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Develop an Architectural Design Approach to Counter-terrorism

تطوير نـهج التصميم المعماري لمواجهة الإرهاب

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Abstract:

Developing an Anti-terrorism Design approach will cause some loss of Design freedom. Protection systems cost money, but technology is helping to making them more affordable in Building Shape, Structure, Materials and its surrounding environment. The Proposed Approach encourage "Security Design" that produce aesthetic and smart solutions with built-in security measures, based on Understanding Building behavior toward the explosions, that helps in suggesting good design solution to face this problem.

The Best Solutions require innovative thinking process experienced in responding to acts of terrorism and the terrorist incidents,then consider all possibleProtection levels in early stage in designing phases.

Keywords:*Anti-terrorism*,*Counter-terrorism*, *Blast loading.*

1- Introduction

After Many terror attacks to big Capital cities around the World (London, Paris, Stockholm, Brussels, Manchester and Nice), Properreactions need to be taken to secure a Build Space without changing its character. Anti-terror architecture is one of the most recent Professional response toward this current global Events.Architects and Urban Planners have learned to negotiate between Aesthetics and Public safety, to provide Balance between Aesthetics and Public Safety elements in the Design.

While New Architectural Trends symbolize the Art of Expression, Architects can ProvideBuilding and Urban Designs with features to resist terrorist attacks and support extra security measures to the Design Process. So, New Architectural Design Approach need to be taken especially in our region.

2- The Objective

This Paper aims to study how to improve Architectural Design Ability to withstand a terrorist attack, to Mitigate Potential Terrorist Attacks and to limit the Blast effects on the Building up to the minimum degree. Based on the hypothesis that better understanding of explosives and its characteristics will enable Designers to make Anti-terror Architectural Design much moreefficiently.Which leads toprovide guidance through Policies and Strategies able to develop Anti-terror Architectural Design Process.

3- Terrorism and Building Attacks

Considering the need for safety usually trumps most other human needs, perhaps it's time to consider combining the need for beauty with the need for safety especially in an era that bears the burden of the "ugliness of terrorism" [1].The Disasters of suddenly willful events result in severe negative economic and social consequences for the populations they affect, often including physical injury, loss of life, property damage and loss, physical and emotional hardship, destruction of physical infrastructure, and failure of Buildings with its operational systems. All Concerned Authorities are responsible for intervening before and during such events, to minimize the harm disasters cause and to restore order [2].

3-1 Explanation of Explosion Basic Principles

An explosion is a very rapid release of stored energy characterized by an audible blast causes high pressure gas, heat, light, sound, and a shock wave[3], [5].Part of the energy is released as ***thermal radiation***, and part is coupled into the air (***air-blast***) and soil (***ground-shock***) as radially expanding shock waves. Air-blast phenomena ***occur within milliseconds*** and the local effects of the blast are often over before the building structure can react to the effects of the blast[4].The shock wave expands outward from the ***explosion in all directions***, ***traveling at supersonic speed*** and exerts pressure on any structure in its path. The pressure wave decays as the distance from the explosion and time increases. There are two aspects of the shock wave that inflict damage, one is the peak amplitude of the pressure and the other is the duration of the pressure applied on the structure [5].

3-2Types ofBuilding Explosion

There are ***three kinds of Building explosions*** which are ***Unconfined Explosions***, ***Confined Explosions*** and ***Attached Explosives to the Structure***.

- ***Unconfined explosions*** can occur outside the building as an air-burst (above the ground level) or a surface burst (on the ground level). In air-burst additional wave occurs as a result of reflection of incident wave on ground level with additional Blast load on the building.

- ***Confined Explosion*** is 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.
- ***Attached Explosives to the Structure*** occurs 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 [6].

4- Building Damage Analysisunder Terrorist Attack

Understanding the building behavior and its functionaluse, under possible threats due to terrorist attacks, is essential in identifying strategiesthat are most likely to be effective to prevent detrimental effects of the attacks.
The extent of Blastdamage is determined by the type, quantity of used explosive, and the distance from the Building [7].

