van	4,000 lbs 1,814 kg	640 ft 195 m	2,750 ft 838 m
		Small Moving Van/ Delivery Truck	10,000 lbs 4,536 kg	860 ft 263 m	3,750 ft 1,143 m
		Moving Van/ Water Truck	30,000 lbs 13,608 kg	1,240 ft 375 m	6,500 ft 1,982 m
		Semi-trailer	60,000 lbs 27,216 kg	1,570 ft 475 m	7,000 ft 2,134 m

- * Based on the maximum amount of material that could reasonably fit into a container or vehicle. Variations are possible.
- ** Governed by the ability of an unreinforced building to withstand severe damage or collapse.
- *** Governed by the greater of fragment throw distance or glass breakage/falling glass hazard distance. These distances can be reduced for personnel wearing ballistic protection. Note that the pipe bombs, suicide belts/vests, and briefcase/suitcase bombs are assumed to have a fragmentation characteristic that requires greater stand-off distances than an equal amount of explosives in a vehicle.

Below table has been prepared by the Department of Defense (DoD) to help specify deflagrating materials and the weight of explosives that may rationally fit within a range of vehicles & containers. It also specifies the safe evacuation distances for inhabitants of conventional buildings. Likewise, the safe evacuation distance for pedestrians open to blast effects is specified in below table. Since a suicide belt, pipe bomb, backpack and briefcase bomb are specially made to hurl flying debris & fragments, safety & security from these gadgets may need larger safe evacuation distances than an equivalent weight of explosives carried in a vehicle.

2.2.5 MECHANISMS OF DAMAGE IN BUILDINGS

Sabotage as a result of the air-blast shock wave can be categorized into:

- Progressive collapse.
- Direct air blast effects

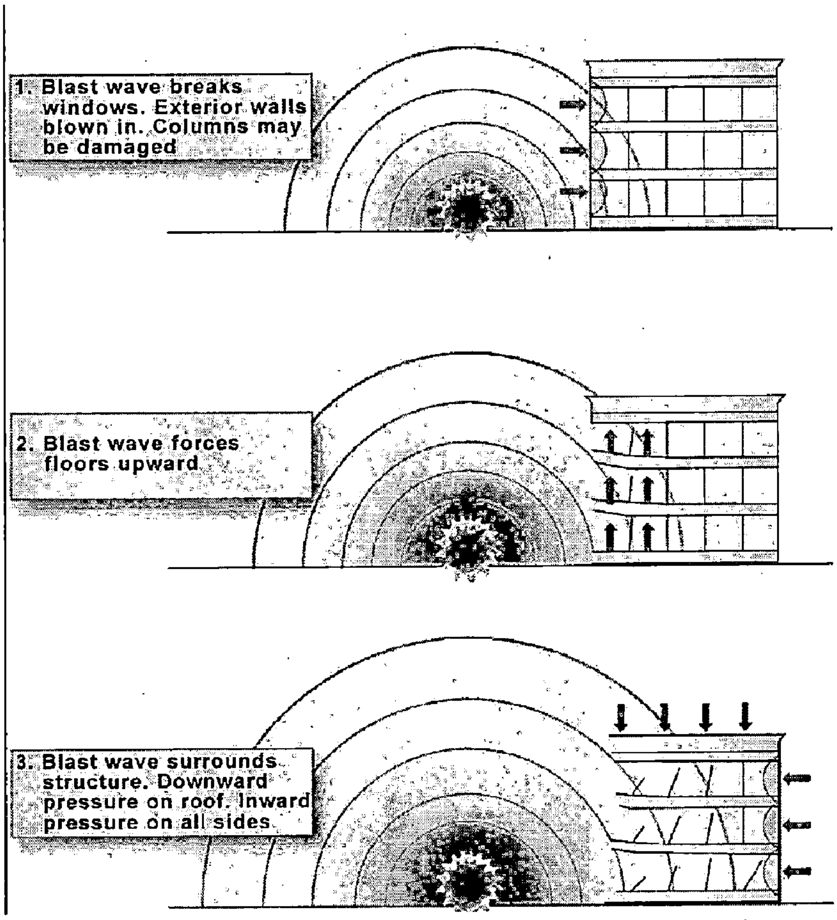
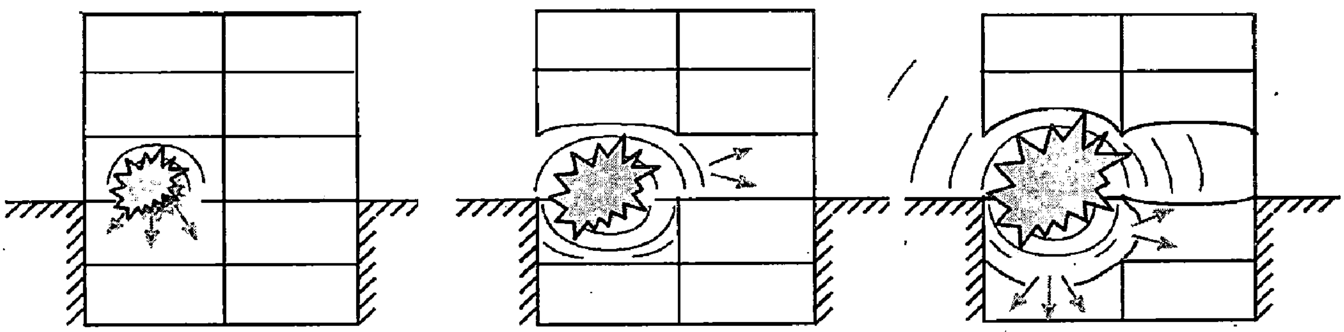


Figure 11: Schematic showing sequence of building damage due to a vehicle weapon, Source: FEMA 426, 2003.

Sabotage caused by the overpressures of the air blast next to the blast location comes under the direct air-blast effects. Localized failure of exterior walls, floor systems, windows, columns and roof systems gets induced. The sequence of localized damage depends on the design and construction of the building.

When the local failure of one structural component results in redistribution of loads to another component which in turn fails, it produces progressive collapse. This ultimately may result in unduly large collapse (partial or full). The weapon or bomb should be placed close to a vital load-bearing structural element to generate a progressive collapse.

The overpressure shock waves may cause window breakage & wall failure when they push on the exterior walls. They penetrate the structure, pushing both downward & upward on the floors & the ceilings as the shock waves continue to expand.



1. **Localized floor breach**
2. **Ceiling uplift, wall and window failure**
3. **Air blast venting to exterior, damage and possible failure of floors and walls on levels above and below**

Figure 12: Schematics showing sequence of building damage due to a package weapon, Source: FEMA 426, 2003.

When vehicle-delivered explosions occur, floor slabs are the most common elements to be damaged. Floor slab failures are also common when the blast is set-off internally. When floor slab systems fail, un-braced heights of supporting columns amplify; this implies increased instability of those columns and hence of the building.

When small hand-carried explosives are planted on floor slabs away from a vertical load-bearing element, local damage takes place. In such internal blasts, multiple reflections of the overpressure shock wave front takes place on the interior surfaces and therefore the blast effects are amplified.

The sabotage associated with a small internal blast in the building includes:

- Damage and breakdown of nonstructural elements (e.g., false ceilings, ducts partition walls, and window finishes)
- Damage and breakdown of floor systems immediately above & below the blast, and of adjacent walls.
- Flying debris produced by furniture and other components.

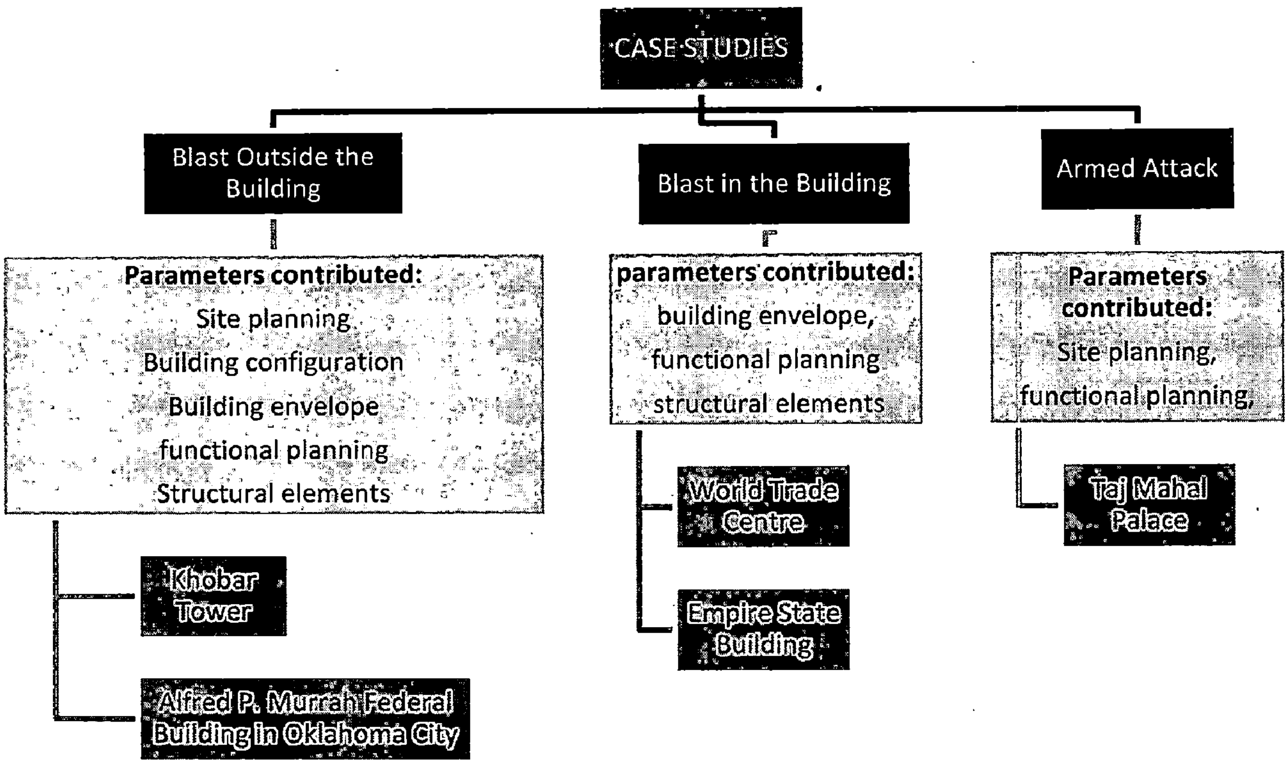
CHAPTER 3. CASE STUDIES

3.1 SELECTION CRITERIA FOR CASE STUDIES

Following design parameter are analyzed in the case studies to formulate the architectural measures to mitigate damage by terrorism:

- Site planning
- Building configuration
- Building envelope
- Functional planning
- Structural elements

Five case studies have been identified according to the type of attack on the building:



3.2 KHOBAR TOWERS BOMBING, SAUDI ARABIA, 1996

There was a terrorist attack on a part of housing complex in Khobar city, Saudi Arabia on June 25th. Attackers parked a tanker truck in a parking lot adjoining the Khobar Tower buildings. This truck parked near Building #131 in the housing complex exploded.

The complex had 12 city blocks. A tanker truck with 5,000 pounds of plastic explosive was driven into the parking lot of the residential complex and was parked about 105 feet from building.

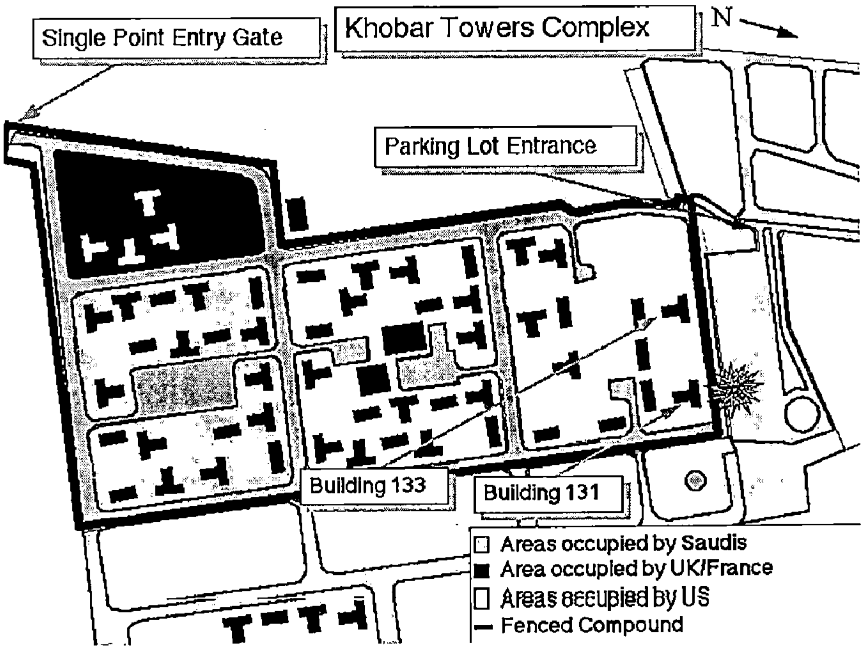


Figure 13: Site plan of the Khobar Towers complex. Source: GlobalSecruity.org

3.2.1 SITE PLANNING

The foremost focus of site planning of the complex was to deter potential attackers from being capable to reach their target. Damage reduces at an exponential rate with respect to distance. The administrators at the Khobar Towers considered this antiterrorism measure by putting Jersey barriers around the site. This barrier was used to obstruct vehicular access to the building complex.

A barrier or fence was constructed along the boundary of the complex to prevent vehicular access. At Building 131, this fence was placed about 105 feet from the Northern façade. This security measure is considered to have minimized sabotage. The barriers deflected the blast overpressure upward & away from the lower floors, possibly avoiding progressive collapse of the building.

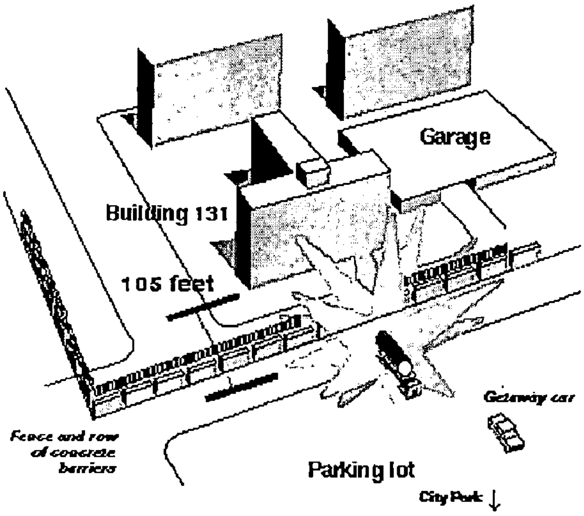


Figure 14: location of the truck at the parking lot outside the perimeter fence.

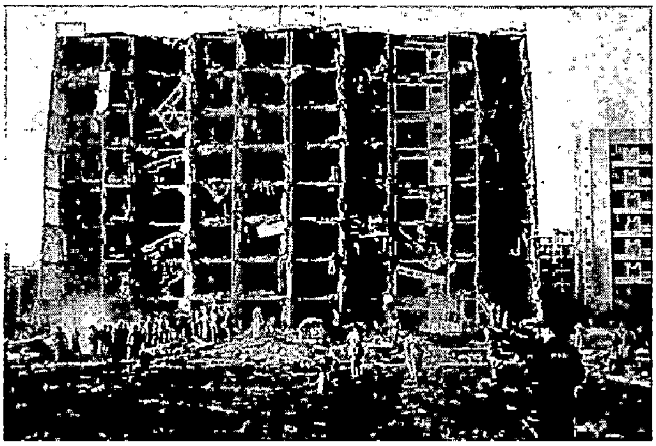


Figure 15: Exterior envelope failure because of direct air-blast effects.

The force of the blast was vast. It heavily damaged six apartment buildings in the compound. 85 feet wide and 35 feet deep huge crater was formed where truck was parked. Windows were ruined in almost every other apartment building in the complex and in neighboring buildings up to a mile away.

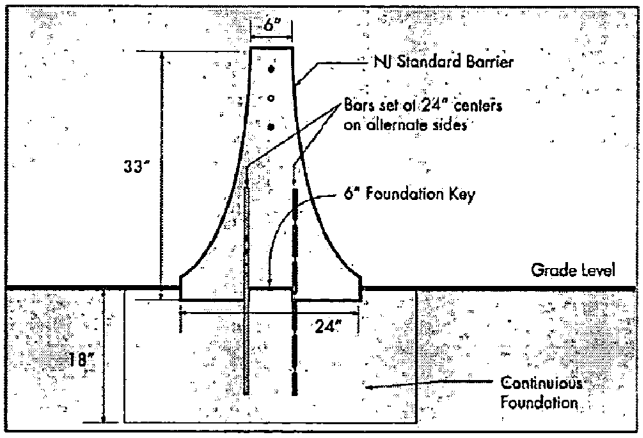


Figure 16: Jersey barrier dimensions & installation for high level of protection. Source: DOD HANDBOOK: selection & application of vehicle barriers, MILHDBK-1013/14, 1999

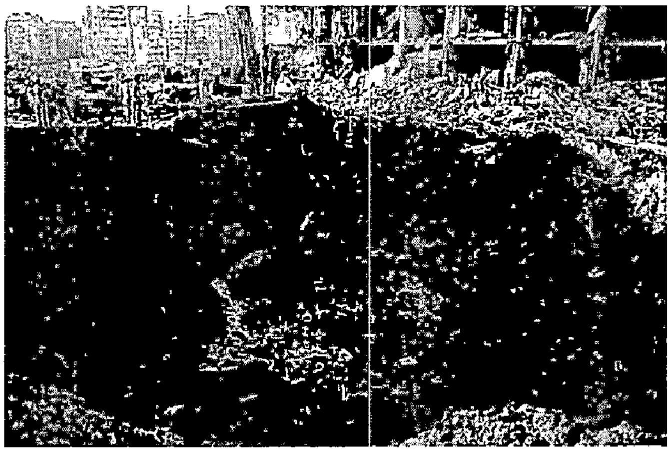


Figure 17: The 85' diameter by 35' deep crater left by the explosion. Source: the Department of Defense, Saudi Arabia

3.2.2 FUNCTIONAL PLANNING

The staircase core was made in thick marble and was placed on the rear of the building away from the threat location, conceivably the safest place in the apartment. Many of the evacuees were in the stairwell when the bomb blasted, thus, staircase position saved the life of many people.

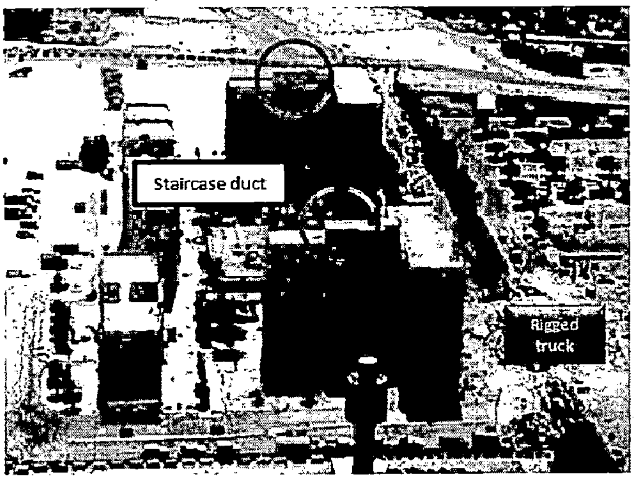


Figure 18: location of staircase duct

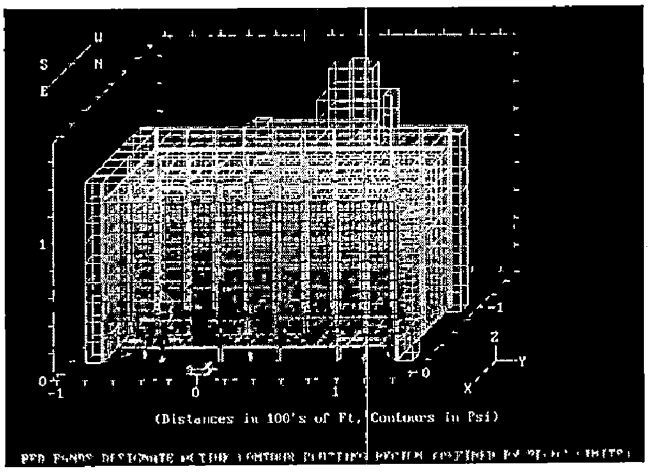


Figure 19: graphic shows the 3d overpressure contour plot on the #131 building

The graphic expresses the 3d overpressure contour on the #131 building. It is visible clearly in the image that the staircase core is on the safest location of the building where blast impact is minimum. Thus, Stair cases play critical role in the case of an attack and emergency, and hence, their location and composition is significant for occupant's evacuation.

3.2.3 STRUCTURAL ELEMENTS

The majority of the compound along with the attacked tower was constructed in precast system. This system later saved a countless lives. The attack did not result in a progressive collapse of the structure. The concrete partitions offered numerous redundant load paths for the forces to be reallocated.

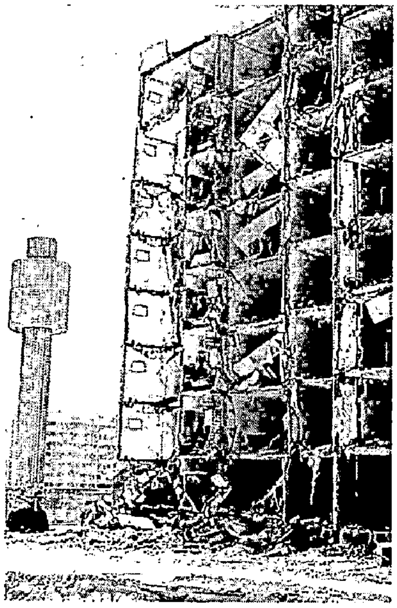


Figure 20: A close up of the precast concrete wall system. Source: The House National Security Committee

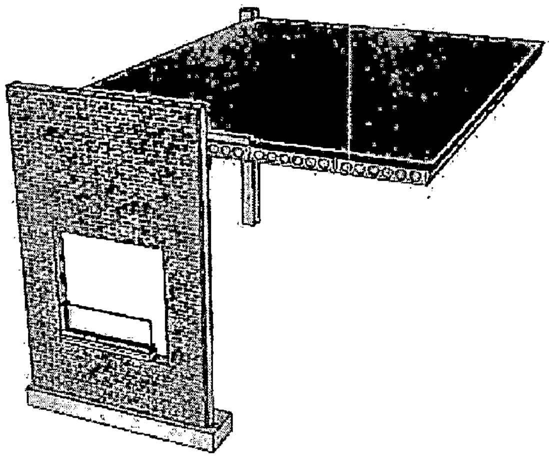


Figure 21: precast wall & floor system

3.2.4 BUILDING ENVELOPE

The cladding turned into high-velocity projectiles and killed many occupants. The building is a precast RC wall structure having vigorous connections between walls and slabs. The high redundancy pattern of the structural system offered by the vertical wall lines provided sideways stability and thereby barred collapse.

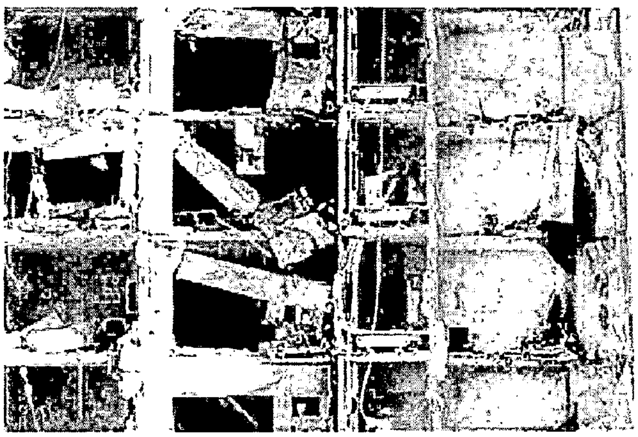


Figure 22: an exterior envelope failure as a result of direct air-blast effects.

Khobar tower is an example of **an envelope failure due to direct air-blast effect.** Direct air-blast refers to the sabotage caused by the intense pressure of the air-blast close to the source of explosives or blast. These may encourage the restricted failure of exterior envelope components.

3.2.5 BUILDING ORIENTATION

In Khobar tower building, the longer facade faces the road with the largest part of openings which lead to an exterior envelope malfunction due to air-blast effects. In security oriented design, the prime concern is the shielding of building and contents against possible blast effects. In security design, the need is to increase the resistance of the structure towards the vulnerable facade.

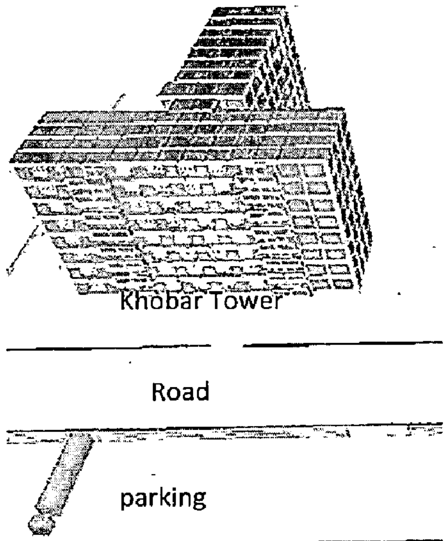


Figure 23: longer facade of the Khobar tower facing the roa

3.2.6 ARCHITECTURAL CONFIGURATION

The profile of the building can have a contributing effect on the overall harm to the structure. Re-entrant corners and cantilevers are likely to entrap the shockwave, which can amplify the effect of the air-blast. In khobar tower, Re-entrant corners do not face the road. They are towards the back side of the block. But long rectangular facade with corners intensified the reflected force of the shock wave.

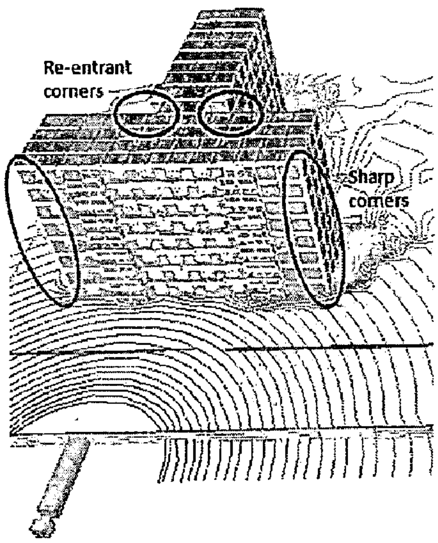


Figure 24: T shaped building with re-entrant corners

3.2.7 BLAST OR EXPLOSION ANALYSIS OF THE KHOBAR TOWERS COMPLEX

The distance between a threat and a target is known as the *stand-off distance*. It is calculated by the type of threat, level of threat, the type of construction and preferred level of security; thus, there is no ideal stand-off distance. Energy of a blast reduces over distance. Analysis of the Khobar Towers Complex shows that the impact will reduce as the stand-off distance increases.

Table 2: Results of computer simulations of effect of stand-off distance on damage to buildings in Khobar Tower site, Dhahran, Saudi Arabia, during the 26 June 196 bombing (FEMA 426, 2003)

Color	Damage Description	Hazard to occupants
Red	Very severe damage, possible collapse	Very high hazard, widespread death & serious injury likely
Yellow	Very unrepairable structural damage	High hazard, death & serious injury possible
Green	Moderate repairable structural damage	Medium hazard, limited casualties & injury possible

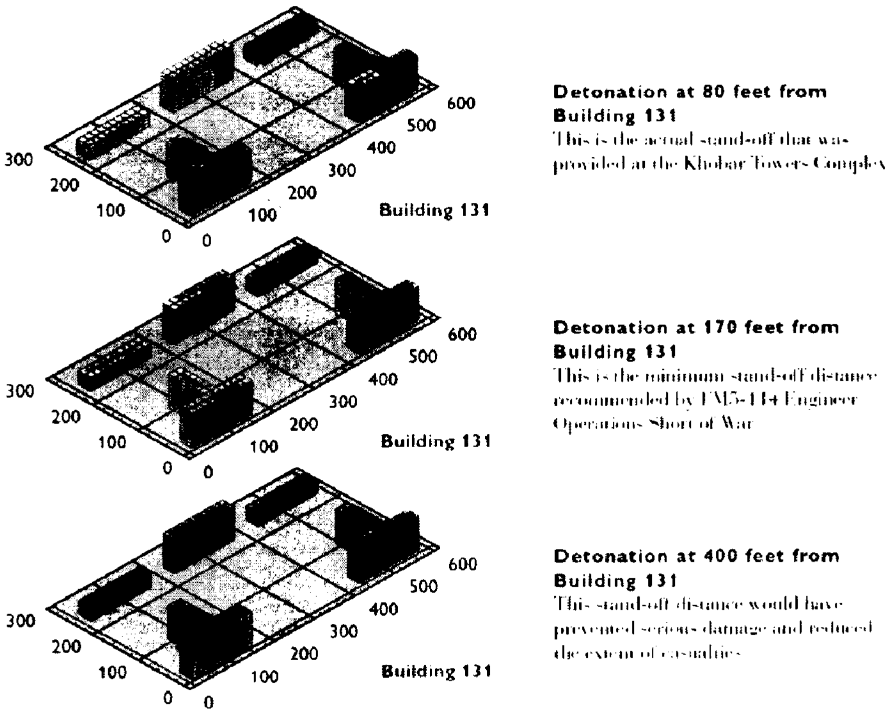


Figure 25: Results of computer simulations of effect of stand-off distance on damage to buildings in Khobar Tower site, Dhahran, Saudi Arabia (FEMA 426, 2003

3.3 ALFRED P. MURRAH FEDERAL BUILDING, OKLAHOMA CITY, 1995

On April 19, 1995, the Alfred P. Murrah Federal Building in city center of Oklahoma City was attacked by the terrorists. Until the September 11, 2001 WTC attacks, it was the most disparaging act of terrorism on America. The blast affected 324 buildings within a block radius, shattered glass in 258 buildings and destroyed 86 cars in the proximity.

The sabotage was caused by a 5000-pound fertilizer bomb packed out into the back of a truck parked on the road in front of building. The blast resulted in a partial collapse of all floors (9) of the building. One third of the building was shattered by the explosion, which formed a 30-foot wide, 8-foot deep depression on road which was next to the building.

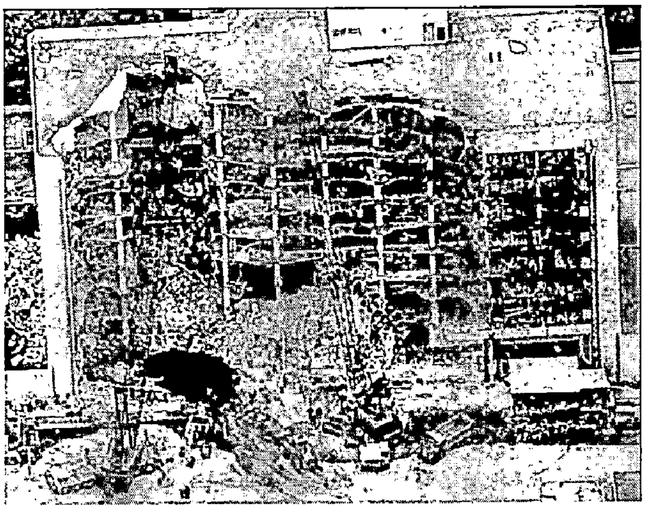


Figure 26: The front wall of the Alfred Murrah Federal Building in Oklahoma City damaged by blast.

In the 1995 Oklahoma City bombing, 8 adjoining buildings also collapsed; most of these collapsed buildings were built in masonry. Thus, the building targeted is at greatest risk, the adjoining buildings may also sustain severe damage or even collapse.

Figure 27: Extensive non-structural damage in the interior of a building impacted by blast

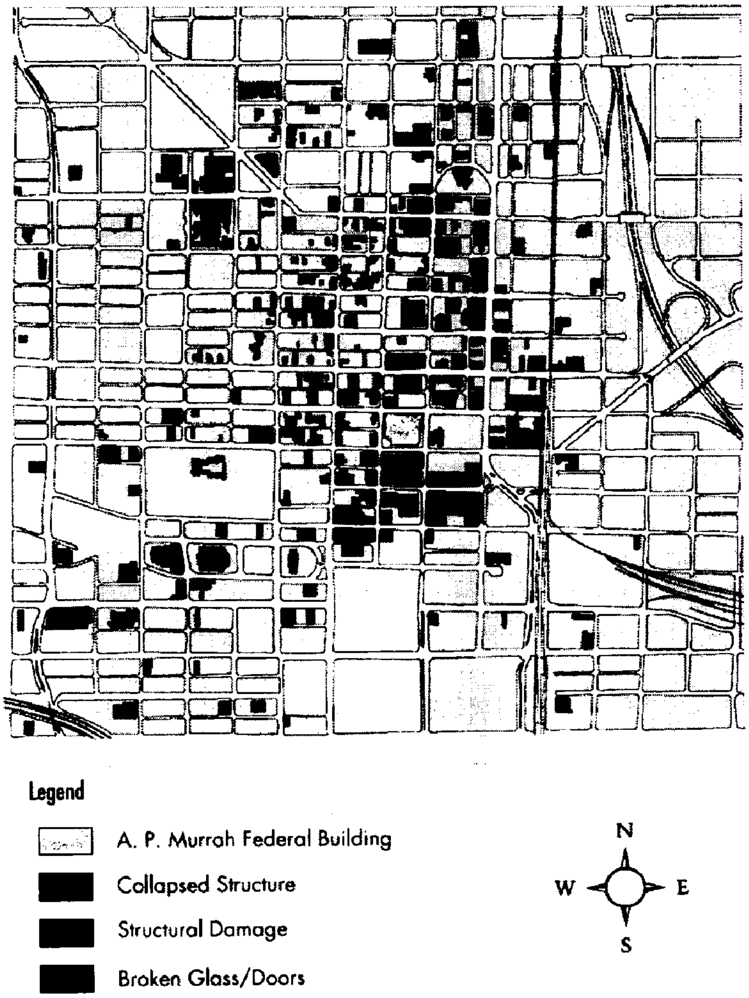


Figure 28: Glass damage from the terrorist bombing in Oklahoma City was reported up to 4,000 feet away from the Murrah Building because the intensity of blast loads varies as a function of height and exposure relative to the point of detonation.

After the attack the government ordered that prefabricated Jersey barriers should be installed around the compound of federal buildings in all major cities to avoid similar attacks.

3.3.1 SITE PLANNING

The Alfred P. Murrah Federal Building was approached through roads on the three sides. The space next to the the building can be left open but should be ensured that no vehicles can drive on that property. Though in Murrah building, no barrier was provided to supervise the entry of vehicles & people in the space around the property. The boundary line needs to be far away from the building as much as possible.

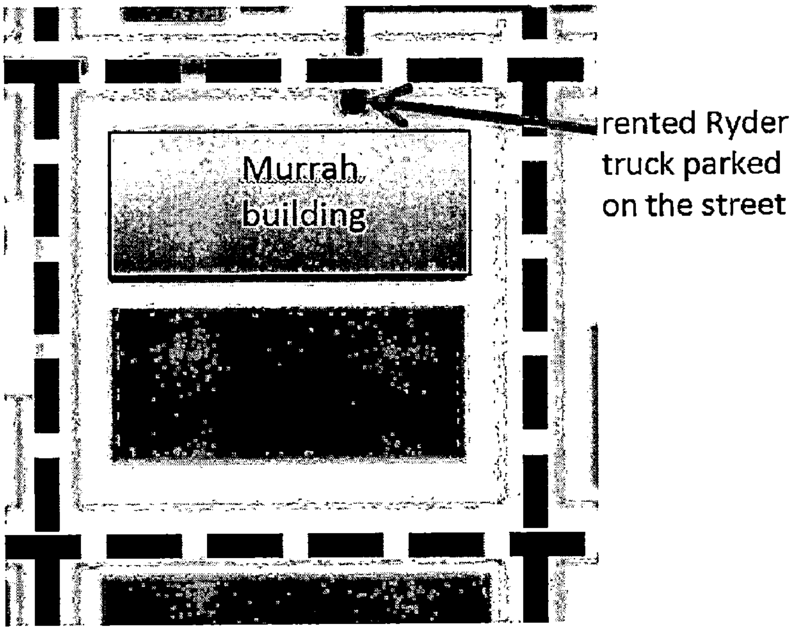


Figure 29: Murrah building with its longer facade towards the main road

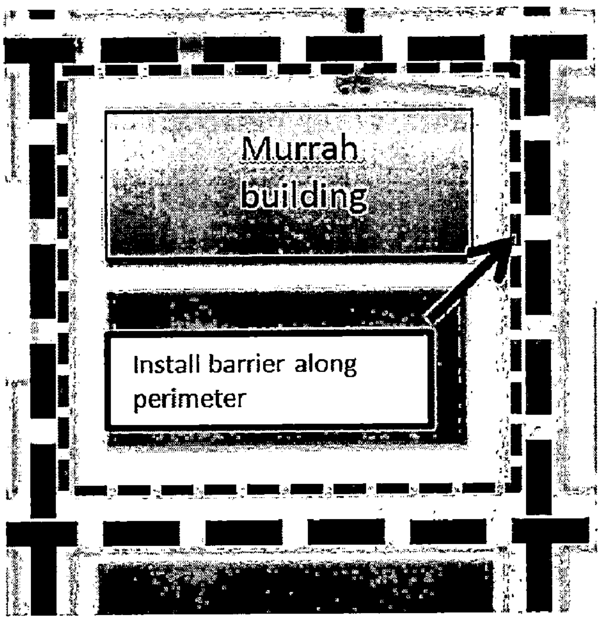


Figure 30: Partial barricading with passive barriers to cover threats in a limited way

3.3.2 PARKING

In Murrah building, parking was not under supervision & vehicles were parked adjacent to the building. Parking lots must be located within the view of occupied buildings and away from the occupied buildings to reduce blast effects of potential vehicle bombs.

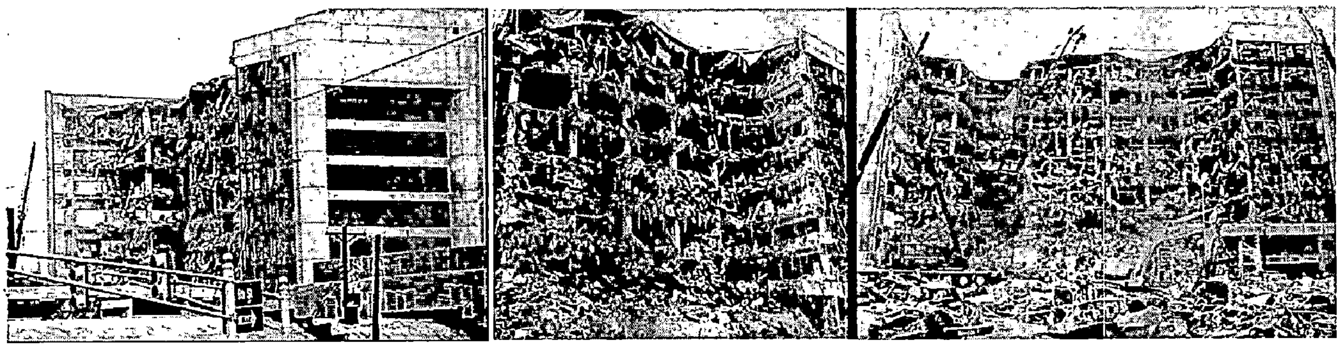
3.3.3 ENTRY CONTROL

There was no entry control on the space around the Murrah building. The building was lacking in perimeter security. The number of roads to the building must be a minimum.

3.3.4 BUILDING ENVELOPE

In the 1995 Oklahoma City bombing, Murrah building partially collapsed while 8 adjoining buildings also collapsed; most of these collapsed buildings were built in brick masonry.

The shattered glass was responsible for injuries to 40% survivors. In the adjoining buildings, 25-30% injuries were due to laceration. The exterior of the building is the first line of defense for the inhabitants against the effects of blast overpressures. Often, the exterior is most vulnerable to explosions because it is built using brittle materials, like glazing for windows, doors, roof systems, and exterior wall /cladding. Thus, a number of special precautions are required to mitigate the effects of aggressive attacks. The building exterior façade and structural system should be hardened to resist the effects of external attacks, if adequate stand-off distances are not available. To protect against blast, structural walls with blast resistance should be used on the vulnerable façade(s) of the building and not masonry walls which produce flying debris.



3.3.5 STRUCTURAL ASPECTS

The buildings made in brick masonry are the most vulnerable to blast as they readily disintegrate into its masonry constituents. Murrah building & surrounding buildings were made up of brick masonry. Choosing a structural system to resist blast loading is an important task. Exteriors of buildings are subjected to a larger demand of blast effects than their interiors, thus, they need to be hardened.

3.4 WORLD TRADE CENTER ATTACK, NEW YORK, 1993 & SEPTEMBER 11, 2001

The W.T.C was attacked twice. A bomb exploded in the basement garage in 1993. On September 11, 2001, the twin towers collapsed as a consequence of attack in which the terrorists hijacked four passenger jet airliners, flying them into the South & North Tower.

3.4.1 1993 WORLD TRADE CENTER BOMBING

A large explosion took place in the parking area of the World Trade Center on February 26, 1993. A 1,500-pound urea-nitrate bomb was exploded in a vehicle parked in the basement parking. The blast formed a 200-foot by 100-foot crater several stories deep. The power and emergency systems of the WTC were ruined. The majority of the injuries were because of smoke inhalation. With thick smoke filling the stairwells which were not pressurized, evacuation was hard for building inhabitants and led to many smoke inhalation injuries.

