ASSESSMENT OF EXPLOSION PROTECTION MEASURES IN COMMERCIAL COMPLEXES IN ABUJA, NIGERIA

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The rise and spread of terrorist activities around the world, with Nigeria featuring prominently among the countries with most astounding human casualties and building destructions, has become a worrisome trend now occupying defensive thinking, militarily. But lately, Abuja, the capital city of Nigeria has had a series of explosive attacks with the utilization of Improvised Explosive Devices in parked or penetrative suicidal vehicular operations with varying degrees of decimations, which calls for the occupation of our defensive thinking as well, architecturally. Commercial complexes happen to fit into the considerations necessitating the need for their protection to mitigate terrorist attacks and ensure building survivability and safety of occupants. This paper set out to assess the blast resistance measures (defensive levels) in commercial complexes in order to come up with protective architectural design methods for new buildings or retrofit methods for existing structures to make them blast resistant buildings. This study utilized primary and secondary data sources. The primary data sources incorporated the utilization of observation schedules in field work, which were analyzed utilizing the SPSS software and the results exported to Microsoft Excel to produce pie charts to determine percentages of the imputed data. The paper studied the generation and reflection of blast wave, which is the chief damage mechanism in an explosion, to understand its behavior. It also used studies of building forms in terms of geometric shapes of buildings and some elements of the building envelope, and use of materials to exploit their energy absorption/reflection capabilities. As part of sustainable design, the effectiveness of the use of plants to reduce blast load impact is presented. The key finding is that the commercial buildings in Abuja are not architecturally in conformity with explosion protection designs and therefore need to be retrofitted to make them blast resistant.

Keywords: Terrorism; Explosion; Commercial Complexes; Blast Resistant Buildings; Building Form

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INTRODUCTION

Terrorism is portrayed as brutality intentionally unleashed on an objective populace with the aim of ingraining a feeling of fear, shock and outrage in their psyches (El-Domiaty, Myers, and Belarbi, 2002). Terrorism has been described as a phenomenon that is highly concentrated and yet globally distributed (Global Terrorism Index Report, 2015). The Global Terrorism Index additionally has it that 75% of lives lost because of terrorist exercises occurred in five nations – Iraq, Afghanistan, Pakistan, Nigeria and Syria. Until recently, Nigeria appeared to have been invulnerable to terrorist activities. The successive gruesome acts of terrorism suffered in the hands of local dissentient forces so far have thoroughly punctured our false sense of immunity (Oyebode, 2011). Our National security environment is now a reflection of the global security challenges (Think Security Africa, 2011).

Subsequen**t** to 2009, terrorists have dispatched assaults on commercial and government structures with the utilization of explosive devices mostly in the Northern parts of the nation, particularly, in and around Abuja the capital city, bringing about the devastation of such buildings and loss of lives or injuries to the occupants of the buildings. Some attacked locations include: the Police Headquarters building on 16 June 2011; the United Nations building on 26 August 2011; Nyanya Motor Park on 14 April 2014 and the Emab Plaza on 25 June 2014. The effect and decimations of/from those blast situations point to the troubling reality that the terrorists are turning out to be progressively more sophisticated and brave in their assaulting abilities and outreach (Human Rights Watch, 2012, Barna, 2014). Plates 1 and 2 below show some bomb blast incidents in the federal capital city of Abuja.

Plate 1: *Emmab Plaza bomb Blast, Abuja*
Source: Mail Online
www.dailymail.co.uk/news/article-2669538/Explosion-rocks-mall-Nigerian-capital.html

Plate 2: *Thisday office bomb Blast, Abuja*
Source: The Christian Science Monitor
www.csmonitor.com/World/Africa/2012/0426/
Separate-bomb-blasts-rock-Nigeria-s- newspapers

Shopping centers, in light of their trademark nature to be swarmed, are potential focuses for terrorist assaults on account of the capacity to exact mass losses, cause gross monetary harm and inculcate fear (US Department of Homeland Security, 2014). Shopping malls are specifically vulnerable to terrorist assaults as a result of ease of accessibility and dense convergence of individuals. Thus this vulnerability has resulted high risk of attacks, with more than 60 terrorist attacks at shopping malls happening all through the world since 1998 (LaTourrette, Howell, Mosher, and MacDonald, 2006).

The larger parts of commercial buildings in Abuja were built preceding the consolidation and arrival of terrorist exercises into the federal capital city. This made this study appropriate to discover the congruity of those structures to blast resistance methodologies, with a specific end goal of improving what is functional in them or acquaint new techniques or installations to make them blast resistant to mitigate terrorist attack.

Aim of the Paper

The aim of this study is to assess the explosion protection measures in commercial complexes in Abuja to ascertain their conformity to explosion protection design, construction and use of materials.