4-1Behavior of Building toward the explosions

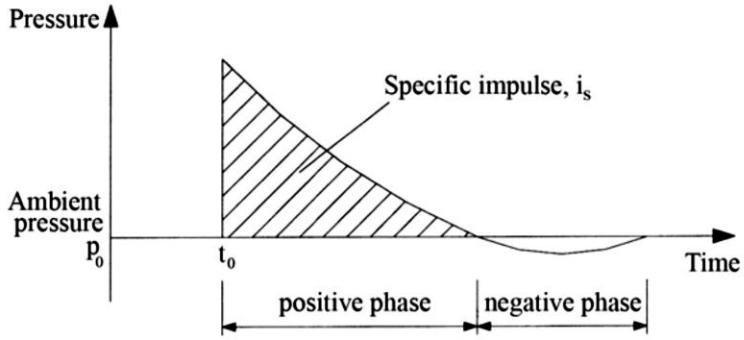
The air blast is the main damage mechanism. Air blast has a primary effect, which is the ambient over-pressure or ***incident pressure***, and a secondary effect, which is the ***dynamic pressure*** or drag load. The first effect is caused by the air blast (due to shock waves) that propagates at supersonic velocity, and compresses air molecules in its path. As the shock wave encounters a wall, it is ***reflected*** thus ***amplifying the overpressure***, often by some significant factor greater than two. The air blast enters the building through wall-openings and failed windows, affecting floor slabs, partitions, and contents within the building. The ***shock waves*** undergo ***diffraction*** as they interact with various surfaces, thus ***increasing or decreasing in pressure*** [3].

4-2Building Hazards in Terrorist Attack

As the shock wave propagates through a building, the pressure engulfs the entire structure first with the walls incident to the blast, then the roof and side walls, and then opposing rear wall last [5].
The biggest dangers to personnel in a building: ***Fragmenting Structural Materials, Breaking Glass***, and ***Building Collapse***.
The interior and exterior walls are typically not load bearing and are usually made of hollow concrete blocks, or metal or wood frames, covered by metal, wood, or gypsum board panels. All of these materials will deform, displace, and/or completely disintegrate when exposed to significant overpressures associated with bomb blasts, posing the greatest threat to loss of life [3].
A possible fire that occurs within the building after an explosion may increase the damage disastrous [6].

4-3 Blast loading on Building

The air shock wave produces an instantaneous increase in pressure above the source. This is commonly referred to as ***"overpressure"***. Then the pressure causing a reversal in the direction of flow, back towards the center of the explosion, known as a ***"negative pressure"*** phase. (Figure 1) Equilibrium is reached when the air is returned to its original state.



(Figure -1) Blast wave pressures plotted against time

The Very fast Air movement under the "***overpressure***" and ***"negative pressure"*** affect all nearby objects and cause huge damage [6]. Currently there are no formal Blast Performance Criteria for civilian buildings. The U.S. Department of Defense, Department of State, and General Services Administration have developed specific anti-terrorism requirements for military, embassy, and federal buildings, respectively. Based on that (Table 1) provides some recommendations for private sector facilities. The expected Pressure ***need to be added in building structure Calculations*** [4].

Tactic	Parameter (Dynamic Pressure)	EstimatedLikelihoodofTerroristAttach				MeasurementofStandoffDistance *R*
		Low	Medium	High	VeryHigh	
Vehicle Bomb	VehicleSize*(lbsGVW)	4,000	4,000	5,000	12,000	Controlledperimeter,vehiclebarrier, or unsecuredparking/road
	ChargeSize *W*(lbsTNT)	50	100	500	2,000	
Placed Bomb	ChargeSize *W*(lbsTNT)	0	2	100	100	Unobstructedspaceorunsecuredparking/road
Standoff Weapon	ChargeSize *W*(lbsTNT)	2	2	50	50	Neighboringstructure

* For barrier design, with maximum velocity based on site configuration.

(Table 1) Recommended anti-terrorism design criteria (Conrath, et. al.) (Courtesy Schmidt, Jon A., "Structural Design for External Terrorist Bomb Attacks," NCSEA, Structure magazine (www.structuremag.org), March, 2003) [4].

4-4 Expected Damage

The Estimated damage that may occur under various incident pressures, presented in (Table 2).Thedamage and personnel injury from Explosive Blast[4].

Damage	IncidentOverpressure(psi)
Typicalwindow glassbreakage	0.15 – 0.22
Minordamagetosomebuildings	0.5 – 1.1
Panelsofsheetmetalbuckled	1.1 – 1.8
Failureofconcrete blockwalls	1.8 – 2.9
Collapseofwood-framedbuildings	Over 5.0
Seriousdamagetosteel-framedbuildings	4 – 7
Severedamagetoreinforcedconcrete structures	6 – 9
Probabletotaldestructionofmostbuildings	10–12

(Table 2) Damage Approximations. (Courtesy Explosive Shocks in Air, Kinney & Grahm, 1985; Facility Damage and Personnel injury from Explosive Blast, Montgomery & Ward, 1993; and TheEffects of Nuclear Weapons, 3rd Edition, Glasstone & Dolan, 1977)[4].