The building survived, but located in the basement were the security office, mechanical spaces, backup generators, smoke evacuation systems, fire standpipes, and fire protection systems and pumps; virtually every backup system the building had was located in the basement. When the bomb went off, it brought down the entire emergency and safety equipment features of the building. The lesson learned from this was to have the distribution of mechanical and safety features of the building in multiple locations, not all located in the out of- sight, out-of-mind proverbial basement location. Another lesson was to plan for redundancy, and space the stairwells to opposite parts of a building plan, and have redundancy in mechanical and fire safety systems.

Figure 31: Underground damage after the bombing in WTC garage caused by the 1993 bomb attack. SOURCE: Corbis

3.4.2 SEPTEMBER 11, 2001 WORLD TRADE CENTER ATTACK

The twin towers collapsed on September 11, 2001 as a consequence of terrorist attacks in which terrorists hijacked passenger jet airliners, flying them into the South and North Tower. The rest of the complex and buildings in the proximity also faced widespread harm due to the fall down of the twin towers. Flying fragments from the collapsing towers sternly damaged adjacent and nearby structures.

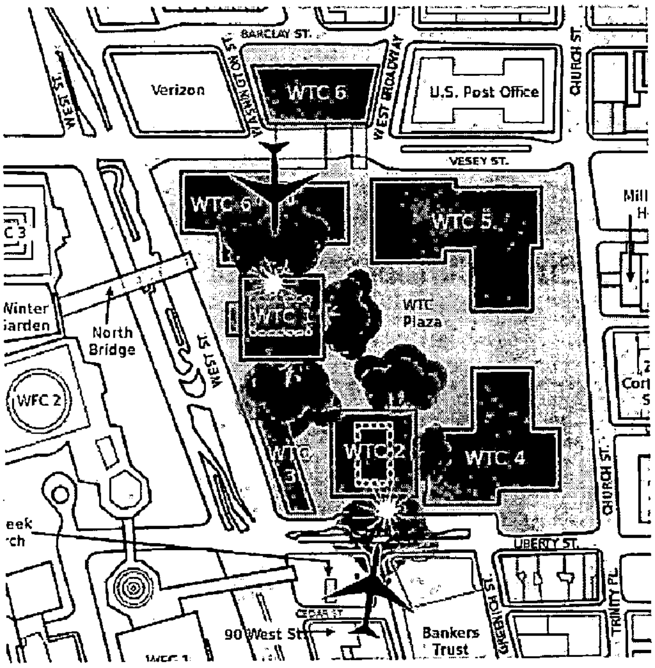


Figure 32: Map showing the attacks on the World Trade Center. Source: Wikipedia

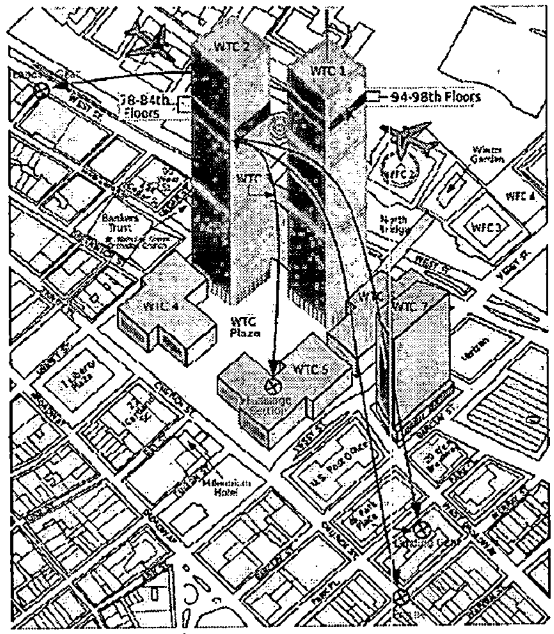


Figure 33: 3D showing attack on WTC towers. Source: Wikipedia.

As per Thomas W. Eagar and Christopher Musso's Special Report on "Why Did the World Trade Center Collapse?" the major events in Twin Tower collapse includes the following:

- The airplane impact with damage to the columns.
- The ensuing fire with loss of steel strength and distortion.
- The collapse, which generally occurred inward without significant tipping

A central core accommodates elevators, stairwells, mechanical risers and utilities, and supports the weight of the floors. There are closely spaced perimeter columns (lightweight steel box section placed 39 inch center to center) that hold the edge of each floor. The Floor trusses are joined between the core structure & the perimeter columns under a 4-inch concrete floor. The work space area has no columns. The width of the building was 208 feet.

The World Trade Center had enormous open floor spaces which permitted fire to spread far more easily. Redundancy was required in the fire suppression system. The airplane collisions disconnected the water supply to the sprinklers in both towers. The stairwells in WTC were not smoke proof which leads to deaths due to smoke inhalation.

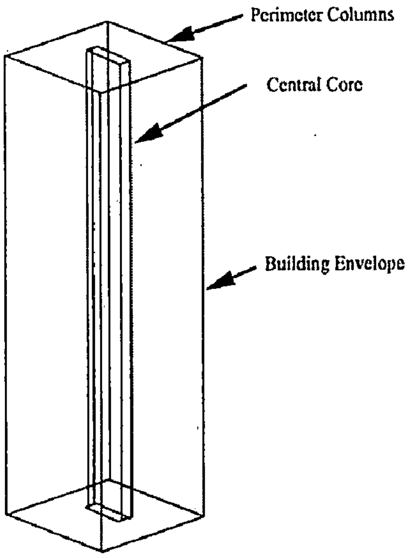


Figure 34: Central core houses elevators and supports the weight of the floors. Source: Wikipedia

The perimeter columns were extremely redundant as WTC survived the loss of numerous perimeter columns as a result of aircraft collision; however the consequent fire led to other steel failures. The failure of the steel was a result of loss of strength because of the temperature of the fire.

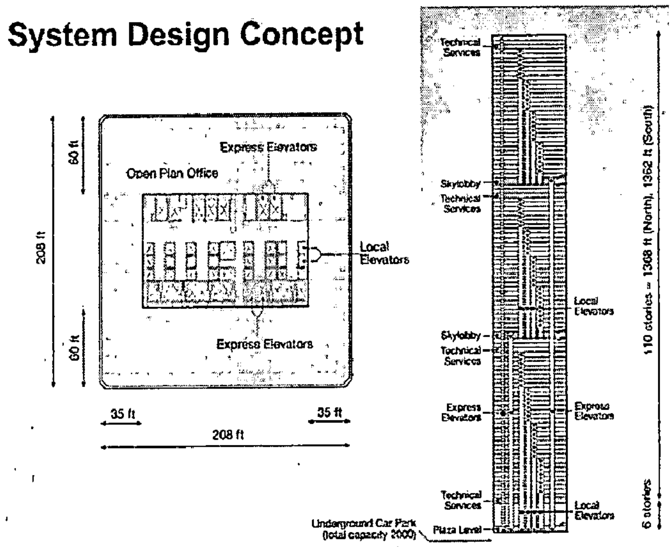


Figure 35: central core houses elevators. Source: Wikipedia

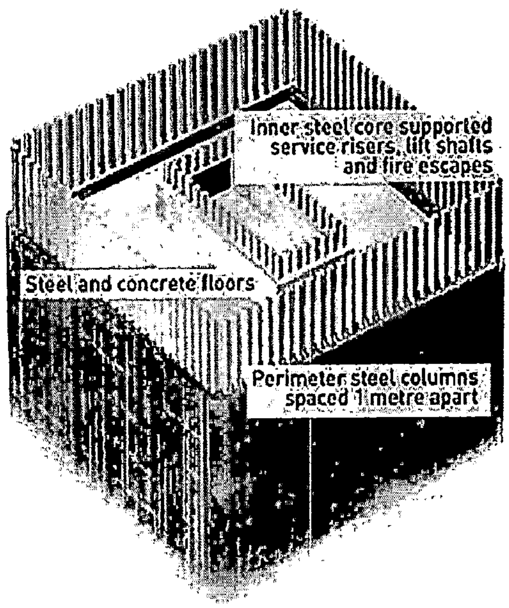


Figure 36: A cutaway view of WTC structure. Source: Thomas W. Eagar & Christopher Musso's Special Report on "Why Did the World Trade Center Collapse?"

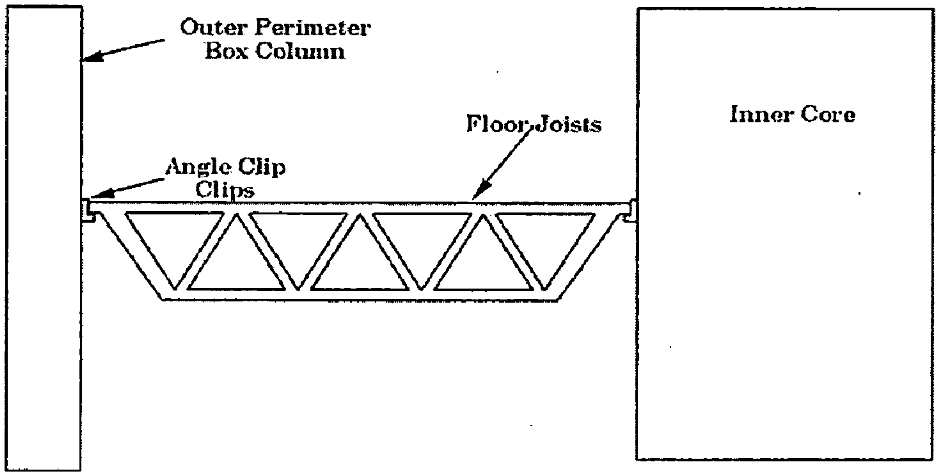


Figure 37: Unscaled schematic of WTC floor joints and attachment to columns. Source: Thomas W. Eagar & Christopher Musso's Special Report on "Why Did the World Trade Center Collapse?"

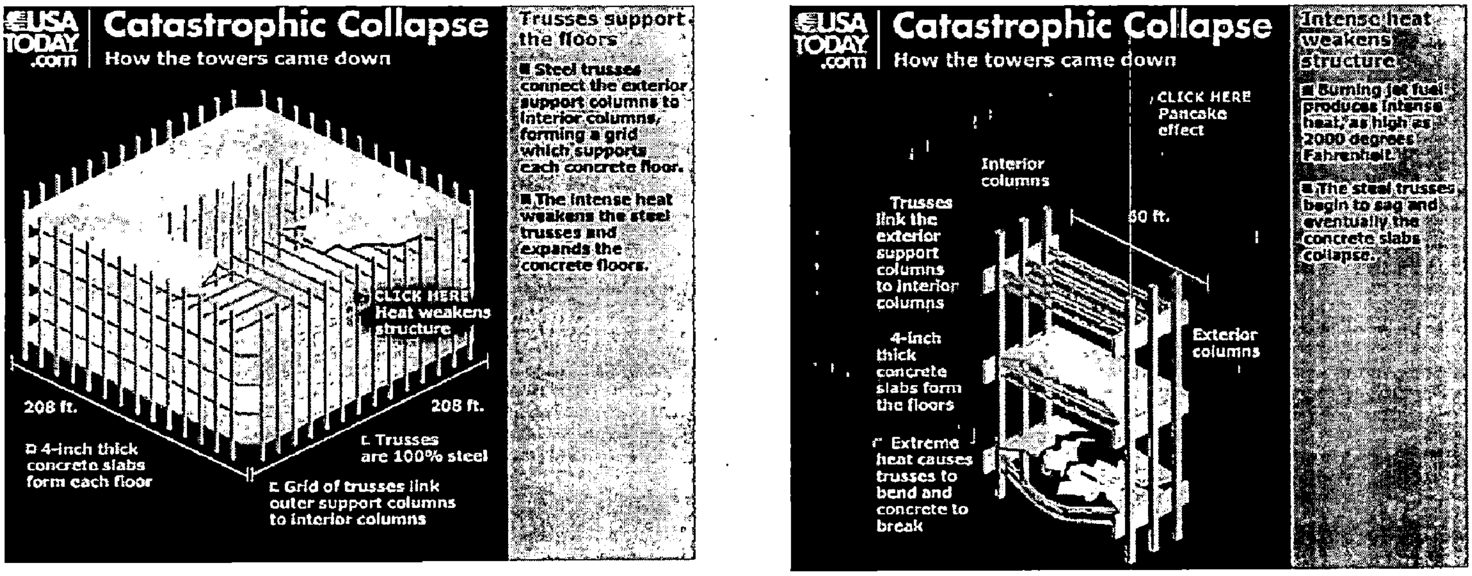


Figure 38: A graphic illustration of the World Trade Center points of impact. Source: USA Today newspaper website

The restrictive factors were the angle clips that detained the floor joists between the perimeter columns and the core. As the joists on the most profoundly burned floors provided way and the perimeter columns commenced to bend outward, the floors on top of them also fell. The lower floor could not bear the weight of ten floors or more above. It caused the buildings to fall down within ten seconds.

3.5 THE EMPIRE STATE BUILDING

On July 28, 1945, a B-25 Mitchell bomber crashed between the 79th and 80th floors (around 295 m above ground level) of the Empire State Building.

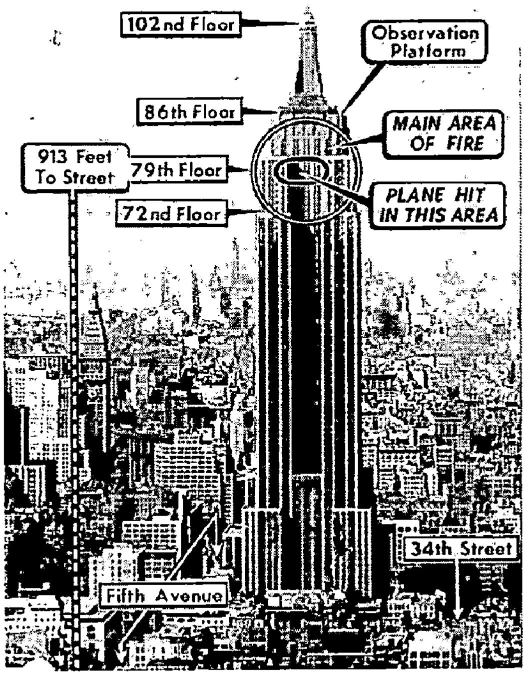


Figure 39: Approximate location of the B-25 crash. Source: http://www.aerospaceweb.org

The B-25 crash ripped an opening about 5.5 m wide by 6 m tall in the north wall of the Building.

- The building has 8 inches thick Indiana limestone exterior wall.
- The structural steel beams are enclosed within limestone walls.
- The building has a reinforced masonry structure.
- The floors or slabs are 8 inches thick comprising of 1" cement over 7 inches of concrete.
- The steel within is protected from extreme heating by this heavy mass which offers excellent fire protection.

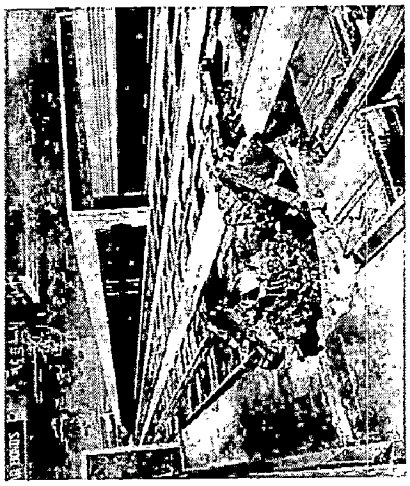


Figure 40: The crash tore a hole about 5.5 m wide by 6 m tall in the north side exterior wall of the Building. Source: http://www.aerospaceweb.org

- There is almost no opening in the floors or slabs of a HVAC system piercing fire partitions, ceilings & floors. Each floor contains its own HVAC unit.
- Stairway in empire state building is a 4-inch brick enclosed smoke proof structure.
- Empire state building would have not fallen down like the WTC towers and survived the collision and fire of the airplane better than the WTC.

3.6 TAJ MAHAL PALACE, MUMBAI TERRORIST ATTACK, 2008

The Taj Mahal Hotel, constructed in 1903, is a heritage building & an icon in Mumbai. It has two wings, the heritage wing with 290 rooms & Taj Towers with 275 rooms. It is constructed of yellow basalt and reinforced concrete. Taj Mahal Hotel's Heritage wing which is 107 years old was badly spoiled in the 26/11 terror attacks by the militants from Pakistan.

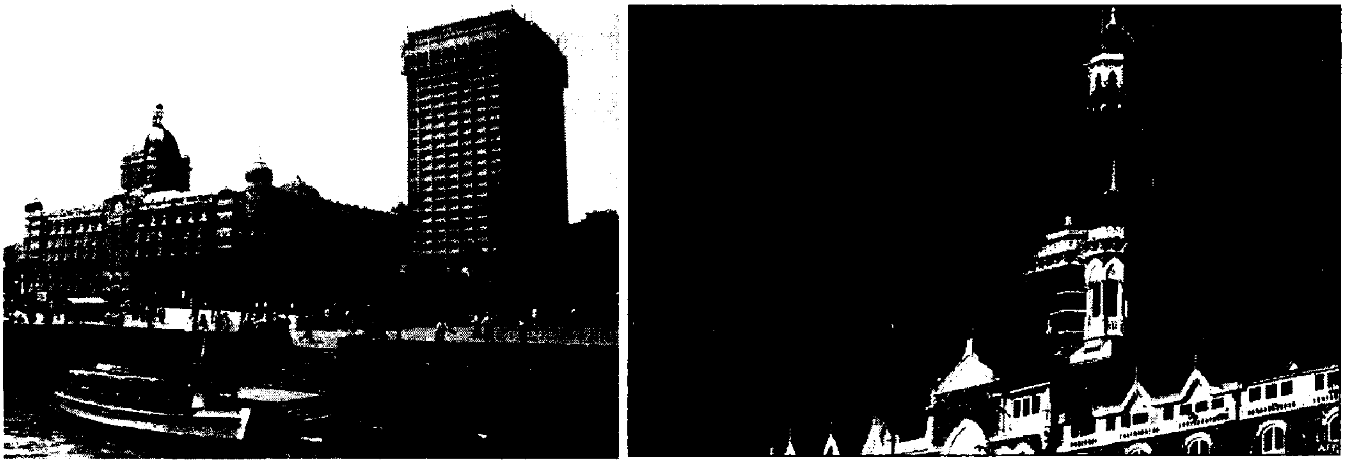


Figure 41: The Taj Hotel, Mumbai

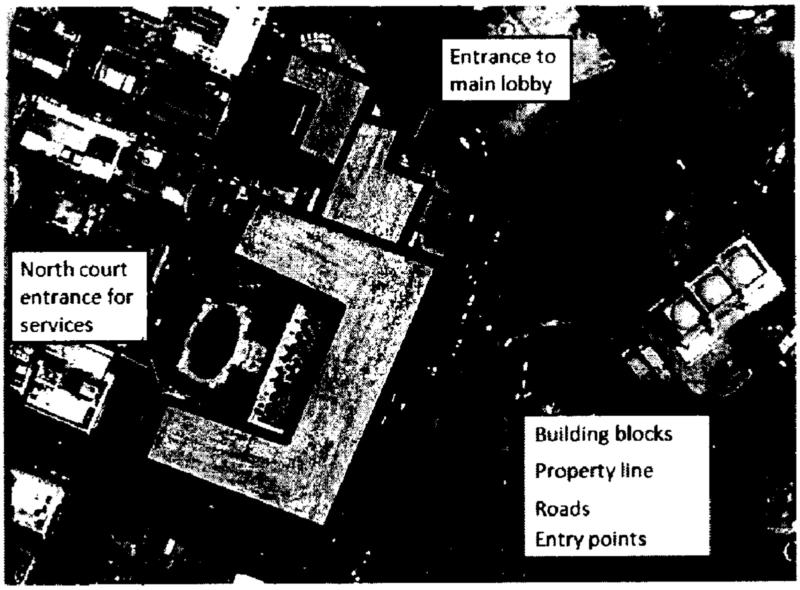


Figure 42: Site plan of Taj Mahal Palace Hotel

Four terrorists targeted the Taj Mahal Hotel who came by sea, sailing from Karachi on a Pakistani cargo vessel. One pair entered the main lobby of the taj mahal palace hotel & second pair penetrated the Taj hotel from the North Court Entrance. They fired haphazardly & hurled grenades. The terrorists moved up to the sixth floor of the heritage wing, killing anyone who came in their way. They set fire to a part of the Taj hotel. The 1st, 5th & 6th floors of heritage wing were badly gutted.

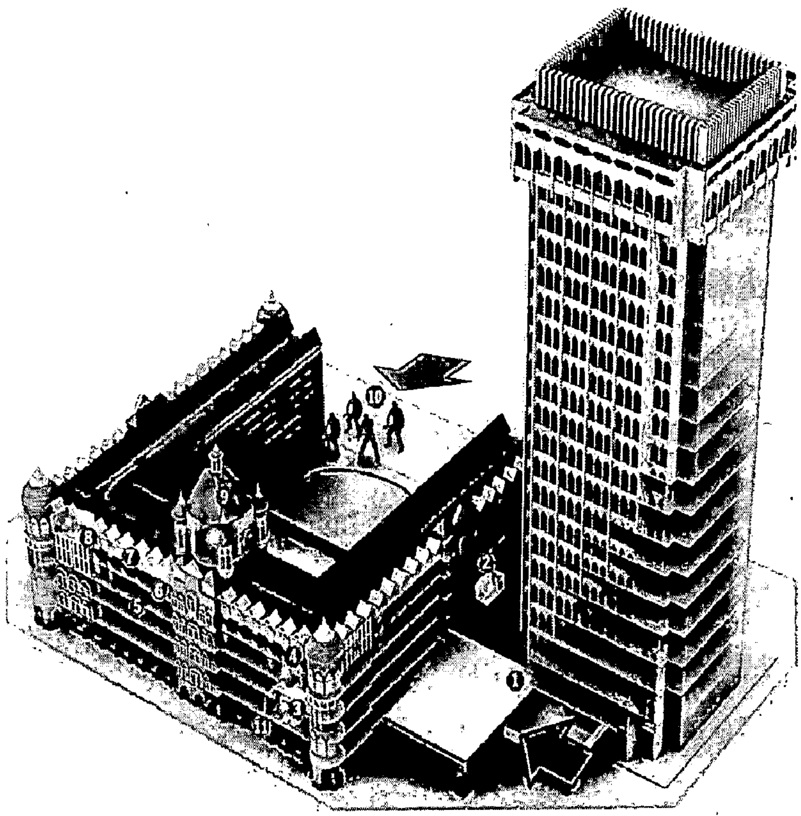


Figure 43: Isometric view of Taj Mahal Palace Hotel. Source: Only Mumbai Blog, Taj mahal hotel condition after the attacks, Nov 30, 2008

Figure 44: Damaged corridor in Taj palace Hotel

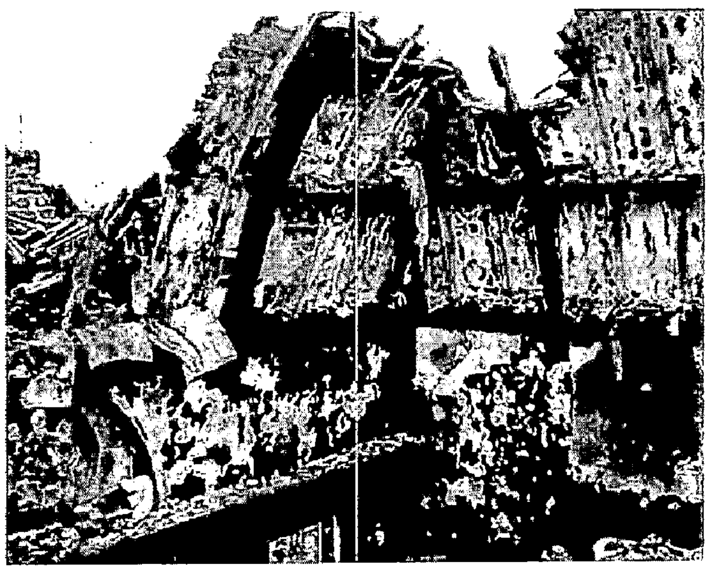


Figure 45: Damaged Dome in Taj Palace Hotel

3.6.1 SITE PLANNING

The building directly abuts the road. There is a lack of security perimeter & open space around the building. Lack of open space around the building & at entry points lead to easy access of intruders with weapons. A security perimeter maintains vehicle Bombs or explosives & Intruders at a distance, thus minimizing possible destruction & sabotage.

Figure 46: Building abutting the road.

3.6.1.1 LANDSCAPING

Figure 47: Heavy vegetation in the north court

In Taj Mahal Palace, heavy foliage in the north court doesn't allow natural surveillance. This creates place for intruder to hide or commit crimes. Two terrorists entered from the poolside at the rear. They had already circumnavigated the hotel via Housekeeping. Landscaping should be designed to reduce interference with sightlines. Make sure that paths have good sightlines to entrances and exits. Vegetation is maintained to ensure that sightlines are unobstructed and opportunities for surveillance are allowed.

3.6.2 FUNCTIONAL PLANNING

Corridors are long, narrow & straight having cut out in the centre. It allows the view of people going in & out of the rooms. The four terrorist moved up to the sixth floor. Straight corridor allowed them to see along their way & killing anyone who came in their way. Thus, the layout of corridors also plays an important role in Security Design.

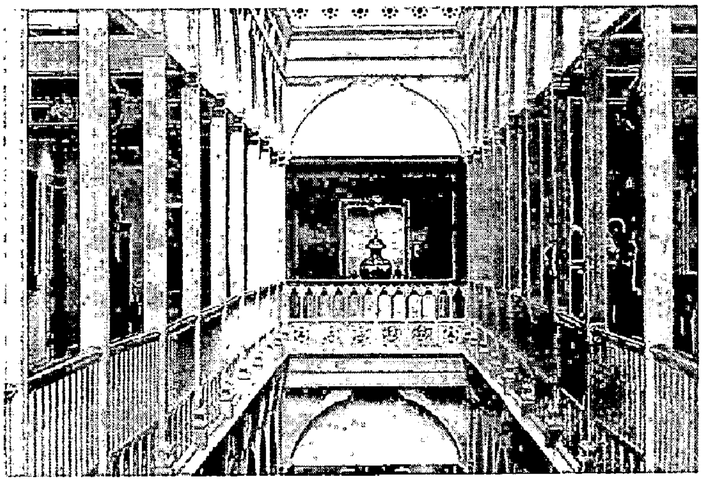


Figure 48: long, narrow & straight corridors

The terrorist moved up to the sixth floor & set fire to a part of the Taj hotel & under the dome. The 1st, 5th & 6th floors of heritage wing were badly gutted. Fired dome filled the smoke inside the atrium, where staircases were open. This might lead to more casualties due to smoke if people would have had been under the dome.

Stair cases play critical role in case of an attack and emergency, and hence, their location and arrangement is critical for evacuation of occupants and for access to security personnel.

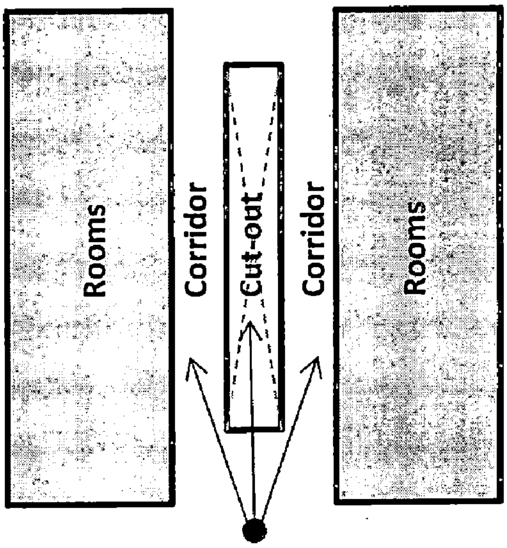


Figure 49: general layout of the rooms in Taj Mahal Palace Hotel. Long, Narrow & Straight corridors or streets allow visual access to places ahead. Thus sequence of events are visible from the person who takes the route.

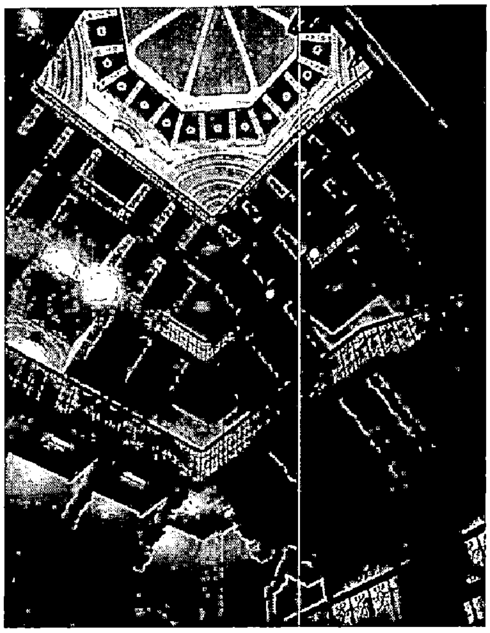


Figure 50: open staircase in the atrium below the central Dome

CHAPTER 4. ANALYSIS & INFERENCES OF CASE STUDIES

4.1 KHOBAR TOWERS BOMBING, SAUDI ARABIA, 1996

Parameter	Findings	Inferences
Site planning	• The stand-off distance (105 ft) was sufficient to avoid the progressive collapse of the building • Jersey barriers were installed around the site to prevent a vehicle from entering the compound. This is just one type of barrier used to bar vehicular access to a building. These deflected the blast energy upward, and away from the lower floors of the building, perhaps even preventing a total collapse of the structure.	• The perimeter line of protection is the outermost line that needs to be designed to prevent carriers of large-scale weapons from gaining access to the site. • The perimeter line should be located as far as is practical from the building exterior. • The area around a building must be separated into zones of different levels of protection, with the building having highest security protection. • This is achieved with physical barriers along with access control measures at designated entry points.
Functional planning	• The stairwell was constructed of heavy marble and was located on the side of the building away from the truck bomb, perhaps the safest location in the building. • Many of the evacuees were in the stairwell when the bomb went off.	• Stair cases play critical role in case of an attack and emergency, and hence, their location and arrangement is critical for evacuation of occupants and for access to security personnel. • Stairwells should be located as remotely as possible from areas where blast events might occur. • Wherever possible, they should not discharge into lobbies, parking, or loading areas. • Staircase (and elevators) should be with heavy weight construction to mitigate damage. • They should be arranged in corners (not staggered in one place).

Building Orientation & configuration	• Longer facade faced the road with maximum openings which lead to an exterior envelope failure due to direct air-blast effects. • In khobar tower, Re-entrant corners did not face road side. They were towards the rear of the block.	• Building must be oriented such that walls with glazing must be oriented perpendicular to the street-side façade to reduce exposure to blast. • The shape of the building has a significant influence on the overall damage sustained by a building under blast loading caused by explosions. • Façades with sharp corners intensify the reflected pressure of the shock wave. • In the path of the shock wave front, a building with an aerodynamic shape will perform better than those without.

Structural elements	• The attacked tower, along with the majority of the compound, was constructed from precast wall and floor systems. This redundant system later proved to save countless lives. • The building is a precast RC large-panel wall structure with robust connections between slabs and walls. • The high redundancy configuration of the structural system offered by the vertical wall lines provided lateral stability and thereby prevented collapse.	• Pre-cast wall & floor system can be used to achieve protection against terrorist attack.

4.2 ALFRED P. MURRAH FEDERAL BUILDING, OKLAHOMA CITY, 1995

Parameters	Findings	Inferences
Site planning	• The Building was approached by roads on three sides. • No barrier was provided to monitor the entry of vehicles & people in the space around the building. • Parking was not under supervision & vehicles were parked adjacent to the building.	• The space around the building can be left open but ensuring that no vehicles can drive on that land. • The perimeter line needs to be as far away from the building as possible • Parking lots should be located away from high-risk buildings to minimize blast effects of potential vehicle bombs.
Structural elements	• Murrah building partially collapsed while 8 adjoining buildings also collapsed; most of these collapsed buildings were Load bearing.	• The load-bearing buildings are the most vulnerable to blast as they readily disintegrate into its masonry constituents.
Building Orientation & configuration	• Longer facade faces the road with maximum openings. • Long rectangular façade with sharp corners intensify the reflected pressure of the shock wave.	• Building must be oriented such that walls with glazing must be oriented perpendicular to the street-side façade to reduce exposure to blast. • Façades with sharp corners intensify the reflected pressure of the shock wave.

4.3 WORLD TRADE CENTER ATTACK, NEW YORK, 1993

Parameters	Findings	Inferences
Functional planning	• Bomb exploded in the underground parking. The bomb opened a 30-m (98 ft) wide hole through four sublevels of concrete. • The power and emergency systems of the World Trade Center were destroyed. • The bomb caused smoke to rise up to the 93rd floor of both towers, including through the stairwells which were not pressurized. • With thick smoke filling the stairwells, evacuation was difficult for building occupants and led to many smoke inhalation injuries.	• Areas that add vulnerability should be placed outside the footprint of the main building. • If that is not possible, at least they must be placed along the exterior of the building. • In no case, such areas should be located directly under the footprint of the main building. • Parking under the building and, where applicable, within its internal courtyard, must be prohibited to the extent possible. • Emergency services (e.g., water sprinklers and power generators) and elevators meant for emergency services should be placed away from the areas that add vulnerability (internal parking areas, loading docks and other high-risk areas).

4.4 WORLD TRADE CENTER ATTACK, NEW YORK, 2001

Parameters	Findings	Inferences
Functional planning	• A central core houses elevators and supports the weight of the floors. • The World Trade Center instead offered vast open floor spaces that appealed to tenants but allowed fires to spread far more easily. • Firefighters can extinguish approximately 2,500 square foot of fire with one hose line. Two hose steams may quench 5,000 square feet of fire. The World Trade Center floor areas were 40,000 square feet in area. • Moreover, the fire suppression system in both towers lacked redundancy and the 767 collisions cut off the water supply to the sprinklers. • The stairwells in WTC were not smoke proof. The smoke in stairway killed many people.	• For life safety in high-rise buildings bring back the smoke proof tower. This allows people to escape fire using smoke free stairways. • Stairs and elevator shaft ways should be enclosed in masonry to prevent smoke spread. • Heating ventilation and air condition HVAC systems should be provided by unit system serving only one or two floors. Central air system serving 10 or 20 floors creates shaft ways and duct systems that penetrate fire rated floors walls partitions and ceilings. Smoke spreads throughout ducts of central HVAC systems.
Structural elements	• A central core houses elevators and supports the weight of the floors. Around the outside of the building are closely spaced (39 inch centers) perimeter columns that are designed to resist lateral wind loads and support the outer edge of each floor. • The ensuing fire was the principle cause of the collapse of WTC. The ensuing fire led to the steel failures. • The failure of the steel was due to two factors: loss of strength due to the temperature of the fire, and loss of structural integrity due to distortion of the steel from the non-uniform temperatures in the fire. • The WTC instead relied on lightweight spay-on coatings for insulation. This insulation was simply blown off the WTC structure by the 767 collisions exposing the steel beams and floor trusses to the raging fire.	• The high rise building framework should be skeleton steel framing not center core steel column framing. • There should be no bearing wall high rise construction. Reduce the size of open floor design. • The steel columns, girders and floor beams should be encased in masonry or other more effective fire retarding material. Spray-on fire retarding is ineffective. • Lightweight bar joists should not be used to support floors in high-rise buildings. • Increase the thickness of concrete in floor construction. The two or three inches of concrete over corrugated steel fails during most serious high rise fires and must be replaced.

4.5 THE EMPIRE STATE BUILDING

Parameters	Findings	Inferences
Functional planning	• Each floor is self contained with its own independent heating and cooling ducts, elevator and utility shafts are surrounded by thick masonry walls, fire partitions separate each floor and rooms within each floor, and the fireproof stairway prevents smoke from rising to upper stories. These features make it very difficult for fire to spread beyond a limited area.	• The Empire State Building is still considered one of the world's safest skyscrapers in a fire.
Structural elements	• The Empire State Building is a reinforced masonry structure in which the structural steel beams are encased within limestone walls or slabs of concrete 8 inches (20 cm) thick. This heavy mass provides exceptional fire protection that insulates the steel within from excessive heating.	• It would have not collapsed like the WTC towers. The Empire State Building would have withstood the impact and fire of the terrorist's jet plane better than the WTC towers.

4.6 TAJ MAHAL PALACE, MUMBAI TERRORIST ATTACK, 2008

Parameters	Findings	Inferences
Site planning	• The building directly abuts the road. There is a lack of security perimeter & open space around the building. Lack of open space around the building & at entry points lead to easy access of intruders with weapons. • Heavy foliage in the north court doesn't allow natural surveillance. This creates place for people to hide or commit crimes. Thus, two terrorists entered from the poolside at the rear.	• The perimeter line should be located as far as is practical from the building exterior to delay an intruder. • Dense and tall vegetation close to the building, which covers the building, can screen unwanted activity outside. Also, grass more than 100mm thick allows concealment of explosions and other weapons. Thus, vegetation should be selected carefully, and maintained to eliminate all concealment possibilities. • Clear sightlines should generally be provided between 0.5m and 2m above natural ground level.

Functional planning	• Corridors are long, narrow & straight having cut out in the centre. It allows the view of people going in & out of the rooms. The four terrorist moved up to the sixth floor of the heritage wing, killing anyone who came in their way. Straight corridor allowed them to see along their way & killing anyone who came in their way.	• Staggered street or corridor pattern help in slowing down movement. It limits visual access to places ahead. Thus the sequences of events are hidden from the person who takes the route. Thus, an outsider is completely unprepared for what's ahead because of the lack of co-ordination between visibility & accessibility.

CHAPTER 5. ARCHITECTURAL MEASURES OF MITIGATION

If appropriately employed, physical security measures will help in achieving objectives mentioned under in prioritized order.

- **Avoiding an attack:** The intruder may become disheartened from targeting the building by making it more complex to execute some of the more clear attack scenarios (such as a parked car in the street),
- **Interrupting the attack:** aptly designed architectural features or landscape can interrupt the implementation of an attack by making it trickier for the attacker to reach the intended target. This will provide the security forces time to assemble and stop the attack before it is implemented. This is done by making a buffer zone between the vital areas of the facility and the publicly accessible areas by providing hindrance path, a serpentine path and a division of functions within the building.
- **Extenuating the effects of the attack:** If above said safety measures are put into practice and the attack still happens, then structural safety efforts will serve to control the extent and consequences of sabotage. Structural safety is a final option that turns out to be worth after all other efforts to prevent the terrorist attack are unsuccessful.

The architectural measures to mitigate damage by terrorism are proposed after analyzing the case studies & literature review. The Architectural mitigation measures are proposed for following parameters:

Site Planning

- Land use planning
- Perimeter line & stand off distance
- Location of building on plot area
- Open space
- Access roads
- Entry control
- Surveillance & line of sight
- parking
- Barriers
- Sign boards
- Route Marking & way finding
- Street Furniture

Building Configuration

- Shape
- Size

Functional Planning

Building Envelope

- Building Exterior
- Exterior Wall Design
- Window & Door Design
- Roof Design

Utilities

- HVAC System
- Electrical System
- Fire protection System

Access Control & Security Systems

- Physical Access Control
- Electronic Access control

5.1 SITE PLANNING

Site planning includes land-use around the building, site selection, building orientation, and incorporation of control points, vehicle access, physical barriers, parking, landscaping and safety of utilities.

The area between the potential blast location and the building interior can be divided into three zones:

- Buffer Zone
- Unsecured area
- Secured area

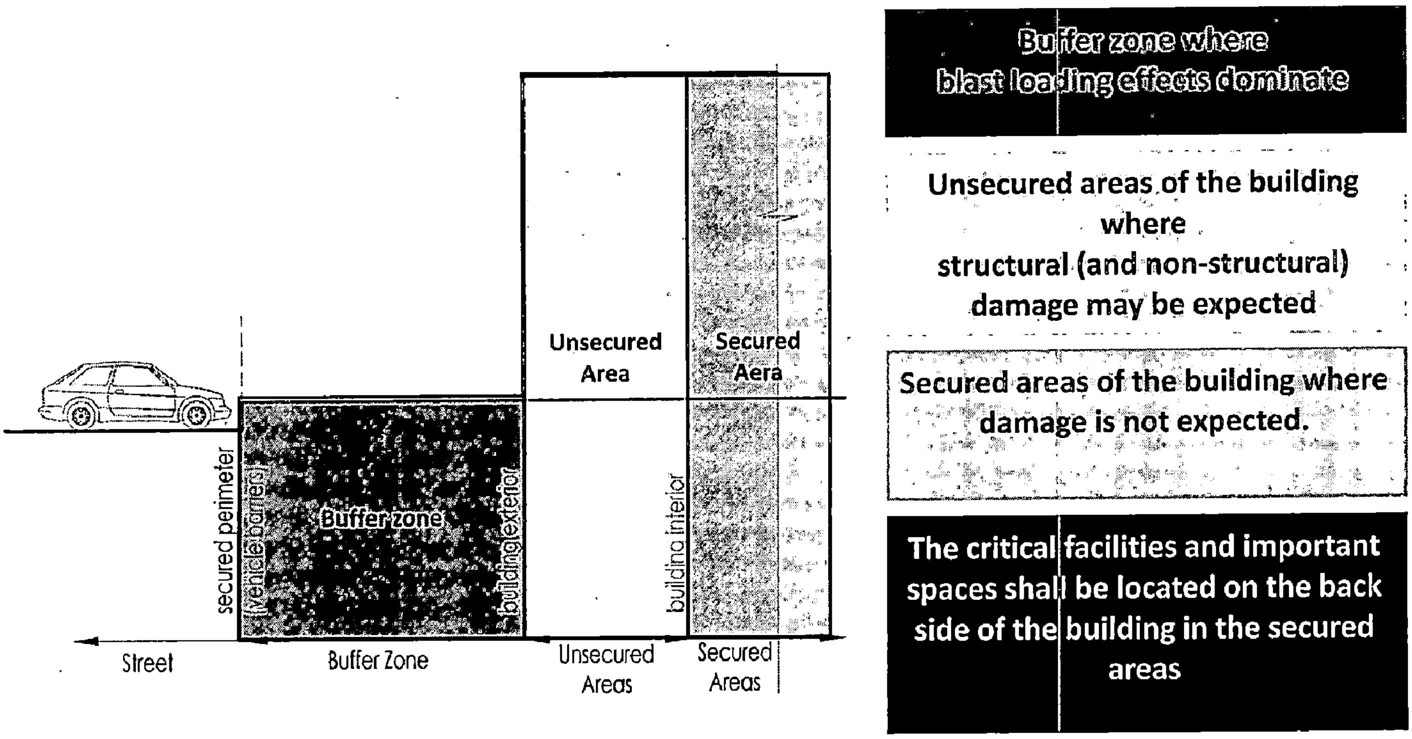


Figure 51: Schematic showing relative spatial demarcation of zones in the event of a blast.