Explosion Protection Dilemma

The components of buildings largely utilized for their aesthetics purpose, particularly glass and ornamental elements, if not properly used will likewise make them vulnerable as they turn into high speed projectiles during explosion events (Lavy and Dixit, 2010). Therefore, balance should be struck between protection and aesthetic choices. Blast protection objectives should also be practicable as it would be irrational, because of restrictive expense, to have a building, other than a hardened military facility to withstand, unscathed, the impact of a bomb directly before it. The main objective of protection design is to minimize damage to the building to ensure its survivability and the safety of occupants (FEMA, 2003b).

Threat Identification

The US Department of Homeland Security (2014) specifies terrorist threats of concern to large shopping malls to include:

- Explosives
- Arson
- Biological agents
- Chemical agents
- Hostage/blockade, and
- Indiscriminate shooting of persons.

This paper focused on threats from explosives. The conventional explosive devices that are utilized in terrorist activities targeted at buildings are called improvised explosive devices (IEDs). IEDs are of diverse sorts depending on their size, design, and composition. The type and degree of harm an IED can cause depends on the means by which it is conveyed to a target. Either of two conveyance mechanisms is typically utilized: vehicle-borne or man-portable devices (Engineering Security, 2009).

Vehicle-Borne Improvised Explosive Devises

A vehicle-borne improvised explosive device (VBIED) has the capacity to carry substantial amount of explosive material capable of significantly damaging or even destroying a building. Because the magnitude of damage a VBIED can inflict depends largely on its closeness to a target, terrorists choose to detonate VBIEDs in vehicles parked outside of buildings, within garages, or in vehicles that ram into buildings.

Man-Portable Improvised Explosive Devises

Man-portable improvised explosive devices (MPIEDs) are mostly used to target people rather than buildings. They tend to be significantly smaller in size than VBIEDs, thus concealable in backpacks and suitcases, making them easier to deliver into a building. Victims of such attacks often get injured by shrapnel, projectiles, furniture fragments and shattered glass, rather than building collapse as in the case of VBIEDs.

The Explosion Phenomenon

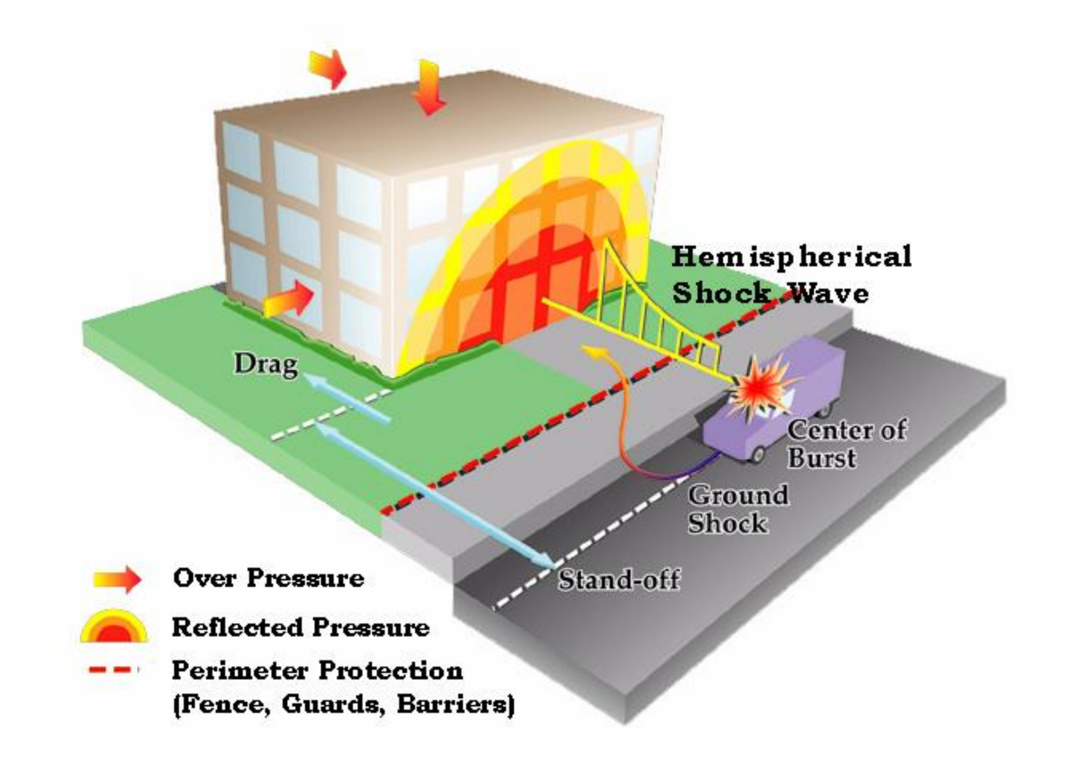


Figure 1- Schematic of vehicle weapon threat parameters and definitions
Source: FEMA427 (2003b): Primer for Design of Commercial Buildings to Mitigate Terrorist Attacks

Explosives are broadly classified into two: low and high explosives. In low explosives, the reaction is essentially thermal in nature, that is, a conflagration. In the case of high explosives, the transfer of energy from the exploded to the unexploded material is through pressure shock, that is, an explosion. The second category is the most imperative in this paper (Sakula, 1997).