5- Building Design forSecurity, Historical Background

Security in the Architectural design means how the security measures and controls are positioned and how they relate to the overall architectural Design. The design of buildings to protect occupants from attack is as old as the history of architecture itself. The development of ***gunpowder*** and ***cannon*** in the middle ages forced walls to become lower and thicker in protection against cannon balls. The eventual result was the ***bastioned fort***, which was developed in increasingly elaborate forms. With a broad open space in front of the moats; the drawbridge, inner and outer entries, the high walls with slit openings and the well-guarded towers.The complex, in its mature form, shows all the elements that are present in today's doctrine of ***the three layers of defense against attack*** [8].Buildings constructed before World War II, are very solidly built, with concrete-encased steel frames, short structural spans, and small window openings. These types of buildings have been found to be very resistant to collapse [8].

Currently, designing buildings for security and safety requires a proactive approach that depend on the security requirements, acceptable levels of risk, the cost-effectiveness of the measures proposed for total design efficiency, evaluation of life cycle cost, and the impact these measures have on the design, construction, and use of the building [9].

6- Relevant Codes, Guidelines and Studies

Design and crime have been formally linked since the 1970's with the creation of a set of principals established to reduce theft, assaults, property damage and anti-social behavior in the public domain. Called "***Crime Prevention ThroughEnvironmental Design***" (**CPTED**)[1].Its principles have evolved to include elements of the built environment that minimize the risk of crime [10], [11].

CPTED however has little to say on such topics as the design of buildings or terrorist activities in particular [10].***But it cradles for specific studies*;**

6-1 Current guidelines on counter-terrorism

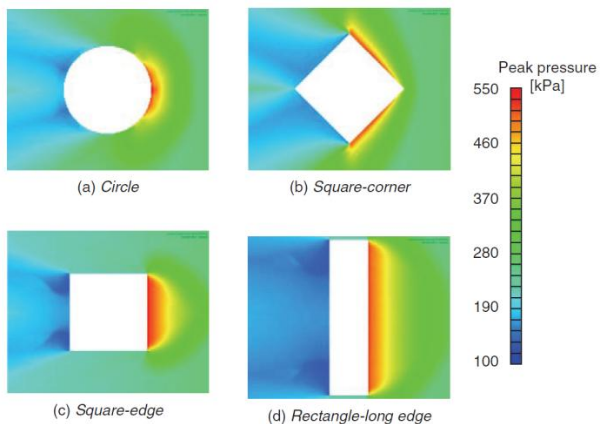
There are some international security guideline on preventing terrorist attacks, such, "***NATO's Policy Guidelines on Counter-Terrorism***", "***The European Union's Policies on Counter-Terrorism***" and the American "***counterterrorism***" Guide, but it's not directed to the design. Just overall policiesfor ***Security Authorities***to defend and control the terror attacks. Western countries that have experienced major terrorism incidents involving explosives in cities (for example UK, USA, Spain) have developed comprehensive ***Counter Terrorism***(CT) procedures and design guidelines for planners and architects to eliminate and inhibit a serious incident in crowded places [10]. "***RIBA[2]guidance on designing for counter-terrorism***" *(2010)and "**IITK-GSDMA Guidelines on Measures to Mitigate Effects of Terrorist Attacks on Buildings**" are examples of these guidelines.*

6-2 Laboratory test of Blast Wave characteristics on geometric shapes

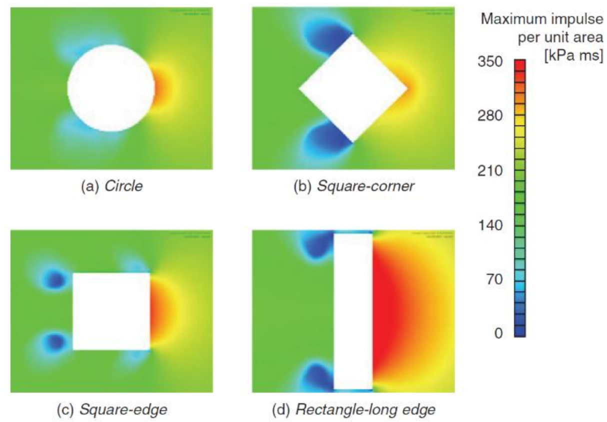
One Germany Study analyzed the Blast load effect on some geometric shapes, (Hyperboloid, Cylinder, step pyramid and Cube shapes) and its different orientationsto provide clear understanding about the influence of shaping on the explosiondesign load, [figure (1)][14].