To defy the worst effects of blast loading, the unsecured areas on the blast side of the building require to be provided with higher hardness. On the other hand, the critical facilities and significant spaces shall be placed on the rear side in the secured areas.

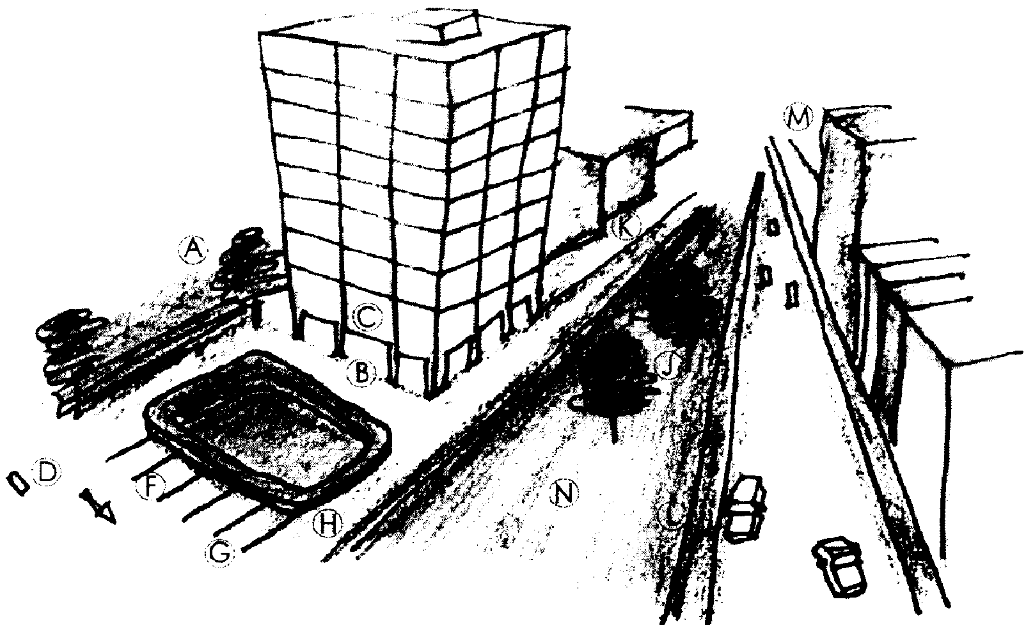


Figure 52: Schematic showing mitigation measures that need to be ensured at the site level and those that need to be avoided. (FEMA 426, 2003)

A	Place assets (like loading dock) outside the building within the view of occupied rooms in the facility
B	Remove parking underneath buildings
C	Reduce exterior signage or other clues of assets locations.
D	Place trash receptacles as far from the building as possible
E	Remove straight lines of approach to the building
F	Place parking to achieve stand-off distance from the building
G	Illuminate building exteriors or sites where exposed assets are situated
H	Reduce vehicle access points
J	Remove possible hiding places near the building; provide a clear view around building.
K	Locate building within the observation of other occupied buildings on the site
L	Maximize distance from the building to the perimeter/site boundary
M	Place building away from natural or manmade vantage points
N	Protect access to power/ heat plants, gas mains, water supplies & electrical services.

5.1.1 LAND-USE PLANNING

The placement of the building on the site is established by the land-uses on the adjacent plot areas. If neighboring plot area has facilities that have high security, the distance between the building and the plot boundary in that direction may be based on conventional site design consideration. Conversely, the building must be placed as far away as possible from the perimeter boundary if the facility on any neighboring plot area is security concern. The footprint of building must be as small as possible to have large open space around the building.

The aspect of land-use involves:

Characteristics of surrounding area (including construction type, occupancies, and nature & intensity of activities in the neighborhood)

if the facility on any neighboring plot area is **security concern, the building must be located as far away** as possible from the primeter

Security concerned Infrastructure includes Electric power system, Telecommunications infrastructure, and Gas & oil facilities.

5.1.2 PERIMETER LINE & STAND OFF DISTANCE

The stand-off distance is the distance between a building or asset and an explosion threat. The blast overpressures & their effects are much lesser at larger stand-off distances.

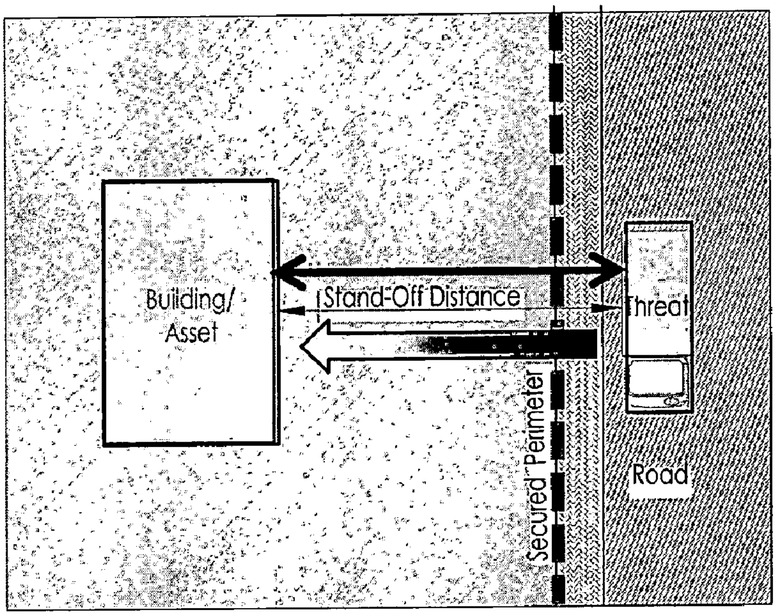


Figure 53: larger open space gives more protection

The outmost line that needs to be designed to avoid transporter of weapons or explosives from getting entry to the site is known as the perimeter line. As air-blast pressures decrease rapidly with distance, the perimeter line must be located as far as practical from the building. The best method to do this is to give an incessant line of security all along the perimeter of the building to keep it away from unchecked vehicles.

Figure 54: Use of bollards to push perimeter line outwards from a building

Many times in urban areas, susceptible buildings are situated where site conditions are rigid. The alternatives are evidently restricted in such cases. Frequently, the perimeter line can be taken out to the walkway by providing bollards, fountains, planters and other obstacles.

- The prime design approach is to keep terrorists away from occupied buildings. Although adequate stand-off distance is not achievable for all time in conventional construction. But still, the most cost-effective solution is to increase the distance between the building & the threat.
- Where there is non-availability of open area around the building, structural hardening is required for the façade towards the road.
- The **structural system and building exterior façade must be hardened** to withstand the terrorist attacks outside the building, if adequate stand-off distances are not available.

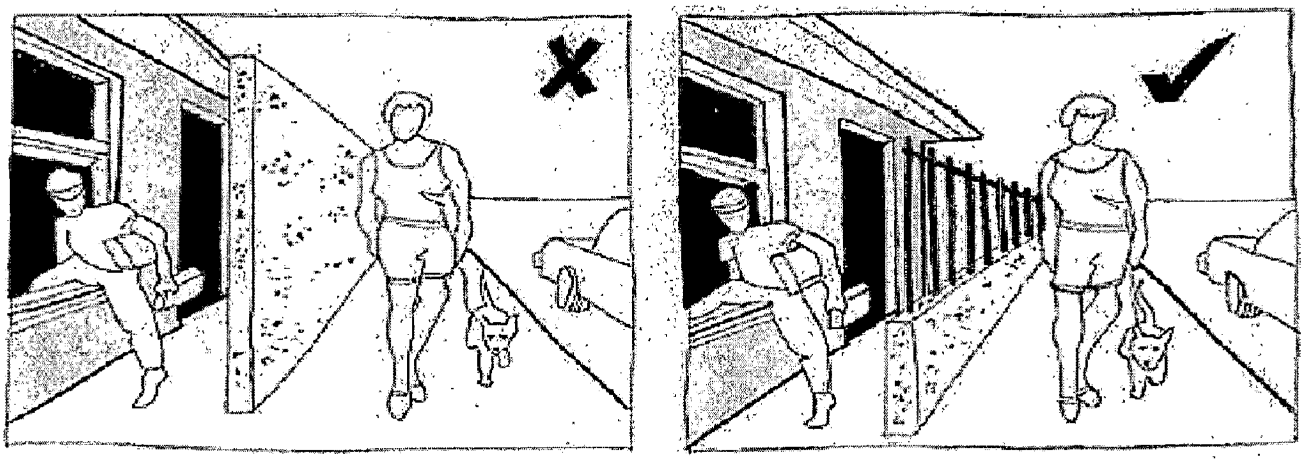


Figure 55: Reduce blank walls overlooking streets, parks, parking areas and other areas.

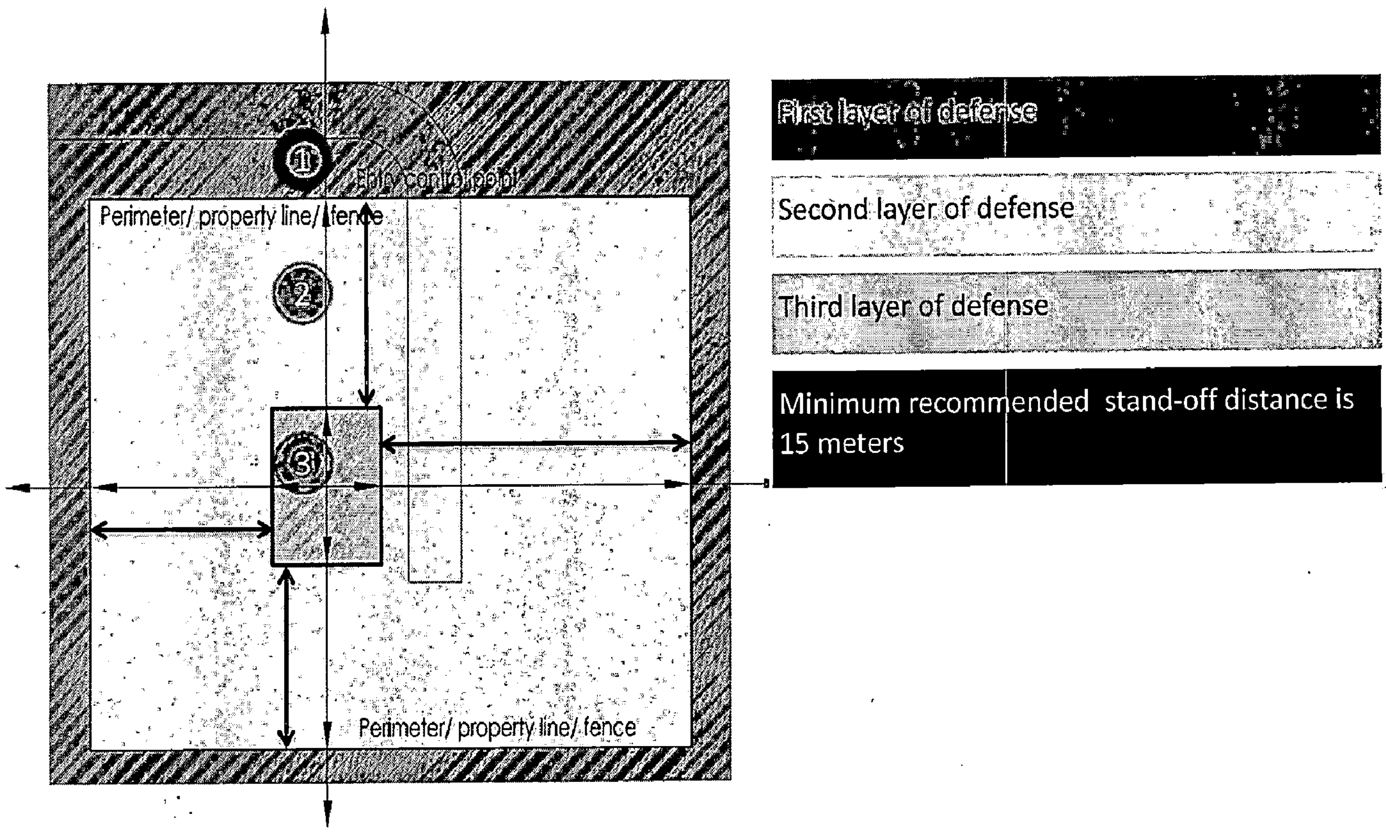


Figure 56: layers of defense around the building

- Reduce blank walls overlooking streets, parks, parking areas and other areas.
- First layer of defense has uncontrolled access of the vehicles. Unscreened vehicles are prohibited to enter the second layer of defense by perimeter/property line /fence. Third layer of defense should have entry to authorized persons only. Third layer needs to be protected from the threats.

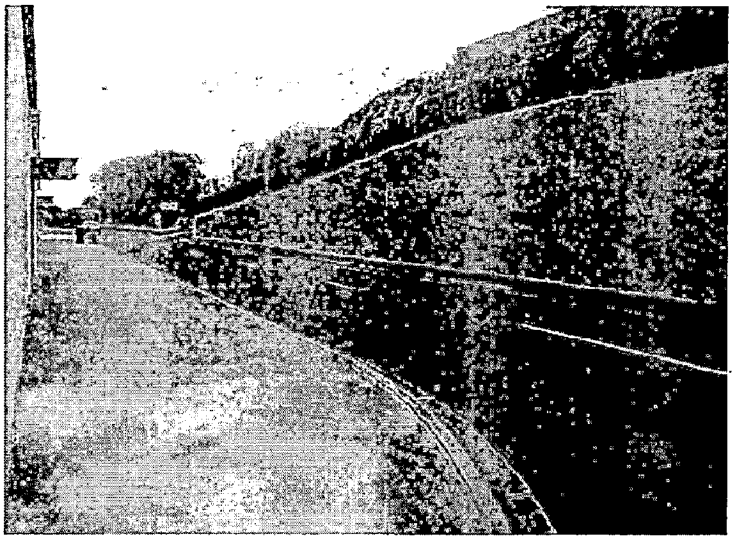


Figure 57: Long blank walls and barriers are not conducive to safe walking.

5.1.3 PLACEMENT OF BUILDING ON PLOT AREA

The type and level of other mitigation measures to be adopted are determined by the placement of the building within the available plot area. Building placement has many aspects to it, and these are explained in the following sub-sections.

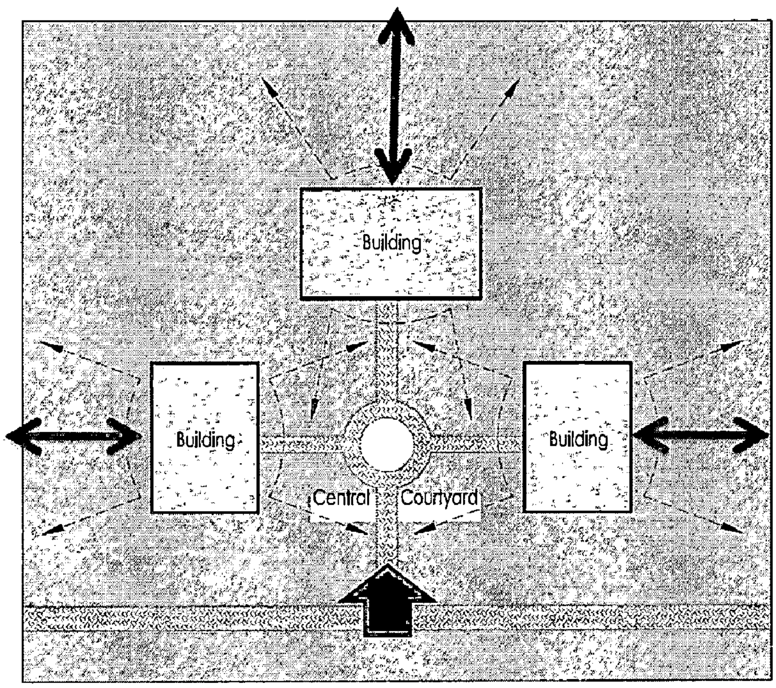


Figure 58: Clustering allows limited views of inside building and effective surveillance with limited number of entry points

When a number of building blocks are to be constructed on a plot area, two possibilities occur, that is clustering and spreading apart the blocks. Each of these alternatives put forward its own merits and threats.

Clustering offers a high population density and hence attracts an attack in the core of the cluster by offering greater chance of fatalities and collateral sabotage. Stand-off distance is maximized from the perimeter, and the perimeter to be shielded & number of entry points minimized. Clustering allows limited views of the inside buildings to outsiders. This option is mostly suitable when a number of critical facilities have to be protected.

Conversely, spreading the building blocks decreases the amount of collateral sabotage, but allows greater access to each individual building block. Also, the number of entry control points is amplified and a relatively smaller area is efficiently made protected from a threat. Evidently, the demerits are many to make this as a viable option.

5.1.3.1 BUILDING ORIENTATION

Orientation of a building implies its orientation with respect to the path of sun in conventional design. It reflects energy efficiency. Conversely, in security-oriented design, the prime concern is the safety & security of building against potential blast while energy efficiency takes the second spot.

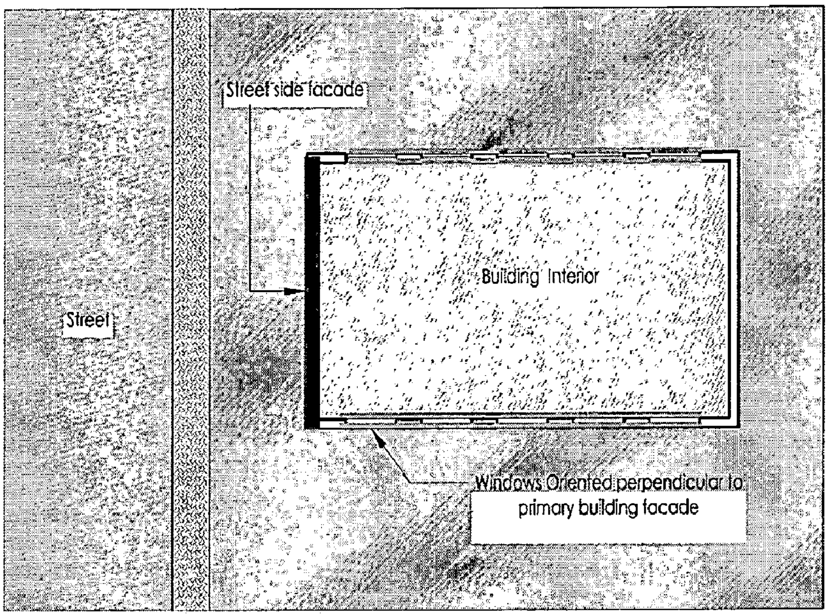


Figure 59: glazing should be avoided on the road side façade. (Source: FEMA 426, 2003)

In security-oriented design, the prime requirement is to enhance the hardness of the structure towards the vulnerable façade. Hardness of the structure is frequently achieved by the use of blank & strong protective elements like RC structural walls, and avoiding vulnerable items like glazing on the façade towards the potential blast location. Building must be oriented such that walls with glazing are away from the street-side façade to reduce exposure to blast.

However, the lack of windows offers little visibility, and restricts prospect to monitor activities outside. Therefore, these challenging demands need to be addressed at the design stage itself.

5.1.4 ACCESS ROADS

Security-oriented design requires a roadway system that reduces the vehicle speed in the proximity of the building to be protected. Thus, the roadway itself is used as a mitigation measure.

- Approach roads to the building should not be straight to prevent the vehicles from gathering high speeds and crash into buildings. They must be made parallel to the façade of the building.

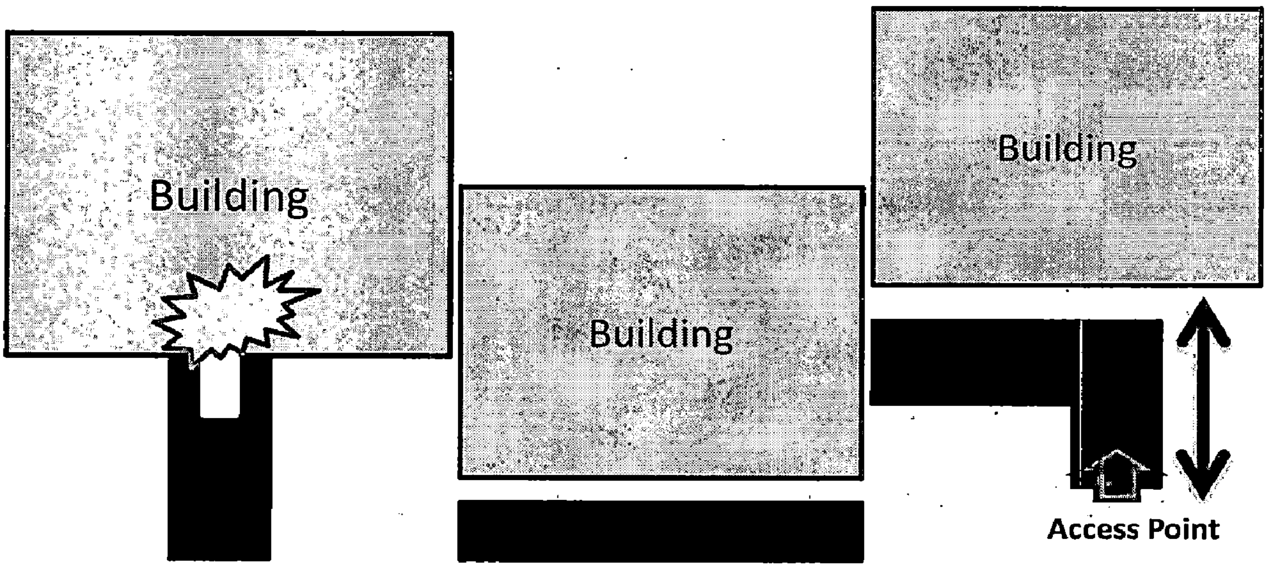


Figure 60: Access road should not be straight to the building instead it should be made parallel to the building. If it's not possible, the road must take a bend to prevent the vehicle from gaining speed.

- At the access point, the road should take a turn to avoid the vehicle from gaining speed to break through the entry control station.
- Place vehicular access points away from approaching streets.

- The traffic calming strategies can be used to force drivers to follow acceptable speeds in the area. It includes measures like raised crosswalks, pavement treatments to create noise, speed humps & riding discomfort and introducing traffic circles.

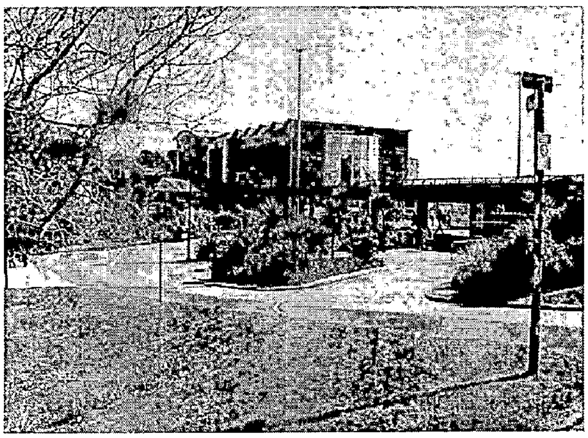


Figure 61: Approach road to the building is parallel to the building

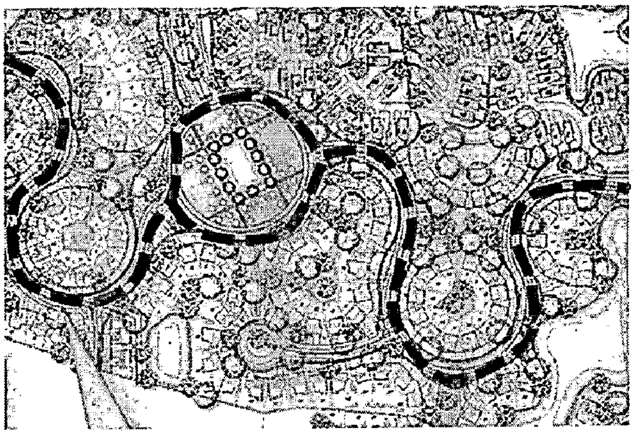


Figure 62: serpentine roads

- Serpentine roads with tight-radius corners are an alternate option. As it reduces the speed of the vehicles taking this path.

5.1.5 OPEN SPACE

Providing open space while designing the site has many benefits.

- Blast intensity decreases considerably with increased distance, and as a result larger open space gives more safety & security.
- It allows effortless inspection of people and vehicles to identify possible intruders and weapons of blast.

The space around a building can be left open but make sure that no vehicles can drive on that land.

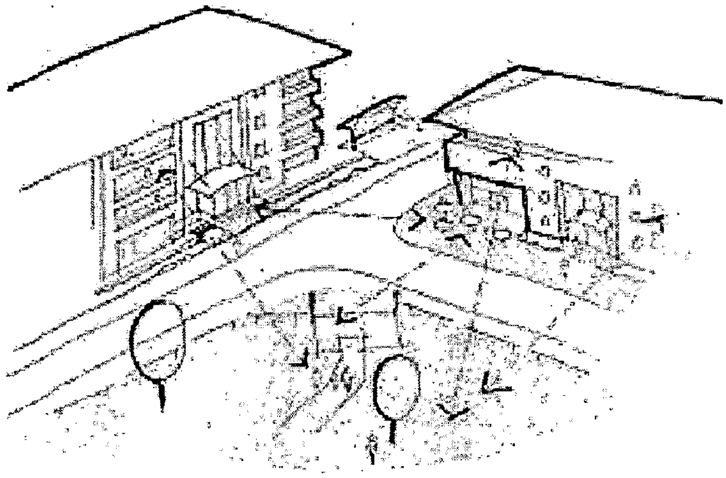


Figure 63: Location of open space & buildings permits for informal surveillance and clear sightlines

5.1.6 ENTRY CONTROL

There are two kinds of entries along the perimeter of a site:

1. formal entrances for people at the openings in the perimeter fence or boundary walls,
2. Entries for utilities (water mains, power lines, sewer pipes, communication lines, gas pipes and storm water drainages)

The access in the former must be restricted in size and only screened people are allowed entry. On the other hand, in the later, the openings should not be too big to allow passage of persons through them. They should be completely sealed. But, in some cases, access only to authorized personnel may be allowed.

- Entrances or access points to buildings must be oriented to look open or active spaces.
- Unauthorized access to the site can be prevented without hindering the smooth flow of authorized access by providing entry control points.
- The layout of an entry control point is influenced by the existing terrain of the site. Normally, flat terrain with no thick vegetation is favored. But, in some sites, a mild rise in height up to the entry control point helps monitoring the arriving vehicles from a distance.
- Buildings which experiences heavy traffic should have entries separated for each type of the traffic (site personnel, visitors, and commercial traffic).

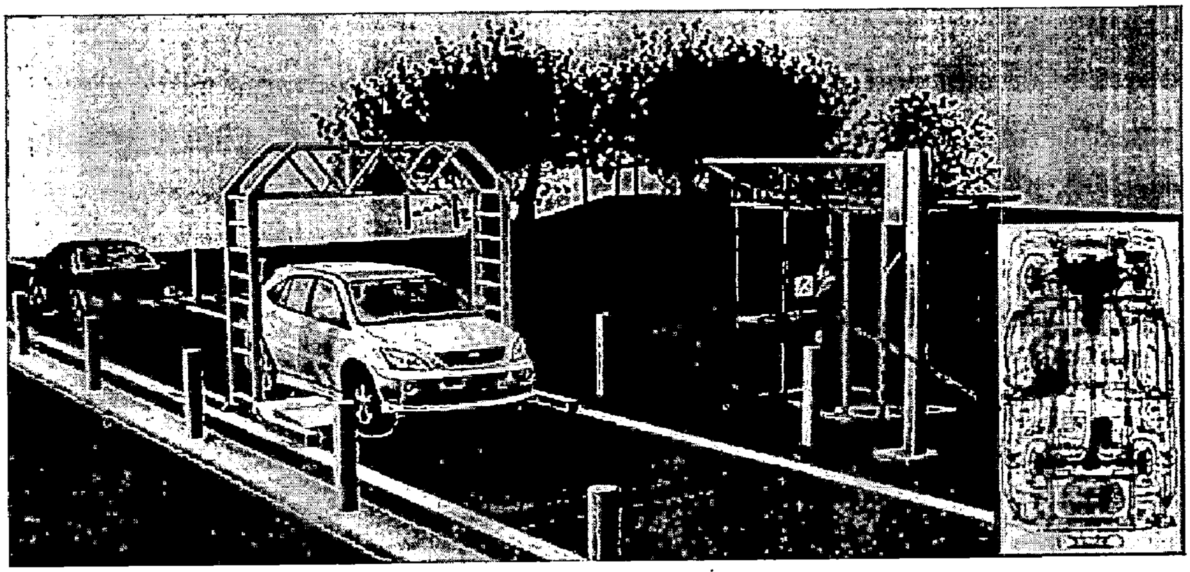


Figure 64: controlled access points for vehicles should be provided to avoid unauthorized access in the site.

- If open area between the building exterior & the perimeter line is obtainable, a lot can be done to take hold of an intruder. Statues, fountains, terraced landscaping, circular driveways, trees, planters and other obstacles can be given to make it complex for an intruder to speedily reach the building.

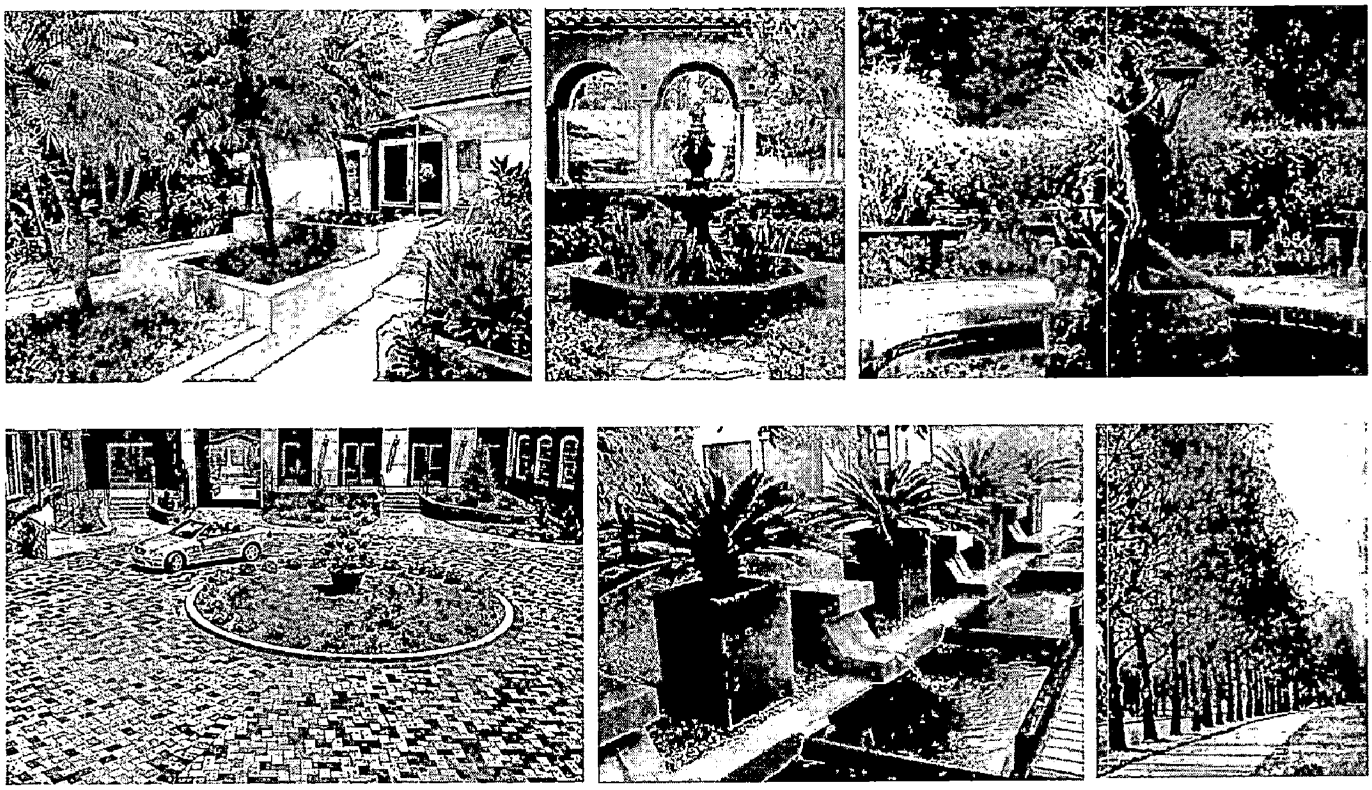


Figure 65: terraced landscaping, fountains, statues, circular driveways, planters, and trees, make it complex for an intruder to speedily reach the building.

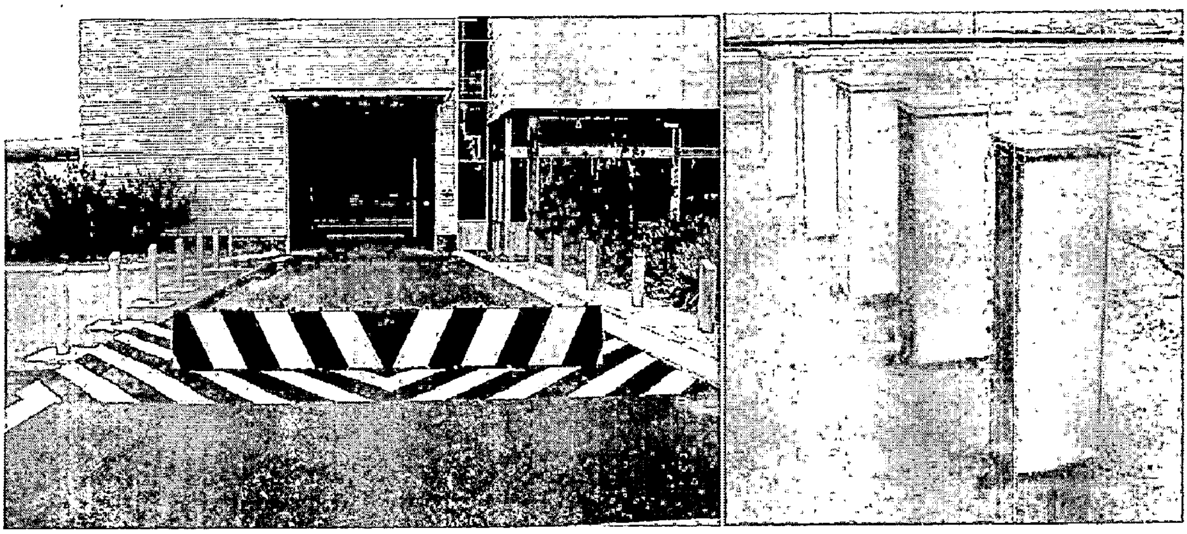


Figure 66: Anti- ram barriers (ARB)

- Limit the number of vehicular access points through the secured perimeter line.

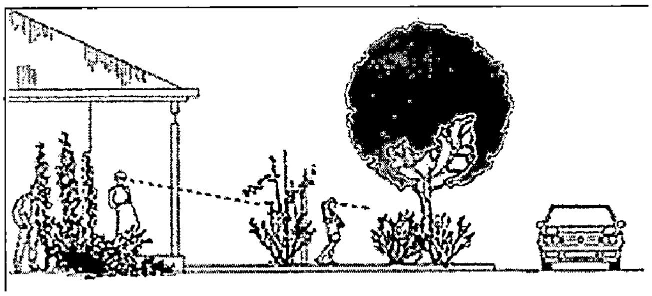
- Anti-ram barriers can be used along curbs, mainly on sides of the building that have a little setback.
- Security guard room & entry control point should allow appropriate verification of the vehicles and its inhabitants. The room must be prepared with computers and communications equipment for use of security personnel.
- When entry is needed for maintenance at the ingress of utilities on the site, special barriers like metal grating shall be used that stop the admission of the intruder.

5.1.7 SURVEILLANCE & LINE OF SIGHT

- Critical buildings should not be constructed on sites whose neighboring sites are elevated.
- Screens can be either natural or man-made. Natural screens are eye-catching and powerful tools for enhancing safety & security. Examples of natural screens are landforms, vegetation and water bodies. These screens not only characterize a space but also prevent unauthorized access.
- The type of vegetation to be used is an important issue. While plant species that are thorn-bearing and have sharp-leaves can prevent aggressors very efficiently. Dense and tall vegetation close to the building, which covers the building, can screen unnecessary activity outside.

Figure 67: landscaping providing good surveillance. a) & b) high canopy trees with a combination of low hedges c) thorn bearing plants deter aggressors very effectively.

- Grass more than 100mm thick permits concealment of explosives. Therefore, vegetation should be chosen cautiously, and maintained to eradicate all concealment possibilities.



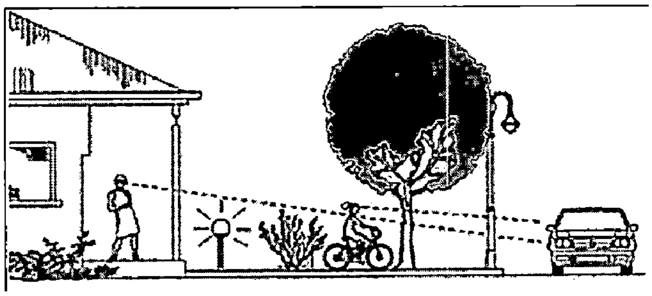


Figure 68: The following examples demonstrate how landscaping can influence lines of vision around a building. First picture demonstrates how the plants do not let people to observe the street generating places for people to hide or commit crimes. Second picture demonstrates how appropriate plants and lighting can let everyone to observe the street, minimizing the incentive for someone to commit a crime in the area.

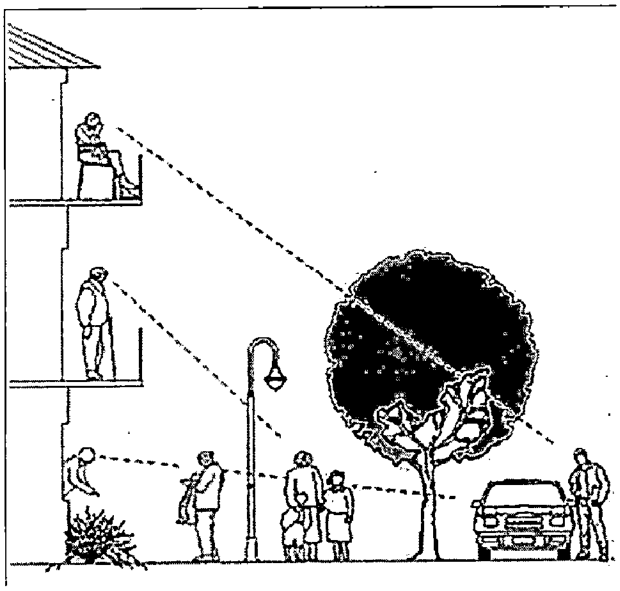
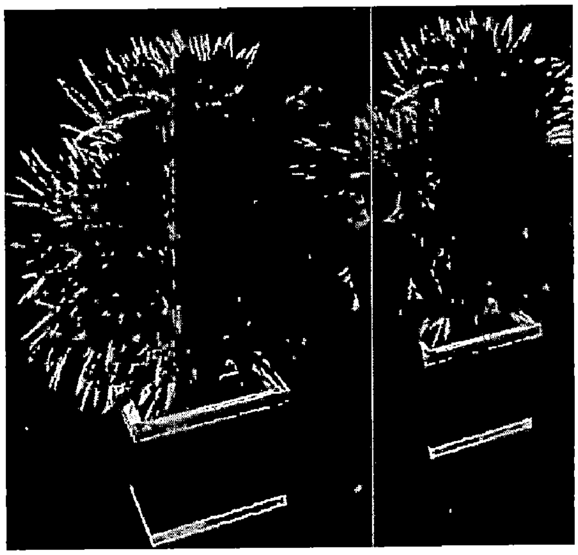


Figure 69: This figure shows good lines of sight on a neighborhood street.

- Clear sight lines should be provided all over areas of open space and between adjoining uses to ensure good surveillance. The ground covers & trees can be provided without hampering the clear views.
- Unobstructed sight lines from within the building should be provided at the access point so that inhabitants can view out into a space before egress.



