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TO STUDY OF ARCHITECTURAL AND MANAGEMENT RELATED ASPECT OF TERRORIST RESISTING BUILDING.

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ABSTRACT

Since the attack on the World Trade Center (WTC), terrorism has become a dominant domestic concern. The protection of buildings has become one of the most important components of this strategy, not only because buildings have been the preferred targets of terrorist attacks, but also because they are the central venue of the Nation's economic life, the embodiment of its wealth and culture. Although these kinds of attacks are exceptional cases, man-made disasters, blast loads are very important parameters in design, architecture point of view and management after such disaster. The objective of this study is to shed light on terrorist resistant building design theories, the enhancement of building security against the effects of explosives in both architectural and management point of view. Firstly, explosives and explosion types have been explained briefly. In addition, the general aspects of explosion process have been presented to clarify the effects of explosives on buildings. To have a better understanding of explosives and characteristics of explosions will enable us to make blast resistant building design much more efficiently. Essential techniques for increasing the capacity of a building to provide protection against explosive effects is discussed both with an architectural and management approach.

Keywords*: *Terrorist attack, terrorist resistant building design, explosive effects.

I. INTRODUCTION

The increase in the number of terrorist attacks especially in the last few years has shown that the effect of blast loads on buildings is a serious matter that should be taken into consideration in the design process. Although these kinds of attacks are exceptional cases, man-made disasters, blast loads are very important parameters in design, architectural point of view and management after such disaster.The main target of this study is to provide guidance to engineers and architects where there is a necessity of protection against the explosions caused by detonation of high explosives. The guidance describes measures for mitigating the effects of explosions, therefore providing protection for human, structure and the valuable equipment inside. The paper includes information about explosives, blast loading parameters and enhancements for blast resistant building design both with an architectural and structural approach. Only explosions caused by high explosives (chemical reactions) are considered within the study. High explosives are solid in form and are commonly termed condensed explosives. TNT (trinitrotoluene) is the most widely known example. There are 3 kinds of explosions which are unconfined explosions, confined explosions and explosions caused by explosives attached to the structure.Unconfined explosions can occur as an air-burst or a surface burst. In an air burst explosion, the detonation of the high explosive occurs above the ground level and intermediate amplification of the wave caused by ground reflections occurs prior to the arrival of the initial blast wave at a building (Fig. 1.1) As the shock wave continues to propagate outwards along the ground surface, a front commonly called a Mach stem is formed by the interaction of the initial wave and the reflected wave. However a surface burst explosion occurs when the detonation occurs close to or on the ground surface. The initial shock wave is reflected and amplified by the ground surface to produce a reflected wave (Fig. 1.2). Unlike the air burst, the reflected wave merges with the incident wave at the point of detonation and forms a single wave. In the majority of cases, terrorist activity occurs in built-up areas of cities, where devices are placed on or very near the ground surface.

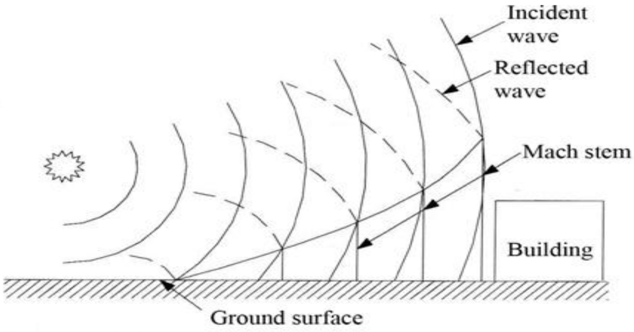

Fig. 1.1 Air burst with ground reflections

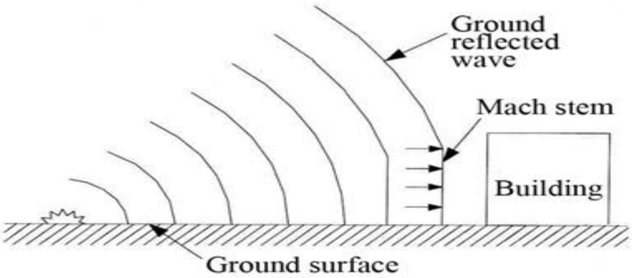

Fig. 1.2 Surface burst

When an explosion occurs within a building, the pressures associated with the initial shock front will be high and therefore will be amplified by their reflections within the building. This type of explosion is called a confined explosion. In addition and depending on the degree of confinement, the effects of the high temperatures and accumulation of gaseous products produced by the chemical reaction involved in the explosion will cause additional pressures and increase the load duration within the structure. Depending on the extent of venting, various types of confined explosions are possible. (Fig.1.3)