Experts on explosion protection basically categorize blast attacks into two:

1. **Standoff explosions –** these are blasts that occur at some significant distance from the target.
2. **Contact detonations –** these occur when an explosive device is placed in physical contact or very close to the structure. Each category has a different damage mechanism and requires a different protection strategy (Steven, 2007.)

A blast is characterized as a great sudden burst of energy in the form of light, heat, sound and a blast wave (FEMA, 2003b). FEMA, (2003b) further portrays a blast wave as exceptionally compacted air traveling outward, radially, at supersonic speed away from the impact source and its intensity gets enhanced by a factor of up to thirteen when it comes in contact with an obstacle. An explosion which occurs at ground creates several effects that cause damage and injury. The effects are dependent on the power, quantity and distance of the explosive device (Protecting Crowded Places, 2012).

A building that is subjected to an explosive action is affected by several pressure types that occur in two phases: the positive pressure phase and the negative pressure phase. The positive pressure phase refers to the sudden outward expansion of energy as the shock waves radiate toward the building in all directions from the source of the explosion causing pressure to envelope the structure, loading the sides and the roof; with possible further amplification if the waves are trapped by the structure. The pressures in the positive phase exert pushing effects on the building's exterior and may end up inducing localized failure of exterior walls, windows, floor systems, columns, and girders. The negative pressure phase refers to the period when the low intensity, longer duration causes inward movement of air to fill the void created by the positive phase. The pressures in the negative phase prompts a reversal of the positive phase loading, thereby pulling structural elements towards the source of the blast, which may pull out windows and sloped roof (FEMA, (2003b).

Causes of Fatalities, Injuries and Damage from Blasts

The main causes of fatalities, injuries and damage as a result of an Improvised Explosive Device (IED) are:

- Direct weapon effects including primary fragments, lung blast damage, thermal burns an ear drum rupture;
- Secondary fragments such as glass, spall (flakes of material that are broken off a larger solid body) and other objects thrown by the blast;
- Collapse causing crush injuries; and
- Post-event falling debris (including glazing, façade, internal walls etc) damaged equipment and damaged infrastructure which can hinder the speedy evacuation of buildings (Protecting Crowded Places, 2012).

RESEARCH METHODS

This study is a descriptive research exercise which utilized primary and secondary data sources. The primary data sources incorporated the utilization of observation schedules in field work. The initial sample population for commercial complexes in Abuja obtained from Abuja Environmental Protection Board (AEPB) was two thousand, two hundred and eighty-three (2283) which included hotels, eateries, hotels and shopping complexes. The population got reduced to seventy-five (75) after selecting only shopping centres/malls as the target for the research. Twenty (20) shopping complexes/malls were further selected at random for analysis. The research parameters utilized included five components of the security design: stand-off distances, wall types, building configuration, roofing system and glazing types. Data was collated based on the above checklist and the information tabulated and analyzed using the SPSS software to produce frequency tables that were exported to Microsoft Excel package for plotting of relevant pie charts to determine the percentages of the computed data. Secondary data sources are published and unpublished literary works to study the generation and reflection of blast waves, some geometric shapes of buildings and use of materials to exploit their energy absorption/reflection capabilities.

FINDINGS AND DISCUSSIONS OF RESULTS

The analysis of the data obtained using observation schedules was tabulated under the individual components of the line of defense concept of the protection design strategies, namely: stand-off distance, wall types, building configuration, roofing system and glazing types – and presented in tables 1.0, 2.0, 3.0, 4.0 and 5.0 respectively.