[1] (**CPTED)** was originally coined and formulated by criminologist C. Ray Jeffery in 1971 since this time the CPTED has a lot of Theoretical Development [11].

[2] **(RIBA)** is The Royal Institute of British Architects. ***RIBA***has issued the advice in an attempt to improve the way architects and planners think about security from the outset in that Guide [12].



Cross sections, peak pressures



Cross sections, maximum impulses per unit area

Figure (1)

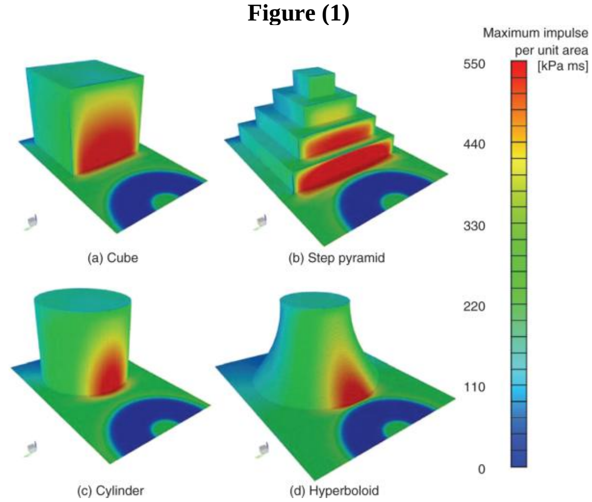


Figure (2)

The Study shows that Blast load for the hyperboloid is the lowest then Cylinder then step pyramid shape. Cube shape receive the biggest Blast load. If the cube rotated 45° to the blast location it will receive less Blast load [figure (2), (1)][14].

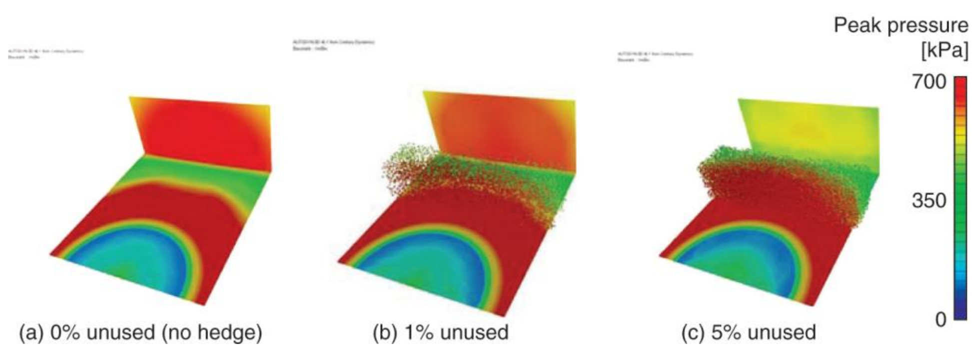


Figure (3)

The Study shows also, that Shrubs hedge reduce blast loads [figure (3)] [14].

Other studiesmentioned that, the building should be designed in such a way as to have ***minimum Reentrant corners***. Reentrant corners enhance the reflection and ultimately result in amplification of the blast loading on the structures. Moreover, it is observed that ***Convex shapes*** [3] ***perform better than Concave shapes*** in blast response mitigation [7], [15].
The plan-shape of a building also has a significant influence on the magnitude of the blast load, for example, ***"U"- or "L-shaped" buildings may increase blast pressure*** locally because of the complex reflections created from its shape, So ***“U”- or “L-shaped”*** buildings are not recommended [4], [6], [7].