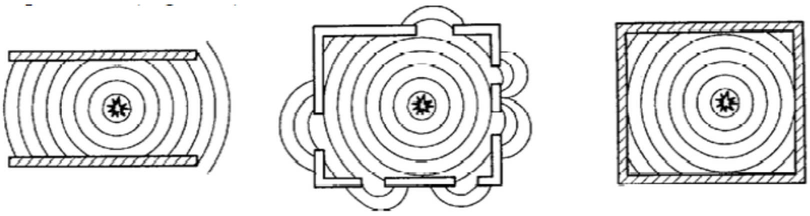

Fig. 1.3 Fully vented, partially vented and fully confined explosions

If detonating explosive is in contact with a structural component, e.g. a column, the arrival of the detonation wave at the surface of the explosive will generate intense stress waves in the material and resulting crushing of the material. Except that an explosive in contact with a structure produces similar effects to those of unconfined or confined explosions. There are many forms of high explosive available and as each explosive has its own detonation characteristics, the properties of each blast wave will be different. TNT is being used as the standard benchmark, where all explosions can be expressed in terms of an equivalent charge mass of TNT. The most common method of equalization is based on the ratio of an explosive's specific energy to that of TNT.

II. LITERATURE REVIEW

A Significant Amount Of Research Work On Various Aspects Of Terrorist Resisting Buildings Published By Many Investigators. Some Papers Are Briefly Described Below,

1) Zeynep Koccaz, Fatih Sutcu, Necdet Torunbalci

Damage to the assets, loss of life and social panic are factors that have to be minimized if the threat of terrorist action cannot be stopped. Designing the structures to be fully terrorist resistant is not an realistic and economical option, however current engineering and architectural knowledge can enhance the new and existing buildings to mitigate the effects of an explosion. The main target of this study is to provide guidance to engineers and architects where there is a necessity of protection against the explosions caused by detonation of high explosives. The guidance describes measures for mitigating the effects of explosions, therefore providing protection for human, structure and the valuable equipment inside. The paper includes information about explosives, blast loading parameters and enhancements for blast resistant building design both with an architectural and management approach.

2) A. Remennikov, D. Carolan

Attacks against buildings using a stationary or moving vehicle laden with large amount of explosive have become the weapon of choice by some terrorist groups. Architectural engineers today face a new challenge and require methods and guidance on how to design structures to resist various hostile acts. Summarises some recent terrorist attacks on civilian buildings with bombs of variable magnitudes and their methods of delivery. The devastating attack against the Alfred P. Murrah Federal Building in Oklahoma City in April 1995, the collapse of both WTC Towers in New York in September 2001, the tragic events in Bali in October 2002, and the most recent bombing of the Australian Embassy in Jakarta in September 2004 have underscored the attractiveness and vulnerability of civilian buildings as terrorist targets. These attacks have also demonstrated that modern terrorism should not be regarded as something that could happen elsewhere. Any nation can no longer believe themselves immune to terrorist violence within their own borders. The fact is that the majority of government and civilian buildings continue to be vulnerable to terrorist attacks.

III.METHODOLOGY

3.1 Methodology for Protective Design of Buildings

The methods for protecting buildings against explosions have been in existence for several decades. The design guidelines have been produced, particularly for high-risk projects such as military facilities and embassies. In response to a potential threat of terrorist bombing attacks and following the events of September 11, 2001, the private sector has became increasingly interested to examine whether design methodologies and construction techniques developed for military purposes could be beneficially applied to civilian structures. Many of the existing buildings have been designed and built with minimum consideration of protection against explosions. It is also unlikely that the building codes will fully incorporate blast resistant design requirements in the near future. Without change of policy and greater awareness among the engineering profession, new buildings will be designed and constructed in a similar fashion. It is agreed that the most effective way to protect a building against blast loads is to stop the attack before it occurs. If the attack does occur, the measures must be employed to ensure that the threat from explosions has minimal effect. This may be achieved by the implementation of a series of redundant physical and operational security measures as well as through achieving protection during the design stage. Considerations should be given how to:

• Minimize the likelihood and magnitude of attack by making the building an unappealing target.