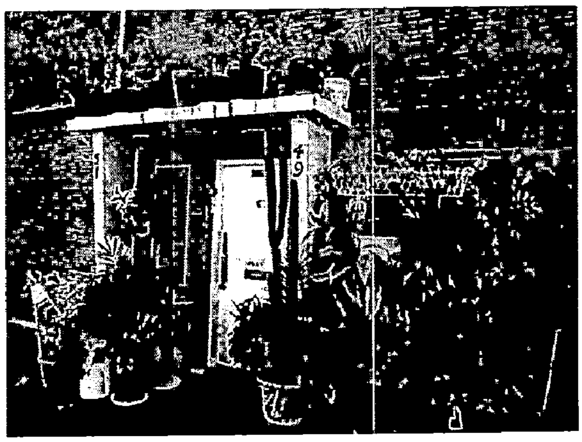


Figure 70: planters providing a concealment point

Figure 71: thicker the vegetation more the sense of fear

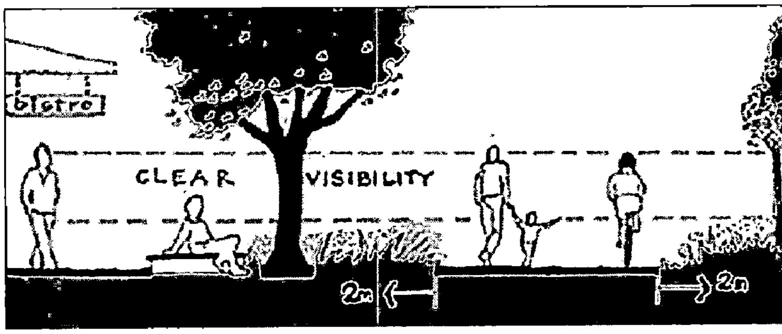


Figure 72: vegetation should not obscure sight lines & movement.

- Clear sightlines must be given between 0.5m and 2m above natural terrain.
- Public admission to the back of buildings should be restricted. Isolated walkway should not be located at the back of buildings. If this is not attainable, improved visibility and lighting should be provided.

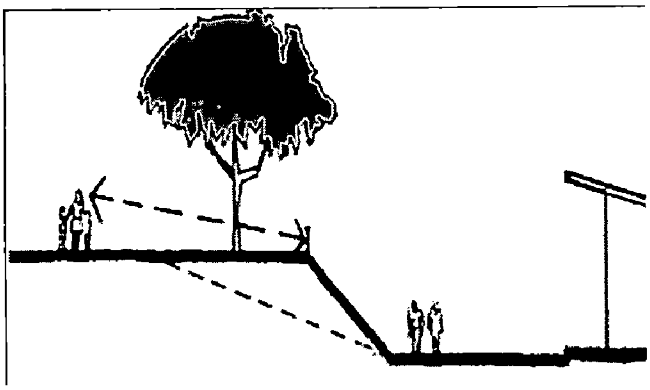


Figure 73: minimize sharp level changes that minimize sightlines

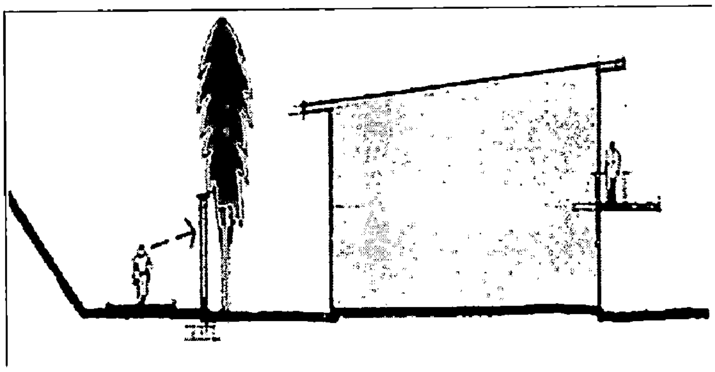


Figure 74: Isolated walkway should not be located at the back of buildings.

- Trees placed near car parks, walkway, street corners; driveways and at the entry points to buildings must have a clear trunk to a recommended height of 1 meter. Groundcovers must have a suggested height of 500mm.
- When safety is an issue, maintain shrubs trimmed to 3'0", or at least below window sills.

- Landscaping choice can impact access to the site and building. Open or surface parking areas frequently have landscaping that may obstruct visibility and offer hiding spaces.
- An efficient method to attain safety & security is to provide a mixture of high-canopy trees and low hedges instead of planting a solid hedge of bushes or trees. This blend provides clear views and no hiding places for intruders.

5.1.8 PARKING

Vehicles carry weapons and invader to a building. Thus, controlling vehicular parking can assist in keeping potential threats away.

Parking facilities are challenging to make into secure environments. They have structural columns, big high-rise garage walls, and multi-levels, which produce poor visibility and make them susceptible to crime. It is tough to manage access to large open parking lots, and they create an attractive environment to commit crime. Parking areas (surface lots, above or below ground) are recognized as segregated, dark, and unsafe environments.

Parking facilities have numerous issues that generate chances of high risk of criminal activity, because there is usually a small level of activity with plenty of hiding places and areas of dark shadows. The main purpose of designing protected garages and parking facilities is to generate an atmosphere that makes potential criminal sense that they will be seen.

The following measures are necessary to decrease parking related risks:

- General parking should be placed away from stand-off zone & within the vision of occupied buildings.
- Parking for both general public & visitors must be kept as one. The number of vehicular entry/exits must be kept to a minimum.
- Parking must not be given under (in the basement of) the critical buildings. The 1993 WTC bombing incident restated that penalty of bombing can be catastrophic when parking is given underneath the building.
- Parking lots should have adequate setback from adjoining properties. In the deficiency of that, structural hardening measures must be undertaken.

- The primary security challenge with parking is the number of entry and exits. From a safety & security viewpoint, the more entrances will allow less ability to control who arrives and leaves.
- The suggested way is to have one means of entry and exit for vehicles.
- If traffic is huge as to need more entry & exits, then at each consequent access point an attendant must be positioned in a booth along with CCTV and good lighting.

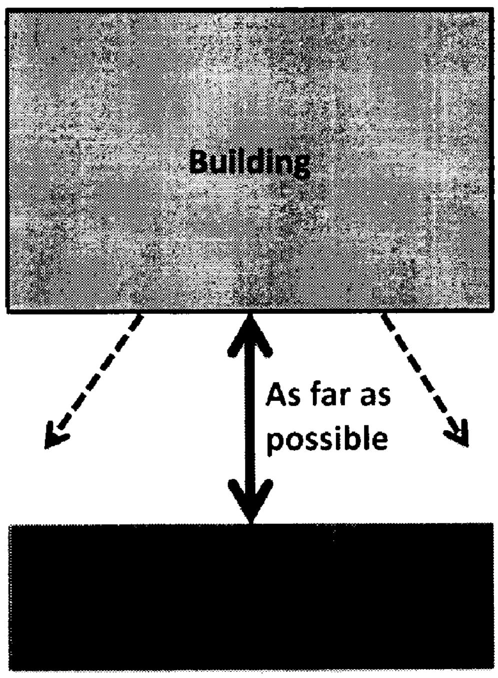


Figure 75: General parking located away from stand-off zone & within the view of occupied buildings.

Figure 76: a) building with plaza; b) basement parking under the building & plaza; c) authorized persons are allowed to park under the foot-print while visitors are directed to park under the plaza or courtyard.

- The parking must be located adjoining to the building under a court or plaza area rather than under the foot-print of the building if basement is used for a high-risk building.
- Parking must be restricted from the interior of courtyards in large building premises.

- Parking inside the secured perimeter should be limited to authorized personnel.
- Curb-side parking in densely occupied areas must be limited to company owned vehicles or chosen member of staff vehicles.
- Parking beneath the building and inside the courtyard, should be prohibited to the extent possible.
- When parking beneath the building becomes necessary, access must be limited to authorized persons only & such areas must be safe, well-lighted, and free of hiding places.
- In parking areas that are built above ground:
  - visibility into and out of the parking area should be maximized;
  - landscaping must not generate hiding places;
  - Elevator and staircases lobbies should be as open & well-lit as possible so that people using the elevators can be observed.
  - Possible hiding places below the stairs should be blocked.
- Vegetation should be planted away from parking lots to let surveillance of pedestrians.
- Position of entry and exit points can help in obstructing or creating chances for strangers to get admission to the parking area.
- To the extent possible, restrict the size of vehicle that is capable to go into the parking by using physical barriers on vehicle height.

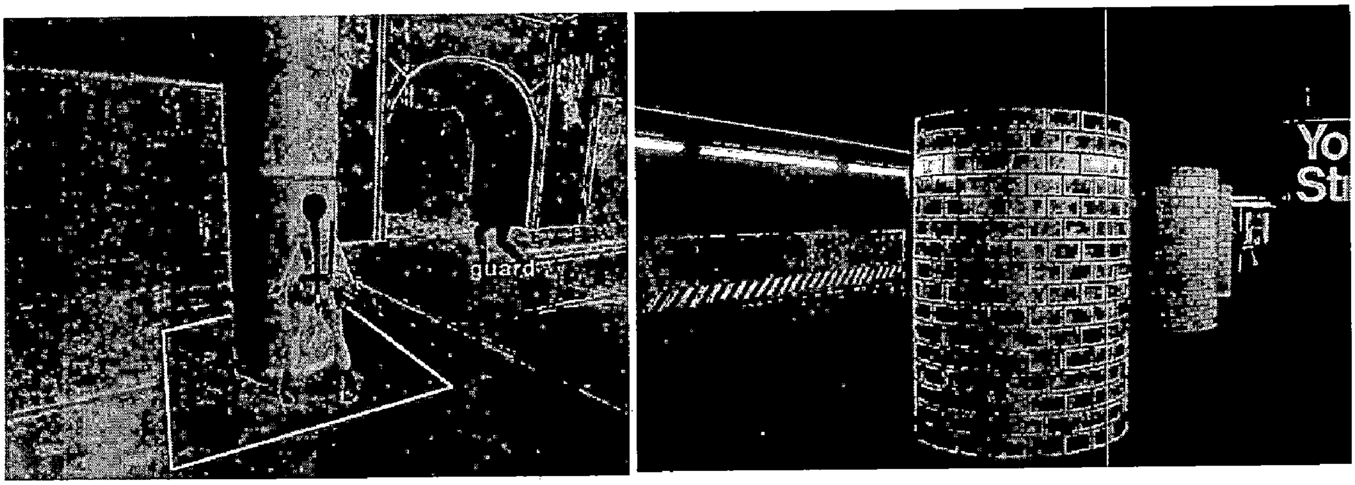


Figure 77: The huge structural columns of this garage are troubling for security concerns because they are difficult to negotiate with a car, can hide people, and make lighting difficult to accomplish.

- A circular column allows better surveillance around the corners than a square or rectangular column. Therefore, a circular column can be used rather than rectangular structural elements in the basement parking.
- For parking, the less structural elements and ramps, the enhanced supervision is by the regulars and attendants of the building.
- Where solid walls are required, portholes and windows can be provided to create porosity that allows casual surveillance.

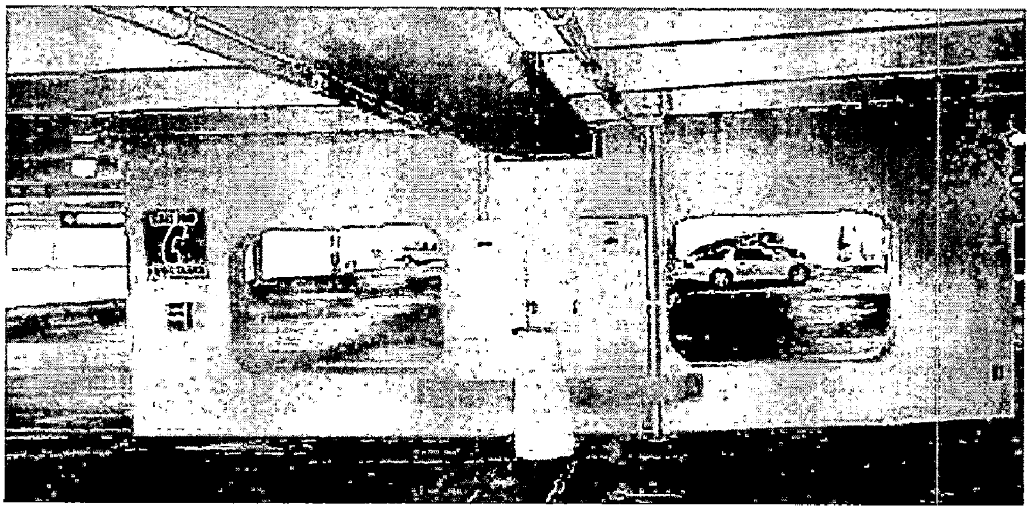


Figure 78: The openings cut into this wall allow views of the parking area.

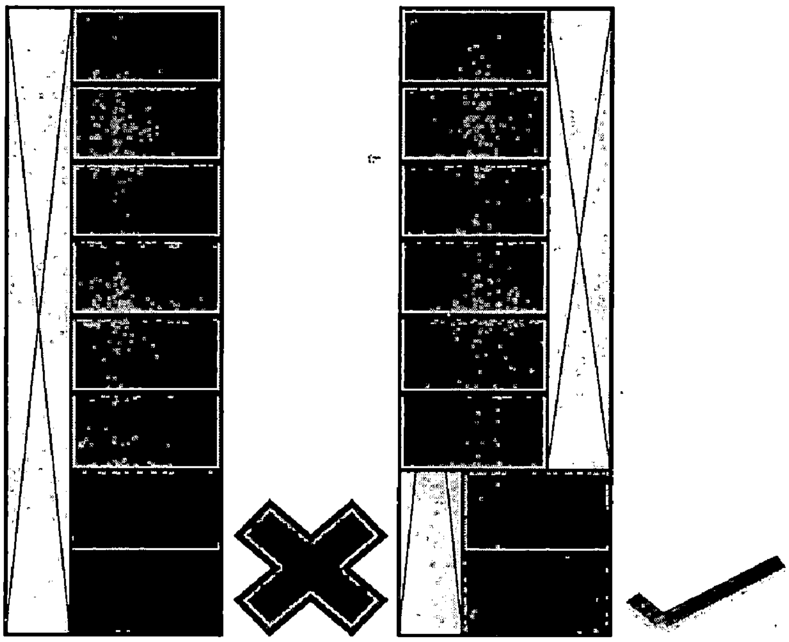


Figure 79: Stairs and elevators must empty to a floor level and then lead to an additional devoted bank of elevators & stairs that can assist access control, screening and supervision by security staff if desired.

- Elevators & Stairs of high-rise buildings that contain residences, offices, or other mixed uses must have the stairs & elevators from basement parking pour out into a lobby and not go straight into the business or resident floors. One can park in the basement parking and catch an elevator up to an office & residential floor, completely circumnavigating the security function.
- Stairs and elevators must empty to a floor level and then lead to an additional devoted bank of elevators & stairs that can assist access control, screening and supervision by security staff if desired.
- In parking lot design, lighting becomes a critical design feature. Lighting should be a combination of high and pedestrian level lighting to reduce the shadows produced by the vehicles.

5.1.9 SIGN BOARDS

- Sufficient sign boards must be given where aggressors are to be kept away.
- Sign boards must not be given to spot sensitive areas and susceptible facilities.
- Inadequate signage about restricted areas, parking and entry points can be counter-productive.
- Warning signs are necessary to distinguish areas that can be accessed by visitors and those by approved personnel only.
- All entry & exit points to the site and to the restricted areas should be clearly marked.
- Buildings should be recognized by their avenue address than by the facility they contain.
- High-risk and utility buildings (e.g., water treatment plants and power plants) should be recognized by minimum number of sign boards, but unauthorized personnel trying to go into them must be warned by sufficient number of sign boards.
- Warning signs must not be located at more than 30m intervals.

5.1.10 WAYFINDING & ROUTE MARKING

A new technology for way-finding or route marking implemented in an emergency condition is photo-luminescent path marking. These signs have tough, everlasting and renewable fluorescence. These self-adhesive signs and tapes will radiate for up to 8 hours if light source is disconnected. These are extremely noticeable during the day. The markings are designed to provide outlines of the outlet path, handrails and stairs to allow inhabitants to distinguish these outlet path components in dark.

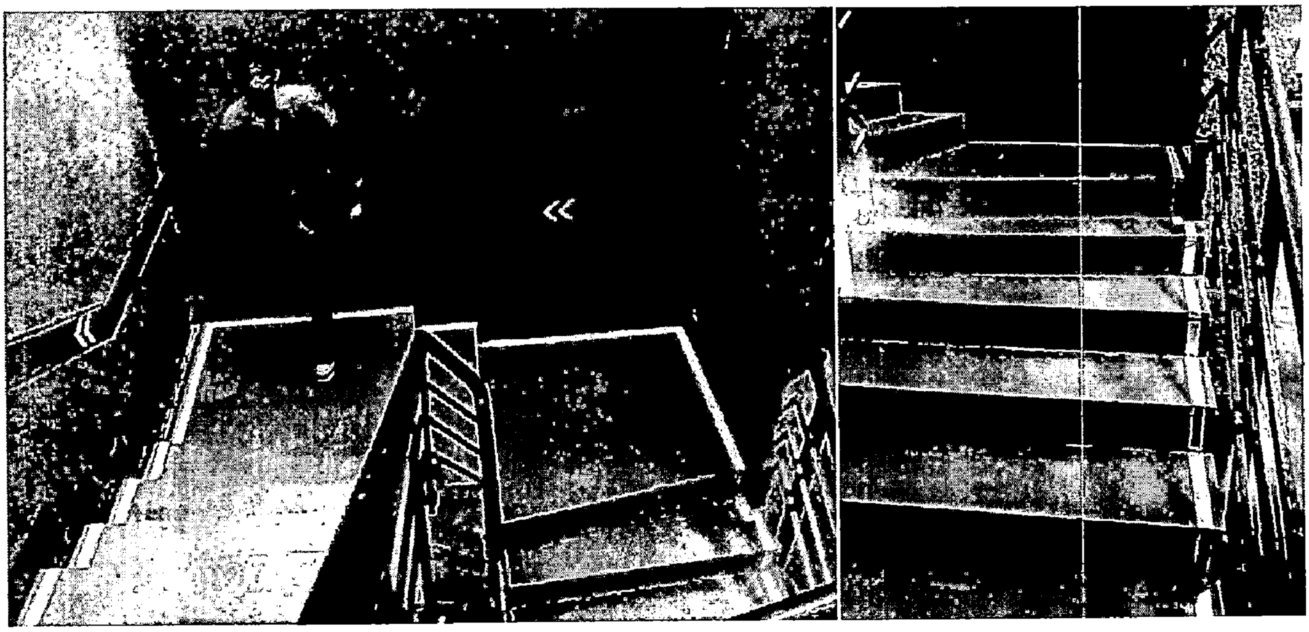
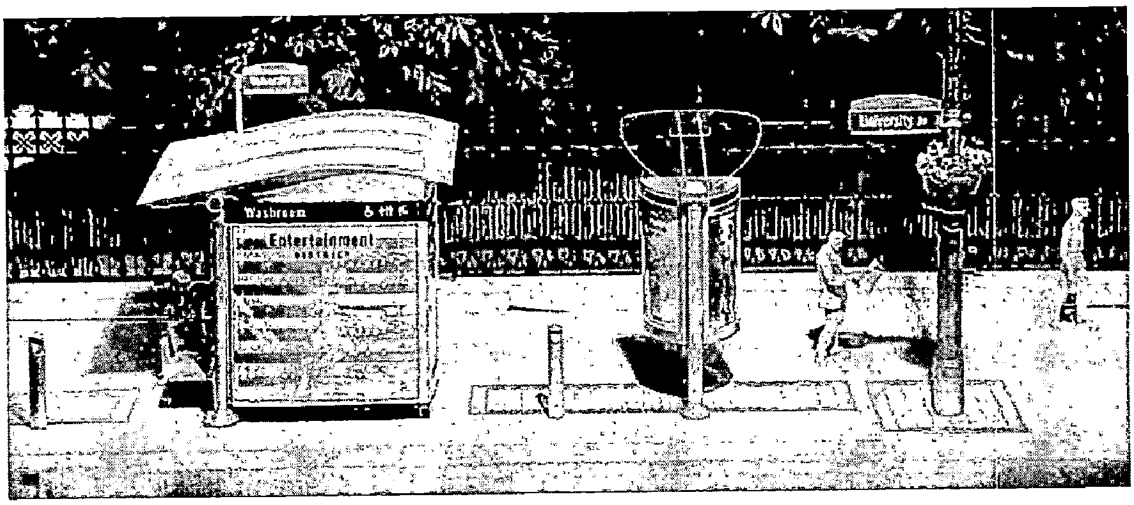


Figure 80: Photo-luminescent signs, stair treads, and route marking

5.1.11 STREET FURNITURE

Street furniture can be both a benefit as well as potential places where invader can fix bombs or explosives. Items like kiosks and light poles can be used to fix surveillance cameras. Street chairs at bus stops and parks can be as efficient as bollards, if intended to defy large blast overpressures. But mail boxes, flower pots, news paper stands and trash cans are likely to be used to conceal weapons.



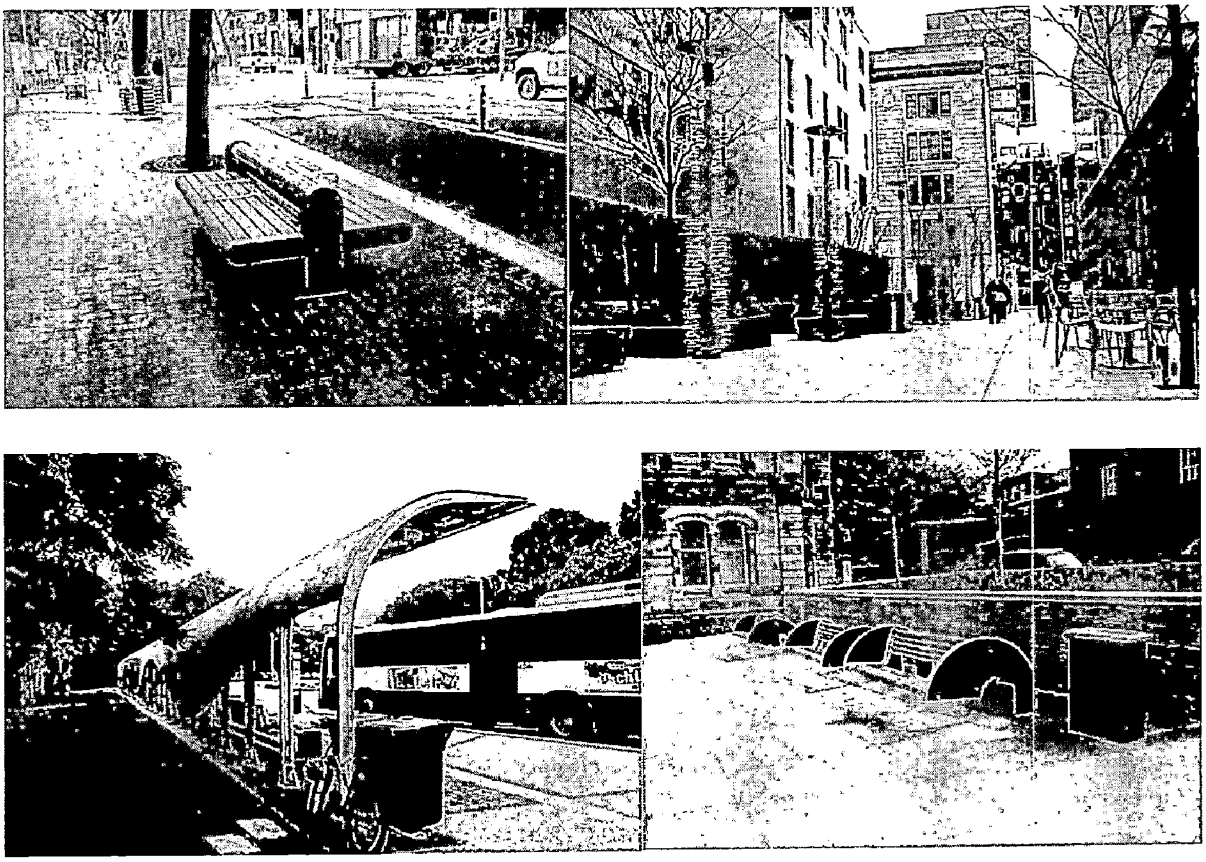


Figure 81: Street furnitures

5.2 BUILDING CONFIGURATION

In blast loading, the shock wave front is customized by the geometry of the earth surface. Thus, the shock wave front acts together with both shape & size of the building and landscape around it. The shape and size of the building can be so selected that effects due to exterior blast around a building are alleviated.

5.2.1 SHAPE

The shape of the building has a considerable influence on the entire sabotage sustained by a building in blast loading caused by blast. In the way of the shock wave front, an aerodynamic building shape will act better than those without. So, the foremost effort in recognizing favorable shape of the building is to spot all its geometric features that deter even aerodynamic flow of shock wave front around it, entrap the shock wave and intensify the effects of air blast. Buildings with simple geometries with negligible ornamentation are appropriate for security-based design.

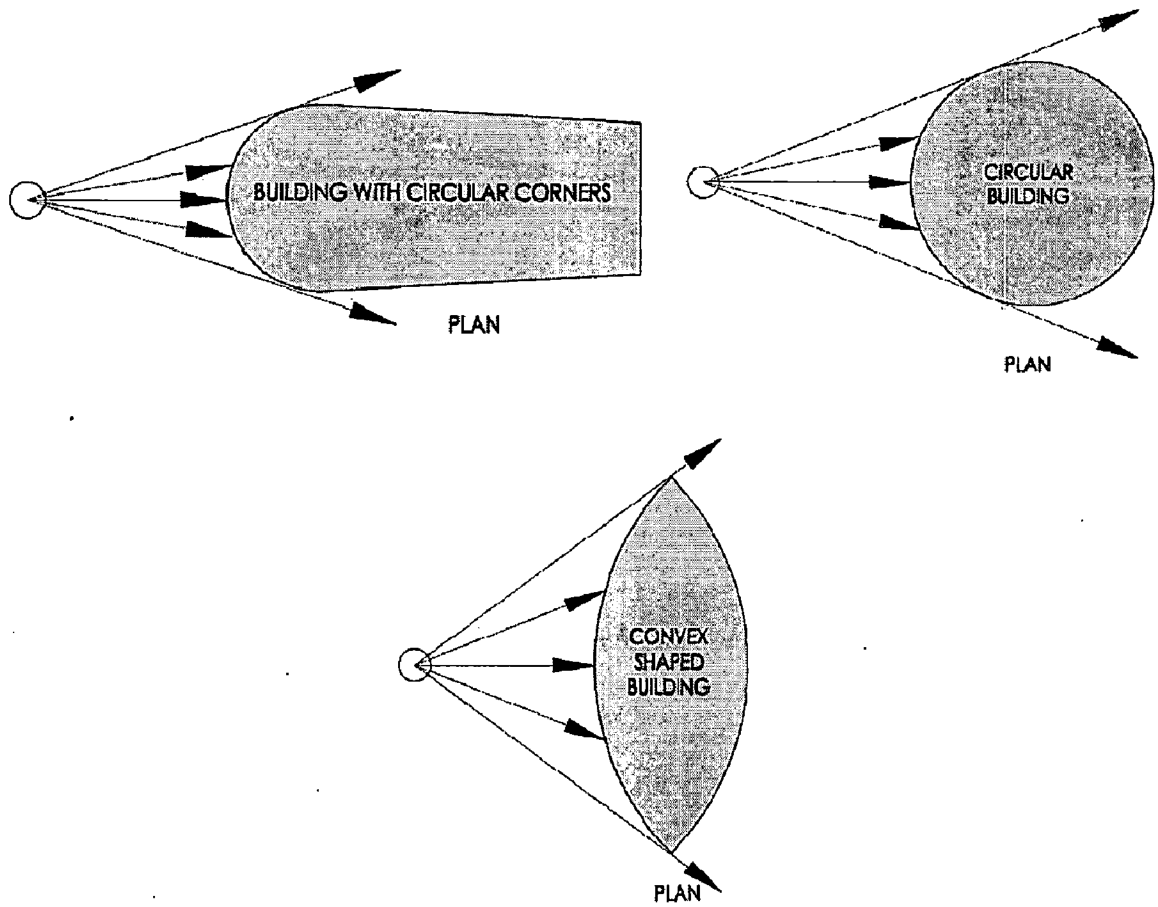


Figure 82: Shapes that dissipate air blast

Circular plan buildings and buildings with circular corners contain fewer intense reflected pressures than a building with sharp corners, as the angle of incidence of the overpressure shock wave front amplifies quickly in a circular building than in a building with sharp corners. Convex shapes are chosen over concave shapes as the concave shapes entrap the shock wave overpressure. The concave shapes contain a number of dead ends inside which entrap the shock wave overpressure. Buildings containing re-entrant corners, (examples are U, T, + or L-shaped buildings) also entraps shock wave over pressure.

Commonly, buildings with simple geometry will perform excellent during blast. Buildings with re-entrant corners (U, V, H and + shapes) have sustained major sabotage. A lot of times, the terrible effects of these sharp corners are prevented by constructing the buildings in two parts by a separation joint at the connection.

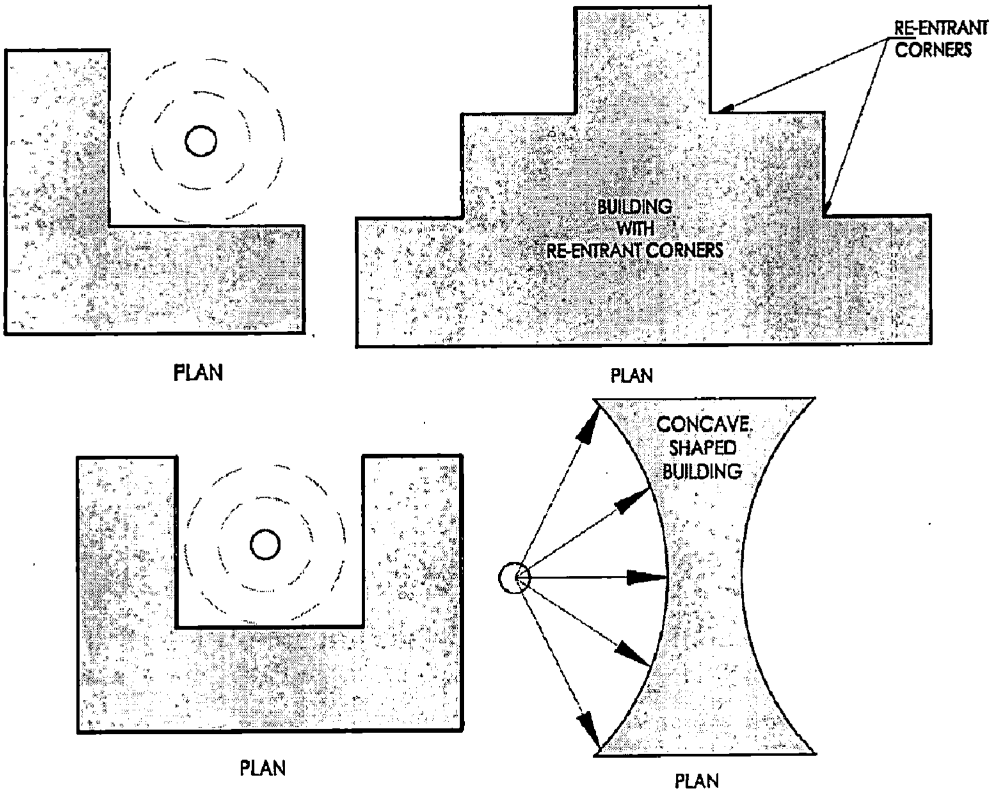


Figure 83: Shapes that accentuate air blast

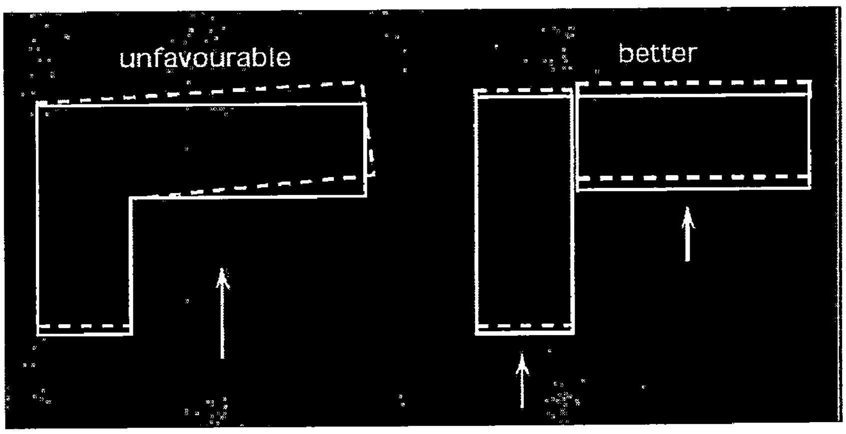


Figure 84: plans with re-entrant corners can be separated into rectangular plan shapes by a separation joint.

While designing commercial and office buildings, often courtyards or plaza-type construction are preferred. In such designs the set-back on the front is kept huge and on the other three sides less or none. This design may create an architectural statement, but makes the building susceptible on the other three sides because of lesser stand-off distance.

5.2.2 SIZE

Vertically-spread and horizontally-spread buildings both put forward challenges. Buildings oriented horizontally have a lesser contact to blast overpressure than those oriented vertically.

Low, Horizontal, Large-footprint Buildings:

- Allocate inhabitants, assets & operations across a large area to lessen sabotage.
- Need the utilization of supplementary measures to avoid introduction of CBR agents because of easier admission to AHU fresh air intakes by aggressors.

Tall, Vertical, Small-footprint Buildings:

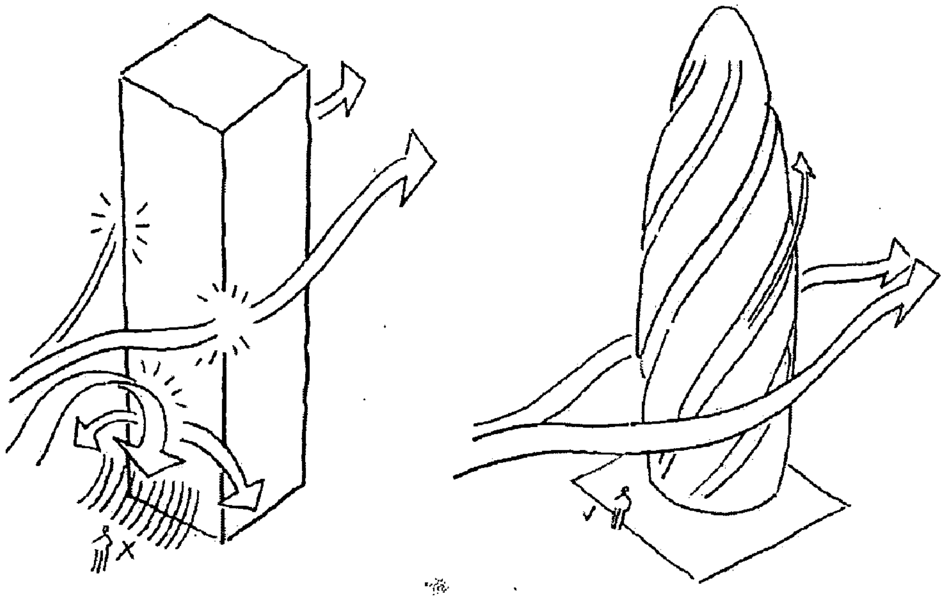


Figure 85: Buildings oriented vertically have a larger exposure to blast effects than oriented horizontally. Vertically oriented building can be designed to mitigate damage by explosion.

- Undergo more widespread sabotage to their façades, structural elements and interiors; disastrous damage or progressive collapse cannot be avoided if a huge explosion takes place near the building.
- Raise occupied areas above screening elements to keep interior spaces away from outside surveillance.
- Offer greater opportunity to raise AHU fresh air intakes to deter the introduction of CBR agents.

5.3 FUNCTIONAL PLANNING

- Areas to be secured must not face a street & areas that add vulnerability. It is suggested to make them face courtyard.
- Areas to be secured require to be segregated sufficiently from the areas which add to vulnerability both within plan and in elevation.
- Areas that add vulnerability must not be located under the footprint of the building. They must be located outside the building. If not possible, they must be located along the edges of the building.
- Such an approach lessens the impact of blast on the building, prevents explosion below the building which can lead to progressive collapse, & trim down the entry of potential attacker inside the building.

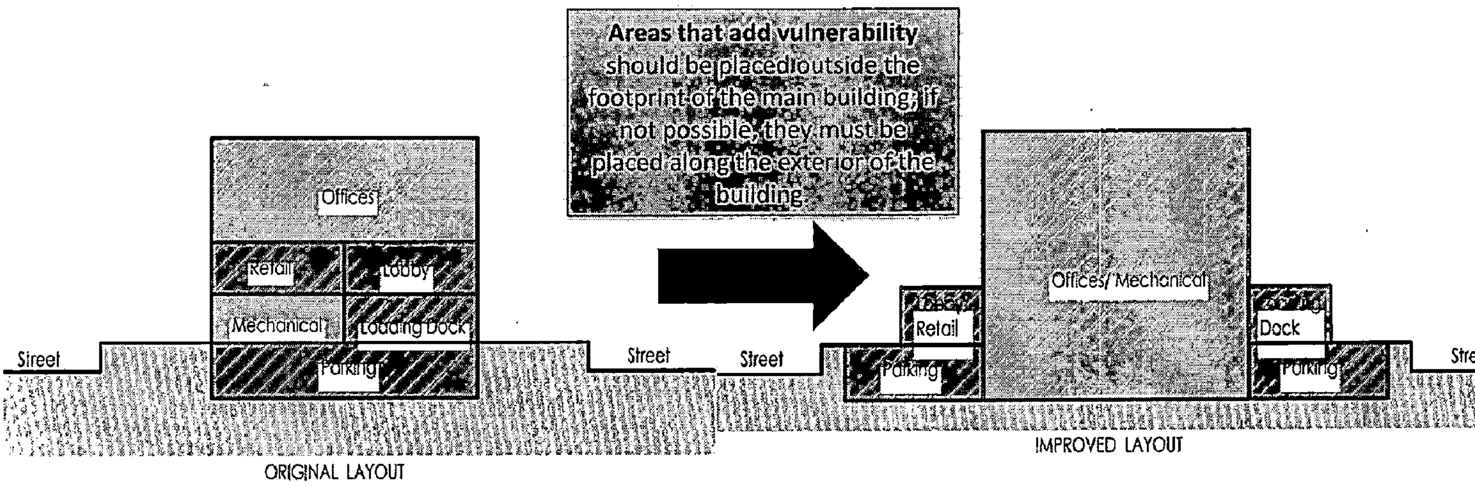


Figure 86: Improving the layout by segregating unsecured and secured areas

- Unsecured areas require to be segregated from the secured areas of the building. Unsecured areas include the lobby, mail room, loading dock, parking, and retail areas.
- Public toilets, entry points to vertical circulation systems & service spaces must not be placed in unsecure areas.
- Buffer areas such as secondary stairwells, corridors, storage areas and elevator shafts must be placed between secured and unsecured public areas.
- Entrances must be planned so as to retain security when public affairs are seized. An auditorium or restaurant is most likely the area often used by outsiders. The entrance to auditorium & restaurant should be designed to allow admission to the auditorium, lobby,

restrooms, and coatrooms without involving visitors to go into other doors or other areas of the building.

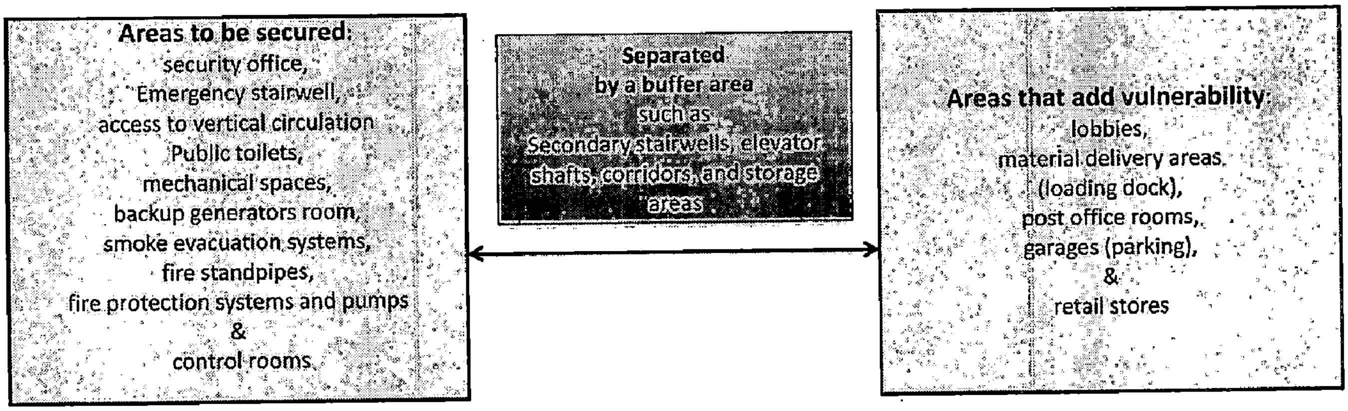


Figure 87: Areas to be secured should be separated by a buffer area from the areas that add vulnerability.