1. Stand-off Distance:

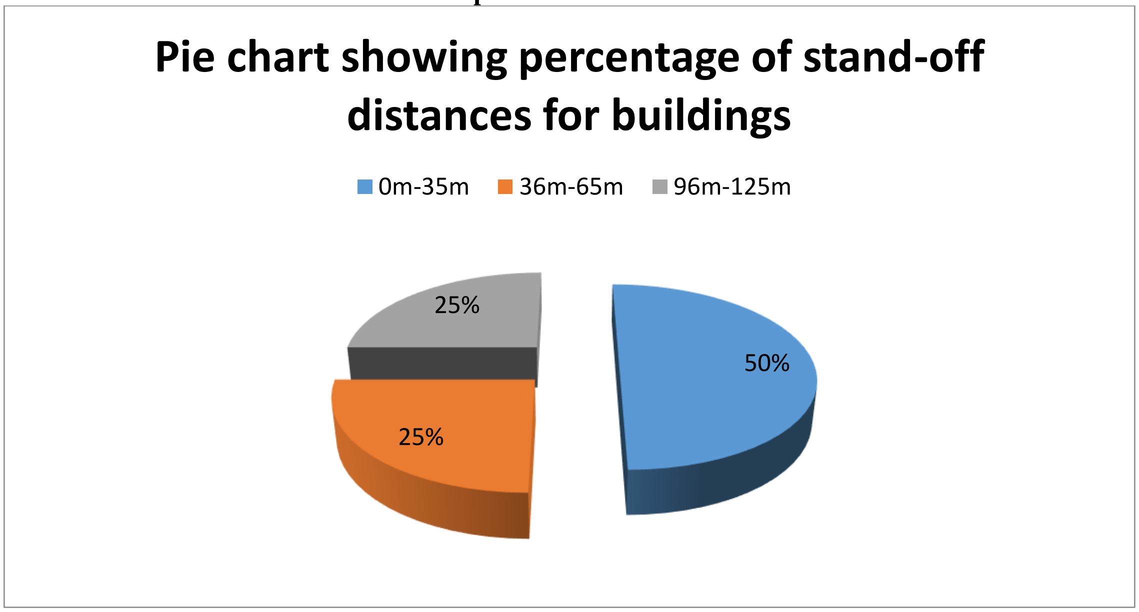
The effect of a blast or impact decreases as distance from it increases. Establishing a separating distance, called stand-off, between a building and possible explosive detonation location is the most effective mitigation measure against explosive attacks (FEMA, 2003b, (LaTourrette, Howell, Mosher, and MacDonald, 2006). This stand-off distance, also referred to as setback zone, is accomplished by setting at the perimeter anti-ram bollards, expansive grower, low level walls, water bodies and different barriers that cannot be compromised by hostile vehicles. However, in urban areas there is much constraint regarding setbacks (PCI Designers Notebook, 2015).

Table 1.0: Distribution of commercial complexes based on stand-off distances

S/N	Samples	0m–35m	36m-65m	66m-95m	96m-125m	126m-165m	Over 156m
1	Ceddi Plaza	O					
2	Silverbird Entertainment	O					
3	Next Cash & Carry				O		
4	Shoprite				O		
5	Banex Plaza	O					
6	Sheriff Plaza	O					
7	Asokoro Shopping Mall				O		
8	Metro Plaza		O				
9	2XL Mall				O		
10	Grand Square		O				
11	Pathfield Mall	O					
12	Dunes Centre		O				
13	Omega Centre		O				
14	Area 11 Mall	O					
15	Danziyal Shopping Mall				O		
16	Bassan Plaza	O					
17	Sahad Stores	O					
18	Jinifa Shopping Complex	O					
19	Exclusive Stores	O					
20	Maitama Shopping Mall		O				
	Total	**10**	**5**		**5**		

Source: Author's Fieldwork (2015)

Chat 1.0: Distribution of commercial complexes based on stand-off distances



Source: Author's Fieldwork (2015)

Vehicle Bomb Explosion Hazard and Evacuation Table

Figure 2: ATF Vehicle Bomb Explosion Hazard and Evacuation Table

ATF	VEHICLE DESCRIPTION	MAXIMUM EXPLOSIVES CAPACITY	LETHAL AIR BLAST RANGE	MINIMUM EVACUATION DISTANCE	FALLING GLASS HAZARD
	COMPACT SEDAN	500 Pounds 227 Kilos *(In Trunk)*	100 Feet 30 Meters	1,500 Feet 457 Meters	1,250 Feet 381 Meters
	FULL SIZE SEDAN	1,000 Pounds 455 Kilos *(In Trunk)*	125 Feet 38 Meters	1,750 Feet 534 Meters	1,750 Feet 534 Meters
	PASSENGER VAN OR CARGO VAN	4,000 Pounds 1,818 Kilos	200 Feet 61 Meters	2,750 Feet 838 Meters	2,750 Feet 838 Meters
	SMALL BOX VAN *(14 FT BOX)*	10,000 Pounds 4,545 Kilos	300 Feet 91 Meters	3,750 Feet 1,143 Meters	3,750 Feet 1,143 Meters
	BOX VAN OR WATER/FUEL TRUCK	30,000 Pounds 13,636 Kilos	450 Feet 137 Meters	6,500 Feet 1,982 Meters	6,500 Feet 1,982 Meters
	SEMI-TRAILER	60,000 Pounds 27,273 Kilos	600 Feet 183 Meters	7,000 Feet 2,134 Meters	7,000 Feet 2,134 Meters

Source: Development of a Landscape Vulnerability Assessment Model in a Heightened Security Environment (www. *scholar.lib.vt.edu/theses/available/etd-05092003-220909/unrestricted/thesisfinal.pdf)*

The table in fig.2 provides the stand-off distances required for different explosive risk types or charge weights. From table.1 the farthest stand-off distance is between 96m-125m which represents 25% of the analyzed complexes, that means 75% of the stand-off distances is less than 66m. Impliedly, a water/fuel truck and/or semi-trailer delivering their respective charge weights of explosives can cause blast waves capable of inflicting great damages and lethal injuries to both the structures and their occupants respectively. Such buildings will require hardening measures to make them withstand blast events with minimum damages.