• Prevent catastrophic collapse of the building to save lives; the collapse is inevitable but must be local.

• Protect the people and assets from the primary and secondary effects of explosion (air-blast pressure, flying debris, etc).

• Provide shelter to the occupants of the building during an explosion and facilitate rescue and evacuation efforts.

• Enable rescue and repair efforts to be performed after an attack.

A flowchart showing the methodology for protecting buildings against explosions is shown in Fig.3.1. The flowchart presents the sequence of activities such that an effective approach for protecting people, property and the business can be achieved.

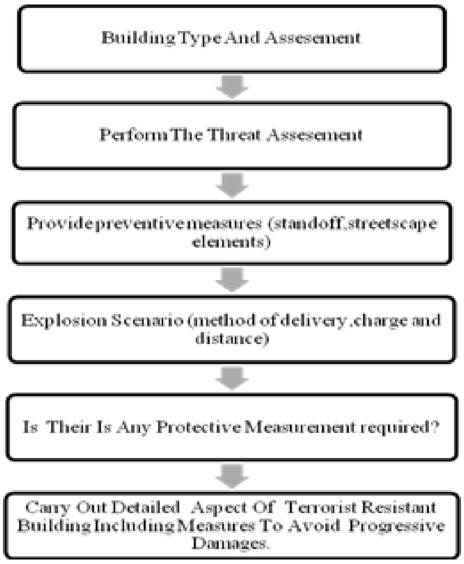

Fig.3.1 Flowchart of the methodology for protective design of buildings

Planning and designing of a new building considering measures to mitigate effects of terrorist attacks on buildings can lead to a very different building than that developed without considering them. Also, many of the mitigation measures are relatively inexpensive and can be easily implemented if incorporated in the early stages of design process. Thus, it is best to include these measures in new buildings from the planning stage itself, rather than include them after the building is built. This chapter describes the various considerations that need to be made while developing new buildings; these include planning, analysis, design and security of new buildings.

3.2 Maximize standoff distance

Maximising the standoff distance keeps the threat as far away from critical buildings as possible. It is the easiest and least costly method for achieving the appropriate level of protection to a critical structure. Many times, vulnerable buildings are located in urban areas where site conditions are tight. When standoff distance is not available, the structure needs to be hardened to give the same level of protection that it would have with a greater standoff. The best way to increase the distance between a potential bomb and the critical building is to provide a continuous line of security along the perimeter of the facility to keep all vehicles as far away from critical assets as possible. The area within the standoff distance can be further partitioned (see Fig. 3.2). The exclusive standoff zone provides a higher level of protection. Using the concept that vehicles are able to carry significantly more explosives than a person with a hand carry packages, the exclusive zone would be limited to pedestrian traffic only. The non-exclusive zone standoff zone would permit entry and parking of cars and trucks, after an initial search at an earlier entry control point.

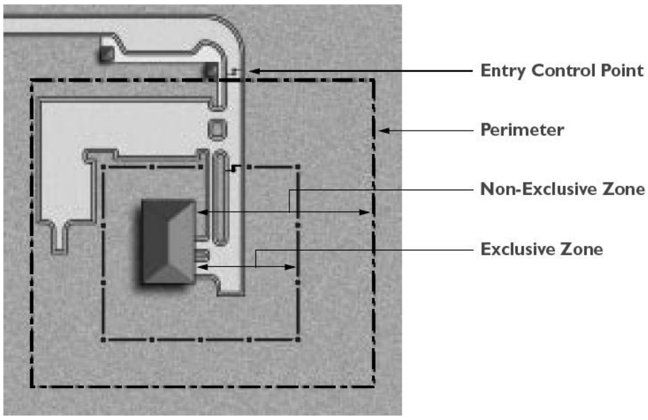

Fig.3.2: Exclusive and non-exclusive standoff zones.

IV. ARCHITECTURAL ASPECT OF TERRORIST RESISTING BUILDING

The target of terrorist resistant building design philosophy is minimizing the consequences to the building and its inhabitants in the event of an explosion. A primary requirement is the prevention of catastrophic failure of the entire structure or large portions of it. It is also necessary to minimize the effects of blast waves transmitted into the building through openings and to minimize the effects of projectiles on the inhabitants of a building. However, in some cases blast resistant building design methods, conflicts with aesthetical concerns, accessibility variations, fire fighting regulations and the construction budget restrictions.