7- Suggested Polices and Strategies to develop Anti-terror Architecture

Mitigating the effects of terrorist attacks on Buildings is possible with some suggested Polices and Strategies in Architectural design stage.
Security Measures to be considered while designing new buildings is the most important Design aspect to counter terrorism. These include design philosophy to be adopted for design of new buildings along with considerations required in site planning, architectural planning and design, and structural aspects, including methods of analysis and design [7]. The next point will summarize the ***suggested Policies and Strategies to reach the asked target***:-

a) ***Create a newParadigm***, overlapped with various disciplines, Technology development, Social attitude, Science advance and specific requirements to provide successful Design Process,in***Project Programming Phase***.

b) ***Special Building Code:*** Building Codes is needed to establish certain Building Code for Terrorism attack, based on Special Safety Studies and the latest Design requirements. ***“Anti-terrorism Building Design Code”(ABDC)***.This Code will ***guide Designers to the latest Security Measures***.

c) ***Additional simulation studies for all geometric forms under Blast load***, can provide a clear understanding about the relation between ***Blast load Pressure*** and the ***geometric forms***, which will guide Architects in shaping the building to protect explosions.***Simple and complex forms to be covered***.

d) ***Protective Structure Design against Blast Effects:*** Building Structureand its External walls*Require More Reinforcement* based on additional structure Calculations of Blast loads. ***Continuous data update need to be applied***.

[3] ***Circular plan buildings*** and ***buildings with circular corner*** surfaces have less intense reflected pressure than a rectangular building with sharp corners, because the angle of incidence of the shock wave increases more rapidly in a rectangular building and with re-entrant corners [7].

e) ***Support Potentially Explosive parts:*** Fuel tanks, Gas, water, steam installations, electrical connections, generators,Machine rooms and water storage systems with all its critical points should be planned to resist any explosion effects with high protection procedures [6].

f) ***Building MaterialsThat Mitigate Shock and Fragmentation Effects:*** Many Metals make great (BPRMs[4]), and the most common include steels (ferrous alloys), aluminum alloys and titanium. The purpose of using metals in structural protection is to: ***Protection*** against fragments and ***Maintaining*** structural integrity. In addition to their inherent strength and toughness and energy absorption capability [3]. Other similar materials such; ***High Strength Fibre ReinforcedConcrete*** (HSFRC), ***Blast-Proof partitions***, ***Blast-resistant glass, Blast Mitigation Fabrics***, and ***Bomb-Proof Wallpaper***provide significant potentialto mitigate the shock loading and further protect occupants from blast overpressures.***All this Materials can be used based onExperimental and Numerical Studies***[16], [17], [18].

g) ***Site security design*****:** The design of the ***Perimeter Barrier System*** is one of the most important aspects of providing building security. ***Access,Egress control points,Passive***[5]*and* ***ActiveBarriers***[6]are important to improve the everyday security and protecting against possible terrorist activity. Authorized access by foot or vehicle is through designated entry points, where desired levels of control can be exercised, such appropriate Screening or Scanning [7], [8].

Landscape architect's understanding of the functional requirements of a site can contribute to the development of desirable site images with built-in physical security that can minimize the damage to the building and the surrounded site [8]. Landscape Areas can be used as natural Barriers to control and direct access control and movement around site. ***Heavy Landscape fence***[7]also, ***can reduce blast pressure load on building*** byreasonable degree.Good Lightingdesign for the site is additional factor.

8- Conclusion

Based on the hypothesis that "***Design can eliminate problems and provide solutions***" and the formula of "***Early Consideration*** plus, ***Creative Thinking*** could provide ***Successful integrated Design Solution***". Architects and designers must

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[4](**BPRMs**): Blast and Penetration Resistant Materials [3].

[5]**Passive Barriers** (fixed) **include**: Walls, berms, engineered planters fixed bollards, heavy objects, reinforced street furniture, fixtures, and trees, Water obstacles, Jersey barriers in fixed and anchored installations and Fences [8].

[6]**Active Barriers** (operable) are used at vehicular access control points, it include: Rotating wedge systems, Rising-wedge barricades, Retractable bollards, Crash beams, Crash gates, Surface-mounted wedges and plates [8].

[7]**Heavy Landscape fence**,consists of trees background and shrubs under trees with Groundcovers under Shrubs.

continually update skills and knowledge in numerous spheres related to Counter-terrorism such as technology development, social attitude, science advance and specific requirements to provide successful Design Process can face the terrorist attack. These issues will create a new ***Paradigm***, overlapped with various disciplines to reach the required results of *Reinforce Building resistance; Shape, Structure and Materials*. In addition to *secure Building critical facilities*.

It is required that special Analysis about terrorism effects involved in early stages of developing the Design process. Also, ***analysis of the blast load effects on the different geometrical forms of the building*** can provide clear guide about the shapes that can reduce the ***Blast pressure load*** of any terror attack.

Site security designwill be implemented through layers of ***Perimeter Barrier Systems*** *and* ***Landscape Design***.

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