2. Wall Types:

The wall types in the checklist for observation and analysis for conformity with explosion protection include: unreinforced masonry, reinforced masonry, reinforced concrete wall and others. From the findings in table 2:0 all the analyzed complexes were constructed with reinforced concrete structural frames but the external wall are all made of unreinforced masonry. Un-reinforced masonry walls (URM) have a low resistance against blast load impact because of their low flexural capacity and their brittle nature of failure. In this way, failure of URM walls was recognized as one of the significant reasons for material damage and loss of human lives (El-Domiaty, Myers & Belarbi, 2002).

Table 2.0: Distribution of commercial complexes based on wall types

S/N	**Samples**	**Unreinforced Masonry**	**Reinforced Masonry**	**Reinforced Concrete**	**Others**
1	Ceddi Plaza	O			
2	Silverbird Entertainment	O			
3	Next Cash & Carry	O			
4	Shoprite	O			
5	Banex Plaza	O			
6	Sheriff Plaza	O			
7	Asokoro Shopping Mall	O			
8	Metro Plaza	O			
9	2XL Mall	O			
10	Grand Square	O			
11	Pathfield Mall	O			
12	Dunes Centre	O			
13	Omega Centre	O			
14	Area 11 Mall	O			
15	Danziyal Shopping Mall	O			
16	Bassan Plaza	O			
17	Sahad Stores	O			
18	Jinifa Shopping Complex	O			
19	Exclusive Stores	O			
20	Maitama Shopping Mall	O			
	Total	20			

Source: Author's Fieldwork (2015)

Existing unreinforced URM walls may be retrofitted with a coating of polymer spray-on to enhance their blast wave resistance. This creative retrofit method exploits the toughness and resiliency of cutting edge polymer materials to adequately deform and dissipate the blast energy while holding in place the fragmented wall particles. In spite of the fact that the sprayed walls might break in a blast occasion, the elastomer material stays in place and contains the debris. The retrofit for URM to mitigate blasts comprises of an interior and exterior (optional) layer of polyurea applied to external walls and ceilings. The polyurea gives a bendable and strong membrane that catches and holds secondary fragments from the wall as it breaks and gets separated due to the impact of the air blast wave (Watch & Tolat, 2011).

3. Building Configuration:

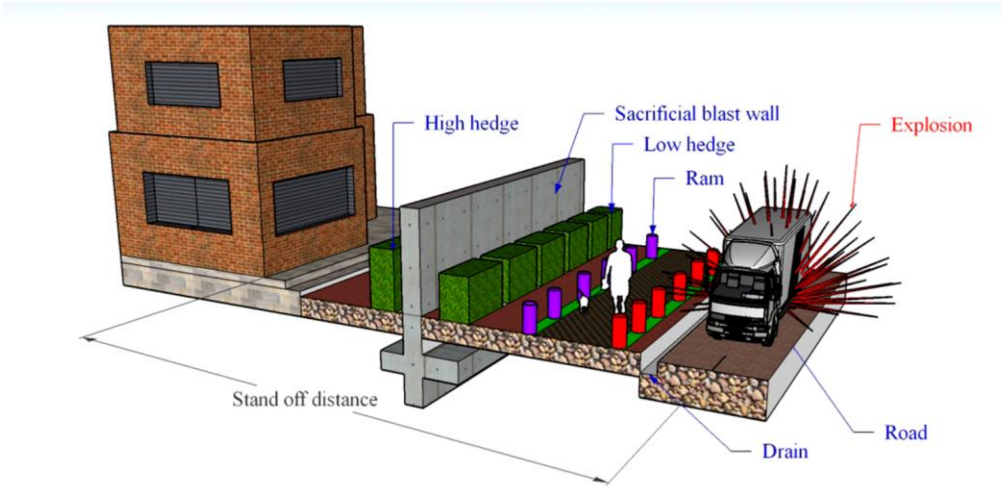
This comprises the different geometrical shapes of the buildings analyzed for conformity with the shapes suitable for explosion protection. They include - Circular, L-Shaped, U-Shaped, Rectangular and Others.

Table 3.0: Distribution of commercial complexes based on building configuration

S/N	**Samples**	**Circular**	**L-shaped**	**U-shaped**	**Rectangular**	**Others**
1	Ceddi Plaza				O	
2	Silverbird Entertainment				O	
3	Next Cash & Carry				O	
4	Shoprite					O
5	Banex Plaza			O		
6	Sheriff Plaza		O			
7	Asokoro Shopping Mall				O	
8	Metro Plaza				O	
9	2XL Mall				O	
10	Grand Square				O	
11	Pathfield Mall				O	
12	Dunes Centre					O
13	Omega Centre			O		
14	Area 11 Mall		O			
15	Danziyal Shopping Mall				O	
16	Bassan Plaza				O	
17	Sahad Stores				O	
18	Jinifa Shopping Complex				O	
19	Exclusive Stores				O	
20	Maitama Shopping Mall				O	
	Total	0	2	2	14	2