4.1 Planning and layout

Much can be done at the planning stage of a new building to reduce potential threats and the associated risks of injury and damage. The risk of a terrorist attack, necessity of blast protection for structural and non-structural members, adequate placing of shelter areas within a building should be considered for instance. In relation to an external threat, the priority should be to create as much stand-off distance between an external bomb and the building as possible. On congested city centers there may be little or no scope for repositioning the building, but what small stand-off there is should be secured where possible. This can be achieved by strategic location of obstructions such as bollards, trees and street furniture.

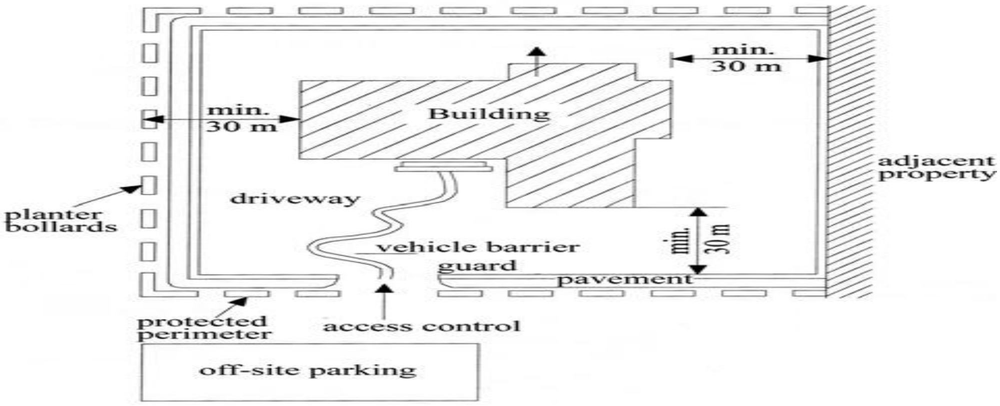

Fig.4.1. Schematic layout of site for protection against bombs

4.2 Structural Form And Internal Layout

Structural form is a parameter that greatly affects the blast loads on the building. Arches and domes are the types of structural forms that reduce the blast effects on the building compared with a cubicle form. The plan-shape of a building also has a significant influence on the magnitude of the blast load it is likely to experience. Complex shapes that cause multiple reflections of the blast wave should be discouraged. Projecting roofs or floors, and buildings that are U-shaped on plan are undesirable for this reason. It should be noted that single story buildings are more blast resistant compared with multi-story buildings if applicable. Partially or fully embed buildings are quite blast resistant. These kinds of structures take the advantage of the shock absorbing property of the soil covered by. The soil provides protection in case of a nuclear explosion as well. The internal layout of the building is another parameter that should be undertaken with the aim of isolating the value from the threat and should be arranged so that the highest exterior threat is separated by the greatest distance from the highest value asset. Foyer areas should be protected with reinforced concrete walls; double-dooring should be used and the doors should be arranged eccentrically within a corridor to prevent the blast pressure entering the internals of the building. Entrance to the building should be controlled and be separated from other parts of the building by robust construction for greater physical protection. An underpass beneath or car parking below or within the building should be avoided unless access to it can be effectively controlled.

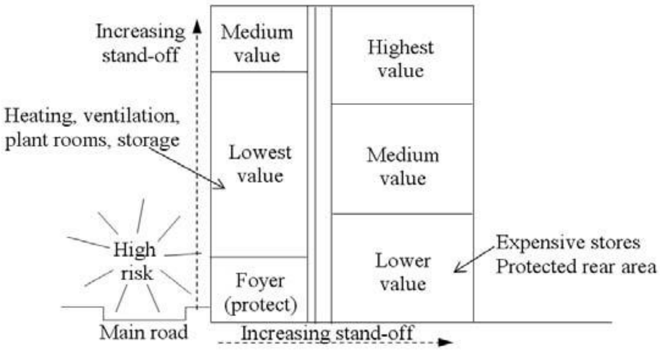

Fig.4.2. Internal planning of a building

A possible fire that occurs within a structure after an explosion may increase the damage catastrophically. Therefore the internal members of the building should be designed to resist the fire.