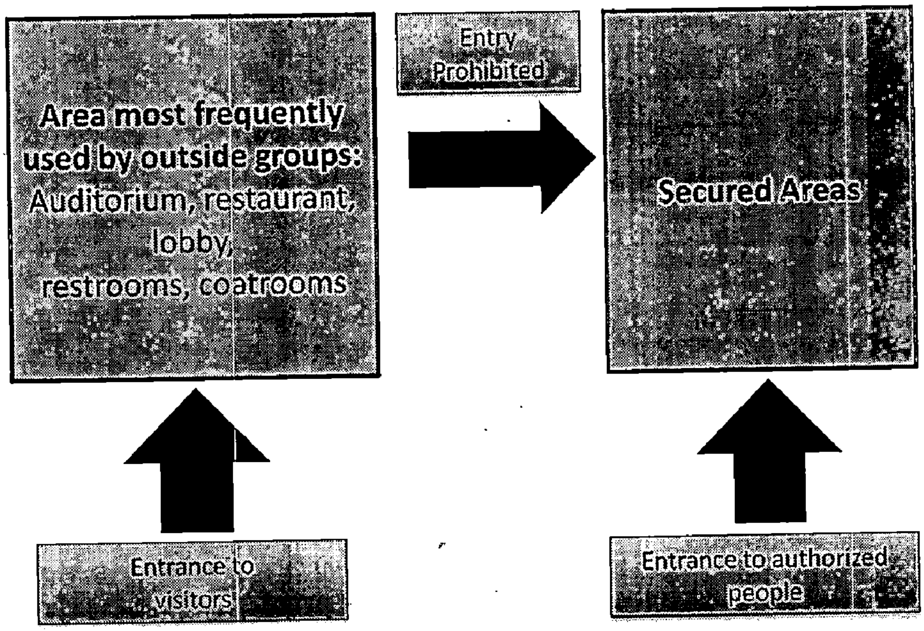


Figure 88: Entrances should be designed so as to maintain security when community affairs are held.

- Information facilities & Security office must be situated at main entrances & designed so as to allow surveillance of who is entering & leaving.
- Stairwells necessary for emergency exit must not empty into lobbies, loading areas or parking. They must be placed in corners (not staggered in one place). These must be situated away from places where explosion or blast events might take place.

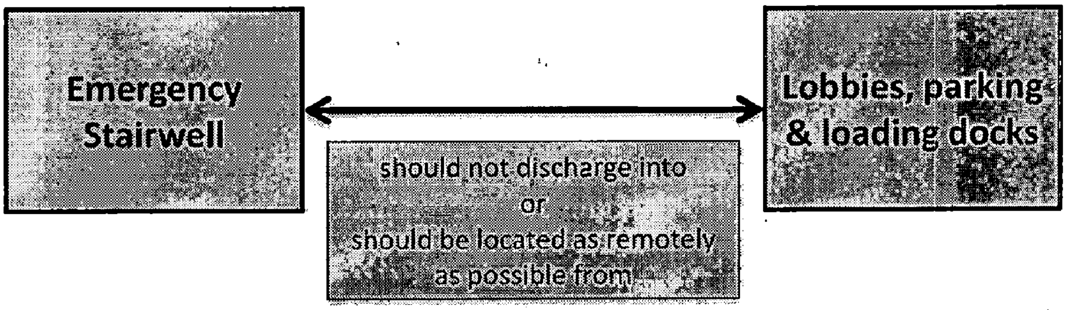


Figure 89: Emergency Stairwells should be placed away from areas where blast events might take place.

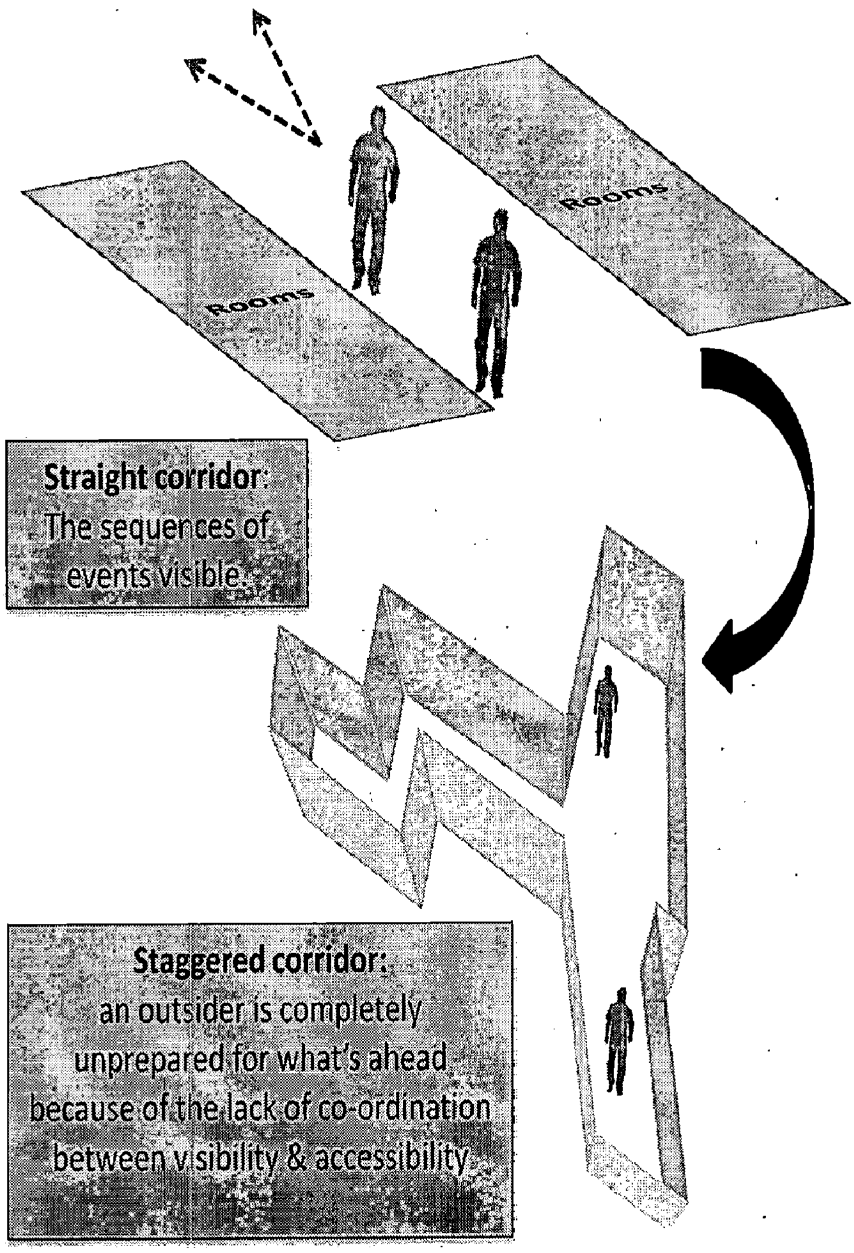


Figure 90: Straight & Staggered corridors

- In Taj Mahal Hotel, Corridors are long, narrow & straight having cut out in the centre. It allows the view of people going in & out of the rooms. The Straight corridor permitted terrorist to see along the way & killing anyone who came in their way. The solution to this is to have staggered corridors. Staggered street or corridor pattern assist in slowing down movement. It limits visual access to places ahead. Thus the sequences of events are hidden from the person who takes the route. Thus, an outsider is completely unprepared for what's ahead because of the lack of co-ordination between visibility & accessibility.
- The structural elements must not be left exposed adjacent the areas that add vulnerability to the building.
- Plinth level of the building should be placed at least 1.2m above ground to prevent vehicles from ramming in as the fender of the vehicle is usually 0.6-0.9m.

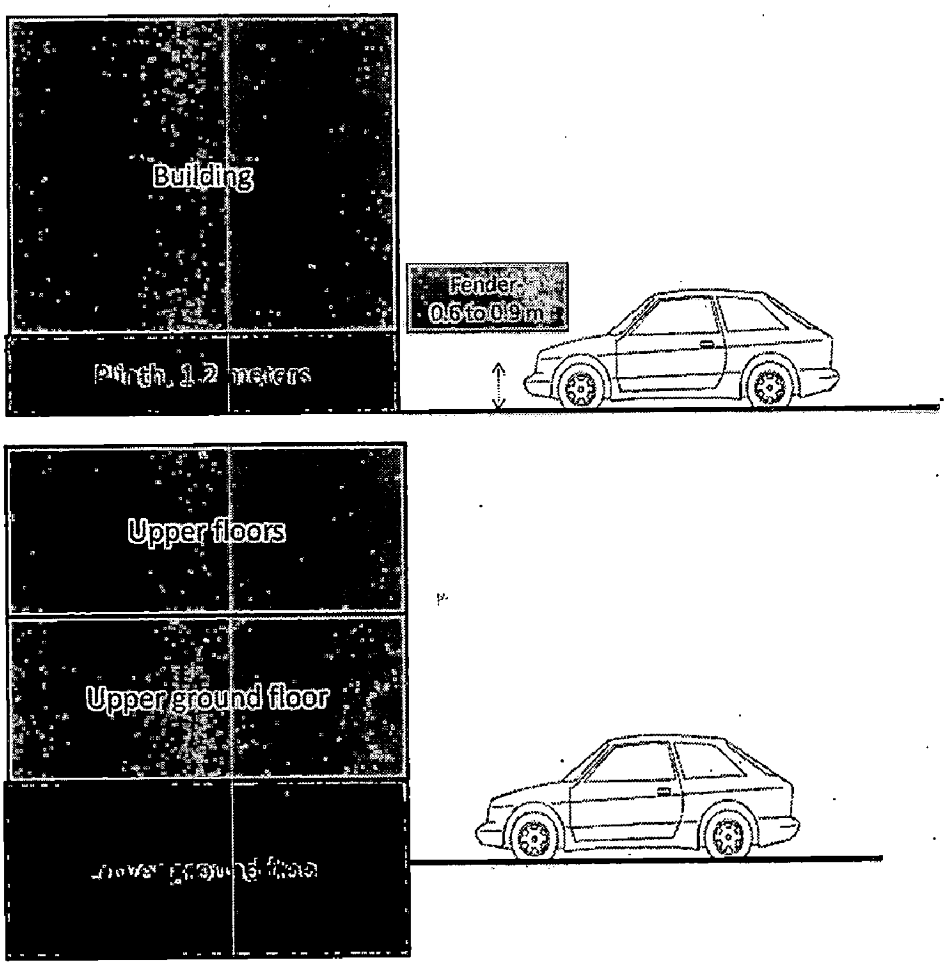


Figure 91: Plinth level of the building should be placed at least 1.2m above the ground. This raised platform can also be achieved by providing activities in lower ground floor or basement.

- Emergency services (e.g., elevators, water sprinklers and power generators) must be placed away from the areas that add vulnerability (loading docks, internal parking areas and other high-risk areas).
- When it is not feasible to segregate spaces that add vulnerability and those that require to be secured, make use of reinforced concrete walls in between these areas.
- Elevator shafts turn into chimneys, spreading heat and smoke from the blast in the basement parking to all floor levels of the building in 1993 WTC terrorist attack. This resulted in smoke inhalation injuries due to delayed evacuation.
- Offices must face internal sites or courtyards because these are regarded high risk buildings & more liable to be targeted by attackers. These must be located away from an uncontrolled public area such as a road.
- Loading docks should be placed such that vehicles are not permitted under the building. The loading area must be hardened for explosion if it is provided under the building.

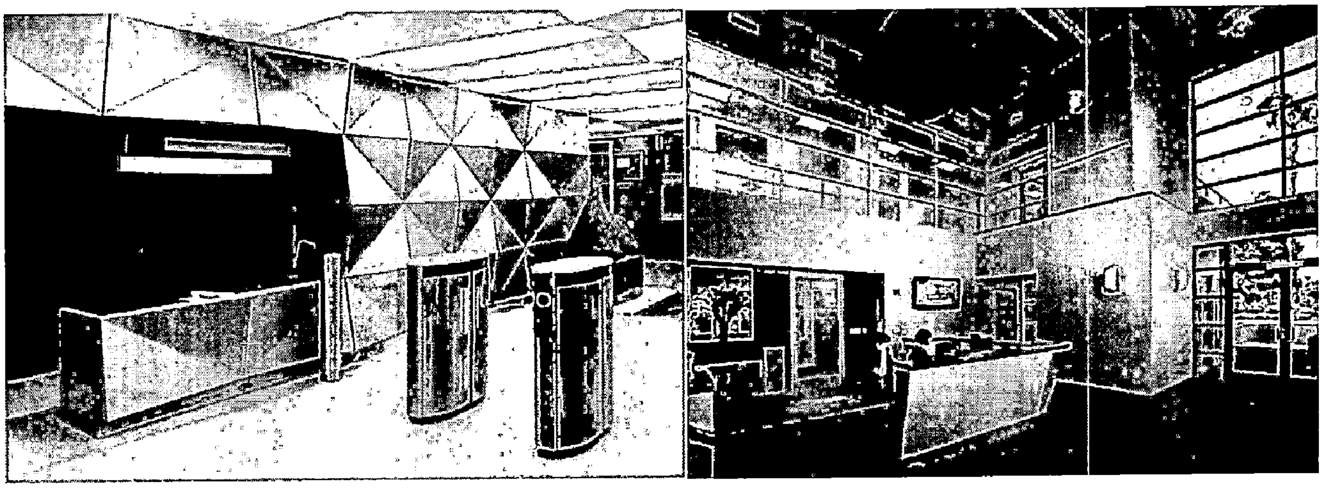


Figure 92: Receptionist in the lobby to screen visitors and employees.

- A reception desk at lobby set up the layering of public versus private entry into the building that checks visitors and outsiders. It must be placed to view all entries and elevators if given.
- Buildings must be oriented to permit views into the site.
- Most buildings directly adjoin public streets and do not have any site perimeter. Security at the main entrances and loading docks are the primary security control points for this building type.
- Replace the garbage cans to transparent or screen materials to decrease the chance for introducing explosives close to the building.

- The office building should have a protected rooftop. Numerous office buildings have chillers, communications towers, elevator equipment, air conditioning units, vents, and other facilities situated on the roof. These critical infrastructures required to be protected from unauthorized access

5.4 BUILDING ENVELOPE

The building envelope system should be such that it opposes the direct shock waves and reflections which take place within a matter of milliseconds.

The **structural system and building exterior façade must be hardened** to withstand the terrorist attacks outside the building, if adequate stand-off distances are not available.

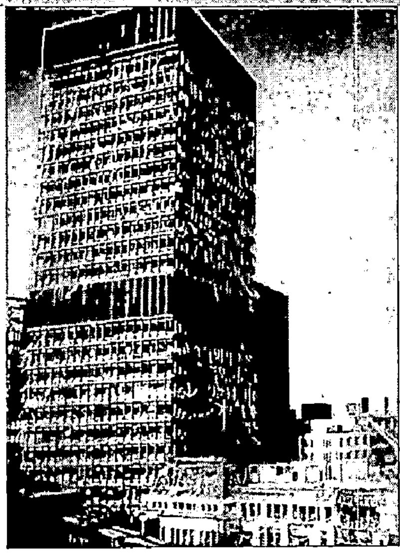


Figure 93: Blast damaged façade

5.4.1 BUILDING EXTERIOR

The building envelope is the component of the building proximate to the bomb or weapon. Thus, it is most susceptible to an exterior blast.

Usually, simple geometries, with nominal ornamentation are recommended because heavy ornamentation on the exterior façade can get turned into flying debris during a blast. Ornamentation should be of lightweight material such as timber or plastic in contrast to other commonly used building materials (e.g., brick, stone, or metal) if provided.

Earth-sheltered buildings & Walls with soil cover act excellent under blast loading because soil is extremely efficient in dropping the impact of blast. Parking must not be allowed on top of the earth sheltered building.

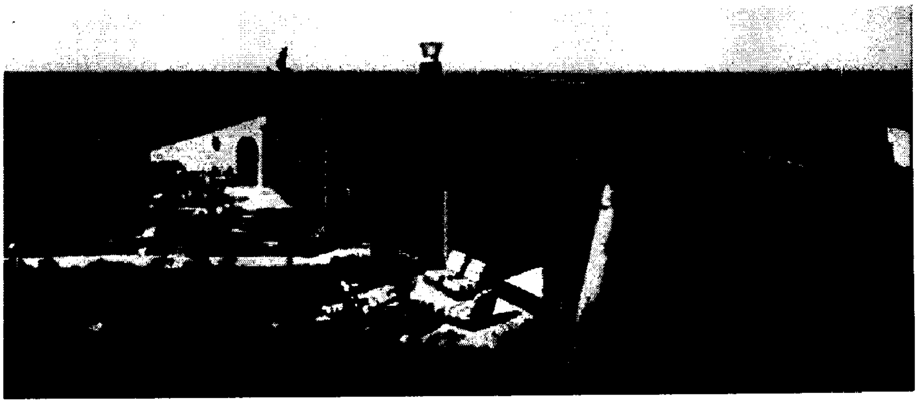


Figure 94: Earth Sheltered structures are highly effective in reducing the impact of explosions

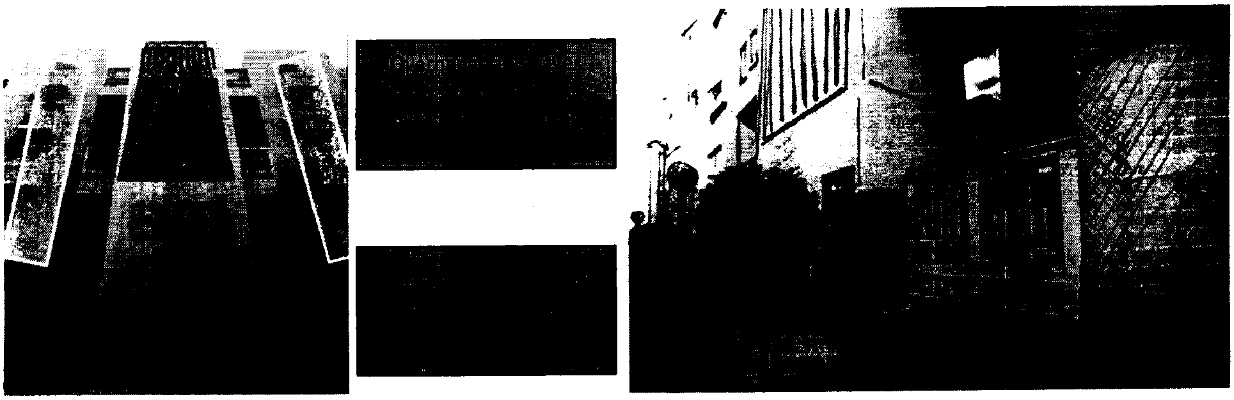


Figure 95: Screens provide privacy for the households while allowing visibility of outdoor areas.

- Overhangs and eaves attract high overpressures during blasts; therefore, such features must be avoided. But, when they cannot be avoided, they must be designed to resist the blast effects.

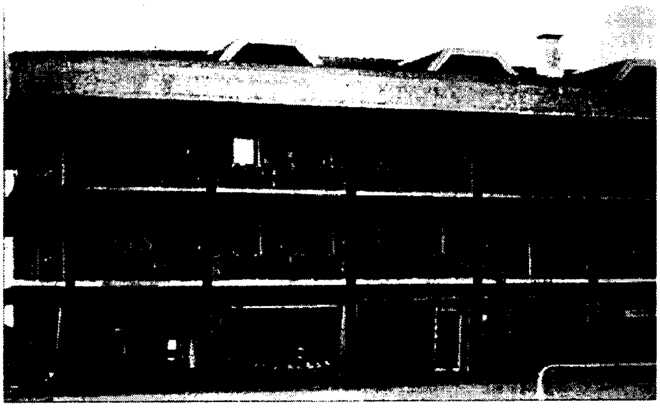


Figure 96: Vertical load carrying elements of the building, like columns and structural walls, should not be exposed on the exterior façade.

- Vertical load carrying members of the building (columns and structural walls) should not be exposed on the exterior façade
- Structural walls with blast resistance must be provided on the vulnerable façade(s) of the building. Masonry walls on the vulnerable façade should be prohibited which produce flying debris.

5.4.2 EXTERIOR WALL DESIGN

The first line of protection is provided by the exterior walls which withstand air-blast overpressures.

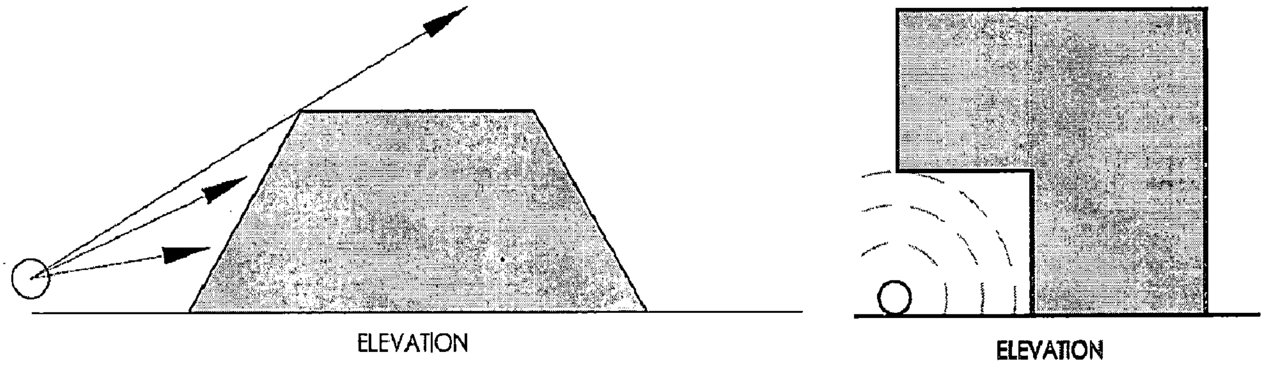


Figure 97: first elevation dissipates while second one accentuates air blast.

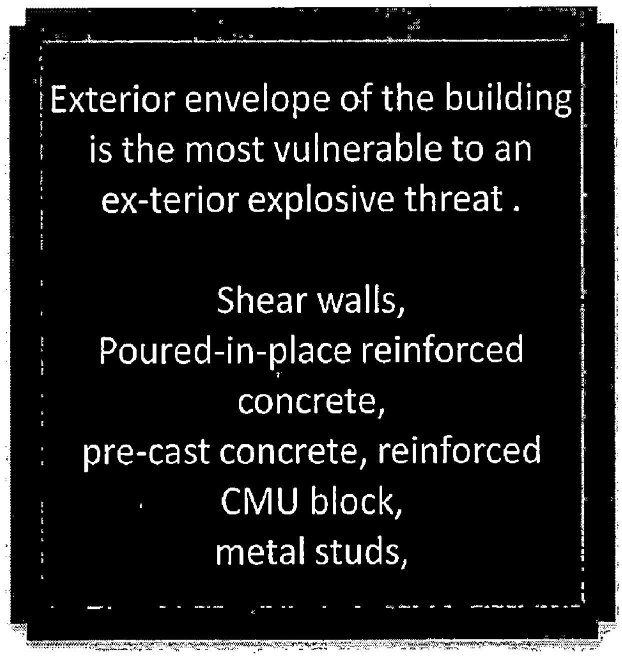


Figure 98: Exterior envelope must be hardened as it is most susceptible to an exterior explosive threat.

Poured-in-place reinforced concrete, reinforced CMU block, pre-cast concrete and metal studs offer the maximum level of protection. Shear walls can also be used on exterior walls. Reinforced wall panels can also be used as these will support in taking the load of a damaged column, thus preventing progressive collapse. Curtain or Masonry walls should not be provided in a security based design as they produce flying debris in a blast event.

5.4.3 WINDOW DESIGN

To alleviate the harmful consequences of flying glass in a blast event, Windows on the exterior façade of a building must be properly designed.

- The amount of blast coming in the interior of the building is directly proportional to the window & opening area or size on the external facade. Thus, reduce the size and number of openings in a facade.
- The glazed area must be restricted to 15 % in the building exterior facades if feasible.
- Laminated glass should be preferred in place of usual glass to reduce fragmentation.
- Glazing in the building interiors must be reduced where a risk subsists.

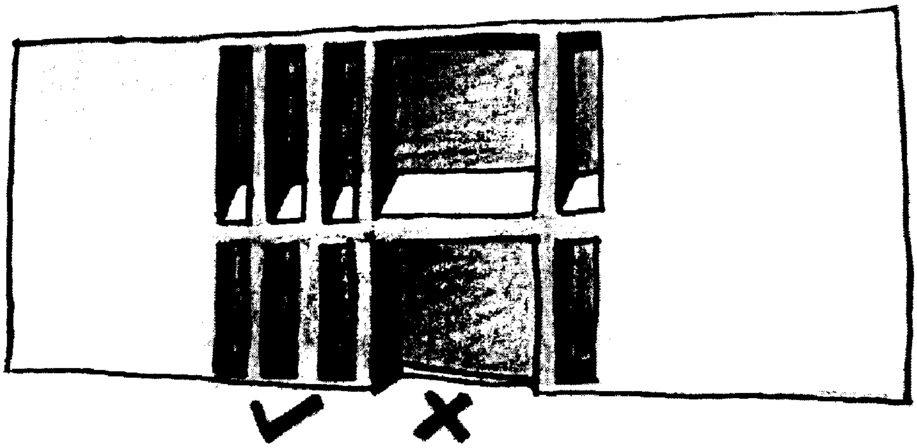


Figure 99: Narrow and recessed windows with sloped sills

- Narrow recessed windows can be considered on external facades as the amount of blast overpressure coming in the interior of the building is directly proportional to the window & opening area or size on the external façade. Sharp corners of sill intensify the blast overpressure thus sloped sills should be used.

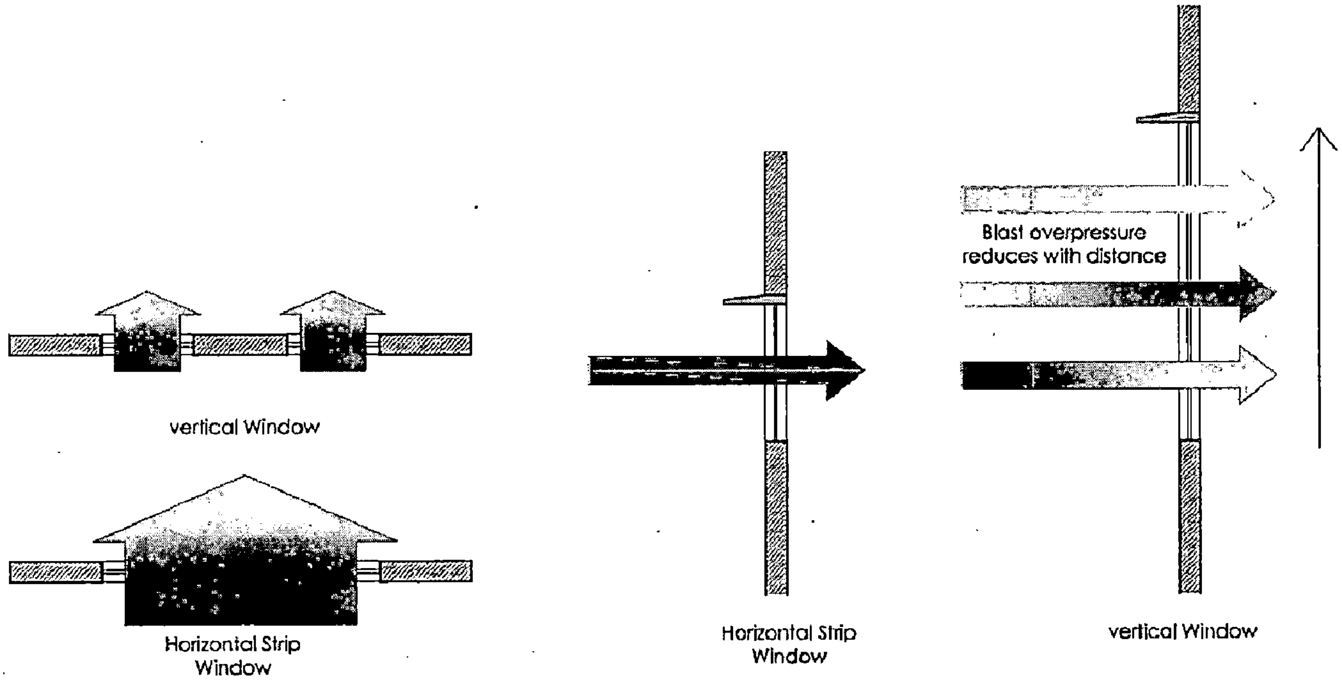


Figure 100: Comparison of Horizontal & Vertical windows

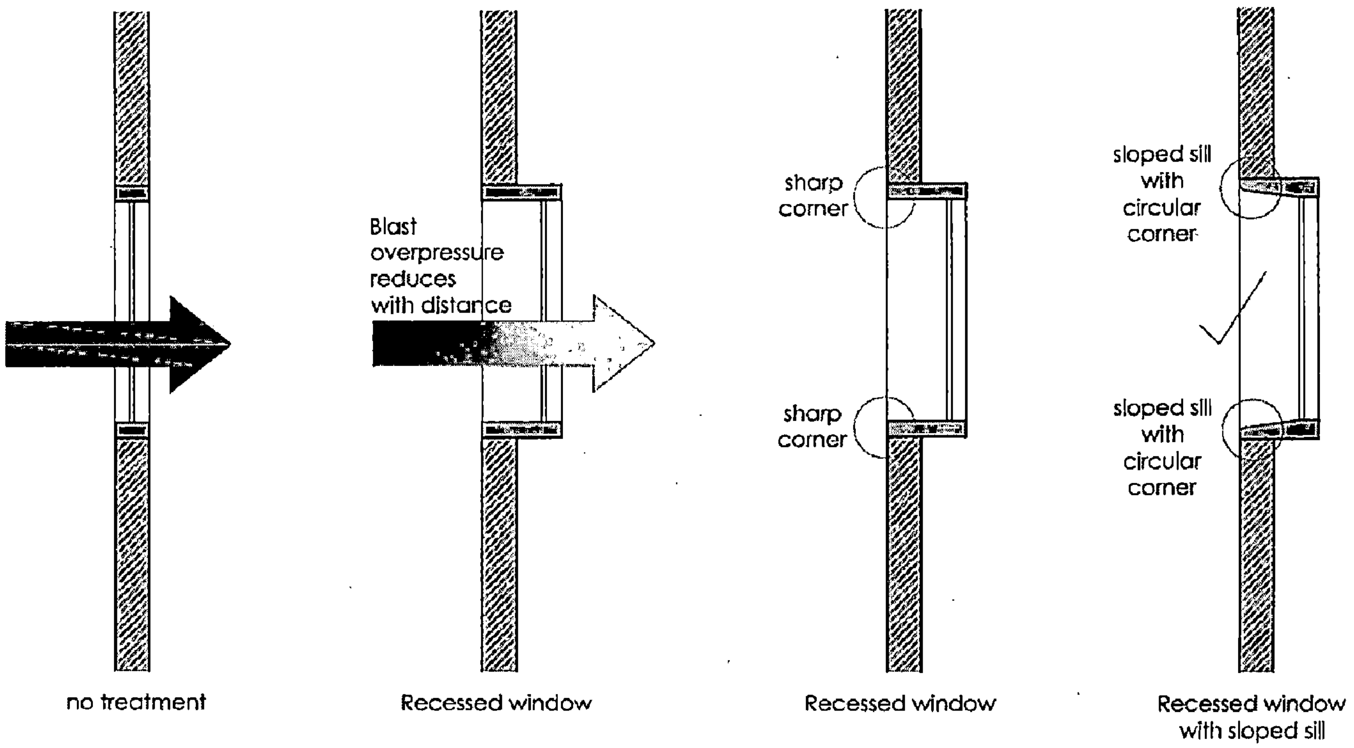


Figure 101: advantage of recessed window

5.4.4 ROOF DESIGN

- External explosion cause downward overpressures on roofs. When this blast overpressure goes into the building through the openings (door & windows), upward pressure is also caused. Thus, the solution is to have a sacrificial sloping or pitched roof on buildings with a confined ceiling. Sloping or pitched roofs deflect explosives thrown at the buildings as well as trim down the effects of blast overpressures.

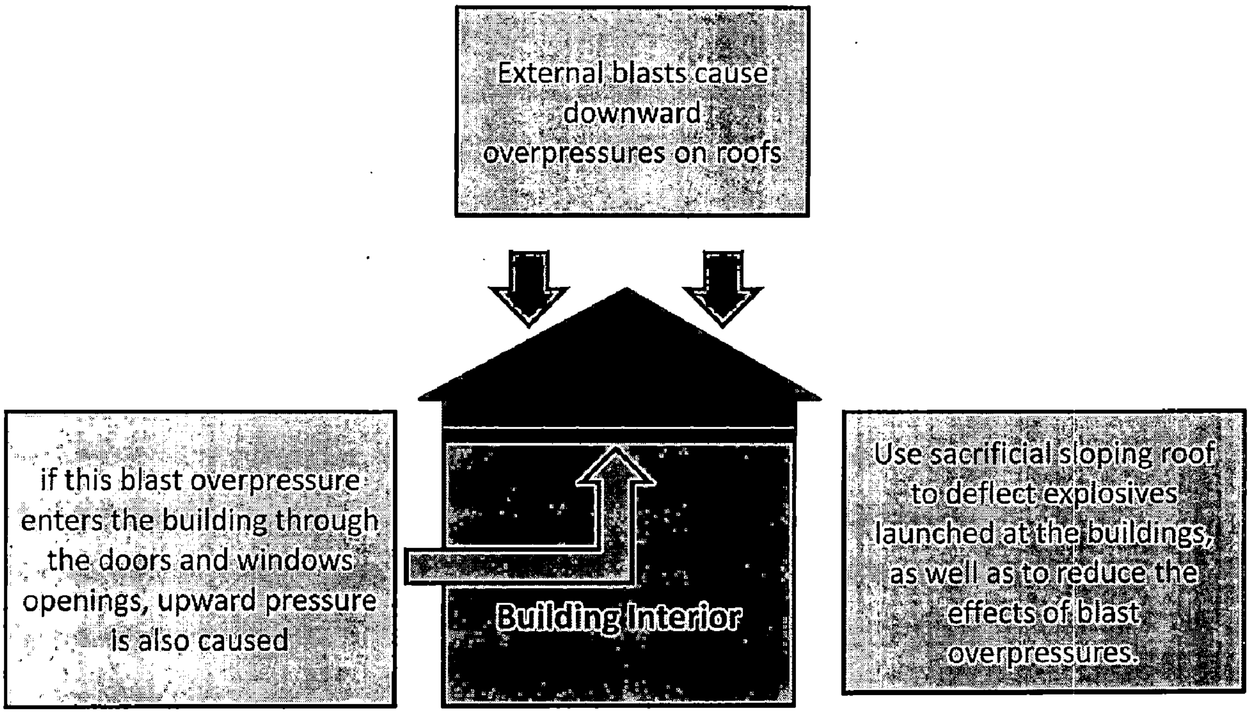


Figure 102: Use sacrificial roof to reduce the effects of blast overpressures

- Entrance to roofs should be restricted to minimize damage in the form of planting explosives or CBR agents. Entry to roofs should only be from internal staircases.

5.5 UTILITIES

Utilities are necessary services that are requisite to be serviceable even after a terrorist attack on the building. Critical services of a building must be placed away from people access places, like roads on which vehicles ply, parking lots, main entrance, and maintenance areas. If not, the structure accommodating these services require to be suitably hardened. Such critical services are:

- Stair cases and other cores passing utilities (e.g., power, water, gas and telephone lines) from one floor to another
- Lifts, their control rooms and machinery
- Back-up power generator
- Central air conditioning systems
- Fire hydrants, fire sprinkler service system and water supply units
- Any fuel storages
- Telephone exchange and distribution system
- Control rooms of centrally controlled buildings
- UPS systems supporting critical and essential services
- Main electrical power feeders line to the building and to the emergency backup power generator

The following measures help minimize the possibility of such hazards:

- The critical services should be concealed, buried underground or properly encased to guard from effects of blasts and other damage possibilities. Such concealments within a building must not be made along perimeter wall of the building. Also, unauthorized admission to these must be prevented with sufficient security measures.
- There should be redundancy in the critical services predominantly in those associated to electricity, life safety, security and post-event emergencies to reduce the likelihood of all utilities being badly damaged by a single terrorist attack. These should not be provided in the same chases.
- A potential threat to HVAC System is the air intake facility (AHU). Elevated air intake units prevent chances of injecting CBR agents by passersby. These units should be constructed flush inside the building wall and provided with screens so that no one can throw any injection into the system.
- It is preferable to have the HVAC system of the whole building to be divided into sub-units covering individual zones.
- Garbage disposal units must be placed as far as possible from the building with at least 10m stand-off distance.

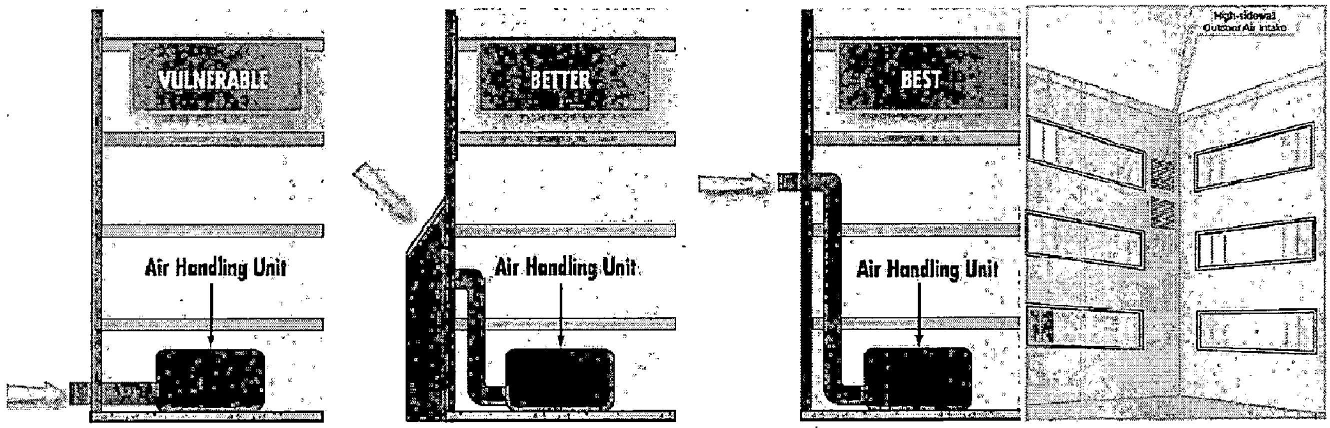


Figure 103: Air intake systems require to be secured by uplifting them from the ground level. (FEMA 426, 2003)

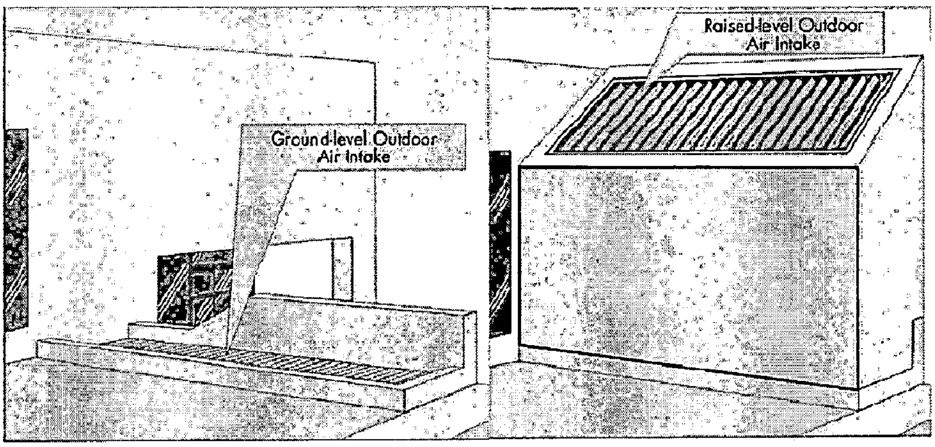


Figure 104: Covers for air intake systems: (a) horizontal covers are not good, and (b) inclined covers are good window (FEMA 426, 2003)

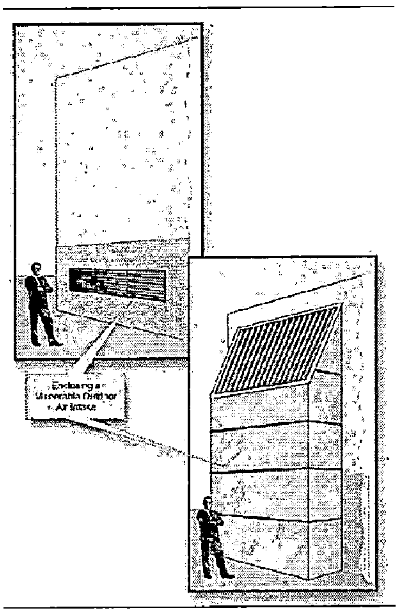


Figure 105: Retrofitting of existing low-level air intake units to prevent injection by passers-by. (Source: FEMA 426, 2003)

5.6 ACCESS CONTROL AND SECURITY SYSTEMS

The area around a building should be divided into zones of different levels of defense, with the building having maximum security. This is attained with physical barriers along with access control measures.