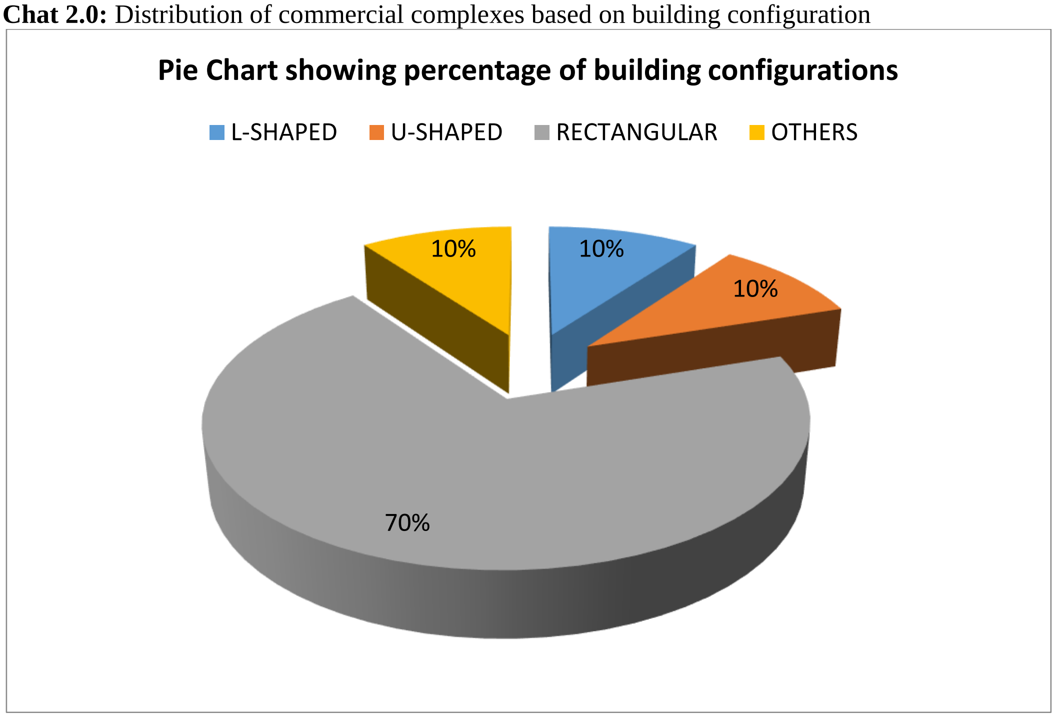
Source: Author's Fieldwork (2015)

Fig.3. Different measures to enhance the protection of building against blast loading



Source: Blast-Resistant Design of Structures
http://www.researchgate.net/publication/262374833

Chat 2.0: Distribution of commercial complexes based on building configuration



Source: Author's Fieldwork (2015)

The configuration of the building can influence the general damage to the structure. For instance, "U"- or "L-shaped" structures might trap the shock wave, which may increase blast pressure locally on account of the resultant complex reflections. Expansive or gradual re-entrant corners have less impact than small or sharp re-entrant corners. By and large, convex as opposed to concave shapes are favored for the building exterior. In a comparative sense, the reflected pressure on a circular building's surface is less intense than that on a flat building (PCI Designers Notebook, 2015). This is based on the fact that the shock front incidence angle on an arched or convex surface increases more quickly from blast than on a planer surface, bringing about decay of reflected pressure all the more quickly for a building with a convex shape (Gebbeken and Doge, 2010). Gebbeken and Doge, further discovered that the blast loading L-shaped structures can be greatly reduced by smoothing out the re-entrant corners in such shapes. From table 1.0 none of buildings analyzed is of circular or convex shape. 70% are rectangular shaped, 10% L-shaped, 10% U-shaped and 10% for others. And they all have sharp edges capable of magnifying the blast wave.

4. **Roofing Systems:**

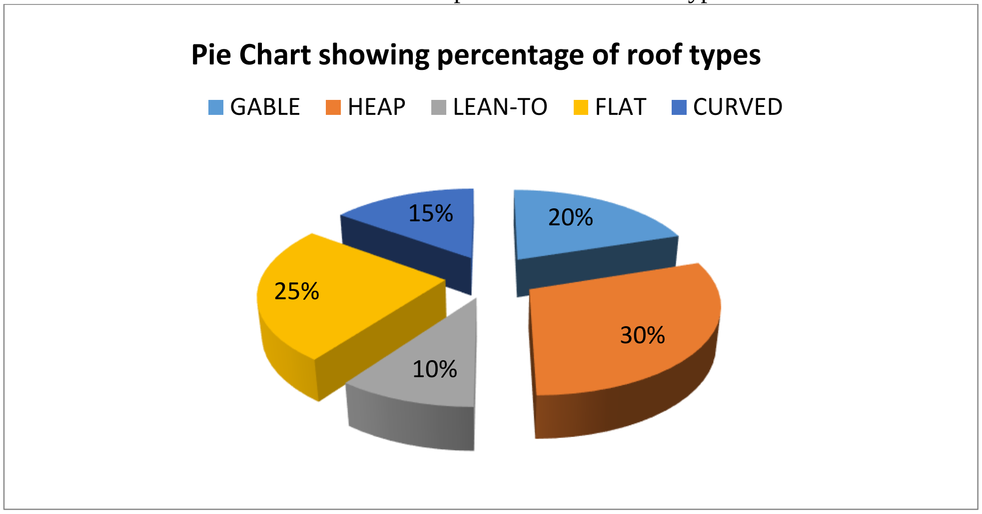
This comprises the different roofing types on the buildings analyzed for conformity with the shapes suitable for explosion protection. They include - Gable, Hip, Lean-To, Flat, Curved and Others.