4.3 Bomb Shelter Areas

The bomb shelter areas are specially designated within the building where vulnerability from the effects of the explosion is at a minimum and where personnel can retire in the event of a bomb threat warning. These areas must afford reasonable protection against explosions; ideally be large enough to accommodate the personnel involved and be located so as to facilitate continual access. For modern-framed buildings, shelter areas should be located away from windows, external doors, external walls and the top floors if the roof is weak. Areas surrounded by full-height concrete walls should be selected and underground car parks, gas storage tanks, areas light weight partition walls, e.g. internal corridors, toilet areas, or conference should be avoided while locating the shelter areas. Basements can sometimes be useful shelter areas, but it is important to ensure that the building does not collapse on top of them. The functional aspects of a bomb shelter area should accommodate all the occupants of the building; provide adequate communication with outside; provide sufficient ventilation and sanitation; limit the blast pressure to less than the ear drum rupture pressure and provide alternative means of escape.

V. MANAGEMENT RELATED ASPECT OF TERRORIST RESISTING BUILDING DESIGN

5.1 The Concept of Risk

The concept of risk is management related aspect commonly used to characterize the likelihood of the occurrence of an unwanted outcome or event. It is commonly associated with terrorist threats, especially if the intelligence or past experience indicates that terrorists target a particular type of facility.

5.2 Risk Assessment Methodology

Risk is the net negative fallout of the prevalent hazard on the asset, the value of the asset, and the vulnerability of the asset, and summarized in the probability Equation. (5.2)

$$\text{RISK} = P\,\{\text{Hazard} \times \text{Value} \times \text{Vulnerability}\} \qquad (5.2)$$

Clearly, comprehensive risk reduction is possible only by the systematic reduction of the negative consequences on each of the three fronts, namely hazard, value and vulnerability. While little improvement may possible on many an occasion with regard to reducing risk from the points of view of hazard and value, it is possible most of the time to build redundancy into the built environment and thereby reduce the risk to the extent possible. Redundancy is required at all levels, namely in systems that deter, detect and deny the terrorist attack, and at all times before, during and after the attack.To reduce the risks and increase safety and security, many factors must be considered. Fig.5.1 depicts the assessment process used to identify the best and most cost-effective terrorism protective measures for a building's unique security needs. The building's risk is calculated based on assessments of the threat/hazards unique to the building, the consequences of an attack or hazard event on the building, and the building's vulnerability to threat/hazards. The risk assessment provides engineers and architects with a relative risk profile that defines which assets are at the greatest risk against specific threats. This approach is based on a three-step process. The first step is to conduct a threat assessment to identify, define, and quantify the threats or hazards . A terrorist threat derives from aggressors (people or groups) known to exist and to have the intent and capability of using hostile actions to achieve their goals. A measure of threat is the probability that a particular type of attack will be mounted against a particular target. The second step of the assessment process identifies the potential consequences of an attack, and the resulting loss of lives or building functions. A consequences assessment looks at the value of a building's critical assets, identifies those that need to be protected, and considers the importance of the building's operations within a wider network of public or private activities. A measure of consequences is the potential magnitude of losses resulting from a successful attack of a specific type on a specific target. The third step identifies potential vulnerabilities of critical assets against a broad range of identified threats or hazards. A measure of vulnerability is the probability that damages or losses will occur as a result of a successful attack of the specified type. The vulnerability assessment provides a basis for determining the type of protective measures required to protect the critical assets. The vulnerability assessment is the bridge in the methodology between threats or hazards, consequences, and the resultant level of risk.As the data are assembled and processed, assessors are able to identify and quantify the risks. Risk assessment involves analyzing the threat or hazard, consequences of a successful attack, and vulnerabilities to determine the level of risk for each critical asset that may represent a legitimate target against each applicable threat. The purpose of risk assessment is to provide information to the building owner and the design community that enables them to decide which protective options are the most feasible and cost effective against which threats. After risks are quantified and ordered, assessors identify and prioritize protection measures that reduce these risks. When the risk assessment process is completed, stakeholders are frequently left with the awareness that the number of assets that may require protective measures exceeds the available resources. Thus, decisions must be made to prioritize and focus the available resources on the most important and most effective mitigation activities. A flowchart showing the risk assessment methodology for protecting buildings against explosions is shown in Fig.5.1. The flowchart presents the sequence of activities such that an effective approach for protecting people, property and the business can be achieved.