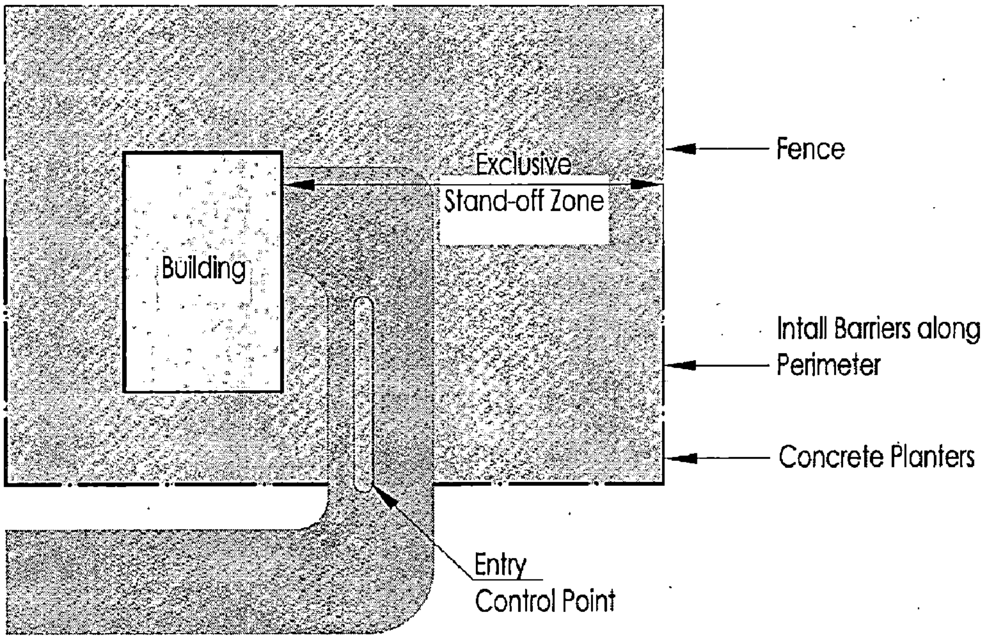


Figure 106: Partial barricading with passive barriers to cover threats in a limited way

Access control is a system which allows an authority to direct access to areas and resources in a given physical facility. Thus access control and security systems can be divided into two classes:

- Physical Access Control
- Electronic Access Control

5.6.1 PHYSICAL ACCESS CONTROL

This is used to enhance perimeter security & provide buffer zone between street, driveways and buildings.

- Perimeter fencing is to slow down the intruder by adding a layer of defense to deter entry & to control vehicular and pedestrian access to the property.
- Natural barriers are Rivers, Thick brush, Mountains, Ravines, and Canyons etc.

- Man-made barriers are Decorative planters, Bollards, K-rail, Welded steel guard rails, Vehicle arrest barriers, Berms / Ditches, Chain link, Concrete walls, Barbed wire, etc.

Figure 107: Physical access control

5.6.2 ELECTRONIC ACCESS CONTROL

- Electronic access control systems minimizes introduction of harmful material, devices and compounds to the site or building.

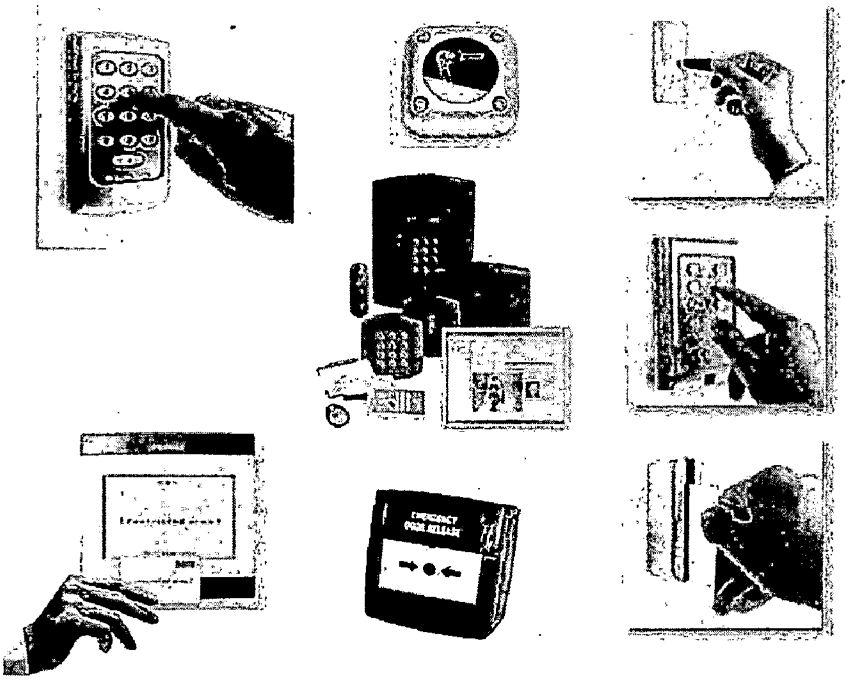


Figure 108: Electronic access control

- The major types of electronic access control systems are:
  - Biometric systems
  - Combination systems
  - Access control system cards
- A holding area for unauthorized vehicles must be provided. A turnaround space must be given so that traffic is not hindered.
- Entry-control stations must be placed close to the perimeter entry point to allow inhabitants inside to keep steady supervision over the entry points and its approaches.
- Entry-control stations must be hardened against attacks. The material for hardening may consist of:
  - Reinforced concrete
  - Bullet-resistant glass
  - Steel plating
  - Bullet-resistant building components which are commercially fabricated.

5.7 CONCLUSION

Terrorist attack on a public building can be deterred by an appropriate design considering following design parameters:

- Site planning
- Building configuration
- Functional planning
- Building envelope
- Location of utilities
- Access control & security system

People live, work & take leisure in environment. Terrorist attack occurs in all environments & is committed by people not buildings or any other component of the environment. The environment is created by the architecture. Finally, the appropriate design & effective use of the built environment can direct to a reduction in the probability of occurrence of terrorist attacks and provides psychological & security in public buildings.

Most important architectural measures to mitigate damage by terrorism are:

- Building should be located as far as practical from the protected perimeter.
- Perimeter should be protected against vehicular invasion by incorporating barrier or landscaping.
- Locate unsecured areas along the exterior of the main structure or outside the footprint of the building.
- Susceptible areas such as the delivery & entry areas should be physically segregated from the rest of the building.
- Lightweight non-structural components or elements must be employed in the building interior and exterior.
- Employ measures to defy progressive collapse.
- Air intake units of AHU should be kept above the ground level as far as practical.
- Segregated redundant electrical & mechanical control systems should be used.

CHAPTER 6. IHC, NEW DELHI- TERROR VULNERABILITY ASSESSMENT

Due to increase in the terrorist attacks on public buildings, there is a need of making the building & it's surrounding/ premise a safer place. India Habitat Center, New Delhi is one of the iconic public buildings in New Delhi which is densely populated. This building not only houses research organizations and offices but also a comprehensive convention centre, club as well as performance venues for cultural activities and numerous restaurants. This iconic building can be a target by the terrorists to create terror among the people in the city. Thus, India Habitat Center, New Delhi has been assessed with respect to Architectural Measures to mitigate damage discussed in earlier chapter (Chapter no.5).

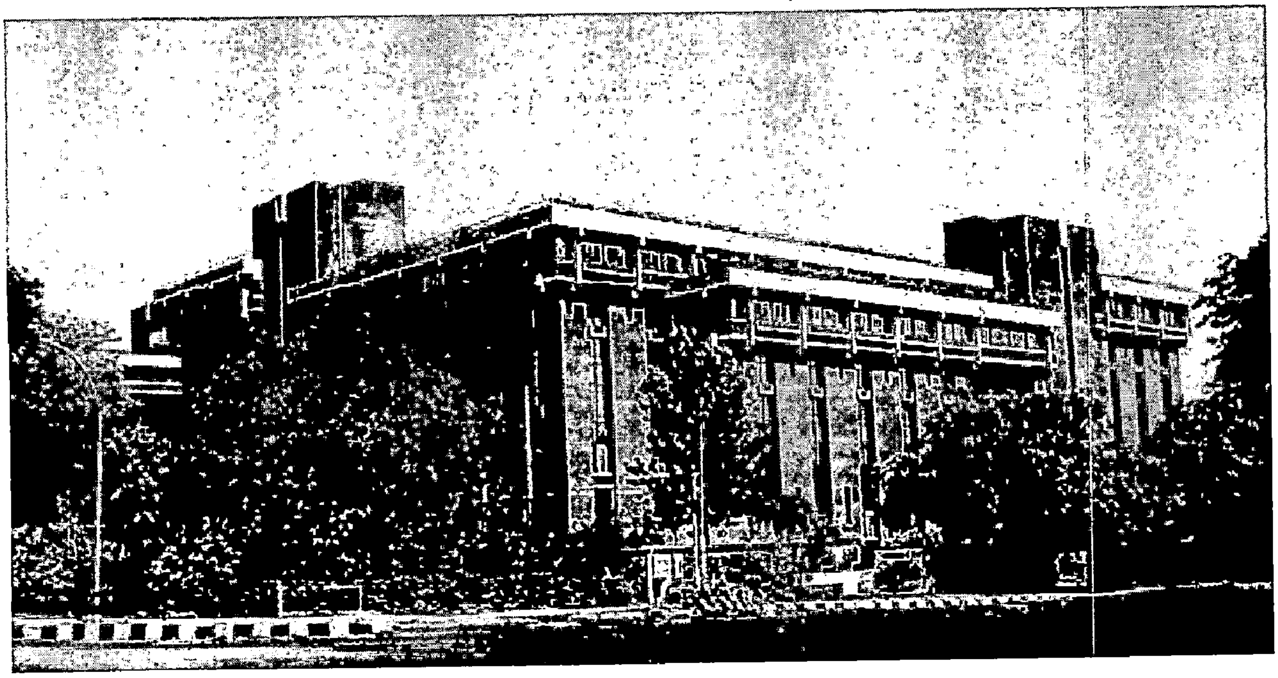


Figure 109: INDIA HABITAT CENTRE, New Delhi

The India Habitat Centre is planned as an assemblage of institutions dealing with a wide variety of issues related to habitat and also to house a variety of functions to stimulate and facilitate many levels of interaction. This building is designed by Architect Joseph Allen Stein. The 9.6 acre site of Lodhi Road was actually a collection of plots owned by various institutions like H.U.D.C.O., TERI, and the Delhi Urban Arts Commission. It is home to about 30-40 institutions in the field of shelter and a unique experiment in generating a building type responsive to the constraints imposed by the city. The various institutions are grouped into a condominium system of cooperatively built space.

6.1 PROJECT DETAILS

Cost of the project	: Rs. 100 crores.
Year of Completion	: 2006
Architect's Name	: J.A. Stein, B.V.Doshi and Bhalla.
Client	: India Habitat Centre
Building Type	: Institutional
Climate	: Composite
Plot Area	: 9.6 acre or 53,241.63 sq.m
Total Built Up Area	: 9609 sq.m

6.2 LOCATION

The India Habitat Centre (IHC) is sited in New Delhi. It is placed off the Lodhi Road on the fringes of Lutyen's Delhi. It is an L-shaped plot having frontages on the three sides. It is bounded by the Max Muller Marg on west, the Vardhman Marg on the south and the Lodhi road on the north. The fourth side is flanked by the Bal Bharthi School.

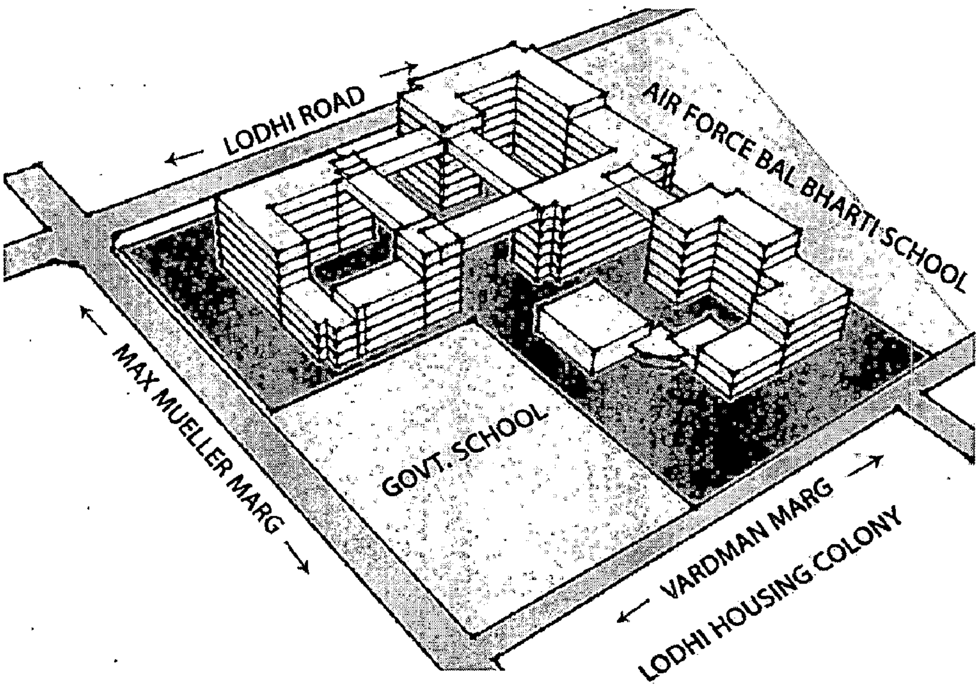
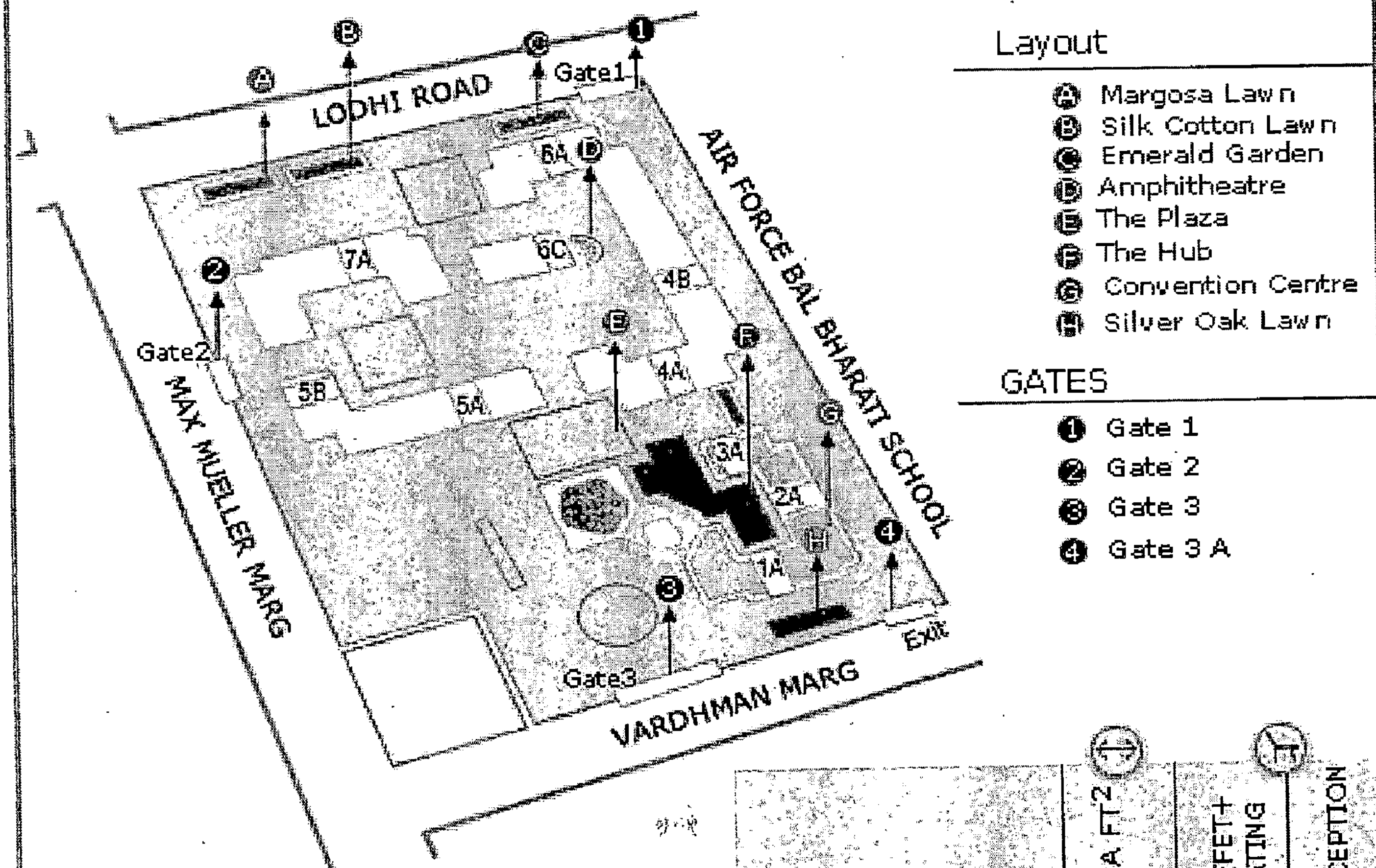


Figure 110: Land use adjacent to IHC building

6.3 ACCESS

The complex has an access from three sides having the lodhi Road on the north, Max Muller Marg towards the west and Vardhaman Marg on the southern side. Thus, it has three main gates, referred to as gate no.1, gate no.2, and gate no.3.



Gate 1	Gate 2	Gate 3
Use Core 4 B from basement parking for :	Use Core 5A/5B/7A from basement parking for :	Use Core 4 A from basement parking for :
▪Eatopia ▪Rooms Block ▪Restaurants ▪Fitness Centre ▪Amphitheatre	▪Visual Arts Gallery ▪Emerald Garden ▪Silk Cotton Lawn ▪Margosa Lawn	▪Convention centre ▪Cultural Venues ▪Remaining Outdoor Areas

	AREA FT2	BUFFET+ SEATING	RECEPTION
Amphitheatre	2650		500
Margosa Lawn	9240	160	450
Silk Cotton Lawn	4000	85	250
The Hub/The Plaza	34460	700	2500
Delhi 'O' Delhi Terrace	3500	56	150
Lite House Terrace	2300	40	100
Silver Oak Lawn	6000	96	250

Figure 111: View of the site showing the different access points. (Source: www.indiahabitat.org)

Gate no.1 directs the vehicles to the surface parking & double level basement parking. This parking basically caters to the public areas like the conference hall, Restaurants, fitness centre, Amphitheatre, etc.

Gate no.2 on the Max Muller Marg is the one, which directly leads to the double level basement. The lifts & stairs then take to the upper levels from this point. The basement parking has been provided for both employees & visitors.

Gate no.3 allows entry to VIPs. It also leads to the double level basement parking. Vehicles are checked on the gates with the help of checking mirror.

6.4 SPATIAL ORGANISATION

- The site is somewhat an L-shaped one which is accessible from the three roads on its three sides while its fourth side is being flanked by Bal Bharti Air Force School.
- The IHC utilizes only 1.4 of the 2.5 FAR permitted at the time of construction.
- The ground was perceived as a vehicle-free environment, and fairly elaborate system worked out to deny entrance to all motorized traffic except for repair and fire.
- All cars and scooters are directed into two levels of basements.
- The conference block is the only one that allows entry to vehicles, though even here they can only pause and have to park elsewhere.
- The complex is however, accessed from all sides, the major pedestrian entrance being from lodhi Road on the north.
- Building volumes are articulated to form interconnected internal courtyards that are the major public spaces.
- The habitat centre is organized as a series of four to seven storey blocks around linked shaded courtyards. The built forms are grouped around courts & shaded by overhead sunscreens.
- The complex has a very well planned segregation of space:
    1. All blocks/ areas, which are expected to experience a large and regular inflow of public have been placed very close to the entrances;
    2. The office areas being given the access from the inside of the courtyards.
    3. Although the public and the semi-public areas have been placed in separate built blocks, the courts and the landscaped areas form a very good connection between the two.

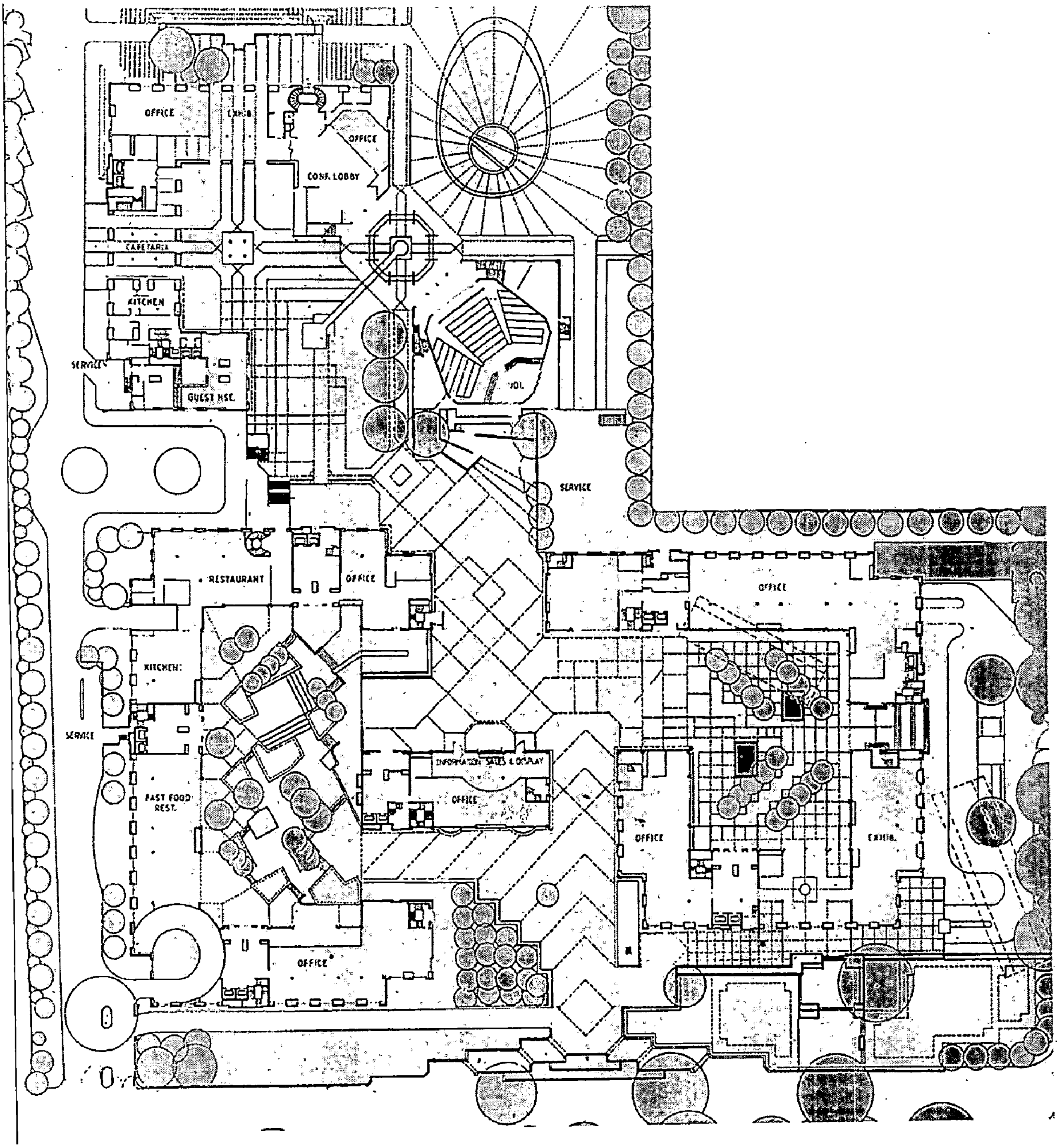


Figure 112: Ground Floor Plan

Figure 113: shaded courtyard

- The landscaping here is integral to the design. Palm trees have been planted to create a refreshing environment inside.

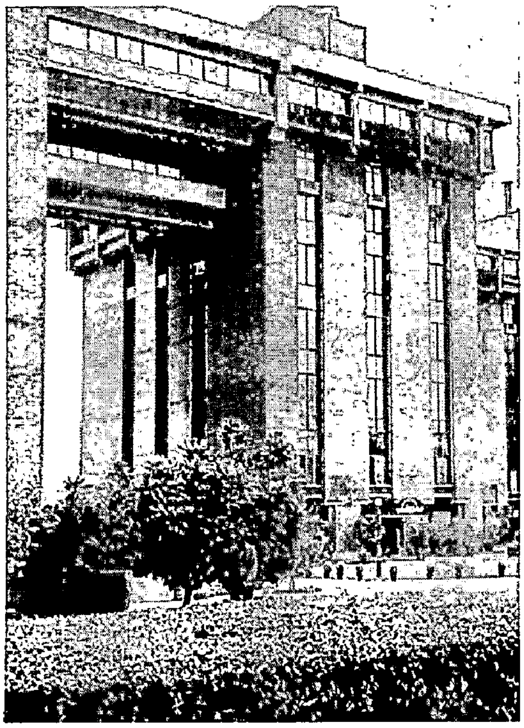


Figure 114: Planters used in the façade

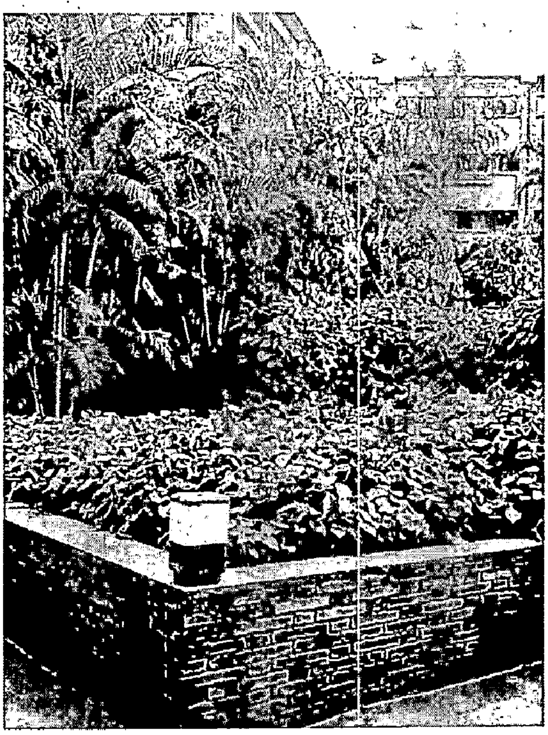


Figure 115: Palm trees

- Each internal courtyard has been designed to impart a distinct to the spaces and is conducive to the type of functions or activities that can be anticipated. This has been achieved by paving patterns in different materials, the use of water, a play of levels and plants.

Figure 116: Stepped Planters

- The courtyards are designed as an example of medium-scale climate modification and extensively shaded by canopies suspended above the open air atrium like outdoor spaces. The pedestrian circulation in the complex is multidirectional and the entire ground floor is pedestrianized reducing the hassle caused by traffic. The organization of these courts is very simple leading to smooth pedestrian circulation.

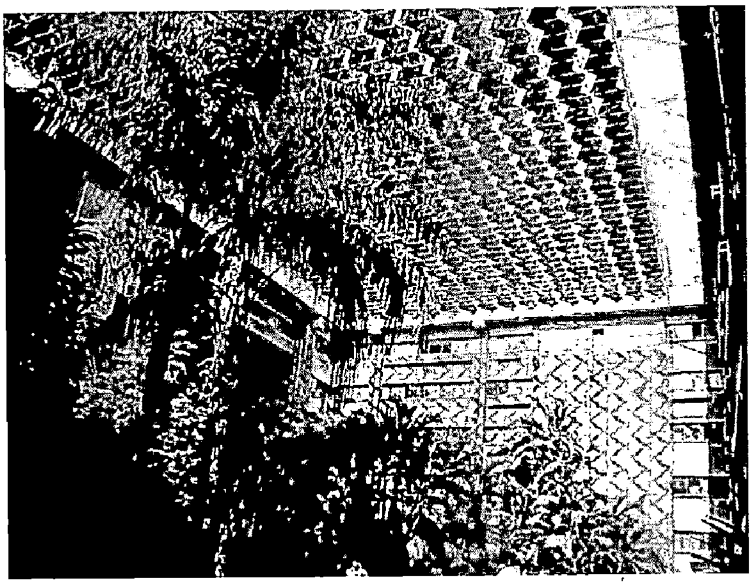


Figure 117: Internal Courtyards

- Buildings are grouped around courtyards, shaded by overhead trusses and enlivened by vertical gardens. These shading canopies over the paved courts provide relief from the tropical sun with fixed shade casting elements, devised to shade the courtyards on summer and let in the sun in winter.

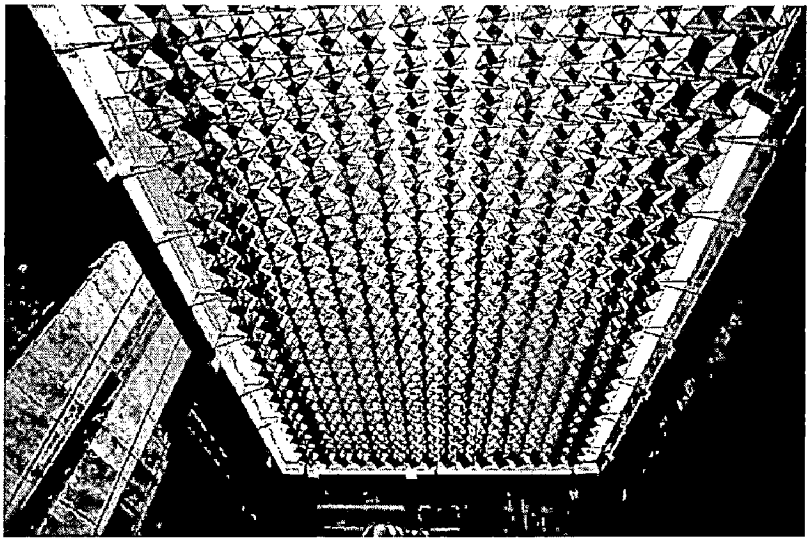


Figure 118: Flat Nylon Panels

Flat nylon panels or sun screens cover the courts and act as ceilings to these areas. They also reduce the heat gain by the buildings surrounding the courts. 1.2 m deep galvanized steel tubular framework stretches edge to edge across the courtyard and is anchored to concrete overhangs at the edges. Flat nylon panels or sun screens approximately 1.6 x 1.4m in size, are anchored at the predetermined angles within this framework to provide the shading element.

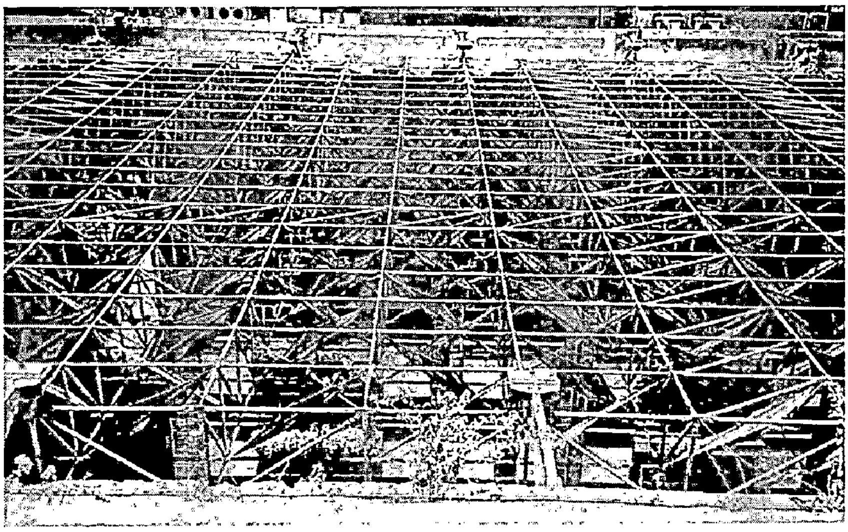


Figure 119: Framework for Shading Devices

The openings on the external façade are kept to less than 50% further reducing the heat gain. The buildings are grouped around semi covered courts and linked at the 5th and 6th floor level and above by bridges to form huge gateways for entrance into various zones/courts. These multi level bridges provide office spaces as well as links between various building zones. The bridges form framed views and vistas and complete the character of the enclosed courts.

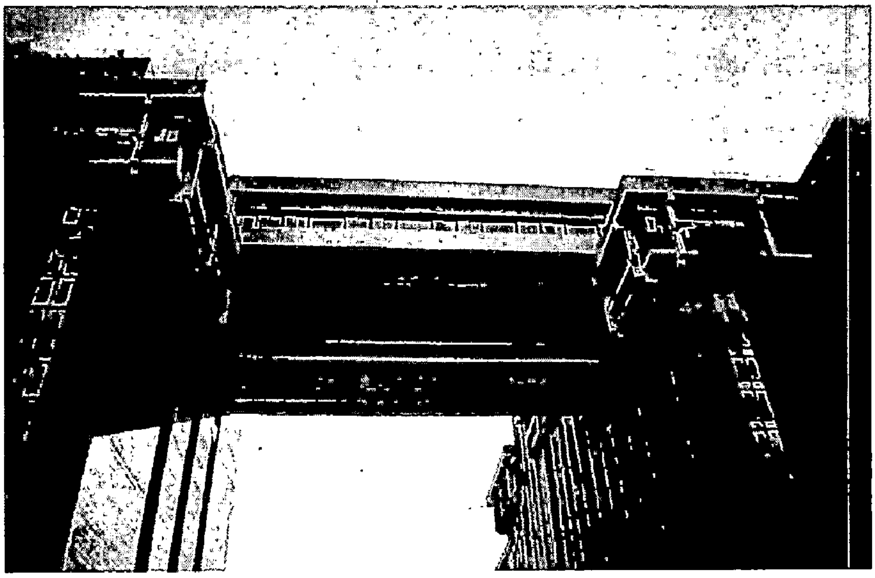


Figure 120: multi level bridges provide office spaces as well as links between various building zones

- The roof of the buildings too, is designed as a series of terraces accessible from various offices and restaurants.

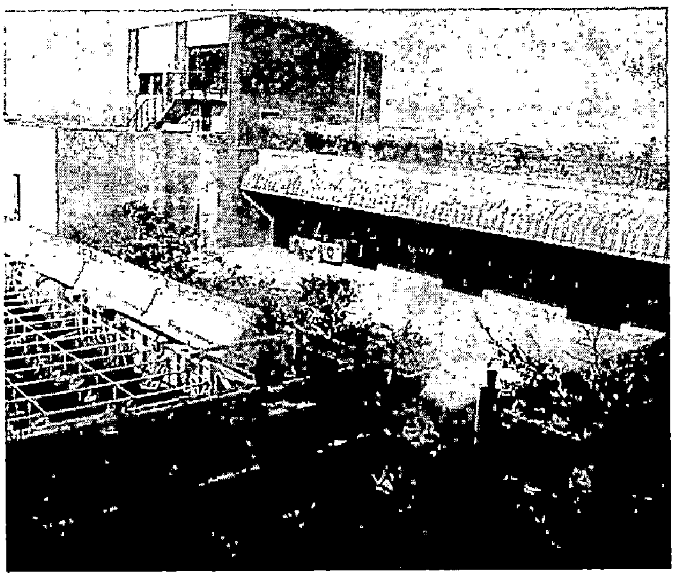


Figure 121: Roof Garden

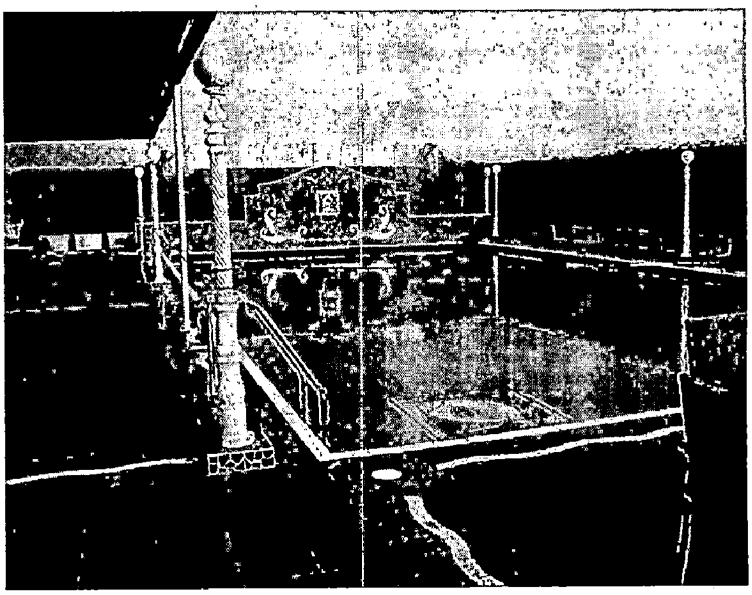


Figure 122: Roof top Pool

6.5 FUNCTIONAL ORGANIZATION OF SPACES

The organization of the built form as institutional and office spaces in a series of four to seven storey blocks around introverted, linked, shaded courtyards, protected from both the excesses of the tropical climate and motor traffic of the adjacent heavily trafficked intersection and enlivened by vertical gardens.

The distribution of various functions on the site is simple enough. There is an entry to the site from each of the three roads abutting it. The two blocks on Lodhi Road are handed over to offices on top and reserved for public facilities on ground floor. The third block, on the south, houses common facilities like a conference centre, a large auditorium, library and a guest house. Two basements housing all the parking and services extend under the entire block. Restaurants and exhibition spaces on the ground floor open out into the courts, with the court also being used for public exhibitions.

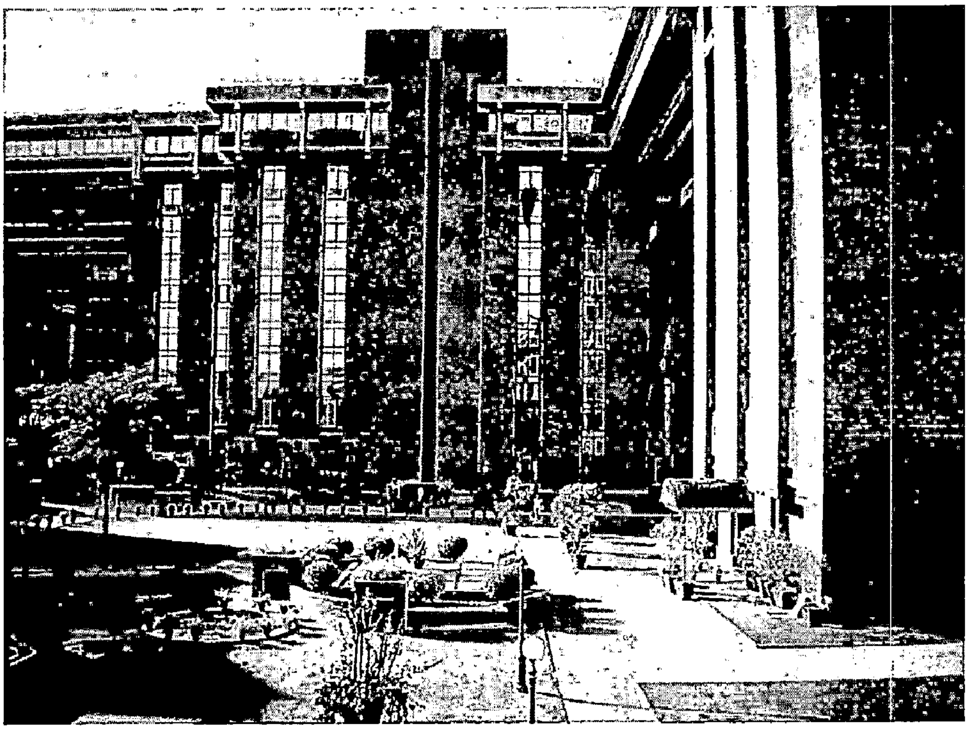


Figure 123: Restaurants and exhibition spaces on the ground floor open out into the courts, with the court also being used for public exhibitions.

The zoning of the functions has been done according to the existing buildings around the site. Hence the blocks that are adjacent to the housing area are reduced in volume to make them compatible to the existing development. The blocks have been progressively reduced in volume and the auditorium is set back substantially for the plot line to create a distinct identity.

Semi public or major office spaces are located in the blocks adjacent to the main street; the associated functions such as guest rooms, staff quarters and the auditorium are to the Lodhi colony housing.

The blocks housing the offices are articulated to form the three courts, the ground floors of which contain public functions such as exhibition spaces. The top two floors of the building have been projected twice. This results in a building shadow that is larger than its footprint. It also creates a classical order of the pediment.

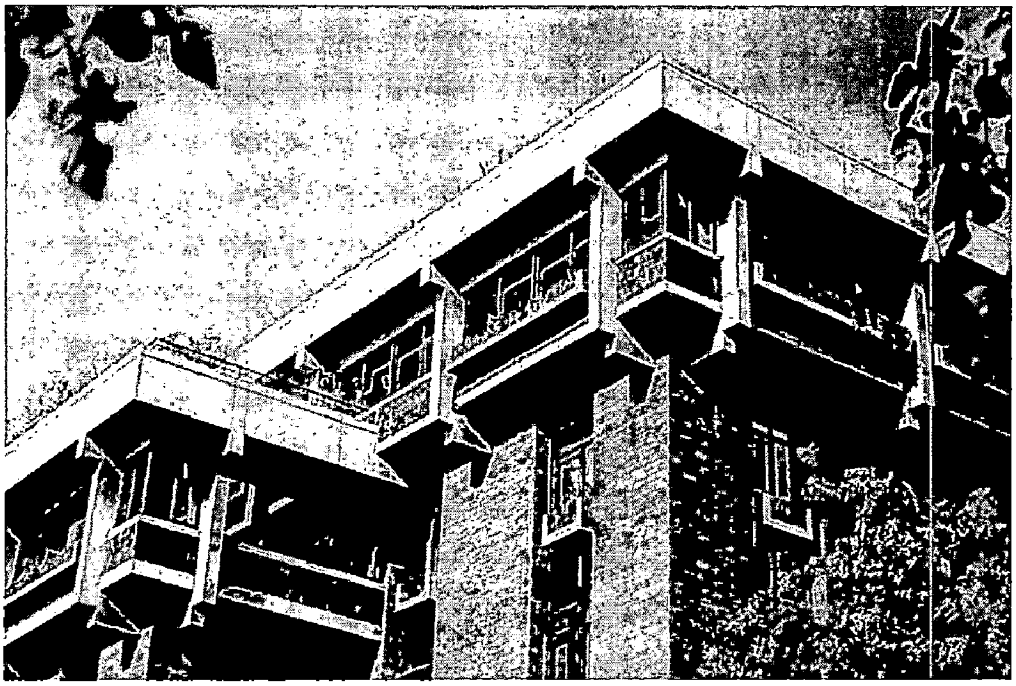


Figure 124: façade configurations with earthy clay tile cladding & exposed R.C.C in cantilevered corridors.