Table 4.0: Distribution of commercial complexes based on roofing systems

S/N	**Samples**	**Gable**	**Hip**	**Lean-to**	**Flat**	**Curved**
1	Ceddi Plaza				O	
2	Silverbird Entertainment					O
3	Next Cash & Carry	O				
4	Shoprite			O		
5	Banex Plaza		O			
6	Sheriff Plaza		O			
7	Asokoro Shopping Mall				O	
8	Metro Plaza	O				
9	2XL Mall				O	
10	Grand Square					O
11	Pathfield Mall	O				
12	Dunes Centre			O		
13	Omega Centre		O			
14	Area 11 Mall		O			
15	Danziyal Shopping Mall				O	
16	Bassan Plaza	O				
17	Sahad Stores				O	
18	Jinifa Shopping Complex					O
19	Exclusive Stores		O			
20	Maitama Shopping Mall		O			
	Total	**4**	**6**	**2**	**5**	**3**

Source: Author's Fieldwork (2015)

Chat 3.0: Distribution of commercial complexes based on roof types



Source: Author's Fieldwork (2015)

The result from table 3.0 shows the roof types for the analyzed complexes.

In a research conducted by Rahim, Bitarafan &, Arefi (2013) using finite element models to test the compatibility of five different roof types – flat roof, gable roof, conical roof, dome roof and pyramidal roof - the flat roof was discovered to be from those exceptionally compatible with explosion protection designs because less surface is exposed to explosion waves compared to the rest. The other roof types fall under roofs that are inconsistent with explosion protection designs. From table 2.0, only 25% of the buildings have flat roofs, which is the most consistent with protection design strategies.

5. **Glazing Types:**

This comprises the different glass types on the buildings analyzed for conformity with the requirements suitable for explosion protection. They include – Annealed Glass, Tempered Glass, Laminated Glass, and Others.

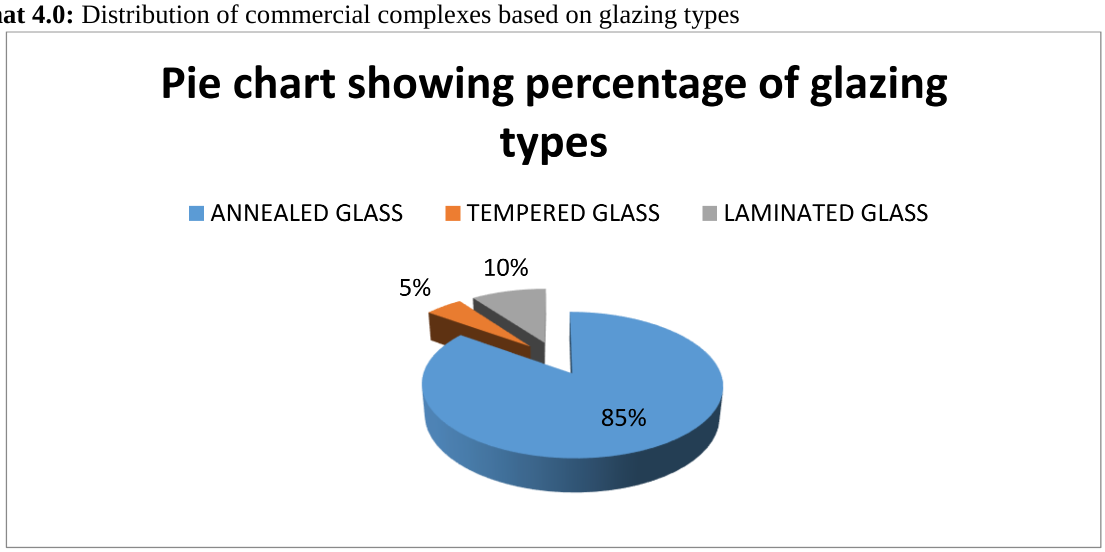
The frequent use of large expanses of glass in the design of buildings for aesthetic reasons has heightened the risk to life from flying and penetrating pieces of shattered glass; making it a cause for greater concern. By nature, glass is very delicate. It is that way since we need to see through it. Being delicate, glass and glazing products are absolutely not able to resist being split, broken, smashed and/or penetrated, contingent on its compositional make-up. Airborne glass pieces propelled in the event of failure of windows and entryways subjected to blast impacts are recognized as major cause of injuries and death (Stiles, 2010).