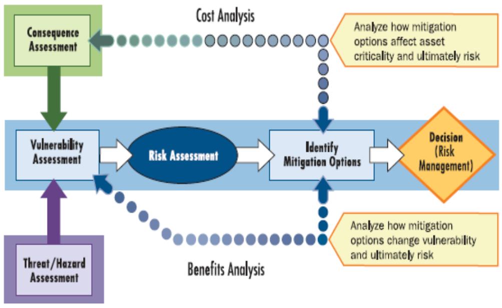

Fig.5.1: Risk assessment methodology for protective design of buildings

5.3 Risk Management

Once risk is identified, it is important to manage risk, basically to reduce it. Three choices are available to the owner on future course of action (Figure 5.2), namely accept the prevalent risk, install reasonable mitigation measures, or undertake comprehensive mitigation measures including hardening of the building. This decision is crucial and is usually made at a level of the organization/system that includes persons who allocate funds.

Fig. 5.2: Possible paths for treating risk

Risk mitigation to built infrastructure subject to security and terrorist threats may comprise many possible, and costly, protective measures Norville and Conrath 2006; Nair 2006; Smith and Hetherington 1994; Ettouney et al. 1996; Longinow and Mniszewski 1996; for example, protective measures may include:

- Enhanced perimeter security.
- Perimeter wall.
- Vehicle barriers and inspection.
- Security personnel.
- Increased standoff.
- Facility design.
- Blast and impact resistant glazing.
- Strengthened perimeter columns and walls.
- Enhanced structural stability measures.
- Enhanced ductility and connectivity.
- Provide alternate load paths.
- Allow rapid evacuation and access to first responders' facility relocation.
- Threat minimization.

5.4 Risk Reduction Process

Whether the building is new or an existing, the formal process for risk reduction involves five steps (Fig 5.4). These steps and the tasks to be undertaken within each of these steps are given below:

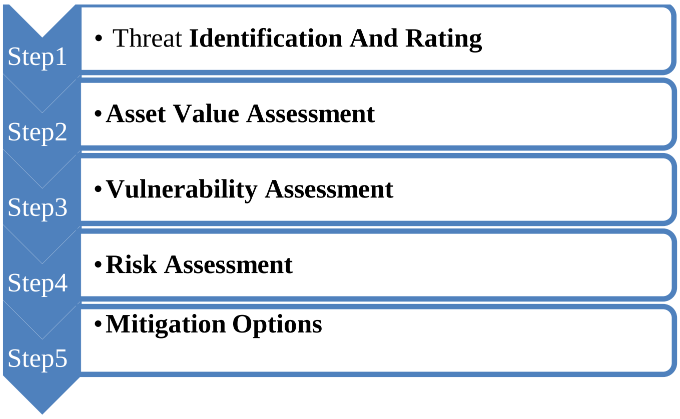

Fig.5.4: Steps involved in the process of risk reduction

Step 1: Threat Identification And Rating

(Identify threats; collect information; determining design basis threat; determine threat rating)

Step 2: Asset Value Assessment

(Identify possible layers of defense; identify critical assets; identify building core functions and infrastructure; determine asset value rating)

Step 3: Vulnerability Assessment

(Organize resources to prepare the assessment; evaluate the site and building; preparing a vulnerability portfolio; determining vulnerability rating)

Step 4: Risk Assessment

(Prepare risk assessment charts; determine risk ratings; prioritise building components)

Step 5: Mitigation Options

(Identify preliminary mitigation options; review mitigation options based on cost estimates; reviewing mitigation, cost, and layers of defense) Clearly, the process of risk reduction is comprehensive and requires a holistic approach. Each of the steps and tasks listed are helpful in designing of terrorist resistant building.

VI. RESULTS AND CONCLUSIONS

The aim in terrorist resistant building design is to prevent the overall collapse of the building and fatal damages. Despite the fact that, the magnitude of the explosion and the loads caused by it cannot be anticipated perfectly, the most possible scenarios will let to find the necessary engineering, architectural and management related solutions for it. In the design process it is vital to determine the potential danger and the extent of this danger. Most importantly human safety should be provided. Moreover, to achieve functional continuity after an explosion, architectural and structural factors should be taken into account in the design process, and an optimum building plan should be put together. During the architectural design, the behavior under extreme compression loading of the structural form, structural elements e.g. walls, flooring and secondary structural elements like cladding and glazing should be considered carefully. In conventional design, all structural elements are designed to resist the structural loads. But it should be remembered that, blast loads are unpredictable, instantaneous and extreme. Therefore, it is obvious that a building will receive less damage with a selected safety level and a blast resistant architectural design. On the other hand, these kinds of buildings will less attract the terrorist attacks.

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