The façade configurations with earthy clay tile cladding & appropriate fenestrations with exposed R.C.C in cantilevered corridors have been skillfully handled to offer mutual shading to the building envelope's components cutting down the thermal effects in the building. The internal facades support light hanging planters with strip windows characterizing the façade.

The buildings themselves never dominate – they merely act as unobtrusive delineators. Service core consisting of two lifts, one staircase, electric and telephone connections (adjustable), duct and toilets for both sexes –serve the office space.

Figure 125: Dead setback

An important consequence of combining the public spaces with offices is the creation of an informal security arrangement. Also the many activity spaces ensure that the campus is alive and populated even after office hours. The edges of the site are dead setbacks with very few people using them. Even the interior plazas are utilized only as circulation spaces. The area near the cafeteria though gets active during the lunch hours.

There are two basements, each 18,000 sq.m in area, that house all the parking and the services. The first basement has only parking while the second houses parking as well as the service areas, maintenance departments etc. These basements can park around 1000 cars. Surface parking area is also provided for 60 cars. There is a separate parking area for private vehicles and chartered buses just outside the site, so that these do not disturb the complex.

The entire building is air-conditioned and the basements are mechanically ventilated. Sprinkler systems are installed in all the usable areas of the complex. The complex has its own water purification plant. Fire escape staircases and lobbies are all pressurized to prevent the spread of fire along the shafts.

The complex is planned and divided into two blocks:

- North Block
- South Block (Convention Centre)

6.5.1 NORTH BLOCK

North block is the block adjoining the Lodhi Road and on the northern side of the site. North Block is further divided into four zones- 4, 5, 6 and 7. This block primarily comprises of office places supported by different areas like exhibition, institutional offices, restaurants and service cores. The Amphitheatre is used for gathering and outdoor performances. It has an area of 300sq.ft.

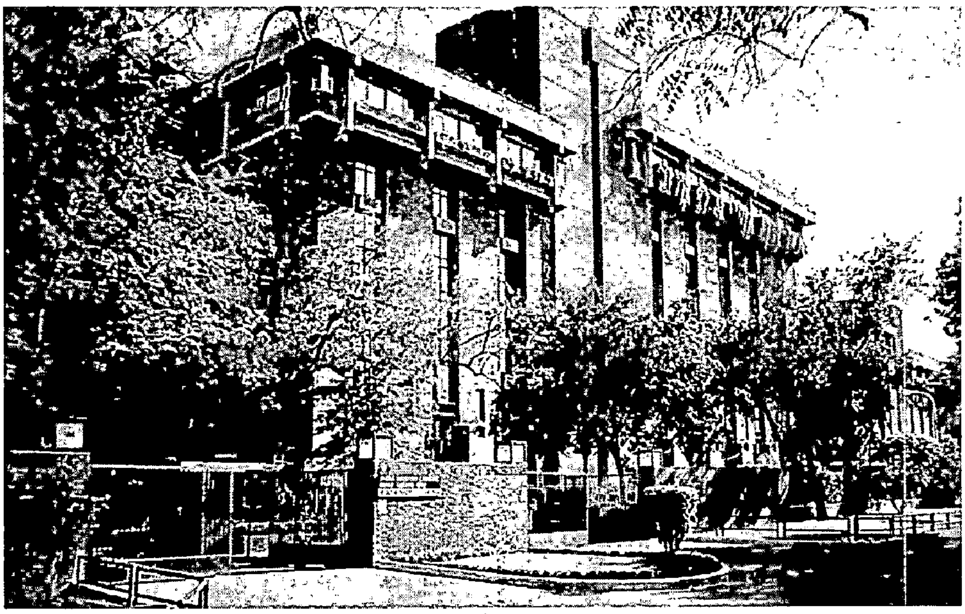


Figure 126: View of North block

6.5.2 SOUTH BLOCK

This block is further divided into 'three' zones – 1, 2 & 3. Zones 1 & 2 houses most of the ancillary facilities for the North block like residential guest rooms, conference, library, health club, swimming pool and restaurant etc. The zone 3 comprises of a 400 seats auditorium.

Figure 127: Convention centre

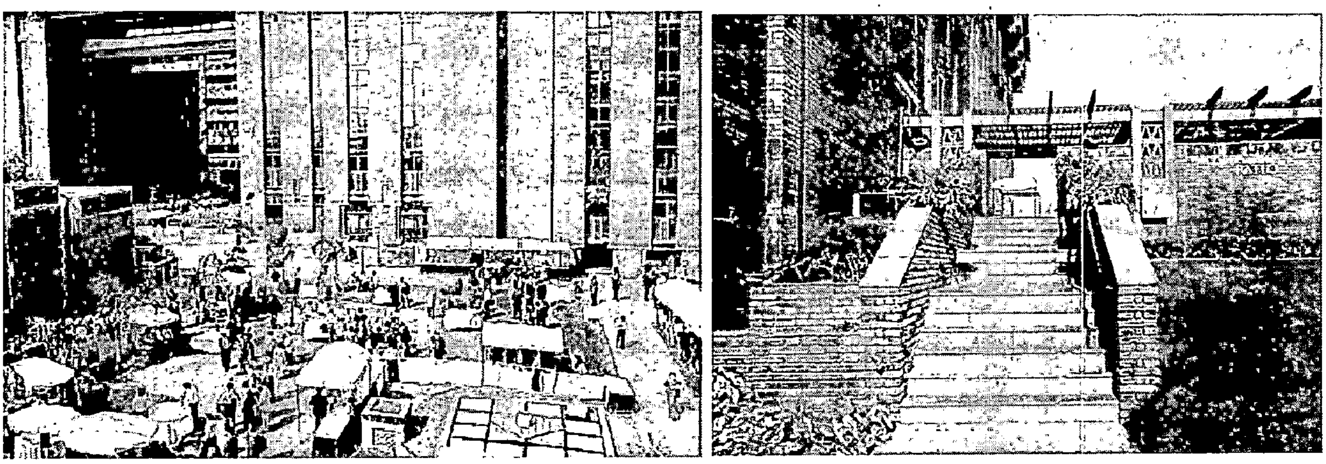


Figure 128: Courtyard & Patio as interactive spaces for outdoor seminar, Exhibitions and lunch parties.

Also the courtyards serve as active exhibition spaces, for various purposes, amongst them to acquaint the public through the medium of displays in the field of habitat. The roof of the buildings too, is designed as a series of terraces accessible from various offices and restaurants.

On the ground floor the Silver Oak patio and Silver Oak Lawn provide a buffer to the conference halls from the main road and this space can be used for outdoor seminars and lunch parties.

The interactive spaces that are the convention hall and auditorium have been placed together and also share a common lobby. They also have a separate entry from the road. The space enclosed by these two activities is the hub of the complex. It is also visually linked to the plaza.

6.6 OBSERVATIONS

6.6.1 SITE PLANNING

- The site has 3 entries. Gate no. 2 & 3 entries lead straight to the building. The vehicles are prohibited from gaining access to the Building through raised platform near Gate no.2 & through circular drive way near Gate no.3. According to mitigation measures, approach roads to the building should not be straight, to prevent the vehicles from gathering high speeds and crash into buildings. But in IHC, it is being prohibited by raised platform.

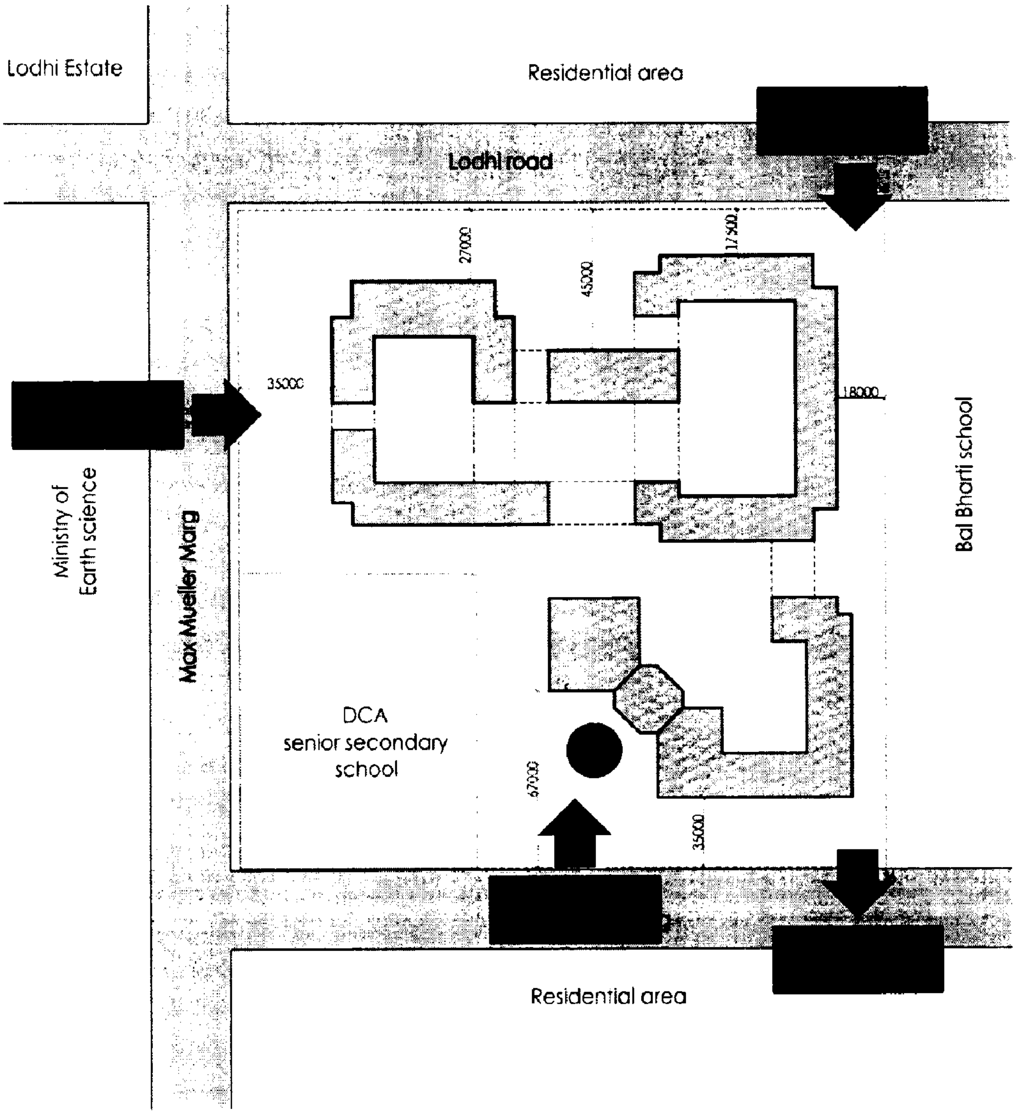


Figure 129: Site Plan: IHC, New Delhi

Figure 130: Stepped entry to raised platform

- All Entry & Exits to the basement parking are under surveillance as they are provided near the gates.

Figure 131: Way to Basement parking

- Both surface & double basement parking are provided in IHC. Gate no. 2 & 3 leads to basement parking while gate no.1 leads to both surface & basement parking. Anyone can park in the basement parking and take an elevator up to the office floor, totally circumnavigating the security function. The Stairs and elevators from the parking floor should empty to a floor level that requires exiting and then lead to another dedicated bank of elevators, stairs, or escalators that can facilitate access control and inspection by security staff if desired. They should not go directly into the business or resident floors.

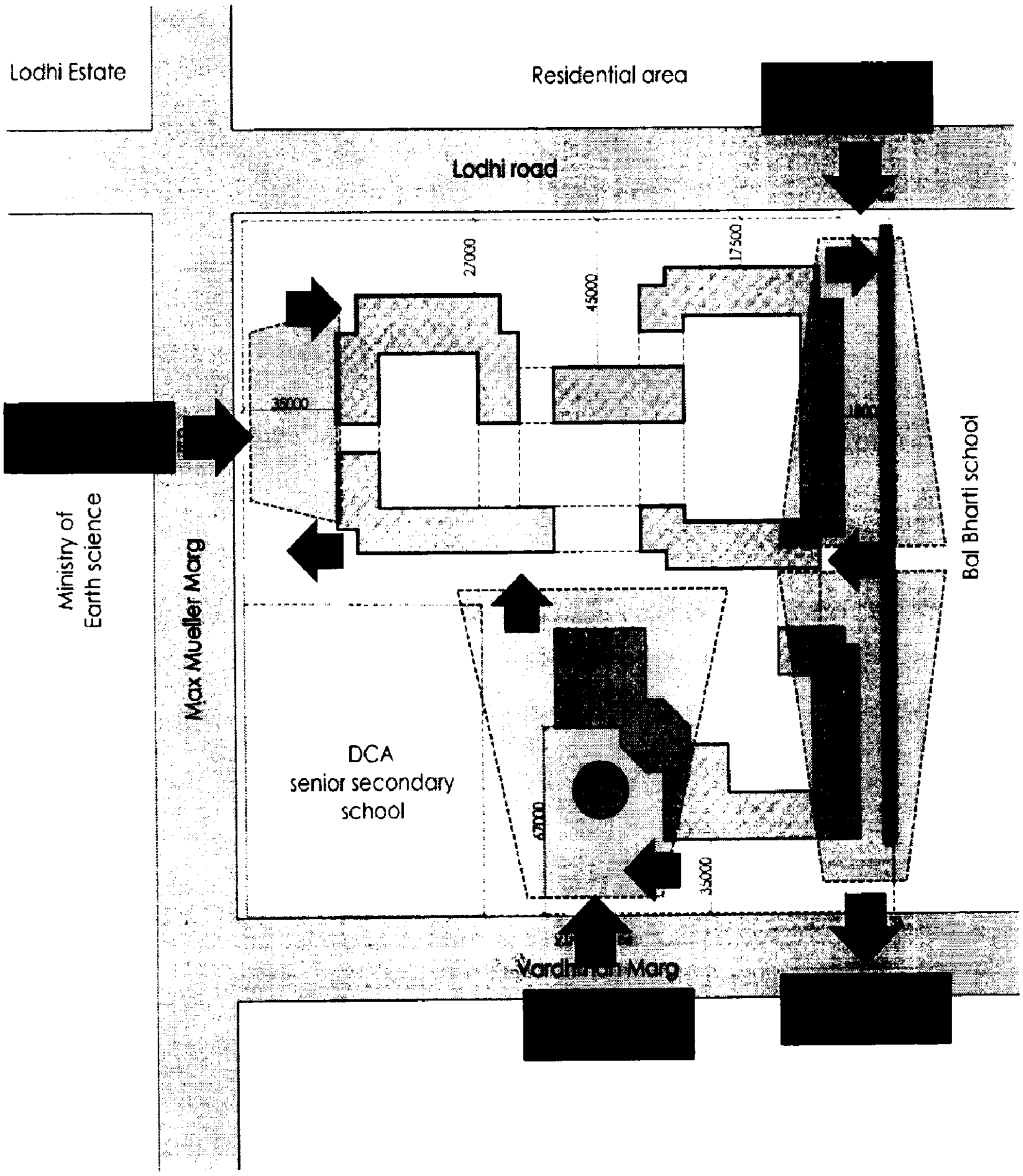


Figure 132: Surface parking, all Entry & Exits to the basement parking are under surveillance

- There are two basements provided for the parking & services. Visitors are allowed to park inside the basement. According to mitigation measures, Parking under the building should be avoided to the extent possible. If not possible access must be limited to authorized persons only. But there is not enough space available on the site to provide surface parking to the visitors. Thus, operational changes are required to restrict the basement parking areas to visitors. Parking directly below the building footprint should be accessible to authorized persons & employees while parking below courtyards can be made available to visitors.

Figure 133: Site plan of IHC, New Delhi

- Palm trees have been planted in the courtyards to create a refreshing environment inside. But this dense vegetation creates hiding places and does not allow clear sightlines. The plants do not allow people to see the other side or other people in the area. This generates place for people to hide explosives or commit crimes. According to mitigation measures, Clear sightlines must be given between 0.5m and 2m above natural terrain.

Figure 134: Dense vegetation creating hiding places & obstructing clear sight lines

- In IHC, surface parking is under surveillance. The parking is visible from the building & the gate no.1. No dense vegetation is provided in the surface parking area. Thus there is no landscape feature which creates hiding places and obstructs visibility.

Figure 135: Surface parking under surveillance

- The edges of the site are dead setbacks with very few people using them. Even the interior plazas are utilized only as circulation spaces. The area near the cafeteria though gets active during the lunch hours. Setbacks can be made active to create surveillance by putting more activities such as lunch parties & exhibitions.

Figure 136: Dead setback

- There are two basements that house all the parking and the services. The first basement has only parking while the second houses parking as well as the service areas, maintenance departments etc. All visitors are allowed to park in the basement. Thus, basement can be an easy target by a terrorist to hamper the functioning of the building. As a general rule, critical services and facilities of a building should be located well away from people access places, like main entrance, parking lots, roads on which vehicles ply and maintenance areas. Critical services should be distributed on the site rather than putting them at one place in the basement where there is less surveillance.

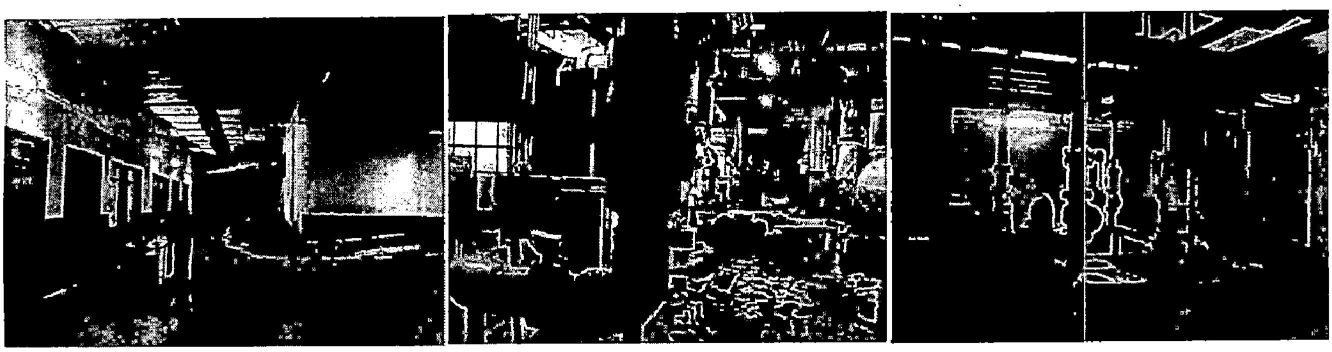
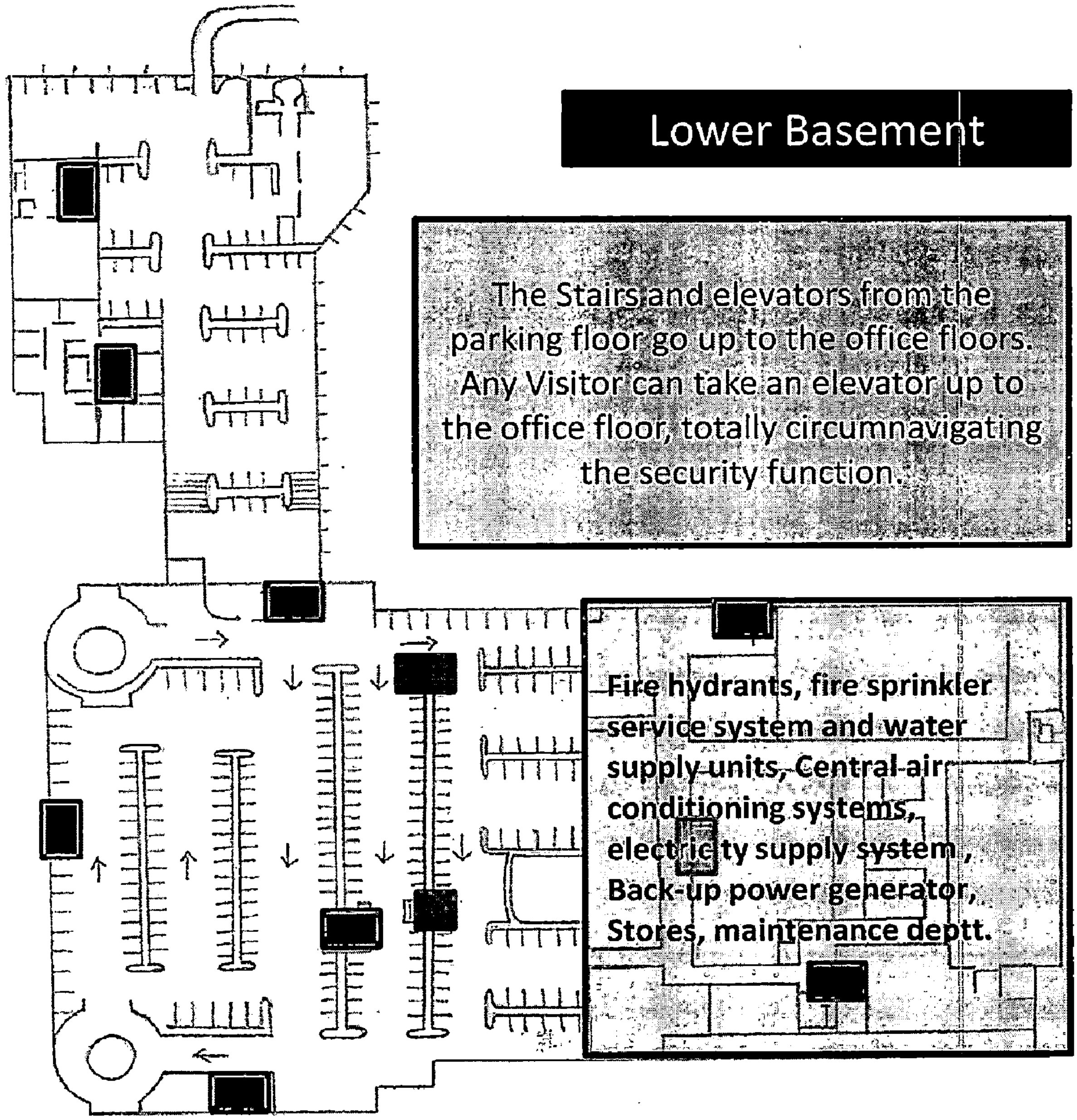


Figure 137: Fire & HVAC System in the lower basement



The first basement has only parking while the second houses parking as well as the service areas, maintenance departments, stores, etc. Thus, basement can be an easy target by a terrorist to hamper the functioning of the building.

Figure 138: services in the lower basement

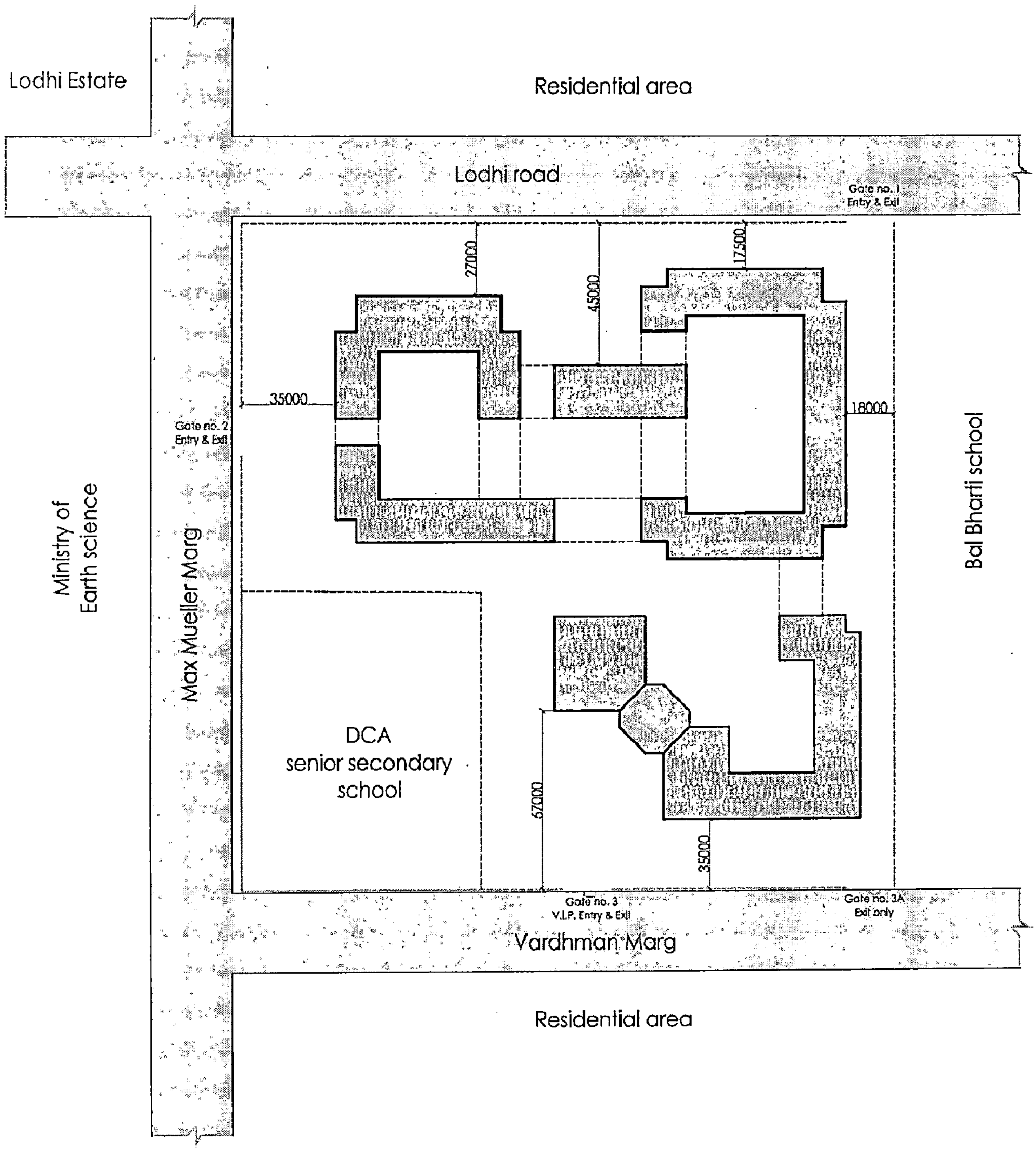


Figure 139: Stand-off distances from the perimeter line

- The stand-off distance on all the sides is greater than 15 m. Thus, the building is fulfilling the minimum standard of stand-off distance.

6.6.2 FUNCTIONAL PLANNING

- As IHC is at a higher plinth, there is an advantage of being able to sight the outside activities from within.

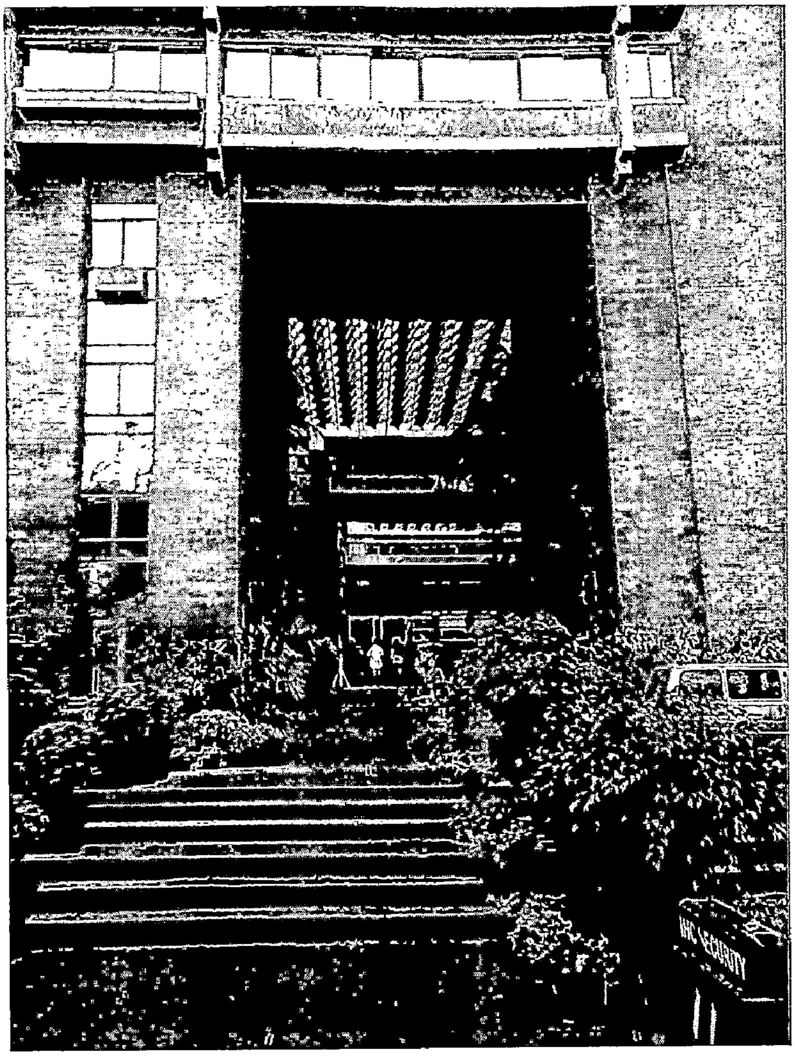


Figure 140: Raised platform allows sight the outside activities from within.

- The complex has a very well planned segregation of spaces. All blocks / areas, which are expected to experience a large and regular inflow of public, have been placed very close to the entrances. The office areas are given access from the inside of the courtyards. Although the public and the semi-public areas have been placed in separate built blocks, the courts and the landscaped areas form a very good connection between the two.

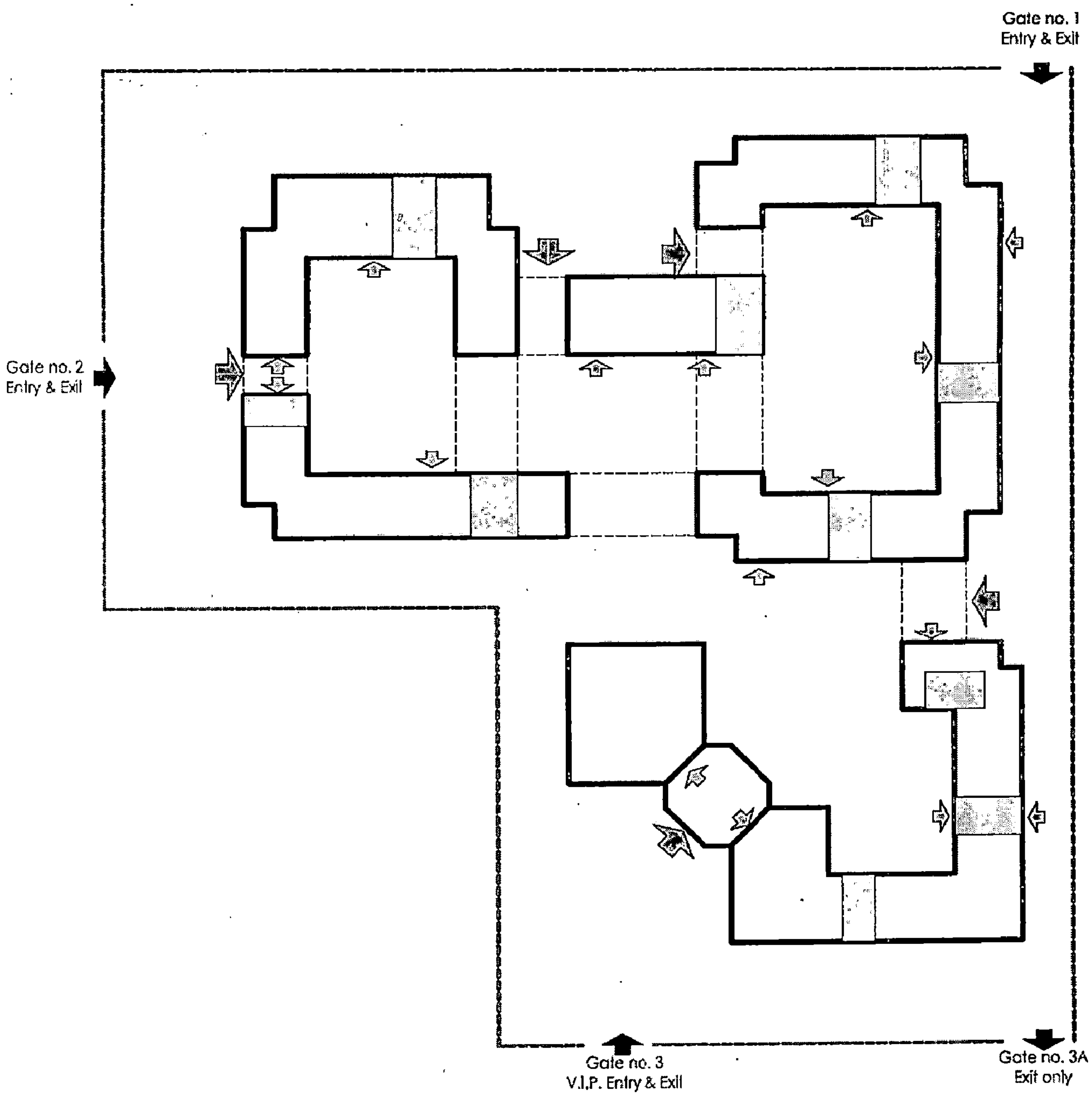
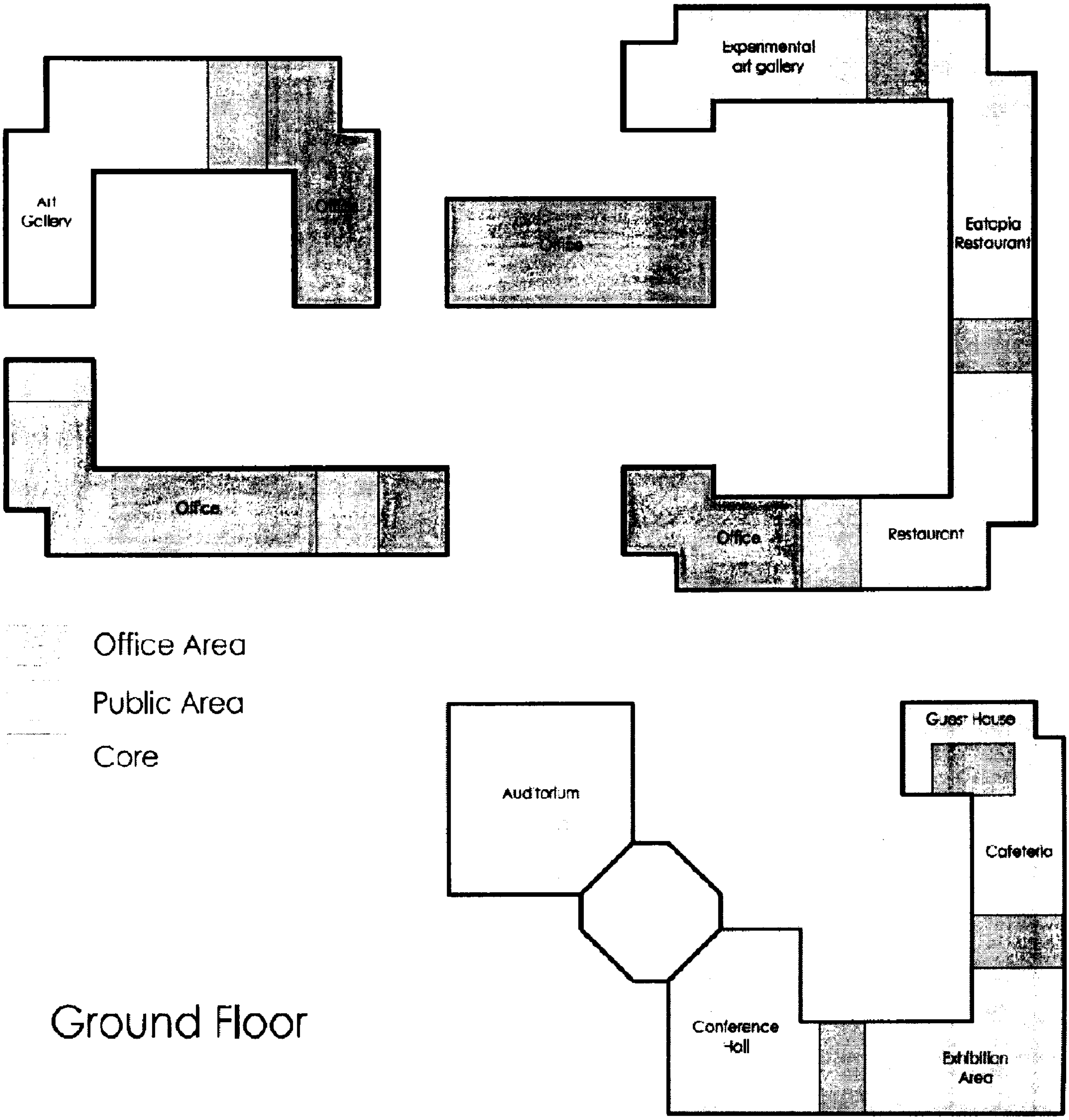
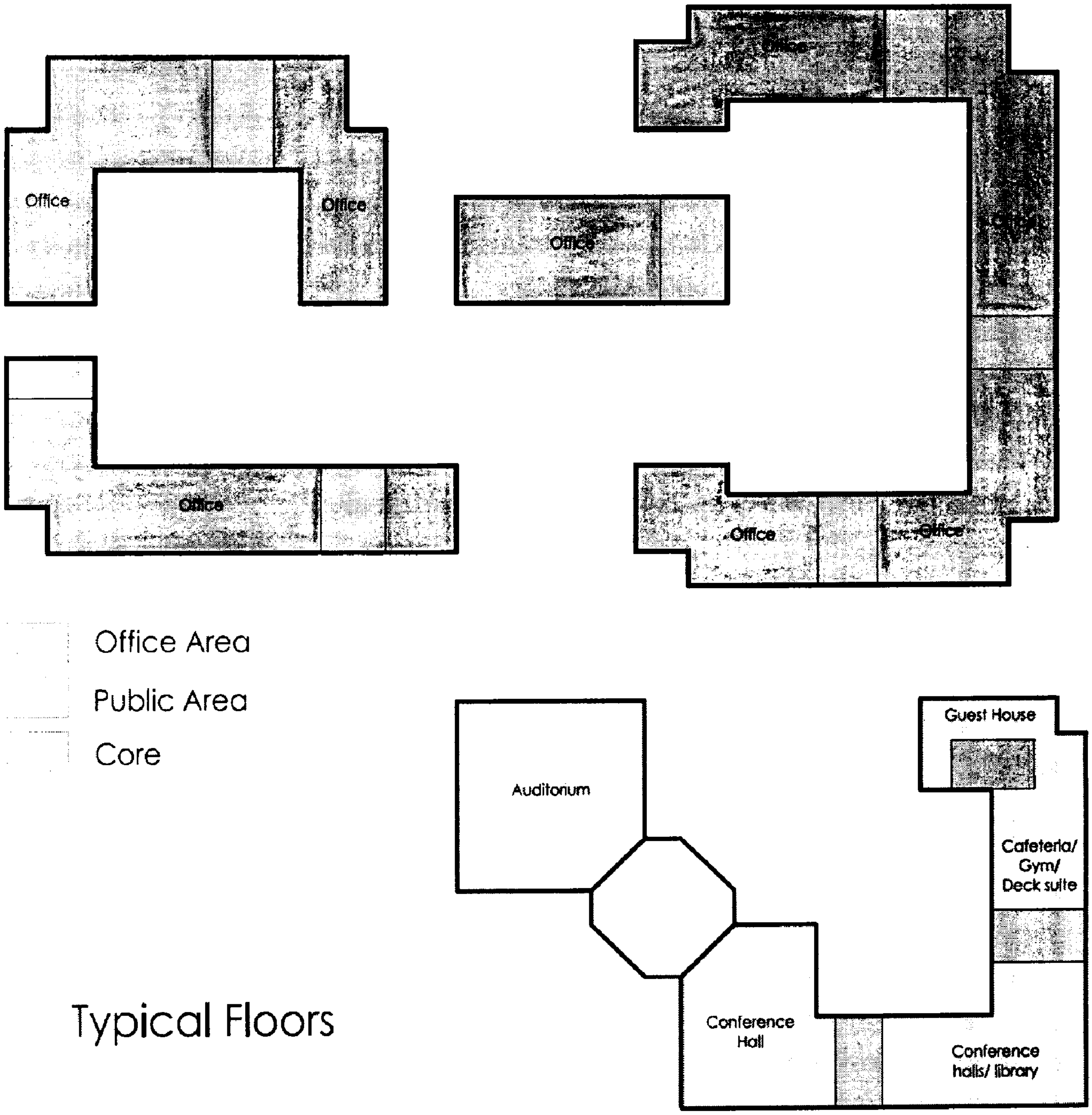


Figure 141: Entry points to the courtyards & the building

- In IHC, the auditorium or restaurant is probably the area most frequently used by outside groups. The entrance is designed to permit access to the auditorium, lobby, restrooms, and coatrooms without requiring visitors to enter other doors or other areas of the building. A complete public block (convention centre) has been segregated from the other semi-pubic blocks (north block) to ensure the security.