Table 5.0: Distribution of commercial complexes based on glazing types

S/N	**Samples**	**Annealed glass**	**Tempered glass**	**Laminated glass**	**Others**
1	Ceddi Plaza			O	
2	Silverbird Entertainment			O	
3	Next Cash & Carry	O			
4	Shoprite		O		
5	Banex Plaza	O			
6	Sheriff Plaza	O			
7	Asokoro Shopping Mall	O			
8	Metro Plaza	O			
9	2XL Mall	O			
10	Grand Square	O			
11	Pathfield Mall	O			
12	Dunes Centre	O			
13	Omega Centre	O			
14	Area 11 Mall	O			
15	Danziyal Shopping Mall	O			
16	Bassan Plaza	O			
17	Sahad Stores	O			
18	Jinifa Shopping Complex	O			
19	Exclusive Stores	O			
20	Maitama Shopping Mall	O			
	Total	**17**	**1**	**2**	

Source: Author's Fieldwork (2015)

Chat 4.0: Distribution of commercial complexes based on glazing types



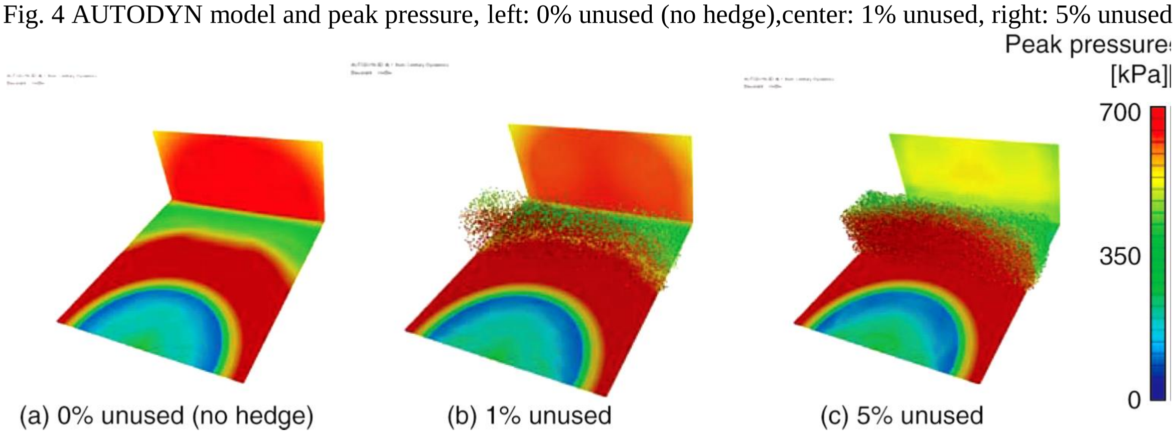
Source: Author's Fieldwork (2015)

It can be observed from table 3:0 that the largest percentage of glass type in use in annealed glass, 85%. Annealed is the most incompatible glazing material in security design because of the great risk it poses to humans; it breaks into large shards with jagged edges capable of serious injuries or death. Tempered glass, with 5% usage, is four times stronger than annealed but equally breaks, though, into smaller pieces. Laminated glass, comprising 10% usage in the table, under the impact of blast wave breaks but is held in place by the polyvinyl butyral (PVB) interlayers preventing it from inflicting lacerations on occupants in the event of a blast (FEMA, 2003a). If annealed glass or tempered glass must be used, then they should be laminated or protected with blast curtains to prevent glass projectiles from harming people during explosions,

6. **The Use of Plants:**

   The use of hedges was largely absent in the complexes visited during the research exercise. In 2010 Nobert Gebbeken and Torsten Doge carried out an investigation on the use of hedges (plants) to reduce blast loads on buildings. The hedge was modeled in AUTODYN where three(3) different models were studied by altering the densities of plants. Model (a) had no plants at all, model (b) had 1% plants, while model (c) had 5% of plants. There was reduction of peak reflected pressures in the models with hedges compared with the model without hedges. Gebbeken and Doge emphasized on the need for further research on this area but the outcome of their investigation can be applied alongside other security measures to mitigate blast effects on buildings and their occupants. Below is the diagram illustrating the models used in their investigation of the use of hedges in fig.4.

Fig. 4 AUTODYN model and peak pressure, left: 0% unused (no hedge),center: 1% unused, right: 5% unused



Source: Author's Fieldwork (2015)

CONCLUSION

In conclusion, the study has shown that majority of the commercial complexes in Abuja are grossly not in conformity with explosion protection design, construction and use of materials, making their defense levels very poor. This non-conformity, yet again, makes the buildings vulnerable to explosive attacks and their construction materials as projectiles constitute great hazard to both the occupants, passersby and those even further away. Therefore, the commercial complexes need to be retrofitted to withstand such attacks to ensure their survivability as well as the safety of their occupants. It is hereby recommended that security strategies be included in the designs of new buildings expected to accommodate large convergence of people as this attracts the attention of terrorists seeking for maximum casualties.

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