Experimental art gallery
Art Gallery
Office
Eatopia Restaurant
Office
Office
Restaurant
Office Area
Public Area
Core
Auditorium
Guest House
Cafeteria
Conference Hall
Exhibition Area
Ground Floor



Typical Floors

- The buildings are grouped around semi covered courts and linked at the 5th and 6th floor level and above by bridges to form huge gateways for entrance into various zones/courts. These multi level bridges provide office spaces as well as links between various building zones. The stand-off distance of bridge from the ground is more than 15 m. Thus, it will survive if a blast takes place below it. The walls below the bridge have fewer windows thus less vulnerable to blast.

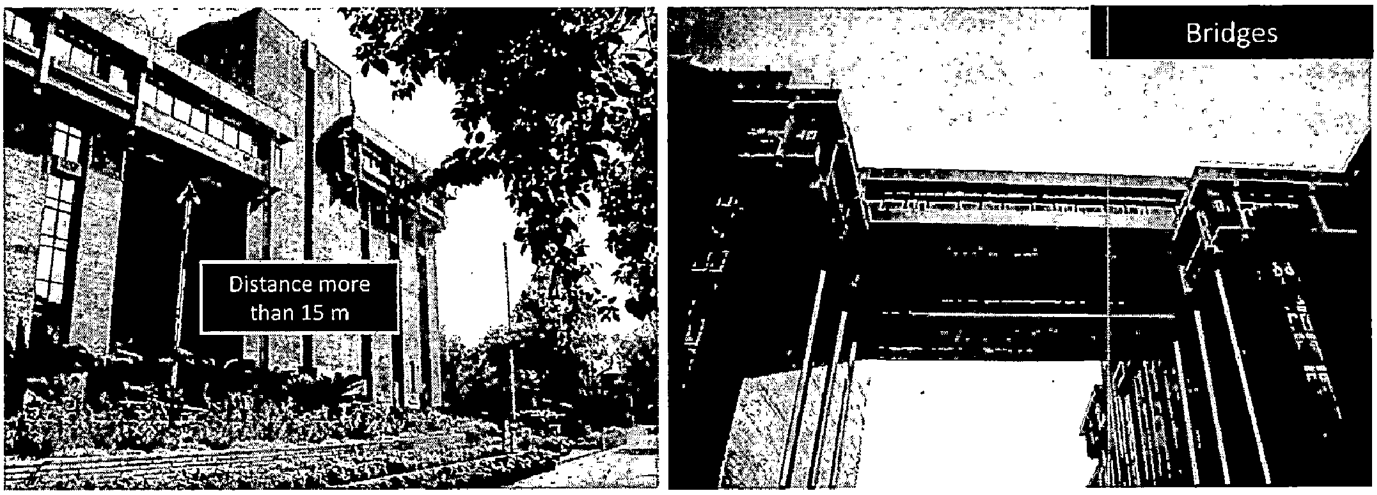


Figure 142: Stand-off distance of bridge is greater than 15m from the ground.

- The courtyards are shaded by overhead trusses with Flat nylon panels. These Flat nylon panels or sun screens are anchored at the predetermined angles within the framework to provide the shading element. These flat nylon panels will not get turned into flying debris which can harm people during a blast because if a blast happens in the courtyard they will be taken in the direction of the blast & away from the building. They will not disintegrate into harmful projectiles as nylon is not a brittle material.

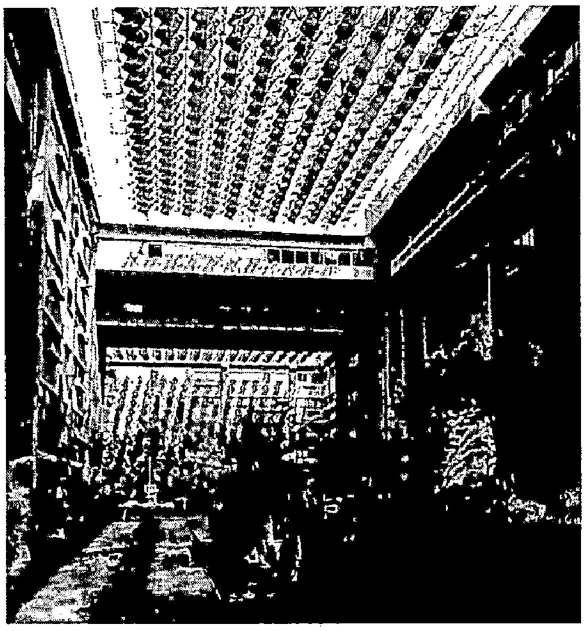


Figure 143: courtyards are shaded by overhead trusses with Flat nylon panels

- The IHC building is divided into seven blocks. These blocks are arranged to form interconnected courtyards. No central core is provided. Each block has its own service core. Only few blocks will get affected if a blast takes place in the service core of any block.

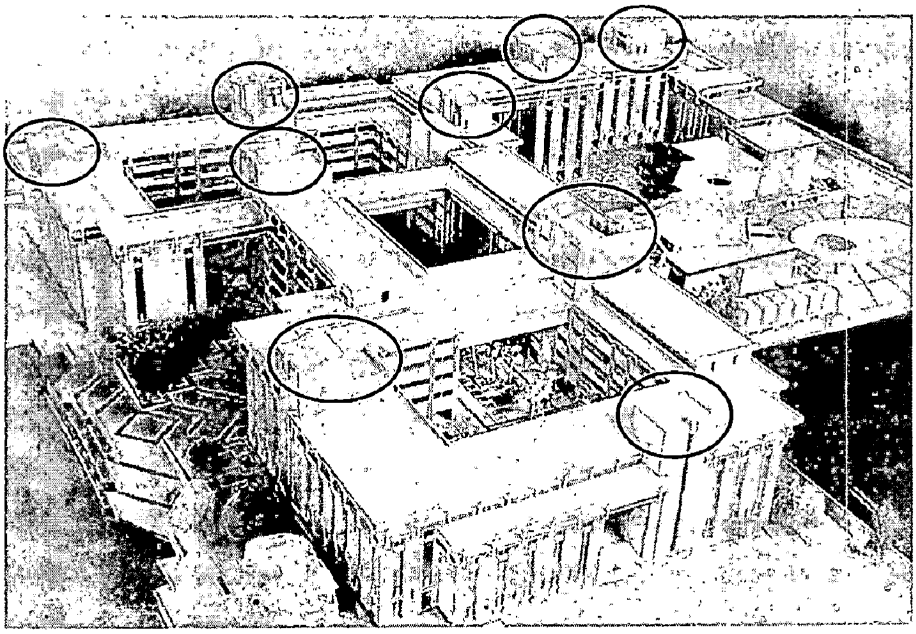


Figure 144: model of the IHC showing service cores

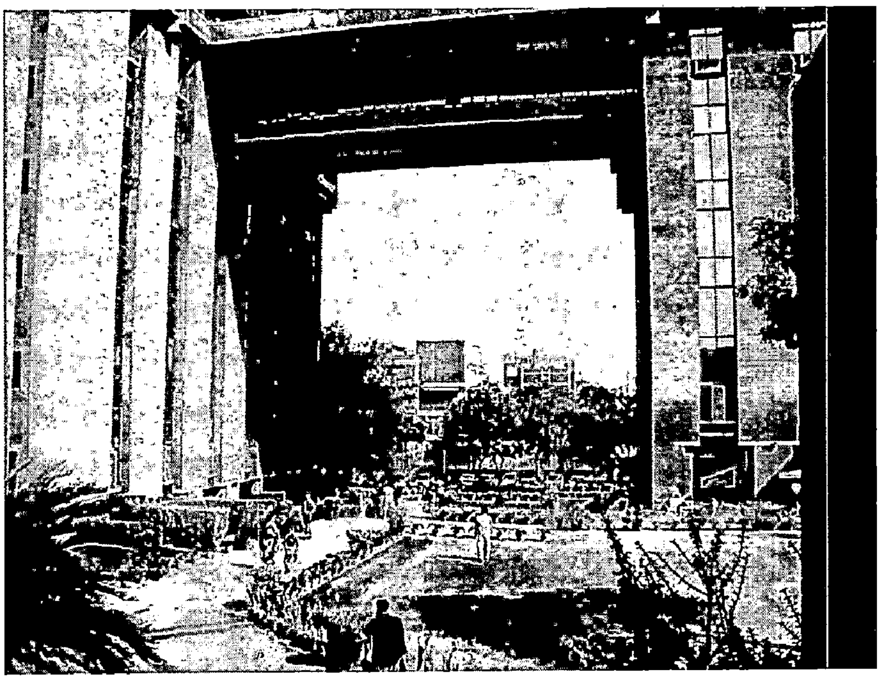


Figure 145: anyone can access courtyard without getting checked

- The location & material of dustbins also play an important role in getting chosen by a terrorist to plant an explosive in it. In IHC, the plastic dustbins are placed along the walls of the building in the courtyard. This might lead to partial collapse of the building if an attack takes place as structural members will get damaged by the impact of blast shockwave. Dustbins should be placed away from the façade. Nowadays blast-proof dustbins are also available in the market that can be employed in the building.

Figure 146: plastic dustbin placed along the wall

6.6.3 BUILDING ENVELOPE

- Long strip windows are provided on the facades facing the courtyards. While the outer facades have long vertical recessed windows. As the volume of blast entering through an opening is directly proportional to the opening size, thus, Long strip windows in the courtyard might lead to more sabotage if a blast takes place in the courtyard.

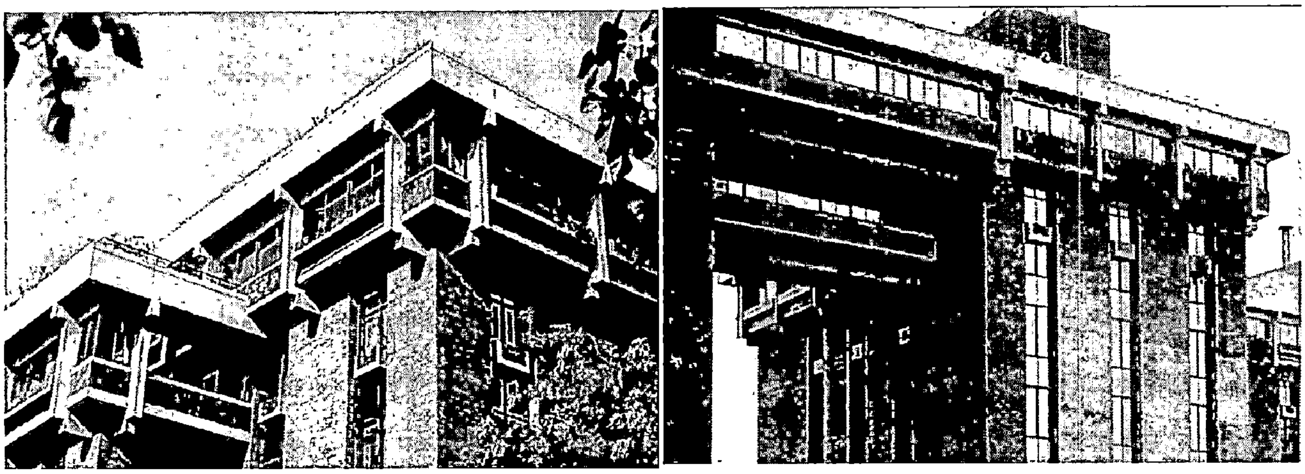


Figure 147: Projected floors made in exposed R.C.C.

- Facades towards the road side have vertical recessed windows which is a better option than long horizontal strip windows.

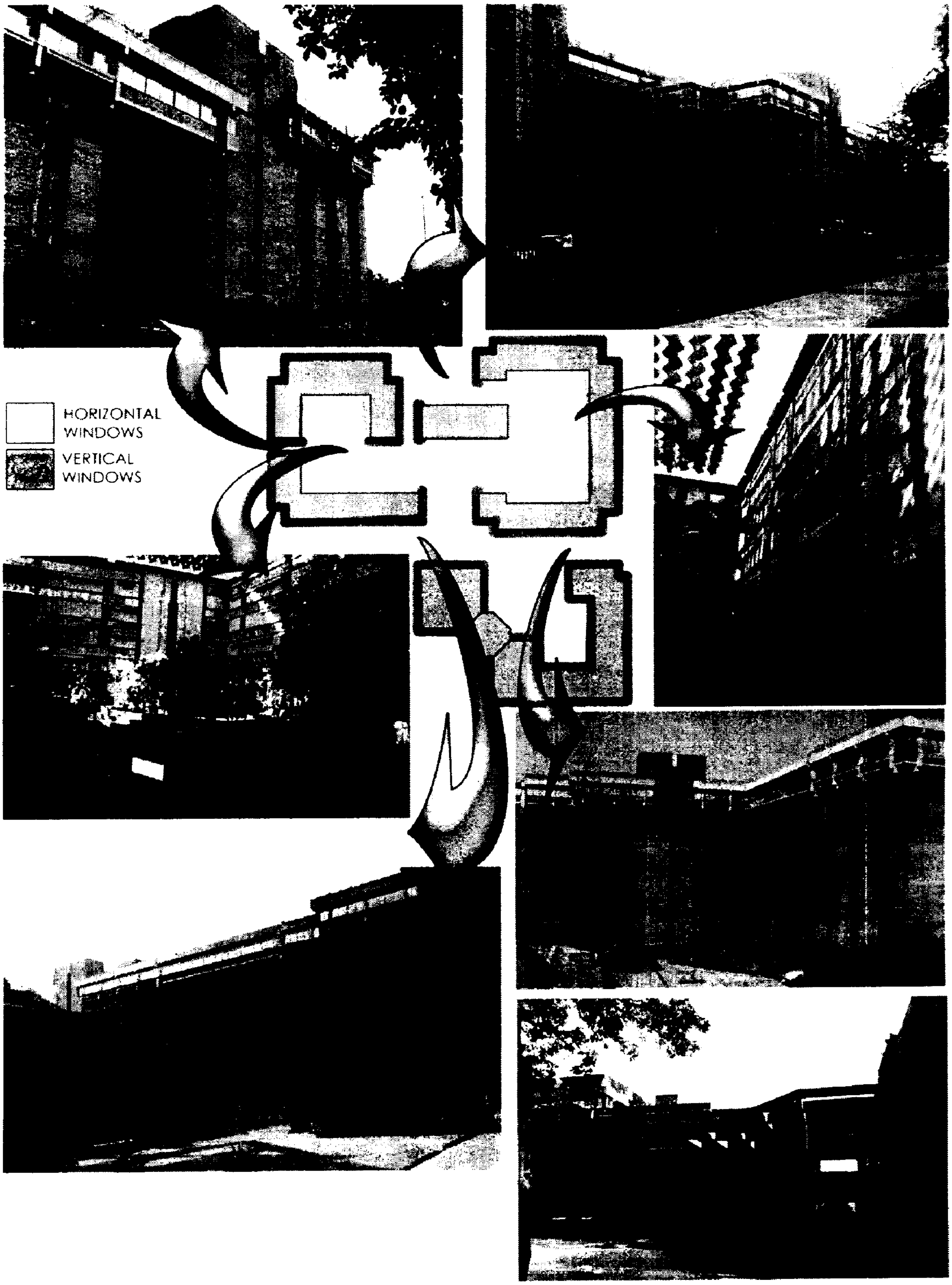


Figure 148: window location

- Reflective laminated glass is used in the windows thus activities inside the building are not visible to the outsiders.
- The openings on the external façade are kept to less than 50% further reducing the heat gain.
- The top two floors of the building which are made in exposed R.C.C have been projected twice. These cantilever structures may be more vulnerable in a blast event as overhangs and eaves attract high overpressures during blasts, and hence such features must be avoided. But being made in R.C.C. these cantilever structures may resist shock waves.

6.6.4 BUILDING CONFIGURATION

In IHC, both exterior & interior facades have re-entrant corners. When blast overpressures are expected, re-entrant corners must be avoided in the exterior of the building as the re-entrant corners trap the shock wave overpressure & the angle of incidence of the shock wave is small. Buildings with circular corners have less intense reflected pressure than a building with sharp corners. If sharp corners are unavoidable, providing separation joints can be a secondary solution.

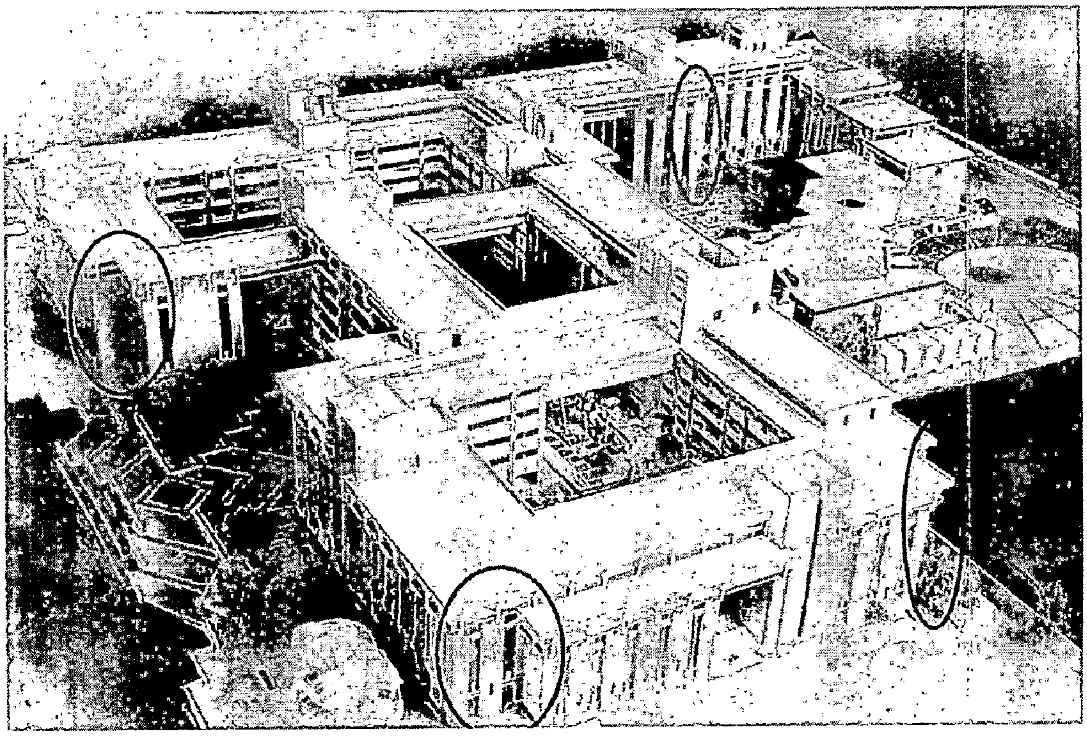


Figure 149: Sharp re-entrant corners in the building

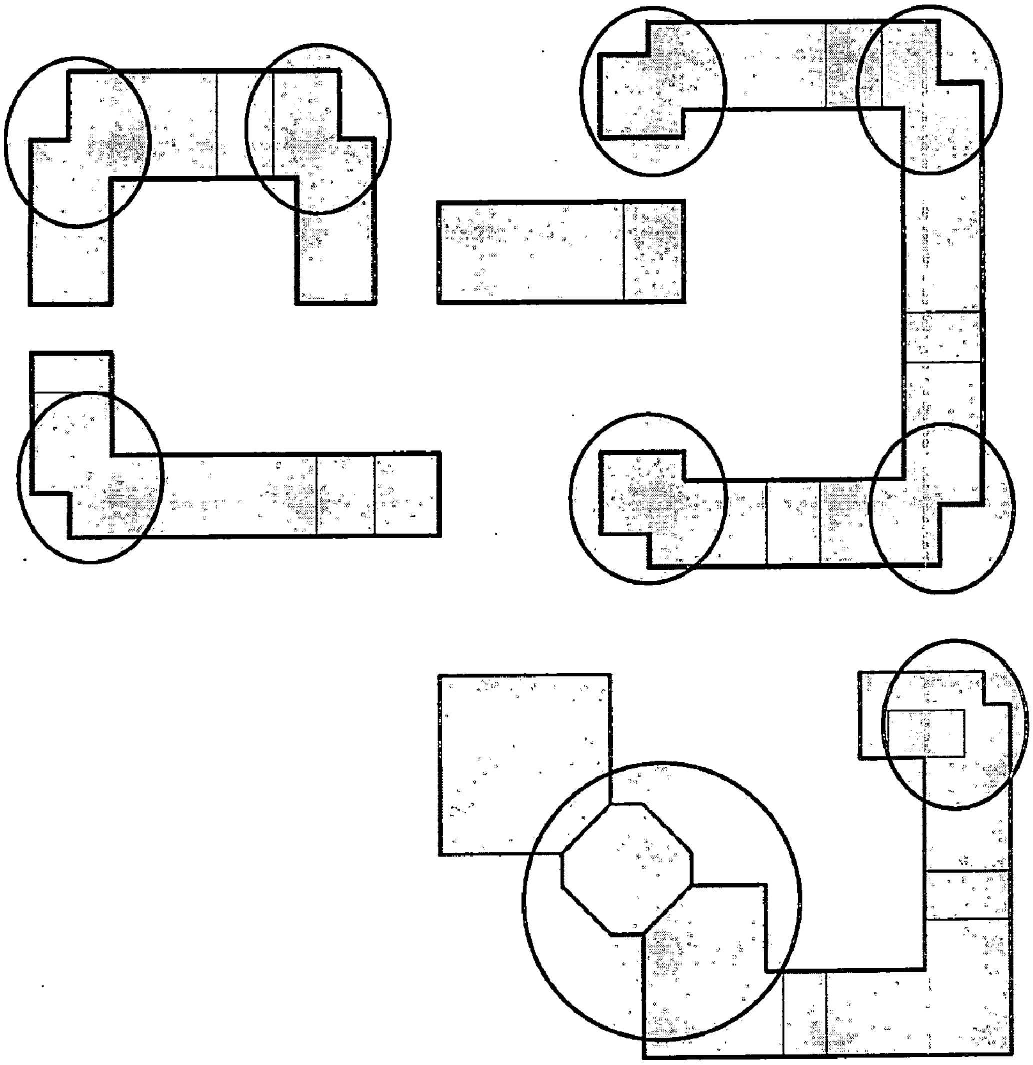


Figure 150: Re-entrant corners in the building

6.6.5 STRUCTURE SYSTEM

- IHC is constructed in reinforced concrete framework with infill of concrete blocks & finished with earthy clay tile cladding. The structural grid is of 5x10x5 m. Reinforced concrete provides the highest level of protection & Infill of concrete blocks minimizes flying debris in a blast as they do not disintegrate into its constituents. But cladding material is not suitable as it readily disintegrates into flying debris in a blast event which can harm people. Exposed structural work is much safer than cladded facades.

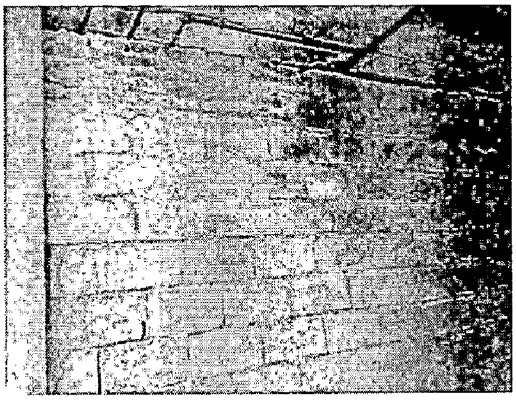


Figure 151: Reinforced concrete Structure with Infill of concrete blocks.

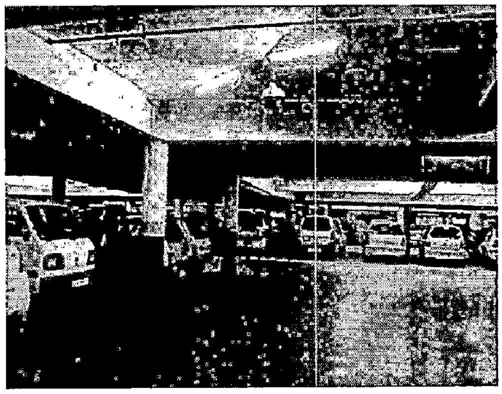


Figure 152: Circular columns in Basement parking

- In IHC, basement has circular columns. A circular column allows for much greater visibility around the corners than a square or rectangular column. Structurally, there is no difference between using the two shapes. It is usually a design decision.

6.6.6 UTILITIES

- AHU's are mounted at a height of 4 meter from the ground floor level. These units are built flush inside the building wall and provided with louvers so that no one can hurl any injection into the system. These elevated air intake units avoid possibilities of injecting CBR agents by passersby.

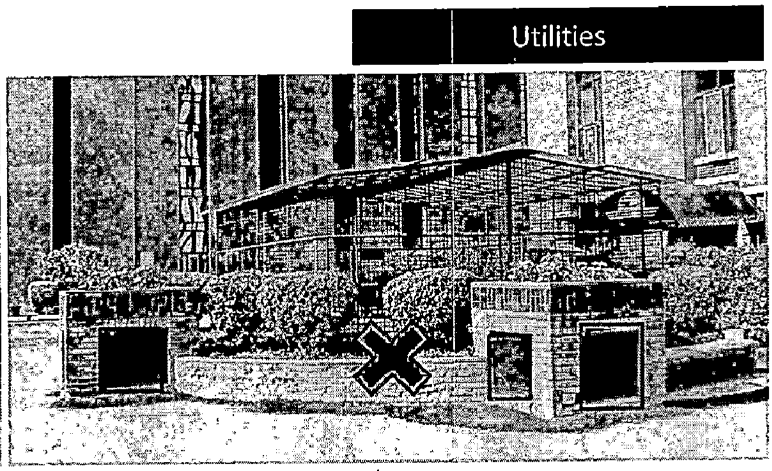


Figure 153: Location of a) AHU intake Unit; b) exhaust duct of basement

- The basements are mechanically ventilated. The exhaust fan ducts are opening into the courtyard at floor level. These ducts are creating a spot to through an explosive in the basement.

- Fire escape staircases and lobbies are all pressurized to prevent the spread of fire along the shafts.

6.6.7 SECURITY SYSTEM

- Service core, lift lobbies & way to public toilets are provided with CCTV system to ensure security.

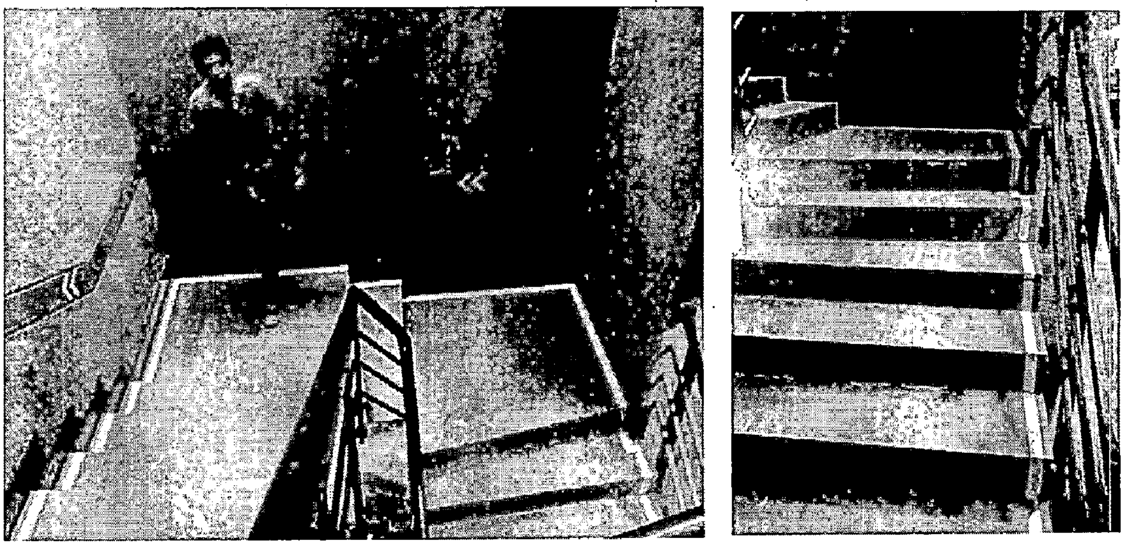


Figure 154: Photo-luminescent exit path marking

- Not all blocks are equipped with checking equipment. This facility is provided only in few blocks like Eatopia restaurant, Auditorium & conference halls.

Figure 155: Entry to Eatopia, convention centre & auditorium are equipped with screening system

- Photo-luminescent exit path marking is adopted in all fire exit staircases. These photo-luminescent self-adhesive signs and tapes will blaze for up to 8 hours after the light source is disconnected. These are also very noticeable during the day.

Figure 156: CCTV in the corridor to the toilet

- Courtyard being socially active and its interfacing with the surrounding blocks makes it a most vulnerable place for any kind of terrorist attack. All the entries to the courtyards are kept unchecked. This makes the whole compound permeable enough for a terrorist to plant an explosive in it. All entries should be kept under surveillance by any means possible i.e. CCTV system, Screening System etc. Checking points should be provided for pedestrians at the entry points. A mechanical solution for accomplishing the diverse security goals in a multi-tenant building is using turnstiles in the checking area.

6.7 TERROR VULNERABILITY ASSESSMENT CHECKLIST

BUILDING VULNERABILITY ASSESSMENT CHECKLIST- IHC, NEW DELHI			
S.no.	Vulnerability Question	Guidance	Observation
1.	site		
1.1	What are the adjacent land uses immediately outside the perimeter of the site/buildings?	Critical infrastructure to consider includes: Electric power system, Telecommunications infrastructure, and Gas & oil facilities.	Adjacent land uses are Institutional & residential buildings. It does not have any critical infrastructure adjacent to it.
1.2	Does the terrain place the building in a depression or low area?	Depressions or low areas can trap heavy vapors	No. Building is made on a raised platform.
1.3	In dense, urban areas, does curb lane parking allow uncontrolled vehicles to park unacceptably close to a building in public rights-of-way?	Where distance from the building to the nearest curb provides insufficient setback, restrict parking in the curb lane.	No, only visitors to IHC are allowed to park in the curb lane.
1.4	Is a perimeter fence or other types of barrier controls in place?	The intent is to channel pedestrian traffic onto a site with multiple buildings through known access control points. For a single building, the intent is to have a single visitor entrance.	Yes. Perimeter fence is provided to control the unauthorized access to the building.
1.5	What are the site access points to the site or building?	The goal is to have at least two access points- one for passenger vehicle & one for delivery trucks due to the different procedures needed for each. Having two access points also helps if one of the access points becomes unusable, then traffic can be routed through the other access points.	There are 3 access points to the site. All three are under surveillance of guards. Gate no. 2 & 3 leads to basement parking while gate no.1 leads to both surface & basement parking.

1.6	Is vehicle traffic separated from pedestrian traffic on the site?	Pedestrian access should not be endangered by car traffic. Pedestrian access, especially from public transportation, should not cross vehicle traffic if possible.	Yes. Central courtyards are kept free from vehicular access by a stepped entry to courtyards. The organization of these courts is very simple leading to smooth pedestrian circulation. The entire ground floor is pedestrianized reducing the hassle caused by traffic.
1.7	Is there vehicle & pedestrian access control at the perimeter of the site?	Vehicle & pedestrian access control & inspection should occur as far from facilities as possible (preferably at the site perimeter).	Yes. But only vehicles are checked before entering the site. No access control for pedestrian is provided.
1.8	What is the minimum distance from the inspection location to the building?	Should not be less than 25 m.	The distance from the inspection location to the building is 35 meters.
1.9	Does site circulation prevent high speed approaches by vehicles?	The intent is to use site circulation to minimize vehicle speeds & eliminate direct approaches to structures.	Yes. Gate no. 2 & 3 entries lead straight to the building. But vehicles are prohibited from gaining access to the Building through raised platform.
1.10	Are there offsetting vehicle entrances from the direction of a vehicle's approach to force a reduction of speed?	Single or double 90 degree turns effectively reduce vehicle approach speed.	Yes. There is one 90 degree turn which takes the building to the basement parking.
1.11	Does adjacent surface parking on site maintain a minimum stand-off distance?	Adjacent public parking should be directed to more distant or better protected areas, segregated from employee parking and away from the building. The specific stand-off distance needed is based upon the design basis threat bomb size & the building construction. For initial screening, consider using 25meters (82 feet) as a minimum with more distance needed for unreinforced masonry or wooden walls.	The curb parking available outside the site maintains a distance of 35 meters. But surface parking inside the site maintains a distance of only 15 meters from the building.

1.12	Do standalone, above ground parking garages provide adequate visibility across as well as into & out of the parking garage?	Potential hiding places & dead ends in the parking areas should be eliminated.	Yes. Landscape features like dense vegetation are avoided in surface parking. It is under the surveillance of guards as it is placed near the gates.
1.13	Do site landscaping & street furniture provide hiding places?	Minimize concealment opportunities by keeping landscape plantings and street furniture away from the building to permit observation of intruders & prevent hiding of packages. If mail boxes are used, the size of the opening should be restricted to prohibit the insertion of packages.	Dense vegetation in the courtyard provides hiding places.
1.14	Is the site lighting adequate from a security perspective in roadway access & parking areas?	Security protection can be successfully addressed through adequate lighting.	Yes. Proper lighting is done in courtyards & parking areas.
1.15	Do signs provide control of vehicles & people?	The signage should be simple & have the necessary level of clarity. However, signs that identify sensitive areas should generally not be provided.	Yes.
1.16	Is there any basement parking?	Basement parking should be avoided if possible.	Yes.
1.17	Who can access basement parking?	It should be allowed to authorize persons only.	Both visitors & staff can access the basement parking.

2.	Architectural		
2.1	Does the site & architectural design incorporate strategies from CPTED perspective?	• Natural access controls • Natural surveillance • Territorial reinforcement • Target hardening • Closed circuit television cameras.	Yes.
2.2	Is it a mixed tenant building?	Separate high risk tenants from low risk tenants & publicly accessible areas. Mixed uses may be accommodated through such means as separating entryways & controlling access etc.	• Yes. It is a mixed tenant building. All blocks / areas, which are expected to experience a large and regular inflow of public, have been placed very close to the entrances. The office areas are given access from the inside of the courtyards.
2.3	Are there trash receptacles & mailboxes in close proximity to the building that can be used to hide explosive devices?	The size of the trash receptacles and mailbox openings should be restricted to prohibit insertion of packages. Street furniture should be kept sufficient distance (10 meters) from the building.	Yes. Trash receptacles are placed just adjacent to the building façade in the courtyard.
2.4	Does security screening cover all public & private areas?	Security screening should cover all public & private areas.	No. It is provided only in Eatopia restaurant & conventional center.
2.5	Are public & private activities separated?	Separate public & private activities.	Yes.
2.6	Are public toilets, service spaces or access to stairs or elevators located in any non-secure areas, including the queuing area before screening at the public entrance?	Public toilets, service spaces or access to stairs or elevators should not be located in non-secure areas.	No. The access to public toilets & elevators is under the surveillance of CCTV system.
2.7	Is access control provided through main entrance points for employees & visitors?	Lobby receptionist, staff escorts, and electronic access control systems.	Yes. Lobby receptionist is provided at each main entrance to the individual block.
2.8	Do foyers have reinforced concrete walls & offset interior and exterior doors from each other?	Consider the exterior entrances to the building or to access critical areas within the building if explosive blast hazard must be mitigated.	IHC is constructed in reinforced concrete framework with infill of concrete blocks. Interior and exterior doors do not offset from each other.

2.9	Do circulation routes have unobstructed views of people approaching controlled access points?	This applies to building entrances & critical areas within the building.	Yes.
2.10	Is roof access limited to authorized personnel by means of locking mechanisms?	Roof access should be limited to authorized personnel.	Entrance to roof top pool is provided to members only. While entry to other areas on the roof top is prohibited.
2.11	Are critical assets (people, activities, building systems & components) located close to any main entrance, vehicle circulation, parking, maintenance area, loading dock, or interior parking?	Critical building components include: emergency generator including fuel systems, fire sprinkler & water supply; main switchgear; telephone distribution; fire pumps; building control systems; UPS systems; HVAC system; elevator machinery & controls; shafts for stairs, elevators, & utilities. Utility systems should be located at least 50 feet from loading docks, front entrances, & parking area.	Service areas like HVAC plant & maintenance departments are placed in the basement just next to the parking.
2.12	Are the critical building systems & components hardened?	Critical building systems & components should be hardened.	Yes. They are constructed in reinforced concrete framework with infill of concrete blocks.
2.13	Are high value or critical assets located as far into the interior of the building as possible & separated from the public areas of the building?	Critical assets such as people & activities are more vulnerable to hazards when on an exterior building wall or adjacent to uncontrolled public areas inside the building.	Office areas are given entrance from the courtyards. They are placed away from the public areas.
2.14	Is high visitor activity away from critical assets?	High risk activities should be separated from low risk activities. Visitor activities should be separated from daily activities.	Yes. A separate block named as south block is given for complete public activities.
2.15	Are stairwells required for emergency egress located as remotely as possible from high risk areas where blast events might occur?	Consider designing stairs so that they discharge into areas other than lobbies, parking or loading docks.	Yes. Provided stairwells for emergency egress are located away from the high risk areas.
2.16	Are stairwell maintained with smoke control systems?	Aids in egress by keeping smoke, heat, toxic fumes etc out of the stairway.	Yes.

2.17	Are enclosures for emergency hardened to limit the extent of debris that might otherwise impede safe passage and reduce the flow of evacuees?	Egress pathways should be hardened & discharged into safe areas.	Yes. They are constructed in reinforced concrete framework with infill of concrete blocks.
2.18	Is interior glazing near high risk areas minimized?	Interior glazing should be minimized where a threat exists and should be avoided in enclosures of critical functions next to high risk areas.	No.

3	Building Envelope		
3.1	What is the designed or estimated protection level of the exterior walls against the postulated explosive threat?	The performance of the façade varies to a great extent on the materials. Shear walls that are essential to the lateral & vertical load bearing system & that also functions as exterior walls should be considered primary structures and should resist the actual blast loads predicted from the threats specified.	Reinforced concrete provides the highest level of protection & Infill of concrete blocks minimizes flying debris in a blast as they do not disintegrate into its constituents. But cladding material is not suitable as it readily disintegrates into flying debris in a blast event which can harm people.
3.2	Is there less than a 40 % fenestration opening per structural bay?	Keep fenestration to below 40% of the building envelope vertical surface area.	Yes.
3.3	Is the glazing laminated or is it protected with an anti shatter film?	The performance of the glass will similarly depend on the material. Glazing may be single pane or double pane, monolithic or laminated.	Glazing provided is laminated.

4	Utility systems		
4.1	Are utility lifelines aboveground, underground or direct buried?	Utility lifelines (water, power, communications etc.) can be protected by concealing, burying or encasing.	They are underground.
4.2	Where are the air intakes and exhaust louvers for the building? (low, high or mid-point of the building structure)	Air intakes should be located as high as possible.	Air Intake units are places away from the reach of passerby (at a height of 4m). While exhaust louvers open directly on the ground floor level in courtyard.
4.3	Are the intakes & exhausts accessible to the public?	They should not be accessible to public.	No.
4.4	Is access to mechanical areas controlled?	Access to mechanical areas should be prohibited.	They are placed in basement next to parking which is not a favorable planning.
4.5	Are there any smoke evacuation systems installed?	For an internal blast, a smoke removal system may be essential, particularly in large, open spaces.	Yes.

6.8 CONCLUSION

- Public buildings have been common targets for terrorist attacks. Making buildings secure from negative effects of terrorist attacks needs a systematic treatment. This study provided a detailed assessment of IHC, New Delhi with respect to planning & design aspects of the mitigation measures in particular.
- As per assessment, the IHC building will survive in a blast event because of its functional & spatial planning.
  - IHC has a raised platform which prevents the vehicles from gathering high speeds and crash into buildings.
  - All Entry & Exits to the basement parking and surface parking are under surveillance as they are provided near the gates.
  - The stand-off distance on all the sides is greater than 15 m. Thus, the building is fulfilling the minimum standard of stand-off distance.
  - Auditorium or restaurant is probably the area most frequently used by outside groups. The entrance is designed to permit access to the auditorium, lobby, restrooms, and coatrooms without requiring visitors to enter other doors or other areas of the building.
  - The complex has a very well planned segregation of public & private spaces. All blocks / areas, which are expected to experience a regular inflow of public, have been placed very close to the entrances. A complete public block (convention

centre) has been segregated from the other semi-pubic blocks (north block) to ensure the security.

- The blocks are arranged to form interconnected courtyards. No central core is provided. Each block has its own service core. Only few blocks will get affected if a blast takes place in the service core of any block.

- Maintenance & some operational changes are required in basement parking & access to the courtyards to make it a perfect security based design.
  - Anyone can park in the basement parking and take an elevator up to the office floor, totally circumnavigating the security function. Elevators & stairs should not go directly into the business or resident floors from parking floor. They should empty to a floor level and then lead to another dedicated bank of stairs or elevators that can facilitate access control and supervision by security staff.
  - Visitors are allowed to park inside the basement and there is not enough space available on the site to provide surface parking to the visitors. Thus, operational changes are required in the basement parking. Parking directly below the building footprint should be accessible to authorized persons while parking below courtyards can be made available to visitors.
  - Dense vegetation creates place for people to hide explosives or commit crimes & does not allow clear sightlines. Maintenance is required to trim & maintain them between 0.5m and 2m above natural terrain for good surveillance.
  - The edges of the site are dead setbacks with very few people using them. Setbacks can be made active to create surveillance by putting more activities such as lunch parties & exhibitions.
  - All critical facilities are placed centrally in the lower basement which can be an easy target by an intruder. Critical services should be distributed on the site rather than putting them at one place in the basement where there is less surveillance.
- There would be less sabotage of property & lives if maintenance & some operational changes are conducted which will discourage the terrorist to select it as a target.

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